Assessing Instream Flows that Support Whitewater Recreation in the San Miguel River Basin.

Aggregating Defined Recreational Flow-Needs and Hydrologic Data to Quantify Existing Whitewater Recreation Opportunities, and Predict a Change to Boatable Days Attributed to Water Rights Development in Montrose County, Colorado.

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Abstract

Streamflow, or the amount of water in a river, affects the quality, quantity, and timing of river-related recreation, such as whitewater boating. In August 2016, American Whitewater was retained by Deere & Ault Consultants to assist in describing the relationship between streamflows and whitewater recreation for the San Miguel River in Southwest Colorado. The goals of the 2016 study are to 1) define the full range of streamflows that support recreational opportunities on the lower San Miguel River, and 2) assist with the assessment of impacts to flow-related whitewater recreation on the San Miguel, attributed to consolidated water rights applications in Montrose County, Colorado. Additionally, this report adds to the dataset used both to a) define recreational attributes and values in the Southwest Basin Implementation Plan and b) supplement the dataset informing the US Bureau of Reclamation's Colorado River Basin Water Supply and Demand Management efforts. This report summarizes the collection and evaluation of data defining whitewater recreation flow-needs on the San Miguel River, and evaluates the predictive change in Boatable Days attributed to potential development of conditional direct flow rights in the Lower San Miguel River.

Contents

I. Background: Whitewater Boating and Instream Flows

Whitewater boating is a flow dependent recreational use of rivers, and considerable work evaluating flow-recreation relationships has occurred over the last several decades (Brown et al., 1991; Shelby, Brown, & Taylor, 1992; Whittaker and Shelby, 2002). Many flow-recreation studies focus on whitewater boating, such as rafting, kayaking, and canoeing, as flow often determines whether people have opportunities to take a trip and what level of challenge or social value is provided (Whittaker & Shelby, 2000). Different flow levels provide for varied whitewater boating opportunities. As flows increase from zero, different paddling opportunities and challenges exist within ranges of flows on a spectrum: too low, minimal acceptable, technical, optimal, high challenge, and too high. Standard methodologies are used to define these flow ranges based on individual and group flow- evaluations. The various opportunities provided by different flow ranges are described as occurring in "niches" (Shelby et al., 1997).

Changes in streamflow can have direct effects on the quality of whitewater boating. Direct effects may change quickly as flows change, such as safety in running rapids, number of boat groundings, travel times, quality of rapids, and beach and camp access (Brown, Taylor, & Shelby, 1991; Whittaker et al., 1993; Whittaker & Shelby, 2002). Indirectly, flow effects wildlife viewing, scenery, fish habitat, and riparian vegetation over the long term as a result of changes in flow regime (Bovey, 1996; Richter et al., 1997; Jackson & Beschta, 1992; Hill et al., 1991).

Streamflow is often manipulated through releases from dams and reservoirs, pipelines, and diversions. Additional scenarios, such as climate change, drought, and new water rights development can all impact flows and recreation quality. Decision-makers within land and resource management and regulatory agencies, and state and local governments are increasingly interested in the extent that flow regimes can be managed to provide desirable recreational resource conditions. In these decision-making settings, specific evaluative information on how flow affects recreation quality is critical, particularly where social values are often central to decision-making (Kennedy and Thomas 1995). American Whitewater is recognized for using best practices and science-based methodologies to define recreation flow needs and has done so in Colorado and across the country – including basin-wide assessments in the Yampa-White, Gunnison, and Colorado River basins, as well as most National Park Units in the Southwest.

II. Introduction

In January of 2010, The Colorado Water Conservation Board (CWCB) announced its intent to appropriate a new instream flow water right for the lower San Miguel River. At the request of the Montrose County Commissioners, San Miguel County Commissioners, and Southwest Water Conservation District, the CWCB delayed its application one year, until 2011, to allow the parties making the request to assess the impact of the proposed CWCB instream flow right on their ability to provide for their future water needs, and to provide the parties time to prepare their own water rights applications for future uses within western Montrose County.

In May of 2010, Deere & Ault Consultants was retained by Montrose County to investigate the potential future water needs in western Montrose County, and to assist in preparing water rights applications to support future development and growth in the area. In December 2010, Montrose County filed six Water Court applications with the District Court Water Division No. 4. In 2012, Montrose County received a consolidated decree for four of the water rights filings made in 2010. The "Consolidated Decree" adjudicated water rights claims made pursuant to Case Nos. 10CW164, 10CW165, 10CW166, and 10CW169. At the request of the CWCB, Montrose County approached American Whitewater for help in understanding the recreational opportunities

or impacts presented by the proposed water projects. American Whitewater was subcontracted by Deere & Ault Consultants in August of 2016, to assist in the investigation of three project scenarios contemplated under the Consolidated Decree, filed by Montrose County in 2010. These scenarios, which estimate stream depletions resulting from the entire 2060 demand (over and above 2010 demands) being met in western Montrose County, include:

- Scenario One (Alt1), which includes Big Bucktail Reservoir, 5,000 acre-feet
- Scenario Two (Alt2), which includes Maverick Draw Reservoir No. 1, 8,400 acre-feet, and
- Scenario Three (Alt3), which includes Maverick Draw Reservoir No. 2, 9,100 acre-feet.

In addition to assisting in the investigation of water rights development for Montrose County, American Whitewater's study presents information that may be considered by the Southwest Basin Roundtable (SWBRT), established under Colorado's Water for the 21st Century Act. The SWBRT identified and mapped the location of environmental and recreational values defined by the Roundtable – including, whitewater recreation on the San Miguel River. The Roundtable adopted a Basin Implementation Plan (BIP, 2015) to address the need to define resource conditions that support these attributes and values, and commits to collaborative efforts to protect these water resources:

'With respect to the Southwest Basin's Environmental and Recreational values and water needs… the Roundtable has identified two methods that it hopes can help address and bridge the need for additional information and tools. These are:

1. *"Evaluation of environmental and or recreation gaps is planned to be conducted for improvement of non-consumptive resources and/or in collaborative efforts with development of consumptive IPPs. The evaluations may be conducted by a subgroup of the Roundtable or by individuals, groups, or organizations with input from the Roundtable. The evaluation may utilize methodologies such as the southwest attribute map, flow evaluation tool, R2 Cross, and any other tools that may be available".*

2. *Where environmental and/or recreational gaps are identified, a collaborative effort will be initiated to develop innovative tools to protect water identified as necessary to address these gaps."*

The results of American Whitewater's San Miguel Flow Study, move implementation of the statewide Colorado Water Plan[1] forward. The State of Colorado's Basin Implementation Plan draft guidance recommends quantification of recreational (boating) values. Section 2.1 of the Guidance[2] calls for the evaluation of nonconsumptive needs in terms if 'measurable outcomes', data, and assessment using methods described in CWCB's Nonconsumptive Toolbox (CWCB, 2013). The toolbox identifies the flow-evaluation methodology developed and used by American Whitewater as an example of 'measurable outcomes' and 'recreation tools' in appendices D and C of the Guidance, respectively.

Through this study, American Whitewater's aim is to 1) address gaps in data and understanding regarding flow conditions necessary to sustain recreational values along the San Miguel river, 2) establish a current baseline of boatable days to quantify recreational opportunities for the San Miguel River, and 3) work with the Basin Roundtable to improve understanding of water needs necessary to sustain river-related recreational boating along the San Miguel river and to develop tools to address gaps in protecting boating values attributed to proposed water rights development.

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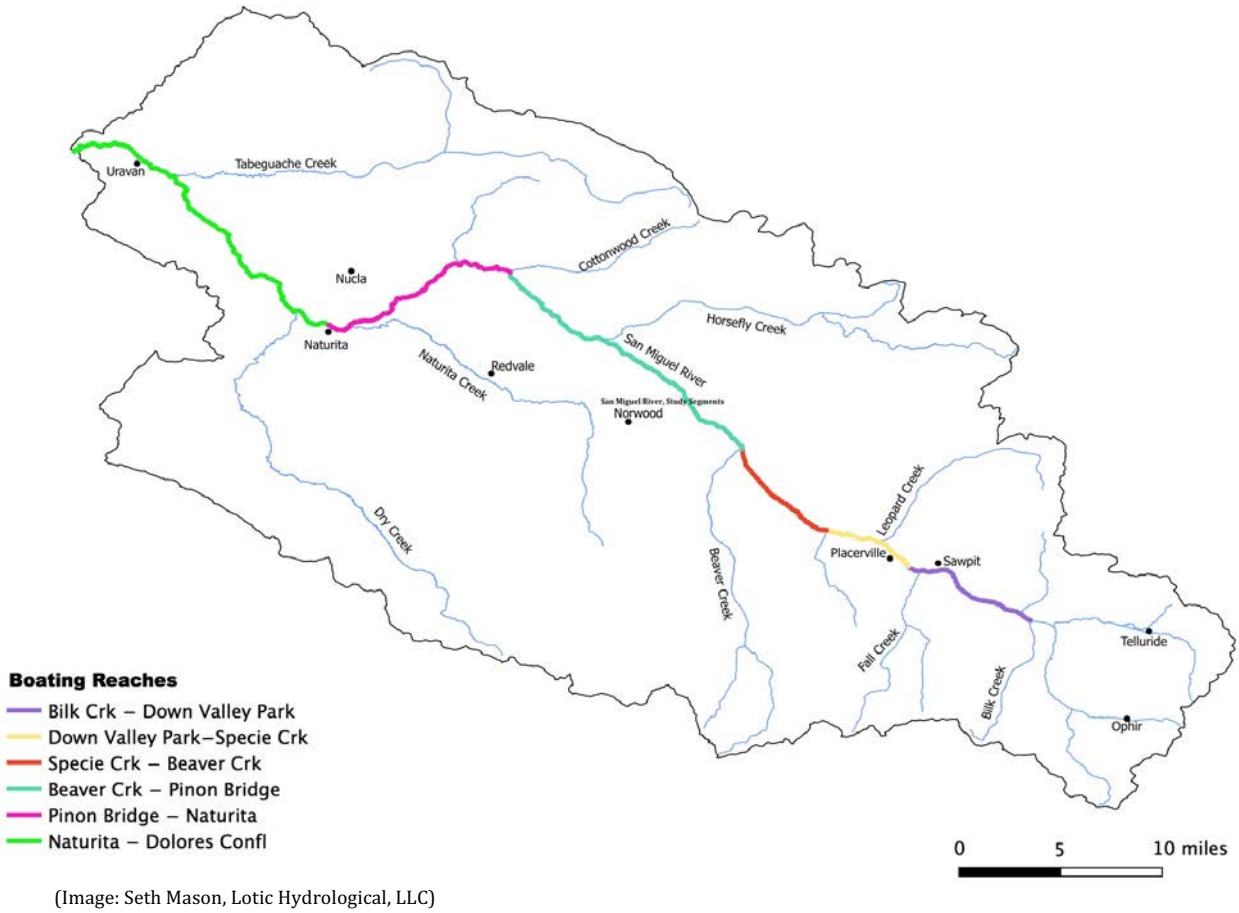
[1] https://www.colorado.gov/pacific/cowaterplan/plan

[2] http://cwcbweblink.state.co.us/WebLink/0/doc/172522/Electronic.aspx?searchid=da8f2c6c-3efa-48d6-a43e-892b5c2bd750

III. Recreational Flow Assessment

A primary component of American Whitewater's 2016 San Miguel Flow Study involved collecting paddler feedback though a Flow-Evaluation Survey (Survey). American Whitewater employed a normative approach using survey-based techniques to collect and organize evaluative information from study participants. This approach is useful for developing thresholds, or standards, that define low, acceptable, and optimal resource conditions for whitewater boating. Thresholds are crucial elements in any effective management or decision-making process (Shelby et al. 1992). The approach examines individual's evaluations of a range of resource conditions (personal norms). Social Norms, developed by aggregating personal norms, describe the group's collective evaluation of resource conditions. This approach has been used to understand streamflows for whitewater boating on the Grand Canyon of the Colorado (Shelby et al. 1992), as well as other high-value recreational river segments in the Colorado River system (Vandas et al. 1990, Shelby & Whitaker 1995, Fey & Stafford 2015).

Figure 1. San Miguel Sub-basin: Whitewater Boating Study Reaches



(Image: Seth Mason, Lotic Hydrological, LLC)

Methods and Locations

Using a web-based survey tool[3], two sets of Survey questions were presented to respondents for which each participant evaluated flows for each study segment, relative to specific US Geological Survey streamflow gages. One set of questions collected information that was used to develop overall flow-evaluation curves (impact acceptability curves), and another set of questions helped identify and explain various points on those same curves.

Overall Flow Evaluations

Overall flow evaluation questions asked respondents to evaluate recreation quality for specific measured flows on each study segment, using a five-point "acceptability" scale (unacceptable -2, slightly unacceptable -1, Marginal 0, Slightly Acceptable 1, Acceptable 2). Aggregate responses are plotted for each flow level, to create a curve. This graphic representation of flows, in most cases, show a bell-shape curve where low flows and high flows provide lower recreational conditions, while medium flows provide more optimal conditions.

Single Flow Judgements

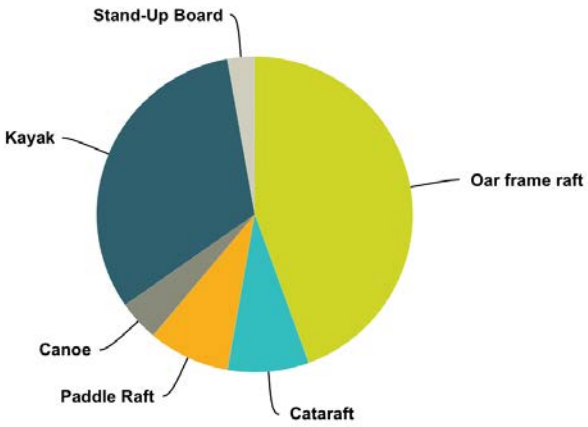
To further explore and characterize the relationship between flows and recreational opportunities described by Flow-curves, American Whitewater presented study participants with a second series of questions for each study segment, each requiring an open-response. Participants reported a single flow-value that provides a distinct class, or "niche" paddling experience along a spectrum: lowest navigable, lowest acceptable, technical, standard, high challenge, and highest safe flow. By aggregating responses to each "niche", median flow values are calculated and then applied to the flow-evaluation curves - refining points along the curve identified as providing distinct whitewater recreation opportunities in relation to the full range of streamflows studied.

A copy of the online Flow-Evaluation Survey, including both sets of questions, is attached (Appendix A). When compiled, the results from these study approaches describe how flows affect recreation quality and identify the range of streamflows that provide whitewater recreation opportunities for each study segment.

An announcement of the survey was emailed to American Whitewater's members within a 40-mile radius of the San Miguel River – including the municipalities of Montrose, Durango, Telluride, Norwood, and Cortez. The announcement was also distributed via American Whitewater's online newsletter. Respondent numbers for the 2016 San Miguel River Flow Survey reflect a valid number of participants for a generally remote or sparsely populated region of western Colorado. For the survey n = 72, where 81% of respondents identified themselves as advanced or expert paddlers, and 93% paddle at least 5-20+ days per season. A wide range of craft types were surveyed with oar frame rafts (45%), kayaks (32%), catarafts (8%), canoes (4%), paddle rafts (8%) and stand-up paddle boards (3%) all represented.

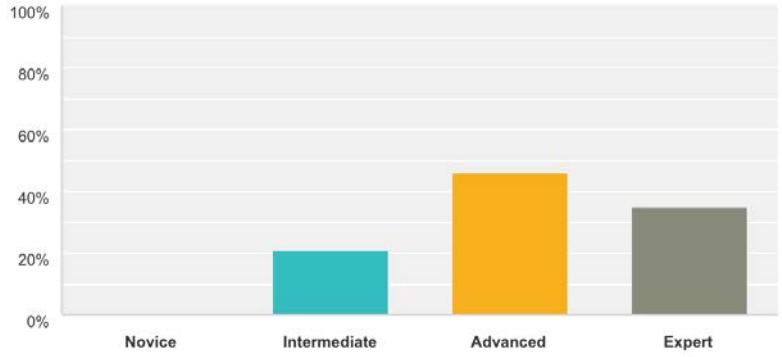
[3] www.surveymonkey.com/

Figure 2. Respondent by Craft Type



Answer Choices	Responses	
Oar frame raft	44.44%	32
Cataraft	8.33%	6
Paddle Raft	8.33%	6
Canoe	4.17%	3
Kayak	31.94%	23
Stand-Up Board	2.78%	2
Total		72

Figure 3. Respondent Skill Level

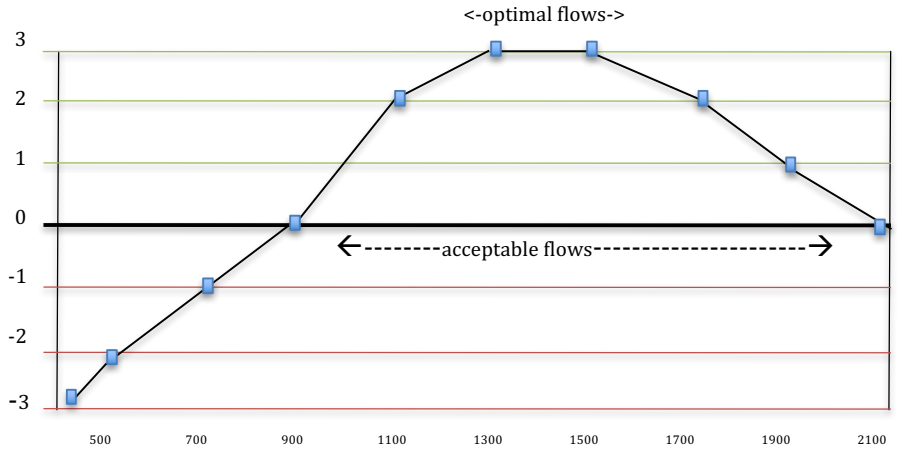


Answer Choices	Responses	
Novice	0.00%	0
Intermediate	20.83%	15
Advanced	45.83%	33
Expert	34.72%	25
Total Respondents: 72		

Structural norm approach

The structural norm model describes norms (evaluative standards) by means of a graphic device referred to as an impact acceptability curve (refer to Vaske et al., 1986 and Shelby et al., 1996 for a complete discussion). The curves describe social norms in terms of averages of individual evaluations. Impacts are displayed on a horizontal axis, with impact increasing from left to right (Figure 4). Evaluation is displayed on the vertical axis, with positive evaluations on the top, negative evaluations on the bottom, and a neutral category in between. The curve can be analyzed for various normative characteristics, including optimum conditions, the range of acceptable conditions, the intensity or strength of the norm, and the crystallization or level of agreement about the norm (Vaske et al., 1986; Shelby et al., 1996).

Figure 4: Example Flow-Curve, 7-Point Impact Acceptability



The high point of the curve corresponds with the optimum or best resource conditions (in this case, steamflow) or the conditions receiving the most positive impact evaluation (+3). Normative evaluations that lie above the neutral line (0), define the range of acceptable resource conditions (see Figure 1; 900-2100 cfs). The relative distance of the curve above or below the neutral line describes norms of higher or lower intensity. Finally, the variation among evaluations at each impact level shows the amount of agreement or crystallization

The approach has been applied extensively to natural resource issues, often with respect to instream flows for recreation (Shelby and Whittaker, 1995; Shelby et al., 1992a; Vandas et al., 1990; Whittaker and Shelby, 2002b). Other applications have extended this approach to different indicators and impacts such as encounter norms that describe how many people are considered to be too many in a given setting (refer to Donnelly et al., 2000; Manning, 2011; Shelby et al., 1996; Vaske & Donnelly, 2002; Vaske et al., 1986, for reviews), campsite impacts or site sharing (Heberlein and Dunwiddie, 1979; Shelby, 1981), fishing site competition (Martinson and Shelby, 1992; Whittaker and Shelby, 1993), discourteous behavior (Whittaker and Shelby, 1988, 1993; Whittaker et al., 2000), and resource indicators such as litter and campsite impacts (Shelby et al., 1988; Vaske et al., 2002).

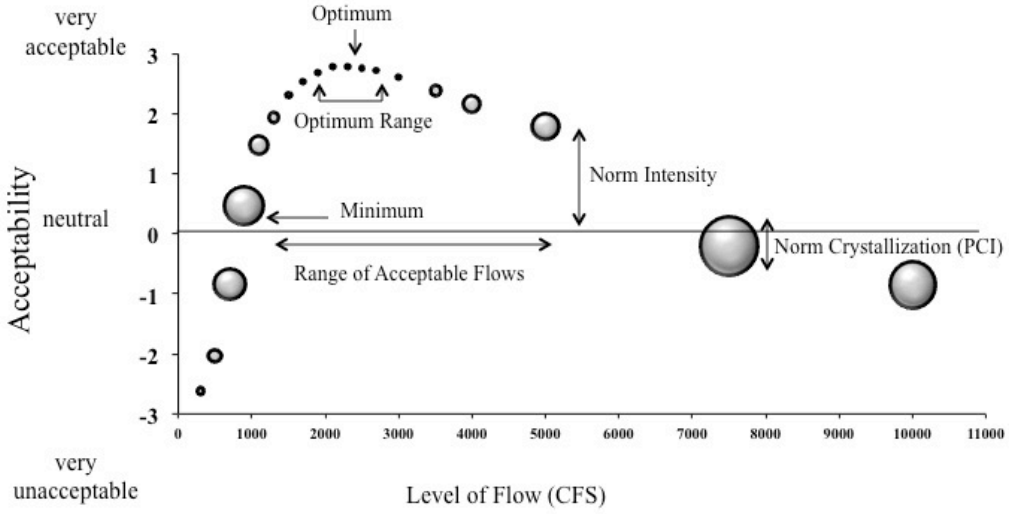
Norm crystallization and Potential for Conflict Index

Defining management standards is often more efficient if there is a high degree of norm crystallization, or consensus, regarding acceptable and unacceptable resource conditions such as streamflow. Traditional measures of norm crystallization have included the standard deviation, coefficient of variation, and interquartile range (Krymkowski et al., 2009; Manning, 2011; Shelby and Vaske, 1991). All of these measures, however, have limitations, and the Potential for Conflict Index$_2$ (PCI_2) was developed to help address these concerns and facilitate understanding and applicability of human dimension findings to managerial concerns.

Although specifics of the PCI_2 are beyond the scope of this report, a detailed description of this statistic is reported in Vaske et al. (2010). In general, the PCI_2 ranges from 0 to 1. The least amount of consensus ($PCI_2 = 1$) occurs when responses are equally divided between two extreme values on a response scale (e.g. 50% extremely unacceptable, 50% extremely acceptable). A distribution with 100% at any one point on the response scale yields a PCI_2 of 0 and suggests unanimous consensus among respondents (see Table 2, row 1).

The PCI_2 results can be displayed using graphs similar to impact acceptability curves (Figure 4). Degree of consensus is illustrated as bubbles where the size of bubble depicts the magnitude of PCI_2 and indicates the extent of crystallization/consensus regarding acceptance of a particular issue (i.e. degree of dispersion). A small bubble represents high crystallization, and a larger bubble represents low crystallization. The center of the bubble represents the mean evaluative response as plotted on the vertical axis, and these points can be joined to form a curve similar to an impact acceptability curve (i.e. central tendency). The bubble's location relative to the neutral point illustrates whether the distribution of acceptance of an impact value (flow) is skewed (Vaske et al., 2010). This method combines the structural norm approach with the PCI_2 to better describe flow-level evaluations.

Figure 5. Example impact acceptability curve with Potential for Conflict Index ($PCI_{2)}$



Results and Discussion

By collecting and organizing survey responses, American Whitewater determined the range of both acceptable and optimal flows on each San Miguel study segment. Acceptable flows are reported to provide a range of resource conditions that directly influence the degree of difficulty, quality of rapids, challenge and enjoyment, from lowest flow to highest flow. Optimal Flows are reported to provide the most desirable conditions for the greatest number of users. The minimum acceptable flow is defined as "the lowest flow you would return to paddle in your preferred craft", not the minimum flow that allows you to navigate the section. At flow levels outside the range of acceptable flows (too low or too high), a percentage of respondents reported they would not make the trip to the river to boat. Conversely, for flows that exist within the optimal range, a significant percentage of respondents indicated they would invest time to return to the river to paddle at those flows.

Potential for Conflict Index data reflect extremely high levels of agreement for optimal flows while some level of disagreement among respondents is apparent at low and high flow values. Figure 5 below, graphically represents the Flow Curve and PCI_2 for the Naturita to Dolores River Confluence Study Segment. While optimal flows are clearly defined, there is disagreement over minimum and higher flows (shown here by PCI_2 bubbles), attributed in past studies to variations in flow preferences for individuals "niche" paddling experiences, and preferences between craft-types, such as kayaks and larger rafts.

Figure 6. Impact acceptability curve with Potential for Conflict Index (*PCI_2*)
San Miguel River, Naturita to Confluence at USGS San Miguel River at Uravan, CO gage

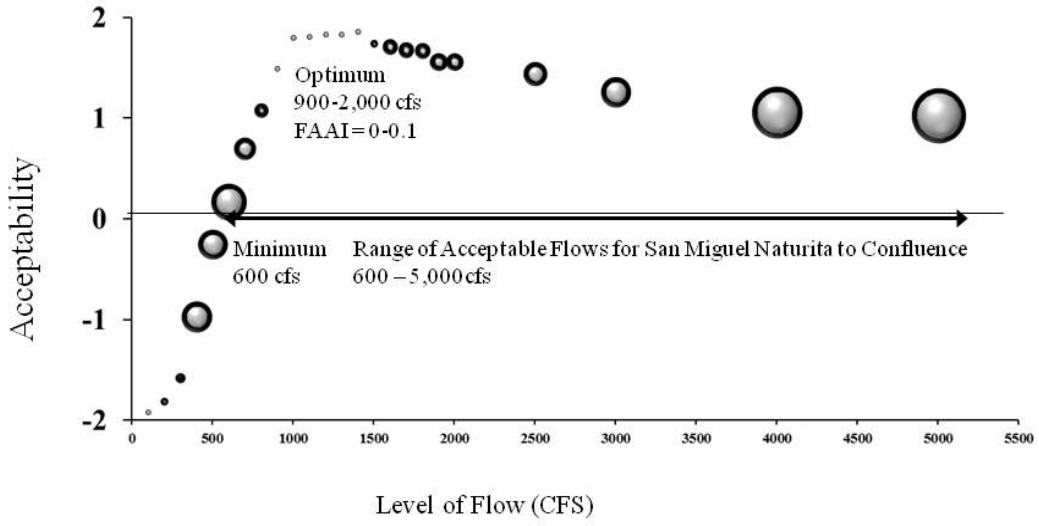


Table 1. San Miguel River Naturita to Confluence Mean Acceptability Scores and PCI_2
(Flows represented are flow levels at USGS San Miguel River at Uravan, CO gage)

Specific Flow CFS	Mean Acceptability	PCI_2
100	-1.92	0
200	-1.81	0.07
300	-1.58	0.09
400	-0.97	0.28
500	-0.25	0.27
600	0.17	0.33
700	0.7	0.2
800	1.08	0.13
900	1.49	0
1000	1.8	0
1100	1.81	0
1200	1.83	0
1300	1.83	0
1400	1.86	0
1500	1.74	0.07
1600	1.71	0.14
1700	1.68	0.14
1800	1.67	0.14
1900	1.56	0.16
2000	1.56	0.16
2500	1.44	0.22
3000	1.26	0.28
4000	1.06	0.47
5000	1.03	0.5

Acceptable and optimal flows are currently enjoyed for at least part of the recreation season, during all year types, on all San Miguel River segments analyzed. Minimum acceptable flows for the segments highest in the drainage, Bilk Creek to Down Valley Park, Down Valley to Specie Creek, and Specie Creek to Beaver Creek were found to be 500cfs, while for segments further downstream, Beaver Creek to Pinon Bridge, Pinon Bridge to Naturita and Naturita to the Dolores Confluence, a slightly higher minimum acceptable flow of 600 cfs was found. *Optimal* flow preferences range between 800 – 2,000cfs, while the full range of acceptable flows ranges from 500 - 5,000+ cfs for all segments analyzed (Table 2). Mean acceptability for high flows never crossed below the neutral line, even up to 5,000 cfs, suggesting that flows in the San Miguel never exceed levels that are too high to meet preferred experiences for most recreational users and study participants.

Table 2. Minimum, Optimal and Range of Acceptable Flows for San Miguel River, by Segment

USGS Gage	San Miguel River Segment	Minimum Flow (CFS)	Optimal Flows (CFS)	Range of Acceptable Flow (CFS)
Placerville	Bilk to Down Valley	500	800 – 2,000	500 – 5,000
Placerville	Down Valley to Specie	500	800 – 2,000	500 – 5,000
Placerville	Specie to Beaver	500	800 – 2,000	500 – 5,000
Brooks Bridge	Beaver to Pinon	600	900 – 2,000	600 – 5,000
Brooks Bridge	Pinon to Naturita	600	1,000 – 2,000	600 – 5,000
Uravan	Naturita to Confluence	600	900 – 2,000	600 – 5,000

IV. Boatable Days Analysis

Quantifying Whitewater Boating Opportunities

Boatable Days is the dominant metric most relevant to managing for flow-dependent recreation opportunities. Evaluations of defined whitewater recreation flows within hydrologic year types describe the number of recreation opportunities, or 'boatable days' within acceptable and optimal flow ranges. Boatable Days have been used to protect, mitigate, or enhance paddling opportunities, where a quantitative metric can be applied (Fey and Stafford, 2009; Shelby and Whittaker, 1995; Whittaker et al., 1993).

American Whitewater's Boatable Days approach, evaluates the frequency of defined acceptable and optimal flows against the hydrologic record for a specific data point. The Boatable Days analysis generates the number of days when resource conditions (streamflow) meet whitewater recreation needs based on flow criteria (determined though survey responses of river users). The resulting metric improves comparability across water rights development scenarios, or other decision-settings where whitewater recreation may conflict with other demands for water resources.

American Whitewater used a 16-year study period from 1995 through 2010, based on similar stream gaging data used by Deere & Ault Consulting in its investigation of unappropriated water availability in western Montrose County associated with each water rights alternative. For this Boatable Days analysis, two gage sites were used as data points - the USGS San Miguel River at Brooks Bridge near Nucla, CO and San Miguel River at Uravan, CO.

Given the variability of historic and future hydrologic conditions in the San Miguel basin, American Whitewater evaluated Boatable Days by hydrologic year type - dry, dry-typical, wet-typical, and wet years classified as $<25^{th}$, $25\text{-}50^{th}$, $50\text{-}75^{th}$, and $>75^{th}$ percentiles respectively. Hydrologic year types for the study period are defined by ranking the total annual volumetric flow (in acre-ft) at the Uravan gage (1954-PRESENT) for the years 1975-2010 and then sorting the total annual flow volumes into quartiles. The period of record utilized in this study, 1995-2010, was then sorted into year types that correspond to the Total Annual volume measured at the Uravan gage for the 1975 – 2010 period of record. By categorizing the 16-year period of record into year types in this way, we end up with an uneven number of years representing each year type, however this approach is

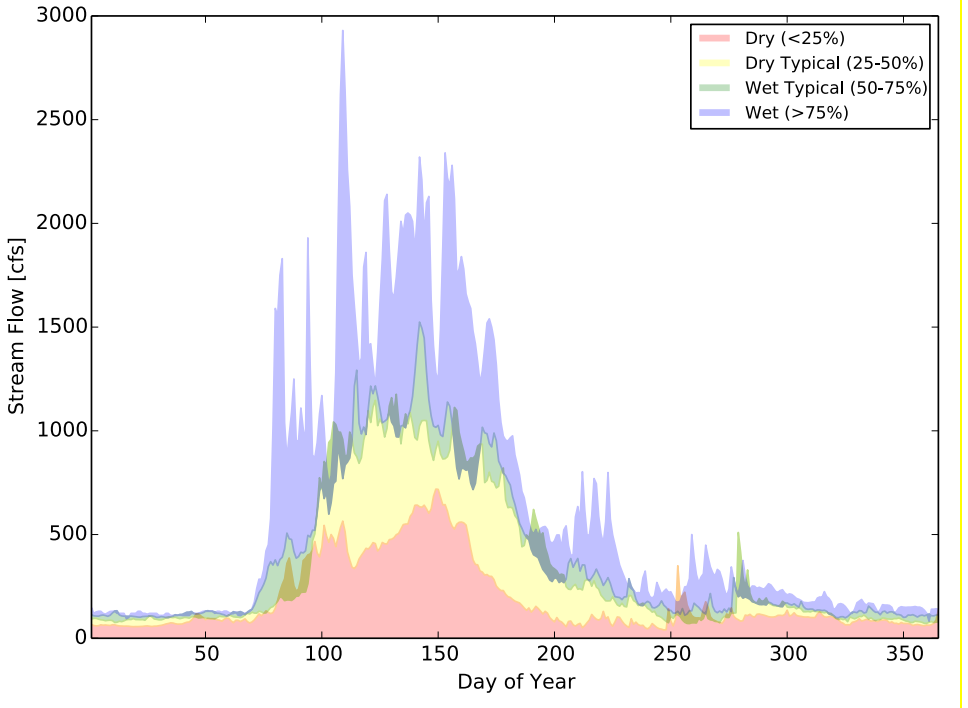
more representative of historical hydrologic conditions in the San Miguel basin, as described by a longer representative study period.

Table 3. Period of Record, sorted by year type - USGS San Miguel River at Uravan, CO gage

Dry	Dry Typical	Wet Typical	Wet
2001	1995	1996	1997
2002	2000	1998	
2003	2006	1999	
2004	2009	2005	
	2010	2007	

The hydrograph in Figure 6 illustrates four hydrologic year-types for the San Miguel River Naturita to Confluence study segment (USGS San Miguel River at Uravan, CO gage). After organizing hydrologic data from 1995-2010 by year type, daily streamflows are compared against preferred flow ranges defined by user surveys described earlier. A Boatable Day is recorded when streamflow measurements fall within the preferred flow range for a particular experience class (e.g. the range of optimal flows) on a particular day. The same analysis was completed for every day of the study period in all year types and for the range of preferred flows for every flow class (low acceptable, optimal, and high acceptable levels). The Boatable Days in each flow class were then aggregated by year, for comparison.

Figure 7. Hydrology – San Miguel River Naturita to Confluence (1995-2010) year types (wet, wet typical, dry typical, and dry) ranked by annual volume at USGS San Miguel River at Uravan, CO gage



The San Miguel currently provides a great number of Boatable Days (days with at least minimum acceptable flows to support whitewater recreation), especially in wet year types, with all six

segments studied boasting at least 110 Boatable Days in very wet years. In typical wet years four of the segments have at least 77 Boatable Days, though the lower San Miguel has significantly greater days within wet-typical conditions (86). In very dry years there are significantly less Boatable Days, however on four of the segments there are still at least 31 days where flows are on average above minimum acceptable levels. In typical dry years, there are fewer Boatable Days than in typical wet years, but four of the six segments still have at least 63 Boatable Days. (see Table 4)

Table 4. Average Annual Boatable Days, or annual days when flows meet or exceed minimum acceptable flows, by year type* for San Miguel River Segments

USGS Gage	San Miguel River Segment	Average Boatable Days by Year Type*			
		Dry	Dry Typical	Wet Typical	Wet
Placerville	Bilk to Down Valley	31	63	77	125
Placerville	Down Valley to Specie	31	63	77	125
Placerville	Specie to Beaver	31	63	77	125
Brooks Bridge	Beaver to Pinon	20	50	62	110
Brooks Bridge	Pinon to Naturita	20	50	62	110
Uravan	Naturita to Confluence	33	64	86	116

**Year types are classified by hydrologic years 1975-2010 at the USGS Uravan Gage, divided into quartiles by yearly volume in cfs (data analyzed is from 1995-2010).*

Quantifying a Change in Boatable Days

The Boatable Days analysis allows for assessing the affect that future reductions in flow, attributed to new projects, will have on boatable days available for whitewater users on the San Miguel. This method allows for a simple sensitivity analysis using historic flow data – in this study 1995-2010 data – using a percent reduction/increase, or specific reduction(cfs) to historic flows, as provided by Deere & Ault Consulting in this study. A percent reduction sensitivity analysis reduces streamflow data within any period of record by a given percentage or flow rate, and recalculates the number of days when boatable flows are available for any given study reach, as the change from current conditions.

The conditional water rights Montrose County adjudicated in the Consolidated Decree contemplate diversion and storage of tributary sources of water that enter the lower San Miguel River. In the case of Big Bucktail Reservoir, additional water from direct diversion from the San Miguel River at the Colorado Cooperative Company's Highline Canal is proposed. In this analysis of Montrose County's conditional water rights, we look at only three project scenarios prepared by Deere & Ault Consulting for Montrose County:

1. *Big Bucktail Reservoir: 6,100 acre-feet, conditional; together with a right to successive refills in the cumulative amount of 12,200 acre-feet, conditional, with a rate of filling the reservoir from the San Miguel River of 135 cfs. The sources of water include Big Bucktail Creek and San Miguel River through the Highline Canal.*

2. *Maverick Draw Reservoir No. 1: 6,700 acre-feet, conditional; together with a right to successive refills in the cumulative amount of 6,700 acre-feet, conditional. The source*

of water for the conditional storage right is Maverick Draw, a tributary of Naturita Creek which is a tributary of the San Miguel River.

3. *Maverick Draw Reservoir No. 2: 5,600 acre-feet, conditional; together with a right to successive refills in cumulative amount of 5,600 acre-feet, conditional. The source of water for the conditional storage right is Maverick Draw, a tributary of Naturita Creek which is a tributary of the San Miguel River.*

Deere & Ault developed the "Montrose County Operations Model" (Operations Model) to simulate the ability of the conditional water rights to meet water demands of the west end of Montrose County. D&A utilized the Operations Model to investigate different reservoir project scenarios (alternatives) to meet increased water demands of 3,200 acre-feet per year (plus reservoir evaporation) between 2010 and 2060.

D&A has prepared a separate report for Montrose County, that provides detailed investigations and elements of proof for the water rights application, including Operations Model calculations of daily direct flow diversions and diversions into storage. The sums of these diversions, minus return flows to the San Miguel River, represents depletions to the San Miguel River used in American Whitewater's analysis of Boatable Days.

American Whitewater evaluated the change to current Boatable Days (1995-2010) from depletions, at two locations along the San Miguel River:

1) Depletion that occurs above the Brooks Bridge gage. The depletion is a result of diversions at the CC Ditch headgate for filling Big Bucktail Reservoir or direct-flow diversions for meeting demand at the Mustang Water Authority plant (i.e., Nucla and Naturita municipal demand) and,

2) Net depletion that occurs at the Uravan gage. This depletion represents the total depletion that is a result of the diversions at the CC Ditch, Nucla Power Plant, Paradox Valley pipeline, etc. The net value has been adjusted for the return flows that accrue at Naturita as a result of the municipal return flows (i.e., effluent, irrigation return flows, etc.).

American Whitewater compared the percent change in flow, and simulated daily depletions (cfs) for the water years 1995-2010, at both the USGS San Miguel River at Brooks Bridge near Nucla, CO and San Miguel River at Uravan, CO gages, to actual 1995-2010 data for the three distinct whitewater recreation segments of the San Miguel that would potentially be effected by Montrose County's conditional water rights (Beaver Creek to Pinon Bridge, Pinon Bridge to Naturita and Naturita to Dolores Confluence). For this analysis, we additionally calculate 5% and 10% flow reduction, as additional reference thresholds.

Table 5. Average annual depletions modeled by D&A, by Alternative.

Scenario	Reservoir	Average Depletion (cfs)	Average Annual Change in Flow (%)
Alternative 1	Big Bucktail	-3.31cfs	-0.97%
Alternative 2	Maverick Draw No. 1	-3.72cfs	-1.09%
Alternative 3	Maverick Draw No. 2	-4.01cfs	-1.17%

Analysis of Scenario One (Alt1), Big Bucktail Reservoir, Scenario Two (Alt2), Maverick Draw Reservoir No. 1, and Scenario Three (Alt3), Maverick Draw Reservoir No. 2, using simulated daily depletion files (1995-2010), result in little or no effect on whitewater recreation opportunities across all three segments and across all four year-types analyzed. In dry year types a 1-day *increase* in Boatable Days is predicted for the Naturita to Dolores confluence segment (Table 6).

Table 6. Current, Predicted Alternatives Reduction*, and 5% and 10% Reduction in Annual Boatable Days, by year type for San Miguel River Segments

Year Type	Alternative	USGS Gage and San Miguel Boatable Days by River Segment		
		Brooks Bridge Gage		Uravan Gage
		Beaver to Pinon	Pinon to Naturita	Naturita to Confluence
Dry	1995-2010	20	20	33
	Alt1	20	20	34
	Alt2	20	20	34
	Alt3	20	20	34
	.95	18	18	28
	.90	16	16	24
Dry Typical	1995-2010	50	50	64
	Alt1	50	50	64
	Alt2	50	50	64
	Alt3	50	50	64
	.95	47	47	60
	.90	43	43	57
Wet Typical	1995-2010	62	62	86
	Alt1	62	62	86
	Alt2	62	62	86
	Alt3	62	62	86
	.95	55	55	80
	.90	50	50	76
Wet	1995-2010	110	110	116
	Alt1	110	110	116
	Alt2	110	110	116
	Alt3	110	110	116
	.95	109	109	114
	.90	107	107	113

**Predicted alternative reductions (Alt1- Alt3) are based on the Montrose County depletions analysis workbook's daily depletions files, prepared by Deere and Ault.*

The effect that modeled daily reductions to streamflow may have on yearly Boatable Days can be assessed for each "niche" opportunity – defined as low, optimal and high streamflow conditions. This analysis is detailed by year type for each San Miguel River segment potentially impacted by depletion that occurs at the Uravan gage, and depletions that occur above the Brooks Bridge gage. For each study segment, all three Alternatives are shown to have little to no change in annual Boatable Days. In dry-typical years, a 1-day *increase* in low flow Boatable Days is predicted for the San Miguel, Naturita to Dolores Confluence segment (Table 7). For the San Miguel Pinion to Naturita segment, a 1-day *increase* in low flow Boatable Days occurs in wet-typical years (Table 8). Above the CCC Ditch and Highline Canal; San Miguel River Beaver Creek to Pinion, no change to Boatable Days was predicted (Table 9).

Table 7. Current, Predicted Alternative Change*, and 5% and 10% Reduction in Annual Boatable Days for low, optimal and high recreation conditions, by year type. San Miguel River, Naturita to Confluence with the Dolores River.

Year Type	Scenario	San Miguel Boatable Days for Naturita to Confluence			
		USGS Gage Uravan			
		Low	Optimal	High	Non-Boatable Days
Dry	1995-2010	25	9	0	331
	Alt1	25	9	0	331
	Alt2	25	9	0	331
	Alt3	25	9	0	331
	.95	22	6	0	337
	.90	21	3	0	341
Dry Typical	1995-2010	22	36	6	268
	Alt1	23	36	6	267
	Alt2	23	36	6	267
	Alt3	23	36	6	267
	.95	21	35	4	305
	.90	21	34	2	308
Wet Typical	1995-2010	41	42	3	279
	Alt1	41	42	3	279
	Alt2	41	42	3	279
	Alt3	41	42	3	279
	.95	41	36	3	285
	.90	42	32	2	289
Wet	1995-2010	18	76	22	249
	Alt1	18	76	22	249
	Alt2	18	76	22	249
	Alt3	18	76	22	249
	.95	17	83	14	251
	.90	26	80	7	252

Table 8. Current, Predicted Alternative Reduction*, and 5 and 10% Reduction Yearly Boatable Days for low, optimal and high recreation conditions, by year type. San Miguel River Segment Pinon to Naturita.

Year Type	Alternative	San Miguel Boatable Days for Pinon to Naturita			
		USGS Gage Brooks Bridge			
		Low	Optimal	High	Non-Boatable Days
Dry	1995-2010	19	1	0	345
	Alt1	19	1	0	345
	Alt2	19	1	0	345
	Alt3	19	1	0	345
	.95	18	1	0	346
	.90	16	0	0	349
Dry Typical	1995-2010	24	25	1	315
	Alt1	24	25	1	315
	Alt2	24	25	1	315
	Alt3	24	25	1	315
	.95	23	23	1	318
	.90	22	20	1	322
Wet Typical	1995-2010	46	15	0	304
	Alt1	47	15	0	303
	Alt2	47	15	0	303
	Alt3	47	15	0	303
	.95	42	12	0	311
	.90	40	10	0	315
Wet	1995-2010	38	70	2	255
	Alt1	38	70	2	255
	Alt2	38	70	2	255
	Alt3	38	70	2	255
	.95	42	67	0	256
	.90	42	65	0	258

Table 9. Current, Predicted Alternative Reduction*, and 5 and 10% Reduction
Yearly Boatable Days for low, optimal and high recreation conditions, by year type.
San Miguel River, Beaver to Pinon.

Year Type	Alternative	San Miguel Boatable Days for Beaver to Pinon			
		USGS Gage Brooks Bridge			
		Low	Optimal	High	Non-Boatable Days
Dry	1995-2010	18	2	0	345
	Alt1	18	2	0	345
	Alt2	18	2	0	345
	Alt3	18	2	0	345
	.95	17	2	0	346
	.90	15	1	0	349
Dry Typical	1995-2010	19	30	1	315
	Alt1	19	30	1	315
	Alt2	19	30	1	315
	Alt3	19	30	1	315
	.95	18	28	1	318
	.90	17	26	1	321
Wet Typical	1995-2010	38	23	0	304
	Alt1	38	23	0	304
	Alt2	38	23	0	304
	Alt3	38	23	0	304
	.95	35	20	0	310
	.90	35	15	0	315
Wet	1995-2010	32	76	2	255
	Alt1	32	76	2	255
	Alt2	32	76	2	255
	Alt3	32	76	2	255
	.95	35	74	0	256
	.90	35	72	0	258

V. Opinions and Conclusion

This report summarizes the analyses conducted by American Whitewater to assist Deere & Ault Consulting in their assessment of impacts to whitewater recreation in the Lower San Miguel River, attributed to consolidated water rights applications filed by Montrose County, Colorado in 2010.

Section 1 of the report describes the conceptual framework for assessing flows for recreation developed by American Whitewater, Confluence Research and Consulting, and Oregon State University. **Section 2** of the report summarizes American Whitewater's 2016 San Miguel River study in the context of the Colorado Water Conservation Board's application for instream flow rights in the Lower San Miguel River, and subsequent conditional water rights filed by Montrose County in 2010. Section 2 also contextualized the study approach and application of the resulting data into implementation of the Colorado Water Plan and the Southwest Basin Roundtable's Basin Implementation Plan.

Section 3 of the report discusses study locations, and methods used to collect and analyze paddler feedback through a Flow-Evaluation survey. The Study follows the State of Colorado's Basin Implementation Plan recommended guidance for quantifying non-consumptive recreational needs, and combines personal evaluations of recreation quality and the structural norm approach; a technique used to graphically represent group evaluations of resource conditions. Flow-Evaluation or Impact Acceptability Curves, describe optimal flows, the range of acceptable flows, norm intensity and level of norm agreement among survey respondents, for five segments of the San Miguel River.

Section 4 applies American Whitewater's Boatable Day metric to identify the quantity and timing of whitewater boating opportunities in the San Miguel River. The metric is used in this study to evaluate the impact to current recreation opportunities (described as Boatable Days) under three water supply project alternatives proposed by Montrose County. Using data provided by Deere & Ault Consulting, the predicted reductions in flow conditions attributable to Montrose County's 2010 Water Rights.

Developing the Boatable Days metric provides the best quantification of river-related recreation opportunities in the San Miguel Basin and enables decision-makers to assess and address the impacts to whitewater boating attributes attributable to future water rights development and water demand scenarios. There are strong economic reasons why integration of this data is defensible and advisable. Whitewater boating in the San Miguel sub-basin, state of Colorado and seven-state Colorado River basin delivers substantial economic benefits to local and regional economies. In the San Miguel sub-basin, commercial rafting alone generated $1.7M in economic impact in 2015 (Greiner, 2015). Commercial rafting in the state of Colorado generated $161,505,808 in economic impact, and supports 2,600 jobs (Loomis, 2008). At the Colorado River basin scale, river-related recreation supports 25,000 jobs and produces $26 billion in economic output (Southwick, 2012).

American Whitewater opinions are stated throughout the report; however, the primary opinions of the researchers are set forth below:

1) Respondent numbers for the 2016 San Miguel River Flow Survey reflect a valid number of participants for a generally remote or sparsely populated region of western Colorado.

2) The range of both acceptable and optimal flows are defined for each segment of the San Miguel addressed in this study. Minimum acceptable flows for the segments highest in the drainage, Bilk Creek to Down Valley Park, Down Valley to Specie Creek, and Specie Creek to Beaver Creek were found to be 500cfs, while for segments further downstream, Beaver Creek to Pinon Bridge, Pinon Bridge to Naturita and Naturita to the Dolores Confluence, a slightly higher minimum acceptable flow of 600 cfs was found. *Optimal* flow preferences range between 800 – 2,000cfs, while the full range of acceptable flows ranges from 500 - 5,000+ cfs for all segments analyzed. At no point in the period of record used in the study, have flows in the San Miguel exceeded levels that provide whitewater recreation opportunities.

3) The San Miguel currently provides a great number of Boatable Days, especially in wet year types, with all study segments providing at least 110 Boatable Days in very wet years. In wet-typical years, four of the segments have at least 77 Boatable Days, though the lower San Miguel has significantly greater days under wet-typical hydrology (86). In very dry years there are significantly less Boatable Days, however on four of the segments there are still at least 31 days where flows are above minimum acceptable levels, on average.

4) The storage and direct diversion scenarios associated with Montrose County's water right applications, are found to have little to no effect on whitewater recreation opportunities on the lower San Miguel River. The predicted change in Boatable Days in relation to current flow conditions, is predicted to cause no impact to the quantity of whitewater recreation opportunities that are available in the San Miguel Basin under current conditions (1995-2010).

Additional Discussion

As a follow-up to the Boatable Days calculation based on year type classifications, researchers also calculated Boatable Days by a monthly volume classification. This new methodology is still in development but we applied these results to cross check the conclusions regarding the effect of flow reductions on whitewater recreation opportunities on the lower San Miguel River. This monthly classification approach, calculates the average monthly flow and then sorts each month by hydrologic condition (i.e. the 25th percentile of all January flows at that the Uravan gage) across the same years in the yearly classification study (1995-2010). The results of the monthly classification were used to calculate the average number of boatable days per month (for each threshold: low/optimal/high) for each hydrological classification (i.e. dry, dry typical, wet typical and wet) and yielded the same conclusion of little to no effect on whitewater recreation opportunities on the lower San Miguel River.

Whitewater Paddling the Lower San Miguel River, Colorado.
Photo, Ben Saheb

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Appendix A: Online Flow Evaluation Survey

As an example of the web-based Flow Evaluation Survey utilized by American Whitewater to collect paddler feedback of flows and recreation quality, both sets of study questions are provided here for the Naturita to Dolores confluence study segment.

Overall Flow Evaluation Questions

4. Comparing Whitewater Flows for Naturita to the Dolores River Confluence (Uravan Section)

For the questions on this page please rate the quality of the run in your particular craft, at each identified flow. Please pay particular attention to the gage referred to and **respond with acceptable flows for that gage only.**

17. Please report the quality of the following flows for Naturita to the Dolores River Confluence (Uravan Section) of the San Miguel River for your craft and skill level. Please consider all the flow-dependent characteristics that contribute to a high quality trip (e.g., boatability, whitewater challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For more information on this stretch of river visit: http://americanwhitewater.org/content/River/detail/id/10895/
Flows represented are for the USGS 09177000 SAN MIGUEL RIVER AT URAVAN, CO gage

	Unacceptable	Slightly Unacceptable	Marginal	Slightly Acceptable	Acceptable
100	◯	◯	◯	◯	◯
200	◯	◯	◯	◯	◯
300	◯	◯	◯	◯	◯
400	◯	◯	◯	◯	◯
500	◯	◯	◯	◯	◯
600	◯	◯	◯	◯	◯
700	◯	◯	◯	◯	◯
800	◯	◯	◯	◯	◯
900	◯	◯	◯	◯	◯
1000	◯	◯	◯	◯	◯
1100	◯	◯	◯	◯	◯
1200	◯	◯	◯	◯	◯
1300	◯	◯	◯	◯	◯
1400	◯	◯	◯	◯	◯
1500	◯	◯	◯	◯	◯
1600	◯	◯	◯	◯	◯
1700	◯	◯	◯	◯	◯
1800	◯	◯	◯	◯	◯
1900	◯	◯	◯	◯	◯
2000	◯	◯	◯	◯	◯
2500	◯	◯	◯	◯	◯
3000	◯	◯	◯	◯	◯
4000	◯	◯	◯	◯	◯
5000	◯	◯	◯	◯	◯

Appendix A, continued:

Single Flow Judgements

18. From a recreational perspective what is the lowest flow required to navigate this stretch? (please specify in cfs)

19. From a recreational perspective what is the lowest flow that provides an acceptable experience on this run? The lowest acceptable is the lowest flow you would return to boat in your preferred craft, not the minimum flow that allows you to navigate. (please specify in cfs)

20. Some people are interested in taking trips at lower flows for a technical trip. Think of this "technical trip" in your craft. What is the best or optimal flow for a technical trip? (please specify in cfs)

21. Many people are interested in a "standard" whitewater trip at medium flows. Think of this "standard trip" in your craft. What is the best or optimal flow for a standard trip? (please specify in cfs)

22. Some people are interested in taking trips at higher flows for increased whitewater challenge. Think of this "high challenge trip" in your craft. What is the best or optimal flow for a high challenge trip? (please specify in cfs)

23. What is the highest safe flow for your craft and skill level? (please specify in cfs)

24. What is your preferred craft for running Naturita to the Dolores River Confluence (Uravan Section) of the San Miguel River? (Choose one)

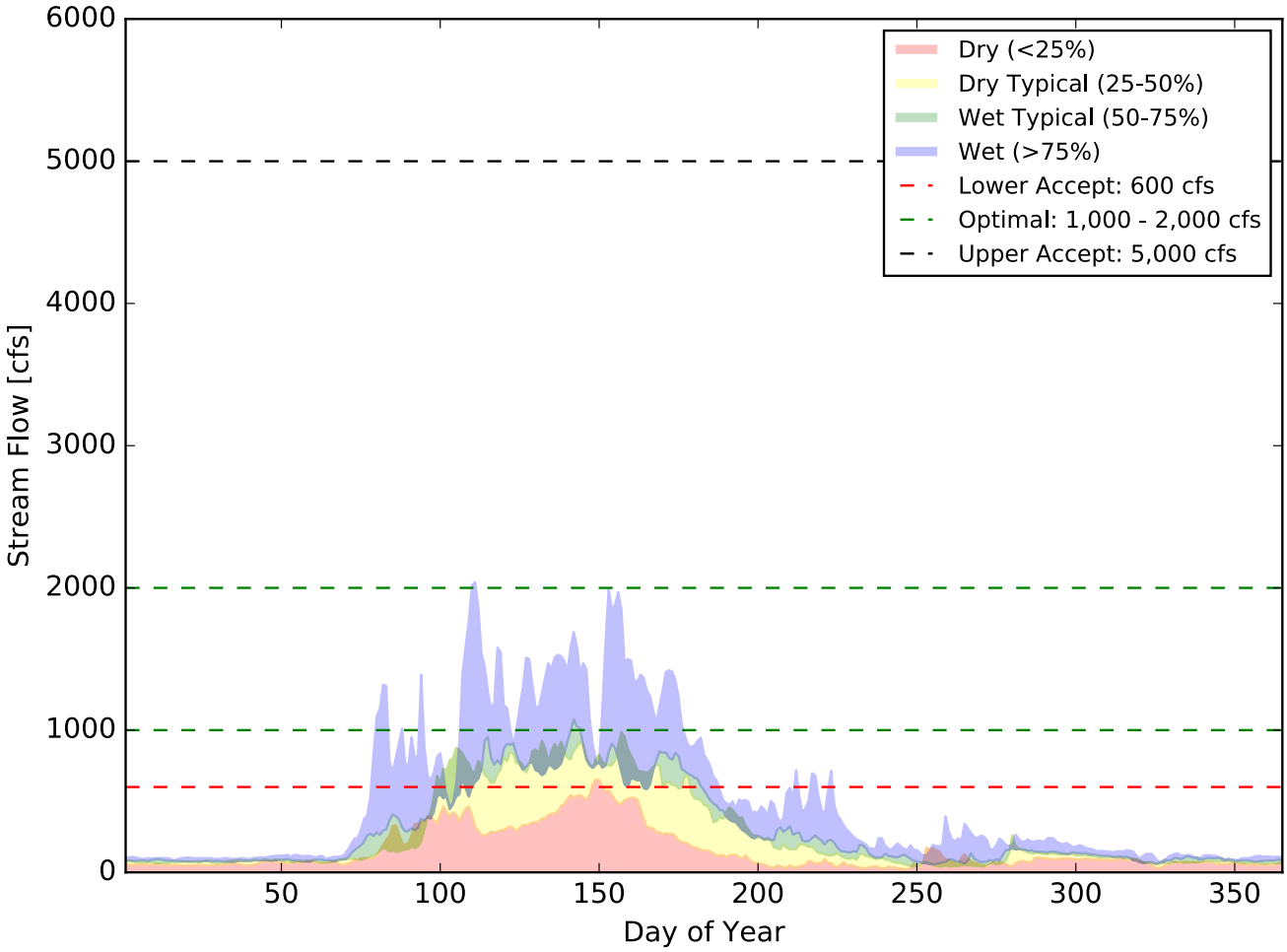
- ☐ Hard shell kayak/canoe
- ☐ Raft/Shredder
- ☐ Inflatable kayak/canoe
- ☐ Open canoe
- ☐ SUP
- ☐ Other (please specify)

25. Do you have any general comments on flows that you feel have not been addressed in the questions we've asked? Specifically if you do not have a good record of flows or dates from when you have run the river please include any qualitative observations on flows needs.

Appendix B:

USGS San Miguel River at Brooks Bridge near Nucla, CO Gage Segments

Figure B1(a) San Miguel River (1995-2010) year types (wet, wet typical, dry typical, and dry ranked by yearly volume in years 1975-2010), with flow thresholds for low, optimal and high, at USGS San Miguel River at Brooks Bridge near Nucla, CO gage.



Pinon to Naturita

Figure B1(b) Impact acceptability curve with Potential for Conflict Index (*PCI_2)* for San Miguel River, Pinon to Naturita at USGS San Miguel River at Brooks Bridge near Nucla, CO gage.

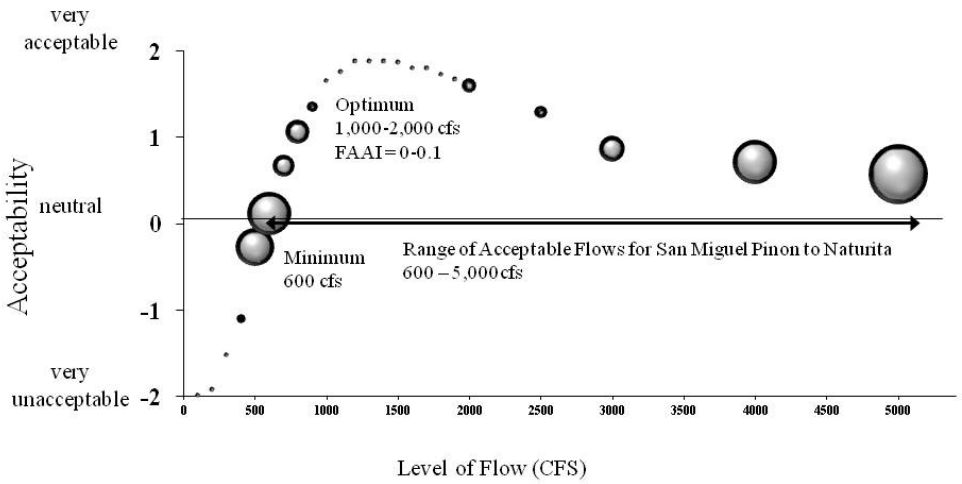


Table B1 San Miguel River Pinon to Naturita Mean Acceptability Scores and PCI_2 (Flows represented are flow levels at USGS San Miguel River at Brooks Bridge near Nucla, CO gage).

Specific Flow CFS	Mean Acceptability	PCI_2
100	100	-2
200	200	-1.93
300	300	-1.53
400	400	-1.11
500	500	-0.28
600	600	0.11
700	700	0.67
800	800	1.06
900	900	1.35
1000	1000	1.65
1100	1100	1.76
1200	1200	1.88
1300	1300	1.88
1400	1400	1.88
1500	1500	1.87
1600	1600	1.8
1700	1700	1.8
1800	1800	1.73
1900	1900	1.67
2000	2000	1.6
2500	2500	1.29
3000	3000	0.86
4000	4000	0.71
5000	5000	0.57

Beaver Creek to Pinon

Figure B2 Impact acceptability curve with Potential for Conflict Index (*PCI_2)* for San Miguel River, Beaver to Pinon at USGS San Miguel River at Brooks Bridge near Nucla, CO gage.

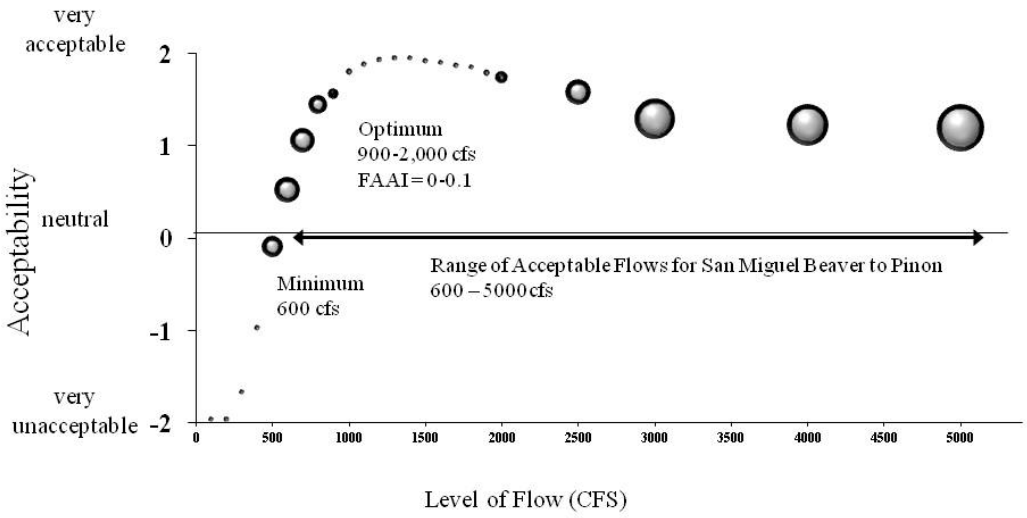
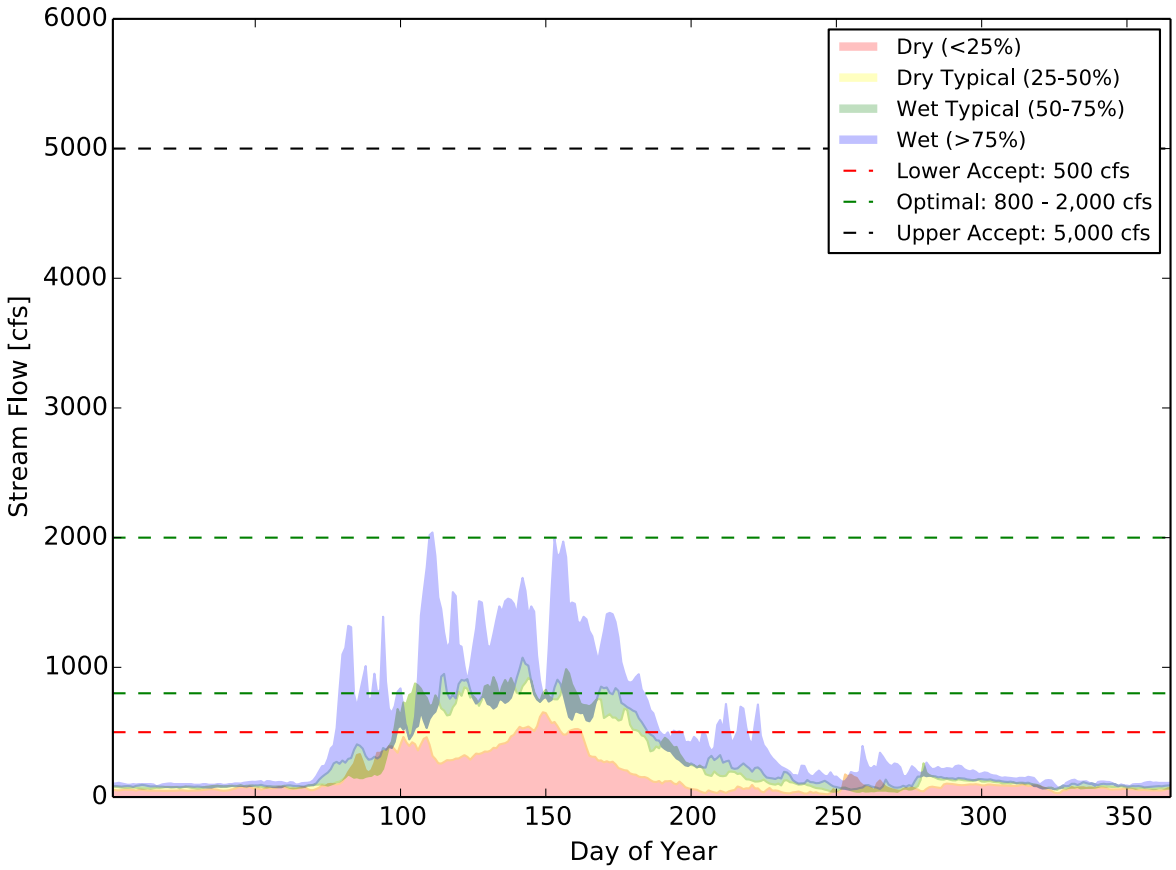


Table B2 San Miguel River Beaver to Pinon Mean Acceptability Scores and PCI_2 (Flows represented are flow levels at USGS San Miguel River at Brooks Bridge near Nucla, CO gage).

Specific Flow CFS	Mean Acceptability	PCI_2
100	-1.97	0
200	-1.97	0
300	-1.68	0
400	-0.98	0.05
500	-0.1	0.21
600	0.52	0.25
700	1.05	0.24
800	1.44	0.18
900	1.56	0.1
1000	1.8	0.06
1100	1.88	0
1200	1.93	0
1300	1.95	0
1400	1.95	0
1500	1.92	0
1600	1.9	0
1700	1.87	0
1800	1.85	0
1900	1.79	0.06
2000	1.74	0.12
2500	1.58	0.24
3000	1.29	0.4
4000	1.22	0.41
5000	1.19	0.47

USGS San Miguel River near Placerville, CO Gage Segments

Figure B3(a) San Miguel River (1995-2010) year types (wet, wet typical, dry typical, and dry ranked by yearly volume in years 1975-2010), with flow thresholds for low, optimal and high.



Specie Creek to Beaver Creek

Figure B3(b) Impact acceptability curve with Potential for Conflict Index (*PCI_2*)
San Miguel River, Specie to Beaver at USGS San Miguel River near Placerville, CO gage.

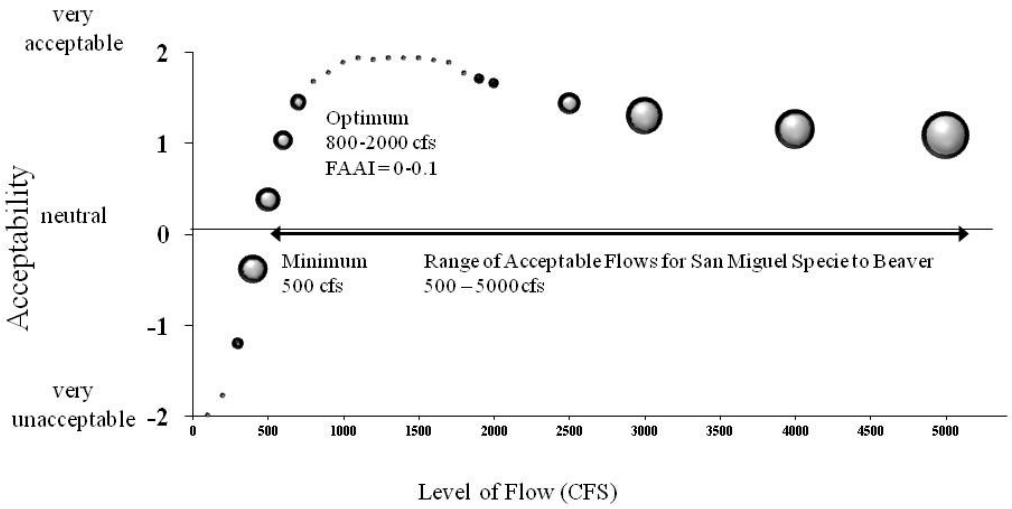


Table B3 San Miguel River Specie to Beaver Mean Acceptability Scores and PCI_2
(Flows represented are flow levels at USGS San Miguel River near Placerville, CO Gage).

Specific Flow CFS	Mean Acceptability	*PCI_2*
100	-2	0
200	-1.78	0
300	-1.21	0.12
400	-0.39	0.29
500	0.38	0.24
600	1.03	0.2
700	1.45	0.16
800	1.68	0
900	1.78	0
1000	1.89	0
1100	1.94	0
1200	1.92	0
1300	1.94	0
1400	1.94	0
1500	1.94	0
1600	1.91	0
1700	1.89	0.07
1800	1.77	0.11
1900	1.71	0.1
2000	1.66	0.1
2500	1.44	0.22
3000	1.3	0.37
4000	1.15	0.4
5000	1.09	0.48

Down Valley Park to Specie Creek

Figure B4 Impact acceptability curve with Potential for Conflict Index (*PCI_2*) for San Miguel River, Down Valley to Specie at USGS San Miguel River near Placerville, CO Gage.

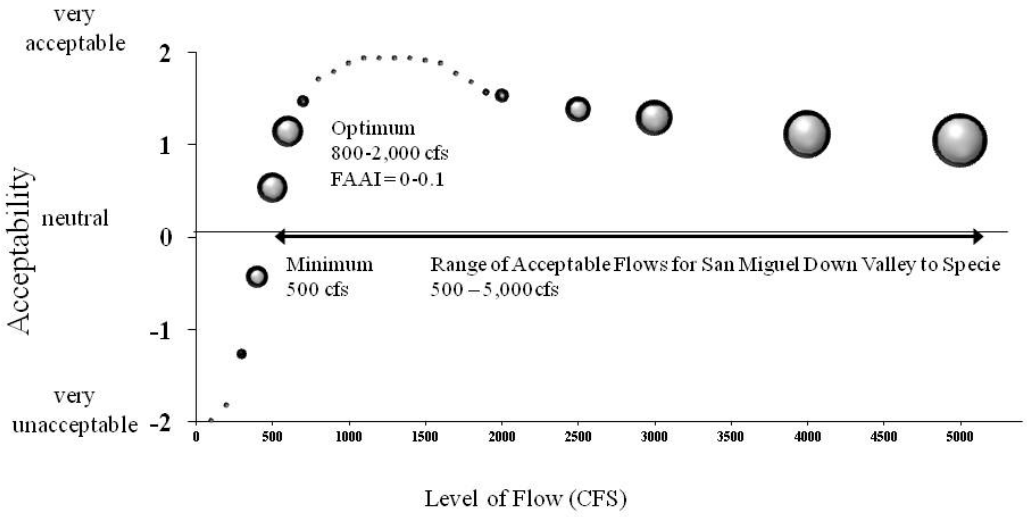


Table B4 San Miguel River Down Valley to Specie Mean Acceptability Scores and PCI_2 (Flows represented are flow levels at USGS San Miguel River near Placerville, CO Gage).

Specific Flow CFS	Mean Acceptability	*PCI_2*
100	-2	0
200	-1.83	0
300	-1.28	0.1
400	-0.44	0.22
500	0.53	0.3
600	1.14	0.3
700	1.47	0.12
800	1.71	0
900	1.79	0
1000	1.88	0
1100	1.94	0
1200	1.94	0
1300	1.94	0
1400	1.94	0
1500	1.91	0
1600	1.88	0
1700	1.77	0
1800	1.68	0
1900	1.57	0.07
2000	1.53	0.14
2500	1.38	0.25
3000	1.29	0.36
4000	1.11	0.47
5000	1.04	0.54

Bilk Creek to Down Valley Park

Figure B5 Impact acceptability curve with Potential for Conflict Index (*PCI_2*) for San Miguel River, Bilk to Down Valley at USGS San Miguel River near Placerville, CO gage.

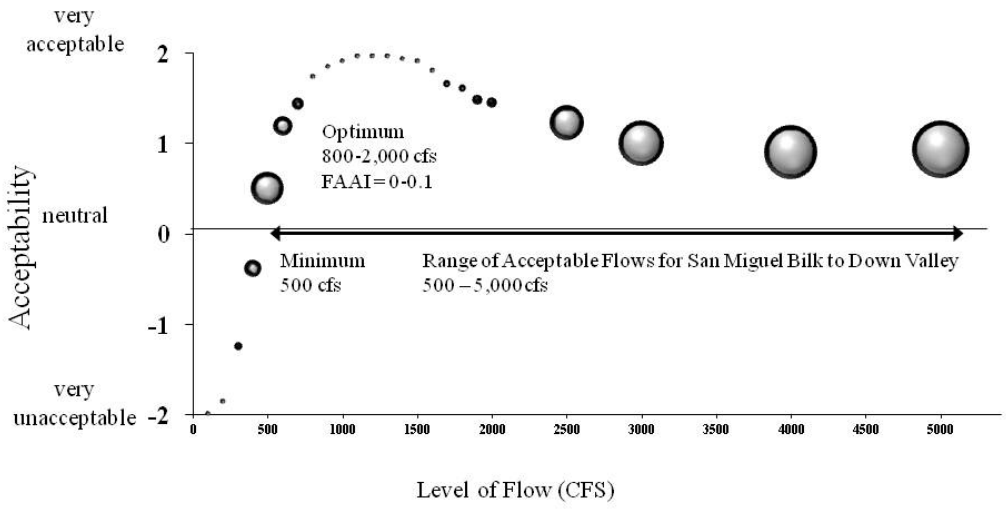


Table B5 San Miguel River Bilk to Down Valley Acceptability Scores and PCI_2 (Flows represented are flow levels at USGS San Miguel River near Placerville, CO gage).

Specific Flow CFS	Mean Acceptability	*PCI_2*
100	-2	0
200	-1.86	0
300	-1.25	0.08
400	-0.39	0.17
500	0.5	0.33
600	1.19	0.19
700	1.44	0.12
800	1.74	0
900	1.85	0
1000	1.91	0
1100	1.97	0
1200	1.97	0
1300	1.97	0
1400	1.94	0
1500	1.91	0
1600	1.81	0
1700	1.66	0.07
1800	1.61	0.07
1900	1.48	0.1
2000	1.45	0.1
2500	1.23	0.35
3000	1	0.46
4000	0.9	0.54
5000	0.93	0.58