American Whitewater

Flow Preference and Economic Impact of River Recreation on the Cache La Poudre - Phase 1

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1 Executive summary

The Protecting Flows in the Poudre River project is focused on quantifying the quality and economic impact of whitewater boating on the Poudre River to support American Whitewater's advocacy efforts. Phase 1 of this study was initiated May 1, 2020 and includes three core tasks: 1) an initial flow preference study of eleven whitewater reaches, 2) an impact assessment quantifying how the proposed Northern Integrated Supply Project will affect whitewater boating conditions, and 3) the development of a preliminary economic model to quantify the economic benefit of Poudre River Whitewater Park visitation to the City of Fort Collins and Larimer County.

Our analyses have revealed the following information:

- The lowest acceptable flow is 355 cfs at the Poudre River Whitewater Park.
- An optimal flow rate of 1400 cfs is preferred by boaters at the Whitewater Park.
- The 40-year (1980–2020) average of annual boatable days is 39 days at the Whitewater Park.
- The proposed Northern Integrated Supply Project (NISP) is planning to divert an average of 37,400 AF per year from the Poudre River through the Poudre Valley Canal. These diversions will impact flow at the downstream Whitewater Park.
- Proposed diversions will occur primarily during peak runoff months (May–June), directly in conflict with ideal whitewater boating conditions.
- Based on historical streamflow observations, NISP is likely to have a marked impact on boating, reducing annual boatable days by 11 ± 7 days at the Poudre River Whitewater Park.
- Preliminary economic impact modeling shows that boating in the canyon contributes at least $1.36 million annually to the local economy, while Whitewater Park activity contributes at least $250,000 annually. These figures are low-end estimates and will be revised as more data is collected on visitation rates in the canyon and at the Whitewater Park.

2 Introduction/Motivation

The objectives of the Protecting Flows in the Poudre River project are to assess boater flow preferences on whitewater reaches along the Poudre River, approximate the annual economic impact of whitewater recreation to the City of Fort Collins, and evaluate the potential impacts of the proposed Northern Integrated Supply Project on boating conditions. The project is designed to be completed over three Phases. This technical memo documents Phase 1 progress. Phase 1 goals are:

1. Develop flow-acceptability curves that integrate all available survey-response data as of this time.
2. Investigate the impact of the Northern Integrated Supply Project (NISP) on whitewater boating conditions at the Poudre River Whitewater Park in downtown Fort Collins.
3. Construct an economic model to estimate the financial impact of the Poudre River Whitewater Park to the City of Fort Collins. Design a survey to quantify consumer spending profiles and integrate these data into the model.
4. Analyze time-lapse camera images of the Whitewater Park to monitor use patterns and conduct an initial analysis.

The Poudre River is a popular recreation destination for whitewater enthusiasts. The river flows from the high peaks of Colorado's Rocky Mountains near Cameron Pass eastwards through the city of Fort Collins, and eventually flows into the South Platte River near Greeley. The river supports a variety of recreational uses, including whitewater boating, fishing, and swimming/tubing. Our investigation considers eleven popular whitewater reaches located between the high-elevation headwaters and downtown Fort Collins (Figure 1). These stretches cater to a diversity of boater skill levels (Table 1). The most challenging stretches are Big South, Spencer Heights, and The Narrows, which contain class V+ rapids. Alternatively, White Mile Run, Grandpa's Gorge, Lower Mishawaka, and Filter Plant contain class II/III rapids, a suitable challenge for most skill levels.

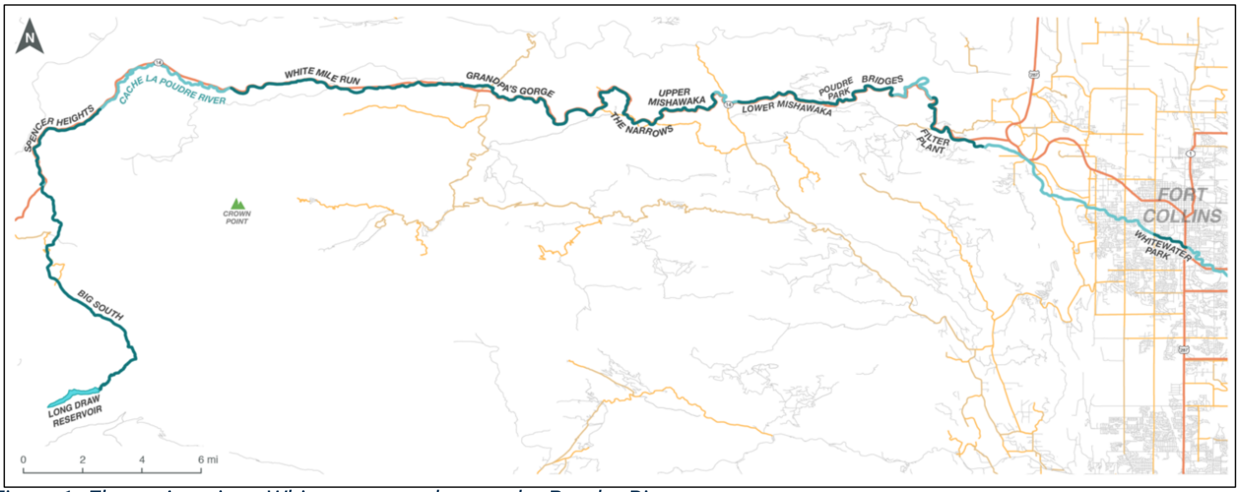

Figure 1. Eleven American Whitewater reaches on the Poudre River.

Table 1. Length and rapid classifications of American Whitewater reaches along the Poudre River. Reach locations are shown in Figure 1.

AW Reach	Length (miles)	Rapid Classification
Big South	12	V+
Spencer Heights	2.4	V
White Mile Run	9.5	III-IV
Grandpa's Gorge	8	II-IV
The Narrows	3.4	IV-V+
Upper Mishawaka	3.3	III-IV
Lower Mishawaka	3	III
Poudre Park	2	III-IV+
Bridges	2	III-IV
Filter Plant	2.4	II-III
Whitewater Park	1.3	II-III

Commercial rafting alone draws nearly 40,000 visitors annually to the Poudre River, producing over $13 million in economic impact (Colorado River Outfitters Association, 2019). The Poudre River National Heritage Area (NHA), which runs from Bellevue to the junction with the South Platte, produces an estimated annual economic impact of $81.6 million from 545,000 annual visitors (Tripp Umbach, 2017).

These figures underline the critical importance of the Poudre River and water-based activities to the regional economy. However, they do not capture the significant non-commercial use of the Poudre River by rafters, kayakers, tubers, and other watersports enthusiasts. Thus, the economic impact of whitewater boating along the Poudre River is poorly quantified. Key information gaps include the number of private users, the distance traveled by private users, user expenditures, and preferred flows. The analyses discussed in sections 3, 5 and 6 begin to fill these information gaps and generate more robust economic impact estimates.

Proposed water storage projects, designed to provide water security to rapidly expanding Front Range municipalities, pose a potential threat to whitewater boating on the Poudre River and subsequent cultural and economic benefits. Specifically, NISP may affect boating conditions by diverting 40,000 AF of flow from the river annually to fill the proposed Glade Reservoir. The analysis presented in section 4 quantifies the impacts of NISP on whitewater boating, in terms of the number of lost boatable days attributable to proposed diversions.

3 Quantifying boater preference on Poudre River

3.1 What is flow preference?

Whitewater boating is a flow-dependent recreational activity. Different flow conditions offer a variety of experiences for any user. For example, very low flows may be difficult to navigate and lead to underwhelming rapid conditions. On the opposite end of the spectrum, extremely high flows may be too dangerous to comfortably navigate. In between these extremes lies a preferred flow rate that gives rise to user-perceived optimal boating conditions. While other variables, such as weather, may influence perceived acceptability, flow rate is understood to be the master variable controlling the quality of boating conditions.

Flow acceptability curves (Stafford, Fey, & Vaske, 2017) plot the perceived acceptability of whitewater conditions as a univariate function of flow rate (Figure 2). Flow acceptability is ranked on a scale of -2 to +2. Unacceptable conditions receive a score of -2, and acceptable conditions receive a score of +2. Neutrally acceptable conditions, suggesting users find the flows neither too high nor too low, are scored with zero. Typically, these curves exhibit an upside-down U shape. The acceptability of boating conditions generally increases from minimum flows to some intermediate flow rate before decreasing as flow rates increase further. The y-intercept (zero-crossings) flow rates indicate thresholds for minimally and maximally acceptable flow conditions. The flow condition associated with peak acceptability score denotes optimal boating conditions.

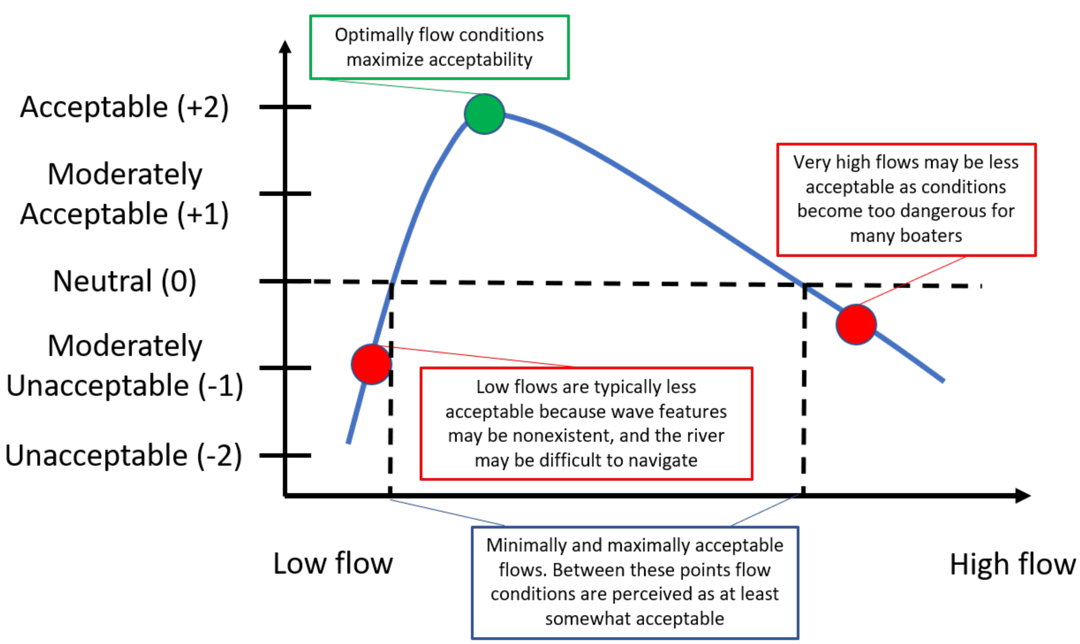

Figure 2. A conceptual schematic of a typical flow-acceptability curve.

Acceptability score is on the y-axis and flow rate is on the x-axis. The curves document a signature of boater preference for a specific river reach and are created by synthesizing survey response data. These curves commonly exhibit an upside-down U shape.

In practice, flow acceptability curves are derived from data collected by surveys that ask a sample of users to rank specified flow conditions as being associated with unacceptable (-2), moderately unacceptable (-1), neutral (0), moderately acceptable (+1), or acceptable (+2) flow conditions. Indeed, perceived flow preferences vary among individual respondents. To account for this variation, the Potential for Conflict Index (PCI_2) quantifies the level of preference disagreement among respondents for a specific flow rate. PCI_2 varies between 0 and 1. A PCI_2 value of 0 indicates unanimous agreement, and PCI_2 index of 1 indicates complete disagreement. For a complete mathematical derivation of PCI_2, refer to Vaske et al., 2010.

3.2 Data collection and analysis methods

We constructed surveys using SurveyMonkey to quantify boater flow preferences for eleven stretches of the Poudre River, including the newly constructed Whitewater Park in downtown Fort Collins (Figure 1). For each stretch, we asked respondents to score the acceptability of boating conditions at specific flow rates or river stage levels. We asked respondents to evaluate boating conditions at the Whitewater Park as a function of flows at the USGS gauge in Downtown Fort Collins, which is located approximately one quarter mile downstream of the park. For the Filter Plant reach, we asked respondents to assess boating conditions against flows at the CO DWR gauge at the Canyon mouth. For reaches above Filter Plant to Spencer Heights, we asked respondents to evaluate conditions against specific rock stages at Pine View (www.poudrerockreport.com). For these reaches, observations at the Canyon mouth gauge are a poor indicator of flow conditions and rock stages are a community accepted benchmark for assessing flows. Finally, we asked respondents to assess conditions on the Big South reach for specific flow intervals at the gauge at La Poudre Pass Creek Below Long Draw Reservoir. As of June 26, 2020, we have received 182 valid survey responses.

We filtered the raw survey response data to mask out respondents deemed to be too inexperienced to accurately assess the full spectrum of flow conditions on any given reach. We removed respondents with a self-identified skill level of novice, a reported annual trip frequency of 1 time per season, or that reported being “not comfortable at all” in assessing flow conditions. These masking rules culled the initial sample size by between 0.0% and 9.8% for each reach.

After removing inexperienced respondents, remaining data were used to derive flow acceptability curves following the methods of Stafford, Fey, & Vaske (2017). This is generally a three-step process. First, we calculated the average acceptability score for each flow bin. Second, we calculated the PCI_2 score for each flow bin (Vaske et al., 2010). Finally, average acceptability scores are plotted as a function of flow and marker sizes reflect the magnitude of the PCI_2 score. Large marker sizes reflect large PCI_2 scores, which indicate stronger disagreement among respondents on the acceptability of flows. Smaller marker sizes reflect lower PCI_2 scores, indicating strong agreement among respondents.

For each reach, we fit a curve to the flow acceptability data that allowed us to approximate the minimally and maximally acceptable flows —i.e., the zero-crossings of the flow-acceptability curve. The acceptable flow range encompasses all flows between the minimally and maximally acceptable flows.

Annual boatable days are the number of days in a year that flows along a river reach are between minimally and maximally acceptable flows. We calculated the number of boatable days for each year of a 40-year flow record at the Poudre River Whitewater Park in Downtown Fort Collins, where long historical gauge records are available. Each year of record was classified as being either wet, wet-typical, dry-typical, or dry. To determine hydrologic year types on the 40-year study period (1980-2019), each year’s annual averaged flows were ranked then divided into quartiles: 75-100% is wet, 50-75% is wet-typical, 25-50% is dry-typical, and 0-25% is dry (Table 2). See Stafford et al. (2017) for further details on the year classification scheme.

Table 2. Historical years used in this study classified as wet, wet typical, dry typical, and dry.

Hydrologic year types	Years
Wet	1980, 1983, 1984, 1997, 1999, 2011, 2014, 2015, 2016, 2017
Wet-typical	1982, 1986, 1993, 1995, 1996, 1998, 2010, 2013, 2018, 2019
Dry-typical	1985, 1990, 1991, 2003, 2004, 2005, 2006, 2007, 2008, 2009
Dry	1981, 1987, 1988, 1989, 1992, 1994, 2000, 2001, 2002, 2012

3.3 Flow preference results

3.3.1 Flow preference curves

The flow preference curve for the Whitewater Park is presented in Figure 3 with the plotted data presented in Table 3. This reach has a minimum acceptable flow of 355 cfs. At this segment, all flows above 355 cfs have an average preference score greater than zero, suggesting that even the highest recorded flows are considered at least minimally acceptable. The Whitewater Park segment has an optimal flow rate of 1400 cfs. PCI_2 scores are relatively high at the Whitewater Park, indicating a lower degree of consensus among respondents in evaluating flows. This makes sense because the Whitewater Park is a new feature (opened in October 2019) and respondents have a relative lack of direct experience.

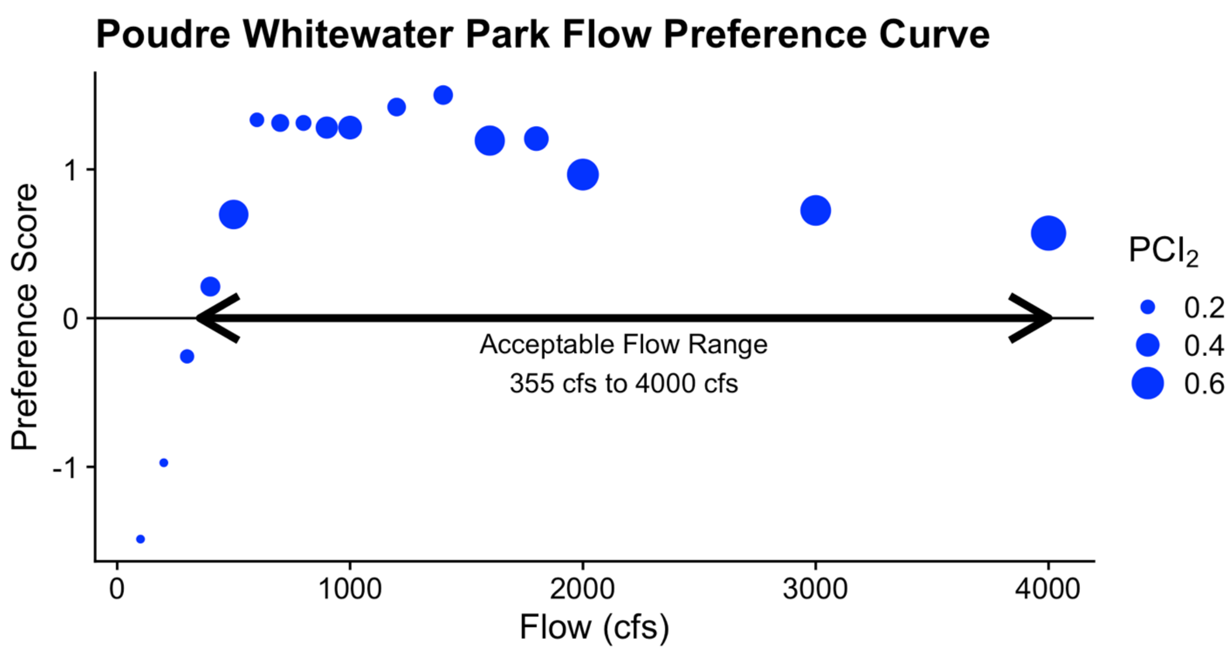

Figure 3.Flow preference curve for the Poudre Whitewater Park. Average preference scores above or equal to zero indicate a given flow passes at least "neutral" acceptability. Flows with preference scores below this threshold are considered unacceptable. The greater the size of the PCI_2 point, the greater the disagreement among survey respondents on the acceptability of a given flow.

Table 3. Average flow preference and PCI_2 values by flow for the Poudre River Whitewater Park. These data can be viewed graphically in Figure 3.

Flow (cfs)	Average Flow Preference	PCI_2
100	-1.49	0.07
200	-0.97	0.07
300	-0.26	0.19
400	0.21	0.32
500	0.70	0.54
600	1.33	0.20
700	1.31	0.27
800	1.31	0.23
900	1.28	0.37
1000	1.28	0.41
1200	1.42	0.29
1400	1.50	0.31
1600	1.19	0.55
1800	1.21	0.43
2000	0.97	0.59
3000	0.72	0.56
4000	0.57	0.66

3.3.2 Historical boatable days

A time series of historical boatable days for the Whitewater Park is shown in

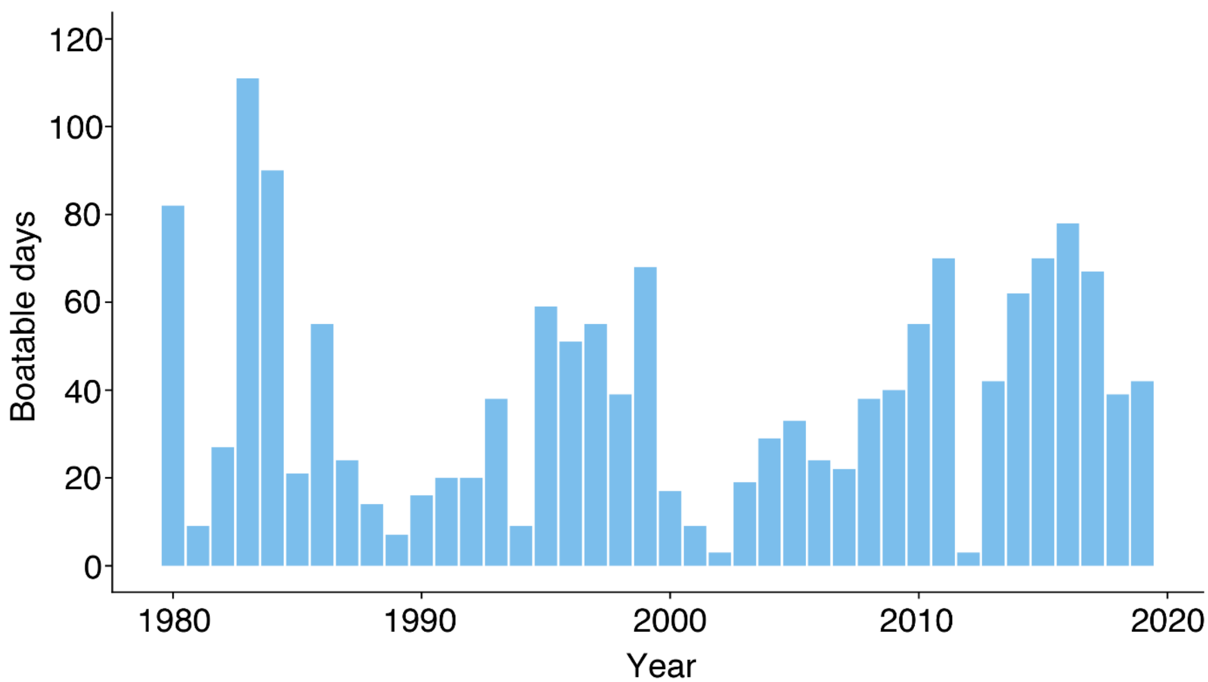

Figure 4. We calculated boatable days for the reach by counting the number of days in each year that flows were within the acceptable flow range (Figure 3). On average, there are 38 boatable days per year at the Whitewater Park. The greatest number of boatable days (111) occurred in a wet year, 1983 (Table 4).

The fewest number of boatable days (2) occurred during a dry year, 2012. The average number of boatable days during a wet year is 74, versus only 11 days during dry years.

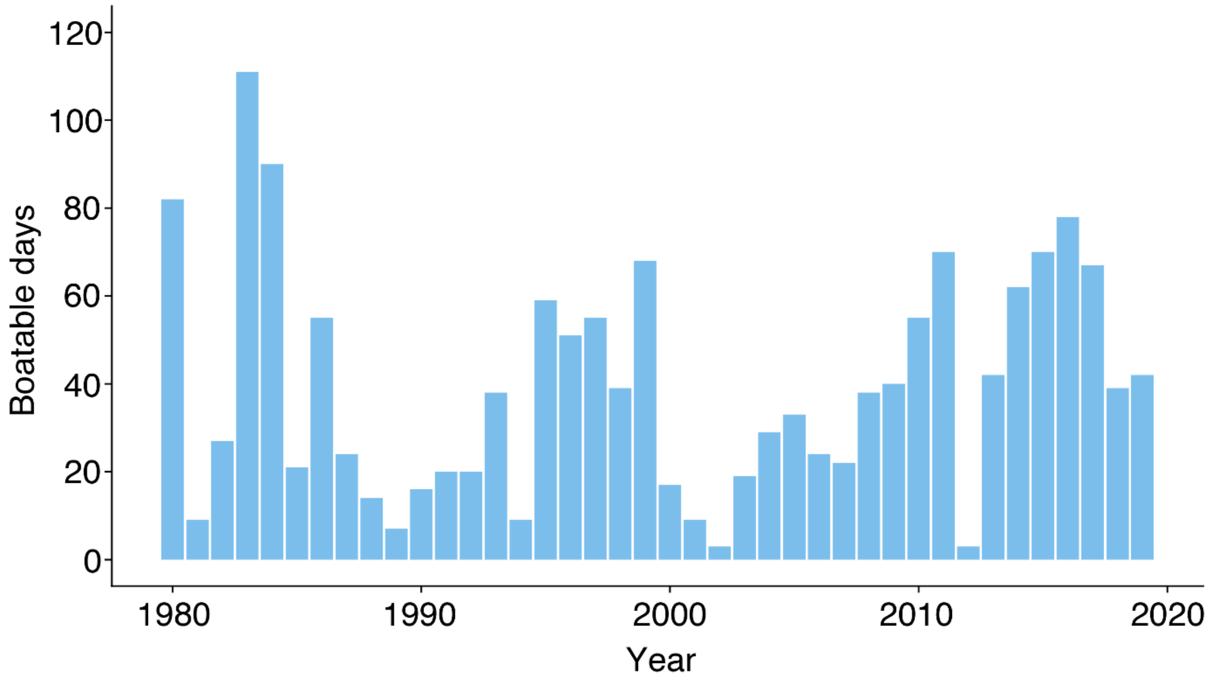

Figure 4. Historical boatable days for the Whitewater Park reach from 1980-2019.

Table 4. Historical boatable days for the Whitewater Park reach from 1980-2019 and year-type classification

Year	Historical boatable days	Hydrologic year type
1980	82	Wet
1981	9	Dry
1982	27	Wet-typical
1983	111	Wet
1984	90	Wet
1985	21	Dry-typical
1986	55	Wet-typical
1987	24	Dry
1988	14	Dry
1989	7	Dry
1990	16	Dry-typical
1991	20	Dry-typical
1992	20	Dry
1993	38	Wet-typical
1994	9	Dry
1995	59	Wet-typical
1996	51	Wet-typical
1997	55	Wet
1998	39	Wet-typical
1999	68	Wet
2000	17	Dry
2001	9	Dry
2002	3	Dry
2003	19	Dry-typical
2004	29	Dry-typical
2005	33	Dry-typical
2006	24	Dry-typical
2007	22	Dry-typical
2008	38	Dry-typical
2009	40	Dry-typical
2010	55	Wet-typical
2011	70	Wet
2012	3	Dry
2013	42	Wet-typical
2014	62	Wet
2015	70	Wet
2016	78	Wet
2017	67	Wet
2018	39	Wet-typical
2019	42	Wet-typical

3.4 Discussion point

- The Whitewater Park was only recently constructed, and respondents likely do not have a strong grasp on how river features vary across flow rates. Therefore, at this time, flow preferences for the Whitewater Park should be marked as preliminary.

4 Evaluating the impacts of the Northern Integrated Supply Project (NISP) on boating conditions

4.1 What is the Northern Integrated Supply Project?

As Colorado's population grows, municipal water demand is likely to exceed available supplies (Colorado Water Conservation Board, 2015). This is especially true for communities served by Northern Water, who's water demands are forecasted to outstrip available supply by 2060. The proposed Northern Integrated Supply Project seeks to bridge water supply gaps in northern Colorado by creating additional water storage to support the delivery of 40,000 AF water per year to 15 communities across northern Colorado. While the proposed NISP will benefit municipal water supplies, it may have deleterious consequences for whitewater boating along the Poudre River. Here, we investigate the ramifications of proposed NISP activities on boating conditions.

To bolster community water supplies, the proposed NISP will create two new reservoirs. The largest of these reservoirs is Glade Reservoir, located northwest of Fort Collins. Its storage capacity is approximately 170,000 AF and will be filled with water diverted from the Poudre River. Because NISP will draw water from the Poudre River, it poses a direct threat to the quality of downstream whitewater boating conditions.

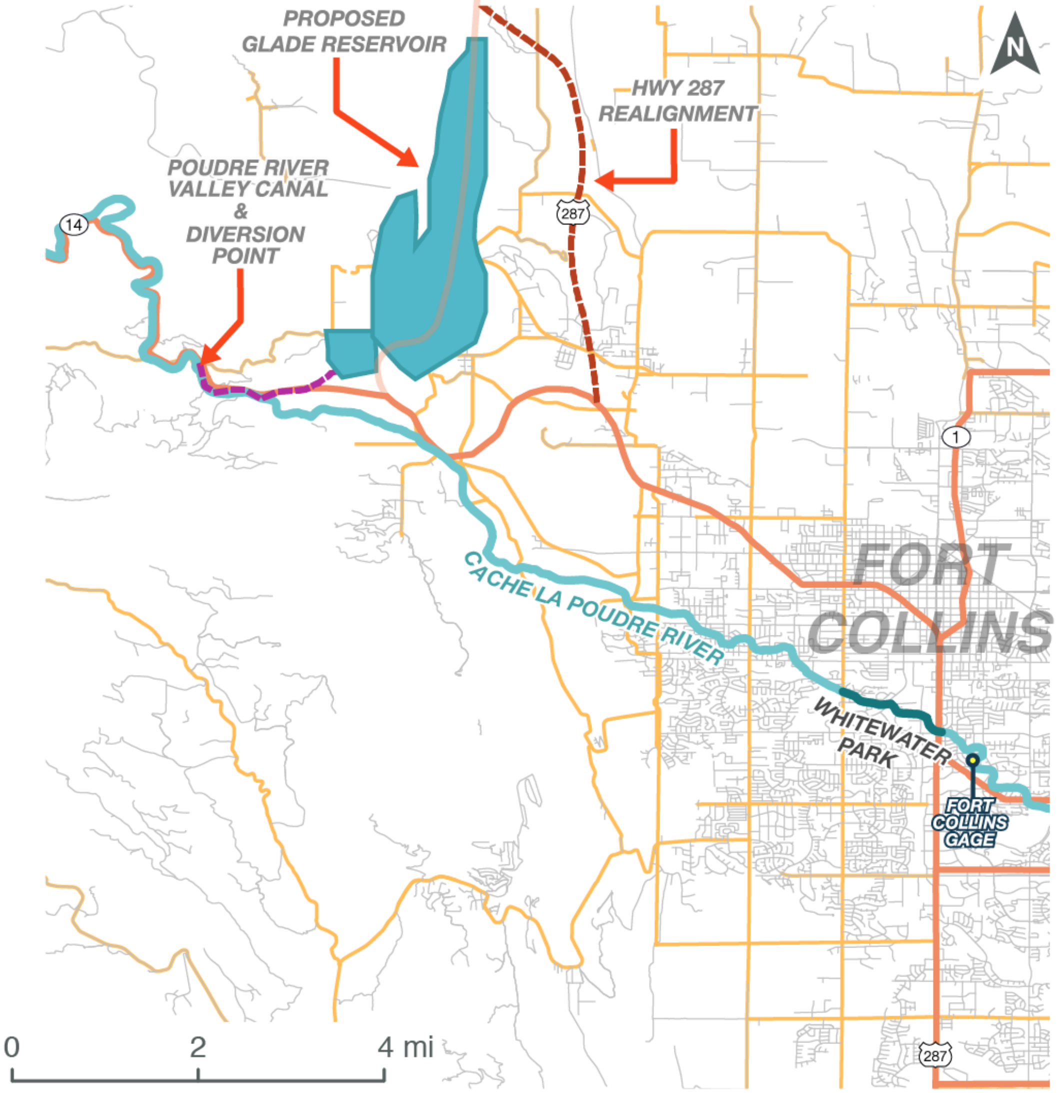

Figure 5. NISP projected builds and stream gage locations in relation to American Whitewater runs.

According to the Final Environmental Impact Statement (FEIS), NISP will impact flows downstream of the Poudre Valley Canal – the primary diversion point for filling Glade Reservoir (FEIS, 2, 4-31). Thus, the Whitewater Park in Downtown Fort Collins (Figure 2) will be impacted by NISP withdrawals. NISP will have no foreseeable impact on upstream boating reaches.

Diversions from the Poudre River to fill Glade Reservoir will alter natural flows between May and June (FEIS, 3, 5-24), the period of peak snowmelt runoff. For this portion of NISP, Northern Water has an existing water right, the Grey Mountain water right. This junior water right has a priority date of May 2, 1980 which allows for diversion from the Poudre River to occur primarily in May and June during high flows (FEIS, 2, 4-31). In the semi-arid western United States, the seasonal regime of high flows during snowmelt runoff is critical for maintaining the physical and ecological integrity of the river corridor. For this reason, the proposed NISP has received much criticism from regional river advocacy groups, such as Save the Poudre (http://www.savethepoudre.org/).

To help inform American Whitewater's stance on the proposed NISP project, this report investigates the likely impact of proposed river diversions on the whitewater boating conditions. Using historical flow records, flow-acceptability curves, and proposed diversion plans, we quantify NISP's likely consequence on the annual duration of acceptable recreational flows (i.e. boatable days) for the Poudre River Whitewater Park in Downtown Fort Collins.

4.2 Data collection and analysis methods

We analyzed daily flow data from the USGS Downtown Fort Collins gauge, which is located downstream of the Whitewater Park. Here, streamflow is heavily affected by upstream diversions and return flows. We retrieved a 40-year record (1980-2020) of streamflow data for the gauge. Each year of record was classified as being either wet, wet-typical, dry-typical, or dry. See Section 3.2 for further details on this classification.

Projected monthly diversion rates were taken from Table 4-10 (p. 4-33) in the FEIS and converted to an effective daily rate (cfs) by assuming a constant diversion rate each day of the month (Table 5). The daily maximum diversion rate in Table 5 was derived by taking the midpoint between the maximum diversion rate reported in the FEIS and the average diversion rate. Similarly, the daily minimum diversion rate in Table 5 was derived taking the midpoint between the minimum diversion rate reported in the FEIS and average diversion rate. We use these diversion rates to approximate how much water is likely to be diverted in wet, wet-typical, dry-typical and dry hydrologic years. During wet years, we assume the NISP will divert at the maximum rate. During dry years, we assume that the NISP will divert at the minimum rate. During wet- and dry-typical years, we assume that the NISP will divert at the average rate. In practice, precise monthly diversion rates will depend on the amount of water NISP has legal right to, which depends on a complex network of competing regional water demands. During very wet years, diversions may be greater than those presented in Table 5**Error! Reference source not found.**, while diversions may be much lower during dry years.

Table 5. Minimum, maximum, and average daily diversion rates by month used in this analysis. These rates are derived from monthly rates presented in Table 4-10 p.4-33 of the FEIS. We apply minimum rates during dry years, average rates during wet- and dry-typical years, and maximum rates during wet years.

Month	Daily minimum diversion rate (cfs)	Daily maximum diversion rate (cfs)	Daily average diversion rate (cfs)
October	0	8.94	0
November	0	0	0
December	0	1.63	0
January	0	20.33	0
February	0	0	0
March	0	9.76	0
April	17.65	212.59	35.29
May	87.01	536.69	174.02
June	156.29	675.58	294.10
July	42.28	122.79	84.57
August	13.82	74.81	27.65
September	0	0	0

We estimate NISP's impact on flows by subtracting projected daily average diversion rates (Table 5) from the 40-year record of daily average flows. We subtract minimum rates during dry years, average rates during wet- and dry-typical years, and maximum rates during wet years. When observed flows are less than 30 cfs, no diversions are simulated. This results in an impacted historical daily flow record that we refer to as “post-NISP discharge”. Flows at the USGS Fort Collins gauge are assumed to be representative of flows through the Whitewater Park.

We evaluate historical and Post-NISP discharge records in terms of the annual flow regime and boatable days. We quantify impacts to the annual flow regime by comparing monthly average flows between historical and post-NISP discharge records. We quantify boatable days by counting and comparing the number of days in each year that flows are equal to or greater than the threshold neutral flow rate observed in each reach’s flow-acceptability curve.

4.3 Results

The changes in streamflow are proportionally larger where there is lower historical discharge (Figure 6). On average, NISP diversions reduce annual flows by 11% at the Whitewater Park. NISP diversions reduce wet year total flows by 13%, wet-typical year flows by 9%, dry-typical flows by 11%, and dry year flows by 8%. Average flows during the month of June (peak runoff) are reduced by 22 – 36%. Monthly average historical and calculated post-NISP flows are presented in tabular form in Appendix B Table 9.

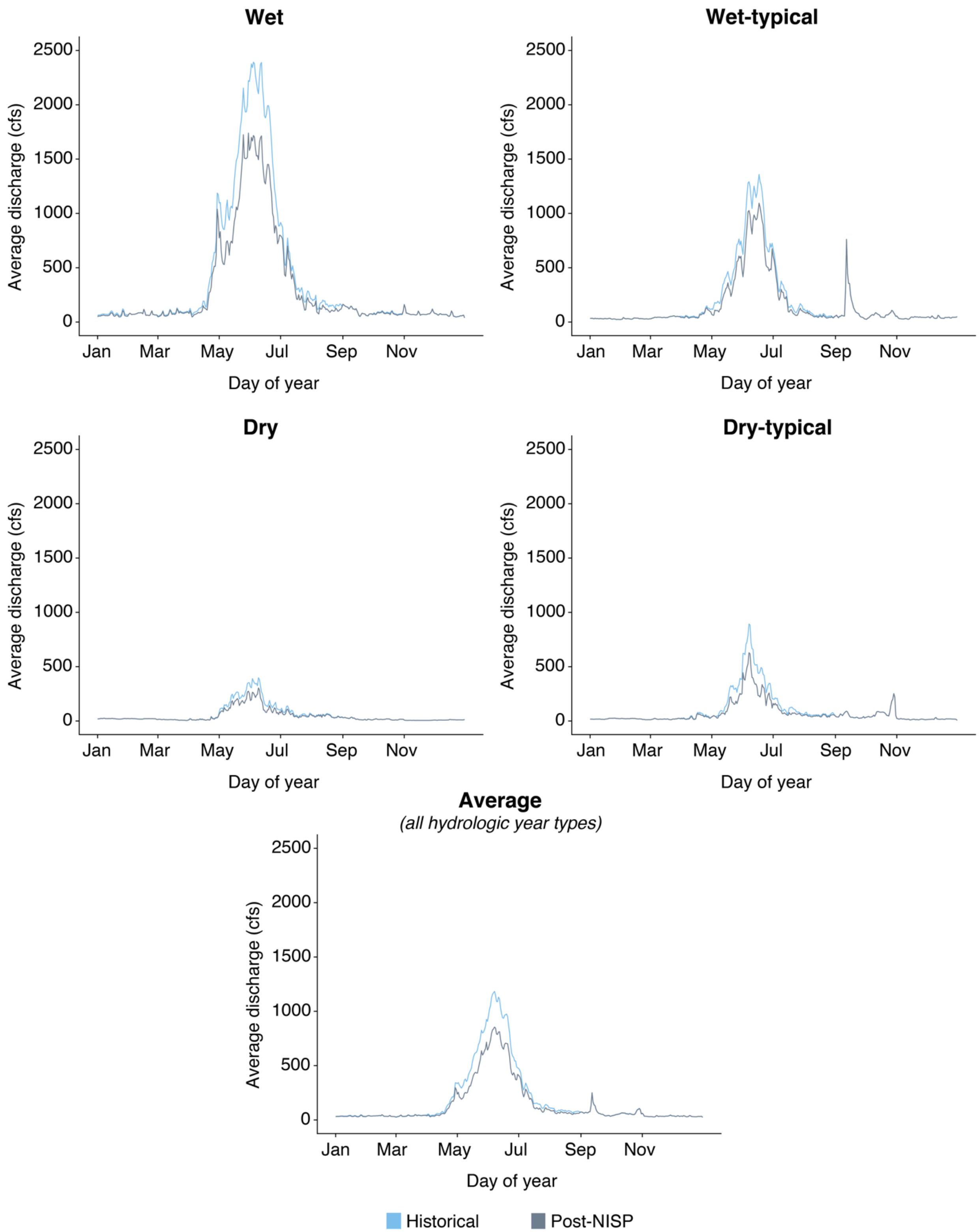

Figure 6. These hydrographs show the impact of NISP diversions on flows categorized by hydrologic year types, including the last plot representing the typical annual flow regime (includes all hydrologic year types) over the 40-year study period. NISP diversions will preserve the timing of high and low flows but reduce the magnitude of peak flows.

To evaluate the potential impact of NISP on whitewater boating, we investigated how proposed diversions would affect boatable days at the Whitewater Park. The red bars in Figure 7 detail the loss in boatable days from NISP diversions and the blue bars indicate the boatable days in a post-NISP environment. Over the 40-year period, the Whitewater Park has an average loss of 11 ± 7 days. The largest reductions were observed during 1998 (wet-typical) and 2008 (dry-typical). During these years, flow values were close to the minimally acceptable flow value and additional diversions eliminated potential boatable days. Minor changes to boatable days occur in years where flows are well above the minimally acceptable flow value. During dry years, such as 2002 and 2012, NISP diversions may eliminate boatable days completely. A tabular form of Figure 7 including hydrologic year classifications is presented in Appendix B Table 8.

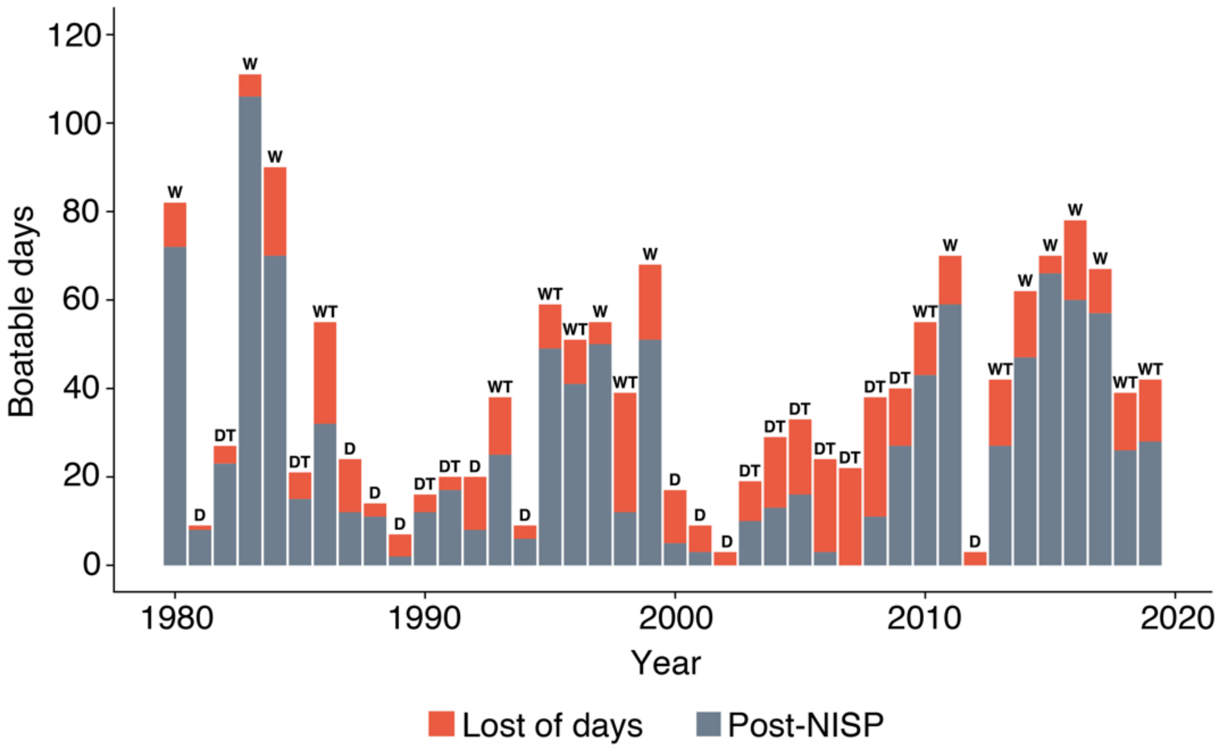

Figure 7. NISP Diversions will reduce the number of boatable days at the Whitewater Park. The total bar height shows the historical number of boatable days for each year in a 40-year record (pre-NISP). Red bars show the reduction in boatable days imposed on the historical record attributable to proposed NISP diversions. Annotations above each bar indicate the hydrologic year classification: wet (W), wet-typical (WT), dry-typical (DT), and dry (D).

4.4 Discussion

- We generated simplified rules for how much NISP is likely to divert, depending on hydrologic year classification. Our diversion rules allowed for year-to-year variability in diversion rates, whereby less water is diverted during dry years and more water is diverted during wet years. However, this remains a large simplification relative to how things are likely to play out in the real world. During very dry years, NISP may not be able to divert any water due to the junior status of the Grey Mountain water right. Conversely, during very wet years, NISP may divert much more water than reported in Table 5. Therefore, our analysis may overestimate NISP impacts during dry years and underestimate impacts during wet years. A more detailed approximation of NISP diversions would require an analysis to understand the priority of the Grey Mountain right, relative to more senior rights, across a variety of hydrologic years.

- We assume that the 40 years of historical flow data used to quantify boatable day impacts is a suitable proxy for future conditions. However, climate change may render historical records to be poor proxies for future conditions. Climate warming in Colorado is projected to reduce mountain snowpack in future years. Because the Poudre River is largely fed by snowmelt, less snow means less runoff, and perhaps lower peak flows (Berghuijs, Woods, & Hrachowitz, 2014; Jennings, Winchell, Livneh, & Molotch, 2018). Moreover, warmer temperatures are likely to increase evapotranspiration, further decreasing runoff (Milly & Dunne, 2020; Udall & Overpeck, 2017; Xiao, Udall, & Lettenmaier, 2018). NISP diversions will further exacerbate flow reductions on top of climate change. Climate change is not considered in the FEIS, presenting a massive blind spot for decision makers when considering reasonably foreseeable impacts. Future work should enumerate the benefit of high flows that NISP will negatively impact.
- To mitigate environmental impacts and low flow conditions, NISP developed a series of diversion programs (FEIS, V. 1, 2-53). In the Conceptual Mitigation Plan, they propose three strategies: releasing water from the Glade Reservoir during low flows near the canyon mouth, implementing a peak flow operations program that allows for flushing of the river in hopes to maintain ecological integrity, and avoiding diversions during critical low-flow periods. However, these strategies most likely do not affect the amount of boatable days since they are designed to increase low flows (not boatable conditions) or sustain brief periods of very high flows (already boatable conditions).

5 Economic benefits of boating and other recreational activities on the Poudre River

5.1 Previous reports

In 2019, the Colorado River Outfitters Association (CROA) estimated commercial rafting on the Poudre River produced $5.1 million in direct expenditures from 37,000 user days, creating over $13 million in total economic impact (CROA, 2019). These calculations were based on user day reports from commercial rafting outfits that have permits to operate on the Poudre River along with an average expenditure value of $135.70 per user day. The commercial outfits run several of the popular river stretches for which we collected flow preference data, many of them pulling out near the Canyon Mouth gage by the end of the Filter Plant reach.

Downstream of the canyon, the Poudre River National Heritage Area (NHA), which runs from Bellevue to the junction with the South Platte, produces an estimated annual economic impact of $81.6 million (Tripp Umbach, 2017). This area encompasses the entirety of the river's stretch through the city of Fort Collins downstream of the NISP diversion, boasting 545,000 annual visitors. While tourism makes up the vast majority of the estimated economic impact of the NHA, the data are not broken out by user type (e.g., kayakers, rafters, fishermen, walkers, sightseers, bicyclists, etc.).

Conservatively, these two reports suggest the economic impact of tourism and recreation on the Poudre River reaches nearly $100 million annually. However, there is a significant amount of missing data, namely the number of non-commercial recreational visitors to the Poudre River broken out by type and each given an average daily expenditure. For example, it is currently unknown how many non-commercial boaters use the river in a given year. Estimating the total economic impact of non-commercial boating and other watersports on the Poudre River is therefore difficult because of a present lack of annual user day and expenditure data.

5.2 Survey-derived estimates of economic impact

While annual user day numbers are still lacking, we used the survey detailed in Section 3.2 to collect information on the total daily expenditures per person, broken out by spending category. We also deployed an additional survey, specific to the Poudre River Whitewater Park, that collected similar expenditure information. After removing outlying expenditure values from the flow preference survey (Section 3.2), we calculated boaters spend an average of $55 per day when recreating on the river reaches shown in Figure 1. From the other survey, we found users of the Poudre River Whitewater Park—a group that include boaters, tubers, fishermen, picnickers, sightseers, and others—spend $30 per trip after filtering out outliers and non-responses. The breakdown by expenditure category from both surveys is shown in Figure 8 below. In addition to the per-trip expenditures, several boaters responded that they spend over $1000 per year on equipment. These values were not included in the category breakdown but are important to local businesses.

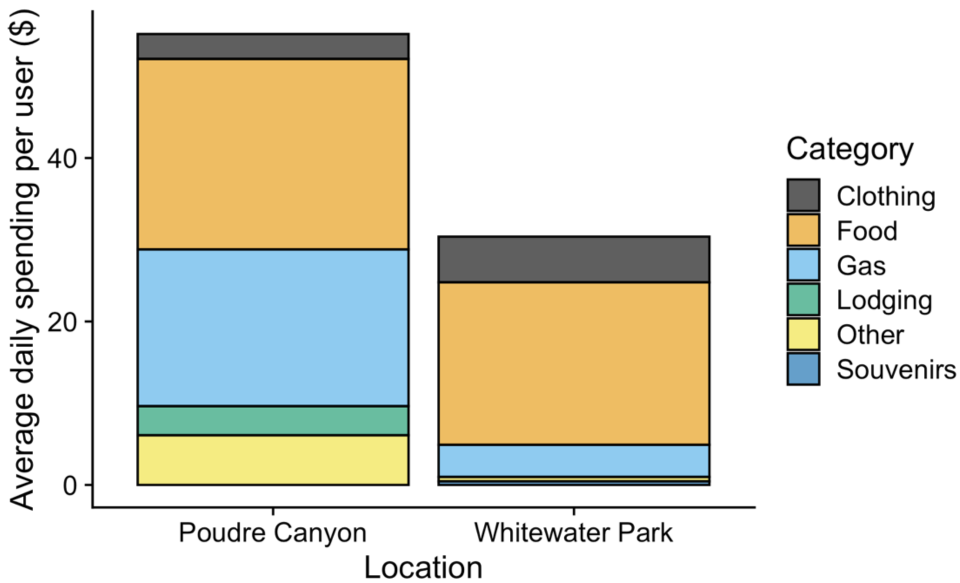

Figure 8. Average daily spending per user. Spending is broken out by the various categories reported in the Poudre River flow preference survey, which primarily covers the Poudre Canyon (left bar), and in the Poudre Whitewater Park survey (right bar).

Table 6. Average spending per category for visitors to Poudre Canyon and the Poudre River Whitewater Park.

Category	Poudre Canyon Average Spending ($)	Whitewater Park Average Spending ($)
Clothing	3.05	5.60
Food	23.31	19.87
Gas	19.18	3.94
Lodging	3.56	0.00
Other	6.08	0.53
Souvenirs	N/A	0.45

In both locations, the surveys indicate that food is the primary expenditure of visitors to the Poudre Canyon and the Whitewater Park. On average, visitors travel a greater distance to get to boating reaches in the canyon (24 mi.) versus the Poudre River Whitewater Park (4.6 mi.), explaining the larger proportion that gas comprises of total spending at the former location. Average lodging expenditures are small for Poudre Canyon visitors and no Whitewater Park users have reported any lodging expenditures to date, again confirming the more local nature of visitation to the latter. Spending in the other and souvenir categories is small at both locations.

These expenditure breakdowns allow us to make preliminary estimates of economic impact once visitation assumptions are taken into account. If we assume non-commercial visitation to the river reaches in Poudre Canyon is equal to the number of CROA-reported commercial user days, we can compute an estimated annual economic impact with the large caveat that this value is based on assumed visitation given a lack of observed data. With this data gap in mind, we used the Regional Input-Output Modeling System (RIMS II) to produce a preliminary total economic impact estimate of $1.36 million for non-commercial boating in the Poudre Canyon. Similarly, we used Poudre Whitewater Park visitation estimates from Loomis and McTernan (Loomis & McTernan, 2011) along with our survey-derived per-day expenditure value to estimate an annual economic impact of $250,000 for the park. Here, we reiterate that both values should be treated as preliminary estimates because there are no reported user day data for either the Poudre Canyon or the Poudre River Whitewater Park.

5.3 Discussion

- Our work thus far has revealed a key data gap in estimating the annual economic impact of non-commercial boating on key reaches of the Poudre River and the Poudre River Whitewater Park. Without adequate measurements of annual user days, any impact estimates will be necessarily preliminary and uncertain. Moving forward, it will be beneficial to monitor use at popular Poudre River boating reaches in order to estimate total annual user days in Poudre Canyon. For the Poudre River Whitewater Park, we will be monitoring city webcam data in order to calculate how many users, broken out by type, visit the park each year.
- Additionally, it will be critical to take into account how reduced flows due to both water development and climate change will affect the economic impact of Poudre River boating. User days are sensitive to flow levels and annual boatable days (Colorado Water Conservation Board, 2020), indicating that years with reduced flow correspond to reduced visitation and, in turn, lower revenue. Furthermore, we would expect these economic effects to be non-linear with greater flow reductions leading to successively larger losses. Previous work shows that the amount each user is willing to pay per trip will decrease as flow goes down. At 300 cfs Poudre River users are willing to pay just $55 per trip, a value markedly lower than the $97 paid at 1900 cfs. Similarly, each user would visit the Poudre just 1.6 times per year at 300 cfs, compared to 14 trips at 1900 cfs (Loomis & McTernan, 2014). Thus, reduced flows drive both lower visitation and decreased spending per user day.
- As important as the economic impacts of maintaining boatable flows are, there are also more-difficult-to-quantify social benefits of the Poudre River. As a hallmark of Fort Collins and Larimer County, the Poudre River is a treasured community resource whose value is inherent. Although our surveys were designed to collect data for flow preference and economic impacts, they have also revealed how central the Poudre River is to people living in its watershed. As one respondent revealed, "We got married on the southeast shore!" Such benefits of the Poudre River should not be overlooked or underestimated.

6 Camera Analysis

6.1 Approach

We analyzed webcam images to quantify the frequency and timing of visitors at the park. The time frame of analysis is from July 7, 2020 to July 14, 2020; each day had 24 photos taken in 30-minute intervals from 7:00am to 6:30pm. A 3x3 grid overlay was placed on each photo to reduce the likelihood of double-counting, and the number of people categorized by specific activity were counted per grid box. The activity categories used correspond to those considered in the Phase I economic survey (Table 7). To improve accuracy, each photo was counted twice by separate individuals, and then their total counts per photo were averaged. This process was repeated for each photo to calculate the number of average daily park users by activity.

Table 7. Activity categories for whitewater park use

Just passing through (people on trails, walkers/bikers)	Watercraft – kayak
Sightseeing/playing with kids/picnicking	Watercraft – raft
Swimmers/waders	Watercraft – SUP
Fisherpeople	Watercraft – surfboard
Other	Watercraft – tube

6.2 Results

Over the eight study period days, we counted an average of 896 visitors per day. Total daily counts ranged from 394 users (on a Tuesday) to a maximum of 1,553 users (on a Sunday), following an expected trend that more visitors come to the park on a weekend (Figure 9). The most popular times of day at the waterpark are between 3:00pm and 4:00pm (Figure 10).

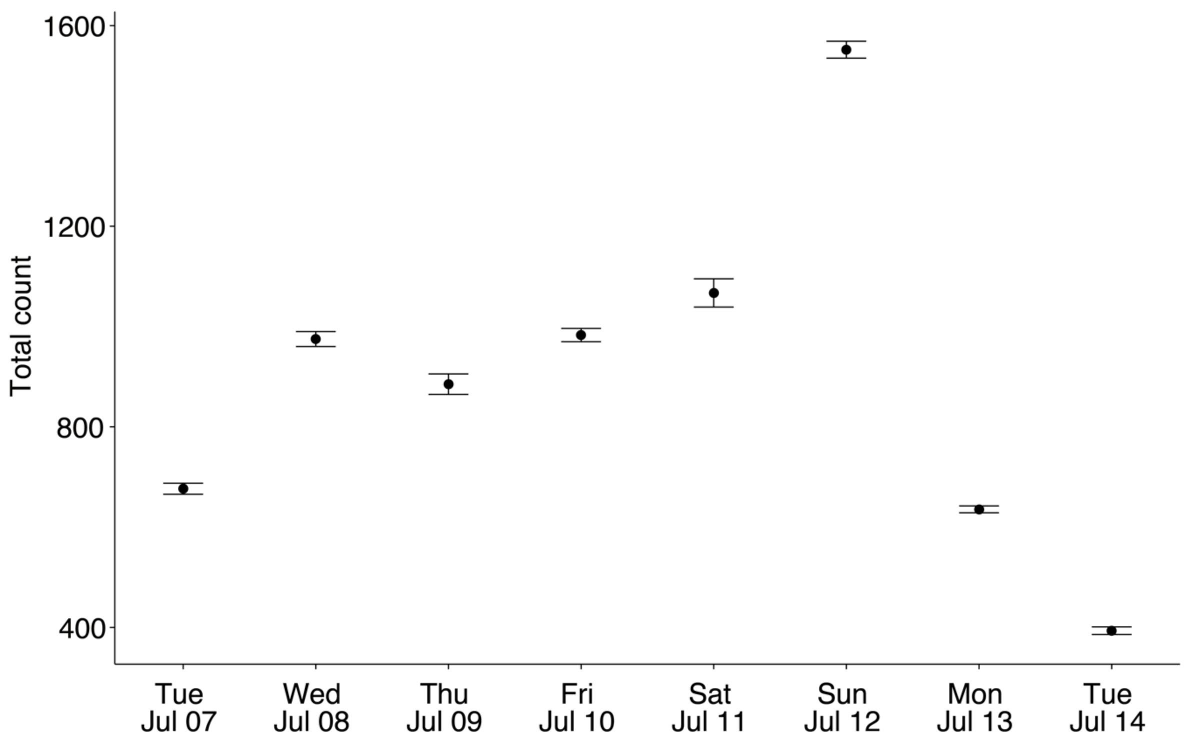

Figure 9. Daily total counts throughout study period

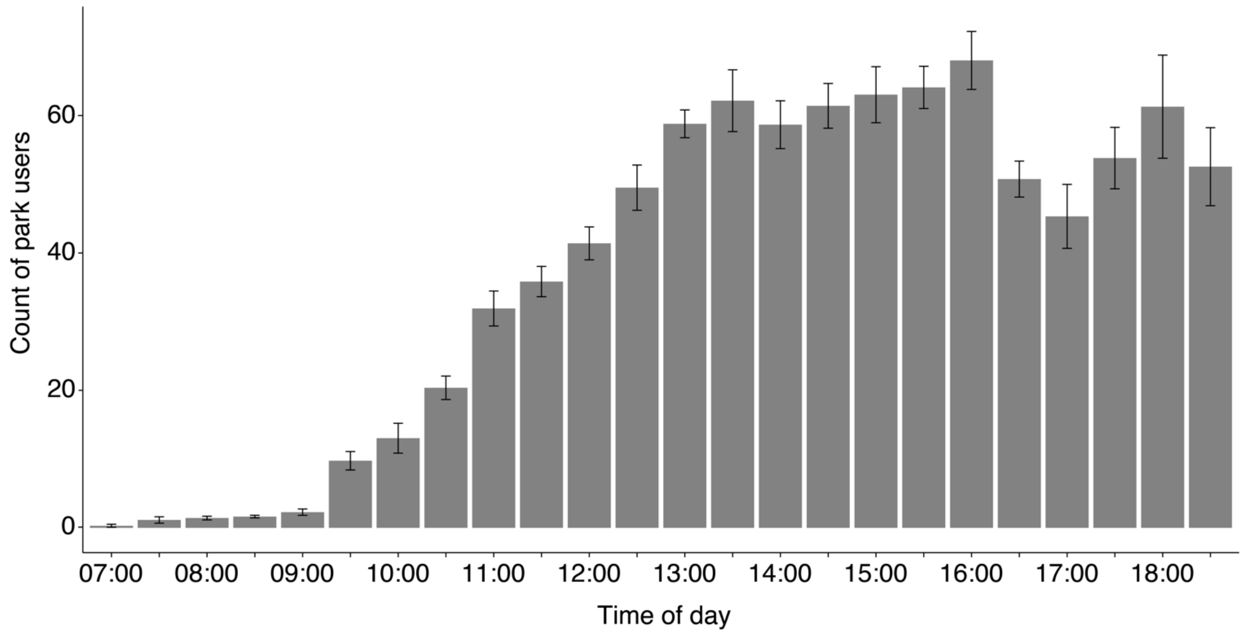

Figure 10. Average count of visitors per hour of day between 7/7/2020 and 7/14/2020.

Our findings suggest that most people at the Whitewater Park engage in sightseeing/playing with kids/picnicking and swimming/wading throughout the day (Figure 11). The most common watercraft activity was tubing, accounting for 92% of total watercraft users (Figure 12).

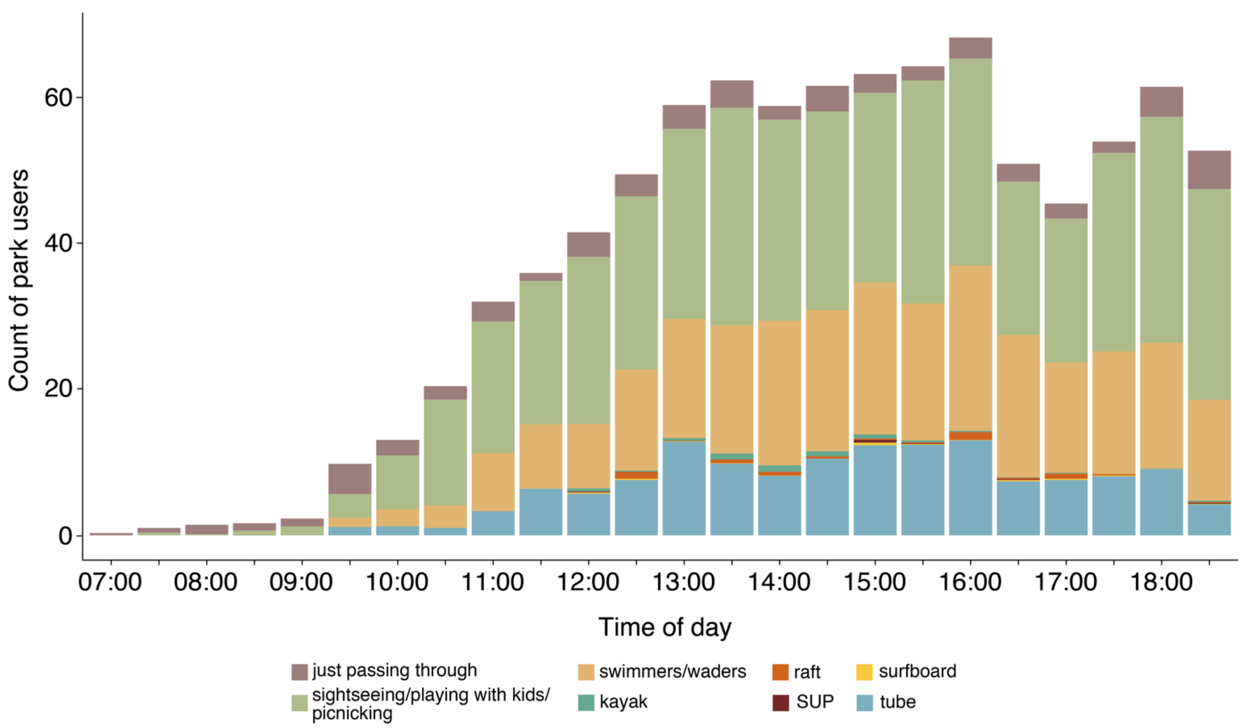

Figure 11. Average visitor count per hour of day split by activity type between 7/7/2020 and 7/14/2020.

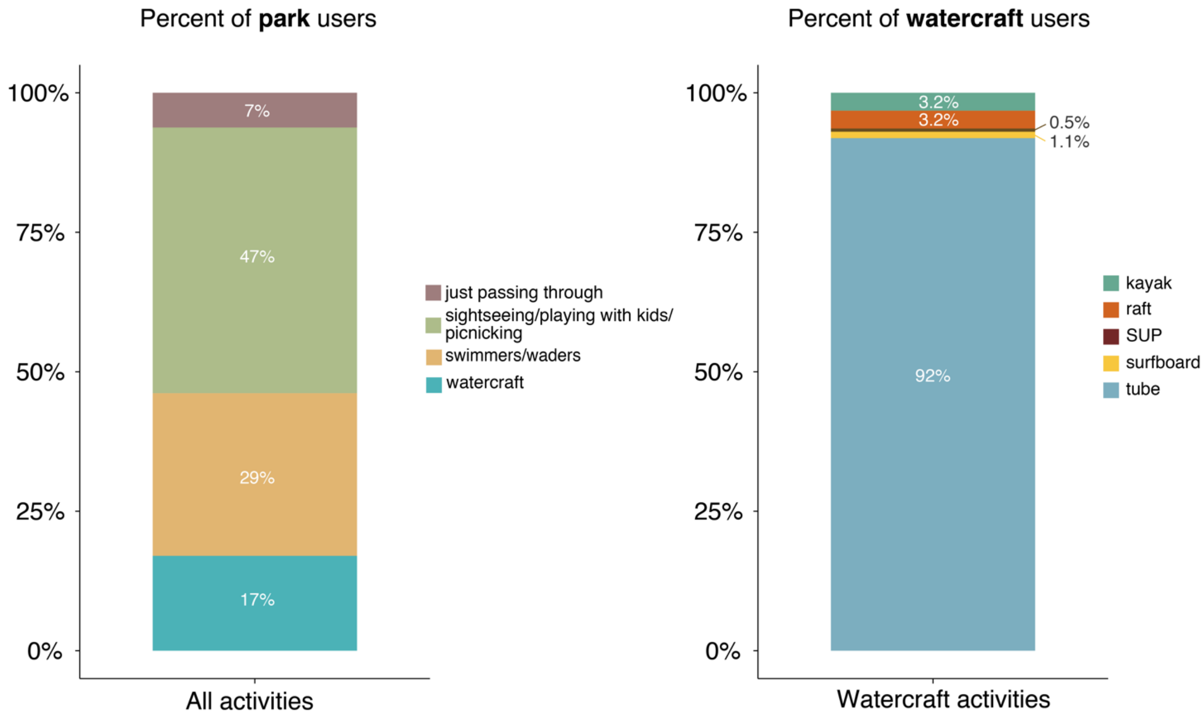

Figure 12. Percentage of park users and watercraft users categorized by activity engagement type.

6.3 Discussion and Challenges

- We devised an assumptions list to accurately categorize people, with the overarching assumption that each person's activity per photo is the only activity they are engaging in for that timestamp. While people are likely to engage in multiple activities during their stay, only one activity per person was captured.
- The total counts reported here are conservative. If there were any people at the park between the periods when images were taken, those people were not accounted for. The last photo taken each day was at 6:30pm. There are certainly park visitors after 6:30pm that were not counted in this study. Additionally, low resolution downloaded images likely caused undercounting of total people in the images.
- For recent photos on the webcam webpage, including the week of July 7 to July 14 at the time of this study, the webpage had two different photos per timestamp, where one photo is wider/higher resolution and the other narrower/lower resolution. We opted to work with the wider/higher resolution for the timestamps where that option was available.
- The webcam image database has a gap between March 17, 2020 and July 7, 2020. This means the peak flow months are not recorded.
- We spent 3-5 minutes counting per photo, equating to 1.5–2 hours in total to count a day for one person. This results in 10.5–14 hours to count a week's worth of photos.

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8 Appendix A – Flow preference curves for all reaches

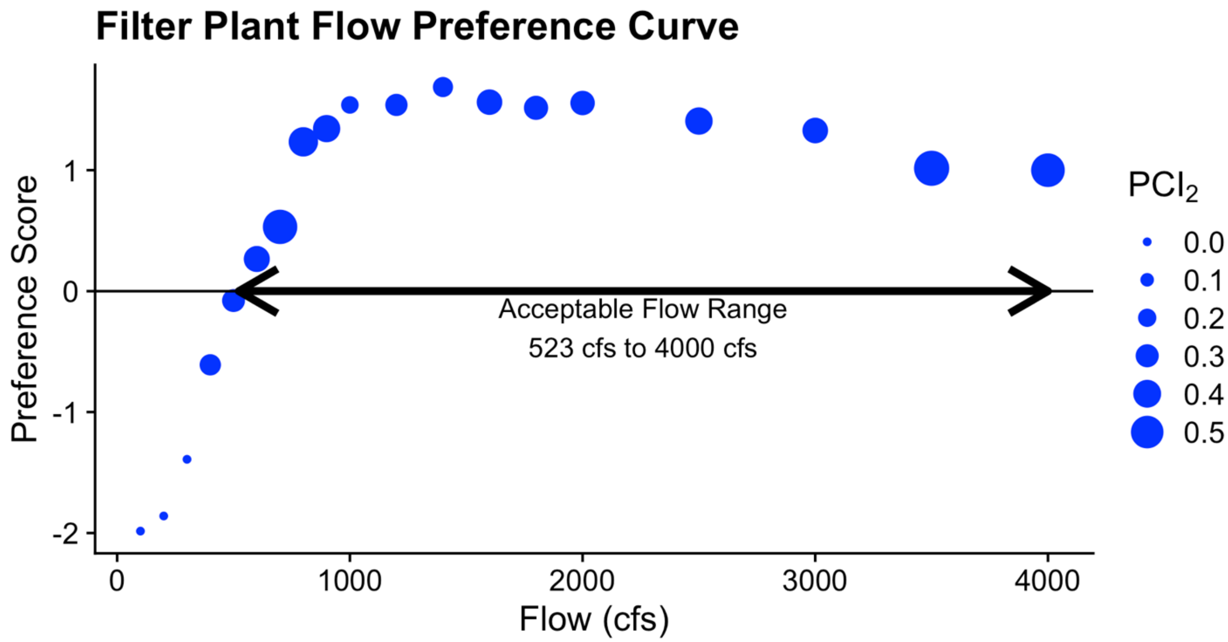

Figure 13. Flow preference curve for Filter Plant

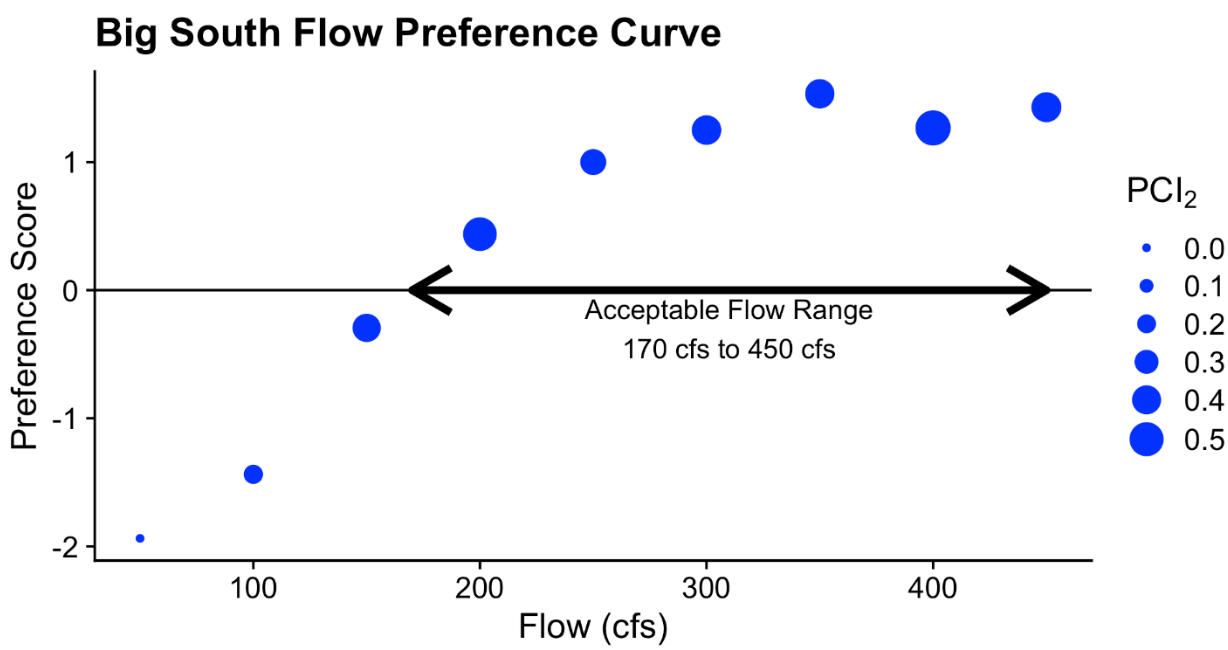

Figure 14. Flow preference curve for Big South

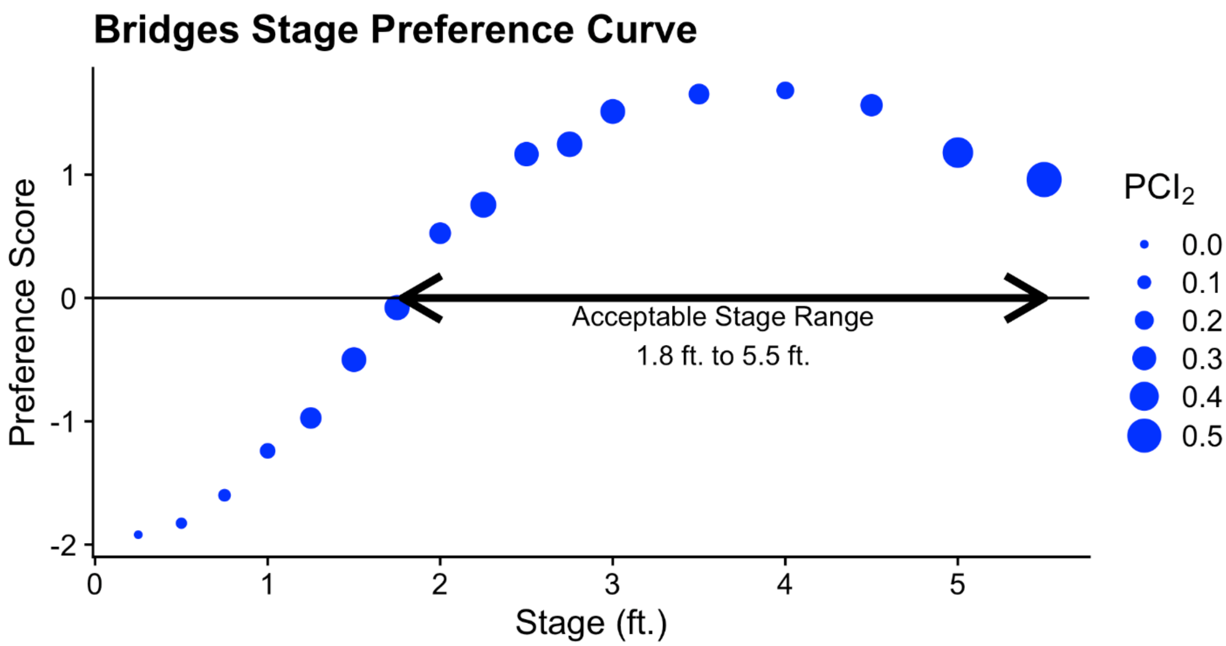

Figure 15. Stage preference curve for Bridges

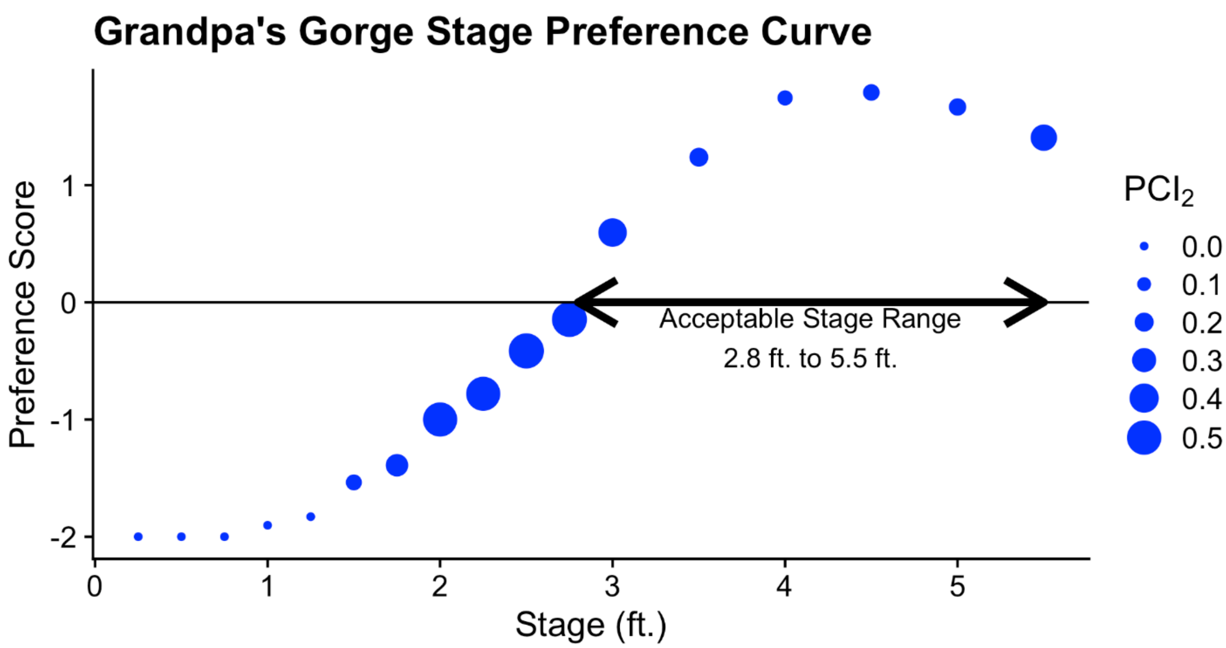

Figure 16. Stage preference curve for Grandpa's Gorge

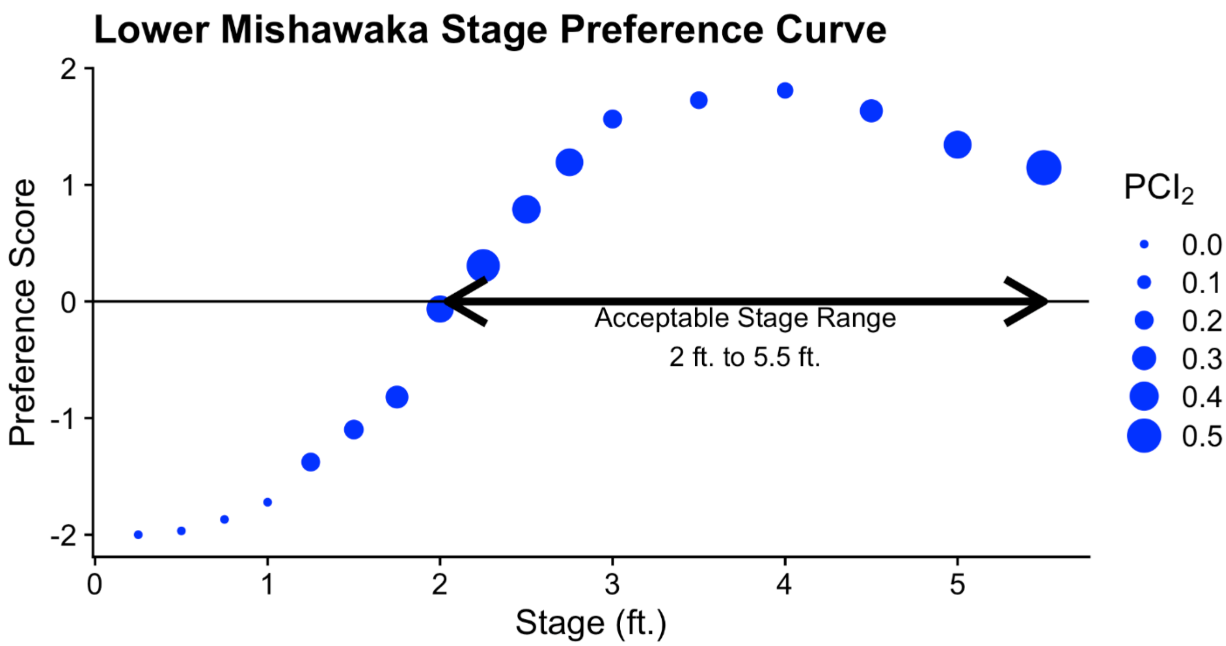

Figure 17. Stage preference curve for Lower Mishawaka

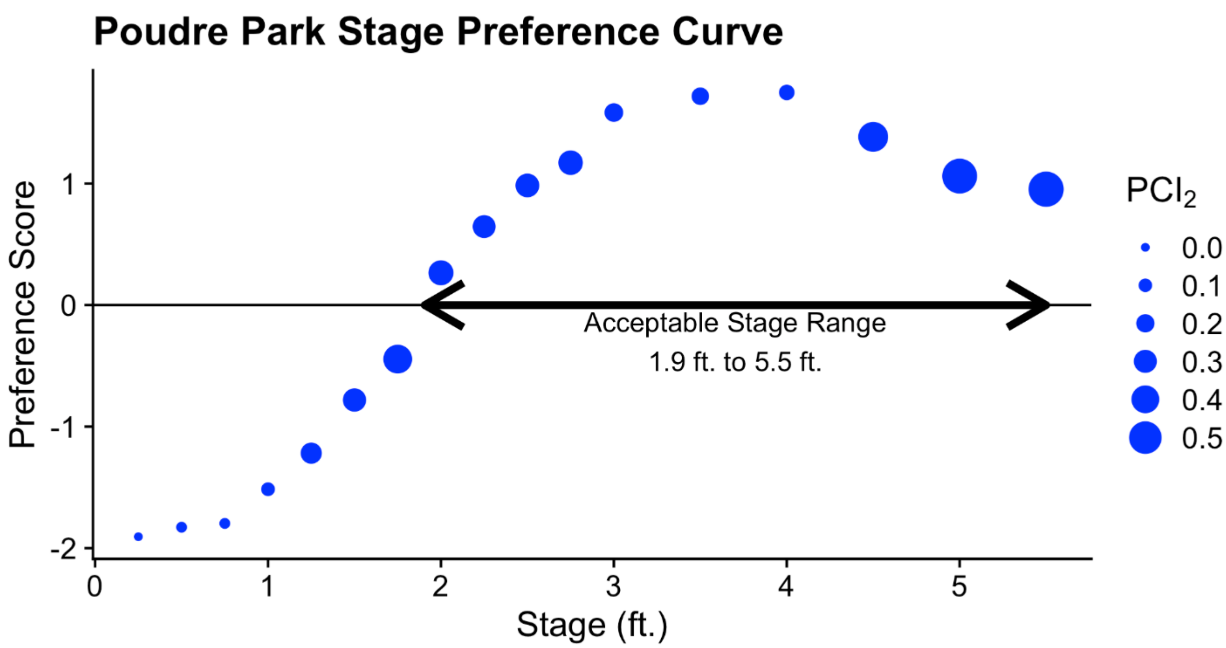

Figure 18. Stage preference curve for Poudre Park

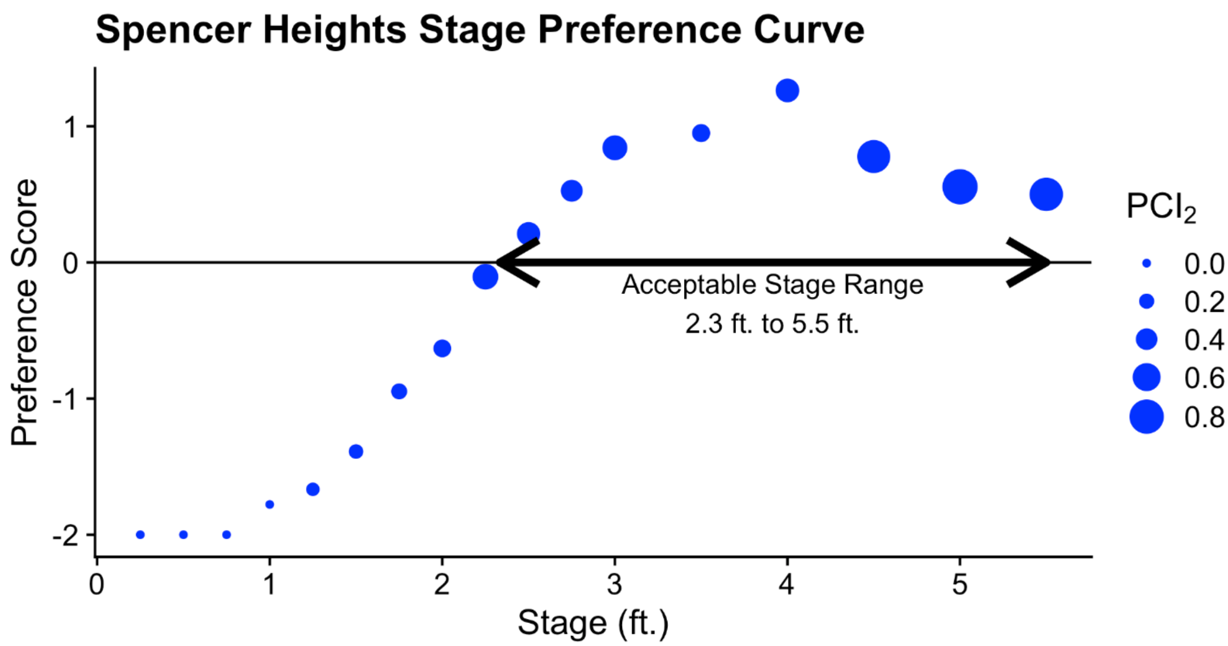

Figure 19. Stage preference curve for Spencer Heights

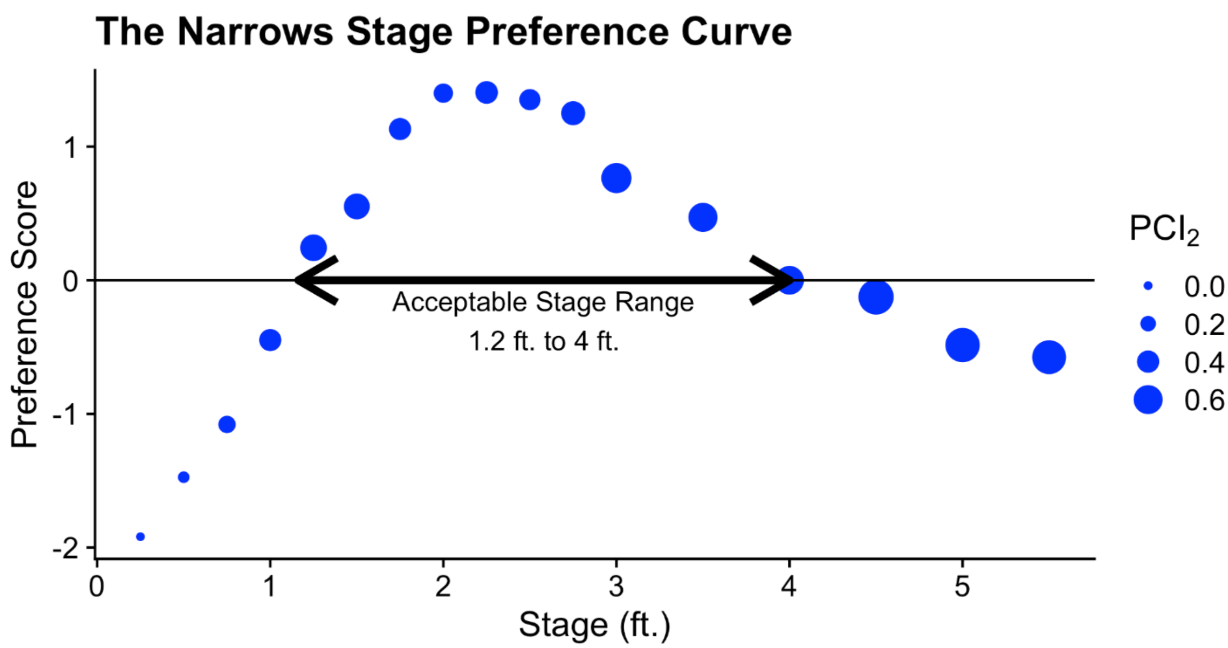

Figure 20. Stage preference curve for The Narrows

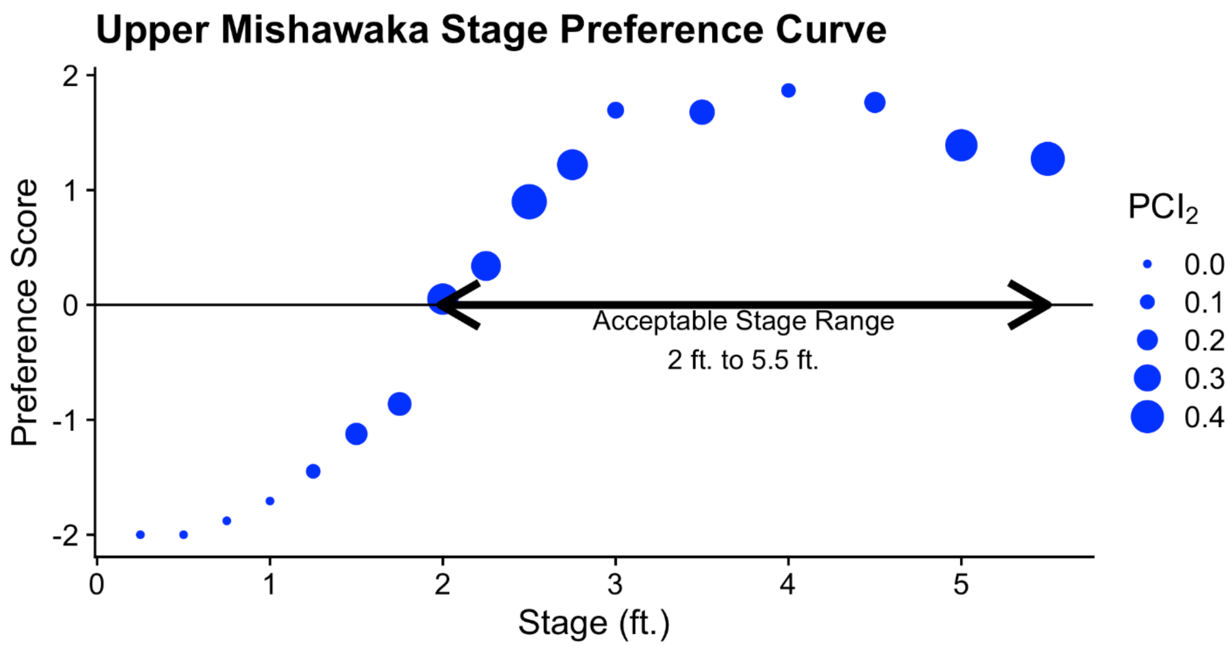

Figure 21. Stage preference curve for Upper Mishawaka

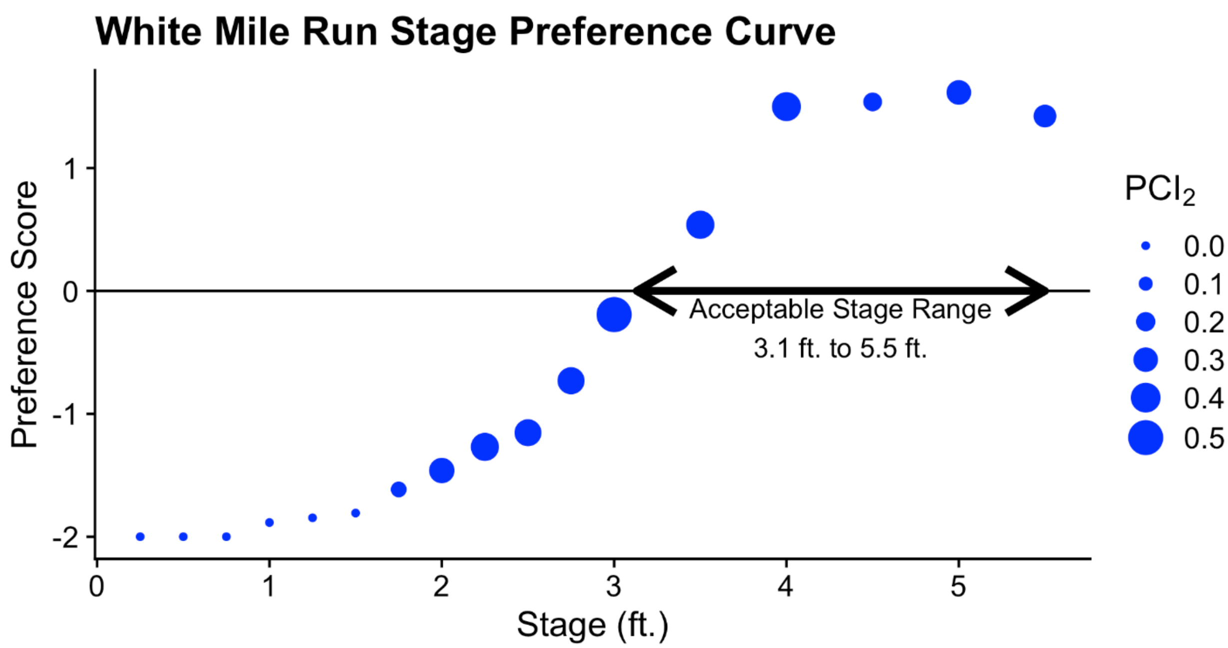

Figure 22. Stage preference curves for White Mile Run

9 Appendix B – Northern Integrated Supply Project Impacts

Table 8. Table digest of Figure 4 and Figure 7, includes hydrologic year type.

Year	Historical boatable days	Post-NISP boatable days	Absolute change in boatable days	Hydrologic year type
1980	82	72	10	Wet
1981	9	8	1	Dry
1982	27	23	4	Wet-typical
1983	111	106	5	Wet
1984	90	70	20	Wet
1985	21	15	6	Dry-typical
1986	55	32	23	Wet-typical
1987	24	12	12	Dry
1988	14	11	3	Dry
1989	7	2	5	Dry
1990	16	12	4	Dry-typical
1991	20	17	3	Dry-typical
1992	20	8	12	Dry
1993	38	25	13	Wet-typical
1994	9	6	3	Dry
1995	59	49	10	Wet-typical
1996	51	41	10	Wet-typical
1997	55	50	5	Wet
1998	39	12	27	Wet-typical
1999	68	51	17	Wet
2000	17	5	12	Dry
2001	9	3	6	Dry
2002	3	0	3	Dry
2003	19	10	9	Dry-typical
2004	29	13	16	Dry-typical
2005	33	16	17	Dry-typical
2006	24	3	21	Dry-typical
2007	22	0	22	Dry-typical
2008	38	11	27	Dry-typical
2009	40	27	13	Dry-typical
2010	55	43	12	Wet-typical
2011	70	59	11	Wet
2012	3	0	3	Dry
2013	42	27	15	Wet-typical
2014	62	47	15	Wet
2015	70	66	4	Wet
2016	78	60	18	Wet
2017	67	57	10	Wet
2018	39	26	13	Wet-typical
2019	42	28	14	Wet-typical

Table 9. Historical and post-NISP average monthly discharge categorized by hydrologic year types.

Month	Wet			Wet-typical		
	Historical average discharge (cfs)	Post-NISP average discharge (cfs)	Percent change (%)	Historical average discharge (cfs)	Post-NISP average discharge (cfs)	Percent change (%)
1	75.6	62.7	17.1	30.1	30.1	0.0
2	76.4	76.4	0.0	31.4	31.4	0.0
3	84.8	77.3	8.9	44.7	44.7	0.0
4	285.1	222.8	21.9	71.3	61.3	14.0
5	1399.7	1010.2	27.8	380.3	278.7	26.7
6	1890.6	1347.9	28.7	1014.6	782.3	22.9
7	464.1	384.5	17.2	274.4	221.2	19.4
8	168.4	121.3	27.9	71.1	57.3	19.4
9	103.6	103.6	0.0	141.7	141.7	0.0
10	84.1	77.6	7.8	62.0	62.0	0.0
11	82.0	82.0	0.0	39.5	39.5	0.0
12	66.4	65.2	1.8	42.4	42.4	0.0

Month	Dry			Dry-typical		
	Historical average discharge (cfs)	Post-NISP average discharge (cfs)	Percent change (%)	Historical average discharge (cfs)	Post-NISP average discharge (cfs)	Percent change (%)
1	21.5	21.5	0.0	19.9	19.9	0.0
2	20.3	20.3	0.0	19.3	19.3	0.0
3	11.1	11.1	0.0	17.7	17.7	0.0
4	17.6	15.7	11.0	41.6	34.3	17.5
5	202.6	150.9	25.5	181.0	114.8	36.6
6	231.2	157.7	31.8	526.3	339.0	35.6
7	75.2	57.9	23.0	119.7	85.4	28.7
8	49.2	44.4	9.8	59.0	47.8	18.9
9	19.8	19.8	0.0	46.4	46.4	0.0
10	14.4	14.4	0.0	81.8	81.8	0.0
11	5.8	5.8	0.0	16.0	16.0	0.0
12	9.8	9.8	0.0	17.5	17.5	0.0