ASSESSMENT OF STREAMFLOW NEEDS FOR SUPPORTING RECREATIONAL WATER USES ON THE RIO GRANDE AND CONEJOS RIVER.

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Summary

The recreational use assessment presented in this report provides important baseline information relating streamflows and recreational use. This body of work directly supports the Rio Grande Headwater Restoration Project's Stream Management Planning efforts. This report discusses study locations, and methods used to collect and analyze streamflow preference information from recreational users. User survey responses provided by 136 respondents were used to delineate acceptable and optimal streamflow thresholds for supporting recreational use activities on 11 segments on the Rio Grande and Conejos River (Table ES.1). Threshold identification supported quantification of the Boatable Days metric for each assessment reach under typical wet, average, and dry hydrological year types. The assessment followed recommendations the State of Colorado's Basin Implementation Plan guidance documents for quantifying non-consumptive recreational needs.

Respondent numbers for the flow preference study conducted in 2019 are robust for a remote or sparsely populated region of southern Colorado. The large number of responses to flow related questions for most reaches made delineation of flow acceptability thresholds fairly straightforward. However, low response rates among survey participants for reaches 6, 8, 9, and 10 may introduce some uncertainty into flow preference threshold delineated for those sections of river. Low response rates may indicate there is little to no use on these sections during most times of the year. Alternatively, it may indicate that the survey distribution did not reach the typical users of these reaches. Future recreational use assessment activities may benefit from targeted outreach to those users known to recreate on these reaches and inquiries into whether or not they have companions or are aware of additional users/groups that recreate at those locations. It may also be useful to ascertain why these reaches may be receiving so little use and whether or not there is opportunity to increase recreational activity through awareness campaigns, development of river access points, or through some other means.

Table ES.1. User-defined flow preferences for reaches included in the Boatable Days assessment.

Reach	River	Reach Description	Min. Acceptable	Min. Optimal	Max. Optimal	Max. Acceptable
1	Rio Grande	Rio Grande Reservoir to Mouth of Box Canyon	350	800	1400	2250*
2	Rio Grande	Box Canyon to Deep Creek/Creede	350	550	1400	2000
3	Rio Grande	Creede to Wagon Wheel Gap	400	600	2100	2750
4	Rio Grande	Wagon Wheel Gap to South Fork	300	600	1800	2800
5	Rio Grande	South Fork to Del Norte (Hwy 112)	350	500	2000	3000
6	Rio Grande	Alamosa to Lasauses	200	500	1000	3000
7	Rio Grande	Lasauses to Lobatos Bridge	300	600	2000	3500
8	Rio Grande	Lobatos Bridge to Lee Trail, NM	300	600	2000	3250
9	Conejos	Platoro Reservoir to South Fork Conejos	150	300	600	1200
10	Conejos	S. Fork Conejos to Hwy 17 Bridge	150	300	550	800
11	Conejos	Hwy 17 to Mogote Campground	300	550	2100	2700**

*The maximum safe release from Rio Grande Reservoir was 1200 cfs throughout the 1998 to 2017 period.
** Flows never reached this max acceptable threshold during the study period, in part due to mandatory flood mitigation measures triggered by a flow of 2300 cfs or greater at the Mogote stream gauge.

Variable streamflow conditions were found to impact use opportunities on all reaches. The total number of Boatable Days generally increase throughout the assessment area as hydrological conditions transition from dry to average to wet. On most reaches, typical daily streamflows rarely exceed the upper flow acceptability threshold. On Reaches 3, 4, and 5, however, that upper limit is exceeded in wet year types. Reach 4 and Reach 5 are the only two reaches where wet years are characterized by pronounced decrease in total annual Boatable Days. Additional work may be required to understand how alternative water management or climate change impacts diminish or increase the number of Boatable Days available to recreational users on each reach, and whether those changes occur in times of the year when recreation is most likely to occur.

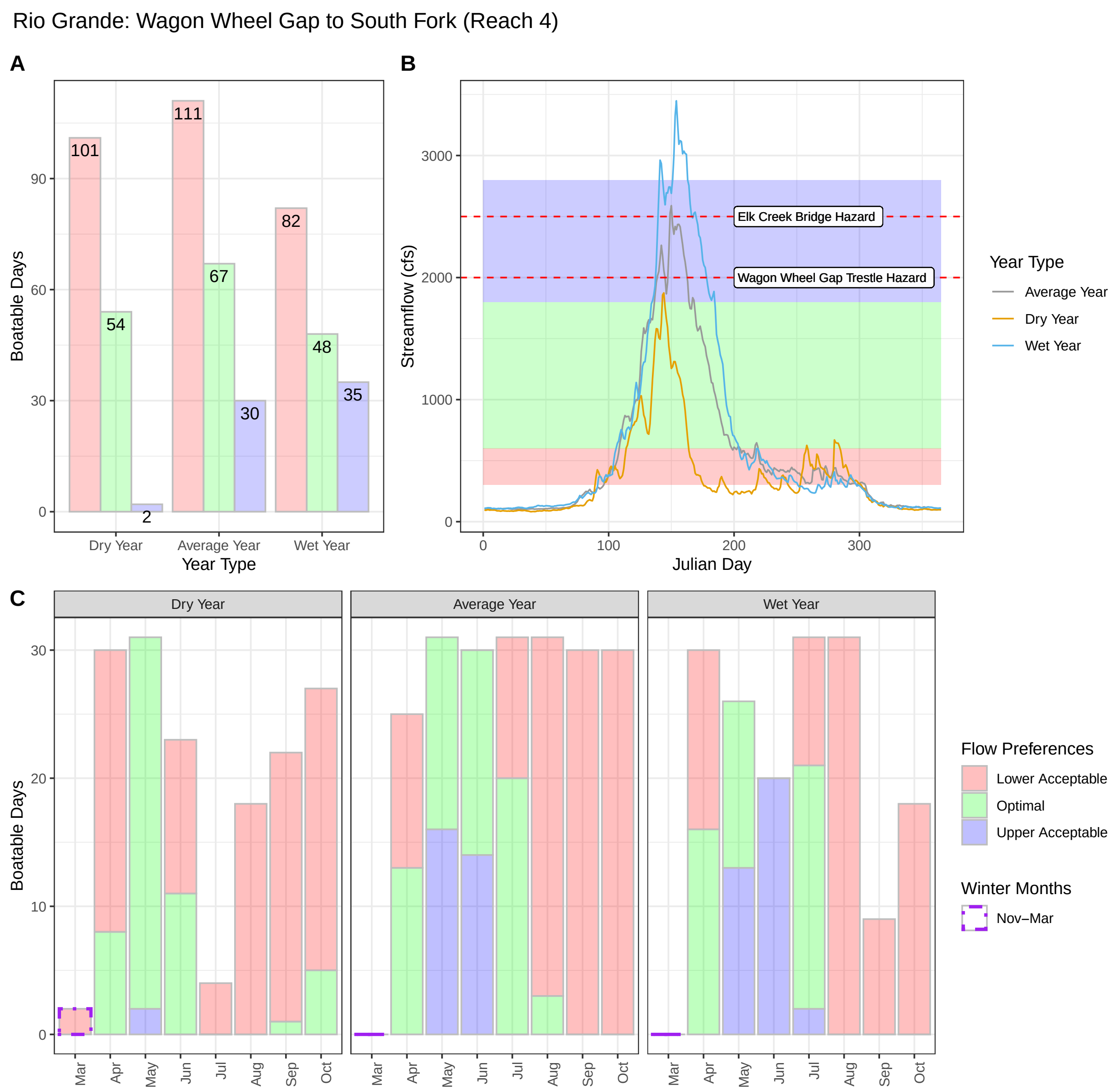

Figure ES.1. Boatable Days totals for the Rio Grande: Wagon Wheel Gap to South Fork. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, average, and dry years. (C) Monthly Boatable Days totals summarized by hydrological year type.

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1. Introduction

Considerable work evaluating relationships between streamflow and recreational use opportunities 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 opportunity to successfully complete a trip. On many river segments, flow level contributes to the risk, challenge, and/or aesthetic attributes of on-water activities (Whittaker & Shelby, 2000). Natural and man-made changes in streamflow can have direct and indirect impacts on recreational boating experiences. Direct effects include navigation, safety/difficulty, travel times, quality of whitewater stretches, and beach and camp access (Brown, Taylor, & Shelby, 1991; Whittaker et al., 1993; Whittaker & Shelby, 2002). Indirectly, variability in streamflow affects 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. The various recreational use opportunities provided by different flow ranges can be delineated into "niches" (Shelby et al., 1997). These flow niches may include: unacceptably low flow; minimum flow acceptable; technical, but enjoyable flows; optimal flows; challenging high flows; and unacceptably high flows. Methodologies developed by American Whitewater are regularly used to delineate user-defined streamflow niches and subsequently quantify recreational user opportunities under different hydrological conditions. Implementation of these assessment methodologies aims to support water management decision-making. Specific evaluative information on how flow affects recreation quality is often critical, particularly where social values are central to decision-making (Kennedy and Thomas 1995). American Whitewater's Boatable Days assessment methodology is recognized as a best practice for defining recreation flow needs and opportunities (Stafford et al., 2016).

The Rio Grande Basin Roundtable (RGBRT) and the Rio Grande Headwaters Restoration Project (the Restoration Project) are undertaking a river recreation assessment as part of a Stream Management Planning effort. In May of 2018, the Restoration Project officially initiated the Stream Management Plan process for the Rio Grande, Conejos River, and Saguache Creek. American Whitewater was invited to join the Technical Advisory Team (TAT) tasked with guiding the SMP process, identifying and prioritizing ecological, recreational, and community values, development of goals for flows and physical conditions to protect and enhance streams, and establishing methods and associated opportunities and constraints to make progress toward goals. As part of this effort, AW was tasked with completing a Boatable Days assessment. The characterization of Boatable Days provides an objective, science-based measure of existing whitewater recreation opportunities related to variability in streamflow on reaches throughout the assessment area (Figure 1, Figure 2, Figure 3). This information aims to support conversations about how whitewater recreation opportunities might change under future hydrological conditions and water management scenarios.

American Whitewater's assessment aims to achieve multiple SMP objectives. The assessment helps meet SMP Objective 3[1] by identifying optimal and acceptable recreational flow preferences on 11 different river segments in the Basin. The Boatable Days Analysis provides the TAT with the necessary quantitative information needed to develop goals to protect and enhance flows for recreation values[2] . The Boatable Days model—as developed for the Rio Grande and Conejos River—can be used to identify opportunities and constraints for implementation of future projects[3].

Figure 1. Upper Rio Grande recreational assessment area. Image provided by Rio Grande Headwaters Restoration Project.

[1] Objective 3: Define and prioritize environmental, recreational, and community values.

[2] Objective 4: Develop goals to improve flows and physical conditions needed to support values.

[3] Objective 6: Identify opportunities and constraints for implementation of projects, and additional data needed to inform project development.

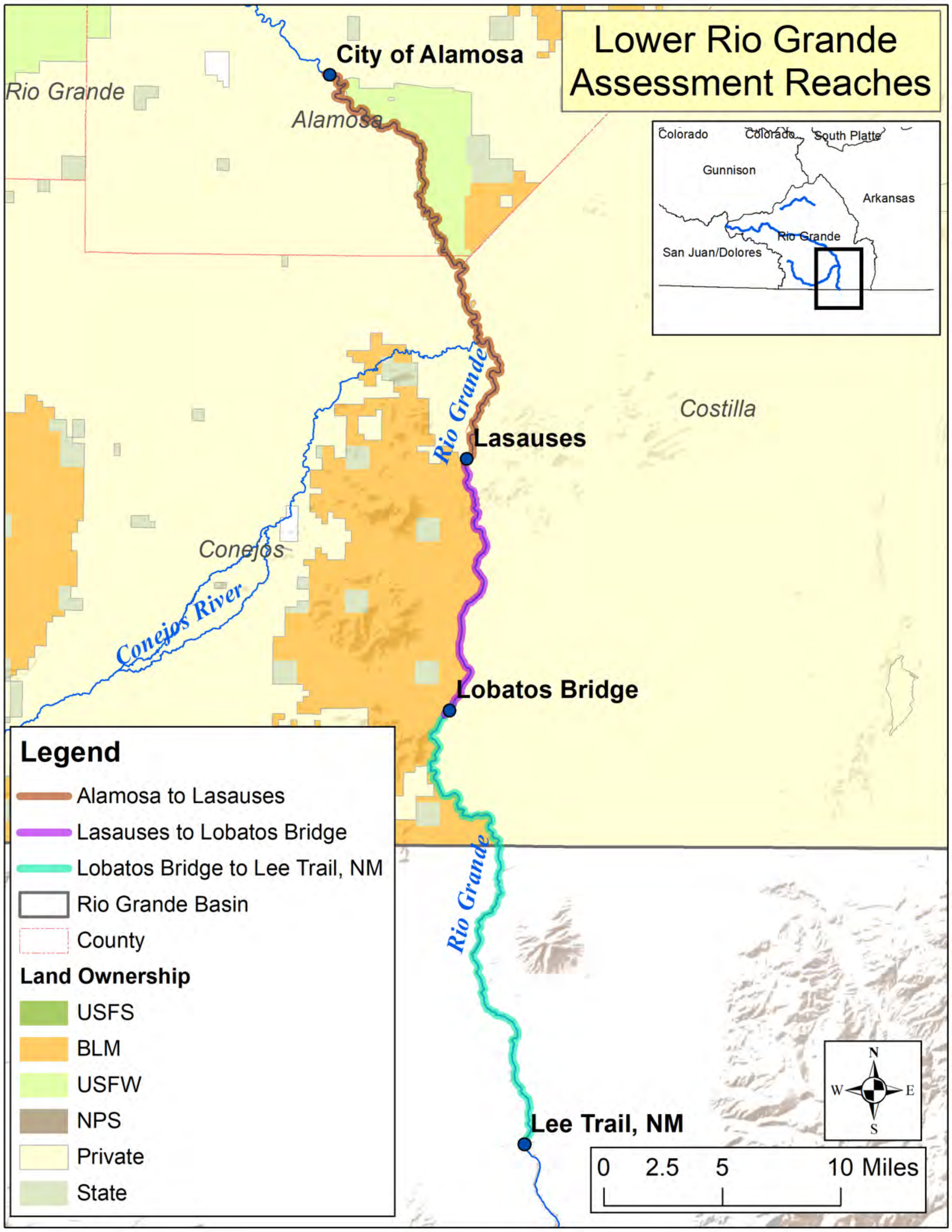

Figure 2. Lower Rio Grande recreational assessment area. Image provided by Rio Grande Headwaters Restoration Project.

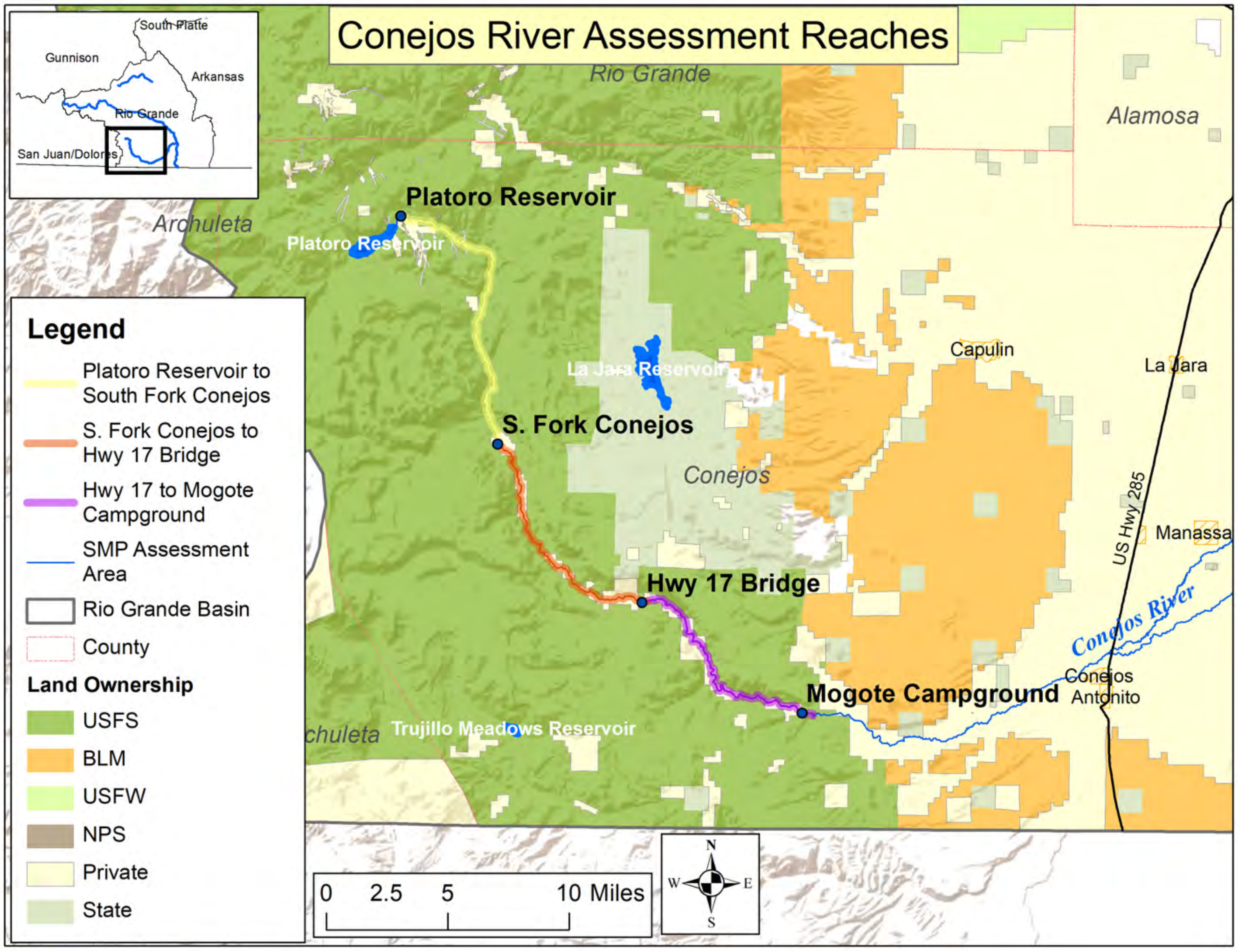

Figure 3. Conejos River recreational assessment area. Image provided by Rio Grande Headwaters Restoration Project.

In addition to meeting objectives of the SMP, the results of this assessment advance implementation of the Colorado Water Plan[4]. The State's draft Basin Implementation Plan Guidance document recommends quantification of recreational values (e.g., boating and fishing). Section 2.1 of the Guidance[5] calls for the evaluation of non-consumptive needs in terms of 'measurable outcomes', data, and assessment using methods described in CWCB's Non-consumptive Toolbox (CWCB, 2013). Appendices C and D of the toolbox identify the flow-evaluation methodology developed and used by American Whitewater as an example of a recreation tool that can produce measurable outcomes. This assessment aims to 1) address gaps in data and understanding regarding flow conditions necessary to sustain recreational values on the Rio Grande and Conejos River and 2) improve stakeholders' collective understanding of existing recreational use opportunities and how these opportunities may be impacted by climate change and consumptive water projects.

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4 https://www.colorado.gov/pacific/cowaterplan/plan

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

2. Study Area

River reaches considered in this assessment were identified collaboratively between American Whitewater, the Rio Grande Basin Roundtable's SMP Committee, and the SMP project coordinator. Eight segments on the Rio Grande and three segments on the Conejos River were determined to have significant recreational values and were, therefore, included in the assessment (Table 1). Saguache Creek was not identified as a recreational planning priority. Each segment was mapped to an existing streamflow gauging station and/or a hydrological simulation modeling node. Mapping streamflow gauge/node locations to each assessment reach considered: 1) the historical period of record (POR) for streamflow observations, 2) the distance between the gauge/node and river segment, and 3) the gauge/node most commonly used by recreationalists to inform their use of the segment. A single stream gauge or simulation node was used to represent flows for adjoining river segments in two locations on the Rio Grande and one location on the Conejos.

Table 1. River segments and corresponding streamflow measurement gauges considered in this study.

Reach	River	Segment Description	Corresponding Stream Gauge/Simulation Node
1	Rio Grande	Rio Grande Reservoir to Mouth of Box Canyon	Rio Grande River at Thirty Mile Bridge Near Creede (RIOMILCO)
2	Rio Grande	Box Canyon to Deep Creek/Creede	Rio Grande River at Thirty Mile Bridge Near Creede (RIOMILCO)
3	Rio Grande	Creede to Wagon Wheel Gap	Rio Grande River at Wagon Wheel Gap (RIOWAGCO)
4	Rio Grande	Wagon Wheel Gap to South Fork	Rio Grande River at Wagon Wheel Gap (RIOWAGCO)
5	Rio Grande	South Fork to Del Norte (Hwy 112)	Rio Grande River Near Del Norte, Co (RIODELCO)
6	Rio Grande	Alamosa to Lasauses	Rio Grande River at Alamosa (RIOALACO)
7	Rio Grande	Lasauses to Lobatos Bridge	Rio Grande River Above Trinchera Creek Near Las Sauses (RIOTRICO)
8	Rio Grande	Lobatos Bridge to Lee Trail, NM	Rio Grande River Near Lobatos (RIOLOBCO)
9	Conejos	Platoro Reservoir to South Fork Conejos	Conejos River Below Platoro Reservoir (CONPLACO)
10	Conejos	S. Fork Conejos to Hwy 17 Bridge	Conejos River Below Platoro Reservoir (CONPLACO)
11	Conejos	Hwy 17 to Mogote Campground	Conejos River Near Mogote (CONMOGCO)

3. Methods

American Whitewater collected recreational user feedback through a web-based survey (Appendix C). Four types of questions were included in the survey. The first type of question captured demographic information about each participant's skill level, frequency of participation in river-related recreation, etc. The second type of question allowed users to assign use-acceptability rankings to various streamflows. The third question type asked users to identify flows associated with different trip types (technical low-water, standard, challenging high-flow, etc.). The fourth type of question focused on participant perspectives on water management planning activities.

These questions were organized around each assessment reach and were supported with general mapping and narrative information about that reach from American Whitewater's website. The Rio Grande Headwaters Restoration Project has the responses from these questions and will utilize them in the larger SMP report. The survey also clearly defined which streamflow measurement gauge to reference when assigning acceptability rankings for conditions on the reach. An announcement of the survey was emailed to American Whitewater's members, posted on the website, distributed via American Whitewater's online newsletter, and shared through the Stream Management Plan email list.

The flow acceptability questions included in the user-survey are the principal focus of this assessment. These questions asked respondents to evaluate recreational use acceptability for a range of measured flows on each study segment using a five-point scale that included the following rankings: Unacceptable, Moderately Unacceptable, Marginal, Moderately Acceptable, and Acceptable. Each ranking in the scale was mapped to an integer value between -2 and 2 where an 'Unacceptable' ranking mapped to a value of -2, a 'Marginal' ranking mapped to a value of 0, and an 'Acceptable' ranking mapped to a value of 2. To further explore and characterize the relationship between flows and recreational use opportunities, the survey posed a series of open-ended questions about streamflows associated with distinct niche experiences. These niche experiences included: lowest navigable flow (minFlow), minimum acceptable flow (lowAcceptable), technical but navigable flows (technicalTrip), flows experienced during a standard trip (standardTrip), challenging high-water (highChallenge), and highest safe flow (highSafe).

The flow options provided in the flow acceptability questions were directly informed by historical hydrology data from each individual stream gauge. The minimum flow option provided for each reach was 100 cfs and the maximum flow option varied depending on historical maximums. The questions that reference the RIOMILCO stream gauge (corresponding gauge for Reach 1 and 2) are an exception. The maximum observed flow at this location is 2,520 cfs. Users on the survey were asked to evaluate flows up to 3,000 cfs. Any survey responses provided for flow values above 2,500 cfs on these reaches were, therefore, considered erroneous.

Flow-acceptability rankings provided through the survey were used to describe preferences among recreational users for various ranges of streamflow. Researchers collecting and organizing survey-based evaluative information often employ a normative approach for analyzing results. The normative approach considers each individual's evaluation (personal norms) of a range of potential conditions. Aggregation of many individuals' personal norms describe a group's collective evaluation (social norms) of resource condition. This approach has been applied extensively in natural resource management settings, often with respect to instream flows for recreation (Shelby and Whittaker, 1995; Shelby et al., 1992a; Vandas et al., 1990; Whittaker and Shelby, 2002b) and is particularly useful for developing thresholds that define low, acceptable, and/or optimal resource conditions (Shelby et al. 1992). Other applications have extended this approach to different indicators and impacts, including: evaluation of how many people are considered 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). Notably, the normative approach was employed to understand user preferences for various streamflows on the Grand Canyon (Shelby et al. 1992) and on several other rivers in Colorado (Vandas et al. 1990, Shelby & Whittaker 1995, Fey & Stafford 2009, Fey & Stafford 2010).

Defining management standards is often more efficient if there is a high degree of consensus (or "norm crystallization") among users regarding acceptable and unacceptable resource conditions. Traditional measures of norm crystallization have included the standard deviation, coefficient of variation, and interquartile range of survey responses (Krymkowski et al., 2009; Manning, 2011; Shelby and Vaske, 1991). The Potential for Conflict Index-2 (PCI2) was developed to help address some of the shortcomings associated with traditional measures of norm crystallization when applied to ordinal data. A detailed description of the PCI2 metric is provided by Vaske et al. (2010). Briefly, computed PCI2 values range from 0 to 1.0 where the least amount of consensus (PCI2 = 1.0) occurs when responses are equally divided between two extreme values on a Likert response scale (e.g. 50% Highly Unacceptable and 50% Highly Acceptable). A set of responses with unanimous consensus among respondents yields a PCI2 value of zero.

The normative approach was the basis for describing use acceptability ranges for streamflows on different reaches within the assessment area. The percentage of responses falling within each acceptability ranking were computed for each streamflow on each reach. The numerical representations of flow acceptability preference rankings were used to compute PCI2 scores for each flow included in the survey. Computed PCI2 values were paired on the percentage of respondents that ranked a given flow as 'Moderately Acceptable' or 'Acceptable' and plotted to create use acceptability curves for each of the study reaches.

Use acceptability curves, tabular data summaries, and responses to open-ended questions about niche conditions were used to delineate various normative streamflow characteristics. These characteristics included a minimum acceptable streamflow, a range of acceptable streamflow conditions, and a range of optimum streamflow conditions. The upper and lower thresholds delineated for acceptable and optimal streamflow conditions were then compared to wet-year, average-year, and dry-year hydrological conditions in order to complete a Boatable Days analysis.

The computation of Boatable Days is the dominant quantitative approach used by American Whitewater to characterize recreational use opportunities on rivers (Fey and Stafford, 2009; Shelby and Whittaker, 1995; Whittaker et al., 1993). The metric itself reflects the number of days in a given year that fall within certain defined flow ranges (i.e. lower acceptable flows, optimal flows, upper acceptable flows). The Boatable Days analysis performed on reaches within the assessment area responded to the inter-annual natural and management-induced variability in streamflows by computing the number of Boatable Days that occur in each of three hydrological year types: wet, average and dry.

Wilson Water Group, LLC. provided streamflow time series data for the three hydrological year types defined here. Representative streamflow time series for each year type on each reach required synthesis of historical data. Daily streamflow data was collected from stream gauges throughout the assessment area for a 20-year period of record. Streamflow time series data from each gauge were then ordered by annual peak flow. Average daily streamflows across all years in the lower 25th percentile of the ordered list were computed to produce a representative dry year streamflow time series. The same approach was used to create representative streamflow series for average and wet years where average year types fell between the 25th and 75th percentiles of annual peak flows and average wet year types were those years that fell within the upper 75th percentile of the ordered list.

4. Results

The web-survey captured responses from 136 recreational users. 63% of respondents indicated they were somewhat comfortable or very comfortable reporting flows, 52% of respondents identified themselves as advanced or expert paddlers, 84% identified as Class III or greater paddlers, and 44% recreate on streams and rivers at least 20 days per season (Figure 4). A wide range of preferred craft types were indicated, including oar frame rafts, kayaks, catarafts, canoes, dories, inner tubes, paddle rafts, skiffs, and stand-up paddle boards.

Survey responses were aggregated by reach, reviewed for quality, and displayed graphically to aid in interpretation (Appendix A). An example summary graphic is included for survey responses for the Wagon Wheel Gap to South Fork section of the Rio Grande (Figure 5).

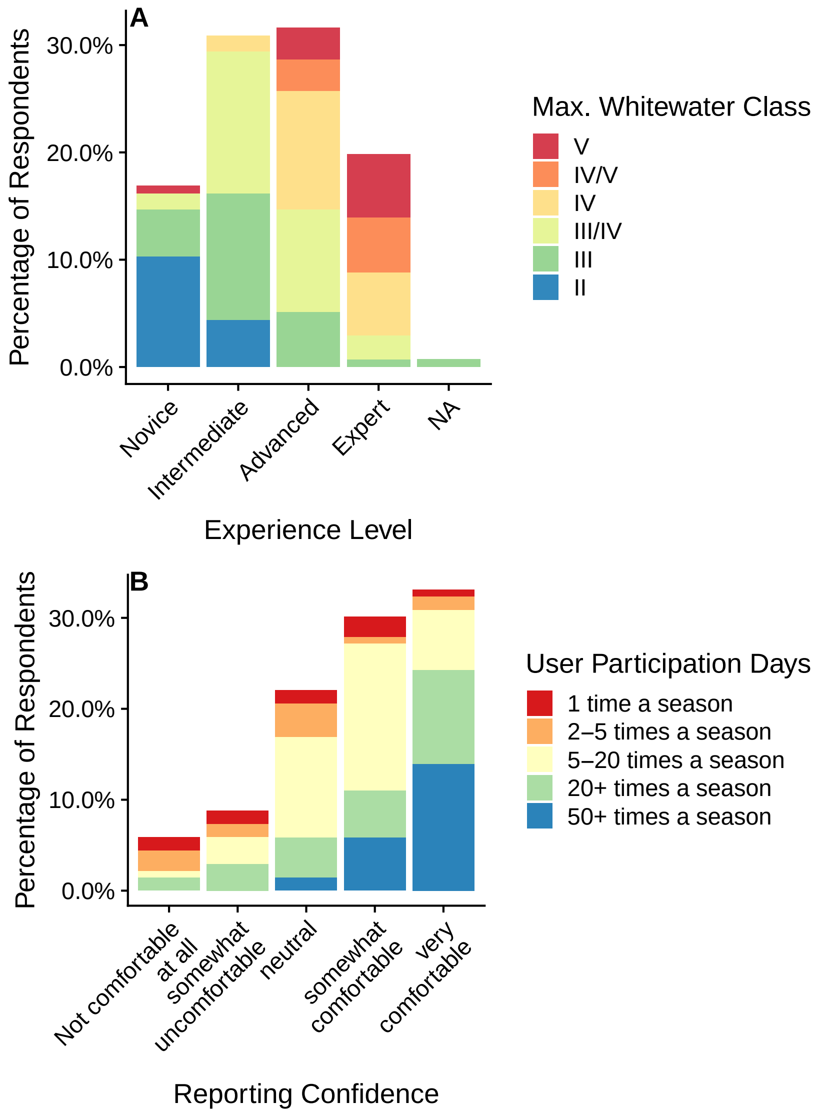

Figure 4. Survey responses from 136 users indicating (A) experience level and maximum comfortable whitewater class; (B) participant confidence in providing flow acceptability rankings for one or more reaches in the assessment area.

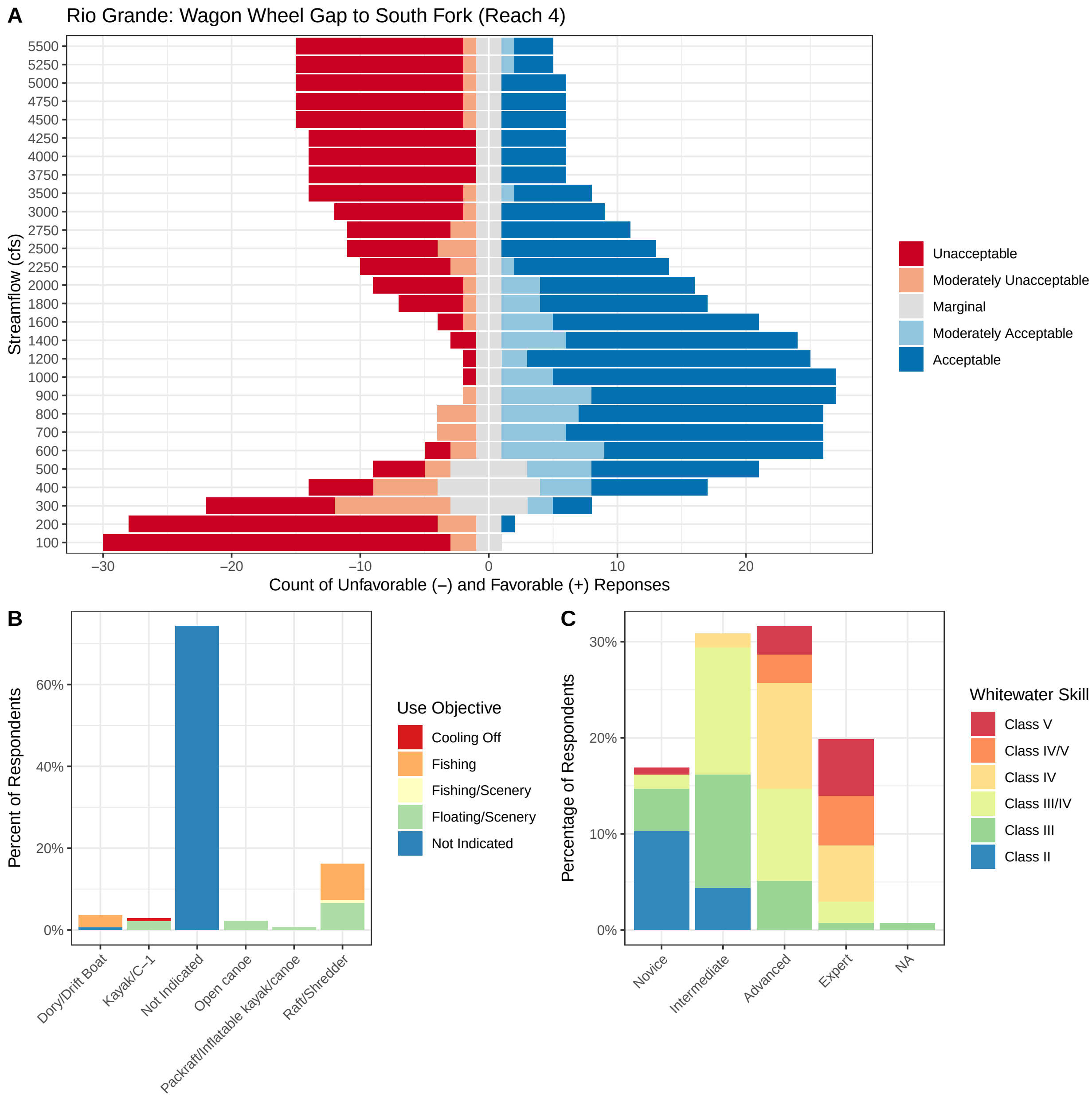

Figure 5. Survey responses for the Wagon Wheel Gap to South Fork section of the Rio Grande. (A) Counts of the various flow acceptability rankings provided by respondents where survey responses reflect streamflow variability as measured at the Rio Grande River at Wagon Wheel Gap (RIOWAGCO). (B) User identified craft types and recreational use objectives for the reach. (C) The self-identified experience and whitewater skill levels provided by survey respondents.

Use acceptability curves, tabular data summaries, and responses to open-ended questions about niche conditions were used to delineate various normative streamflow characteristics, including the 'Minimum Acceptable', 'Minimum Optimal', 'Maximum Optimal', and 'Maximum Acceptable' streamflow on each reach (Table 2).

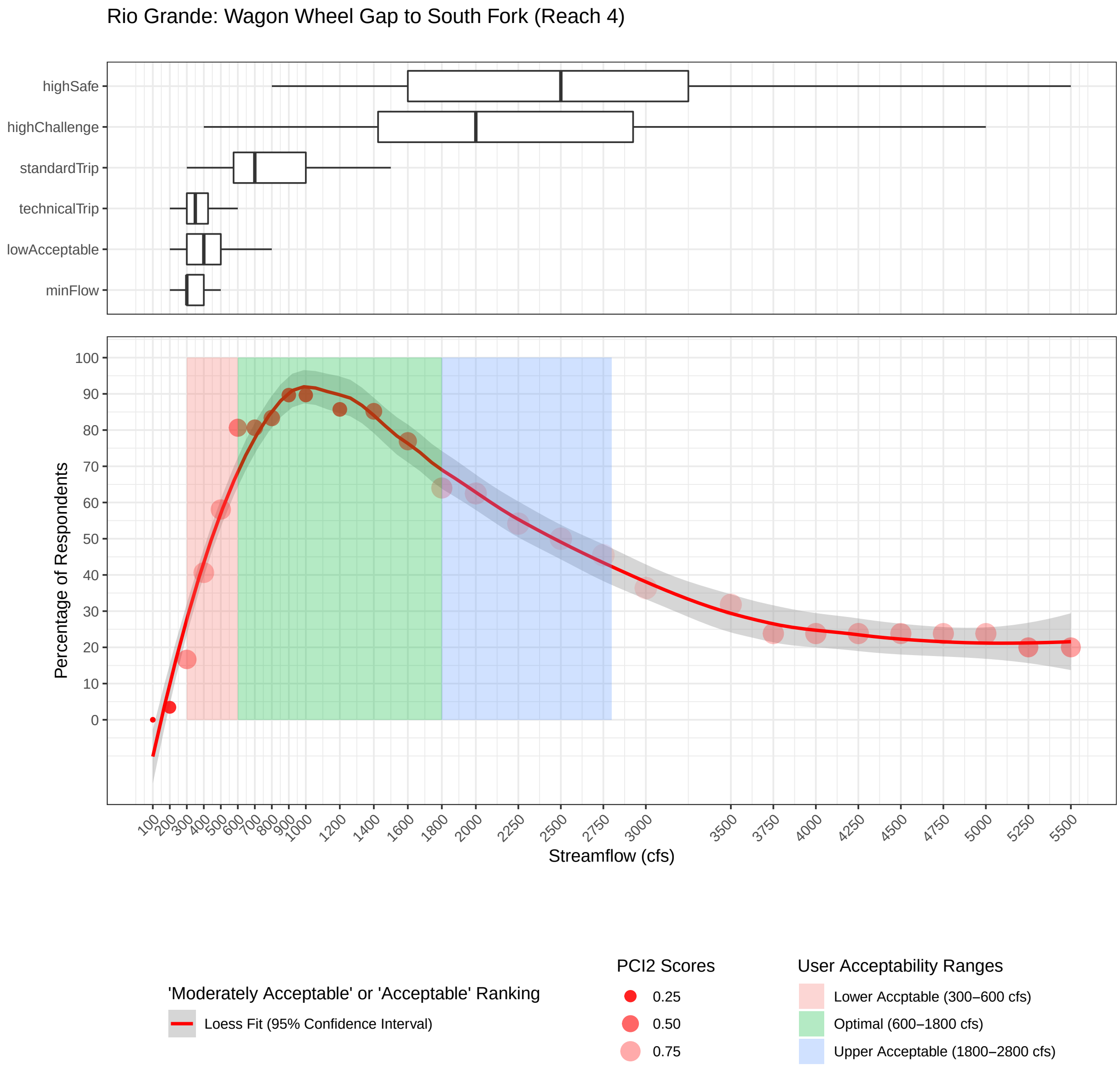

Figure 6. Flow preferences reported by users for the Rio Grande: Wagon Wheel Gap to South Fork. (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges.

Responses provided for Reach 6 and Reach 8 of the Rio Grande along with Reach 9 and Reach 10 of the Conejos made delineation of the upper bound for the maximum acceptable flow difficult. Responses to open ended questions suggest that the difficulty or risk for navigation on the Rio Grande reaches in question do not change appreciably as flows increase. These reaches are relatively low-gradient and do not include many navigation hazards. Results for Reach 6 may be affected by a small number of respondents providing flow acceptability rankings. It appears that the lack of a discernable upper bound on acceptable flows for reaches 9 and 10 on the Conejos River may also be due to a limited number of survey respondents for these reaches.

Table 2. Flow preference thresholds delineated for each reach in the assessment area. All values are reported in cubic feet per second (cfs).

Reach	River	Reach Description	Min. Acceptable	Min. Optimal	Max. Optimal	Max. Acceptable
1	Rio Grande	Rio Grande Reservoir to Mouth of Box Canyon	350	800	1400	2250*
2	Rio Grande	Box Canyon to Deep Creek/Creede	350	550	1400	2000
3	Rio Grande	Creede to Wagon Wheel Gap	400	600	2100	2750
4	Rio Grande	Wagon Wheel Gap to South Fork	300	600	1800	2800
5	Rio Grande	South Fork to Del Norte (Hwy 112)	350	500	2000	3000
6	Rio Grande	Alamosa to Lasauses	200	500	1000	3000
7	Rio Grande	Lasauses to Lobatos Bridge	300	600	2000	3500
8	Rio Grande	Lobatos Bridge to Lee Trail, NM	300	600	2000	3250
9	Conejos	Platoro Reservoir to South Fork Conejos	150	300	600	1200
10	Conejos	S. Fork Conejos to Hwy 17 Bridge	150	300	550	800
11	Conejos	Hwy 17 to Mogote Campground	300	550	2100	2700

*The maximum safe release from Rio Grande Reservoir was 1200 cfs throughout the 1998 to 2017 period.
** Flows never reached this max acceptable threshold during the study period, in part due to mandatory flood mitigation measures triggered by a flow of 2300 cfs or greater at the Mogote stream gauge.

Minimum acceptable flows on the Rio Grande generally range between approximately 350-400 cfs, optimal flows range between approximately 600-2000 cfs, and the upper acceptable flows range between ~2000-3000 cfs. A maximum acceptable flow of 2250 cfs was delineated for Reach 1. However, due to infrastructure constraints, the maximum safe release from Rio Grande Reservoir was 1200 cfs between 1998 and 2017. Therefore, this maximum acceptable flow did not occur during the study period. Improvements to the reservoir's outlet works, progressing under the Rio Grande Reservoir Phase II Rehabilitation Project, will substantially increase the maximum permissible release from the reservoir. No clear flow preference patterns exist for the Conejos River reaches. Variability in flow thresholds between reaches can be attributed to different user groups recreating in different locations, the unique geomorphic or hydraulic characteristics of each reach, and/or variability in the sample size of respondents providing flow rankings on each reach and for each listed streamflow. A maximum acceptable flow of 2700 cfs was delineated for Reach 11 on Conejos River. It is important to note that flood mitigation requirements are triggered if streamflow at the Mogote stream gauge (CONMOGCO) reaches or exceeds 2300 cfs. Under this scenario, the operator of Platoro Reservoir and other partners take actions (e.g. utilize Platoro Reservoir flood control storage) to reduce flows and mitigate flooding risk in downstream communities. Stream flows on Reach 11, therefore, never reached the maximum acceptable flow preference threshold during the study period and are unlikely to do so in the future.

Flow preference thresholds were used to compute the number of Boatable Days associated with different hydrological conditions on each reach in the assessment area (Table 3). Results were summarized graphically and in tabular form (Appendix A). Boatable Days totals falling within the range of "Upper Acceptable" flows never exceed zero on several reaches of the Rio Grande. This is due, in some locations, to the lack of a discernible upper bound on the range of “Optimal” flows identified by recreational users. In other locations, the streamflow time series supplied by Wilson Water Group, LLC to characterize dry, average, and wet year types never exceeded the upper bound of user-defined “Optimal” flows. A different representation of hydrological year types will result in different Boatable Days totals.

Table 3. Boatable Days falling within each acceptability category calculated for reaches within the assessment area for typical dry, average and wet hydrological year types.

Reach	River	Description	Acceptability Category	Dry Year	Avg. Year	Wet Year
1	Rio Grande	Rio Grande Reservoir to Mouth of Box Canyon	Lower Acceptable	38	38	40
			Optimal	0	25	43
			Upper Acceptable	0	0	0
			Total Days	38	63	83
2	Rio Grande	Box Canyon to Deep Creek/Creede	Lower Acceptable	17	11	24
			Optimal	21	52	59
			Upper Acceptable	0	0	0
			Total Days	38	63	83
3	Rio Grande	Creede to Wagon Wheel Gap	Lower Acceptable	43	62	31
			Optimal	56	80	59
			Upper Acceptable	0	17	21
			Total Days	99	159	111
4	Rio Grande	Wagon Wheel Gap to South Fork	Lower Acceptable	101	111	82
			Optimal	54	67	48
			Upper Acceptable	2	30	35
			Total Days	157	208	165
5	Rio Grande	South Fork to Del Norte (Hwy 112)	Lower Acceptable	54	56	74
			Optimal	119	127	87
			Upper Acceptable	12	26	19
			Total Days	185	209	180
6	Rio Grande	Alamosa to Lasauses	Lower Acceptable	47	146	204
			Optimal	0	1	45
			Upper Acceptable	0	0	0
			Total Days	47	147	249
7	Rio Grande	Lasauses to Lobatos Bridge	Lower Acceptable	0	39	74
			Optimal	0	0	47
			Upper Acceptable	0	0	0
			Total Days	0	39	121
8	Rio Grande	Lobatos Bridge to Lee Trail, NM	Lower Acceptable	7	137	141
			Optimal	0	46	95
			Upper Acceptable	0	0	2
			Total Days	7	183	238
9	Conejos	Platoro Reservoir to South Fork Conejos	Lower Acceptable	53	56	44
			Optimal	0	17	31

Reach	River	Description	Acceptability Category	Dry Year	Avg. Year	Wet Year
			Upper Acceptable	0	0	0
			Total Days	53	73	75
10	Conejos	S. Fork Conejos to Hwy 17 Bridge	Lower Acceptable	53	56	44
			Optimal	0	17	31
			Upper Acceptable	0	0	0
			Total Days	53	73	75
11	Conejos	Hwy 17 to Mogote Campground	Lower Acceptable	29	30	40
			Optimal	29	59	64
			Upper Acceptable	0	0	0
			Total Days	58	89	104

Table 4. Boatable Days analysis results broken out by month for the Rio Grande: Wagon Wheel Gap to South Fork. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
Mar	Lower Acceptable	2	0	0
Apr	Lower Acceptable	22	12	14
	Optimal	8	13	16
May	Optimal	29	15	13
	Upper Acceptable	2	16	13
Jun	Lower Acceptable	12	0	0
	Optimal	11	16	0
	Upper Acceptable	0	14	20
Jul	Lower Acceptable	4	11	10
	Optimal	0	20	19
	Upper Acceptable	0	0	2
Aug	Lower Acceptable	18	28	31
	Optimal	0	3	0
Sep	Lower Acceptable	21	30	9
	Optimal	1	0	0
Oct	Lower Acceptable	22	30	18
	Optimal	5	0	0

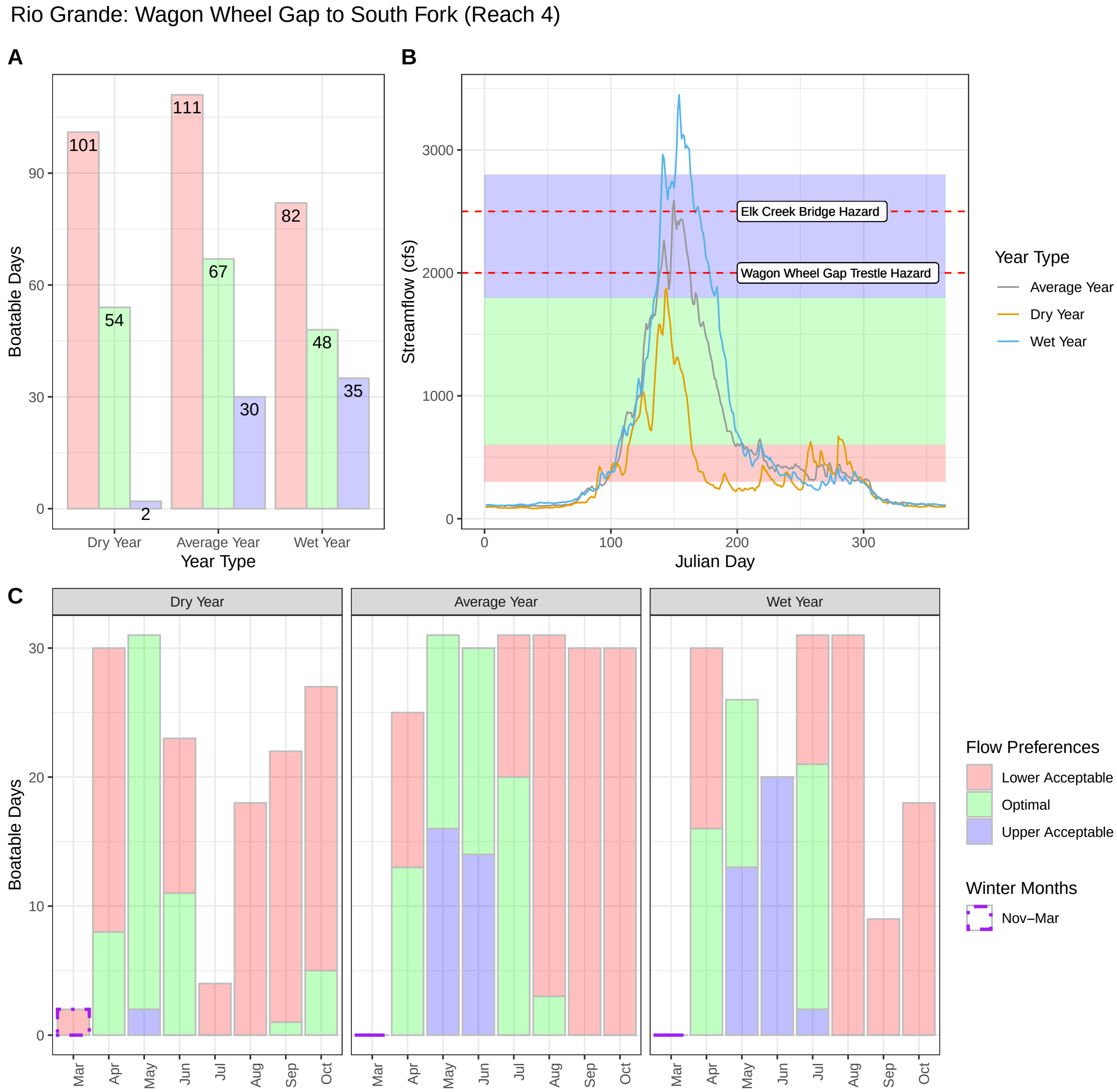

Figure 7. Boatable Days totals for the Rio Grande: Wagon Wheel Gap to South Fork. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, average, and dry years. Flows associated with specific navigational hazards are labeled. (C) Monthly Boatable Days totals summarized by hydrological year type.

It is important to note the difference between a Boatable Day and a user-day. A Boatable Day describes when acceptable flows are met to provide an *opportunity* for recreation. User-days indicate the actual numbers of recreational users present on a reach over a period of time. User-days are affected by numerous factors including weather, hazards, river access, etc. while Boatable Days are solely affected by flow conditions. Boatable Days totals for two reaches include days in fall, winter and spring months when current recreational use is known to be light. Totals for the

Alamosa to Lasauses section includes days in November, December, January, and February. Totals for the Lobatos Bridge to Lee Trail, NM section includes days in November and February. It is unlikely that there is much use on these segments during the fall and winter months due to weather conditions, ice hazards on the river, and limited river access due to snow and road closures. When using the Boatable Days analysis results to inform management decisions it will be particularly useful to consider the monthly Boatable Days totals during the typical user-season rather than the annual totals. While ice coverage varies depending on the year and the location, ice has potential to impact user days on most reaches between November 1 and March 31.

Additional constraints or hazards limit recreational use on several segments of the Rio Grande (Table 5). Low bridges are the most common type of navigational hazard. These bridges can make passage for rafts and dories extremely dangerous at high flows. Other craft types like kayaks may be able navigate these hazards at the full range of flows identified by users as falling within optimal or acceptable bounds for recreational use. Navigational hazards and other limitations were not used to modify Boatable Days calculations because they are expected to apply differently to various craft types. However, it is likely that knowledge of these hazards impacted survey respondents' flow preferences and identification of high safe flow levels. On multiple reaches, the highest safe flow corresponds with hazard-related thresholds. On other reaches the high acceptable flow exceeds the flow thresholds identified for hazards in that reach; this is likely due to variations in craft type and skill level among survey respondents.

Table 5. Known recreational use constraints or navigation hazards on segments of the Rio Grande.

Reach	Hazard Name	Notes
1	Box Canyon Bridge	Low bridge at Mouth of Box Canyon (Forest Rd 520.21). No discrete flow threshold is available, but this is never passable by any craft type.
2	Rio Oxbow Ranch Private Bridge	The bridge is always passable with drift boats. However, flows > 1,000 cfs (at RIOMILCO gauge) presents issues for rafts with fishing frames.
2	Kansas Club Bridge	Walking bridge for a private fishing club. At high flows, boats must stay river left and be aware of hanging rope and cables. No discrete flow threshold is available.
2	Antlers Resort Bridge	This is a walking bridge that presents an extreme navigation hazard at high flows. Dories and rafts/frames cannot pass at flows > 770 cfs.
2	Broadacres Bridge	This bridge is passable on river left at all flows and river right at most flows. No discrete flow threshold is available.
3	Wason Railroad Bridge	This bridge is hazardous at high flows due to the accumulation of debris on the pilings. No discrete flow threshold is available
4	Wagon Wheel Gap Railroad trestle	Due to the bridge's angle across the river and the debris accumulation on pilings, this bridge presents an extreme navigation hazard and most flows. Local outfitters do not attempt passage of this bridge if flows are > 2,000 cfs (at RIOWAGCO gauge).
4	4UR Bridge (Goose Creek Rd)	This private bridge is a minor obstacle at high flows.
4	Elk Creek Bridge	Passage is not suggested if the flow is at or above 2,500 cfs here.
5	Independent D "W-shaped" diversion dam	A "W-shaped" diversion dam presents a serious navigation hazard to boaters.
5	Hanna Lane/County Rd 17	Dories can safely pass under this bridge up to 5,000, raft frames up to 4,000 cfs (at RIODELCO gauge).
5	Flying W Bridge	Dories can safely pass under this bridge up to 3,500 cfs, and Rafts up to 2,500 cfs (at RIODELCO gauge).

5	Rio Grande Canal diversion dam	This river-wide diversion dam creates a 10+ foot drop. This is a mandatory portage (on the south bank of the river).
6	Westside Ditch diversion dam	This diversion dam is not passable, regardless of flow. Boaters must portage around this structure.
6	Chicago Ditch diversion dam	This diversion dam is not passable, especially at low flows. Boaters must portage around this structure.
6	Meadow Overflow Ditch diversion dam	This diversion dam is not passable, regardless of flow. Boaters must portage around this structure.
6	New Ditch diversion dam	This diversion dam is not passable, regardless of flow. Boaters must portage around this structure.
6	County Rd Z	This bridge is hazardous at high flows. No discrete flow threshold is available.
8	Lobatos Bridge to Lee Trail, NM	This section is closed to recreational uses between April 1 and May 31 due to nesting raptors.

5. Discussion and Conclusions

This report discusses study locations, and methods used to collect and analyze streamflow preference information from recreational users. User survey responses provided by 136 respondents were used to delineate acceptable and optimal streamflow thresholds for supporting recreational use activities on 11 segments on the Rio Grande and Conejos River. Threshold identification supported quantification of the Boatable Days metric for each assessment reach under typical wet, average, and dry hydrological year types. The assessment followed recommendations the State of Colorado's Basin Implementation Plan guidance documents for quantifying non-consumptive recreational needs.

Respondent numbers for the flow preference study conducted in 2019 are robust for a remote or sparsely populated region of southern Colorado. The large number of responses to flow related questions for most reaches made delineation of flow acceptability thresholds fairly straightforward. However, low response rates among survey participants for reaches 6, 8, 9, and 10 may introduce some uncertainty into flow preference threshold delineated for those sections of river. Low response rates may indicate there is little to no use on these sections during most times of the year. Alternatively, it may indicate that the survey distribution did not reach the typical users of these reaches. Future recreational use assessment activities may benefit from targeted outreach to those users known to recreate on these reaches and inquiries into whether or not they have companions or are aware of additional users/groups that recreate at those locations. It may also be useful to ascertain why these reaches may be receiving so little use and whether or not there is opportunity to increase recreational activity through awareness campaigns, development of river access points, or through some other means.

Variable streamflow conditions were found to impact use opportunities on all reaches. The total number of Boatable Days generally increase throughout the assessment area as hydrological conditions transition from dry to average to wet. On most reaches, typical daily streamflows rarely exceed the upper flow acceptability threshold. On Reach 4 and Reach 5, however, that upper limit is exceeded in wet year types and on Reach 3, optimal flows are exceeded in wet year types leading to a significant decrease in the number of Boatable Days with optimal flows. These are the only three reaches where wet years are either characterized by pronounced decrease in total annual Boatable Days or significant decrease in days with optimal flows.

The assessment followed recommendations in the State of Colorado's Basin Implementation Plan guidance documents for quantifying non-consumptive recreational needs. In addition to completing a quantitative Boatable Days analysis, results from open-ended recreational user survey questions were evaluated. Responses to these questions provide insights into the recreational community's views on environmental, regulatory, and infrastructure management issues affecting reaches within the planning area (Appendix B). High priority issues identified by multiple users included the following:

- Coordinated reservoir releases and consistent flows for fishing and boating on the Rio Grande
- Removal or mitigation of boating hazards (fencing, diversions, bridges, etc.)
- River access improvements

Survey respondents also indicated which reaches they considered priorities for recreational paddling improvements (Figure 10). The sections of the Rio Grande between Texas Creek and South Fork ranked highest. The section between Lasauses and Lobatos Bridge ranked lowest. Rankings for the Conejos River segments were not requested in the survey. The desire for improvements on high-priority reaches may or may not be flow-based.

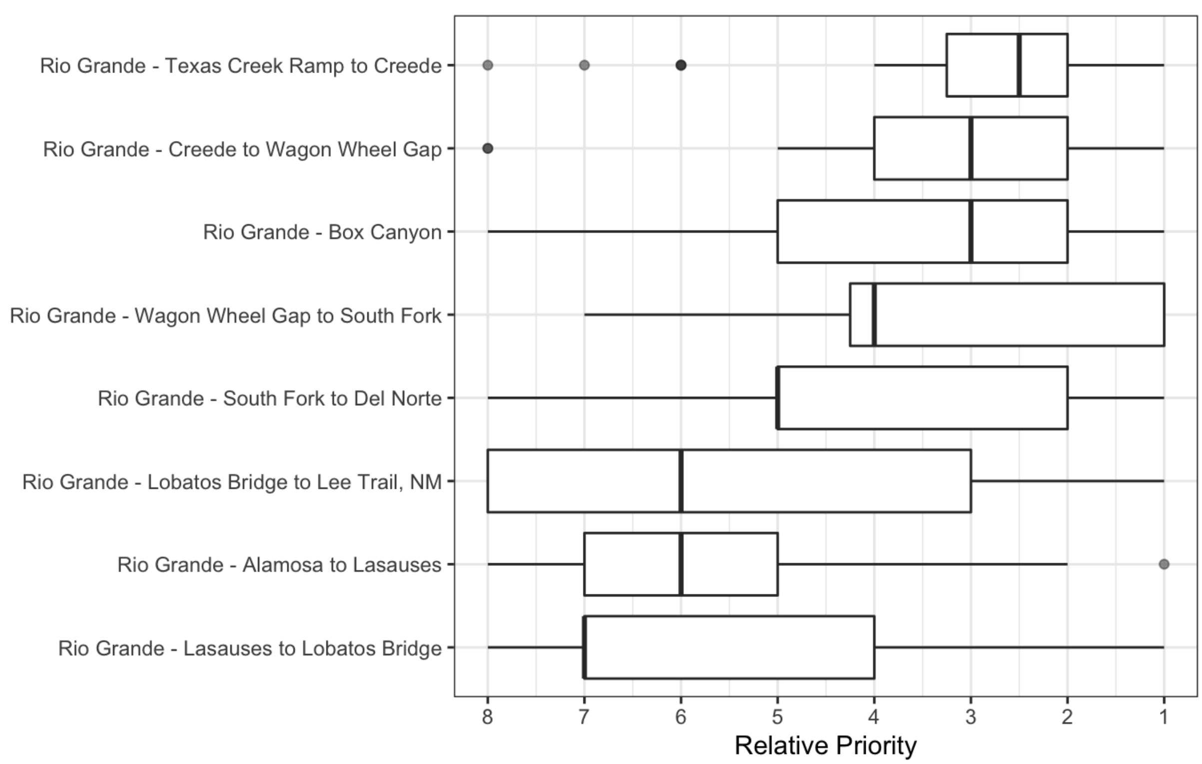

Figure 8. Distribution of survey responses indicating reaches that are the highest priority for recreational paddling improvements. A median score equal to 1 indicates a very high priority while a score of 8 indicates a very low priority. A wider box indicates a greater spread in the survey responses. A narrow box indicates a high degree of agreement between survey respondents.

The results presented in this report represent important baseline information characterizing the relationships between flows and recreational use. As such, this body of work directly supports the Rio Grande Headwater Restoration Project's Stream Management Planning efforts. Future efforts may choose to build upon this assessment by calculating the number of Boatable Days available in a greater diversity of hydrological year types, under various water management scenarios, or in anticipation of altered future hydrology due to climate change.

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APPENDIX A: Analysis Results by Reach

Rio Grande: Rio Grande Reservoir to Mouth of Box Canyon

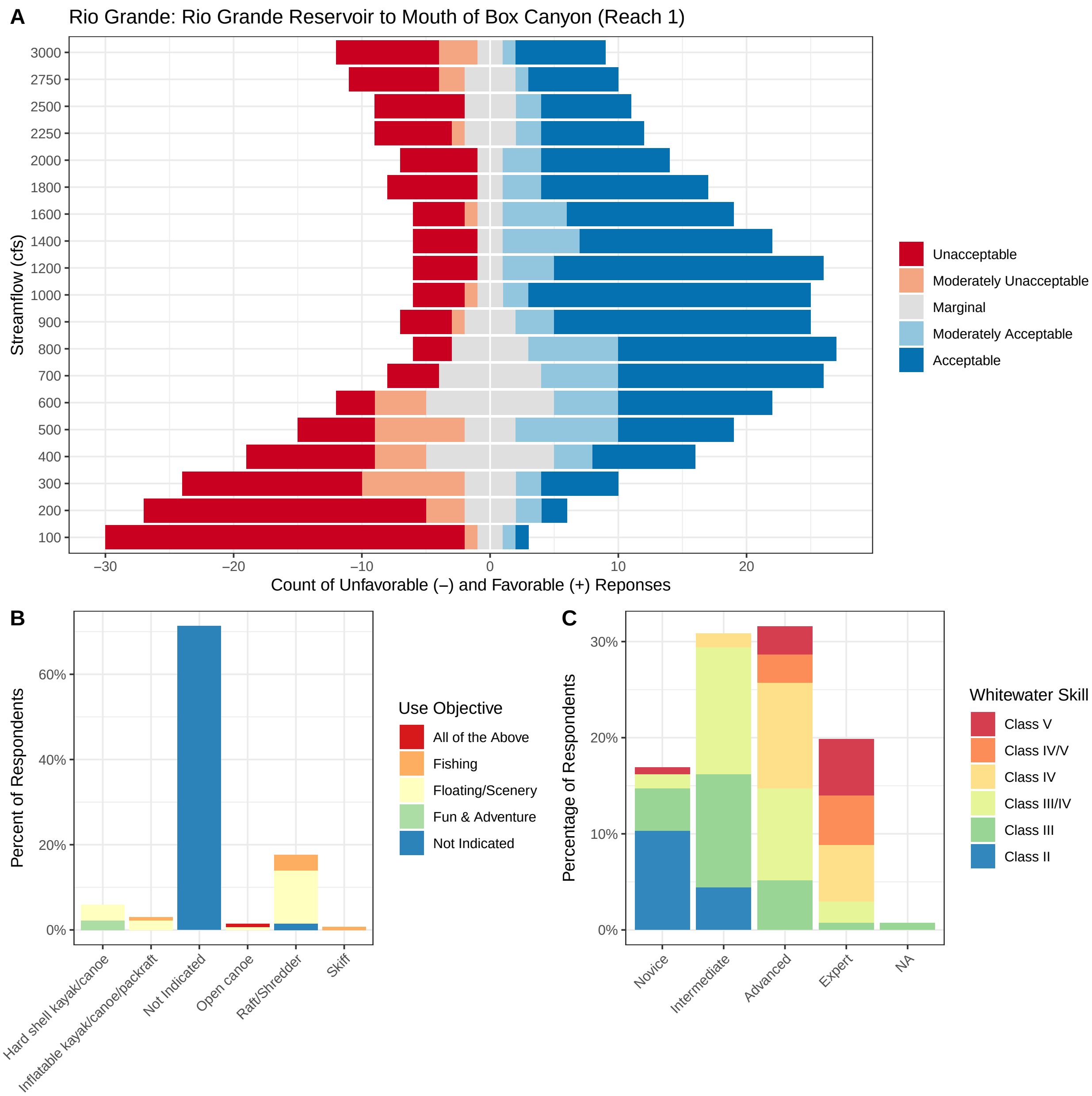


Figure 1: Survey responses for the Rio Grande, Rio Grande Reservoir to Mouth of Box Canyon. (A) Flow acceptability rankings. (B) User identified preferred craft types and recreational use objectives. (C) User identified whitewater navigation expertise.

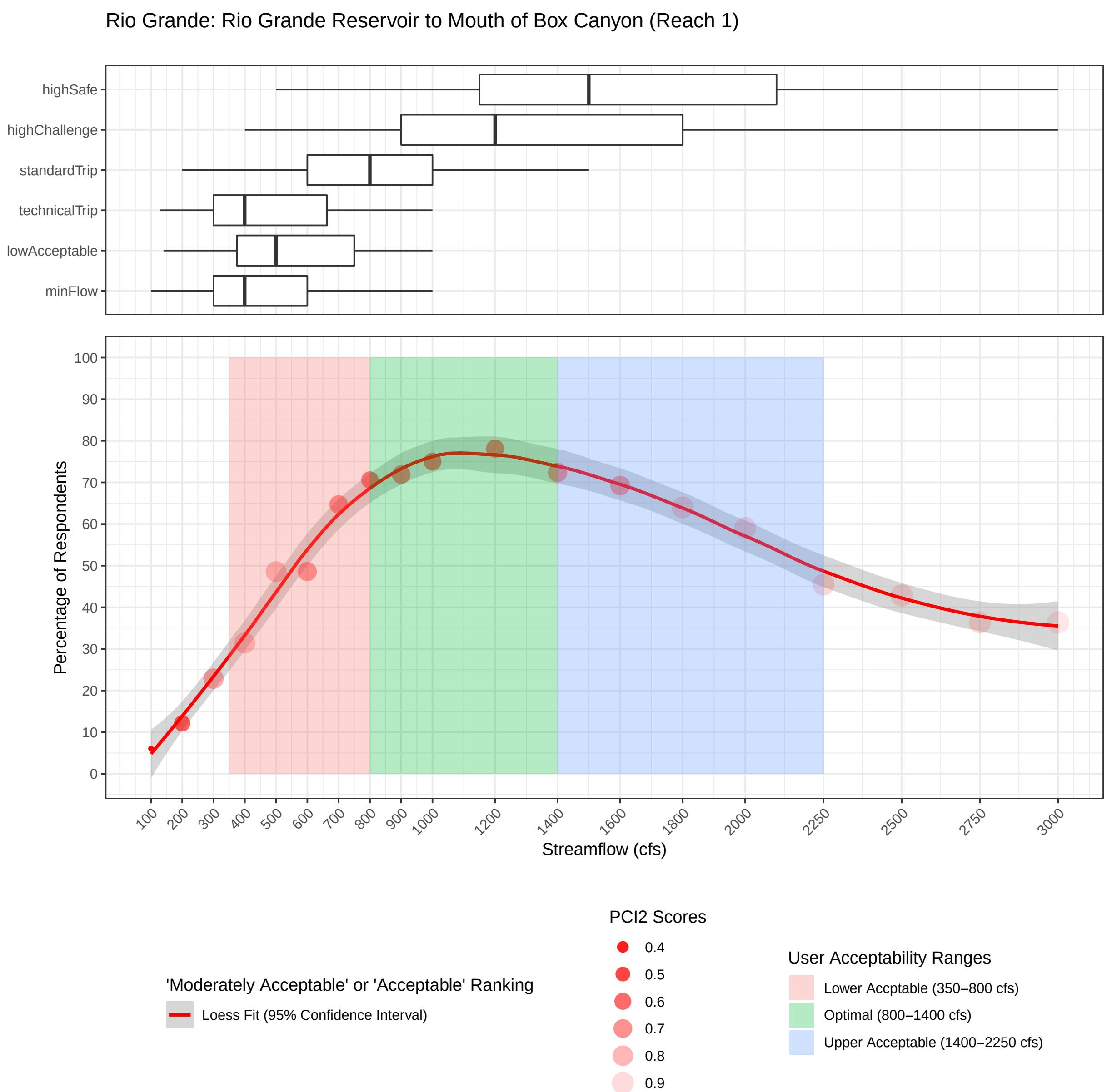


Figure 2: Flow preferences reported by users for the Rio Grande: Rio Grande Reservoir to Mouth of Box Canyon. (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges. Note: the maximum safe release from Rio Grande Reservoir was 1200 cfs throughout the 1998 to 2017 period.

Table 1: Summarized open-format flow-preference question responses for Reach 1, Rio Grande: Rio Grande Reservoir to Mouth of Box Canyon. Note: the maximum safe release from Rio Grande Reservoir was 1200 cfs throughout the 1998 to 2017 period.

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	300	400	600	35
Low Acceptable Flow (cfs)	375	500	750	35
Technical Flow (cfs)	300	400	662	32
Standard Trip Flow (cfs)	600	800	1000	35
Challenging High Flow (cfs)	900	1200	1800	29
Highest Safe Flow (cfs)	1150	1500	2100	27

Table 2: PCI2 analysis results for Reach 1, Rio Grande: Rio Grande Reservoir to Mouth of Box Canyon.

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
100	0.3216912	-2.0	33	2176	700
200	0.5698529	-2.0	33	2176	1240
300	0.7924837	-1.0	35	2448	1940
400	0.8366013	0.0	35	2448	2048
500	0.8169935	0.0	35	2448	2000
600	0.7140523	0.0	35	2448	1748
700	0.6851211	1.0	34	2312	1584
800	0.6185121	1.5	34	2312	1430
900	0.6777344	2.0	32	2048	1388
1000	0.6435547	2.0	32	2048	1318

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
1200	0.6601562	2.0	32	2048	1352
1400	0.7357143	2.0	29	1680	1236
1600	0.7485207	1.5	26	1352	1012
1800	0.8846154	2.0	25	1248	1104
2000	0.8863636	1.0	22	968	858
2250	0.8946281	0.0	22	968	866
2500	0.9136364	0.0	21	880	804
2750	0.9070248	0.0	22	968	878
3000	0.9297521	-0.5	22	968	900

Table 3: Boatable Days analysis results broken out by month for the Rio Grande: Rio Grande Reservoir to Mouth of Box Canyon. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
Apr	Lower Acceptable	0	0	2
May	Lower Acceptable	27	19	21
	Optimal	0	8	10
Jun	Lower Acceptable	11	13	0
	Optimal	0	17	30
Jul	Lower Acceptable	0	6	17
	Optimal	0	0	3

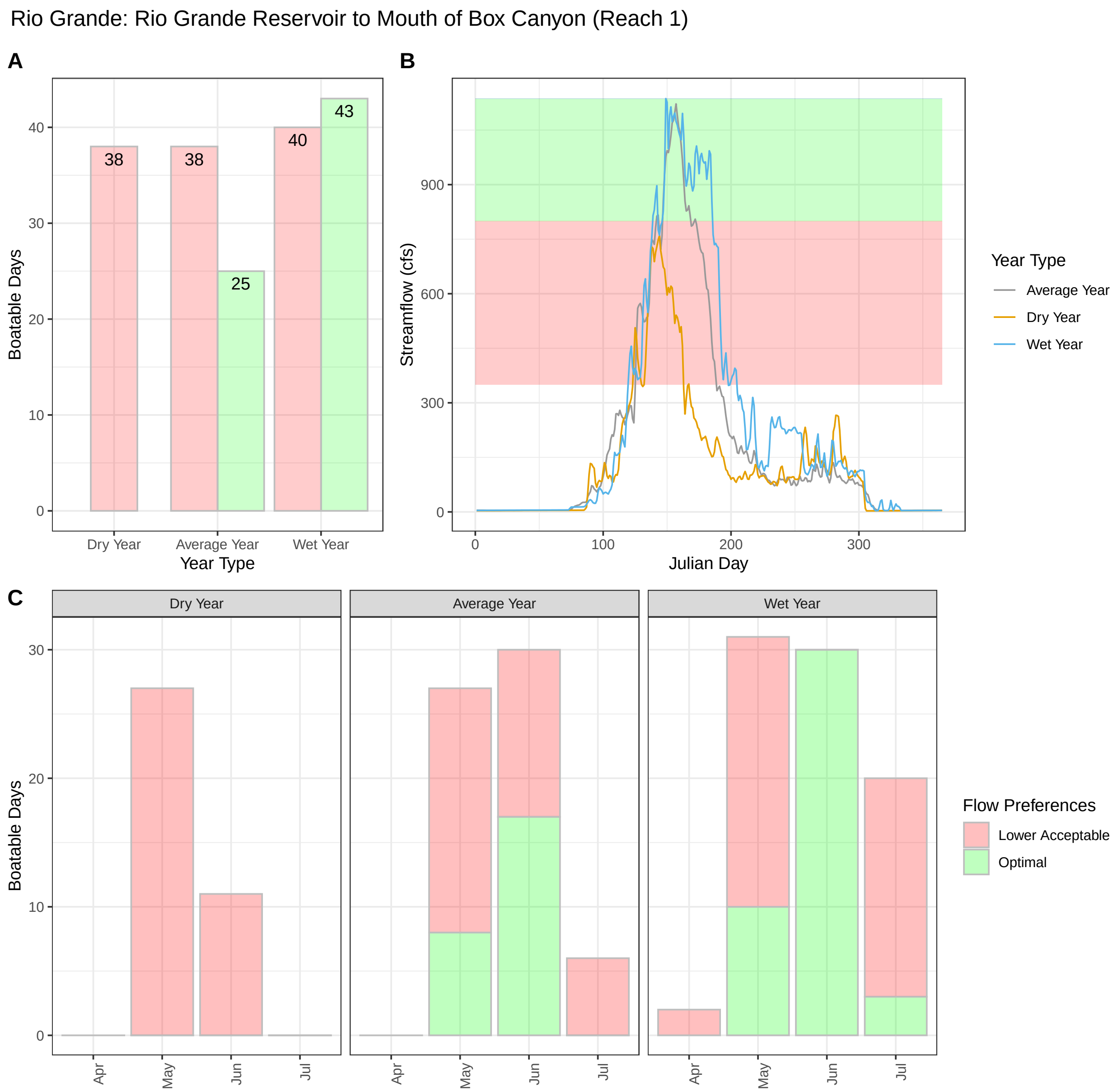


Figure 3: Boatable Days analysis results for the Rio Grande: Rio Grande Reservoir to Mouth of Box Canyon. (A) Total Boatable Days by year type and acceptability category; (B) flow acceptability ranges compared to typical wet, average, and dry year streamflow time series; and (C) monthly Boatable Days totals summarized by year type and acceptability category.

Rio Grande: Box Canyon to Deep Creek/Creede

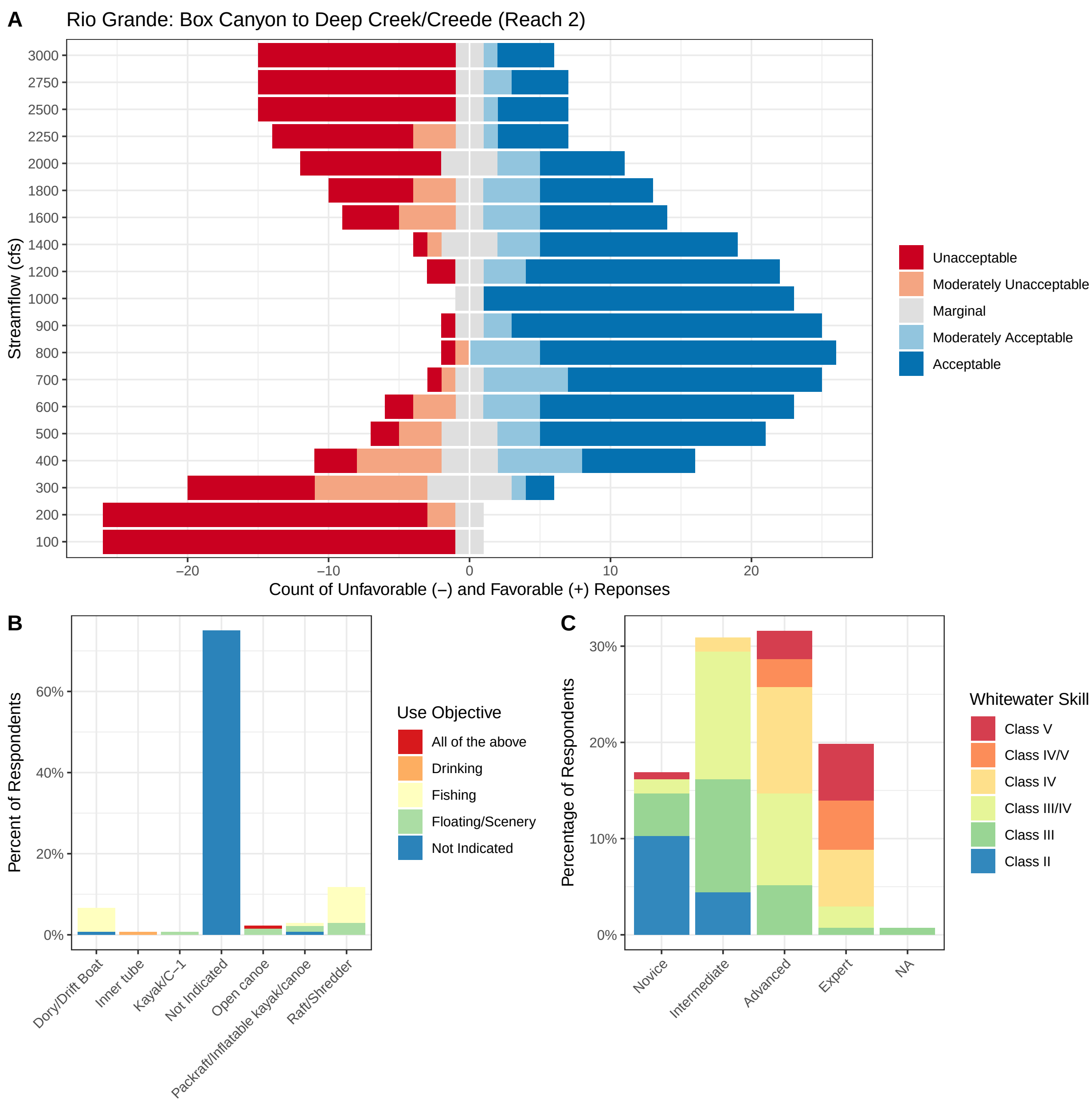


Figure 4: Survey responses for the Rio Grande, Box Canyon to Deep Creek/Creede. (A) Flow acceptability rankings. (B) User identified preferred craft types and recreational use objectives. (C) User identified whitewater navigation expertise.

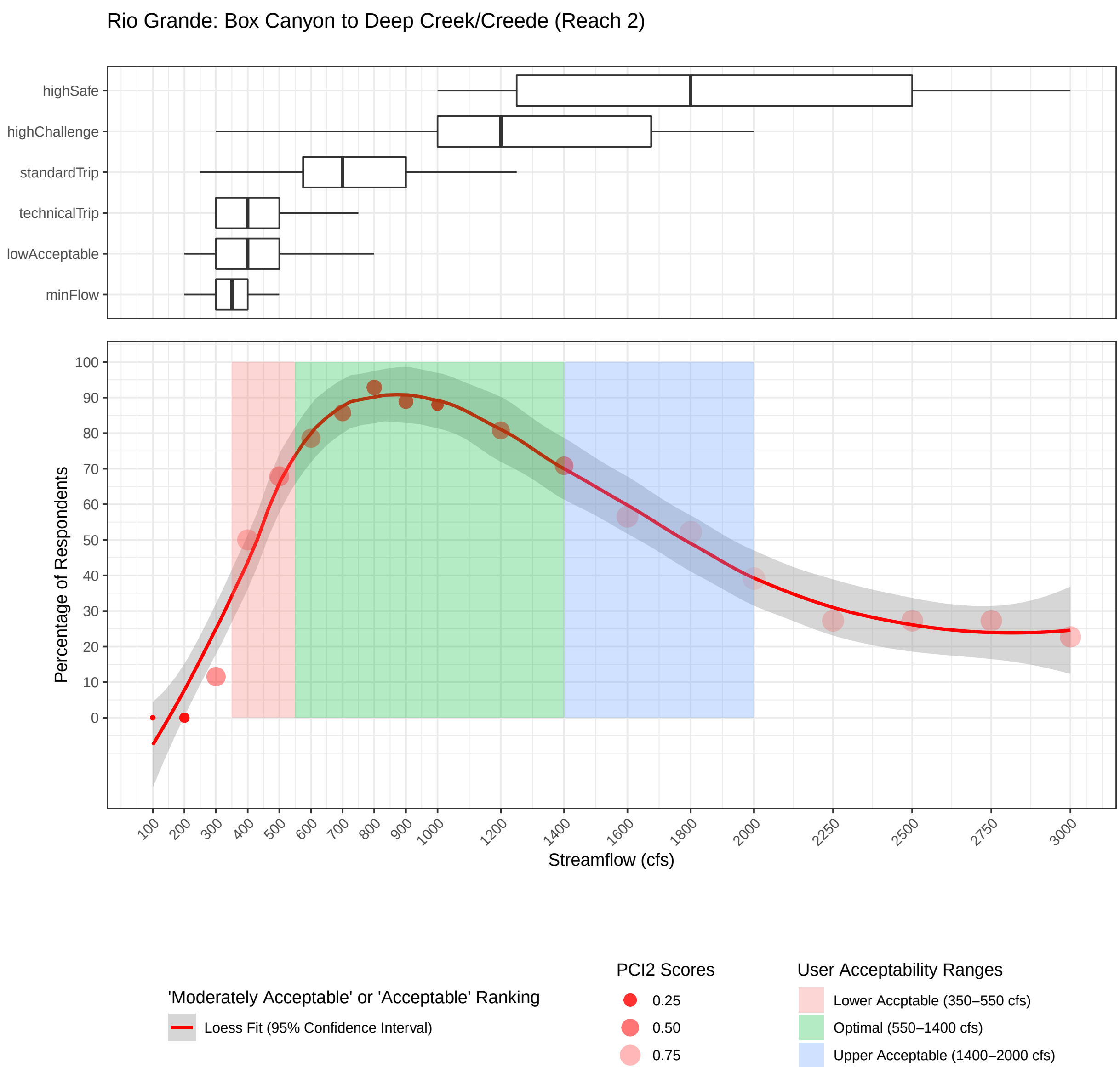


Figure 5: Flow preferences reported by users for the Rio Grande: Box Canyon to Deep Creek/Creede. (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges.

Table 4: Summarized open-format flow-preference question responses for Reach 2, Rio Grande: Box Canyon to Deep Creek/Creede.

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	300	350	400	28
Low Acceptable Flow (cfs)	300	400	500	28
Technical Flow (cfs)	300	400	500	24
Standard Trip Flow (cfs)	575	700	900	28
Challenging High Flow (cfs)	1000	1200	1675	22
Highest Safe Flow (cfs)	1250	1800	2500	22

Table 5: PCI2 analysis results for Reach 2, Rio Grande: Box Canyon to Deep Creek/Creede.

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
100	0.0739645	-2.0	26	1352	100
200	0.1390533	-2.0	26	1352	188
300	0.6257396	-1.0	26	1352	846
400	0.7678571	0.5	28	1568	1204
500	0.6760204	2.0	28	1568	1060
600	0.6109694	2.0	28	1568	958
700	0.4528061	2.0	28	1568	710
800	0.3545918	2.0	28	1568	556
900	0.3214286	2.0	27	1456	468
1000	0.2115385	2.0	25	1248	264
1200	0.5103550	2.0	26	1352	690
1400	0.5659722	2.0	24	1152	652

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
1600	0.8560606	1.0	23	1056	904
1800	0.9090909	1.0	23	1056	960
2000	0.9242424	0.0	23	1056	976
2250	0.8636364	-1.0	22	968	836
2500	0.8367769	-2.0	22	968	810
2750	0.8099174	-2.0	22	968	784
3000	0.7871901	-2.0	22	968	762

Table 6: Boatable Days analysis results broken out by month for the Rio Grande: Box Canyon to Deep Creek/Creede. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
Apr	Lower Acceptable	0	0	2
May	Lower Acceptable	9	6	11
	Optimal	18	21	20
Jun	Lower Acceptable	8	0	0
	Optimal	3	30	30
Jul	Lower Acceptable	0	5	11
	Optimal	0	1	9

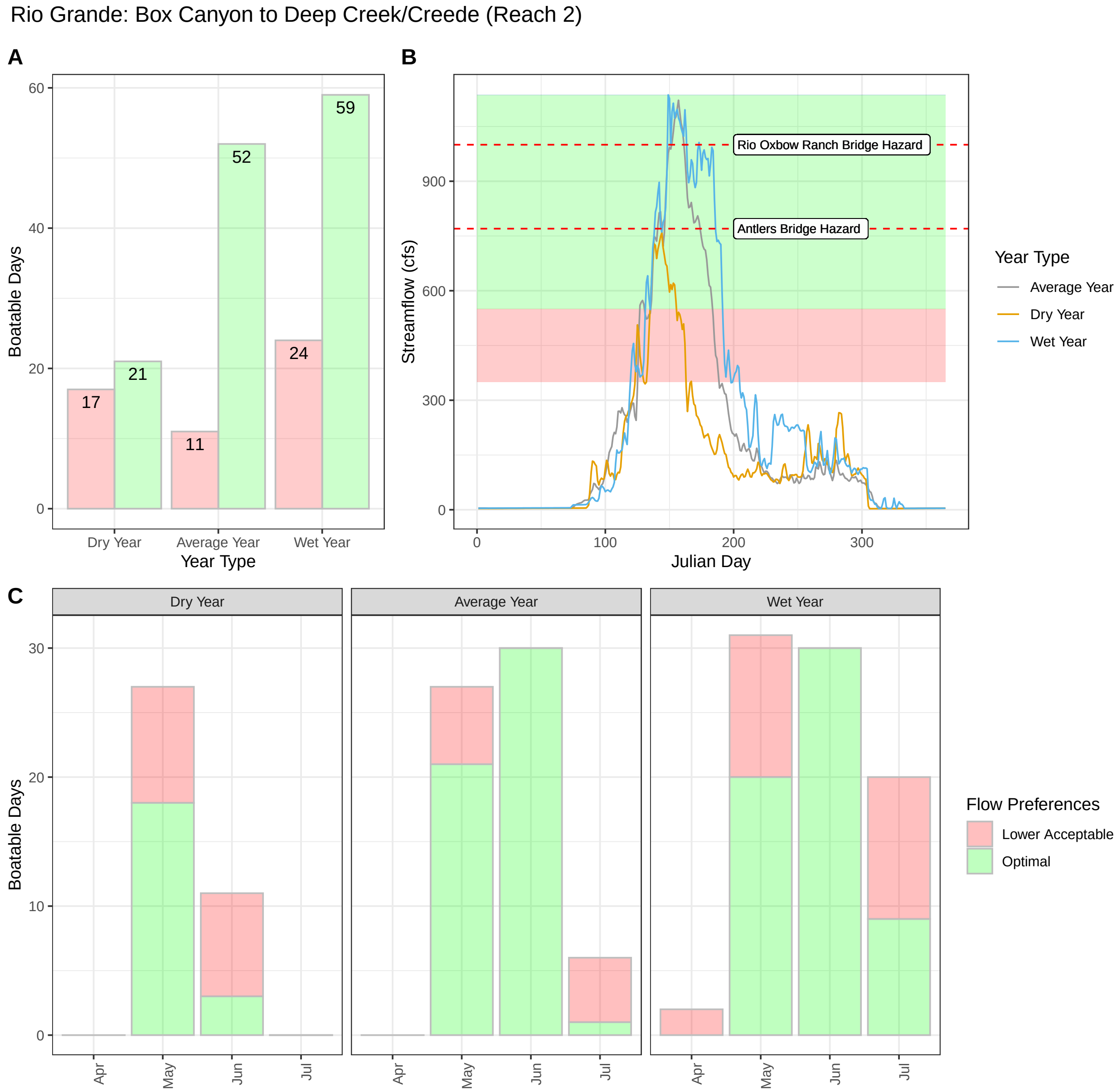


Figure 6: Boatable Days analysis results for the Rio Grande: Box Canyon to Deep Creek/Creede. (A) Total Boatable Days by year type and acceptability category; (B) flow acceptability ranges compared to typical wet, average, and dry year streamflow time series; and (C) monthly Boatable Days totals summarized by year type and acceptability category.

Rio Grande: Creede to Wagon Wheel Gap

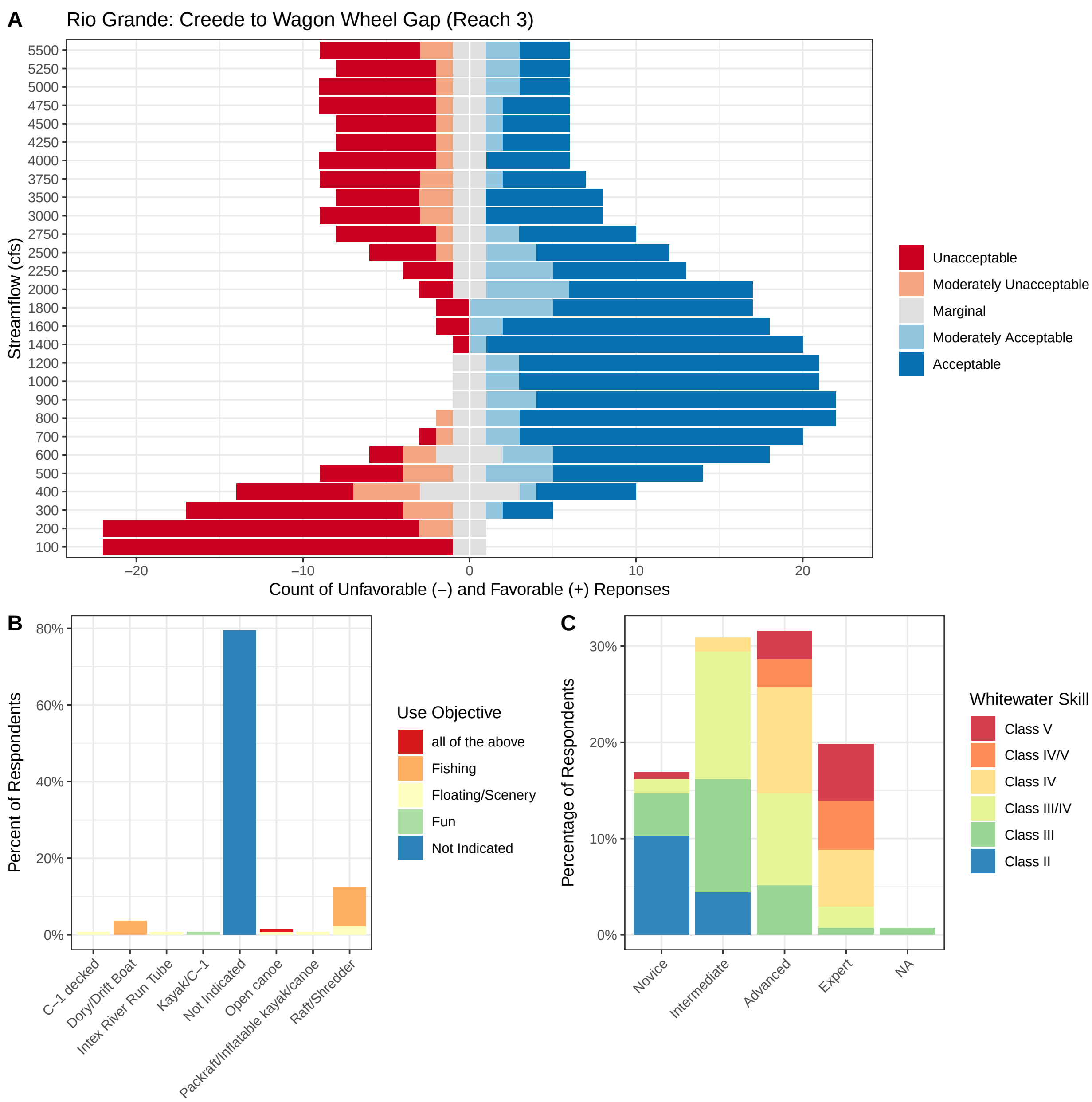


Figure 7: Survey responses for the Rio Grande, Creede to Wagon Wheel Gap. (A) Flow acceptability rankings. (B) User identified preferred craft types and recreational use objectives. (C) User identified whitewater navigation expertise.

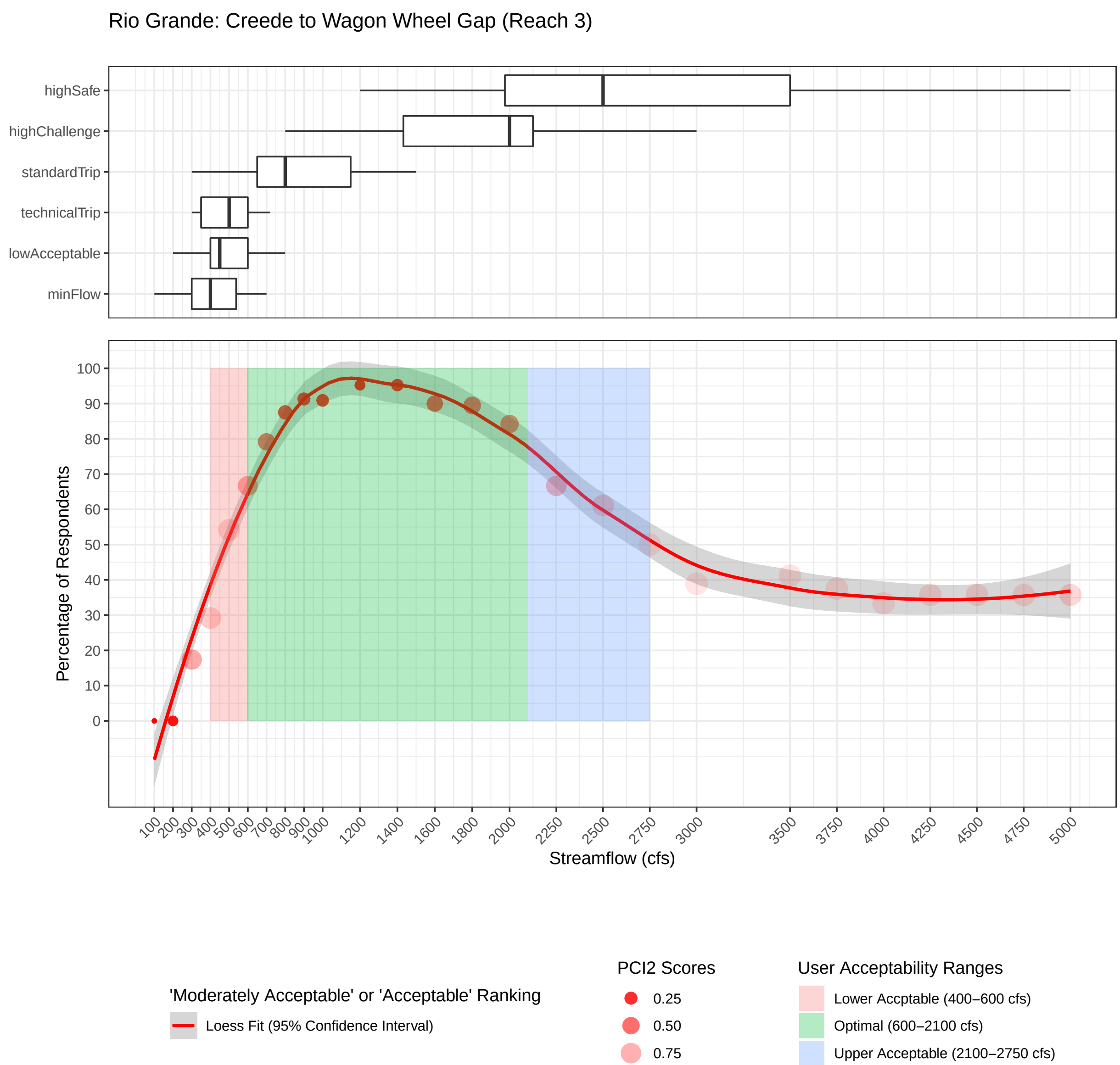


Figure 8: Flow preferences reported by users for the Rio Grande: Creede to Wagon Wheel Gap. (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges.

Table 7: Summarized open-format flow-preference question responses for Reach 3, Rio Grande: Creede to Wagon Wheel Gap.

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	300	400	538	23
Low Acceptable Flow (cfs)	400	450	600	23
Technical Flow (cfs)	350	500	600	21
Standard Trip Flow (cfs)	650	800	1150	22
Challenging High Flow (cfs)	1432	2000	2125	20
Highest Safe Flow (cfs)	1975	2500	3500	19

Table 8: PCI2 analysis results for Reach 3, Rio Grande: Creede to Wagon Wheel Gap.

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
100	0.0867769	-2.0	22	968	84
200	0.1611570	-2.0	22	968	156
300	0.7159091	-2.0	23	1056	756
400	0.8489583	0.0	24	1152	978
500	0.8697917	1.0	24	1152	1002
600	0.6857639	2.0	24	1152	790
700	0.4878472	2.0	24	1152	562
800	0.3142361	2.0	24	1152	362
900	0.2500000	2.0	23	1056	264
1000	0.2314050	2.0	22	968	224
1200	0.1681818	2.0	21	880	148
1400	0.2227273	2.0	21	880	196

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
1600	0.4300000	2.0	20	800	344
1800	0.5166667	2.0	19	720	372
2000	0.5666667	2.0	19	720	408
2250	0.7469136	1.0	18	648	484
2500	0.8580247	1.0	18	648	556
2750	0.9475309	0.5	18	648	614
3000	0.9444444	0.0	18	648	612
3500	0.9375000	0.0	17	576	540
3750	0.9335938	-0.5	16	512	478
4000	0.9464286	-1.0	15	448	424
4250	0.9285714	-0.5	14	392	364
4500	0.9285714	-0.5	14	392	364
4750	0.9285714	-1.5	14	392	364
5000	0.8928571	-1.5	14	392	350
5250	0.9166667	-1.0	13	336	308
5500	0.8877551	-1.0	14	392	348

Table 9: Boatable Days analysis results broken out by month for the Rio Grande: Creede to Wagon Wheel Gap. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
Mar	Lower Acceptable	1	0	0
Apr	Lower Acceptable	10	7	2
	Optimal	8	13	16
May	Optimal	31	23	16
	Upper Acceptable	0	8	10
Jun	Lower Acceptable	5	0	0
	Optimal	11	21	6
	Upper Acceptable	0	9	11
Jul	Lower Acceptable	0	11	10
	Optimal	0	20	21
Aug	Lower Acceptable	2	26	18
	Optimal	0	3	0
Sep	Lower Acceptable	18	15	0
	Optimal	1	0	0
Oct	Lower Acceptable	7	3	1
	Optimal	5	0	0

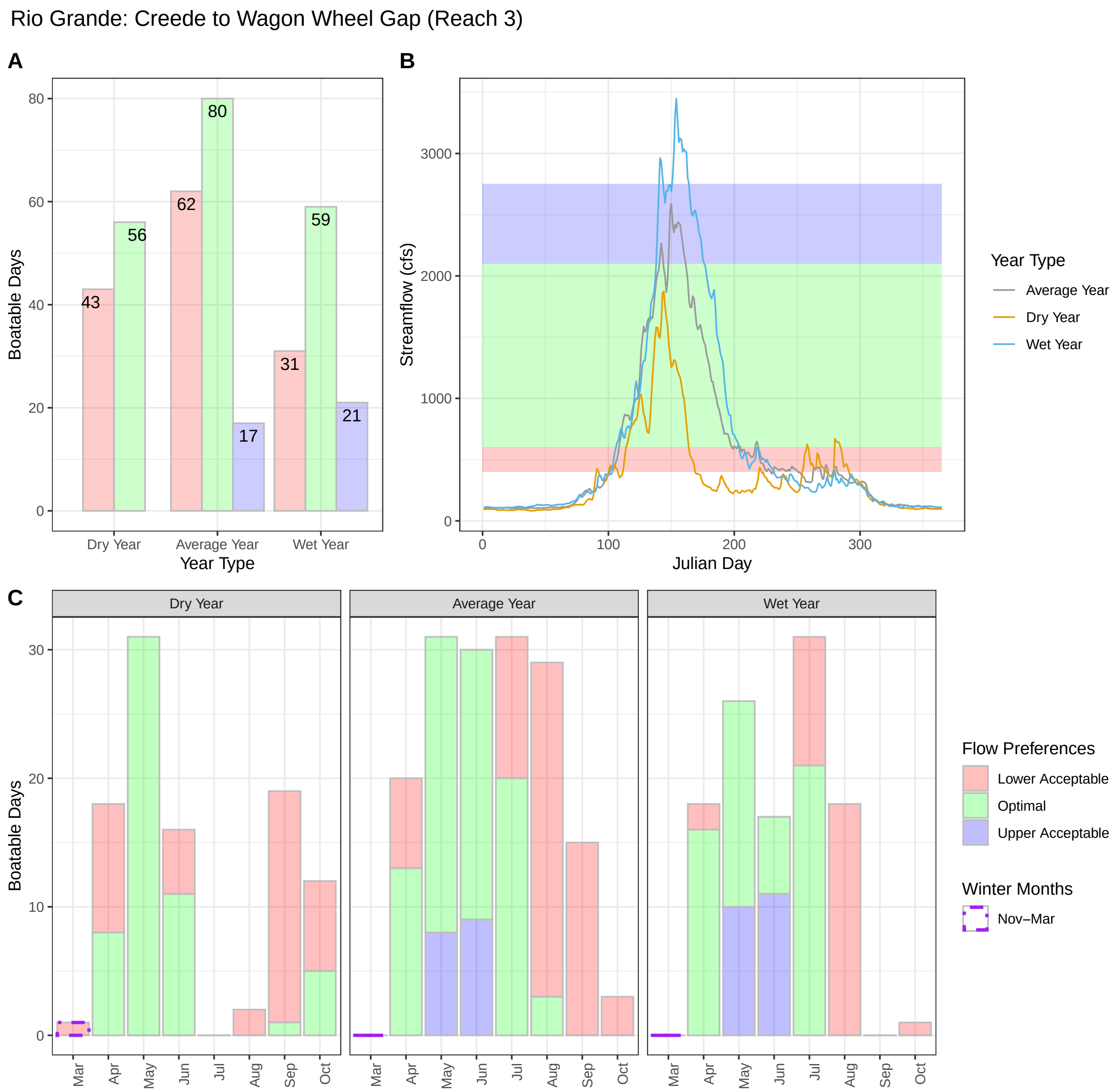


Figure 9: Boatable Days analysis results for the Rio Grande: Creede to Wagon Wheel Gap. (A) Total Boatable Days by year type and acceptability category; (B) flow acceptability ranges compared to typical wet, average, and dry year streamflow time series; and (C) monthly Boatable Days totals summarized by year type and acceptability category.

Rio Grande: Wagon Wheel Gap to South Fork

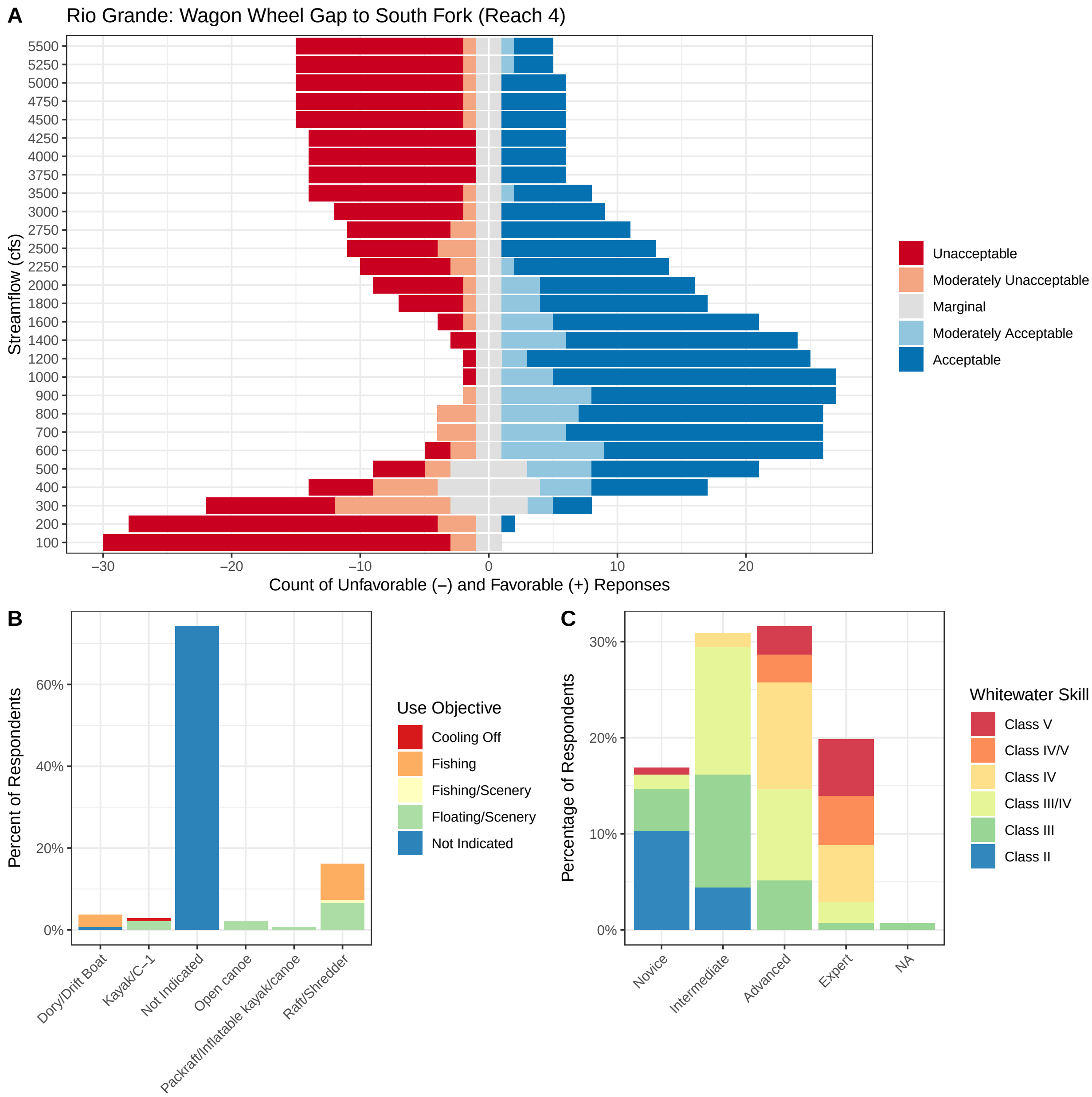


Figure 10: Survey responses for the Rio Grande, Wagon Wheel Gap to South Fork. (A) Flow acceptability rankings. (B) User identified preferred craft types and recreational use objectives. (C) User identified whitewater navigation expertise.

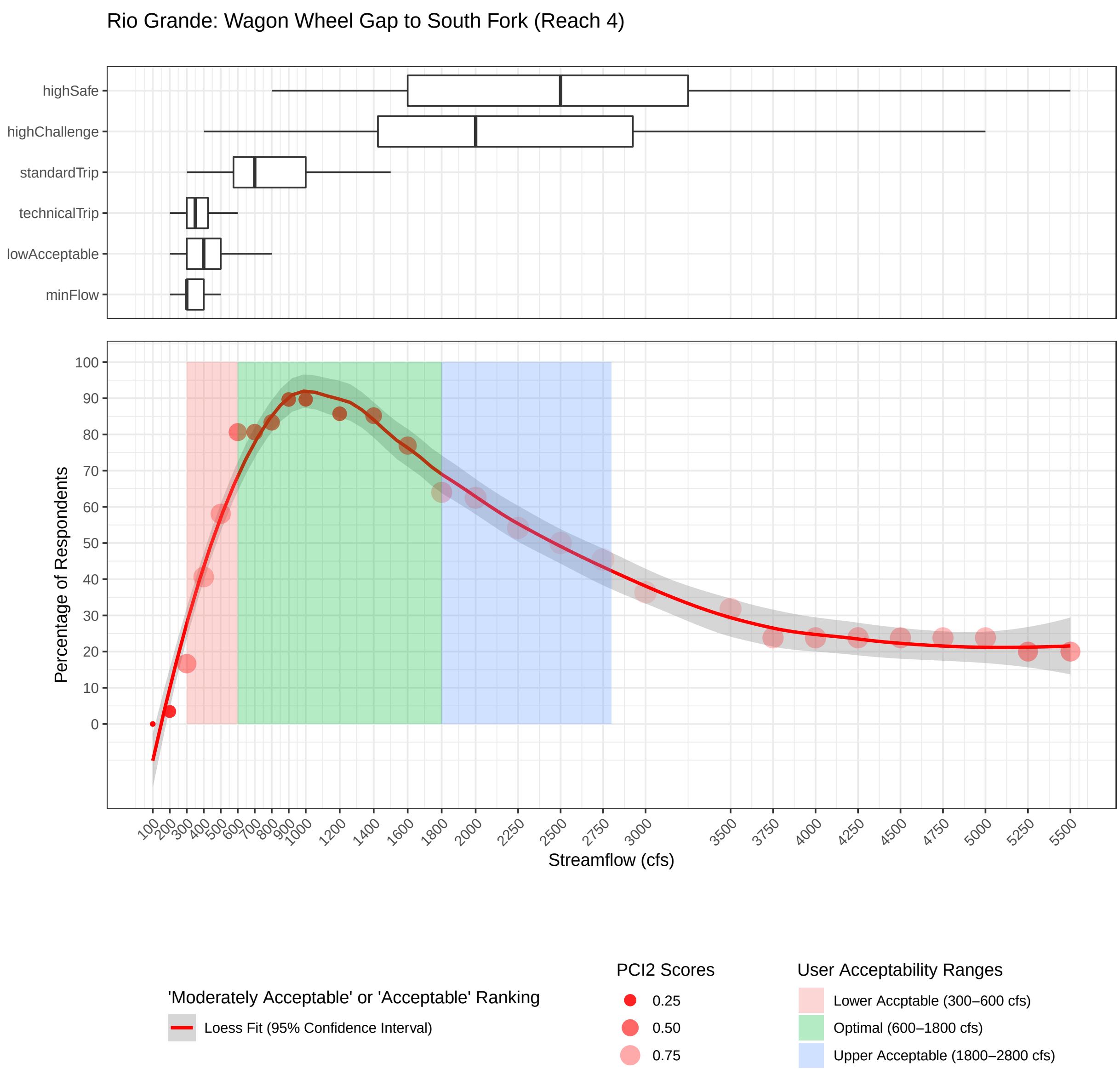


Figure 11: Flow preferences reported by users for the Rio Grande: Wagon Wheel Gap to South Fork. (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges.

Table 10: Summarized open-format flow-preference question responses for Reach 4, Rio Grande: Wagon Wheel Gap to South Fork.

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	300	300	400	28
Low Acceptable Flow (cfs)	300	400	500	28
Technical Flow (cfs)	300	350	425	27
Standard Trip Flow (cfs)	575	700	1000	28
Challenging High Flow (cfs)	1425	2000	2925	26
Highest Safe Flow (cfs)	1600	2500	3250	27

Table 11: PCI2 analysis results for Reach 4, Rio Grande: Wagon Wheel Gap to South Fork.

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
100	0.1222222	-2.0	30	1800	220
200	0.2738095	-2.0	29	1680	460
300	0.6833333	-1.0	30	1800	1230
400	0.7900391	0.0	32	2048	1618
500	0.7562500	1.0	31	1920	1452
600	0.5770833	2.0	31	1920	1108
700	0.4729167	2.0	31	1920	908
800	0.4611111	2.0	30	1800	830
900	0.3523810	2.0	29	1680	592
1000	0.3428571	2.0	29	1680	576
1200	0.3596939	2.0	28	1568	564

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
1400	0.4862637	2.0	27	1456	708
1600	0.5872781	2.0	26	1352	794
1800	0.8237179	2.0	25	1248	1028
2000	0.9131944	1.5	24	1152	1052
2250	0.9392361	1.5	24	1152	1082
2500	0.9496528	1.0	24	1152	1094
2750	0.9752066	0.0	22	968	944
3000	0.9607438	-0.5	22	968	930
3500	0.9049587	-2.0	22	968	876
3750	0.8363636	-2.0	21	880	736
4000	0.8363636	-2.0	21	880	736
4250	0.8363636	-2.0	21	880	736
4500	0.8227273	-2.0	21	880	724
4750	0.8227273	-2.0	21	880	724
5000	0.8227273	-2.0	21	880	724
5250	0.7250000	-2.0	20	800	580
5500	0.7250000	-2.0	20	800	580

Table 12: Boatable Days analysis results broken out by month for the Rio Grande: Wagon Wheel Gap to South Fork. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
Mar	Lower Acceptable	2	0	0
Apr	Lower Acceptable	22	12	14
	Optimal	8	13	16
May	Optimal	29	15	13
	Upper Acceptable	2	16	13
Jun	Lower Acceptable	12	0	0
	Optimal	11	16	0
	Upper Acceptable	0	14	20
Jul	Lower Acceptable	4	11	10
	Optimal	0	20	19
	Upper Acceptable	0	0	2
Aug	Lower Acceptable	18	28	31
	Optimal	0	3	0
Sep	Lower Acceptable	21	30	9
	Optimal	1	0	0
Oct	Lower Acceptable	22	30	18
	Optimal	5	0	0

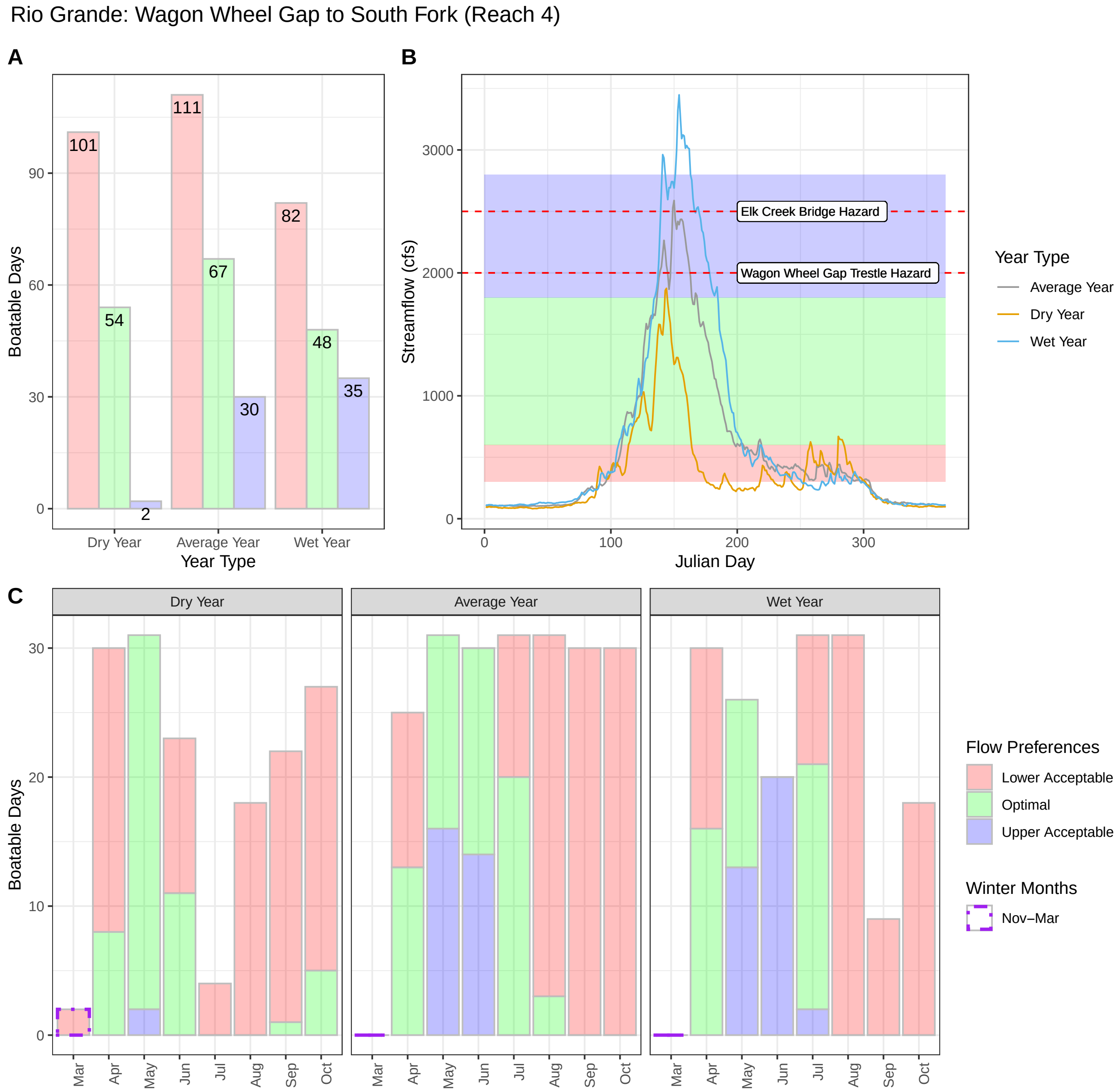


Figure 12: Boatable Days analysis results for the Rio Grande: Wagon Wheel Gap to South Fork. (A) Total Boatable Days by year type and acceptability category; (B) flow acceptability ranges compared to typical wet, average, and dry year streamflow time series; and (C) monthly Boatable Days totals summarized by year type and acceptability category.

Rio Grande: South Fork to Del Norte (Hwy 112)

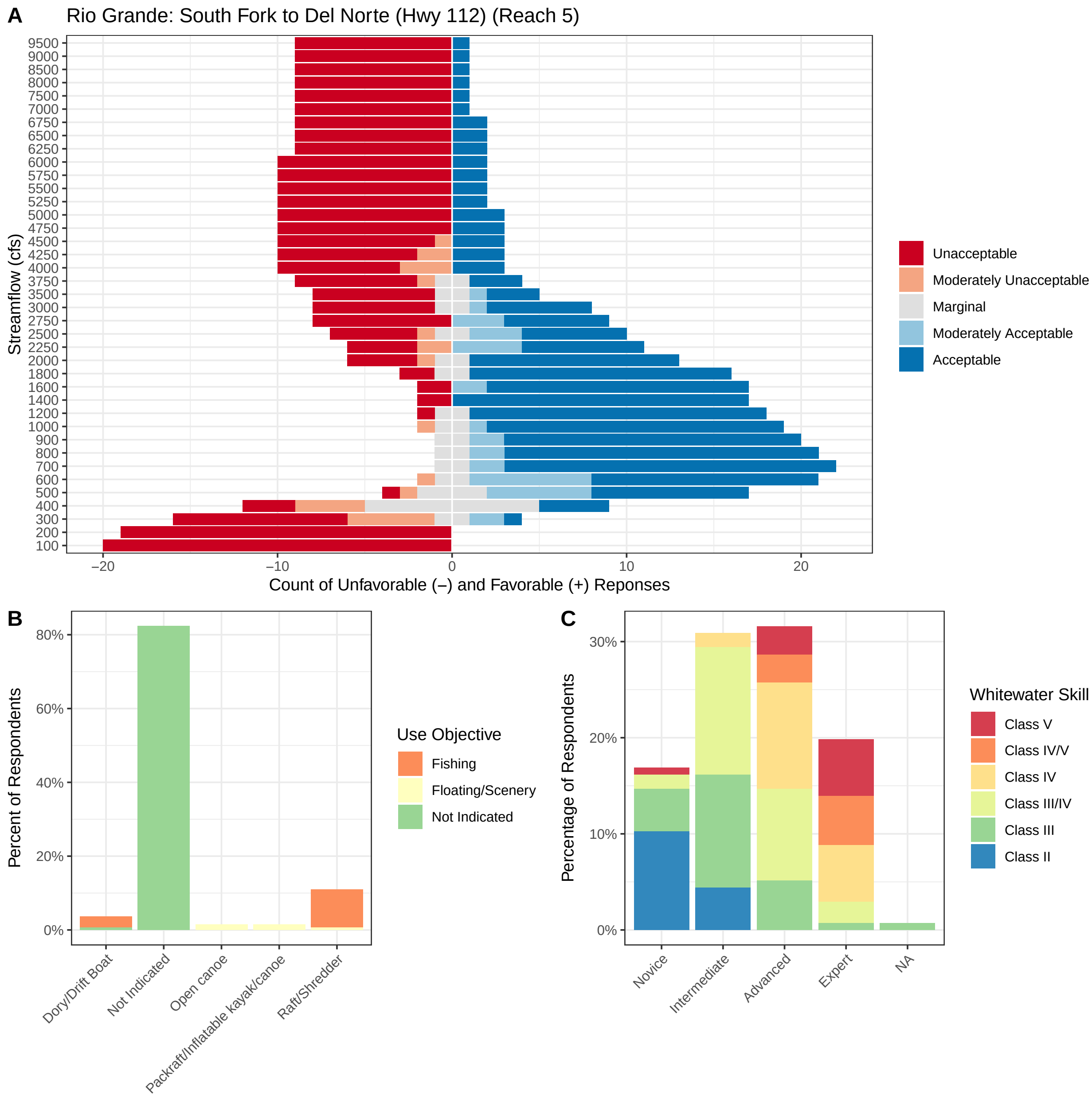


Figure 13: Survey responses for the Rio Grande, South Fork to Del Norte (Hwy 112). (A) Flow acceptability rankings. (B) User identified preferred craft types and recreational use objectives. (C) User identified whitewater navigation expertise.

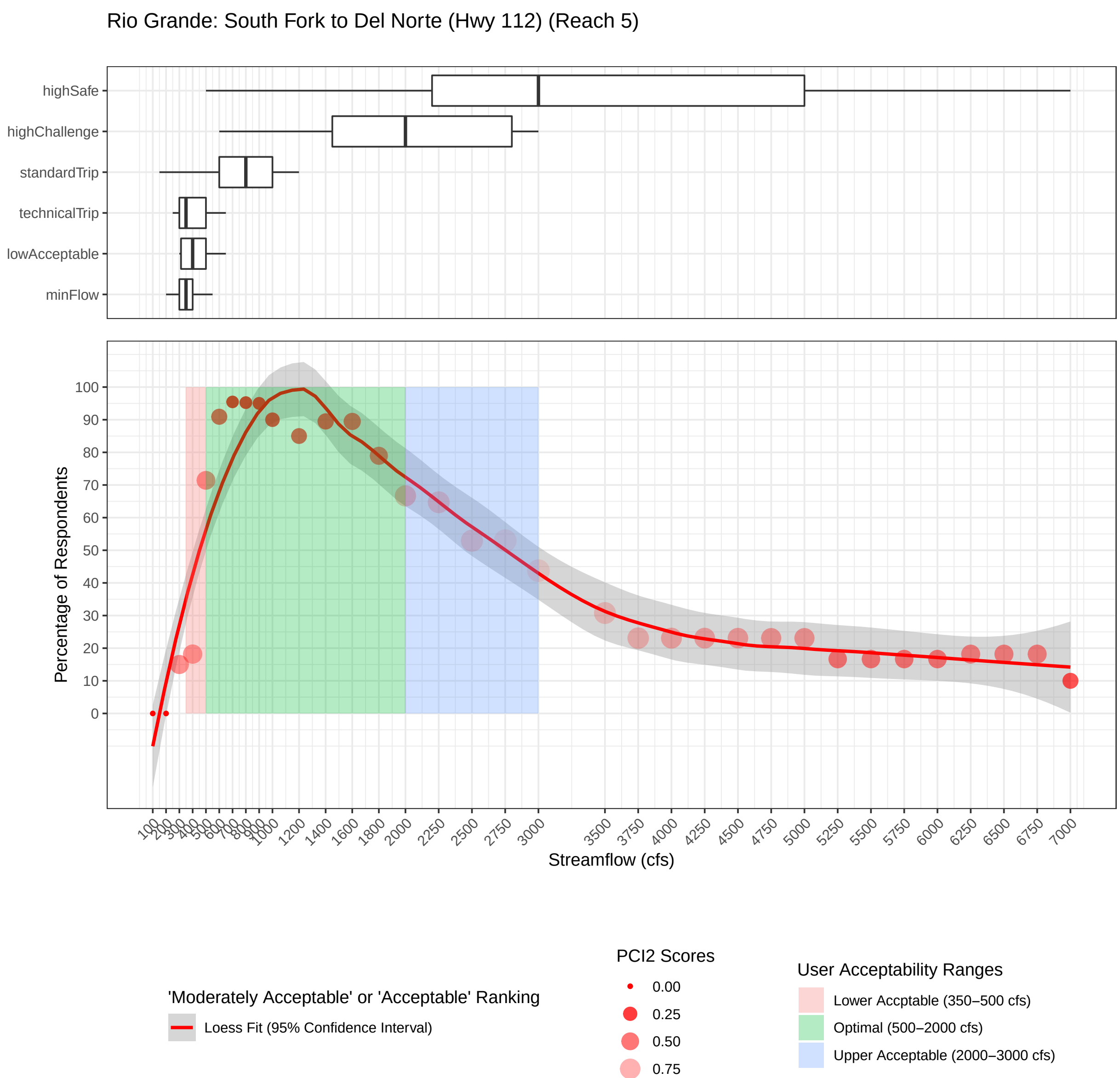


Figure 14: Flow preferences reported by users for the Rio Grande: South Fork to Del Norte (Hwy 112). (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges.

Table 13: Summarized open-format flow-preference question responses for Reach 5, Rio Grande: South Fork to Del Norte (Hwy 112).

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	300	350	400	20
Low Acceptable Flow (cfs)	312	400	500	18
Technical Flow (cfs)	300	350	500	15
Standard Trip Flow (cfs)	600	800	1000	17
Challenging High Flow (cfs)	1450	2000	2800	15
Highest Safe Flow (cfs)	2200	3000	5000	13

Table 14: PCI2 analysis results for Reach 5, Rio Grande: South Fork to Del Norte (Hwy 112).

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
100	0.0000000	-2.0	20	800	0
200	0.0000000	-2.0	19	720	0
300	0.6125000	-1.5	20	800	490
400	0.6322314	0.0	22	968	612
500	0.5818182	1.0	21	880	512
600	0.3677686	2.0	22	968	356
700	0.1611570	2.0	22	968	156
800	0.1681818	2.0	21	880	148
900	0.1750000	2.0	20	800	140
1000	0.2650000	2.0	20	800	212
1200	0.3500000	2.0	20	800	280
1400	0.3777778	2.0	19	720	272
1600	0.4500000	2.0	19	720	324

Flow (cfs)	PCI2	**Median Likert Response**	**n**	**Max. Distance**	**Total Distance**
1800	0.5222222	2.0	19	720	376
2000	0.8179012	2.0	18	648	530
2250	0.8819444	1.0	17	576	508
2500	0.9166667	1.0	17	576	528
2750	0.9791667	1.0	17	576	564
3000	0.9726562	0.0	16	512	498
3500	0.8928571	-2.0	13	336	300
3750	0.8452381	-2.0	13	336	284
4000	0.7857143	-2.0	13	336	264
4250	0.7738095	-2.0	13	336	260
4500	0.7500000	-2.0	13	336	252
4750	0.7142857	-2.0	13	336	240
5000	0.7142857	-2.0	13	336	240
5250	0.5555556	-2.0	12	288	160
5500	0.5555556	-2.0	12	288	160
5750	0.5555556	-2.0	12	288	160
6000	0.5555556	-2.0	12	288	160
6250	0.6000000	-2.0	11	240	144
6500	0.6000000	-2.0	11	240	144
6750	0.6000000	-2.0	11	240	144
7000	0.3600000	-2.0	10	200	72
7500	0.3600000	-2.0	10	200	72

Table 15: Boatable Days analysis results broken out by month for the Rio Grande: South Fork to Del Norte (Hwy 112). Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
Mar	Lower Acceptable	3	16	13
	Optimal	2	0	3
Apr	Lower Acceptable	0	5	0
	Optimal	30	25	30
May	Optimal	19	5	5
	Upper Acceptable	12	12	8
Jun	Lower Acceptable	10	0	0
	Optimal	19	7	0
	Upper Acceptable	0	14	8
Jul	Lower Acceptable	8	0	0
	Optimal	1	31	28
	Upper Acceptable	0	0	3
Aug	Lower Acceptable	21	0	12
	Optimal	7	31	19
Sep	Lower Acceptable	3	11	20
	Optimal	19	19	0
Oct	Lower Acceptable	9	22	29
	Optimal	22	9	2
Nov	Lower Acceptable	0	2	0

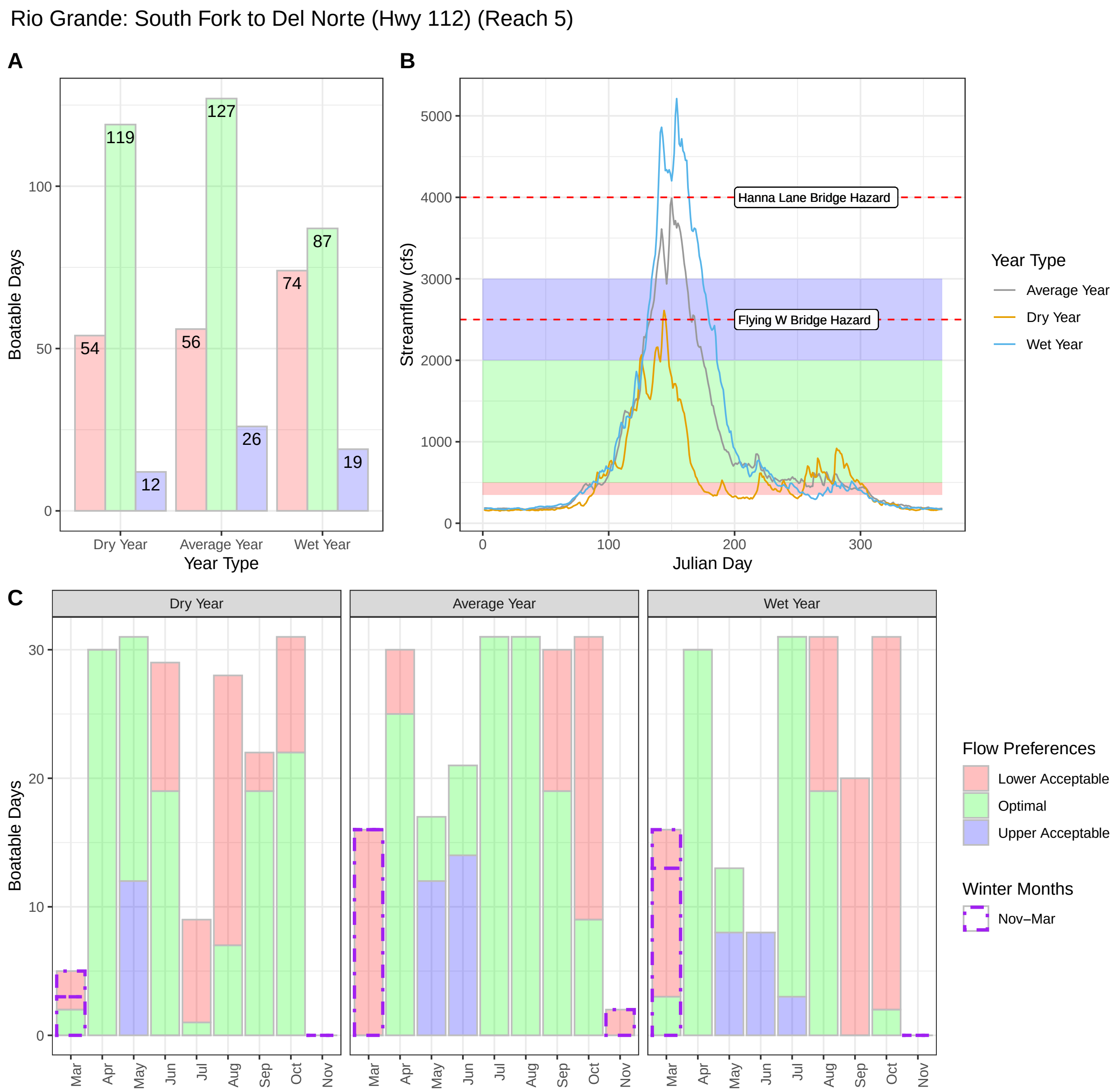


Figure 15: Boatable Days analysis results for the Rio Grande: South Fork to Del Norte (Hwy 112). (A) Total Boatable Days by year type and acceptability category; (B) flow acceptability ranges compared to typical wet, average, and dry year streamflow time series; and (C) monthly Boatable Days totals summarized by year type and acceptability category.

Rio Grande: Alamosa to Lasauses

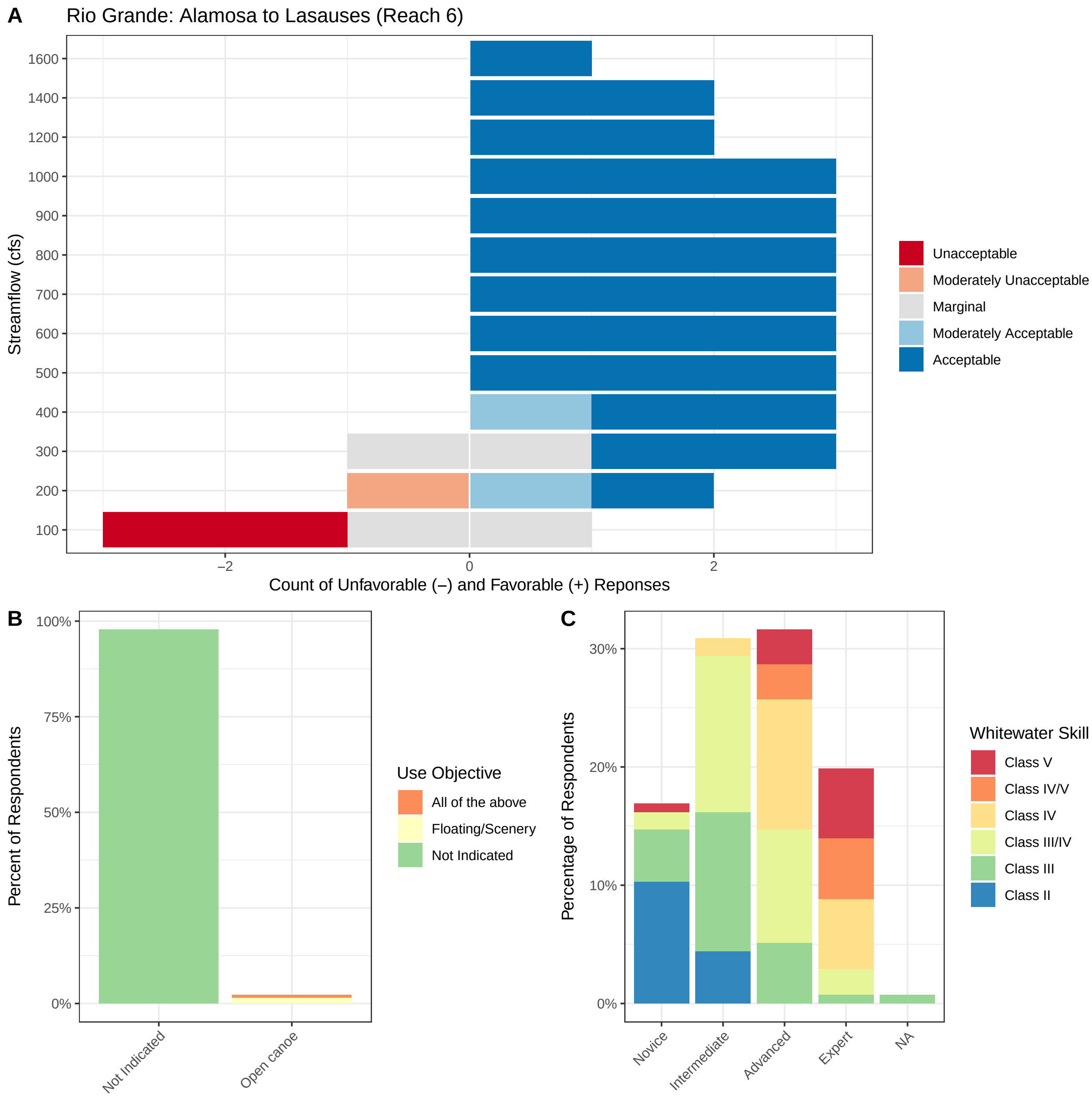


Figure 16: Survey responses for the Rio Grande, Alamosa to Lasauses. (A) Flow acceptability rankings. (B) User identified preferred craft types and recreational use objectives. (C) User identified whitewater navigation expertise.

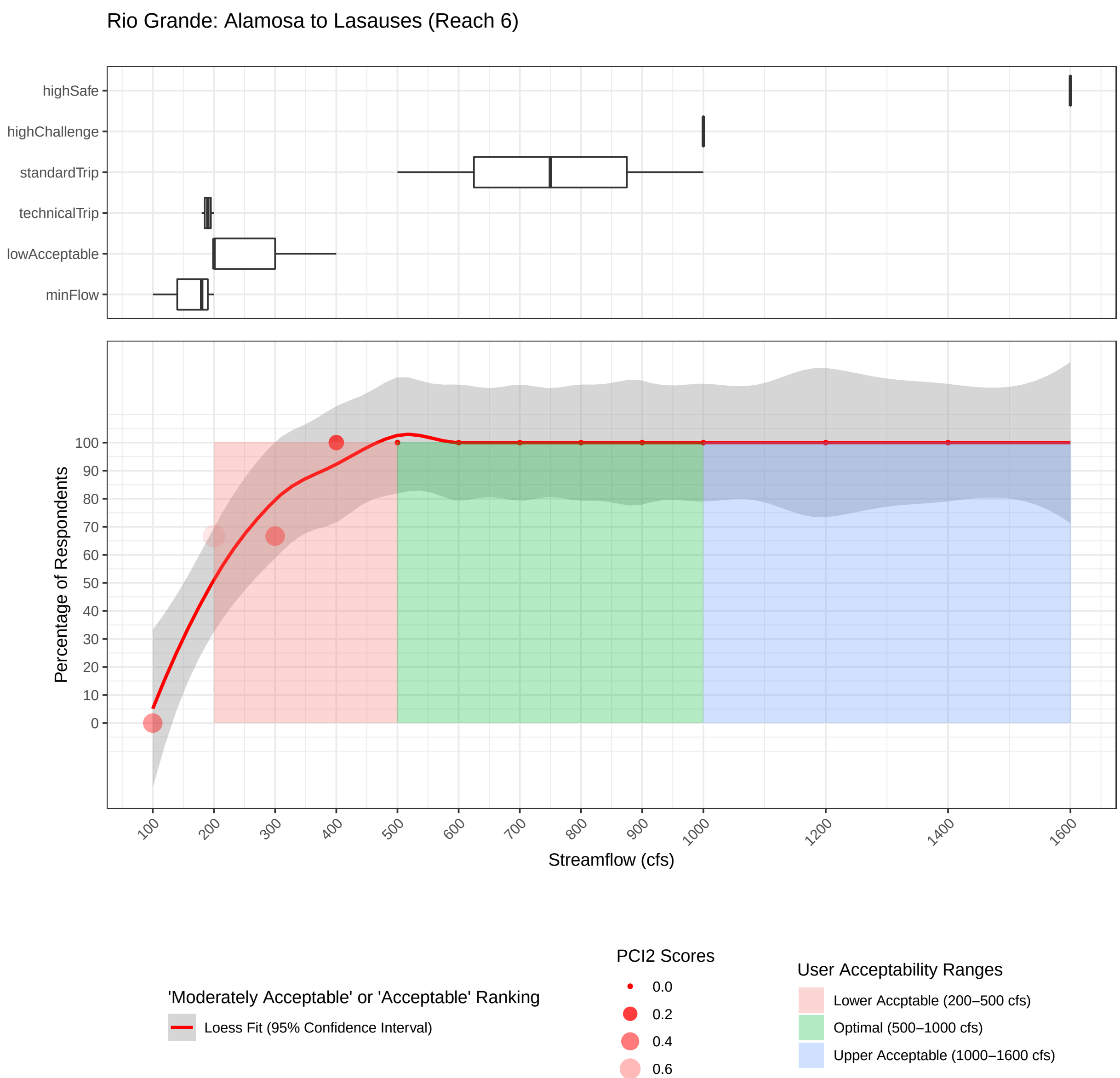


Figure 17: Flow preferences reported by users for the Rio Grande: Alamosa to Lasauses. (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges.

Table 16: Summarized open-format flow-preference question responses for Reach 6, Rio Grande: Alamosa to Lasauses.

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	140	180	190	3
Low Acceptable Flow (cfs)	200	200	300	3
Technical Flow (cfs)	185	190	195	2
Standard Trip Flow (cfs)	625	750	875	2
Challenging High Flow (cfs)	1000	1000	1000	1
Highest Safe Flow (cfs)	5000	5000	5000	1

Table 17: PCI2 analysis results for Reach 6, Rio Grande: Alamosa to Lasauses.

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
100	0.50	-2	3	16	8
200	0.75	1	3	16	12
300	0.50	2	3	16	8
400	0.25	2	3	16	4
500	0.00	2	3	16	0
600	0.00	2	3	16	0
700	0.00	2	3	16	0
800	0.00	2	3	16	0
900	0.00	2	3	16	0
1000	0.00	2	3	16	0
1200	0.00	2	2	8	0
1400	0.00	2	2	8	0
1600	NaN	2	1	0	0

Table 18: Boatable Days analysis results broken out by month for the Rio Grande: Alamosa to Lasauses. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
Jan	Lower Acceptable	0	0	10
Feb	Lower Acceptable	13	21	22
Mar	Lower Acceptable	17	30	31
	Optimal	0	1	0
Apr	Lower Acceptable	0	4	22
May	Lower Acceptable	0	28	15
	Optimal	0	0	16
Jun	Lower Acceptable	10	21	1
	Optimal	0	0	29
Jul	Lower Acceptable	0	1	31
Aug	Lower Acceptable	0	0	31
Sep	Lower Acceptable	0	0	24
Nov	Lower Acceptable	7	27	15
Dec	Lower Acceptable	0	14	2

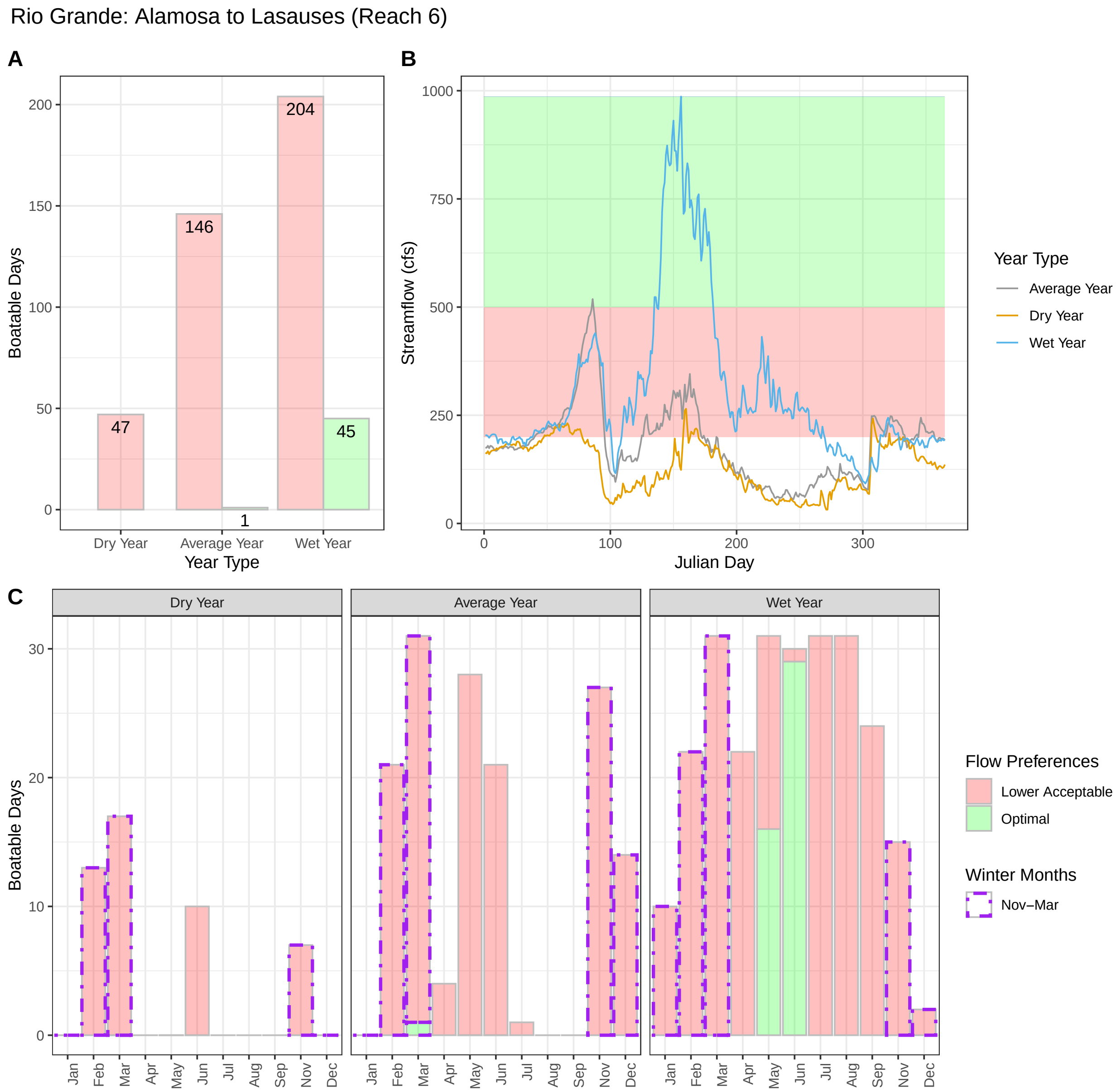


Figure 18: Boatable Days analysis results for the Rio Grande: Alamosa to Lasauses. (A) Total Boatable Days by year type and acceptability category; (B) flow acceptability ranges compared to typical wet, average, and dry year streamflow time series; and (C) monthly Boatable Days totals summarized by year type and acceptability category.

Rio Grande: Lasauses to Lobatos Bridge

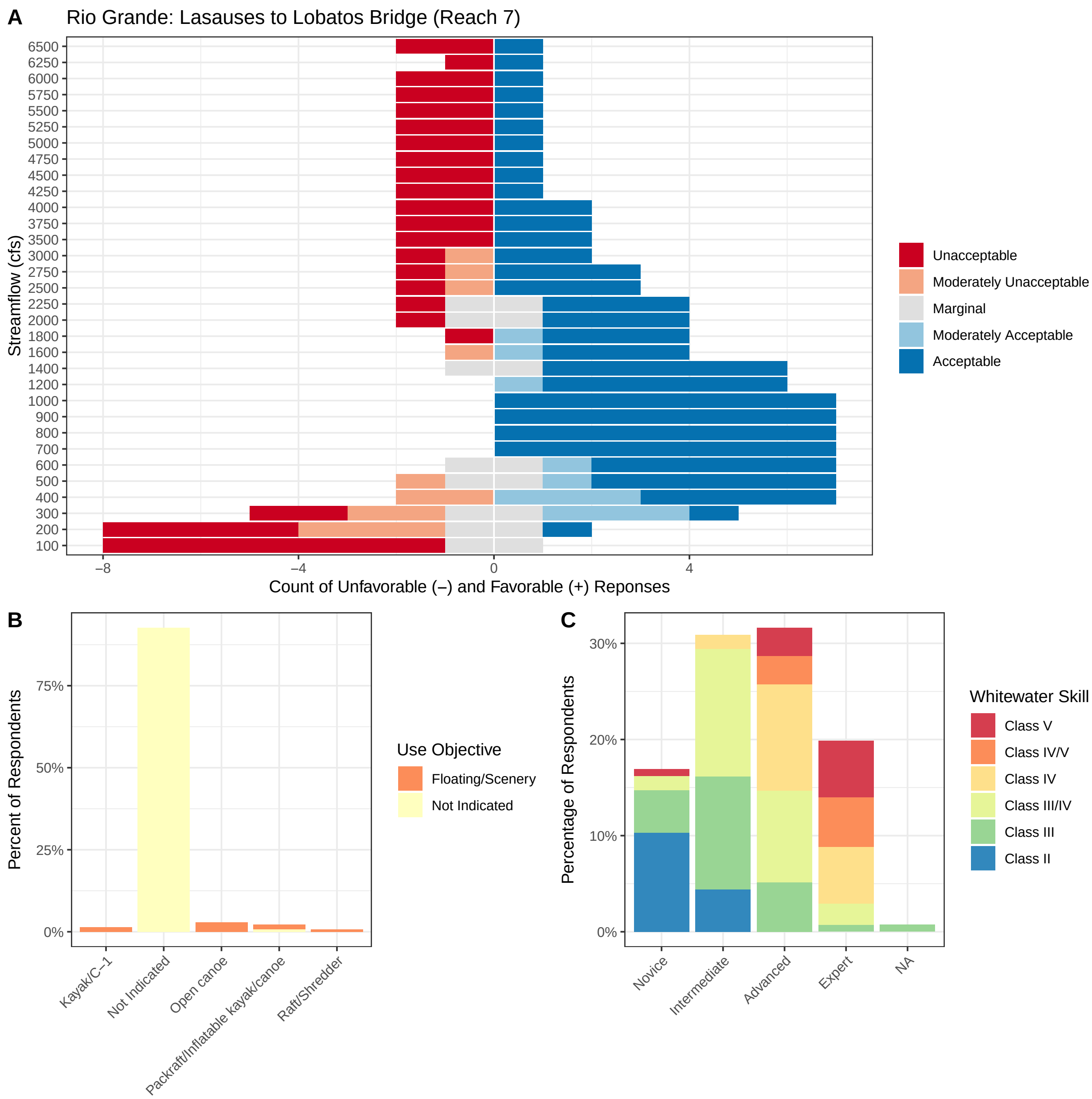


Figure 19: Survey responses for the Rio Grande, Lasauses to Lobatos Bridge. (A) Flow acceptability rankings. (B) User identified preferred craft types and recreational use objectives. (C) User identified whitewater navigation expertise.

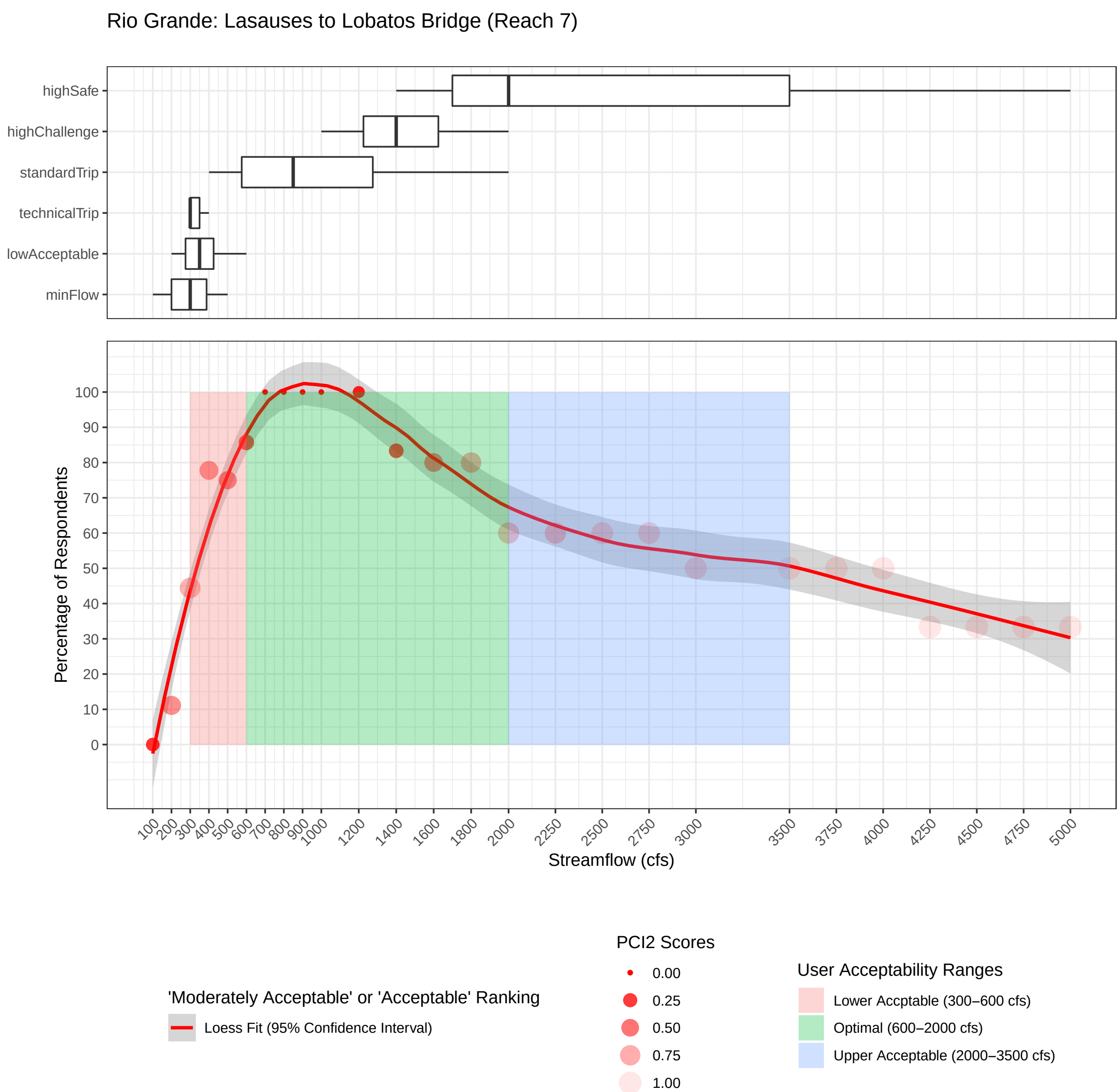


Figure 20: Flow preferences reported by users for the Rio Grande: Lasauses to Lobatos Bridge. (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges.

Table 19: Summarized open-format flow-preference question responses for Reach 7, Rio Grande: Lasauses to Lobatos Bridge.

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	200	300	388	8
Low Acceptable Flow (cfs)	275	350	425	8
Technical Flow (cfs)	300	300	350	5
Standard Trip Flow (cfs)	575	850	1275	8
Challenging High Flow (cfs)	1225	1400	1625	4
Highest Safe Flow (cfs)	1700	2000	3500	3

Table 20: PCI2 analysis results for Reach 7, Rio Grande: Lasauses to Lobatos Bridge.

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
100	0.2187500	-2.0	8	128	28
200	0.6250000	-1.0	9	160	100
300	0.7750000	0.0	9	160	124
400	0.6000000	1.0	9	160	96
500	0.5312500	2.0	8	128	68
600	0.3333333	2.0	7	96	32
700	0.0000000	2.0	7	96	0
800	0.0000000	2.0	7	96	0
900	0.0000000	2.0	7	96	0
1000	0.0000000	2.0	7	96	0
1200	0.1388889	2.0	6	72	10
1400	0.2777778	2.0	6	72	20

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
1600	0.5833333	2.0	5	48	28
1800	0.7500000	2.0	5	48	36
2000	0.8333333	2.0	5	48	40
2250	0.8333333	2.0	5	48	40
2500	0.9166667	2.0	5	48	44
2750	0.9166667	2.0	5	48	44
3000	0.9375000	0.5	4	32	30
3500	1.0000000	0.0	4	32	32
3750	1.0000000	0.0	4	32	32
4000	1.0000000	0.0	4	32	32
4250	1.0000000	-2.0	3	16	16
4500	1.0000000	-2.0	3	16	16
4750	1.0000000	-2.0	3	16	16
5000	1.0000000	-2.0	3	16	16
5250	1.0000000	-2.0	3	16	16
5500	1.0000000	-2.0	3	16	16
5750	1.0000000	-2.0	3	16	16
6000	1.0000000	-2.0	3	16	16
6250	1.0000000	0.0	2	8	8
6500	1.0000000	-2.0	3	16	16

Table 21: Boatable Days analysis results broken out by month for the Rio Grande: Lasauses to Lobatos Bridge. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
Feb	Lower Acceptable	0	0	1
Mar	Lower Acceptable	0	24	30
Apr	Lower Acceptable	0	4	10
May	Lower Acceptable	0	3	14
	Optimal	0	0	17
Jun	Lower Acceptable	0	8	0
	Optimal	0	0	30
Jul	Lower Acceptable	0	0	12
Aug	Lower Acceptable	0	0	7

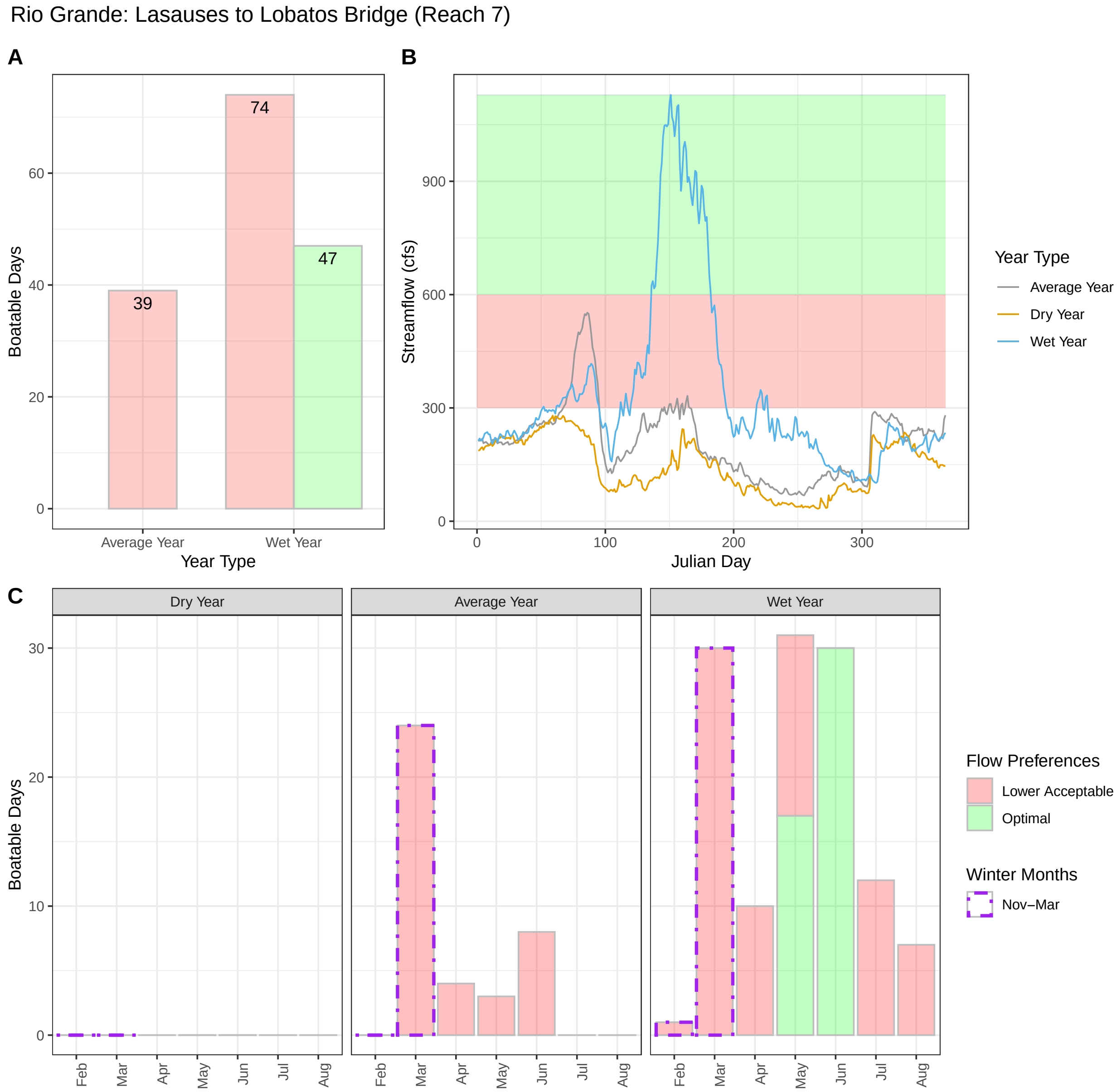


Figure 21: Boatable Days analysis results for the Rio Grande: Lasauses to Lobatos Bridge. (A) Total Boatable Days by year type and acceptability category; (B) flow acceptability ranges compared to typical wet, average, and dry year streamflow time series; and (C) monthly Boatable Days totals summarized by year type and acceptability category.

Rio Grande: Lobatos Bridge to Lee Trail, NM

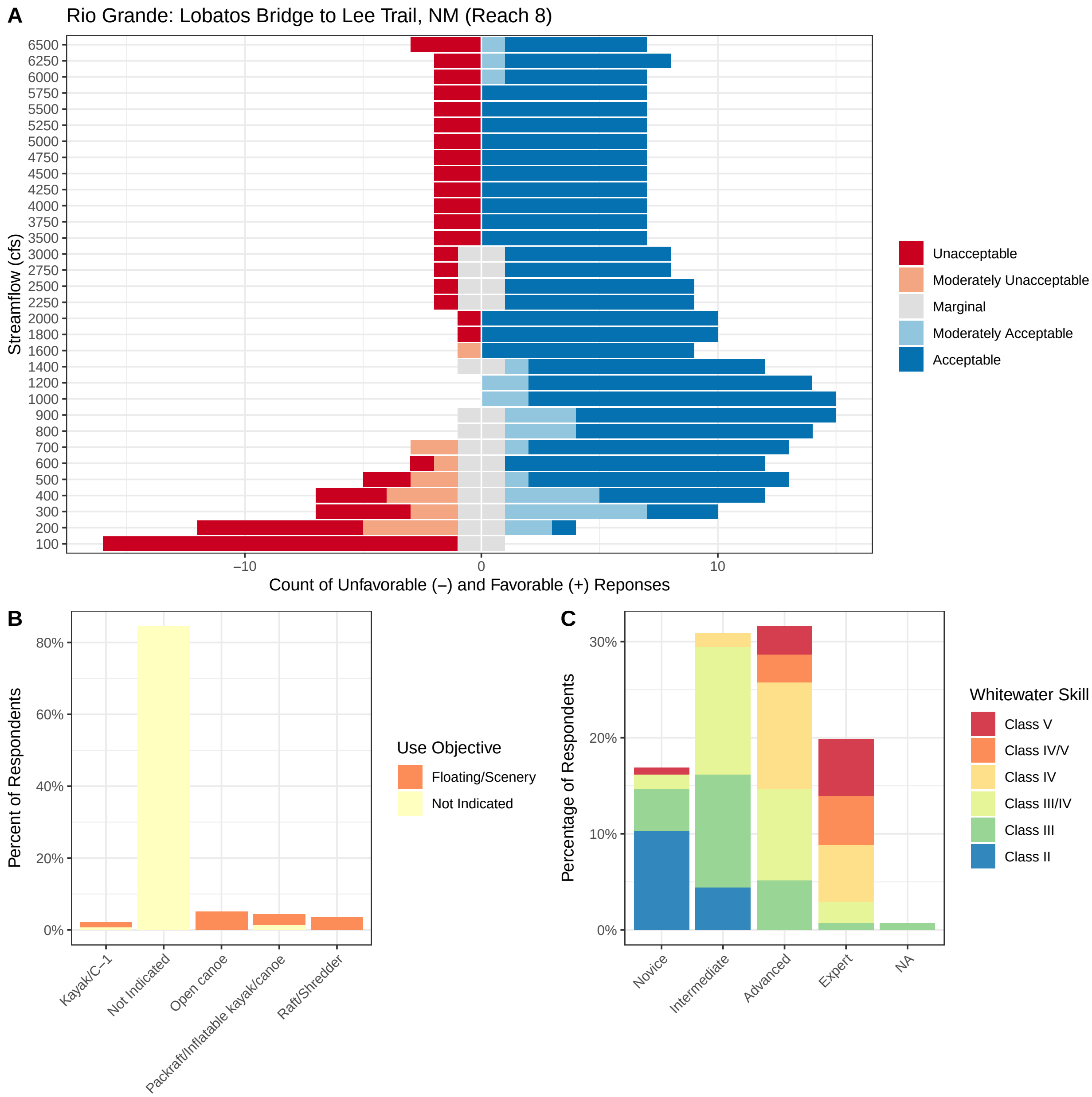


Figure 22: Survey responses for the Rio Grande, Lobatos Bridge to Lee Trail, NM. (A) Flow acceptability rankings. (B) User identified preferred craft types and recreational use objectives. (C) User identified whitewater navigation expertise.

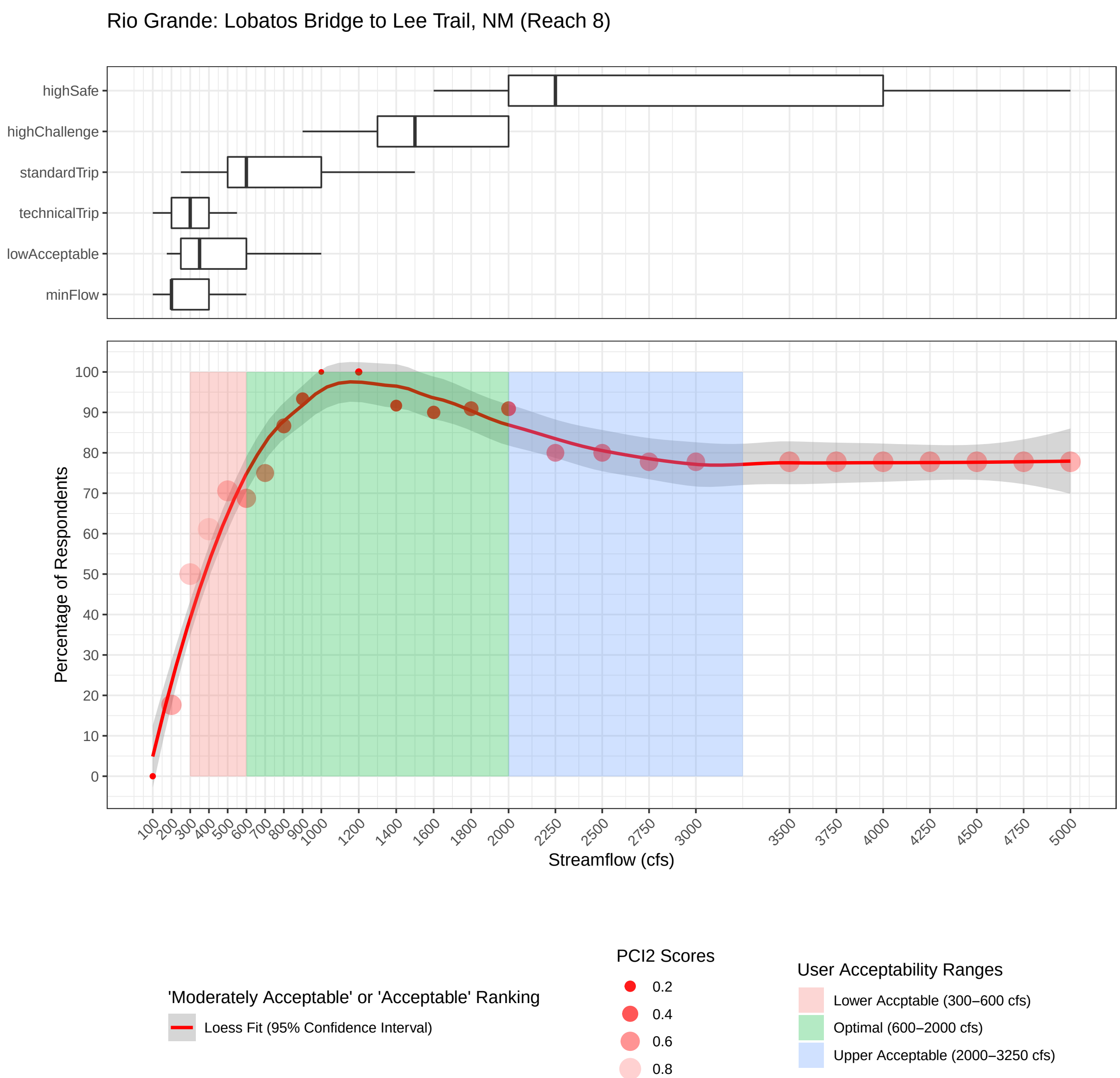


Figure 23: Flow preferences reported by users for the Rio Grande: Lobatos Bridge to Lee Trail, NM. (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges.

Table 22: Summarized open-format flow-preference question responses for Reach 8, Rio Grande: Lobatos Bridge to Lee Trail, NM.

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	200	200	400	17
Low Acceptable Flow (cfs)	250	350	600	17
Technical Flow (cfs)	200	300	400	15
Standard Trip Flow (cfs)	500	600	1000	15
Challenging High Flow (cfs)	1300	1500	2000	9
Highest Safe Flow (cfs)	2000	2250	4000	8

Table 23: PCI2 analysis results for Reach 8, Rio Grande: Lobatos Bridge to Lee Trail, NM.

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
100	0.1171875	-2.0	16	512	60
200	0.6736111	-1.0	17	576	388
300	0.7839506	0.5	18	648	508
400	0.8364198	1.0	18	648	542
500	0.7222222	2.0	17	576	416
600	0.5976562	2.0	16	512	306
700	0.5117188	2.0	16	512	262
800	0.3392857	2.0	15	448	152
900	0.2589286	2.0	15	448	116
1000	0.1160714	2.0	15	448	52
1200	0.1224490	2.0	14	392	48
1400	0.2152778	2.0	12	288	62

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
1600	0.2700000	2.0	10	200	54
1800	0.3333333	2.0	11	240	80
2000	0.3333333	2.0	11	240	80
2250	0.5000000	2.0	10	200	100
2500	0.5000000	2.0	10	200	100
2750	0.5500000	2.0	9	160	88
3000	0.5500000	2.0	9	160	88
3500	0.7000000	2.0	9	160	112
3750	0.7000000	2.0	9	160	112
4000	0.7000000	2.0	9	160	112
4250	0.7000000	2.0	9	160	112
4500	0.7000000	2.0	9	160	112
4750	0.7000000	2.0	9	160	112
5000	0.7000000	2.0	9	160	112
5250	0.7000000	2.0	9	160	112
5500	0.7000000	2.0	9	160	112
5750	0.7000000	2.0	9	160	112
6000	0.7500000	2.0	9	160	120
6250	0.6900000	2.0	10	200	138
6500	0.8700000	2.0	10	200	174

Table 24: Boatable Days analysis results broken out by month for the Rio Grande: Lobatos Bridge to Lee Trail, NM. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
Jan	Lower Acceptable	0	0	28
Feb	Lower Acceptable	0	19	29
Mar	Lower Acceptable	7	16	19
	Optimal	0	15	12
Apr	Lower Acceptable	0	20	12
	Optimal	0	1	18
May	Lower Acceptable	0	17	0
	Optimal	0	14	29
	Upper Acceptable	0	0	2
Jun	Lower Acceptable	0	14	0
	Optimal	0	16	30
Jul	Lower Acceptable	0	11	25
	Optimal	0	0	6
Aug	Lower Acceptable	0	0	21
Sep	Lower Acceptable	0	0	1
Nov	Lower Acceptable	0	26	6
Dec	Lower Acceptable	0	14	0

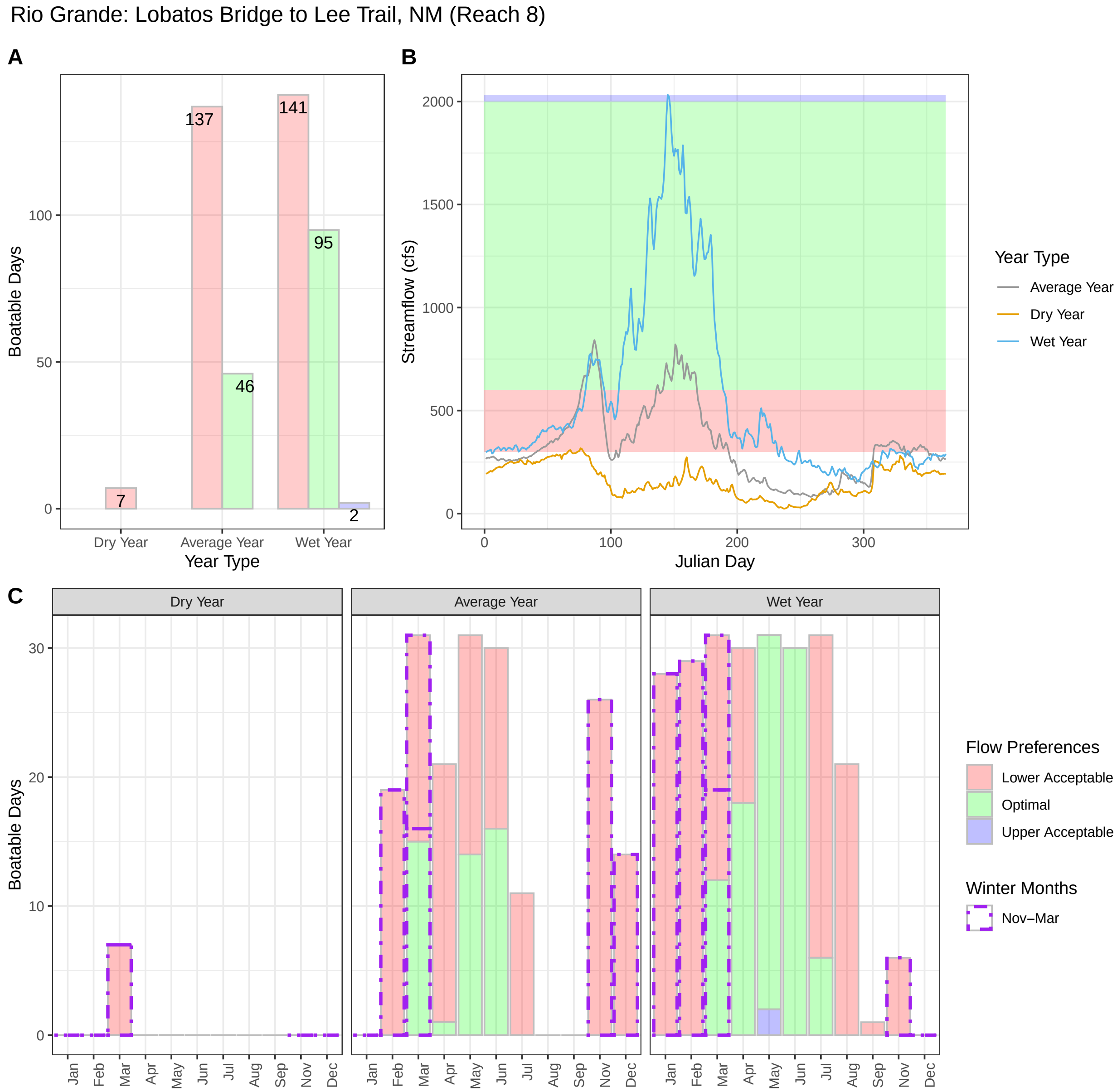


Figure 24: Boatable Days analysis results for the Rio Grande: Lobatos Bridge to Lee Trail, NM. (A) Total Boatable Days by year type and acceptability category; (B) flow acceptability ranges compared to typical wet, average, and dry year streamflow time series; and (C) monthly Boatable Days totals summarized by year type and acceptability category.

Conejos River: Platoro Reservoir to South Fork Conejos

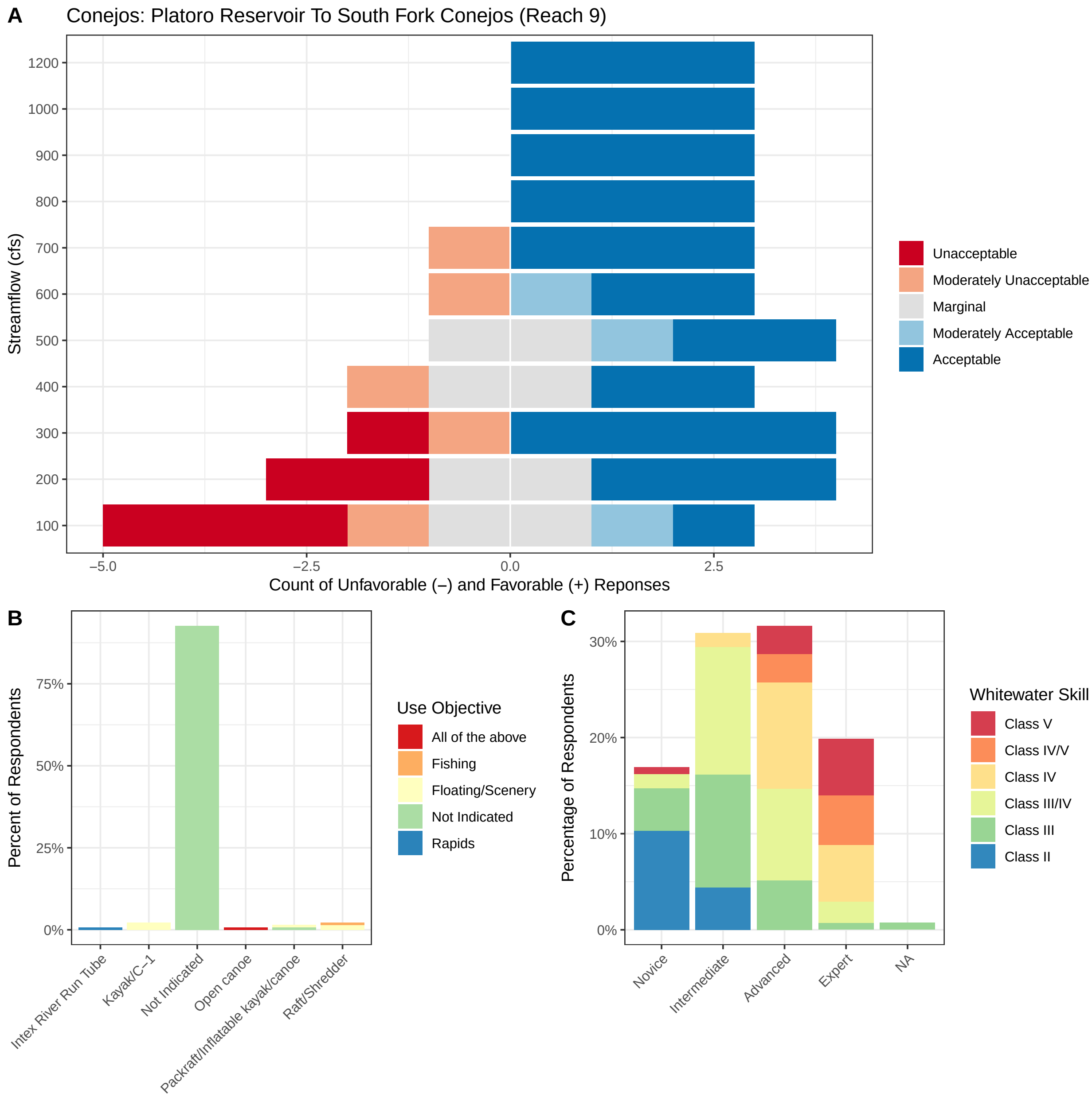


Figure 25: Survey responses for the Conejos, Platoro Reservoir to South Fork Conejos. (A) Flow acceptability rankings. (B) User identified preferred craft types and recreational use objectives. (C) User identified whitewater navigation expertise.

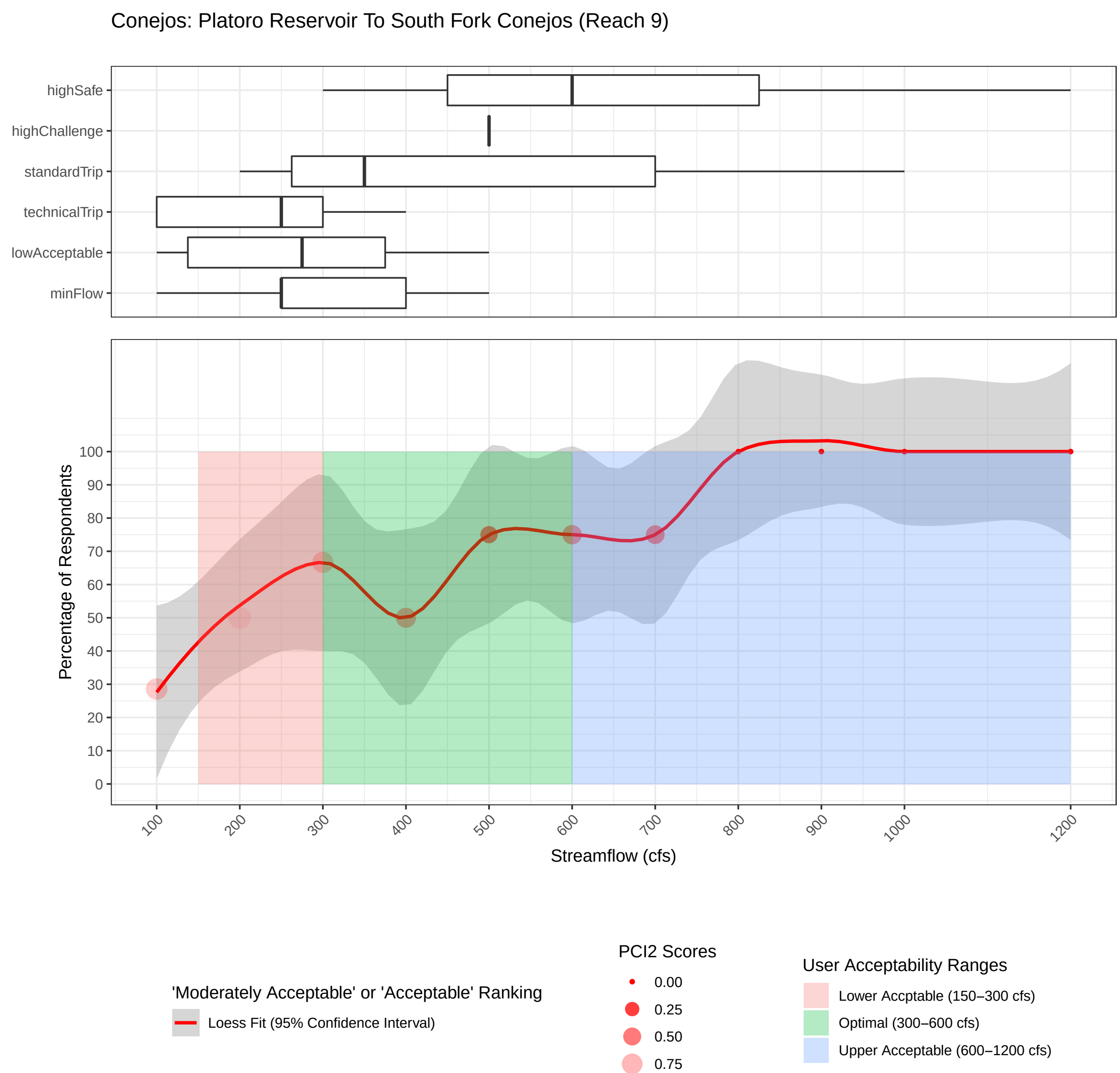


Figure 26: Flow preferences reported by users for the Conejos: Platoro Reservoir to South Fork Conejos. (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges.

Table 25: Summarized open-format flow-preference question responses for Reach 9, Conejos: Platoro Reservoir to South Fork Conejos.

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	138	250	362	6
Low Acceptable Flow (cfs)	138	275	375	6
Technical Flow (cfs)	100	250	300	5
Standard Trip Flow (cfs)	262	350	700	6
Challenging High Flow (cfs)	500	500	500	5
Highest Safe Flow (cfs)	450	600	825	4

Table 26: PCI2 analysis results for Reach 9, Conejos: Platoro Reservoir to South Fork Conejos.

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
100	0.8333333	-1.0	7	96	80
200	0.9444444	1.0	6	72	68
300	0.8055556	2.0	6	72	58
400	0.6875000	1.0	4	32	22
500	0.4375000	1.5	4	32	14
600	0.6250000	1.5	4	32	20
700	0.5625000	2.0	4	32	18
800	0.0000000	2.0	3	16	0
900	0.0000000	2.0	3	16	0
1000	0.0000000	2.0	3	16	0
1200	0.0000000	2.0	3	16	0

Table 27: Boatable Days analysis results broken out by month for the Conejos: Platoro Reservoir to South Fork Conejos. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
May	Lower Acceptable	22	17	11
	Optimal	0	10	1
Jun	Lower Acceptable	28	23	1
	Optimal	0	7	29
Jul	Lower Acceptable	3	16	30
	Optimal	0	0	1
Aug	Lower Acceptable	0	0	2

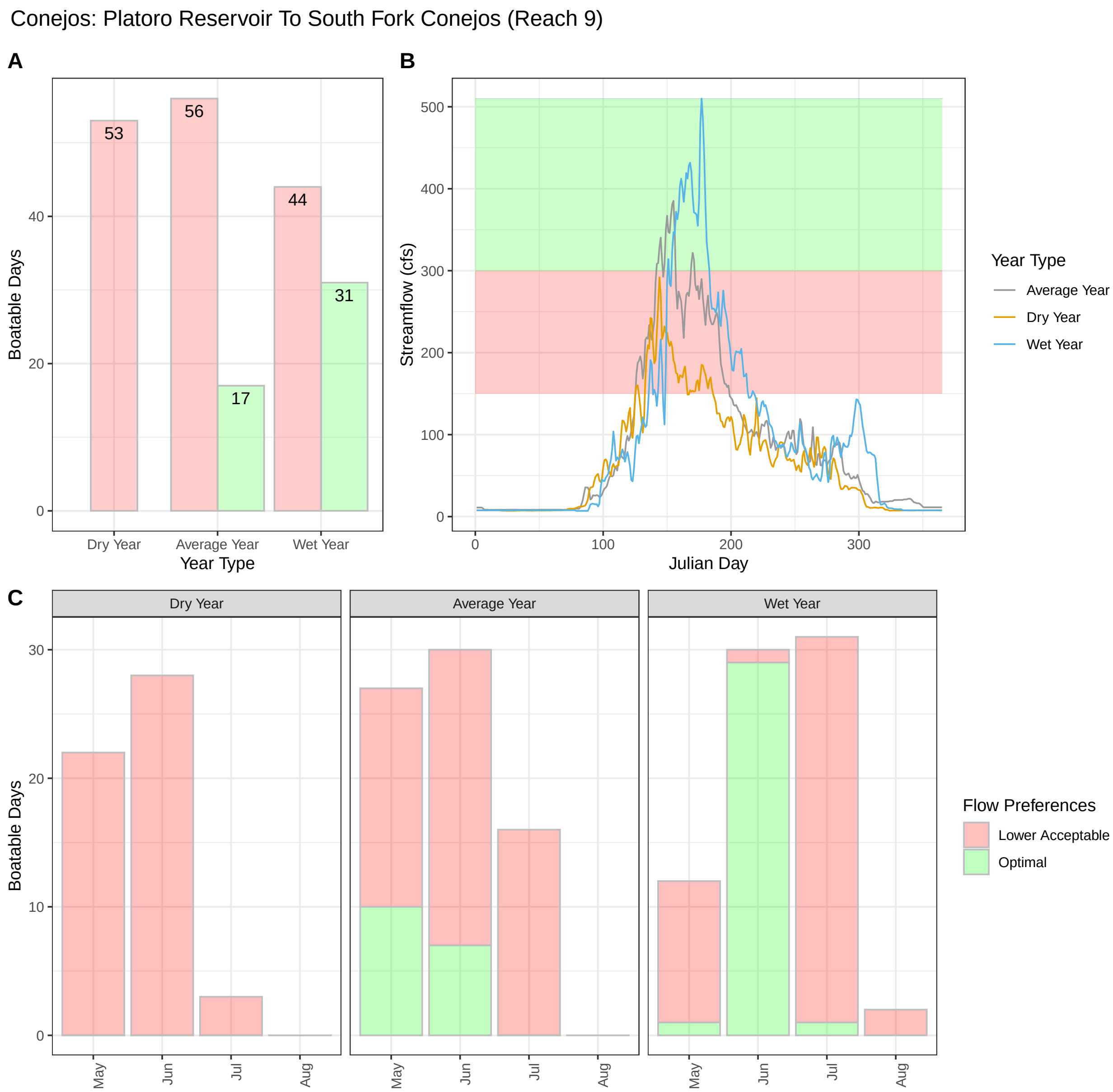


Figure 27: Boatable Days analysis results for the Conejos: Platoro Reservoir to South Fork Conejos. (A) Total Boatable Days by year type and acceptability category; (B) flow acceptability ranges compared to typical wet, average, and dry year streamflow time series; and (C) monthly Boatable Days totals summarized by year type and acceptability category.

Conejos River: South Fork Conejos to Hwy 17 Bridge

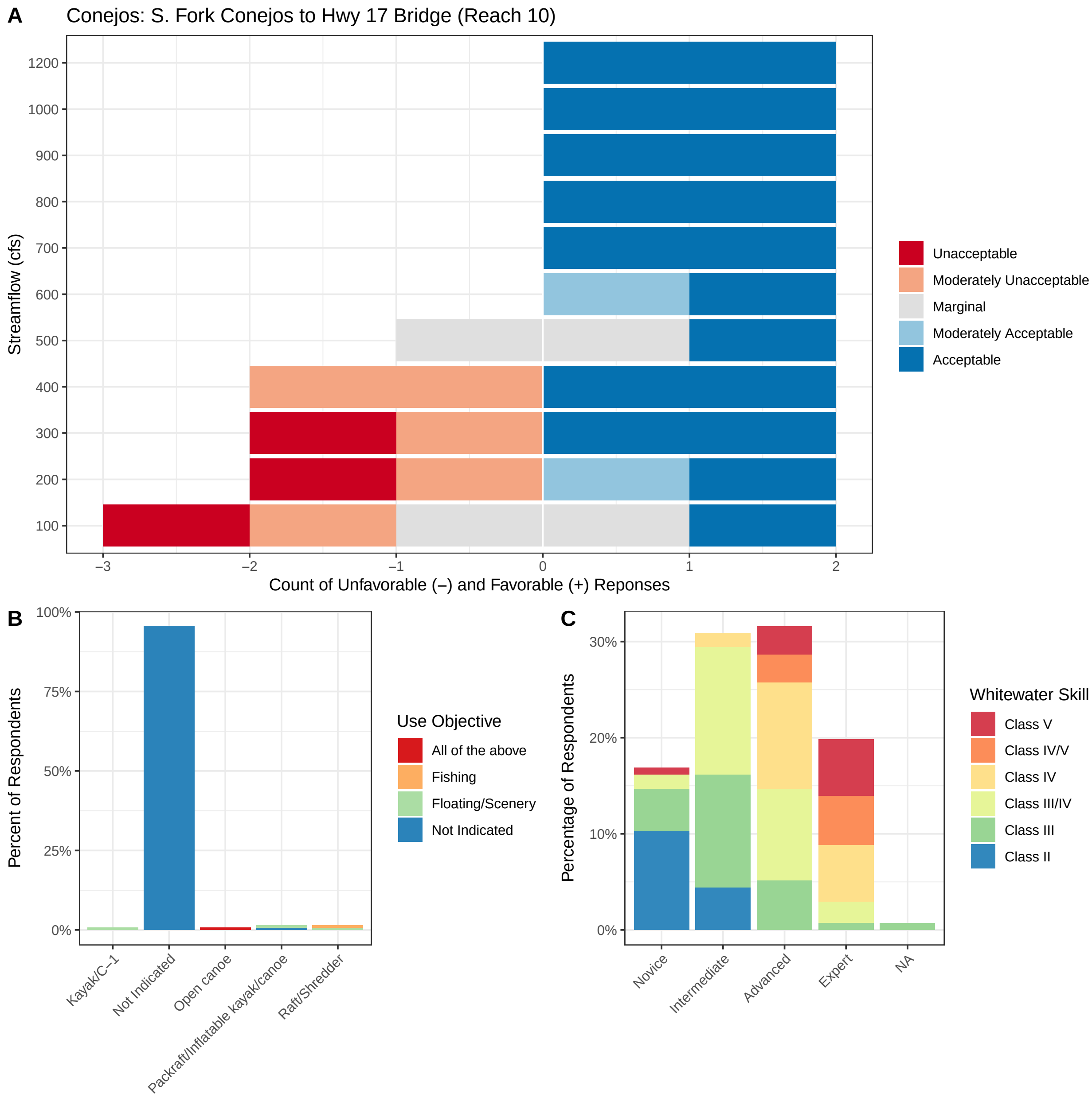


Figure 28: Survey responses for the Conejos, S. Fork Conejos to Hwy 17 Bridge. (A) Flow acceptability rankings. (B) User identified preferred craft types and recreational use objectives. (C) User identified whitewater navigation expertise.

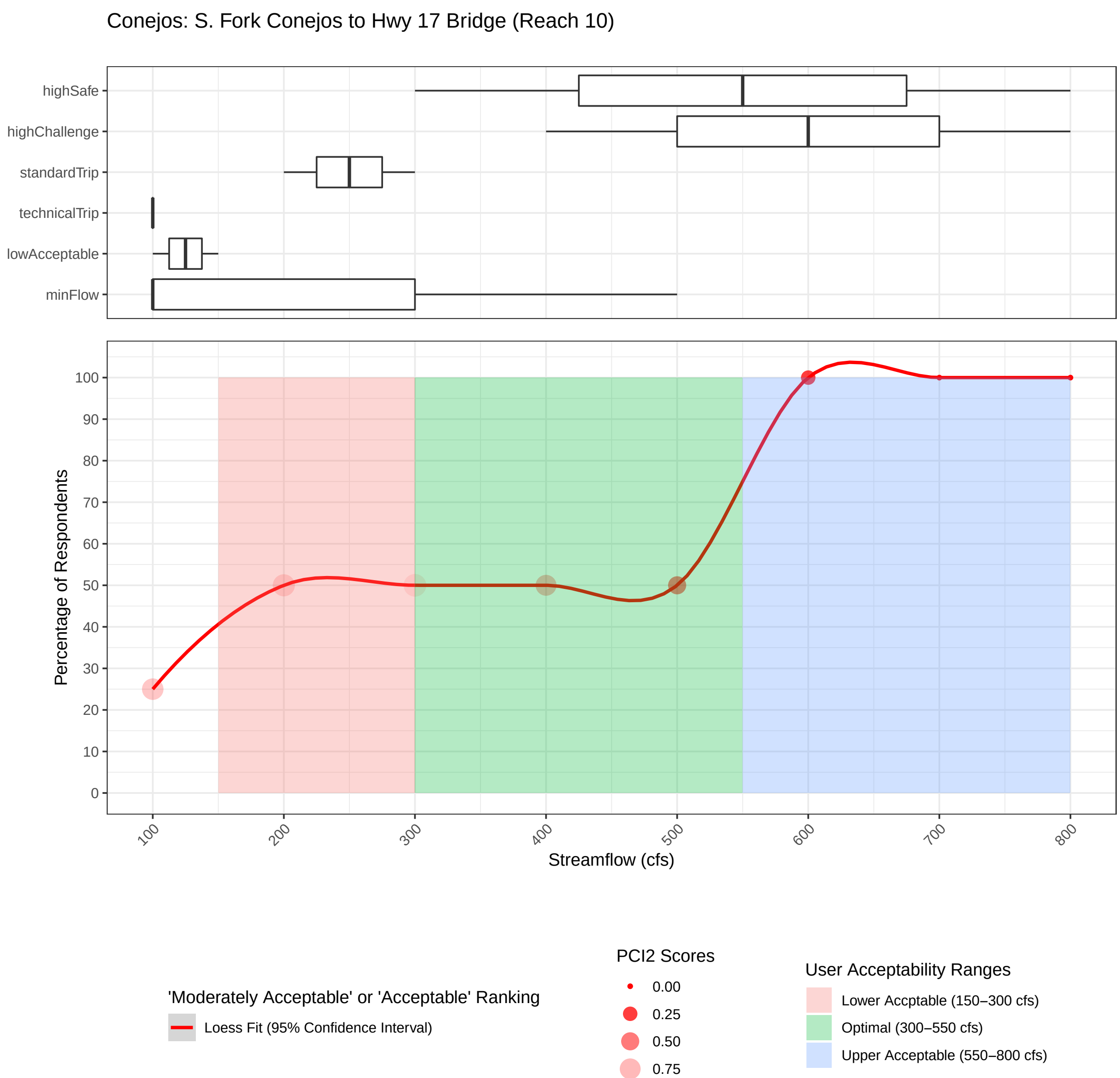


Figure 29: Flow preferences reported by users for the Conejos: S. Fork Conejos to Hwy 17 Bridge. (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges.

Table 28: Summarized open-format flow-preference question responses for Reach 10, Conejos: S. Fork Conejos to Hwy 17 Bridge.

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	100	100	300	3
Low Acceptable Flow (cfs)	125	150	525	3
Technical Flow (cfs)	100	100	100	2
Standard Trip Flow (cfs)	250	300	650	3
Challenging High Flow (cfs)	500	600	700	2
Highest Safe Flow (cfs)	425	550	675	2

Table 29: PCI2 analysis results for Reach 10, Conejos: S. Fork Conejos to Hwy 17 Bridge.

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
100	0.8125	-0.5	4	32	26
200	0.8750	0.0	4	32	28
300	0.9375	0.5	4	32	30
400	0.7500	0.5	4	32	24
500	0.5000	1.0	2	8	4
600	0.2500	1.5	2	8	2
700	0.0000	2.0	2	8	0
800	0.0000	2.0	2	8	0
900	0.0000	2.0	2	8	0
1000	0.0000	2.0	2	8	0
1200	0.0000	2.0	2	8	0

Table 30: Boatable Days analysis results broken out by month for the Conejos: S. Fork Conejos to Hwy 17 Bridge. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
May	Lower Acceptable	22	17	11
	Optimal	0	10	1
Jun	Lower Acceptable	28	23	1
	Optimal	0	7	29
Jul	Lower Acceptable	3	16	30
	Optimal	0	0	1
Aug	Lower Acceptable	0	0	2

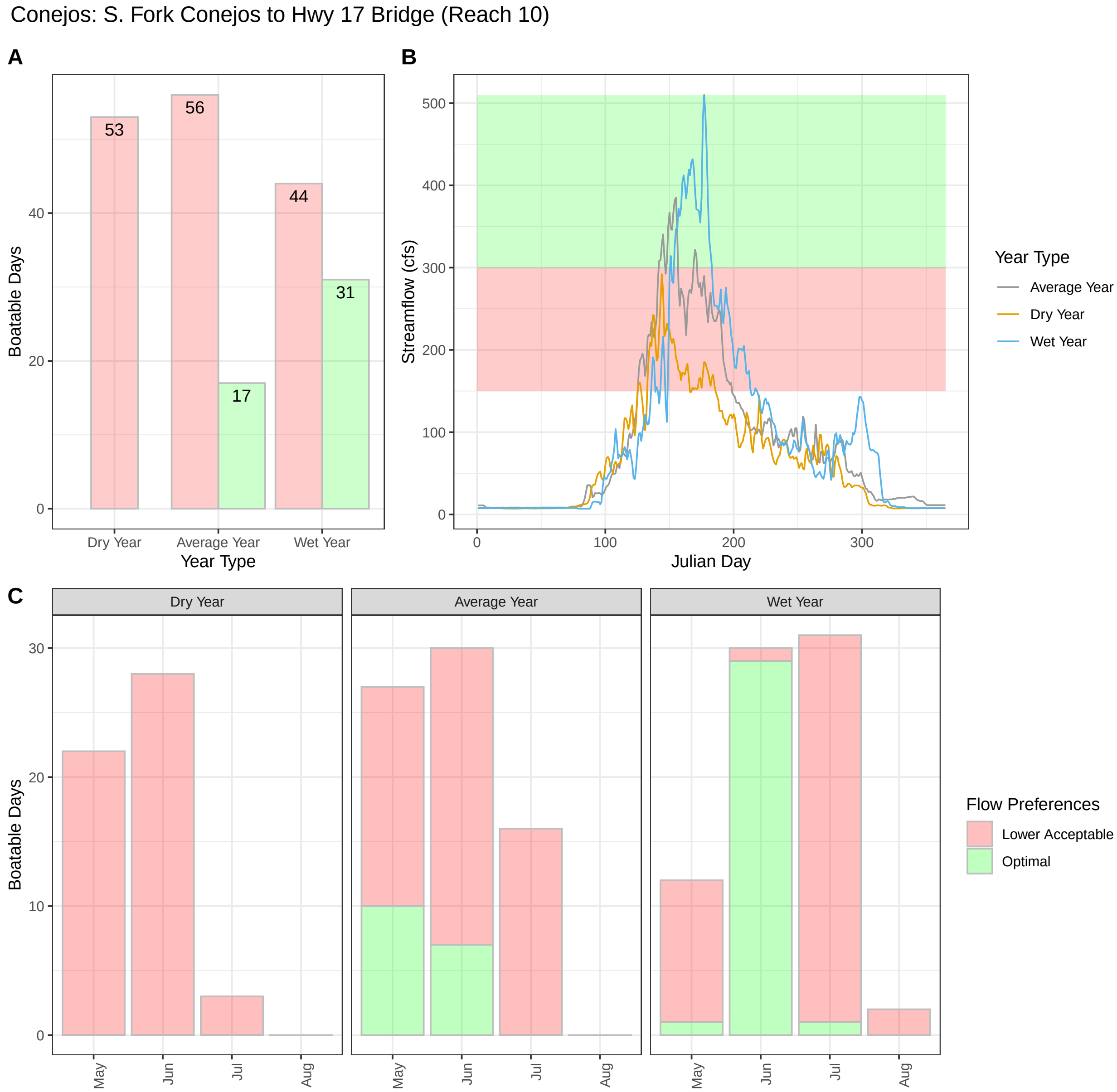


Figure 30: Boatable Days analysis results for the Conejos: S. Fork Conejos to Hwy 17 Bridge. (A) Total Boatable Days by year type and acceptability category; (B) flow acceptability ranges compared to typical wet, average, and dry year streamflow time series; and (C) monthly Boatable Days totals summarized by year type and acceptability category.

Conejos River: Hwy 17 to Mogote Campground

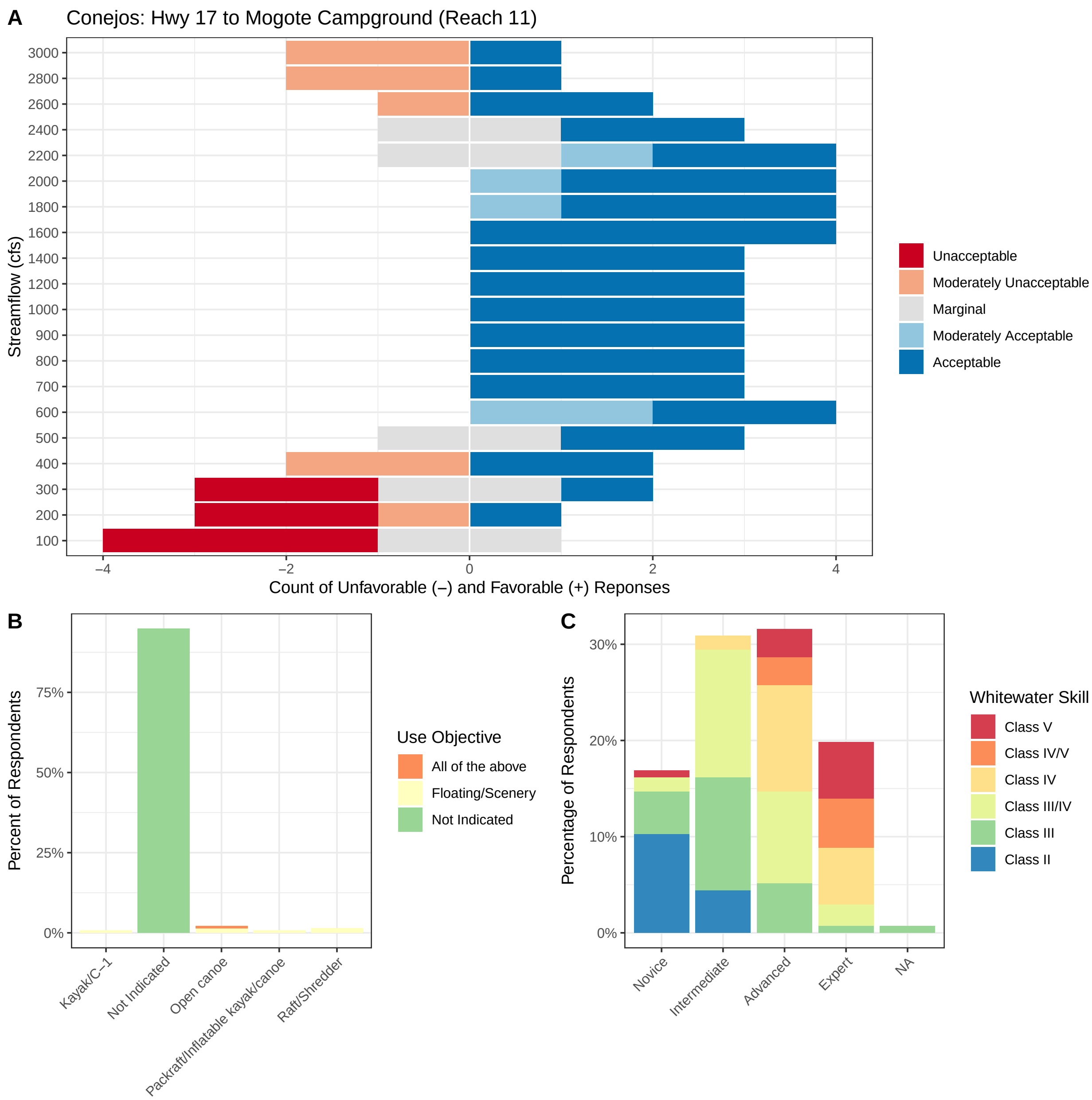


Figure 31: Survey responses for the Conejos, Hwy 17 to Mogote Campground. (A) Flow acceptability rankings. (B) User identified preferred craft types and recreational use objectives. (C) User identified whitewater navigation expertise.

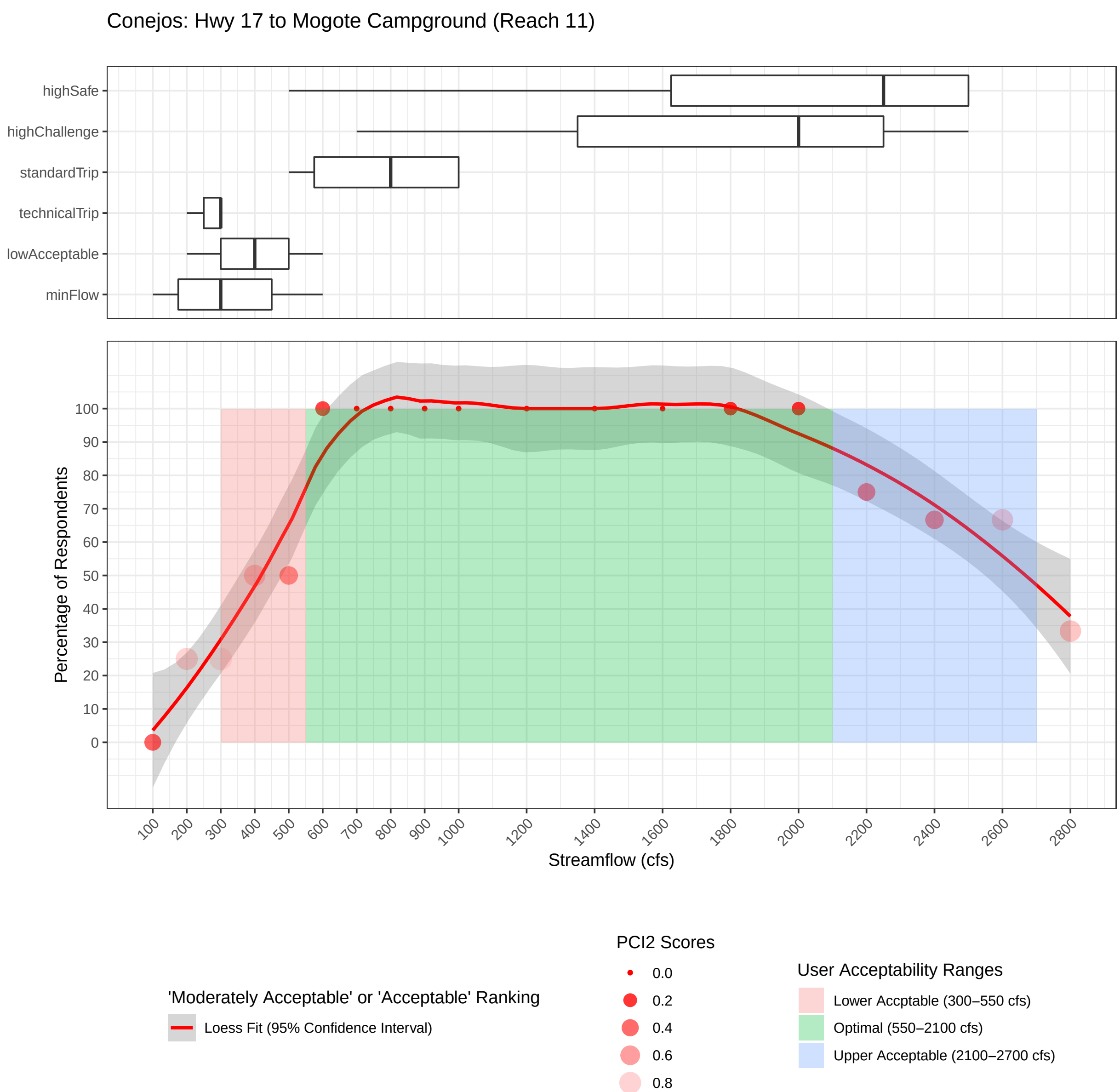


Figure 32: Flow preferences reported by users for the Conejos: Hwy 17 to Mogote Campground. (Top) Boxplot of responses to open-ended questions about different categories of flow. (Bottom) PCI2 analysis results overlaid on the percentage of respondents that ranked a given flow as "Moderately Acceptable" or "Acceptable". The percentage of respondents in those categories across the full range of flows was fit with a Loess curve to support visualization of flow acceptability ranges.

Table 31: Summarized open-format flow-preference question responses for Reach 11, Conejos: Hwy 17 to Mogote Campground.

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	175	300	450	4
Low Acceptable Flow (cfs)	300	400	500	3
Technical Flow (cfs)	250	300	300	3
Standard Trip Flow (cfs)	575	800	1000	4
Challenging High Flow (cfs)	1350	2000	2250	3
Highest Safe Flow (cfs)	1625	2250	2500	4

Table 32: PCI2 analysis results for Reach 11, Conejos: Hwy 17 to Mogote Campground.

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
100	0.3750	-2.0	4	32	12
200	0.8125	-1.5	4	32	26
300	0.8750	-1.0	4	32	28
400	0.7500	0.5	4	32	24
500	0.5000	1.0	4	32	16
600	0.2500	1.5	4	32	8
700	0.0000	2.0	3	16	0
800	0.0000	2.0	3	16	0
900	0.0000	2.0	3	16	0
1000	0.0000	2.0	3	16	0
1200	0.0000	2.0	3	16	0
1400	0.0000	2.0	3	16	0

Flow (cfs)	PCI2	Median Likert Response	n	Max. Distance	Total Distance
1600	0.0000	2.0	4	32	0
1800	0.1875	2.0	4	32	6
2000	0.1875	2.0	4	32	6
2200	0.4375	1.5	4	32	14
2400	0.5000	2.0	3	16	8
2600	0.7500	2.0	3	16	12
2800	0.7500	-1.0	3	16	12
3000	0.7500	-1.0	3	16	12

Table 33: Boatable Days analysis results broken out by month for the Conejos: Hwy 17 to Mogote Campground. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Acceptability Category	Dry Year	Avg. Year	Wet Year
Apr	Lower Acceptable	8	11	13
	Optimal	0	0	4
May	Lower Acceptable	7	3	4
	Optimal	24	28	27
Jun	Lower Acceptable	14	0	0
	Optimal	5	30	30
Jul	Lower Acceptable	0	16	23
	Optimal	0	1	3

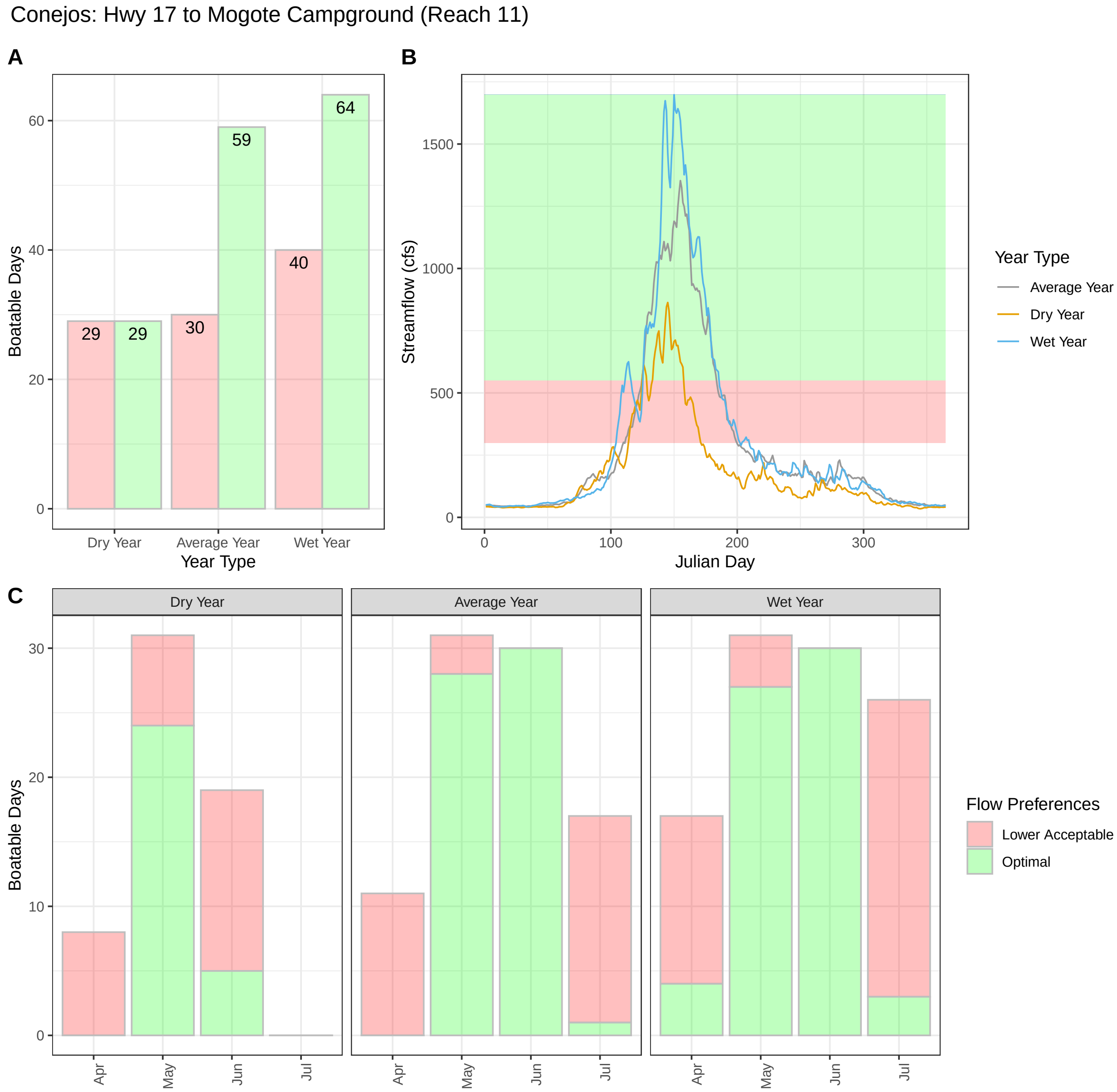


Figure 33: Boatable Days analysis results for the Conejos: Hwy 17 to Mogote Campground. (A) Total Boatable Days by year type and acceptability category; (B) flow acceptability ranges compared to typical wet, average, and dry year streamflow time series; and (C) monthly Boatable Days totals summarized by year type and acceptability category.

APPENDIX B: Web Survey

1. PLEASE READ THIS BEFORE COMPLETING THE SURVEY

American Whitewater and the Rio Grande Headwaters Restoration Project needs your help to define streamflows that support the full range of recreational boating opportunities on the Rio Grande and Conejos Rivers in Southern Colorado.

Information collected by this study will be used to assess river-dependent recreation as part of a joint stream management planning effort between American Whitewater and the Rio Grande Headwaters Restoration Project. We have developed this survey so individuals and outfitters can report how changes in stream flows affect recreation quality on each of our targeted river segments. Your input will help American Whitewater identify the full range of flows necessary to support recreation experiences, from technical low water to challenging high water opportunities. The information you provide will support development of multipurpose projects in the Basin and can help protect and enhance economies that rely on environmental and recreational water uses.

The river segments targeted by this study include:

1) Rio Grande Box Canyon (CO, this not the Taos Box)

2) Rio Grande from Box Canyon to Creede (CO, not the Taos Box)

3) Rio Grande from Creede to Wagon Wheel Gap

4) Rio Grande from Wagon Wheel Gap to South Fork

5) Rio Grande from South Fork to Del Norte

6) Conejos River from Platoro Reservoir to South Fork Campground

7) Conejos River from South Fork to Hwy 17 Bridge

8) Conejos River From Highway 17 Bridge, to Mogote Camp Ground

9) Rio Grande ~~River~~ From Alamosa to Lasauses

10) Rio Grande from Lasauses to Lobatos Bridge

11) Rio Grande from Lobatos Bridge to Lee Trail, New Mexico

You will only be asked to respond to survey questions for the segments you have personally experienced.

Please encourage your fellow paddlers to participate in this study.

2. Survey Overview

American Whitewater is conducting the study because decades of research confirms that changes in stream flow, or the amount of water in a river, fundamentally affects recreation quality in most river settings. In the short term, flows determine whether a river provides opportunities for boating and angling, and they affect attributes such as the challenge of whitewater or trip aesthetics. Longer-term flow regimes may also have effects on ecological resources, riparian environments, or channel features such as beaches, pools, rapids, and riffles.

American Whitewater is presenting two series of questions for each study segment in this web-based survey. The first series will ask participants to evaluate flows and overall recreation quality using a five-point "acceptability" scale (unacceptable -2 and acceptable 2) for flows measured at specific data nodes or stream gages. These individual evaluations of flows will be aggregated into social norms to describe overall flow-recreation quality, and allow AW to create Flow-Agreement Acceptability curves (FAAI) that graphically represent this important relationship. In most cases, FAAI curves show inverted U-shapes where low flows and high flows provide less acceptable recreation conditions, while medium flows provide more acceptable (greater value) conditions.

To further refine and validate results from the flow-evaluation curves, a set of single-flow judgments will be requested of survey respondents. For each study segment, respondents will be asked to report a single flow value that provides a distinct paddling experience or "niche" along a spectrum: low, technical, standard, high challenge, and maximum or "highest acceptable" flow. Overlaying these specific flow evaluations on overall flow-evaluation curves provides greater detail for understanding the effect that changes in streamflow can have on recreation quality.

Please take your time responding to the questions in this study. Your thoughtful participation is important to advancing good water policy and river management in the State. For more information on the Rio Grande Basin Stream Management Plan, please visit American Whitewater's Project Page.

3. Participant Information

Please describe yourself. American Whitewater uses your personal information only to ensure accuracy and avoid duplication in our web-based survey methods. We do not sell or distribute your information.

* 1. Your name

* 2. How would you describe your skill level on the river?

- [ ] Novice
- [ ] Intermediate
- [ ] Advanced
- [ ] Expert

* 3. What is the highest class of rapid you confidently paddle?

( ) Class II ( ) Class III ( ) Class III/IV ( ) Class IV ( ) Class IV/V ( ) Class V

4. Would you characterize yourself as a private or commercial boater?

- [ ] Private
- [ ] Commercial (guide)
- [ ] Commercial (customer)

5. Your Email

6. Your Phone

7. Your Street Address

* 8. Your City

* 9. Your State

* 10. Your Zip Code

* 11. How often do you participate in river-recreation activities? (check only one)

- 1 time a season
- 2-5 times a season
- 5-20 times a season
- 20+ times a season
- 50+ times a season

* 12. How confident are you in reporting flows that you have experienced on the river?

- Not comfortable at all
- somewhat uncomfortable
- neutral
- somewhat comfortable
- very comfortable

Next, we will ask you about specific study segments. Both sets of study questions will be presented for each segment. Lets get to it!

4. Rio Grande River - Box Canyon

* 13. Have you floated or paddled the Box Canyon section of the Rio Grande in Colorado? (This is not the Taos Box section in NM)
For more information and a map of this stretch of river, visit theAmerican Whitewater River Page.

- ◯ Yes
- ◯ No

5. Box Canyon Flow Survey

For the questions on this page, please rate the quality of the run at each specified flow <u>for your preferred craft-type</u>. Please pay particular attention to the gage and report acceptable flows for that gage only.

* 14. What is your preferred craft for paddling the Box Canyon section of the Rio Grande River? (Choose one)

- [ ] Hard shell kayak/canoe
- [ ] Raft/Shredder
- [ ] Inflatable kayak/canoe/packraft
- [ ] Open canoe
- [ ] Other (please specify)

* 15. What is your primary recreational objective on the Box Canyon section of the Rio Grande River? (Choose one)

- [ ] Floating/Scenery
- [ ] Fishing
- [ ] Exercise
- [ ] Other (please specify)

16. With your preferred craft-type in mind, please consider all the flow-dependent characteristics that contribute to a high quality experience (e.g., depth, challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For comparative purposes, please rate the acceptability of each flow level.

Flows represented are measured by the CO DWR Gage **Rio Grande at Thirty Mile Bridge near Creede.**

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
100	○	○	○	○	○
200	○	○	○	○	○
300	○	○	○	○	○
400	○	○	○	○	○
500	○	○	○	○	○
600	○	○	○	○	○
700	○	○	○	○	○
800	○	○	○	○	○
900	○	○	○	○	○
1000	○	○	○	○	○
1200	○	○	○	○	○
1400	○	○	○	○	○
1600	○	○	○	○	○
1800	○	○	○	○	○
2000	○	○	○	○	○
2250	○	○	○	○	○
2500	○	○	○	○	○
2750	○	○	○	○	○
3000	○	○	○	○	○

17. What is the minimum flow required to float your preferred craft on this stretch? (please specify in cfs)

18. With your particular craft in mind, what is the lowest acceptable flow that provides a reasonable 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)

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

20. Many people are interested in a "standard" river trip at average flows. Think of this "standard trip" in your craft and for your primary objective. What is the best flow for a standard trip? (please specify in cfs)

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

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

23. 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.

24. Are there other concerns or opportunities on this stretch of river that you would like to report? These could be related to safety, aesthetics, crowding, access facilities, or other factors.

6. Rio Grande River - Box Canyon to Creede

* 25. Have you floated or paddled the Rio Grande from the Mouth of Box Canyon to Creede (Airport Rd)? For more information on this stretch of river visit the American Whitewater River Page.

- ◯ Yes
- ◯ No

7. Box Canyon to Creede - Flow Survey

For the questions on this page, please rate the quality of the run at each specified flow <u>for your preferred craft-type</u>. Please pay particular attention to the gage and report acceptable flows for that gage only.

* 26. What is your preferred craft for paddling Rio Grande from Box Canyon to Creede? (Choose one)

- [ ] Dory/Drift Boat
- [ ] Packraft/Inflatable kayak/canoe
- [ ] Kayak/C-1
- [ ] Open canoe
- [ ] Raft/Shredder
- [ ] Other (please specify)

* 27. What is your primary recreational objective on this section of the Rio Grande River? (Choose one)

- [ ] Floating/Scenery
- [ ] Fishing
- [ ] Exercise
- [ ] Other (please specify)

28. With your preferred craft in mind, please consider all the flow-dependent characteristics that contribute to a high quality experience (e.g., depth, challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For comparative purposes, please rate the acceptability of each flow level.

Flows represented are measured by the CO DWR Gage Rio Grande at Thirty Mile Bridge near Creede.

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
100	○	○	○	○	○
200	○	○	○	○	○
300	○	○	○	○	○
400	○	○	○	○	○
500	○	○	○	○	○
600	○	○	○	○	○
700	○	○	○	○	○
800	○	○	○	○	○
900	○	○	○	○	○
1000	○	○	○	○	○
1200	○	○	○	○	○
1400	○	○	○	○	○
1600	○	○	○	○	○
1800	○	○	○	○	○
2000	○	○	○	○	○
2250	○	○	○	○	○
2500	○	○	○	○	○
2750	○	○	○	○	○
3000	○	○	○	○	○

29. What is the minimum flow required to float your preferred craft on this stretch? (please specify in cfs)

30. With your particular craft in mind, what is the lowest acceptable flow that provides a reasonable 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)

31. Some people are interested in taking trips at lower flows for a technical experience. Think of this “technical trip” in your craft and for your primary objective. What is the best flow for a technical trip? (please specify in cfs)

32. Many people are interested in a “standard” river trip at average flows. Think of this “standard trip” in your craft and for your primary objective. What is the best flow for a standard trip? (please specify in cfs)

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

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

35. 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.

36. Are there other concerns or opportunities on this reach of river that you would like to report? These could be related to safety, aesthetics, crowding, access facilities, or other factors.

8. Rio Grande River - Creede to Wagon Wheel Gap

* 37. Have you floated or paddled the Rio Grande from Creede to Wagon Wheel Gap in Colorado? For more information and a map of this stretch of river, visit the American Whitewater River Page.

- Yes
- No

9. Creede to Wagon Wheel Gap - Flow Survey

For the questions on this page, please rate the quality of the run at each specified flow for your preferred craft-type. Please pay particular attention to the gage and report acceptable flows for that gage only.

* 38. What is your preferred craft for the Rio Grande River from Creede to Wagon Wheel Gap? (Choose one)

- ☐ Dory/Drift Boat
- ☐ Packraft/Inflatable kayak/canoe
- ☐ Kayak/C-1
- ☐ Open canoe
- ☐ Raft/Shredder
- ☐ Other (please specify)

* 39. What is your primary recreational objective on this section of the Rio Grande River? (Choose one)

- ☐ Floating/Scenery
- ☐ Fishing
- ☐ Exercise
- ☐ Other (please specify)

40. With your preferred craft-type in mind, please consider all the flow-dependent characteristics that contribute to a high quality experience (e.g., depth, challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For comparative purposes, please rate the acceptability of each flow level.

Flows represented are measured by the CO DWR Gage Rio Grande at Wagon Wheel Gap.

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
100	○	○	○	○	○
200	○	○	○	○	○
300	○	○	○	○	○
400	○	○	○	○	○
500	○	○	○	○	○
600	○	○	○	○	○
700	○	○	○	○	○
800	○	○	○	○	○
900	○	○	○	○	○

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
1000	○	○	○	○	○
1200	○	○	○	○	○
1400	○	○	○	○	○
1600	○	○	○	○	○
1800	○	○	○	○	○
2000	○	○	○	○	○
2250	○	○	○	○	○
2500	○	○	○	○	○
2750	○	○	○	○	○
3000	○	○	○	○	○
3500	○	○	○	○	○
3750	○	○	○	○	○
4000	○	○	○	○	○
4250	○	○	○	○	○
4500	○	○	○	○	○
4750	○	○	○	○	○
5000	○	○	○	○	○
5250	○	○	○	○	○
5500	○	○	○	○	○

41. What is the minimum flow required to float your preferred craft on this stretch? (please specify in cfs)

42. With your particular craft in mind, what is the lowest acceptable flow that provides a reasonable 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)

43. Some people are interested in taking trips at lower flows for a technical experience. Think of this “technical trip” in your craft and for your primary objective. What is the best flow for a technical trip? (please specify in cfs)

44. Many people are interested in a “standard” river trip at average flows. Think of this “standard trip” in your craft and for your primary objective. What is the best flow for a standard trip? (please specify in cfs)

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

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

47. 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.

48. Are there other concerns or opportunities on this reach of river that you would like to report? These could be related to safety, aesthetics, crowding, access facilities, or other factors.

10. Rio Grande River - Wagon Wheel Gap to South Fork

* 49. Have you floated or paddled the Rio Grande from Wagon Wheel Gap to South Fork Colorado? For more information and a map of this stretch of river, visit theAmerican Whitewater River Page.

- ○ Yes
- ○ No

11. Wagon Wheel Gap to South Fork - Flow Survey

For the questions on this page, please rate the quality of the run at each specified flow for your preferred craft-type. Please pay particular attention to the gage and report acceptable flows for that gage only.

* 50. What is your preferred craft for the Rio Grande River from Wagon Wheel Gap to South Fork, Colorado? (Choose one)

- [ ] Dory/Drift Boat
- [ ] Packraft/Inflatable kayak/canoe
- [ ] Kayak/C-1
- [ ] Open canoe
- [ ] Raft/Shredder
- [ ] Other (please specify)

* 51. What is your primary recreational objective on this section of the Rio Grande River? (Choose one)

- [ ] Floating/Scenery
- [ ] Fishing
- [ ] Exercise
- [ ] Other (please specify)

52. With your preferred craft-type in mind, please consider all the flow-dependent characteristics that contribute to a high quality experience (e.g., depth, challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For comparative purposes, please rate the acceptability of each flow level.

Flows represented are measured by the CO DWR Gage Rio Grande at Wagon Wheel Gap.

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
100	○	○	○	○	○
200	○	○	○	○	○
300	○	○	○	○	○
400	○	○	○	○	○
500	○	○	○	○	○
600	○	○	○	○	○
700	○	○	○	○	○
800	○	○	○	○	○

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
900	◯	◯	◯	◯	◯
1000	◯	◯	◯	◯	◯
1200	◯	◯	◯	◯	◯
1400	◯	◯	◯	◯	◯
1600	◯	◯	◯	◯	◯
1800	◯	◯	◯	◯	◯
2000	◯	◯	◯	◯	◯
2250	◯	◯	◯	◯	◯
2500	◯	◯	◯	◯	◯
2750	◯	◯	◯	◯	◯
3000	◯	◯	◯	◯	◯
3500	◯	◯	◯	◯	◯
3750	◯	◯	◯	◯	◯
4000	◯	◯	◯	◯	◯
4250	◯	◯	◯	◯	◯
4500	◯	◯	◯	◯	◯
4750	◯	◯	◯	◯	◯
5000	◯	◯	◯	◯	◯
5250	◯	◯	◯	◯	◯
5500	◯	◯	◯	◯	◯

53. What is the minimum flow required to float your preferred craft on this stretch? (please specify in cfs)

54. With your particular craft in mind, what is the lowest acceptable flow that provides a reasonable 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)

55. Some people are interested in taking trips at lower flows for a technical experience. Think of this “technical trip” in your craft and for your primary objective. What is the best flow for a technical trip? (please specify in cfs)

56. Many people are interested in a “standard” river trip at average flows. Think of this “standard trip” in your craft and for your primary objective. What is the best flow for a standard trip? (please specify in cfs)

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

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

59. 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.

60. Are there other concerns or opportunities on this reach of river that you would like to report? These could be related to safety, aesthetics, crowding, access facilities, or other factors.

12. Rio Grande River - South Fork to Del Norte

* 61. Have you floated or paddled the Rio Grande from South Fork to Del Norte, Colorado?
For more information and a map of this stretch of river, visit the American Whitewater River Page.

- ◯ Yes
- ◯ No

13. South Fork to Del Norte - Flow Survey

For the questions on this page, please rate the quality of the run at each specified flow <u>for your preferred craft-type</u>. Please pay particular attention to the gage and report acceptable flows for that gage only.

* 62. What is your preferred craft for the Rio Grande River from South Fork to Del Norte? (Choose one)

- ☐ Dory/Drift Boat
- ☐ Packraft/Inflatable kayak/canoe
- ☐ Kayak/C-1
- ☐ Open canoe
- ☐ Raft/Shredder
- ☐ Other (please specify)

* 63. What is your primary recreational objective on this section of the Rio Grande River? (Choose one)

- ☐ Floating/Scenery
- ☐ Fishing
- ☐ Exercise
- ☐ Other (please specify)

64. With your preferred craft-type in mind, please consider all the flow-dependent characteristics that contribute to a high quality experience (e.g., depth, challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For comparative purposes, please rate the acceptability of each flow level.

Flows represented are measured by the CO DWR Gage <u>Rio Grande River near Del Norte</u>

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
100	○	○	○	○	○
200	○	○	○	○	○
300	○	○	○	○	○
400	○	○	○	○	○
500	○	○	○	○	○
600	○	○	○	○	○
700	○	○	○	○	○
800	○	○	○	○	○
900	○	○	○	○	○

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
1000	○	○	○	○	○
1200	○	○	○	○	○
1400	○	○	○	○	○
1600	○	○	○	○	○
1800	○	○	○	○	○
2000	○	○	○	○	○
2250	○	○	○	○	○
2500	○	○	○	○	○
2750	○	○	○	○	○
3000	○	○	○	○	○
3500	○	○	○	○	○
3750	○	○	○	○	○
4000	○	○	○	○	○
4250	○	○	○	○	○
4500	○	○	○	○	○
4750	○	○	○	○	○
5000	○	○	○	○	○
5250	○	○	○	○	○
5500	○	○	○	○	○
5750	○	○	○	○	○
6000	○	○	○	○	○
6250	○	○	○	○	○
6500	○	○	○	○	○
6750	○	○	○	○	○
7000	○	○	○	○	○
7500	○	○	○	○	○
8000	○	○	○	○	○
8500	○	○	○	○	○
9000	○	○	○	○	○
9500	○	○	○	○	○

65. What is the minimum flow required to float your preferred craft on this stretch? (please specify in cfs)

66. With your particular craft in mind, what is the lowest acceptable flow that provides a reasonable 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)

67. Some people are interested in taking trips at lower flows for a technical experience. Think of this “technical trip” in your craft and for your primary objective. What is the best flow for a technical trip? (please specify in cfs)

68. Many people are interested in a “standard” river trip at average flows. Think of this “standard trip” in your craft and for your primary objective. What is the best flow for a standard trip? (please specify in cfs)

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

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

71. 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.

72. Are there other concerns or opportunities on this reach of river that you would like to report? These could be related to safety, aesthetics, crowding, access facilities, or other factors.

14. Conejos River - Platoro to South Fork Campground

* 73. Have you floated or paddled the Conejos River from Platoro to the South Fork Campground? For more information and a map of this stretch of river, visit theAmerican Whitewater River Page.

○ Yes

○ No

15. Platoro to South Fork Confluence - Flow Survey

For the questions on this page, please rate the quality of the run at each specified flow<u>for your preferred craft-type</u>. Please pay particular attention to the gage and report acceptable flows for that gage only.

* 74. What is your preferred craft for the Conejos River from Platoro to South Fork Campground? (Choose one)

- [ ] Packraft/Inflatable kayak/canoe
- [ ] Kayak/C-1
- [ ] Open canoe
- [ ] Raft/Shredder
- [ ] Other (please specify)

* 75. What is your primary recreational objective on this section of the Conejos River? (Choose one)

- [ ] Floating/Scenery
- [ ] Fishing
- [ ] Exercise
- [ ] Other (please specify)

76. With your preferred craft-type in mind, please consider all the flow-dependent characteristics that contribute to a high quality experience (e.g., depth, challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For comparative purposes, please rate the acceptability of each flow level.

Flows represented are measured by the CO DWR Gage Conejos River below Platoro Reservoir.

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
100	○	○	○	○	○
200	○	○	○	○	○
300	○	○	○	○	○
400	○	○	○	○	○
500	○	○	○	○	○
600	○	○	○	○	○
700	○	○	○	○	○
800	○	○	○	○	○
900	○	○	○	○	○
1000	○	○	○	○	○
1200	○	○	○	○	○

77. What is the minimum flow required to float your preferred craft on this stretch? (please specify in cfs)

78. With your particular craft in mind, what is the lowest acceptable flow that provides a reasonable 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)

79. Some people are interested in taking trips at lower flows for a technical experience. Think of this “technical trip” in your craft and for your primary objective. What is the best flow for a technical trip? (please specify in cfs)

80. Many people are interested in a “standard” river trip at average flows. Think of this “standard trip” in your craft and for your primary objective. What is the best flow for a standard trip? (please specify in cfs)

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

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

83. 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.

84. Are there other concerns or opportunities on this reach of river that you would like to report? These could be related to safety, aesthetics, crowding, access facilities, or other factors.

16. Conejos River - South Fork to Hwy 17 Bridge

* 85. Have you floated or paddled the Conejos River from South Fork Campground to Highway 17 Bridge? For more information and a map of this stretch of river, visit the American Whitewater River Page.

- Yes
- No

17. South Fork Confluence to Highway 17 Bridge - Flow Survey

For the questions on this page, please rate the quality of the run at each specified flow <u>for your preferred craft-type</u>. Please pay particular attention to the gage and report acceptable flows for that gage only.

* 86. What is your preferred craft for the Conejos River from South Fork Campground to Highway 17? (Choose one)

- ☐ Packraft/Inflatable kayak/canoe
- ☐ Kayak/C-1
- ☐ Open canoe
- ☐ Raft/Shredder
- ☐ Other (please specify)

* 87. What is your primary recreational objective on this section of the Conejos River? (Choose one)

- ☐ Floating/Scenery
- ☐ Fishing
- ☐ Exercise
- ☐ Other (please specify)

88. With your preferred craft-type in mind, please consider all the flow-dependent characteristics that contribute to a high quality experience (e.g., depth, challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For comparative purposes, please rate the acceptability of each flow level.

Flows represented are measured by the CO DWR Gage Conejos River below Platoro Reservoir.

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
100	○	○	○	○	○
200	○	○	○	○	○
300	○	○	○	○	○
400	○	○	○	○	○
500	○	○	○	○	○
600	○	○	○	○	○
700	○	○	○	○	○
800	○	○	○	○	○
900	○	○	○	○	○
1000	○	○	○	○	○
1200	○	○	○	○	○

89. What is the minimum flow required to float your preferred craft on this stretch? (please specify in cfs)

90. With your particular craft in mind, what is the lowest acceptable flow that provides a reasonable 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)

91. Some people are interested in taking trips at lower flows for a technical experience. Think of this “technical trip” in your craft and for your primary objective. What is the best flow for a technical trip? (please specify in cfs)

92. Many people are interested in a “standard” river trip at average flows. Think of this “standard trip” in your craft and for your primary objective. What is the best flow for a standard trip? (please specify in cfs)

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

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

95. 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.

96. Are there other concerns or opportunities on this reach of river that you would like to report? These could be related to safety, aesthetics, crowding, access facilities, or other factors.

18. Conejos River - Hwy 17 Bridge to Mogote Campground

* 97. Have you floated or paddled the Conejos River from Highway 17 Bridge to Mogote Campground? For more information and a map of this stretch of river, visit the American Whitewater River Page.

- ◯ Yes
- ◯ No

19. Highway 17 Bridge to Mogote Campground - Flow Survey

For the questions on this page, please rate the quality of the run at each specified flow for your preferred craft-type. Please pay particular attention to the gage and report acceptable flows for that gage only.

* 98. What is your preferred craft for the Conejos River from Highway 17 Bridge to Mogote Campground? (Choose one)

- [ ] Packraft/Inflatable kayak/canoe
- [ ] Kayak/C-1
- [ ] Open canoe
- [ ] Raft/Shredder
- [ ] Other (please specify)

* 99. What is your primary recreational objective on this section of the Conejos River? (Choose one)

- [ ] Floating/Scenery
- [ ] Fishing
- [ ] Exercise
- [ ] Other (please specify)

100. With your preferred craft-type in mind, please consider all the flow-dependent characteristics that contribute to a high quality experience (e.g., depth, challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For comparative purposes, please rate the acceptability of each flow level.

Flows represented are measured by the CO DWR Gage Conejos River near Mogote.

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
100	○	○	○	○	○
200	○	○	○	○	○
300	○	○	○	○	○
400	○	○	○	○	○
500	○	○	○	○	○
600	○	○	○	○	○
700	○	○	○	○	○
800	○	○	○	○	○
900	○	○	○	○	○
1000	○	○	○	○	○
1200	○	○	○	○	○
1400	○	○	○	○	○
1600	○	○	○	○	○
1800	○	○	○	○	○
2000	○	○	○	○	○
2200	○	○	○	○	○
2400	○	○	○	○	○
2600	○	○	○	○	○
2800	○	○	○	○	○
3000	○	○	○	○	○

101. What is the minimum flow required to float your preferred craft on this stretch? (please specify in cfs)

102. With your particular craft in mind, what is the lowest acceptable flow that provides a reasonable 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)

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

104. Many people are interested in a "standard" river trip at average flows. Think of this "standard trip" in your craft and for your primary objective. What is the best flow for a standard trip? (please specify in cfs)

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

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

107. 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.

108. Are there other concerns or opportunities on this reach of river that you would like to report? These could be related to safety, aesthetics, crowding, access facilities, or other factors.

20. Rio Grande River - Alamosa to Lasauses

* 109. Have you floated or paddled the Rio Grande from Alamosa to Lasauses, through the Alamosa National Wildlife Refuge?
For more information and a map of this stretch of river, visit theAmerican Whitewater River Page.

- ( ) Yes
- ( ) No

21. Alamosa to Lasauses - Flow Survey

For the questions on this page, please rate the quality of the run at each specified flow<u>for your preferred craft-type</u>. Please pay particular attention to the gage and report acceptable flows for that gage only.

* 110. What is your preferred craft for the Rio Grande River from Alamosa to Lasauses, through the Alamosa National Wildlife Refuge? (Choose one)

- ☐ Dory/Drift Boat
- ☐ Packraft/Inflatable kayak/canoe
- ☐ Kayak/C-1
- ☐ Open canoe
- ☐ Raft/Shredder
- ☐ Other (please specify)

* 111. What is your primary recreational objective on this section of the Rio Grande River? (Choose one)

- ☐ Floating/Scenery
- ☐ Fishing
- ☐ Exercise
- ☐ Other (please specify)

112. With your preferred craft-type in mind, please consider all the flow-dependent characteristics that contribute to a high quality experience (e.g., depth, challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For comparative purposes, please rate the acceptability of each flow level.

Flows represented are measured by the CO DWR Gage Rio Grande River at Alamosa

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
100	○	○	○	○	○
200	○	○	○	○	○
300	○	○	○	○	○
400	○	○	○	○	○
500	○	○	○	○	○
600	○	○	○	○	○
700	○	○	○	○	○
800	○	○	○	○	○
900	○	○	○	○	○
1000	○	○	○	○	○
1200	○	○	○	○	○
1400	○	○	○	○	○
1600	○	○	○	○	○
1800	○	○	○	○	○
2000	○	○	○	○	○
2250	○	○	○	○	○
2500	○	○	○	○	○
2750	○	○	○	○	○
3000	○	○	○	○	○
3500	○	○	○	○	○
3750	○	○	○	○	○
4000	○	○	○	○	○
4250	○	○	○	○	○
4500	○	○	○	○	○

113. What is the minimum flow required to float your preferred craft on this stretch? (please specify in cfs)

114. With your particular craft in mind, what is the lowest acceptable flow that provides a reasonable 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)

115. Some people are interested in taking trips at lower flows for a technical experience. Think of this “technical trip” in your craft and for your primary objective. What is the best flow for a technical trip? (please specify in cfs)

116. Many people are interested in a “standard” river trip at average flows. Think of this “standard trip” in your craft and for your primary objective. What is the best flow for a standard trip? (please specify in cfs)

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

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

119. 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.

120. Are there other concerns or opportunities on this reach of river that you would like to report? These could be related to safety, aesthetics, crowding, access facilities, or other factors.

22. Rio Grande River - Lasauses to Lobatos Bridge

* 121. Have you floated or paddled the Rio Grande from Lasauses to Lobatos Bridge, Colorado?
For more information and a map of this stretch of river, visit the American Whitewater River Page.

- Yes
- No

23. Lasauses to Lobatos Bridge - Flow Survey

For the questions on this page, please rate the quality of the run at each specified flow<u>for your preferred craft-type</u>. Please pay particular attention to the gage and report acceptable flows for that gage only.

* 122. What is your preferred craft for the Rio Grande River from Lasauses to Lobato Bridge? (Choose one)

- [ ] Dory/Drift Boat
- [ ] Packraft/Inflatable kayak/canoe
- [ ] Kayak/C-1
- [ ] Open canoe
- [ ] Raft/Shredder
- [ ] Other (please specify)

* 123. What is your primary recreational objective on this section of the Rio Grande River? (Choose one)

- [ ] Floating/Scenery
- [ ] Fishing
- [ ] Exercise
- [ ] Other (please specify)

124. With your preferred craft-type in mind, please consider all the flow-dependent characteristics that contribute to a high quality experience (e.g., depth, challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For comparative purposes, please rate the acceptability of each flow level.

Flows represented are measured by the CO DWR Gage <u>Rio Grande River near Lobatos</u>

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
100	○	○	○	○	○
200	○	○	○	○	○
300	○	○	○	○	○
400	○	○	○	○	○
500	○	○	○	○	○
600	○	○	○	○	○
700	○	○	○	○	○
800	○	○	○	○	○
900	○	○	○	○	○

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
1000	○	○	○	○	○
1200	○	○	○	○	○
1400	○	○	○	○	○
1600	○	○	○	○	○
1800	○	○	○	○	○
2000	○	○	○	○	○
2250	○	○	○	○	○
2500	○	○	○	○	○
2750	○	○	○	○	○
3000	○	○	○	○	○
3500	○	○	○	○	○
3750	○	○	○	○	○
4000	○	○	○	○	○
4250	○	○	○	○	○
4500	○	○	○	○	○
4750	○	○	○	○	○
5000	○	○	○	○	○
5250	○	○	○	○	○
5500	○	○	○	○	○
5750	○	○	○	○	○
6000	○	○	○	○	○
6250	○	○	○	○	○
6500	○	○	○	○	○

125. What is the minimum flow required to float your preferred craft on this stretch? (please specify in cfs)

126. With your particular craft in mind, what is the lowest acceptable flow that provides a reasonable 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)

127. Some people are interested in taking trips at lower flows for a technical experience. Think of this “technical trip” in your craft and for your primary objective. What is the best flow for a technical trip? (please specify in cfs)

128. Many people are interested in a “standard” river trip at average flows. Think of this “standard trip” in your craft and for your primary objective. What is the best flow for a standard trip? (please specify in cfs)

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

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

131. 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.

132. Are there other concerns or opportunities on this reach of river that you would like to report? These could be related to safety, aesthetics, crowding, access facilities, or other factors.

24. Rio Grande River - Lobatos Bridge, Colorado to Lee Trail, New Mexico

* 133. Have you floated or paddled the Rio Grande from Lobatos Bridge, Colorado to Lee Trail, New Mexico?

For more information and a map of this stretch of river, visit theAmerican Whitewater River Page.

- ◯ Yes
- ◯ No

25. Lobatos Bridge to Lee Trail - Flow Survey

For the questions on this page, please rate the quality of the run at each specified flow for your preferred craft-type. Please pay particular attention to the gage and report acceptable flows for that gage only.

* 134. What is your preferred craft for the Rio Grande River from Lobatos Bridge to Lee Trail, New Mexico? (Choose one)

- ☐ Packraft/Inflatable kayak/canoe
- ☐ Kayak/C-1
- ☐ Open canoe
- ☐ Raft/Shredder
- ☐ Other (please specify)

* 135. What is your primary recreational objective on this section of the Rio Grande River? (Choose one)

- ☐ Floating/Scenery
- ☐ Fishing
- ☐ Exercise
- ☐ Other (please specify)

136. With your preferred craft-type in mind, please consider all the flow-dependent characteristics that contribute to a high quality experience (e.g., depth, challenge, safety, availability of surfing or other play areas, aesthetics, and length of run). For comparative purposes, please rate the acceptability of each flow level.

Flows represented are measured by the CO DWR Gage Rio Grande River near Lobatos

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
100	○	○	○	○	○
200	○	○	○	○	○
300	○	○	○	○	○
400	○	○	○	○	○
500	○	○	○	○	○
600	○	○	○	○	○
700	○	○	○	○	○
800	○	○	○	○	○

	Unacceptable	Moderately Unacceptable	Marginal	Moderately Acceptable	Acceptable
900	○	○	○	○	○
1000	○	○	○	○	○
1200	○	○	○	○	○
1400	○	○	○	○	○
1600	○	○	○	○	○
1800	○	○	○	○	○
2000	○	○	○	○	○
2250	○	○	○	○	○
2500	○	○	○	○	○
2750	○	○	○	○	○
3000	○	○	○	○	○
3500	○	○	○	○	○
3750	○	○	○	○	○
4000	○	○	○	○	○
4250	○	○	○	○	○
4500	○	○	○	○	○
4750	○	○	○	○	○
5000	○	○	○	○	○
5250	○	○	○	○	○
5500	○	○	○	○	○
5750	○	○	○	○	○
6000	○	○	○	○	○
6250	○	○	○	○	○
6500	○	○	○	○	○

137. What is the minimum flow required to float your preferred craft on this stretch? (please specify in cfs)

138. With your particular craft in mind, what is the lowest acceptable flow that provides a reasonable 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)

139. Some people are interested in taking trips at lower flows for a technical experience. Think of this “technical trip” in your craft and for your primary objective. What is the best flow for a technical trip? (please specify in cfs)

140. Many people are interested in a “standard” river trip at average flows. Think of this “standard trip” in your craft and for your primary objective. What is the best flow for a standard trip? (please specify in cfs)

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

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

143. 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.

144. Are there other concerns or opportunities on this reach of river that you would like to report? These could be related to safety, aesthetics, crowding, access facilities, or other factors.

26. Stream Management Planning

145. Assuming challenges could be addressed, what is your hope/vision for the Rio Grande and Conejos Rivers in 25 Years?

146. What are your top 3 infrastructure goals or needs that the Stream Management Plan should focus on? These can be related to diversion structures, storage, gage data, boat ramps, or other factors.

First Priority

Second Priority

Third Priority

147. What are your top 3 regulatory goals that the Stream Management Plan should focus on? These can be related to water quality, species of concern, future flow retiming, or other needs.

First Priority

Second Priority

Third Priority

148. What are your top 3 environmental goals or needs that the Stream Management Plan should focus on? These can be related to habitat, channel form and function, flows, or other factors.

First Priority

Second Priority

Third Priority

149. Please describe any opportunities you think exist for improving recreational use and access on the Rio Grande or Conejos Rivers.

150. Which of the following Rio Grande River reaches do you consider to be priorities for boating improvements? Please rank in order of importance with #1 being the most important.

- A. Rio Grande - Box Canyon
- B. Rio Grande - Texas Creek Ramp to Creede
- C. Rio Grande - Creede to Wagon Wheel Gap
- D. Rio Grande - Wagon Wheel Gap to South Fork
- E. Rio Grande - South Fork to Del Norte
- F. Rio Grande - Alamosa to Lasauses
- G. Rio Grande - Lasauses to Lobatos Bridge
- H. Rio Grande - Lobatos Bridge to Lee Trail, NM

151. Please explain your ranking.

152. Do you have any final comments to add, that may not have been captured by the survey?

27. This Completes the Survey.

Thank you for your participation in this survey!

Your responses will help American Whitewater and Rio Grande Headwaters Restoration Project create Stream Management Plans (SMPs) in the Rio Grande Basin that include robust community engagement. Your feedback allows us to characterize and prioritize environmental and recreational values, and create SMPs that will be used to inform multi-objective projects to restore and protect the natural and cultural resources within the basin.

153. Would you like more information about American Whitewater and our work to Protect, Restore, and Enjoy our nations rivers?

- ◯ Yes
- ◯ No

28. Sign-Up

154. American Whitewater's BETA Newsletter is a monthly summary of AW's Stewardship Work across the Country. Please sign-up using the fields below.

Name	
Address	
Address 2	
City/Town	
State/Province	-- select state --
ZIP/Postal Code	
Country	
Email Address	
Phone Number	

29. Thank You!

From all of us at American Whitewater and the Rio Grande Headwaters Restoration Project, thank you for your participation. We appreciate your time and hope you continue to enjoy and explore the basin's river resources.

APPENDIX B: CHANNEL MIGRATION ANALYSIS

Document Creation: Generated on Aug. 13, 2019 by Elizabeth Langford, Michael Blazewicz, and Katie Jagt.

Updates: None.

GENERAL INFORMATION

Title of Dataset: Historic Channel Margin Delineations for Select Stretches of the Rio Grande and Conejos Rivers, Colorado

Principal Investigator: Michael Blazewicz, Round River Design, Inc., michael@roundriverdesign.com

Co-investigators: Katie Jagt, PE, Watershed Science and Design, PLLC, katiejagt@watershedscienceanddesign.com

Elizabeth Langford, eglangford@mail.coloradomtn.edu

Alternate Contact(s): Daniel Boyes daniel@riograndeheadwaters.org or Emma Reesor emma@riograndeheadwaters.org, Rio Grande Headwaters Restoration Project

Funding sources: The *Rio Grande, Conejos River, and Saguache Creek Stream Management Plans: Phase 1, Geomorphic Assessmen*t is funded by Rio Grande Headwaters Restoration Project through a grant provided by the Colorado Water Conservation Board (CWCB).

Intended Use: Historic channel margins were delineated using available aerial photography for the years 1960, 1975, 1998 and 2017. These delineations identify an approximated, but not exact, location of the channel margin at the time the image was taken. Error exists in the delineations both as a result of difficulties in identifying the banklines due to obscurance from vegetation, clarity of the photographs, and multiple channel threads that make it difficult to choose a main bankline. Additionally error is introduced where the photos have been shot at an oblique angle and/or where georectification of the photos is inexact despite our best efforts to rectify them. These files are intended to be used to investigate at the reach level (1:8000 or greater) locations where significant channel migration have occurred in recent history in order to assist in the geomorphic assessment of the streams for stream management planning. These delineations are not intended to be used for calculating channel migration or bank erosion rates and SHOULD NOT be used for identification or location of fluvial hazards.

SHARING/ACCESS INFORMATION

Licenses/restrictions placed on the data, or limitations of reuse: None

Recommended Citation: Rio Grande Headwaters Restoration Project (2019). Rio Grande, Conejos River, and Saguache Creek Stream Management Plans: Phase 1, Geomorphic Assessment. Report prepared for the Colorado Water Conservation Board and the Rio Grande Basin Roundtable Alamosa, CO.

Citation for and links to publications that cite or use the data:

Rio Grande Headwaters Restoration Project. (2019). Rio Grande, Conejos River, and Saguache Creek Stream Management Plans: Phase 1. Report prepared for the Colorado Water Conservation Board and the Rio Grande Basin Roundtable Alamosa, CO.

STUDY INFORMATION

Study Dates: June-August 2019

Source of Aerial Photos: All Aerials are from The Land Processes Distributed Active Archive Center (LP DAAC), located at USGS/EROS, Sioux Falls, SD. http://lpdaac.usgs.gov

Years of imagery delineated: 1960/1966, 1975, 1998, 2017. These years were selected based on data availability, hydrology data, and interval between photos.

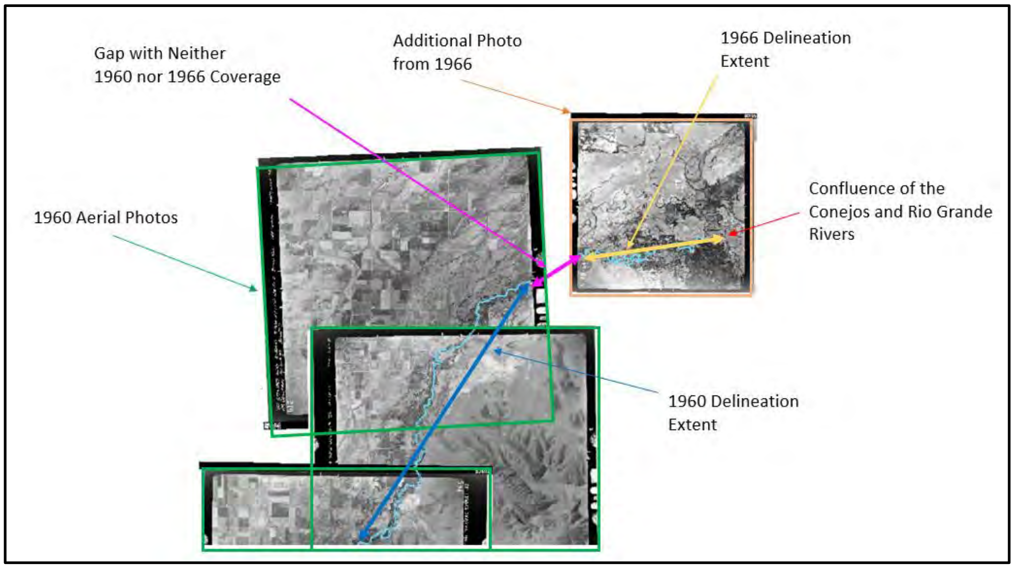
Geographic Area Covered: Conejos: Start: 106°11’16.293”W 37°3’14.678”N

End: 105°44’1.584”W 37°18’14.543”N

Rio Grande: Start: 105°58’46.123”W 37°33’49.439”N

End: 105°50’31.579”W 37°27’41.114”N

Data gaps: There is one data gap in the 1960 Conejos delineation--the image for the river stretch immediately upstream of the confluence of the Conejos and the Rio Grande. A portion of this area is covered by an image from 1966, however, a gap remains between the 1960 imagery and the 1966 imagery. The aerial image from 1966 is listed under 1SVBBI00100341.tif and covers the stretch from 105°47’45.488”W, 37°17’50.898”N to 105°44’1.584”W 37°18’14.543”N. This is the only reach in the 1960 delineations that is from 1966 data.



DATA & FILE OVERVIEW

File list (filenames, directory structure (for zipped files) and brief description of all data files):

1960 Conejos.shp_v1: Channel Margin Delineation for the Conejos River in 1960.

1975 Conejos.shp_v1: Channel Margin Delineation for the Conejos River in 1975.

1998 Conejos.shp_v1: Channel Margin Delineation for the Conejos River in 1998.

2017 Conejos.shp_v1: Channel Margin Delineation for the Conejos River in 2017.

1960 Rio Grande_v1.shp: Channel Margin Delineation for the Rio Grande in 1960.

1975 Rio Grande_v1.shp: Channel Margin Delineation for the Rio Grande in 1975.

1998 Conejos_v1.shp: Channel Margin Delineation for the Rio Grande in 1998.

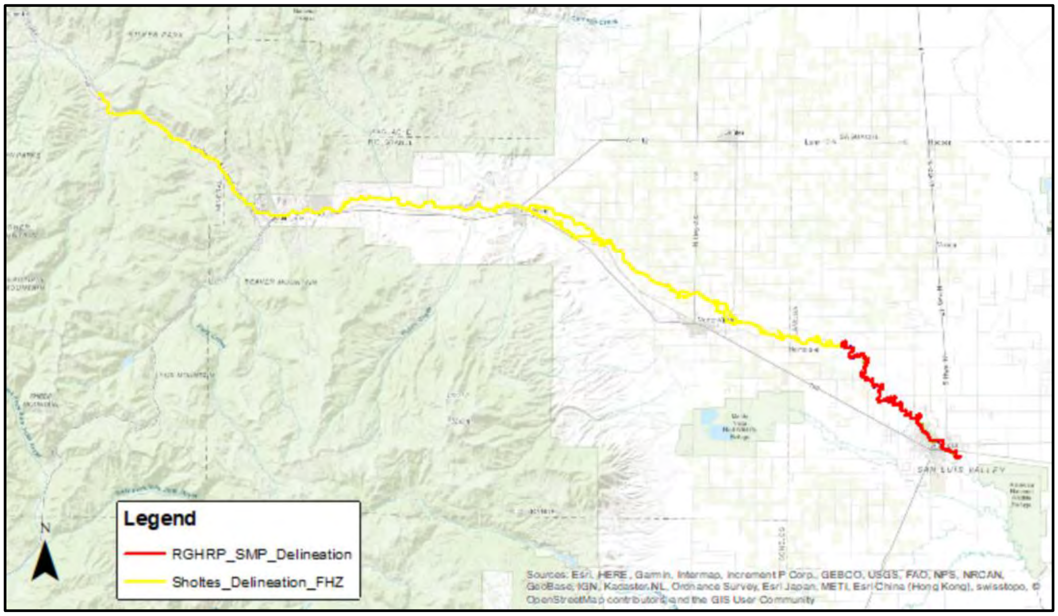
2017 Conejos_v1.shp: Channel Margin Delineation for the Rio Grande in 2017.

Each .shp consists of the following individual files: .shp, .shx, .prj, .dbf, .sbn .xml, .sbx, .cpg

Additional related data that is not included in the current data package:

Additional reaches of the Rio Grande had channel margins delineated by Joel Sholtes, University of Colorado as a portion of the Colorado Fluvial Hazard Mapping Pilot Project, CWCB, 2019.

Rio Grande: Start: 106°50'34.81"W, 37°47'0.47"N



End: 105°58’46.123”W, 37°33’49.439”N

Projected Coordinate System: NAD_1983_UTM_Zone_13N

Geographic Coordinate System: GCS_North_American_1983

Datum: D_North_American_1983

Prime Meridian: Greenwich

False Easting: 500000

False Northing: 0

Base Projection: Transverse_Mercator

Scale Factor: 0.99960000

Central_Meridian: -105.0

Latitude of Origin: 0.0

Attribute data: FID: EMPTY

SHAPE: POLYLINE

RIVER NAME: The river the margin delineation is for (Rio Grande or Conejos)

YEAR: Aerials from this year were used in the creation of the file. Note, 1966 is listed as 1960 for the one reach where 1966 photos were used.

METHODOLOGICAL INFORMATION

Description of methods used for collection/generation of data:

Memo: “Delineating Channel Margins” by Joel Sholtes, PhD, University of Colorado:

- Yellow lines indicate channel margins of “active channel”. This includes un-vegetated bars and islands.
- Use vegetation as a guide to channel margin: un-vegetated bars and islands are considered active channel
- Where tall trees are on stream banks and obscure bank line, approximate channel margin as middle of closest tree canopy.
- Keep polyline endpoints in same direction.

Standards and calibration information, if appropriate: Range of scale used in Arcmap used for visual delineations: 1:2,000-1:4,000

Describe any quality-assurance procedures performed on the data: Data was compared with LiDAR to ensure no major bedrock formations were mapped as part of the historic channels.

ADDITIONAL DATA-SPECIFIC INFORMATION

Georectification: The 1960 and 1975 aerial imagery was georectified by Daniel Boyes at the Rio Grande Headwaters Restoration Project in Fall 2018. In some locations (Rio Grande 1960, Conejos 1975) the georectification was adjusted by Elizabeth Langford in the Summer of 2019. The adjustments were done by manually adding additional feature-to-point control points based on the local roads of Colorado shapefile (CDOT) as well as the NHD Stream layer, where appropriate. Elizabeth Langford also georectified raw aerial imagery for the 1975 Rio Grande delineation. A combination of raw data and previously georectified images were used for the 1975 Conejos delineation.

Local Roads of Colorado (downloaded July 2019): https://data.colorado.gov/Transportation/Local-Roads-in-Colorado/qvrk-xsmj

National Hydrography Dataset (downloaded July 2019): https://viewer.nationalmap.gov/basic/?basemap=b1&category=nhd&title=NHD%20View

Aerial Images Used:

CONEJOS

1960
1SVBBI00100341.tif
A5504201106121.tif
A5504200703221.tif (up to 30m off)
A5504201105961.tif (up to 20m off)
A5504201105941.tif
A5504201105631.tif
A5504201105661.tif (up to 40m off)
A5504201105651.tif

1975
1VDSD003700791.tif
1VDSD003400621.tif
1VDSD0039001412.tif
1VDSD003900031.tif

1998
03710543.SWS.1032802.tif
03710664.SWS.1034021.tif
03710664.NWS.1034019.tif
03710664.NES.1034018.tif
03710663.SES.1034044.tif
03710557.NWS.1032813.tif
03710557.NES.1032812.tif
03710550.NWS.1032730.tif
03710549.SWS.1032703.tif
03710549.SES.1032702.tif
03710549.NES.1032700.tif
03710542.SWS.1032728.tif
03710542.SES.1032727.tif

2017
ortho_1-1_1n_s_co021_2017_1sid

RIO GRANDE

1960
1VADR000400731.tif (up to 45m off)
A5504201508811.tif
A5504200602581.tif

1975
1VDSD003400671.tif

1998
03710525.NWS.1032689.tif
03710534.NWS.1032721.tif
03710533.NES.1032692.tif
0310525.SWS.1032691.tif
03710525.SES.1032690.tif

2017
ortho_1-1_1n_s_co003_2017_1.sid

APPENDIX C: SMP TRACER GRAVEL STUDY

RIO GRANDE STATE WILDLIFE AREA CHANNEL BED MOBILITY STUDIES

An important part of river function is the movement of sediment through a river corridor and mobilization of the sediments on the channel bed. These studies look at how much flow is needed in the Rio Grande to pick up and move the bed material and how frequently these flows occur.

IMPORTANCE OF BED MOBILITY

Rivers adjust their shape and composition in response to the sediment and water supplied from the watershed and adjacent hillslopes and channel banks. The movement of sediment on a streambed affects instream and riparian habitat at various scales: At smaller scales, a lack of bed mobility may allow the buildup of fine particles such as sands and silts in the interstitial spaces between larger grains of sediment such as cobbles and gravels. These interstitial spaces are important for fish species but also for key components to the food web such as algae, zooplankton, phytoplankton, and macroinvertebrates.

At larger scales, the mobilization and deposition of bed sediments creates and maintains pools and riffles. Over the long term, changes in the bed surface caused by the mobility of the sediment on the bed are necessary to maintain habitat quality in river systems. Evacuating fine sediment from pools and the deposition of coarse sediment on bars may increase the quality and quantity of habitat used for spawning and rearing. Conversely, a lack of flows that trigger bed mobility will tend to cause either long-term scour or aggradation and tends to simplify the channel, reduce bedform variability, and homogenize aquatic and riparian habitat. Riparian vegetation establishment and succession is dependent upon the mobilization and deposition of sediment within the stream corridor.

The Rio Grande at the State Wildlife Area near Monte Vista, looking upstream on August 29, 2019. Approximate flow 300 cfs.

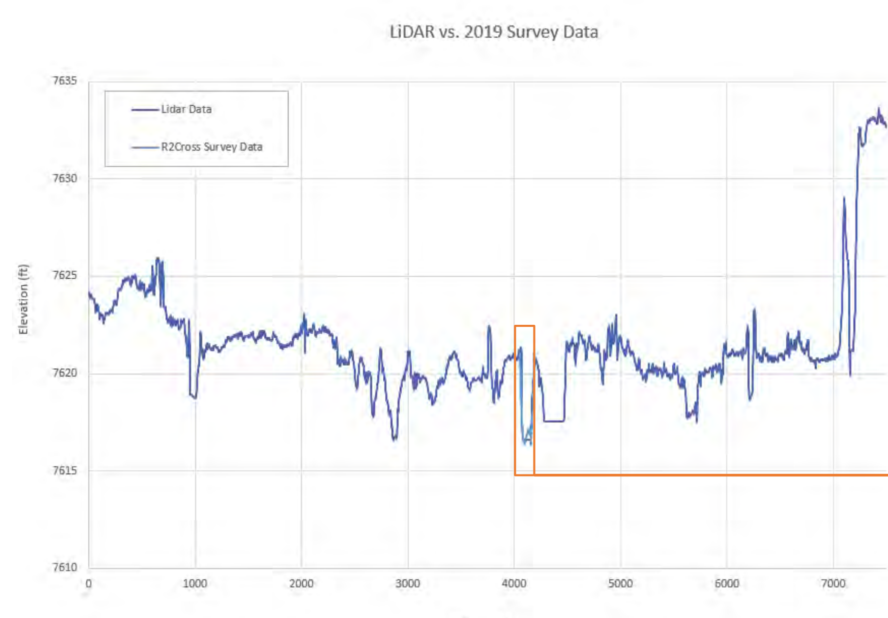
SEDIMENT CHARACTERISTICS

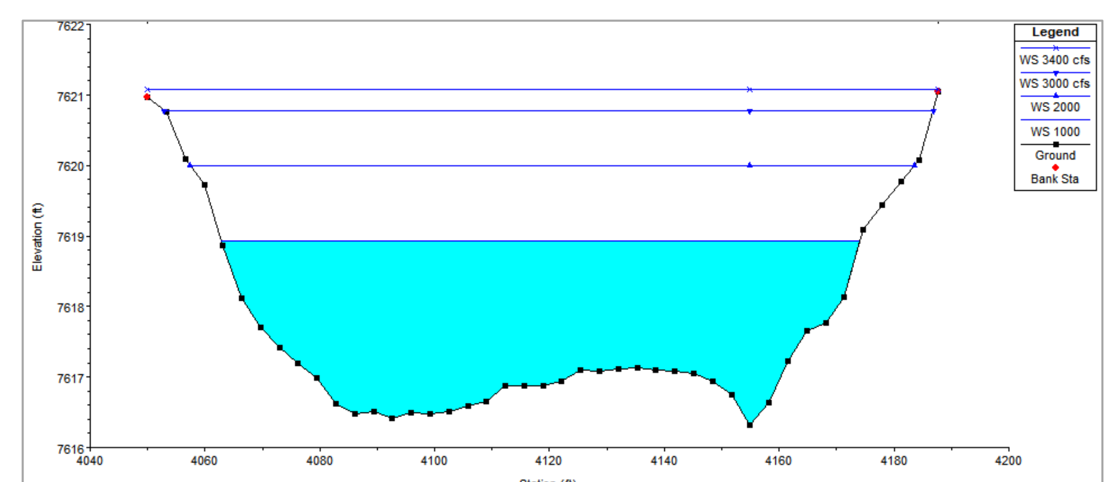
Description of Particle Size	Size (mm)	Pebble Count
Sand and Silts	<2	0
Very Fine Gravel	2 - 4	0
Fine Gravel	4 - 6	0
Fine Gravel	6 - 8	0
Medium Gravel	8 - 11	1
Medium Gravel	11 - 16	6
Coarse Gravel	16 - 22	8
Coarse Gravel	22 - 32	22
Very Coarse Gravel	32 - 45	26
Very Coarse Gravel	45 - 64	27
Small Cobble	64 - 90	9
Small Cobble	90 - 128	1
Large Cobble	128 - 180	0
Large Cobble	180 - 256	0

The Rio Grande channel bed at the State Wildlife Area has an average grain size of 29mm, which is classified as a coarse gravel.

CHANNEL GEOMETRY AND HYDRAULICS

The Rio Grande State Wildlife Area has full topographic coverage by the LiDAR. This was supplemented with survey data collected by the RGHRP in the summer of 2019. Hydraulic calculations were done using the survey data. For the purposes of this study, we are concerned only with flows that remain in the main channel of the Rio Grande. Simple calculations were done using the manning's equation to determine that the maximum capacity of the main channel is approximately 3400 cfs to 3600 cfs.





INCIPIENT MOTION CALCULATIONS—WHEN DO THE PARTICLES ON THE CHANNEL BED MOVE?

For the Rio Grande at the State Wildlife Area near Monte Vista, CO, flows between **900 and 1200 cfs** begin to mobilize the particles on the channel bed.

There are two ways we can calculate this:

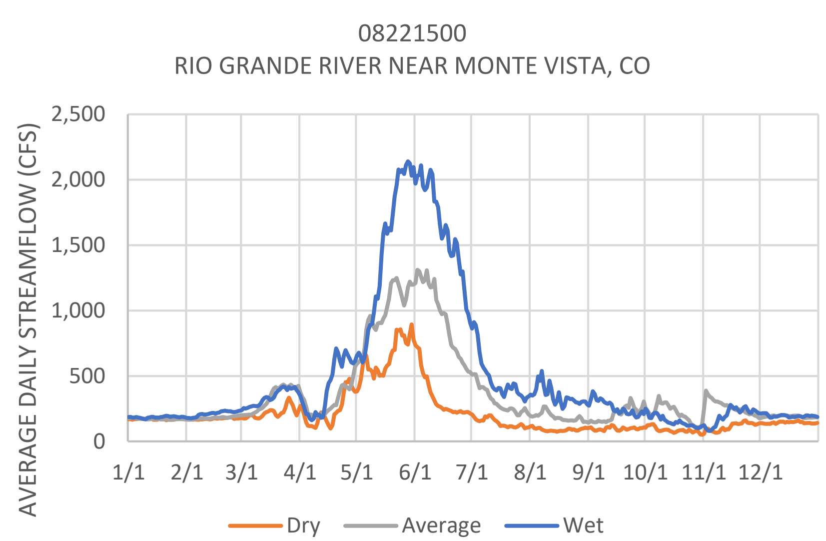
1) We calculate the critical shear stress, which uses a standardized value (0.047) for the "average" critical value of the Shields Parameter (t_{*c}) that has been observed to cause particle movement in a suite of flume and channel experiments as well as the average grain size in the channel which our team has measured. We then compare the critical shear stress to the shear stress in the channel as calculated using a hydraulic model—when the channel shear stress exceeds the critical shear stress, the average grain size is said to be mobilized.
2) By using the Shields diagram, which illustrates the mobilization threshold as a function of two variables: the critical shear force (t_*) and the particle Reynolds number (Re_*). Each of these variables is calculated for every flow that is expected in the channel and uses the average grain size of the channel bed. The τ_* and Re_* are plotted for each flow and if the point is above the line on the Shields diagram, the flow can mobilize the grains on the bed. For this gravel-bedded system, the critical shear force threshold is approximate 0.050 for all particle Reynolds numbers (the area shaded in blue, below).

CRITICAL SHEAR STRESS

Flow (cfs)	D50 of Channel Bed (mm)	Particle Class	τ_o Channel Shear from HEC-RAS (lb/ft2)	τ_c Critical Shear Stress (lb/ft2)	Conclusion
100	29	coarse gravel	0.14	0.4606	No Movement
200	29	coarse gravel	0.20	0.4606	No Movement
300	29	coarse gravel	0.24	0.4606	No Movement
400	29	coarse gravel	0.28	0.4606	No Movement
500	29	coarse gravel	0.32	0.4606	No Movement
600	29	coarse gravel	0.35	0.4606	No Movement
800	29	coarse gravel	0.41	0.4606	No Movement
1000	29	coarse gravel	0.47	0.4606	Flow Moves Particle
1200	29	coarse gravel	0.52	0.4606	Flow Moves Particle
1400	29	coarse gravel	0.56	0.4606	Flow Moves Particle
1600	29	coarse gravel	0.6	0.4606	Flow Moves Particle
1800	29	coarse gravel	0.63	0.4606	Flow Moves Particle
2000	29	coarse gravel	0.66	0.4606	Flow Moves Particle
2200	29	coarse gravel	0.69	0.4606	Flow Moves Particle
2400	29	coarse gravel	0.72	0.4606	Flow Moves Particle
2600	29	coarse gravel	0.75	0.4606	Flow Moves Particle
2800	29	coarse gravel	0.78	0.4606	Flow Moves Particle
3000	29	coarse gravel	0.81	0.4606	Flow Moves Particle
3200	29	coarse gravel	0.83	0.4606	Flow Moves Particle
3400	29	coarse gravel	0.86	0.4606	Flow Moves Particle

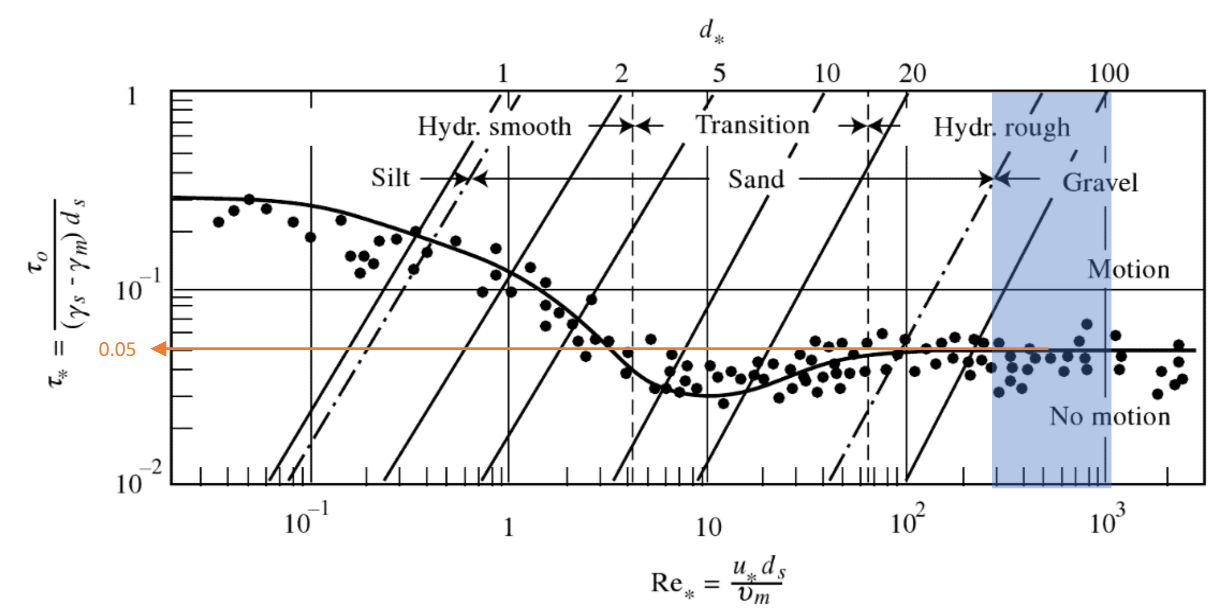
According to the analysis of historic flows, bed mobilizing flows are present in the channel at the Monte Vista gauge for approximately 30 days during Average years and for 55 days during Wet years.

However, if significant flow (greater than approximately 200cfs) is diverted out of the channel between the gauge and the State Wildlife Area during peak of runoff in Average years, these flows will no longer have the strength to mobilize the channel bed.



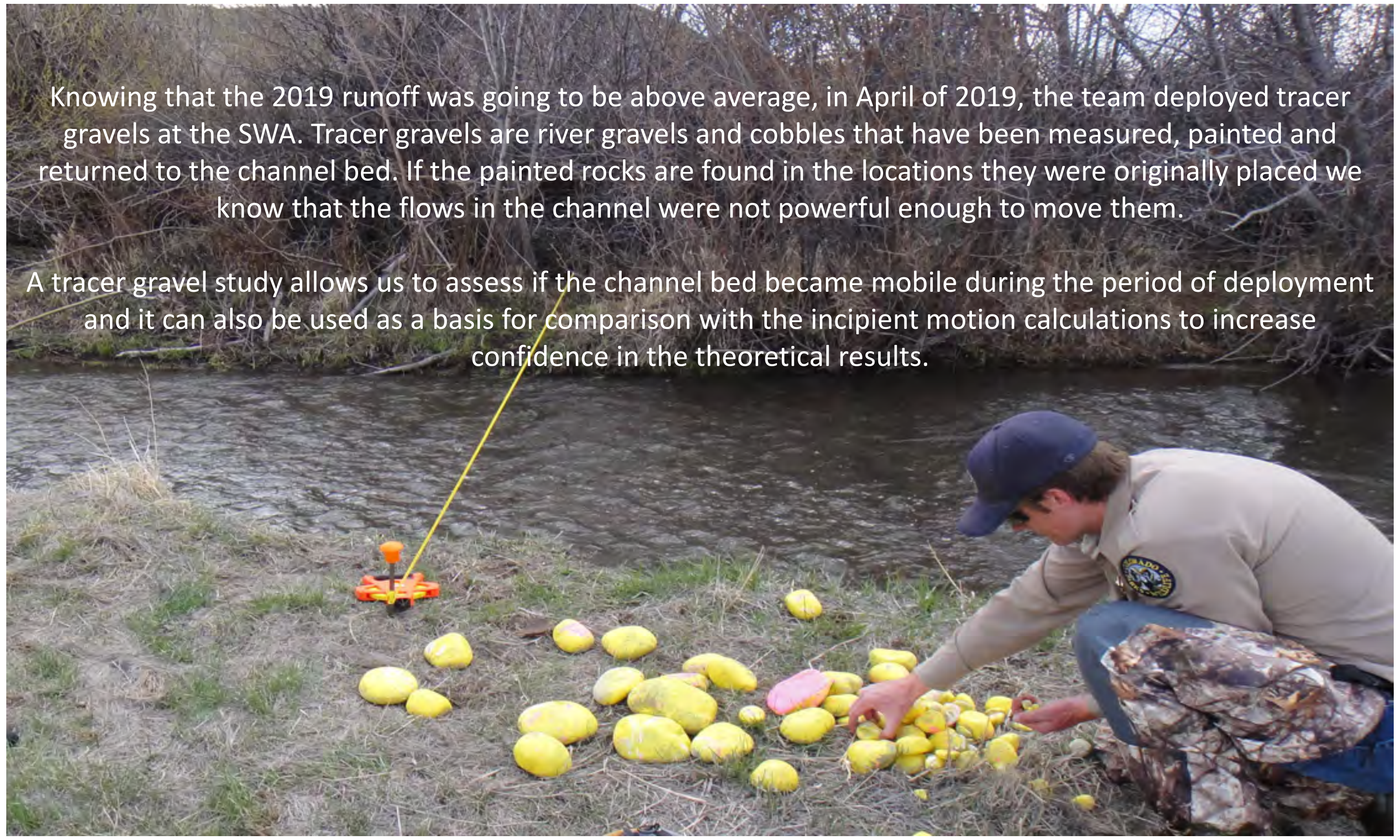
SHIELDS DIAGRAM

Flow (cfs)	D50 of Channel Bed (mm)	Particle Class	τ_* Critical Shear Force (unitless)	Re_* Particle Reynolds number (unitless)	Location on Shields Diagram	Conclusion
100	29	coarse gravel	0.014	320		
200	29	coarse gravel	0.020	383	Below	No movement
300	29	coarse gravel	0.024	419	Below	No movement
400	29	coarse gravel	0.029	453	Below	No movement
500	29	coarse gravel	0.033	484	Below	No movement
600	29	coarse gravel	0.036	506	Below	No movement
800	29	coarse gravel	0.042	548	Below	No movement
1000	29	coarse gravel	0.048	587	Below	No movement
1200	29	coarse gravel	0.053	617	Below	Flow moves particle
1400	29	coarse gravel	0.057	641	Below	Flow moves particle
1600	29	coarse gravel	0.061	663	Below	Flow moves particle
1800	29	coarse gravel	0.064	679	Below	Flow moves particle
2000	29	coarse gravel	0.067	695	Above	Flow moves particle
2200	29	coarse gravel	0.070	711	Above	Flow moves particle
2400	29	coarse gravel	0.073	726	Above	Flow moves particle
2600	29	coarse gravel	0.077	741	Above	Flow moves particle
2800	29	coarse gravel	0.080	756	Above	Flow moves particle
3000	29	coarse gravel	0.083	770	Above	Flow moves particle
3200	29	coarse gravel	0.085	780	Above	Flow moves particle
3200	29	coarse gravel	0.085	821	Above	Flow moves particle



TRACER GRAVEL STUDY—WHAT BED MOBILITY WAS OBSERVED IN 2019?

During the 2019 runoff we observed a highly mobile channel bed **at the Rio Grande State Wildlife Area**.

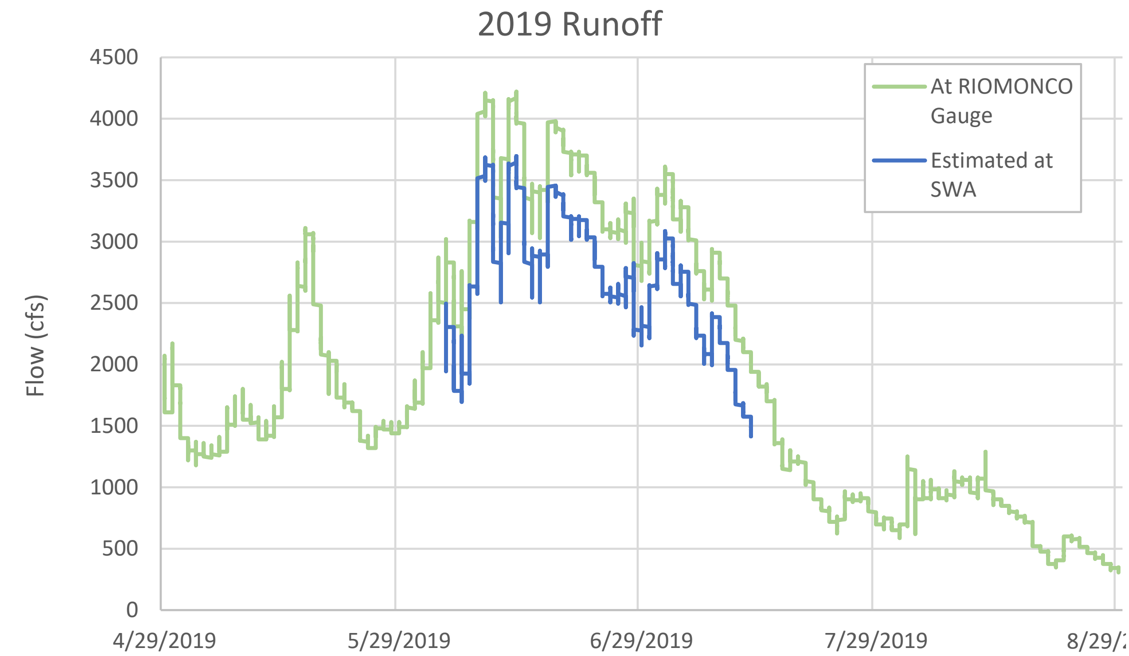


We deployed 99 gravels and cobbles at the Rio Grande State Wildlife Area on April 29, 2019 and recovered the tracer gravels on August 29, 2019. We recovered 100% of the tracer gravels that were larger than 64 mm either at the transect or immediately downstream. We recovered two of the 22 tracer gravels that were between 32mm and 64 mm downstream of the transect. We recovered no gravels smaller than 32mm.

This leads us to conclude that the flows in 2019, which peaked around 3500 cfs, were strong enough to mobilize gravels (grains smaller than 64mm) but not cobbles (grains larger than 64mm). The native bed material has only a very small fraction of particles larger than 64mm which leads us to conclude that between May and August, the entire bed of the Rio Grande became mobilized.

Tracer Gravel Counts

Size (mm)	Native Material	Deployed Gravels	Deployed and Recovered at Transect	Deployed and Recovered d/s of Transect	Percent of Tracers Recovered
< 4	2				n/a
4 - 8					n/a
8 - 16	7	25	0	0	0%
16 - 32	48	30	0	1	3%
32 - 64	35	22	0	2	9%
64 - 128	5	16	16	0	100%
128 - 256		6	4	2	100%



For the Rio Grande at the State Wildlife Area near Monte Vista, CO, experienced peak flows around **3500 cfs.** This is calculated by looking at the flows measured at the RIOMONCO gauge and subtracting the flows diverted out of the channel by the water delivery infrastructure—the average diversion was approximately 525 cfs through the peak of runoff.

The Rio Grande State Wildlife Area on June 18, 2019, near the peak of flows for 2019. While the off-channel and floodplain areas are certainly wet, the difference in the color of the water (brown in the channel and blue on the floodplain and in the oxbow lakes) indicate that the channel is not actively overtopping to the south at the time of this photo.

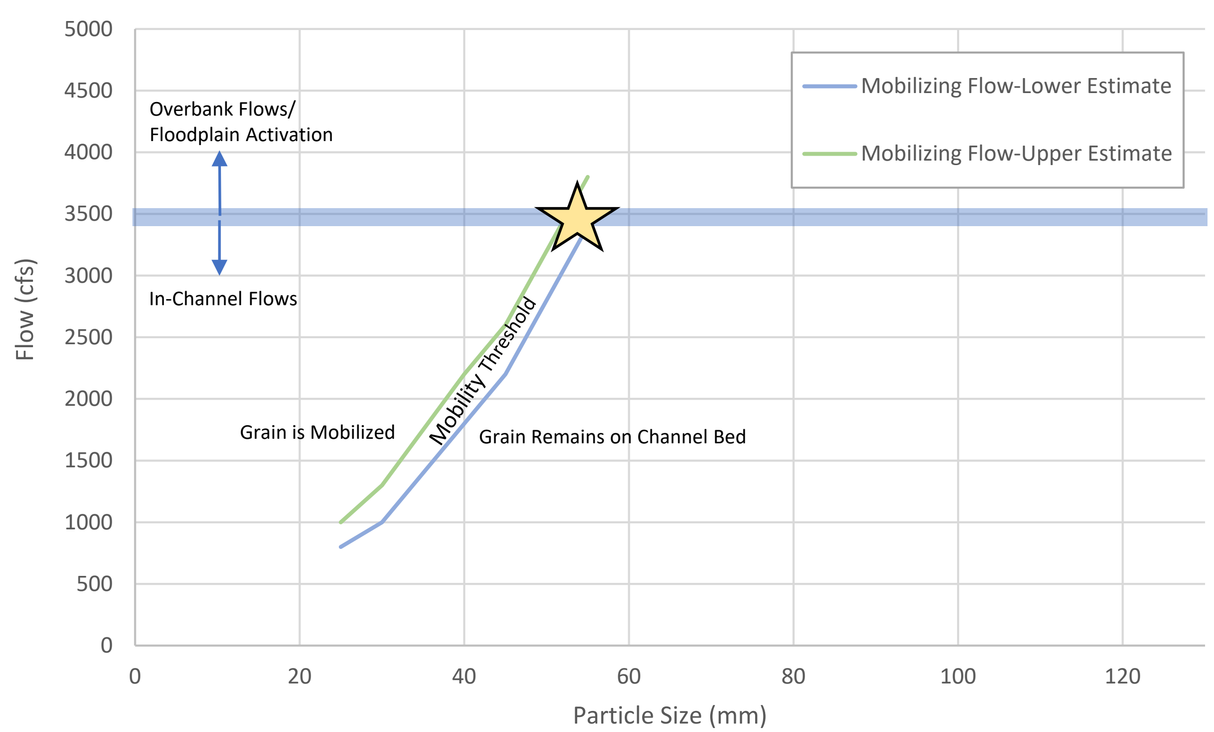
TRACER GRAVEL STUDY—HOW DO THE CALCULATIONS COMPARE TO THE INCIPIENT MOTION CALCULATIONS?

The results from the tracer gravel study support the incipient motion calculations. The gravels that we placed before runoff, and then found, on the channel bed after runoff are the sizes that we would expect to persist in place based on the flows that this reach of the Rio Grande experienced between May and August 2019. The material that was mobilized are of sizes that the calculations suggest should have been mobile during the 2019 flows.

This analysis increases confidence in the ability of the Incipient Motion Calculations to predict bed mobility for the Rio Grande.

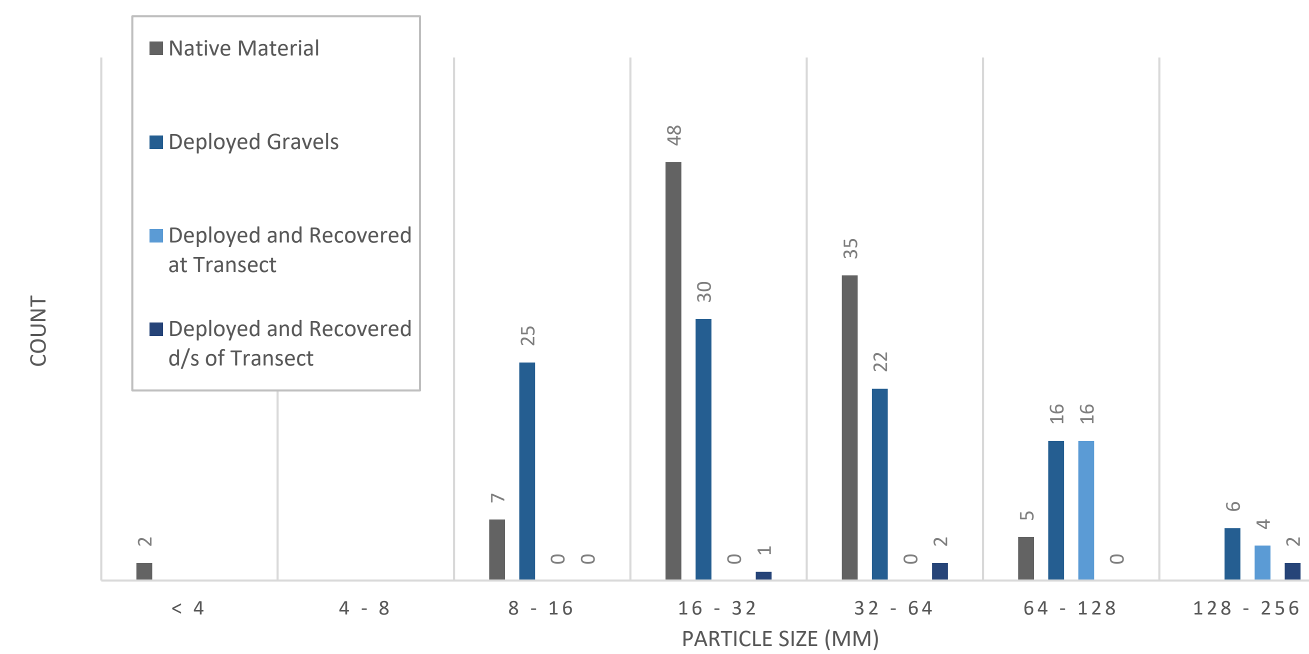
CALCULATED BED MOBILITY

The calculated flows that are necessary to trigger the mobilization of sediment of various sizes within this reach are shown below. According to these calculations, the flows experienced by this reach in 2019, approximately 3500 cfs, had enough energy to mobilize sediment particles smaller than approximately 55mm (denoted by yellow star). Particles smaller than 55mm should have been picked up and transported as bedload; particles larger than 55mm should have remained on the channel bed.



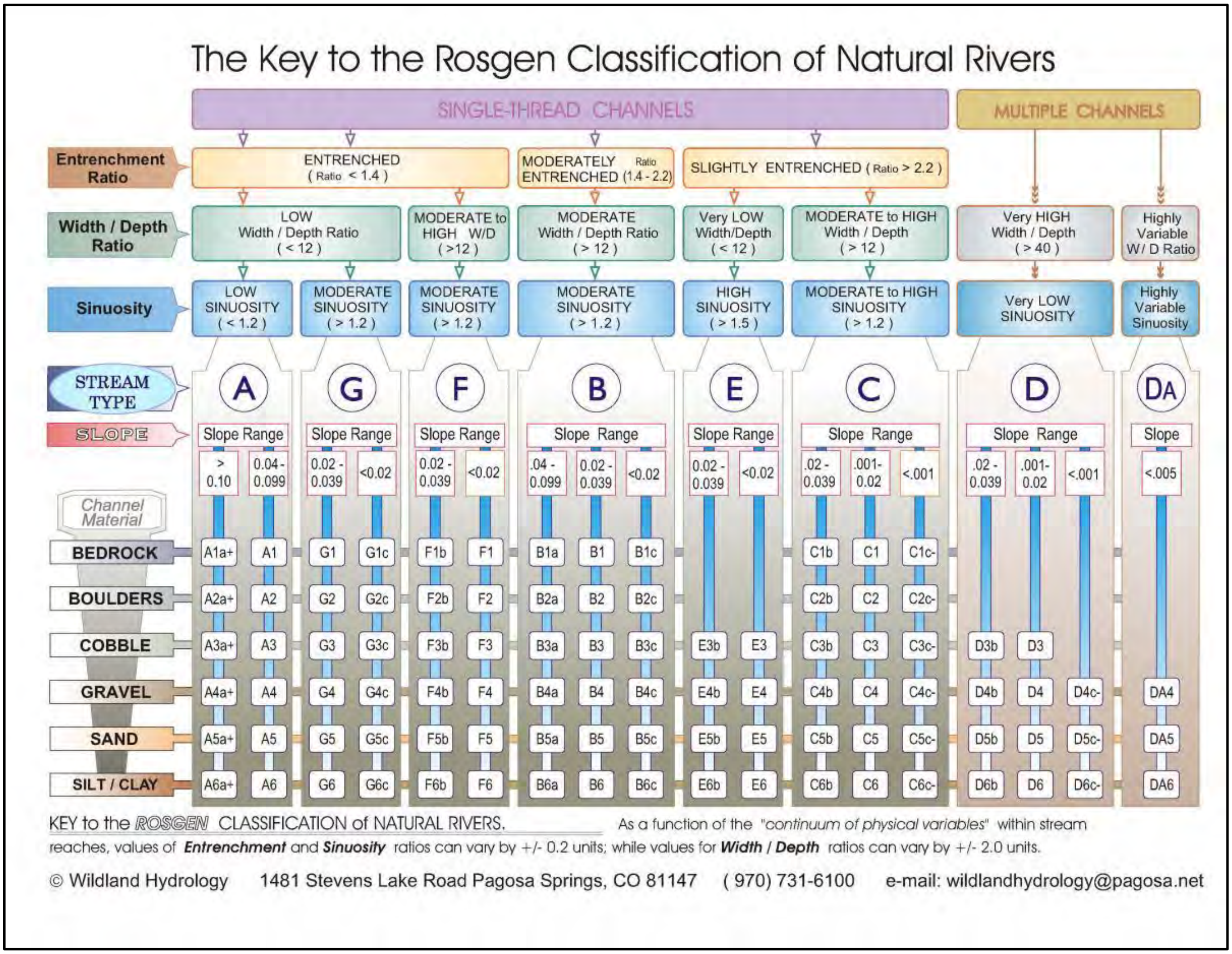
OBSERVED BED MOBILITY

The RGHRP team recovered all tracer gravels larger than 64 mm. Two of these had moved slightly downstream and were found within 100 feet of their initial placement locations. All tracer gravels that were between 32 and 64 mm were mobilized; two of this size class were recovered within 100 feet of their placement locations—and both recovered gravels were measured at 55mm. All grains smaller than 32mm were mobilized and only one was recovered within 100 feet of the placement cross-section.



APPENDIX D: STREAM CLASSIFICATION SYSTEM SUMMARIES

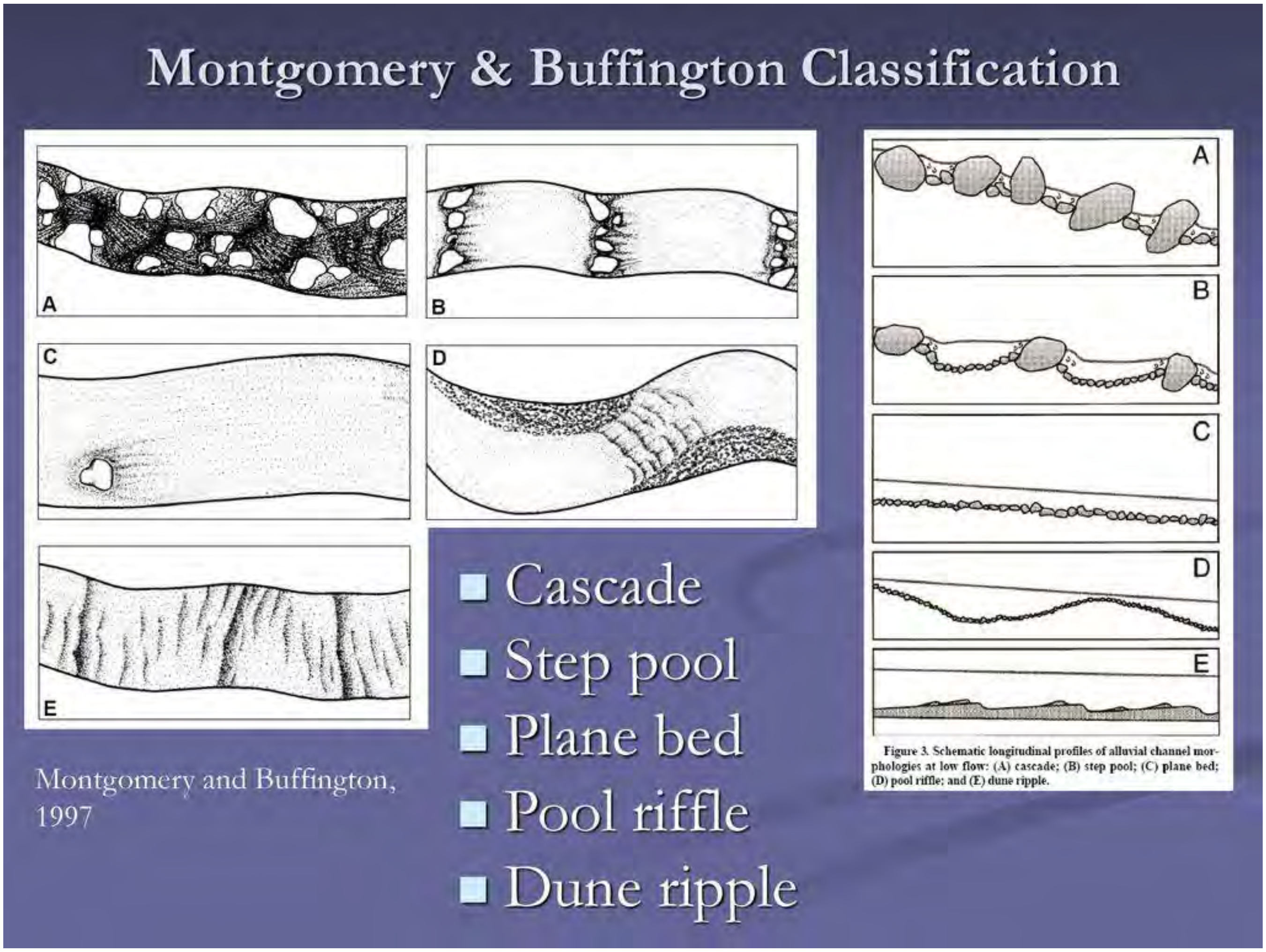
Rosgen Stream Classification System:
A classification system developed by David Rosgen, Ph.D., in which morphological arrangements of stream characteristics are organized into relatively homogeneous stream types using an alphanumeric system. The classifications assigned in this Rapid Geomorphic Assessment would be considered Level II classification, although for a true Level II classification the Rosgen system stipulates that field data must be collected which was not possible given the limited budget assigned for this project.



Reference: Rosgen, D. L. (1996). *Applied river morphology*. Pagosa Springs, Colo: Wildland Hydrology.

Montgomery-Buffington Bedform Classification System:

A classification system that couples reach-level channel processes with the spatial arrangement of reach morphologies, their links to hillslope processes, and external forcing by confinement, riparian vegetation, and woody debris defines a process-based framework within which to assess channel condition and response potential in mountain drainage basins.



Reference: David R. Montgomery, John M. Buffington; Channel-reach morphology in mountain drainage basins. *GSA Bulletin* ; 109 (5): 596–611. doi: https://doi.org/10.1130/0016-7606(1997)109<0596:CRMIMD>2.3.CO;2

Stream Evolution Model:

The Stream Evolution Model (SEM) described by Cluer and Thorne in 2014 was used to assess the current channel condition and active processes in terms of streambed adjustment.

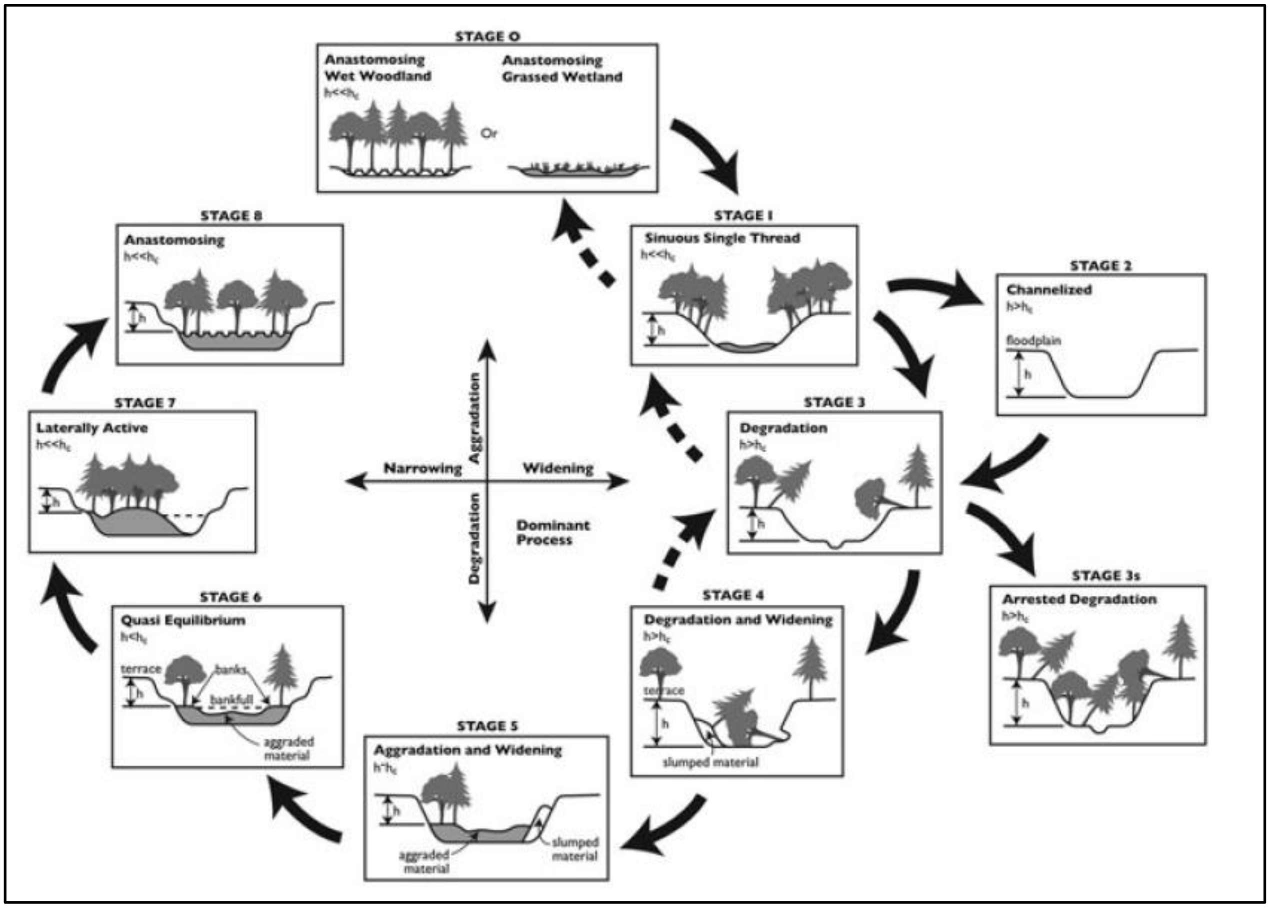


Figure 5. Stream Evolution Model showing geomorphic changes through the four processes of narrowing, widening, aggrading, and/or degrading (Cluer and Thorne, 2014).

Table I. Previous Channel Evolution Models and the proposed Stream Evolution Model with description of reach-average characteristics, or stages

Schumm *et al*., 1984	Simon and Hupp, 1986	SEM		Description
		0. Anastomosing		Pre-disturbance, dynamically meta-stable network of anabranching channels and floodplain with vegetated islands supporting wet woodland or grassland. $Qs_{in} \geq Qs_{out}$, $h << h_c$
I. Undisturbed	I. Pre-modified	- Single Thread Channels -	1.Sinuous	Dynamically stable and laterally active channel within a floodplain complex. Flood return period 1-5 yr range. $Qs_{in} \geq Qs_{out}$, $h << h_c$
	II. Constructed		2. Channelized	Re-sectioned land drainage, flood control, or navigation channels. $Qs_{in} \leq Qs_{out}$, $h > h_c$
II. Degradation	III. Degradation		3. Degrading	Incising and abandoning its floodplain. Featuring head cuts, knick points or knick zones that incise into the bed, scours away bars and riffles and removes sediments stored at bank toes. Banks stable geotechnically. $Qs_{in} < Qs_{out}$, $h > h_c$
			3s. Arrested degradation	Stabilized, confined or canyon-type channels. Incised channel in which bed lowering and channel evolution have been halted because non-erodible materials (bed rock, tight clays) have been encountered. $Qs_{in} \sim Qs_{out}$, $h > h_c$
III. Rapid Widening	IV. Degradation and widening		4. Degradation and widening	Incising with unstable, retreating banks that collapse by slumping and/or rotational slips. Failed material is scoured away and the enlarged channel becomes disconnected from its former floodplain, which becomes a terrace. $Qs_{in} < Qs_{out}$, $h > h_c$
			4-3. Renewed incision	Further head cutting within Stage 4 channel. $Qs_{in} < Qs_{out}$, $h >> h_c$
IV. Aggradation	V. Aggradation and widening		5. Aggrading and widening	Bed rising, aggrading, widening channel with unstable banks in which excess load from upstream together with slumped bank material build berms and silts bed. banks stablizing & berming. $Qs_{in} > Qs_{out}$, $h \sim h_c$
V. Stabilization	VI. Quasi-equilibrium		6. Quasi-equilibrium	Inset floodplain re-established. quasi-equilibrium channel with two-stage cross-section featuring regime channel inset within larger, degraded channel. Berms stabilize as pioneer vegetation traps fine sediment, seeds and plant propagules. $Qs_{in} \sim Qs_{out}$, $h < h_c$
	VII. [1]Late-stage evolution		7. Laterally active	Channel with frequent floodplain connection develops sinuous course, is laterally active and has asymmetrical cross-section promoting bar accretion at inner margins and toe scour and renewed bank retreat along outer margins of expanding/migrating bends. $Qs_{in} \geq Qs_{out}$, $h << h_c$
		8. Anastomosing		Meta-stable channel network. Post-disturbance channel featuring anastomosed planform connected to a frequently inundated floodplain that supports wet woodland or grassland that is bounded by set-back terraces on one or both margins. $Qs_{in} \geq Qs_{out}$, $h << h_c$

[1] Suggested by Thorne (1999)

Table II. Physical and vegetative attributes for each stage in the Stream Evolution Model

SEM Stage		Physical Attributes			Vegetation Attributes
		Hydrologic Regime	Hydraulics and Substrate	Dimensions and Morphology	
0. Anastomosing. Dynamically meta-stable network of anabranching channels with vegetated islands.		Floods diffused over the full width of the floodplain so flood peaks are maximally attenuated. Flood pulses diffused and subdued. High water table and close connection between stream flow and ground water ensures reliable base flows and continuous hyporhesis, though flow in smaller anabranches may be ephemeral.	Multiple channels provide maximum in-channel hydraulic diversity through partition of discharge between branches that widens range of in-channel depth/velocity combinations. Anabranches create multiple, marginal deadwaters. Wide range of substrate grain sizes arranged into numerous, well-sorted bed patches.	Multiple anabranches, islands and side channels maximize. Morphological features abound in-channel and on the extensive and fully connected floodplain, providing a high capacity to store sediment and wood and supporting diverse wetlands. Bank heights are low with stability enhanced by riparian margins, but some river cliffs are generated by localised erosion. Network and floodplain are highly resilient to disturbance, buffering the system.	Frequent, small channel adjustments and high, reliable water table create ubiquitous settings for proliferation and succession of aquatic, emergent, riparian and floodplain plants. Wet woodlands on islands and floodplain supply and retain wood, and widespread vegetation proximal to channels produces abundant leaf litter.
Single Thread Channels	**1.Sinuous, single-thread .** Stable and laterally active. Sediment sorting and transfer.	Floods up to bankfull discharge retained in-channel reducing attenuation. Larger floods still spill to floodplain, attenuating their peaks. Close connection between groundwater and stream flow ensures reliable base flows and good hyporhesis.	Range of in-channel depth/velocity combinations up to bankfull flow provides moderate hydraulic diversity and frequent deadwaters along remaining channel boundaries. Substrate sorting varies between thalweg and alternate or point bars, with different degrees of armoring. Variation in bed morphology continues to supports a high degree of substrate patchiness.	Wetted area relative to flow, shoreline length and complexity decrease due to switch to single channel. Though bedforms and bars remain widespread, frequency of islands, confluences and diffluences is greatly reduced, adversely affecting capacity to store sediment and wood. Higher banks are less stable with river cliffs found along outer margins of bends. Floodplain extent and connectivity undiminished, but number of side channels and functionality of connected wetlands reduced.	Decreases in hydraulic and morphological diversity trigger reductions in quantity and quality of aquatic, riparian and, especially, emergent plants. Floodplain communities remain diverse, but transition from wetland to more terrestrial assemblages. Reductions in extent of woodlands due to switch from multiple to a single channel decrease recruitment of wood and leaf litter.
Single Thread Channels	**2. Channelized.** Re-sectioned land drainage, flood control, or navigation channels.	Flood flows retained in-channel up to design discharge, enhancing flood pulses. Flood attenuation reduced. Efficient drainage speeds post-flood recession and lowers groundwater, so base flows and hyporhesis are impaired.	Artificially high in-channel discharge capacity coupled with uniformity of depth/velocity combinations reduces hydraulic diversity and compromises functionality of any marginal deadwaters. Bed substrate scoured, with sorting impacted and patchiness reduced through extreme armoring or paving.	channelization reduces wetted area, shoreline length and complexity relative to flow. Some bedforms and bars remain but islands, side channels, and confluences/diffluences are eradicated. Capacity to store sediment and wood reduced, or eliminated by channel maintenance. Banks stable or revetted, with river cliffs eliminated. Extent, connectivity and functionality of riparian zone, floodplain and wetlands all diminished.	Aquatic and emergent plants destroyed during construction with recovery limited to patches and narrow belts. Riparian plants only contribute wood and leaf litter if some of riparian corridor is left in place. Floodplain vegetation communities disconnected from channel may transition further to terrestrial assemblages.
Single Thread Channels	**3. Degrading.** Incising and abandoning its floodplain. Banks stable geotechnically.	Concentrates progressively greater flood peaks in-channel, further amplifying flood pulse Flood attenuation ineffective. Groundwater recharge is minimal, making base flow unreliable. Hyporheic zone damaged or destroyed by scour at bed and bank toes.	Bed lowering, removal of bars and riffles and scour at bank toes reduces hydraulic diversity means there are few, if any, marginal deadwaters. Bed substrate continues to be scoured, with sorting impacted and patchiness reduced through extreme armoring or paving.	Degradation reduces wetted area, shoreline length and complexity relative to flow compared to Stage 1. Bedforms, bars and islands scoured, confluences/diffluences eradicated and side channels, floodplain and wetlands abandoned. Capacity to store sediment and wood effectively lost. Banks mostly stable with local river cliffs. Functionality of the riparian zone is diminished due to reduced connectivity with channel.	Aquatic and most emergent plants destroyed by incision; only seasonal and annual species remain. Riparian vegetation undercut and increasingly unstable leading to artificially elevated inputs of wood. Input of leaf litter, seeds and propagules continues, but retention reduced. Floodplain vegetation stressed due to lower water table
Single Thread Channels	**3s. Arrested degradation.** Confined or canyon-type channels.	Concentrates a wide range of flood peaks, providing no effective flood attenuation and maximal flood pulse effects. Groundwater recharge is minimal, base flow unreliable and hyporheic zone remains damaged or destroyed.	Similar to Stage 3, though there may be some limited recovery of hydraulic diversity due to presence of invasive or remnant riparian plants and accumulation of log jams formed by tress that have fallen into the degraded channel. Limited sediment retention, sorting and patch development.	Natural or artificial stabilization locks in dimensions and morphology developed in Stage 3. Limited capacity to store sediment and wood once degradation ceases. Banks mostly stable but extent of river cliffs may increase. Functionality of the riparian zone remains diminished and channel is permanently disconnected from its floodplain and wetlands.	Relative stability allows for early succession in emergent and riparian plant communities, improving supply of leaf litter. Wood recruitment continues, limited by the proximity, width and contiguity of woodlands on surrounding floodplain and terrace surfaces.
Single Thread Channels	**4. Degradation and widening.** Incising with unstable, retreating banks.	Concentrates an extreme range of flood peaks, negating flood attenuation and further amplifying flood pulse effects. Groundwater recharge, base flow generation and hyporheic connectivity are all dysfunctional	Hydraulic diversity remains low due to channel scour and efficient downstream transport of woody debris. Deadwaters continue to be absent or dysfunctional. Bed scour continues to adversely impact substrate sorting and patchiness.	Sediment inputs from bank retreat initiates limited bedform and bar development, but mass failures eliminate stable banks and increase the extent of river cliffs that destroy riparian margins. Wetted area, shoreline length and complexity relative to flow all remain low. No recovery of capacity to store sediment and wood, and floodplain still disconnected.	Aquatic plant community remains dysfunctional due to on-going bed degradation and riparian plants are destroyed by rapid widening. Wood recruitment may increase if banks are forested, though retention depends on trees being large relative to increasing channel width.
Single Thread Channels	**4-3. Renewed incision.** Further head cutting within Stage 4 channel.	Increased range of floods retained in-bank continues to amplify flood pulse effects. Flood attenuation, groundwater recharge, base flow generation and hyporheic connectivity all remain dysfunctional.	Renewed incision maintains limited range of depth/velocity, combinations and so hydraulic diversity remains low. No new marginal deadwaters are created. Channel scour effectively eliminates functionality of substrate sorting and patchiness in providing habitat and ecosystem benefits.	Renewed scour removes embryonic bedforms and bars formed in Stage 4. Degree of disconnection of side channels, floodplain and wetlands due to channel incision increases. Any stored sediment or wood is flushed downstream. Continued bank retreat forms river cliffs that erode any remaining riparian fringe.	Aquatic, emergent, riparian and floodplain plant communities all depleted and dysfunctional. Low supply of leaf litter but wood recruitment maintained until proximal supply is exhausted. Retention depends on trees being large relative to increasing channel width.
Single Thread Channels	**5. Aggrading and widening.** Bed rising, banks stablising & berming.	No significant improvement in flood attenuation but flood pulse effects not quite as marked. Groundwater recharge remains dysfunctional, and base flows are still unreliable, but some hyporheic connectivity is recovered.	Aggradation renews depth/velocity variability that to improve hydraulic diversity. Small marginal deadwaters may develop, but these are not yet functional in providing habitat and ecosystem benefits. Bars and log jams begin to improve sediment sorting and patchiness.	Wetted area, shoreline length and complexity relative to flow all remain low. Aggradation generates some bedforms and bars but channel remains dysfunctional with regard to effective storage of sediment and wood. Bank stability improves marginally compared to Stage 4 allowing some recovery in riparian fringe. Floodplain connectivity begins to recover due to aggradation at bed and berm formation at banks.	Some return of aquatic plants. Bars and berms provide opportunities for emergent and riparian plants. Floodplain plant community remains isolated from channel physically and hydrologically. Widening may continue to recruit wood if there are proximal trees and supply of leaf litter may be renewed as well.
Single Thread Channels	**6. Quasi-equilibrium.** Regime channel and proto-floodplain re-established.	Remains disconnected from former floodplain, but increased boundary roughness and emergent riparian stands damp flood pulse effects and reintroduce some flood attenuation. Groundwater recharge and base flow functions begin to recover and hyporhesis continues to improve.	Developing regime channel interacts with proto-floodplain surfaces to dissipate energy and increase hydraulic diversity. Accumulation of sediment and colonization of bars and berms by emergent and riparian vegetation increases number and functionality of marginal deadwaters. Patches of contrasting substrate size and sorting develop accordingly.	Wetted area, shoreline length and complexity relative to flow all remain low. Bedforms and bars recover to pre-disturbance levels restoring some capacity to storage of sediment and wood. Bank stability continues to improve at expense of river cliffs, allowing further recovery in riparian fringe. Floodplain connectivity continues to recover and new side channels may be created, though wetlands remain disconnected.	Relatively stable channel margins and inset features provide sites for development of aquatic, emergent and riparian plant communities. Aggradation improves connectivity with and functionality of floodplain plants, maintaining wood recruitment and enhancing supply of leaf litter.
Single Thread Channels	**7. Laterally active.** Regime channel develops sinuous course.	Increases in flow resistance due to development of channel and inset floodplain roughness further damp flood pulse effects while returning groundwater recharge, base flow and hyporheic functionality back close to Stage 1 level.	Development of planform sinuosity and interaction with maturing floodplain enhance hydraulic diversity and make marginal deadwaters fully functional. Substrate sorting enhanced and patchiness becomes fully functional. Hydraulic and substrate attributes recover to Stage 1 levels.	Growth of sinuous channel increases wetted area, shoreline length and complexity. Bedforms and bars persist and new islands, confluences and diffluences develop, increasing capacity to storage of sediment and wood. Renewed bank erosion at bends broadens range of bank morphologies. Extent of new side channels increase with some wetlands created.	Extent of riparian and floodplain plant communities increases at expense of opportunities for emergent plants. Stabilisation of banks reduces wood recruitment but extension and maturing of riparian and floodplain communities maintain supply of leaf litter.
8. Anastomosing. Meta-stable anabranching network.		Hydrologic attributes and functions similar to Stage 0 but network inset within the channel created in Stage 4 as modified in Stage 7.	Hydraulic and substrate attributes and functions similar to Stage 0, but network inset within the channel created in Stage 4 as modified in Stage 7.	Morphological attributes and functions similar to Stage 0, but wetted area, shoreline length, and extent of floodplain and its features diminished because network is inset within the valley created in Stage 4.	Hydrological, hydraulic and morphological attributes and functions similar to those of Stage 0 allow vegetation attributes to recover to pre-disturbance levels.

Reference: Cluer, B. and Thorne, C. 2014. A Stream Evolution Model Integrating Habitat and Ecosystem Benefits. River Res. Applic., 30: p.135-154. doi:10.1002/rra.2631

Sediment Regime:

The size, quantity, sorting, and distribution of sediments, which may differ between stream types due to their proximity to different sediment sources, their hydrologic regime, their stream, riparian and floodplain connectivity, and valley and stream morphology.

Sediment Regime	Narrative Description
Transport	Steeper bedrock and boulder/cobble cascade and step-pool stream types; typically in more confined valleys, do not supply appreciable quantities of sediments to downstream reaches on an annual basis; little or no mass wasting; storage of fine sediment is negligible due to high transport capacity derived from both the high gradient and/or natural entrenchment of the channel.
Confined Source and Transport	Cobble step pool and steep plane bed streams; confining valley walls, comprised of erodible tills, glacial lacustrine, glacial fluvial, or alluvial materials; mass wasting and landslides common and may be triggered by valley rejuvenation processes; storage of coarse or fine sediment is limited due to high transport capacity derived from both the gradient and entrenchment of the channel. Look for streams in narrow valleys where dams, culverts, encroachment (roads, houses, etc.), and subsequent channel management may trigger incision, rejuvenation, and mass wasting processes.
Unconfined Source and Transport	Sand, gravel, or cobble plane bed streams; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to entrenchment or incision and associated bed form changes; these streams are not a significant sediment supply due to boundary resistance such as bank armoring, but may begin to experience erosion and supply both coarse and fine sediment when bank failure leads to channel widening; storage of coarse or fine sediment is negligible due to high transport capacity derived from the deep incision and little or no floodplain access. Look for straightened, incised or entrenched streams in unconfined valleys, which may have been bermed and extensively armored and are in Stage II or early Stage III of channel evolution.
Fine Source and Transport & Coarse Deposition	Sand, gravel, or cobble streams with variable bed forms; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to vertical profile and associated bed form changes; these streams supply both coarse and fine sediments due to little or no boundary resistance; storage of fine sediment is lost or severely limited as a result of channel incision and little or no floodplain access; an increase in coarse sediment storage occurs due to a high coarse sediment load coupled with the lower transport capacity that results from a lower gradient and/or channel depth. Look for historically straightened, incised, or entrenched streams in unconfined valleys, having little or no boundary resistance, increased bank erosion, and large unvegetated bars. These streams are typically in late Stage III and Stage IV of channel evolution.
Coarse Equilibrium (in = out) & Fine Deposition	Sand, gravel, or cobble streams with equilibrium bed forms; at least one side of the channel is unconfined by valley walls; these streams transport and deposit coarse sediment in equilibrium (stream power—produce as a result of channel gradient and hydraulic radius—is balanced by the sediment load, sediment size, and channel boundary resistance); and store a relatively large volume of fine sediment due to the access of high frequency (annual) floods to the floodplain. Look for unconfined streams, which are not incised or entrenched, have boundary resistance (woody buffers), minimal bank erosion, and vegetated bars. These streams are Stage I, late Stage IV, and Stage V.
Deposition	Silt, Sand, gravel, or cobble streams with variable and braided bed forms; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to changes in slope and/or depth resulting in the predominance of transient depositional features; storage of fine and coarse sediment frequently exceeds transport**. Floodplains are accessed during high frequency (annual) floods. Look for unconfined streams, which are not incised or entrenched, have become significantly over-widened, and if high rates of bank erosion are present, it is offset by the vertical growth of unvegetated bars. These regimes may be located at zones of naturally high deposition (e.g., active alluvial fans, deltas, or upstream of bedrock controls), or may exist due to impoundment and other backwater conditions above weirs, dams and other constrictions.

** Use of the "Deposition" regime characterization may be rare, but valuable as a planning tool, where the reach is storing far more than it is transporting during some defined planning period. The extreme example would be that of an impounded reach where all of the course and a great percentage of the fine sediments are being deposited, rather than transported downstream. This man-made condition may change, thereby changing the sediment regime, but is not likely over the period at which the corridor plan will be used.

Reference: https://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_rivercorridorguide.pdf

River Styles

A scientific tool used to describe and explain the diversity and distribution of river types in a catchment according to river character and behavior. The River Styles Framework differs from other classification systems (e.g. Rosgen Stream Classification) in that it provides an open-ended process for description rather than fitting rivers into pre-existing categories. It was developed by researchers at Macquarie University.

Reference: https://www.mq.edu.au/about/about-the-university/faculties-and-departments/faculty-of-science-and-engineering/departments-and-centres/department-of-environmental-sciences/engage/river-styles-framework