Flows and Recreational Floating on the Niobrara National Scenic River, Nebraska

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April 2008

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Executive Summary

For approximately 100 miles through Nebraska's Sand Hills, the Niobrara River is "a mountain stream in a prairie state," offering outstanding scenery, plant communities, wildlife, and recreation opportunities. Congress recognized these values by designating a 76-mile reach east of Valentine as the Niobrara National Scenic River (NSR) in 1991.

The Nebraska Game and Parks Commission (NGPC) and the National Park Service (NPS) are concerned about impacts from water development on the river's natural resource values, including recreational floating. This report reviews river recreation on the Niobrara NSR and assesses how flows may affect recreational floating values.

Methods

Following established protocols, the study included several flow-recreation study methods, including: (1) a review of existing information (including a National Park Service user survey; (2) a summary of recreation-relevant hydrology; (3) boating-based reconnaissance of several river segments at low to moderate flows; and (4) interviews with outfitters and other experienced river users with knowledge of flows and recreation. Information was integrated to estimate the availability and quality of recreation opportunities under existing and alternative flow regimes.

The study included river segments from Nenzel to Highway 137, but focused on the western half of the Niobrara NSR, which has higher recreation use.

Hydrology information was developed to describe the range of flows available during recreation seasons. Throughout the report, flows are referenced to the United States Geological Survey (USGS) gage near Sparks (USGS Number 06461500), which is ideally located near the middle of the 30.4-mile high use reach.

Fieldwork on the river was conducted in May 2006 and July 2007, allowing observations at about 440 and 800 cfs (at the USGS Sparks gage). An outfitter focus group was conducted in July 2007 and phone interviews were conducted in fall 2007. The interview panel included 27 outfitters, agency staff, and experienced users who had taken many trips on the river at different flows.

Findings

The Niobrara River from Cornell Dam to Norden Bridge provides "outstandingly remarkable" opportunities for regional floaters. Information from a National Park Service user survey shows that most Niobrara floaters are from Nebraska, part of family groups, have little experience on the Niobrara, and rudimentary boating skills. About 90% rent canoes, kayaks, or tubes from one of 13 outfitters; about 56% use canoes and kayaks and 42% use tubes.

Annual use ranges from 33,000 to 44,000 people in recent years. Nearly 80% of use occurs on Saturdays, 10% on Sundays, and the remaining 10% through the rest of the week. Most use occurs from Memorial Day through Labor Day, although there is some use from early May through October.

Several launch areas allow a variety of trip options. The highest use levels are between Cornell Bridge and Smith Falls State Park, but there is high use downstream to Rocky Ford. Use from Rocky Ford to Norden Bridge is substantially lower. Use downstream of Norden Bridge and upstream of Valentine is very low.

The two basic types of float trips available on the Niobrara are (1) tubing and (2) boating in canoes and kayaks. Boating could be further divided into "scenic boating" (the majority of trips) and "whitewater boating" (which focuses on three Class II-III rapids and is more rare).

A list of ten potential flow-dependent trip attributes for tubing and boating was developed from fieldwork and the outfitter focus group. Follow-up interviews rated each attribute on "importance" and "flow effect." Taken together with information from fieldwork and findings from other flow-recreation studies, four attributes (boatability, safety, aesthetics, and rate of travel) appear most relevant for assessing flows for Niobrara floating opportunities.

Insufficient flows can eliminate recreation opportunities completely, decrease the number of days those opportunities are provided, or diminish their quality. On the Niobrara, low flows increase boatability problems and safety concerns, decrease aesthetics, and decrease the rate of travel (which can adversely affect trip schedules and the amount of time enjoying the river's values).

Most Niobrara boaters and tubers are not "calibrated" to flows at the USGS Sparks gage, and depend on outfitters or agency staff to provide information about which flows are floatable and which provide high quality trips. Outfitters, agency staff, and experienced users can specify those flows.

Based on interview information (and supported by fieldwork), flows higher than 460 cfs provide acceptable boating opportunities and flows between 600 and 900 cfs provide optimal boating opportunities. Tubing flows are similar except at the high end of the optimal range. Whitewater at the three Class II-II rapids becomes optimal above about 800 cfs.

Flows between 340 cfs and 460 cfs are boatable and tubable, but offer lower quality opportunities. Flows below 340 cfs (rarely observed in the period of record) are considered "unboatable."

Boating flows on the Nenzel to Anderson reach are likely to be similar to those identified for the Niobrara NSR minus tributary and groundwater inputs. This reach has scenery and channel characteristics similar to the Niobrara NSR through the Fort Niobrara NWR.

Before completion of Merritt Reservoir in 1964, flows were, on average, optimal (600 to 900 cfs) about 79% of the days in the primary recreation season (Jun-Aug). There were no low quality (340 to 460 cfs) or unboatable (less than 340 cfs) days.

Since completion of Merritt Reservoir in 1964, flows have been, on average, optimal (600 to 900 cfs) about 34% of the days and less-than-optimal but still acceptable (460 to 600 cfs) about 39% of the days in the primary recreation season. Flows provided low quality boating opportunities (340 to 460 cfs) about 18% of days, with less than 1% of days unboatable.

Additional water withdrawals from the watershed (based on analysis of ***illustrative*** 50 or 100 cfs reduction scenarios) would decrease the number of optimal or acceptable days and increase the number of low quality and unboatable days. A 100 cfs reduction scenario would produce 35% low quality and 12% unboatable days in the primary recreation season. The effects described above would be lesser in wetter-than-average years and greater in drier-than-average years.

Introduction

The Niobrara River flows eastward approximately 486 miles from its headwaters in eastern Wyoming foothills to the confluence with the Missouri River near Niobrara, Nebraska (see Figure 1 on page 3). For roughly 100 miles through the eastern Sand Hills, the river is "a mountain stream in a prairie state," offering outstanding scenery, plant communities, wildlife, and recreation opportunities. In 1991, Congress recognized these values by designating a 76-mile reach east of Valentine as the Niobrara National Scenic River (NSR). The National Park Service manages the river in cooperation with the Niobrara Council (a state-recognized group with representatives from local, state, and federal government; local landowners; area industries; and environmental groups).

The Upper Niobrara watershed includes two major Bureau of Reclamation water development projects that affect flows on the Niobrara NSR: (1) Box Butte Reservoir provides storage for the Mirage Flats Irrigation Project (1946) in northwestern Nebraska, and (2) Merritt Dam and Reservoir (1964) on the Snake River (a south bank tributary southwest of Valentine), provides irrigation storage for the Ainsworth Irrigation District. Taken together, the two projects provide storage and diversion for 46,662 irrigated acres. In recent years, additional surface water diversions and ground water development upstream of the Niobrara NSR reach may also have affected river flows in the reach.

The Nebraska Game and Parks Commission (NGPC) and National Park Service (NPS) are concerned about impacts from water development on natural resource values, including recreation. In May 2006, the NGPC Board of Commissioners directed agency staff to develop instream flow recommendations for fish, wildlife and recreation resource needs in the Niobrara River. NPS agreed to provide assistance in seeking state-based flow recommendations to help meet NPS objectives for designated Niobrara reaches in the National Wild and Scenic River System.

To address this issue, NGPC contracted with Confluence Research and Consulting (CRC) in June 2007 to review river recreation [floating] in the Niobrara corridor and assess how flows may affect it. The resulting study reported here was largely conducted prior to state action that declared most of the upper Niobrara River to be "fully appropriated" in October 2007.

Study Goals and Objectives

The overall goals of the study are to assess relationships between flows and recreation opportunities, and document effects of potential water withdrawals on river recreation.

Specific objectives include:

- Identify flow-dependent recreation opportunities on different segments of the Niobrara, with a focus on scenic floating in canoes, kayaks, and tubes.
- Describe flow-quality relationships and flow ranges for each type of opportunity.
- Describe current recreation-relevant hydrology, and estimate the number of days that provide different types of recreational opportunities.
- Describe potential effects of water withdrawals on the availability and quality of Niobrara river recreation.

Methods

Investigators applied several standard flow-recreation study methods (Whittaker et al., 1993; Whittaker, Shelby, & Gangemi, 2006), including:

- A review of existing information.
- A summary of recreation-relevant hydrology.
- Boating-based reconnaissance of several river segments at low to moderate flows.
- Interviews with outfitters, agency staff, and experienced recreation users with knowledge of flows and recreation.

Information was integrated to estimate the number of days that different opportunities would be available under existing and alternative flow regimes.

Geographic Scope

Investigators reviewed information about flows and recreation on a roughly 100 mile reach of the Niobrara from Nenzel to Highway 137 near Newport; about 76 miles of this is the designated Niobrara NSR (Figure 2). Most attention was focused on the western half of the Niobrara NSR, which has higher recreation use (see Figure 3). This 30.4 mile reach starts at Cornell Dam and ends at Norden Bridge. The 4.8 miles from Borman Bridge to Cornell Dam within the Fort Niobrara National Wildlife Refuge is closed to boating to protect wildlife habitat and wilderness values. Specific segments of interest include:

- Cornell Bridge to Berry Bridge. This 7.6 mile reach offers scenic floating and wildlife viewing opportunities. The first 6 miles is within the Fort Niobrara National Wildlife Refuge (NWR; managed by US Fish and Wildlife Service) and most of this reach is also designated Wilderness. It is the only reach with a daily river access fee. Cornell Dam was part of a hydroelectric project operated from 1915 to 1983; it is a run-of-river project, backs up roughly 2 miles of sediment-filled reservoir, and is under consideration for removal.
- Berry Bridge to Brewer Bridge. This 6.8 mile reach offers scenic floating opportunities and access to Smith Falls State Park (which charges a fee for vehicle access).
- Brewer Bridge to Rocky Ford. This 7.8 mile reach offers scenic floating opportunities, with a few short rapids. There are several private fee campgrounds.
- Rocky Ford to Norden Bridge. This 8.2 mile reach offers scenic floating opportunities. There are some private fee campgrounds, but use levels are lower than on upstream segments.

Investigators also collected general information about flow-dependent recreation use on other reaches of the river, including:

- Nenzel Bridge to Borman Bridge. This 32-mile reach is occasionally used for scenic floating and boat-based wildlife viewing, and includes a scenic 10-mile segment between Nenzel Bridge (about 5 miles south of Nenzel) and Anderson Bridge Wildlife Management Area (WMA; a non-fee NGPC public use area).
- Norden Bridge to Highway 137 Bridge. This 40.1 mile reach is the eastern half of the Niobrara NSR. Its offers a shallow and more braided channel compared to upstream reaches, making floating difficult except during high flows. It has much lower recreation use levels, most associated with bank-based fishing, wading, swimming, picnicking, camping and other outdoor recreation uses at private areas.

Figure 1. Regional context of the Niobrara watershed in Wyoming, Nebraska, and South Dakota.

Figure 2. The study reviewed information for Niobrara from Nenzel to Highway 137.

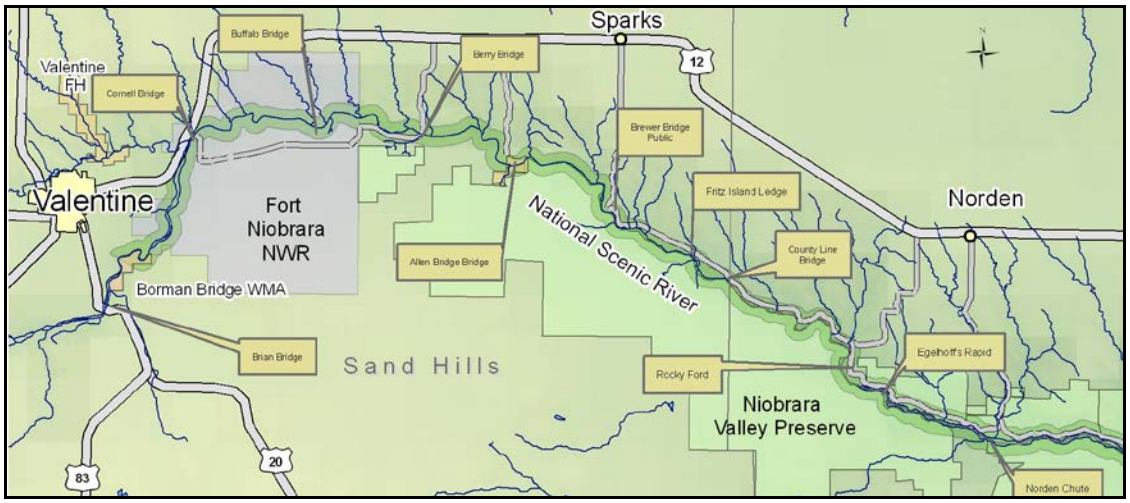

Figure 3. The study focused on the Niobrara River from Cornell Bridge to Norden Bridge, the reach with the highest recreation use.
(Map Sources: Nebraska Game and Parks Commission).

Review of Existing Information

This review included maps, photographs, guidebooks, tourist and outfitter websites, Niobrara NSR management plans and associated documents, a 2001 National Park Service-sponsored survey of users, and use data. These materials provided background on existing or potential recreation opportunities, flow-related attributes, and the people that use the river. References include a list of documents and websites.

Recreation-Relevant Hydrology

Hydrology information was developed to describe the range of flows available during recreation seasons. Throughout the report, we reference flows at the USGS gage near Sparks (USGS Number 06461500), immediately downstream of Berry Bridge (RM 12.4). This gage is ideally located near the middle of the 30.4-mile high use segment of the Niobrara NSR, and there is little accretion from springs or tributaries relative to the main stem flow through the NSR corridor. The gage has a continuous record from October 1945 through the present (61 years), including periods before the construction of the major water development project in the basin (Merritt Reservoir). Hydrology work also analyzed the frequency of days when flows are in prescribed ranges for recreation opportunities under historical and potential flow regimes.

Interviews with Experienced Resource Users

The study included a focus group meeting with river outfitters (who rent canoes, kayaks, and tubes or provide other services for Niobrara boaters) and follow-up interviews with outfitters and other experienced river users. This provided information about types of recreation opportunities, use levels, attributes of trips affected by flows, the importance of those attributes for high quality trips, and flow ranges for boating and tubing.

The ***outfitter focus group*** meeting was conducted on July 18, 2007 at Dryland Aquatics near Sparks. Eleven outfitters attended and the meeting lasted about 2 hours. Discussion focused on (1) a description of the study and its objectives; (2) river use and user characteristics; (3) types of trips; (4) trip attributes that might be affected by flow; and (5) knowledge of the USGS Sparks gage.

Following the focus group meeting, CRC prepared a short "fact sheet" describing Niobrara NSR hydrology to help calibrate knowledge of river conditions with flow measurements at the USGS Sparks gage. The description included instructions to access the gage via the internet and summary hydrology information for the period of record and recent wet, average, and dry years. It also showed flows for 2007 (to date). The document was sent to all 13 outfitters in preparation for interviews in early fall; similar information is provided in the hydrology section of this report.

The ***phone interviews*** were conducted from September 11 through November 6, 2007. The interview panel was developed from the list of outfitters and through networking with outfitters and agency staff; the goal was to identify users that had taken many trips on the river at different flows. Previous research has shown that many users can identify important flow-related attributes and conditions, but only experienced users have sufficient knowledge to identify specific relationships between flows and conditions (Shelby, Brown, and Baumgartner, 1992; Whittaker and Shelby, 2002).

In all, 37 potential interviewees were identified and 27 completed interviews. Of the 10 who did not, 3 phone numbers were unreachable and 7 did not return calls after repeated messages. This is a 79% response rate, considered excellent in survey research. The final list of interviewees included:

- 11 outfitters
- 5 NPS rangers, technicians, or former staff
- 7 non-commercial boaters
- 4 others (2 Nature Conservancy staff and 2 landowners)

Collectively, the panel averaged 24.3 years of boating experience on the Niobrara. The outfitters on the panel averaged 17.1 years providing outfitting services. Respondents reported an average of 16.4 days per year boating on the river, but several noted that their boating use varied considerably from year to year. Outfitters themselves averaged 5.1 days per year on the river.

The interview followed a structured format summarized in Appendix A. Questions focused on (1) respondent characteristics; (2) the importance of trip attributes and how much flow affects them; and (3) specified flow ranges for different types of recreation opportunities. All interviews were conducted by Doug Whittaker and were coded directly into a database.

Fieldwork

Fieldwork was conducted from July 17-19, 2007 to target mid-summer flows. Whittaker and Shelby were joined on various segments by staff from NGPC, NPS, USGS, University of Nebraska-Lincoln (UNL), and The Nature Conservancy (TNC). Fieldwork was conducted in 14 to 17 foot open canoes and 12 to 13 foot recreational kayaks (craft commonly in use on the river and available from outfitters). It focused on (1) documenting flow-dependent attributes; (2) assessing "boatability problems" for different craft; (3) evaluations of flow-dependent trip attributes; and (4) evaluating flows for different types of recreation opportunities.

Specific segments, date floated, and flows from the Sparks gage are listed below:
- Cornell Dam to Brewer Bridge on July 17 at 442 cfs.
- Brewer Bridge to Norden Bridge on July 18 at 447 cfs.
- Nenzel Bridge to Anderson Wildlife Management Area (WMA) on July 19. Flows at the Sparks USGS gage were 433 cfs, but that included an estimated 130 cfs from tributaries (e,g, Snake River, Schlagel Creek, Minnechaduza Creek) or flow accretion between Anderson Bridge WMA and the USGS gage at Sparks, so observed flows in the upstream Nenzel to Anderson reach were probably about 300 cfs.

Whittaker had also previously boated the Niobrara following a river management symposium in May 2006 at substantially higher flows, using a 17-foot open canoe. Specific segments included:
- Cornell Dam to Smith Falls State Park on May 13, 2006 at 804 cfs.
- Smith Falls State Park to Rock Barn on May 14, 2006 at 797 cfs.

Integration and Analysis

Information was integrated to:
- Identify flow-dependent recreation opportunities.
- Describe seasonality of recreation use (full and primary use seasons).
- Identify flow-related recreation attributes and discuss how they change with flow.
- Develop flow ranges for important recreation opportunities.
- Summarize the frequency of days recreation opportunities have been available through the period of record.
- Summarize days of recreation opportunities if additional water is removed from the basin.

Findings and Discussion

Boating and Tubing Recreation

Recreation Values

The Niobrara NSR, particularly the western 30 miles from Cornell Dam to Norden Bridge, is a renowned and popular boating river. It is identified as one of the country's "Ten Best Paddling Rivers" by Backpacker Magazine (January, 1988) and "100 Best Outdoor Adventures" by National Geographic Adventure magazine (April, 2000). Canoeing, kayaking, tubing, and related activities are the "most heralded" recreation opportunities among the river's "outstandingly remarkable" recreation values (NPS, 2006, p.22). The 2006 General Management Plan identifies other important recreation attributes including spectacular scenery, riverside camping, over 230 documented falls (Mason, 2005), wildlife, botanical diversity, and historic bridges or ranch buildings in a rural setting (NPS, 2006, pp. 97-100).

Floater and Float Trip Characteristics

A user survey conducted for NPS by researchers from the University of Minnesota in 2001 (Davenport et al., 2002) provided useful information about floaters and their trips; this survey was a separate effort from the interviews with experienced users for this study. Along with information from interviews, agency staff, websites, guidebooks, and fieldwork, it suggests several conclusions about floaters and their trips:

- Most Niobrara floaters are from Nebraska (66%) or neighboring states (24%); only 10% are from outside the region. Among Nebraskans, 59% come from Omaha/Lincoln and only 6% are from the local area.
- Most floaters spend a night at motels/cabins (30%) or campgrounds (54%; including private car-accessible campgrounds or a public campground at Smith Falls State Park). Nearly all campers leave their gear with their vehicles and float segments of the river as day trips.
- Most floaters are part of family groups and about half (54%) are females. Among adults (children were not surveyed), 73% are between 35 and 60, with 20% under 35 and 7% over 60.
- Most group sizes are small (62% less than 6), although about 30% travel in groups of 7 to 20 and 8% in groups over 20 (organizations included fraternities, sororities, scout groups and other youth groups).
- Many Niobrara floaters have little experience on the river. Forty-two percent are first-time floaters, 20% are second-time floaters, and only 8% have taken 10 or more trips.
- Most floaters (particularly tubers) have only rudimentary boating skills. Marketing information suggests the river requires little previous experience, little paddling or "steering" is required, and the few difficult rapids can be portaged.
- Most float the river only one day per trip (81%), even though they may have spent a night in the area. Less than 1% spent three or more days on a trip.
- Over 60% decide to take the trip between one and six months in advance, and only 12% plan trips in less than a week. Floaters with more experience tend to plan further in advance.
- About 90% of floaters rent canoes, kayaks, or tubes from one of 13 outfitters. Outfitters also provide shuttle services and camping on private land.
- Outfitted trips use canoes (50%), kayaks (8%), and tubes (42%). Less than 1% reported using rafts.

- On non-outfitted trips, floaters use canoes (58%), kayaks (18%), tubes (20%), and rafts (4%). Non-outfitted use makes up about 10% of the users.
- The use of tubes has increased in recent years (15% as their primary craft in 1993 and 31% in 2001). Tubes are typically tied together as they float the river. Fort Niobrara NWR regulations limit this to five tubes, but downstream of the refuge, it is common to see 10 to 15 tied together.
- Canoes and kayaks rent for $25 to $50 per day, while tubes are about $20 to $30 per day (depending on size).
- Most outfitter canoes are "recreational" (rather than whitewater) models 14 to 17 feet long, made of aluminum or polyethylene, and designed for two paddlers.
- Most kayaks are single person "recreational" models about 12 to 13 feet long. They are not rented with spray skirts and generally are not designed for more challenging whitewater (Class III or higher).
- Most tubes have PVC bladders with nylon or vinyl covers designed to be pulled behind powerboats. Diameters range from about 64 to 100 inches. A few outfitters offer traditional truck tire tubes covered with canvas.

Use Levels and Patterns

Use levels are challenging to quantify on the Niobrara NSR because users are not required to register (except in Fort Niobrara NWR). However, NPS has made use estimates in the past and initiated an improved use estimation program in 2001. Some summary findings:

- In 1993, use was estimated at about 30,000 floaters per year, and recent estimates (2001 through 2006) have ranged between 33,416 and 39,685 per year. In 2007, NPS estimated that there were 44,499 floaters.
- In 1993, about 23,000 floaters started their trips at Cornell Bridge in the Fort Niobrara NWR; by 1997, the number had reached 32,000. In 1999, new regulations (e.g., no alcohol, limits on the number of tubes tied together, and user fees) reduced the number of people launching in the NWR; by 2006, it was about 10,000. Stable to increasing use levels for the entire river, however, suggest that many users simply altered their initial launch site from the Fort Niobrara NWR to accesses downstream of the refuge boundary (NPS, 2006).
- Approximately 80% of use occurs on Saturdays, with 10% on Sundays, and the remaining 10% through the rest of the weekdays (NPS, 2006).
- Based on NPS counts, busy summer Saturdays can produce more than 2,000 people on the river per day, with peak use in the middle of the day (11 to 3 pm). As many as 1,400 boats have passed Smith Falls State Park in this 4 hour period on a peak use Saturday (an average of 350 boats per hour or 6 boats per minute). Agencies have recorded as many as 540 people per hour (about 9 people per minute). This can create "boat jams" at rapids, attraction sites, or shallow areas.
- Substantial use occurs from Memorial Day through Labor Day, although there is some use from early May through October. It is sometimes possible to boat the river in the winter, but use is very low. For the purposes of this report, the "full recreation season" is May through October (184 days).
- The highest use occurs from June through August, hereafter referred to as the "primary recreation season" (92 days). Tubing is more temperature-dependent and is less likely to occur outside this primary season.

Segments

- The most popular "first day" trips are from ***Cornell Bridge to Smith Falls State Park or Brewer Bridge,*** but some boaters travel to other private landings or camping areas between Brewer Bridge and Rocky Ford. Those who float a "second day" typically travel from ***Smith Falls State Park*** (or nearby private camping areas) ***to Rocky Ford*** (or nearby private camping areas).
- Some tubers and boaters start below Fort Niobrara NWR (e.g., Berry Bridge, Smith Falls State Park) to avoid Fort Niobrara fees and regulations or allow shorter trips.
- Use ***below Rocky Ford*** is substantially lower than upstream. Most outfitters require boaters to portage Rocky Ford (the only Class III rapid on the river), making it a logical take-out. Other outfitters request take-outs on their own properties, which can also shorten trips. Less than 10% of outfitted use continues below Rocky Ford to Last Chance, Rock Barn, or Norden Bridge. This reach has one Class II rapid (Egelhoffs); below Rock Barn it provides a more braided alluvial channel that can be difficult to negotiate at low water. The reach ends at Norden Falls, a Class IV rapid created as the river cuts into the Rosebud Formation. In the 1970s, this rapid was smaller and farther downstream (under the bridge); it has cut back about 50 yards upstream and is steeper.
- Floating use on the ***Niobrara NSR downstream of Norden Bridge*** is very low, and is usually limited to spring or early summer high flows because the river is more braided and shallow. Outfitters do not market trips on this reach. The primary recreation uses on this reach appear to be catfishing and occasional swimming or wading. No additional information has been collected about these trips or associated flow needs.
- Floating use on the ***Niobrara above the NSR*** (Nenzel to Borman Bridge near Valentine) is also thought to be low. One interviewee heard of a multi-day trip from the Wyoming border and Palmer (1996) has written of a similar trip, but most use appears to be on segments downstream of Nenzel. Some outfitters have offered occasional guided trips or rented boats on this reach in the past, but none currently market this trip. Additional information about this reach and flow needs is limited to the Nenzel to Anderson WMA segment observed during fieldwork. This reach has high quality recreation values, including scenic sand hill cliff faces, a largely undisturbed riparian zone, and several interesting Class II rapids.

Trip Types

The two basic types of float trips available on the Niobrara are (1) tubing and (2) boating in canoes and kayaks.

Tubing generally occurs during the primary recreation season (June through August). It involves slow-paced, relaxing travel down the river and socializing with friends and family. Many people tie tubes together and periodically get off to swim, visit springs or falls, or push tubes back into the main current or away from shallow areas. Tubes tend to travel about half the speed of boats, which reduces the river distance traveled during a typical day trip.

Tubers run the few Class I-II rapids (e.g., Fritz's Island Ledge Rapid), but generally are not interested in whitewater or route finding in a craft that is not designed for maneuvering. Only one outfitter offers clients a "steering stick" (a 6 foot pole), although some tubers request paddles. Tubers sometimes have water fights (usually within their groups) using soaker toys, buckets, etc. Especially on summer Saturdays, tubing is a higher density "party" experience. On other days of the week, tubing groups tend to be smaller and there is less interaction between groups.

Boating in canoes, kayaks, and rafts occurs through the full recreation season (May through October), although use is higher in the primary season (June through August). This opportunity includes relaxing travel and socializing, but requires more active participation than tubing. Boaters have to maneuver their craft to stay in the channel, avoid hitting rocks, or handle the river's riffles and rapids. Saturdays in summer offer the higher density "party experience" described above, but other days offer opportunities for exploration at attraction sites and solitude while on the river.

Conceptually, boating could be further split into ***"scenic boating"*** (the majority of trips) and ***"whitewater boating"*** (which focus on negotiating or "playing" in the few Class II-III rapids). Many scenic boaters run and enjoy the river's rapids (although most do not run Class III Rocky Ford and hardly any run Class IV Norden Falls), but whitewater boaters specifically seek the larger waves and more powerful hydraulics available at higher flows.

Interviewees reported that few Niobrara boaters are interested in this whitewater opportunity. Most don't own whitewater craft or possess specialized whitewater skills. The rapids are few and spaced far apart, and interesting hydraulics occur only at relatively high flows (see "specified flows" below). The present report identifies flow effects on whitewater at the three Class II-II rapids.

Flow-Dependent Attributes

A list of potential flow-dependent trip attributes for tubing and boating was developed from fieldwork and discussion at the outfitter focus group. This list was developed specifically for the Niobrara, but it is similar to attributes identified in other studies. During interviews, respondents were asked to rate each attribute on "importance" and "flow effect" scales. The ten attributes were:

- Safety conditions (avoid capsizing or hitting rocks)
- Aesthetics of the water
- Boatability (hitting rocks, becoming "stopped," contacting the channel with paddles, or dragging boats across shallow areas)
- Time at falls/springs while staying on a trip schedule
- Amount of paddling required to keep on a trip schedule
- "Boat jams" (multiple boats clogging routes)
- Biting beetles ("toe biters") present in shoreline algae
- Rate of travel (how the speed of the river current affects trip schedules)
- Exposed mud along shorelines
- Multiple routes through rapids

Attribute Importance

The "attribute importance" scale ranged from 1= "not at all important" to 4= "extremely important." Figure 4 arrays the attributes from most- to least-important based on the percent who reported each attribute very or extremely important.

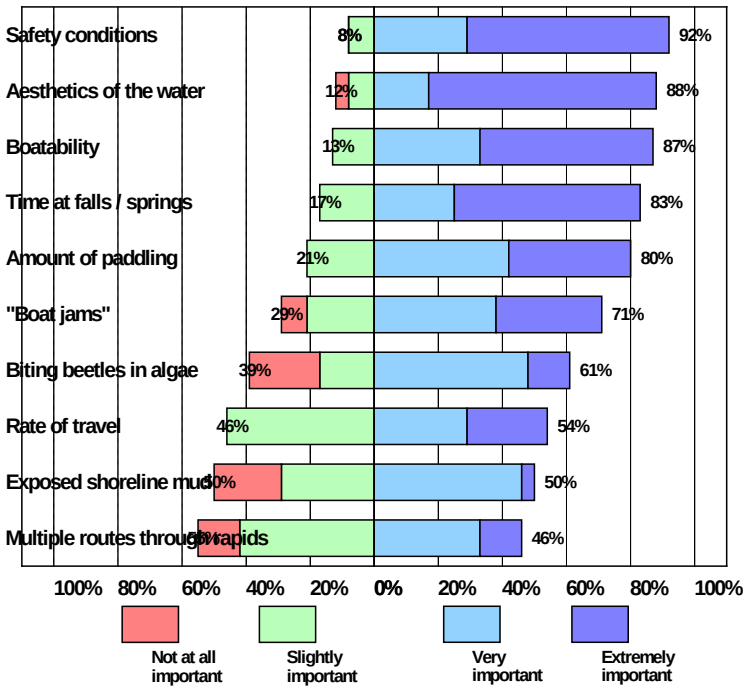

Figure 4. Interviewee assessments of the importance of potential flow-dependent trip attributes on the Niobrara River NSR.

Findings suggest:

- Most attributes are very or extremely important to a majority of interviewees.
- The most important attributes were safety, aesthetics, boatability, time at falls, and no need to paddle harder/longer to keep on a trip schedule.
- The least important were multiple routes through rapids, exposed shoreline mud, rate of travel, and few biting beetles in riparian algae.

Flow Effects on Trip Attributes

The "flow effect" scale ranged from 1= "flow has no effect" to 4= "flow has a large effect." Figure 5 arrays the attributes from most- to least-affected based on the percent reporting a medium or large flow effect.

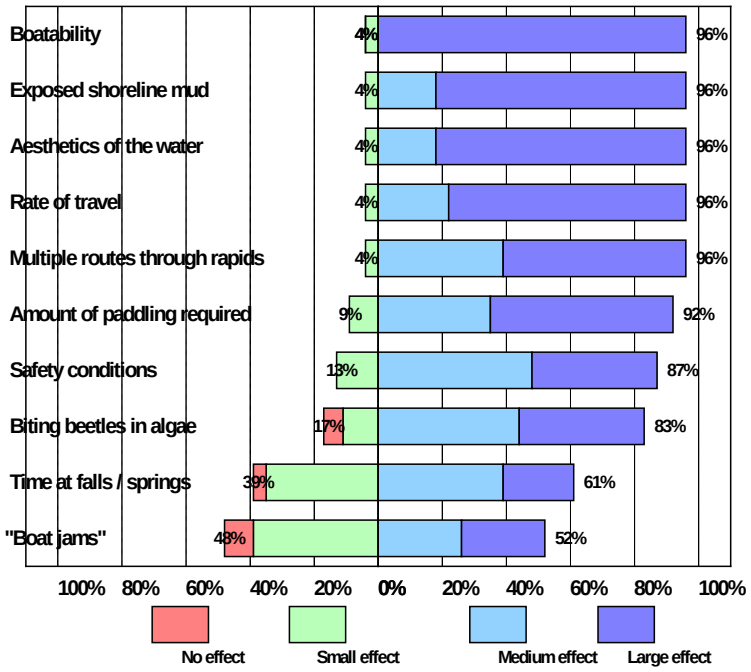

Figure 5. Interviewees' assessments of the size of flow effects on trip attributes on Niobrara NSR.

Findings suggest:

- All but two attributes are moderately or substantially affected by flow. The greatest effect was on boatability; 96% of interviewees reported flow had a large effect.
- Other large flow effects were reported for amount of exposed shoreline mud, aesthetics of the water, rate of travel, and multiple routes through rapids.
- The number of "boat jams" is related to the number of floaters, although 52% believe low flows have a medium or large effect on this problem.
- Sufficient time at falls / springs is related to trip planning, but 61% believe low flows have a medium or large effect by making travel slower.

Most Relevant Flow-Dependent Attributes

Taken together with information from fieldwork and findings from other flow-recreation studies, four attributes appear most relevant for assessing flows for Niobrara boating:

Boatability

Boatability refers to traveling with minimal numbers of "stops" (where the boat becomes grounded) or "boat drags" (where boaters get out of their craft to pull it off the obstacle or drag it to deeper water). Boatability is probably the most important flow-dependent recreation attribute on the Niobrara.

Most Niobrara canoes and kayaks require depths of 6 to 8 inches to pass over an obstacle (although this depends on boat size and load). Moderate flows tend to provide multiple routes down the river even for relatively unskilled floaters. At low flows, it is more challenging to avoid hitting rocks or becoming stuck on sand bars or ledges. A deeper part of the channel (the "thalweg") may remain boatable, but users need skill "reading water" and controlling their boats (which is lacking in many Niobrara floaters) to find and stay in it. In some riffles, particularly when the river channel becomes wider and braided, there may not be a boatable channel at low flows.

Boatability also includes "paddle-hits" as boaters take normal strokes. Even if a boat can float in six to eight inches of water, normal paddle strokes require 14 to 18 inches. When the water is too shallow, paddlers use sweeping strokes or "dig sand" to propel the boat; either technique is awkward and inefficient. Occasional paddle-hits are normal, but over long stretches they become tedious and erode boating quality.

Tubers have "tube-ability" problems at low flows, particularly when many tubes are tied together. Although tubes generally require less depth than boats (depending on size and load of the tube), they are challenging to maneuver. The Niobrara has a wide thalweg and laminar current at moderate flows; at lower flows, the thalweg narrows and meanders within the channel, increasing opportunities for tubes to become grounded or caught in eddies.

"Boatability problems" may damage equipment, diminish the quality of boating or tubing trips, or lead to "unboatable" conditions. Flow ranges (discussed below) help define those points.

Boating Safety

Boating safety is another important flow-dependent trip attribute; it can be affected by low or high flows. At low flows, boatability problems require maneuvering to stay in the main channel or avoiding rocks. For the less skilled these maneuvers can put boats perpendicular to the current, increasing the risk of capsizing if they hit a rock. Even if a boat becomes stopped or grounded, additional skill is required to get out and pull the boat off the rock; the situation is exacerbated if a deeper channel or swift currents are adjacent. Tubers have similar concerns. Although getting on and off these more stable craft is generally easier, tubers have to do this more often to stay in the current.

High flows present other safety concerns, although the Niobrara does not have many rapids with steep gradients or constrictions to create substantial waves or hydraulics. At higher flows though, current speed is faster and boaters unfamiliar with waves, hydraulics, and crossing eddy lines can "swamp" their craft or capsize. Discussion about whitewater (below) identifies threshold flows for larger waves and hydraulics in major rapids, which are desirable attributes for skilled boaters but potential hazards for the less skilled.

Interviewees rated safety as the most important flow-dependent trip attribute, although they recognized that many variables also affect safety. Several outfitter web pages highlight safety issues and encourage floaters to consider skill levels and the ages of children when choosing craft, trip segments, and the rapids they run (e.g., most discourage running Rocky Ford and Egelhoff's Narrows).

Aesthetics

Aesthetics of the water were rated among the most important flow-dependent attributes. This is consistent with the flow-aesthetics literature, which suggests (1) riverside recreational opportunities are enhanced by the aesthetics of moving water (Moore et al., 1990); (2) flows have significant effects on overall scenic evaluations (Brown and Daniel, 1991); and (3) recreation users can specify evaluations of flow levels (Land and Water Associates, 1992; Shelby et al., 1994).

While a review of river aesthetics research is beyond the scope of this report, very low and very high flows are generally rated lower than medium flows (Land and Water Associates, 1992; Brown et al, 1992). Issues at low flows usually include an exposed channel perimeter, stagnation, and the absence of visually-interesting currents and rapids (Shelby and Whittaker, 1999). Low flow aesthetic issues are important on the Niobrara, where ledges and mud flats become exposed at lower flows.

Rate of Travel

Rate of travel is a final important flow-dependent attribute. Interviewees reported that flows (and related current speeds) have a substantial effect on rate of travel (and the need to paddle harder / longer to keep on a trip schedule). They also recognized the importance of having time to stop at the falls and springs along the river.

Flows have a greater effect on rate of travel for tubers because they have less ability to increase their speed by paddling. When flows are low, some users plan shorter trips (and outfitters encourage this to meet their own daily schedules). Most information materials include estimates of floating times between access sites, indicating the importance of this variable.

Summary of Recreation-Relevant Hydrology

This section summarizes relevant hydrology during the recreation season (May through October) through a series of hydrographs. Figure 6 summarizes median daily flows for the period of record, while Figures 7 and 8 show flows for example wet and dry years (recent examples near the 25th and 75th percentiles). Similar information was provided to outfitters as a "hydrology fact sheet" to help them calibrate to the USGS gage.

Daily Flows Over the Period of Record

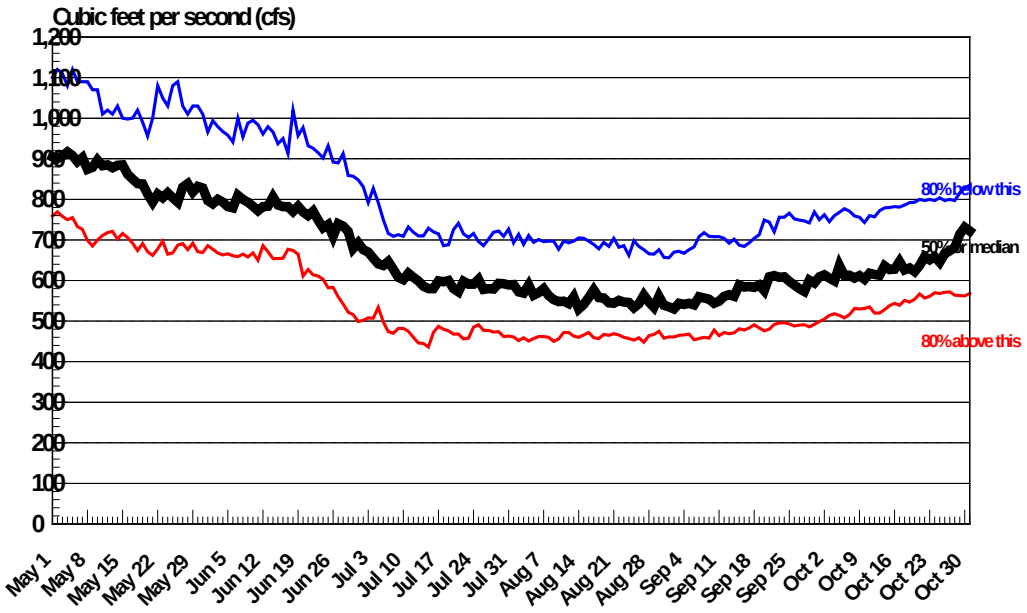

Figure 6. Median daily flows from May through October for the period of record (1946 to 2007) at USGS Sparks Gage (06461500).

Figure 6 summarizes median daily flows from April through October over 61 years of record. The ***thick black line*** shows the median or "typical" flow. In general, "typical" flows in early May are about 900 cfs, but they drop to 700-800 cfs by June, to 500-600 cfs from July through early September, and then rise to 600-700 cfs in October. The ***red line*** shows flows that might be expected during drier periods; only 20% of flows are lower (and 80% are higher) for each date. Similarly, the ***blue line*** shows flows that might be expected during wetter periods; only 20% of flows are higher (and 80% are lower) for each date.

The red and blue lines can be used to define a "typical range" of flows – most flows will be within these limits, which tend to be about 100 cfs higher or lower than the median. Because the Niobrara is a groundwater influenced stream, there is relatively less seasonal or year-to-year flow variation than on rivers with more water from rain or snow-melt. However, any individual year will have more flow variation than shown in these hydrographs (which are based on data collected for many years). In addition, recent year medians are probably slightly less than historical medians because water development has occurred in the basin (this issue is examined in greater detail in the "comparing flow regimes" section below).

Daily Flows in an Example "Wet" Year

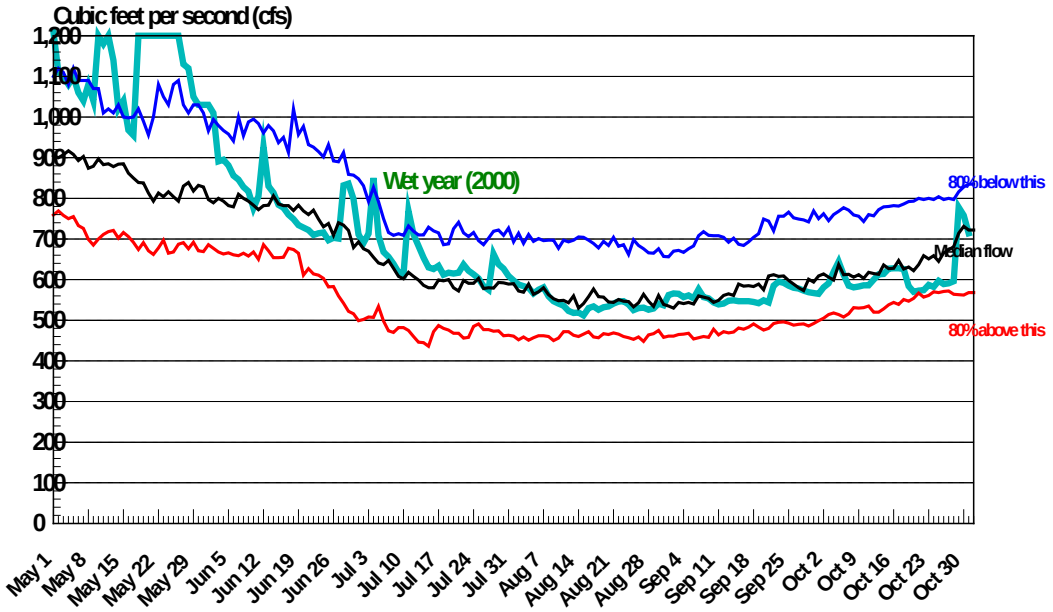

Figure 7. Median Daily flows May through October at USGS Sparks Gage (06461500) in an example "wet" year (with comparisons to the period of record).

Figure 7 shows an example "wet" year (2000) during the recreation season (May through October). For comparison purposes, the graph also shows "typical" flows (the black line) and the "typical range" (defined by the red and blue lines) from Figure 5. This wet year had a large peak in late May (the actual peak was 1,470, but has been truncated for display purposes) and several smaller peaks in mid-summer, but it generally followed the median and never fell below 500 cfs.

Daily Flows in an Example "Dry" Year

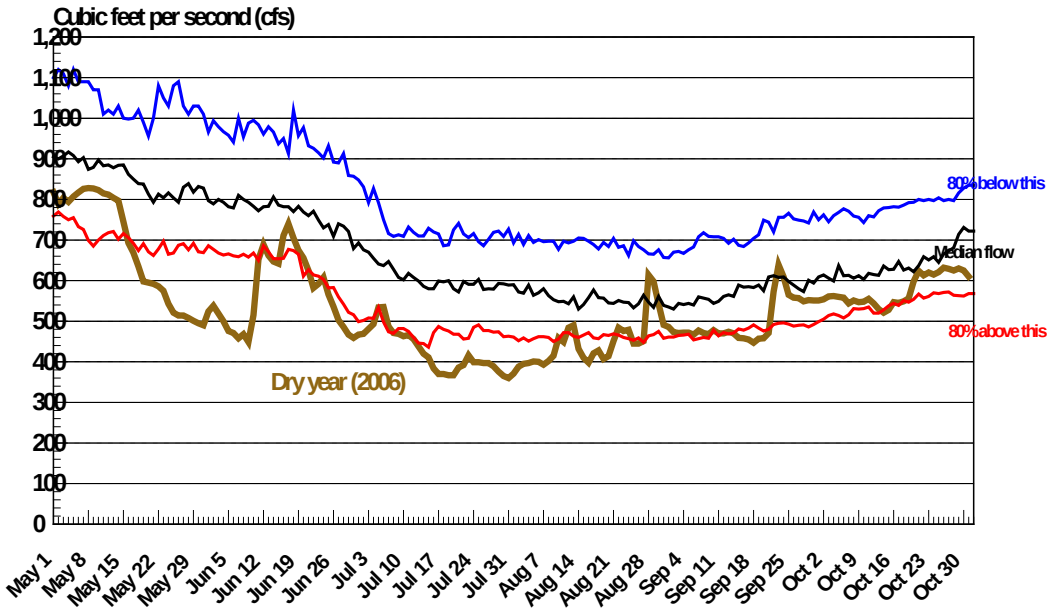

Figure 8. Median Daily flows May through October at USGS Sparks Gage (06461500) in an example "dry" year (with comparisons to the period of record).

Figure 8 shows an example "dry" year (2006). For comparison purposes, the graph also shows "typical" flows (the black line) and the "typical range" (defined by the red and blue lines) from Figure 5. This dry year had flows 100 to 200 cfs below "typical" levels for most of the recreation season. For about 26 days from July 16 to Aug. 8, the flow was at or below about 400 cfs (the low was about 360 cfs); it was also close to 400 cfs on August 16-17 and 19-20, before rising above 450 cfs for the rest of the season.

Flow Requirements for Boating Opportunities

Gage Calibration

On some whitewater rivers with highly "specialized" users, many boaters use detailed gage information to assess recreation attributes. Most Niobrara boaters and tubers are not "calibrated" to flows at the USGS Sparks gage in this way, which is not unusual given the characteristics of the river and its users. First, because the river is largely groundwater-fed, flows have been remarkably stable from year-to-year and through the recreation season (particularly the high use primary season). Second, many Niobrara users are first-time visitors and do not have previous trips to use for comparisons; they depend on outfitters to provide information about trip planning and whether flows are adequate. Third, many experienced Niobrara floaters live near the river and use informal gages such as "marker rocks" to indicate flows and assess conditions for boating. To help interviewees become calibrated to the USGS Sparks gage, we sent them a hydrology "fact sheet" to put them on an "equal footing" regarding this gage.

"Specified Flows" from Interviews

Interviewees were asked to specify flows that provide boatable conditions and identify acceptable and optimal flow ranges. Table 1 provides medians and the inter-quartile range (25^{th} and 75^{th} percentile responses) for several "specified flows." A median is the 50 percentile response (half the responses are lower and half are higher). Note: It is possible for the 25^{th} percentile and median (or the 75^{th} percentile and median) to be the same if enough respondents indicated the same response.

Table 1. Median flows and interquartile ranges for recreation opportunities on Niobrara NSR.

Specified flow for floating opportunities	Median (cfs)	25^{th} to 75^{th} percentile	*N*
Lowest flow that allows use of the river for transportation (minimum boatable flow)	340	319 to 336	10
Lowest flow that provides an acceptable quality "scenic trip"	460	450 to 500	21
Lowest flow that provides an optimal quality "scenic trip"	600	550 to 600	18
Highest flow that provides an optimal quality "scenic trip"	900	750 to 1,000	12
Highest flow that provides an acceptable quality "scenic trip"	1,200	1,050 to 1,200	4
Lowest flow that provides optimal whitewater in the three Class II-III rapids	800	740 to 1,000	10

The ***minimum boatable flow*** for "scenic trips" is about ***340 cfs***, which is close to the lowest summer flow in the period of record (320 cfs in 1980). In 2006, flows reached as low as 360 cfs on several days at the end of July, and several interviewees remembered them. The ***acceptable range*** is between ***460 and 1,200 cfs***. There was considerable agreement about the low end of this range (note the narrow inter-quartile range), but less agreement about the high end because fewer respondents had on-river experience at high flows which occur outside the primary season. The ***optimal range*** is between ***600 and 900 cfs***.

Median responses for ***tubing*** were similar to those for boating. Forty-one percent who estimated boating flows said tubing flows were the same; among those who reported differences, medians were similar to boaters for the lowest usable flow (350 cfs), the lowest acceptable flow (450 cfs), and the lowest optimal flow (600 cfs). However, optimum tubing ends around 750 cfs; higher flows tend to be colder or have hydraulics that can be problematic for inexperienced tubers.

Respondents familiar with the ***whitewater opportunities*** were asked to identify the lowest flow that creates higher quality whitewater in the three major rapids (Fritz's Island Ledge (Class II), Rocky Ford (Class III), and Egelhoff's Rapid (Class II)). The median response was ***800 cfs,*** although the inter-quartile range showed less agreement than specified flows for "scenic trips."

Fieldwork Assessments

Fieldwork on the Niobrara in July 2007 was conducted at about 440 cfs. Skilled boaters in lightly loaded craft were able to boat the entire river from Cornell Bridge to Norden Bridge, but all had multiple hits and stops, and some had to pull their boats across shallow stretches (particularly below Rocky Ford). "Paddle hits" were common for long stretches. Additional boatability issues included an unrunnable ledge on the right side of at Fritz's Island; required portaging at Rocky Ford; and the lack of powerful hydraulics at Egelhoff Rapid. Recreational canoers and tubers were seen dragging through shallow stretches or pushing their craft into the main current. Rate of travel was slow, requiring concerted paddling to keep on a trip schedule. Swimming areas with deeper holes were rare, and they attracted use when available.

Whittaker's River Management Society trip in May 2006 was at about 800 cfs. There were no boatability issues, the ledge at Fritz's Island was runnable (although shallow), and there were substantial waves and hydraulics at Egelhoff's Rapid. Class III Rocky Ford was also runnable (in a raft or canoes with floatation), and provided powerful hydraulics. However, even higher flows are necessary to kayak or raft Class IV Norden Falls with its current channel characteristics. At 800 cfs, the channel was filled to the vegetation line, with little exposed mud or ledges.

On the upstream Nenzel to Anderson segment, there were slightly more boatability problems than on the NSR, with acceptable but not optimal conditions (comparable to the segment below Rocky Ford). The estimated flow in the reach was 300 cfs (about 130 cfs less than the flow at the USGS Sparks gage due to tributary and groundwater inputs between Anderson and the gage). Although only about one-quarter of the Nenzel segment provided a wide alluvial channel, these areas consumed about half of the trip time due to stops and boat drags. The one substantial rapid (Class II-III Galloway's Rapid) was also unrunnable. The remainder of the segment offered high quality boating, with several long Class II rapids, high bluff and riparian scenery, wildlife, clear water, and stunning channel features (Rosebud sandstone ledges and drifting underwater sand formations). Boating flows on this reach are likely to be similar to those identified for the Niobrara NSR minus tributary inputs; the reach has channel characteristics similar to the Niobrara NSR through Fort Niobrara NWR.

Integrated Flow Evaluation Curve and Range Bar

Flow evaluation curves show how incremental changes in flows are related to recreation quality (Whittaker and Shelby, 2002). The curves are drawn on a graph that shows flow along the horizontal axis (in cfs at the relevant gage) and recreation quality along the vertical axis (the evaluation scale runs from totally unacceptable to totally acceptable with a mid-point at "marginal"). Curves typically have inverted U-shapes.

A curve for "scenic floating" was developed for this study (Figure 9). Key points on the curve are based on ***median responses*** to the specified flow questions for boating in the ***experienced user interviews*** (Table 1). The ***shape of the curve*** is based on ***previous studies, fieldwork, and professional judgment***. A "range bar" is superimposed to show ranges defined by the "threshold" medians in Table 1.

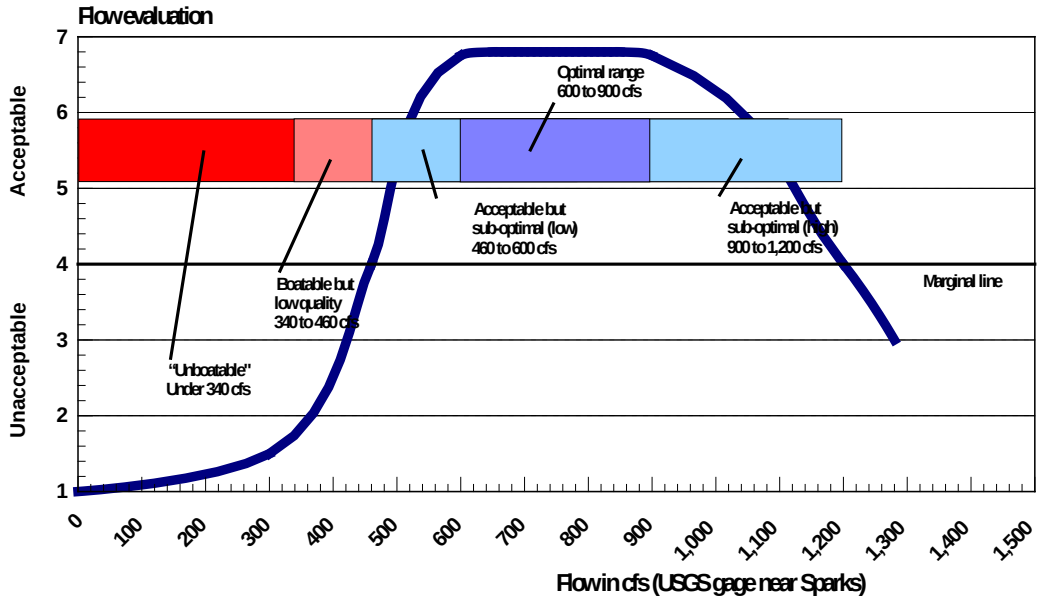

Figure 9. Flow evaluation curve and range bar for "scenic floating" opportunities on Niobrara NSR.

The curve shows that from 340 to 600 cfs, relatively small flow increases produce substantial improvements in quality. Flows change from unacceptable to acceptable around 460 cfs, and by 600 cfs they are near optimal. Boating is optimal from 600 to 900 cfs, and through this range increases in flows make little difference in quality.

A "tubing" curve (not shown) would be similar in shape to the "scenic floating" curve, but would begin to decline about 750 cfs. A whitewater curve (not shown) would become acceptable about 600 cfs and become optimal about 800 cfs; there is insufficient information to define when it would begin to decline (flows higher than 1,200 cfs are rarely available or boated).

Comparing Pre-Merritt, Post-Merritt and Potential Flow Regimes

This section compares the number of days that flows are in the range bar identified in Figure 9. Four different hydrologic regimes are considered:

1. The period of record before Merritt Reservoir was filled in 1964, which describes a "nearly-unmodified" regime. This is identified as ***"Pre-Merritt Reservoir."***
2. The period of record from 1964 to the present, which reflects the influence of Merritt Reservoir and any additional water development in the basin. This describes the "post-Merritt" regime, labeled ***"Post-Merritt Reservoir."***
3. A "flow scenario" where 50 cfs is removed from the post-Merritt regime, which illustrates how "modest" additional water depletion would affect recreation on the river. This is labeled the ***"Minus 50 cfs scenario."***

   A "flow scenario" where 100 cfs is removed from the post-Merritt regime, which illustrates how more substantial water depletion would affect recreation on the river. This is labeled the ***"Minus 100 cfs scenario."***

The "Minus 50 cfs" and "Minus 100 cfs" scenarios are intended to be ***illustrative;*** the amount of additional depleted water in these scenarios are round numbers designed to examine impacts of different levels of potential water losses. These scenarios were developed prior to recent state action declaring the upper basin to be "fully appropriated" pending a review of potential impacts of future depletions.

Analyses first show comparisons for the entire period of record (Figure 10), and then for an example wet year (2000, Figure 11) and dry year (2002, Figure 12). In all cases, we show results for the full recreation season (May-Oct) and primary recreation season (Jun-Aug).

Comparisons for the Period of Record

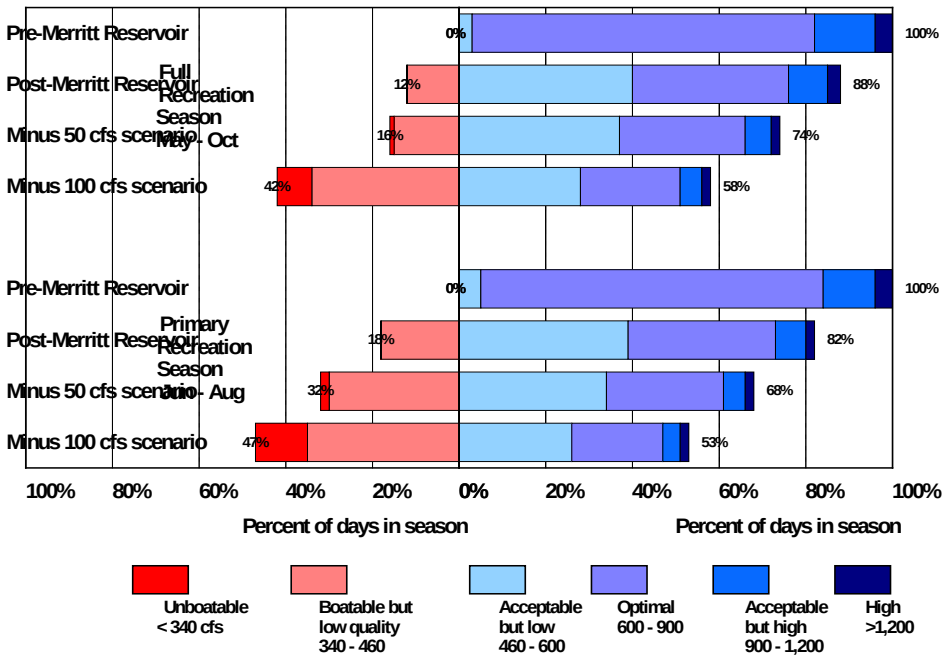

Figure 10. Percent of days in different flow ranges for recreation seasons for pre- and post-Merritt Reservoir periods and under conceptual withdrawal scenarios for Niobrara River NSR.

In Figure 10, comparisons of the ***top two bars*** for each recreation season illustrate the effect of Merritt Reservoir on Niobrara flows. Before Merritt, optimal or higher flows were (on average) available almost all of the full recreation season. Since Merritt, less than half the full recreation season has had optimal or higher flows, and about three weeks (12%) have been boatable but low quality (340 to 460 cfs).

Because floating use has grown since Merritt Reservoir was completed, users are probably accustomed to the post-Merritt regime (with substantial water removed). The post-Merritt regime also includes additional water development impacts from other diversions and ground water pumping.

In Figure 10, the "Minus 50 cfs" and "Minus 100 cfs" scenarios in the ***bottom two bars*** for each recreation season illustrate potential impacts on recreation compared to post-Merritt hydrology. In the "Minus 100 cfs" scenario, almost half (47%) of the days in the high use primary recreation season would be "boatable but low quality" or "unboatable."

Similar analyses follow for example wet (Figure 11) and dry (Figure 12) years. As one would expect, the effects of withdrawal scenarios are lesser in a wet year, but greater in a dry year. In the wet year, the "Minus 100 cfs scenario" produces 26% "boatable but lower quality" days and no "unboatable days" during the primary recreation season. In the dry year, the "Minus 100 cfs scenario" produces 27% "boatable but low quality" days and 44% "unboatable" days.

Example "Wet" Year

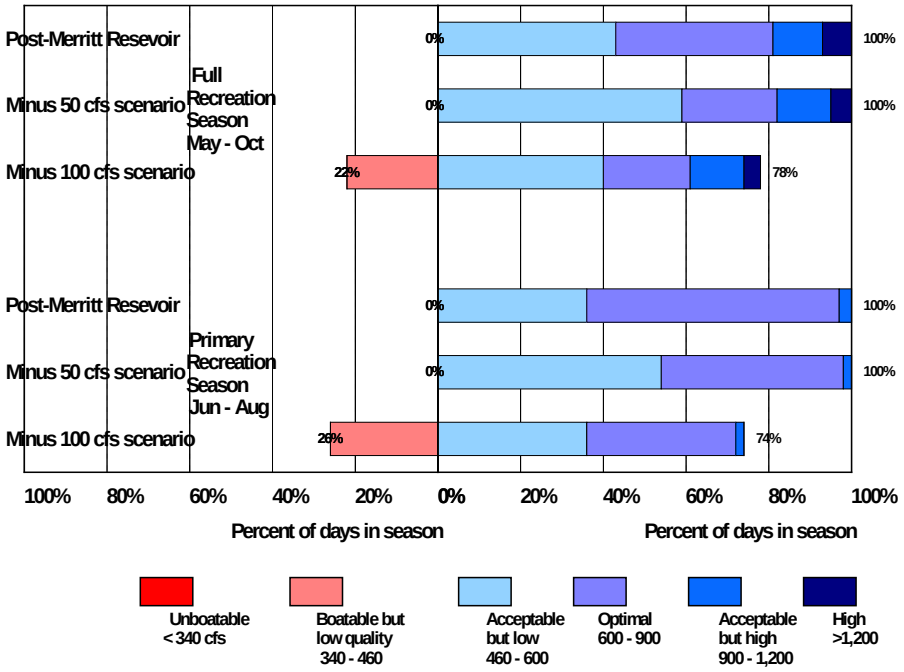

Figure 11. Percent of days in different flow ranges under post-Merritt and withdrawal scenarios in an example "wet" year (2000) on the Niobrara NSR.

Example "Dry" Year

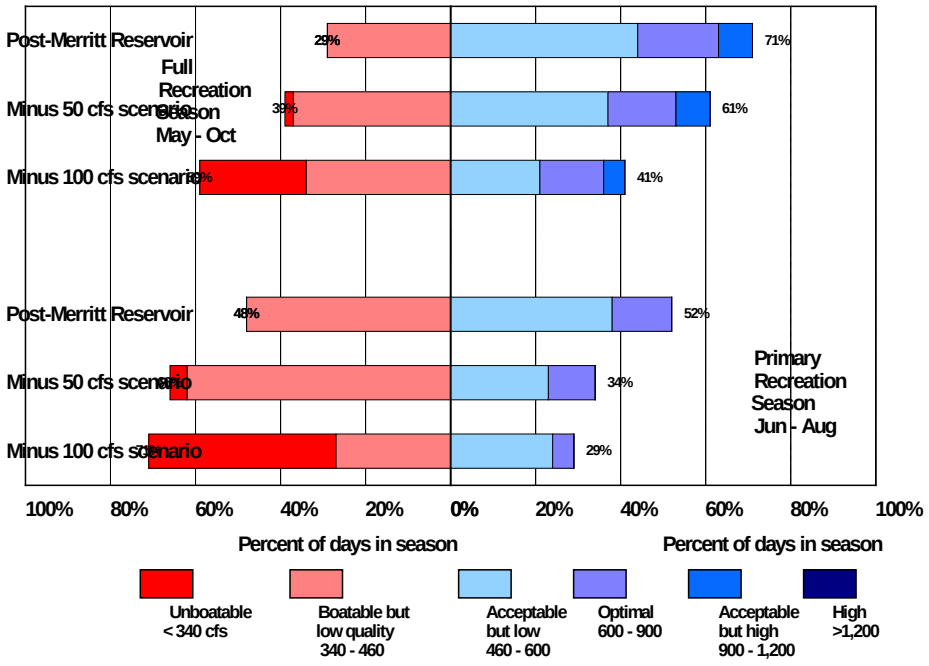

Figure 12. Percent of days in different flow ranges under post-Merritt and withdrawal scenarios in an example dry year (2002) on the Niobrara NSR.

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Appendix: Interview Questions

A. Identification

1. Name of interviewee.
2. Affiliation (if they have one).
3. Date of interview.

B. Profile Interviewee

1. How many years have you been outfitting (if outfitter).
2. How many years have you been taking boating trips on the river?
3. How many days per year on the river (on average)?

C. Attribute importance

Rate on a 4 point scale:
1. Not at all important.
2. Slightly important.
3. Very important.
4. Extremely important.

How important …

1. …is it to be able to boat/tube without becoming stopped/grounded or repeatedly hitting bottom with your paddle?
2. …is it to have multiple route choices through rapids or boulder gardens?
3. …is it to have safe conditions (for example, being able to avoid capsizing from hitting rocks)?
4. …is a well-paced current and its effect on rate of travel down the river?
5. …is it to have sufficient time to spend at falls or springs rather than being in your boat to stay on your trip schedule?
6. …is it to not have to paddle harder/longer to keep on your trip schedule?
7. …are the aesthetics of the water (the sights and sound of the water in the river)?
8. …is having minimal exposed mud along shorelines?
9. …is it to have few biting beetles or "toe biters" present among shoreline algae/vegetation?
10. …are having few "boat jams" (where multiple boats or tubes clog routes)?

D. Effect of flows on attributes

Please describe the effect that flow levels have on the following attributes?
Rate on a 4 point scale:
1. No effect.
2. Small effect.
3. Medium effect.
4. Large effect.

How much does flow effect…

1. …boatability such as the number of times boats/tubes become stopped/grounded or paddle repeatedly hits the bottom of the channel?

2. …the number of route options through rapids or boulder gardens?

3. …safety conditions (for example, being able to avoid capsizing, hitting rocks)?

4. … the pace of the current and its effect on rate of travel down the river?

5. …having sufficient time to spend at falls or springs rather than having to be in your boat/tube in order to meet your trip schedule?

6. …the need to paddle harder or longer to keep on your trip schedule?

7. …the aesthetics of the water (the sight and sounds of the water in the river)?

8. …the amount of exposed mud along shorelines?

9. …the number of biting beetles (or "toe biters") present in shoreline algae or vegetation?

10. …the number of "boat jams" (where multiple boats clog routes through rapids)?

E. Specified Flows

1. Do you pay attention to a gage, and if so, which one(s)?

2. How calibrated are you to the USGS gage at Sparks (Berry Bridge)?
   1=No knowledge.
   2=Some limited familiarity but depends on his/her own marker rocks.
   3=Good knowledge, but also watches own marker rocks.
   4=Excellent knowledge and uses it regularly.

Please specify the following (using the Sparks gage or provide date when that flow was observed).

	Canoeing / kayaking	Tubing (if different)	Whitewater (if different)
Lowest boatable flow to use the river for transportation			
Lowest acceptable flow (provides an acceptable quality trip)			
Lowest flow that provides optimal quality trips			
Highest flow that provides optimal quality trips			
Highest boatable flow			