SNOHOMISH COUNTY
PUD
PUBLIC UTILITY DISTRICT No. 1

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July 23, 1990
PUD-19221

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

Dear Ms. Cashell:

RE: Henry M. Jackson (Sultan River) Project
FERC No. 2157 Articles 55 and 56
Adult Fish Passage Study - Final Report

Please find enclosed the report "Adult Fish Passage (Powerhouse Berm) Study". Public Utility District No. 1 of Snohomish County (District) is submitting this report as fulfillment of one of several obligations under Articles 55 and 56 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).

Mr. Ken Searon of your staff was informed by phone in late June that this report would be submitted to the FERC in early July, 1990. However, unforseen delays in document preparation and printing have kept us from submitting it until now.

With the construction of Stage II of the Sultan River Project, the District agreed to conduct several multiyear studies of anadromous fish passage above the Powerhouse. The purpose of the study was to determine whether or not the powerhouse berm facilitates successful upstream migration of anadromous fish past the powerhouse tailrace area. This issue has been affirmatively resolved with the Washington Department of Fisheries regarding the fall spawning salmon (See Appendix F, WDF letter of March 20, 1989, paragraphs 1 and 2). The same conclusions have been drawn for the winter and summer-run steelhead trout. However, because the Washington Department of Wildlife had concerns about the winter-run steelhead response during years of higher spring runoff, a third study in a series of three was conducted in the spring of 1990 when runoff was moderately higher than normal. That study will be sent to the FERC at the end of 1990 after the Joint Agencies have had an opportunity to comment. However, the results support the conclusions of earlier studies that the powerhouse berm successfully attracts anadromous fish into the upper reaches of the Sultan River. Therefore, the requirements of Articles 55 and 56 relating to the fish passage issue should be satisfied with the submittal of this final report.

The Licensee is mindful of the Joint Agencies concerns about the powerhouse berm as an unnatural structure in the Sultan River. District personnel will continue to monitor visually the fish passage area in the course of daily operations. Any signs of abnormal fish behavior such as death or injury will be recorded and reported to the Joint Agencies. Furthermore, the District expects to continue sending a representative on the annual fall spawning survey conducted by the Washington Department of Fisheries. Finally, in the spirit of the second revised Project operating plan submitted under Article 57, the District is open to discussing any future issues regarding powerhouse fish passage with the Joint Agencies.

Very truly yours,

Richard E. Johnson, Director
Construction and Operations

BFM:vb/2071U
Enclosures
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. N. Earl (w/o attachment) - E4
D. Hale/G. Mixdorf - E4
R. E. Johnson (w/o attachment) - OP
J. B. Olson - E3
B. F. Meaker - BB
D. A. Dole - BB

HENRY M. JACKSON HYDROELECTRIC PROJECT

(Federal Energy Regulatory Commission Project No. 2157)

Licensees

Public Utility District No. 1 of Snohomish County
and City of Everett, Washington

ADULT FISH PASSAGE (POWERHOUSE BERM) STUDY

License Articles 55 and 56 - Final Report

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October 1989

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APPENDIX D: 1987 and 1989 Steelhead survey redd location maps, Sultan River, with notations pertaining to the chinook spawning survey index areas.

Appendix D-1: 1987 steelhead surveys.
Appendix D-2: 1989 steelhead surveys.

APPENDIX E: Final reports on winter-run steelhead spawning surveys - Sultan River, Washington.

Appendix E-1: 1987 Final Report.
Appendix E-2: 1989 Final Report.

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EXECUTIVE SUMMARY

The Henry M. Jackson Hydroelectric Project on the Sultan River was completed in 1984. A fish passageway was incorporated into the powerhouse design to reduce the potential for delay and injury of adult salmonids migrating upstream past the powerhouse. Chinook , coho and steelhead have historically spawned in areas upstream from the powerhouse. A study of these species was initiated in the fall, 1984 to determine if the passageway successfully facilitated migration past the powerhouse, to monitor adult upstream migrations and to investigate project effects through comparison of pre-project and post-project spawning distribution. The results are:

- Chinook Salmon

  Visual observations were used to monitor chinook passage in the powerhouse vicinity and to evaluate spawning distribution within the Sultan River. The visual observations of 7 individual chinook, indicated that chinook could easily migrate past the powerhouse during periods of moderate to low powerhouse discharge, as were encountered during the observation period. The post-project (1984, 1985, 1986, 1987, and 1988) areal distribution of spawning chinook differed from the historical chinook distribution within the Sultan River: a higher percentage were remaining in the lower river (downstream from the powerhouse). This distribution change did not appear to be caused by a migration barrier created by the powerhouse discharge. In some years however, the total number of adult fish above the powerhouse was greater than during pre-project years.

- Coho Salmon

  Spawning ground surveys were used to evaluate project effects on the coho migration. These surveys, and additional observations of coho fry made during snorkeling surveys, indicated that coho were able to migrate past the powerhouse and successfully spawn in areas upstream from the powerhouse. Due to the limited amount of information available (historic and current) on coho distribution within the Sultan River, plus favorable study results, further evaluation of project effects on coho is not warranted.

- Winter-run Steelhead

  A radio tagging study was conducted to monitor winter-run steelhead passage in the powerhouse vicinity. Spawning surveys were used to evaluate spawner distribution within the Sultan River. The radio tagging results, while limited (two tagged fish migrated past the powerhouse), indicated that winter- run steelhead could migrate past the powerhouse during potentially confusing flow situations without any delay or entry into the discharge canals. The 1985 areal distribution of winter-run steelhead spawning was similar to pre-project distributions observed in 1979 and 1980. This suggests that winter-run steelhead were able to successfully migrate past the powerhouse during a variety of flow scenarios which occurred during the 1985 winter-run steelhead migration.

- Summer-run Steelhead

  Adult distribution surveys were conducted to evaluate project effects on the migration of summer-run steelhead. The results of these surveys showed that summer-run steelhead successfully migrated past the powerhouse and distributed throughout the Sultan River. Direct observations of summer-run steelhead in areas upstream from the powerhouse also indicated that those fish had not been physically injured while migrating past the powerhouse.

The Sultan River fish passage study results indicated that under the flow conditions encountered during the study period: (1) the fish passageway did not appear to hinder the upstream migration of adult salmonids; (2) the powerhouse discharge did not create a migration barrier, although a downstream shift in chinook spawning has been noted; and (3) adult salmonids were not delayed or injured while migrating past the powerhouse. It is not possible at this time to determine if mitigative action is warranted regarding the shift in chinook spawning distribution. Spawning distribution should continue to be monitored closely to determine if spawning success or production is being hindered.

No delay, injury or shift in spawning distribution has been detected with the other fish species that were studied (winter-run and summer-run steelhead and coho salmon). However, further studies were requested by both the Washington Departments of Fisheries and Game (now Wildlife). Fisheries requested a continuation of fall salmon spawning surveys and Game wanted additional winter-run steelhead spawning ground surveys because powerhouse discharge during the 1985 migration was only moderate. A "worst case" scenario of prolonged high flow powerhouse discharge was desired by Wildlife to confirm the radio telemetry results because only two of 20 radio-tagged fish actually migrated upstream past the powerhouse. Winter-run steelhead migration and distribution might be affected during periods of higher project discharge which might create a more confusing situation for fish passage than periods of lower powerhouse discharge. To address this concern, three more steelhead spawning ground surveys will be conducted through 1990, if necessary. If a high powerhouse discharge scenario should occur prior to then, further surveys might not be needed, depending upon satisfactory results. Additional steelhead spawning surveys in this supplemental series were conducted in 1987 and 1989. The series may conclude in 1990. The reports for these supplemental surveys are presented in the appendices.

INTRODUCTION

PROJECT BACKGROUND

The Jackson Hydroelectric Project is located on the Sultan River in northwestern Washington State (Figure 1). Public Utility District No. 1 of Snohomish County (PUD) is the owner and operator (the project is co-licensed with the City of Everett). The 112 megawatt project, completed in 1984, became economically attractive due to projected load growth and notice of insufficient allocation from the Federal power marketing authority (Bonneville Power Administration).

The Sultan River watershed has historically been managed for the City of Everett's water supply. In 1927 the City of Everett's Diversion Dam at river mile (RM) 9.7 was constructed to divert water from the Sultan River to Lake Chaplain (Everett's 14,000 acre-feet storage reservoir). In 1965 Culmback Dam was constructed at RM 16.5 and Spada Lake, a new 34,245 acre-feet storage reservoir, was created to enhance Everett's water supply. This storage was increased in 1984 to 153,260 acre-feet by increasing the dam height.

The Jackson Project was designed to take advantage of abundant precipitation (annually averaging 147.2 inches at Culmback Dam) and high hydraulic head (1,100 feet). Power production, however, has third priority for water from the Sultan Basin. Municipal water supply and instream flow requirements dictate operation after high flow periods and when storage is reduced at Spada Lake. Fulfilling these requirements led to an interesting "plumbing" design and operating scheme (Figure 2). Water is routed from Spada Lake to the powerhouse via eight miles of tunnel and pipeline. After dropping 1,100 feet to reach the powerhouse, water destined for Everett's municipal supply and fish flows for the Sultan River are re-routed uphill 400 feet in 4 miles to Lake Chaplain. At this point water to provide adequate instream flows is diverted another mile and one-half back to the Sultan River through yet another tunnel and pipeline. Due to the high hydraulic head provided at Spada Lake, water is moved through the entire system without pumping.

ANADROMOUS FISH RESOURCE

The Sultan River and its tributaries are utilized for spawning and rearing by chum, pink, coho and chinook salmon, steelhead and sea-run cutthroat trout, and Dolly Varden. These anadromous salmonids utilize the area between the mouth of the Sultan River and the Everett Diversion Dam (RM 9.7). No spawning or rearing occurs above RM 9.7 because the Everett Diversion Dam is a block to upstream migration.

The primary species of concern that utilize the five mile reach between the powerhouse (RM 4.5) and Everett Diversion Dam (RM 9.7) are chinook and summer and winter-run steelhead. Coho usage of the area above the powerhouse has been minimal and sporadic in recent years. Spawning above the powerhouse by chum and pink salmon has never been documented.

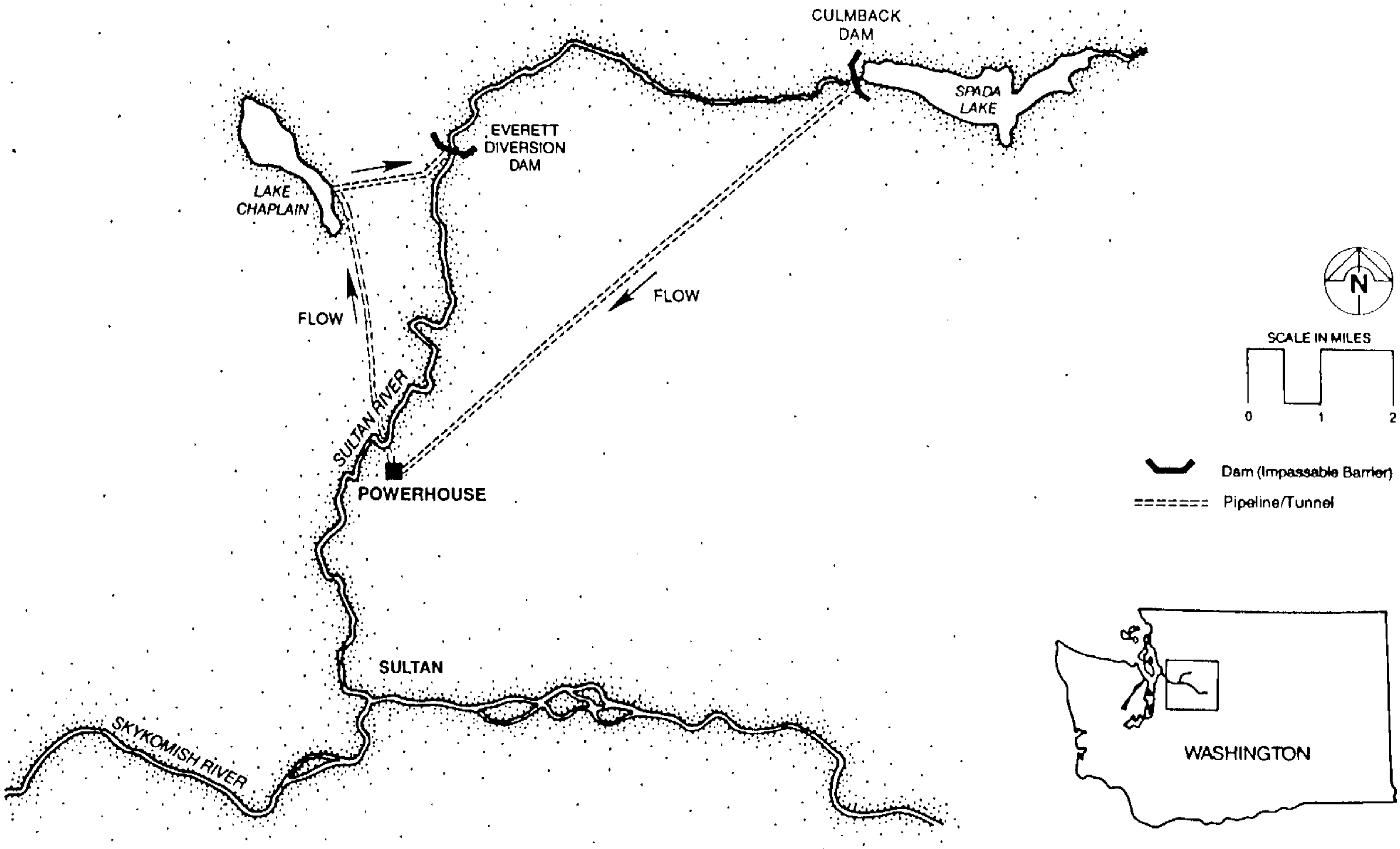


Figure 1.
Jackson Project vicinity map

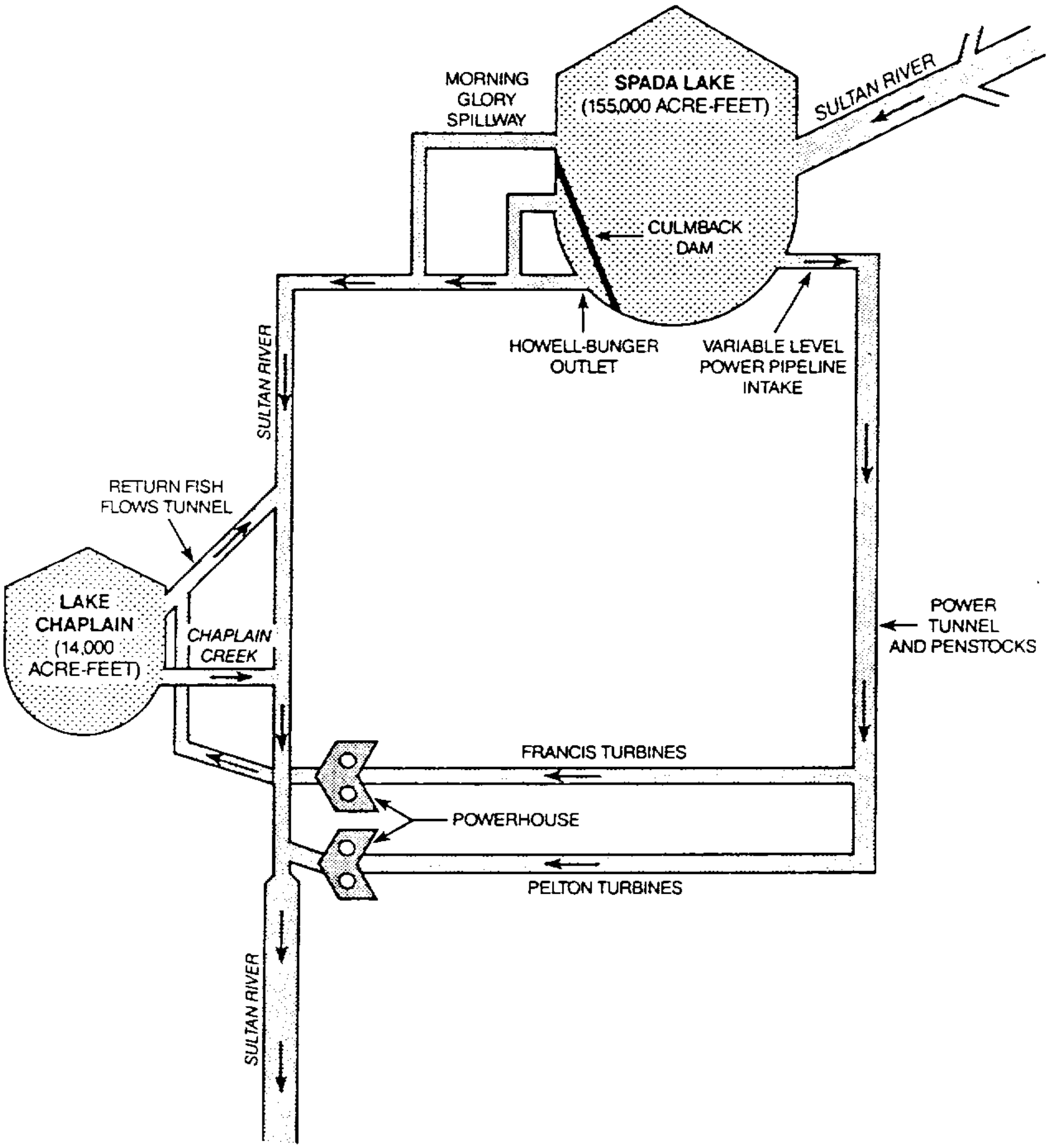


Figure 2. Jackson Hydro Project "plumbing" design.

FLOW REGIME

The powerhouse is sited on the east (left) bank of the river at RM 4.5 (Figure 3). Although the project has four turbines, only two units discharge directly into the river. Flow from the two Francis units goes into the pipeline connecting the powerhouse with Lake Chaplain (See Figure 2) and does not discharge into the river at the powerhouse. The Pelton units discharge into the river at the powerhouse and have a combined flow of 1,300 cubic feet per second (cfs) when at full power (650 cfs each). This discharge enters the river perpendicular to the channel with a maximum velocity of 4.8 feet per second (fps); average velocities are about 2.6 fps (Federal Energy Regulatory Commission 1981a).

As part of the Federal Energy Regulatory Commission (FERC) license for operating the Jackson Project, certain minimum flows must be maintained. The required minimum instream flow at the powerhouse is 165 cfs for June 16 to September 14 and 200 cfs for September 15 to June 15. These minimum flows are provided by the fish flow re-routed to the Everett Diversion Dam and by the discharge at the powerhouse. These flows are augmented by a 20 cfs release from Culmback Dam and run-off from tributaries below the dam. Sometimes re-routed fish flows, tributary run-off and releases from Culmback Dam are adequate for meeting minimum instream requirements. At such times the powerhouse contribution is reduced proportionately. During high runoff periods little, if any, powerhouse discharge is required to meet minimum flows. Therefore, the ratio of powerhouse discharge to total flow is small. Conversely, during low runoff periods more powerhouse discharge is required to meet minimum flows and the ratio of powerhouse discharge to total flow increases considerably. This ratio also increases during periods of high power generation. Discharge from the powerhouse can range from 0 to 85 percent of total flow depending on a variety of circumstances (runoff, power generation, reservoir level in Spada Lake, etc.). The percentage of total flow provided by the powerhouse may play an important role in fish passage at the powerhouse. High powerhouse discharge could potentially affect migration past the powerhouse by presenting a confusing flow attraction to migrating adults.

PROJECT DESIGN FEATURES

Recognizing that certain flow regimes may create passage problems for adult fish migrating upstream past the powerhouse, the fish management agencies required mitigative steps. The key element for this mitigation is a low-head dam, referred to as the fish passage berm, installed at the upstream end of the powerhouse (see Figure 3).

This berm has a passageway or slot near the powerhouse to concentrate the river flow into an area that can be more easily detected by migrating fish. (Photographs of the powerhouse tailrace area during various flow regimes are in Appendix A.) Location of the passageway on the powerhouse side was based on consultant recommendation and experience with the Faraday project in Oregon (Gunsolus and Eicher 1970). The concentration of downstream flow increases velocities through the slot to about 7 fps depending on the total discharge. The resultant flow emerges into the tailrace as a plume. This concentrated or increased flow velocity is intended to attract migrating adult fish upstream past the powerhouse when the Pelton turbines are in operation. When the project is shutdown (no discharge from the Pelton turbines), there are no alternative or confusing/competing flows. The Francis turbines (which re-route flows to the diversion dam) do not create a competing flow as the water is routed via pipeline under the river.

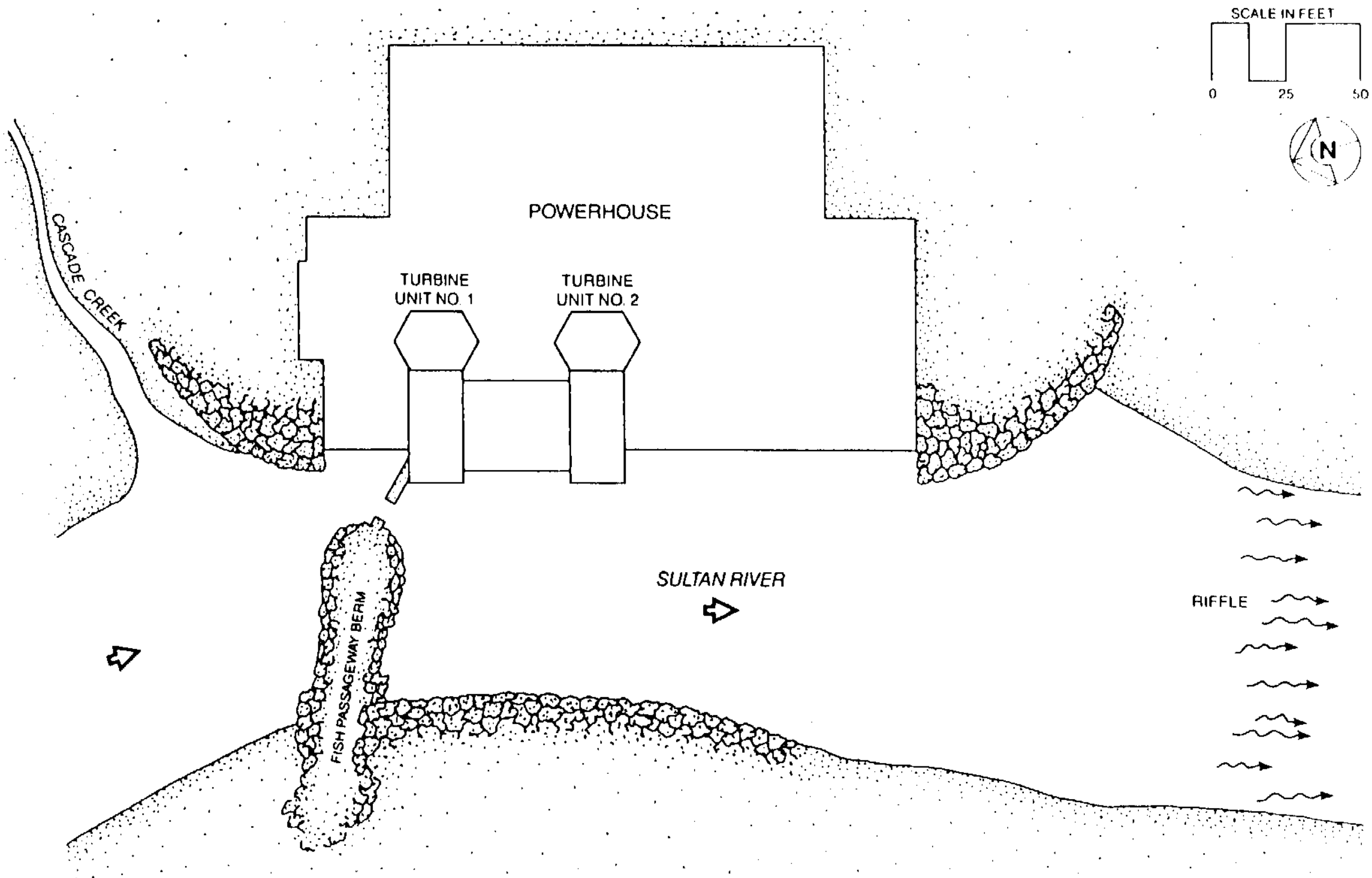


Figure 3. Powerhouse and
fish passageway berm.

The design of certain features of the powerhouse has significant bearing on adult fish behavior and related potential migration problems that could be encountered. The height of the Pelton turbine runners above the bed of the river channel and the discharge canal dimensions were determined based upon powerhouse siting, site conditions, potential river flood stages and operational limits. A cross-section view of the discharge canal and turbine runner pit are shown in Figure 4.

The Pelton turbine runners are approximately 40 feet from the river channel (discharge canal mouth) and 19 feet above the floor of the canals. The actual distance between the water surface and the Pelton turbine runners, however, is dependent on discharge and tailrace elevation. During an average water year at average flow the turbine runner would be approximately 11.5 feet above the water surface. This design feature reduces the possibility of fish striking the runners during power operation. In addition, flow velocities, high water turbulence, air depression system noise (when operating) and no plunge pool inside the canal all suggest that adult fish which enter the canal would be unable to strike the runners.

Screening the discharge canals to block fish entry is another possible mitigative measure. Initially, screening the discharge canals (which transport water from the Pelton turbines to the river) was not a requirement; although the capability to do so was required to be incorporated in the powerhouse design. Screening would prevent fish entrance into the discharge canals, but does not address the flow attraction problem and introduces the potentially harmful situation of injury due to screen abrasion. Screening could also create an operational problem -- an undesirable backwater effect due to reduction of the cross-sectional area of the canal mouth.

When river flows are high, powerhouse discharge will be a significantly lower portion of the total river flow past the powerhouse. At such times the powerhouse discharge should be less attractive or confusing to upstream migrating adult fish. For example, water begins flowing over the berm at about 485 cfs when the Pelton turbines are operating at full production. Steelhead trout were reported swimming over the berm in that flow regime during testing of the Pelton turbines in the Spring, 1984 (Metzgar 1985).

Besides designing and constructing the fish passage berm as part of the mitigation plan (Exhibit S - revised, Snohomish PUD and Everett 1983), the FERC order approving construction of Stage II of the Jackson Project required an evaluation of the proposed fish berm and associated powerhouse tailrace structures (FERC 1981b). This report represents partial fulfillment of the requirements of FERC License Articles 55 and 56.

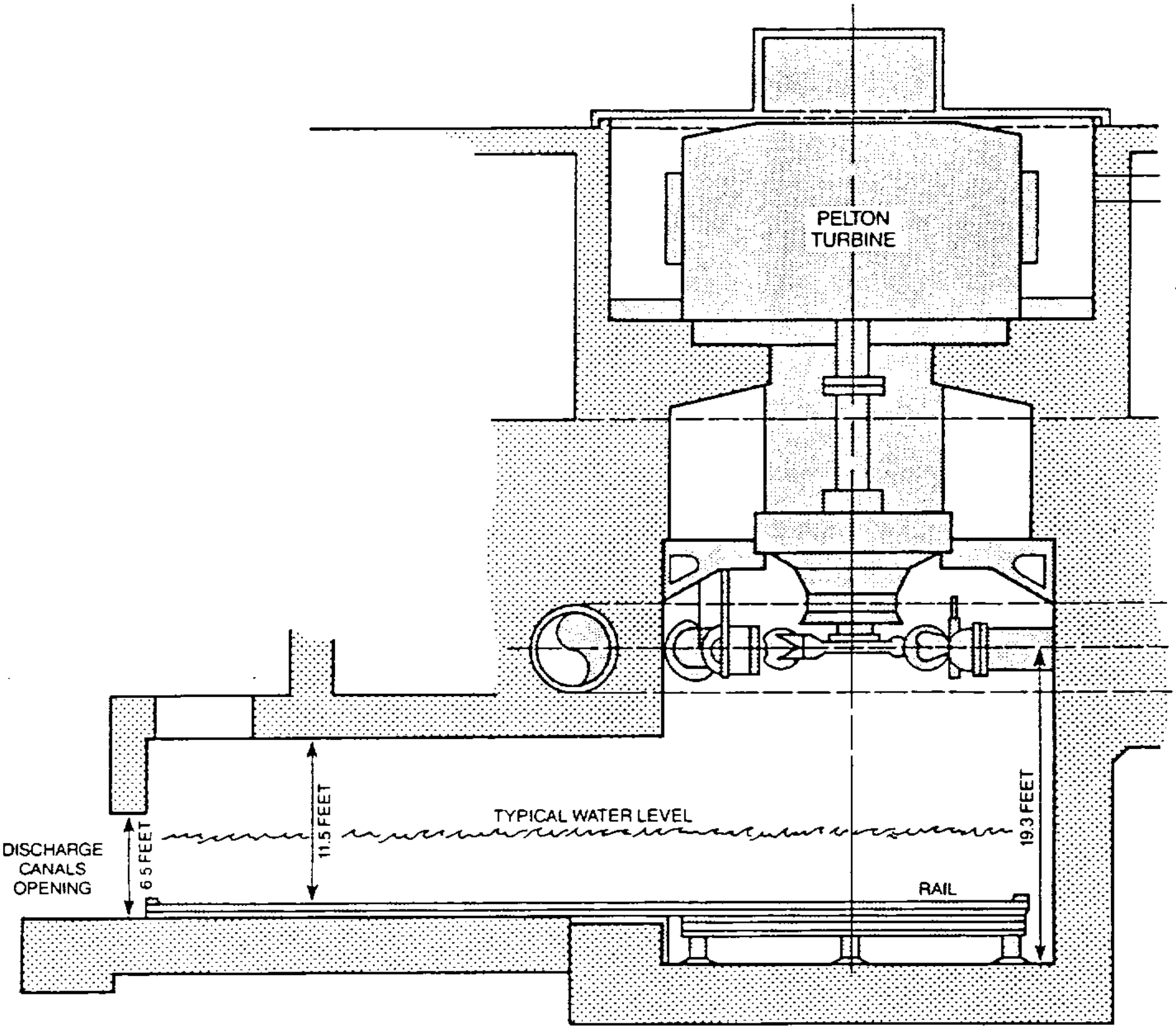


Figure 4. Discharge canal cross-section.

STUDY OBJECTIVES

The fishery agencies identified two concerns about adult migration past the powerhouse:

1) delay - due to inability to find the berm slot and thus fail to reach upstream spawning areas in time; or expend too much energy in attempting to find the slot and be unable to spawn successfully upon reaching spawning areas.

2) injury - caused by entry into the discharge canals and subsequent contact with the turbine runner or walls/ floor of the canals due to turbulence or flow/velocity changes.

To address these concerns, a mitigation study plan was designed to evaluate the berm effectiveness and monitor adult fish behavior in the vicinity of the powerhouse, especially the tailrace and berm slot areas (Snohomish Co. PUD 1983). The plan was prepared in cooperation with the Washington Departments of Fisheries (WDF) and Game (WDG), National Marine Fisheries Service (NMFS), U.S. Fish & Wildlife Service (USFWS), and Tulalip Indian Tribes. (Note: WDG subsequently renamed Department of Wildlife). The FERC project license required that this plan be acceptable to these agencies and submitted six months prior to the start of power operations.

The primary study objective was to determine if the berm passageway would successfully facilitate upstream migration of anadromous adult salmonids past the powerhouse. The main emphasis was on fish behavior in the tailrace area based on visual observations and monitoring movements of radio-tagged fish. The effects, if any, on fish migration were also assessed by comparing pre-project versus post-project spawning distribution in the Sultan River. Fish entry and injury in the discharge canals were also evaluated.

Another study objective was to determine which powerhouse operating scenarios provide the best passage conditions. To address this objective, the preferred method would have been visual observations during a variety of discharge scenarios (downstream unit full generation, upstream unit full generation, and both units full generation, etc.) However, an uncommonly low runoff year during the initial field studies, resulting in low water storage of Spada Lake, and average conditions in subsequent years have prevented observing a variety of pre-chosen "worst case" discharge scenarios. Consequently, study results were limited to a relatively narrow range of discharge scenarios.

Field studies commenced with the 1984 run of chinook salmon and continued through the subsequent winter and summer steelhead trout migrations in the Sultan River. Based on the results of the 1984 chinook surveys, it was determined that further surveys should be conducted during subsequent years on chinook migration. Therefore, results from the 1985 and 1986 chinook salmon spawning surveys are presented in the report text while the 1987 and 1988 results are in Appendix B. Based on the results of the 1984-85 steelhead and coho studies, it was determined that further studies were not necessary in 1985 and 1986. Other winter-run steelhead surveys were conducted, however, in 1987 and 1989 because hydropower operations in 1985 did not represent a "worst case" powerhouse discharge scenario for the tailrace/passageway area. The results are presented in Appendix E.

METHODS

A variety of methods were employed to collect the data used to evaluate upstream migration of anadromous salmonids past the Jackson Hydro Project. The following sections describe the various methodologies utilized to collect data on chinook, coho, and winter and summer-run steelhead.

CHINOOK

Visual observations were used as the primary means for evaluating the ability of the fish berm to facilitate upstream migration of chinook. Project effects on fall chinook migration were further evaluated by comparing pre-project and post-project spawning distribution, timing and abundance. Pre-project data were available from previous spawning surveys conducted by WDF. Under- water observations made while snorkeling were also used to directly evaluate fish behavior.

Visual Observations

Fish observations from counting towers have previously been used to successfully estimate spawning escapements (Cousens et al. 1982). Observations during this study were made from the powerhouse deck and were concentrated on the berm slot area. The tailrace area downstream from the slot and the pool immediately upstream were also observed (Figure 5). During each hour of observation, approximately 45 minutes were spent viewing the primary area (berm slot) and about 15 minutes on the other areas.

Chinook observations were made from September 13 through October 8, 1984. A nine-day gap in the monitoring occurred between September 15 and September 23. This was due to the absence of fish during the first two days' survey and a lack of fish in a snorkeling survey of the lower river conducted on September 17. Visual observations were discontinued after October 8th because it was assumed that the upstream migration period for chinook was over. This assumption was based on the historical peak of spawning activity (from WDF data) during the first week of October and the results of a spawning ground survey conducted October 9, 1984.

Initially, observations were made during two periods of the day: 4 to 5 hours beginning about dawn and 4 to 5 hours ending at dusk. These time periods were chosen based on the anticipation of seeing the most fish movement. Shortly after starting the observations we realized that movement past the powerhouse was not related to any specific time of day. Therefore, the observation period was changed to cover as many daylight hours as possible and not just emphasize the beginning or end of the daylight period.

Observers wore polarized sunglasses to increase visual penetration into the water. They took occasional 5 to 10 minute breaks from the slot observation post to survey areas downstream and upstream from the powerhouse and to break the monotony of continuous observations at one location.

All observations of fish movement and passage past the powerhouse were recorded on maps of the river channel area. Recording the data in this manner provided an accurate description of fish locations and their movements. Records were also kept of river water temperature, weather conditions (cloud cover and precipitation), power generation, stream flow and the time that fish movements occurred.

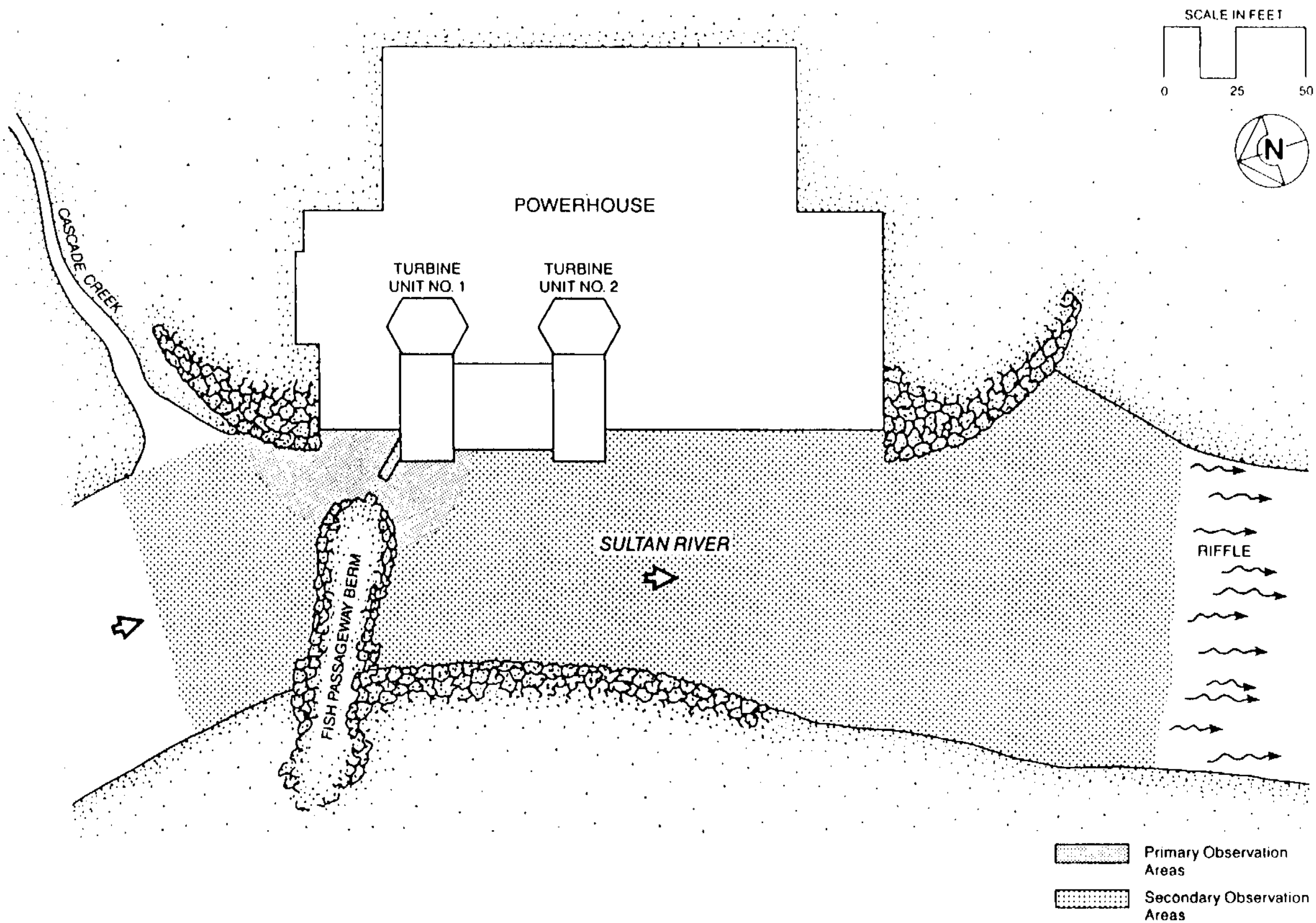


Figure 5. Jackson Hydro Project adult fish passage visual observation areas.

Spawning Ground Surveys

Chinook spawner surveys were conducted on the Sultan River in 1984 through 1988 by the PUD. During these surveys four index areas were used (Figure 6). These areas were selected to correspond with the index areas previously established by WDF. The upper river areas (Diversion Dam, Gold Camp, and Chaplain Gage) were surveyed on foot while the lower river was surveyed from a rubber raft. In the lower river all braided channels were surveyed on foot when use of the raft was not practical. During the surveys observers (wearing polaroid glasses) counted redds, live adults, jacks and carcasses.

In addition to the data collected on live adults, dead adults, and redds; we also estimated the visibility for each index area surveyed. The visibility estimates are used for adjusting the raw counts for fish that may have been overlooked due to observation conditions. These visibility adjustments are also used by WDF in expanding the raw counts to run size estimates which are used for stock management purposes.

Snorkeling Observations

Snorkeling observations of chinook salmon were made on September 17 and 28, 1984. On both occasions a reach of the lower river was surveyed to determine run timing and help predict fish arrival at the powerhouse. The tailrace area was also snorkeled on September 17 to observe flow, current conditions and fish behavior. Additionally, on September 28 two pool areas located approximately 200 meters above the powerhouse were snorkeled to observe chinook which had successfully migrated past the project.

COHO

The coho migration was judged too sparse and sporadic to be effectively monitored through visual observation. Therefore, the primary means of assessing coho use of the fish berm passageway was to compare pre-project and post-project spawning distribution, timing and abundance. Pre-project data were available from previous spawning surveys conducted by WDF. A secondary means of assessing coho migration was the limited use of snorkeling observations to directly observe fish behavior.

Spawning Ground Surveys

Coho spawning ground surveys were conducted on the Sultan River on November 8 and December 5, 1984. On December 5, the usual index areas above and below the powerhouse were surveyed by foot. However, on November 8, a snorkel survey was conducted in a portion of the upper reach instead of the usual foot survey. During both surveys the lower river (BPA power lines to Kien's Bar) was surveyed from a rubber raft. As with the chinook surveys, all braided channels were surveyed on foot when use of the raft was not practical.

Snorkeling Observations

Snorkeling observations of coho salmon were made on November 8, 1984. These observations were made between Chaplain Gage and the tailrace area in conjunction with a spawning survey in the lower river.

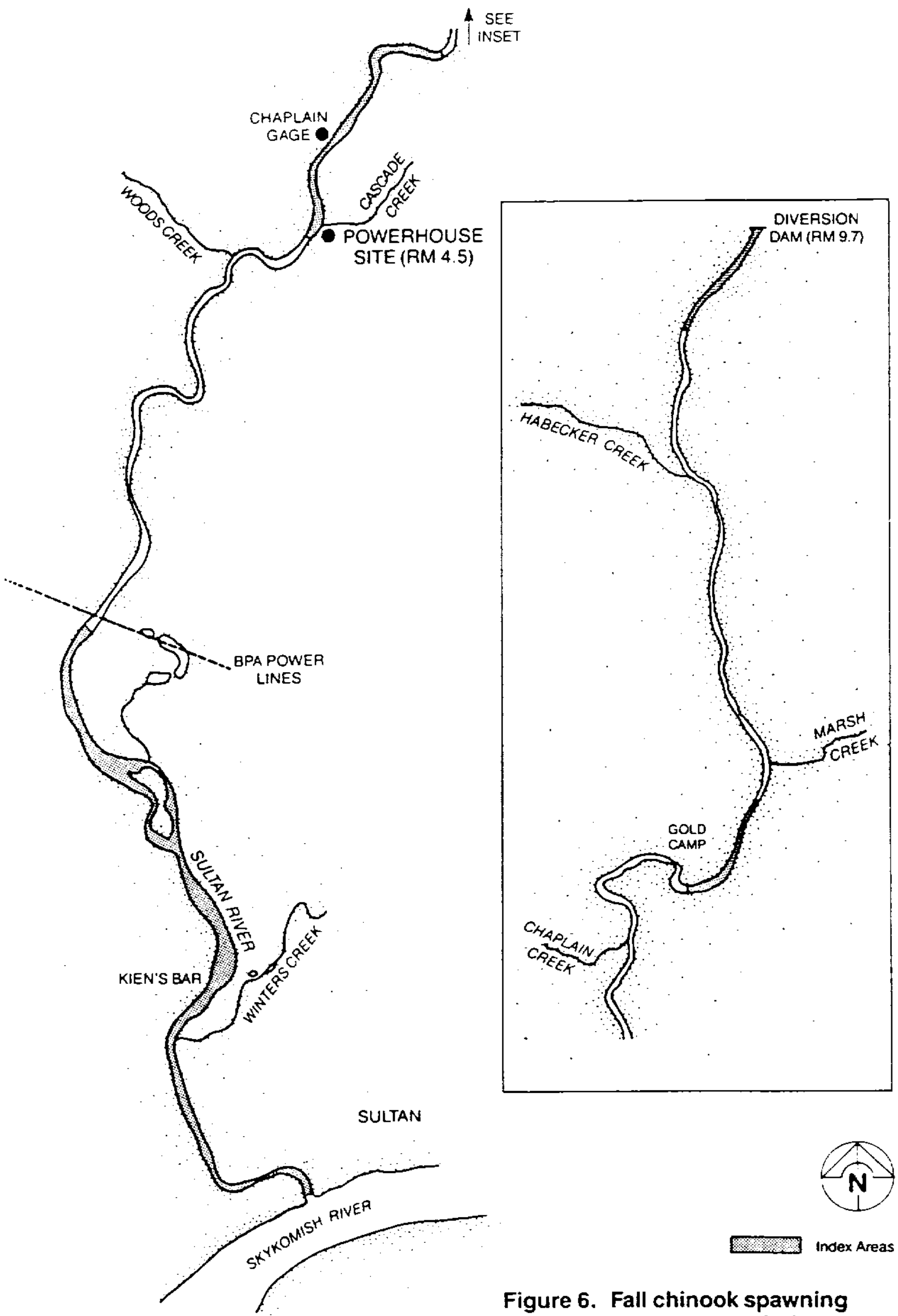


Figure 6. Fall chinook spawning ground survey index areas.

WINTER-RUN STEELHEAD

Visual observations of winter-run steelhead were expected to be unfeasible due to high flows, turbidity, powerhouse shadows (low sun angle/light penetration), turbulence and adverse weather conditions that commonly occur during their migration. Therefore, radio telemetry tagging was selected as the primary method for monitoring steelhead behavior at the powerhouse. Radio telemetry tagging has been used successfully for monitoring steelhead migrations in Alaska (Burger et al. 1983, Turner et al. 1984) and Idaho river systems (Stabler et al. 1982).

Pre-project versus post-project spawning distribution comparisons were used as a secondary means of assessing the effects of powerhouse operations on the migration of winter-run steelhead.

Radio Telemetry Tagging

Steelhead were collected for tagging using a Sacramento River hoop trap. The trap was located at approximately RM 3.3, near the entrance to a canyon which extends nearly to the powerhouse. This site was chosen because very little, if any, steelhead spawning has historically occurred in this canyon reach; and therefore most fish migrating to and subsequently tagged at this location would be destined for spawning areas upstream from the powerhouse. An attempt was made to tag only wild steelhead by tagging those fish with non-stubbed dorsal fins over two inches in height, a criteria used by WDG in managing sport harvest of wild and hatchery steelhead. Hatchery fish have been planted in the lower Sultan River, but WDG was primarily concerned about project effects on native fish migration. Therefore, our tagging efforts were focused on wild fish.

The trap was airlifted to the collection site via helicopter on January 10, 1985. It was fished five days per week from then until January 30. During this period the trap was checked daily during weekdays and winched from the river on to shore during weekends to reduce the potential for poaching. Between January 31 and February 11 the trap was not fished due to low, clear water conditions. From February 11 to March 28 the trap was fished seven days a week and checked at least three times a week, generally Monday, Wednesday and Friday.

To improve trap effectiveness in the extremely clear water of the Sultan River, leads were installed on the trap in an attempt to increase its catch rate. These leads consisted of loose panels of bright plastic flagging. The leads were attached to the downstream end of the trap and extended to either bank at a 45 degree angle. The lead to the west bank extended all the way to the shore while the east bank lead extended to mid-channel. The leads were installed on March 11.

Captured steelhead chosen for tagging were transferred to an anesthetic bath containing a 50 ppm solution of MS-222. Following anesthesia fish were tagged with radio transmitters. The tags were lubricated with glycerin and inserted down the esophagus of the fish. The first five steelhead tagged were held in a live cage for 24 hours to determine the effects of tagging and potential problems associated with tag regurgitation. After determining that tag regurgitation or immediate reaction to tagging was not a problem, subsequently tagged fish were held l-2 hours until they had recovered fully, and then released immediately upstream from the trap site. No tagged fish were recaptured in the trap. Records were kept on length, sex, and condition, and scale samples were taken from each tagged fish.

The transmitters used were model no. P40-500L-6V manufactured by Smith-Root, Inc. They were powered by six-volt lithium batteries having a 90-day life. The cylindrically shaped transmitters (7.5 cm long, 1.63 cm diameter) were fitted with 15 cm antennas. In addition, each tag had a unique radio frequency and/or pulse rate for identification. Therefore, evaluation of migration patterns was possible for each individual fish.

Antennas for monitoring tagged fish were installed at three locations in the powerhouse vicinity: just downstream from the powerhouse, in the discharge canals about halfway between the mouth and the turbine pit, and in the first large pool area about 200 m upstream from the passageway berm (Figure 7). Long wire antennas were suspended above the river at two locations. The downstream location determined when a fish arrived at the powerhouse site, and the upstream location determined when it left the site. Therefore, the amount of time a fish spent in the powerhouse vicinity was determined by subtracting the time of arrival from time of departure. In addition, underwater antennas were placed in the discharge canals to detect entry into and the amount of time that fish spent in the canals.

The movements of tagged fish at the three powerhouse locations were monitored with automatic, self-recording field data loggers (FDL-l0ER) manufactured by Smith-Root, Inc. Basically, this equipment constantly scans the water for the presence of radio telemetry tags. The size of the area scanned (see Figure 7) was determined by a sensitivity setting on the receiver (SR-40), which is a part of the data logger. When a tag was detected the data logger was activated and information such as time of detection, duration of detection and tag frequency and pulse rate were recorded. The use of automated data loggers eliminated the need for labor intensive tracking of fish, yet still provided continuous information on the movements of fish in the areas of greatest concern. It was then possible to relate this information to powerhouse operation and discharge.

The detection limits of the radio telemetry monitoring antennas were calibrated by using a radio tag implanted in a dead trout (approximately steelhead size). This was done to insure that the tested signal imitated the signal strength anticipated from a tagged steelhead. The boundaries of the tag detection areas resulting from final calibration are depicted in Figure 7.

In addition to continuously monitoring the locations near the powerhouse, the entire river was aerially surveyed occasionally for tagged fish. These surveys provided additional information about the movement of tagged fish. The surveys were accomplished by mounting an OM-40 whip antenna aboard a helicopter equipped with an SR-40 search receiver. Through manipulation of signal reception strength the location of each tagged steelhead was found within approximately 50 m. Tagged fish locations were plotted on river maps for each survey. (See Appendix C).

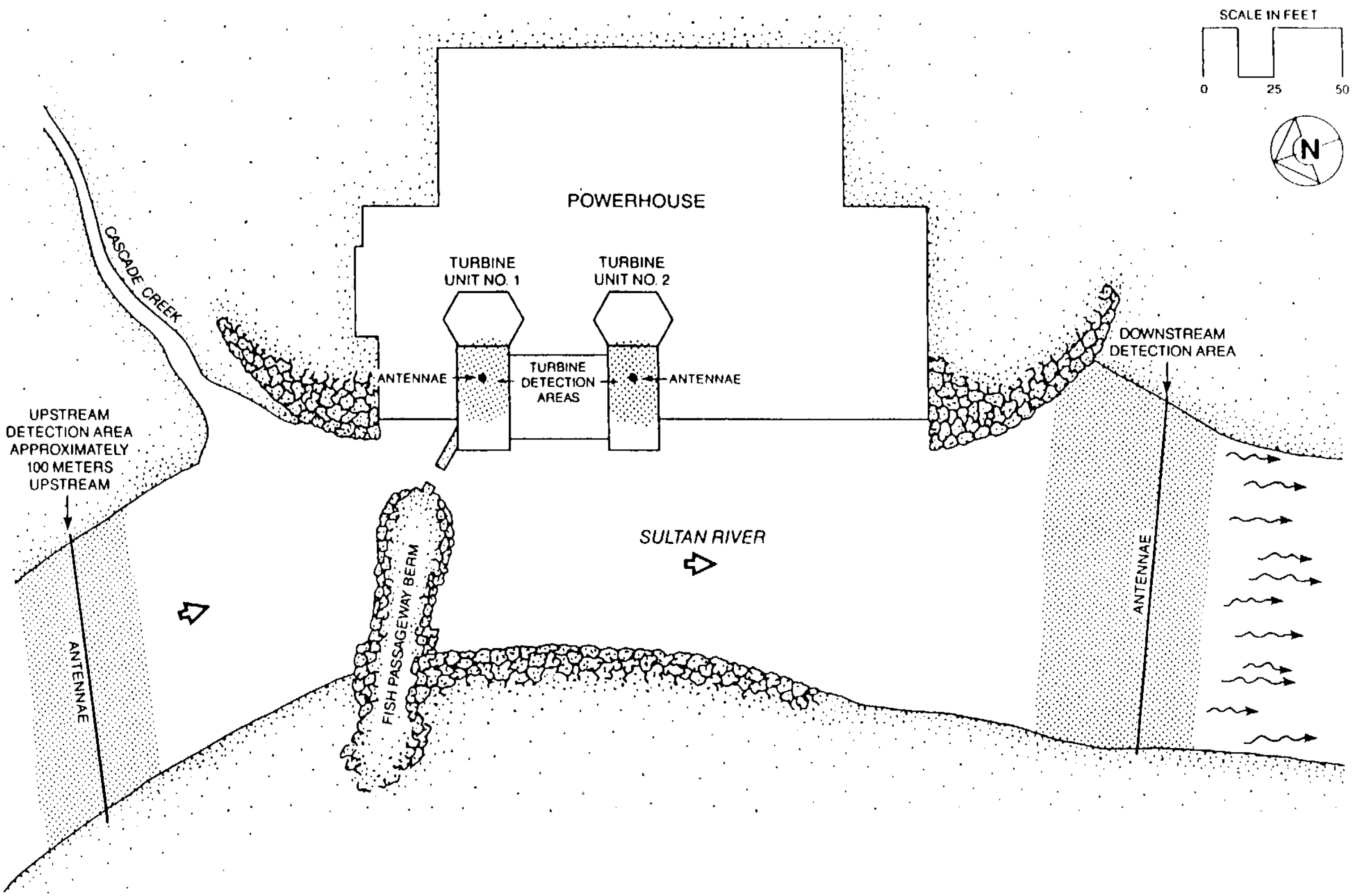


Figure 7. Radio telemetry tag detection zones in the Jackson Powerhouse vicinity.

Spawning Ground Surveys

Ten steelhead spawning surveys were conducted on the Sultan River between February 4 and June 12, 1985. These surveys were all conducted from a helicopter. The entire reach from the mouth (RM 0.0) to the Everett Diversion Dam (RM 9.7) was inspected during each survey. All redds were counted, mapped and classified as above or below the project (RM 4.5) for each survey.

SUMMER-RUN STEELHEAD

Snorkeling surveys were used as the primary means to assess summer-run steelhead use of the fish berm passageway. Initially, visual observations from the powerhouse were planned as an additional method to evaluate this use. While conditions during the summer-run steelhead migration were ideal for visual observations, the sparse, sporadic nature of the run would have made visual observations from the powerhouse inefficient. In addition to direct fish observations, temperature monitoring above and below the fish berm was also initiated during the summer-run steelhead migration.

Snorkeling Observations

Six snorkeling surveys for summer-run steelhead were conducted between June 26 and September 16, 1985. During each complete survey seven index reaches (Figure 8) were snorkeled over a two day period. These reaches were selected to represent the various types of holding area habitat most likely to be used by summer-run steelhead above and below the powerhouse. An attempt was made to survey the entire reach (RM 0.0 to 9.7); however, due to safety factors this was not practical.

While surveying an index reach two divers would float downstream, each inspecting one side of the channel as well as the center of the stream. This method maximized the area covered while concentrating the observation made in the main channel. All adult steelhead were counted and classified as either winter-run or summer-run fish. Notes were also taken on other fish species and life stages observed. The final survey (initiated on September 16) was not completed due to high flows and turbidity on September 17. Therefore, only the index areas above the powerhouse were inspected during the final survey.

Temperature Monitoring

Water temperature monitoring was accomplished through the use of two Ryan (Model J) continuous recording thermographs. These thermographs were anchored to the river bottom in moderate current areas above and below the powerhouse (Figure 9). This monitoring was undertaken in an effort to determine whether the temperature of the attractant water in the fish passageway differed significantly from the river water below the powerhouse due to a difference in temperature of the water being discharged from the powerhouse. This information was collected in an effort to determine if the potential for a thermal block in migration existed at the powerhouse.

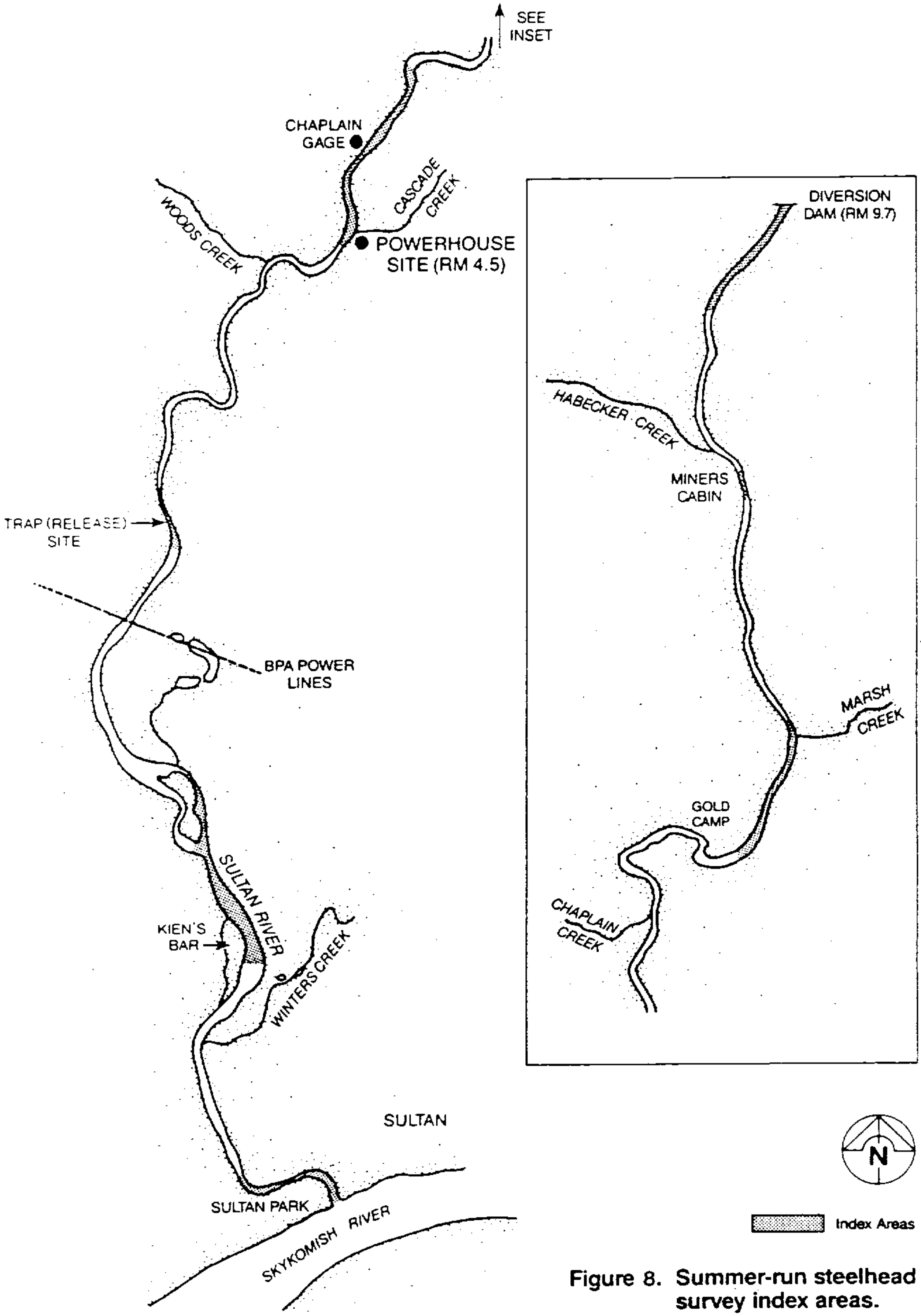


Figure 8. Summer-run steelhead survey index areas.

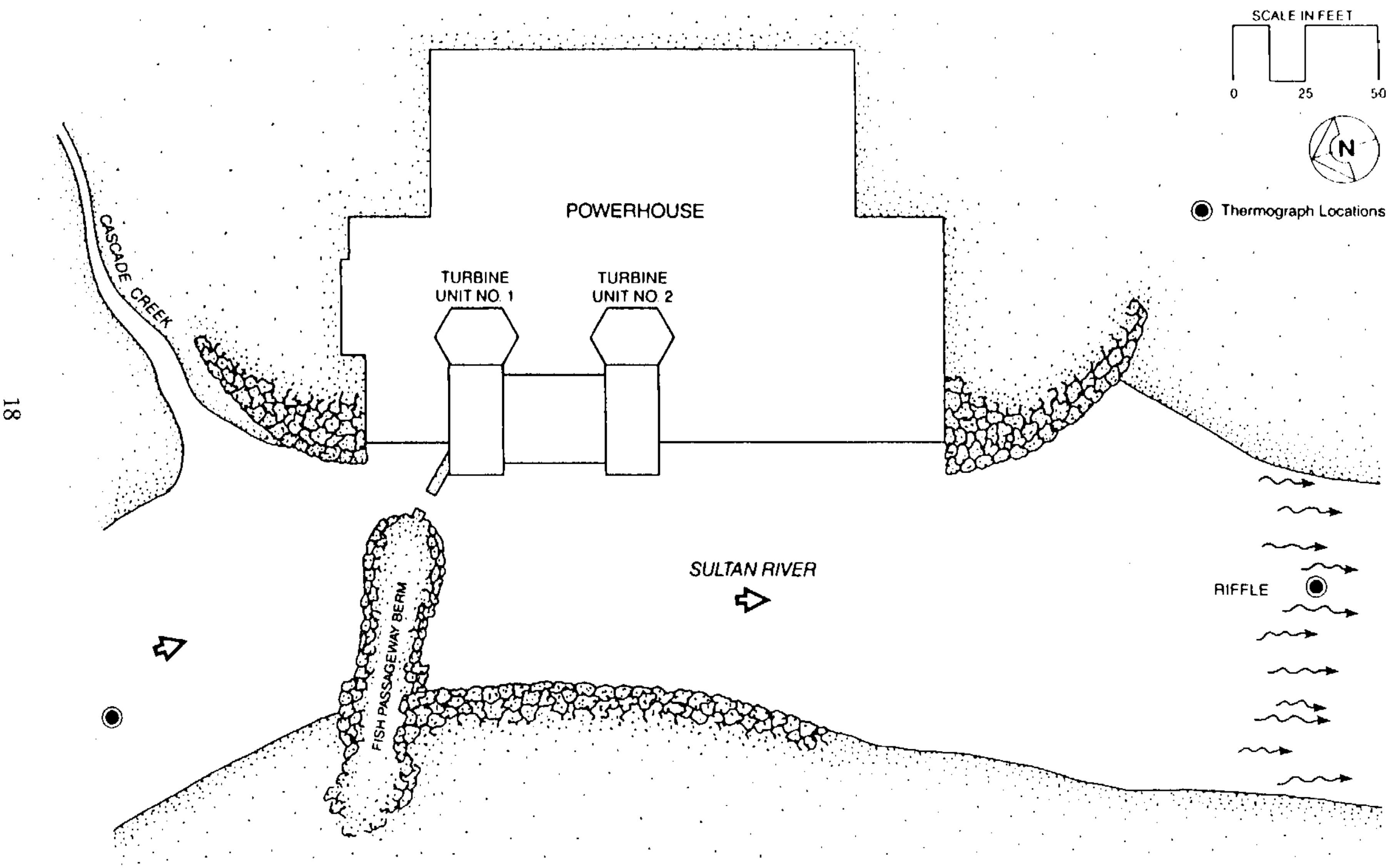


Figure 9. Thermograph locations.

RESULTS

CHINOOK

Visual Observations

A total of 119 observation hours were completed at the Jackson Project powerhouse from September 13 to October 8, 1984. During these observation periods the average flow through the fish passage slot and the powerhouse were 183.1 cfs and 43.8 cfs, respectively (Table 1). Of the ten chinook observed in the tailrace area, seven were observed moving through the fish passage slot into the pool area upstream from the berm.

Anywhere from 35 minutes to 2 hours elapsed between the time a fish was first observed in the tailrace and the time it passed upstream through the slot. During this time fish did not exhibit any behavior indicating confusion or difficulty locating the slot. Those fish that took the longest time to pass through the slot spent the majority of their time holding or meandering in the tailrace area. In one instance, a pair of chinook appeared to be investigating potential spawning sites in the tailrace area before moving upstream. No fish were observed entering either discharge canal during operation or when they were shut down.

Fish that passed through the slot would often fall back into the tailrace area. In some cases the same fish would fall back several times before it migrated all the way upstream out of the powerhouse vicinity. On one occasion two fish that appeared to be spawn-outs were observed moving downstream out of the project area. These fish were first observed in the forebay upstream from the berm, moved downstream through the slot and eventually moved downstream out of the powerhouse tailrace. Aside from this one occurrence, all other fish that were observed continued their migration upstream past the powerhouse.

Based on spawning ground data collected by WDF on October 1, 1984, it appears that the visual observations did not account for several of the adult chinook that migrated past the powerhouse prior to that date. There were a total of 11 adults observed in the index reaches upstream from the powerhouse on the October 1 survey. Prior to this date, the monitoring observations had detected only one fish migrating past the powerhouse. The lack of detection of adults by the monitoring observations may be due to several possible factors: 1) the fish migrated at night after daily observations had ceased, 2) the fish were unobservable due to the path they chose (in the shadows or too deep), and 3) the fish migrated past the powerhouse during the nine-day period (September 15 - 23) that observations did not occur. The presence of unaccounted for fish does not decrease the merit of the observations that were made. However, it does warrant noting that the conclusions are based on fish present during the latter part of the run and are not inclusive of the behavior of fish from earlier portions of the run.

Table 1. Summary of the number of chinook observed in the powerhouse vicinity and the existing flow conditions, September 13 to October 8, 1984[1].

				Number of chinook observed by location			Chinook observed leaving project	
Date	Observation Time	Slot Flow (cfs)	Turbine Flow (cfs)	Tail-race	Pass. Slot	Fore-bay	Up-stream	Down-stream
9/13	0600-1100 1600-2000	121	64	-	-	-	-	-
9/14	0630-1130	121	64	-	-	-	-	-
9/24	0630-1030 1430-1930	203	64	-	-	-	-	-
9/26	1430-1930	195	39	-	-	-	-	-
9/27	0645-1115 1500-1930	195	39	-	-	-	-	-
9/28	0645-1015 1500-1930	192	39	-	1	1	1	-
9/29	0700-1230 1400-1930	186	39	-	-	-	-	-
10/1	0830-1800	183	39	2	2	2	-	2
10/2	0900-1800	216	39	1	1	1	-	-
10/3	0815-1715	186	39	2	2	2	1	-
10/4	0900-1800	186	39	-	-	1	1	-
10/5	0830-1730	186	39	5	1	5	4	-
10/6	0815-1715	186	39	-	-	2	2	-
10/8	0830-1720	186	39	-	-	-	-	-
Total[1]		183.1	43.8	10	7	14	9	2

[1] Values are the average flow during the 119 hours of observations and the total chinook observed at each location for the specified periods and may include the same fish observed earlier at another location.

As indicated in Table 1, 14 fish were observed in the forebay area upstream from the berm. Most of these fish were the same ten observed in the tailrace. The reason more fish were observed in the forebay is likely attributable to better viewing conditions there(less turbulence), and the fact that some fish may have been present in the forebay when observations began and had therefore already migrated through the tailrace area. Immediately after fish passed upstream through the slot they would tend to hold in the dark deep pool formed by the corner of the powerhouse and the berm wall. After a brief holding period in this hole they would continue to migrate upstream. Although some chinook spent up to two hours meandering in the pools above and below the powerhouse, none showed any difficulty in moving upstream past the project.

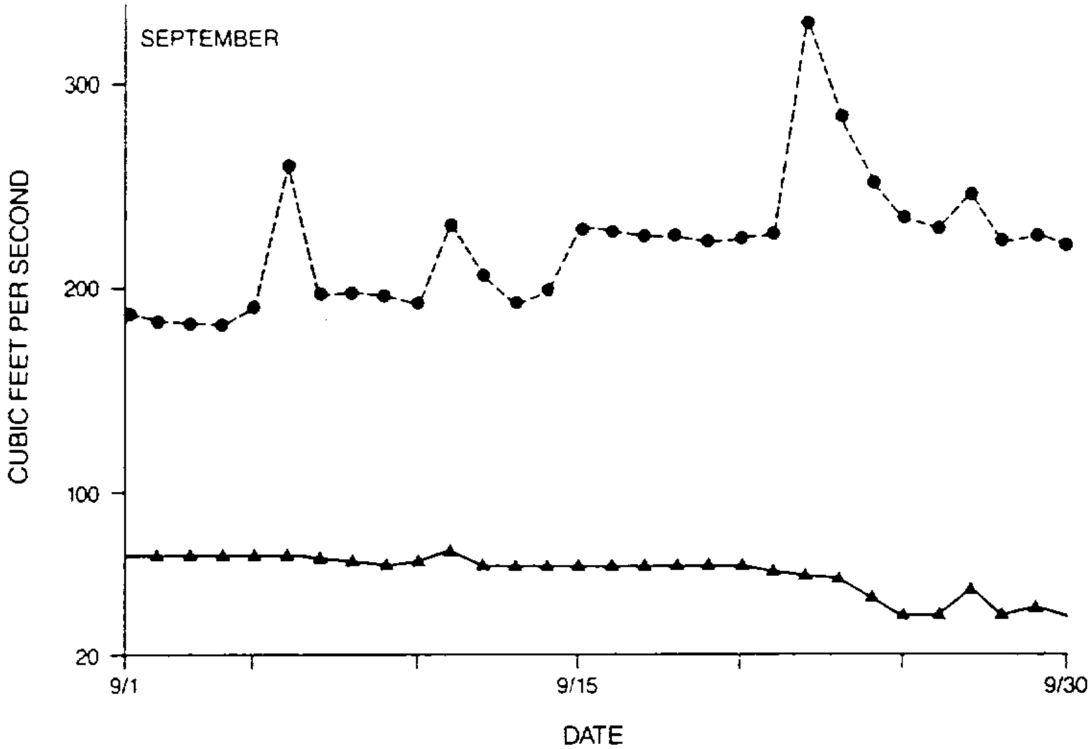
Throughout the visual observation period river flow remained fairly constant with approximately 186 cfs in the river above the powerhouse and 225 cfs below the powerhouse discharge (Figure 10). Therefore, approximately 18 percent (40 cfs) of the total flow was being discharged from the powerhouse and 82 percent was passing through the slot. Flows from the powerhouse were either all from Unit 1 or all from Unit 2 (see Figure 9), there was no apportioning of discharge between the two units due to the low amount being discharged. Visual observations were made on days when discharge from the powerhouse was as follows: September 13, 14, and 24 Unit 1 was discharging, from September 25 to October 1 Unit 2 was discharging, and from October 2 to October 8 Unit 1 was discharging. Due to relatively low reservoir levels, no observations were possible during periods of higher powerhouse discharge. Visual observations of chinook passage were discontinued after October 8, 1984.

<u>Spawning Ground Surveys</u>

In 1984 spawning ground surveys were conducted on October 1, 9, and 15. The survey on October 1 was conducted by WDF, the surveys on the 9th and 15th by Parametrix. Index areas similar to those established by WDF were surveyed on October 9 and 15, 1984 following an initial reconnaissance on October 8. These dates were chosen for surveys based on historical spawning data from WDF and snorkeling observations made on September 17 and 28. On both dates that snorkeling occurred, observations were made in the powerhouse vicinity and the lower one to two miles of the river. Snorkeling on the 28th identified four completed redds and a substantial amount of spawning activity in the lower river. This indicated that the peak of chinook spawning had not yet occurred, but was near.

On October 9 river discharge was 178 cfs above the powerhouse and 231 cfs below the powerhouse, visibility was excellent and the weather was overcast. On October 15 river flow was 202 cfs above the powerhouse and 250 cfs below the powerhouse, visibility was good and the weather was overcast with some rain in the late afternoon.

In 1985, chinook surveys were conducted on October 2, 9, and 18. The surveys on October 2 and 9 were conducted jointly by WDF and Parametrix, the survey on October 18 was conducted just by Parametrix. On October 2, 9, and 18, discharge above the powerhouse and below the powerhouse (above/below) averaged 198/214 cfs, 328/351 cfs, and 301/385 cfs, respectively. In 1986, surveys were conducted on September 25 (Parametrix alone) and October 2 (joint survey with WDF). Flows on these dates averaged 264/267 cfs and 164/280 cfs, respectively.



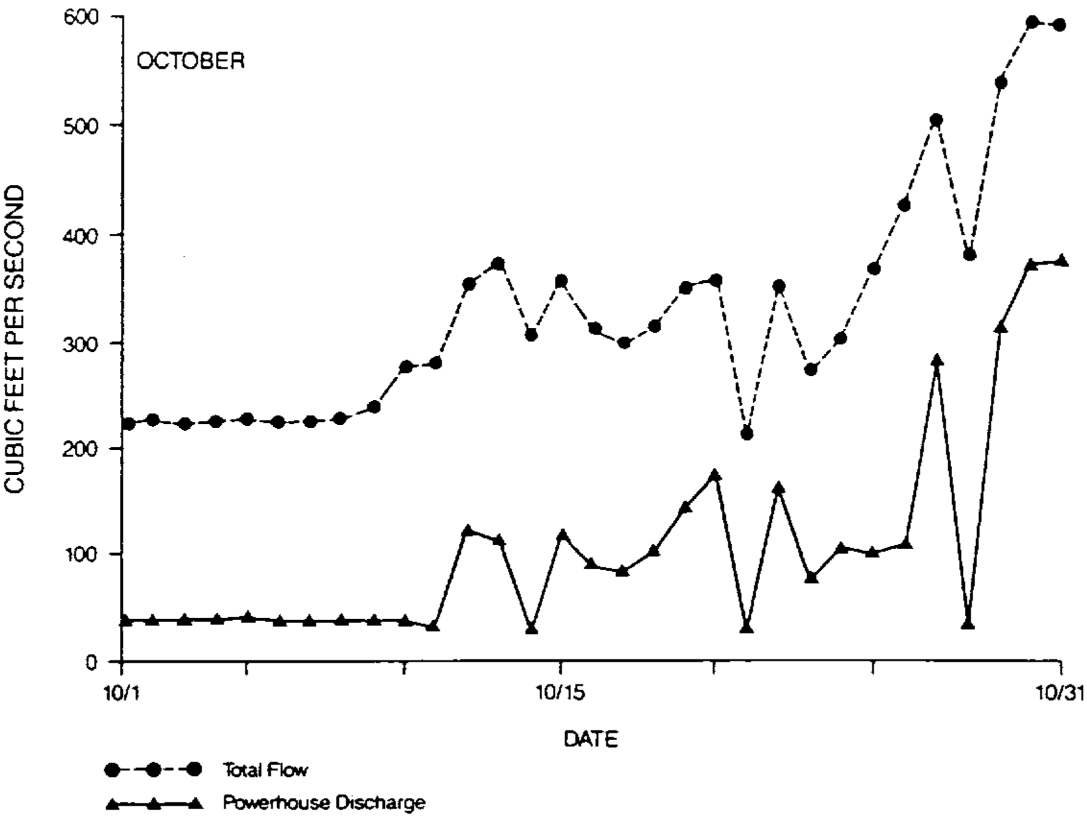


Figure 10. **Daily mean flow of Sultan River below the powerhouse (including powerhouse discharge) and daily mean powerhouse discharge during September and October, 1984.**

The results of the chinook surveys are summarized in Tables 2, 3, and 4. The survey area represents 4.2 miles (43 percent) of the river available to anadromous fish. However, the most productive (and accessible) areas were covered by the surveys. Based on the date that the most fish were observed, peak spawning counts are best represented by the October 1 survey in 1984, the October 2 survey in 1985, and the October 2 survey in 1986. Surveys on dates before and after that point do not reflect peak spawning conditions. In general the majority of the spawners were observed in the lower portion of the river, downstream from the powerhouse. This reach is the location of a substantial share of anadromous fish spawning in the Sultan River (Snohomish PUD and Everett 1983).

Comparisons with pre-project spawning distribution and a discussion of fish berm and powerhouse operation effects on distribution in each of the post-project years are presented in the DISCUSSION section. Results of the 1987 and 1988 surveys, conducted because of a WDF concern about the proportional distribution of spawners upstream/downstream from the powerhouse, are presented in Appendix B.

Snorkeling Observations

Snorkeling observations of chinook salmon were conducted on September 17 and 28, 1984. On September 17 observations were made in the vicinity of the powerhouse and the lower two miles of the river. No chinook were observed in the vicinity of the powerhouse on that day. In the lower river three live chinook and one carcass were counted. On September 28 the two pools located approximately 200 meters upstream of the powerhouse and the lower mile of the river were snorkeled. No chinook were observed in the pools upstream of the powerhouse. In the lower one mile of the river 15 adult chinook were observed as well as one completed redd and a number of partial redds. Chinook adults and redd building activity were observed in almost every riffle area in the lower mile of the river.

COHO

Spawning Ground Surveys

Results of the spawning ground surveys for coho are summarized in Table 5. Index areas were surveyed on November 8 and December 5, 1984. A spawner survey was also attempted on November 20, but high turbidity levels in the river made it impractical. During both coho surveys counts were also made of incidental species of salmon observed. This additional information on the incidental species (chum and chinook) is also presented in Table 5.

On November 8 river discharge was 120 cfs above the powerhouse and 1400 cfs below the powerhouse, visibility was excellent above the powerhouse while only moderate below the powerhouse due to the higher discharge in the lower river. During the survey on December 5 the discharge above the powerhouse was 106 cfs and below the powerhouse the discharge was 489 cfs, visibility was good in both areas during the survey.

Table 2. Summary of chinook spawning ground surveys in the Sultan River during 1984.

	Redds	Live Adults	Live Jacks	Dead Adults	Dead Jacks	Visibility[a](%)
			BPA Powerline to River Mouth (reach length = 2.7 miles)			
10/01[b]	9	76	0	16	0	90
10/09	67	31	2	37	0	
10/15	69	7	0	11	0	
			Chaplain Gage (reach length = 0.6 miles)			
10/01	4	6	0	1	1	90
10/09	6	1	0	0	0	
10/15	4	2	0	0	0	
			Gold Camp (reach length = 0.4 miles)			
10/01	7	3	0	1	0	90
10/09	5	0	0	1	0	
10/15	3[c]	0	0	0	0	
			Diversion Dam (reach length = 0.5 miles)			
10/01[a]	0	0	0	0	0	90
10/09	4	0	0	0	0	
10/15	7	0	0	0	0	

[a] Visibility estimates were not determined on October 9 and 15, 1984.

[b] Draft data from October 1 were provided by WDF, 1984.

[c] Areas recently dredged, spoils could have been observed as redds.

Index areas above the powerhouse were not surveyed on November 8 due to the results of preliminary snorkeling observations. The lower half of the index area near the Chaplain gage was thoroughly snorkeled on this date. No coho redds and only one adult were observed during this snorkeling effort. The lower index area from the BPA lines to the mouth of the Sultan was surveyed on both dates, but observations downstream from Kien's Bar (RM 1.2) are questionable due to low light intensity creating poor observation conditions.

Table 3. Summary of chinook spawning ground surveys in the Sultan River during 1985.

	Redds[a]	Live Adults	Live Jacks	Dead Adults	Dead Jacks	Visibility(%)
			BPA Powerline to River Mouth (reach length = 2.7 miles)			
10/02	9[b]	28	1	10	0	85
10/09	4[b]	26	1	15	0	90
10/21	5[b]	10	4	10	0	---[c]
			Chaplain Gage (reach length = 0.6 miles)			
10/02	2	4	0	0	0	80
10/09	3+1 partial	0	0	0	0	80
10/18	1	0	0	0	0	---[c]
			Gold Camp (reach length = 0.4 miles)			
10/02	2	0	0	0	0	85
10/09	1 potential	0	0	0	0	90
10/18	3	3	4	0	0	---[c]
			Diversion Dam (reach length = 0.5 miles)			
10/02	1.5	0	0	0	0	85
10/09	2	0	0	0	0	---[c]
10/18	3	0	0	0	0	---[c]

a Redd counts may include duplicate counts of the same redd from week to week.

b Chinook redds included in the count represent only redds distinguishable from pink redds, and therefore is most likely an underestimate of the total number of chinook redds because many are not distinguishable from pink redds.

c Surveys conducted on these dates were past the peak of spawning and therefore visibility estimates were not determined.

Table 4. Summary of Sultan River chinook spawning surveys in the Sultan River during 1986.

Date	Redds[a]	Live Adults	Dead Adults	Jacks	Visibility(%)
		BPA Powerline to River Mouth (reach length = 2.7 miles)			
09/25	59	97	9	1	85
10/02	66	101	38	0	90
		Chaplain Gage (reach length = 0.6 miles)			
09/25	9	25	0	3	85
10/02	15	19	1	0	90
		Gold Camp (reach length = 0.4 miles)			
09/25	3	7	0	1	85
10/02	8	12	1	2	85
		Diversion Dam (reach length = 0.5 miles)			
09/25	5	20	0	0	85
10/02	5	11	1	0	90

[a] Redd counts may include duplicate counts of the same redd from week to week.

Snorkeling Observations

On November 8 snorkeling observations were conducted from the tailrace area to a riffle approximately 400 yards upstream. Visibility was excellent above the powerhouse. Visibility in the tailrace area, however, was partially obscured due to turbulence in the water column near the turbine discharge areas. No fish were seen in the tailrace area below the berm but one adult male coho was observed in the pool above the powerhouse. The fish appeared to be partially spent but still in good condition with no visible scars.

Table 5. Summary of coho spawning ground surveys in the Sultan River during 1984.

Survey Site	Survey Length (mi.)	Date	Number Redds	Species	Adults[a] Live	Dead
BPA powerlines to Kien's Bar	1.5	11/8	30	Coho	10	0
				Chinook	10	0
				Chum	2	0
		12/5	132[b]	Coho	8	4
				Chinook	2	0
				Chum	64	41
Powerhouse to 200 yds. above Chaplain gage	0.6	12/5	5	Coho	1	0
				Chinook	0	0
				Chum	0	0
Portal Tunnel to Diversion Dam	0.5	12/5	1	Coho	0	0
				Chinook	0	0
				Chum	0	0

[a] No jacks were observed.

[b] Approximately 75% of these redds were chum salmon redds.

WINTER-RUN STEELHEAD

Radio Telemetry Tagging

Winter-run steelhead trapping was initiated on January 10 and continued through May 6, 1985. During this period a total of 32 winter-run steelhead were captured and 26 received radio tags. Other species of fish (particularly coho) were also frequently captured in the traps. A summary of the fish captured is presented in Table 6.

Scale samples were collected from captured steelhead to determine their age and origin (hatchery or wild). These scale samples were subsequently analyzed by WDG biologists. Results of these analyses appear in Table 7.

During the four month period (February 16 to June 3, 1985) that the radio telemetry monitoring equipment was in operation, two radio tagged steelhead were detected while migrating past the powerhouse. The first fish was a 68 centimeter male, tagged and released on March 22, 1985. Initial detection at the downstream antenna (see Figure 7) occurred at approximately 1655 hrs PST on April 1. The fish spent between 6 and 12 minutes in the downstream detection area before continuing upstream. The next detection of the fish was at the upstream antenna (approximately 200 meters upstream from the powerhouse) between 1800-2200 hrs PST. During the one to five hour period it took the fish to migrate past the powerhouse and through the fish passageway, it was not detected within the discharge canal of the turbine operating at that time (Unit No. 2). River flow and turbine discharge remained fairly constant during this five hour period with 308 to 336 cfs through the fish passage slot and 283 to 305 cfs through Turbine No. 2 (Turbine No. 1 was off) for a combined river flow of 613 to 619 cfs below the powerhouse.

Detection within the vicinity of the upstream antenna continued for 64 to 72 hours until the fish left the area on April 4th between 1400 and 1800 hrs PST (Figure 11). This fish probably spawned within the detection zone of the upstream antenna. Subsequent spawning surveys identified a redd within this detection area.

The second radio tagged steelhead detected while migrating past the project was a 65.5 cm male tagged and released on February 25. This fish moved past the powerhouse on April 2nd. The monitoring equipment was being used between 1200 - 1440 hrs PST on that date to conduct a helicopter survey. The fish was initially detected from the helicopter approximately 700 meters downstream of the project at roughly 1300 hrs PST. The next detection of the fish was at the upstream antenna between 1440 and 1840 hrs PST. The fish apparently moved past the downstream antenna during the helicopter flight and spent between 2 to 6 hours moving past the project. The downstream antenna was tested immediately after this event and found to be functioning properly. There was no detection of the fish within the discharge canal of the turbine operating during that 2 to 6 hour time period. This lack of detection, however, does not preclude the possibility of the fish entering the canal during the 2 hour period the monitor was off during the flight. Subsequent to completion of the helicopter survey, monitoring of the discharge canals was resumed at 1440 hrs PST.

Table 6. Summary of winter-run steelhead trap monitoring and tagging data, January 1 to May 6, 1985.

Date	Hours Fished	Species	Number Captured	Lengths (cm)	Tag Release Date
1/10-1/16	66				-
1/17	24	Coho	1	49	-
1/18	24	Coho	1	48	-
1/22	24	-	0	-	-
1/23	26	Coho	1	41	-
1/24-1/30	98	-	0	-	-
2/12-2/15[a]	96	-	0	-	-
2/18	73	Steelhead	4	58-69.5	2/19
		Coho	1	40	-
2/19-2/20	47	-	0	-	-
2/22	28	Steelhead	2	64,75.5	2/24
		Coho	1	39.5	-
2/23	29	-	0	-	-
2/25	48	Steelhead	3	58.5-68.5	2/25
2/27	53	Coho	2	41,48	-
3/01	45	Sucker	1	38.5	-
3/04	71	Coho	1	46	-
3/06	48	-	0	-	-
3/08	49	Steelhead	1	65	3/08
		Sucker	1	44	3/08
3/11-3/13	119	-	0	-	-
3/15	49	Steelhead	2	69,80	3/15
3/18	74.5	Cutthroat	1	43	-
3/20	43	Steelhead	1	65	-
3/22	47.5	Steelhead	4	66-71	3/22
3/25-3/29	168.5	-	0	-	-
4/01	72	Steelhead	7	50-82	4/01
4/03-4/08	118.5	-	0	-	-
4/10	48	Sucker	1	42	-
4/12	48	Steelhead	1	46	-
		Steelhead	2	64,67.5	4/15
4/15	48	Sucker	1	40	-
4/19	48	Steelhead	2	43,64	4/19
4/22	73	Sucker	1	43	-
4/23	23	-	-	-	-
4/26	72	Steelhead	1	65	4/26
4/29	72	Steelhead	2	52,70	4/29
		Sucker	1	43	-
5/02	71	Sucker	1	48	-
5/03-5/06	96	-	0	-	-

[a] Trap not fished for 10 days

Table 7. Summary of data from WDG scale analysis on steelhead captured from the Sultan River during 1985.

Date of Capture	Age[1]	Fork Length (cm)	Sex	Dorsal Condition[2]	Origin[3]
2/22	1.2+	75.5	F	NS	H
2/22	1.1+	64	M	NS	H
2/25	1.1+	58.5	F	NS	H
2/25	1.1+	68.5	M	NS	H
2/25	1.1+	65.5	M	NS	H
3/8	1.1+	65	F	NS	H
3/15	1.2+	80	F	NS	H
3/20	1.1+	65	M	S	H
3/22	1.1+	68	M	NS	H
3/22	1.1+	66	M	NS	H
3/22	1.1+	67	M	NS	H
3/22	1.1+	71	M	NS	H
4/1	-	70	M	S	Unknown
4/1	R.2+	82	F	NS	"
4/1	1.1+	77	M	NS	H
4/1	R.+	50	M	NS	Unknown
4/1	1.1+S+	80	M	S	H
4/1	1.1+	73	M	S	H
4/1	1.+S+	58	M	NS	H
4/12	-	48	M	S	H
4/15	1.1+	64	M	S	H
4/15	1.1+	67.5	M	S	H
4/19	R.+	43	F	NS	Unknown
4/19	1.1+	64	M	S	H
4/26	1.1+	65	F	S	H
4/29	1.+S+	52	M	S	H
4/29	R.1+	70	M	NS	Unknown

[1] Age Code Example: 1.2S+ = 1 - years in freshwater
2 - years in saltwater
S - spawning check
+ - partial year in saltwater
R - regenerated scale (years in freshwater unknown)

[2] S = stubbed, NS = not stubbed (observed during tagging)

[3] H = hatchery, W = wild (based on scale analysis)

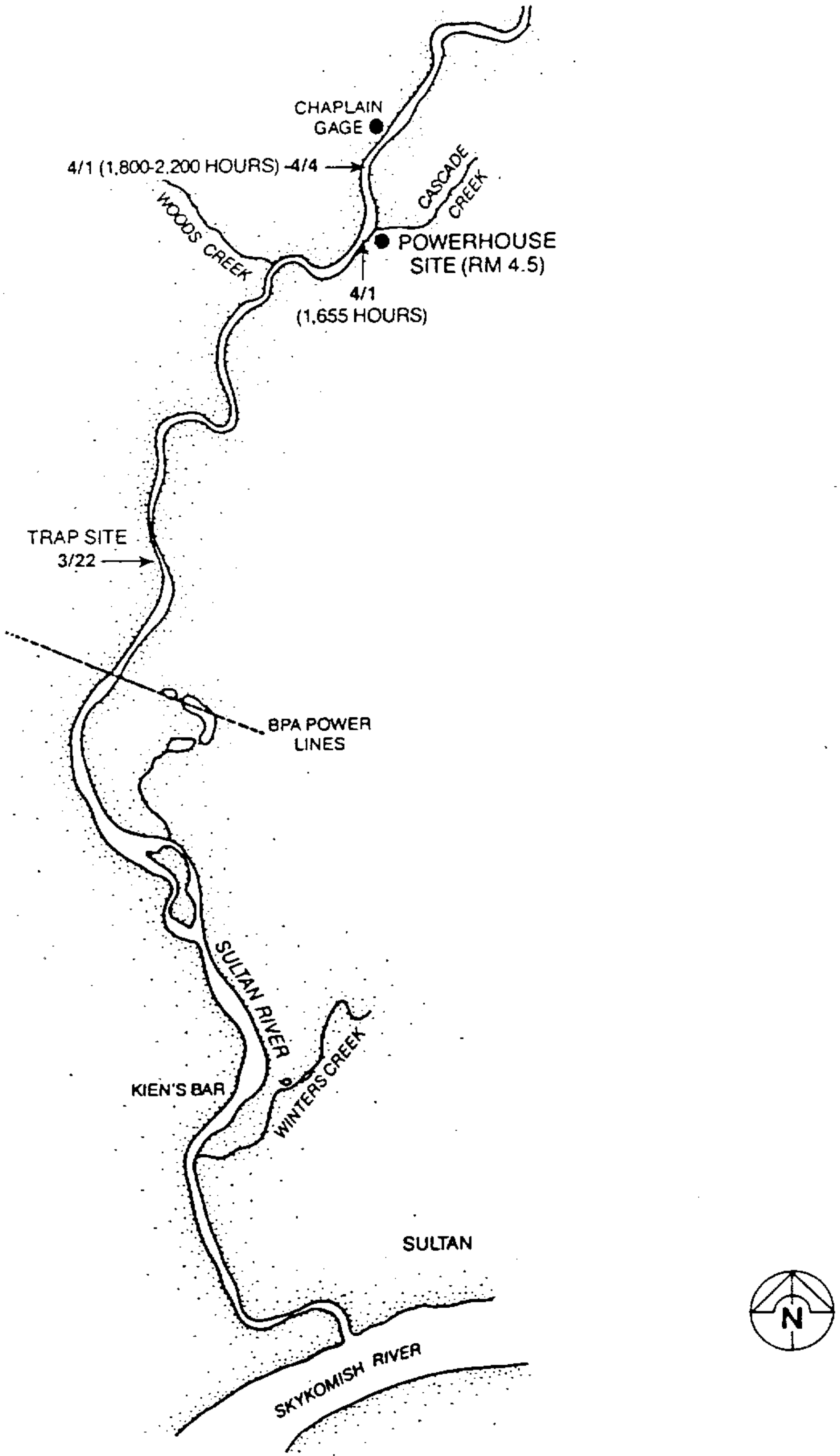


Figure 11. Locations of a radio tagged steelhead detected during helicopter flights and stationary monitoring (68 cm male released 3/22/85).

River flow and turbine discharge remained constant during passage of the second radio tagged steelhead with approximately 276 cfs through the fish passage slot and 354 cfs being discharged from Turbine No.2 (Turbine No. 1 was off) for a combined river flow of 630 cfs below the project. This fish was located above the project during subsequent helicopter surveys (Figure 12).

Nine aerial surveys for radio tagged steelhead were completed between March 6 and June 12, 1985. These surveys further verified that two radio tagged steelhead had migrated above the powerhouse. Tracks (or position logs) for these two fish are presented in Figures 11 and 12.

The remaining 24 tagged steelhead did not migrate upstream as far as the powerhouse. Some of these fish migrated upstream part way to the powerhouse, while others moved downstream following tagging, and a few migrated completely out of the Sultan River and were detected in the Skykomish River. The lack of migrants passing the powerhouse may have been the result of inadvertently tagging mostly or only hatchery fish (see Table 7). Since hatchery fish are released about 1.5 miles below the powerhouse they might be less prone than wild fish to return to spawning areas above the powerhouse.

Two tags were apparently regurgitated near the trap site and were found on the bottom of the river. One tagged fish was caught by an angler fishing upstream from the trap site, while another was reportedly captured by a dog downstream from the trap site. Detection tracks from helicopter surveys for those fish that did not migrate past the powerhouse are presented in Appendix C.

Spawning Ground Surveys

A total of ten steelhead redd surveys were completed from a helicopter between February 4 and June 12, 1985. On all flights the entire Sultan River from the mouth to the Diversion Dam was surveyed. Water clarity and light conditions ranged from good to excellent throughout the surveys.

To obtain an accurate redd estimate, redd life must be factored in to avoid recounting the same redds on subsequent surveys. Redd life factors were different upstream and downstream from the powerhouse due to distinctly different flow regimes in these reaches during the winter-run steelhead spawning ground surveys. Redd life downstream from the powerhouse was estimated at approximately two weeks, but was estimated at four weeks upstream from the powerhouse. These estimates were based on observations of artificial redds below the powerhouse and natural redds above the powerhouse.

In the downstream area, where redd life was estimated to be two weeks, the count of all observed redds were adjusted to actual counts of new redds by subtracting the preceding survey's count of new redds. Subtraction of the previous week's new count was determined to be appropriate since the surveys were conducted approximately every two weeks, the same time period as the redd life estimate. Survey data for March 6 can be used as an example of how redd life was applied (Table 8). The survey conducted on March 6 identified five redds below the powerhouse. Based on the redd life data and the previous survey's count, two of these redds were old. Therefore, the March 6 data were adjusted to a total of three new redds for the reach below the powerhouse. This process was repeated for each survey's total redd count. In the reach upstream of the powerhouse redd life was estimated to be four weeks. Therefore the total counts in the upper reach were adjusted by subtracting the new count from the two preceding surveys.

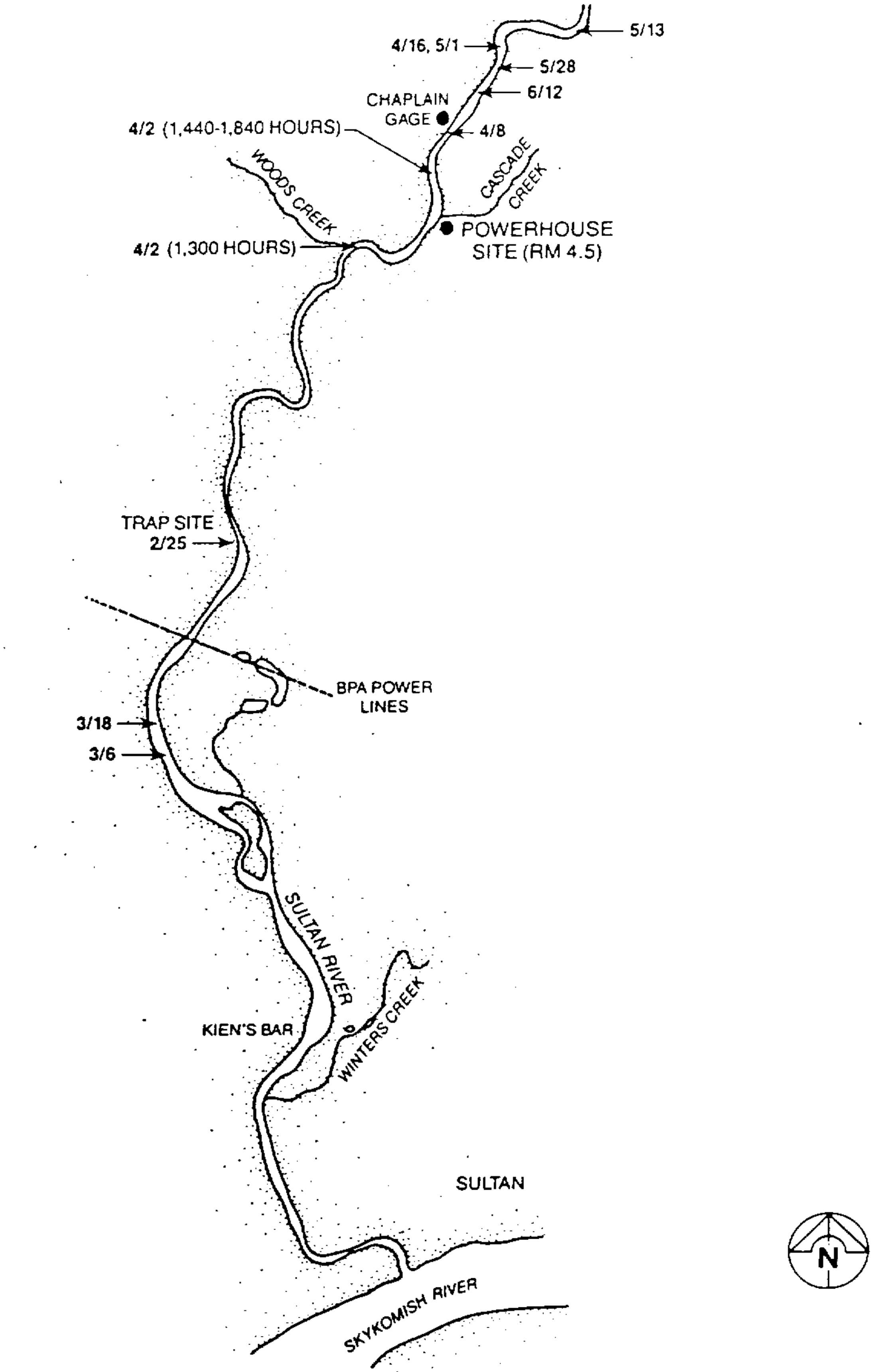


Figure 12. Locations of a radio tagged steelhead detected during helicopter flights and stationary monitoring (65.5 cm male released 2/25/85).

A total of 222 redds were counted during the steelhead spawning ground surveys. Approximately 41% (N=90) of these redds were sighted upstream from the powerhouse while 59% (N=132) were observed downstream from the powerhouse. After the redd life factors were applied, it was calculated that a total of 100 new redds were observed. Thirty percent (N=30) were sighted upstream from the powerhouse while 70% (N=70) were downstream. Spawning activity peaked on or near May 2nd when 27 new redds were counted. A summary of these surveys and the redd life applications is presented in Table 8.

SUMMER-RUN STEELHEAD

Snorkeling Observations

Summer-run steelhead index areas were surveyed on six occasions between June 26 and September 17, 1985. The final survey on September 17 was not completed because of high flows and turbidity encountered on that date. The results of these surveys appear in Table 9.

While summer-run steelhead were present in the Sultan River during the entire sampling period, their abundance apparently peaked during the month of July. During July the average number of summer-run steelhead counted per mile of stream surveyed (x = 1.7) was over four times the average for June, August and September (x = 0.37). Summer-run steelhead also appeared to be more abundant above the powerhouse than below. The average number of summer-run steelhead observed per mile of stream surveyed above the powerhouse (x = 1.4) was over twice that of the lower sections of the Sultan River (x = 0.6).

On June 24 a summer-run steelhead carcass was found in the tailrace area just downstream of the powerhouse. This fish appeared to be a female in good condition with no external marks or scars. During the study none of the summer-run steelhead observed exhibited any scars or external marks.

Temperature Monitoring

Water temperatures in the powerhouse vicinity were monitored from July 25 to September 24, 1985. During most of this period the powerhouse was not in operation due to scheduled maintenance. During the period of project operation the temperature of the attractant water remained approximately three degrees centigrade higher (warmer) than the temperature of the river below the powerhouse. While the powerhouse was shut down the temperature of the attractant water generally varied less than 0.5 degrees (probably variation between instruments) from temperatures recorded below the powerhouse (Figure 13).

Table 8. Summary of winter-run steelhead spawning ground surveys in the Sultan River during 1985.

Date	Total Number of Redds		Number of Redds Below the Powerhouse		Number of Redds Above the Powerhouse	
	Observed	(a)	Observed	(a)	Observed	(a)
2/04	0	(0)	0	(0)	0	(0)
2/18	3	(3)	2	(2)	1	(1)
3/06	8	(5)	5	(3)	3	(2)
3/18	21	(15)	12	(9)	9	(6)
4/08	21	(4)	9	(0)	12	(4)
4/16	20	(10)	7	(7)	13	(3)
5/02	41	(27)	25	(18)	16	(9)
5/13	49	(19)	32	(14)	17	(5)
5/28	37	(9)	23	(9)	14	(0)
6/12	22	(8)	17	(8)	5	(0)
Total Redds Observed)	222		132 (59%)		90 (41%)	
Total Redds (Adjusted)	100		70 (70%)		30 (30%)	

a Calculated number of new redds counted during each survey.

Table 9. Summary of summer-run steelhead snorkeling observations in the Sultan River during 1985.

	June 26		July 9/10		July 24/25	
	Flow (cfs)	Adults	Flow (cfs)	Adults	Flow (cfs)	Adults
Diversion Dam	106	9[a]	125	2	109	2
Miners Cabin	106	0	125	0	109	0
Gold Camp	106	0	125	0	109	0
Chaplain Gage	106	1[b]	125	3	109	1[c]
Trap Site	506	0	570	1	436	0
Kien's Bar	506	1	570	0	436	1
Sultan Park	506	0	570	0	436	0

	August 6/7		August 28/29		Sept. 16/17	
	Flow (cfs)	Adults	Flow (cfs)	Adults	Flow (cfs)	Adults
Diversion Dam	164	0	162	1	309	2
Miners Cabin	164	0	162	0	309	0
Gold Camp	164	0	162	0	309	0
Chaplain Gage	178	1	162	1	309	0
Trap Site	190	0	176	0	441	d
Kien's Bar	190	0	176	0	441	d
Sultan Park	190	0	176	0	441	d

[a] Of this total, 8 fish were winter-run steelhead.

[b] Winter-run steelhead.

[c] Summer-run carcass.

[d] Not surveyed.

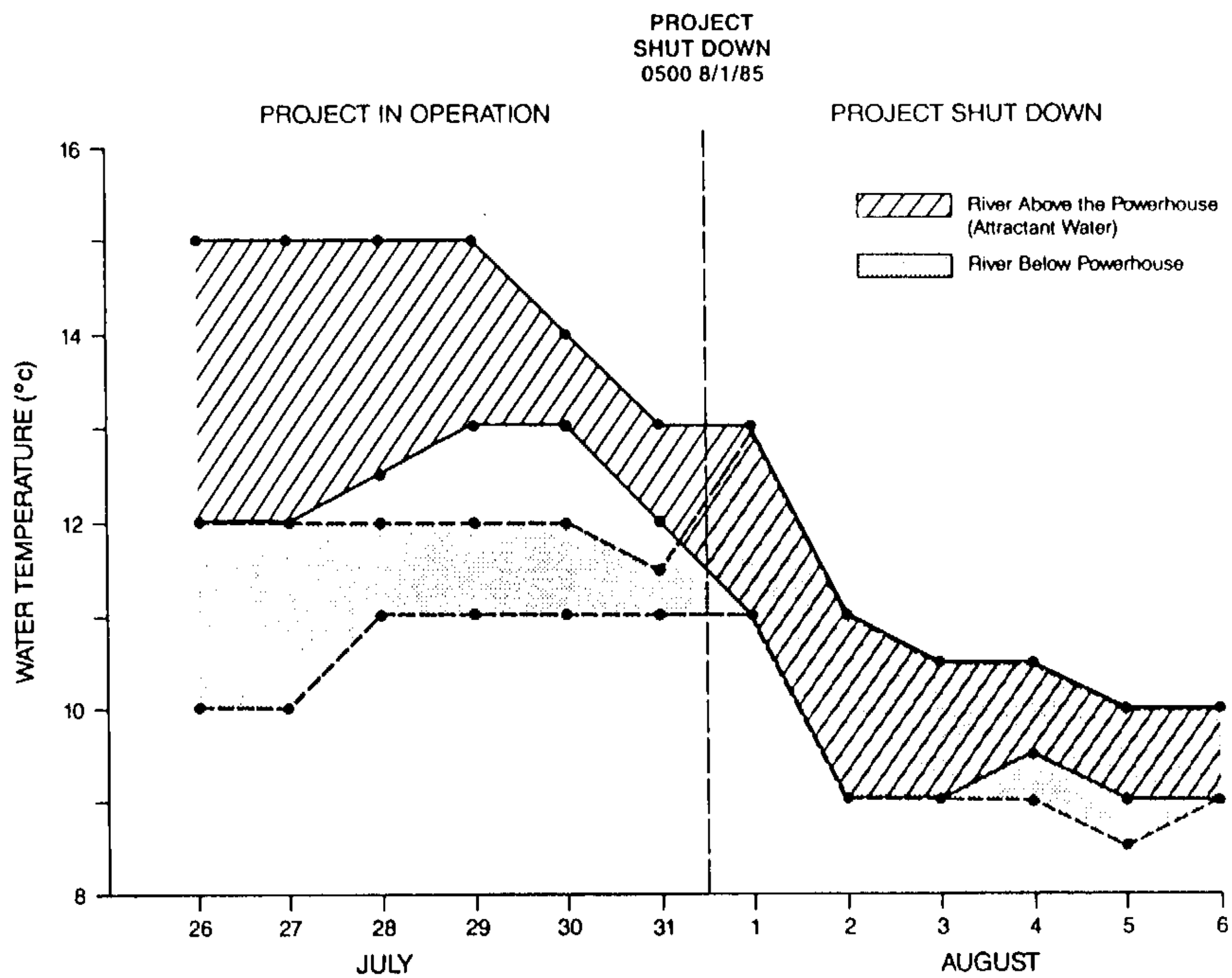


Figure 13. Daily maximum-minimum temperature ranges above and below the Jackson Powerhouse on the Sultan River, 1985.

DISCUSSION

This investigation studied three fish species (chinook, coho, and winter/summer-run steelhead). Two distinct issues associated with adult upstream migration of these species were investigated: (1) passage at the powerhouse; and (2) spawner distribution within the Sultan River (upstream and downstream from the powerhouse). Study results concerning these issues and implications (if any) are discussed for each species as warranted.

CHINOOK

Passage

Although visual observations at the powerhouse were made over a prolonged period, only a small number of chinook were detected. Many of the chinook observed in the index areas upstream from the powerhouse during the peak spawner survey on October 1, 1984 were not detected in the visual observations made at the powerhouse. The observations that were made showed those fish that did migrate as far as the tailrace were able to quickly find and migrate through the passageway in the powerhouse berm. Fish observed in the tailrace were not delayed nor did they show any signs of physical injury that might have occurred while migrating past the powerhouse.

Fish also did not appear confused or misguided by the varying flow/velocity situations that occurred at the powerhouse. This was indicated by the fact that none of the chinook observed attempted to migrate into the discharge canals regardless of whether or not water was being discharged. Relatively low flows were being discharged during the majority of the chinook migration. Powerhouse discharge (average of 43.8 cfs) represented about 15 to 35 percent of the total flow, while the remainder flowed through the berm passageway slot. On the majority of the observation dates, the discharge from the powerhouse was about 15 percent of the total flow.

This study focused on the effect of the powerhouse berm (passageway) and project operation on adult upstream migration (specifically, delay or injury). Based on the results of the visual observations during the chinook migration, the physical presence of the powerhouse and its discharge did not create a situation that affected upstream migration at the powerhouse. The passageway provided adequate conditions for chinook migration past the powerhouse. All of the fish observed in the tailrace easily located the passageway (slot) and proceeded upstream without delay or injury.

Although the flow conditions during the visual observations did not appear to hinder the passage of fish, they do not represent the worst case scenario. This scenario would consist of full powerhouse operation and minimum diversion dam flows (i.e., low slot flows). This could create a situation with the powerhouse discharge providing more than 90% of the total downstream river flow. Whether this type of situation would create fish passage problems could not be determined.

Distribution

The results of the fall chinook distribution studies (spawning ground surveys) differ from the results of the visual observations. While the visual observations indicated that passage was not impaired at the powerhouse and passageway slot, the distribution data indicate that spawner use of the areas upstream from the powerhouse has significantly decreased since the project was completed.

Spawner survey data collected after the powerhouse was completed were compared with data collected during project construction and prior to project construction. Comparisons were made using two sets of data. The first set that was used were field observations (raw counts) expanded to escapement estimates. The expansion factors include visibility, distance surveyed, length of river section, catch to escapement ratio based on nose tag data, and estimating total fish for the entire spawning season based only on a peak survey. This data set was used in part because it had been historically established as the standard method for utilizing the spawning survey data. The expansion factors include some assumptions that have not been tested (i.e., that the areas surveyed are representative of the entire reach for which they are expanded). Although the assumptions have not been tested, the expansion factors are basically constants that do not change from year to year with the exception of the visibility estimates. Therefore, use of the expanded data set should reflect any changes that have occurred in spawner distribution.

Since the expanded data set is comprised of numbers that have been inflated, analyses performed with this set uses percentages rather than the actual numbers. The percentage of spawners upstream from the powerhouse versus the percentage downstream is the basis for the comparison, and the comparison investigates whether or not this distribution changed with time. Use of percentage data requires an arcsin transformation before statistical analyses can be conducted. A summary of the expanded data set used in the analyses is presented in Table 10.

Analysis of variance (ANOVA) was used to determine if the percentage of spawners upstream from the powerhouse was different in pre-project years versus post-project years. Bruya (personal communication, 1987) tested the pre-project years (1978, 1979, 1980 & 1982) against the post-project years (1983-1986) and determined that spawner use upstream from the powerhouse had significantly decreased in the post-project years ($F = 10.544$; $P = .0175$). An alternative approach to this analysis is to exclude 1982 from the pre-project data base. Exclusion of 1982 is justified because it does not represent true pre-project conditions. Construction was occurring during the chinook migration in 1982 that included a coffer dam in place and the river diverted through culverts. ANOVA excluding 1982 from the pre-project data, however, does not change the results; a significant different between pre-project and post-project still exists ($F = 7.059$; $P = .0446$). However, the test excluding 1982 has a higher "p" value associated with it, indicating it is not as highly significantly different as the analysis that includes 1982.

Table 10. Estimated spawner escapement for the Sultan River, separated by location upstream and downstream from the powerhouse, 1978-1986 (from Bruya, personal communication, 1987)

Year	Total Escapement Estimate	Percent Upstream Powerhouse	Percent Downstream Powerhouse	Arcsin Transformed % Upstream
1978	473	63	37	52.54
1979	545	63	37	52.54
1980	939	75	25	60.00
1982	455	71	29	57.42
1983	615	58	42	49.60
1984	357	30	70	33.21
1985	162	31	69	33.83
1986	798	52	48	46.15

A second data set was created that was intended to eliminate some of the assumptions and expansions that are used in the first data set, and rely more on raw counts. This data set still uses the visibility estimates to adjust the raw counts, but does not utilize any of the other expansion factors. The validity of using this data set is also based on some assumptions that are inherent to both data sets, but different than the assumptions required for expansion. The primary assumption is that the areas that are inventoried will be sensitive to any changes that occur in spawner distribution. Therefore, the areas inventoried should be representative of the spawning habitat that is usable. This assumption is corroborated by other spawning ground data collected from the entire river, not just index reaches. Steelhead surveys in 1985 and 1987 consisted of flying the entire river and identifying redds from a helicopter. These surveys indicate that the heaviest spawning occurs in those areas that are inventoried during the chinook surveys (see Appendix D), and that minimal spawning occurs in the reaches that are not inventoried. However, verification of this same trend for chinook should occur before the assumption is finally validated. Another assumption is that the distribution of fish observed during the peak survey is representative of the distribution of the entire run. No data has been collected from studies designed to support or refute this assumption. However, 1984 surveys, which encompassed a two-week period, did not suggest a shift with time. In the future, periodic additional surveys may be warranted to verify this assumption.

A summary of the raw-count data expanded only for visibility is presented in Table 11. The analyses conducted with this data set, raw counts adjusted for visibility estimates, consisted of chi-square or contingency table tests. The first test examined data from years 1978-1986 and was intended to determine if there was a difference in spawning distribution during those years. In statistical terms the null hypothesis was H_o: proportion of spawners below the powerhouse is the same for 1978-1986 (and hence proportion above is the same for 1978-1986). The results of that test verified there was a significant difference between the years 1978-1986 (X^2=60.86, p<.0001).

Table 11. Summary of new spawner counts, adjusted for visibility, used in pre-project and post-project distribution comparisons.

Year[1]	Above Power-house	Visibility	Above Adjusted	Below Power-house	Visibility	Below Adjusted
1978	30	.95	32	65	.85	76
1979	38	.95	40	60	.75	80
1980	61	.80	76	93	.95	98
1982	35	.90	39	44	.80	55
1983	21	.50	42	53	.50	106
1984	11	.90	12	92	.90	102
1985	4	.80	5	38	.85	45
1986	45	.90/.85	51	139	.90	154

[1] Data from 1981 are excluded due to poor survey conditions (visibility) that year rendering the data unreliable.

The next test examined only pre-project years to establish whether or not there was a difference in the proportions for those years. The years 1978-1980 and 1978-82 were tested as pre-project conditions. Inclusion of 1982 in the pre-project years is questionable because construction activity during that year's chinook migration created conditions which were substantially different from previous years (i.e., coffer dam in place and river diverted through culverts). The results of the pre-project comparison indicated that there is a significant difference between the years grouping 1978-1980 ($X^2=6.55$, $p=.0372$), but there is no significant difference between the pre-project grouping of 1978-1982 ($X^2=7.19$, $p=.0656$). The fact that a significant difference occurred between the pre-project years 1978-80 is an indication that there is some natural variation in the pre-project baseline.

The data from the pre-project years 1978-1980 were pooled and compared against the years 1984, 1985, and 1986 on an individual basis. Post-project years were compared individually against the baseline because each year represents a unique brood's escapement to the upper river that should not be affected by earlier or later years. The years 1982 and 1983 were excluded from the comparisons because they are not true post-project years. The results of these comparisons are summarized in Table 12. All of the post-project years analyzed (1984, 1985, and 1986) were significantly different from the pre-project years (1978 - 1980). These results are consistent with the analysis using the first set of data (expanded counts) and reflects the fact that a significant shift in spawning distribution has occurred since the construction of the Jackson Project. The shift has been toward a lesser use of the spawning area located upstream from the powerhouse. The chi-square results also indicate that although there has been a significant decrease in the usage of the upstream areas, the upstream distribution has improved in 1985 and 1986 over 1984 (Table 12). See also 1987 and 1988 results in Appendix B. The 1988 survey had the highest number of fish observed (236) and the highest proportion of fish above the powerhouse (.458) of any previous year (either pre- or post-project).

Table 12. Summary of chi-square analyses for post-project years compared to pre-project baseline.

Year	X^2	p	Conclusion
1984	24.77	<.0001	Significant Difference
1985	11.40	.0011	Significant Difference
1986	8.18	.0046	Significant Difference

Identification of a shift in spawning distribution leads to further questions including: 1) what was the cause of the shift, and 2) what is the overall effect of the shift on chinook production? It should be noted that it was neither the original objective nor a part of the study design to address these questions. However, some of the data collected during the study provide insight into some of the answers. One of the most obvious potential causes was discharge from the powerhouse creating a migration blockage. However, this theory is contradicted by the visual observations which did not detect passage problems for the fish which migrated to the powerhouse. This theory is also contradicted by the distributions observed in 1983 and 1985, years when the powerhouse was complete, but not discharging to the river. Both of these years had distributions that differed from pre-project conditions, with 1985 having a significantly different distribution (p=.0011).

Temperature differences created by the operation of the project (diverting water from depth in Spada Lake via pipeline and discharging to river) is another possible theory that may account for the distribution shift. However, the fact that the project was shut down during the 1983 and 1985 migrations once again contradicts this theory.

A change in spawning habitat availability due to project operation is another factor which potentially could account for the change in distribution. It is possible that through the re-regulation of Sultan River flow due to project operation the spawning area in both the upper and lower river may have changed. Such change could be an increase in spawning habitat in the lower river if post-project flows in the lower river were substantially different (either higher or lower) than pre-project flows, or if they were more consistent and stable. Preliminary analyses of pre-project and post-project flow data by WDF (Bruya, personal communication, 1987) indicate that post-project lower river flows are within the range of lower river flows that occurred pre-project. Therefore, it does not appear likely that post-project flows have created a situation where more spawning habitat is available in the lower river than was pre-project.

Other factors which are non-project related may also be responsible for a shift in spawning distribution. Data from 1985 represent the lowest usage of the spawning area upstream from the powerhouse of all the post-project years. The escapement to the Sultan River during 1985 was also substantially lower than any year to date. Likewise, 1986, which had the highest usage of the upper river spawning area of the post-project years, had an escapement that was considerably higher than the other post-project years. WDF analysis of this run size data (Bruya 1987) resulted in a very low correlation between run size and spawner use of the upper river, indicating that it does not play a major role in determining distribution. (The 1988 survey results subsequent to this study analysis show the highest total number, and highest proportion of upstream spawners. See Appendix B.)

Although no data are available to substantiate whether or not the shift is a natural phenomenon, shifts in chinook distribution have been noted to occur without any obvious causative explanation. One example of such a shift is the fall chinook distribution in the Hanford Reach of the Columbia River. In recent years (1983 and 1984) very few redds have been observed in the Coyote Rapids vicinity, an area that had received moderate to heavy use in the past (Grant Co. PUD, 1985). This shift away from the Coyote Rapids area has occurred despite an increase in spawning escapement to the Hanford Reach in recent years. It is recognized that the Columbia system is substantially different than the Sultan River, but evidence of naturally occurring chinook spawner decreases in certain areas despite escapement increases is relevant regardless of the system. Another example of an apparent naturally occurring shift is the distribution of summer chinook spawning in the Wenatchee River system. Over the past several years there has been a dramatic increase in the use of a specific area located in the upper Wenatchee River that had previously received little if any spawning (Chelan Co. PUD, 1985). During this time run size did not change appreciably and no other substantial changes to the system have occurred that could explain the shift in spawner distribution.

The fact that a shift in chinook spawning distribution has occurred coincident with the operation of the fish passage berm and a new hydro facility warrants concern for the potential effect on chinook production. Based on the observations of spawning in the lower river, there did not appear to be superimposition or lack of adequate habitat to support those fish that spawned there in 1984-1986. Based only on spawning habitat, it does not appear that production would have been affected by the distributions that occurred in 1984, 1985, and 1986. However, other factors affecting production, such as rearing habitat, have not been addressed and need to be considered before final conclusions pertaining to production can be made.

After considering several of the factors that could account for a shift in spawning distribution, it is not possible to clearly identify any one factor as causative. Perhaps the shift is not the result of a single factor, but rather a combination of many factors. In any case, a shift in distribution has occurred coincident with the completion of a new hydro project. Spawning distribution should continue to be closely monitored to determine if the shift continues, and most importantly to determine if spawning success is being hindered. In years when spawning escapement is high, there should be an awareness that there is a potential loss of production from the Sultan system due to the distribution of spawners in the river. Redd site competition and redd superimposition in the lower river may be one indication of under-utilization of the upper river and over-utilization of the lower river. However, too much value should not be placed on superimposition as chinook are known to spawn heavily and superimpose on favored habitat regardless of the availability of similar quality habitat nearby. Until such time that chinook spawning success is hindered, or a specific cause for the shift is identified, remedial actions do not seem appropriate.

COHO

Distribution

Due to the limited information available on the historical distribution of coho in the Sultan River, and limited observations, any conclusions regarding project effects on coho distribution are tentative. Spawning surveys and snorkeling observations made on the 1984 coho run indicated that they could successfully migrate past the powerhouse.

In addition to these data, numerous schools of juvenile coho were observed in areas upstream from the powerhouse during snorkeling observations for summer-run steelhead. The majority of these schools were observed in the Gold Camp and Chaplain Gage areas. These observations provide evidence that in 1984 coho migrated to and successfully spawned in areas upstream from the powerhouse.

WINTER-RUN STEELHEAD

Passage

The majority (24 of 26) of steelhead tagged with radio transmitters did not continue to migrate upriver after tagging. One possible explanation is that tagging caused the fish to sulk and inhibited further upstream migration. Another possibility is that the majority of the fish tagged were not destined to spawn in the upper river. This behavior could be due to the origin of most, or all, of the tagged fish. Results of the subsequent scale analyses indicated that 100 percent of the readable scales were from hatchery fish originally planted downstream from the powerhouse. These results were not expected as most of the tagged fish had dorsal fins larger than two inches with no indication of stubbing. These characteristics are generally used to distinguish wild from hatchery steelhead in the field.

Two of the tagged steelhead migrated through the project vicinity and continued upstream. These fish migrated past the project during potentially confusing flow regimes (near equal flows through the fish passageway slot and turbine discharge) and were not delayed nor did they enter operating turbine discharge canals. Unfortunately, the limited sample size of two fish does not provide conclusive results regarding the steelhead's ability to migrate unaffected past the project.

Distribution

Redd counts made during 1985 showed that the spawning distribution of winter-run steelhead within the Sultan River had not changed significantly from the historical distribution established from data gathered in 1979 and 1980. In 1985, 30 percent of the steelhead redds counted (adjusted for redd life) occurred upstream from the powerhouse; while in 1979 and 1980, 29 and 30 percent, respectively, of the counted redds (also adjusted for redd life) were located upstream from the powerhouse (WDG and Snohomish Co. PUD 1982). The steelhead spawning distribution in later surveys (1987 and 1989) has remained essentially the same (Appendix E). However, a "worst case" scenario– extended period of high flow discharge from the powerhouse– has not occurred yet.

Based on the data collected on the 1985 winter steelhead run, it appears that the fish passageway effectively facilitated the upriver migration of winter-run steelhead. Project operation appeared to have no influence on the distribution of steelhead spawning within the Sultan River. 1985 tended to be a "dry" year in terms of discharge from the powerhouse during the steelhead migration. Discharge from the project was relatively minimal during the migration time period. Consequently, the WDG requested, and Snohomish PUD agreed, to monitor steelhead migrations during a year in which runoff was higher and project operation was more typical of "worst case" passage conditions. The agreement reached was to monitor steelhead migrations from 1987 through 1989, or until a "worst case" project operation scenario occurred if it occurs sooner than 1989. The results of two of these surveys are presented in annual reports, which are in Appendix E. No evidence has been found indicating any problem with either upstream migration or distribution for winter-run steelhead.

SUMMER-RUN STEELHEAD

Distribution

The distribution of summer-run steelhead observed in the Sultan River indicates these fish successfully used the fish berm passageway and distributed themselves throughout the Sultan River from the mouth to the Everett Diversion Dam. Two basic trends were discernable in the distribution of summer-run steelhead. First, more fish were holding in the upper reaches of the river upstream from the powerhouse than the lower sections of the river downstream from the powerhouse. Secondly, summer-run steelhead abundance within the Sultan River peaked during July, followed by a sharp decrease in August.

The decrease in the number of observed summer-run steelhead (particularly in the upper reaches of the Sultan River) coincided with the shut down of the Jackson Hydro Project in 1985. When the project shut down, river flows increased and water temperature decreased in the reach upstream from the powerhouse. These two factors may have prompted downstream fish movement or decreased the efficiency of the observers in the upper river, or both.

ADDENDUM

ADDITIONAL SPAWNING GROUND SURVEYS

After the results of the 1984 (and especially 1985) chinook salmon spawner survey the WDF advised the PUD about its concern over the change (decrease) in the proportion of adult fish spawning upstream from the powerhouse. WDF requested additional surveys in subsequent years, and the PUD agreed to conduct them.

The WDW also requested additional spawning surveys on the winter-run steelhead, as explained earlier on pp. 44-45. Thus, later reports were forthcoming on 1987 and 1989 steelhead spawning ground surveys, which are in Appendix E. One more steelhead survey remains from the agreed upon series of three. The survey probably will be conducted in 1990, assuming it is requested by WDW. The results will be presented in a separate report, which will be submitted to the fish resource agencies for review prior to transmittal to the FERC.

A draft of this final main report was prepared by the PUD with assistance from its consultant, Parametrix, Inc., and submitted to the agencies for review. Survey reports of later years (in Appendices B, and E) were also prepared and submitted to the agencies for their review. This report and the later individual survey reports were revised to reflect agency review comments (Appendices F and G). However, as each additional survey and its report were completed, this main report became increasingly difficult to revise and update to reflect subsequent results. Therefore, the coverage, statistical analyses and text revising were limited finally to years 1984-86. At key places in this report references are made to the subsequent years' survey results when they bear on conclusions.

Based on the results of the 1988 survey on fall salmon spawning (principally chinook), the PUD advised the WDF that further surveys by the utility weren't justified. The WDF advised in reply that it intended to continue its fall salmon spawning surveys of the Sultan River and invited the PUD to continue in a cooperative effort. (See Appendix F). On October 2, 1989, the WDF in cooperation with the two federal agencies (NMFS and USFWS) and the PUD conducted another spawner survey on the Sultan River. The WDF will be preparing the results.

MITIGATIVE PLAN

The study results indicate no further action(s) are necessary beyond the additional spawning ground surveys, which either have been completed or are pending. The agencies have advised the PUD, however, that the situation could change in the future, During consultations between the PUD and the fish agencies mitigative plan elements regarding adult fish passage were identified and discussed, The understanding between the PUD and the Joint Agencies about those elements is as follows:

1. **Mitigation Studies**

Studies will be conducted to determine whether the powerhouse berm facilitates successful upstream migration of anadromous fish and whether entry into Powerhouse draft tube outlets caused injury to such anadromous fish. Those studies have been conducted and completed the results are the basis for this report. Previous drafts of this report and the salmon and steelhead spawning survey reports (Appendices B and E) were sent to the Joint Agencies for their review/comment. Their responses are provided in Appendices F and G.

Except as discussed below in Mitigative Plan Element #2, this element has been completed.

2. **Winter-run Steelhead Trout Surveys**

Additional winter-run steelhead trout spawning surveys were requested. Two of the three have been completed and reports presented herein (Appendix E). The remaining survey in the present understanding between the Washington Department of Wildlife and the PUD may be conducted in 1990, depending upon the outcome of WDW/PUD consultations. Anticipated river flows, power operations and project snowmelt runoff will be key factors in determining whether on not to proceed with the next winter-run steelhead spawning survey.

3. **Powerhouse Discharge Canal Screening**

During Stage II licensing Joint Agencies expressed concern about the possible consequences of adult fish entry into the discharge canals of the Pelton turbines (Units 1 and 2). Consequently, the PUD agreed to provide screening of the canals, if later operational experience and mitigation studies showed the need for it. This mitigative plan element still remains in effect, if needed.

4. **Fish Passage Berm/Powerhouse Tailrace Monitoring**

The PUD will continue visual monitoring of the tailrace area, particularly during the fall salmon spawning migratory period and the upriver steelhead spawning run. The purpose of this monitoring is to detect possible blockage/passage problems of injured/dead adult fish caused by or related to power operation discharges from the Pelton turbines. Passage problems could be symptomized by schooling of adults and disoriented (abnormal) behavior. If such conditions are observed, the PUD will immediately notify the Joint Agencies. Subsequent PUD/Joint Agencies field observations and consultations would be anticipated to evaluate the situation and consider mitigative action.

5. **Fish Passage Berm Maintenance**

As a facility of the FERC-licensed hydroelectric project, the PUD will maintain the fish passage berm to that its operational function continues to be effective.

Maintenance repair work was conducted on the berm during 1989. Such work in the future will be done as before, preceded by consultations with the Joint Agencies concerning the design, scope of work and hydraulics permitting of maintenance efforts.

6. Future Salmon Spawning Surveys

In 1989 the PUD participated in a cooperative effort with the Washington Department of Fisheries on the agency's annual survey of the fall salmon spawner run in the Sultan River. The PUD intends to continue that participation in the future.

7. Supplemental Instream Flows

During the pink salmon spawning runs (in odd-numbered years) since completion of Jackson Project (Stage II), the Washington Department of Fisheries has requested additional instream flow to improve lower river spawning habitat areas for large numbers of adult spawners. The PUD will continue to cooperate with the Joint Agencies in that regard to the extent that it is possible to do so in the future. Each year and each situation for flow supplementation must be evaluated as a specific or unique opportunity. The PUD is optimistic that the present cooperative and mutually productive situation will continue concerning project operation and fishery production and mitigation.

8. Annual Report

Along with other aquatic resources obligations the PUD will include information on adult fish passage past the powerhouse and the fish passage berm, as warranted in the annual report on Jackson Project operations related to FERC license Article 57 (Flood Control).

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