SNOHOMISH COUNTY
PUD
PUBLIC UTILITY DISTRICT No. 1
2320 California St., Everett, Washington 98201 258-8211
Mailing Address: P. O. Box 1107, Everett, Washington 98206

October 22, 1990
PUD-19335

Ms. Lois Cashell
Federal Energy Regulatory Commission
825 North Capitol Street NE
Washington, D.C. 20426

Dear Ms. Cashell:

RE: Henry M. Jackson Hydroelectric Project
FERC No. 2157 Article 55
Revised Final Powerhouse Downramping Study Report

On June 7, 1990, the Snohomish County Public Utility District No. 1 (District) submitted, under License Article 55, a report "Downramping Regime for Power Operations to Minimize Stranding of Salmonid Fry in the Sultan River" (PUD-19146). Subsequently, we discovered that Appendix F, Agency Consultation, was only partially complete. After discussions with FERC personnel, we decided to resubmit the entire report with a complete Appendix F and minor revisions to the preface and Addendum for clarity. Therefore, please find enclosed the revised downramping report which should supersede the previous submittal.

Again, the District is submitting this report as fulfillment of one of several obligations under Article 55 of the amended Project License (17 FERC ¶ 61,056) and the Settlement Agreement (22 FERC ¶ 61,140) between the Licensees and the Joint Agencies (Washington Departments of Fisheries and Wildlife, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the Tulalip Tribes).

After an involved study by the District consultant and lengthy consultations with the Joint Agencies related to License Article 57 (Flood Control), the parties involved have agreed to a schedule of downramping rates for Project operation. The downramping rates developed out of the process of this study and consultation with the Joint Agencies are unique to the Sultan Basin aquatic resources and Jackson Project operational constraints.

The purposes for which the study was undertaken have been concluded and reflected in the Second Interim Operating Plan submitted to the FERC for approval earlier this year (PUD-18897). Therefore, this is the final report on downramping based on Article 55 requirements of the amended Project License and the Settlement Agreement. However, in light of continuing Article 57 consultations with the agencies, which also bear on this matter, it should be recognized that further study and adjustment of downramping practices may be appropriate.

Very truly yours,

ORIGINAL SIGNED BY R. E. JOHNSON

Richard E. Johnson, Director
Construction and Operations

BJM
Enclosures
BFM:vr
cc: Joint Agencies
Bell & Ingram (Attorneys for Tulalip Tribes)
A. Martin, FERC (Portland)
bcc: B. Jones, City of Everett
C. Olivers, City of Everett
C. Earl (w/o attachment) - E4
D. Hale/G. Mixdorf - E4
R. Johnson (w/o attachment) - OP
B. Meaker - BB
D. Dole - BB

Downramping Regime for Power Operation To Minimize Stranding of Salmonid Fry in the Sultan River

Henry M. Jackson Hydroelectric Project
Snohomish County, Washington
FERC No. 2157

Prepared by
Forrest W. Olson
CH2M HILL

October, 1990

Project Leader
Roy G. Metzgar
Snohomish County Public Utility District No. 1
P.O. Box 1107
Everett, Washington 98206

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PREFACE

This report in its final form was issued to the Joint Agencies in 1987 and Table 9 in Chapter 5 reflects the provisional downramping rates that were agreed to by the Joint Agencies at that time. Subsequently, these rates were renegotiated with the Joint Agencies during consultations on the Jackson Hydroelectric Project operating guidelines for flood control. Because of those consultation agreements Chapter 5 of the downramping report has been superseded and is no longer valid. The revised downramping rates are outlined in the report addendum titled "Henry M. Jackson Hydroelectric Project, Revised Downramping Rate Schedule, October, 1990."

HENRY M. JACKSON HYDROELECTRIC PROJECT
REVISED DOWNRAMPING RATE SCHEDULE

Addendum to

DOWNRAMPING REGIME FOR POWER OPERATION TO MINIMIZE STRANDING OF SALMONID FRY IN THE SULTAN RIVER

INTRODUCTION

The hydroelectric downramping rate schedule presented in the following pages represents revisions in the provisional rate schedule that was previously negotiated with the Joint Agencies in 1986 and 1987. The provisional rates are included in Table 9 of the enclosed report titled "Downramping Regime for Power Operation To Minimize Stranding of Salmonid Fry in the Sultan River." The revised rates resulted from consultations with the Joint Agencies under License Article 57 pertaining to flood control. The flood control negotiations produced significant changes in the operational flexibility of the project, thus affecting the need for and frequency of downramping. This, in turn, prompted the agencies to request revisions in the downramping rates that generally were more conservative (i.e., lower) than the provisional rates.

OPERATIONAL CHANGES

The Jackson Hydroelectric Project is operated on an intermediate-cycle basis (rather than on a load-following basis). Plant operation is dictated by flood control rule curves depicting the status of the water surface elevation in Spada Lake. The plant operating mode for each of the four rule curves is discussed in Chapter 1 of the enclosed downramping report. The original rule curves are shown in Figure 2 of that report and Figure 1 of this addendum. When the lake is in States 1 and 2 (high pool), the plant is operated at maximum capacity. When the lake is in State 4 (low pool), the plant is operated minimally as needed to meet water supply and instream flow requirements. The intermediate lake level, State 3, represents the discretionary zone in which downramping (and upramping) is used to conserve water.

The original rule curves had a narrow band (5 feet) of discretionary operation for State 3 during the winter period. Operational experience has shown that the lake level can be too easily drawn into State 4 under certain hydrologic conditions. One of the District's goals is to offset its Bonneville Power Administration costs for monthly peak-hour demand. Therefore, project operation attempted to maintain the lake surface at the high end of this narrow State 3 zone from November 1 to February 15. This required ramping up to meet the early morning power demands, ramping down during midday, ramping up again to cover an evening power peak, and finally ramping down

to minimum flows during the night. The Joint Agencies were sensitive to the frequent Sultan River fluctuation and its potential impacts on egg incubation and fry stranding.

In the flood control negotiations the District proposed expanding the State 3 zone as a means to solving the mutual goals of meeting power peaks and reducing frequency of fluctuating the project power level and hence the flows in the Sultan River. The District sought to increase the depth of State 3 by lowering the State 3/4 boundary line elevation in Spada Lake and extending the time period during which this lower elevation could be maintained. These changes would also increase the incidental flood control capabilities of the project.

The outcome of the flood control negotiations was the revised rule curves for Spada Lake (Figure 1). Changes from the original rule curves included lowering the State 3/4 boundary line elevation 15 feet (from elevation 1425 to 1410) and extending the time period for State 3 minimum from 4.5 months (November 1 to February 15) to 7.0 months (October 1 to April 30). The Joint Agencies were agreeable to the revised rule curves on an interim basis if the District could demonstrate reduced frequency of ramping events. Therefore, the District will be documenting ramping frequency with annual reporting requirements on project operations for the interim operating plan period November 1, 1989, to June 30, 1995.

REVISED DOWNRAMPING SCHEDULE

The revised downramping rates and explanatory footnotes are included in Table 1 and supersede the provisional rates shown in Table 9 of the downramping report. These rates differ from the provisional rates in two general regards. First, the District accepted more conservative rates in most cases, recognizing that more rapid rates would provide little practical benefit in terms of energy value since they were in effect during times of the year when ramping rarely occurred. Second, many of the provisional rates requiring field verification were lowered to the more conservative, verified rates to eliminate the need for further field tests. The District accepted those reductions, recognizing that the frequency of ramping events would be greatly reduced under the new operating guidelines in effect for Spada Lake.

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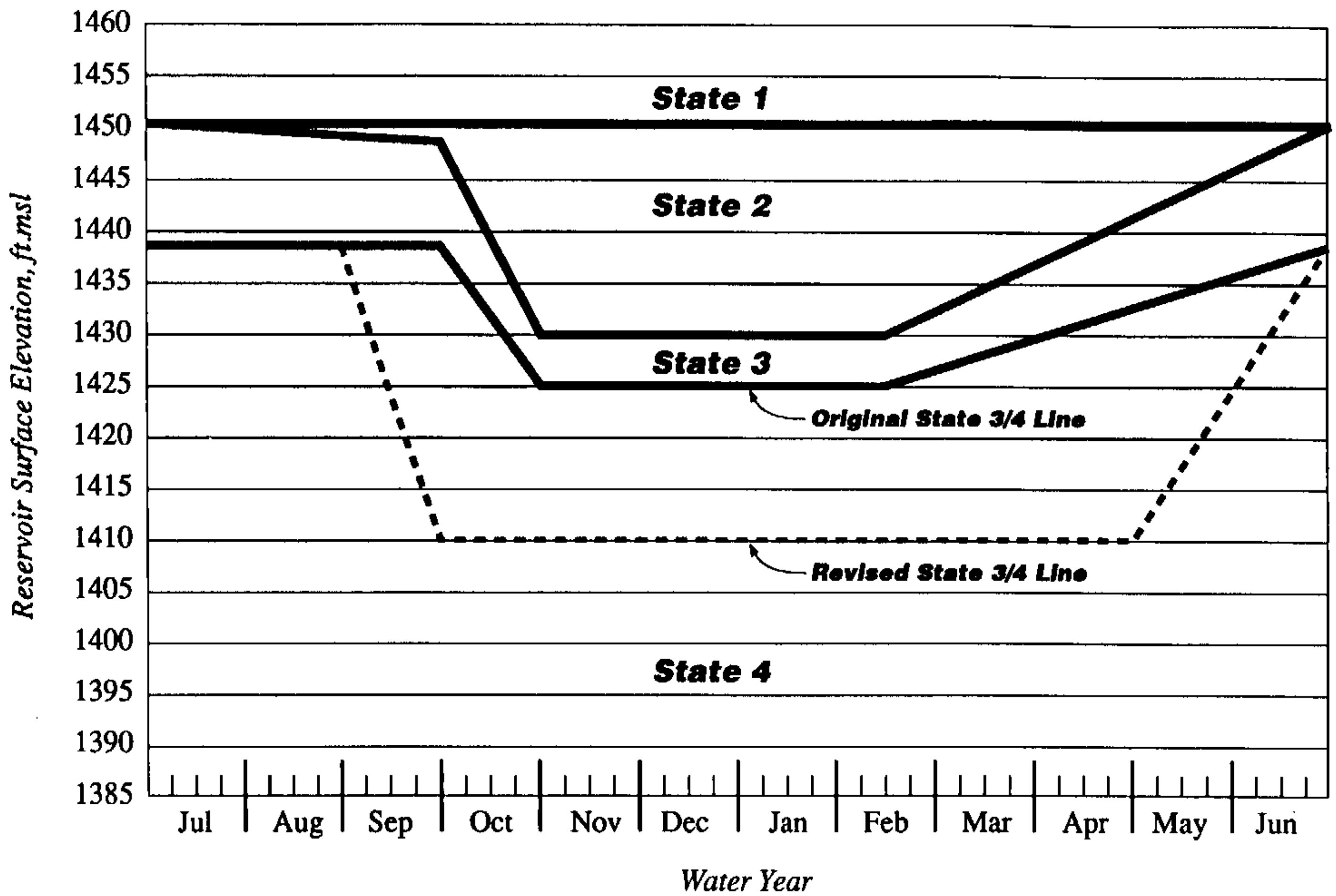

Figure 1.
Rule Curves for Reservoir Operation - Spada Lake

Table 1
Jackson Hydroelectric Project
Downramping Rate Schedule[a]

Flow Range (cfs)	March 1[b] to May 31		June 1[b] to September 15	
	Day	Night	Day	Night
1,500 to 750	4	4	2	1
750 to 600	2[c]	2[c]	2[c]	1[c]
600 to 300	2	4	2	1[d]
300 to min	2	2	2	1[d]
	September 16 to October 31		**November 1 to February 28**	
	Day	**Night**	**Day**	**Night**
1,500 to 750	2	1	4	4
750 to 600	2[c]	1[c]	2[c]	2[c]
600 to 300	2	2	4	4
300 to min	2	2	4	4

[a]For normal operation. Not for power-generating equipment failures or forced outages. Units are in inches per hour at the powerhouse.
[b]This date may be adjusted annually by determining time of emergence with cumulative water temperature information. Upon notification to the District from the Washington Departments of Fisheries and Wildlife that either salmon or steelhead trout fry are expected to emerge from the river gravel, based on water temperature unit calculations (see River Temperature), the District will shift to the designated slower downramping rates.
[c]If river flow prior to downramping has exceeded 1,000 cfs for more than 72 hours, downramp through this flow range (750 to 600 cfs) only after holding flow constant between 750 and 850 cfs for at least 6 hours of daylight and one overnight period.
[d]Avoid any scheduled flow reduction.

For many cases, different downramping rates are recommended for day and night. However, if downramping is to occur during the twilight period (1 hour before to 1 hour after sunrise or sunset), the lower of the two stipulated day or night rates should be used. For example, a 4-inch-per-hour springtime downramp intended for night should not be initiated at the powerhouse until 1 hour after sunset. As another example, if a summer afternoon downramp initiated at 2 inches per hour is to extend past sunset, the ramping rate should be reduced to 1 inch per hour at 1 hour before sunset. These precautionary guidelines should minimize the potential for stranding during the twilight hours when the juvenile fish are shifting their diurnal behavior patterns.

ABSTRACT

The objective of this study was to develop a downramping regime for the Jackson Hydroelectric Project on the Sultan River in Washington that minimizes the stranding of juvenile salmon and steelhead trout while providing flexibility for power production benefits. The results of this study indicate that a downramping rate of 6 in/hr measured at the powerhouse tailwater, as initially stipulated in the project license, would be acceptable under some conditions but would cause excessive stranding of salmonid fry under other conditions. Susceptibility to stranding was particularly evident for salmon fry less than 50 mm long and for steelhead fry less than 40 mm long. Chinook fry were more susceptible to stranding during the day, whereas steelhead fry were more susceptible at night. Because of differences in streambed morphology, stranding potential was greater in some flow ranges than in others. On the basis of these findings a downramping regime was developed with rates ranging from 1 in/hr to 6 in/hr depending on season, river stage, and time of day. The study results strongly indicate the need to evaluate fry stranding potential on a river-by-river basis to account for differences in channel morphology, fish species, fry emergence time, and fish growth.

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INTRODUCTION

When salmon and steelhead fry emerge from streambed gravel, they tend to seek the quiet, shallow waters near the shoreline. During this period, which lasts several months for each species, the fry are susceptible to sudden flow changes such as those that may occur below hydroelectric facilities. If reduction of flow is too rapid, the young fry are often trapped or stranded in shallow areas along the shoreline. Once stranded, they either die from lack of water or, if caught in shallow depressions, become susceptible to bird predation and elevated temperatures. Although a sudden flow reduction may kill only a small portion of the population, repeated fluctuations, which typically occur below hydroelectric facilities operated for meeting variable electrical load, can cause significant cumulative mortalities.

To reduce fry stranding caused by hydroelectric project operation, a maximum flow reduction or "downramping" rate must be specified for each project. This rate is designed to lower the water-surface level slowly enough to enable the fry to react safely to the temporary dewatering of their habitat. Because streambed morphology and fish utilization are different for each case, an acceptable ramping rate regime must be established on a project-by-project basis. Guidelines for establishing interim rates are based on experience with other projects. Response is measured after a project begins operations and is used to confirm or revise the downramping rates.

Upramping (flow increase and subsequent rise in water level) is not believed to produce fry stranding. Consequently, no upramping constraints are required to protect juvenile fish.

The Henry M. Jackson Hydroelectric Project began operation in June 1984. The license to operate the project, issued by the Federal Energy Regulatory Commission (FERC), stipulates a maximum 6 inches per hour downramping rate as measured at the powerhouse tailrace. However, in accordance with an agreement[1] between the Joint Agencies[2] and the Snohomish County Public Utility District No. 1 (the District) and approved by the FERC,[3] a ramping rate study was initiated in

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[1]Uncontested Offer of Settlement--Joint Agencies, March 24, 1982.

[2]The Joint Agencies include the Washington State Departments of Fisheries and Game (WDF and WDG, respectively), U.S. Fish and Wildlife Service, National Marine Fisheries Service, and the Tulalip Indian Tribes.

[3]Approval Order: 22 FERC ¶61,140 (Issued February 9, 1983).

the first year of project operation. Until study results became available on the licensed ramping rate, the District conservatively downramped flow reductions at 3 inches per hour or less, usually at night.

1. OBJECTIVE

The objective of this study was to develop a downramping regime for the Jackson Project that minimizes stranding of juvenile salmon and steelhead trout in the lower Sultan River while maximizing power production benefits.

2. PROJECT DESCRIPTION AND OPERATION

The Jackson Project is located on the Sultan River in western Washington. This watershed has been managed for the City of Everett's water supply since the early 1900's. Water storage components were added through the years. One of these, Culmback Dam, is located at river mile (RM) 16.5 and was built in 1965. The dam crest was raised 62 feet in 1984 to provide additional storage and hydraulic head for hydroelectric generation.

The 112-MW Jackson Project consists of a 153,260-acre-foot reservoir (Spada Lake) behind Culmback Dam, an 8-mile tunnel and pipeline, and a powerhouse at RM 4.3 containing two 8.4-MW Francis turbines and two 47.5-MW Pelton turbines (Figure 1). Water diverted from Spada Lake drops 1,100 feet to the powerhouse. Water passed through the Francis units is rerouted uphill 400 feet through a 3-mile-long pipeline where a portion enters Lake Chaplain for Everett's water supply and the remaining portion is returned via tunnel to the river at RM 9.7, immediately below the diversion dam, for instream flow needs. After these two priorities have been met, additional water, when available from Spada Lake, is passed through the Pelton units and then discharged to the river.

The lower Sultan River has an average annual flow of 733 cfs following withdrawal for Everett's water supply. The monthly average flows prior to operation of the powerplant are shown in Appendix A. Instream flow requirements for fish at the powerhouse are 165 cfs from June 16 to September 14 and 200 cfs from September 15 to June 15.

Plant operation depends on the amount of water stored in Spada Lake. A series of seasonal water storage curves, based on the water level (state) of Spada Lake, dictate the general mode of operating the powerhouse (Figure 2). When water is abundant and Spada Lake is in states 1 and 2, the powerhouse is operated at maximum capacity. This equates to a constant

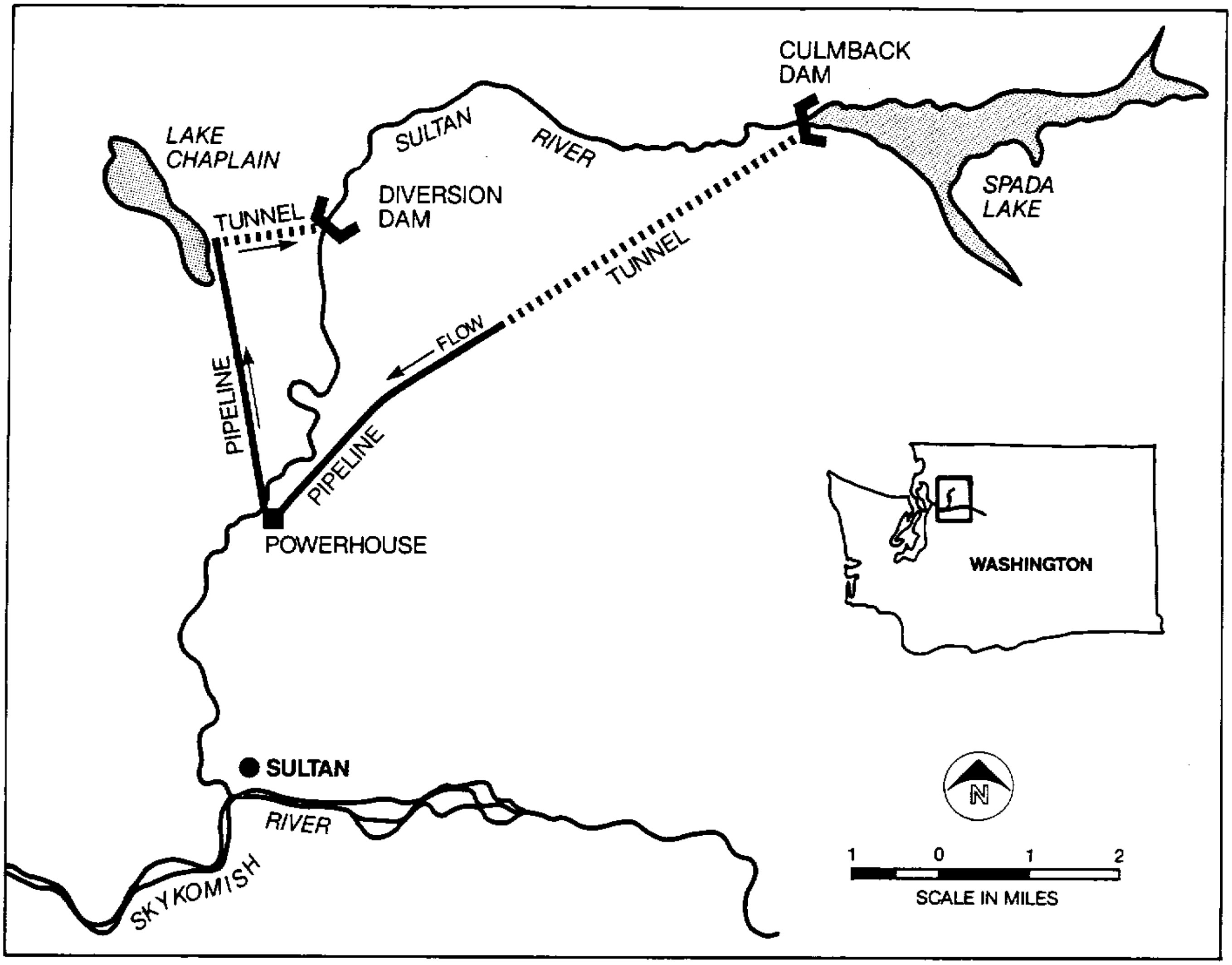
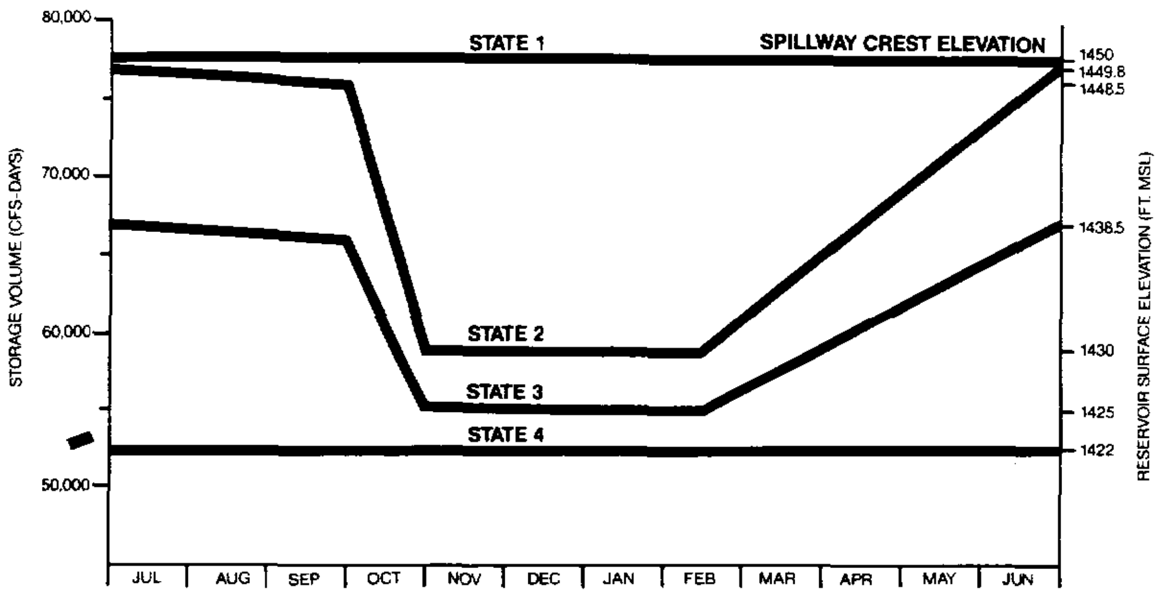


Figure 1
JACKSON HYDROELECTRIC PROJECT

powerhouse discharge of approximately 1,300 cfs through the Pelton units. When the lake is in state 3 and high power production is needed, the powerhouse is operated on a daily intermediate cycle, to the extent permitted by river fluctuation rates (ramping) downstream of the powerhouse. This typically means that the turbines are gradually increased up to maximum generation during the morning when load demand increases and then reduced at night when load demand is lowest.

During the summer when Spada Lake is in state 3 the powerhouse is generally operated to conserve water to provide greater assurance that the reservoir can meet the needs of Everett's water demand and instream flows during late summer. In the spring when the reservoir is filling, the Powerhouse is operated to avoid state 2 or to avoid lossing water by filling too rapidly thus having to spill. The powerhouse is operated preferentially during the day, when power demand is greatest, consistent with ramping rates.



Source: Figure H-3, Exhibit H — Application for Amended License, FERC Project No. 2157, September 1979

Figure 2
RESERVOIR OPERATION GUIDELINES, SPADA LAKE

When the reservoir is in state 4, water is released from Spada Lake specifically to meet the instream flow requirements and Everett's water demand, only the Francis units are used for power generation. However, when instream flows arriving at the powerhouse are inadequate to meet the higher downstream requirements, a Pelton unit is operated to provide the additional needed flow.

3. DESCRIPTION OF FISHERY

The Sultan River supports runs of fall chinook, coho, chum, and pink salmon and steelhead trout. All of these anadromous fish spawn below river mile (RM) 9.7 where the City of Everett's water diversion dam has blocked upstream passage since 1927. Pink and chum salmon spawn predominantly in the lower 3 miles of the river. Pink salmon spawn only in odd-numbered years in Washington State.

Chinook and pink salmon are the most abundant salmon using the Sultan River. Between 1978 and 1985, the annual spawning escapement of fall chinook averaged 504 fish and ranged from 939 in 1980 to 162 in 1985 (WDF file information). The WDF estimates of pinks spawning in the Sultan River average 3,355 fish in the four odd-year cycles since 1979, with a low of 1,087 occurring in 1981 and a high of 6,604 in 1985.

Estimated numbers of coho and chum spawners are not available but probably are several hundred each in most years. However, in December 1985, approximately 2,000 chums were observed spawning in the lower Sultan River. It is speculated that many of these fish were forced to spawn in the Sultan River because of record low flows in the traditional chum spawning areas of the nearby Skykomish River sloughs.

Annual steelhead catches in the Sultan River have ranged from 50 to 180 since 1974 (WDG catch statistics). Most of these are winter-run fish caught from December through February, but as many as 38 summer-run steelhead have also been reported caught in a single year. These catch statistics do not reflect the total contribution of Sultan River steelhead because many fish originating from this river are caught in the intensive sport fishery downstream in the Skykomish and Snohomish Rivers and in the Indian net fishery at the mouth of the Snohomish River.

Steelhead spawning escapement estimates for the Sultan River are not available. However, 61 steelhead redds were observed on May 17, 1985, in the lower 2.5 river miles.

4. REVIEW OF OTHER STUDIES

Several studies have been conducted on the stranding of juvenile salmonids below hydroelectric projects. These studies indicate that several variables affect the degree of fry stranding during rapidly decreasing flow events. These variables include fish species, fry abundance and size, streambed morphology, substrate type, flow duration, and downramping rates. These are discussed below.

- Fish species. Most fry stranding studies have concentrated on chinook fry because this species is vulnerable to stranding. Coho salmon appear to be less susceptible to gravel bar stranding compared to chinook but may be more prone to pothole entrapment because of their habitat association with large organic debris. Chum and pink salmon fry, in particular, do not seem as susceptible to stranding as chinook, probably because of their preference for greater water velocity as well as their tendency to migrate rapidly downstream shortly after emergence. Results of steelhead fry stranding tests on the Skagit River were inconclusive; these tests were not started until mid-August and therefore may not have reflected conditions during the early period of fry emergence when stranding susceptibility would likely be greatest (Woodin et al., 1984).

- Abundance of fry. The number of fry present in potential stranding areas will influence the amount of stranding. However, it is difficult to accurately assess the number of fry present because of a lack of nonobtrusive assessment techniques and because of the rapidly shifting nature of fry populations, especially during the emergence period (Woodin et al., 1984).

- Size of fish. Work conducted on the Columbia, Cowlitz, and Skagit Rivers has indicated that chinook salmon juveniles over 50 millimeters in length are much less prone to stranding than those under 50 millimeters (Bauersfeld, 1977, 1978, and Woodin et al., 1984). Size-frequency information for stranded steelhead fry is very limited. However, recent work on the Skagit River suggests that steelhead fry less than 40 millimeters are particularly prone to stranding (Keith Kurko, Seattle City Light, personal communication).

- Streambed morphology. This has been recognized as an important factor in determining stranding potential, but one that is difficult to evaluate given the infinite types of streambed configurations. During the Cowlitz River studies, however, WDF determined that most of the chinook stranding occurred on gravel bars of less than 2 percent slope; chinook stranding was rarely observed on slopes greater than 4 percent (Bauersfeld, 1978). Side channels and associated potholes also can be problem areas (Woodin et al., 1984).

- Substrate type. The influence of substrate on stranding potential has not been evaluated independently; however, stranding has been observed in all types of substrate ranging from sand to boulder. Most studies have concentrated on cobble and gravel because this substrate is typical of low-gradient sites where fry stranding is most likely to occur and is the substrate of preference for salmonid fry rearing (Bovee, 1978). Sandy areas often have shallow depressions prone to rapid percolation and therefore may be of special concern if fry are present. In addition, wetted organic debris (root wads, logs, leaf piles) is often a preferred cover habitat for juvenile salmon and trout and, consequently, can be an area of concern if occurring in the dewatered zone.

- Day versus night. The Skagit River studies found that chinook fry are much more vulnerable to stranding during daylight hours than at night. With steelhead, however, there did not appear to be a difference between day and night susceptibility to stranding on the basis of the limited Skagit River data (Woodin et al., 1984).

- Flow duration and level prior to downramping. During the Lewis River studies it was observed that an extended period of uniform high flow might significantly affect stranding of juvenile salmon during subsequent flow reduction (Phinney, 1974). Presumably, the fry have some territorial tendencies and thus are more reluctant to leave an area once they have become accustomed to it.

- Downramping rate. Logically, a lower rate of flow reduction will strand fewer fry. This has been demonstrated on the Skagit and Lewis Rivers for chinook salmon during daylight hours and for steelhead trout fry on the Skagit River during day and night hours (Woodin et al., 1984; Phinney, 1974).

Data from these studies were insufficient to demonstrate the relationship between downramping rate and salmon fry stranding at night.

Because several of these variables can simultaneously affect stranding, a particular ramping rate may be safe under some conditions but not under others. Therefore, it is desirable for both fish protection and power production to determine the various conditions affecting stranding and develop a flexible ramping rate regime accordingly. Consequently, in this study particular attention was paid to species, day versus night, initial flow level and change, streambed morphology, and size of fish.

Chapter 2
METHODS

All variables affecting fry stranding could not be fully evaluated given the constraints imposed by power production and natural flow events. Therefore, experimental design emphasized testing of variables most likely to influence stranding as well as those controllable factors most important to power production. In addition, the Joint Agencies wanted to evaluate variables sufficiently but avoid excessive fish mortalities during testing. Thus, a conservative approach was employed that consisted of (1) examining those areas where stranding was thought to be most probable, (2) identifying potentially sensitive flow ranges based on streambed morphology, (3) testing relatively low ramping rates initially and evaluating the results before proceeding, and (4) having crews on the river during all day tests to salvage fry trapped in potentially lethal situations. Because of the limited number of tests and fewer stranded fish with this approach, the results did not lend themselves to statistical analysis. Estimating total fry losses or developing stranding rates were not study objectives.

1. SELECTING STUDY SITES

The study area was the lower 3 miles of the Sultan River (Figure 3). This is a relatively wide (approximately 200 feet), low-gradient (20 feet per mile) reach that has several gravel bars and side channels with fry stranding potential. The 1.5-mile section of river upstream of the study reach to the powerhouse is in a narrow canyon where fry stranding potential is believed to be less than it is in the lower river. Therefore, it was assumed that a safe downramping regime for the lower river would be safe for the canyon reach as well.

The lower river was rafted on January 13, 1985, with representatives of the Joint Agencies, to select study sites. The river flow was approximately 320 cfs as measured at the powerhouse. Four major sites were selected where fry stranding observations were conducted during downramping tests. These included Ames Bar, Kien's Island, Kien's Bar, and Winter Creek Islands (Figure 3). Adjacent areas were also added to the surveys to include important side channels and potholes. The areas surveyed covered approximately 20 percent of the stream shoreline downstream of the Bonneville Power Administration (BPA) powerlines. However, this represented approximately 80 percent of the area where stranding was likely to occur, in the judgment of the consultant field crew.

2. SURVEYING STUDY SITES

At each of the four major study sites, cross sections were surveyed with a level and rod to determine beach gradients perpendicular to the direction of waterflow. A temporary benchmark was established at each site. Water surface elevations (WSE) were then measured at each cross section for several river flows ranging between 1,300 and 240 cfs. Substrate size (boulder, cobble, gravel, sand) was observed along each transect. This information was then plotted to help determine the flow range(s) within which stranding might be most probable.

3. DETERMINING SENSITIVE FLOW RANGES

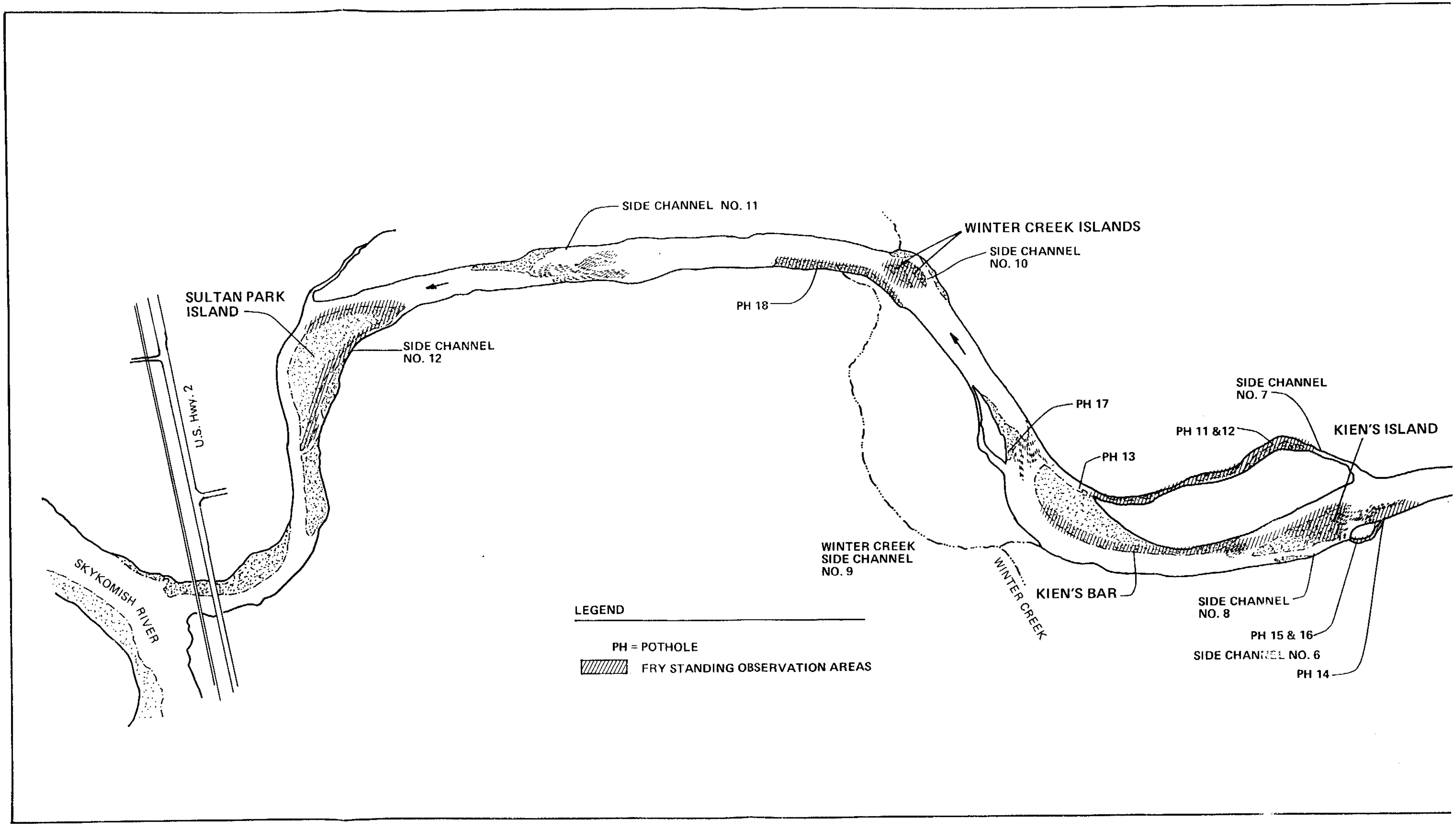
For most stream channels there is a river stage, usually near the toe of the bank, above which the wetted perimeter increases relatively little with increased flow. Consequently, the probability of fry stranding greatly diminishes when flow fluctuations occur above this stage. This concept as it relates to fry stranding was developed from observations made on the North Fork Lewis, Cowlitz, and Skagit Rivers by WDF.

The potentially sensitive flow ranges were determined using a two-step process. First, the surveyed cross-sectional plots were reviewed to identify flow ranges in which beach slopes of less than 2 percent occurred. This provided preliminary identification of sensitive flow ranges. Second, the lower 3 miles of river were inspected with WDF to verify and modify, if necessary, the preliminary conclusions through general observation of this entire river reach. Special attention was given to those areas where the streambed morphology suggested potential stranding conditions.

4. DETERMINING DOWNRAMPING LAGTIME AND ATTENUATION

To interpret the relationship between downramping and fry stranding, it is important to relate the hydraulic changes initiated at the powerhouse to the resultant physical changes downstream where fry stranding can occur. Therefore, the following three downramping features were evaluated:

- Lagtime of river flow decrease from the powerhouse to various sites downriver
- Attenuation of the flow reduction at several downstream locations, both at the beginning and at the conclusion of the flow-change event



SIDE CHANNEL NO. 11
WINTER CREEK ISLANDS
SIDE CHANNEL NO. 10
SULTAN PARK ISLAND
PH 18
SIDE CHANNEL NO. 12
U.S. Hwy. 2
SIDE CHANNEL NO. 7
PH 17
PH 11 &12
KIEN'S ISLAND
PH 13
WINTER CREEK SIDE CHANNEL NO. 9
WINTER CREEK
KIEN'S BAR
SKYKOMISH RIVER
SIDE CHANNEL NO. 8
PH 15 & 16
SIDE CHANNEL NO. 6
PH 14
LEGEND
PH = POTHOLE
FRY STANDING OBSERVATION AREAS

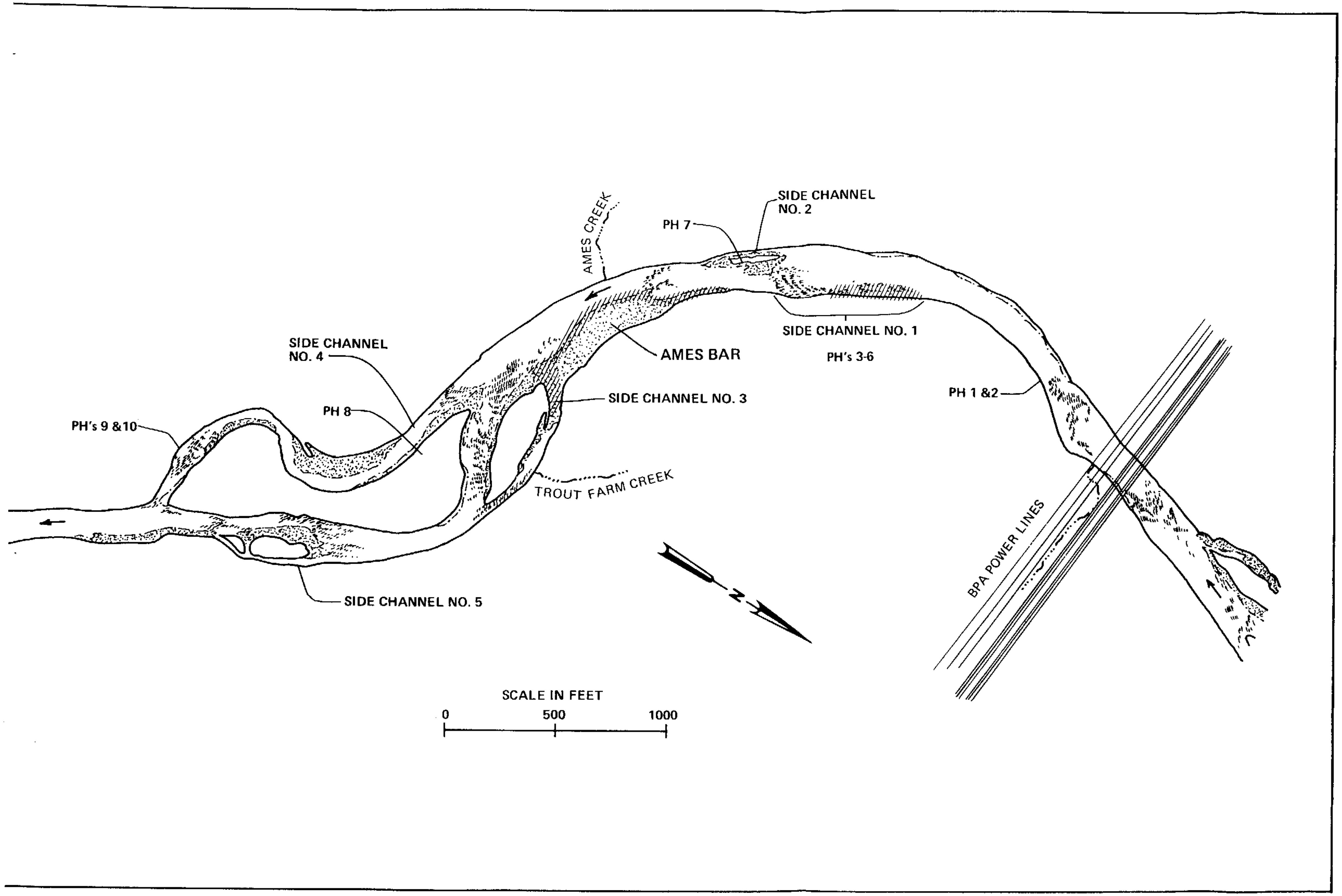


Figure 3
LOWER SULTAN RIVER
STUDY AREA

- Relationship between the drop rate of water surface elevation (inches per hour) at the powerhouse tailwater and the rate observed at potential stranding areas downstream

These tasks were accomplished by installing temporary staff gages at four sites: the BPA powerline crossing, Ames Bar, Kien's Bar, and Sultan Park. These staff gages were monitored continuously during four downramping events prior to fry emergence. Staff gage readings were recorded and plotted at 10-minute intervals. The four test conditions were:

- Flow range 1,500 to 800 cfs, downramping rate 6 in/hr
- Flow range 1,500 to 800 cfs, downramping rate 3 in/hr
- Flow range 800 to 260 cfs, downramping rate 6 in/hr
- Flow range 800 to 240 cfs, downramping rate 3 in/hr

Attenuation and lagtime were determined by reviewing the plots of time versus water-surface elevation. Rates of change in water surface elevation were computed for the linear portion of the downramping event.

5. IDENTIFYING POTHOLES AND SIDE CHANNELS

Potholes are defined as depressions in the streambed, often associated with organic debris, that provide good rearing habitat for juvenile salmon. At certain flows these potholes become disconnected from the main river channel, thereby potentially trapping fish. Under some conditions of flow and duration, these potholes may be completely dewatered, stranding any fish present.

To assess whether pothole stranding associated with flow reduction is a significant problem in the lower Sultan River, the entire river below the BPA lines was surveyed by foot. Eighteen potholes were located and marked. These were then monitored at several flows during the study period and inspected following downramping events to assess whether fish were being trapped or stranded in these areas. The main river flow at which each pothole becomes disconnected from the river and the flow at which each pothole becomes completely dewatered were estimated by inspecting them at various flow levels. Similarly, twelve side channels in the lower river were inspected to determine the river flow at which watering and dewatering commence.

6. IDENTIFYING WINTER HABITATS

During the winter period, November 1 to March 1, juvenile salmon and steelhead are not thought to be susceptible to stranding because of their relatively large size and shift in habitat preference. Juvenile coho move to tributaries, wall-based side channels, percolation channels, riverine ponds, and around large woody debris (Bustard and Narver, 1975; Peterson, 1982a and 1982b; Peterson and Reid, 1984; Scarlett and Cederholm, 1984). Juvenile steelhead and rainbow trout tend to inhabit crevices in the substrate in pools during the winter (Bjornn, 1971; Campbell and Neuner, 1985), and some migrate to small runoff tributaries (Cederholm and Scarlett, 1981).

Electrofishing was conducted on December 11 and 12, 1985, to locate fish in areas thought to provide winter refuge habitat for juvenile salmon and steelhead. River flow was stable both days at 225 cfs. Sampled areas included the BPA powerline crossing, potholes No. 1 and 2 and adjacent river shoreline, side channel No. 1, upper Ames Bar, side channel No. 3, side channel No. 5 and adjacent main river, side channels No. 6, 7, and 8, Kien's Bar, Winter Creek (side channel No. 9), pothole No. 17, side channel No. 12, and a small runoff tributary entering the left bank below side channel No. 12 (Figure 3).

The results of these surveys were used to determine if overwintering fish are located in areas that could be affected by winter downramping. In addition, the results helped identify sites to be inspected for stranded fish during subsequent winter downramping tests.

7. CONDUCTING DOWNRAMPING TESTS

After reviewing physical and hydraulic information from the previous tasks, a downramping test program was developed to evaluate the degree of salmon and steelhead fry stranding that might occur under various operational test conditions. Tests were conducted in two flow ranges: from 1,300 to 750 cfs and from 600 to 200 cfs. Testing was avoided between 750 and 600 cfs because of three potentially sensitive side channels and associated potholes in this flow range. Downramping rates between 2 and 8 inches per hour (as measured at the powerhouse) were tested under day and night conditions (Table 1). Day and night tests for the same flow range and ramping rate were paired during the same week to minimize the influence of fry population differences on the results.

Immediately following each downramping test, study sites and adjacent areas were inspected for stranded or trapped fry. For this study, stranding meant those fry that were lost or

Table 1
DOWNRAMPING TEST CONDITIONS

Flow Range (cfs)	Day[a]	Night[b]	Ramping Rate at Powerhouse (inches/hr)				
			2	3	4	6	8
Salmon							
1,300 to 750	X					X	
1,300 to 750	X					X	
1,300 to 750		X				X	
1,300 to 750		X					X
670 to 530	X		X				
600 to 260	X		X				
600 to 230		X				X	
1,250 to 750	X				X		
1,000 to 500	X				X		
1,460 to 750	X				X		
1,460 to 750	X				X		
Steelhead							
610 to 360	X				X		
575 to 285		X				X	
610 to 330		X			X		
610 to 345		X	X				
545 to 195	X		X				
530 to 170		X	X				
570 to 210	X		X				
560 to 190	X			X			
Winter (all species)							
1,330 to 300	X					X	
1,350 to 300	X					X	
1,350 to 450	X				X		

[a] Downramping started between 7:00 and 9:30 a.m. for salmon and winter tests and 6:00 to 8:00 a.m. for steelhead tests.

[b] Downramping started at 1:00 to 2:00 a.m. for salmon tests and 11:00 p.m. to 12:00 a.m. for steelhead tests.

would have been lost if not rescued. Observations were made by slowly walking back and forth in the dewatered zone from end to end and then back again. Care was taken to avoid frightening fish near the shoreline. Stranded fry were collected and identified. Live fish were counted and then returned to the river; only dead fry were measured. Special attention was given to areas containing leaf piles or other organic debris. Occasionally, some of the organic material was moved to locate fry, but we did not move larger rocks or dig into the substrate. Following each nighttime downramping test, the survey crew began site inspections at dawn to ensure that scavenging birds would not bias the findings. The survey crews remained onsite during the daytime downramping test to ward off birds. However, this concern over bird scavenging was not substantiated by observations. Birds generally appeared disinterested in feeding along the shoreline following downramping tests.

Chapter 3
RESULTS AND DISCUSSION

1. SENSITIVE FLOW RANGES

Review of the stream channel cross-sectional plots (Appendix B) gives a limited indication of flow ranges that might be of concern regarding fry stranding. Some low-gradient areas were identified in the 500 to 750 cfs and 1,300 to 1,500 cfs ranges. From observation of the entire study reach on February 28, 1985, it was determined that a flow of 600 cfs inundates most streambed areas of concern up to the toe-of-bank. Thus, flow fluctuations occurring above that stage would be less likely to strand fry. However, 600 to 750 cfs was identified as a range of concern because three side channels (No. 1, 3, and 6, Figure 3) become dewatered during flow reductions within this range. Although these side channels are relatively short compared to others, they represent areas of potentially significant fry stranding if flows fluctuate too rapidly and frequently through this range. In addition, 7 of the 18 identified potholes occur in these side channels. Therefore, these side channels were given special attention during subsequent fry stranding tests.

2. DOWNRAMPING LAGTIME AND ATTENUATION

Downramping lagtime and attenuation are important factors in establishing ramping rates, if fry stranding susceptibility differs between day and night. For example, if a night downramping rate is stipulated, it must be initiated at the powerhouse with sufficient lead time to produce the desired nighttime effect downriver where stranding can occur.

Downramping tests of 3 in/hr and 6 in/hr were conducted at a high flow range (1,300 to 800 cfs) and a low flow range (800 to 240 cfs) to determine the lagtime between the initiation of downramping at the powerhouse and the onset of detectable flow drop at four locations in the lower river. The results of these tests are shown in Appendix C and summarized in Table 2. The lagtime of the flow drop between the powerhouse and the BPA lines (1.5 miles) was approximately 20 minutes. The lagtime at the most downstream site, near the river mouth (4.2 miles), was approximately 70 minutes. Only slight differences were observed in lagtime for the two flow ranges and two rates tested.

The rate of decrease in the river stage was attenuated only a small amount at the onset of the downramping events. This suggests that there is little bank storage of water in the reach below the powerhouse. The rate of attenuation was greater at the completion of the downramping events. The

Table 2
DOWNRAMPING LAGTIME AND ATTENUATION IN LOWER SULTAN RIVER

Site	Distance From Powerhouse (mi)	Lagtime (minutes from powerhouse)				Attenuation (minutes to stabilize relative to BPA site)			
		1,300 - 800 cfs		800 - 240 cfs		1,300 - 800 cfs		800 - 240 cfs	
		6 in/hr	3 in/hr	6 in/hr	3 in/hr	6 in/hr	3 in/hr	6 in/hr	3 in/hr
BPA Crossing	1.5	20	20	30	35	-	-	-	-
Ames Creek Bar	2.3	25	30	35	40	25	10	30	10
Kien's Bar	3.2	40	40	60	50	40	20	45	30
Sultan Park	4.2	50	60	70	70	60	40	90	70

greatest time to stabilize occurred with the 6 in/hr test from 800 to 240 cfs. The river stage near the mouth stabilized approximately 1.5 hours after completing flow reduction at the powerhouse.

Water-surface drop rates in downriver stranding areas were considerably less than the drop rates at the powerhouse tailwater. For example, a 6-in/hr powerhouse ramping rate produced only a 3.5-in/hr drop rate at Kien's Bar (Table 3). Similarly, a 3-in/hr rate at the powerhouse resulted in a 2-in/hr rate at Kien's Bar. These differences in drop rate are largely due to differences in channel configuration, which affects the stage-discharge relationship at each site.

Table 3
RATE OF CHANGE IN RIVER STAGE DURING DOWNRAMPING

Test Conditions at Powerhouse		Water Surface Drop (inches/hr)			
Flow Range	Ramp Rate (inches/hr)	BPA Crossing[a]	Ames Bar[a]	Kien's Bar[a]	Sultan Park[b]
1,300 to 800 cfs	6	3.5	3.4	3.5	4.6
1,300 to 800 cfs	3	2.2	2.0	2.3	3
800 to 250 cfs	6	4.1	3.7	3.6	4.2
800 to 250 cfs	3	2.0	2.2	2.0	2.4

[a]Wide channel with fry stranding potential.

[b]Confined channel with no fry stranding potential.

In the Sultan River below the powerhouse the downramping lagtime is short and flow attenuation is minimal between the powerhouse and the downriver fry stranding areas. Therefore, the lead time for downramping events is of only minor concern for this project.

3. SALMON

OBSERVATIONS OF FRY STRANDING

Chinook salmon fry were first observed along the stream margin during the first week of March in 1985 and on February 16, 1987. By late March their number had noticeably increased during both years.

The results of the fry stranding tests are presented in Table 4. One hundred and three stranded salmon fry were observed during this study; 89 were chinook, 12 were coho, and only 2 were chum. Chum fry were noticeably abundant in

Table 4
SUMMARY OF SALMON FRY STRANDING OBSERVATIONS

Test Conditions: Flow Range (cfs) (Δ cfs)	Test Conditions: Downramp Rate (in/hr)	Test Conditions: Time and Date	Survey Area[b]	Number Stranded	Total[c] (No./Δ 100 cfs)	Comments
1,300-750 (550)	6	Day 4-4-85	Ames Bar - Upper	7		o Kien's Bar not surveyed.
			Ames Bar - Lower	6	17	o All chinook.
			Kien's Island	0	(3.1)	
			Sultan Island	4		
1,300-750 (550)	6	Day 4-23-85	Ames Bar - Upper	16		o 28 chinook, 2 coho, 1 chum.
			Ames Bar - Lower	0		o Flow was approx. 1,300 cfs uniform for 2 weeks prior to test.
			Kien's Island	0	31	o Many fry observed in side channels No. 1 and 6 after test at 750 cfs. Most had moved out by following a.m.
			Kien's Bar	12	(5.6)	
			Sultan Island	3		
1,300-750 (550)	8	Night 4-6-85	Ames Bar - Upper	12		o All chinook.
			Ames Bar - Lower	16		o Sixteen in lower Ames Bar, all in one pothole. Exit dug out, problem spot corrected.
			Kien's Island	0	32	
			Kien's Bar	4	(5.8)	
			Sultan Island	0		
1,300-750 (550)	6	Night 4-25-85	Ames Bar - Upper	1		o One chum, one chinook.
			Ames Bar - Lower	0		o Noticeably more fry in river compared to early April.
			Kien's Island	0	2	
			Kien's Bar	1	(0.4)	
			Sultan Island	0		
670-530 (140)	2	Day 4-27-85	No. 1 Side Channel	0		o One chinook.
			Ames Bar	0		o Rain and inflow limited test.
			Kien's Island	0	1	o No. 1 side channel includes river side of island.
			Kien's Bar	1	(0.7)	
			Winter Island	0		
			Winter Bar	0		
			Sultan Island	0		
600-260 (340)	2	Day 5-11-85	No. 1 Side Channel	0		o Two chinook, one coho.
			Ames Bar	2		o Fry observed actively leaving shallows.
			Kien's Island	0		
			Kien's Bar	0	3	
			Winter Island	0	(0.9)	
			Winter Bar	0		
			Sultan Island	1		
600-230 (370)	6	Night 5-17-85	No. 1 Side Channel	1		o Seven coho at Sultan in pothole below 300 cfs.
			Ames Bar	2		o Two coho at Winter Bar below 300 cfs.
			Kien's Island	0		
			Kien's Bar	0	13	
			Winter Island	0	(3.5)	
			Winter Bar	2		
			Sultan Island	8		

[a] Stranded fry were those that had died or were about to die from dewatering.

[b] Winter Creek areas added at lower flow range.

[c] Approximately half the stranded fry were saved.

Table 4
(continued)

Test Conditions							
Flow Range (cfs) (Δ cfs)	Downramp Rate (in/hr)	Time and Date		Survey Area[b]	Number Stranded	Total[c] (No./Δ 100 cfs)	Comments
1,250-750 (500)	4	Day	5-23-86	Ames Bar	0	0 (0)	
				Kien's Island	0		
				Sultan Island	0		
1,000-500 (500)	4	Day	6-3-86	Ames Bar	0	0 (0)	
				Kien's Island	0		
				Sulton Island	0		
				Side channels 1, 3, & 6	0		
1,460-750 (710)	4	Day	3-27-87	Ames Bar	0	0 (0)	
				Kien's Bar & Island	0		
				Sultan Island	0		
				Winter Cr.	0		
1,460-750 (710)	4	Day	3-26-87	Ames Bar	1	4 (0.6)	
				Kien's Bar	3		
				Kien's Island	0		
				Sultan Island	0		

[a] Stranded fry were those that had died or were about to die from dewatering.

[b] Winter Creek areas added at lower flow range.

[c] Approximately half the stranded fry were saved.

the side channel behind Kien's Bar and at the mouth of Winter Creek, but none were observed stranded. Their preference for higher velocity water compared to chinook and coho suggests lower susceptibility to stranding. Pink fry are present only in even-numbered years and therefore were not tested in 1985.

High-Flow-Range Tests. Four initial tests were conducted at the high-flow range (1,300 to 750 cfs). Less stranding was anticipated at those flows because most low-gradient areas are inundated above 750 cfs. Daytime testing started with the licensed downramping rate of 6 in/hr; 17 and 31 stranded salmon fry were observed during two tests conducted under these conditions. The 17 stranded fry on April 4 did not include Kein's Bar because of the landowner's unexpected denial of access. If Kien's Bar had been included in the survey, the total count probably would have been greater.

Two night tests were conducted at the high-flow range under similar prior-flow conditions, one at 6 in/hr and one at 8 in/hr. The 6-in/hr results (2 stranded fish) were more favorable than the 8-in/hr results (32 stranded fish). Half of the fry stranded during the 8-in/hr test, however, were in one pothole that was subsequently modified to prevent stranding. This caused an unintentional bias with the two subsequent high-flow tests conducted on April 23 and 25, 1985. The 6-in/hr downramping rate at night with flows between 1,300 and 750 cfs was tested with abundant numbers of fry along the shoreline. Based on limited results (one test), a night ramping rate of 6 in/hr seems to be acceptable for salmon fry. This conclusion is supported by the higher stranding total for the 8-in/hr test (32 fry) versus the 6-in/hr test (2 fry).

Results of the two high-flow tests conducted on April 23 (day) and April 25 (night) at a downramping rate of 6 in/hr demonstrated strong fry stranding differences between day and night. Only 2 stranded salmon fry were observed in the night test, compared to 31 in the day test. This difference is consistent with the findings on the Skagit River (Woodin et al., 1984) and confirms that salmon fry are more susceptible to stranding during the day than at night at the same ramping rate.

Low-Flow-Range Tests. The day downramping rate of 2 in/hr was tested twice in the low-flow range. The first test was limited by heavy surface runoff, but the results suggested that there were no major stranding problems. Repetition of the test on May 11 confirmed that 2-in/hr downramping during the day was relatively safe for salmon (three fry stranded).

Because earlier findings indicated that chinook salmon fry are less susceptible to stranding during darkness, a 6-in/hr downramping test was conducted at night (May 17) at the low-flow range. Thirteen stranded fry were observed; however, nine of these were coho fry stranded in two depressions below the 300-cfs waterline. From the results of this test we concluded that a 6-in/hr downramping rate at night was relatively safe at flows between 600 and 300 cfs but not below 300 cfs. Subsequent observations along the study reach revealed other depressions below the 300-cfs waterline and confirmed our belief that a 6-in/hr night downramping rate would be ill advised below this water level.

Flow Conditions Prior to Test. Downramping tests conducted on April 4, May 11, and May 17 were preceded by approximately 4 days of relatively stable flow (<150-cfs fluctuation). Tests conducted on April 25 and April 27 were preceded by other downramping tests 2 days earlier (Table 4). However, the test conducted on April 23 (6 in/hr, day) was preceded by two weeks of relatively uniform flow of approximately 1,300 cfs. This prior period of uniform flow did not appear to influence the degree of stranding during the test significantly, but immediately following the test at approximately 1:00 p.m. several hundred salmon fry were observed in two small side channels (No. 1 and 6) that dewater between 750 and 600 cfs. Had the flow reduction continued down to 600 cfs or below, many of these fry probably would have become stranded.

The following morning at dawn both side channels were reinspected, and only about 10 fry were observed. It is not known whether the large number of fry observed immediately following the initial flow reduction had been residing in the side channels during the extended period of high flow or if they moved into these areas during the test. The latter is more likely because both side channels had very little low-velocity habitat available at 1,300 cfs. Also, immediately upstream of these two side channels are long stretches of shallow backwater and submerged brush where fry are likely to reside at high flow (1,300 cfs). Therefore, many fry could have simply moved downstream and diverted into these side channels as the flow dropped from 1,300 to 750 cfs.

These are the only two side channels in the lower river that have high-flow fry habitat immediately upstream, and therefore they probably represent the worst case for stranding potential under these flow-change conditions. In any case, these observations suggest that the magnitude of flow change and perhaps the rate of downramping should be limited following an extended period of uniform high flow. Day downramping through the range of 600 to 750 cfs should be done gradually under these circumstances; a continuous delay period consisting of 6 hours of daylight and one night is apparently sufficient for the fish to redistribute to safer areas. It was not determined if the fish redistributed during the daylight or night hours or both.

Salmon Fry Behavior. On several occasions during day downramping, fry behavior in shallow shoreline depressions was observed from camouflaged positions. Salmon fry typically began swimming about in a definite response to decreasing water depth. Movement was not quick or frantic but appeared to be a deliberate search for an exit route from the shallow areas. Salmon fry (mostly chinook) did not seek hiding areas around boulders or organic debris. In one instance in which approximately 50 fry were observed in one depression, the fish aggregated into a tight school upon sensing the depth change and finally vacated the shallow area in a unified group response.

Observation of fry behavior during night flow reduction was not possible. However, since salmon fry were less susceptible to stranding at night, either the behavioral response to flow reduction at night is different or the fry simply station themselves farther offshore. Behavioral response to river flow is probably the reason because other studies have found that juvenile salmon tend to move inshore at night in streams (Bauersfeld, 1977; NESCO, 1983).

Most stranded salmon fry were readily visible in open areas. Chinook and coho salmon fry were rarely found under and around rocks. Consequently, the surveys were believed to have detected nearly all of the salmon fry stranded at the study sites.

Length Frequency of Stranded Salmon. The 44 stranded chinook fry that were measured ranged in length (total) between 30 and 48 millimeters (Figure 4). Similarly, 11 of 12 stranded coho fry were between 35 and 46 millimeters long, and one was 55 millimeters (Figure 4). Although lengths of fish occurring in the river during tests were not determined, these data suggest that relatively smaller fry were most susceptible to stranding. This conclusion is also supported by the fact that only one juvenile salmon, a 50-mm coho, was stranded during the eight downramping tests conducted during the steelhead fry period between June 28 and August 1. By this time most salmon had grown to larger than 50 mm. The size range of stranded fry observed on the Sultan River is consistent with findings on the Columbia River (Bauersfeld, 1977) and Cowlitz River (Bauersfeld, 1978) and is in accordance with chinook fry habitat preference for shallow, quiet waters near shore (NESCO, 1983). Presumably,

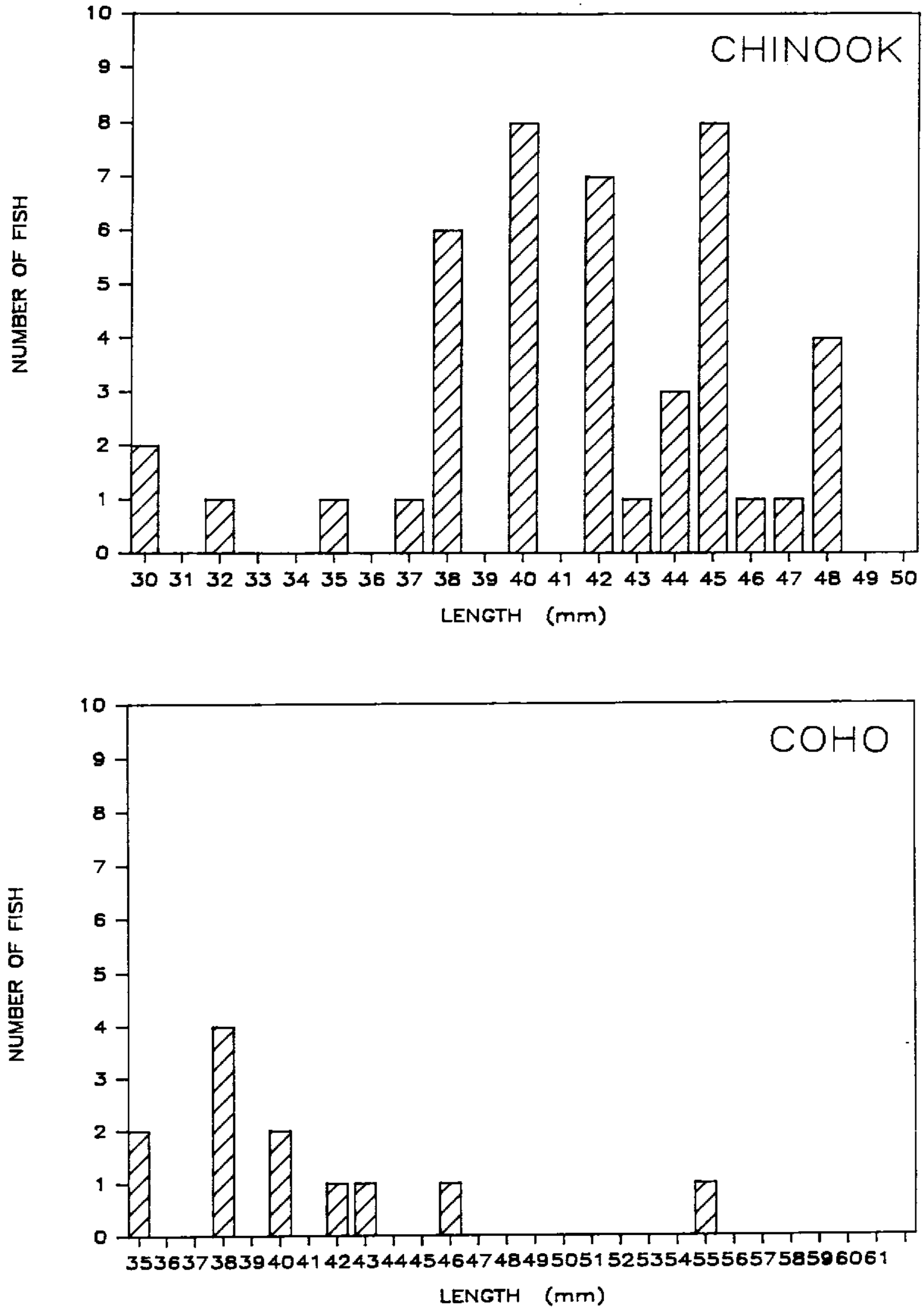


Figure 4.
LENGTH FREQUENCY OF STRANDED SALMON

as the juveniles grow, they tend to move offshore to deeper, higher velocity waters where they become less prone to stranding.

4. STEELHEAD

OBSERVATION OF FRY STRANDING

Steelhead fry began emerging in early June and were abundant by late June. They were more widely distributed in a greater variety of habitat types than salmon fry. For example, they were observed at the top end of low-gradient islands and in shallow margins of riffles where salmon fry were seldom found. However, steelhead also were observed in quiet waters inhabited by salmon fry.

Downramping tests to assess steelhead fry stranding began on June 28, 1985. By this time the stage of Spada Lake prevented operation of the Pelton units, except for maintaining instream flow requirements; therefore, flows above 610 cfs could not be tested. In addition, the powerhouse was shut down for inspection and maintenance between August 2 and October 15, 1985, which prevented any controlled river fluctuations and opportunity for testing during this period.

Initially, downramping rates that were found earlier to be safe for salmon fry were tested. This was believed to be a safe approach. However, our findings indicated that this was not the case.

The results of the various steelhead fry downramping tests are shown in Table 5. Findings of the first three tests conducted at downramping rates of 4 and 6 in/hr for both day and night produced numerous mortalities at the study sites and suggested that steelhead fry were more susceptible to stranding than were chinook fry. For example, a 6-in/hr ramping rate at night stranded 90 steelhead fry on July 2, whereas a similar test conducted for salmon on May 17 stranded only 2 chinook fry. However, steelhead fry appeared to be much more abundant than chinook during the respective tests, and this may have accounted for some of the observed differences.

The results strongly suggest that steelhead fry are more susceptible to stranding at night. This is the opposite of the study findings for chinook. Two daytime tests at 2-in/hr and 4-in/hr downramping stranded 10 and 19 steelhead fry, respectively. Similar night tests at 2 in/hr and 4 in/hr stranded 37 and 55 fry, respectively. When the range of flow fluctuation during each test is factored in, the comparisons suggest that steelhead fry were approximately three to five times more susceptible to stranding at night.

Table 5
SUMMARY OF STEELHEAD FRY STRANDING OBSERVATIONS

Test Conditions						
Flow Range (cfs) (Δ cfs)	Downramp Rate (in/hr)	Time and Date	Survey Area	Number Stranded	Total (No./Δ 100 cfs)	Comments
610-360	4	Day 6-28-85	Ames Bar and Side Channel	16		
(250)			Kien's Island	3	19	
			Kien's Bar	0	(7.6)	
			Winter Bar and Island	0		
			Sultan Island	0		
575-285	6	Night 7-2-85	Ames Bar and Side Channel	36		
(290)			Kien's Island	5		
			Kien's Bar	40	90	
			Winter Island	2	(31.0)	o Full moon.
			Winter Creek Mouth	0		
			Sultan Island	7		
610-330	4	Night 7-3-85	Ames Bar and Side Channel	32		
(280)			Kien's Island	2		
			Kien's Bar	18	55	o One coho fry also stranded.
			Winter Bar and Island	0	(19.6)	
			Sultan Island	3		
610-345	2	Night 7-9-85	Ames Bar and Side Channel	19		
(265)			Kien's Island	5	37	o Fifteen additional steelhead trapped fry but not stranded.
			Kien's Bar	11	(14.0)	
			Winter Bar and Island	0		
			Sultan Island	2		
545-195	2	Day 7-14-85	Ames Bar and Side Channel	7		
(350)			Kien's Island	2	10	
			Kien's Bar	0	(2.9)	
			Winter Bar and Island	1		
			Sultan Island	0		
530-170	2	Night 7-26-85	Ames Bar and Side Channel	0		
(360)			Kien's Island	0	23	
			Kien's Bar	14	(6.4)	
			Winter Bar and Island	5		
			Sultan Island	4		
570-210	2	Day 7-28-85	Ames Bar and Side Channel	0		
(360)			Kien's Island	3		
			Kien's Bar	0	4	
			Winter Bar and Island	0	(1.1)	
			Sultan Island	1		
560-190	3	Day 8-1-85	Ames Bar and Side Channel	2		
(370)			Kien's Island	0		
			Kien's Bar	1	3	
			Winter Bar and Island	0	(0.8)	
			Sultan Island	0		

Note: Stranded Fry were those that had died or were about to die from dewatering.

The degree of steelhead fry stranding correlated directly with downramping rate. Night tests conducted at 6-, 4-, and 2-in/hr downramping rates during the same week stranded 90, 55, and 37 fry, respectively. A similar correlation occurred for day downramping; the 4-in/hr test on June 28 stranded 19 fry while the 2-in/hr test on July 14 stranded 10 fry. Although this relationship is based on limited data, it is in accord with the results of the Skagit River studies, during which an average of nearly three times fewer steelhead fry were observed stranded at a downramping rate of 700 cfs per hour compared to those stranded at 2,000 cfs per hour (Woodin et al., 1984).

Two-inch-per-hour downramping tests during both night and day were conducted during the second week of July and then duplicated during the last week of July. A comparison of the stranding rates for these two time periods suggests that the population of steelhead fry was becoming less susceptible to stranding by late July, presumably as the fish grew and moved offshore.

Steelhead Fry Behavior. The daytime behavior of steelhead fry during downramping was quite different from the behavior of chinook. When steelhead fry were exposed to decreasing water depth in depressions, they began to search randomly for an escape route. Their movements were relatively frantic and fast compared to those of chinook under similar circumstances. Although many steelhead fry were able to avoid being stranded, others seemed content to simply hide under a rock until they could not escape.

Stranded steelhead fry were more difficult to locate than salmon fry. This was partly because of their smaller size (33 mm average for steelhead versus 42 mm for chinook) and partly because of their greater tendency to become stranded in crevices between cobbles. The efficiency of detecting stranded steelhead fry was judged by the survey crew to be about 70 percent in the areas inspected.

Length Frequency of Stranded Steelhead. Stranded steelhead fry ranged between 25 and 40 mm in length (total) although most were 30 to 34 mm (Figure 5). No steelhead fry larger than 40 millimeters were stranded. This provides important information in determining the time period when stranding susceptibility is most critical. Apparently, when juvenile steelhead exceed 40 millimeters, the probability of stranding greatly diminishes.

A total of 93 juvenile steelhead were electrofished from several locations along the lower river on August 22, 1985. Their average length was 46 mm, and only 5 of the 93 fish were less than 40 mm long (Figure 6). Therefore, by August 22, few steelhead fry were of a size susceptible to stranding.

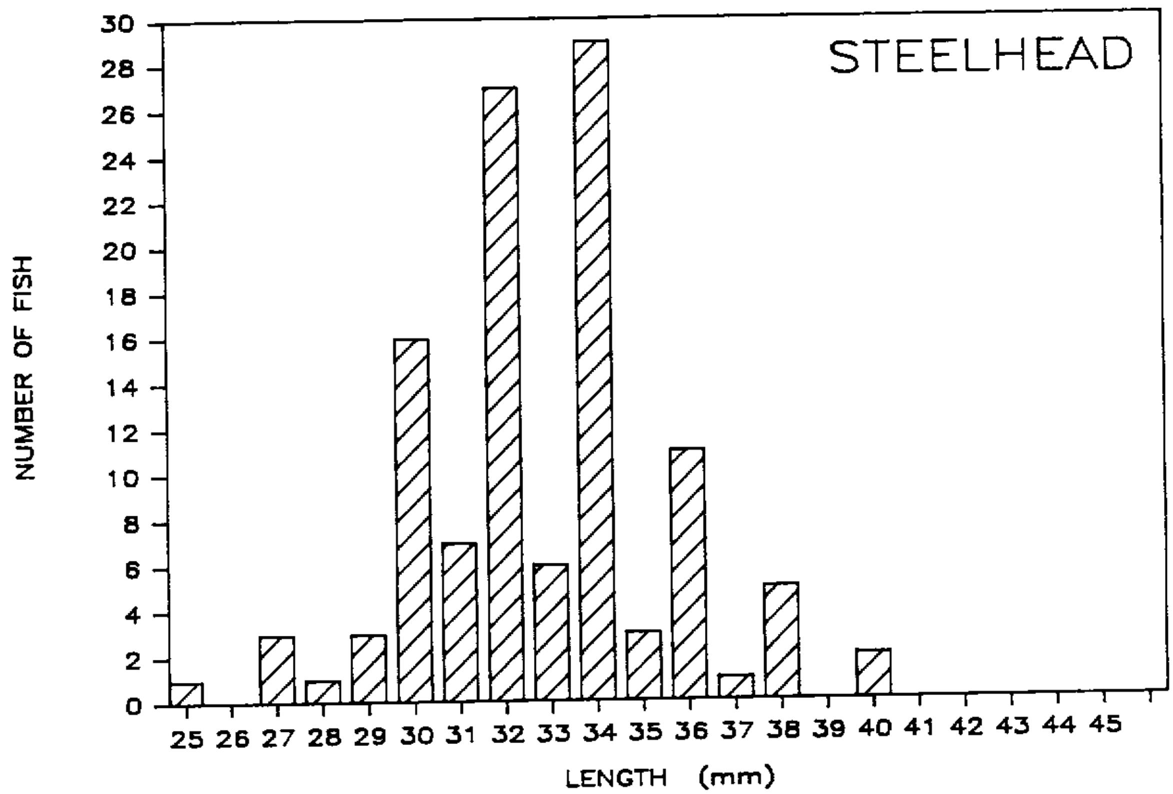
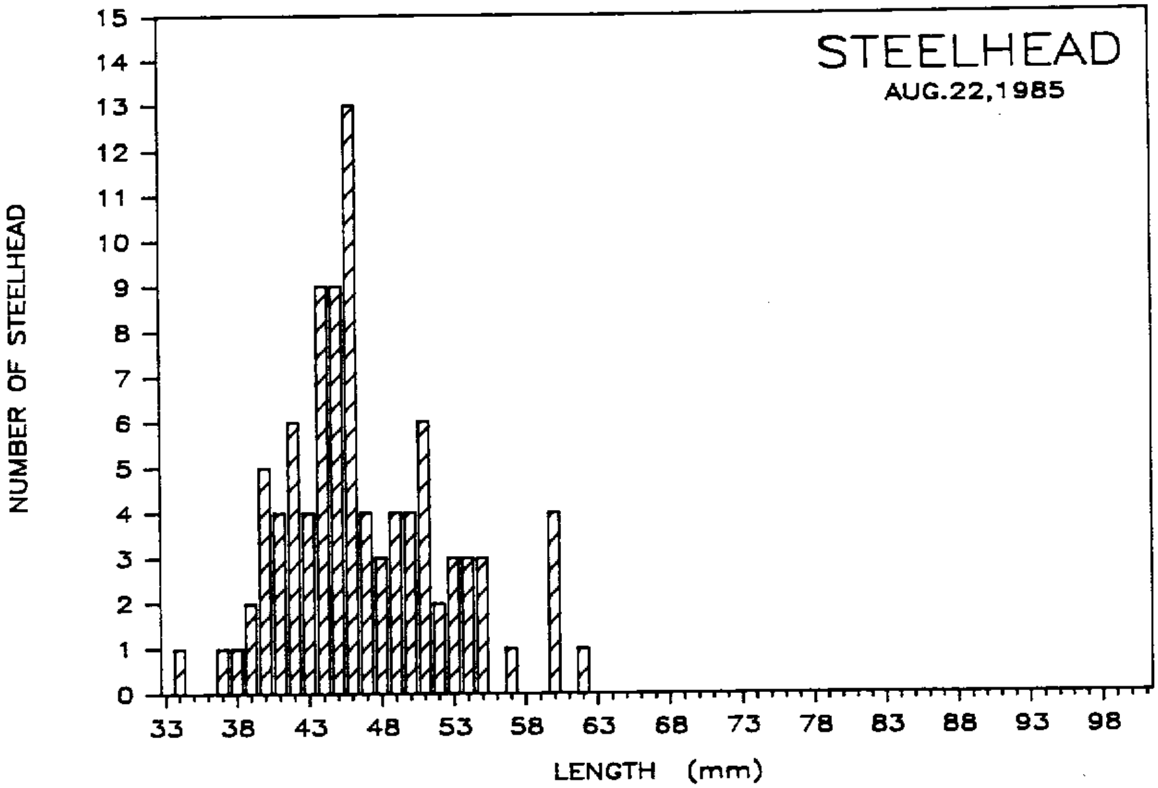


Figure 5.
LENGTH FREQUENCY OF STRANDED STEELHEAD



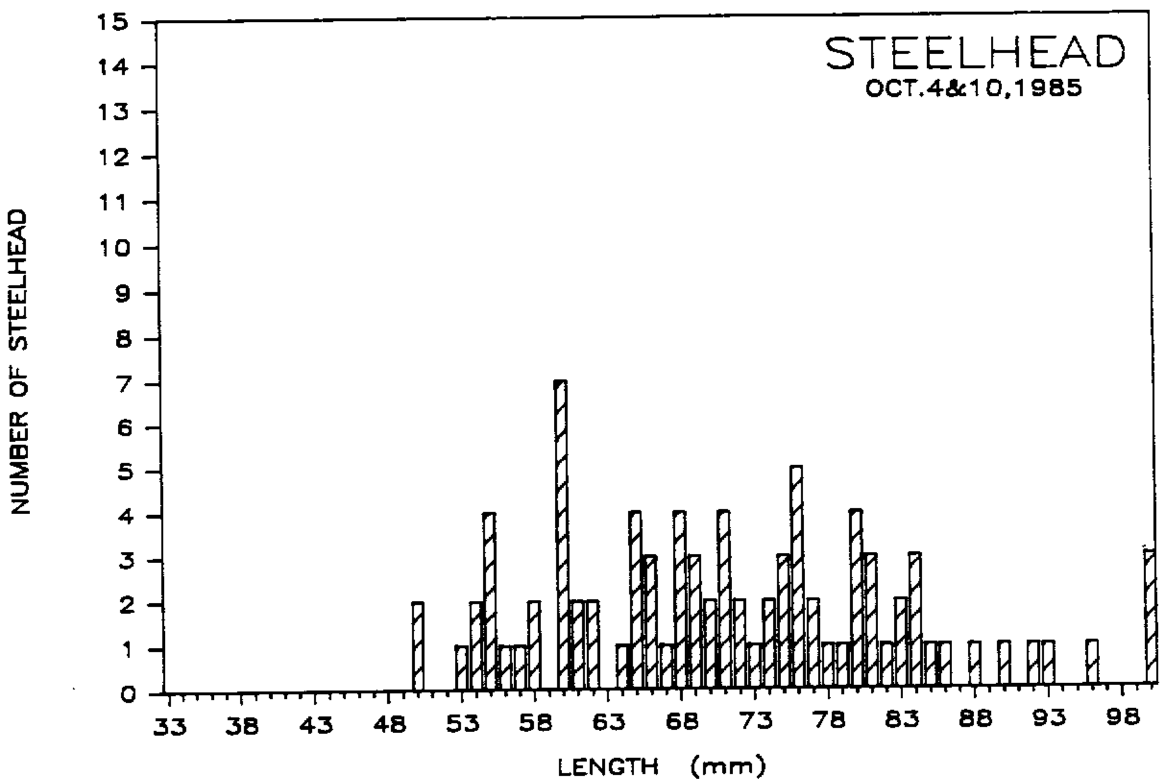


Figure 6.
LENGTH FREQUENCY OF ELECTROFISHED STEELHEAD IN AUGUST & OCTOBER, 1985

On October 4 and 10, the lower river was again electrofished to follow the progress of steelhead growth. By this time the average length had increased to 71 mm. The smallest fry was 49 mm (Figure 6).

The size of juvenile steelhead in the Sultan River is much greater than that reported for the Skagit River in 1976, 1977, and 1980 through 1983. In the Skagit system, steelhead fry in mid-August averaged only about 35 mm, and they generally did not reach 50 mm until October or November (Woodin et al., 1984; Graybill et al., 1979). A later emergence time in the Skagit River, from mid-July to mid-August, probably accounts for much of the steelhead size difference between the two rivers. However, it is also apparent that conditions in the lower Sultan River are favorable to rapid growth. These differences in growth and emergence time point out the need to evaluate the potential for fry stranding on a river-by-river basis.

5. POTHOLES AND SIDE CHANNELS

Eighteen potholes were identified in the lower 3 miles of river. These included all of the depressions that were initially judged to have significant stranding potential (see Appendix D for descriptions). These potholes were monitored during downramping tests to determine actual or potential fry stranding. Eleven of the eighteen potholes remained watered at the streamflows maintained through the study period (Table 6).

Of the remaining seven potholes, stranding was observed in only one (No. 14) on one occasion. This incident followed a regular operational downramping of 3 in/hr at night. This pothole was inspected on several other occasions after it had been dewatered during downramping, and no additional stranding was observed. Therefore, we concluded that repeated stranding was unlikely to occur in this pothole.

The watered status of 12 side channels along the lower Sultan River was checked at various river stages to determine the total river flow at which each side channel begins flowing at its upstream end (Table 7). Only side channels No. 1 (upper end), 3, 6, and 12 stopped flowing within the range of flows controlled by the powerhouse between March 1 and June 15. No stranding was observed in side channels No. 3, 6, or 12 during any of the downramping tests. The relatively steep gradient (greater than 3 percent) of these side channels between potholes probably accounted for the observed lack of stranding. The upper end of side channel No. 1 was the only channel where stranding was observed. One chinook fry was stranded during a 6-in/hr nighttime downramping test, and a total of 17 steelhead fry were stranded during three

Table 6
LOWER SULTAN RIVER POTHOLE STATUS[a]

No.	Approximate River Flow (cfs) When Disconnected	Approximate River Flow (cfs) When Dry	Dry in Summer	Maximum Fry Observed[b]	Comments
1	300	<200	No	Several	
2	200	<200	No	Many	
3	400	240	Yes	Few	No stranding observed
4	650	300	Yes	0	No stranding observed
5	650	<200	Yes	Several	
6	650	<200	No	Many	
7	600	<200	Yes	1	
8	>1,300	See comments	Yes	0	Not included in further observations because of river connection at flow above powerhouse control
9	500	300	Yes	Several	Fry escaped when downramped from 600 to 240 cfs
10	600	500	Yes	Few	
11	400	<200	Yes	Few	
12	1,000	600	Yes	0	
13	400	<200	No	Few	
14	600	500	Yes	Several	Only pothole where stranding (10 fry) was observed on one occasion; drains interstitially
15	700	<200	Yes	Few	
16	500	<200	Yes	Many	Interstitial flow in, surface flow out at 500 cfs
17	400	<200	No	0	
18	<200	<200	Yes	Many	

[a] See Figure 3 for location and Appendix D for description.

[b] Few = <5, several = 5-20, many = >20.

Table 7
LOWER SULTAN RIVER SIDE CHANNEL STATUS

No.[a]	Length (ft)	River Flow (cfs) When Channel Flow Starts	Comments
1	200	650	Contains potholes No. 3 through 6; lower half starts flowing at 200 cfs
2	370	<165	
3	700	700	Lower 500 feet always watered by Trout Farm Creek; upper 200 feet have 3.0 percent gradient
4	1,860	<165	Contains potholes No. 9 and 10 near lower end
5	470	<165	
6	200	700	Potholes No. 14 through 16; upper 50 feet have 3.3 percent gradient; outflow from interstitial source at approximately 500 cfs
7	1,490	200	Potholes No. 11 through 13; small tributary and interstitial water maintains flow in lower half below 200 cfs
8	560	200	Interstitial water maintains ponding and outflow below 200 cfs
9	2,140	200	Winter Creek enters approximately 100 feet from top end; intermittent flow in late summer
10	230	<165	No cover
11	420	<165	No cover
12	930	450	Ponded area of approximately 5,000 ft^2; outflow at 165 cfs

[a]See Figure 3 for location.

nighttime tests (six fry at 6 in/hr, eight fry at 4 in/hr, and three fry at 2 in/hr).

After June 15, when the minimum streamflow decreased from 200 cfs to 165 cfs, inflow to side channels No. 7, 8, and 9 ceased. However, below the powerhouse all three of these channels maintained intermittent surface flow from interstitial water sources. Entrapment of juvenile steelhead and coho occurred in these areas, but stranding or lethal temperatures did not.

6. WINTER HABITAT AND DOWNRAMPING

Electrofishing was used to locate overwintering juvenile salmon and steelhead and to identify their winter habitat preferences. Fifty-eight coho, 119 steelhead, and 15 chinook were collected on December 11 and 12, 1985, in the study area (Table 8). Water temperatures ranged from 3°C in the river to 0°C in Winter Creek. Length frequency data for these fish are presented in Appendix E. All species occurred in very slow or zero-velocity water. Nearly all coho and chinook were found in association with woody debris. Most steelhead were found in crevices among clean cobbles and boulders (that is, with no noticeable sand or silt) except those collected in Winter Creek. In that small tributary, all 28 collected steelhead were found near woody debris; no cobble or boulder substrate was identified in Winter Creek.

Nearly all overwintering fish were located in areas not thought to be at risk of dewatering during downramping. These included percolation channels, permanent potholes, and tributaries.

Two winter downramping tests were conducted during daylight hours at 6 in/hr. On January 14, 1986, the river was downramped from 1,330 cfs to 300 cfs. Areas inspected included those identified earlier as being winter habitats: BPA powerline crossing, side channels No. 1, 3, 5, 6, 8, and 12, Ames Bar, Kien's Island, and pothole No. 17. Only one small juvenile steelhead (58 mm) was observed stranded. This occurred at the lower end of side channel No. 12 at the base of a small willow bunch.

A second 6-in/hr test was conducted during daylight on February 4, 1986, through a flow change from 1,350 cfs to 330 cfs. This test differed from the first in that the powerhouse had been operating at full generation (approximately 1,350 cfs) for 16 days prior to downramping. This test was considered a worst-case situation regarding winter stranding potential, based on the assumption that fish had ample opportunity to redistribute to shallower habitats in the dewater zone prior to the downramp. Also, the amplitude of flow change was nearly maximum possible from the powerhouse.

Table 8
ELECTROFISHING CATCHES OF JUVENILE SALMON AND STEELHEAD IN LOWER SULTAN RIVER, DECEMBER 11 AND 12, 1985

Location[b]	Number of Fish by Substrate Type[a]					
	Coho		Chinook		Steelhead	
	LOD	Cobble	LOD	Cobble	LOD	Cobble
BPA Powerline Crossing	0	0	0	0	0	0
Potholes 1 and 2	0	0	0	0	0	0
Side Channel 1	2	NA[c]	2	NA	4	NA
Ames Bar, upper	NA	0	NA	0	NA	1
Side Channel 3	4	1	0	0	0	13
Side Channel 5	3	0	3	0	3	14
River Near Channel 5	NA	0	NA	0	NA	0
Side Channel 6	0	0	0	0	0	0
Side Channel 7	4	0	1	0	3	1
Runoff Tributary to S.C. 7	0	NA	0	NA	4	NA
Side Channel 8	3	0	0	0	0	6
Winter Creek	11	NA	7	NA	26	NA
Pothole 17	0	0	1	0	0	34
Side Channel 12	1	0	1	0	6	0
Runoff Tributary at Sultan	30	NA	0	NA	1	NA

[a]LOD = Large organic debris; Cobble = 75-300 mm diameter.

[b]See Figure 3 (map).

[c]NA = Not applicable.

Six stranded steelhead juveniles were observed following this test: two at the upper end of Ames Bar (51 mm and 63 mm), two near pothole No. 17 (76 mm and 89 mm), one in a gold dredger's depression at the upper end of Sultan Island (58 mm), and one at the upper end of Kien's Island (57 mm).

A 4 in/hr daytime test was conducted on February 16, 1987, at a flow range from 1,350 to 450 cfs. Two newly emerged chinook fry and two juvenile steelhead (75 mm and 80 mm) were stranded. Both steelhead were observed near the water's edge and probably stranded at 500 to 600 cfs.

Chapter 4
SUMMARY OF FINDINGS

1. Most conclusions regarding the major variables affecting stranding (e.g., day versus night, ramping rate, and flow range) were based on one or two paired comparisons. The limited number of tests and small numbers of fry actually stranded did not allow statistical testing.

2. The downstream lagtime of powerhouse downramping events is approximately 15 minutes per stream mile.

3. Chinook fry were first observed in early March 1985.

4. Steelhead fry were first observed in early June 1985.

5. Most fry stranding (all species) occurred on river bars of less than 4 percent gradient.

6. Fry stranding in potholes is not a significant problem in the lower Sultan River.

7. Chinook fry were much more susceptible to stranding during day compared to night.

8. No chinook fry longer than 50 mm were stranded.

9. Steelhead fry appeared to be more susceptible to stranding during night compared to day.

10. Coho and chum fry appeared to be less susceptible to stranding than chinook fry.

11. Compared to chinook fry, steelhead fry were as, or more, susceptible to stranding.

12. No steelhead fry longer than 40 mm were stranded in tests conducted prior to the lastest summer test on August 1, 1986.

13. Nearly all juvenile steelhead sampled in the Sultan River exceeded 40 mm in length by mid-August.

14. Downramping when river flows are greater than 750 cfs should strand fewer fry than when flows are below 600 cfs.

15. Rapid downramping between 750 and 600 cfs immediately following a period of uniform high river flow may cause significant salmon fry stranding in two side channels.

16. Most overwintering juvenile salmon and steelhead were located in areas of low risk to dewatering during downramping.

17. Differences in channel morphology, emergence time, and fish growth indicate the need to evaluate fry stranding potential on a river-by-river basis.

18. A single, simple downramping rate of 6 inches per hour is not suitable for the Jackson Project's Pelton turbine discharges to the Sultan River.

19. Downramping rates for the Jackson Project require consideration of the presence or absence of salmonid fry and their size, the flow range in the river and the extent of change of discharge from the powerhouse, and the time of day when downramping.

Chapter 5
RECOMMENDATIONS

1. DOWNRAMPING

The results of this study indicate that a single ramping rate of 6 inch/hour, as currently stipulated in the project license, would sometimes cause fry stranding losses deemed unacceptable by the Joint Agencies. Downramping rates that prevent significant fry stranding vary seasonally, dielly, by species, and by river stage. Therefore, a downramping regime is recommended that considers these factors to protect the fisheries resource and provide operational flexibility for power production and water conservation purposes.

The recommended downramping rates by date and river stage are presented in Table 9. These recommendations are discussed below.

SEASONS

Recommended downramping rates are divided into four seasons based on biological considerations. The first season, March 1 to May 31, corresponds to the period of salmon fry emergence. Chinook and pink fry typically start emerging in March. If winter stream temperatures are exceptionally warm, fry may begin emerging in late February. However, given the temperature control capabilities and requirements of the project, the probability of unusually warm incubation temperatures and subsequent early emergence is quite low. Nevertheless, cumulative temperature units should be computed for each year's incubation period for steelhead as well as for salmon to anticipate any early emergence of fry. Also, field checks should be conducted at the time of anticipated emergence to verify the start of the fry period.

Many salmon are still at a size vulnerable to stranding in early June. However, steelhead begin emerging in early June and the ramping rates recommended to protect steelhead fry are equal to or lower than those recommended for salmon.

September 1 was determined to be the date when most juvenile steelhead had grown out of the fry stage and thus became less susceptible to stranding. This conclusion was based on one year's data comparing the length frequency of stranded steelhead fry to the length frequency of fry electrofished along the stream margins during mid-August. This transition period still needs to be verified with additional electrofishing in early September.

From September 1 to October 31, most juvenile salmon and steelhead reside in their summer rearing areas. These

Table 9
RECOMMENDED DOWNRAMPING RATE SCHEDULE[a]

Flow Range (cfs)	March 1[b] to May 31		June 1[b] to August 31	
	Day	Night	Day	Night
1,500 to 750	4	6[c]	2	2[c] (1)[d]
750 to 600	2[e]	2[e]	2[e]	2[c] (1)[de]
600 to 300	2	6	2	1[c]
300 to min	2	2	2	1[c]
	Sept. 1 to Oct. 31		Nov. 1 to Feb. 28	
	Day	Night	Day	Night
1,500 to min	4[c] (2)[d]	2[c] (1)[d]	4[c] (2)[d]	6[c] (4)[d]

Note: Units are in inches per hour at the powerhouse.

[a]For normal operation. Not for power-generating equipment failures or forced outages.

[b]These dates may be adjusted annually by determining time of emergence with cumulative water temperature information and direct field observations.

[c]Need to verify.

[d]Operate at this rate until higher rate is verified as safe.

[e]If river flow prior to downramping has exceeded 1,000 cfs for more than 72 hours, downramp through this flow range (750 to 600 cfs) only after holding flow constant between 750 and 850 cfs for at least 6 hours of daylight and one overnight period.

juveniles are not highly susceptible to stranding because of their increased size. Therefore, less restrictive ramping rates are recommended during this period. However, these rates need to be verified with actual downramping tests.

Coincident with storms in late October or early November, juvenile coho and steelhead redistribute to winter refuge areas (Cederholm and Scarlett, 1981). As determined by electrofishing and confirmed with winter downramping tests, the winter habitats are located in areas not highly affected by river fluctuations. Therefore, less restrictive downramping rates should be acceptable for this period for all flow ranges within the project's control. However, there was some concern that the six stranded steelhead observed during one of the 6-in/hr tests did not represent all of those stranded; additional stranding may have occurred unnoticed within the substrate. Therefore, it was concluded that 4 in/hr would be safer than 6 in/hr during the day. However, 2 in/hr is temporarily recommended pending verification of 4 in/hr. Similarly, it is recommended that night downramping during the winter be limited temporarily to 4 in/hr until 6 in/hr can be tested and verified as safe.

FLOW RANGES

Downramping recommendations vary depending upon the stage of the river below the powerhouse. Four flow ranges were identified on the basis of relative potential for salmon fry stranding.

At flows above 750 cfs, the river stage is generally above the toe-of-bank and thus most low-gradient stranding areas are inundated. Therefore, the least restrictive ramping rates are recommended for this flow range during the salmon fry period. However, because the relationship between stranding and gravel-bar gradient was not as apparent for steelhead as it was for salmon, the recommended ramping rates between June 1 and February 28 do not vary by flow range, except for the 750- to 600-cfs range, as discussed below.

Between 750 and 600 cfs, flow into three side channels ceases thereby creating a potential for stranding if downramping occurs too rapidly. In addition, special precaution is needed if downramping through this range is preceded by an extended period of high flow. Therefore, during the fry period, if the river flow prior to downramping has exceeded 1,000 cfs for more than 72 hours, the downramp should be paused just above 750 cfs for at least 6 hours of daylight and one overnight period to allow fry entering these side channels to distribute to safe areas. The minimum time period of 72 hours for this recommendation is based on test results indicating that 96 hours of high flow prior to ramping did not appear to increase the likelihood of stranding in these side channels, but a 2-week period probably would have, at least for salmon fry. High flows are defined as those greater than 1,000 cfs for purposes of applying the recommendation. This was conservatively selected after observing a potential stranding situation when downramping followed a 2-week period of constant flow of approximately 1,300 cfs.

It was not determined if the side channels within the 750- to 600-cfs flow range also presented a potential stranding situation for steelhead fry. However, on the chance that it may present a problem, precautionary ramping also is recommended for the steelhead fry period.

At river flows between 600 and 300 cfs, low-gradient gravel bars with stranding potential become exposed. However, differences in stranding were not observed at these flows compared to those above 750 cfs at the downramping rates tested during the salmon fry period. Downramping rates of 2 in/hr during the day and 6 in/hr at night are recommended as safe for the March 1 to May 31 period.

Below 300 cfs, an increasing number of streambed depressions become exposed. Coho fry appeared to be vulnerable to stranding in these areas and thus a 2-in/hr downramping rate is recommended for both day and night at these flows during the spring and summer.

RAMPING DURING TWILIGHT

For most cases different downramping rates are recommended for day and night. However, if downramping is to occur during the twilight period (1 hour before to 1 hour after sunrise or sunset), the lower of the two stipulated day or night rates should be used. For example, a 6-in/hr springtime downramp intended for night should not be initiated at the powerhouse until 1 hour after sunset. As another example, if a summer afternoon downramp initiated at 2 in/hr is to extend past sunset, the ramping rate should be reduced to 1 in/hr at 1 hour before sunset. These precautionary guidelines should minimize the potential for stranding during the twilight hours when the juvenile fish are shifting their diurnal behavior patterns.

2. ADDITIONAL TESTS

Several of the recommended downramping rates need further testing to verify their safety for juvenile fish. A night ramp of 6 in/hr from 1,300 to 750 cfs was tested only once and found to be relatively safe for salmon. However, because night downramping at this flow range will be needed for water management purposes, it is recommended that this test be repeated for confirmation.

During the June 1 to August 31 period, steelhead fry were found to be highly susceptible to stranding at night. Therefore, a downramping rate of only 1 in/hr was recommended. However, an unusually wet summer would be required to provide sufficient water for conducting these tests. Since this rate was not tested, it needs to be verified.

Rates of 2 in/hr and 1 in/hr for day and night, respectively, are recommended for September and October, but these rates are thought to be conservative, considering the increased size of the steelhead present in the river. Therefore, it is recommended that additional downramping tests at 4 in/hr be conducted during September and October. Testing during this period will also better define the transition period when steelhead grow beyond the stage of susceptibility to stranding.

Winter downramping tests were limited to two at 6 in/hr and one at 4 in/hr during the day. Some stranding during the 6 in/hr tests was identified and, consequently, 2 in/hr was initially recommended. Subsequently, a 4-in/hr rate was tested and two stranded steelhead were observed. An additional 4 in/hr daytime test is needed during the winter.

No nighttime downramping tests were conducted during the winter. However, the 3-in/hr rate used in normal operation in 1985 appeared to be safe based on several observations in the field. A rate of 4 in/hr was subsequently recommended. If a faster rate is desired, 6 in/hr should be tested.

Chapter 6
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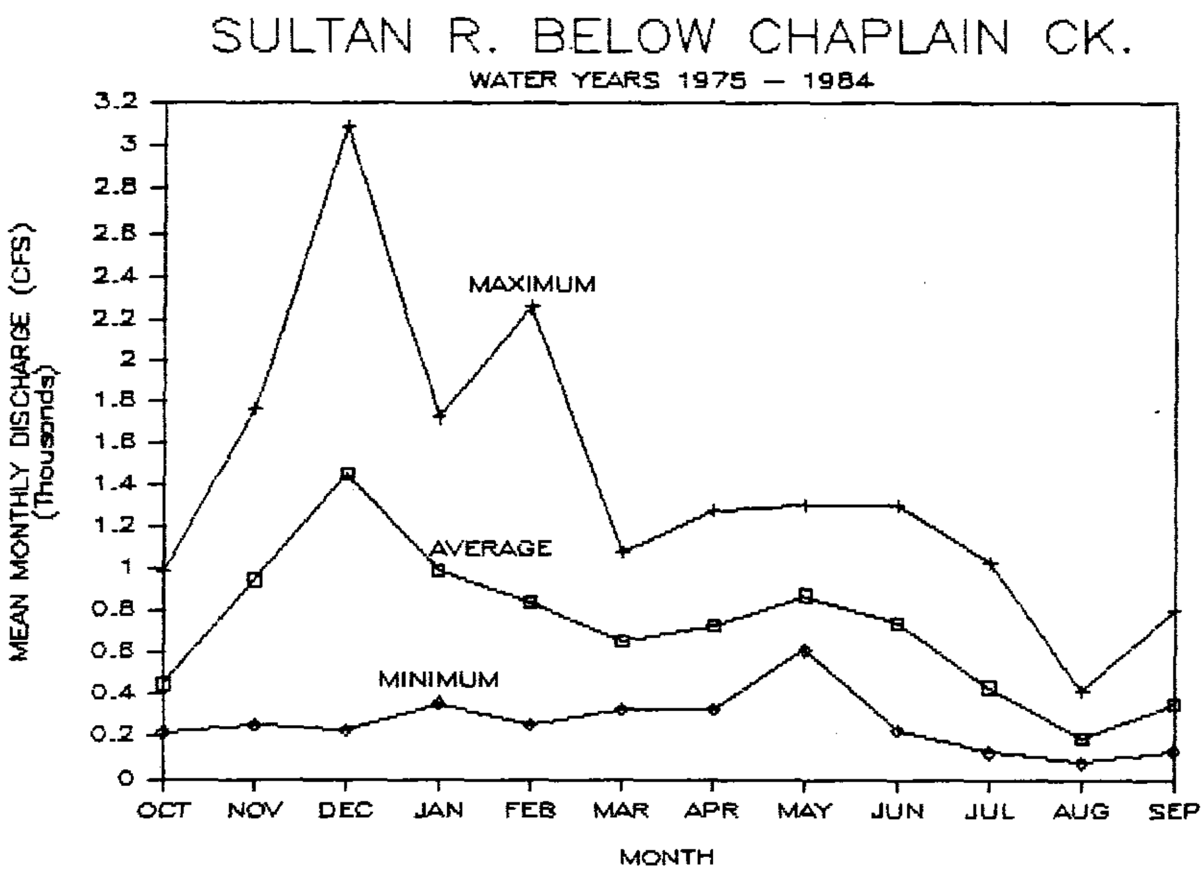
Appendix A

MONTHLY AVERAGE FLOWS BEFORE POWERHOUSE OPERATIONS

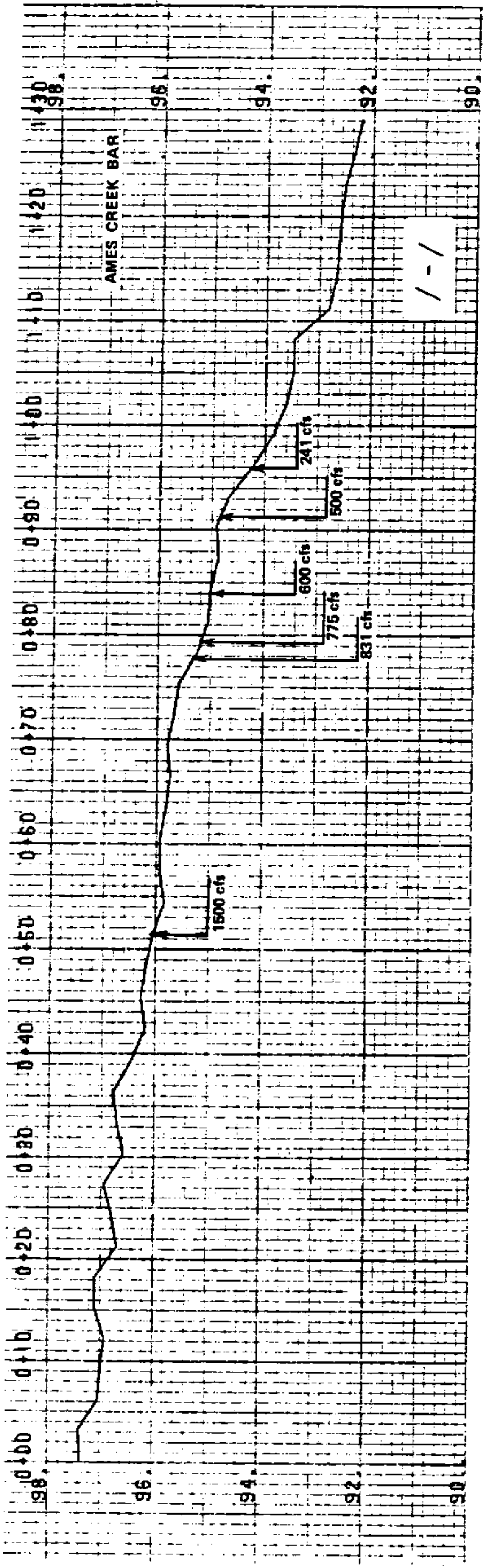
SULTAN RIVER BELOW CHAPLAIN CREEK NR SULTAN, WA
MEAN MONTHLY DISCHARGE (CFS)
WATER YEARS 1975 - 1984

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1975	-	649	1266	1207	454	533	331	1143	969	533	296	246
1976	969	1766	3091	1719	671	414	772	1299	950	667	420	347
1977	295	349	751	1039	259	480	888	860	590	127	258	408
1978	371	1760	1931	620	533	671	559	711	440	188	201	806
1979	251	788	623	362	820	1081	666	866	519	415	98.8	137
1980	237	254	2526	446	652	629	934	611	570	244	120	512
1981	311	1587	2014	579	1316	331	1276	781	1305	298	138	225
1982	992	684	934	1320	2255	811	612	1088	1115	696	237	311
1983	414	737	1163	1576	622	784	794	663	716	1027	77.9	469
1984	224	897	231	1020	815	774	509	695	231	171	115	140
MEAN MONTHLY Ave	452	947	1453	989	840	651	734	872	741	437	196	360
MEAN MONTHLY Max	992	1766	3091	1719	2255	1081	1276	1299	1305	1027	420	806
MEAN MONTHLY Min	224	254	231	362	259	331	331	611	231	127	78	137



Appendix B

STREAM CROSS-SECTIONAL PLOTS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500 cfs
600 cfs
775 cfs
831 cfs
1500 cfs
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0+10
0+20
0+30
0+40
0+50
0+60
0+70
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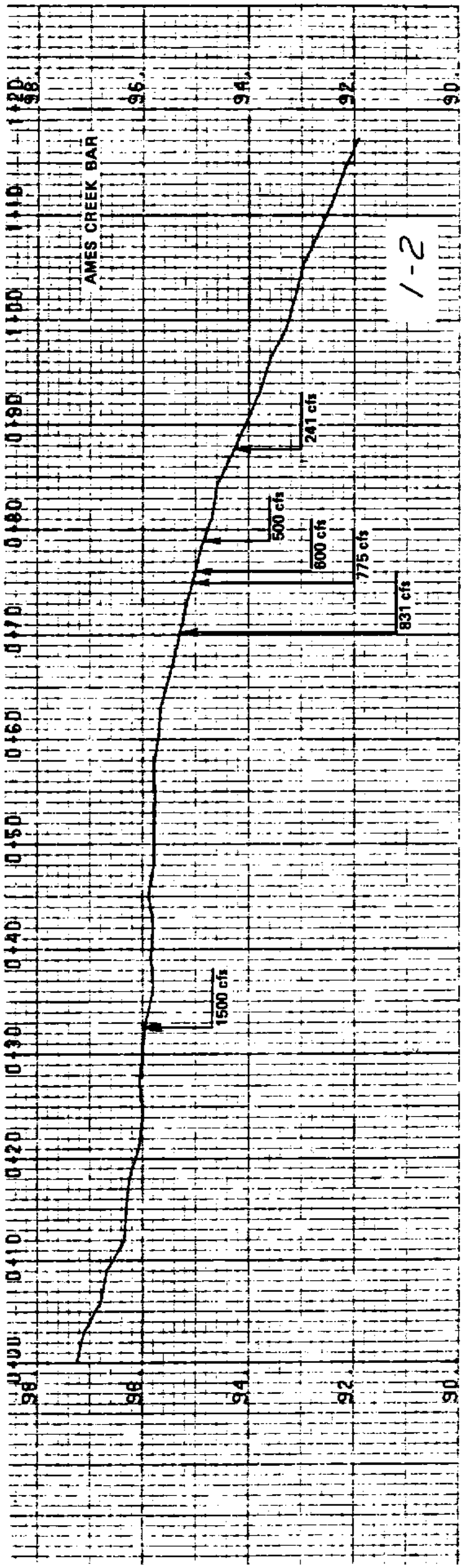
1+10
1+20
1+30
98
96
94
92
90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98
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92
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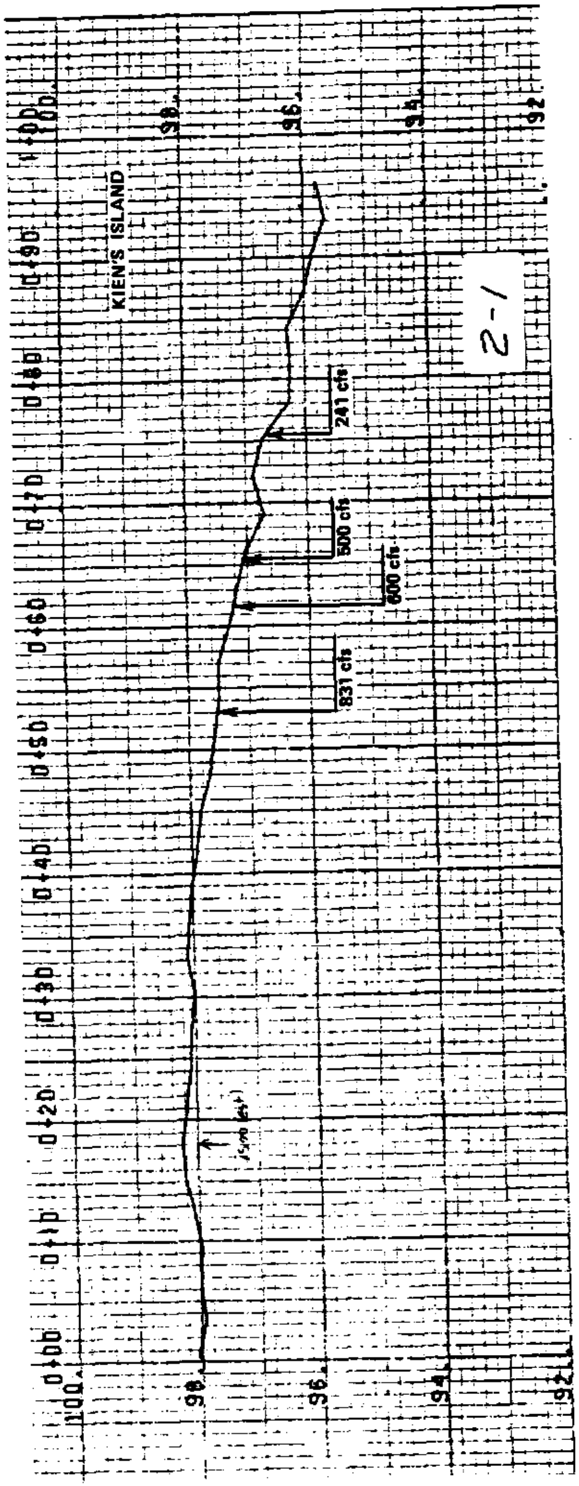
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600 cfs
831 cfs
0+00
0+10
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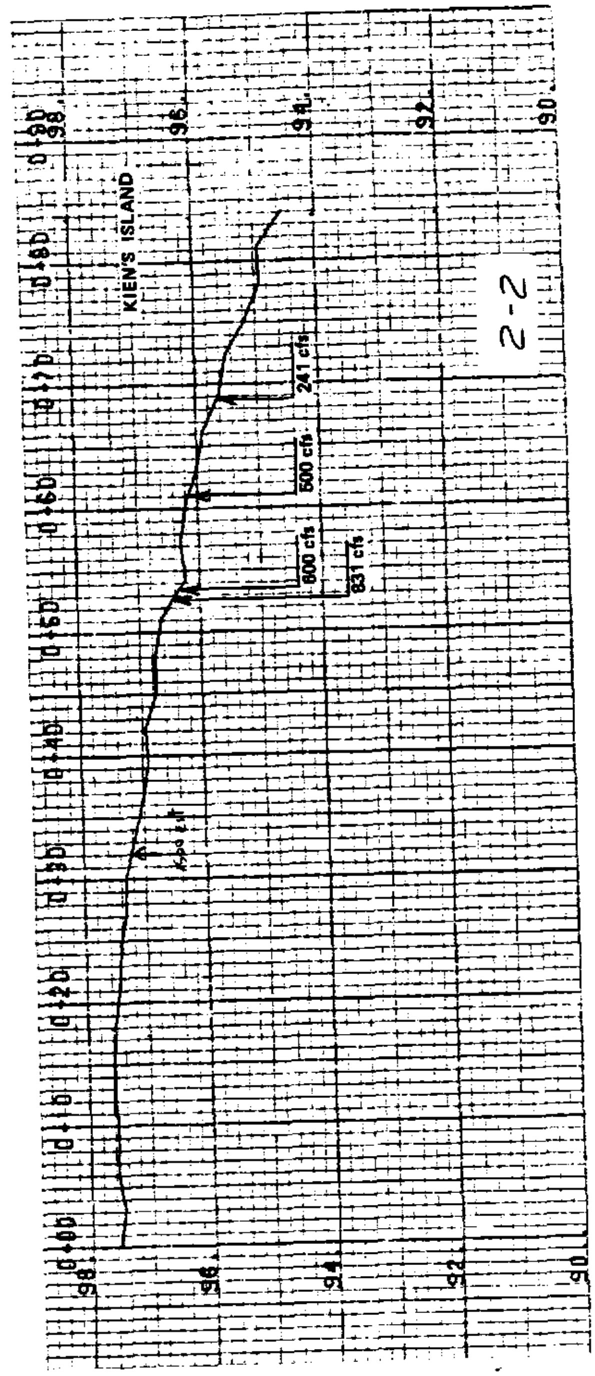
100
98
96
94
92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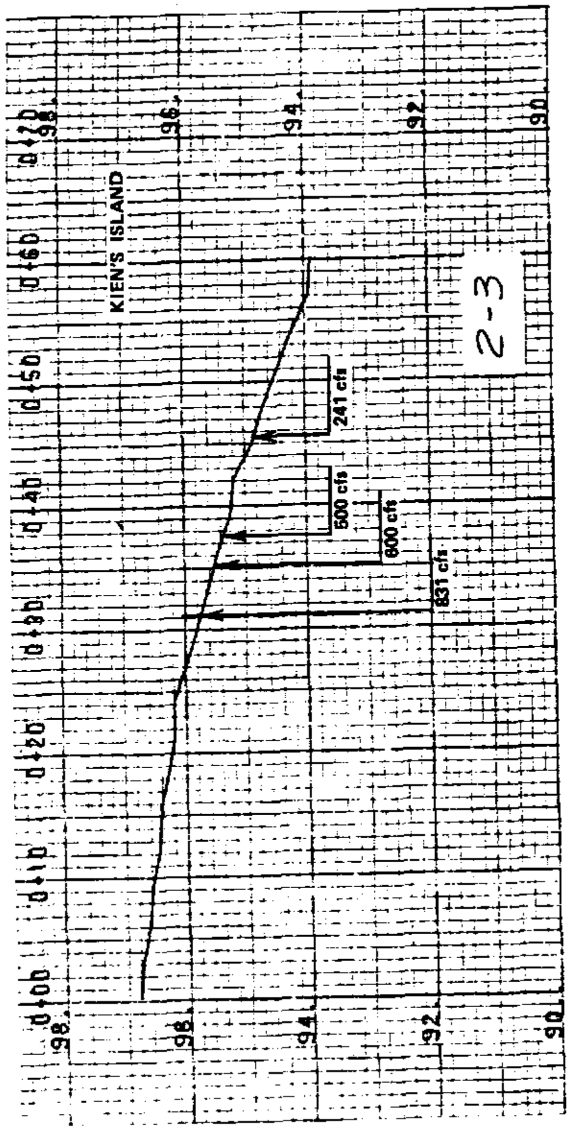
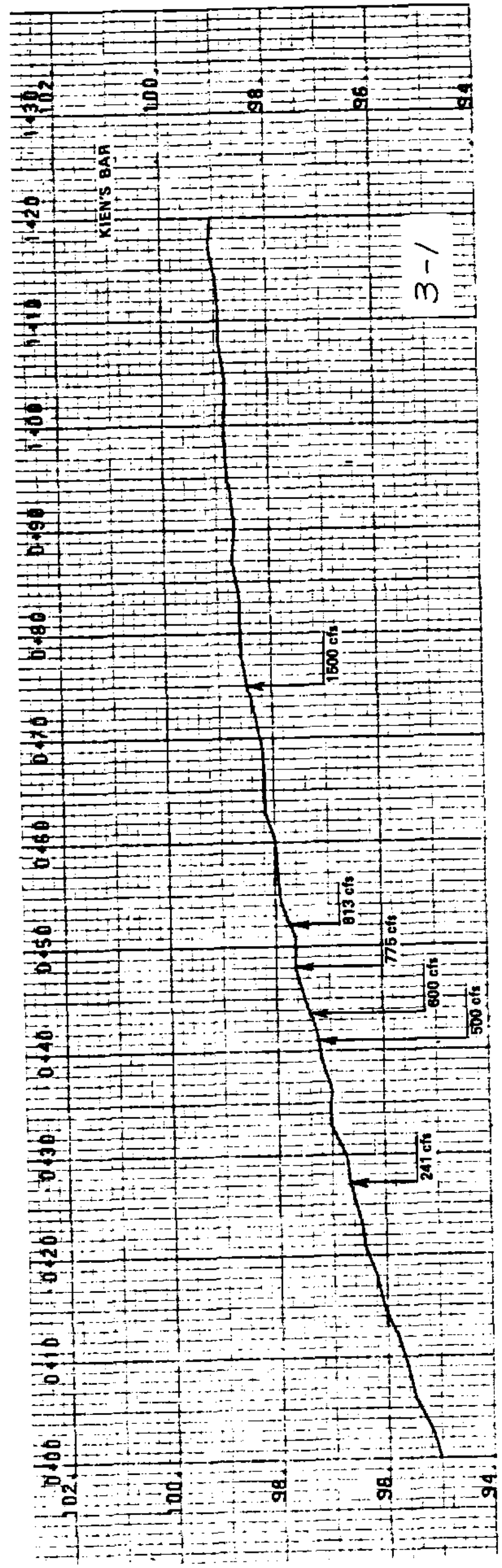


KIEN'S ISLAND
2-3
241 cfs
500 cfs
600 cfs
831 cfs
98
96
94
92
90



KIEN'S BAR
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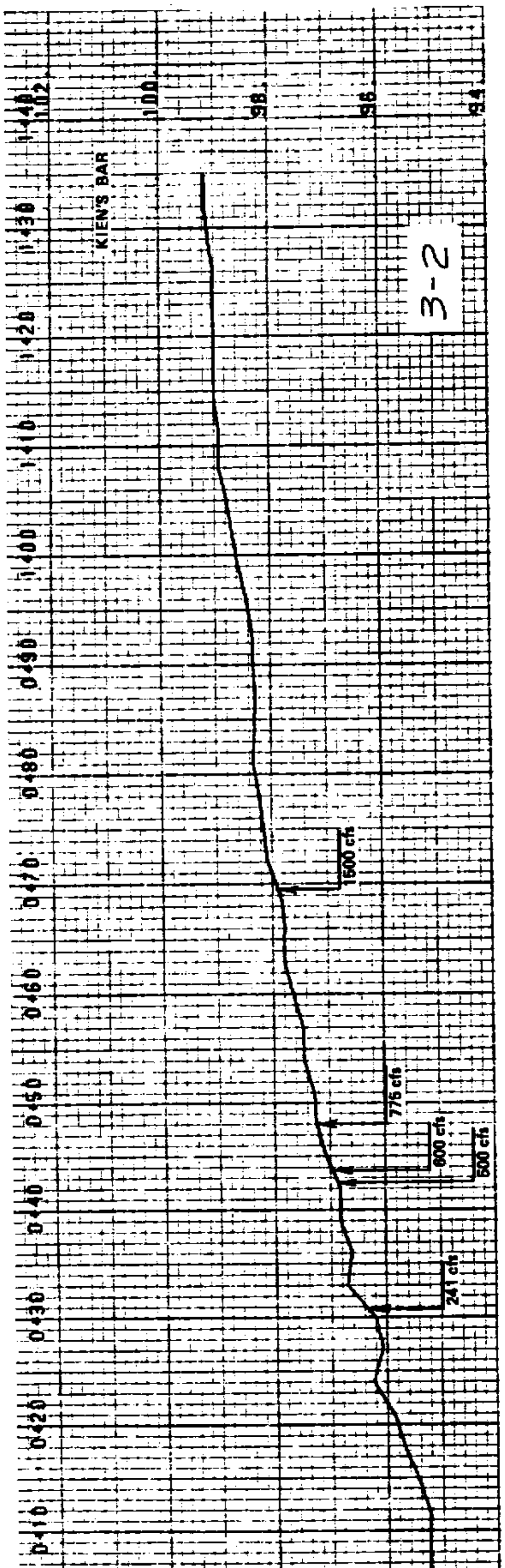
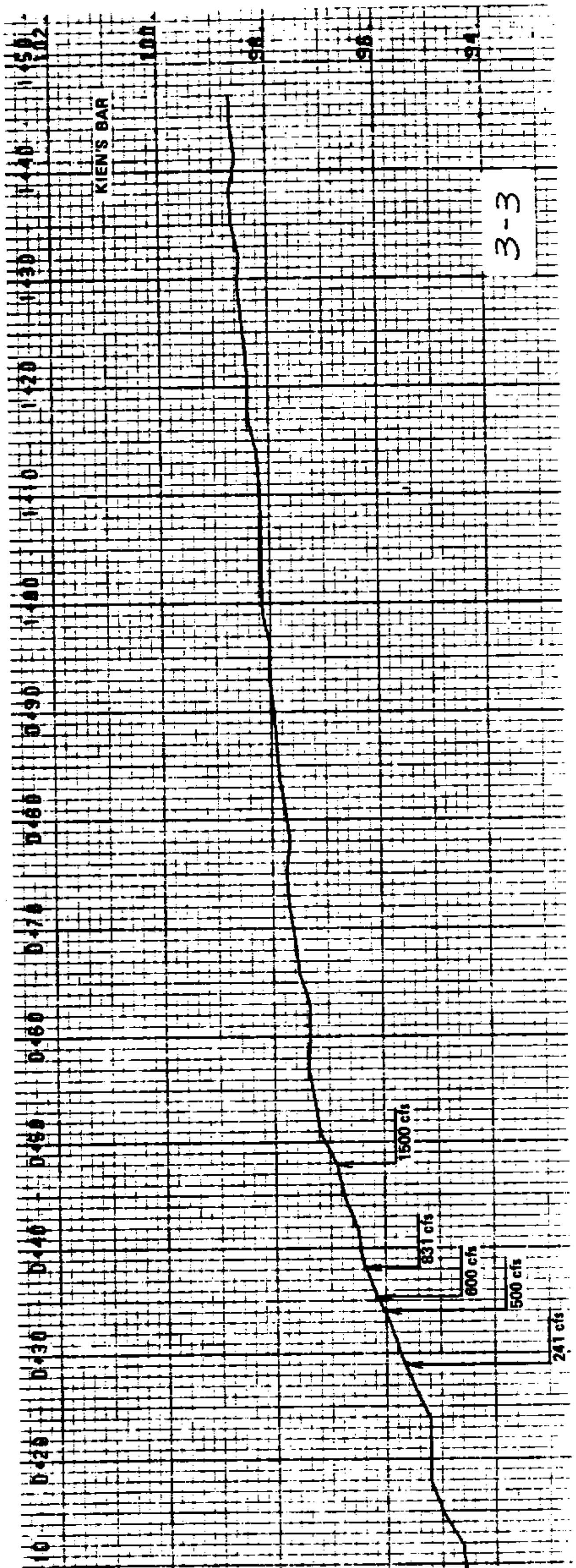
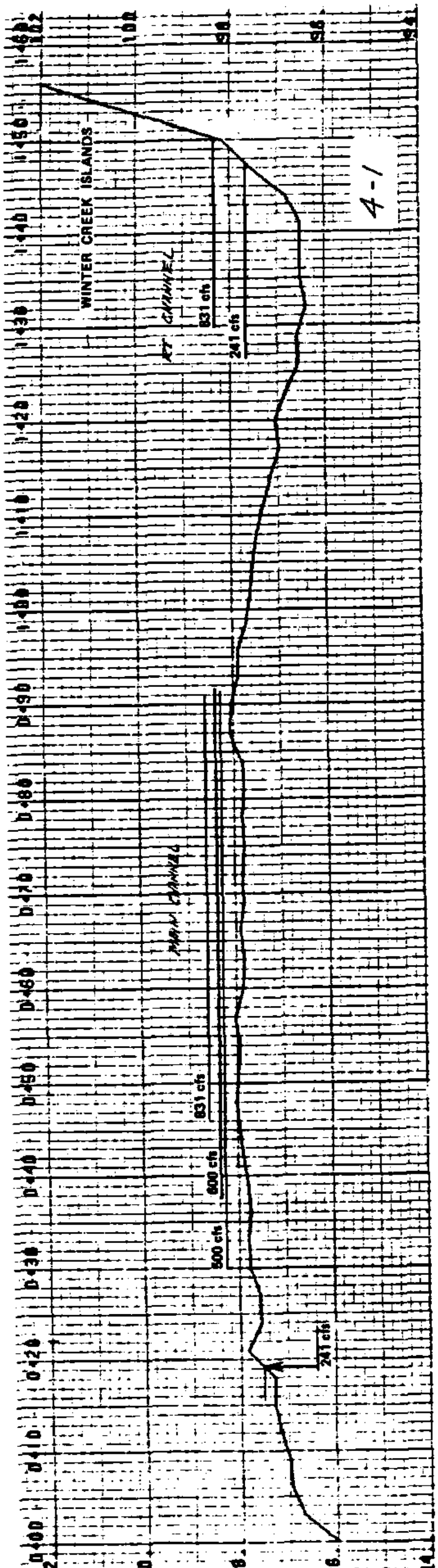
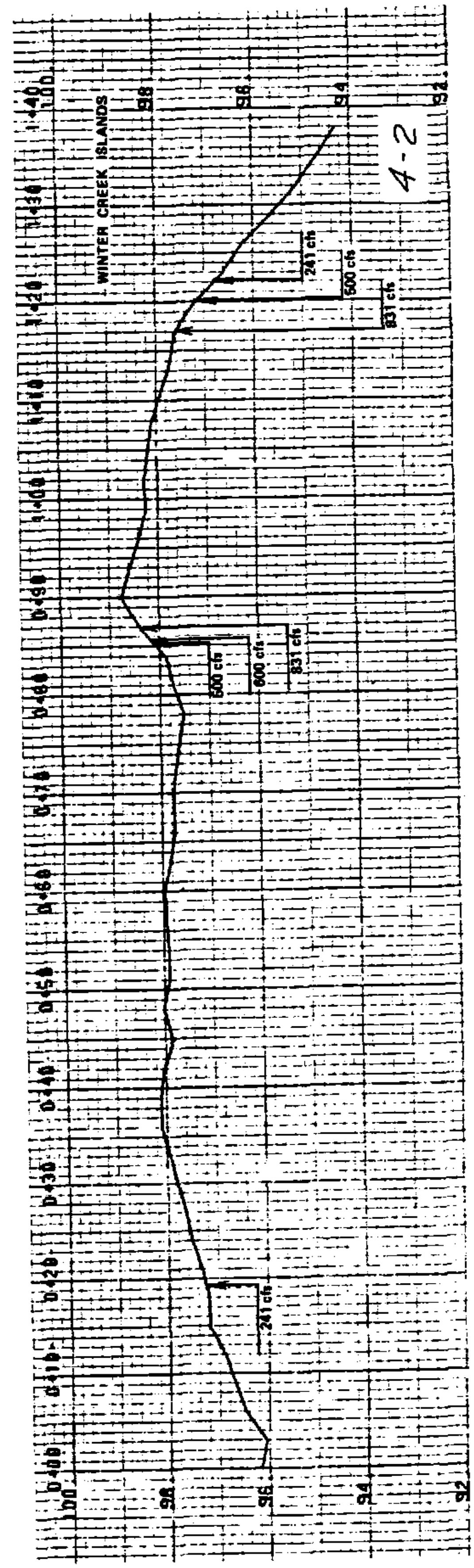
1500 cfs
813 cfs
775 cfs
600 cfs
500 cfs
241 cfs
102
100
98
96
94


3-2
KIEN'S BAR
1500 cfs
775 cfs
600 cfs
500 cfs
241 cfs

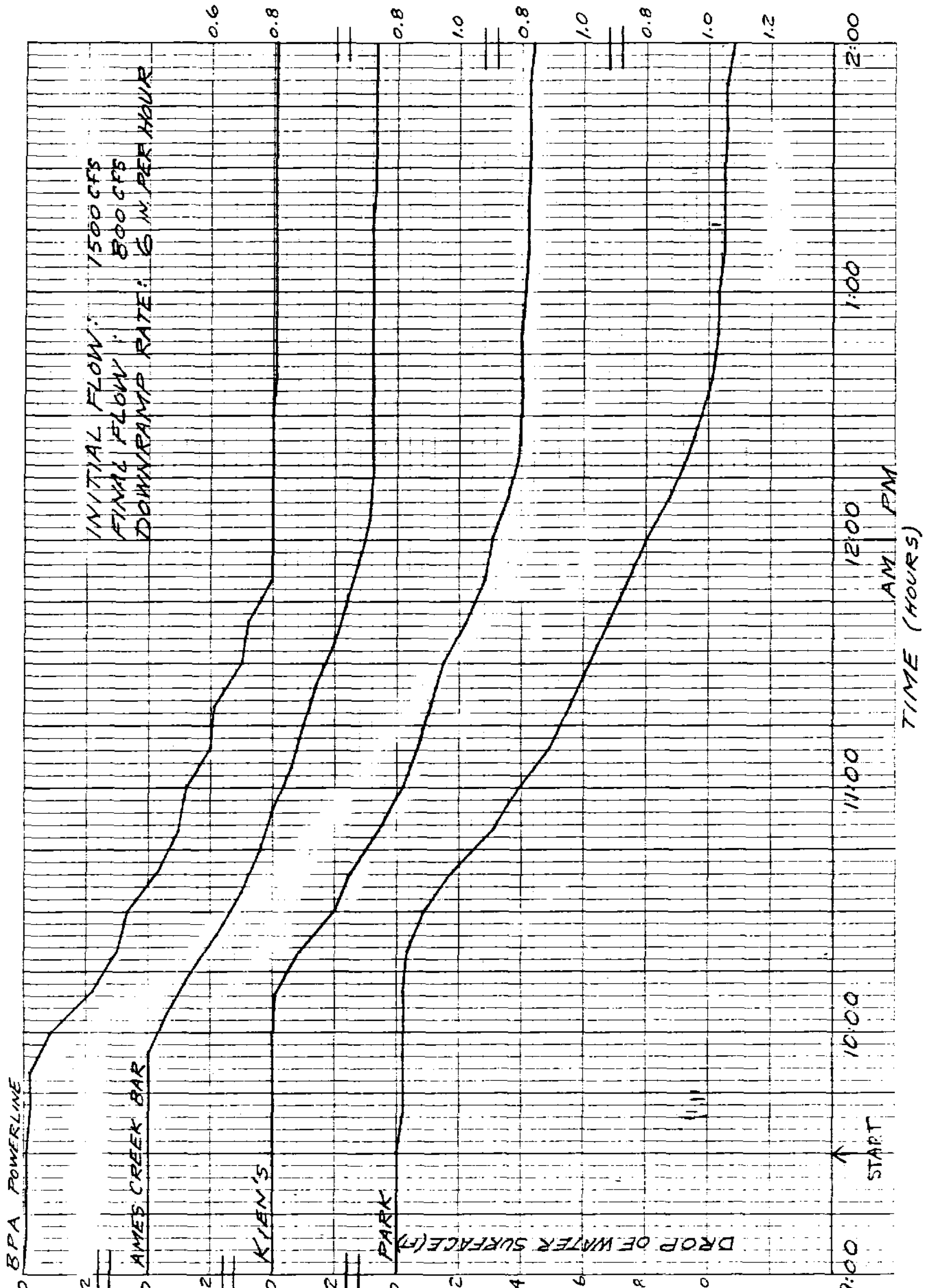

3-3
KIEN'S BAR
1500 cfs
831 cfs
600 cfs
500 cfs
241 cfs

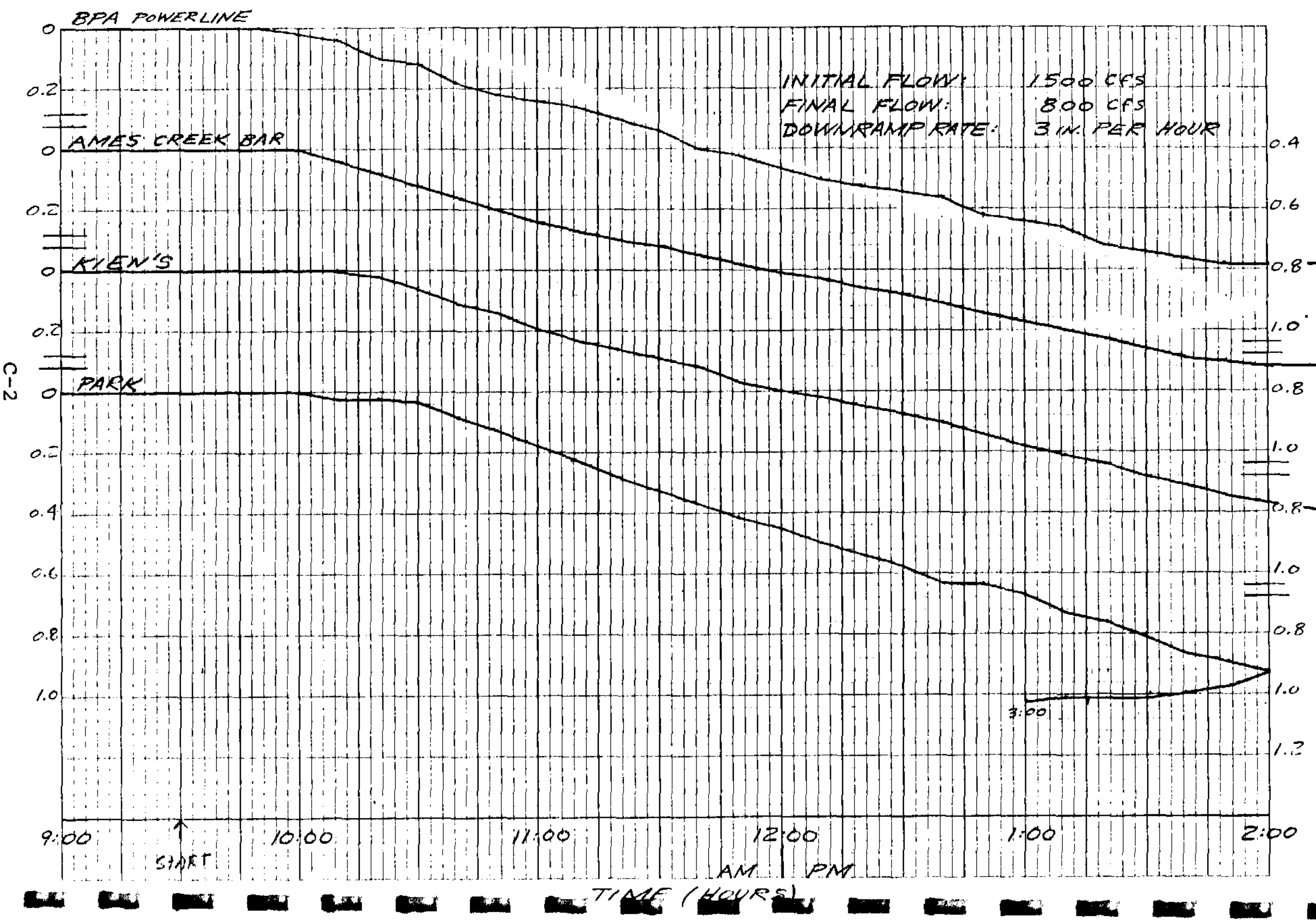

WINTER CREEK ISLANDS
4-1
831 cfs
241 cfs
600 cfs
500 cfs

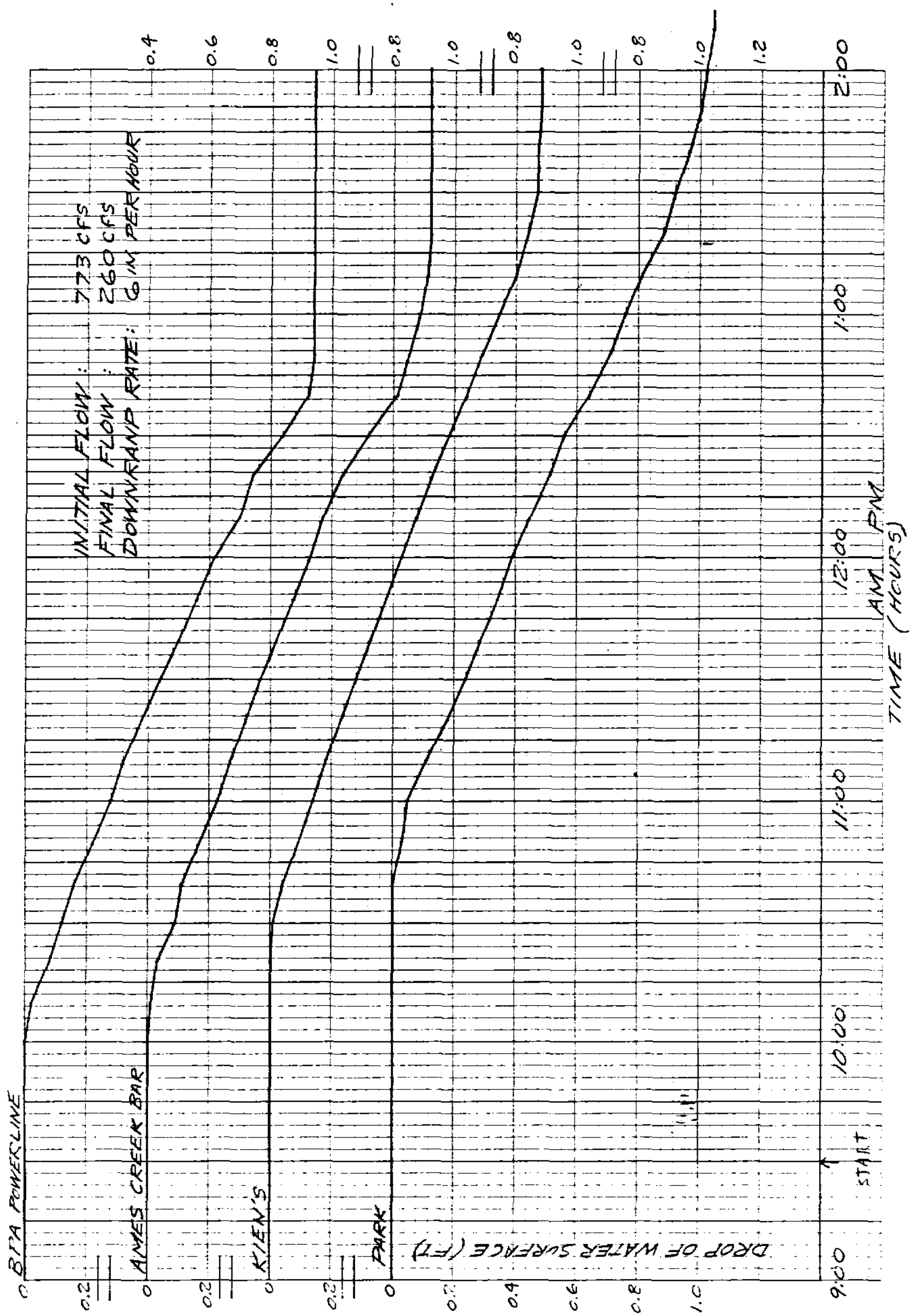

WINTER CREEK ISLANDS
4-2
241 cfs
500 cfs
831 cfs
600 cfs

Appendix C

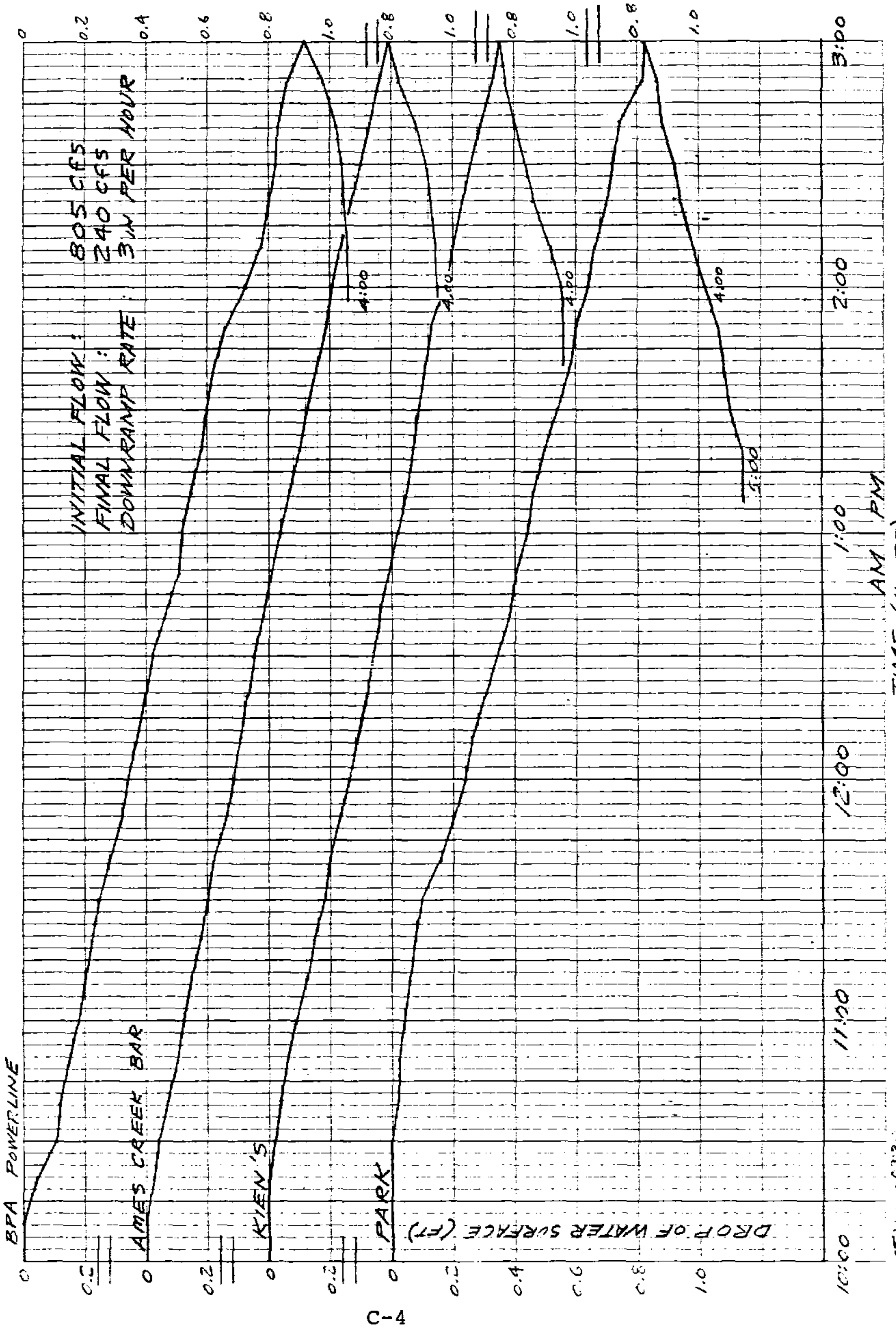
DOWNRAMPING LAGTIME AND ATTENUATION


INITIAL FLOW: 1500 CFS
FINAL FLOW: 800 CFS
DOWNRAMP RATE: 6 IN. PER HOUR
BPA POWERLINE
AMES CREEK BAR
KYEN'S
PARK
DROP OF WATER SURFACE (FT)
START
9:00
10:00
11:00
12:00
1:00
2:00
AM
PM
TIME (HOURS)


BPA POWERLINE
AMES CREEK BAR
KIEN'S
PARK
INITIAL FLOW: 1500 CFS
FINAL FLOW: 800 CFS
DOWNRAMP RATE: 3 IN. PER HOUR
9:00
START
10:00
11:00
12:00
1:00
2:00
3:00
AM
PM
TIME (HOURS)



INITIAL FLOW: 773 CFS
FINAL FLOW: 260 CFS
DOWNRAMP RATE: 6 IN PER HOUR
BPA POWERLINE
AMES CREEK BAR
KIEN'S
PARK
DROP OF WATER SURFACE (FT)
START
9:00
10:00
11:00
12:00
1:00
2:00
AM PM
TIME (HOURS)



INITIAL FLOW: 805 CFS
FINAL FLOW: 240 CFS
DOWNRAMP RATE: 3 IN PER HOUR
BPA POWERLINE
AMES CREEK BAR
KIEN'S
PARK
DROP OF WATER SURFACE (FT)
TIME (HOURS)
AM PM
10:00
11:00
12:00
1:00
2:00
3:00

Appendix D

DESCRIPTION OF POTHOLES

MEMORANDUM

TO: Forrest Olson, CH2M Hill
FROM: Tina Miller, SHAPIRO
DATE: February 22, 1985
RE: Pothole Survey on the Sultan River

A survey for potholes (depressions that retain water after the river level has dropped) on the Sultan River was completed by Forrest Olson and Tina Miller on February 15, 1985. We identified a total of 17 potholes from below the BPA powerline crossing to the mouth of Winters Creek. Each pothole was flagged and numbered. Measurements for width, length, maximum depth, and average depth were collected. Notes describing substrate type, cover, and whether or not the pothole was connected to the river were made. The river flow had been fairly constant at 300 cfs for the past week and was raised to 500 cfs between 9 A.M. and 10 A.M. the morning of the 15th. We observed the river level rising throughout the morning, demonstrating a lag time situation does exist. The pothole locations were approximately located on the GeoEngineers' base map provided by CH2M Hill. A description of each pothole (PH) follows.

Potholes #1 and 2: Location - several hundred feet downstream of BPA powerlines on the left bank

PH #1
- Dimensions: 16 x 4 ft.; depth - .8 ft. (max), .4 ft. (avg)
- Substrate: Cobble (6" - 12"), decaying vegetable matter, some iron color was present.
- Comments: There is a root wad on the bank, and overhanging vegetation covers approximately 60-80% of the pothole. The edge of the pothole was close to being connected to river at 10:30 A.M. (300+ cfs). It was connected to PH #2 and river at 5:30 P.M. (500 cfs).

PH #2
- Dimensions: 40 x 10 ft.; depth - .9 ft. (max), .5 ft. (avg)
- Substrate: Big cobble (8" - 12"), decaying vegetable matter.
- Comments: Located downstream of PH #1, connected to river at 10:30 A.M. (300+ cfs). A depth increase of 2.5 inches was observed by 5:30 P.M. (500 cfs).

Potholes #3, 4, 5, 6: Location - first side channel on left bank (approx. 1,000 ft. downstream of BPA power lines)

PH #3
- Dimensions: 4 x 3 ft., depth - .15 ft. (max), .1 ft. (avg)
- Substrate: Sand and cobble, root wad and leaves.
- Comments: Potential size is 18 ft. x 5 ft. This pothole fills from the upstream end; the river started to flow into it at 10:30 A.M. (300+ cfs).

PH #4 Dimensions: 15 x 4 ft.; depth - .2 ft (max), .1 ft. (avg)
Substrate: Cobble (4" - 12"), roots and decaying vegetation.
Comments: Not connected to river at this time.

PH #5 Dimensions: 35 x 6 ft.; depth - .6 ft. (max), .4 ft. (avg)
Substrate: Cobble (4" - 12"), boulders (> 12")
Comments: Connected to river at 10:42 A.M. Could become three separate potholes at low flows. There are root wads available for cover along the bank.

PH #6 Dimensions: 32 x 15 ft.; depth - 1.3 ft. (max), .8 ft. (avg)
Substrate: Sand and silt, roots and leaves.
Comments: Connected to river by several inches of water, fills at downstream location. A log is present across the pothole mouth. The bank is eroding in places.

<u>Pothole #7</u>: Location - island area below side channel (right bank)

Dimensions: 7 x 4 ft.; depth - .3 ft. (max), .2 ft. (avg)
Substrate: Gravel and cobble (2" - 4 ").
Comments: Pothole would connect to river with an additional 100 cfs flow. This area has several depressed areas which could potentially be potholes at a lower flow.

<u>Pothole #8</u>: Location - Big Island

Dimensions: 40 x 8 ft.; depth - 2.0 ft. (max), .8 ft. (avg)
Substrate: Cobble and decaying vegetation.
Comments: Not connected to the river at this flow. This pothole has a downstream opening on the left side of the island.

<u>Potholes #9, 10</u>: Location - Right bank downstream of Big Island; several springs located here (Spring Bar)

PH #9 Dimensions: 15 x 15 ft.; depth - .6 ft. (max), .3 ft. (avg)
Substrate: Cobble, some sand and gravel, few leaves.
Comments: Connected to river, lots of logs cover this pothole.

PH #10 Dimensions: 20 x 6 ft.; depth - approx. 1.0 ft.
Substrate: Cobble (> 6").
Comments: This is a potential pothole which is void of water at this time. A river flow of another 100 cfs would probably fill it.

Potholes #11, 12, 13: Location - Kien's side channel

PH #11 Dimensions: 8 x 2 ft.; depth - approx. .1 ft.
Substrate: Gravel, few cobbles (2" - 4").
Comments: At this time (12:30), the pothole was three pools (1.5 x .5, 1.2 x 1, and 1 x .5). Potholes are located behind three logs. Minimum cover is available.

PH #12 Dimensions: 10 x 5 ft.; depth - .2 ft. (max), .1 ft. (avg)
Substrate: Gravel (2" - 4"), 10% cobble.
Comments: Forrest Olson estimated this pothole would probably be connected to the river at 1,000 cfs. Minimal fish cover is available.

PH #13 Dimensions: 12 x 7.5 ft.; depth - 6 ft. (max), .3 ft. (avg)
Substrate: Gravel and sand.
Comments: Connected to river at 500 cfs. There is a log present along the bank for cover.

Potholes #14, 15, 16: Location - side channel upstream of Kien's Island (left bank). Several redds located in this side channel are dry at this flow.

PH #14 Dimensions: 10 x 6 ft.; depth - approx. 2.0 ft.
Substrate: Boulders and some sand.
Comments: This pothole is dry at this time. It would probably fill with another 100 cfs flow.

PH #15 Dimensions: 14 x 6 ft.; depth - .4 ft. (max), .3 ft. (avg)
Substrate: Cobble (4" - 6") and mud, decaying vegetable matter.
Comments: The bank is about 2 ft. high on the right side. Overhanging vegetation is providing cover for this pothole.

PH #16 Dimensions: 15 x 6 ft.; depth - .4 ft. (max), .3 ft. (avg)
Substrate: 80% mud, 20% gravel.
Comments: Lots of overhanging vegetation and a few logs provide cover.

Pothole #17: Location - Next bar downstream of Kien's bar

Dimensions: 60 x 12 ft., depth - approx. 1.0 ft.
Substrate: Cobble and silt.
Comments: Connected to river at 500 cfs. Two dead salmon were observed in this pothole.

Appendix E

LENGTHS OF ELECTROFISHED SALMONIDS DURING THE WINTER

LENGTHS OF ELECTROFISHED SALMONIDS DURING THE WINTER

SULTAN RIVER
LENGTH FREQUENCY OF ELECTROFISHED SALMONIDS

C O H O

DATE	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122	124	TOTAL
	L E N G T H I N M M																																							
12-11&12-85									1			3	1		6	3	4	1	5	2	1	1		1		1	2		2	2	1	2	5	2	1	2	7	1	1	58

S T E E L H E A D

DATE	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112
	L E N G T H I N M M																																
12-11&12-85	2	2	1	2	4	4	1	4	5	2	2	6	4	12	7	7	8	3	5	5	2	1		6	5		5		1	1			

DATE	114	116	118	120	122	124	126	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160	162	164	TOTAL
	L E N G T H I N M M																										
12-11&12-85			1			1				1				1						2	1	1		1		1	117

C H I N O O K

DATE	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	TOTAL
	L E N G T H I N M M																																		
12-11&12-85															1				1	2		2		3	1	2	1		1				1		15