Youghiogheny River Recreational Capacity Study

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EXECUTIVE SUMMARY

Section A: Introduction

This study was designed to obtain the types of information needed by the Maryland Department of Natural Resources (MDNR) to create a plan that will facilitate effective management of the Upper Youghiogheny River corridor now and in the future. Study objectives included:

1) To identify the hydrological characteristics of the Upper Youghiogheny River, including the travel time characteristics of Deep Creek Lake hydropower releases, the limiting factors for whitewater boating navigability on the river, and the long-term availability and dependability of navigable flows for whitewater boating.

2) To examine existing and potential recreational uses of the Youghiogheny River and its immediate vicinity.

3) To assess the resources available to respond to emergency situations that can arise within the river corridor.

4) To describe the environmental impacts of recreation on the Youghiogheny Wild River segment.

5) To identify the economic impacts resulting from whitewater boating on the Youghiogheny.

6) To identify optimum capacities of the Youghiogheny River corridor for whitewater boating.

7) To evaluate various management alternatives and develop recommended strategies for management of recreational activities within the river corridor.

Section B: Hydrological Assessment

This section of the study considers the hydrological characteristics of the river and their implications for whitewater boating. This assessment focuses on three major questions. First, what are the travel time characteristics of Deep Creek Lake hydropower releases into the Youghiogheny River? Secondly, what are the limiting factors for raft, kayak, and canoe navigability on the Upper Youghiogheny? Finally, based on historical records, what is the long-term availability and dependability of navigable flows for whitewater boating?

Travel Time Characteristics of Deep Creek Lake Hydropower Releases

This section describes river flow characteristics between Sang Run and Friendsville (the "Upper Yough" section) from a Deep Creek hydropower release. These characteristics are useful for understanding the time limits on raft, kayak and canoe navigability from hydropower releases. In particular, the most limited periods, which typically occur during the late summer, are addressed.

From flow theory, the time period of full elevated flow from a hydropower release becomes progressively less at positions further downstream. In other words, with a two-hour generation release, the time period of full flow at Sang Run is less than two hours, the time period of full flow at Gap Falls is less than the time period at Sang Run, etc.

From field measurements at times of very low natural river flow, the full elevated flow (2.0 feet on the Sang Run gauge) from a three-hour generation release lasts for approximately one hour and 20 minutes at National Falls and one hour at Cheeseburger. From these measurements, it can be accurately predicted that full flow for a two-hour release lasts 20 minutes at National Falls and for only an "instant" in the area of Powerful Popper to Cheeseburger Falls. This area is the last of the tightly spaced Class 5 rapids.

Despite the lack of measurements for a two-hour release, the measured data provide meaningful insight concerning the capacity limitations for the Upper Yough at very low natural flows. The measurements of three-hour releases and conditional predictions for two-hour releases are consistent with comments from experienced raft guides and boaters saying there are "15 to 20 minutes of water" in the lower section of the Upper Yough. This period of water exists because the drop in water level initially falls slowly. The predictions are also consistent with the comment that the lower section has "more push" with a three-hour release versus a two-hour release. There is "more push" because there is a full elevated flow in the lower section with a three-hour release.

The time duration of navigable water increases significantly with relatively small increases in natural flow. For example, the period before an experienced boater would notice a reduction in water level at Cheeseburger Falls increases from 20 minutes at a flow of 2.0 feet to 35 minutes at 2.1 feet and 70 minutes at 2.2 feet.

Minimum Time Limits for Raft, Kayak and Canoe Navigability

The travel time characteristics of hydropower releases, combined with the topography of the river at Lost and Found rapids, results in this area becoming the most limiting factor to boating on the Upper Youghiogheny River. The most severe limitations are found during two-hour releases at times of very low natural river flow (2.0 feet on the old Sang Run gauge). Under these conditions it is likely that some rafts will be forced into "unacceptable" flow levels if there are more than 15 to 20 rafts on the river. Some private boaters may also be impacted by being forced to take a less preferred route or to run the rapids at an undesirably low water level.

The current whitewater boating regulations limit the number of commercial customers to 72 per day. Assuming three customers per raft, this limit allows 24 commercial rafts per day. In reality, 72 customers generally will translate into more than 24 rafts because some rafts will have fewer than three customers. In addition, there are no restrictions on private rafting activity so it is likely that private rafts would increase the total number of rafts on the river to some degree. Thus, under the current regulations, it is possible that the number of rafts using the river will exceed the number that can safely negotiate the most limiting "bottleneck" on the river during two-hour releases when natural flow is very low. Such conditions can be expected to occur some years during June and July. For example, these conditions were found during the very dry summer of 1988 but did not occur during 1989.

Under less limiting conditions resulting from longer hydropower releases, higher natural flow, or both, the period of navigability at Lost and Found increases substantially so it is unlikely that the number of boats currently permitted on the river would exceed the limits of navigability.

Long-Term Availability and Dependability of Navigable Flows for Whitewater Recreation

In general, there are three hydrological periods (spring, June/July, and August/September/October) defining a different availability and dependability of navigable flows for whitewater recreation.

In the spring (April, May), natural flows are often sufficient for navigation without a hydropower release. Because of the higher base flows in the spring, a release can often make the river too high for many boaters.

In the June/July period, natural river flows are sufficiently low most of the time so that a hydropower release is needed for navigability and the river is seldom too high with a release. Because of generally low inflow into Deep Creek Lake and evaporation from the lake, releases are generally infrequent and of short duration. It is projected that 19 and 35 percent of the years for June and July, respectively, can only have the minimum one two-hour release per week with some lowering of the lake below 2460 feet (maximum of 1.0 feet below 2460). For a minimum of 4 hours of water, the projections are 30 and 55 percent of the years for June and July, respectively, However, the lake levels will be lower at the end of July with a maximum of 1.2 feet below 2460 feet.

In the August/September/October period, natural flows are generally even lower than in June/July. However, in the later part of August, the lake level starts to be lowered, adding significant amounts of water for hydropower generation. For most years there is sufficient water during the months of August and September for a minimum of 17 hours of generation a week. For October the minimum is 10 hours.

During times of very low river flows, evaporation from the lake can exceed the lake inflow. Evaporation is estimated to be 0.17 inches a day (0.44 feet per week or 25 cfs). A single two-hour generation release uses water that would lower the lake by 0.33 inches. In recent dry years (1987 and 1988), average generation in July was approximately 5 hours of generation per week, using the equivalent of 0.32 feet of water. Thus, during dry periods, the amount of water loss to evaporation exceeds the amount of water used for generation, with both factors contributing to a lowering of the lake level.

Since a large part of the decreasing lake level is a result of evaporation and leakage, small increases in the length of power generation would cause small changes in the Deep Creek Lake level. One additional hour of generation per week during June and July would lower the lake level at the end of July by 0.13 feet (1.6 inches).

Section C: Recreational Use Assessment

This component examines the recreational uses of the Upper Youghiogheny River corridor. The assessment focuses first on documenting whitewater boating use patterns and then on various other recreational activities occurring within the river corridor.

A variety of data sources contributed to this recreational use assessment, including various published reports and public documents, interviews with knowledgeable parties, use statistics submitted by all commercial outfitters offering whitewater trips on the river, counts of river users by study personnel, and surveys of river users and adjacent landowners.

Whitewater Boating on the Upper Youghiogheny

Whitewater boating on the Upper Youghiogheny was observed during two distinct sampling periods, August 15 - October 14, 1988 and April 14 to August 11, 1989. The *total number of boats* on the river on any given day ranged from zero to 117, and averaged 49 during 1988 and 33 during 1989. The number of *rafts* on the river was nearly identical during 1988 and 1989 (average = 17 per day each year). The major difference between years was much smaller numbers of kayakers during 1989, which probably resulted largely from the higher water levels present in 1989.

The number of raft customers (average = 41 in 1988 and 43 in 1989) was usually well below the limit of 72 per day imposed in the newly-enacted whitewater boating regulations. For the majority of days during both 1988 and 1989, there were 48 or fewer commercial customers on the river.

Records submitted by all commercial outfitters indicated that commercial rafting has grown steadily and dramatically since the beginning of commercial outfitting on the Upper Yough in 1980. Use trends on other eastern rivers and results of our visitor surveys suggest that boating use levels on the Upper Yough will continue to increase. The lack of growth in rafting use between 1988 and 1989 is likely attributable to the whitewater boating regulations that took effect at the beginning of the 1989 season, along with the higher water levels that diverted some rafters to other rivers.

Total whitewater boating use during 1988 was estimated from a combination of data sources used in this study. Approximately 10,000 boaters ran the Upper Youghiogheny during 1988, 6,400 of whom were rafters and 3,600 were users of single-person craft (mostly kayaks). This estimate was needed to identify the economic impact of boating on the Upper Yough (Section F of this report) and for developing recommendations for management.

Other Recreational Uses of the Youghiogheny River Corridor

Relatively little information exists about the extent and nature of other recreational activities occurring in the Youghiogheny River corridor. Camping is one popular activity that occurs in three state parks located within or near the river corridor and at other public and private areas. With campgrounds typically full on summer weekends, the amount of overnight camping in these parks has remained quite consistent since 1985.

Growth in the numbers of campers during weekdays and during spring or fall may contribute to the growth of whitewater boating in the future.

Estimates from surveys of Maryland fishing license holders reveal that nearly 10,000 anglers fished the Upper Yough or its tributaries during 1987. Much of this angling takes place on Muddy Creek and Bear Creek and on the Youghiogheny near Swallow Falls State Park. Relatively little fishing occurs downstream from the park because of limited public access to the river. Angling along the river can be expected to increase if public access is provided to additional riparian lands that are acquired by the state.

White-tailed deer and wild turkey are the two primary targets of hunters in the river corridor. Hunting occurs on state forest lands and private lands leased by hunting clubs and individuals. About half of the riparian landowners hunt on their own property. As in the case of fishing, any additional public lands opened to hunting can be expected to attract numerous hunters, especially on opening weekends.

Available demand projections suggest that participation rates for all outdoor recreation activities in Garrett County will increase in the future. Future growth in outdoor recreation participation in the Youghiogheny corridor will be influenced by the amount of new public access developed. With a vast majority of lands within the corridor being held by private landowners and the Pennsylvania Electric Company, public access to the river and riparian land areas is highly limited. Without additional public access, recreational use of the river will remain much like it is today.

Section D: Emergency Services Assessment

This section of the study examined the availability of emergency rescue, medical, and fire services in the river corridor. The assessment documents the amount of personnel and equipment available to respond to emergencies and identifies factors limiting the provision of emergency services within the corridor. Recommendations resulting from this analysis focus on reducing or eliminating the identified limitations to the provision of emergency services in the Upper Youghiogheny corridor.

Data for this assessment were collected from a variety of relevant published documents and through interviews with many local officials, experts on river safety, and persons knowledgeable about conditions in the Youghiogheny River corridor.

Emergency management may be accomplished in two ways: through prevention of emergency situations and through implementation of appropriate procedures when prevention fails. The MDNR should consider both of these aspects in the development of its river management plan.

The existing whitewater boating regulations contain several provisions aimed at preventing emergencies involving commercial boaters. The current regulations should be expanded, however, to deal with three issues that are not adequately covered. First, the regulations do not specify a minimum level of experience *on the Upper Youghiogheny* for all boating guides and trip leaders. Secondly, the regulations do not adequately address the level of skill required of private boaters using the Upper Youghiogheny. Finally, the regulations do not deal with the increasing risk of mishaps under increasing water flow conditions.

Emergency rescue, medical and fire services in the Youghiogheny River corridor are provided by a variety of organizations and governmental entities. A fairly complete network of services exists to render emergency medical services to accident victims once they have been removed from the river corridor. The greatest difficulty in providing emergency services within the corridor involves getting victims from the point of the accident to a place where the institutionalized system of emergency medical services can take over.

Several characteristics of Garrett County, including its size, terrain, remoteness, wilderness character, and the marginal condition of many of its roads, limit the effectiveness of traditional emergency services. These characteristics lead to problems of communication and problems of distance. Focusing more specifically on the river corridor itself, there is no suitable road access into the corridor for use by emergency vehicles. In addition, rescue personnel cannot easily access the river corridor on foot. Another limiting factor is that emergency rescue calls from the river corridor are generally received late in the day, when it is too late to safely mount rescue operations.

Section E: Environmental Impact Assessment

This section of the report examines the environmental impacts associated with recreation in the Upper Youghiogheny River Corridor. The assessment draws upon previous research on the ecological impacts of river recreation, field observations along the river, and visitor and landowner perceptions of resource impacts to evaluate the extent of impact along the river and suggest management strategies for mitigating existing impacts.

Previous studies indicate that the impacts of recreation on river environments are complex and not fully understood. Riparian areas impacted by recreational activities generally are small or insignificant compared to the total resource area in question. Impacts of recreation also are often small in relation to impacts from other disturbances and natural forces such as annual flooding.

Recreation impacts generally are found only at shoreline areas where use is concentrated, such as access points, popular stopping points, and campsites. Non-motorized boating generally produces no significant impacts on water quality or shoreline areas other than those areas used by boaters. Overnight use areas typically show the greatest amount of environmental impacts.

The amount of impact is *not* directly tied to the amount of use a given area receives. The extent of impact depends more on such factors as type of use, type of environment and site management. In short, while environmental impacts have been documented at concentrated use areas on many rivers, these impacts generally have not posed a limiting factor to recreational use of rivers. None of the studies examined included recommendations to limit the ***number*** of people using the river. Studies typically have recommended restrictions on certain activities at specified locations, alterations in site design and management, and educational programs aimed at influencing visitor behavior so as to reduce their impacts on the environment.

Applying the results of previous research to the Upper Youghiogheny leads to the conclusion that the environmental impact of recreation on the Upper Yough is exceptionally low. Environmental impacts are confined to a small number of access points and are minor when compared to the overall river corridor or

recreation sites on other nearby wild and remote rivers. The low level of impacts found are the result of several unique features of the Upper Youghiogheny, including: (1) there are few access points to the river, (2) there are few stopping places along the whitewater segment between Sang Run and Friendsville, (3) none of the access points on the river are used for overnight camping or food preparation, two activities that tend to produce the greatest impacts, and (4) the number of people using the river is relatively small.

On the other hand, some impacts are evident at river access points and it is important to identify ways of reducing these impacts and preventing further impacts from occurring. The most significant impact at put-in and take-out points is loss of vegetation and soil erosion, especially on certain relatively steep banks used for boat launching. These impacts probably are a result of using less than optimal locations for access points and lack of site management and development to protect the areas from impact. Some of these localized impacts can be mitigated through management while others may be unavoidable since the areas in question are located on private land.

Surveys of whitewater boaters and landowners asked respondents their perceptions of a list of potential resource impacts along the Upper Youghiogheny. Most rafters felt that all of the resource impacts listed were not a problem on the Upper Yough. Kayakers were more sensitive to some impacts, including litter, muddy water, and improper disposal of human wastes. Twenty-five percent of the kayakers felt that logging of forests that was visible from the river was a serious problem. But most kayakers also felt that most types of impact considered were not a problem on the Upper Youghiogheny.

Landowners were much more likely than whitewater boaters to perceive environmental problems along the river. They tended to view litter as the most serious environmental problem. The majority of landowners were concerned about the erosion of river banks, trampled vegetation, improper disposal of human wastes, fires, and disturbance of wildlife, although most did not feel that these were serious environmental problems. In contrast to the whitewater boaters, most landowners did not consider logging to be a problem. This difference in perceptions is not surprising and probably reflects landowners values regarding the right to pursue logging operations on their property.

The data collectively support the conclusion that environmental impacts are *not* a limiting factor to recreation on the Upper Youghiogheny. Recommendations derived from this assessment emphasize pursuing a variety of management alternatives to mitigate existing impacts while facilitating recreational use of the river.

Section F: Economic Impacts of Whitewater Boating

This section assesses the economic impact of whitewater boating in the Upper Youghiogheny River corridor on Garrett County and the state of Maryland during the 1988 boating season. The economic benefits attributable to whitewater boaters are documented, as are the economic impacts resulting from the commercial rafting operations on the river. The effects of the wild river designation on property values within the corridor are also examined.

A variety of data sources contributed to this economic impact assessment. Primary data were collected from boaters and commercial outfitters through mail survey techniques. The response rate was 80 percent from the outfitters and 73 percent from the boaters. Other primary data were collected through interviews with local realtors and government officials. Secondary information on land transactions within the corridor was obtained from published reports and public documents.

About 90 percent of the individuals who went whitewater boating on the Upper Youghiogheny during 1988 were non-Maryland residents who came to Garrett County for the primary reason of running the Upper Yough. These boaters spent over $2 million during their trips to western Maryland. Over $500,000 of this total was spent for raft and guide services.

Whitewater boaters spent nearly $800,000 within Garrett County. Virtually all of this money was brought in by non-Garrett County residents. County restaurants received the largest share of these expenditures (24 %), followed by overnight accommodations (19%), auto-related expenditures (16%), food and beverage purchases (14%) and other retail-related sales (14%).

Of the one million dollars in direct expenditures made within Maryland (excluding raft and guide fees), nearly 90 percent was contributed by visitors from other states or countries. Maryland restaurants received 25 percent of this total spending, followed by auto-related expenses (18%), accommodations (17%), food and beverage purchases (14%) and retail purchases (13%).

Besides the direct expenditures made by the boaters, there is an additional economic impact due to what is called the multiplier effect. In this case, it was estimated that the combined direct and induced impacts from out-of-state visitors (excluding raft and guide fees) was $1,277,188 in Garrett County and $1,442,827 for the state of Maryland. In addition, it is estimated that $228,534 was paid by rafters to the three outfitters who reside within Garrett County. The other seven outfitters operating on the river maintain their businesses in nearby states.

In addition to the amount spent by individual users, the commercial rafting companies operating on the Upper Youghiogheny reported spending an additional $192,911 within Garrett County. The largest expenditure category was for wages, followed by expenditures on food and beverages.

From information gathered through interviews with local realtors and an analysis of property transactions made within the corridor from 1979 to the present, it does not appear that the corridor classification has had a significant effect on land prices.

Section G: Visitor Survey Results

This section of the report presents the major findings of the surveys of whitewater boaters that were conducted during the 1988 and 1989 boating seasons. The purpose of these surveys was to obtain background information on the boaters who use the Upper Youghiogheny as well as information regarding boaters' expectations and perceptions of their experience on the river and their preferences related to several management issues.

Several survey techniques were used to collect the various types of data that were needed from whitewater boaters. Onsite interviews were conducted at put-in and take-out points to obtain boaters' reactions immediately prior to and after their river trips, respectively. Mail questionnaires were sent to individuals who had been contacted in the field to collect more detailed information from boaters after they had returned home from their trips.

Nearly 1,500 onsite surveys were completed during the course of the study. Seventy-three percent of the mail questionnaires sent to boaters sampled in the field were returned in usable form.

Most of the boaters sampled in the study were out of state visitors who traveled to western Maryland primarily to run the Upper Youghiogheny. The Upper Youghiogheny River is used for whitewater boating by two distinct user groups that are seeking different types of experiences and that evaluate their river experiences differently. This is not to say there are no commonalities between the groups. Both commercial rafters and private boaters (kayakers) placed high importance on running the rapids and considered the Upper Yough to be more fun than other rivers they have run. Both groups generally reported high levels of satisfaction and were in favor of regulating boating on the river.

Many of the differences between rafters and kayakers seem to be related to varying levels of experience on the river. Most rafters were customers of commercial outfitters who were on their first trip on the Upper Yough. They were seeking thrills and excitement under the protective guidance of an experienced river guide. Most kayakers were expert paddlers with considerable experience on the Upper Yough. They too were seeking a challenge, but were also concerned with developing their skills, escaping crowds and enjoying the natural surroundings. It is not surprising that the kayakers were more sensitive to varying river conditions.

Results of the visitor surveys suggest several conclusions that are particularly relevant to the assessment of the capacity of the Upper Youghiogheny for whitewater boating. First, boaters sampled between August 1988 and August 1989 were generally very pleased with their boating experiences. Thus, under the conditions that occurred during this period, the numbers of boaters using the river generally do not appear to have been above the social capacity. Secondly, the quality of the boating experience on the Upper Youghiogheny is related to the number of people using the river. The relationship between quality and density is not a simple one, however. This relationship is intertwined with water release conditions such that problems are found only when high raft densities occur on two-hour water releases. Finally, current users of the Upper Youghiogheny tend to support the regulation of whitewater boating on the river, although rafters and kayakers differ considerably in their reactions to specific proposed management alternatives.

Section H: Landowner Survey Results

The purpose of the Youghiogheny River Landowner Survey was to collect information on how lands within the scenic and wild river corridor were used and to obtain the viewpoints of landowners on various problems, conflicts, and management issues. Over two-thirds of the landowners returned the mail questionnaire

sent to them.

The main themes underlying most landowner responses were that they highly value their privacy and want to be able to use their land as they see fit.

Fifty-eight percent of the landowners reported that there was a house on their property. However, only two out of five landowners resided permanently on their land and one-fifth lived on their property seasonally. Most absentee landowners lived in Maryland.

About half of the landowners surveyed used their land for recreational purposes, with the most common activities being fishing (50%) and hunting (44%). Only eleven percent indicated that they had ever been boating on the Youghiogheny.

Landowners noted a rise in river boating activity over the past few years, yet three-quarters of them reported not having had any problems with boaters. It seems that landowners generally do not mind others using the river, as long as the river users respect their private property rights.

The most common problems reported by landowners were trespassing, invasion of privacy, and vandalism. These were rated as the most serious problems in the corridor and the source of many of the user/landowner conflicts and environmental problems. One-fourth of the landowners reported that boaters often cross their land without permission, while 17 percent indicated they would allow boaters to cross their land if they asked permission.

In keeping with the value placed on privacy, very few landowners indicated that they were interested in providing formal access to the river across their land. Further, any potential management action that would increase access to the river was strongly opposed. A minority of landowners were interested in selling their property to the state, however.

Landowners generally were opposed to the development of any recreational facilities in the corridor. Further, any management action restricting recreational use of the river and enhancing enforcement of current rules and regulations was supported. They also supported the enhancement of the river's fisheries resources.

Overall, landowners showed mixed reactions to the Scenic and Wild River designation of the Youghiogheny River. They felt that they should be able to use their property as they wished and that the state has no business "meddling in their affairs." By the same token, landowners were concerned about the environmental quality of the river area and wanted to see the river remain in its natural condition.

Section I: Recreational Capacity Assessment

This section integrates results from the various components of the study and applies these results to the specific task of assessing the capacity of the Youghiogheny River corridor for recreation. This assessment is based on the principles and procedures described in the Visitor Impact Management framework developed by the National Parks and Conservation Association.

For purposes of this assessment, it is assumed that the management objectives for the Upper Youghiogheny River corridor include: maintaining the primitive character of the wild river corridor, providing

for recreational use of the corridor that is compatible with the primitive character of the area, ensuring high quality whitewater boating experiences, minimizing conflicts between visitors and landowners, minimizing conflicts between various user groups, and maintaining the highest possible degree of safety among river users.

Study results suggest that, for the most part, these management objectives are being met. There does not appear to be a need to limit the number of people using the river from an environmental standpoint. Some capacity limitations were identified, however, on the basis of river hydrology and the quality of the visitor experience.

Results of both the hydrological assessment and visitor surveys imply that there is no single capacity of the Upper Youghiogheny for whitewater boating. The capacity varies as river conditions change. Under the current limit of 72 commercial raft customers, it is possible that the number of rafts on the river will exceed the number that can safely negotiate the lower part of the class V rapids during two-hour releases when natural flow is very low. On the other hand, the current limit is below the river's capacity during those times when more water is available, such as during three-hour releases and two-hour releases at higher natural flow levels.

Historical data show that river conditions vary significantly from year to year and generally are not predictable. The most limiting conditions of two-hour releases combined with very low natural flow occur relatively infrequently on the Upper Youghiogheny. Thus, higher use limits could often be accommodated on the river. The dilemma in establishing use limits that respond to varying river capacities involves balancing the need for flexibility with the need for ensuring that boat densities will not exceed a safe and socially acceptable level.

Recommendations

The following are the major recommendations for management that were derived from this study. Some of these recommendations are closely tied to individual sections of this report (e.g. recommendations related to emergency services and environmental impacts), while others represent a synthesis and interpretation of the various types of data collected. The recommendations are presented according to the major questions that prompted this study to be undertaken.

Recommendations Related to Emergency Services in the River Corridor

1) MDNR regulations related to commercial whitewater boating should be amended to establish minimum levels of experience on the Upper Youghiogheny River for commercial trip leaders and guides. Specifically, it is recommended that trip guides must have made a minimum of ten trips on rivers of comparable or higher AWA class rating, at least three of which were on the Upper Youghiogheny. Trip leaders should have made at least twenty trips on comparable rivers and six trips on the upper Yough. Finally, in light of the increased risk associated with running the river at higher water levels, guides leading trips at higher flow levels should be required to attest that they have made a minimum of three trips on the river when the river flow was equal to or higher than the conditions for the particular trip to be guided.

2) Erection of prominent warning signs at river access points used by private boaters is recommended. These signs should indicate (at minimum) the extent of the hazards and the associated risks of whitewater boating on the Upper Youghiogheny. They should also clearly identify the increased risks of running the river at higher water levels. See page D-6 for recommended sign wording.

3) MDNR should pursue several actions to improve accessibility to the river corridor for emergency rescue vehicles. These actions include establishing agreements with landowners to allow access of emergency vehicles and personnel to the abandoned logging road between Friendsville and National Falls and improving the road to allow access for 4-wheel drive emergency vehicles. MDNR assistance to and cooperation with local emergency providers in the procurement of at least one emergency vehicle capable of using this route is also strongly suggested.

4) It is recommended that MDNR, in conjunction with commercial outfitters and the Maryland Institute of Emergency Medical Services, seek to establish a regular schedule of emergency medical training for guides and trip leaders. This training should include specialized courses in

river rescue, rappeling and cross-country travel for direct providers of emergency services to the corridor. See page D-20 for further discussion of river rescue training alternatives.

5) MDNR should assist those local providers likely to be first at the scene of an emergency rescue situation in procuring specialized rescue equipment, including rappeling harnesses, ropes and Stokes baskets for the removal of victims. Additionally, MDNR assistance and cooperation in the procurement of portable lighting for nighttime search and rescue operations is strongly suggested.

6) MDNR tests of the effectiveness of VHF transmission in the corridor are recommended, as is examination of the legal issues related to allowing outfitters to access VHF band frequencies for emergency calls.

7) It is recommended that MDNR act as a sponsoring agency in negotiating agreements with land owners for the caching of backboards at selected recommended locations, and that MDNR work in cooperation with outfitters to see that these caches are secure and well maintained.

8) Emergency rescue plans specifying how various types of emergencies will be handled should be required of each commercial outfitter as part of the annual permitting process. See page D-22 for a listing of issues that should be addressed in the outfitters' emergency rescue plans.

9) Amendment of MDNR regulations to require minimum first aid supplies and equipment (including snake bite anti-venom kits) to be carried on each commercial trip is recommended. See page D-21 for a list of suggested items that should be included in the basic first aid kit.

Recommendations Related to Mitigating Environmental Impacts within the Youghiogheny Corridor

10) There is no need to establish a limit on the number of people allowed to use the river on the basis of environmental carrying capacity. Instead, MDNR should pursue a variety of management alternatives to mitigate existing impacts while facilitating recreational use of the river.

11) It is recommended that MDNR complete the acquisition of the Natural Lands Trust property (currently in progress) and conduct minimal site improvements consistent with the wild and primitive character of the area. These improvements should include a delineated parking area with a hardened surface such as gravel to reduce impacts on vegetation, and composting toilets and changing rooms to eliminate any future problem with improper disposal of human wastes.

12) We recommend that MDNR try to maintain the relatively pristine character of the river corridor by minimizing the creation of additional access points to the river. Any areas opened to recreation without suitable site hardening will become impacted just as the existing access points on the Upper Yough and recreation sites at other rivers are impacted.

13) We encourage park management at Swallow Falls State Park to pursue their plans for site development to mitigate trampling impacts in the falls area.

14) We further recommend that MDNR, in cooperation with the licensed commercial outfitters, initiate a minimum impact education program aimed at teaching river users how to minimize their own impacts on the environment. Such a program may also help to reduce conflicts between river users and landowners and conflicts between different types of recreational boaters. See page E-16 for further information on recommended contents for such an educational program.

15) Since many of the existing impacts occur on private land used as access points to the river, it is recommended that MDNR work with the owners of these properties to try to encourage them to take actions to minimize environmental impacts on their property. Such actions might include site hardening and education of clients using the site. In keeping with the wild and primitive character of the area, site alterations should be limited to the minimum necessary to protect the area from ecological degradation.

16) Since logging evoked very different responses from whitewater boaters and landowners, it is important that the MDNR enforce existing land use regulations in the corridor to prevent *unlawful* operations that negatively impact boaters while protecting landowners' rights to use their property in accordance with the land use guidelines.

17) Finally, it is important to monitor selected environmental indicators in the future. This monitoring should focus on further loss of vegetation and soil erosion at river access points, since these were the most noteworthy types of environmental impact identified.

Recommendations Related to the Capacity of the River

18) Restrictions on the number of boats allowed on the river should be designed to provide enough flexibility to respond to varying river capacities while still being practical to both commercial outfitters and MDNR.

19) The current limit of 72 commercial customers per day should be converted to the equivalent number of rafts (24 rafts with a maximum of three customers per raft). Both the hydrological assessment and the boater surveys identified the number of rafts, rather than the number of customers, as the most critical limiting factor on the river. Under the current allocation of customers among outfitters, 72 customers would result in more than 24 rafts to the extent that boating groups elect to run the river with fewer than three customers in some rafts.

20) The revised limit of 24 commercial rafts should remain in effect for those times when two-hour releases are likely to occur. This limit should be increased by 50 percent to 36 rafts when it is known that water releases will be three hours or longer (such as from late August through September as a result of the annual drawing down of the Deep Creek Lake level) and when the river is navigable without a hydropower release (such as during spring runoff). For practical purposes, the commercial capacity should be 36 rafts during the spring and fall and 24 rafts during the summer, although the boundaries between these seasons may vary from year to year depending on climatological conditions.

21) MDNR, in cooperation with the commercial outfitters, should pursue negotiations with PENELEC aimed at increasing the predictability of hydropower generation schedules. These negotiations should seek a commitment from PENELEC for a minimum of one three-hour release a week throughout the summer, to be scheduled on Fridays to enable outfitters to plan trips accordingly. If such an agreement is reached, the 36 raft capacity should be in effect for those days included in the agreement.

22) Final decisions on use limits for particular days should be at the discretion of the Youghiogheny River manager. The manager should have the authority to set boundaries between seasons and to approve the 36 raft capacity on the basis of prevailing climatological conditions that allow some predictability of river flow conditions.

Recommendations on the Allocation of Customers Among Commercial Companies

23) It is recommended that the number of companies operating on the river be reduced through one of the following ways:

a) Attrition. The companies permitted to offer whitewater trips on the Upper Youghiogheny would be limited to those operating on the river during the 1988 boating season. The number of companies would decline in time if any existing companies elect to discontinue running the Upper Yough for any reason.

b) Elimination of Some Existing Companies. Companies could be denied permits to operate on the river on the basis of some criteria such as level of experience on the river, repeated violations of the whitewater boating regulations, etc. The difficulty in implementing this option is deciding how many companies should be eliminated. This decision would have to be at the discretion of the river manager, since the data collected in this study do not provide a basis for this determination.

24) The suggested limits of 24 and 36 rafts should be allocated to permitted outfitters in direct proportion to each company's level of previous activity on the river.

Limitations on Private Use of the Upper Youghiogheny

25) It does not appear to be necessary *at the present time* to introduce restrictions on private boating activity on the river.

Minimizing Conflicts Between Landowners and Whitewater Boaters

26) Any management action proposed for the Upper Youghiogheny River corridor should undergo thorough review by landowners prior to implementation. While the mechanism for this input already exists via the Youghiogheny River Advisory Board, special efforts should be made to ensure that any new actions are designed to prevent trespassing and invasion of privacy.

27) Greater efforts should be made by both MDNR and commercial outfitters to educate river users about the private property rights of riparian landowners. The problems of trespassing and invasion of privacy may be reduced substantially by making more river users aware of their rights and those of adjacent landowners. This educational effort should be integrated with the minimum impact education program discussed on page E-16.

Recommendations About Further Development of the River Corridor

28) It is recommended that MDNR focus its acquisition and development efforts within the corridor on expansion and/or improvements to existing developed areas and access points, such as Swallow Falls State Park and Sang Run. Other lands within the corridor that have been or will be acquired by the state should be left in their natural state in order to preserve the wild and primitive character of the river corridor.

Acknowledgements

The authors would like to express their appreciation to the following individuals, without whose help this study could not have been completed.

Thanks are extended to Steve Taylor, who conducted the hydrological analysis and provided helpful advice and assistance with various other aspects of the study. We are also grateful to The Pennsylvania Electric Company (PENELEC) for providing data needed for the hydrological assessment.

We would like to thank the commercial outfitters operating on the Upper Youghiogheny for their cooperation in allowing us to interview their customers, for providing us with the data we requested, and for providing us with the opportunity to experience the Upper Youghiogheny firsthand.

We appreciate the assistance of the many individuals who helped with various tasks throughout the project. Roger Moore, Steve Burr and Stuart Cottrell helped with data collection. Susan McDade, Janet Haner, and Philip Wang handled most of the data entry. Ellen Drogin provided valuable assistance with computer analysis.

Special thanks are extended to those who helped in the preparation of this report. Dr. Frank Guadagnolo provided valuable assistance in report design and layout. Lisa May prepared the data tables and performed other valuable word processing tasks. Mary Dunkle provided administrative support services. Ann Harpster handled printing of the report as well as the study questionnaires.

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Section A

Introduction

State government protection of unique free-flowing and scenic rivers dates back to as early as 1905 (Threinen 1970). Congress recognized the need for states to establish natural river protection programs through the Wild and Scenic Rivers Act (P.L. 90-542). The Youghiogheny River in Western Maryland was designated a scenic and wild river by the Maryland General Assembly in 1968 (Figure A-1). In 1976, the Maryland Department of Natural Resources (MDNR) identified a "scenic corridor" along the wild segment of the River and promulgated land use regulations, consistent with the Maryland Scenic and Wild Rivers Act, within the corridor (Maryland DNR 1988).

To date, little information exists to characterize the recreational use of the Youghiogheny and the impacts resulting from this use. A variety of types of information are needed to provide the basis for the development of a river management plan. This study was designed to obtain the types of information needed by the Department of Natural Resources to create a plan that will facilitate effective management of the river corridor now and in the future.

Study Objectives

1) To identify the hydrological characteristics of the Upper Youghiogheny River, including the travel time characteristics of Deep Creek Lake hydropower releases, the limiting factors for whitewater boating navigability on the river, and the long-term availability and dependability of navigable flows for whitewater boating.

2) To examine existing and potential recreational uses of the Youghiogheny River and its immediate vicinity.

3) To assess the resources available to respond to emergency situations that can arise within the river corridor.

4) To describe the environmental impacts of recreation on the Youghiogheny Wild River segment.

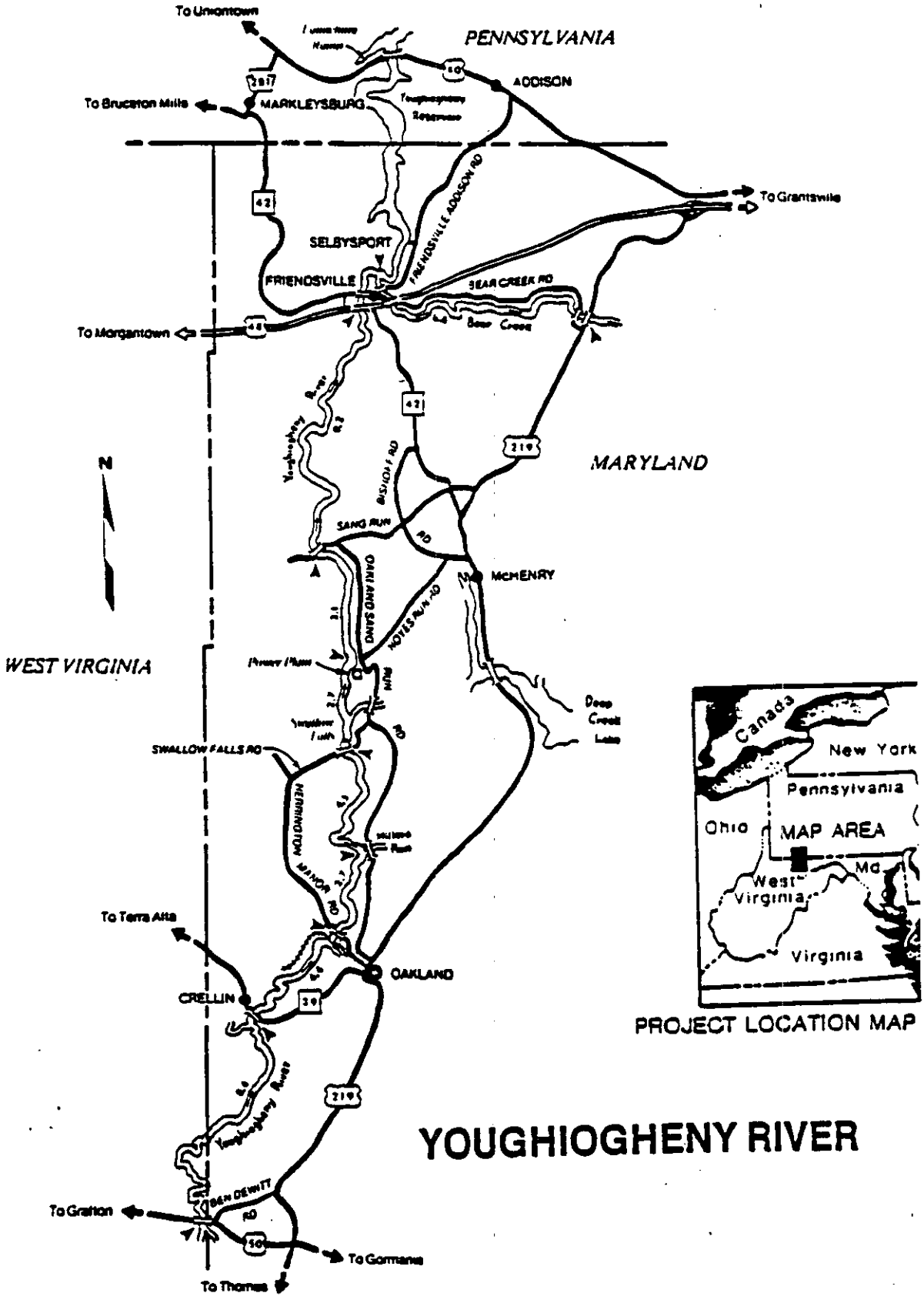
5) To identify the economic impacts resulting from whitewater boating on the Youghiogheny.

6) To identify optimum capacities of the Youghiogheny River corridor for whitewater boating.

7) To evaluate various management alternatives and develop recommended strategies for management of recreational activities within the river corridor.

Study Approach

Any study designed to address the objectives listed above must be interdisciplinary and comprehensive. This study used a variety of approaches and data collection procedures to address the various objectives. The major theme of the study revolved around the Visitor Impact Management (VIM) framework developed by



Source: Maryland and Delaware Canoe Trails.

Figure A-1. Location Map of the Youghiogheny River

the National Parks and Conservation Association (Graefe et al. 1987). The VIM framework was the result of a comprehensive review and synthesis of literature related to recreational carrying capacity. The goal of this literature review was to develop a management framework that: (1) incorporated current scientific understanding of the nature and causes of visitor impacts in recreation areas, (2) would assist managers and planners with the difficult task of identifying and controlling undesirable recreation impacts, and (3) would avoid the problems that have limited the effectiveness of many previous "carrying capacity" studies.

The Visitor Impact Management Framework

Recreation researchers have become increasingly suspect of the carrying capacity concept in recent years. A large body of literature demonstrates that environmental and recreational quality are multi-faceted concepts that can be threatened by a number of interrelated types of impacts (Graefe et al. 1984a, 1984b; Kuss and Graefe 1985). Impacts to the environment and recreation experience may vary considerably in extent and severity and may be influenced by other factors besides use levels. Visitor Impact Management is built upon the commonly recognized principle that effective management involves both scientific and judgmental components (Shelby and Heberlein 1987). Effective management involves more than carrying capacities and use limits. While use quotas represent one potential strategy for controlling visitor impacts, it is important to remember the findings of many previous studies that have found only weak or insignificant relationships between impacts and use levels. In such instances, establishing capacities and limits may do little to reduce the impact problems they were intended to solve, whereas other potential management strategies may be quite effective.

The VIM framework centers around a sequential process for assessing and managing visitor impacts. The steps in this process are designed to facilitate dealing with three basic management issues: (1) the identification of problem conditions (or unacceptable visitor impacts), (2) the determination of potential causal factors contributing to the occurrence and severity of the unacceptable impacts, and (3) the selection of potential management strategies for ameliorating unacceptable impacts.

This study was designed to collect the types of information that are needed to address these issues. The methods used included field observations and surveys of visitors and owners of land within the river corridor, coupled with use of a wide variety of existing data sources. A detailed description of the methods used to address each objective is provided in the section corresponding to that objective.

This report is organized according to the study objectives listed earlier. A section is devoted to each of the first five objectives. Objectives 6 and 7 are addressed in the final chapter. In addition, recommendations are presented in each section to the extent that they are derived from the individual sections, and all recommendations resulting from the study are presented at the front of the document.

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Section B

Hydrological Assessment*

This section of the study considers the hydrological characteristics of the river and their implications for whitewater boating. This assessment focuses on three major questions. First, what are the travel time characteristics of Deep Creek Lake hydropower releases into the Youghiogheny River? Secondly, what are the limiting factors for raft, kayak, and canoe navigability on the Upper Youghiogheny? Finally, based on historical records, what is the long-term availability and dependability of navigable flows for whitewater boating?

Overall Hydrological Characteristics

Figure B-1 shows the Youghiogheny River from Swallow Falls State Park to Friendsville. There are two whitewater sections. The Top Yough is from Swallow Falls to Hoyes Run. The Upper Yough is from Sang Run to Friendsville. The Top Yough can be navigated only at times when there are sufficient natural flows. The Upper Yough is navigated at times when natural flows are sufficient and when water is added to the river by hydropower generation from Deep Creek Lake. A hydropower generation release makes the Upper Yough navigable at times with the lowest of natural river flows.

The Deep Creek hydropower station has two turbines which in general operate together with a total flow of approximately 630 cfs (315 cfs each). Sometimes in the fall, there will be one-turbine operation so maintenance can be performed on the other turbine. Both the duration of a hydropower release and the daily frequency of releases are essentially dependent on the availability of water from Deep Creek Lake. There is a preference for weekday generation because the demands for electrical power are higher on weekdays. The starting time of a release is dependent on the timing of the daily peak demand and the operation of the system's other power plants. In the summer, typical announced releases of two hours or longer start in a period between mid-morning to mid-afternoon.

Deep Creek Lake has a surface area of 3600 acres (or 5.7 square miles) with a drainage area of 65 square miles (including the lake surface). Hydrologically, this is a large surface area given the size of the drainage area. As a consequence, in a very dry summer, the lake evaporation rate will exceed the lake inflow and the lake level will recede even without hydropower releases. On the other hand, because of the large surface area, the lake can catch and hold the runoff of rains for generation during days or even weeks after the natural river flow has receded from the rains.

The USGS has measured Youghiogheny River flows at Oakland since 1942 (drainage area of 135 square miles) and at Friendsville since 1899 (drainage area of 295 square miles). Monthly average generation and end-of-the-month lake levels were obtained from the power company for the period of 1970 through 1988.

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* This part of the study was completed by Steve Taylor, Consulting Engineer, Silver Spring, Maryland.

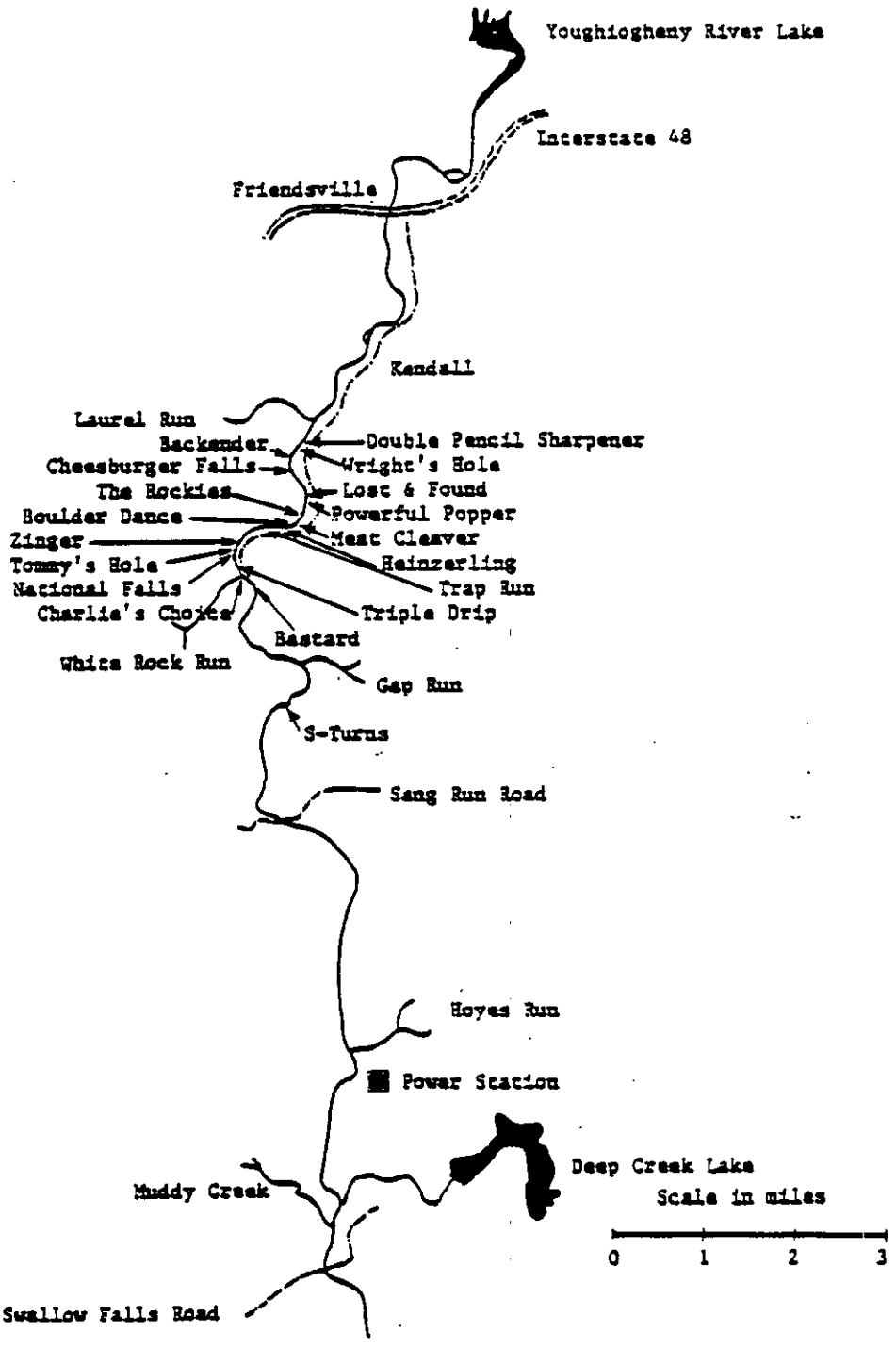

Figure B-1. Map of the Upper Youghiogheny River

Navigable River Flows and Gauge Levels

A simple river level gauge on the Sang Run bridge, which has no recorder, is the gauge used by most boaters. In the summer of 1988, the existing gauge was removed due to bridge repairs. After the repairs, a new gauge was installed. At times of very low natural flows, 2.0 feet on the "old" gauge during a hydropower release corresponds to 3.25 feet and 660 cfs at the Friendsville gauge (630 cfs hydropower release plus 30 cfs natural flow). At this flow, the "new" gauge reads approximately 0.1 feet lower than the "old" gauge (i.e., 2.0 on the "old" equals "1.9" on the "new" gauge).

Most hard boaters (those who paddle kayaks and canoes) and raft guides consider 2.0 feet at the Sang Run gauge ("old" gauge) to be the minimum navigable level. With lower levels more rocks become exposed and passages become more restricted. Thus, the run becomes more "technical," which makes both raft and kayak navigation more difficult.

Since rafts are larger in size and less controllable than hard boats, they frequently stick on rocks and have a higher probability of pinning at water levels below 2.0 feet at Sang Run. Flows below 2.0 feet would not support a commercial raft operation. Because of the small boat size, skilled hard boaters can negotiate the tighter constrictions, but the risk of pinning and boat damage is higher. Thus, even though levels below 2.0 feet are more navigable by hard boats than rafts, many hard boaters will not run the river below 2.0 feet.

A stream guide for canoe and kayaking states that "1.7 feet (Sang Run 'old' gauge) is about minimum" (Gertler, 1989). When hard boaters talk about running the river below 2.0 feet, they are referring to natural flow conditions. With natural flows such that the Sang Run gauge is near 2.0 feet, significant amounts of additional natural flow enter the river along the run. Thus, with natural flows at 2.0 feet or below, there is noticeably more water in the Class V section of the river than with the same gauge reading resulting from a hydropower release. Informal observations suggest that with natural flow at 1.9 feet, the run is more like a level of 2.0 feet with a hydropower release, especially at the lower part of the Class V section.

Small increases in the Sang Run gauge reading significantly increase the difficulty of the boating. Generally, flows greater than 2.2 feet at Sang Run ("old" gauge) are considered to be significantly more difficult. Many canoeists and kayakers will not paddle the Upper Yough above 2.2 on the old gauge. Flows above 2.5 are navigated by only the most experienced experts and well seasoned raft customers. Flows above 2.8 to 2.9 are generally considered too high for commercial raft trips. The 2.0 minimum and the 2.2 and 2.5 difficulty criteria for the Upper Yough also apply to the Top Yough.

Table B-1 shows the Friendsville gauge readings that approximately correspond to the Sang Run "old" and "new" gauges. As the table shows, there are relatively large increases in river flow for each 0.1 foot increase in river level, which explains the increased boating difficulty with a small increase in Sang Run gauge level. For the range of flows given in Table B-1, the "new" gauge reads 0.1 foot lower than the "old" gauge.

Table B-1. Gauge Comparison

Friendsville Level	Friendsville cfs	"old" Sang Run Gauge Level	"new" Sang Run Gauge Level
3.25	660	2.0	1.9
3.35	770	2.1	2.0
3.45	890	2.2	2.1
3.55	1010	2.3	2.2
3.65	1140	2.4	2.3
3.75	1280	2.5	2.4

The National Weather Service provides early morning USGS gauge readings at Friendsville on a telephone tape recording. These early morning readings are almost always natural flow levels. Appendix 1 provides a procedure to compute the Sang Run gauge level from a natural flow reading at Friendsville.

At low natural flows of less than 100 cfs at Friendsville, elevated flows from a hydropower release take approximately 2 hours to arrive at Sang Run and 6 hours to arrive at Friendsville. Release times later than 6 hours before dark are not usable for whitewater recreation. In mid-summer, the latest time for the start of a "just usable" release is 3:00 p.m. (i.e., arrival time in Friendsville is 9:00 p.m.). As the days shorten in the late summer, the latest time for a usable release becomes 2:00 p.m. In the early fall, it becomes 1:00 p.m.

Travel Time Characteristics of Deep Creek Lake Hydropower Releases

Background

This section of the User Capacity Study describes river flow characteristics between Sang Run and Friendsville (the Upper Yough section) from a Deep Creek hydropower release. These characteristics are useful for understanding the time limits on raft, kayak and canoe navigability from hydropower releases. In particular, the most limited periods, which typically occur during the late summer, are addressed.

Natural river flows during summer and fall are typically too low for whitewater boating and the Upper Yough can be navigated only during a hydropower release. During the summer, there is generally less water for hydropower generation than other times of the year. Thus, the time duration of releases is typically only two hours, and releases do not occur every day. For maintenance reasons, however, the power company likes to exercise its equipment at least once a week. Starting in approximately 1987, the power company informally agreed with the rafting interests to schedule the once-a-week release on Fridays. In very dry summers, there is typically only one or two releases a week, with the release being two hours long. However, after Labor Day, there is always more water for hydropower generation, and releases are more frequent and longer in duration.

This study was commissioned on August 5, 1988. Preliminary work for field measurements started August 18 through 19. There had been essentially only two-hour releases since the middle of June. However, the following week a relatively large rain occurred and the power company started its annual intentional lowering of the lake level (see following section on long-term availability of water). Thus, there were mostly three- to five-hour releases every weekday and some weekend days between August 18 and the start of the October 3 maintenance outage. Detailed measurements of the hydropower release's travel time started on September 2, 1988. Due to the very dry conditions throughout the summer, the natural flow of the Youghiogheny at this time was very low and comparable to the late summer conditions. However, the shortest release time observed was three hours rather than two hours. Some detailed flow time measurements were made in early October, with slightly higher natural flows.

The hydrological part of the study was continued through the 1989 season. However, the summer and fall of 1989 were very wet seasons. Rains throughout the summer kept the natural river flows high such that the two-hour releases that occurred resulted in relatively high flows (a minimum of 2.0 on the new Sang Run gauge or 2.1 on the old gauge). Thus, no field measurements were taken for two-hour releases at the lower flows that often occur during the summer. However, there is sufficient information from the measurements collected to assess the hydrological limits to navigability.

Theory

Engineering theory relevant to the travel time of hydropower releases on the Upper Yough is addressed in the civil engineering topic of "unsteady open channel flow." Equations and numerical modeling methods exist only for uniformly shaped and sloped channels. Since the Upper Yough is highly non-uniform, accurate travel times must be measured. However, certain qualitative characteristics, as derived from the equations, are applicable and are observed in the measured data. As a consequence, certain predictions can be accurately made using the results from the measured data.

Key theoretical elements which must be appreciated in order to understand the measured data are: 1) downstream travel of the hydropower release water and 2) downstream travel time of "simple waves," which control the elevation (or depth) of river flow from a hydropower release. As explained below, the "waves" have downstream velocities that are not the same as the water's velocity. Also involved is the effect of pools, both big and small, which act as small dams temporarily storing the hydropower water and gradually releasing the water as the river elevation changes.

When the hydropower generation starts, it creates a disturbance which sends out a "simple wave" from the power plant. From a point on shore, this "simple wave" is seen as an increase in water depth over a short time period (approximately 15 minutes). This wave, designated "rising wave," travels downstream on the natural flow in the river. Natural flow is the river flow before the hydropower release.

When the hydropower generation stops, it sends out another "simple wave" which is seen as a decrease in water depth from shore. This wave, designated "falling wave," travels on the river flow which is the sum of the water released by the generation and the natural flow.

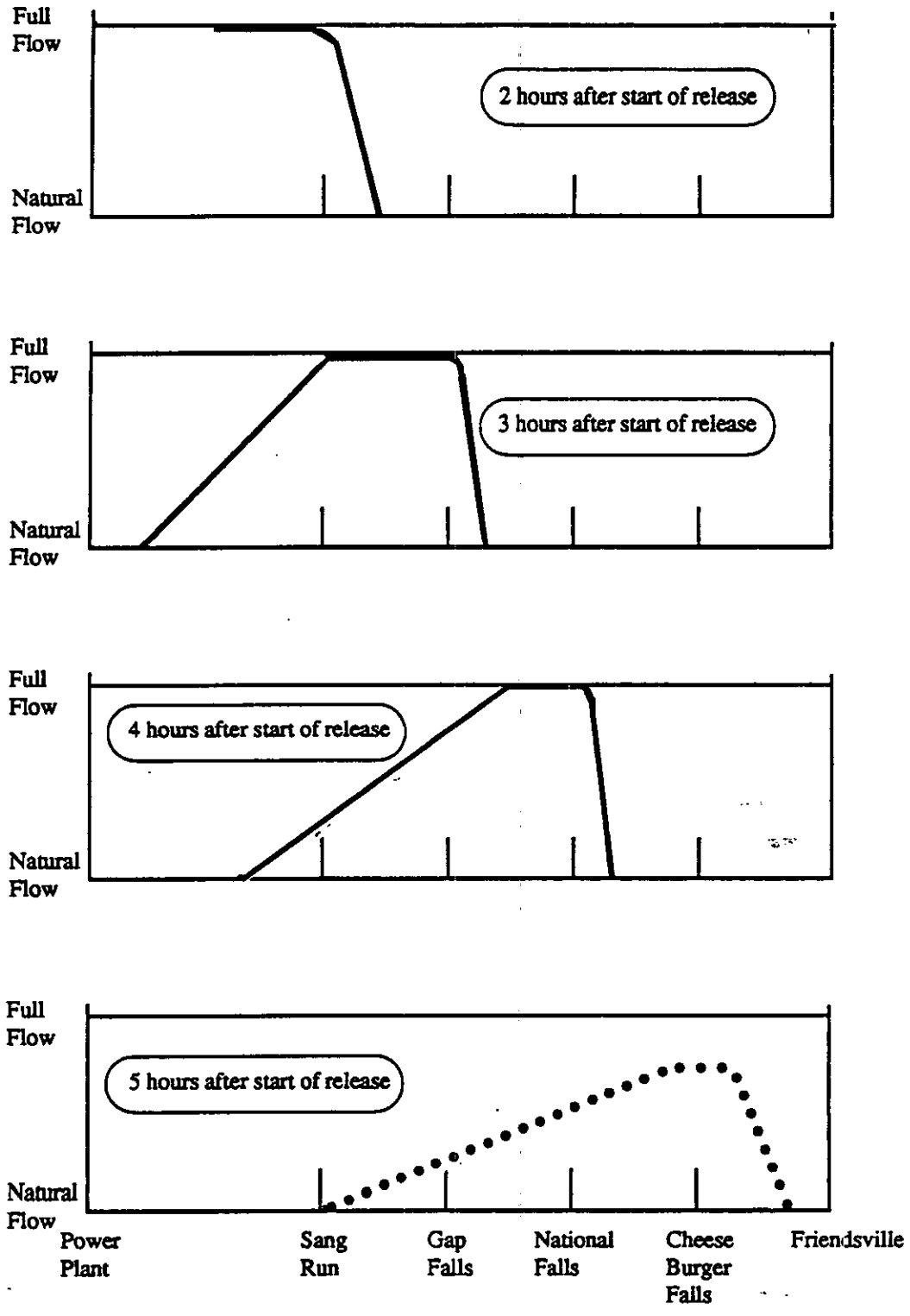

Figure B-2. Predicted Downstream Elevations Relative to Full Flow for Two-Hour Hydropower Release with Very Low Natural River Flow.

The rising and falling waves created from a hydropower release move at different downstream velocities because the velocities of both waves are proportional to the depth of the river flow upon which they travel. Thus, a rising wave travels slower than the falling wave.

At times of very low natural flow on the Upper Yough and thus very low water depth, the velocity of the rising wave is only slightly faster than the velocity of the actual water released by the hydropower station. As a practical matter, both the rising wave and the water travel at essentially the same speed. On the other hand, the falling wave will travel much faster than both the rising wave and the water released by the hydropower station.

Figure B-2 demonstrates the two different wave speeds by showing the downstream movement of the falling and rising waves for a two-hour release. At two hours after the start of the release, the rising wave has just arrived at Sang Run. One hour later (three hours after the start of the release), the rising wave has just arrived at Gap Falls and the falling wave has arrived at Sang Run. The falling wave has traveled the distance from the power house to Sang Run in approximately one-half the time of the rising wave. Thus, for this section of the stream, the falling wave has approximately twice the speed. Since the falling wave has an overall higher velocity, at approximately four hours and 40 minutes after the start of the release, the falling wave catches up to the rising wave in the area of Cheeseburger Falls for a two-hour hydropower release with very low natural river flow.

The water released by the hydropower generation moves downstream with a velocity that is a complicated function of river bed slope, water depth and river bottom resistance. A major part of this resistance is a ponding of the water which, in effect, is like many small dams which can hold water with increased water depth. The water flow resistance due to ponding has a significant impact on the change in water elevation from a falling wave.

As Figure B-2 shows, the falling wave is elongated as it moves downstream. The elongation is a result of the water not keeping up with the falling wave, primarily due to the flow resistance, especially the resistance from ponding. In other words, the change in river depth with the falling wave is much slower because of all the little dams slowly draining the hydropower release water.

For a particular natural flow, there is no theoretical reason why the downstream speed of both the rising wave and the initial part of the falling wave should vary with the time period of generation. Thus, measurements of wave travel time during a three-hour period of generation can be used to accurately predict wave travel times for two-hour periods of generation.

However, at the points downstream of where the rising and falling wave meet, accurate predictions are not possible for a two-hour release. In addition, the characteristics of the falling wave (elevation versus time) at a particular location may not be the same as for the measured three-hour release and cannot be accurately predicted from the measured three-hour data.

Travel Time Measurement Method

Field work for the measurements of flow elevations from Deep Creek hydropower releases were performed by Mr. Taylor and assistants navigating the river in kayaks. In addition, some measurements were collected at Sang Run and Friendsville by the study's user survey personnel and from USGS measurements at Friendsville.

On August 18, 1988, there was a 5.5-hour-long release due to the traditional Upper Yough Race. This opportunity was used to establish reference elevations for the full flow at that time (2.0 feet on the Sang Run gauge). The elevation of distinctive natural marks on rocks versus the water surface was noted in pools located near the rapids of Warm Up Riffle, Bastard, National Falls, Meat Cleaver, Cheeseburger and Double Pencil Sharpener. The pools and the locations in the pools were selected so as to have minimum water surface level fluctuation.

On August 31 gauges were placed in these pools. A gauge consists of a two-foot-long wooden stick, 1/2 inch by 2 inches, with sections of carpenters' rule stapled to the wood. Some gauges are installed on wooden stakes driven into the mud banks where such banks could be found. Others are wedged between rocks and wired to rocks.

The general method of observation for the rising wave was performed by following a rising wave in a kayak. Since the rising wave moves downstream relatively slowly at the very low natural flows, detailed measurements of the rising elevation were made at most of the stations in one day. In other words, the elevation changes could be observed at a gauge station and the observer could then catch up to the front of the wave just in time to observe the changing elevation of the next station.

For a falling wave, detailed measurements of elevation changes were made by stopping at the station and watching the elevation change over a period of 30 minutes to one hour. Since the falling wave moves relatively quickly, only one detailed measurement is possible per observer per day.

Due to the consistency of the very low natural flows, measurements are essentially repeatable over a period of many days. Thus, it is not necessary to take all of the measurements during one day. Observations at different places on consecutive days were combined to form a more complete data set. To be sure the flows were repeatable, certain measurements were taken each day.

In addition to the detailed measurements, spot measurements were made on other river trips by Mr. Taylor.

With a relatively small increase in the natural flow level, the rising wave moves significantly faster. Mr. Taylor could just barely keep up to the wave and record data when the full flow at Sang Run was 2.3 feet on the old gauge (2.2 feet on the new gauge). With flows higher than approximately 2.3 feet at Sang Run, it could be impossible to keep up with the rising flow in the Class 5 section of the river.

Measured Data

Even though the gauges are located in pools to minimize water level fluctuations, surface oscillations at the gauges were typically on the order of 0.5 to 0.75 inch with a period of 3 to 7 seconds. However, from watching the oscillations over a period of 20 to 45 seconds, a median reading of the oscillations can be made. Thus, measuring wave travel times is subject to error caused by making elevation readings within approximately 0.25 to 0.5 inches.

For the rising wave, the water surface elevation typically increases rapidly to within 1.0 inches of full flow. The last 1.0 inch of increase takes approximately 5 minutes and it is difficult to determine precisely when the full flow occurs. Thus, the arrival time for the rising wave is assumed to be 1.0 inch below full flow.

Likewise, the arrival time of the falling wave is assumed to be when the measured elevation is 1.0 inch below the full flow elevation. Using this amount of changed elevation assures that one is seeing the arrival of the falling wave and not observing oscillations.

It is in the rapids where navigation problems occur due to low water levels. However, the waves and oscillations in the rapids can be many inches, making it considerably less accurate for measuring wave travel times than in the pools.

Flow theory predicts that changes in water surface elevations for the rapids will typically be more than elevation changes in the pools. Thus, with a 1.0-inch change in the pools, the change in water surface elevation in the rapids could be many inches. For example, the elevation change in a small sheltered pool at the base of the rapid of Cheeseburger was approximately 2.4 inches when the gauge in the upstream pool changed by 1.0 inch.

Measured travel times for the rising and falling waves from the start of three-hour-long releases are given in Table B-2. The table shows data for two natural flow conditions such that full flow readings at Sang Run were 2.0 and 2.1 feet (old gauge). The listed rising wave times in hours and minutes are when the measured elevations are approximately within one inch of the full flow elevation. The listed falling wave times are when the measured elevations are approximately one inch below the full flow elevation. The time of 0:00 is the start of power plant generation.

For the measured three-hour release with 2.0 feet at Sang Run (old gauge) for full flow, Table B-2 shows the full flow at Cheeseburger lasting for one hour. For a release with full flow at 2.1 feet at Sang Run, the rising wave arrives 30 minutes sooner. The falling wave arrives only 10 minutes sooner. Thus, the full flow with the higher natural flow in Table B-2 lasts for 20 minutes longer than the lower flow.

With the higher natural flow, the full flow level is higher. Figure B-3 shows measured falling waves at Cheeseburger Falls for the release shown in Table B-2. The full flow for the higher natural flow is approximately two inches higher. Thus, in addition to the longer full flow period of 20 minutes, the period of navigability will be even longer due to the additional time for the falling wave to reach a minimum navigable level.

Table B-2. Measured Travel Times for Rising and Falling Wave From Three-Hour Hydropower Release

Location	Full Flow 2.0 at Sang Run*			Full Flow 2.1 at Sang Run*		
	Rising Wave	Falling Wave	Full Flow	Rising Wave	Falling Wave	Full Flow
Power Plant	0:00	3:00	3:00	0:00	3:00	3:00
Sang Run	2:05	4:05	2:00	1:55	—	—
Warm Up Riffle	3:10	4:30	1:40	2:50	—	—
Bastard	3:40	5:05	1:25	2:20	—	—
National Falls	3:50	5:10	1:20	—	—	—
Meat Cleaver	4:20	—	—	3:50	—	—
Cheeseburger	4:40	5:40	1:00	4:10	5:30	1:20
Double P	5:00	—	—	—	—	—
Kendall	5:10	—	—	—	—	—
Friendsville	6:15	—	—	—	—	—

The dashed lines indicate either missing or non-detailed measurements.

*Flow levels correspond to the old Sang Run Gauge

Prediction of Travel Times for a Two-Hour Release

As discussed under theory, there is no theoretical reason why the speed of both the rising wave or the initial part of the falling wave should change with generation period until these waves meet. Thus, the measured times from a three-hour release can be used to predict the travel times for the wave up to the point where the falling wave catches the rising wave. Table B-3 shows the predicted values for a two-hour release with full flow of 2.0 feet at Sang Run.

For the measured three-hour release, Table B-3 shows full flow at Cheeseburger lasting for one hour. This translates into essentially full flow for zero time for a two-hour release (or for an "instant" given the definition used for the arrival of the rising and falling waves). To be more precise, the location where full flow lasts for only an instant during a two-hour release is slightly upstream, probably at Lost and Found or Powerful Popper.

At the higher natural flow level (2.1 feet on the old Sang Run gauge), it is predicted that full flow at Cheeseburger for a two-hour release would last for 20 minutes versus only an "instant" at the lower natural flow (2.0 feet at Sang Run). In addition, the period of navigability will be longer due to the higher flow level as shown on Figure B-3 with 2.1 feet full flow at Sang Run. From field measurements, full flow at Cheeseburger

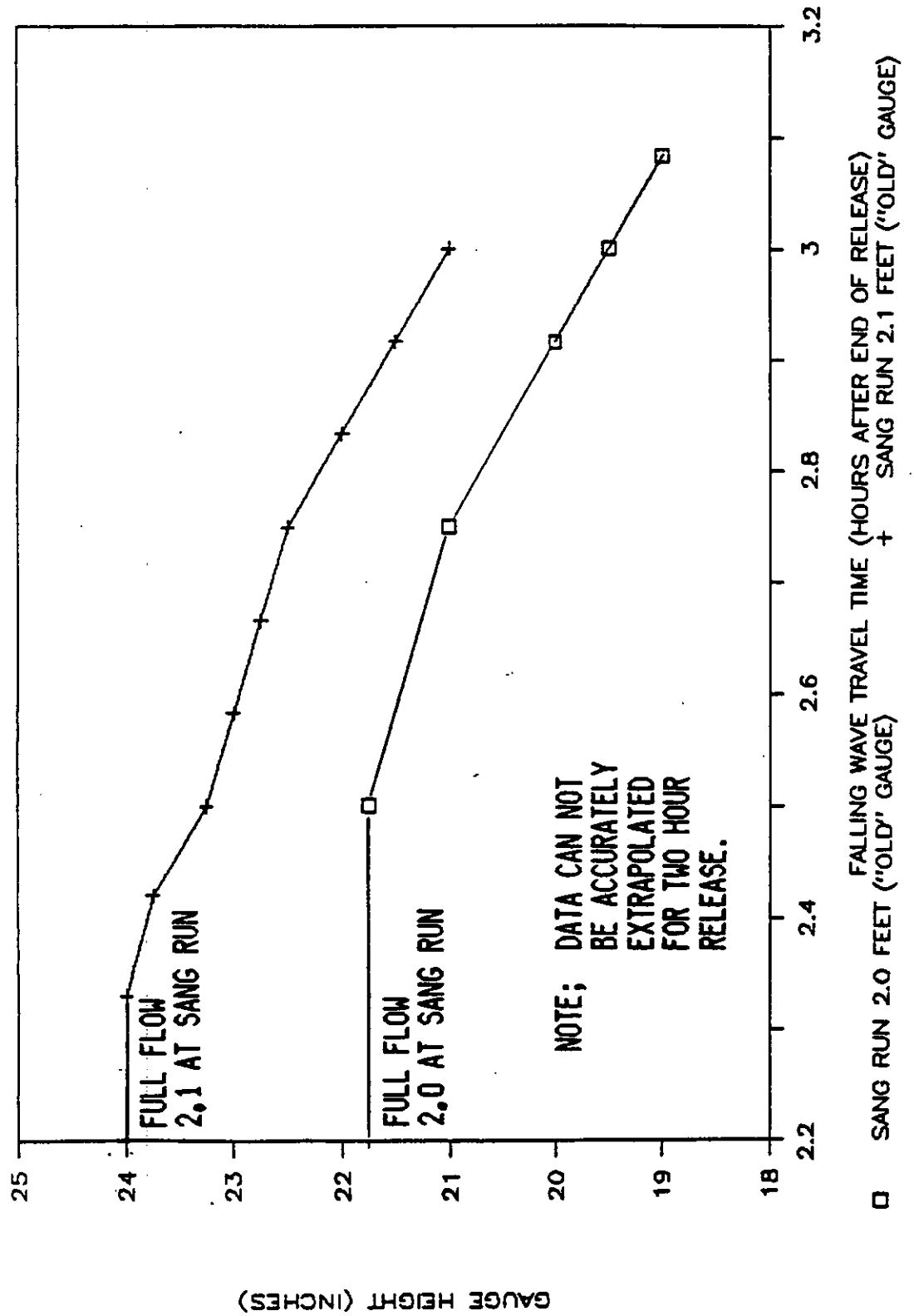

Figure B-3. Falling Wave Gauge Height at Cheeseburger Falls for a Three Hour Hydropower Release

is estimated to last 55 minutes when the Sang Run old gauge is 2.2 feet. Arrival time is estimated to be three hours and 30 minutes.

The falling waves for the two natural flow levels shown in Figure B-3 have a similar pattern. This pattern may not be the same for a two-hour release, although the differences are probably minor. Thus, as a practical matter, the measured falling wave shown in Figure B-3 can be used as the falling wave for a two-hour release.

Table B-3. Travel Times for Rising and Falling Wave From Hydropower Release for Full Flow of 2.0 at Sang Run*

	Three-Hour Release *Based on Measurements*			Two-Hour Release *Based on Predictions*		
Location	Rising Wave	Falling Wave	Full Flow	Rising Wave	Falling Wave	Full Flow
Power Plant	0:00	3:00	3:00	0:00	2:00	2:00
Sang Run	2:05	4:05	2:00	2:05	3:05	1:00
Warm Up Riffle	3:10	4:45	1:35	3:10	3:45	0:35
Bastard	3:40	5:05	1:25	3:40	4:05	0:25
National Falls	3:50	5:10	1:20	3:50	4:10	0:20
Meat Cleaver	4:20	—	—	4:20	—	—
Cheeseburger	4:40	5:40	1:00	4:40	4:40	0.00
Double P	5:00	—	—	*Predictions after the falling wave*		
Kendall	5:10	—	—	*meets the rising wave cannot be*		
Friendsville	6:15	—	—	*accurately made.*		

The dashed lines indicate either missing or non-detailed measurements.

*Flow level corresponds to the old Sang Run gauge

Hydrological Navigation Times

Raft guides with more than three years experience were questioned on the time duration of navigable flows in the lower part of the Class 5 section with low natural flow conditions and a two-hour release. The answers ranged from 15 to 20 minutes. In addition, many of the guides talked about the flows having "more push" in the lower part of the Class 5 section with a three-hour or longer release. Both of these comments are explained by the predicted rising and falling wave travel times.

Measurements of the falling wave show that in the beginning it slowly recedes on the order of 0.75 inch for 15 minutes, and then the rate increases. As shown in Figure B-3, the rate of change starts off slowly

and then increases. From the perspective of the boater, the beginning part of the falling wave would not be significantly lower water.

If rafting and boating parties took longer than 15 to 20 minutes to navigate the lower Class 5 section of the river during a two-hour release with low natural flow conditions, the river level would probably start to rapidly decrease. Thus, it is reasonable to say that the duration of navigable flows is on the order of 15 to 20 minutes.

The predictions for a two-hour release suggest that for low flow conditions, the river water surface level does not rise to the full flow level in the river below the Powerful Popper to Cheeseburger section. Given that full flow would only last for an instant in this area, most raft guides, even on a carefully timed trip, would see something less than full flow starting around Meat Cleaver and on down the river. Less elevation means less current velocity. Thus, it is reasonable for raft guides to describe the river in the lower Class 5 section as having "less push" with a two-hour release.

The duration of full flow from the perspective of the boater can also be estimated from the field measurements. There are two classifications of navigation times based on the flow level, in particular, the levels from the falling wave. The first classification is when an experienced boater first notices the level falling and is designated "Notice Level Reduction." The second classification is when there has been a water level reduction such that the character of the rapids is significantly changed and rocks have water lines higher than the result of wave action. This level is defined as a level 0.1 feet lower on the Sang Run gauge versus the full flow level and is designated "Minus 0.1 Foot Reduction." The estimated navigation times at Cheeseburger Fall based on these classifications are given in Table B-4. The "Notice Level Reduction" times are the sum of the estimated full flow period of the respective Sang Run gauge level plus the first 15 to 20 minutes of the falling wave which is slowly receding.

Table B-4. Estimated Hydrological Navigation Times at Cheeseburger Falls by Full Flow Gauge Reading at Sang Run (Old Gauge)

Sang Run Gauge (Old) (feet)	Notice Level Reduction (minutes)	Minus 0.1 Foot Reduction (minutes)
2.0	20	35
2.1	35	50
2.2	70	85

Table B-5. Percent of Time That Flow at Sang Run with a Hydropower Release is Equal to or Less Than the Designated Level

Sang Run Gauge (Old) (feet)	July	August
2.0	15	20
2.1	50	60
2.2	75	90

The corresponding percent of time the flow at Sang Run with a hydropower release is equal to or less than the designated level is given in Table B-5 (see the following section on long-term availability of water for further information on this issue). In mid and late summer, approximately 50 percent of the time water levels with a hydropower release will be equal to or below 2.1 feet (Sang Run "old" gauge). Approximately 20 percent of the time levels with a hydropower release will be equal to or just slightly below 2.0 feet.

Conclusion

From flow theory, the time period of full elevated flow from a hydropower release becomes progressively less at positions further downstream. In other words, with a two-hour generation release, the time period of full flow at Sang Run is less than two hours, the time period of full flow at Gap Falls is less than the time period at Sang Run, etc.

From field measurements at times of very low natural river flow, the full elevated flow (2.0 feet on the Sang Run gauge) from a three-hour generation release lasts for approximately one hour and 20 minutes at National Falls and one hour at Cheeseburger. From these measurements, it can be accurately predicted that full flow for a two-hour release lasts 20 minutes at National Falls and for only an "instant" in the area of Powerful Popper to Cheeseburger Falls. This area is the last of the tightly spaced Class 5 rapids.

Despite the lack of measurements for a two hour release, the measured data provide meaningful insight concerning the capacity limitations for the Upper Yough at very low natural flows. The measurements of three hour releases and conditional predictions for two-hour releases explain the comments on navigability from experienced raft guides and boaters. The predictions are consistent with comments saying there is "15 to 20 minutes of water" in the lower section of the Upper Yough. This period of water exists because the drop in water level initially falls slowly. The predictions are also consistent with the comment that the lower section has "more push" with a three-hour release versus a two-hour release. There is "more push" because there is a full elevated flow in the lower section with a three-hour release.

The time duration of navigable water increases significantly with relatively small increases in natural flow. For example, the period before an experienced boater would notice a reduction in water level at Cheeseburger Falls increases from 20 minutes at a flow of 2.0 feet to 35 minutes at 2.1 feet and 70 minutes at 2.2 feet.

Minimum Time Limits for Raft, Kayak and Canoe Navigability

The following paragraphs describe the major impact from the minimum time limits of elevated flows on the Upper Yough for a two-hour Deep Creek hydropower release with low natural river flows. This description is based on informal observations over the last two summer seasons when raft usage has greatly increased.

As reported previously, raft, kayak and canoe navigation on the Upper Yough is typically only possible with a hydropower release from Deep Creek Lake. Many of these releases in the spring and summer last for only two hours. The duration of elevated navigable flows from a two-hour release is much less than two hours. In particular, at times of low natural flows (less than 100 cfs, which results in a reading of 2.0 on the old Sang Run gauge or 1.9 on the new gauge), predictions from field measurements are consistent with comments from experienced raft guides and private boaters saying there is "15 to 20 minutes of water" in the lower Class 5 section of the river. It is predicted that with very low natural flow conditions, the "15 to 20 minutes of water" is not the full flow of the release, but the beginning part of the receding flow. The first 15 minutes of the receding flow falls slower than the following 15 minute period.

With a large number of rafts on the Upper Yough, navigation problems are particulary evident at the rapid "Lost and Found" at times when there is a two-hour release with very low natural flow conditions. The upper section of "Lost and Found" is a six to seven foot drop(or falls) formed by a "line of boulders" and an island. There are numerous small, unnavigable channels through the boulders and to the left of the island, which pass some of the flow. There is only one route for rafts in the upper section which passes part of the river flow. At approximately half way down this line of boulders there is a rock called the "Divider." The channel to the left of the Divider Rock looks passable from the very top of the rapid but just over the limp is an "under-cut rock" called "Tombstone." Boaters have long recognized the danger of the left channel from this rock and thus the reason for its name. Unfortunately, in 1989, the only whitewater recreational death on the Upper Yough occurred at this rock. The channel to the right of the Divider Rock is the only passable route for rafts. With releases at low natural flows, this right channel is slightly narrower than the typical four man raft used on the Upper Yough. With receding flow, rocks both before the constriction and in the constriction become exposed. As a consequence, with a two hour release and very low natural flows, rafts typically become temporarily stuck in the constriction.

A raft's approach to the constriction is at an angle compared to the direction it needs to face in order for it to negotiate the constriction. If the raft does not change its angle as it enters the constriction, it is all the more likely to be stuck.

When a raft is properly aligned in the constriction and becomes stuck, it is often dislodged by the customers and guides bouncing on the raft. However, when the raft is stuck at an angle, the guide and sometimes the customers have to get out of the raft to dislodge it. With the exposure of rocks both before and in the constriction from the receding flow, more rafts are likely to be stuck in the constriction at a misaligned angle, with guides and possibly customers needing to get out of the raft to dislodge it.

The constriction is not the only difficulty that slows raft traffic. In the second section of the rapid is a large hydraulic (or "hole") capable of flipping a raft if not avoided or aggressively negotiated through powerful and coordinated paddling. As a consequence of this hydraulic, rafters generally do not start the rapid until the raft before them successfully clears the hydraulic.

Because rafts become stuck in the constriction and wait until the previous raft successfully clears the lower section, the negotiation of Lost and Found takes considerably longer to pass raft traffic compared to other significant downstream rapids. Thus, Lost and Found is a "bottleneck" with rafts and boaters (kayakers and canoeists) collecting and waiting above the rapid for their turn.

The time required for one raft to negotiate Lost and Found can vary depending on how much time it takes to dislodge a raft stopped by the constriction. Detailed time measurements of raft and boater traffic were made in 1989. These observations were made at a relatively higher river flow (2.1 feet at the old Sang Run gauge) than the lower flows that cause the "15 to 20 minutes of navigable water." Thus, the rafts were less susceptible to becoming temporarily stuck. Nonetheless, these observations of raft traffic and approximate time periods are instructive for understanding the problem of crowding on the Upper Yough.

The observed time period between rafts within a company without any raft getting stuck ranged from 30 to 50 seconds, with an average of 35 seconds. No raft started to negotiate the rapid until the previous raft had passed the lower hydraulic. One raft became temporarily stuck and took 65 seconds. No kayakers were present when the rafts were negotiating the rapid.

The time interval was also measured for some kayakers. Approximately one-third of the kayakers observed would start to paddle the rapid as soon as the previous kayaker passed the Divider Rock. The time interval between these kayakers was 5 to 10 seconds. The other kayakers were doing things that delayed their run such as emptying their boats and talking to the observer. There was no incentive to run the rapid as soon as possible because there were no rafts in sight and the release was three hours long.

The above measured minimum time period between kayaks is from a limited number of kayaks negotiating only part of the Lost and Found rapid in the channel to the right of the Divider. Because kayaks typically stop in the eddies above the hole at the bottom, kayakers will stop running the upper part of the rapid until the eddies become clear or partially clear. Thus, the minimum time period between kayakers for running the whole rapid is longer than the above measurements. Because of the lack of incentive to run the rapid as quickly as possible in order to keep moving downstream, minimum time periods for kayakers to run the whole rapid using the right channel were not measured in 1989. Furthermore, the navigation of kayakers at Lost and Found with heavy traffic also includes kayakers taking an alternate route.

The time between kayaks and canoes can be less because they do not become stuck in the constriction and do not wait for other boaters to successfully negotiate the hydraulic. Many boaters stop before the hydraulic (i.e. eddy out) and wait for fellow boaters to negotiate the upper section. As more boaters arrive in the eddy(s) other boaters leave the eddy and negotiate the hydraulic. Thus, a number of hard boaters can negotiate the rapid in the same time period as one raft. In addition, these boaters often make use of the time periods between rafts due to time delays resulting from rafters getting organized to run the drop.

With lower flow conditions, the time period between rafts which do *not* become stuck would probably be slightly longer than the observed average of 35 seconds. In addition, with lower flow more rafts would become temporarily stuck. Thus, it is estimated that one raft would take on the order of 45 to 75 seconds to negotiate the rapid, with an average time between rafts of one minute.

With navigable flow levels in the lower Class 5 section lasting on the order of 15 to 20 minutes and with each raft taking approximately one minute to run "Lost and Found," there are upper limits on the number of rafts that can navigate this rapid during a two-hour release at low natural flow conditions. Assuming one raft per minute, more than 15 to 20 rafts means that some rafts will be using "unacceptable" flow levels. At some point, some rafts will be faced with an absolutely unnavigable rapid requiring a carry. And this analysis does not consider the private boaters in kayaks and canoes.

These boaters also have an optional route for the upper section which can not be negotiated by rafts. When crowded, many boaters use this option to get ahead of the group of rafts waiting to negotiate the rapid. The optional route is a sharp drop over a ledge in which a boat scrapes and generally bumps against a rock. The boater drops into a small pool just above the hydraulic. Most boaters prefer to negotiate the main route with the constriction but take the optional route (called "sneak route") to get around the waiting rafts and stay with the higher flow.

Since many raft trips generally travel the Upper Yough on the forward part of the flow and can be closely spaced, many hard boaters elect (many feel forced) to stay behind the rafts and accept the lower flow levels when negotiating the lower Class 5 section. Boaters elect to stay away from closely spaced rafts because contact between a kayak or canoe and a raft has a relatively high probability of injury for the boater. Boater contact with a raft can mean being flipped upside down, ending up under the raft and dragged into bodily contact with bottom rocks. On the other hand, rafts can bump into each other with generally little consequence. Thus, with large numbers of rafts on the river, some boaters reluctantly elect to navigate on the lower receding flows behind most of the rafts.

Conclusion

The travel time characteristics of hydropower releases, combined with the topography of the river at Lost and Found rapids, results in this area becoming the most limiting factor to boating on the Upper Youghiogheny River. The most severe limitations are found during two-hour releases at times of very low natural river flow (2.0 feet on the "old" Sang Run gauge). Under these conditions it is likely that some rafts will be forced into "unacceptable" flow levels if there are more than 15 to 20 rafts on the river. Some private boaters may also be impacted by being forced to take a less preferred route or to run the rapids at an undesirably low water level.

The current whitewater boating regulations limit the number of commercial customers to 72 per day. Assuming three customers per raft, this limit allows 24 commercial rafts per day. In reality, 72 customers generally will translate into more than 24 rafts because some rafts will have fewer than three customers. In

addition, there are no restrictions on private rafting activity so it is likely that private rafts would increase the total number of rafts on the river to some degree. Thus, under the current regulations, it is possible that the number of rafts using the river will exceed the number that can safely negotiate the most limiting "bottleneck" on the river during two-hour releases when natural flow is very low. Such conditions can be expected to occur some years during June and July. For example, these conditions were found during the very dry summer of 1988 but did not occur during 1989.

Under less limiting conditions resulting from longer hydropower releases, higher natural flow, or both, the period of navigability at Lost and Found increases substantially so it is unlikely that the number of boats currently permitted on the river would exceed the limits of navigability.

Long-Term Availability and Dependability of Navigable Flows

In this section, the long-term availability and dependability of navigable flows for whitewater recreation from May through October are estimated from hydrological data.

Frequency of Navigability from Natural Flow Without a Hydropower Release

Figure B-4 shows the estimated flow frequency curves for Friendsville assuming no releases from Deep Creek Lake. These curves are computed from hydrological data measured at Oakland multiplied by a factor of 1.72 to account for the difference in drainage areas. These curves give the estimated percentage of time the flow will equal or exceed a particular flow value in a given month. For example, for the top graph, the value of 650 cfs on the vertical axis corresponds to 53 percent on the horizontal axis for the month of April. Thus, for April the flow will equal or exceed 650 cfs 53 percent of the time.

Table B-6 gives the percentage of time the estimated natural flows are within the defined ranges of the Sang Run "old" Gauge.

A problem for many boaters in the spring months is that the natural flow will have a high frequency of being slightly below the minimum (2.0 feet at Sang Run or approximately 650 cfs), but with a release adding 600 cfs, the flow will be too high for their level of difficulty (see Table B-1).

The curves in Figure B-4 are based on 25 years of daily average data. Thus, the curves combine data from both dry and wet years. For a particular month in a drier than average year, this month's days will have flows that correspond to the lower side of the respective curve. Likewise, the wetter than average months will have daily flows corresponding to the higher side of the curve. For example, for the month of July, Figure B-4 gives a value of 40 percent at 150 cfs. Thus, for 40 percent of the days during 25 years of July months, the estimated natural flows at Friendsville were equal to or greater than 150 cfs. However, for 20 percent of the years, July had daily flows that were nearly always above 150 cfs. The number of days for these wet years which had flows greater than 150 cfs ranged from 24 to 30 (out of 31 days). On the other hand, for 25 percent of the years July had daily flows that had only a few days above 150 cfs. The number of days for these dry years which had flows greater than 150 cfs ranged from 0 to 6.

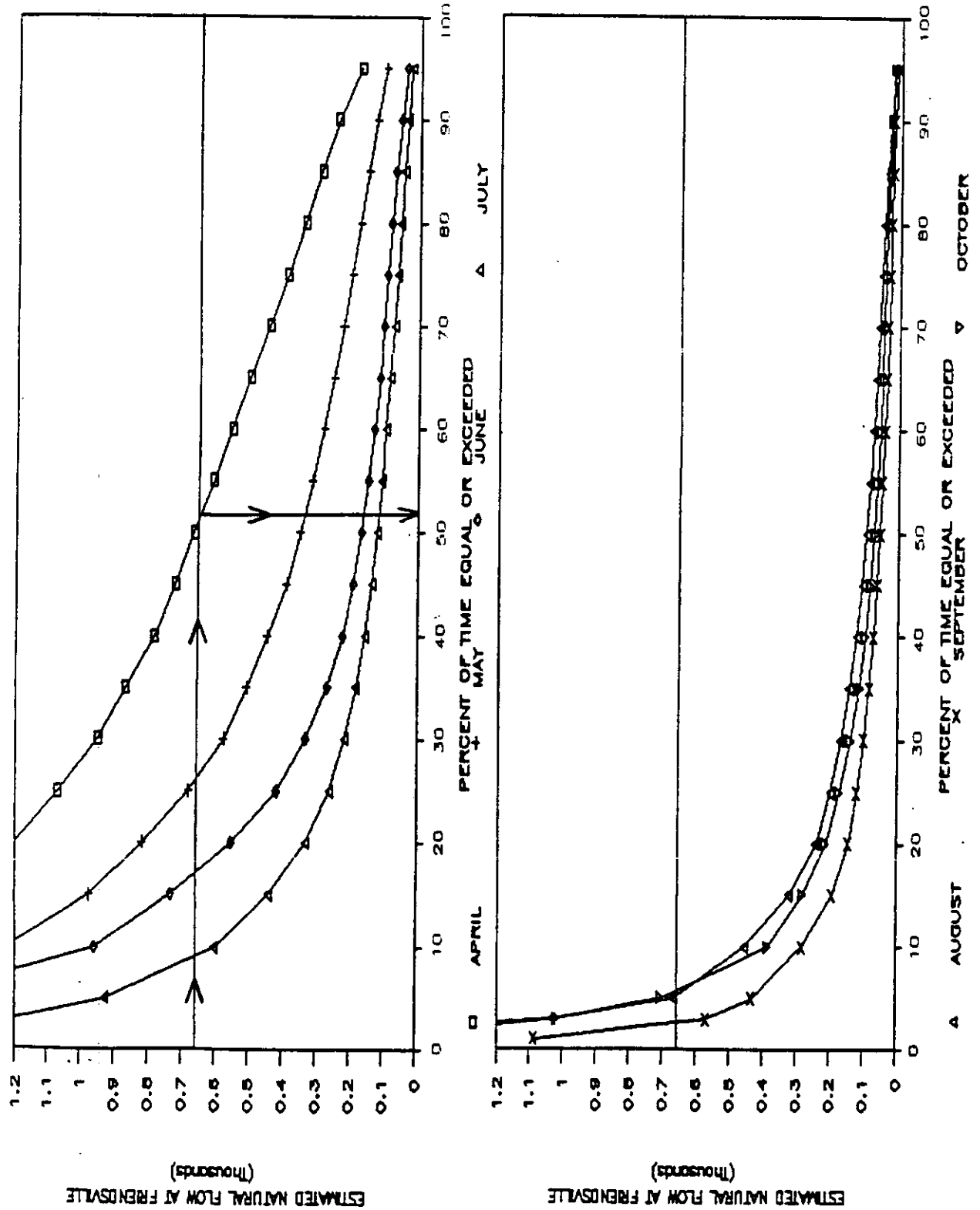

Figure B-4. Estimate Frequency of Flow at Friendsville Without a Hydropower Release

Table B-6. Percent of Time Natural Flows Are Within Defined Range of the Sang Run Gauge

Range of Sang Run "old" Gauge	Apr	May	June	July	Aug	Sept	Oct
2.0-2.3	25	13	8	5	7	3	7
2.3-2.5	8	2	2	2	3	1	2
>2.5	20	12	8	3	3	1	3
	53	27	16				

Deep Creek Lake Level

Hydropower releases are managed such that the lake level is at its maximum level in May/June and approximately four feet lower in October through December. Before 1981, the lake was gradually lowered throughout the summer and early fall. Starting in 1981, the management of the Deep Creek Lake level changed.

Monthly power generation and end-of-the-month Deep Creek Lake levels were obtained from the Pennsylvania Electric Company for the years 1970 through 1988 (19 years). The records before this time were not readily available.

Figure B-5 shows the end-of-the-month lake levels for May through October. For May and June most years had levels within the range of 2461 to 2459. The year-to-year variation within this range is essentially the result of the "catchment" nature of the operations. The variations occur because runoffs from rains are caught and held, which raises the lake level. The "caught" water is then used over time for generation. The relatively low values in 1976 on Figure B-5 were the result of a very dry spring such that the lake did not refill from the lower winter pool level.

Figure B-5 shows the end-of-the-month levels for September and October to be generally between 2457 and 2455, which is generally four feet lower than May and June. The relatively large values in 1975 were probably the result of very wet months. The relatively low values in 1980 were probably a result of an extended maintenance outage for both turbines in October. In anticipation of this outage the lake was additionally lowered beyond the target.

For July and August on Figure B-5 (bold lines), the overall end-of-the-month lake levels are higher after 1981. This reflects the change in lake management after 1981. The new lake level management since 1981 is not formally defined. Figure B-6 shows the official operational rule curve for Deep Creek and the actual lake levels in 1988. Normally, a lake level would closely follow an operational curve. However, the actual lake level for 1988 and other years, especially years since 1981, do not follow the curve. The new lake level management consists of only an informal agreement to keep the lake level above 2458 feet elevation before Labor Day. This has been done in recent years(see Figure B-5).

In practice, for the months of July since 1981 which were relatively wet Julys (82, 84, 85, 86), Figure B-5 shows the end-of-the month July lake level between 2459.8 and 2460.3 feet elevation. Thus, it would

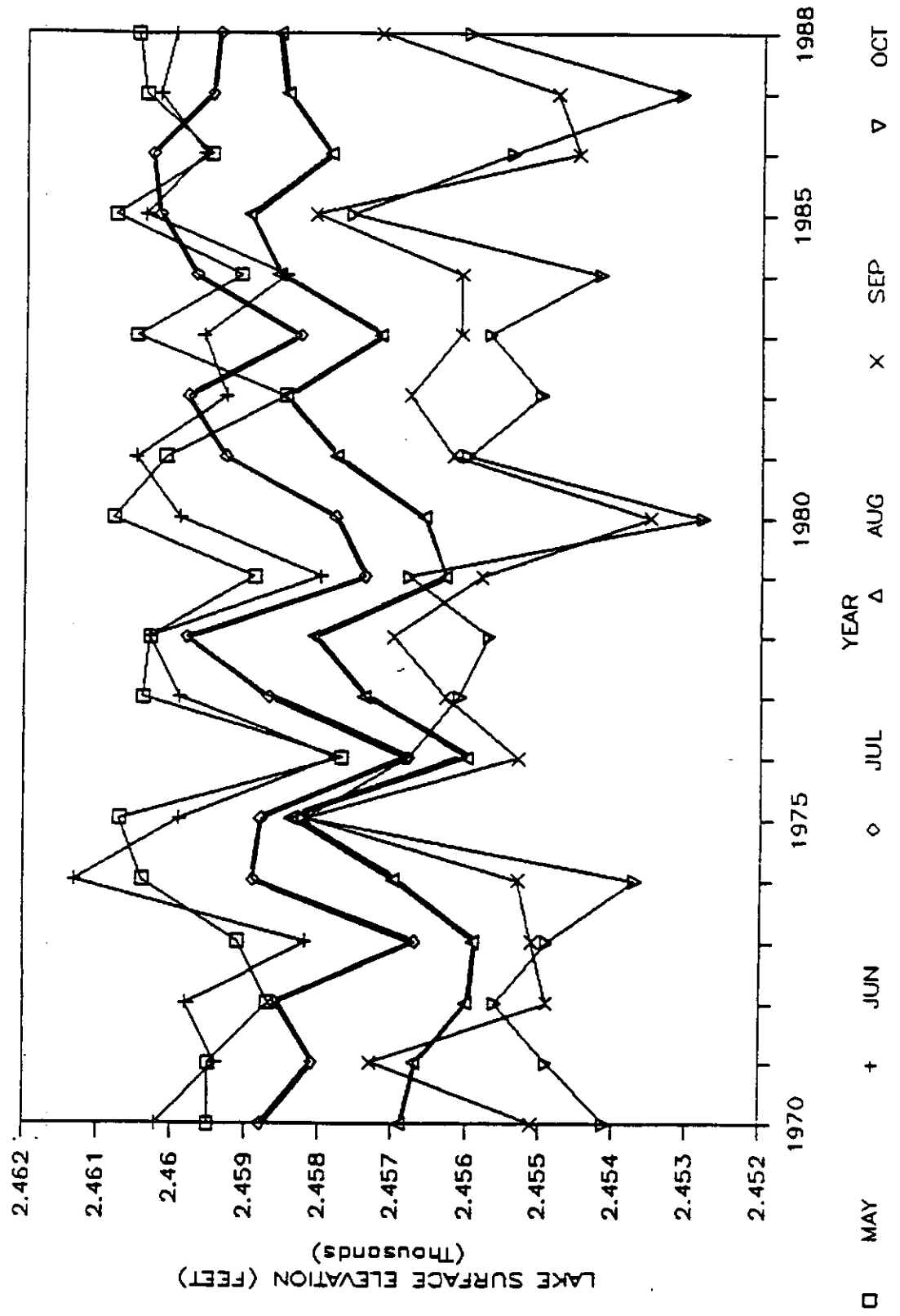

Figure B-5. End-of-Month Deep Creek Lake Level for May through October; 1970 to 1988

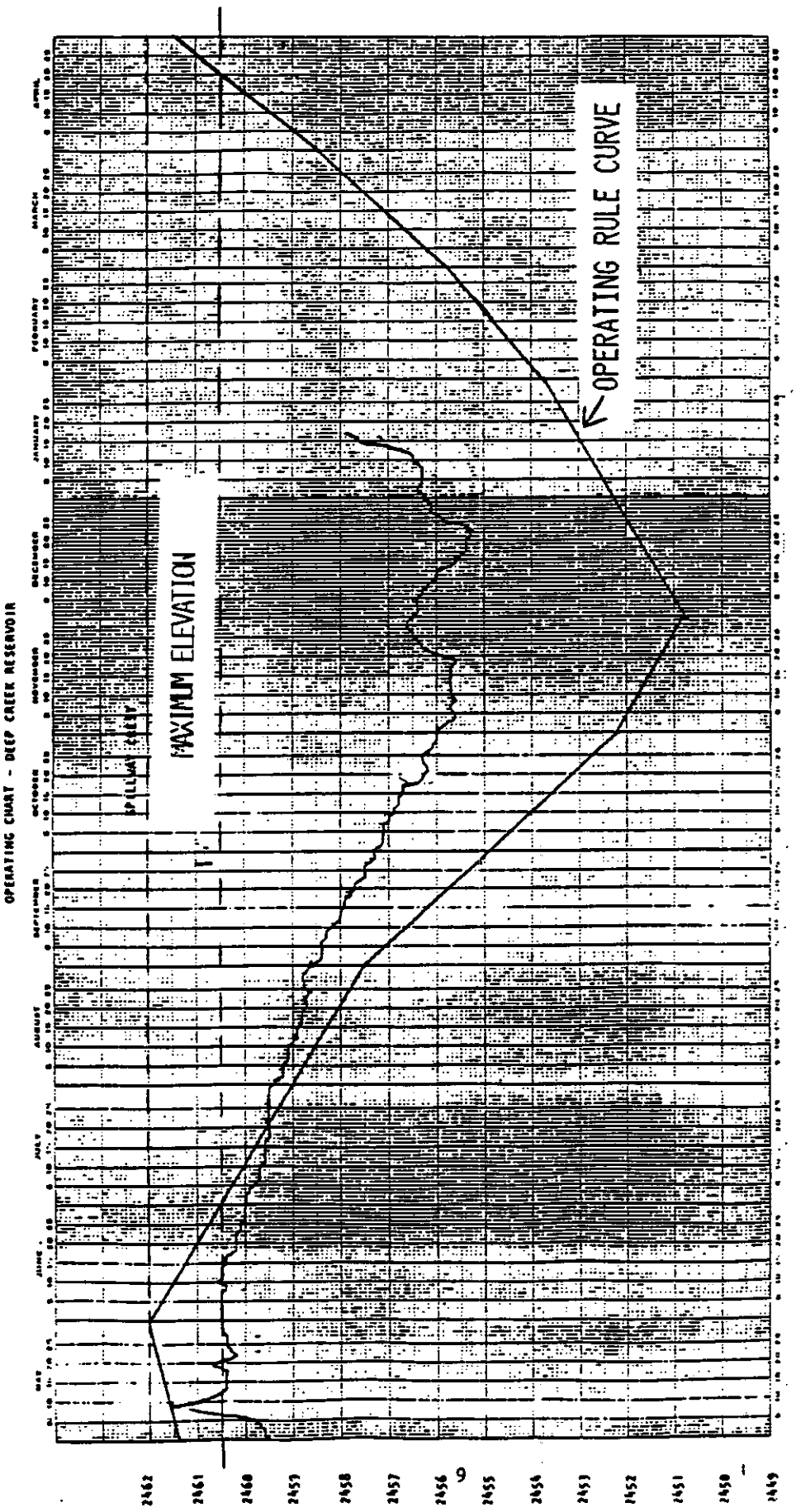

Figure B-6. Deep Creek Operational Rule Curve and Actual Lake Level; May 1988 to January 1989

appear that approximately 2460 feet is the target level for the end of July. However, for the dry years(83, 87, 88), the lake level was allowed to fall significantly below 2460. In 1983, 1987 and 1988, the end-of-the-month lake level was 2458.3, 2459.5 and 2459.4, respectively.

Overall Monthly Frequency of Hydropower Releases

Because of the changed lake level management, the frequency of future hydropower generation can not be predicted by directly analyzing the historical records. In addition, the power company's 1970 to 1988 records cover wetter than average years. Thus, in order to predict the monthly frequency of hydropower releases, the 1970 to 1988 data was first hydrologically characterized and compared with the natural flows at Oakland using regression. Then, the regression results were used to estimate monthly frequency of generation for all years with the new lake level management. The calculation procedure used is discussed in more detail in Appendix 2.

From inspection of the actual end-of-the-month lake levels in Figure B-5 since 1981, the assumed lake level management is given in Table B-7. For maintenance reasons, the power company likes to generate for a minimum of two hours per week. In recent years, in cooperation with the whitewater outfitters, the minimum release was scheduled on Fridays. Thus, a minimum of one two-hour release is assumed in the calculation procedure.

Table B-7. Assumed Deep Creek Lake Level Management for Estimated Generation

Month	Target Level at end of month (Elevation)	Monthly Level Change (Feet)
May	2460.0	-
June	2460.0	0.0
July	2460.0	0.0
August	2458.5	-1.5

635

Figure B-7 shows the estimated power generation using the calculation procedure with lake management defined by Table B-7 for the years 1942-1988 (i.e., a generation flow of 600 cfs and a minimum of one two-hour release a week). The June graph shows 9 years out of 47 (19 percent) with only the minimum one two-hour release per week (equal to 2.0 on the figure). The July graph shows 17 years (35 percent) with only the minimum one two-hour release per week. Yet, in both June and July there are years when there is considerably more hours of generation per week.

The August graph shows no years with the minimum two-hour releases. This occurs because the lake level has started to be lowered in the later part of August. Likewise for September and October, there are no

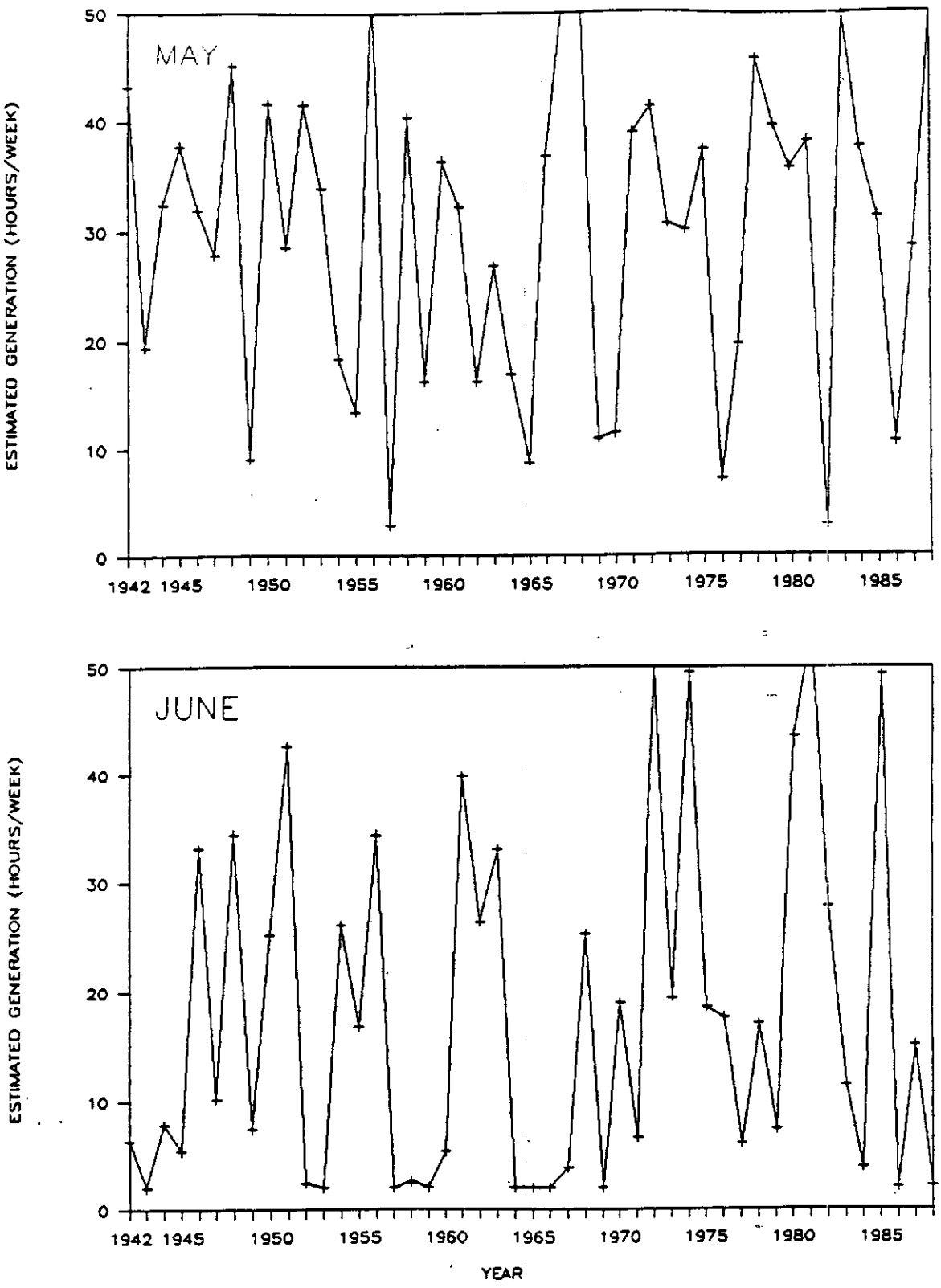

Figure B-7. Estimated Generation with New Lake Management and Minimum of One Two-Hour Release a Week

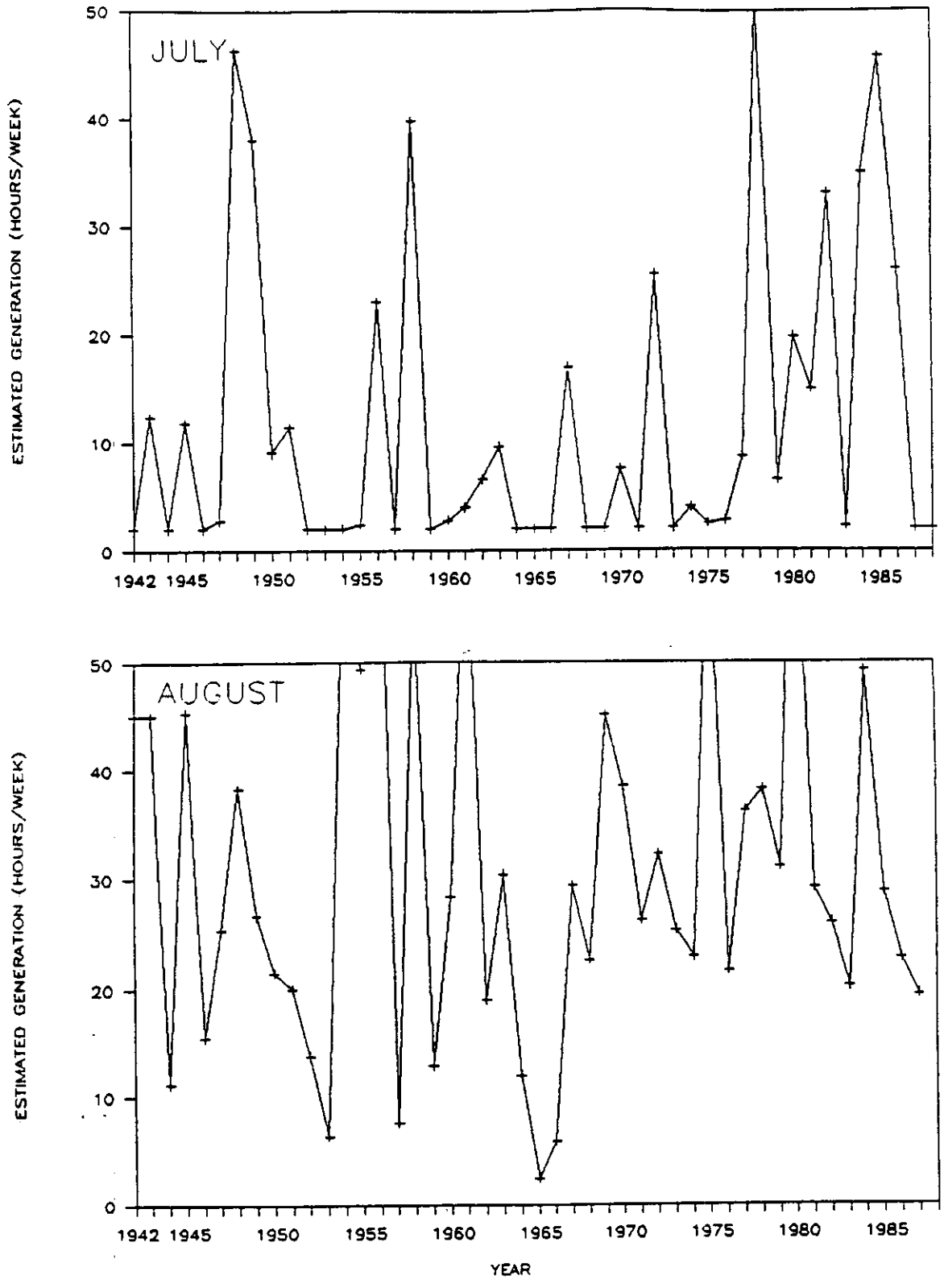

Figure B-7, Continued.

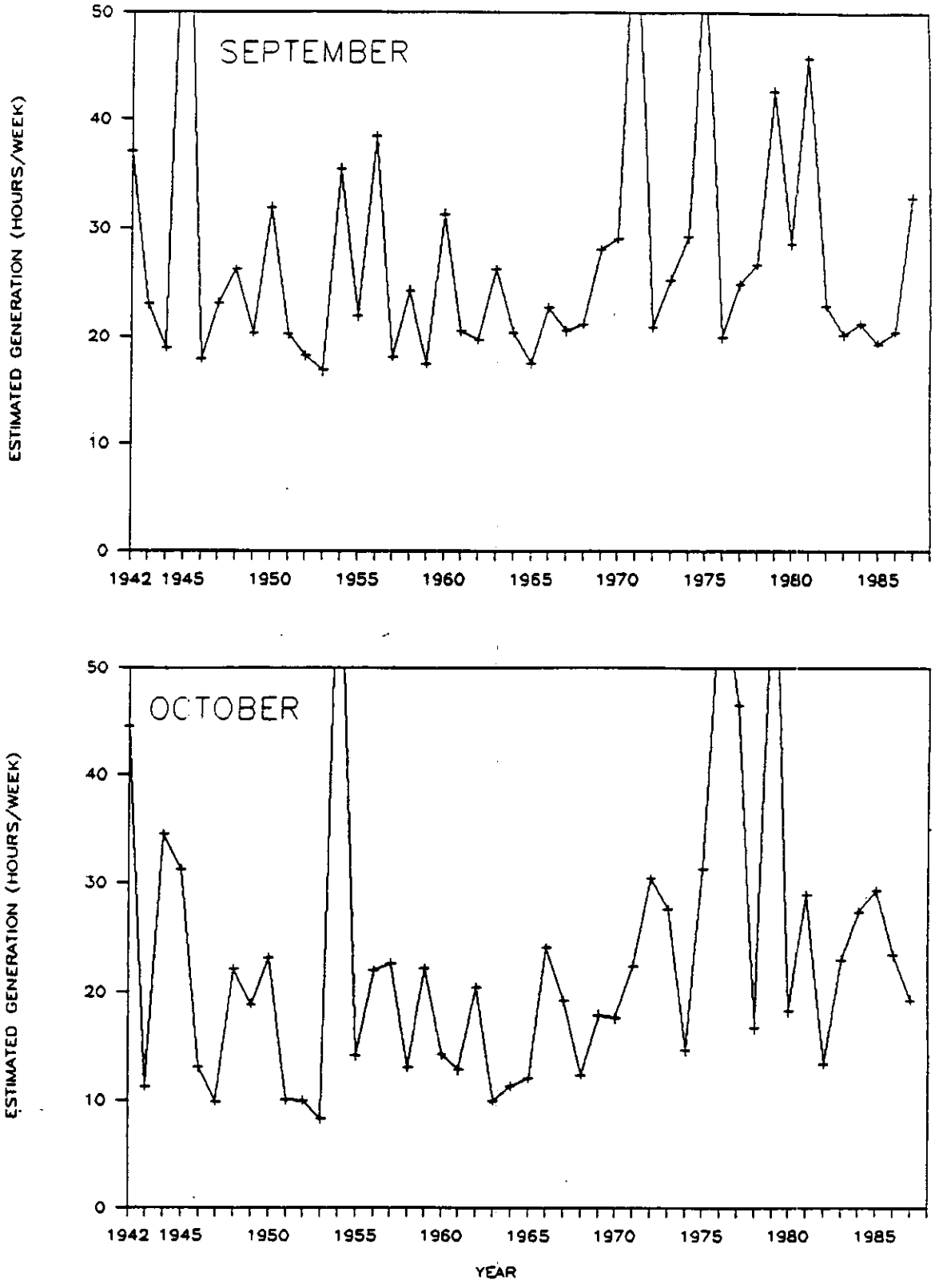

Figure B-7, Continued.

years with the minimum two-hour releases, also due to lowering of the lake level. One foot of lake level change supplies enough water for 72 hours of generation at 600 cfs (69 hours at 635 cfs).

Note that the September graph shows no year below 17 hours of generation per week and the August graph shows only 11 out of 46 years below 20 hours of generation per week. Twenty hours a week is approximately 3 hours a day which is essentially what occurred for the remainder of the season after the start of this study in 1988.

From these graphs, the estimated hydropower generation with the assumed lake management shown in Table B-5 predicts the monthly generation hours with the following long-term frequency (Table B-8).

Table B-8. Average Percentage of Time Estimated Generation is Within Designated Range

	May	June	July	Aug	Sept	Oct
One two-hour release a week	-	19	35	-	-	-
2.0 to 4.0 hours/week	4	11	20	2	-	-
4.0 to 10.0 hours/week	6	17	13	6	-	4
10.0 to 20.0 hours/week	22	19	11	15	24*	46
20.0 to 30.0 hours/week	8	11	6	35	52	30
>30.0 hours week	60	23	15	42	24	20

*No years below 17 hours per week

In the months when it is estimated there is only the minimum two-hour release per week, there is some lowering of the lake level below the target levels given in Table B-7. For June, with 19 percent of the months projected to have only the minimum of one two-hour release per week, none of the levels is more than 0.5 feet below the target level of 2460 feet. For July, with 35 percent of the months projected to have only the minimum of one two-hour release a week, none of the levels is more than 1.0 feet below the target level of 2460 feet.

If the minimum release each week is assumed to be four hours instead of a single two-hour release, the estimated percent of months with the four-hour minimum would be the sum of the first two rows of Table B-8. However, the lake levels are slightly lower. For June, with 30 percent of the years projected to have only the minimum of four hours of generation a week, none of the levels is more than 0.6 feet below the target level of 2460 feet. For July, with 55 percent of the years projected to have only the minimum of four hours of genera-

tion a week, none of the levels is more than 1.2 feet below the target level of 2460 feet. For July, 17 percent of the years have levels more than 0.5 feet below the target level of 2460 feet.

In the recent very dry summers of 1987 and 1988, the Deep Creek Lake level actually receded at the end of July to essentially 2459.5 feet. Reducing the target level from 2460.0 to 2459.5 reduced the estimated percentage of years with one two-hour release a week from 35 percent to 9 percent. The percentage of years with 2.0 to 4.0 hours of releases per week is reduced from 20 percent to 11 percent.

Subsequent to the preparation of the material for this report, it was learned that the actual release rate for full flow hydropower generation in recent years is closer to a value of 635 cfs versus the assumed 600 cfs used in the above calculations. This change has a relatively small effect on the results, however, given the overall purposes of this study. For example, the estimated percentage of years with one two-hour release a week increases from 35 percent to 42 percent.

It is important to note that not all of the predicted generation hours given in the graphs and Table B-8 would be available for whitewater recreation. There is some emergency generation, some generation for peak power demand in the evenings, and some "only-one-turbine" generation due to planned maintenance. In addition, in the late fall with the shorter days, some generation starts too late in the day such that it can not be used by whitewater boaters. For example, in July 1988, there was 19.7 hours of generation, or an average of 4.6 hours per week. However, not all 19.7 hours of generation was available for navigation. The USGS data shows that 14 percent of this generation was not available because it was not of two-hour duration. All of the two-hour releases and a single three-hour release (total of 17 hours) occurred at times of the day that could have been used for whitewater recreation provided it was adequately announced. In July 1987, there was 25.2 hours of generation with only 5 percent of the generation less than two-hour releases. All of the other releases were two hours (12 releases). In 1987 and 1988 there were three and one two-hour releases, respectively, that were just usable for whitewater recreation because of a 3:00pm starting time.

At present there is about 7 cfs continuous leakage through the power station. This leaking water provides relatively cold water habitat for trout. The cold water may be particularly helpful to the trout during times of very low river flow in the summer/fall months. The State of Maryland Fisheries Division is presently studying the Youghiogheny fishery, including exploring the idea of adding some additional continuous flow to the leakage to expand the trout habitat and using releases to cool the stream. With some additional continuous flow, there will be less water for generation. Thus, in dry times, there may not be enough water for even the minimum one two-hour generation release a week during June and July.

The consideration of alternative management plans for hydropower releases was not a requirement of this study. Depending on the management objectives, studying alternative plans may require a more detailed and accurate consideration of hydrological issues than developed by this study and presented in this report.

The calculation procedure also gives an estimate of lake evaporation at times of very low flow. The estimate is 25 cfs or 0.17 inches per day (0.44 feet per month). This estimate compares closely with measured pan evaporation rates at the Savage Dam located seven miles to the east of Deep Creek Lake. The sum of evaporation and the 7 cfs continuous leakage is estimated to be 32 cfs or 0.21 inches a day (0.54 feet a month).

Assuming no power generation, there needs to be at least 32 cfs inflow to Deep Creek Lake during the summer/fall months to keep the lake level from falling due to water loss from evaporation and leakage. Based on Oakland flow data, monthly average inflows are estimated to be below 32 cfs during 30, 35 and 50 percent of the years for July, August, and September, respectively. With lake inflow less than 32 cfs, evaporation and leakage would lower the lake even without a hydropower release. A single two-hour generation release at 600 cfs uses water that would lower the lake 0.33 inches (0.35 inches at 635 cfs). Thus, it is understandable why in a very dry summer there can not be a two-hour release every weekday until the later part of August when the lake level is intentionally lowered.

Lake Level and Generation in Recent Dry Years

In the recent very dry years of 1987 and 1988, evaporation, power generation, and leakage gradually lowered the lake level throughout the summer from its target maximum level of 2460.5 feet elevation. The end-of-month lake level, difference in level from the maximum level and estimated hours of generation for these years is presented in Table B-9.

Table B-9. Average Monthly Generation and End-Of-Month Lake Level for the Recent Very Dry Years of 1987 and 1988

	1987			1988		
Month	Level	Below Max.	Gener. Hours/ Week	Level	Below Max.	Gener. Hours/ Week
May	2460.4	-0.1	19.2	2460.5	0.0	54.6
June	2460.2	-0.3	9.5	2460.0	-0.5	10.8
July	2459.5	-1.0	5.7	2459.4	-1.1	4.5
August	2458.5	-2.0	11.7	2458.6	-1.9	9.6

In July 1987 and 1988, water used for power generation is equivalent to a lake level decrease of 0.37 and 0.29 feet, respectively. The actual decrease in lake levels during July (0.7 and 0.6 feet, respectively) was more than these values. This occurred because water loss from evaporation, equivalent to an estimated 0.54 feet of lake level decrease, was considerably more than lake inflow.

In both 1988 and 1989, three-hour generation nearly every weekday started in approximately mid-August. Thus, the increased lowering of the lake and increased average generation in August.

Since a large part of the decreasing lake level is a result of evaporation and leakage, small increases in generation do not cause relatively large changes in lake level. Assuming an additional hour of generation per week in June and July (9 hours for 9 weeks), the lake level would be 0.13 feet lower (1.6 inches) at the end of July than given in Table B-9.

Conclusion

In general, there are three hydrological periods (spring, June/July and August/September/October) defining a different availability and dependability of navigable flows for whitewater recreation.

In the spring (April, May), natural flows are often sufficient for navigation without a hydropower release. Because of the higher base flows in the spring, a release can often make the river too high for many boaters.

In the June/July period, natural river flows are sufficiently low most of the time so that a hydropower release is needed for navigability and the river is seldom too high with a release. Because of generally low inflow into Deep Creek Lake and evaporation from the lake, releases are generally infrequent and of short duration. It is projected that 19 and 35 percent of the years for June and July, respectively, will only have the minimum one two-hour release per week with some lowering of the lake below 2460 feet (maximum of 1.0 feet below 2460). For a minimum of 4 hours of water, the projections are 30 and 55 percent of the years for June and July, respectively, However, the lake levels will be lower at the end of July with a maximum of 1.2 feet below 2460 feet.

In the August/September/October period, natural flows are generally even lower than in June/July. However, in the later part of August, the lake level starts to be lowered, adding significant amounts of water for hydropower generation. For most years there is sufficient water during the months of August and September for a minimum of 17 hours of generation a week. For October the minimum is 10 hours.

During times of very low river flows, evaporation from the lake can exceed the lake inflow. Evaporation is estimated to be 0.17 inches a day (0.44 feet a month or 25 cfs). A single two-hour generation release uses water that would lower the lake by 0.33 inches. In recent dry years (1987 and 1988), average generation in July was approximately 5 hours of generation per week using the equivalent of 0.32 feet of water. Thus, during dry periods, the amount of water loss to evaporation exceeds the amount of water used for generation, with both factors contributing to a lowering of the lake level.

Since a large part of the decreasing lake level is a result of evaporation and leakage, small increases in the length of power generation would cause small changes in the Deep Creek Lake level. One additional hour of generation per week during June and July would lower the lake level at the end of July by 0.13 feet (1.6 inches).

References

Gertler, E. 1989. *Maryland and Delaware Canoe Trails.* 3rd edition. Springfield, VA: Seneca Press.