

EVALUATION OF FISH FACILITIES AND PASSAGE AT
FOSTER AND GREEN PETER DAMS ON THE
SOUTH SANTIAM RIVER DRAINAGE IN OREGON

by
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TABLE OF CONTENTS

	<u>Page No.</u>
INTRODUCTION	1
THE FOSTER-GREEN PETER PROJECT.....	2
<u>General</u>	2
<u>Upstream-Migrant Facilities</u>	7
<u>Foster Dam</u>	7
<u>Green Peter Dam</u>	11
<u>Downstream-Migrant Facilities</u>	12
<u>Foster Dam</u>	12
<u>Green Peter Dam</u>	14
METHODS AND EQUIPMENT.....	18
<u>Upstream Migrants</u>	18
<u>Foster Dam</u>	18
<u>Green Peter Dam</u>	19
<u>Downstream Migrants</u>	20
<u>Foster Dam</u>	20
<u>Green Peter Dam</u>	22
<u>Limnological Observations</u>	26
RESULTS.....	26
<u>Upstream Migration</u>	26
<u>Foster Dam</u>	26
<u>Numbers</u>	26
<u>Timing and Delays</u>	29
<u>Collection Efficiency of Ladder Entrances</u>	33
<u>Drop-back and Recapture</u>	33
<u>Handling of Fish</u>	36
<u>Hopper Transfer System</u>	36
<u>Mortalities</u>	37
<u>Green Peter Dam</u>	38
<u>Numbers</u>	38
<u>Timing and Delays</u>	40
<u>Drop-back into Tailrace</u>	44
<u>Hopper Transfer System</u>	44
<u>Mortalities</u>	44
<u>Spawning</u>	45
<u>Downstream Migration</u>	47
<u>Green Peter Dam</u>	47
<u>Sampling Techniques at Evaluator</u>	47
<u>Passage Success</u>	49
<u>Numbers of Emigrants</u>	52
<u>Timing of Emigrants</u>	56
<u>Size</u>	57

	<u>Page No.</u>
<u>Affect of Facilities on Survival</u>	62
<u>Operational Tests</u>	66
<u>Stoplog Wells</u>	71
<u>Catch by Anglers</u>	71
<u>Foster Dam</u>	72
<u>Passage Success</u>	72
<u>Numbers of Emigrants</u>	76
<u>Timing</u>	76
<u>Survival and Condition of Emigrants</u>	80
<u>Operational Tests</u>	84
<u>Catch by Anglers</u>	85
<u>Limnology</u>	85
<u>Green Peter Dam</u>	85
<u>Physical Observations in the Reservoir</u>	85
<u>Effects of the Reservoir on the Stream</u>	
<u>Below the Dam</u>	86
<u>Biological Observations in the Reservoir</u>	88
<u>Foster Dam</u>	89
<u>Physical Observations in the Reservoir</u>	89
<u>Effects of the Reservoir on the Stream</u>	
<u>Below the Dam</u>	91
<u>Biological Observations in the Reservoir</u>	93
CONCLUSIONS.....	94
RECOMMENDATIONS.....	96
<u>General</u>	96
<u>Passage of Adults</u>	98
<u>Passage of Downstream Migrants</u>	100
SUMMARY.....	102
ACKNOWLEDGEMENTS.....	110
LITERATURE CITED.....	111

LIST OF FIGURES

<u>Figure No.</u>		<u>Page No.</u>
1	Location Map of Foster and Green Peter Dams.....	3
2	Aerial View of Foster Dam, Reservoir and Drainage Area...	4
3	Aerial View of Green Peter Dam, Reservoir, and Drainage Area.....	5
4	Aerial View of Foster Dam Showing Location of Fish Ladder and Entrances.....	8
5	Diagram of Foster Dam Adult Facility.....	9
6	Schematic Diagram of Foster Dam Adult Fishway Water Supply and Flow Controls.....	10
7	Schematic Diagram of Green Peter Dam Adult Fishway Water Supply and Flow Controls.....	13
8	Aerial View of Green Peter Dam Showing Location of Downstream-Migrant Collection Facility and Spillway Bays.....	15
9	Diagram of Green Peter Downstream-Migrant Collection Facilities.....	16
10	Diagram of Green Peter Downstream-Migrant Collection Horn and Separator Unit.....	17
11	Turbine Nets in Foster Dam Tailrace.....	21
12	Scoop Traps Operated Below Foster Dam.....	21
13	Aerial View of Green Peter Evaluator (A) and Discharge Chute (B).....	23
14	Schematic Diagram of the Downstream-Migrant Counting Facility, Green Peter Dam.....	24
15	Upstream Migrant Chinook Counts, Stream Flows and Water Temperatures at Foster Dam, May-September 1967-71.....	30
16	Spring Chinook and Winter Steelhead Collected in the Green Peter Upstream-Migrant Facilities, by 3-Day Periods, Expressed as a Percentage of the Total Run, 1967-71....	41
17	Size of Wild-Reared Juvenile Spring Chinook Salmon Emigrating from Green Peter Reservoir, 1966-69 Broods..	60

LIST OF FIGURES (con'd)

<u>Figure No.</u>		<u>Page No.</u>
18	Numbers of Marked Wild-Reared Spring Chinook Released at the Green Peter Evaluator and Collected in the Foster Turbine Nets, March-June 1970.....	78
19	Numbers of Tagged Winter Steelhead Released at the Green Peter Evaluator and Collected in the Foster Turbine Nets, March-June 1970.....	79
20	Survival of Yearling Hatchery Chinook Passing Through the Turbines During Automatic Cam Operation, Foster Dam, 1969.....	83
21	Formation and Disintegration of Thermal Stratification in Green Peter Reservoir, 1969.....	87
22	Formation and Disintegration of Thermal Stratification in Foster Reservoir, 1969.....	90

LIST OF TABLES

<u>Table No.</u>		<u>Page No.</u>
1	Counts of Upstream-Migrant Salmon and Steelhead at Willamette Falls and Foster Dam, 1967-71.....	27
2	Numbers and Percentages of Winter Steelhead Collected at Foster Dam, by Month 1967-71.....	32
3	Numbers of Adult Fish Marked and Recaptured at Foster Dam, Selected Months, 1968 and 1971.....	35
4	Counts of Upstream Migrant Salmon and Steelhead at Foster and Green Peter Dams, 1967-71.....	39
5	Efficiency of Collection, Downstream-Migrant Facility, Green Peter Dam, 1968-70.....	51
6	Estimated Numbers of Wild-Reared Salmonids Collected by the Green Peter Downstream-Migrant Facilities, October-July 1968-71.....	53
7	Numbers of Hatchery Chinook Fry and Estimated Numbers of Wild Chinook Fry Available Above Green Peter Dam, and the Percentage Emigrating Downstream, 1967-70.....	54
8	Wild-Reared Juvenile Chinook Counted at the Evaluator, Green Peter Dam, 1968-71.....	58

LIST OF TABLES (con'd)

<u>Table No.</u>		<u>Page No.</u>
9	Unmarked Juvenile Winter Steelhead Counted at the Evaluator, Green Peter Dam, 1968-71.....	59
10	Mortality of Wild-Reared Emigrants by Run Year, Green Peter Evaluator, 1968-71.....	64
11	Effect of a Submerged Mercury Vapor Light on the Daily Catches of Fish Emigrating from Green Peter Reservoir, 1969-70.....	68
12	Average Catch-per-Day when Operating a Mercury Vapor Light at Selected Depths, Green Peter Dam, December-February 1970 71.....	68
13	Average Catch-per-Day When Operating the Horn Intake at Selected Depths at Green Peter Dam, June 1970.....	70
14	Summary of Recovery Rates for Test Fish Used in Downstream-Migrant Studies at Foster Dam, 1969-70.....	74
15	Estimated Numbers of Salmonids Emigrating Through the Penstocks of Foster Dam, May-June 1969 and March-June 1970.....	77
16	Assigned Turbine Mortality of Wild-Reared Downstream Migrants Collected in the Turbine Nets at Foster Dam, 1969-70.....	81
17	The Estimated Survival of Juvenile Salmonids Emigrating from Foster Reservoir, 1968-69.....	84
18	Selected Water Temperatures and Dissolved Oxygen Data, Summer and Fall Seasons, Green Peter Reservoir, 1968-70	88
19	Selected Water Temperatures and Dissolved Oxygen Data, Summer and Fall Season, Foster Reservoir, 1968-70.....	91
20	Temperature in Degrees Centigrade of South Santiam River below Foster Dam, 1962-71.....	92

EVALUATION OF FISH FACILITIES AND PASSAGE AT
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INTRODUCTION

The U. S. Army Corps of Engineers completed construction of the Green Peter-Foster project in the spring of 1969. Green Peter Dam began impounding water in October 1966 and Foster Dam began in December 1966. Prior to impoundment, the Oregon Game Commission using Corps funds, chemically treated the reservoir areas and the tributary streams above both dams to control undesirable species of fish. Spring chinook and winter steelhead are indigenous to the South Santiam system above Lebanon, Oregon. Coho, sockeye, and summer steelhead were introduced in 1961, 1967, and 1969, respectively. Provisions at the project for evaluating anadromous fish runs consist of adult handling and counting facilities at both dams and a special downstream-migrant collection and counting facility at Green Peter Dam. No provisions were made for counting or handling downstream migrants at Foster Dam. Juvenile fish must pass through the spillway or turbines at that dam. Subsequent to construction of Green Peter and Foster dams, Pacific Power and Light Company agreed to deactivate their turbines on the unscreened Lebanon Canal during the November-June downstream migration period of hatchery and wild anadromous salmonids.

From July 1967 through October 1971, the Fish Commission of Oregon conducted an evaluation study designed to determine the efficiency of the fish passage facilities. The study was financed by the Corps and supervised by a steering committee composed of one member each from the Corps of Engineers, Fish Commission of Oregon, Oregon Game Commission, Bureau of Sport Fisheries and Wildlife, and the National Marine Fisheries Service.

THE FOSTER-GREEN PETER PROJECT

General

The Foster-Green Peter Project consists of Foster Dam on the South Santiam River, Green Peter Dam on the Middle Santiam River (Figure 1), and a salmon hatchery located immediately below Foster Dam.

Foster Dam (Figure 2), a rockfill structure 4,565 feet long and 126 feet high, impounds water from both the South and Middle Forks of the Santiam River. It contains a hydroelectric power plant with two Kaplan turbines rated at 10,000 kilowatts each. When full, the pool formed by the dam is 3.5 miles long and covers 1,220 surface acres, with a total storage capacity of 61,000 acre feet. Additional to regulating discharges from Green Peter Dam, Foster Reservoir is also operated for the benefit of flood control, power production, downstream navigation, irrigation, recreation, domestic water supply, fish life and pollution abatement.

Green Peter Dam (Figure 3), on the Middle Santiam River 6 miles above Foster Dam, impounds water from both the Middle Fork and Quartzville Creek. It is a concrete structure 1,500 feet long and 360 feet high. A hydroelectric power plant at the dam contains two Francis turbines rated at 40,000 kilowatts each. When full, the reservoir formed by the dam extends 10 miles upstream and covers 3,720 surface acres, with a total storage capacity of 430,000 acre feet. Green Peter Dam is operated primarily for flood control, power production, navigation, irrigation, recreation, domestic water supply, fish life, and pollution abatement.

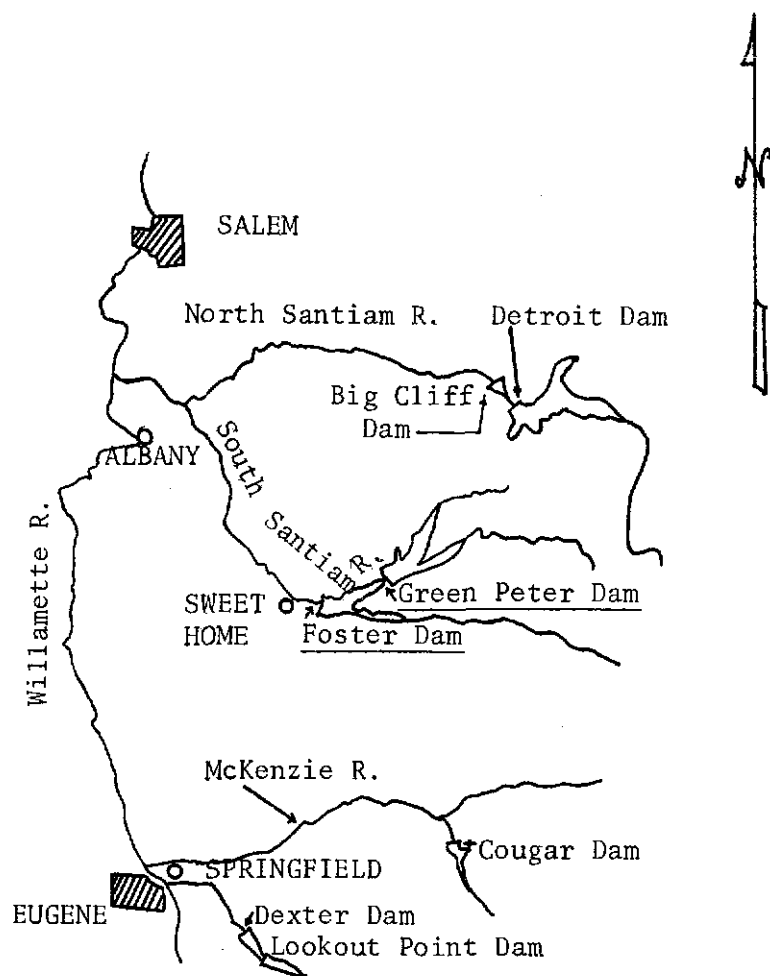


Figure 1. Location Map of Foster and Green Peter Dams



Figure 2. Aerial View of Foster Dam, Reservoir, and Drainage Area



Figure 3. Aerial View of Green Peter Dam, Reservoir,
and Drainage Area

The Corps annually regulates water levels in the two reservoirs according to a "rule curve," which attempts to maintain water impoundment commensurate with project aims. In an average water year, the Corps holds reservoir levels at minimum pool elevation (Foster Reservoir 613, Green Peter Reservoir 922 ^{1/}) from mid-November to February 1 to provide storage for winter freshets. Reservoir filling begins in February, and with favorable conditions maximum conservation pool (Foster 637, Green Peter 1,010) is attained by May. The Corps maintains these levels until August or September when reservoir evacuation begins in preparation for the winter flood season. The reservoirs reach minimum pool by mid-November and the cycle is repeated.

Discharges below Foster Dam may vary from a minimum of 400 cfs to the maximum capability of 196,000 cfs. Flows in the short river section between Green Peter Dam and the upper reaches of Foster Reservoir range from 50 cfs to a maximum discharge capability of 110,000 cfs. Maximum flood on record was 90,000 cfs in 1861.

Anadromous fish passing the projects include: spring chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), and sockeye salmon (*O. nerka*), and winter- and summer-run steelhead (*Salmo gairdneri* var.). Resident species present in both reservoirs include rainbow trout (*S. gairdneri*), cutthroat trout (*S. clarki*), and dace (*Rhinichthys* sp.) and coarse-scaled suckers (*Catostomus macrocheilus*). In addition to the foregoing, the following species are only found in Foster Reservoir:

^{1/} Reservoir levels expressed as "feet above mean sea level."

whitefish (*Prosopium williamsoni*), redbreasted shiners (*Richardsonius balteatus*), squawfish (*Ptychocheilus oregonensis*), bluegill (*Lepomis macrochirus*), bullhead catfish (*Ictalurus* sp.) and lamprey (*Lampetra planeri*).

Upstream-Migrant Facilities

Foster Dam. Fish passing upstream at Foster Dam enter either the tailrace or spillway ladder entrance (Figure 4), then pass up a short ladder section to the trapping area. Trapping and transport equipment for adult fish ascending the ladder includes: the holding pool, fish-sweep, anesthetic tank, fish-hopper, and craneway-hoists.

The holding pool which is located at the head of the fish ladder has a finger weir at the downstream end allowing entry but resisting escape. From this pool, all fish are crowded into an anesthetic tank by the fish-sweep. Once in the anesthetic (Tricaine Methanesulfonate, MS-222), all fish are counted and examined for marks, tags, injuries, and occasionally other information. Scrap fish are placed back downstream and the desirable species placed in the 1,000 gallon fish-hopper for transport over the dam. The fish-hopper is operated by craneway-hoists located on top of the dam (Figure 5). Manual operation of the craneway-hoists allows for emptying the hopper into either the forebay or into a transportation truck on top of the dam.

The water source for operating the Foster Dam adult collection facilities originates in the upstream end of the number 1 penstock (Figure 6). Two intakes, located at different levels within the penstock, allow mixing for proper water temperature in the fish ladder. However, the upper intake, which is 38 feet deep at full conservation pool, is

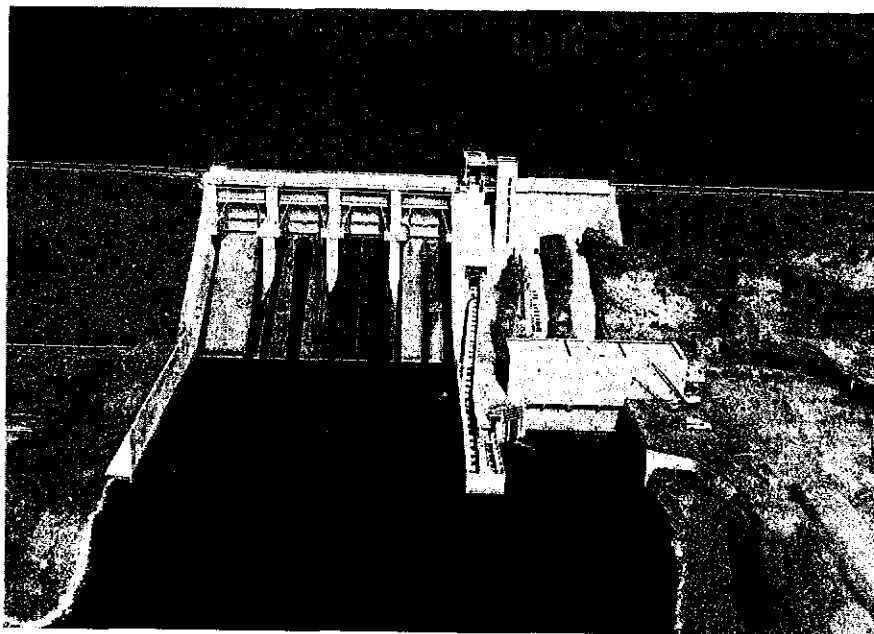


Figure 4. Aerial View of Foster Dam Showing Location of Fish Ladder and Entrances

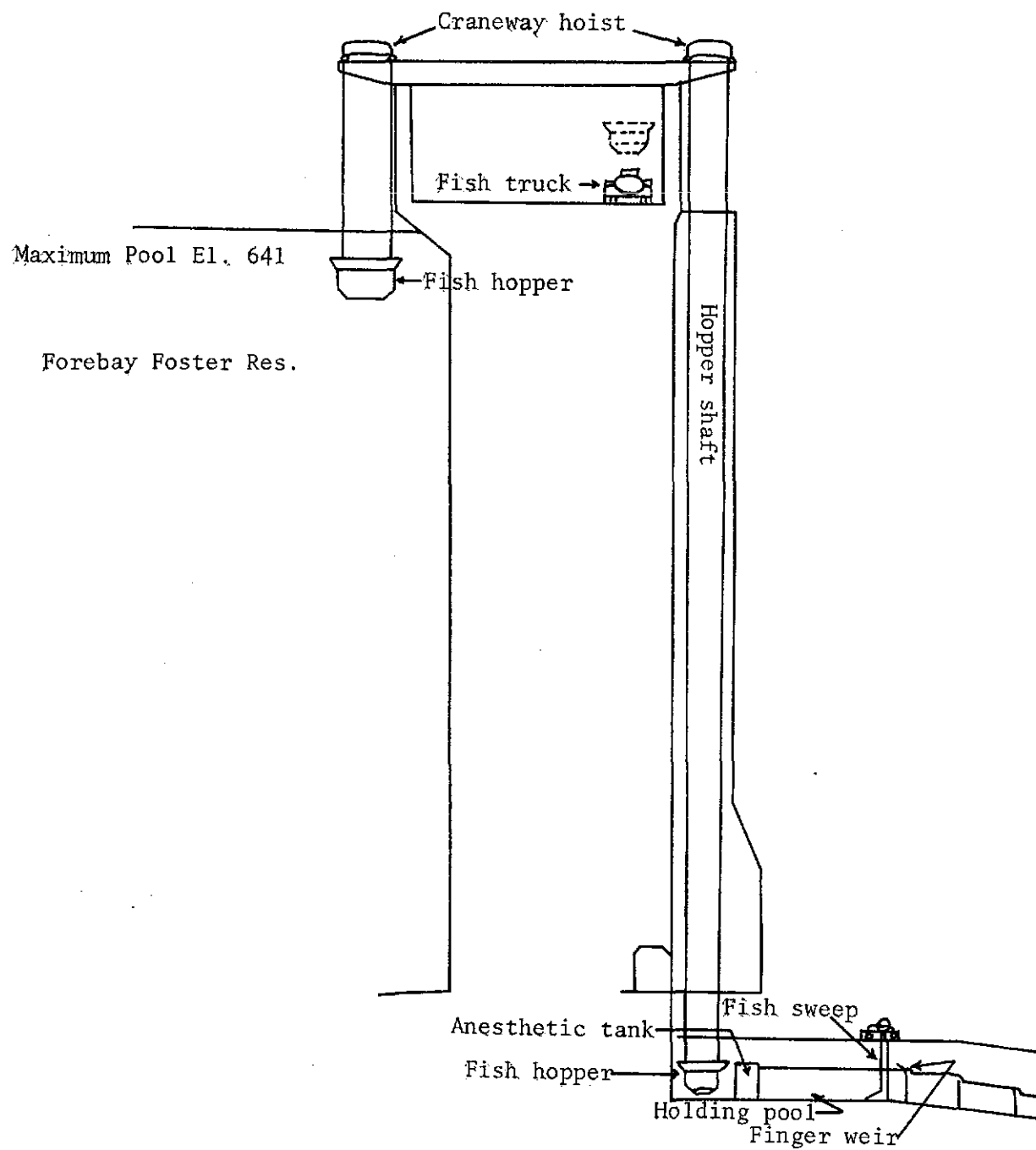


Figure 5. Diagram of Foster Dam Adult Facility

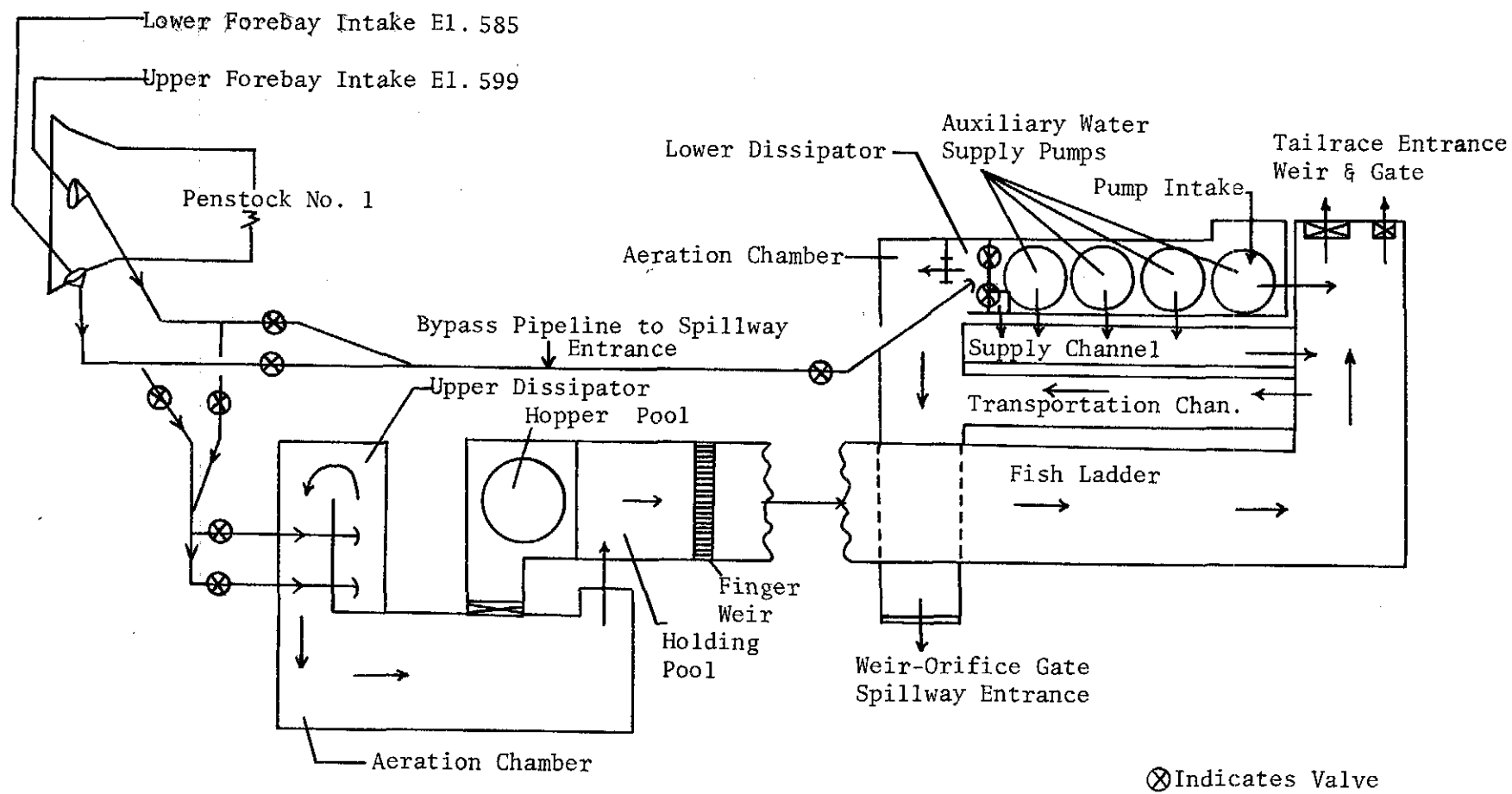


Figure 6. Schematic Diagram of Foster Dam Adult Fishway Water Supply and Flow Controls
 Note: Arrows show direction of water flow.

located too deep to increase the ladder water temperature in the spring and summer. Water entering the intakes is routed through two distribution systems. The first supplies water to the holding pool from where it passes down the fish ladder. The second system provides supplemental attraction flow at the spillway entrance to the ladder. The spillway entrance is a 4-foot wide weir orifice gate automatically controlled to provide predetermined entrance velocities. Flows from the spillway entrance are usually a constant 100 cfs. Pumps add auxiliary water to the tailrace entrance. Attraction flow at the tailrace entrance may vary from 41-160 cfs depending upon tailrace water levels. Fish enter the ladder from the tailrace either through a 6-foot wide weir-orifice gate or an 18-inch wide free flow slot. The weir-orifice gate at the tailrace is controlled similarly to the spillway entrance gate.

The main fish ladder is designed with a 1 on 10 slope. It is 8 feet wide with 6-foot overflow weirs located 10 feet apart. Each weir has an 18-inch square submerged orifice located at the bottom center. Drop between pools is maintained at 1 foot with 37 cfs flow. A transportation channel connecting the spillway entrance with the tailrace entrance pool (Figure 6) is 4 feet wide and is designed to maintain velocities of 1-2 fps throughout its length.

Green Peter Dam. Trap and transport equipment for adult fish ascending the Green Peter fish ladder are similar to those described for Foster Dam. Two major differences are incorporated into the Green Peter facilities. The first of these is in the Green Peter holding pool. Instead of a fish-sweep, there is a brail located on the floor which

is raised to crowd the fish into the fish-hopper. No provisions were made for anesthetizing, handling, or sorting fish at Green Peter. The second modification is the placement of two fish-hoppers on a turntable just upstream from the holding pool (Figure 7). This dual system allows one hopper to be in fishing position while the other is being lifted over the dam.

The water supply for operation of the Green Peter fish ladder originates in the penstock entrance similar to Foster Dam. The water passes through a 1,000 kilowatt fish-water turbine and energy dissipator before entering the fish ladder. A standby system may also pass water directly from the penstock to the energy dissipator and into the fish ladder (Figure 7). Auxiliary attraction water is added by pumps at the fishway entrance when the power units are operating. The pumps add up to 110 cfs, making a total attraction water discharge of 160 cfs at the fishway entrance. The fish ladder weirs and slope are designed the same as the Foster ladder.

The ladder entrance from the tailrace is through either a 3-foot-wide weir-orifice gate or through an 18-inch wide free flow slot. Operation of the entrance gates and auxiliary attraction flow is similar to that at Foster Dam.

Downstream-Migrant Facilities

Foster Dam. No collection or transport facilities were provided for juvenile salmonids at Foster Dam, but the Kaplan turbines installed at Foster Dam were designed to satisfactorily pass downstream migrants. The center line of the penstock entrance is at elevation 590, between

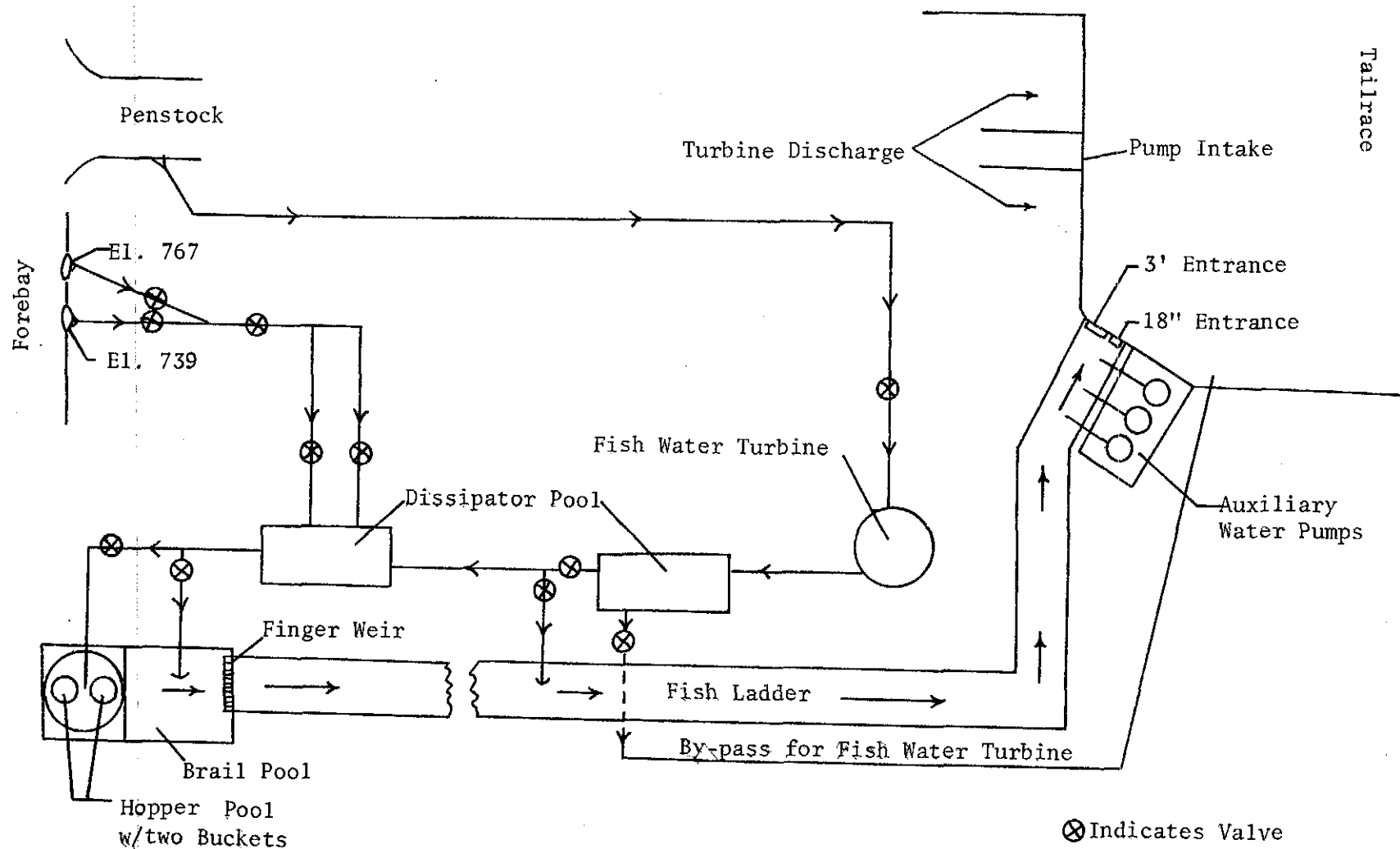


Figure 7. Schematic Diagram of Green Peter Dam Adult Fishway Water Supply and Flow Controls
 Note: Arrows show direction of water flow.

23 and 50 feet from the surface depending on reservoir level. This location was incorporated into the design of the dam to gain maximum attraction (commensurate with powerhouse operation) of juvenile salmon moving through the reservoir. The generating units are primarily operated at 88% efficiency, or above 800 cfs discharge during the fall, winter, and spring. High efficiency is generally associated with maximum survival of downstream migrants.

Downstream migrants may also exit from Foster Reservoir through the spillway gates during spill periods. Flows through the spillway depend on releases needed to maintain desired pool elevations. The spillway crest is at elevation 596 which locates this downstream-migrant egress route between 17- and 44-feet deep depending on reservoir elevation.

Green Peter Dam. The Green Peter fingerling collection facility (Figure 8) is located near the spillway, penstocks, and regulating outlets in the reservoir to take advantage of all attraction as an aid to collect emigrating fish for passage downstream. The major components of the system as shown in Figure 9 are: the separator unit, attraction water pumps, well, the transport-pipe system, and the collection horn.

The horn (Figure 10) which is 20 feet high and 6 feet wide, is designed to operate with the center line from 15 to 30 feet deep. This 15-foot range is available at all pool elevations from 1,015 (maximum pool) to 922 (minimum conservation pool), a spread of 93 feet vertically.

Flow through the system is provided by two 100-horsepower pumps which draw water from the bottom of the well and discharge it back

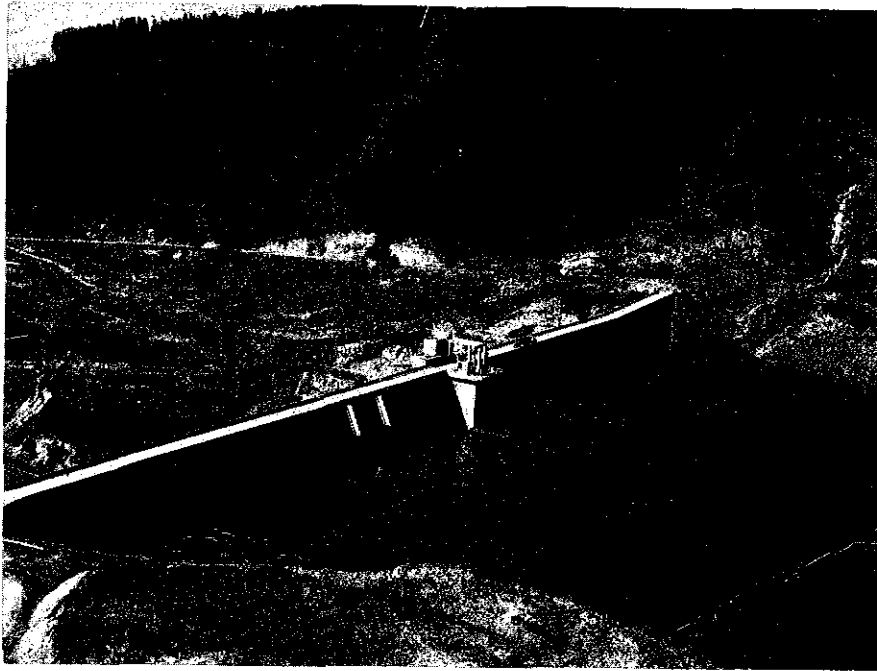


Figure 8. Aerial View of Green Peter Dam Showing Location of Downstream-Migrant Collection Facility (Center of Photo) and Spillway Bays (Left Center of Photo)

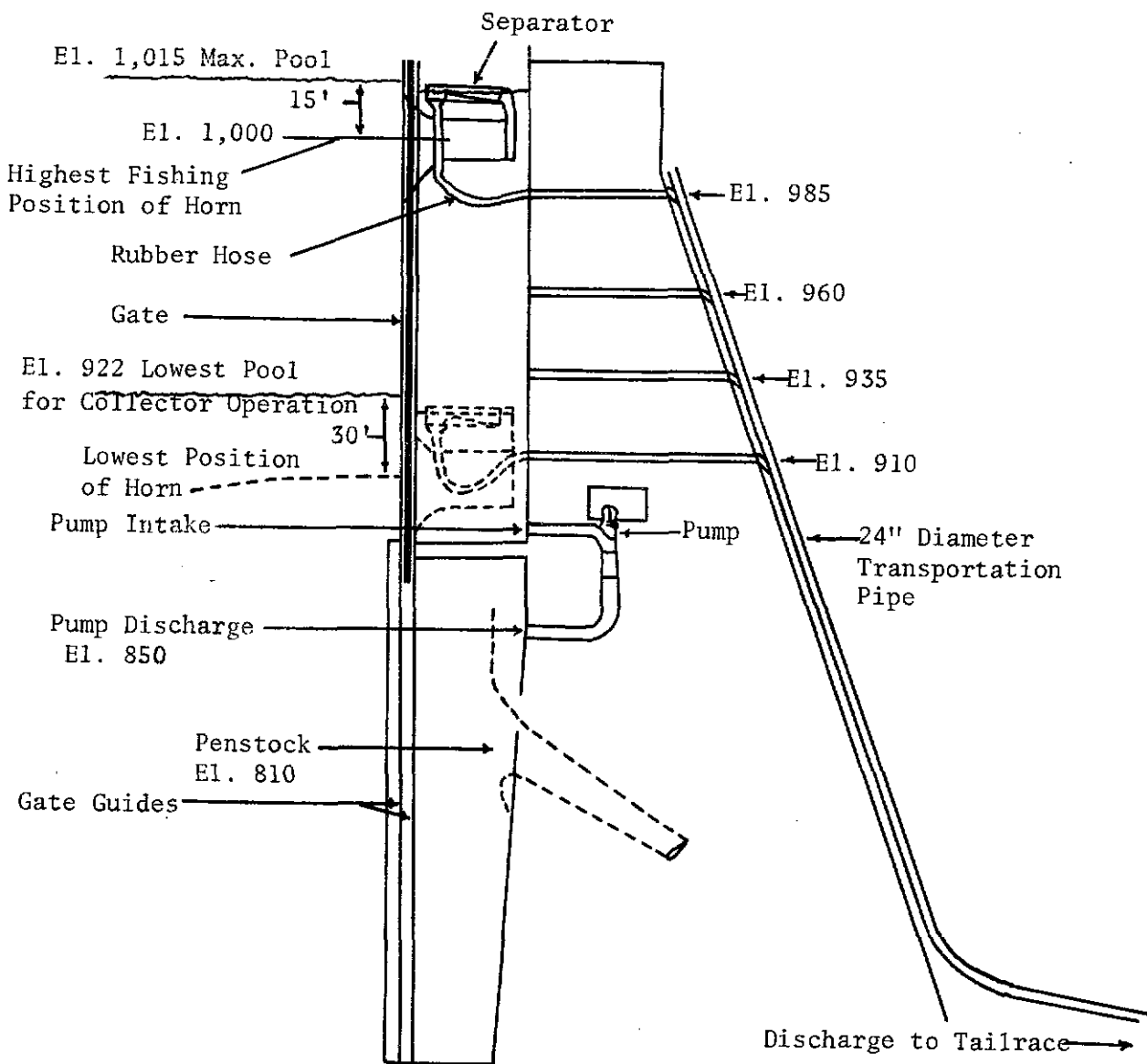


Figure 9. Diagram of Green Peter Downstream-Migrant Collection Facilities

Supporting Framework and Hoisting
Mechanism Omitted

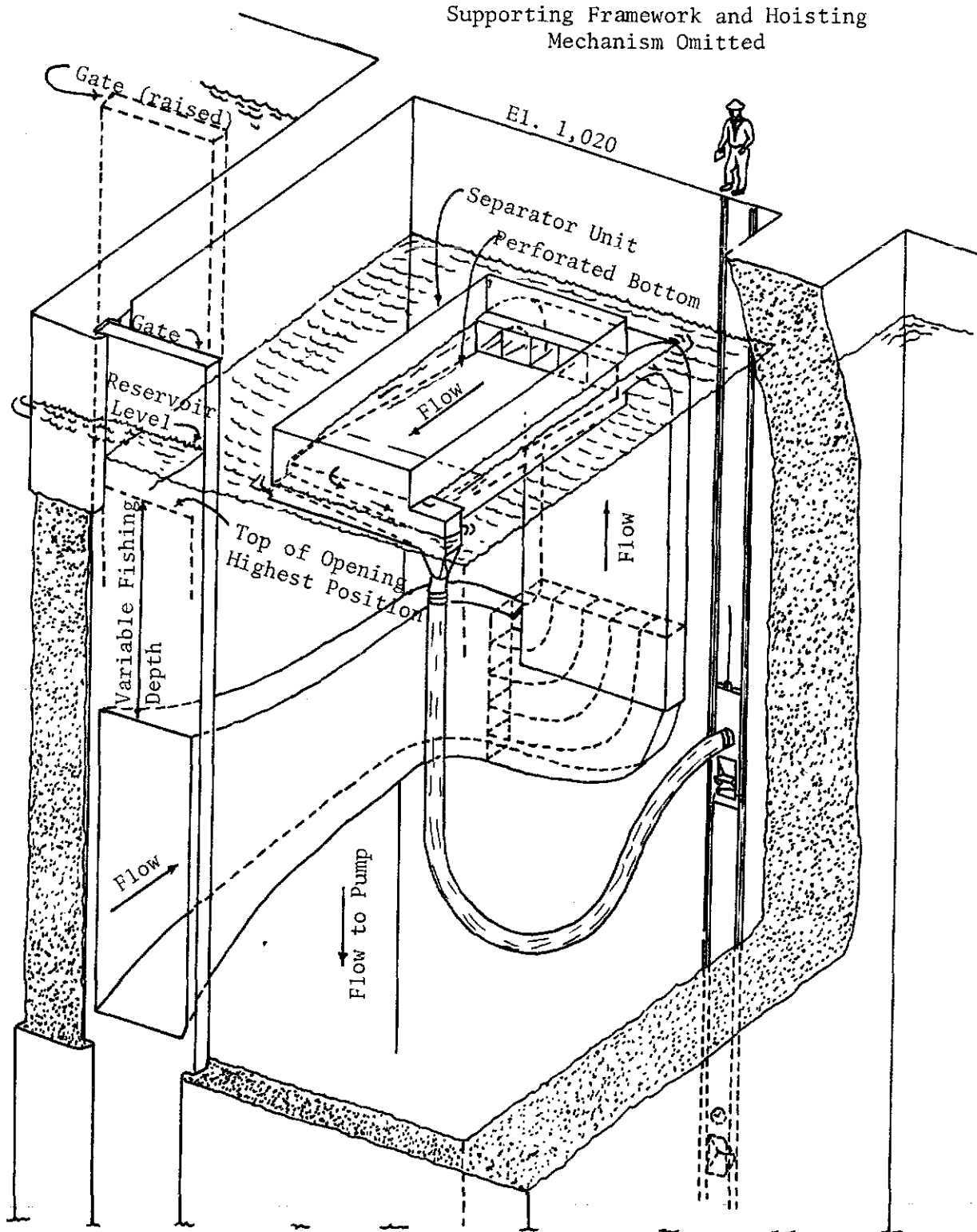


Figure 10. Diagram of Green Peter Downstream-Migrant Collection Horn and Separator Unit

into the forebay. With both pumps in operation a differential of approximately 3.5 to 4 feet is maintained between water in the forebay and that in the well. This differential causes water to flow into the horn, through the vaned conduit, and across the separator unit (Figure 10). Fish passing through the horn enter an approach velocity of 0.1 foot per second, 18 feet from the horn. This velocity increases to about 10.0 fps at the throat of the horn and across the separator screen. All but approximately 6-10 cfs passes through the perforated plate. The remaining 6-10 cfs and captured fish enter a trough at the end of the separator leading to a 12-inch flexible hose attached to one of four 12-inch laterals passing through the dam to the 24-inch transportation conduit.

The flexible hose is reinforced rubber with a smooth interior surface to prevent abrasions to the fish. The flexible hose connects to one of the four laterals depending on forebay elevation. The laterals are black iron pipe which have been coated with vinyl to prevent rusting and provide a smooth transportation surface. From the laterals, fish and water enter the stainless steel transport pipe on the downstream face of the dam. At the downstream end of the powerhouse, this stainless steel pipe changes to a vinyl-lined iron pipe which extends 300 feet downstream providing a deceleration zone before entering the rubber-lined chute that extends under the evaluator to the tailrace.

METHODS AND EQUIPMENT

Upstream-Migrants

Foster Dam. We counted all anadromous fish passing the project to determine numbers and timing for each species. We compared

these data to the volume and temperature of water discharged from the dam to determine if relationships existed.

Study personnel qualitatively observed the efficiency of the ladder, holding pool, and fish handling operations. At our request, the Corps manipulated entrance gates to enable us to observe changes in passage efficiency.

We tagged adult salmonids collected at the dam and released them into the forebay or above the reservoir to determine the numbers of fish dropping back downstream via the spillway or turbines and then re-entering the fishway. Additionally, tagging enabled us to determine the site of release of identifiable fish recovered on the spawning grounds.

Standard U.S. Geological Survey gauging stations on the South Santiam River relayed flow data to Foster Dam via a telemeter system. We obtained stream temperatures from the USGS and from our own recording thermometer located in the spillway basin at Foster. We also recorded fishway water temperatures from the loading pool area of the fish ladder.

Green Peter Dam. We counted and examined adult fish at Green Peter Dam. Fish in the holding pool were placed into the fish-hoppers by a false floor brail which forced fish through a counting and observation area. No provisions were made for anesthetizing or physically handling fish in the Green Peter fishway. We recorded species, numbers, and visible marks or tags each time the facility was operated.

Flows obtained by the Corps in the Middle Santiam below Green Peter Dam and water temperatures taken from a recording thermometer maintained below the dam were compared with fish counts where possible.

We conducted surveys in streams above the reservoir to determine spawning success of fish passing the project. Uniquely marked fish transported from Foster and Fall Creek dams were placed upstream for tests of spawning success and distribution.

Downstream-Migrants

Foster Dam. Since no counting facilities were provided at Foster Dam, sampling gear was utilized during periods of peak emigration. The gear used to collect downstream migrants at Foster Dam consisted of two draft tube nets positioned over the discharge ports of unit number 1, and two scoop traps fished downstream to sample fish emigrating via the spillways and turbines combined (Figures 11 and 12).

In 1969, the Corps installed the turbine nets during April and conducted passage survival tests through mid-May. We utilized the nets from mid-May until June 27 to enumerate numbers and species of downstream migrants. In 1970, we began fishing the nets on March 26 and discontinued fishing on June 18. The deteriorated condition of these nets after the 1970 season precluded using them for further tests.

The scoop traps were fished downstream of the dam during periods of spillway discharge. In 1969, we operated these traps for 9 days. During 1970 the scoop traps were operated 11 days from April to June. Due to poor sampling efficiency and operational difficulty, the scoop traps were not used for further tests.

In 1969 and 1970, we released groups of marked chinook and steel-head into Foster Reservoir for tests of passage success. Estimates of successful passage were made by expanding sample catches made in both the turbine nets and scoop traps. Additional to reservoir releases,

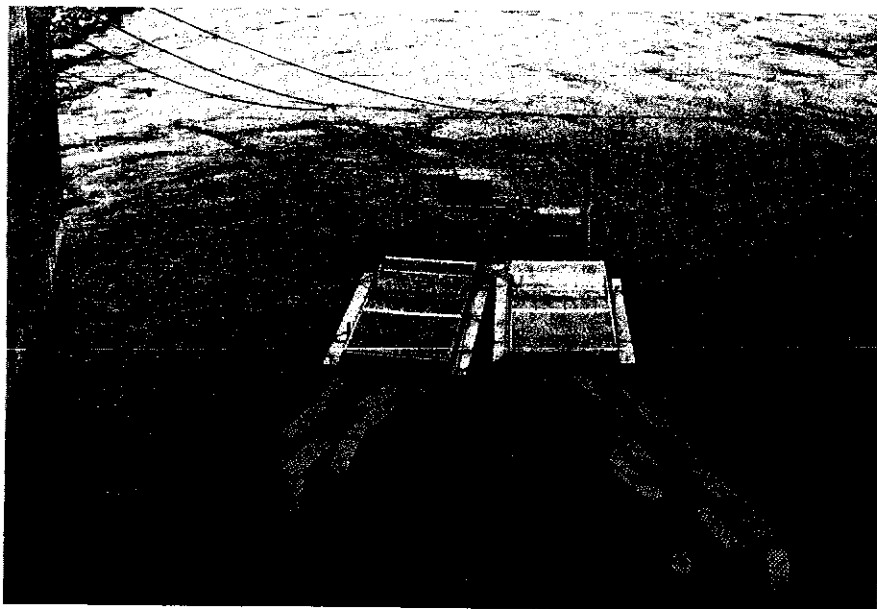


Figure 11. Turbine Nets in Foster Dam Tailrace

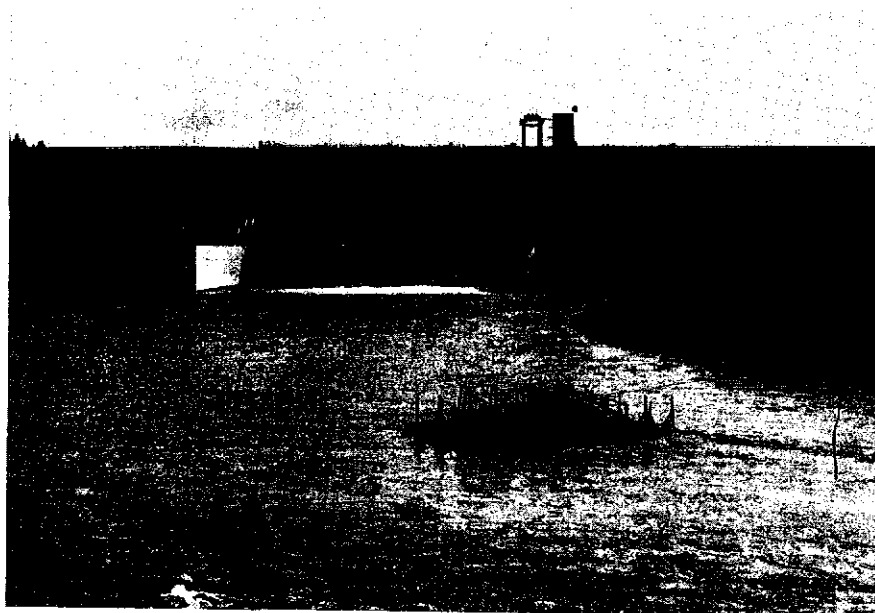


Figure 12. Scoop Traps Operated Below Foster Dam

marked test fish were released into the stilling basin during periods of spill to evaluate scoop trap efficiency.

All fish entering both the turbine nets and scoop traps were counted daily. The usual counting method was to anesthetize all live fish and examine for species, marks, and injuries.

Green Peter Dam. All fish leaving Green Peter Reservoir via the collection facility were enumerated at the trapping and counting facility located at the discharge end of the transport-pipe system (Figure 13). This facility (hereinafter called the evaluator) consisted of an inclined section of perforated plate where fish were separated from the 6-10 cfs of transport water. After the water dropped through the plate, fish slid into a well where they were held until removed for counting and examination (Figure 14). After counting all fish during the first downstream-migrant season, we decided to estimate subsequent runs of fish by sampling a portion of the emigrants. This was accomplished by installing a trap door by-pass (sampler plate) in the perforated plate section. The trap door was driven by an electric motor and automatically operated on a selected time basis. Depending on numbers of fish emigrating, a $1/3$, $1/5$, or $1/10$ sample was counted.

Operation of the downstream-migrant collector generally began in October and continued until the end of June. Closure of the facility during the summer months was necessary to prevent subsmolt fish from emigrating. We felt these fish would survive better if they remained and grew in the reservoir until fall.

We released marked populations of yearling chinook and 2-year-old steelhead into the reservoir to determine success of passage of downstream

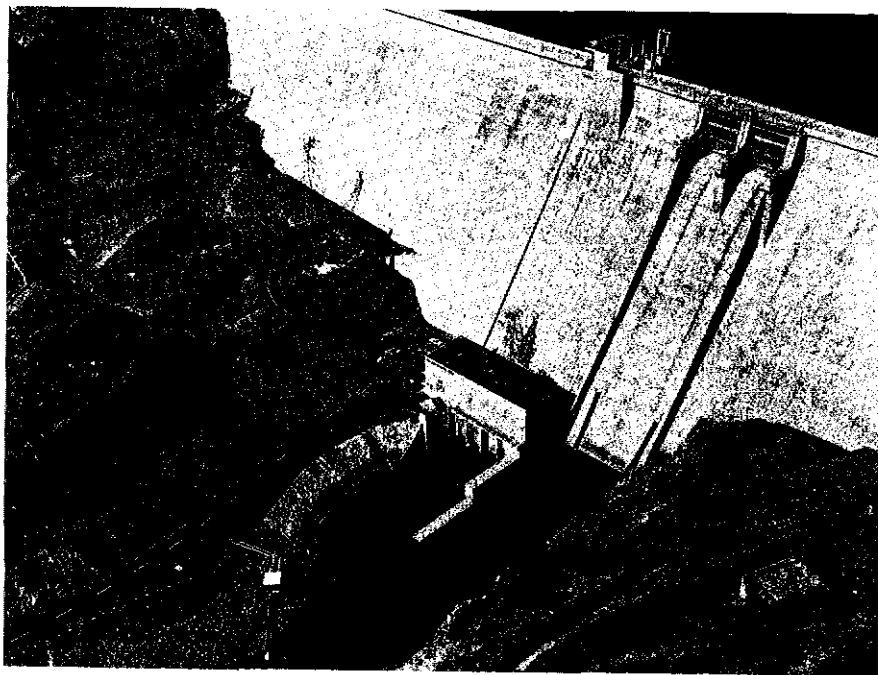
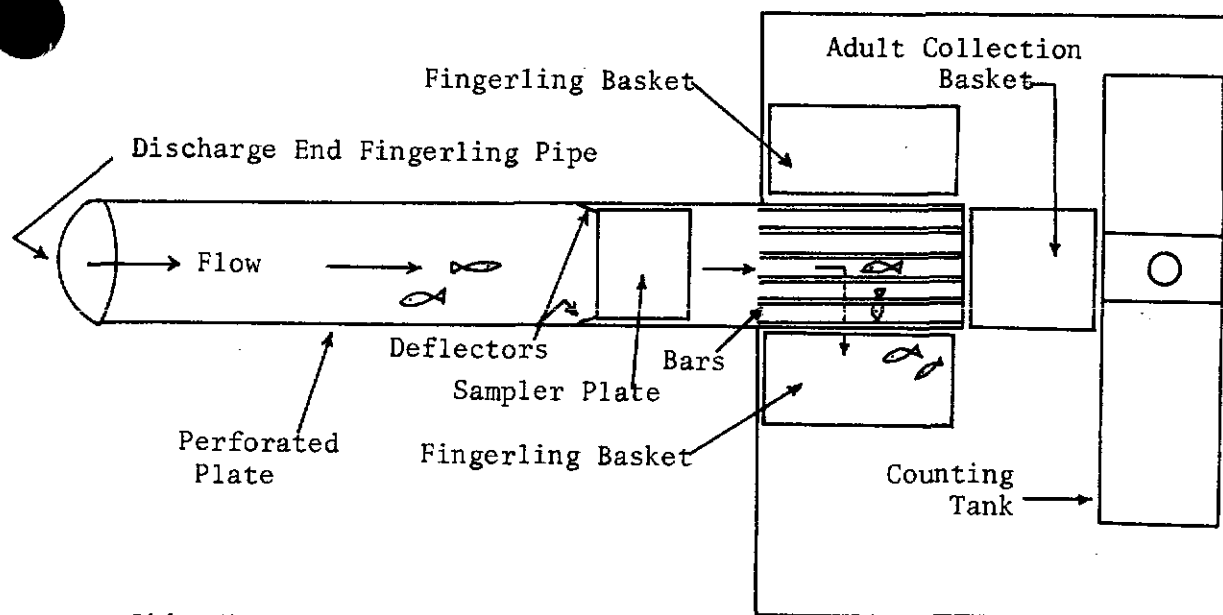


Figure 13. Aerial View of Green Peter Evaluator (A)
and Discharge Chute (B)



Side View

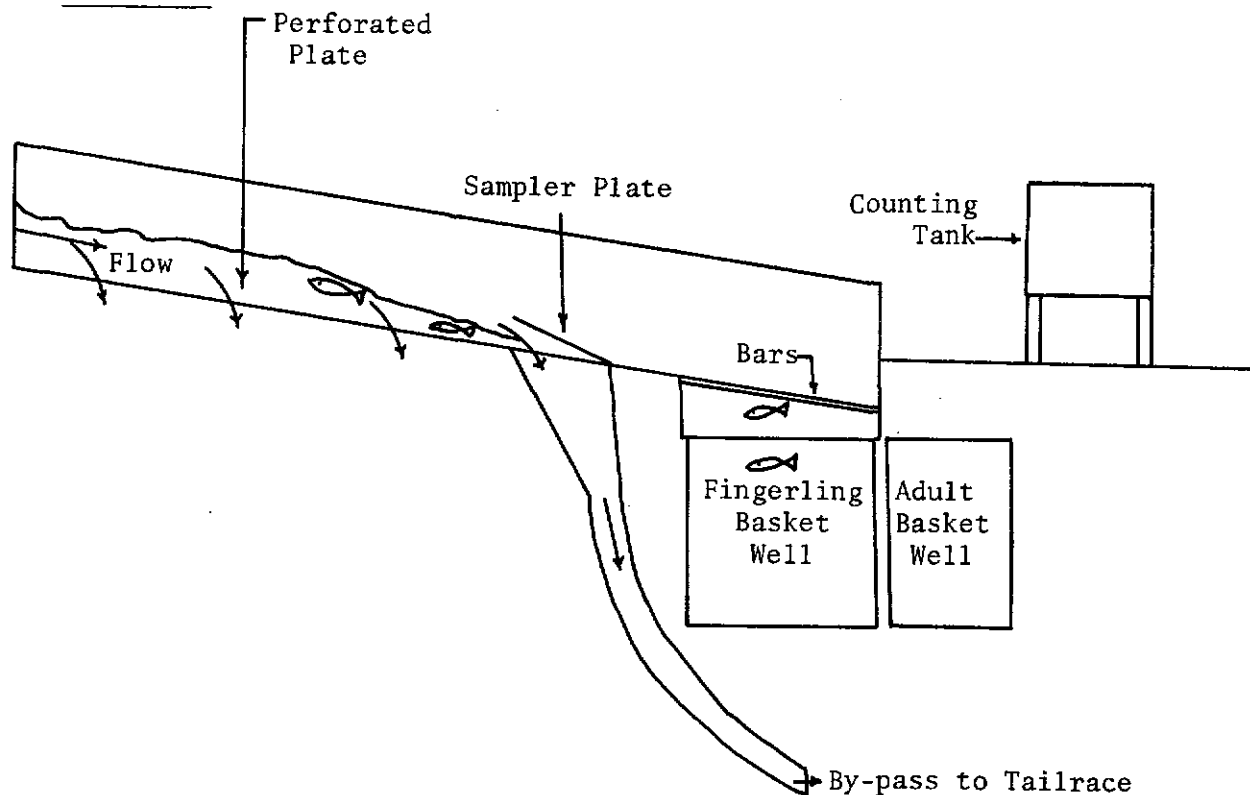


Figure 14. Schematic Diagram of the Downstream-Migrant Counting Facility, Green Peter Dam

migrants. We subsequently collected and enumerated these marked fish in the evaluator after they had passed through the reservoir and entered the collection facility. We also collected information on growth of salmon within the reservoir and upstream areas by releasing groups of marked 0-age chinook in both locations and monitoring these fish within the reservoir with gill nets and as they emigrated.

We tested a 400 watt mercury-vapor light submerged at the entrance to the fish horn to determine if it aided collection of downstream migrants.

We regularly recorded mortalities and periodically recorded relative physical condition by checking fish collected at the evaluator for contusions and abrasions. We introduced marked groups of juvenile fish into specific locations in the passage system to determine areas where injuries might occur.

We counted fish by species and marks and recorded other pertinent data daily when fish were migrating. Generally the type of marks used enabled us to recognize test fish without using anesthetic. In cases where this was not possible we would count out all easily recognized marks and species before anesthetizing the remaining fish. At all times we attempted to reduce the numbers of times fish were physically handled or subjected to stress during counting operations.

No attempt was made to evaluate fish passage through the turbines. We believe it to be minimal. Since the penstocks are located 112 feet deep or deeper depending on the level of the pool.

Limnological Observations

We periodically recorded certain limnological factors in the reservoirs. We took water temperature profiles with an electric thermistor and, using a Kemmerer bottle, obtained water samples for dissolved oxygen analysis from the surface, bottom, and, when present, the thermocline. We used a modified Winkler titrametric method to analyze dissolved oxygen and measured relative water turbidity with a standard Secchi disc.

RESULTS

Upstream Migration

Foster Dam

Numbers. Upstream-migrant salmon and steelhead trout counted annually at Foster Dam from 1967-71 and the comparison of these counts with counts at Willamette Falls are shown in Table 1. Numbers of chinook ranged from 285 in 1968 to 4,884 in 1971. The numbers of winter steelhead varied between 1,100 in 1968 and 4,259 in 1971. The fishery agencies estimated that the South Santiam above Foster Dam had annual runs of 1,400 chinook and 2,600 winter steelhead previous to construction of the Green Peter-Foster Project (Foster Reservoir Design Memorandum No. 9, 1963).

Chinook annually counted from 1967 to 1969 were not affected by the project as juveniles and counts in these 3 years did not approach the estimated annual number. Additionally, returns from 1967 to 1969 were augmented by releases of approximately 147,000 yearlings from the old South Santiam Hatchery above the Foster Dam site during 1965-67.

Table 1. Counts of Upstream-Migrant Salmon and Steelhead at Willamette Falls and Foster Dam, 1967-71 1/

	1967	1968	1969	1970	1971
<u>Spring Chinook</u>					
Willamette Falls	56,200	31,500	33,700 (2,573)	34,200 (771)	43,396 (633)
Foster	664 (12)	285 (28)	810 (80)	1,593 (157)	4,884 <u>2/</u> (78)
% to Foster	1.2	0.9	2.4	4.7	11.0
<u>Coho</u>					
Willamette Falls	8,698 (1,614)	17,700 (5,300)	17,292 (14,032)	37,355 (19,453)	23,765 (6,599)
Foster	298 (130)	1,037 (675)	1,077 (835)	1,378 (434)	511 (253)
% to Foster	3.4	5.9	6.2	3.7	2.1
<u>Sockeye</u>					
Willamette Falls	0	0	-	887	952
Foster	-	-	0 (40)	636 (305)	610 (4)
% to Foster	-	-	-	71.8	60.1
<u>Winter Steelhead</u>					
Willamette Falls	14,600	6,400	8,400	4,700	26,647
Foster	2,731	1,100	1,415	1,468	4,259
% to Foster	18.7	17.2	16.8	31.3	16.0
<u>Summer Steelhead</u>					
Willamette Falls	-	-	-	157	2,308 <u>3/</u>
Foster	-	-	-	- (150)	2,813 <u>2/</u> (83)
% to Foster	-	-	-	95.5	111.4

1/ Includes live and dead fish removed from the Foster collection facility. Does not include fall chinook. Jacks shown in parentheses included in totals.

2/ Includes 128 adult chinook and 243 summer steelhead which entered the ladder at the South Santiam Hatchery.

3/ Early run summer steelhead (March, April) could not be distinguished from winter steelhead at Willamette Falls.

Spring chinook returning to Foster Dam in 1970 and 1971 were affected by the project as juveniles and were largely produced from releases in Green Peter Reservoir of 268,000 and 1,900,000 fry in 1967 and 1968, respectively. The 3,855 chinook counted at Foster Dam in 1971 (exclusive of chinook reared at South Santiam Hatchery which were estimated by sampling the entire return to Foster Dam for tetracycline marked hatchery fish) represents 8.9% of those counted over Willamette Falls or a six-fold increase over the 1.5% average in 1967-69.

The number of winter steelhead counted at Foster Dam exceeded the estimated run for this species in 2 of 5 years of the study. The count of steelhead at Foster Dam as a percentage of those passing Willamette Falls ranged between 16.0% and 18.7% except in 1970, when 31.4% were collected.

Coho salmon were introduced into Wiley Creek in 1961 and in the South Santiam River above Wiley Creek in 1964. Yearly plants of fry, fingerlings, and adults were made above Foster Dam until 1969. Sockeye fingerlings were introduced into Green Peter Reservoir in 1968 and 1969. No subsequent releases of sockeye have been made. Summer steelhead were produced entirely in the South Santiam Hatchery below Foster Dam. 1/ The first releases were made in 1969 as yearling smolts.

1/ Sockeye and summer steelhead were not introduced until after Green Peter and Foster dams were essentially complete. These species are briefly mentioned in this report. Additional information of reservoir studies, spawning success, etc., of these species can be obtained by writing: Fish Passage Section, FCO Management and Research Division, 17330 S. E. Evelyn Street, Clackamas, Oregon 97015.

Timing and Delays. The number of upstream-migrant chinook collected at Foster Dam, tailrace water temperatures, and project discharges, summarized annually by 3-day periods for 1967-71, are shown in Figure 15. In 1967, the collection frequency of chinook at Foster Dam was bimodal with the first peak occurring 17 days after the peak count at Willamette Falls. Water discharged from Foster Dam in early 1967, was largely from the South Santiam. Green Peter Reservoir filling for the first time during this period allowed little discharge from the Middle Fork.

A small run of spring chinook returned to Foster Dam in 1968 and little can be said regarding its timing.

Chinook returning to Foster in 1969 peaked 32 and 68 days after the peak count at Willamette Falls. Large numbers of fish observed holding in the tailrace in early June did not pass upstream until late July and September. In 1969, we believed that large discharges of cold water (50 F or less) from Foster Dam in late May and again in late June and early July, coinciding with large releases of cold water from Green Peter Dam, delayed chinook at Foster Dam. Studies at Cougar Dam indicated temperatures below 45 F (7.7 C) delayed upstream passage of chinook (Ingram, FCO unpublished data). However, discharges of cold water in 1970 and 1971 at Foster Dam appeared not to affect the timing of the chinook migration. We theorized that other qualities of water, including contaminants such as residual quantities of H_2S and leaching from concrete in the dam, discharged from Green Peter and subsequently from Foster may have been the important factor affecting the upstream migration of chinook in 1969. The quality of water discharged from

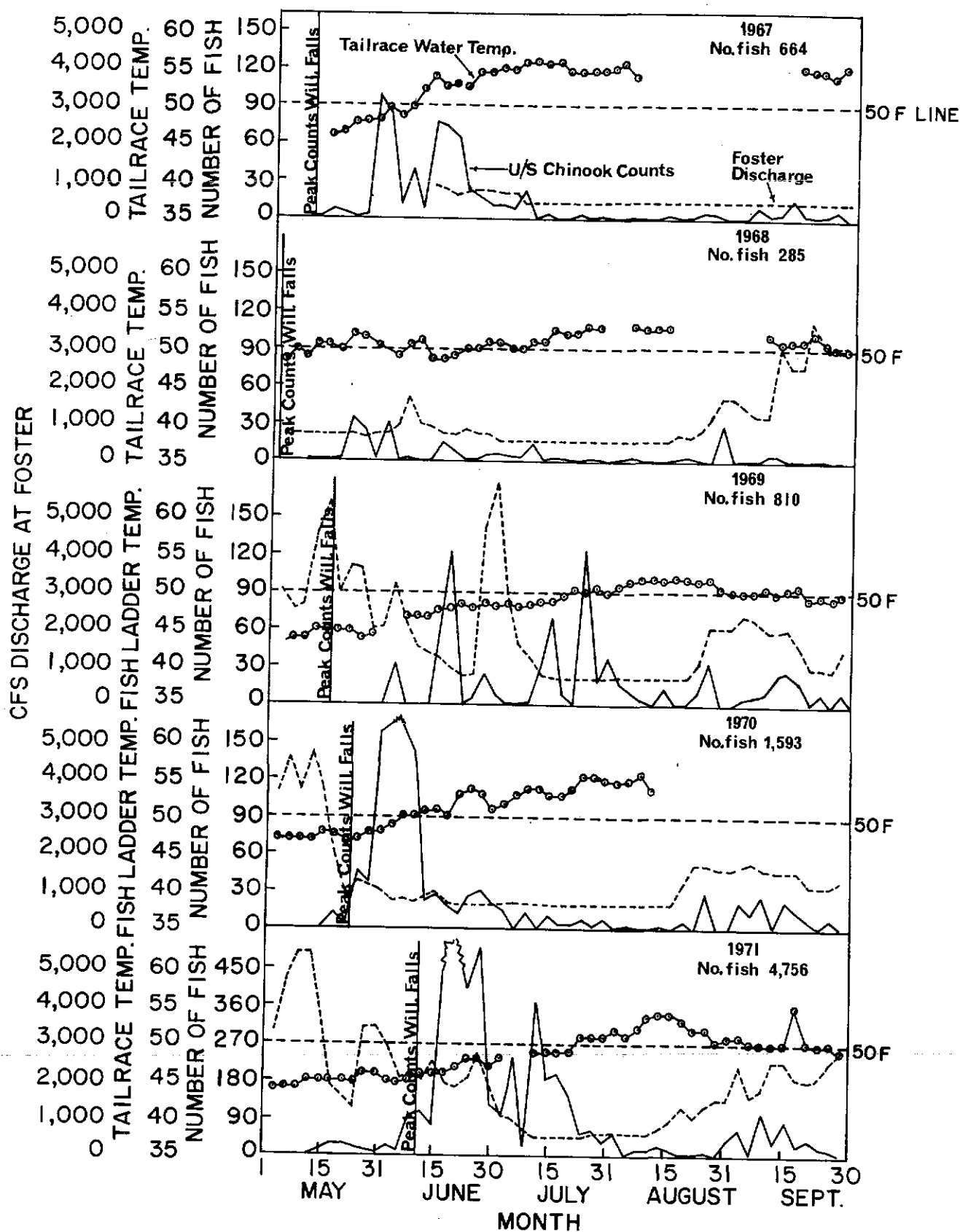


FIGURE 15. UPSTREAM MIGRANT CHINOOK COUNTS, STREAM FLOWS, AND WATER TEMPERATURES AT FOSTER DAM, MAY - SEPTEMBER 1967-71

Green Peter may be improving as the reservoir ages. In 1971 a large number of chinook was observed holding in the Green Peter tailwater for the first time.

Chinook returning to Foster Dam during 1970 and 1971 passed downstream as smolts through Green Peter and Foster dams. In these years the peak count of chinook at Foster Dam followed the peak at Willamette Falls by 10-12 days.

Chinook appeared delayed for 20-25 days below Willamette Falls in 1971 and many fish arriving late at Foster held in the tailrace. Our studies at other projects, such as Cougar Dam (Ingram and Korn, 1969), generally indicated that during mid-summer spring chinook began holding in suitable areas whether or not they were delayed in passing upstream during the spring. This phenomenon also occurred at Fall Creek (Smith and Korn, 1970). We feel that fish holding in the Foster tailrace in 1971 resulted from delays downstream and did not indicate a passage problem at Foster Dam. We expect the normal timing of the chinook run, barring delays downstream, to approximate that observed in 1970.

The numbers and percentages of adult steelhead passing Foster Dam, by month, are shown in Table 2. Counts of steelhead peaked in late April and early May during every year of the study. Steelhead were not observed holding in the tailrace and we believe they experienced no delays at Foster Dam.

No delays were observed for coho salmon. These fish were collected at Foster from September to December each year. In 1967-69 and 1970-71, counts peaked in mid-October and late September, respectively.

Table 2. Numbers and Percentages of Winter Steelhead Collected at Foster Dam, by Month 1967-71

Year Month	1966-67		1967-68		1968-69		1969-70		1970-71	
	Number	%	Number	%	Number	%	Number	%	Number	%
December			4	0.4	6	0.4	1	0.1	28	0.7
January			0	0	5	0.4	0	0	11	0.3
February	(Fishway opened		3	0.3	2	0.2	30	2.0	208	4.9
March	March 12)									
	76	2.8	145	13.2	126	8.9	113	7.7	223	5.2
April	1,685	61.7	526	47.8	766	54.1	661	45.0	2,378	55.8
May	959	35.1	413	37.5	481	34.0	640	43.6	1,366	32.1
June	11	0.4	9	0.8	29	2.0	23	1.6	45	1.0
July		0	0	0	0	0	0	0	0	0
Total	2,731	100	1,100	100	1,415	100	1,468	100	4,259	100

Collection Efficiency of Ladder Entrances. We determined the efficiency of the two ladder entrances in attracting upstream migrants largely through subjective observations. In 1967, winter steelhead and chinook runs were collected using only the spillway entrance. The turbine tailrace area was sealed by a coffer dam during this time. No steelhead and few chinook were observed holding below Foster in 1967.

From 1968 through 1971, both entrances were operated. Chinook and winter steelhead were observed entering both the entrance from the tailrace and transportation channel from the spilling basin entrance. Chinook were observed holding in front of both ladder entrances as well as in the lower tailrace and spilling basin during late July and August. We did not observe a preference by any species for either entrance. Both entrances were operated as an overflow and a submerged orifice during the study. No detailed tests were conducted of overflow versus orifice operation of the ladder entrances. However, our observations indicated that chinook and winter steelhead preferred an orifice opening. The top of the orifice was located approximately 2 feet below the tailrace water level with the orifice opening about 3 feet deep. A differential head of 1.5 feet between the inside and outside of the entrances was maintained.

Diel movement of chinook and steelhead generally peaked in late afternoon.

Drop-back and Recapture. In 1968 we marked adult spring chinook, coho, and winter steelhead released into Foster forebay to determine the number of these fish dropping back to the tailrace

through the spillway or turbines and collected again in the upstream-migrant facilities (Table 3). In 1971, we only tagged winter steelhead.

The hopper release site in the Foster forebay is adjacent to and between both the spillway bays and turbine intake area. We assumed the opportunity for adults to pass downstream during periods of spill was greater through the tainter gates than the turbines because both turbine intakes are covered with trash racks. In 1968 the total percentage drop-back and recovery in the fishway was 2.5, 5.1, and 13.1% for winter steelhead, chinook, and coho, respectively. The high percentage drop-back observed for coho coincided with the largest discharge through the tainter gates for any period tested.

Possible causes for adult fish returning downstream after release into the forebay include: 1. Injury due to handling, 2. Only partial recovery from anesthetic, 3. Rejection of the Foster forebay water, 4. High flows through adjacent tainter gates attracted fish downstream before they became oriented to the Foster forebay environment, and, 5. Fish put into Foster forebay were not destined for areas above that dam. We felt that some regulation of the tainter gates could reduce the number of fish returning to the tailrace.

In 1971, we requested that during periods of upstream migration, the Corps avoid spilling from gate 4 located adjacent to the hopper release site. On May 5, 1971, we released 100 tagged steelhead into Foster forebay. Foster Dam spilled in amounts greater than 2,500 cfs until May 15. One tagged adult steelhead or 1% of the release, was recaptured in the Foster fish ladder. We believe that additional tests

Table 3. Numbers of Adult Fish Marked and Recaptured at Foster Dam,
Selected Months, 1968 and 1971

			Turbines Operating	Gate 4 Operated	Spill No. Avg. Days cfs		Fish Marked Number	Recaptures in Fishway Foster Number %	
Winter Steelhead	1968	Mar.	No	X	31	973	146	10	6.8
		Apr.	No		31	772	514	8	1.6
		May	No		31	715	420	7	1.7
		June	Yes		30	872	11	2	18.3
		Total			123	833	1,091	27	2.5

Chinook	1968	May	No		31	715	103	0	0
		June	Yes		30	872	50	2	4.0
		July	Yes		31	567	50	5	10.0
		Aug.	Yes		28	449	52	5	9.6
		Sept.	Yes		27	1,223	18	2	11.1
		Total			147	758	274	14	5.1

Coho	1968	Sept.	Yes		27	1,223	81	1	1.2
		Oct.	Yes	X	27	2,689	299	41	13.7
		Nov.	Yes	X	26	3,778	28	8	28.6
		Dec.	Yes	X	14	5,178	11	5	45.4
		Total			94	2,939	419	55	13.1

Winter Steelhead	1971	May			14	2,635	100 1/	1	1.0

^{1/} All fish tagged with vinyl darts on May 5, 1971.

on all species should be conducted to determine if restricting the use of gate 4 during spill periods remains a valid operational procedure to reduce the number of adults dropping back from the forebay to the tailrace.

Handling of Fish. Fish were crowded and lifted from the loading pool into the 1,000 gallon anesthetic tank with the power-sweep. Salmon, steelhead, and trout were placed in the hopper and the trash fish, composed mainly of suckers but also including squawfish and lamprey, were returned to the Foster tailrace or killed. After 3 months operation, it became evident that fish were being crushed against the anesthetic tank by a 6" grating on the toe of the sweep. We could not eliminate this mortality by changes in the operational procedure. In 1967, the grating was removed and the lower edge of the toe allowed to slide along the bottom of the holding pool. Subsequent operation of the sweep indicated this alteration was a satisfactory solution.

We found other weaknesses in the adult fish handling system at Foster Dam. Principally, salmonids may be injured and bruised when the toe of the sweep is lifted out of the water to let fish slide into the anesthetic tank. Time out of the water was 8-10 seconds depending on the number of fish crowded. This problem has not been corrected.

The number of trash fish collected at Foster varied between 60 in 1967 and 2,054 in 1971. A means other than buckets should be provided for their removal from the anesthetic tank if we continue to collect them in increasing numbers.

Hopper Transfer System. We observed the 1,000 gallon-capacity hopper at Foster Dam to determine fish loading limits and operational problems. The time required to transfer adults to the forebay was 5 minutes at full pool and 6 minutes at minimum pool.

The water quality in the hopper was tested when transporting 102 adult chinook into the forebay. The dissolved oxygen decreased from 11.2 to 5.6 mg/liter with a water temperature of 10 C and transportation time of 5 minutes. The percentage decrease of dissolved oxygen was great and we believe the remaining 5.6 mg/liter was inadequate because further depletion of oxygen would occur with any delay in transporting fish from the hopper to the forebay. Despite the observed depletion, the fish appeared in good condition on egress into the forebay. We believe the present loading capacity of the hopper is 80 adult anadromous salmonids. If increased adult runs at Foster Dam make it advantageous to haul more than 80 adults per load, free oxygen should be discharged into the hopper during transit.

A problem was observed with the curtain on top of the hopper which prevents fish from jumping out during transfer. When the hopper is lowered too deep into the forebay, water floods above the curtain causing it to partially float above the hopper. At this time some adults may swim onto the top of the curtain and become trapped when the hopper begins to raise from the forebay. Attempts to correct this problem have not been successful.

Mortalities. Most mortalities observed in the Foster upstream-migrant facilities occurred early in 1967, and were caused from fish being crushed by the 6" grating on the sweep toe. This defect has been corrected as previously explained. The few additional adult mortalities were caused by poor operational procedures and have largely been eliminated. The number of adult anadromous salmonids killed in 1971 in the Foster upstream-migrant facilities totaled 12 or 0.1% of the total run collected at Foster Dam.

Some snagging and harassment of fish in the holding pool has occurred. Frequent checks by operators at Foster Dam and state police have relieved but not prevented this problem.

Green Peter Dam

Numbers. Upstream-migrant salmon and steelhead trout annually counted at Green Peter Dam from 1967-71 and the comparison of these counts with the numbers of live upstream migrants released into Foster forebay are shown in Table 4. Coho, sockeye, and summer steelhead were introduced above Green Peter Dam in 1966, 1967, and 1970 respectively. We discontinued releases of adult and juvenile coho above Green Peter Dam after 1967, because studies at other impoundments with downstream passage facilities indicated large numbers of juvenile coho became residuals and eventually predators on subsequent broods of salmon and steelhead. Additionally, the large coho smolts emigrating from some reservoirs appears to stimulate returns of jacks rather than adults.

The number of chinook arriving at Green Peter Dam ranged from 14 in 1968 to 655 in 1971 and winter steelhead ranged from 94 in 1969 to 826 in 1967. Previous to construction of the project, the fishery agencies estimated that the Middle Santiam above Green Peter Dam had annual runs of 800 chinook and 2,200 winter steelhead (Design Memorandum No. 13, 1962, USCEC). Chinook counted annually from 1967-71 never approached the estimated number. The percentage of fish released into Foster and subsequently collected at Green Peter Dam has gradually increased from 4.9% to 19.7% since 1968. However, releases of fry in Green Peter Reservoir in 1967 and 1968 may have largely accounted for the increased adult returns in 1970 and 1971.

Table 4. Counts of Upstream-Migrant Salmon and Steelhead at Foster and Green Peter Dams, 1967-71 1/

	1967	1968	1969	1970	1971
<u>Spring Chinook</u>					
Foster	662 (12)	284 (28)	801 (80)	844 (97)	3,325 (78)
Green Peter	92	14	70 (4)	157 (4)	655 (9)
% to Green Peter	13.9	4.9	8.7	18.6	19.7
<u>Coho</u>					
Foster	298 (130)	1,031 (671)	1,073 (834)	1,378 (434)	511 (253)
Green Peter	6 (5)	282 (235)	-	-	-
% to Green Peter	2.0	27.4	-	-	-
<u>Sockeye</u>					
Foster	-	-	40	630	605 (4)
Green Peter	-	-	17	173	146
% to Green Peter	-	-	42.5	27.5	24.1
<u>Winter Steelhead</u>					
Foster	2,693	1,098	1,412	1,449 (46)	4,254
Green Peter	826	279	94	265	766
% to Green Peter	30.7	26.4	6.7	18.3	18.0
<u>Summer Steelhead</u>					
Foster	-	-	-	150 (150)	2,206 (83)
Green Peter	-	-	-	0	142
% to Green Peter	-	-	-	0	6.4

1/ Foster upstream counts include only fish put live into Foster Reservoir. Jacks shown in parenthesis included in totals.

The number of adult winter steelhead returning to Green Peter did not equal the estimate for this species in any year of the study. The percentage of fish collected at Green Peter Dam, of those adults released live into Foster Reservoir, decreased from 30.7% to 6.7% during the first 3 years of the study. In 1970 and 1971, steelhead passage from Foster Dam to Green Peter Dam approximated 18.0%.

Sockeye produced entirely above Green Peter Dam did not return in substantial numbers to that project as expected. The percentage of fish collected in the Green Peter upstream-migrant facilities from adult releases into Foster forebay varied from 24.1% to 42.5% in 1971 and 1969, respectively. Some adult sockeye were observed spawning in the South Santiam River above Foster Dam.

Adult summer steelhead destined for the South Santiam Hatchery were collected in the Foster fish ladder and released into Foster Reservoir. There were 142 or 6.5% of those placed above Foster collected in the Green Peter upstream-migrant facilities during 1971.

Timing and Delays. Timing of the adult chinook and winter steelhead migration at Green Peter Dam was summarized by 3-day periods annually for 1967-71 (Figure 16). The chinook migration at Foster Dam peaked in late May and early June 1967 and during July in 1969, but did not peak at Green Peter Dam until August and September in both of these years. In 1968, there were too few fish (14) to determine timing at Green Peter. Chinook returning to Green Peter Dam in 1970 and 1971 passed downstream through the project as juveniles. During 1970 counts peaked in June, 9 days after the peak count at Foster Dam. In 1971 counts peaked in late June 3 days after the peak count at Foster

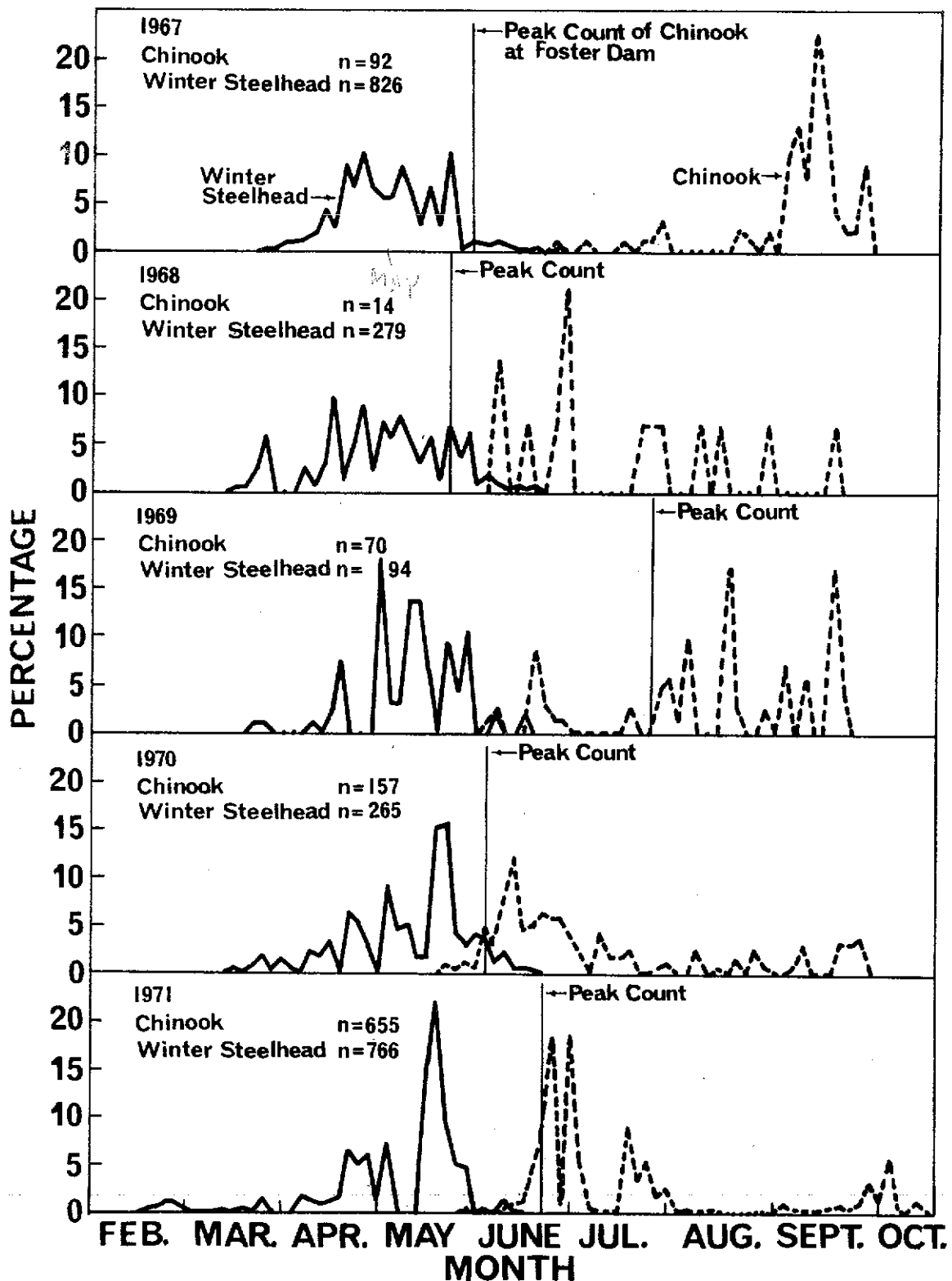


FIGURE 16. SPRING CHINOOK AND WINTER STEELHEAD COLLECTED IN THE GREEN PETER UPSTREAM MIGRANT FACILITIES, BY 3-DAY PERIODS, EXPRESSED AS A PERCENTAGE OF THE TOTAL RUN, 1967-71

Dam. However, a delay of at least 20 days in the upstream migration of chinook over Willamette Falls in 1971 is reflected in the later timing of chinook collected at Green Peter Dam.

Although the bulk of the chinook run collected in 1970-71 at Green Peter Dam arrived shortly after release above Foster Dam, the percentage of chinook released into Foster Reservoir and subsequently collected at Green Peter Dam remained relatively low (see Table 4). This occurred even though the bulk of the chinook returning in 1970-71 apparently reared as juveniles in Green Peter Reservoir.

In 1970, there were 418 4-year-old chinook (1966 brood) released into Foster forebay that were believed destined for Green Peter Dam. Chinook fry released above Green Peter Dam was the origin of this brood year. Prior to closure of the two dams, a chemical treatment program eliminated the 1966-brood wild chinook stock in the Middle and South Santiam rivers above the dams. The total number of adult chinook collected at Green Peter Dam in 1970 was only 157 fish or 37.6% of the 4-year-old fish released into Foster forebay. This recovery percentage is maximal because it assumes all chinook collected at Green Peter were 4-year olds.

Prior to 1971, few adult fish had been seen in the Green Peter tailrace. In late June 1971, we observed 500-800 chinook holding immediately below Green Peter Dam. These fish held in the tailrace throughout the summer but did not move into the fish facilities in early September as anticipated. They appeared to move downstream out of the Middle Fork at that time. We observed only 12 chinook redds in the Middle Fork between Green Peter Dam and the Foster pool

in 1971. We could not determine if these fish spawned elsewhere. It is possible this group of fish would have entered the Green Peter fish facilities in May and early June if they had not been delayed at Willamette Falls.

The timing of adult winter steelhead collected at Green Peter Dam is shown in Figure 16 and appears similar to that observed at Foster Dam (Table 2). Counts of these fish at Green Peter peaked between late April and late May during every year of the study. The numbers of steelhead collected at this dam were low during all years of the study. Spawning ground surveys conducted in the Middle Santiam River before construction of the Green Peter-Foster project and counts of dead juvenile salmonids made in areas above Foster Dam during the fish eradication program in 1966, indicated approximately 60-70% of the adult steelhead passing above Foster Dam should spawn in the Middle Fork. The percentage of winter steelhead arriving at Green Peter, shown in Table 4, has never approached this estimate.

In 1971 we observed a substantial number of steelhead holding 1 to 2 miles below Green Peter Dam. Also, we noted these fish were most active during the middle and late afternoon. We requested the Corps to reduce the discharge from Green Peter Dam to 50 cfs from 2-6 PM during several periods in April and May. During the first 3 days of this operation, collection of steelhead in the upstream-migrant facilities at Green Peter Dam substantially increased. No improvement in passage at Green Peter could be demonstrated for other species by reducing flows during the peak months of migration. Flows in the late afternoon during the chinook run (late May-September) do not generally exceed the minimum 50 cfs.

Drop-back Into Tailrace. Small numbers of adult chinook and steelhead were observed returning to the Green Peter tailrace via the downstream-migrant facility in each year of the study. The percentage of adult chinook returning to the tailrace after release into Green Peter Reservoir was 0%, 1.7%, 1.2%, and 0.1% in 1968, 1969, 1970, and 1971, respectively. Unspawned steelhead were also observed in the downstream-migrant facility. However, difficulty in determining unspawned steelhead adults from kelts precluded making an estimate of the percentage of drop-backs for this species.

Hopper Transfer System. The two 1,000-gallon-capacity hoppers at Green Peter Dam were observed to determine operational problems. The time required to transfer adults to the forebay varied between 15 and 20 minutes at full pool and minimum pool, respectively.

Water quality in the hopper during transit over the dam was not tested. However, based on the water quality observed in the Foster fish hopper and the transit time over Green Peter Dam, we believe the present loading capacity of the hopper is 50 adult salmonids.

Mortalities. The number of adult mortalities observed in the upstream-migrant facility at Green Peter during the 5 years of study included 12 steelhead and one chinook. These mortalities all resulted from fish jumping over the loading pool entrance gate into the loading pool then jumping out of the loading pool onto the floor. A plywood barrier 18" high was installed over the gate between the two pools. However, the barrier must be enlarged to completely block the opening between the two pools. Adults are prevented from jumping onto the floor from the holding area by a fence.

Spawning

Chinook spawning ground surveys were made above Green Peter and Foster dams from 1969-71. The majority of chinook available to spawn above Green Peter were transferred from Fall Creek Dam in 1969, transported from the Foster upstream-migrant facilities in 1970, and released into the forebay from the Green Peter upstream-migrant collection system in 1971. All chinook available to spawn in the South Santiam River above Foster Dam were released into the Foster forebay via the upstream-migrant facilities.

In 1969, 785 and 660 adult chinook were available to spawn above Green Peter Dam and in the South Santiam above Foster Dam, respectively. Few fish or redds could be located during limited spawning ground surveys in September and October 1969. Four trainees were hired in 1970 and 1971 to conduct extensive spawning ground surveys in known spawning areas. Other areas were checked by permanent personnel for possible chinook spawning. In 1970, 730 and 699 adult chinook were available to spawn above Green Peter and Foster dams, respectively. We found 8.3 spawners-per-redd or a total of 80 redds above Green Peter Dam and 7.2 spawners-per-redd or a total of 94 redds above Foster Dam. In 1971 680 and 2,602 chinook were available to spawn above Green Peter and Foster dams, respectively. There were 15.8 spawners-per-redd or 43 total redds observed above Green Peter Dam and 17.3 spawners-per-redd or a total of 150 redds above Foster Dam. Spring chinook spawning ground surveys conducted by the FCO on other standard survey areas in Oregon including Lookingglass Creek, a Columbia River tributary, indicated the number of adults released upstream per redd counted

varied between two and four. This implies that the number of adult chinook surviving to spawn of those released above Green Peter and Foster dams in 1970 was less than 50% and less than 30% in 1971.

Probable factors causing the low survival of adults to spawning include:

1. July and August water temperatures in summer holding areas during 1969, 1970, and 1971 frequently exceeded 21.1 C in Quartzville Creek, and 19.5 C in the Middle Fork of the Santiam above Green Peter Dam. The South Santiam River water temperatures above Foster Dam during the same periods occasionally exceeded 21.1 C.
2. Adult chinook arriving at Foster Dam in 1970 and 1971 were in poor condition. Many were bruised, cut, or scaled. In 1971, we determined from a sample of 1,125 adult chinook observed at Foster Dam that 11% had severe injuries. Additionally, from a sample of 88 fish, only 12.5% were determined to be absolutely free of visible injuries. In both years fish apparently were injured at Willamette Falls during construction of the new fish ladder.
3. Poaching occurred in many areas where adult fish were holding during the summer. Deep pools in Quartzville Creek, in which adult chinook were observed holding during the summer, were also extensively used for swimming by the public.

High, turbid water during March, April, and early May in all upstream areas precluded conducting spawning ground surveys for winter steelhead.

Chinook transported and released above Green Peter Dam in 1970 and 1971 were marked with an adipose clip and tagged with a color-coded vinyl tag. We hoped to determine if fish released into the forebay via the upstream-migrant facilities spawned as successfully as those transported and released into upper reservoir areas. A total of 561 and 35 were tagged in 1970 and 1971, respectively. The results of these tests were indeterminate because: (1) small numbers of fish were observed on spawning grounds, (2) the inability of the observers to sight these small tags on live fish and, (3) the small numbers of tagged fish released.

Downstream Migration

Green Peter Dam

Sampling Techniques at Evaluator. At the conclusion of the 1968 downstream migration it was obvious that we could not effectively handle and count 100% of the smolts anticipated to be collected in the Green Peter downstream-migrant system in subsequent years. In September 1968, we incorporated into the evaluator the sampling device previously described in the Methods and Equipment section. During 1969-71, we generally collected and counted 1/3 of the fish emigrating via the collection system and allowed 2/3 to pass directly into the tailrace. An exception was made during a few days in 1971, when the total daily downstream count exceeded 25,000 fish. During these periods we collected and counted 10 or 20% of the emigrants. Additionally, we counted 100% of the emigrants when it was anticipated the total daily count would drop below 1,000 fish-per-day.

To test the sampling device for accuracy, we counted, on selected days, both the fish collected in the evaluator and the fish to be passed into the tailrace when the timer was set to collect 1/3 of the downstream migrants. We conducted a chi-square analysis of these data and found no significant difference between the number of wild and hatchery chinook, wild and hatchery steelhead, coho and trout actually collected and the expected numbers of each to be collected as determined by the timer (total: $\chi^2_{95} = 0.1715$ with 1 d.f.). ^{1/} However, some of the observed daily sampling fractions for chinook fluctuated significantly from the expected ($p = 0.05$). We observed chinook emigrating in small groups or clusters and believe this caused the fluctuations in daily sampling fractions. The sampling fraction for sockeye could not be verified because of erratic results of the daily samples. We observed sockeye emigrating in large schools indicating the observed sampling fraction could have varied markedly from the expected.

In 1971, we tested the accuracy of the sampling device when collecting 10 and 20% of the fish emigrating through the downstream-migrant system. Chinook were the only fish collected at this time. We used a T - statistic to test the hypothesis that the actual sampling fractions did not differ from the expected fractions set on the timing device. The 10% and the 20% sampling fractions, as predicted by the timer, did not differ significantly from the observed sampling fractions (10% fraction: $T_{95} = 1.27$ with 18 d.f.; 20% fraction: $T_{95} = 0.43$ with

^{1/} In the interest of brevity, we have not included complete statistical analyses in the text of this report. Interested persons may obtain copies of full analyses used by writing: Biometrics Section, Fish Commission of Oregon Management and Research Headquarters, 17330 S.E. Evelyn Street, Clackamas, Oregon 97015.

35 d.f.). The sampling fractions observed for individual hourly time periods varied considerably, and this again appeared to be caused by chinook often emigrating through the downstream-migrant system in small groups.

Although, we found considerable variance between the expected sampling fraction and the observed sampling fraction for individual time periods, we feel the sampling device accurately predicted the total number of smolts emigrating through the Green Peter downstream-migrant system each month.

Passage Success. All juvenile spring chinook and winter steelhead used for passage tests in 1968 were marked with fin clips for identification. It was necessary to anesthetize all fish collected in the evaluator to observe these marks. We found that handling wild chinook in this manner caused significant mortalities. In 1969, we tagged groups of chinook and steelhead for passage tests with a color-coded vinyl dart tag. In 1970, we used color-coded vinyl string tags applied with a sewing needle. Test fish could then be identified when swimming in an upright position. This permitted all fish collected in the evaluator to be counted, identified, and captured and released with a small dip net while unanesthetized in the counting tank. Handling mortality of wild chinook was reduced by this method.

We tested groups of fish marked with vinyl darts and string tags for survival to emigration. Comparable groups of chinook tagged with the vinyl string and vinyl dart tags in 1969-70 indicated that dart tags may have affected the passage success of test fish. Of the chinook tagged with vinyl darts and vinyl strings, we respectively recovered 62.4% and 74.4% at the evaluator.

Based on previous fish passage evaluations, we believe at least 70% of the marked smolts released into a reservoir must be passed downstream to indicate successful collection efficiency of the downstream-migrant transport system. As seen in Table 5, recoveries of marked chinook smolts through the transport system in 1968 and 1969 at Green Peter exceeded 75% and in three of the four tests were over 82%. However, recoveries of marked winter steelhead from 1968-70 did not exceed 57% and mostly were under 44% (Table 5).

In 1968, a defect in the evaluator holding system allowed smolts to jump out of the collecting baskets and pass downstream through the drain without being counted. Tests conducted June 14-28, 1968, indicated 16.4% of the hatchery chinook and 14.3% of the hatchery steelhead egressed from the evaluator undetected. Jumping out of the collecting baskets may have been greater in June when the water temperatures were higher and the fish more active, than during April and May. Therefore, the passage success for marked chinook and steelhead smolts released into the upper reservoir and forebay in 1968, was undoubtedly greater than observed. This defect was corrected before the 1969 downstream migration began.

At the end of the second year of testing, we judged the collection efficiency of the downstream migrant system at Green Peter successful for spring chinook. The emigration rates for test groups of winter steelhead appears to be inadequate. The highest rate of emigration (56.6%) found during the study was observed for wild winter steelhead tagged at the evaluator and released into the upper reservoir. However, of 61,300 marked summer steelhead pre-smolts released into Green Peter

Table 5. Efficiency of Collection, Downstream-Migrant Facility, Green Peter Dam, 1968-70

Mark	Release Date	Source	Release Area		No. Released	No. Recovered 1/		Total	% Recovered
			Upper Res.	Forebay		Primary Migration	Residual Migration		
SPRING CHINOOK									
AD	4/68	Hatch.	X		10,469	7,879	- 2/	7,879	75.3
AN	4/68	"		X	10,458	8,620	- 2/	8,620	82.4
Blue									
Dart	3/69	"	X		9,828	8,057	29	8,086	82.3
Brown									
Dart	3/69	"		X	4,869	4,088	11	4,099	84.2

WINTER STEELHEAD									
LV	4/68	Hatch.	X		6,242	2,341	- 2/	2,341	38.9
RV	4/68	"		X	3,166	1,390	- 2/	1,390	43.9
Brown									
Dart	4/69	"		X	4,962	2,020	452	2,472	49.8
Blue									
Dart	4/69	"	X		10,313	2,790	705	3,495	33.9
Yellow									
Dart	4/69	Wild	X		3,030	896	118	1,014	33.5
White									
Vinyl	3/70	Hatch.	X		2,133	827	3	830	38.9
Blue									
Vinyl	4/70	"	X		2,116	921	5	926	43.8
Gray									
Vinyl	5/70	"	X		2,079	831	0	831	40.0
Red									
Vinyl	4/70	Wild	X		1,633	924	1	925	56.6

1/ All fish were released as smolted downstream migrants. The primary migration occurred in the winter during the year of release and in the following spring. The residual migration occurred in the fall, 1 year after release and the spring of the following year.

2/ Fish were not handled with anesthetic in 1969. Therefore, we could not determine the residual migration of these groups of test fish.

Reservoir in February 1971 by the OGC 41,088 or 67% were collected in the Green Peter downstream-migrant facilities. We believe that passage efficiency of the test groups of winter steelhead may not reflect the total capability of the downstream-migrant system to capture wild steelhead for the following reasons:

1. Hatchery steelhead used in tests may not have been properly conditioned to light and water temperature to migrate downstream during the year of release. The size of hatchery test fish at release fell within the size range of wild smolts emigrating from the reservoir. Releases of comparable groups of tagged steelhead in March, April, and May 1970 did not show appreciable differences in collection rates (Table 5).
2. Handling and marking wild steelhead smolts at the evaluator for release into Green Peter Reservoir may have caused excessive delayed mortality.
3. Marked steelhead jumping out of the holding baskets at the evaluator in 1968 reduced recovery rates.
4. Recovery rates may have been reduced in 1969 by the use of dart tags on marked test fish.

We believe the final determination of the success or failure of the transport system to collect downstream-migrant steelhead will have to be based on subsequent returns of adult steelhead to the project.

Numbers of Emigrants. The numbers of reservoir-reared anadromous fish and resident trout annually collected by the Green Peter downstream-migrant facility during the study are shown in Table 6.

Table 6. Estimated Numbers of Wild-Reared Salmonids Collected by the Green Peter Downstream-Migrant Facilities, October-July 1968-71 1/

Year	Species					Total
	Chinook	Winter Steelhead	Coho	Sockeye	Trout	
1968						
Live	67,479	49,849	80,375	37,983	3,417	239,103
Dead	2,352	157	399	217	32	3,157
Total	69,831	50,006	80,774	38,200	3,449	242,260
1969						
Live	344,567	53,918	384	17,995	3,526	420,390
Dead	4,544	440	4	187	33	5,208
Total	349,111	54,358	388 <u>2/</u>	18,182	3,559	425,598
1970						
Live	109,172	31,729	40	2,540	12,500	155,981
Dead	4,295	151	0	41	117	4,604
Total	113,467	31,880	40	2,581	12,617	160,585
1971						
Live	770,324	9,127	-	3,778	16,389	799,618
Dead	4,930	25	-	7	107	5,069
Total	775,254	9,152	-	3,785	16,496	804,687

1/ Does not include hatchery-reared chinook and steelhead smolts used to test passage success.

2/ The adult coho run was discontinued above Green Peter Dam in 1968.

Winter steelhead smolts were the progeny of adults which spawned in streams above the reservoir. We believe the chinook, coho, sockeye, and trout emigrants primarily resulted from hatchery releases of fry and fingerlings above Green Peter Dam. The largest outmigration of chinook was 804,687 in 1971 and of winter steelhead was 54,358 in 1969.

The numbers of hatchery fry chinook, coho, and sockeye released above Green Peter Dam, the estimated contribution of juvenile chinook from natural spawning and the estimated smolt migration expressed as a percentage of the total fry population, 1967-70, are shown in Table 7. Production of wild chinook fry was estimated by assuming that we counted all redds on the spawning grounds, that each redd contained 5,000 eggs, and that 30% of the eggs deposited survived to emergent fry. The 30% figure is the approximate average survival from egg to fry found for spring chinook at the Carmen-Smith spawning channel.

Table 7. Numbers of Hatchery Chinook Fry and Estimated Numbers of Wild Chinook Fry Available Above Green Peter Dam, and the Percentage Emigrating Downstream, 1967-70

Year of Release	Brood	No. Hat. Fry Released	Est. No. Wild Fry 1/	Total	% Emigrating D/S by Brood Year
<u>Chinook</u>					
1967	1966	267,746	0	267,746	21.5
1968	1967	1,877,497	118,500	1,995,997	17.8
1969	1968	835,206	3,000	838,206	12.4
1970	1969	4,775,455	183,000	4,958,455	15.4
<u>Coho</u>					
1967	1966	1,611,991	-	1,611,991	5.0
<u>Sockeye</u>					
1967	1966	140,000	-	140,000	27.3
1968	1967	200,000	-	200,000	9.1

1/ Estimates were not made for contribution of natural spawning coho or sockeye.

The total emigration of chinook, coho, and sockeye was generally low each year compared to the number of fish planted in the reservoir. We believe the relatively small number of these emigrants reflected natural mortality in the reservoir and not low collection efficiency of the transport system. Although the percentage of 1966-brood planted fry chinook emigrating from the reservoir as smolts was small, the return as adults of this brood year was substantial. We observed 1,282 or 0.48% of the 267,746 fry plant returning to Foster Dam as 4- and 5-year-old adults during 1970-71. From releases of 1+ smolts, the percentage return of spring chinook adults in 1969 and 1970 to FCO hatcheries in the Willamette Basin did not exceed 0.30%.

We released marked chinook fry of varying sizes in streams and reservoir areas above Green Peter Dam in 1969 and 1970 to determine optimum size, time, and area of release to promote maximum survival. In 1969 we released 102,500 fry at 1,021/lb, and 90,500 fry at 501/lb in Quartzville Creek during April and June, respectively. Of these releases, 10.3% of the fry released at 1,021/lb and 8.3% of the fry released at 501/lb were collected in the evaluator. Of the smaller fry at release counts peaked in March and April, while those larger at release emigrated mainly in May and June. We believe that substantial numbers of those released in April moved directly into the reservoir and benefited from the reservoir environment which resulted in higher survival, while most of the fish from the June release reared in the stream and did not begin moving into the reservoir until late spring of 1970. Less than 1% of the later release was collected in the evaluator prior to April 1970 as opposed to 6% of the earlier release.

In April 1970 we released 101,100 and 103,400 marked fry into Green Peter Reservoir at 1,083/lb and 506/lb, respectively. Of these, 9.0% of the smaller fry at release and 16.7% of the larger fry at release were subsequently collected in the downstream-migrant facility as smolts. While these tests were not definitive we currently believe that the release of fry 500/lb or larger into the reservoir before May significantly reduced natural mortality due to predation.

Timing of Emigrants. The amount of time the downstream-migrant facility was operational appeared to control the timing of the chinook emigration during fall and winter. The facility was deactivated in October and November 1968 to repair the transportation pipes. In December, January, and February 1969-71, intermittent operation of the downstream-migrant facilities was necessitated by rapid rises in the Green Peter forebay. High inflows in these months each year caused constant supervision of the facility by maintenance personnel. Also, spilling from the regulating outlets into the tailrace produced high nitrogen levels in the downstream-migrant egress area.

We did not activate the downstream-migrant facility each fall until there was sufficient water in the Willamette at Oregon City Falls to minimize passage of juveniles through turbines at that location. Beginning in 1971, we delayed starting the downstream facility until early November to coincide with the annual November-June shut down of Pacific Power and Light's turbines on the Lebanon Canal below Foster Dam. Some smolts may continue to emigrate downstream via the unscreened canal which begins at Lebanon Dam and flows into the Calapooya River immediately above its confluence with the Willamette River.

The Green Peter downstream-migrant facility was deactivated approximately July 1 every year to allow maximum growth of each brood year of chinook. Substantial numbers of 0+ chinook began emigrating in late June during each year of the study. We wanted these fish to remain in the reservoir for additional growth prior to emigration.

Table 8 shows the collection of juvenile chinook by month at the evaluator. In 1968, the downstream-migrant facility did not become operational until April 9. Emigration peaked during April of that year. In 1969-71 we observed peaks of chinook emigration during the fall and early spring of each year. Approximately 50% of the total migration for the 1968 and 1969 broods occurred in the fall during the first 60 days of operation. The peak emigration in early spring occurred in March and February in 1970 and 1971, respectively.

Table 9 shows the collection of unmarked juvenile winter steelhead by month at the evaluator. We observed 69-88% of the steelhead migration in April and May each year. Emigration peaked annually during the first half of May.

Sockeye and coho principally emigrated from Green Peter Reservoir as 1+ fish in the spring of each year. The downstream migration of sockeye peaked in May during all years of the study. A secondary fall emigration of sockeye, observed only in 1968, was composed largely of 1967-brood fish. Coho emigration peaked in May during 1968. Few coho emigrants were collected in subsequent years.

Size. The mean size of wild-reared downstream-migrant chinook collected at the Green Peter Evaluator is shown in Figure 17. The size of the 1966-brood chinook was larger as 1+ fish than in any other brood. We believe this was due to the small number released,

Table 8. Wild-Reared Juvenile Chinook Counted at the Evaluator,
Green Peter Dam, 1968-71 1/

Year	Month <u>2/</u>	1966 Brood	1967 Brood	1968 Brood	1969 Brood
1968	Jan. <u>3/</u>	4,791			
	Feb.	-			
	March	-			
	April	29,621			
	May	21,683	79		
	June	3,502	1,311		
	July <u>3/</u>	40	8,804		
	Oct. <u>3/</u>	33	14,353		
	Nov.	-	-		
	Dec.	77	89,124		
1969	Jan. <u>3/</u>	36	64,786		
	Feb. <u>3/</u>	0	5,793		
	March	8	93,437		
	April	62	55,756	168	
	May	49	16,323	94	
	June	13	7,080	1,864	
	July <u>3/</u>		27	28	
	Oct. <u>3/</u>		355	7,053	
	Nov.		355	36,141	
	Dec.		355	10,227	
1970	Jan.		320	4,256	
	Feb. <u>3/</u>		27	14,413	
	March	1	78	15,453	
	April		600	9,174	11
	May	1	473	4,908	422
	June		126	3,147	5,574
	Oct. <u>3/</u>			80	32,535
	Nov.			94	204,602
	Dec.			14	157,769
1971	Jan. <u>3/</u>			25	64,183
	Feb.			44	182,337
	March			57	58,522
	April			153	32,061
	May			186	22,503
	June			25	6,930
TOTALS		59,917	359,562	107,604	767,449

1/ Includes live and dead fish.

2/ Downstream-migrant facility initially activated January 16, 1968.
Facility deactivated August and September each year of the study and
during July 1970-71.

3/ Months when downstream-migrant facility was operated less than 20 days.

Table 9. Unmarked Juvenile Winter Steelhead Counted at the Evaluator, Green Peter Dam, 1968-71 1/

Year	Month <u>2/</u>	Catch Multi-aged Steelhead Smolts
1968	January <u>3/</u>	2
	February	-
	March	-
	April	12,482
	May	31,829
	June	5,153
	July <u>3/</u>	540
	October <u>3/</u>	89
	November	-
	December	2,297
1969	January <u>3/</u>	1,606
	February <u>3/</u>	62
	March	1,743
	April	16,563
	May	22,366
	June	9,589
	July <u>3/</u>	43
	October <u>3/</u>	3
	November	138
	December	298
1970	January	358
	February <u>3/</u>	1,026
	March	3,964
	April	9,520
	May	12,396
	June	4,177
	October <u>3/</u>	0
	November	208
	December	73
1971	January <u>3/</u>	30
	February	157
	March	104
	April	2,413
	May	5,399
	June	768
TOTAL		145,396

1/ Includes live and dead fish.2/ Facility deactivated August and September each year of the study and during July 1970-71. Downstream-migrant facility initially activated January 16, 1968.3/ Months when downstream-migrant facility was operated less than 20 days.

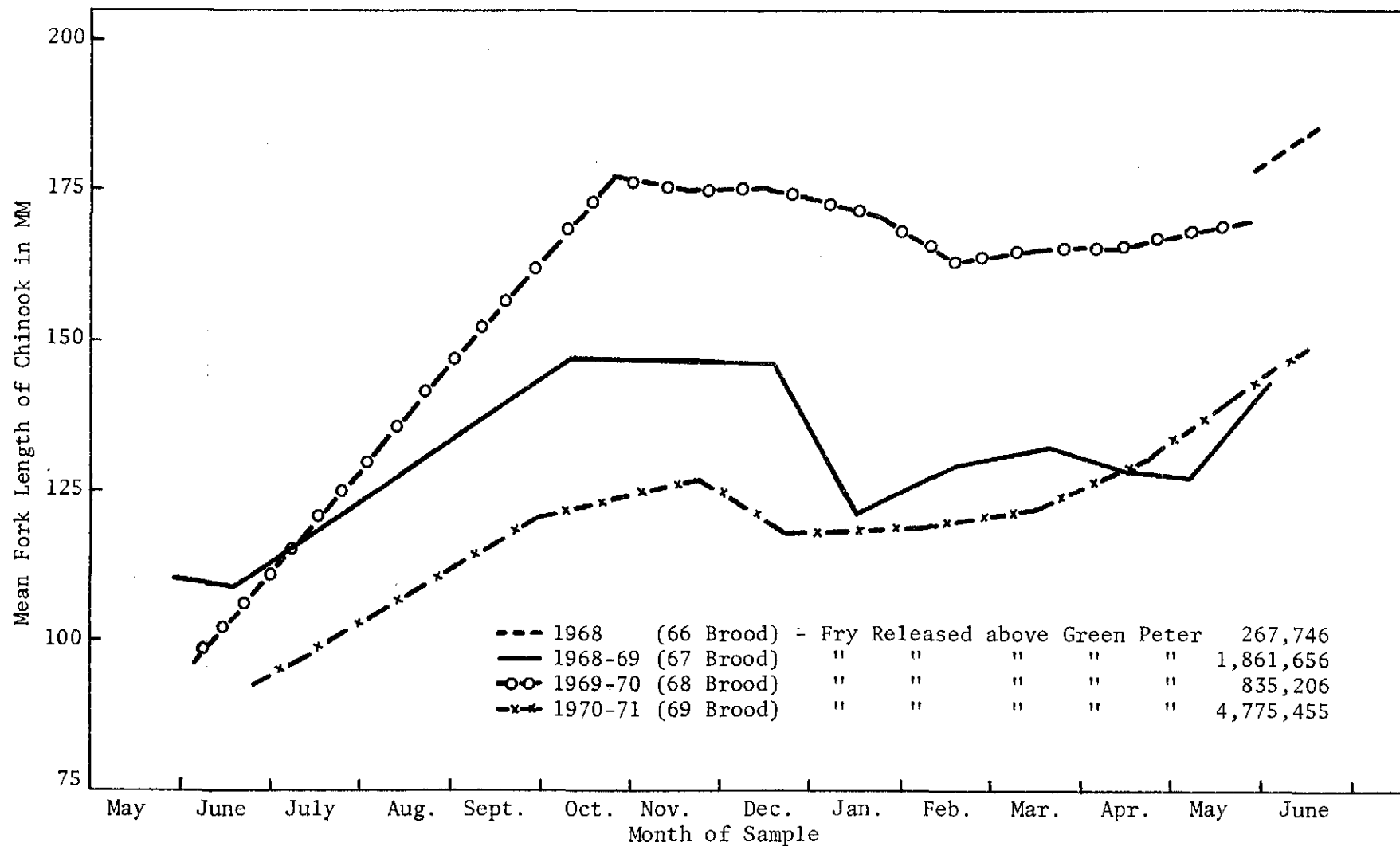


Figure 17. Size of Wild-Reared Juvenile Spring Chinook Salmon Emigrating from Green Peter Reservoir, 1966-69 Broods

little competition in the new reservoir, and smolts forced to remain in the reservoir until April 1968 when passage facilities became operational. We observed the largest smolts of the 1967- and 1968-brood years emigrating in the fall of 1968 and 1969, respectively. Fish of the 1969 brood emigrated at a larger size in the spring than they did in the fall. However, the mean size of the 1969 brood collected at the evaluator during the peak migration periods in the fall (November and December) and early spring (February and March) was similar. During each complete year of study, the average size of chinook emigrating in the winter was less than that observed the previous fall or subsequent spring.

We liberated groups of marked chinook fry into areas above Green Peter Dam during 1969 and 1970 to determine the optimum size at release to produce the largest numbers and size of smolts at emigration. We released marked 1968 brood chinook fry having an average size of 1,121 fish/lb into upper Quartzville Creek in April 1969. Smolts from this group averaged 10 mm larger at emigration than a comparable group of marked fry with an average size of 501 fish/lb at release, liberated at the same site in June 1969. Also, a higher percentage of the fish 1,021/lb at release emigrated from the reservoir (see page 52). The time of release and entry into the reservoir undoubtedly also affected the size at emigration.

In April 1970, we liberated two marked groups of 1969 brood chinook fry into Green Peter Reservoir. The size of these groups at release averaged 1,083 fish/lb and 506 fish/lb. The group liberated at 1,083 fish/lb. was 4 mm larger at emigration than those released at 506 fish/lb. However, a higher percentage of the fish larger at release emigrated from the reservoir (see page 53).

The number of chinook fry released above Green Peter Dam during each year of the study appeared to be the largest single factor affecting the size of smolts emigrating from the reservoir (Figure 17). Reduction in the size of smolts emigrating from the reservoir was observed when large releases of chinook fry were made. The largest plant of fry was made in 1970 (1969 brood) and produced the smallest size smolts that emigrated from Green Peter Reservoir during the study. The optimum size of chinook emigrants released downstream to produce the maximum adult returns has not been established for reservoir-reared spring chinook.

The average size of steelhead emigrating from Green Peter Reservoir from April-June in 1968, 1969, 1970, and 1971 was 178 mm, 187 mm, 197 mm, and 176 mm, respectively. The number of chinook fry released into Green Peter Reservoir also appeared to affect the size of winter steelhead smolts at emigration. In 1969-71, the average size of emigrating winter steelhead smolts was smaller during corresponding years of large releases of chinook fry than during years when small numbers of fry were released.

The average size of sockeye collected in the evaluator during the peak migration period in May and June, 1968-69, was 191 mm and 139 mm, respectively. The average size of coho emigrating in 1968 was 171 mm.

Affect of Facilities on Survival. Many of the emigrants passing through the transport system at Green Peter Dam sustained injury during the April-July 1968 migration period. Most of these injuries resulted from smolts passing through 350 feet of rusted black iron pipe in the downstream-migrant system. The incidence of these injuries observed on chinook smolts exceeded 30% at times.

In October 1968, the Corps coated with vinyl all portions of the transfer and transportation pipes that were constructed of black iron. Subsequent catches of smolts in the evaluator were free of injuries caused by abrasion on rusted iron pipes.

Additional injury and mortality was observed in 1968. The majority of the mortality appeared caused by crowding and handling in the evaluator. In November 1968, we modified the evaluator wells to increase the number of smolts that could be held 24 hours before they were counted and released. Additionally, we incorporated a sampling device, previously described, into the counting facility which allowed a portion of the fish to be bypassed without handling. The increased holding area and sampling device helped reduce the number of injuries and mortality of juvenile salmonids passing downstream through the collection system.

Direct mortalities counted at the evaluator during the study period appear in Table 10. Mortalities at the evaluator were substantially higher for chinook than for the other species. A major portion of the chinook mortality occurred on 1 or 2 days each year and was due to trash blocking the evaluator entrance or low water at the evaluator caused by incorrectly setting the separator.

In 1970 we conducted tests to estimate mortalities to juveniles in the downstream system that were not attributable to the evaluator. We released 10,175 marked hatchery chinook smolts into the downstream-migrant system at the separator and 5,218 marked chinook smolts into the Green Peter tailrace. These fish were bypassed under the evaluator. From this test, we collected 30.1% of the fish released at the separator and 30.0% of those released in the tailrace in the turbine nets at

Foster Dam. The similar survival found for these two test groups of chinook indicates that the mortality to fish emigrating via the Green Peter downstream-migrant facility is minimal.

Table 10. Mortality of Wild-Reared Emigrants by Run Year, Green Peter Evaluator, 1968-71

Year	Primary Months Caught	Total Estimated Run	Numbers Handled in Evaluator		
			Live	Dead	% Mortality of Handled Fish
<u>CHINOOK</u>					
1968	4/68-7/68	69,831	67,479	2,352	3.4
1969 ^{1/}	12/68-6/69	349,111	142,895	4,544	3.1
1970 ^{2/}	10/69-6/70	113,467	83,927	4,295	4.9
1971 ^{3/}	11/70-6/71	775,254	213,348	4,930	2.3
<u>STEELHEAD</u>					
1968	4/68-7/68	50,006	49,849	157	0.3
1969 ^{4/}	12/68-6/69	54,358	23,800	440	1.8
1970	10/69-6/70	31,880	28,183	151	0.5
1971	11/70-6/71	9,152	3,920	25	0.6
<u>COHO</u>					
1969	4/68-7/68	80,774	80,375	399	0.5
<u>SOCKEYE</u>					
1968	4/68-7/68	38,200	37,983	217	0.6
1969	12/68-6/69	18,182	7,591	187	2.4
1970	10/69-6/70	2,581	1,977	41	2.0
1971	11/70-6/71	3,785	1,804	7	0.4

^{1/} Chinook killed on 1 day, due to low water in evaluator, totaled 1,471.

^{2/} Chinook killed on 2 days, due to low water and trash in evaluator, totaled 2,241.

^{3/} Chinook killed on 1 day, due to low water and trash in evaluator, totaled 966.

^{4/} Steelhead killed on 2 days, due to trash in evaluator, totaled 159.

However, in 1971 some smolts of all species caught at the evaluator continued to show injuries. These injuries included hemorrhaged eyes, torn gill covers, and body abrasions. The incidence of these injuries on chinook varied between 8 and 17.5%. Additionally, many fish had split fins. In 1971, we released wild smolts at various points in the downstream-migrant system to locate possible injury areas. We found the expansion joint between the 24" stainless steel transportation pipe and the 24" vinyl-coated transportation pipe had a large unprotected lip facing upstream. This area was filled with rubber epoxy. We estimated from releases of fish onto the separator that 9.3% of the chinook smolts passing through the system to the evaluator were injured. The largest number of injuries observed were hemorrhaged eyes. In June 1971, after repairing the expansion joint, we observed that only 1.4% of the test fish released into the system were injured. However, in June we were only able to conduct one test using 71 fish. We feel this test should be duplicated to verify our results.

From February to April 1971, we observed that the percentage of chinook collected at the evaluator with the lower fins (anal, ventrals, and pectorals) split from the margin to the base varied between 8 and 20%. This type of injury appeared most severe on larger smolts. Little change was made by filling the expansion joint in the transportation pipe. We found this type of injury on chinook smolts that had been released on the perforated plate areas in both the separator and evaluator. Close inspection of the perforated plate in the separator indicated it was installed incorrectly, with the rough side facing up. Emigrants may "rub" the surface of this plate while

swimming against the current on the separator. We believe most of the severe "split fin" injury is coming from this area. This plate should be inverted or changed as soon as practical.

Operational Tests. We conducted tests to determine the correct procedure for operating the downstream-migrant system at Green Peter Dam to collect maximum numbers of emigrants. These tests included: (1) operating the system with one or two attraction water pumps, (2) determining the correct position of the entrance horn in relation to the water surface, and (3) using mercury vapor lights at the entrance of the facility to attract fish.

Tests using submerged mercury vapor lights to attract juveniles into the submerged horn openings in the Fall Creek downstream-migrant system clearly showed that substantially more fish were collected when lights were used (Smith and Korn, 1970). Based on these data, we elected to use a mercury vapor light at the horn entrance of the Green Peter downstream facility to increase the catch of emigrants.

We submerged a 400-watt mercury vapor light 14-17 feet below the surface and 5 feet in front of the horn entrance. This location placed the light approximately in the center of the horn opening. From March to June 1969, we conducted an experiment to simultaneously test both the effect of lights and use of one or two attraction water pumps on the numbers of wild chinook and steelhead collected. We conducted an analysis of variance and found that the computed values of F for comparisons between fish collected when lights were used, and those taken when lights were not used, were not quite large enough to be significant at the 95% confidence level. This was true for both chinook and steelhead. Comparisons of fish counts when operating one or two attraction water pumps are described later in the text.

In 1970, we redesigned the experiment to test only the effect of the mercury vapor light on the collection of smolts during the spring migration period (March-May). We included in the test catches of wild and hatchery steelhead, wild-reared chinook, sockeye, and trout. An analysis of variance of daily catches for each species was prepared. The daily catches of all species except sockeye were larger when the light was used. Catches of sockeye decreased when the light was used. The amount of decrease was large enough to indicate a real behavioral difference between sockeye and the other species tested. The numbers of sockeye emigrating from Green Peter Reservoir may have been significantly reduced in all years a mercury vapor light was used (1969-71).

The computed efficiency factors for each species when the light was used as compared to no light are shown in Table 11. The results of the 1970 tests were not inconsistent with the results obtained in 1969. The 95% confidence limits of the efficiency factors determined in 1969 and 1970 for chinook and steelhead overlap extensively. This suggests that the effect of lighting was probably not much different in the 2 years. However, the effect of lighting may depend on environmental factors such as water turbidity, which were not considered in this experiment.

In both 1969 and 1970, the emigration of steelhead was influenced more by light than was the emigration of chinook. Additionally, the monthly analysis of data suggests the response of steelhead and chinook to lighting is greater in March than it is in May.

Table 11. Effect of a Submerged Mercury Vapor Light on the Daily Catches of Fish Emigrating from Green Peter Reservoir, 1969-70

Species	Year	Efficiency Factor (light vs no light)	95% CL	
			95% CL	95% CL
Chinook	1969	1.662:1	(0.910	3.034)
	1970	1.595:1	(1.044	2.438)
Steelhead (Wild)	1969	1.936:1	(0.914	4.100)
	(Wild) 1970	2.978:1	(2.025	4.379)
	(Hatch.) 1970	3.292:1	(2.040	4.800)
Trout	1970	2.075:1	(1.600	2.882)
Sockeye	1970	0.379:1	(0.208	0.694)

We also were interested in determining changes in the collection of emigrants when the mercury vapor light was operated at depths other than 14-17 feet. In December, January, and February 1970-71, we compared the average daily catch in the downstream-migrant facility while operating the mercury vapor light at depths of 4, 14, and 24 feet. The comparisons are shown in Table 12.

Table 12. Average Catch-per-Day when Operating a Mercury Vapor Light at Selected Depths, Green Peter Dam, December-February 1970-71

No. Days (Random Selection)	Light Location (Depth in Feet)	Average Daily Catch by Species			
		Chinook	Steelhead	Sockeye	Trout
12	4	5,771	1	3	19
13	14	3,327	2	0	15
12	24	3,634	5	5	10

The average daily catch of chinook and trout was substantially larger when the light was located 4-feet deep than it was when the light was at the other two depths. The average daily catch of steelhead

and sockeye appeared largest when the light was at a depth of 24 feet; however, few steelhead and sockeye emigrated during the tests. We believe this test should be repeated in the spring during the peak steelhead and sockeye migration.

In April-June 1969, we compared the collection of wild-reared chinook and steelhead emigrants in the downstream-migrant facility with one and both of the two 100-horsepower attraction water pumps in operation. Utilizing one pump reduced approximately in half the attraction water into the facility and the velocity over the perforated plate in the separator. This method of operation would extend the total life of the attraction water system in the downstream-migrant facility. Analysis of variance was used to determine the effect of changing from two-to-one pump operation. Additionally, we tested the effect of time periods (April, May, or June) on the catch of smolts. The catch of wild-reared chinook was significantly reduced when operating with one attraction water pump ($F_{95} = 16.07$ with 1,6 d.f.). However, operation of one pump did not significantly reduce the catch of wild steelhead ($F_{95} = 3.16$ with 1,6 d.f.).

Independent of changes in operation of the light and pumps, the effect of monthly time periods on the collection of both chinook and steelhead was significant (chinook - $F_{95} = 21.67$ with 2,6 d.f.; steelhead - $F_{95} = 14.40$ with 2,6 d.f.). This suggests that the effect of lights and pumps on the catch of emigrants may differ during other segments of the downstream migration. However, we believe operating the downstream-migrant system with two attraction water pumps and a submerged mercury vapor light will give the highest overall collection of smolts.

The horn-shaped entrance to the Green Peter downstream-migrant facility, which is 6 feet wide and 20 feet high, can be operated at selected depths in relation to the surface of the forebay. These depths, measured from the center line of the horn to the forebay surface, ranged from 15 to 30 feet deep. In our studies of juvenile salmonid behavior in Oregon's reservoirs, we determined that smolted chinook and steelhead tend to inhabit the upper 15 feet of water, near the shore line, during the spring months (Korn, et. al., 1967). We generally operated the downstream-migrant facility with the center line of the horn located from 15 to 18 feet deep during the fall, winter, and early spring. We were interested in determining if this fishing position of the horn was also best during June when the surface water temperature warmed above 13 C. In June 1970, we compared the average daily catch of wild-reared salmonids in the downstream-migrant facility when the center line of the horn was located at 17 and 25 feet below the surface. These comparisons are shown in Table 13. The average catch per day for all species considered was higher when the horn intake was located at 17 feet than it was at 25 feet.

Table 13. Average Catch-per-Day When Operating the Horn Intake at Selected Depths at Green Peter Dam, June 1970

No. Days (Random Selection)	Horn Depth in Feet (Center Line)	Average Daily Catch by Species			
		Chinook	Steelhead	Sockeye	Trout
5	17	210	210	19	115
3	25	184	29	7	34

Stoplog Wells. The two intake-stoplog wells for the penstocks at Green Peter have upper openings at elevation 940. This is 20 feet above the minimum conservation pool elevation. These 6 x 15 foot openings covered with large mesh gratings are located near or above the forebay surface during some periods from November to February. A gill net set in one stoplog well in November 1970, collected 111 chinook smolts. We fished the stoplog well again with a gill net January 5 and 6, 1971 and caught 36 and three chinook, respectively. In January 1971 we covered the grating on the upper opening of each stoplog well with 1/4-inch mesh screen. A gill net fished in the well January 6, 1972, collected only four chinook and two rainbow trout. It appears most fish were entering the stoplog wells through the upper openings instead of through the opening into the penstocks. We believe few fish are emigrating from Green Peter Reservoir through the penstocks.

Catch by Anglers. In 1968 and 1969, Green Peter Reservoir was open to angling from late April to late October. We conducted a survey of the sport catch of salmonids in the reservoir on weekends and holidays during April to June 1968. Total estimates were made for bank anglers and boat anglers. The total estimated catch of salmonids during the 15 weekend days and holidays was 26,110. This total included: 56% rainbow, 23% coho, 10% wild-reared chinook, 1% marked hatchery chinook, 8% wild steelhead, and 2% marked hatchery steelhead.

In 1970 and 1971, the OGC opened an additional winter season from January 1 to late April. The daily bag limit was reduced from ten to five fish during this season. The OGC determined the average

catch during the winter period in 1970 was comprised of 97.7% rainbow, 2.1% wild-reared chinook, and 0.3% sockeye. In 1971, the average catch included 98.6% rainbow, 0.6% wild-reared chinook, 0.2% wild steelhead, and 0.6% sockeye. Light angling pressure was observed in the winter season during both 1970 and 1971.

Conversations with anglers and periodic observations indicated that many anadromous fish, particularly chinook, were caught and released because they were under the 6-inch size limit. This was apparent in 1971 when most of the yearling chinook present in the reservoir were less than 5 1/2 inches in length. We feel hooking undersized fish caused some mortality. Weekly observations by SCUBA divers in North Fork Reservoir resulted in the collection of numerous dead fish and indicated most of the dead fish found were killed by angling (Gunsolus and Eicher, 1970).

Angling in Green Peter Reservoir undoubtedly affects the populations of anadromous salmonid smolts available to emigrate, but we do not know if the sport catch significantly reduces the number of adults produced.

Foster Dam

Passage Success. Salmonid smolts produced above Foster Dam must emigrate by passing through the reservoir and the turbines or spillways of the dam. This necessitated using turbine nets and scoop traps to determine passage success. The two turbine nets were placed on the draft tubes exiting from a single turbine. We assumed that fish emigrated through each of the two turbines proportional to the amount of discharge to expand our catch and estimate total emigration through

both turbines. The turbine nets were used to estimate passage during periods when no spill occurred. When Foster Dam spilled, scoop traps were fished downstream to estimate total number of anadromous fish passing through the spillway and turbines.

Passage tests were conducted in the spring of 1969-70. The highest passage rates respectively estimated for marked chinook and steelhead released into Foster Reservoir were 70.1% in 1969 and 60.8% in 1970 (Table 14). In 1969, turbine mortality tests precluded starting passage tests until May 20, well after the normal peaks of the chinook and steelhead migrations. In 1970 recovery rates of marked steelhead were largest for fish released into the reservoir in March and lowest for those released in May. It appears that only small numbers of steelhead smolts entering Foster pool after April successfully emigrate downstream from Foster Reservoir during the primary migration season. Some steelhead entering Foster pool late may emigrate from the reservoir during the fall freshets if not caught by anglers during the summer.

Time did not permit us to conduct passage tests for coho salmon. However, timing of the coho migration closely parallels that observed for steelhead. We feel coho faced problems similar to steelhead in emigrating from Foster Reservoir.

We believe there may be considerable variation between the estimated passage rates and the actual numbers of marked fish emigrating from Foster Reservoir. Sources of variation include:

1. Water velocities below Foster Dam during periods of spill were not high enough to produce the trapping velocities needed in the scoop traps to capture large uninjured smolts.

Table 14. Summary of Recovery Rates for Test Fish Used in Downstream-Migrant Studies at Foster Dam, 1969-70

Mark	Release Date	Source	Release Area		Number Released	No. Passed Downstream		% Estimated to Pass Through Turbines & Spillways
			Green P. Tailrace	Upper Foster Reservoir		Number Caught	Total Estimate	
SPRING CHINOOK								
Ad	5/69	Hatch.		X	10,509	3,216	7,372	70.1
RP								
RM	3/70	"	X		10,175	3,198	4,444	43.7
LP								
LM	3/70	"	X		5,218	1,644	2,336	44.8

WINTER STEELHEAD 1/								
Ad	5/69	"		X	10,205	215	602	5.9
RP	3/70	"		X	5,210	733	3,164	60.8
LP	5/70	"		X	5,284	455	673	12.7
White Vinyl	3/70-6/70	"	X		820	153	445	54.5
Blue Vinyl	4/70-6/70	"	X		906	153	297	32.8
Gray Vinyl	5/70-6/70	"	X		807	52	56	6.9
Red Vinyl	4/70-6/70	Wild	X		910	185	438	48.1

1/ All groups of test fish marked with vinyl tags were released into Green Peter Reservoir, then collected in the downstream-migrant facility and liberated live into the Green Peter tailrace. Number released refers only to those discharged into the tailrace.

Scoop trap efficiency determined by releasing marked hatchery smolts below the dam was only 7.5% and 1.5% for chinook and steelhead, respectively. Scoop traps were used to estimate emigration from Foster Reservoir only during 9 days in 1969, and 11 days in 1970. However, substantial numbers of emigrants may have migrated downstream during these few days of spill.

2. The inner liner of one turbine net was ripped open in late May 1970 but not noticed until June 10. Many marked chinook and steelhead may have passed downstream through this net undetected.
3. Some dead fish were caught in pockets in the turbine nets and not washed into the live box until they were decayed beyond recognition.

We believe that the downstream-migrant tests did not provide adequate information to assess with certainty the success or failure of emigrants to pass out of Foster Reservoir. To augment our data, we released comparable groups of marked hatchery summer steelhead smolts into Foster Reservoir and tailrace during April of 1971 and 1972. Additionally, comparable groups of marked hatchery chinook smolts were released into Foster Reservoir and tailrace during April and November 1971. We hope to determine if significant differences occur in adult returns between those groups of smolts released above and below Foster Dam. However, differences in angling mortality on groups of marked juvenile steelhead released above and below Foster Dam in 1971 may cloud assessment of the adult steelhead returns. Marked chinook smolts appeared to suffer little mortality due to fishing.

Numbers of Emigrants. The catch in the turbine nets and estimated numbers of wild-reared salmon and trout emigrating downstream through the penstocks at Foster Dam during the spring of 1969 and 1970 is shown in Table 15. We did not begin fishing the turbine nets in 1969 and 1970 until the major portion of the wild chinook migration had passed downstream. In 1970, 29,911 live wild steelhead and 38,745 live wild chinook were passed into Foster Reservoir via the Green Peter downstream-migrant system after March 1. The estimated emigration from Foster Reservoir through the penstocks was 16,956 steelhead and 10,837 chinook. The remainder of the steelhead and chinook released from Green Peter and the unknown numbers entering Foster Reservoir from the upper South Santiam River either emigrated downstream through the spillway or remained in the reservoir.

Timing. We were unable to determine the principle timing of the downstream migration at Foster Dam for any species in 1969 or for wild-reared chinook in 1970. The turbine nets, not available in 1969 until late May, were not installed until early March in 1970 because we estimated they could not withstand the water pressure from the turbines for more than 4 months.

The principle migration of wild steelhead occurred in late April and May in 1970. Catches in the turbine nets peaked on April 29 and May 25. The principle coho migration occurred in May 1970, catches peaked on May 13 and 24.

The numbers of marked wild-reared chinook and tagged wild and hatchery steelhead released from the Green Peter downstream-migrant facilities in the spring and subsequently collected in the Foster turbine nets are shown in Figures 18 and 19. Catches of chinook in

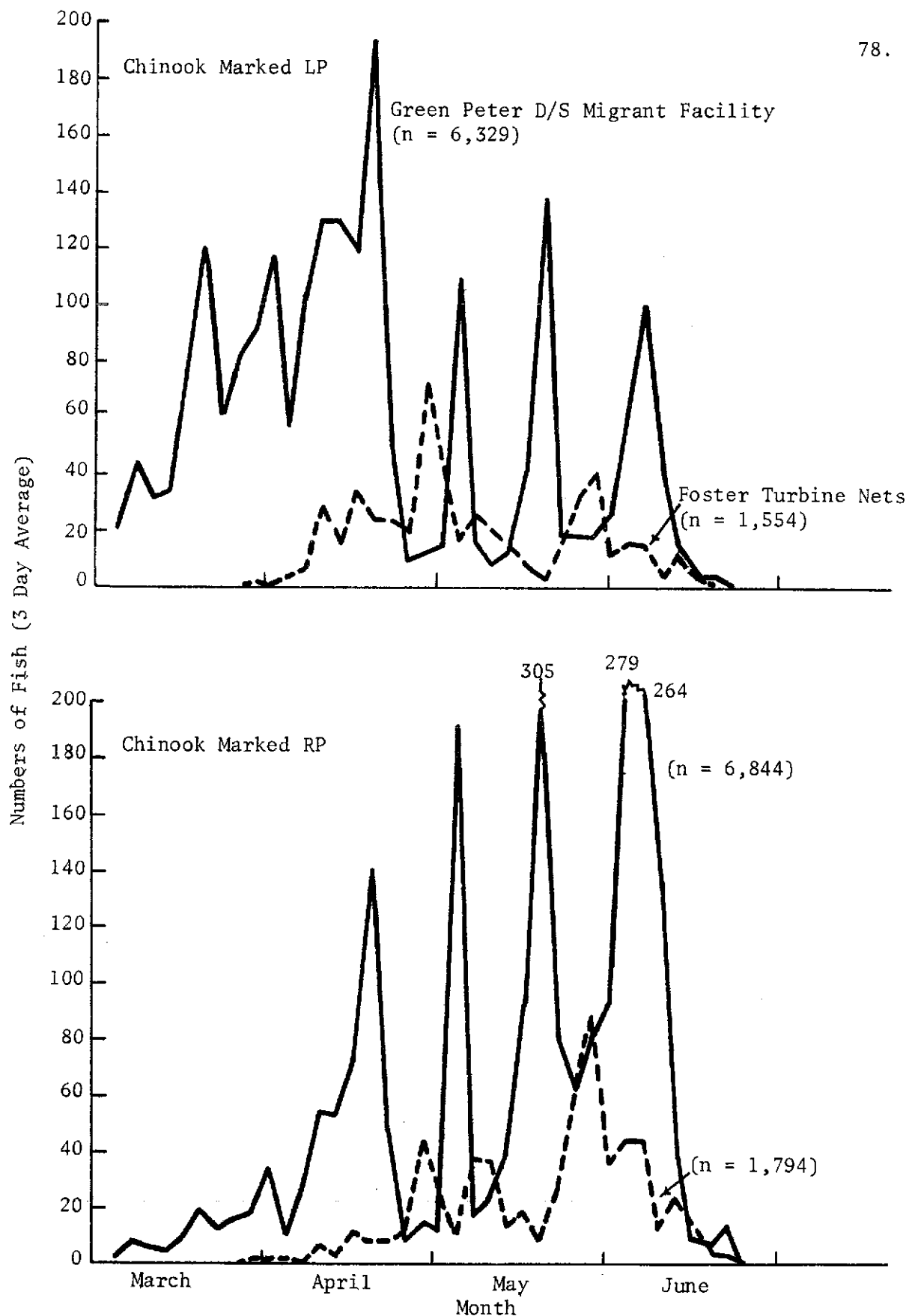


Figure 18. Numbers of Marked Wild-Reared Spring Chinook Released at the Green Peter Evaluator and Collected in the Foster Turbine Nets, March-June 1970

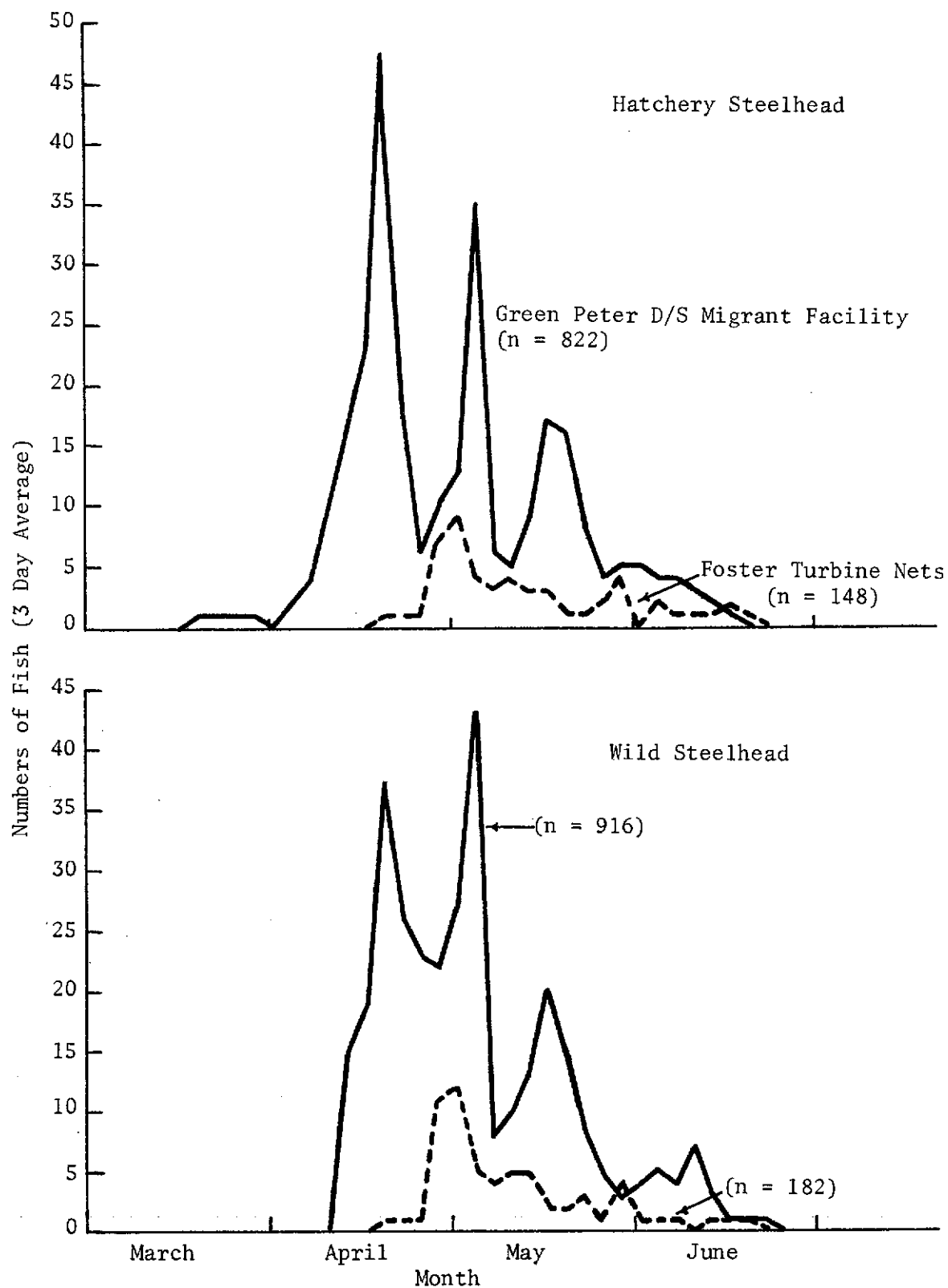


Figure 19. Numbers of Tagged Winter Steelhead Released at the Green Peter Evaluator and Collected in the Foster Turbine Nets, March-June 1970

the turbine nets peaked approximately 9 days after the peak releases of these fish from Green Peter. Catches of both wild and hatchery steelhead in the turbine nets peaked approximately 12 days after the peak releases of these fish from the Green Peter downstream-migrant facility.

We fished gill nets in Foster Reservoir on a monthly basis during the fall, winter, and spring of 1969. Few chinook were collected in the fall and winter even though a large number (160,000) emigrated downstream from Green Peter Reservoir during this period. Smolts appeared to rapidly move through Foster Reservoir during this time. The largest catches of chinook, steelhead, coho, and sockeye were made in mid-June, well after the emigration of these species peaked. It appears substantial delays in emigrating from Foster Reservoir are suffered by all anadromous species entering the reservoir in the late spring.

Survival and Condition of Emigrants. The total mortality of juvenile downstream-migrants collected in the turbine nets during 1969 and 1970 was high (Table 16). Most of the dead fish appeared to have been killed in the nets after passing through the turbines. The percentage of juvenile emigrants that were cut or chopped, apparently by the turbine, did not exceed 7.1% of the total catch. We believe this to be a minimum figure since other observed mortalities with no external injuries may also have been caused by the turbine. The mortality of steelhead kelts collected in the turbine nets was extremely high. The highest observed mortality of kelts apparently caused by contact with the turbine blades was 41% in 1970. It appears that few kelts passing downstream through the turbines will survive to return a second time to spawn.

Table 16. Assigned Turbine Mortality of Wild-Reared Downstream Migrants Collected in the Turbine Nets at Foster Dam, 1969-70

Run Year	Date Collected	No. Coll. in Turbine Nets			Apparent Turbine Mortality	
		Live	Dead	% Dead	Number	%
<u>CHINOOK</u>						
1969	5/20 - 6/27	2,784	1,163	29.5	234	5.9
1970	3/26 - 6/18	5,977	2,385	28.5	526	6.3
<u>STEELHEAD</u>						
1969	5/20 - 6/27	3,139	1,483	32.1	192	4.2
1970	3/26 - 6/18	8,106	3,635	31.0	640	5.5
<u>COHO</u>						
1969	5/20 - 6/27	227	41	15.3	3	1.1
1970	3/26 - 6/18	2,718	934	25.6	141	3.9
<u>SOCKEYE</u>						
1969	5/20 - 6/27	1,510	687	31.3	97	4.4
1970	3/26 - 6/18	57	31	44.3	5	7.1
<u>TROUT</u>						
1969	5/20 - 6/27	92	33	26.4	5	4.0
1970	3/26 - 6/18	1,044	198	15.9	14	1.1
<u>STEELHEAD KELTS</u>						
1969	5/20 - 6/27	18	41	69.5	13	22.0
1970	3/26 - 6/18	26	118	81.9	59	41.0

The Corps of Engineers conducted tests from April 23 to May 3, 1969 to determine the survival of downstream-migrant salmonids passing through the turbines at Foster Dam. 1/ The survival of downstream-migrant chinook during automatic cam operation at three selected forebay levels is shown in Figure 20. 2/ Survival appeared to be slightly higher at full pool (110 feet gross head) than at minimum conservation pool (36 feet gross head). The estimated average survival by month during the 1968-69 downstream migration based on the results of the Corps tests with hatchery chinook is shown in Table 17. We computed the percentage survival from the number of hours per megawatt the Foster turbines actually operated at a given gross head. Mortality of juvenile chinook which emigrated throughout the fall and winter, approximated 12%. An average mortality of 8% was estimated for juveniles emigrating only in April-June. However, mortalities based on tests conducted with hatchery fish may not be entirely applicable to wild emigrants due to differences in size, condition, and behavior. The kill of wild chinook smolts apparently due to the turbines, was approximately 1.4 and 3.5% higher than that of hatchery chinook in 1969 and 1970, respectively, based on an examination of dead fish found in the turbine nets. Hatchery chinook released in 1969 and

1/ All information concerning tests conducted by the Corps of Engineers on survival of downstream migrants through the Foster turbines was based on preliminary data obtained by letter from Ed Mains, Program Director, Fisheries Engineering Research Program, North Pacific Division, Corps of Engineers. A final report will be submitted by the Corps at a later date.

2/ Automatic cam is the operation of a turbine based on an established relationship between the gate opening and blade angle to produce the highest power output at a given head. Both units at Foster Dam are normally operated in this manner.

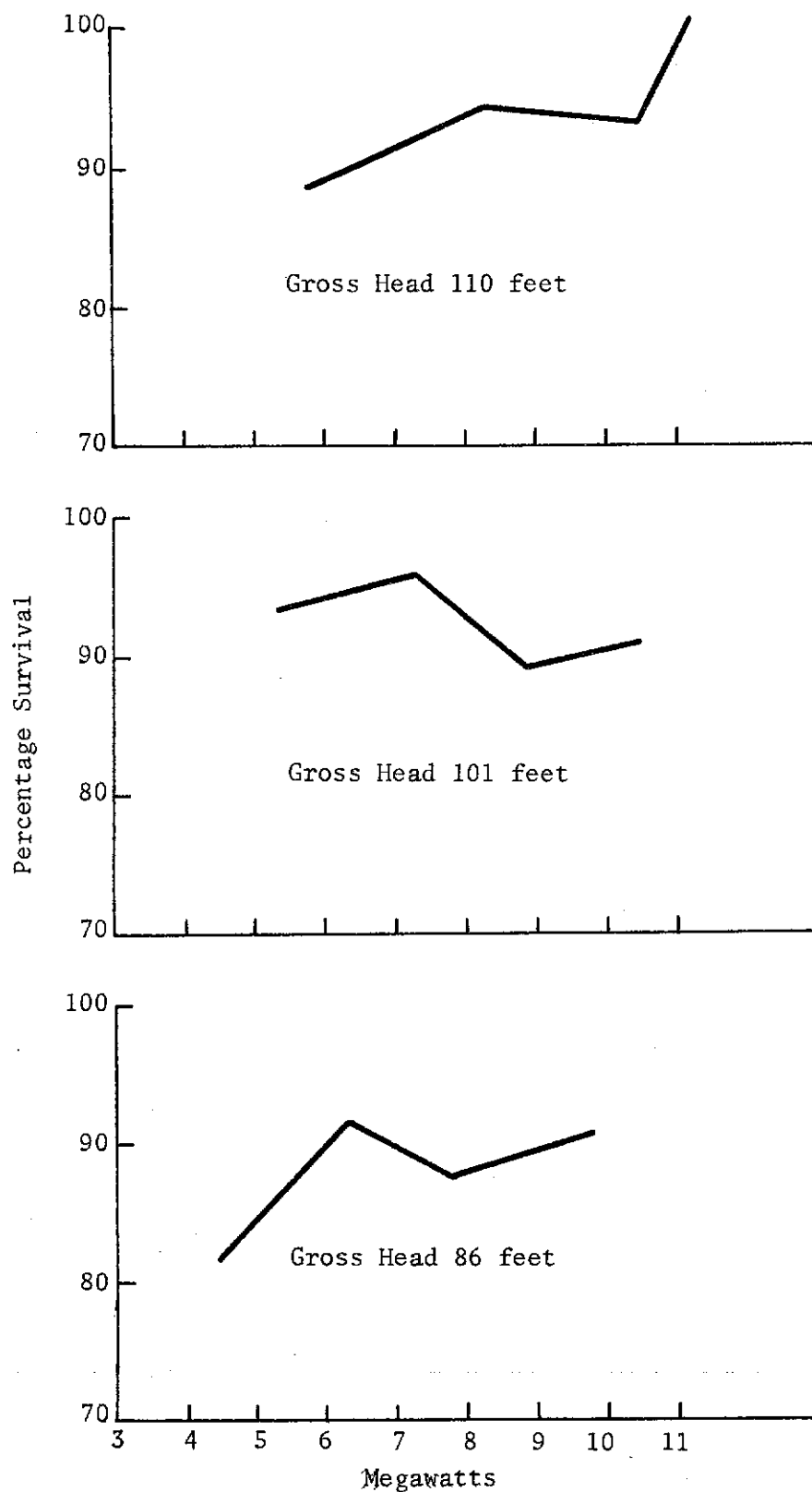


Figure 20. Survival of Yearling Hatchery Chinook Passing Through the Turbines During Automatic Cam Operation, Foster Dam, 1969

Table 17. The Estimated Survival of Juvenile Salmonids Emigrating from Foster Reservoir, 1968-69 (Based on Corps Turbine Mortality Tests)

Year	Month	Average Gross Head	Average Percentage Survival
1968	Dec.	92.6	88.9
1969	Jan.	92.0	88.8
	Feb.	92.0	86.6
	Mar.	96.0	88.0
	Apr.	99.1	91.2
	May	107.5	92.6
	Jun.	107.5	91.7
Average	-	-	89.9

1970, respectively, averaged 5-10 mm and 26-31 mm larger than wild chinook passing through the downstream-migrant facility.

The number of juvenile salmonids passing downstream from Foster Reservoir through the South Santiam Hatchery water supply was determined on 6 days in June 1971. We collected 32 wild chinook, 112 wild steelhead, 271 hatchery steelhead, 86 coho, and 46 trout. Of these, 34.4%, 38.4%, 48.3%, 51.2%, and 32.6%, respectively, were dead. The upper intake which operates during this period, was the probable point of entry by emigrants into the water supply system. This intake at full pool, is located 4.5-6.0 feet below the water surface on the upstream side of Foster Dam and operates from approximately May 1 to October 15. The lower intake also operates during this period but is located 60.5-52.0 feet below the surface. We believe few fish emigrated through the lower opening.

Operational Tests. Tests using submerged mercury vapor lights at the turbine intakes and spillway crest on Gate #4 could not be completed because of the short time the scoop traps were operated. However,

based on the data obtained at Fall Creek and Green Peter dams, we believe mercury vapor lights operated in the turbine intake area and at one spillway crest during the spring migration period will enhance the downstream migration of smolts.

Catch by Anglers. Foster Reservoir was open to angling from late April to October 31, 1968-70. In 1971, the OGC extended the general trout season in Foster Reservoir to December 31. Catches in gill nets in 1969-70, indicated the largest number of legal trout were present in the reservoir in the fall. It appears that many trout present in the reservoir during the winter pass downstream of Foster Dam during periods of high discharges of water.

Angler catch data were collected in Foster Reservoir only by the OGC. Catches during November and December in 1971, included 36% rainbow, 62% steelhead, and 2% chinook. However, few anglers participated in the fishery. The catch of chinook in any year during the regular fishing seasons in 1968-70 did not exceed 4% of the total angler catch. The steelhead catch varied from 10 to 57% during the same period. Angling pressure was heaviest from late April to July. It appears that substantial numbers of steelhead smolts entering Foster Reservoir may be caught by anglers in certain years.

Limnology

Green Peter Dam

Physical Observations in the Reservoir. We usually obtained water temperature profiles and dissolved oxygen samples from the reservoir at monthly intervals in the spring, summer, early fall, and occasionally

in the winter from 1968 to 1970. Physical limnological data was collected in 1967, while the reservoir was initially filling. However, we do not feel the information obtained during this stream-to-reservoir transition period is comparable to subsequent years.

The reservoir remained stratified to some degree throughout the winter months each year. The thermocline usually formed about mid-May and disintegrated by late October (Figure 21). Surface to bottom water temperatures in the reservoir varied from 23.4 to 6.7 C during the summer from 1968-70. We observed a surface to bottom temperature range of 8.4 to 3.9 C during the winter months.

Table 18 lists selected water temperatures and dissolved oxygen concentrations at mid-reservoir during possible critical periods in the summer and fall, 1968-70. Dissolved oxygen concentrations ranged from 5.2 mg/liter at the bottom to 11.2 mg/liter near the surface during this period. Temperatures ranged from 21.7 C at the surface to 6.7 C on the bottom during these years.

Effects of the Reservoir on the Stream Below the Dam. Flows in the Middle Santiam below Green Peter Dam varied from 50-12,000 cfs. All water is discharged downstream through the turbines except during periods of excessive inflows that usually occur from December-March. Water in excess of power generation needs during these periods is discharged downstream through the regulating outlets. Releases through these outlets caused the tailrace water to become supersaturated with nitrogen, at times in excess of 120%. The number of days that regulating outlets at Green Peter Dam spilled water was 32, 11 1/2, 11 3/4, and

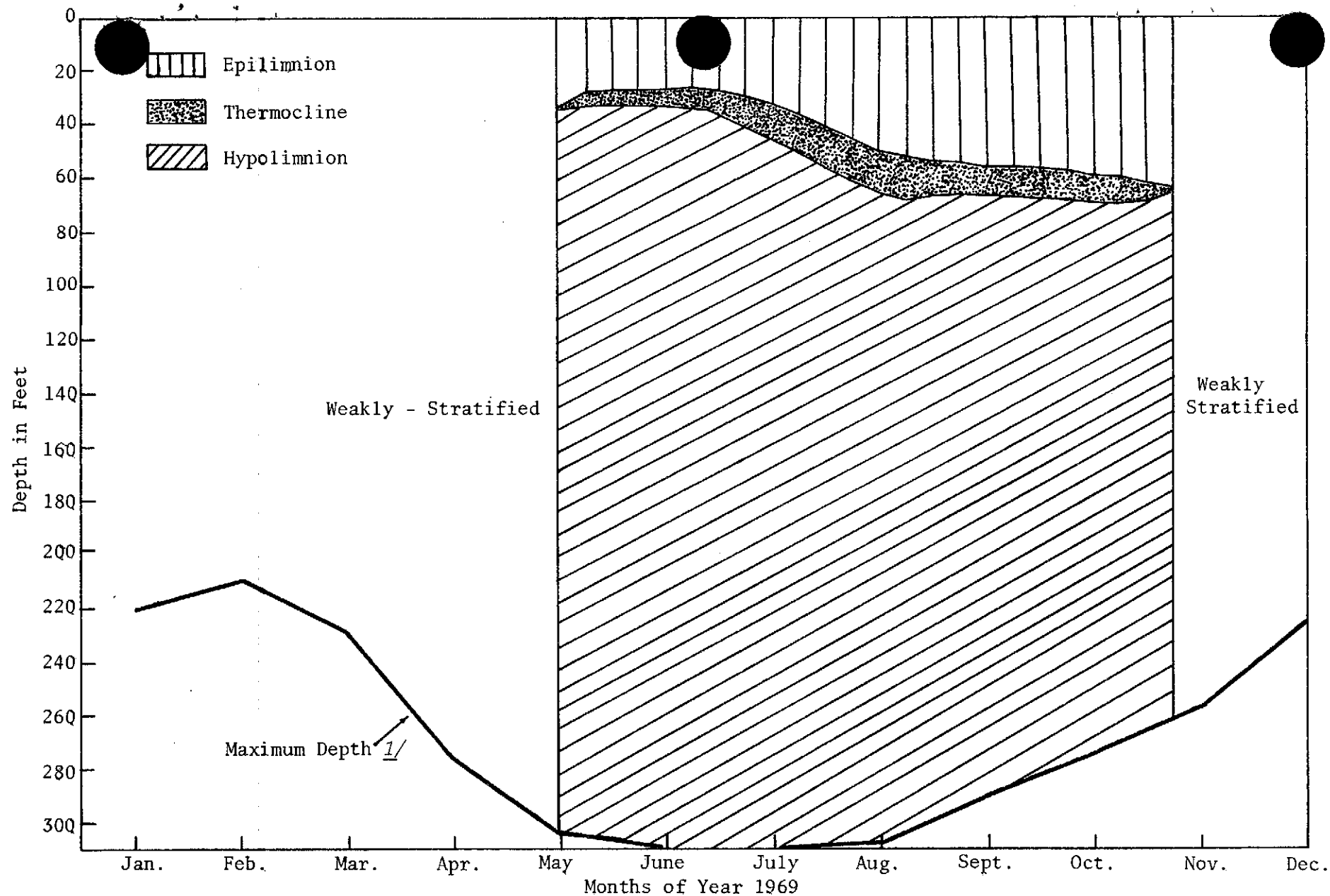


Figure 21. Formation and Disintegration of Thermal Stratification in Green Peter Reservoir, 1969

^{1/} Maximum depth changes with time due to fluctuations in pool level

Table 18. Selected Water Temperatures and Dissolved Oxygen Data,
Summer and Fall Seasons, Green Peter Reservoir, 1968-70

Period	Depth in Feet			Temperature in C			O ₂ Conc. in Mg/liter		
	EPI	THERM	HYPO	EPI	THERM	HYPO	EPI	THERM	HYPO
1968									
Summer (6-5-68)	0-31	35-36	36-240	17.8-13.9	13.9-12.2	12.2-7.2	9.6	10.0	10.4
Fall (8-21-68)	0-34	34-48	48-193	21.7-20.0	20.0-12.2	12.2-7.2	8.0	7.2	8.4
1969									
Summer (6-12-69)	0-27	27-30	30-81	17.2-16.1	16.1-13.4	13.4-7.2	9.6	9.0	10.6
Fall (9-26-69)	0-64	64-65	65-170	20.0-15.0	15.0-14.5	14.5-7.8	8.8	6.0	8.0
1970									
Summer (6-24-70)	0-29	29-32	32-150	20.6-16.7	16.7-12.8	12.8-7.2	10.0	8.2	10.0
Fall (9-10-70)	0-47	47-51	51-123	19.5-18.9	18.9-13.9	13.9-8.4	11.2	8.6	5.2

16 1/2 in each of the years from 1968-71 inclusive. We deactivated the downstream-migrant facility during spill periods in 1969-71 to prevent juvenile salmonids from entering the nitrogen supersaturated water.

Yearly water temperatures in the river immediately below Green Peter Dam varied from 2.3 to 11.7 C from 1968-71. The maximum temperature was recorded between October 15 and November 15 each year. Temperatures during the spring each year (March-July) ranged from 2.8 to 8.9 C.

Biological Observations in the Reservoir. In their chemical treatment of the reservoir area and its tributaries in the fall of 1966, the OGC did an excellent job of reducing indigenous populations of rough fish. Undesirable species of fish found in the reservoir area during chemical treatment included bullhead, coarse-scaled sucker, squawfish,

redside shiner, gold fish (*Carassius auratus*), bridgelip sucker (*C. columbianus*), dace, and bluegill. Subsequent catches in gill nets set by the FCO and OGC and catches at the evaluator indicated that all but the dace, coarse-scaled suckers, and lamprey larvae were eliminated. Traps fished by the OGC during the summer of 1971 in upper Green Peter Reservoir collected many coarse-scaled suckers. Although suckers increasingly infested the reservoir, we anticipated many years of good production of anadromous salmonids. We do not believe dace or lamprey cause a serious predator or competitor problem to salmonids in the reservoir; however, suckers may compete with salmonids for food.

Foster Dam

Physical Observations in the Reservoir. We collected physical limnological data in a similar manner as described for Green Peter Reservoir. Foster Reservoir remained weakly stratified throughout the winter months. A thermocline began to form about mid-May and usually disintegrated by October (Figure 22). Surface to bottom water temperatures in the reservoir varied from 21.1 to 6.7 C during the summer months. We observed a surface to bottom temperature range during the winter months of 9.5 to 4.5 C.

Table 19 lists selected water temperatures and dissolved oxygen concentrations at mid-reservoir during possible critical periods in the summer and fall, 1968-70. Dissolved oxygen concentrations ranged from 9.0-11.6 mg/liter at the bottom to 9.0-10.4 mg/liter on the surface during this period. Oxygen concentrations in Foster Reservoir appeared adequate during all months tested during 1968-70. Temperatures ranged from 20.0 C at the surface to 7.2 C on the bottom during these years.

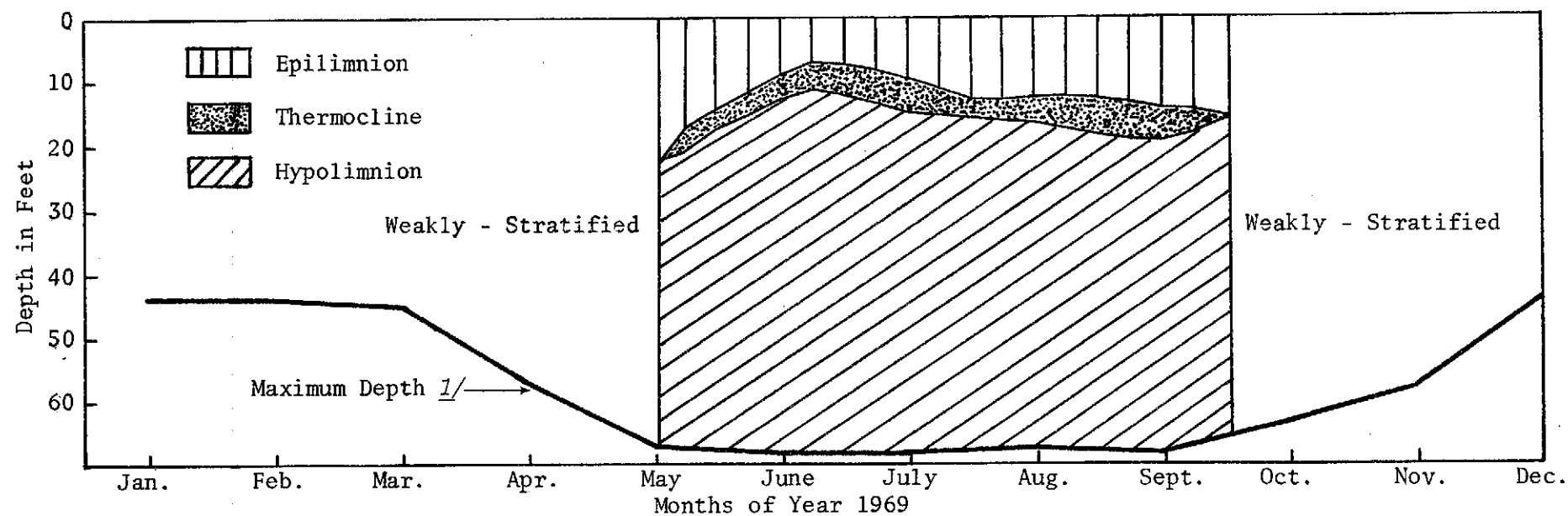


Figure 22. Formation and Disintegration of Thermal Stratification in Foster Reservoir, 1969

1/ Maximum depth changes with time due to fluctuations in pool level

Table 19. Selected Water Temperatures and Dissolved Oxygen Data,
Summer and Fall Season, Foster Reservoir, 1968-70

Period	Depth in Feet			Temperature in C			O ₂ Conc. in Mg/liter		
	EPI	THERM	HYPO	EPI	THERM	HYPO	EPI	THERM	HYPO
1968 Fall (8-22-68)	0-17	17-22	22-39	19.5-18.9	18.9-15.0	15.0-10.6	9.0	9.0	9.0
1969 Summer (6-10-69)	0- 9	9-13	13-62	17.8-16.7	16.7-13.4	13.4- 7.2	10.4	10.6	11.6
1969 Fall (8-28-69)	0-14	14-20	20-33	20.0-18.9	18.9-13.9	13.9-10.6	9.4	10.0	10.8
1970 Summer (6-11-70)	0.16	16-17	17-63	18.4-17.8	17.8-15.6	15.6- 8.4	10.2	10.0	11.2

Effects of the Reservoir on the Stream Below the Dam. We compared pre-project and post-project water temperatures in the stream below Foster Dam (Table 20). These data, from the U. S. Geological Survey gauging station near Foster, indicate that releases of impounded water reduce Diel variation in stream temperatures. Post-impoundment mean daily high and low water temperatures were lower during June-September and higher in November and December over pre-impoundment readings.

Post-impoundment manipulation of discharges obviously changed the volume of flows below the project. Flows from Foster Reservoir were generally dictated by the amount of discharge from Green Peter Dam except during freshets. Minimum discharges from Foster in the summer during the study period were not less than 500 cfs. The mean preproject (1962-66) flows at Foster, Oregon, in August and September seldom exceeded 250 cfs. Flows as low as 100 cfs were recorded during these periods.

Table 20. Temperature in Degrees Centigrade of South Santiam River
below Foster Dam, 1962-71 ^{1/}

Year	Temperature Range		Months											
			J	F	M	A	M	J	J	A	S	O	N	D
1962	High	Max.	7.2	5.6	7.8	10.6	12.2	18.9	23.4	21.7	20.0	14.5	10.6	8.4
		Avg.	4.5	5.0	5.0	8.4	9.5	15.6	20.0	19.5	17.2	11.1	8.9	6.7
	Low	Min.	1.1	1.1	1.1	5.6	10.0	9.5	13.9	16.1	12.2	8.4	5.6	2.8
		Avg.	4.0	4.5	4.5	6.7	8.4	13.4	18.9	18.4	16.1	10.0	7.8	6.1
1963	High	Max.	6.7	8.4	9.5	11.1	17.2	21.1	20.0	21.7	--	15.0	8.9	8.4
		Avg.	3.4	7.2	7.2	8.9	12.2	16.1	17.8	18.9	--	11.7	7.8	6.1
	Low	Min.	1.1	2.8	5.0	5.6	6.7	11.1	12.2	15.6	--	6.7	5.6	3.9
		Avg.	2.8	6.7	6.7	7.2	10.0	14.5	15.6	17.8	--	11.1	7.2	5.6
1964	High	Max.	8.4	7.2	8.9	9.5	11.7	16.1	21.1	21.1	17.2	14.5	10.0	--
		Avg.	6.7	6.1	6.7	7.8	8.9	11.7	18.4	18.9	15.6	11.7	6.1	--
	Low	Min.	4.5	4.5	5.0	5.0	6.1	8.4	12.8	14.5	13.4	8.9	2.8	--
		Avg.	6.1	5.6	6.1	6.1	7.2	10.0	16.7	17.8	15.0	11.1	5.6	--
1965	High	Max.									20.6	16.1	12.2	8.4
		Avg.				N o	D a t a				17.2	13.4	8.9	4.5
	Low	Min.									11.1	10.0	3.9	0.0
		Avg.									13.9	11.7	8.4	3.9
1966	High	Max.	6.7	7.2	9.5	10.6	15.6	20.6	23.4	24.5	22.8	--	10.6	--
		Avg.	5.0	5.6	6.7	8.4	11.7	16.7	20.6	21.7	18.9	--	7.8	--
	Low	Min.	2.8	2.8	2.8	4.5	6.7	8.9	12.2	16.1	13.9	--	5.0	--
		Avg.	4.5	3.9	5.0	5.6	8.4	14.5	18.4	19.5	16.7	--	7.2	--
1967	High	Max.	6.1	6.7	7.2	--	--	15.0	15.6	--	--	16.1	11.1	8.9
		Avg.	5.0	5.6	6.1	--	--	13.9	14.5	--	--	13.4	10.6	7.2
	Low	Min.	3.9	4.5	5.0	--	--	9.5	12.2	--	--	10.6	8.9	5.6
		Avg.	4.5	5.0	5.6	--	--	11.7	12.8	--	--	12.2	10.0	6.7
1968	High	Max.	6.7	--	8.9	12.2	16.1	12.2	12.8	--	12.8	--	--	--
		Avg.	5.6	--	7.2	9.5	12.2	11.1	12.2	--	11.7	--	--	--
	Low	Min.	3.9	--	5.6	7.8	8.9	8.9	9.5	--	10.0	--	--	--
		Avg.	5.6	--	6.7	8.4	10.6	10.0	11.1	--	10.6	--	--	--
1969	High	Max.	--	--	7.8	8.9	10.0	12.2	12.2	13.4	13.4	13.4	11.1	8.9
		Avg.	--	--	6.1	7.8	8.9	10.6	11.7	12.8	11.7	11.1	10.0	7.8
	Low	Min.	--	--	4.5	6.1	6.1	8.4	8.9	11.1	10.0	9.5	8.9	6.7
		Avg.	--	--	5.6	6.7	7.2	9.5	10.6	11.7	10.6	10.0	9.5	7.8
1970	High	Max.	7.8	7.8	8.9	10.0	11.1	12.2	12.2	12.8	12.2	11.7	10.0	7.8
		Avg.	6.7	7.2	7.8	9.5	10.0	11.7	12.2	12.2	11.7	10.6	8.9	6.7
	Low	Min.	5.0	5.6	6.7	7.8	7.8	9.5	10.6	10.6	9.5	8.4	6.7	5.0
		Avg.	6.1	6.7	7.8	8.4	8.9	11.1	11.7	11.1	10.6	10.0	8.9	6.1
1971	High	Max.	6.1	5.6	7.2	8.4	10.6							
		Avg.	5.6	5.6	6.1	7.8	9.5			N o	D a t a			
	Low	Min.	4.5	4.5	3.9	6.1	6.7							
		Avg.	5.0	5.0	5.6	7.2	7.8							

^{1/} Gaging station located immediately above the town of Foster during 1962-66 and 300 yards below Foster Dam from 1966-71.

In 1970-71 we requested the Corps to hold the average daily discharges below Foster Dam at 1,500 cfs, ± 400 cfs from September 10 to October 15 and to discharge not less than 1,000 cfs from October 15 to December 15. This allowed chinook spawning below the project in shallow areas, access to redds during spawning and prevented these redds from being left out of the water after spawning.

After December 15, discharges from Foster Dam generally exceeded 1,000 cfs until the following spring.

Biological Observations in the Reservoir. The OGC also chemically treated the South Santiam River above the Foster Dam site in the fall of 1966. However, a fish-tight barrier installed in the Foster diversion tunnel washed out before the tunnel could be closed in December 1966. Incomplete chemical treatment on access through the diversion tunnel allowed undesirable species of fish to reinfest the reservoir. These included coarse-scaled suckers, squawfish, reddsides, shiners, brown bullheads, and bluegills. Subsequent sets of gill nets by the FCO and OGC caught few squawfish. Catches of suckers decreased from 1969 to 1970. However, catches of reddsides shiners increased substantially from 1968 to 1971. One gill net set in upper Foster Reservoir in June 1970 collected over 4,000 reddsides shiners in one night's fishing. We believe competition for food from undesirable species and predation in Foster Reservoir has retarded reservoir rearing of salmonids, and retreatment of the reservoir area and its tributaries is necessary if we are to produce a significant number of salmon smolts in this impoundment.

CONCLUSIONS

We reached the following conclusions based on the results of this study:

1. In Green Peter Reservoir, juvenile spring chinook grew to migrant size in 6 to 8 months and, based on returns of adults in 2 years, survived adequately under present environmental conditions. We found that the 1966 chemical treatment of the reservoir was largely successful. However, suckers are beginning to infest the reservoir. Angling in the reservoir does not presently appear limiting in maintaining anadromous fish runs passing above the project.

2. Adequate environmental conditions for salmonids exist in Foster Reservoir. However, populations of rough fish infested the reservoir after chemical treatment in 1966 and redbreasted shiners increased substantially in subsequent years. Angling in the reservoir did not substantially affect populations of juvenile salmon. However, anglers caught large numbers of steelhead smolts during the spring in certain years.

3. We judged the downstream-migrant transport system at Green Peter Dam successful in passing chinook emigrants. Successful passage of steelhead smolts is questionable. Small numbers of downstream migrants are injured by the collection system, exclusive of the evaluator, and mortality appears negligible. Submerged mercury vapor lights improved collection of juvenile fish, particularly steelhead. The number of chinook fingerlings released into the reservoir appeared to influence the subsequent size of downstream migrants.

4. Juvenile chinook appeared to successfully migrate from Foster Reservoir. However, steelhead passage success was questionable. All salmonid migrants entering Foster Reservoir in the late spring suffered substantial delays in passing downstream of the dam. Turbine mortality to juveniles does not presently appear limiting to maintaining anadromous fish runs above Foster Dam.

5. The 3,775 wild-reared adult spring chinook returning to Foster Dam in 1971 was substantially greater than the estimated preproject run above that site. This run resulted primarily from juvenile salmon that reared in Green Peter Reservoir. We believe future returns of spring chinook to the Green Peter-Foster project will continue to be substantially greater than preproject estimates. Returns of adult winter steelhead, based on parent-to-adult returns, increased slightly in 1971.

6. The upstream-migrant facilities at Foster Dam successfully collected all species of adult fish. The upstream-migrant facilities at Green Peter Dam did not collect adults successfully during the initial phases of the study. However, water discharged from the turbines and fish facilities appeared to be increasingly accepted each year by adult chinook and steelhead. Reducing the discharge from Green Peter Dam to 50 cfs during afternoon periods in April appeared to enhance passage of upstream-migrant steelhead at that dam.

7. Prespawning mortality of adult chinook above Foster and Green Peter dams in 1970 and 1971, appeared extensive. However, this may partly be attributed to delays in passage and injuries sustained at Willamette Falls in both years.

8. Chinook fingerlings released at 506/lb into Green Peter Reservoir survived better than those released at a smaller size. Chinook released into the reservoir appeared to survive to emigration at a higher rate than those released into stream areas above the reservoir. Releasing hatchery-spawned chinook fingerlings into the reservoir appears to be a successful and economic method of replacing spawning losses and enhancing the adult chinook run returning to the Green Peter-Foster Project.

RECOMMENDATIONS

As a result of data presented in this report, we recommend the following pertaining to fish passage at the Green Peter-Foster Dam complex:

General

1. Continue to pass anadromous fish at Green Peter and Foster dams. Continue to maintain the fish facilities in good operating order by a system of regular preventative maintenance.
2. Retain the Corps Projects' Steering Committee to periodically review and guide fish passage operations at Foster and Green Peter dams.
3. The Corps should notify state and federal fisheries agencies of any changes in the basic physical operation of the reservoirs, such as changes in filling or evacuation schedules, spill through the Green Peter regulation outlets and spillway, etc.

4. We believe that additional tests pertaining to the following should be conducted.
 - a. The value of restricting the use of tainter gate 4 at Foster Dam during periods of spill to reduce drop back of adults from the forebay to the tailrace.
 - b. Final determination of steelhead passage success.
 - c. The effects of a submerged mercury vapor light located in front of the Green Peter downstream migrant collector on steelhead and sockeye emigrants during the spring migration.
5. The authors believe the following recommendations, which pertain to management of the reservoir, are sufficiently important for inclusion in this report.
 - a. The state fisheries agencies should maintain surveillance of and compile data on fish runs above Foster and Green Peter dams. The state agencies will utilize the data to manage fish populations in the South Santiam above Foster Dam and as a guide for passage and management programs at pending Corps projects.
 - b. Chemically treat Foster Reservoir and the upstream areas, excluding areas above Green Peter, to eliminate scrap fish. This would provide rearing area for an additional 1.5+ million spring chinook and summer steelhead fry and fingerlings. Since it is not possible to fix blame for the infestation of scrap fish in Foster, we propose that the Corps provide the materials and the state fisheries agencies the manpower needed for treatment.

6. Continue to maintain daily discharges below Foster Dam between 1,100 and 1,800 cfs from September 10 to October 15, and maintain minimum discharges of 1,000 cfs from October 15 to December 15. These flows are necessary for successful spawning of spring and fall chinook below the project.

Passage of Adults

1. Operate the upstream-migrant facilities at Foster and Green Peter dams from February 1 to December 15 each year. Continue to separate rough fish from salmonids at the Foster adult facility. If any rough fish are collected in the Green Peter upstream-migrant facilities, install a separating device there. Confine normal fishway maintenance that requires deactivating the upstream-migrant facilities to the winter shutdown period.
2. Operate auxiliary attraction water systems in upstream-migrant facilities at both dams at full capacity, regardless of tailwater level. Continue to operate the ladder entrances with orifice openings, maintaining a 1-1 1/2 foot head differential between the inside and outside of each ladder entrance.
3. Continue to hold flows below Green Peter Dam to a minimum for 4 hours each afternoon in April and May to stimulate adult winter steelhead passage.
4. Refrain from spilling through the tainter gate nearest the spillway ladder entrance (No. 4 gate) at Foster Dam. Discharges through this gate conceal the attraction flow from the spillway ladder entrance. Adults entering the forebay from the hopper may drop-back through this gate before they can become oriented and move upstream.

5. The Corps of Engineers should count all upstream migrants collected at both projects. Pertinent biological data will be taken by state fishery biologists. Fish should be passed upstream at both dams as follows except when the Corps and fishery agencies agree to other procedures.
 - a. At least once each day when an average of 10 or more adults/day are collected.
 - b. Monday, Wednesday, and Friday when an average of 1-10 adults/day are collected.
 - c. Monday and Friday when an average of less than one adult/day is collected.

Each day the fishway is checked, the fishway operator must fill out a fishway form and send summaries to the appropriate agencies at the end of each month.

6. The maximum loading capacity of the 1,000-gallon fish hoppers in the Foster and Green Peter upstream facilities is 80 and 50 adult salmonids, respectively. However, we recommend a separate oxygen system in the Foster fish hopper to increase the loading capacity at that facility.
7. Continue to use tricaine methane sulfonate (MS-222) as an anesthetic for adults in the Foster upstream-migrant facility. The dosage to be used in the anesthetic tank is 150 grams to 800 gallons of water (1:19,000).
8. Consult with biologists at the project to eliminate adults getting on top of the Foster fish hopper curtain at release into the forebay.

9. An alternate means of crowding adults into the anesthetic tank at Foster Dam should be investigated. We feel the present crowding keeps the thrashing adults out of water too long before depositing them into the tank. This may injure the fish.
10. Install screening or netting between the loading and hopper pool at Green Peter Dam to prevent adults from jumping into the hopper pool and then onto the floor.

Passage of Downstream Migrants

1. Operate the Green Peter downstream-migrant system from November 1 to July 1 each season. From December 15 to March 1, this facility may be deactivated when Green Peter Reservoir is filling faster than 6 feet/day and during periods when water is discharged through the regulating outlets or spillway. A fishery agency representative should always be notified before the downstream-migrant facility is deactivated. This facility should be operated with two attraction water pumps at all times.
2. Operate the spillway-bay flood lights and the underwater mercury vapor light in the Green Peter forebay when the downstream-migrant facility is running. Locate the mercury vapor light approximately four feet in front of the horn and five feet below the water surface. Reposition the mercury vapor light each time the intake gate is reset. Record all changes made in the downstream-migrant facility and underwater light.

3. Fishing depth of the Green Peter downstream-migrant intake horn attached to the separator should be 17 feet deep, measured from the horn center line to water surface.
4. Inspect and maintain the 1/4-inch screen covering the upper opening of the Green Peter turbine intake stoplog wells annually.
5. Maintain the evaluator intact to allow the state fisheries agencies to collect pertinent biological data from emigrants. The information is vital to the continuing management of the fishery and applicable to other proposed Corps projects with similar downstream-migrant facilities.
6. At 3-year intervals, inspect the vinyl coating in the four connecting pipes between the Green Peter separator and stainless steel transportation pipe and in the transportation pipe between the powerhouse and evaluator. Repair the coating on the concrete u-shaped slide between the downstream end of transportation pipe and the tailrace. Each year, inspect the expansion joint at the downstream end of the stainless steel transportation pipe to insure the joint filler remains smooth.
7. Invert or smooth the perforated plate on the Green Peter separator to prevent fin and eye damage to emigrants.
8. Coat with vinyl the inside of the intake horn attached to the separator at Green Peter Dam to prevent fin damage from rust nodules, particularly in the neck of the horn where the highest water velocities occur.

9. Operate submerged mercury vapor lights at Foster Dam in the number 2 spillway bay and in the penstock area from March 1 to July 15 each year. The light located in the spillway bay should be deactivated when there is no spill.
10. The South Santiam Hatchery water intake located at elevation 630 in Foster forebay should be screened to prevent emigration of downstream-migrants through this water system. The screen should cover the intake when this water supply is activated in the spring and can be removed after July 15 each year.

SUMMARY

The Fish Commission of Oregon conducted a 4-year study to evaluate facilities for passage of anadromous salmonids at Foster and Green Peter dams. The study began July 1, 1967, and was financed by the U. S. Army Corps of Engineers. A committee comprised of one member each from the Corps, Fish Commission, Game Commission, Bureau of Sport Fisheries and Wildlife, and the National Marine Fisheries Service supervised the study.

The Corps constructed Foster Dam on the South Santiam River in the vicinity of Foster, Oregon. The dam is a rock fill structure 4,565 feet long, 126 feet high, and produces 20,000 kilowatts of power. At full pool the reservoir covers 1,220 surface acres and extends from the dam to points 3.5 miles up the South and Middle Santiam rivers.

Green Peter Dam was constructed on the Middle Santiam River 3 miles upstream from its confluence with the South Santiam River. The dam is a concrete structure 1,500 feet long, 360 feet high and produces 80,000

kilowatts of power. At full pool, the reservoir covers 3,720 surface acres and extends from the dam to points 8.5 miles up Quartzville Creek and 9.5 miles up the Middle Santiam River.

Anadromous species of salmonids present above the Foster Dam site prior to impoundment, included spring chinook, winter steelhead, and coho. Summer steelhead and sockeye were introduced after the project began impounding water. Passage tests were conducted using only spring chinook and winter steelhead as test fish. All upstream and downstream migrants were enumerated.

Collection facilities at Foster Dam for adult migrants consist of a short fishway leading to a fish trap, located next to the penstocks in the main dam structure. Fish are transferred from the trap to a hopper, hauled vertically through the dam, and released into the forebay. Juvenile salmonids passing downstream must emigrate through the penstocks or spillways, located 23-50 feet from the surface depending on the reservoir level.

Collection facilities provided at Green Peter for adult migrants were similar to those constructed at Foster Dam. The downstream transport system consists of a separator and attached fish horn capable of operating at all forebay levels between minimum conservation pool and full pool. Downstream-migrants are passed from the separator into a transportation pipe which discharges into the tailrace.

Corps and FCO personnel trapped upstream-migrating fish at Foster and Green Peter dams. Rough fish were removed at Foster Dam and adult salmon and steelhead released into the forebay at both projects. No rough fish were observed in the Green Peter upstream-migrant facilities.

We recorded volume and temperatures of reservoir discharges and attempted to relate these factors to adult counts. We were generally unable to determine if a relationship existed between low water temperatures, water quality, and migration of adult chinook at Foster Dam. However, a delay observed in 1969 may have been caused by one or both of these factors. No other delays in the upstream migration of salmonid adults at Foster Dam were observed. However, adult chinook delayed downstream and arriving at Foster after July 1, held in the tailrace until late summer and early fall.

In 1970 and 1971, we observed significant increases in the numbers of adult spring chinook returning to Foster Dam. We ascribed this increase to releases of chinook fry and fingerlings above Green Peter Dam and the large rearing area provided by the reservoirs. Adult steelhead returns increased substantially in 1971, the first adult return from parents which spawned above the projects.

The upstream migration of chinook and steelhead appeared to be delayed at Green Peter Dam. The peak of the chinook migration did not appear in the upstream-migrant facilities in 1967 and 1969 until August and September. Preproject estimates indicated that 60-70% of the adult chinook and steelhead passing above Foster Dam would spawn in the Middle Fork. The percentage of these fish arriving at Green Peter Dam never approached this estimate. Low temperatures and quality of water discharged from Green Peter may be the causative factors. However, numbers of chinook observed in the upstream facilities peaked during June in 1970-71 and large numbers of steelhead and chinook observed for the first time in the tailrace area and immediately downstream indicated conditions may be improving.

Few adult fish were killed directly by the collection facilities. However, we believe the method of lifting fish from the loading pool to the anesthetic tank at Foster Dam may have contributed to prespawning mortalities of adult salmonids. The crowding and lifting mechanism should be modified in the near future to provide a smooth transfer of adults from the loading pool to the anesthetic tank.

During 1968 and 1971, some marked salmonid adults collected in the Foster upstream-migrant facilities had returned to the tailrace via the spillway and turbines after release into the forebay. This problem appeared to be significantly reduced by eliminating spill through the tainter gate nearest the hopper release site during adult migration periods.

We found little or no direct mortality resulting from transporting up to 102 adult fish over Foster Dam in the fish hopper. Because of near-critical dissolved oxygen levels remaining in the hopper at maximum loads, we recommend hauling no more than 80 adults per trip. Based on results at Foster Dam and the increased time required for transport, we recommend load limits of 50 adults in the Green Peter fish hoppers.

Many of the adult chinook released above Foster and Green Peter dams in 1970-71 apparently died before spawning. In 1970 and 1971, respectively, we observed 7.2-8.3 and 15.8-17.3 spawners per redd. This implies that the number of adult chinook surviving to spawn of those released upstream of Green Peter and Foster dams was less than 50% in 1970 and less than 30% in 1971. Poor survival to spawning

appeared to be caused by poor condition of the fish arriving at Foster Dam and excessive water temperatures and poaching during the summer in the upstream holding areas.

The Corps installed a permanent evaluator at the downstream end of the transportation pipe of the Green Peter downstream-migrant facilities. A sampler was incorporated in the evaluator to reduce the number of juveniles that had to be handled and counted. We generally sampled 1/3 of the emigration and passed the remaining 2/3 into the tailrace uncounted. Juveniles migrating downstream from Foster Reservoir must emigrate through the spillways or penstocks. We tested passage from Foster Reservoir in the spring using turbine nets and scoop traps to collect marked and unmarked fish and estimate emigration of juveniles through the penstocks and spillways, respectively.

Collection of marked juvenile chinook released into Green Peter Reservoir ranged between 75 and 84%. At the end of the second year of testing, we judged the collection efficiency of the downstream-migrant system successful for spring chinook. Emigration rates for winter steelhead varied between 33 and 57%. However, of the summer steelhead presmolts released above Green Peter Dam in February 1971 by the OGC, 67% were collected in the downstream-migrant facilities. Because of the large variability in the results of tests determining passage success of winter steelhead, we believe the final determination of success or failure of the transport system to collect this species will have to be based on adult returns to the project.

Collection of juvenile spring chinook and winter steelhead released into Foster Reservoir ranged from 44-70% and 6-61%, respectively.

However, poor collection efficiency rates in the scoop traps and mechanical problems with the turbine nets reduced the significance of our results. In 1970-71, we released marked groups of chinook and steelhead smolts into Foster Reservoir and tailrace. We hope to compare the returns of adults from these groups to assess the relative success of emigration of juvenile chinook and steelhead from Foster Reservoir. Passage efficiency for other species of anadromous salmonids was not tested at either dam.

We determined from releases of marked fish and late spring catches in gill nets that juvenile migrants entering Foster Reservoir after April each year suffered substantial delays in passing out of the reservoir. No delays in emigrating from Foster Reservoir could be demonstrated for chinook entering this impoundment in the fall and winter.

Annual counts of wild-reared downstream-migrant chinook at Green Peter Dam varied between 70,000 and 775,000. The majority of these smolts were produced from releases of hatchery chinook fingerlings above Green Peter Dam. The largest counts of downstream-migrant winter steelhead, coho, and sockeye was 54,000, 80,000, and 38,000, respectively. Adult coho runs were discontinued above Green Peter Dam in 1969. Estimates were not made of the total emigration of juvenile salmonids from Foster Reservoir.

The emigration of juvenile chinook from Green Peter Reservoir peaked in the fall and early spring each year while the steelhead, coho, and sockeye emigration peaked in the spring.

Juvenile salmonids passing downstream through the Green Peter collection system sustained abrasion injuries in 1968. The Corps coated all black iron pipes in the transport system with vinyl. Subsequent injuries have primarily been caused by the evaluator. It appears few smolts are injured when passing downstream through the system and bypassing the evaluator.

Mortality of juvenile salmonids passing through the turbines at Foster Dam was determined by the Corps of Engineers. They estimated the mortality varied between 8.9 and 12.0%. However, tests were based on releases of hatchery fish. Mortality of wild smolts may have been somewhat higher. Mortality of juveniles passing downstream through the spillway was not tested.

A 400-watt underwater mercury vapor light submerged in the forebay in front of the Green Peter downstream-migrant facility substantially increased the collection of all species of juvenile emigrants except sockeye. This light appeared to repel sockeye smolts. We recommend that submerged mercury vapor lights be installed at Foster Dam above the penstock intake and in one spillway bay during the spring to enhance fish passage from Foster Reservoir.

We designed tests to determine methods of operating the Green Peter downstream-migrant facility to get the highest collection efficiency. We concluded from these tests that the center of the intake horn should be located approximately 17 feet deep. Additionally, the facility collected more fish when operating with two attraction water pumps than with one.

Gill nets fished in the Green Peter penstock intake stoplog wells during minimum pool periods in the winter indicated juvenile fish were entering the upper openings of these wells. We had the Corps screen these openings.

Catches by anglers in both reservoirs during the regular summer trout season and in the special fall season in Foster and special winter season in Green Peter do not appear limiting to enhancement of the chinook runs or maintenance of the steelhead runs passing the projects. However, in certain years the catch of steelhead smolts by anglers in Foster Reservoir appeared substantial in April and May.

The U. S. Geological Survey and Corps provided us with data on volumes and temperatures of the discharge from both reservoirs. Releases of water through the Green Peter regulating outlets occurred during periods of high winter inflows and caused the tailrace to become super-saturated with nitrogen, in excess of 120% at times. During these periods we deactivated the downstream-migrant facility.

Releases of impounded water below Foster Dam reduced Diel variation in stream temperatures. Post-impoundment mean daily high and low water temperatures were lower during June-September and higher in November and December than preimpoundment readings.

We took water temperature profiles and dissolved oxygen samples from the reservoirs. Green Peter and Foster reservoirs remained weakly stratified throughout the winter. A thermocline was observed from mid-May to late October in both reservoirs. Dissolved oxygen was adequate during all periods of the year after 1967.

Chemical treatment of the reservoir and upstream areas by the OGC appeared to remove all but the dace and coarse-scaled suckers from

Green Peter Reservoir. Undesirable species of fish reinfested Foster Reservoir apparently by moving through the diversion tunnel soon after the chemical treatment program was completed. Subsequent sets of gill nets in Foster Reservoir by the FCO and OGC caught few squawfish and decreasing numbers of suckers. However, substantial numbers of redbside shiners were caught.

We recommend continuation of fish passage at Green Peter and Foster dams and suggest that the steering committee be retained to guide operation of the fish facilities at these projects.

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LITERATURE CITED

- Anon. 1962. Green Peter Project, Middle Santiam River, Oregon, Design Memorandum No. 13. Fish Facilities, U. S. Army Engineer District, Portland, Corps of Engineers, March 1962.
- Anon. 1963. Foster Reservoir, South Santiam River, Oregon, Design Memorandum No. 9 and Supplements A, B, C. Spillway, Power Intake and Fish Facilities. U. S. Army Engineer District, Portland, Corps of Engineers, April 1963.
- Gunsolus, Robert T., and George J. Eicher. Evaluation of Fish-Passage Facilities at the North Fork Project on the Clackamas River in Oregon. Fish Commission of Oregon, Portland General Electric Company, September 1970.
- Ingram, Paul G. and Lawrence Korn. 1969. Evaluation of fish passage facilities at Cougar Dam on the South Fork McKenzie River in Oregon. Fish Commission of Oregon, Proc. Report, 76 p.
- Korn, L. N., Larry H. Hreha, Roland G. Montagne, William G. Mullarkey, and Emery J. Wagner. 1967. The effects of small impoundments on the behavior of juvenile anadromous salmonids. Fish Commission of Oregon Proc. Report, 127 p.
- Mattson, Chester R. 1948. Spawning ground studies of Willamette River spring chinook salmon. Fish Commission of Oregon, Research Briefs, Vol. 1, No. 1, pp 21-32.
- Smith, Eugene M. and Lawrence Korn. Evaluation of fish facilities and passage at Fall Creek Dam on Big Fall Creek in Oregon. Fish Commission of Oregon, Proc. Report, 83 p.