Effects of Streamflows on River Trips on the Colorado River in Grand Canyon, Arizona

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ABSTRACT: Effects of flows on whitewater boating can be profound, but there is little evidence that shows impacts on specific trip attributes. A normative approach developed in other resource management applications is used to develop evaluative information about streamflows for whitewater trips in the Grand Canyon, below Glen Canyon Dam. A mailed survey was completed by 134 commercial river guides and 152 private trip leaders. Questions covered the effects of flows on trip quality and scheduling, quality and safety of rapids, camping, and visits to off-river attraction sites. For positive characteristics, such as the overall evaluation, ratings follow a bell-shaped curve, where flows below about 10,000 cubic feet per second (cfs) and above about 45,000 cfs are considered unsatisfactory, and 20,000–25,000 is the optimum. For negative characteristics, such as the likelihood of accidents, ratings follow a "U"-shaped curve. The study identifies the diversity of attributes affected by flows, evaluates specific effects of flows on those attributes, and presents methods for data collection, analysis, and interpretation. Such information is particularly helpful for developing flow requests, integrating recreation needs with the needs of other resources, and developing flow scenarios for dam operation. Changes in operating regimes for Glen Canyon Dam are being considered, based on this and other research conducted as part of the Glen Canyon Environmental Studies.

KEY WORDS: Instream flow, recreation norms, streamflow standards, whitewater boating.

INTRODUCTION

Streamflows affect river-related recreation in a variety of ways, and whitewater boating is one type of recreation in which effects can be profound. Understanding the relationship between streamflow and recreation is particularly important for rivers with flows that are dam regulated and, therefore, can be managed. Such information might also play a part in future construction or operation of dams or be used in applications for instream flow water rights.

There are few studies that identify specific recreation attributes affected by changes in streamflow. There is also little work that shows how to determine the specific relationship between flow level and a particular attribute (e.g., the point at which flows become acceptable or unacceptable, the point at which a certain percentage of passengers have to walk around rapids, etc.). Only by knowing how various flow levels affect specific attributes can managers provide high-quality recreation opportunities. In general, research on recreation and streamflows is recent and has been conducted in a variety of settings for different purposes (Brown et al. 1991; Shelby et al. 1992).

The relationship of recreation to streamflow, like other human-resource interactions, has both descriptive and evaluative components (Shelby and Heberlein 1986). The descriptive component shows the effects of different management alternatives on resource conditions. The evaluative component shows how humans respond to the physical conditions, helping to decide which set of conditions is better or more desirable.

To understand the effects of streamflows on recreation, descriptive information is needed that explains how different hydrologic regimes produce different biophysical conditions. Evaluative information is also needed to show what flows are necessary to provide minimally acceptable to high-quality conditions for desired recreation experiences. Descriptive and evaluative information combine to show the relationship between flows and recreation experiences. This approach fits with models for determining appropriate instream flows for recreation as well as recreation planning (Shelby et al. 1992).

Evaluative decisions about what "should" be are among the most difficult issues in resource management. Methods for collecting and analyzing evaluative information have received considerable attention in the resource management field. The basic strategy is to measure personal norms at the individual level, then aggregate data to develop group norms and assess the level of agreement. Normative information is particularly helpful in developing standards that define minimally acceptable or optimal conditions.

A normative approach has been applied to a variety of issues, including (1) encounter norms and norm agreement among anglers, canoers, and tubers on the Brule River in Wisconsin (Vaske 1977; Vaske et al. 1986); (2) encounter norms among Wisconsin deer and pheasant hunters (Heberlein and Alfano 1983); (3) river and camp encounter norms for floaters on three western whitewater rivers (Shelby 1981); (4) encounter norms for individuals mooring their boats off the Apostle Island National Lakeshore (Heberlein et al. 1986); (5) norms for perceived ecological impacts at wilderness campsites (Shelby et al. 1988); (6) norms for wildlife management practices (Vaske and Donnelly, unpublished paper); (7) different types of norms for different impacts (Whittaker and Shelby 1988); (8) encounter and proximity norms for salmon anglers in different types of settings (Martinson and Shelby, in press); (9) similarities and differences in ecological impact norms of interest groups (Shelby and Shindler 1992); (10) streamflow needs for different types of recreation (Shelby and Whittaker, unpublished paper); (11) results of exceeding norms for backpackers on the Appalachian Trail (Patterson and Hammitt 1990); and (12) impact and crowding issues on the New River in West Virginia (Roggenbuck et al. 1991; Williams et al. 1991). Shelby and Vaske (1991) offer an overview of this literature on recreation norms. We used the concept of recreation norms in our study to develop evaluative information about streamflows for river running in the Grand Canyon.

Objectives for this paper are to: (1) show the diversity of attributes affected by flows, even within a single activity (multi-day river trips in the Grand Canyon); (2) show the specific effects of flows for selected attributes; and (3) present methods of data collection, analysis, and interpretation for documenting effects of flows on recreation. Implications for assessing trade-offs are discussed briefly, although this is not a primary purpose.

METHODS

Our study was conducted as part of the Glen Canyon Environmental Studies (GCES), a series of studies managed by the U.S. Bureau of Reclamation to determine the downstream impacts of various release patterns from Glen Canyon Dam. The GCES are particularly relevant because flow regimes are currently being restructured as a result of findings from the project. The Grand Canyon Recreation Study was commissioned to examine the impacts on recreational activities and experiences, one of which is whitewater boating. The goal of the whitewater project was to identify the attributes of whitewater boating trips affected by flows and then to evaluate the effects of flows on those attributes. Baumgartner (1986) provides a complete study description.

River trips in the Grand Canyon are 225–280 miles in length and generally take 5–18 days. During the day, boaters float on the river, run whitewater rapids, and stop at attraction sites such as water falls or side canyons. At night, they camp on undeveloped beaches. Oar-powered trips take 5–18 days, using rafts or dories ranging in size from 14–22 feet. Motorized trips are shorter (5–9 days) and utilize larger (33–40-foot) rafts with 25–40-horsepower outboard motors. Commercial trips are operated by outfitters, whereas private trips are conducted on a do-it-yourself basis.

Flows in the Grand Canyon are regulated by Glen Canyon Dam. The dam is generally operated as a peaking power facility to supply power needs in the Southwest, with flows coming up in the morning and going down in the evening. It is possible for flows to fluctuate from 3,000 cubic feet per second (cfs) to 30,000 cfs in a matter of hours, with the stage level downstream rising or falling a number of feet. Reconstructed virgin flows at Lees Ferry indicate that mean monthly flows were historically about 10,000 cfs in the winter months; 20,000 cfs in April and August; and 50,000, 70,000, and 40,000 cfs in May, June, and July.

Pretesting and focus group meetings indicated that passengers on commercial and private whitewater boating trips were able to identify the important attributes of trips, but due to passengers' lack of experience, they were unable to specify the ways those attributes were affected by flow. To better understand the effects of flow, a survey was conducted using a sample of commercial guides and private trip leaders. Unlike passengers, guides and trip leaders have more whitewater boating experience. In addition, they pay attention to flow release data from Glen Canyon Dam, they have run the river many times at different levels, and they have observed the impact of flow on various trip attributes. Questions used in the study were developed in conjunction with this group, and item wording was pretested to verify that questions made sense to respondents.

The sample of commercial guides was selected from the National Park Service (NPS) file, with random selection of 190 names from the 450 included in the file. For private trips, the NPS file identifies the most experienced boatman for each trip, hereafter referred to as the trip leader. Trip launch records for 1985 produced a list of 195 private trip leaders.

A mailed survey was conducted by sending an advance letter, a survey and cover letter, a reminder/thank you postcard, and (for nonrespondents) up to two follow-up mailings. Of the 385 surveys mailed, 16 were undeliverable. Responses were received from 80 commercial motor guides, 54 commercial oar guides, and 152 private trip (all oar) leaders, for response rates of about 78% for all three groups. Respondents were asked to answer all questions based on the type of boat they used most often for their trips.

Questions about flow effects included four general categories (the wording of specific questions is given in the text of the results section). Effects on the overall quality of the trip were assessed by asking about overall preference for flow, the need to row or motor more or less in order to stay on schedule, and changes in trip itinerary. Effects on rapids were assessed by asking about the quality of the ride in rapids, safety, and having passengers walk around rapids. Effects on camping were assessed by asking about getting to camp at reasonable times, hurrying to break camp, flood-

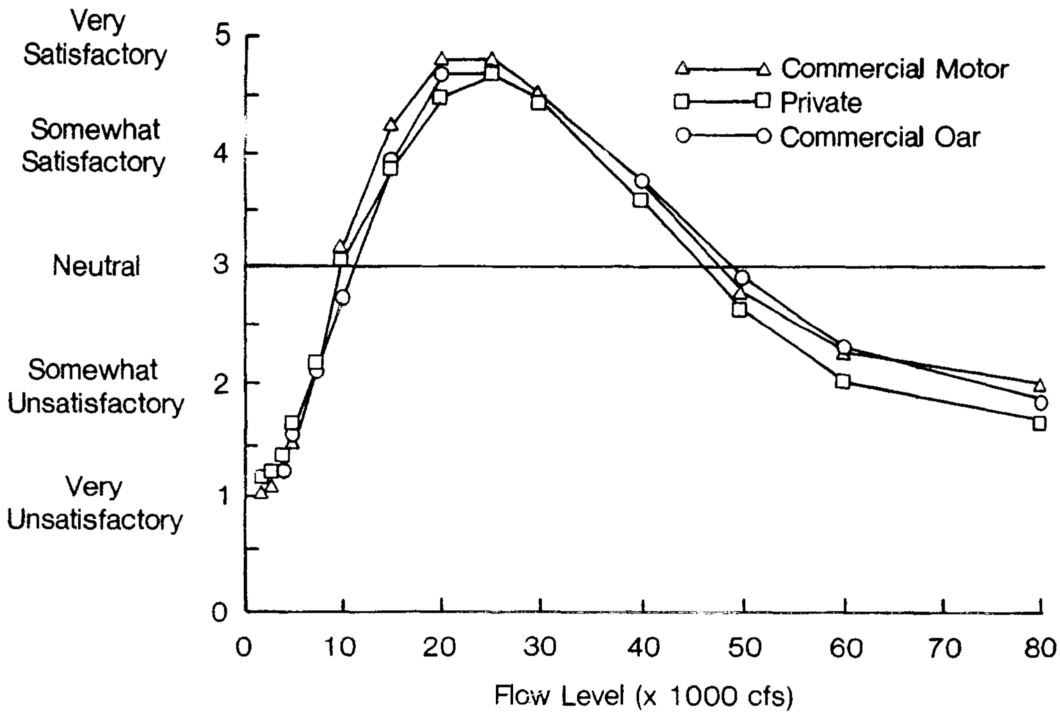

FIGURE 1. *Guides' constant flow level preference ratings.*

ing of camps, and stranding or moving camping gear. Effects on visits to attraction sites were assessed by asking about the amount of time for hikes.

RESULTS

Overall Trip Quality

Respondents were asked, "How would you evaluate each of the following water levels? Assume the water level would be constant for the entire trip." Respondents were given 14 different levels ranging from 2,000 to 80,000 cfs, and were asked to rate each one from 1 (very unsatisfactory) to 5 (very satisfactory). Averaging each group's evaluations for each flow level makes it possible to plot flow evaluation curves as shown in Figure 1. The curves show considerable agreement among the three groups. Flows are rated as unsatisfactory below about 10,000 cfs, the point where the curves cross the neutral line. The highest ratings are reached at 20,000–25,000 cfs, after which they begin to drop. The curves cross the neutral line again at about 45,000–50,000 cfs, suggesting that flows above this level are too high. There was also considerable agreement within groups; the 95% confidence intervals for the mean ratings at any given flow level are about ±0.2 rating units for all groups. It should be noted that on average across flow levels, a sample size of about 15 respondents is needed to estimate the mean preference ±0.5 rating units. At the higher flow levels where there is less agreement, a sample size of about 30 is needed for the same precision. Required sample sizes are also greater for questions that show less agreement (e.g., the need to hurry to break camp). In general, there was greater agreement within groups at the lowest and most preferred flow levels, with less agreement at the highest flows.

Respondents were asked to indicate the low flow levels at which they had to "row or run the motor more than usual to make up some time," and the high flow levels at which they could "row less than usual or turn off the motor because you are ahead of schedule." For each question, respon-

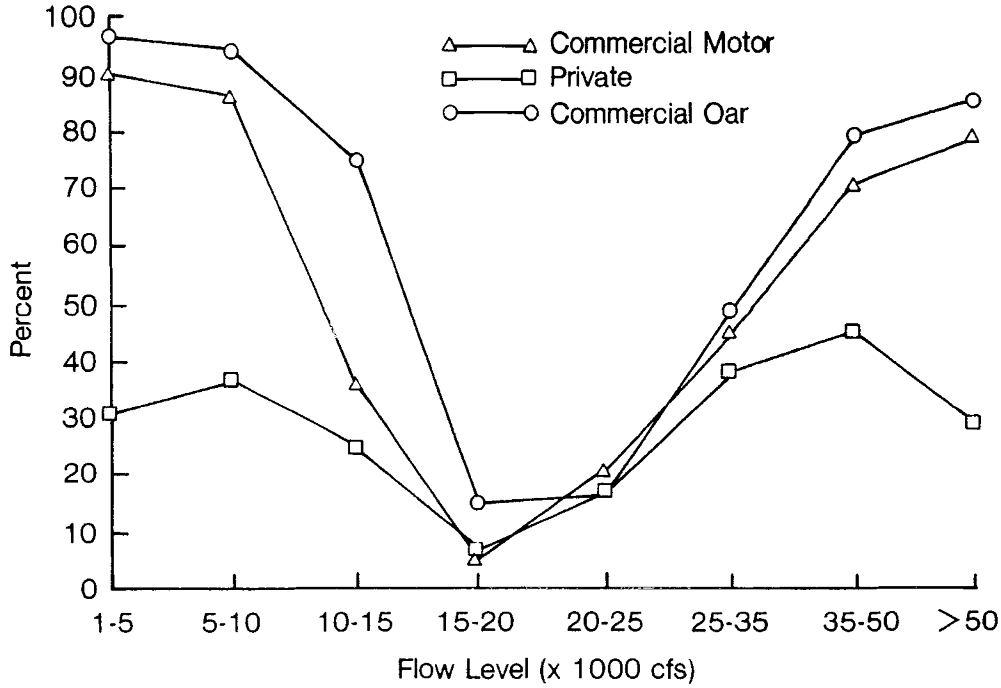

FIGURE 2. ***Percent of respondents who run motor or row more or less than usual to compensate for current speed.***

dents were given the flow alternatives listed in Figure 2; they simply checked those that were applicable. Results show that these adjustments are more likely for commercial guides than for private trip leaders, perhaps because the former are on tighter schedules. The percent of respondents who make such adjustments is greatest for flows from 1,000–10,000 cfs and from 35,000–50,000 cfs. Trip schedules are apparently geared for the 15,000–25,000 cfs range, where the fewest adjustments are reported.

Respondents were asked what they would do if their trip "was making good time and 6–8 fewer hours of river time was needed to complete the trip in the scheduled time." The seven possible responses are listed in Table 1; respondents answered by indicating how likely each one was on

TABLE 1
Reported adaptations to extra time on a raft trip

	Commercial motor	Commercial oar	Private trips
Percent who would be *very likely* to:			
Stop at additional attractions	86%[a,b]	94%[a]	77%[b]
Spend more time at attractions	78[a]	88[a]	66[b]
Spend a layover day	13[a]	50[b]	61[b]
Make camp earlier	30	24	47
Stay in camp later	20	22	27
Take longer lunch breaks	14	14	20
Spend more time scouting rapids	3	2	10
Turn motor off and float	66[a]	36[b]	—[c]

[a,b] Different superscripts indicate differences between means or percentages are statistically significant at the 0.05 level.
[c] — indicates questions not asked of private guides.

TABLE 2
Effects of flows on trip characteristics

	Commercial motor	Commercial oar	Private trips
Mean flow level for *best ride* for passengers (cfs)	20,901[a]	23,490[b]	25,208[b]
Standard deviation	5,828	8,552	7,802
Mean *minimum* level (cfs) for safety with passengers	8,405	9,198	9,025
Standard deviation	3,344	4,859	4,271
Mean *maximum* level (cfs) for safety with passengers	59,014[a]	54,910[a]	47,210[b]
Standard deviation	25,292	23,635	16,306
Percent who felt that certain flow levels cause problems with access and use of camps	80%[a]	96%[b]	86%[a,b]
Mean constant flow level below which getting to camp on time is a problem (cfs)	8,125[a]	9,298[a,b]	10,025[b]
Standard deviation	3,221	3,983	4,642
Mean constant flow level above which campsites are limited (cfs)	41,017	44,500	41,375
Standard deviation	13,640	13,902	13,671
Mean daily fluctuation range above which problems occur at campsites (cfs)	9,549	10,467	8,709
Standard deviation	5,019	7,409	5,829
Percent who felt that certain flow levels cause problems with attraction sites	87%[a,b]	96%[a]	85%[b]
Mean constant flow level below which there would not be time for certain attraction sites (cfs)	8,746[a]	10,398[b]	10,156[b]
Standard deviation	3,237	4,285	4,176
Mean constant flow level above which there would be extra time for attraction stops (cfs)	29,312	32,896	30,441
Standard deviation	11,103	10,133	9,392

[a,b] Different superscripts indicate differences between means or percentages are statistically significant at the 0.05 level.

a scale from 1 (not at all likely) to 3 (very likely). All three groups indicated they would be most likely to spend the extra time at scheduled and additional attraction sites. Commercial oar guides and private trip leaders indicated they would also spend a layover day at a campsite, while motor guides would turn off the motor and float. Spending more time in camps, at lunch breaks, and scouting rapids were less likely alternatives.

Rapids

Respondents were asked about the effects of flow on the quality and safety of rapids (again assuming constant flow). Average responses for the level that provides "the best ride for passengers" are shown in Table 2. The average for commercial motor guides is about 20,900 cfs, whereas the averages for commercial oar guides and private trip leaders are about 23,500 and 25,200 cfs, respectively.

Minimum and maximum levels for "running safely with passengers" are shown in Table 2. The average minimums for the three groups range from 8,400–9,200 cfs. The average maximums are about 47,200 cfs for private trip leaders and 54,900 and 59,000 cfs for commercial oar and motor guides, respectively.

Respondents were asked, "do you feel that accidents such as losing equipment, damaging a boat, or passengers falling out of a boat are more likely under certain flow levels?" Depending on the group, 81–93% of the respondents said "yes." These respondents were asked to check the flow levels at which they thought accidents were more likely to happen (Figure 3). All three groups indicated that accidents were more likely at low and high flows than at medium flows.

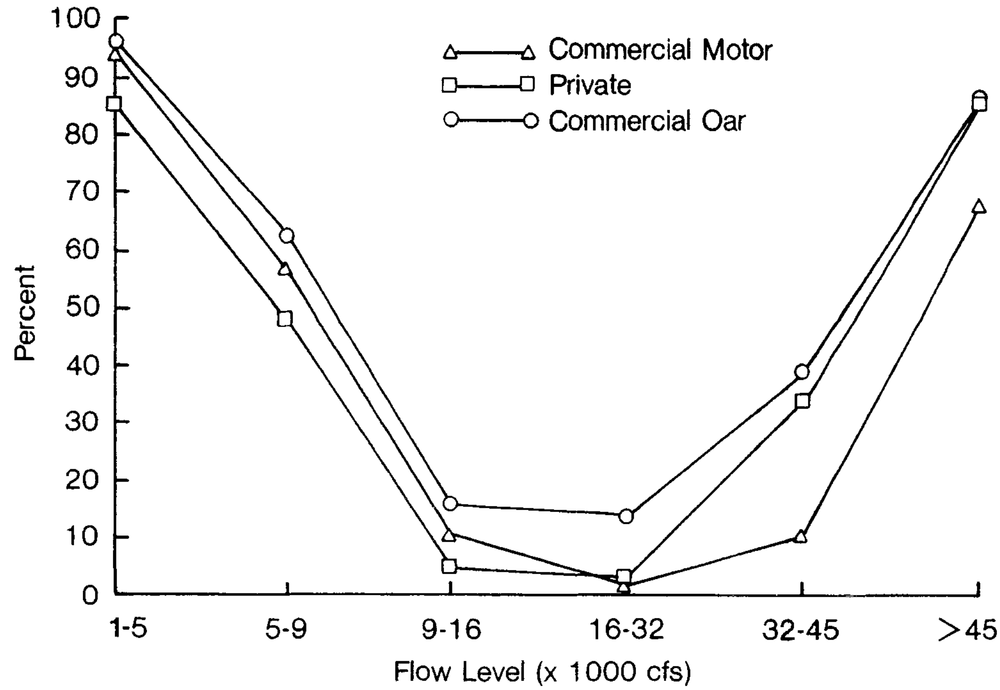

FIGURE 3. *Percent of respondents who think accidents are more likely to happen at constant flow levels.*

Respondents were also asked about having passengers walk around rapids because the flow is too low or too high, which is related to concerns about safety. As Figure 4 shows, this is most likely at very low and very high flows. Commercial oar guides are most likely to have passengers walk around rapids.

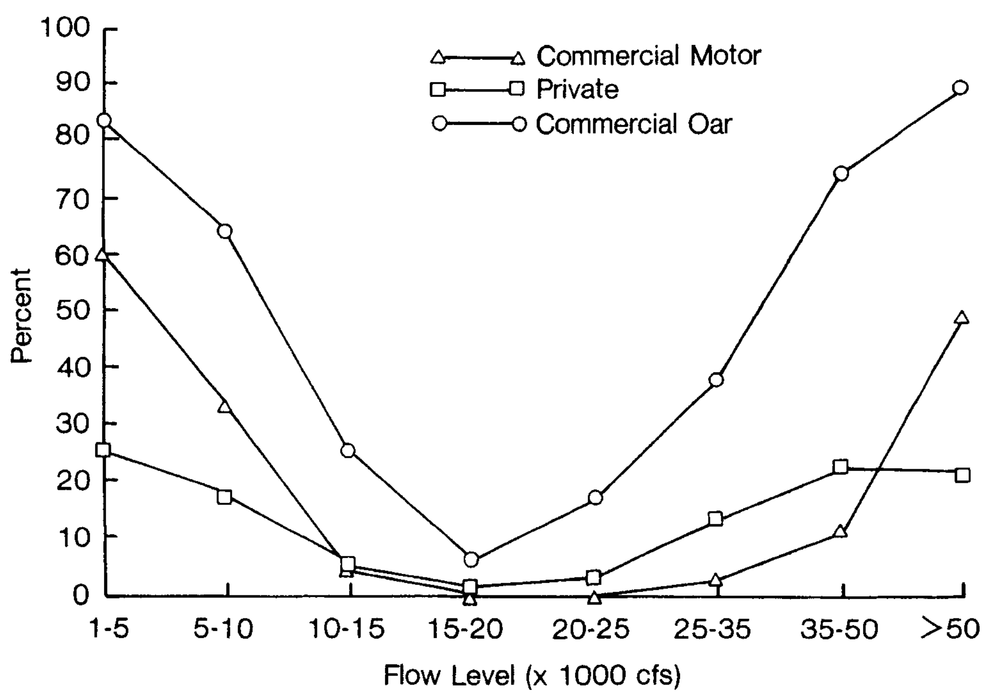

FIGURE 4. *Percent of respondents who have passengers walk around rapids at constant flows.*

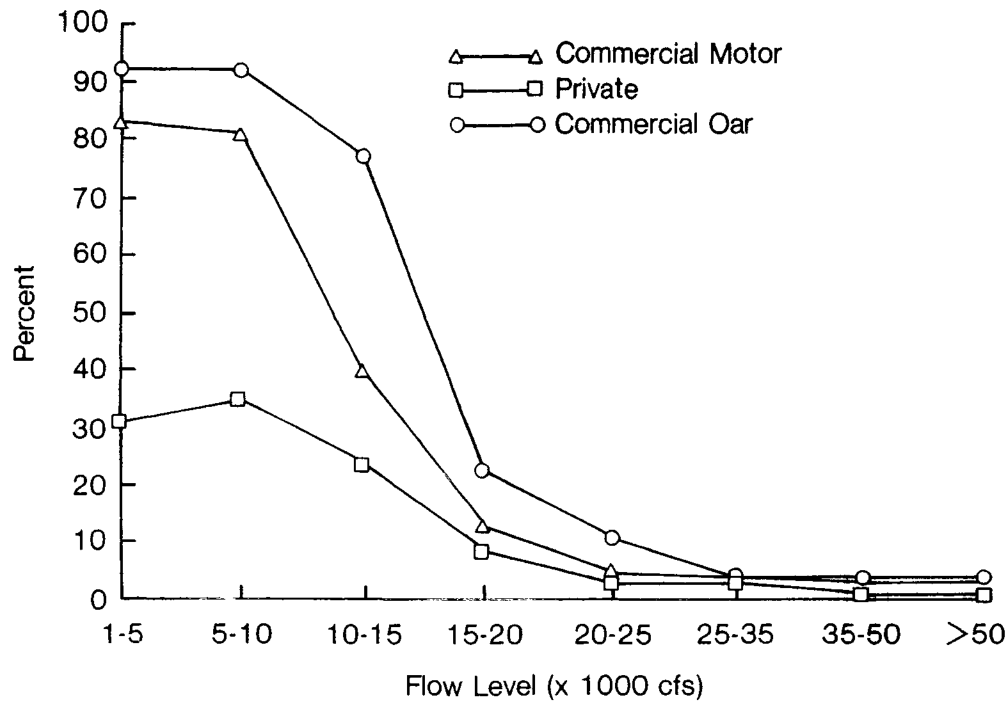

FIGURE 5. *Percent of respondents who have passengers hurry to break camp at constant flows.*

Camps

Respondents were asked if "certain flow levels cause problems with access to or use of campsites," and 80–96% said "yes." These respondents were asked to indicate the level at which specific problems occurred (Table 2). Below a flow of about 10,000 cfs, there are problems getting to camp on time (Figure 5). Above flows of about 41,000 cfs, important camps might be unavailable because they are under water. Fluctuations in flow also affect camping. With daily fluctuations greater than 9,000–10,000 cfs, respondents report problems with boats left "hanging" on beaches by receding water, problems loading boats, or having to move camp gear to avoid being inundated.

Attraction Sites

Respondents were asked whether "certain flow levels cause problems with access to or use of attraction sites," and 85–96% said "yes." These respondents were asked to indicate the level at which specific problems occurred (Table 2). Respondents reported that flows below 8,700–10,400 cfs would not allow enough time for stops at attractions because of the need to "make up time," whereas flows above 29,000–33,000 cfs would permit extra time for stops.

Flow Release Scenarios

Respondents were presented with four different flow scenarios, each representing a different way to "spend" the available annual "water budget." Scenario A provided constant flows in the 8,300–14,600-cfs range, with no daily fluctuations. Scenario B provided constant flows of 25,000 cfs during the summer season, with daily fluctuations from 1,000–31,000 cfs the rest of the year. Scenario C provided daily fluctuations from 3,000–31,500 cfs during the summer and from 1,000–31,000 cfs during the rest of the year. Scenario D provided daily fluctuations from 8,000–25,000 cfs throughout the year.

Respondents were asked to evaluate each scenario on a five-point scale, from "completely acceptable" to "completely unacceptable." Results indicate that the moderate daily fluctuations of Scenario D were most acceptable (Table 3). This scenario was preferred because it offered the high flows

TABLE 3
Percent ranking scenarios as unacceptable[a]

	Commercial motor	Commercial oar	Private trips
Scenario D (moderate daily changes)	16%[b]	33%[c]	34%[c]
Scenario A (constant daily flows)	25[b]	44[c]	33[b,c]
Scenario B (less severe daily changes)	59	54	53
Scenario C (severe daily changes)	91	89	93

[a] Percent ranking scenario as somewhat or completely unacceptable on a five-point scale that also included "neutral" and "somewhat" or "completely acceptable" categories.
[b,c] Different superscripts indicate differences between means or percentages are statistically significant at the 0.05 level.

necessary for efficient travel times and the best ride through rapids, without the hazards of low flows and extreme or unpredictable fluctuations.

DISCUSSION

Streamflow affects a variety of resource values. If flow studies only consider the impacts on a single resource value (e.g., power generation, fishery, recreation), it is likely that the broad range of possible outputs will not be optimized. To include recreation benefits, it is important to specify the relation between flow and important characteristics of recreation experiences.

Our study shows that flow affects recreation experiences in many ways, even within the single activity of multi-day river trips. These factors include overall quality of the trip, trip itinerary, quality of rapids, safety of rapids and the ability to allow passengers to run them, getting to camps at reasonable times, availability of camps, hanging or moving camps, and the amount of time for stops at attraction sites.

Our study also shows how flow affects specific attributes. For positive characteristics such as the overall evaluation, the ratings followed a bell-shaped or inverted "U" curve, where very low and very high flows are considered unsatisfactory. For negative characteristics such as the likelihood of accidents, having passengers walk around rapids, or rowing or motoring to compensate for current speed, the ratings follow a "U"-shaped curve. The curves can be used to show the general relationship between flow and characteristics of the recreation experience or to identify the specific effect of a particular flow on a particular trip attribute.

This kind of information can be used to develop standards for flow management regimes. Given management objectives that specify the types of recreation opportunities to be provided, the data indicate ways in which flows affect important characteristics of recreation experiences. It is also possible to get users to evaluate different flow scenarios.

This kind of information is also important for assessing trade-offs between different resource outputs. For example, the flow scenarios evaluated by respondents in this study were developed with possible alternatives for power generation in mind. Subsequent studies have also documented the effects of flows on other resource conditions, including beaches, riparian vegetation, and fish and wildlife habitat. The Bureau of Reclamation and the National Park Service are currently considering the complex trade-offs between resource outputs, trying to develop flow regimes for Glen Canyon Dam that strike a balance. Although this optimization process is beyond the scope of the present paper, it clearly requires the kind of detailed information for all resource values that is developed here for recreation.

Our study suggests methods for collecting information about the effects of flow on recreation. The attributes to be investigated were identified through the attribute survey of passengers and a focus group meeting with guides. The guides' survey then provided the opportunity to quantify the effects of flows on those attributes. For example, passengers indicated that important characteristics of trips included camping, exciting rides through (rather than walking around) rapids, and stopping for hikes at attraction sites. The guides' survey identifies the flows that avoid problems at camps, allow passengers the best ride through rapids, and provide the time for stops at attractions.

The Grand Canyon study was more elaborate than may be necessary for some other locations. However, it provides an extensive list of attributes potentially affected by flows, which is particularly useful when trying to identify important flow-related attributes in a new setting. The study also provides methods for quantifying flow-attribute relationships. It also became clear during this study that inexperienced users (in this case passengers) were unable to identify the ways in which flow affected river trips, even though they could identify the characteristics of the trip that were important to them.

This paper provides several different types of analyses for evaluating different flows. We find the curves particularly useful because they show the full range of effects of flow, rather than the single point provided by measures of central tendency, such as means or medians. Curves are also clear and visually appealing, and they are intuitively meaningful to people in the hydrology field who are accustomed to hydrographs.

Any discussion of streamflows for recreation should require curves showing the effects of the complete range of flows for the particular activity in question (Shelby et al. 1992). Even if curves are generated as "hypothesized" relationships, without supporting data, they still force a clearer understanding of the assumptions about how flow affects recreation quality. When requesting a single flow, the curve clarifies whether the request will provide minimum or optimum flows.

Our research suggests some interesting topics for future studies. First, it is important to investigate the development of overall evaluation curves. Researchers should explore additional survey questions that focus on building this knowledge. Next, it is important to develop techniques to integrate information about recreation flow needs with the needs of other instream uses of water, such as fisheries, channel maintenance, sediment transport, and recreation, into a single set of recommendations. Finally, standards are needed to guide analysts in conducting future studies of recreation flow needs. By using a common set of standards, we can develop a base of comparable data. These questions provide promising research opportunities with important management implications.

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