THE RELATION OF STREAMFLOW TO HABITAT FOR ANADROMOUS FISH IN THE STILLAGUAMISH RIVER BASIN, WASHINGTON

By S. S. Embrey

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 86-4326

Prepared in cooperation with the

STILLAGUAMISH INDIAN TRIBE

Tacoma, Washington
1987

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U. S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
1201 Pacific Avenue - Suite 600
Tacoma, Washington 98402-4384

Copies of this report
can be purchased from:

U. S. Geological Survey
Books and Open-File Reports
Federal Center, Box 25425
Denver, Colorado 80225

CONTENTS

ILLUSTRATIONS

TABLES

TABLES--continued

CONVERSION FACTORS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound units	By	To obtain SI units
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
square foot (ft^2)	0.09294	square meter (m^2)
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
degree Fahrenheit (°F)	$^\circ C = 5/9\,(^\circ F-32)$	degree Celsius (°C)
degree Celsius (°C)	$^\circ F = 9/5\,^\circ C + 32$	degree Fahrenheit (°F)

THE RELATION OF STREAMFLOW TO HABITAT FOR ANADROMOUS FISH IN THE STILLAGUAMISH RIVER BASIN, WASHINGTON

By S. S. Embrey

ABSTRACT

The techniques of Instream Flow Incremental Methodology were used to determine the habitat available over a range of simulated streamflows for anadromous fish in certain reaches of streams in the Stillaguamish River basin, Washington. The stream discharge-habitat relations were used to identify that discharge termed the optimum discharge, which provides maximum habitat, for a particular species and life stage of fish. Optimum discharges varied throughout the Stillaguamish River basin because each discharge-habitat relation was unique. These discharge-habitat relations may also be used in subsequent analyses that incorporate historical streamflow records.

The mainstem of the Stillaguamish River is used primarily as a migration route by anadromous fish, but it is also used by chinook and coho salmon and steelhead trout for rearing and by steelhead adults and pink salmon for spawning. Optimum discharges, in cubic feet per second, ranged as follows in the mainstem Stillaguamish River: chinook fry, 600; steelhead--juveniles, 1,000, adults, 2,000; coho juveniles, 400; and pink spawning, 800.

The North Fork Stillaguamish River is used for spawning and rearing by all the study fish species. Optimum discharges there ranged as follows: chinook--spawning, 500 to 1,300, fry, 150 to 400; coho--spawning, 500 to 700, juveniles and fry, 50 to 200; steelhead--adults, 500 to 1,170, spawning, 800 to 900, fry, 50 to 140, juveniles, 300 to 500; chum spawning, 200 to 600; pink spawning, 300 to 600.

All the study species spawn and rear in the South Fork Stillaguamish River, but coho spawn and rear fry only at the most upstream study site and chum spawn only at the most downstream site. Optimum discharges on the South Fork ranged as follows: chinook--spawning, 300 to 900, fry, 70 to 300; coho juveniles, 50 to 100; steelhead--adults, 300 to 900, spawning, 250 to 1,200, fry, 45 to 1,600, juveniles, 200 to 500; pink spawning, 100 to 1,200; coho--spawning, 140, fry, 50; chum spawning, 100.

Four tributary streams are used by all species except Pilchuck and Canyon Creeks, which are not used by chum salmon. Optimum discharges for all tributary streams ranged as follows: chinook--spawning, 170 to 750, fry 50 to 170; coho--spawning, 90 to 350, fry, 20 to 80, juveniles, 35 to 130; steelhead--adults, 170 to 500, spawning, 130 to 400, fry, 20 to 70, juveniles, 70 to 350; pink spawning, 70 to 300; chum spawning in Squire Creek and Jim Creek, 70 to 450.

Water temperatures measured in late summer at Pilchuck Creek--17.5°C (Celsius), Jim Creek--16.0°C, mainstem of the Stillaguamish River--17.0°C, South Fork Stillaguamish River at Arlington--17.0°C and near Verlot--14.5°C all exceeded the ranges of temperatures preferred by different life stages for certain activities. No water temperatures measured in this study exceeded 20°C.

INTRODUCTION

An investigation of streamflows and their relation to anadromous-fish habitat in the Stillaguamish River basin in western Washington was done by the U.S. Geological Survey from 1982 to 1985 in cooperation with the Stillaguamish Indian Tribe. Although the Stillaguamish Tribe has no distinct tribal land, it has established the right to harvest the anadromous fish (fish that pass upstream from the sea into fresh waters to spawn) and to protect and manage the fish and their habitat in the Stillaguamish River basin. The Tulalip Tribe, whose reservation land adjoins the basin, shares the interests of the Stillaguamish Tribe concerning the fish resources in the basin and the results of this study because of inter-tribal treaty agreements that provide for fish-hatchery production and harvest allotments in the basin.

Purpose and Scope

This report documents the results of the study to determine the relations between stream discharge and habitat available for anadromous fish at selected sites in the Stillaguamish River basin. These relations were used to identify the discharge that provides maximum habitat, or the optimum discharge, for a particular species and life stage of fish. In addition to information on the effects of discharge on fish habitat, managers need historical streamflow records for developing programs to protect and manage the anadromous fish and water resources of the area. However, the development of hydrographs and streamflow records for ungaged sites was not within the scope of this study. The Washington Department of Ecology, which is responsible for allocating and administering the use of surface water within the State through their instream-resources protection program (Washington Department of Ecology, 1983), may develop hydrographs and streamflow records for the ungaged study sites in the basin as they have done for other streams in Washington.

The U. S. Geological Survey and the Stillaguamish Tribe began a 2-1/2-year study in October 1982, using the techniques of Instream Flow Incremental Methodology (IFIM) developed by the U. S. Fish and Wildlife Service (Bovee, 1978 and 1982). Fish habitat in IFIM is defined as the streambed area that has acceptable water depth, velocity, and substrate particle size preferred by fish.

During 1983 and 1984, stream-discharge data and descriptions of substrate composition were collected at 14 study sites to determine habitat area, and at two tributary entrances to examine passage conditions for upstream migration. Water samples for chemical analyses were collected at 11 sites to document baseline water-quality conditions within the basin as requested by the Stillaguamish Indian Tribe (table 1). The locations of data-collection sites are shown on the basin map (fig. 1).

Table 1.--Identification of data-collection sites and stream segments in the Stillaguamish River basin

Survey station number	Study site number	Stream	Study site name	Segment boundary (river miles)	Segment length, in miles	River mile location
---	1	Stillaguamish River	mainstem at Arlington	11.0 - 17.5	6.5	---
---	2	Pilchuck Creek	near Arlington	0.0 - 3.5	3.5	---
---	3	Pilchuck Creek	Passage-Flow cross section	----	---	---
---	4	North Fork Stillaguamish River	at Wiersma Bar	0.0 - 14.3	14.3	---
---	5	North Fork Stillaguamish River	near Oso	14.3 - 20.0	5.7	---
---	6	North Fork Stillaguamish River	near Hazel	20.0 - 24.3	4.3	---
---	7	North Fork Stillaguamish River	at Blue Slough	24.3 - 31.2	6.9	---
---	8	Squire Creek	near mouth near Darrington	0.0 - 1.0	1.0	---
---	9	South Fork Stillaguamish River	at Byle's Farm at Arlington	17.5 - 26.2	8.7	---
---	10	South Fork Stillaguamish River	at Chappel road near Granite Falls	26.2 - 33.6	7.4	---
---	--	South Fork Stillaguamish River	-----	33.6 - 41.5	7.9	---
---	12	South Fork Stillaguamish River	at Moore's Farm near Verlot	41.5 - 48.5	7.0	---
---	--	South Fork Stillaguamish River	-----	48.5 - 53.4	4.9	---
---	14	South Fork Stillaguamish River	at Marten Creek near Silverton	53.4 - 61.6	8.2	---
---	15	Jim Creek	at mouth at Arlington	0.0 - 2.3	2.3	---
---	16	Jim Creek	Passage-Flow cross section	-----	---	---
---	17	Jim Creek	below 4-mile bridge near Arlington	2.3 - 5.5	3.2	---
---	--	Canyon Creek	-----	0.0 - 1.2	1.2	---
---	19	Canyon Creek	near Granite Falls	1.2 - 9.8	8.6	---
12168600	20	Stillaguamish River	at Arlington	-----	---	17.8
12167400	21	Pilchuck Creek	near Silvana	-----	---	0.1
12166900	22	North Fork Stillaguamish River	at Cicero	-----	---	9.5
12166300	23	North Fork Stillaguamish River	near Oso	-----	---	17.6
12165500	24	North Fork Stillaguamish River	near Darrington	-----	---	30.0
12165000	25	Squire Creek	near Darrington	-----	---	1.0
12164510	26	South Fork Stillaguamish River	at Arlington	-----	---	18.2
12160400	27	South Fork Stillaguamish River	near Verlot	-----	---	47.2
12158500	28	South Fork Stillaguamish River	at Silverton	-----	---	60.7
12164000	29	Jim Creek	near Arlington	-----	---	0.1
12161400	30	Canyon Creek	at Masonic Park near Granite Falls	-----	---	5.5

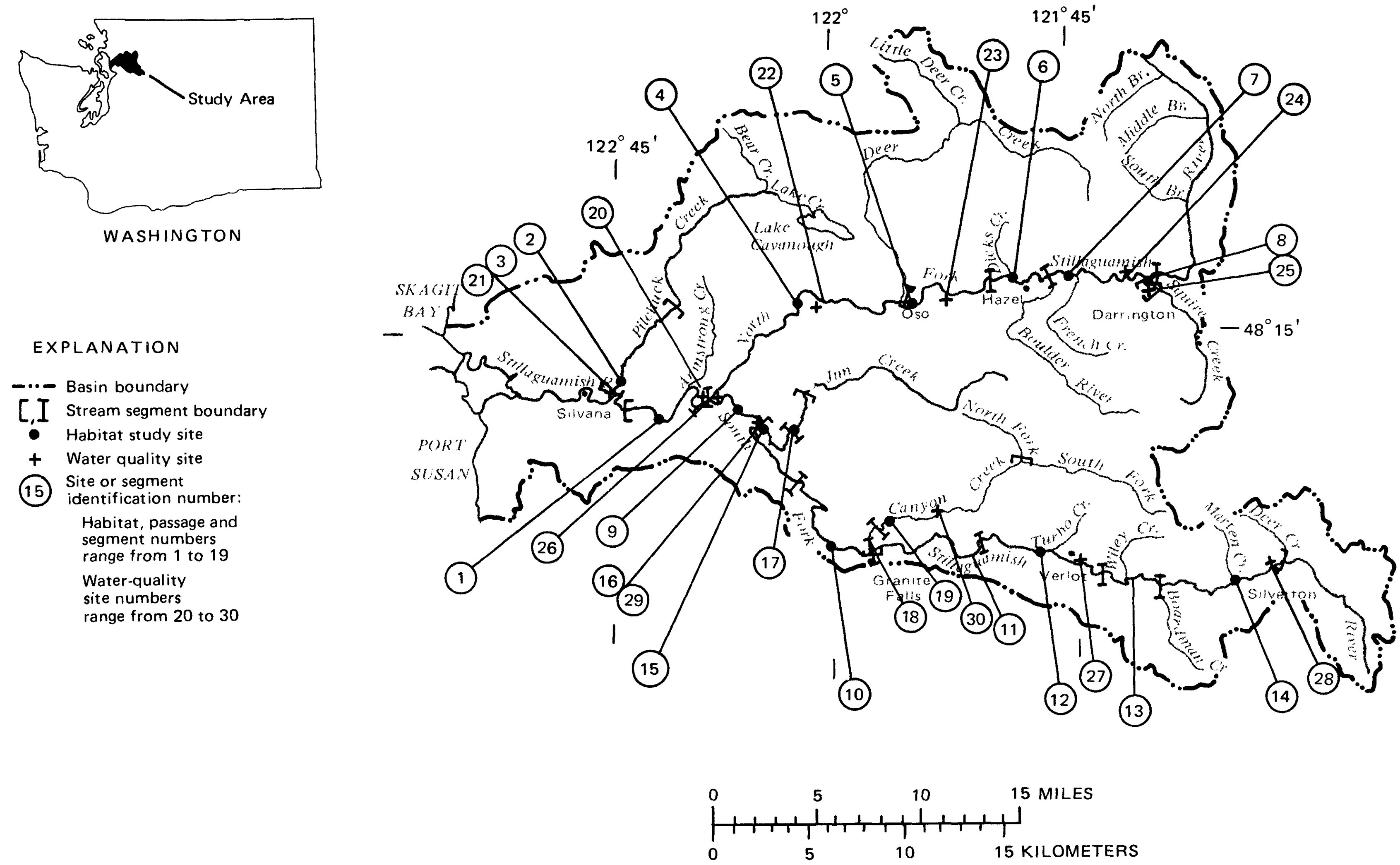


Figure 1.--Map showing locations of study sites and river segments in the Stillaguamish River basin.

Previous Studies

Two previous studies (Swift, 1976; 1979) discuss the stream discharges preferred by steelhead trout and salmon for spawning and rearing. The preferred discharges for spawning were determined from relations between discharge and spawnable area at 84 study sites on 28 streams in Washington, including 3 study sites on the North Fork Stillaguamish River. Spawnable area was defined as the streambed area meeting the criteria for specific ranges of preferred velocity and depth, without consideration of substrate material. Preferred discharges for rearing were determined from relations between discharge and wetted perimeter at the same study sites. Discharges preferred for spawning and rearing by steelhead were determined from measurements made at 54 of the same study sites on 18 of the streams.

Acknowledgments

Randy Williams of the Stillaguamish Tribe assisted with various aspects of the data collection and provided valuable technical advice concerning the behavior and distribution of anadromous fish in the Stillaguamish basin. Daryl Williams of the Tulalip Tribe provided technical advice and assisted in data collection. The following people and agencies provided suggestions and technical assistance: Dave Somers of the Tulalip Tribe, Brad Caldwell of the Washington State Department of Fisheries, Hal Beecher of the Washington Department of Game, Phil Wampler of the U.S. Fish and Wildlife Service-Fisheries Assistance Office, Jon Linvog of the National Marine Fisheries Service-NOAA, and the U.S. Fish and Wildlife Service-Ecological Services Division. The author extends appreciation to the landowners who permitted access to the study sites through their property.

DESCRIPTION OF THE BASIN AND FISHERY

The Stillaguamish River basin (fig. 1) is located in Skagit and Snohomish Counties in the State of Washington. The drainage area of the basin is 684 square miles and includes more than 975 miles of rivers and tributaries. The two main branches of the Stillaguamish River, the North and South Forks, flow westerly from the forested foothills of the Cascade Range. The mainstem of the Stillaguamish River meanders across lowland, alluvial floodplains into Port Susan, an arm of Puget Sound. The maritime climate in the basin is influenced by the Pacific Ocean to the west and the Cascade Range to the east. Mean annual precipitation ranges from 30 inches in the western lowlands to more than 140 inches in the forested eastern region. Monthly average air temperatures range from about 39° to 64° Fahrenheit.

Four species of Pacific salmon--coho (Oncorhynchus kisutch), pink (O. gorbuscha), chum (O. keta), and three subspecies or races of chinook (O. tshawytscha)--and two species of anadromous trout--searun cutthroat (Salmo clarki) and two subspecies of steelhead (S. gairdneri)--migrate, spawn, and rear in the Stillaguamish River system. The anadromous char, Dolly Varden (Salvelinus malma), are also present in the Stillaguamish River basin. Our investigation of fish habitat included three life stages for coho, two life stages for summer chinook, one for pink and chum salmon, and four for winter steelhead trout.

The Stillaguamish Tribe (1981) summarized the value of the fishery by species and economic importance to the tribe in its Fisheries Management Annual Report. Summer chinook and coho salmon and winter steelhead trout ranked highest in economic importance. At the time of their report, summer chinook salmon made up about 90 percent of the total chinook catch by the tribe. (Spring chinook salmon are considered commercially extinct due to minimal numbers. The small run of fall chinook is not easily distinguished from the summer run, and little is known about the distribution of this fish in the basin.) During the study, coho salmon were the most important commercial fish and comprised nearly 50 percent of the total gross income to the tribal fishery. Chum salmon were next in importance, harvested along with coho or winter steelhead. However, the stock of chum, as well as pink salmon, in the Stillaguamish basin has been depressed since the 1970's and the number of returning spawners in the Stillaguamish basin is unpredictable. Summer steelhead trout are harvested incidentally during the summer chinook and pink salmon harvest.

The mainstem of the Stillaguamish River is used primarily as a migration route by adult anadromous salmon and trout and as a rearing area by juvenile fish. Parts of the mainstem just below Arlington provide some spawning area for pink salmon. The lower reaches of Pilchuck Creek, tributary to the Stillaguamish River, are used by steelhead trout and chinook, coho, and pink salmon during all life stages. Pilchuck Creek is not utilized by chum salmon. The accessible tributaries to Pilchuck Creek are used by coho and some are used by pink salmon.

The lower North Fork Stillaguamish River from the confluence at Arlington and upstream to Oso provides rearing area for steelhead trout, pink, chum, and chinook salmon juveniles, and some spawning area for these species. Upstream from Oso, the North Fork is used by steelhead trout and all four species of salmon for spawning and rearing. The most important spawning areas are in the upper reaches of the North Fork, upstream from Boulder River at RM (river mile) 24 to about RM 36, where steelhead trout, chinook, coho, pink, and chum salmon spawn and rear. Steelhead and coho spawn and rear in the small accessible streams entering the North Fork and its larger tributaries. Squire Creek, an important tributary in the upper reaches of the North Fork, is used extensively by steelhead and salmon for spawning and rearing.

The lower South Fork Stillaguamish River from its confluence with the North Fork Stillaguamish and upstream to Granite Falls also provides rearing area and some spawning area for steelhead, pink, chum, and chinook juveniles. A fish ladder, installed at Granite Falls in 1954, provides passage for steelhead, chinook, coho, and occasionally pink salmon to the upper South Fork basin. The 9-mile reach from Robe to Boardman Creek is used by rearing and migrating steelhead and chinook and coho salmon, but provides limited spawning area for the salmon. The upper South Fork provides spawning and rearing habitat for steelhead, chinook, coho, and the infrequent pink salmon that pass Granite Falls. Tributaries to the upper South Fork are used mainly by steelhead and coho for spawning and rearing.

Lower Jim Creek, a tributary to the South Fork Stillaguamish River, provides spawning and rearing area for steelhead and the four species of salmon. A waterfall at RM 4.3 partly blocks the passage of adults, particularly during low flows. Above RM 4.3 the stream is used by coho and steelhead when it is accessible.

Steelhead, chinook, coho, pink, and a few chum salmon spawn and rear in the short reach of Canyon Creek between its confluence with the South Fork Stillaguamish River and the cascade falls at RM 1.2. With adequate water flow, steelhead, coho, and some chinook and pink salmon can ascend the falls to use the upper reaches of Canyon Creek and its tributaries. Juveniles rear throughout the accessible areas.

METHODS OF STUDY

An Overview of Instream Flow Incremental Methodology

The procedure IFIM used for the investigation of fish habitat (Bovee, 1982) is expressed in an assemblage of computer programs named PHABSIM, for the Physical Habitat Simulation system (Milhous and others, 1984). These computer programs are used to determine available fish habitat over a range of stream discharges at study sites within selected reaches of a river. The necessary data for the programs, including water depths and velocities, and streambed materials are collected at specific cross sections at study sites. The PHABSIM programs used in this study were the IFG-4 model, including the passage-flow option, the HABTAT model, and a program for time-series analysis.

The IFG-4 model is a hydraulic simulation program that uses a stage-discharge rating-curve approach to simulate stream discharge, water depths and velocities at each of several channel cross sections that represent a study site. The data required to calibrate the IFG-4 model are obtained from at least three measurements of water-surface elevation, stream discharge, and water depths and velocities at each cross section. The model develops relations among these measured parameters to simulate the hydraulic characteristics in individual cells (verticals in the cross section) of each cross section over a range of discharges.

The passage-flow option of the IFG-4 model evaluates at different discharges the water widths that have depths adequate for passage. One guideline for depth and width is available from the Oregon State Game Commission (Thompson, 1972). In the guideline for depth, adult chinook salmon require a minimum depth of 0.8 foot and all other adult salmon and steelhead require at least 0.6 foot. The guideline for width states that the discharge should be such that the continuous adequate width will be at least 10 percent of the total surface width, or that adequate discontinuous widths should sum at least 25 percent of the total surface width.

The HABTAT model compares the biological preferences of fish to the physical habitat available in the stream. The fish preferences applied in this study are the specific water depths, velocities, and sizes of substrate material that are preferred during different life stages. Fish preferences are commonly expressed as preference-factor curves, and are usually developed by fisheries biologists. Methods of directly entering descriptions of cover (some type of protection for fish) into the HABTAT model have been proposed by Bovee (1982). Because it is difficult to quantify cover in terms of field measurements and its importance to the fish, biologists have incorporated certain aspects of cover into some of the depth and substrate preference curves used in this study. The descriptors of physical habitat included in this study are the water depths and velocities simulated by IFG-4 and the observed substrate particle sizes at each site. The comparison of preference-curve values to the physical habitat is made in each cell of each cross section at a study site. HABTAT determines, according to the preferences, the total streambed area that is usable at different discharges, hereafter referred to as habitat area or simply as habitat, and produces a continuous relation between discharge and habitat area that is unique to each life stage of individual fish species at a study site.

Time-series analysis is one application of the discharge-habitat relations. It is a PHABSIM program that uses a historic record of streamflow to obtain an equivalent record of habitat area. Time-series analyses are useful for investigating the effects of sequences of extreme discharge or of streamflow regulation schedules on habitat area. The time-series program was applied to only one study site as an example, because a continuous record of streamflow is required and only one site is located at a stream-gaging station.

Data Collection and Compilation

Site Selection

The three major rivers and four tributaries in the basin were included in this study at the request of the Stillaguamish Indian Tribe. These seven streams were divided into 17 segments chosen according to IFIM guidelines (Bovee, 1982). Segments are characterized by similarities in flow quantities; channel pattern, slope and shape; sediment transport and water quality; fish passage barriers; and intensity of use by fish. According to the guidelines, a habitat-study site was selected randomly in each segment from among all of the possible sites reflecting the similarities within each segment (see figure 1 and table 1); three segments were eliminated because of safety hazards to persons and equipment. Each habitat-study site was verified on-site by representatives of state, federal, and tribal agencies to typify the stream segment. Two fish-passage sites (sites 3 and 16), both at the mouths of tributaries, were added by the Stillaguamish Indian Tribe.

Of the eleven water-quality sites, four (sites 22, 23, 24, and 26) were located where water-quality data had been collected previous to this study by either WDOE or the U.S. Geological Survey. Two sites, one on Canyon Creek and the other on the South Fork Stillaguamish River near Verlot, were included to provide information on streams or parts of streams where no water-quality or streamflow data had been gathered previously. The remaining five sites were located where previous streamflow measurements have been made by the U. S. Geological Survey.

Field Procedures

A habitat-study site is a short reach of stream channel described by several cross sections positioned to represent most of the different hydraulic and biologic characteristics of the reach. In this study, the sites were represented by four to eight cross sections. In general, reach length at habitat sites ranged from about eight to twelve times the channel width as recommended by Bovee (1982). Only one cross section was used to represent each fish-passage study site, and it was located at a place where water depths were minimum. At each study site the ends of each cross section were marked with long-term reference points, and the locations, dimensions, and elevations of each cross section were documented by transit survey.

Water-surface elevation, total stream discharge, and water depths and velocities at about 20 to 35 verticals were generally measured three times during the data-collection period at each cross section of the habitat and fish-passage sites. These were used for the IFG-4 model calibration, and were usually made when streamflow ranged from low to medium. At two of the habitat-study sites, the mainstem Stillaguamish River (site 1) and the South Fork Stillaguamish River at Chappel Road (site 10), the third and highest discharge measurement for the data sets was not obtained. At the Pilchuck Creek fish-passage site, only one discharge measurement at low flow could be obtained at a time when flow was not being influenced by backwater. The methods used for these discharge measurements followed procedures outlined in the U.S. Geological Survey's "Measurement and Computation of Streamflow..." (Rantz and others, 1982, Volumes I and II). Substrate particle sizes were determined once at each habitat cross section using procedures described by Trihey and Wegner (1981).

Two to three sets of water samples at each water-quality site were collected and analyzed for turbidity, specific conductance, pH, dissolved oxygen, nutrients, major ions, trace metals, suspended solids and sediment, and temperature. The equal transit rate method and the equipment described by Guy and Norman (1970) were used to obtain the samples; the techniques of sample preparation, preservation, and analytical procedures followed standard U.S. Geological Survey methods and those described by Skougstad and others (1979).

Habitat Preference Curves

A habitat preference factor is an expression on a scale of 0 to 1 of the relative degree of preference by fish for a particular combination of substrate sizes, or for water depth or velocity. The preference-factor curves for water depths, velocities, and substrate used in this study (Appendix A) were obtained from a number of sources (identified in Appendix A), and were agreed upon for use in this study at a meeting of fisheries biologists on June 27, 1984. Agencies represented at the meeting were the Stillaguamish Indian Tribe, the Washington State Departments of Fisheries and Game, and the U.S. Geological Survey. Each curve is unique to individual fish species and life stages in the Stillaguamish River basin and represents current understanding of fish behavior and the physical conditions preferred by fish.

For the purpose of IFIM studies, substrate is defined as the material that lies on or near the surface of the streambed. Substrate of gravels and cobbles is the primary material in which adult salmon and steelhead trout lay their eggs and the primary habitat for newly-hatched fish (alevins). A qualitative description provided by Williams and others (1975) of the distribution of substrate materials in the Stillaguamish River basin and the substrate observed in this study in the 19 stream segments is given in table 2.

Table 2.--Description of substrate in Stillaguamish River basin, by stream segment

Stream	Study site No.	Substrate description[1]: from Williams, R. Walter, and others, 1975	Substrate description[1]: observed during 1983 and 1984
Mainstem	1	mainly cobble-gravel with moderate-sized gravel below Cook Slough divergence.	mostly medium gravel mixed with sand; sand and fines in pool bottoms.
Pilchuck Creek	2	pool-riffle stream with mainly gravel and cobble and sand bottom pools.	mostly medium and large gravels mixed with some sand and small cobbles.
North Fork	4	riffles are mainly gravel and mixed cobble with layers of silt deposition in the slower waters and pools.	medium and large gravels mixed with small cobble; gravels and sand in the slower waters and pools.
North Fork	5	pool-riffle stream of gravel and cobble with heavy silt deposits over gravels and in pools.	medium and large gravels with small cobble; some sand in slower, deeper areas.
North Fork	6	riffle-pool stream with suitable spawning gravels; some turbidity at higher flows.	small and medium gravels mixed with sand.
North Fork	7	predominantly clean cobble and gravels.	small and large cobbles mixed with gravels and with some sand in deeper, slower areas.
Squire Creek	8	predominantly clean cobble and gravels.	medium and large gravels mixed with small cobble; some sand in deeper, slower areas.
South Fork	9	mainly cobble with numerous boulder-strewn areas.	medium and large gravels with nearly 40-50 percent sand.
South Fork	10	mainly cobble and gravels; some braiding and increasing silt deposition	mostly large or small cobble mixed with medium gravel; mixed with sand in pools and along water edges.
South Fork	--	steep, narrow canyon with mostly cobble and boulder.	--------------------------------------
South Fork	12	predominantly cobble and boulders with some increased siltation on spawning beds during periods of heavy runoff.	mostly large gravel mixed with large cobble in riffles and with sand in slower and deeper areas
South Fork	--	cascades in places; large gravels, large boulders and cobble in the few existing riffles.	--------------------------------------
South Fork	14	mainly cobble and large gravels with numerous boulders; some good quality gravel riffles and patch gravel areas are scattered in this section.	small and large cobbles with sections of boulders; patches of mixed sand and small gravel in and around cobble areas.
Jim Creek	15	mainly gravels and cobbles.	mostly mixtures of medium gravel and small cobble; some large gravel and areas of sand.
Jim Creek	17	mainly gravels and cobbles.	mixture of medium and large gravels with cobble; mostly sand in slower and deeper areas.
Canyon Creek	--	rapids and cascades; large cobble and boulders; a few patch gravel riffles in the lower one-half mile.	--------------------------------------
Canyon Creek	19	large cobble and gravels with a number of boulder-strewn sections; gravel in patches or along short beach strips.	small and large cobbles with sections of boulders; patches of mixed sand and small gravel in and around cobble areas.

[1] The ranges of size in millimeters and inches of the substrate particles are given in appendix B.

Preference-factor curves for substrate in Washington State are generated by a 3-digit substrate code that expresses the size range of the dominant substrate particles, the size range of subdominant particles, and the percentage of abundance of dominant particles. A description of the substrate code numbers for particle size range is given in appendix B, along with an example of the 3-digit substrate code that employs these numbers.

RELATIONS OF STREAMFLOW TO HABITAT FOR ANADROMOUS FISH

Streamflow and Habitat

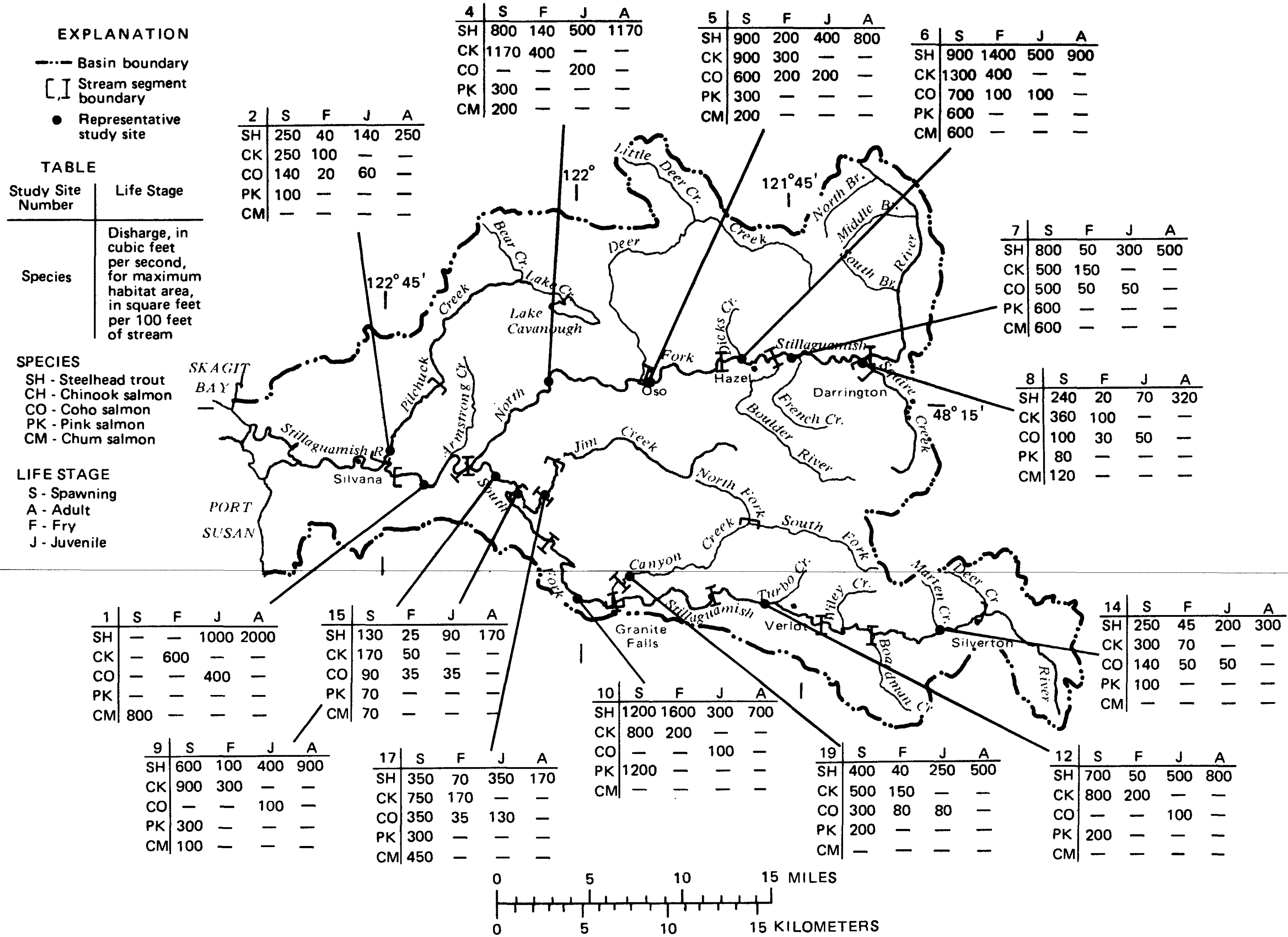
The computer program HABTAT uses the results of hydraulic simulation (IFG-4) and fish preference information to develop the relations between stream discharge and habitat for each species and lifestage. Graphs of these relations allow for comparison of habitat among individual life stages and species. Tables comparing discharge and corresponding habitat area are included to provide the information needed for further analysis. Charts showing the time of year when different life stages and species are present in the segments of the Stillaguamish River system supplement the discharge-habitat curves and tables; these are based on information from Williams and others, 1975; Dennis Dickson, Stillaguamish Indian Tribe, oral commun., 1985; Randy Williams, Stillaguamish Indian Tribe, oral commum., 1985. For the convenience of the readers, the timing charts and discharge-habitat curves (figures 2 through 27) and the tables of habitat area according to discharge and tables of IFG-4 model calibration techniques and accuracy of simulations (tables 3 through 31) are grouped together for each habitat-study site and arranged by site number at the end of the report as follows:

The maximum amount of habitat available for certain life stages at each habitat-study site and its corresponding stream discharge (optimum discharge) varies throughout the Stillaguamish River basin because each discharge-habitat relation is unique. Optimum discharges for spawning and rearing are lowest in study sites 2 (Pilchuck Creek), 8 (Squire Creek), 15 (Jim Creek), and 14 (South Fork Stillaguamish River at Marten Creek), the smallest streams in the study (figure 28). With some exceptions, optimum discharges for spawning, rearing, and adults increase with an increase in the size of the stream. Optimum discharges for rearing of steelhead fry at study site 6 (North Fork Stillaguamish River near Hazel) and study site 10 (South Fork Stillaguamish River at Chappel Road) of 1,400 and 1,600 ft^3/s respectively, and of 1,200 ft^3/s for spawning of pink salmon at site 10, exceeded optimum discharges at other study sites by about 1,000 ft^3/s. These optimum flows may be influenced more by cross-sectional area at these sites than by velocity because of the stage that would be needed to submerge parts of extensive gravel bars and increase the available habitat.

Optimum discharges determined by IFIM were compared with discharges determined in previous studies (Swift, 1976 and 1979) to be preferred by salmon and steelhead trout for spawning and rearing at two study sites in the North Fork Stillaguamish River (table 32). The discharges previously reported to be optimum for spawning were determined using depth-velocity criteria (DVC discharges) and discharges optimum for rearing, using wetted-perimeter criteria (WPC discharges). In addition, regression equations were developed in these studies to provide optimum discharges using an average of the toe-of-bank widths for the study site (TOB discharges) as well as other channel and basin parameters. Site B of the previous study is in this study's segment 6, represented by the North Fork Stillaguamish River at Blue Slough study site, and site C is in segment 4, represented by the North Fork Stillaguamish River near Oso.

In general, the DVC discharges for spawning by salmon and steelhead are lower than the optimum IFIM discharges for spawning. The TOB discharges for spawning tend to be similar or somewhat higher than IFIM optimum discharges for salmon, but are lower than IFIM discharges preferred by steelhead. The IFIM optimum discharges differed the most from DVC discharges for coho salmon spawning at Blue Slough and for pink and chum salmon spawning at Oso. The range of optimum IFIM discharges for salmon rearing shown in table 32 is a combination of the optimum discharges for coho and chinook fry, and coho juveniles. At the Oso site, the WPC discharges preferred for rearing by salmon and steelhead trout tend to be near the lower discharge values given by IFIM. At the Blue Slough site, however, the WPC discharge for salmon rearing is equal to the higher IFIM discharge, and is intermediate to the optimum IFIM discharges for steelhead rearing.

The IFG-4 hydraulic simulation model was used to simulate streamflow at the 14 habitat sites in this study and to develop the hydraulic parameters required by the HABTAT model for computing habitat area. Several types of indices may be used to evaluate the IFG-4 model's ability to simulate and predict the hydraulic characteristics of a site from sets of calibration (measured) stream-discharge data. Two principal indices used to evaluate the



1	S	F	J	A
SH	—	—	1000	2000
CK	—	600	—	—
CO	—	—	400	—
PK	—	—	—	—
CM	800	—	—	—

2	S	F	J	A
SH	250	40	140	250
CK	250	100	—	—
CO	140	20	60	—
PK	100	—	—	—
CM	—	—	—	—

4	S	F	J	A
SH	800	140	500	1170
CK	1170	400	—	—
CO	—	—	200	—
PK	300	—	—	—
CM	200	—	—	—

5	S	F	J	A
SH	900	200	400	800
CK	900	300	—	—
CO	600	200	200	—
PK	300	—	—	—
CM	200	—	—	—

6	S	F	J	A
SH	900	1400	500	900
CK	1300	400	—	—
CO	700	100	100	—
PK	600	—	—	—
CM	600	—	—	—

7	S	F	J	A
SH	800	50	300	500
CK	500	150	—	—
CO	500	50	50	—
PK	600	—	—	—
CM	600	—	—	—

8	S	F	J	A
SH	240	20	70	320
CK	360	100	—	—
CO	100	30	50	—
PK	80	—	—	—
CM	120	—	—	—

9	S	F	J	A
SH	600	100	400	900
CK	900	300	—	—
CO	—	—	100	—
PK	300	—	—	—
CM	100	—	—	—

10	S	F	J	A
SH	1200	1600	300	700
CK	800	200	—	—
CO	—	—	100	—
PK	1200	—	—	—
CM	—	—	—	—

12	S	F	J	A
SH	700	50	500	800
CK	800	200	—	—
CO	—	—	100	—
PK	200	—	—	—
CM	—	—	—	—

14	S	F	J	A
SH	250	45	200	300
CK	300	70	—	—
CO	140	50	50	—
PK	100	—	—	—
CM	—	—	—	—

15	S	F	J	A
SH	130	25	90	170
CK	170	50	—	—
CO	90	35	35	—
PK	70	—	—	—
CM	70	—	—	—

17	S	F	J	A
SH	350	70	350	170
CK	750	170	—	—
CO	350	35	130	—
PK	300	—	—	—
CM	450	—	—	—

19	S	F	J	A
SH	400	40	250	500
CK	500	150	—	—
CO	300	80	80	—
PK	200	—	—	—
CM	—	—	—	—

Figure 28.--Map showing optimum stream discharges for different life stages of steelhead trout and salmon at study sites in the Stillaguamish River basin.

Table 32.--Comparison of stream discharges providing maximum habitat area as obtained from IFIM and from a previous study, for two sites on the North Fork Stillaguamish River

DVC/WPC site identi-fication	IFIM site number	Toe-of-bank width in feet	Stream discharge, in cubic feet per second, for spawning[1]											
			Chinook			Coho			Pink and Chum			Steelhead		
			DVC	TOB	IFIM	DVC	TOB	IFIM	DVC	TOB	IFIM	DVC	TOB	IFIM
B	7 (Blue Slough)	183	380	870	500	200	510	500	530	870	600	600	650	800
C	5 (near Oso)	192	760	920	900	370	540	600	780	920	200(chum) 300(pink)	650	690	900

DVC/WPC site identi-fication	IFIM site number	Stream discharge, in cubic feet per second, for reering					
		Salmon			Steelhead		
		WPC	TOB	IFIM[2]	WPC	TOB	IFIM
B	7	150	250	50 to 150	150	270	50(fry) 300(juvenile)
C	5	200	270	200 to 300	200	290	200(fry) 400(juvenile)

[1] IFIM discharges are those obteined in this study; DVC (depth-velocity criteria), WPC (wetted-perimeter criteria), and TOB (regression equation using average toe-of-bank width) discharges are those obtained in a previous study (Swift, 1976 and 1979).]

[2] The range of discharges includes optimum discharges for chinook and coho fry, and coho juveniles.

accuracy of the hydraulic simulations are the Velocity Adjustment Factor (VAF) and Velocity Predication Error (VPE). The VAF is the ratio between measured discharge and the discharge computed from model-predicted parameters, and accounts for sources of measurement error resulting in some difference between the two discharges. The discussion of VAF, how it is computed and applied to each velocity in the cross section, is found in Milhous and others (1984, p. IV-12). Qualitative values for the VAF's which have been proposed by the Instream Flow Group (Milhous and others, 1984, p. J-1) are as follows:

Velocity Adjustment Factor	Ability of IFG-4 model to simulate stream discharge
0.90 to 1.10	good
0.85 to 0.89, 1.11 to 1.15	fair
0.80 to 0.84, 1.16 to 1.20	marginal
0.70 to 0.79, 1.21 to 1.30	poor
less than 0.70, greater than 1.30	very poor

VAF ratios have been computed by IFG-4 for each measured discharge used for model calibration at each cross section in a study site. Out of a total of 255 VAF's for calibration discharges at all cross sections in the study, five (2 percent) fell outside the "good" range of 0.9 to 1.10 (see end of report); two of these were from simulations of Pilchuck Creek near Arlington and three from Jim Creek at the mouth. The lowest VAF (0.725) was computed for the low-flow calibration discharge at cross-section 4 at Pilchuck Creek. No calibration VAF's exceeded 1.10.

The VPE is a measure of the model's ability to simulate the mean-column velocity (v) at each vertical in the cross-section for each calibration discharge. It is computed by the equation:

$$VPE = \frac{v_{measured} - v_{computed}}{v_{measured}}$$

The averages of VPE's for each cross section are listed in the tables of calibration and simulation details for each study site at the end of the report. Also listed are measured and predicted water-surface elevations, measured and predicted maximum velocities for each calibration discharge, and predicted maximum velocities for the highest and lowest simulated discharges. One method of computing discharge for egg incubation is to determine a streamflow or a range of flows with a water-surface elevation equal to one-half foot less than the elevation at preferred spawning flows (H. A. Beecher, Washington Department of Game, oral commun., 1985). The point-of-zero flow in a cross section and the regression coefficients (alpha and beta) for the stage-discharge equation for given discharges are provided in the tables of calibration details to compute flows of interest for incubation.

In the discussion of the simulation statistics used to evaluate the model's accuracy, it is necessary to relate the model's results to the physical characteristics of the study site and the limitations of the model to simulate certain hydraulic conditions. For IFG-4 to accurately simulate a natural condition, it is assumed that all the streamflow data were collected under steady-flow conditions in a stream channel that does not change over the course of the discharge measurements, and that a unique stage-discharge relation exists at a cross section that can be expressed in log-log linear form. The more the natural conditions at a study site deviate from these assumptions, the less accurately the model will predict velocities at all points in the cross section near the value of the measured velocities. Prediction problems were most frequently noted in the simulation of velocities near the edges of water and where backwater caused little or no velocity at one or more calibration discharges.

Streamflow and Passage

Water depths of 0.6, 0.8, and 1.0 foot were specified with the option in the IFG-4 model to evaluate water depth and streamwidth for fish-passage conditions at the Jim Creek passage-flow cross section (site 16 in figure 1). The analysis includes a list of total streamwidths, the longest continuous sections of the streamwidth, and the sum length of discontinuous sections of streamwidths that have the specified minimum water depths over a range of simulated streamflows. A graph of these results (fig. 29) shows the changes in total streamwidth and the longest continuous streamwidths of a certain water depth with changes in the quantity of streamflow.

The lowest streamflows that will provide a minimum width of stream with sufficient water depths for fish passage (fig. 29b) occur at the points where the lines that represent 10 and 25 percent of the total streamwidth (discussed on page 9) intersect the lines of longest continuous streamwidth. The points of intersection show that a discharge of about 18 ft^3/s provides a minimum 10-percent streamwidth with a depth of 0.6 foot for passage of pink, coho, and chum salmon, and steelhead trout; a discharge of 37 ft^3/s provides a minimum 10-percent streamwidth with a depth of 0.8 foot for chinook salmon. Discharges that provide a minimum 25-percent streamwidth are 50 ft^3/s for chinook salmon and 25 ft^3/s for the other species.

The single streamflow measurement at Pilchuck Creek passage-flow cross section (site 3 in figure 1) indicated the channel conditions that migrating fish may encounter during late summer flows. At a discharge of 31 ft^3/s, no water depth exceeded 0.9 foot, and 85 percent of the total streamwidth was less than 0.6 foot in depth.

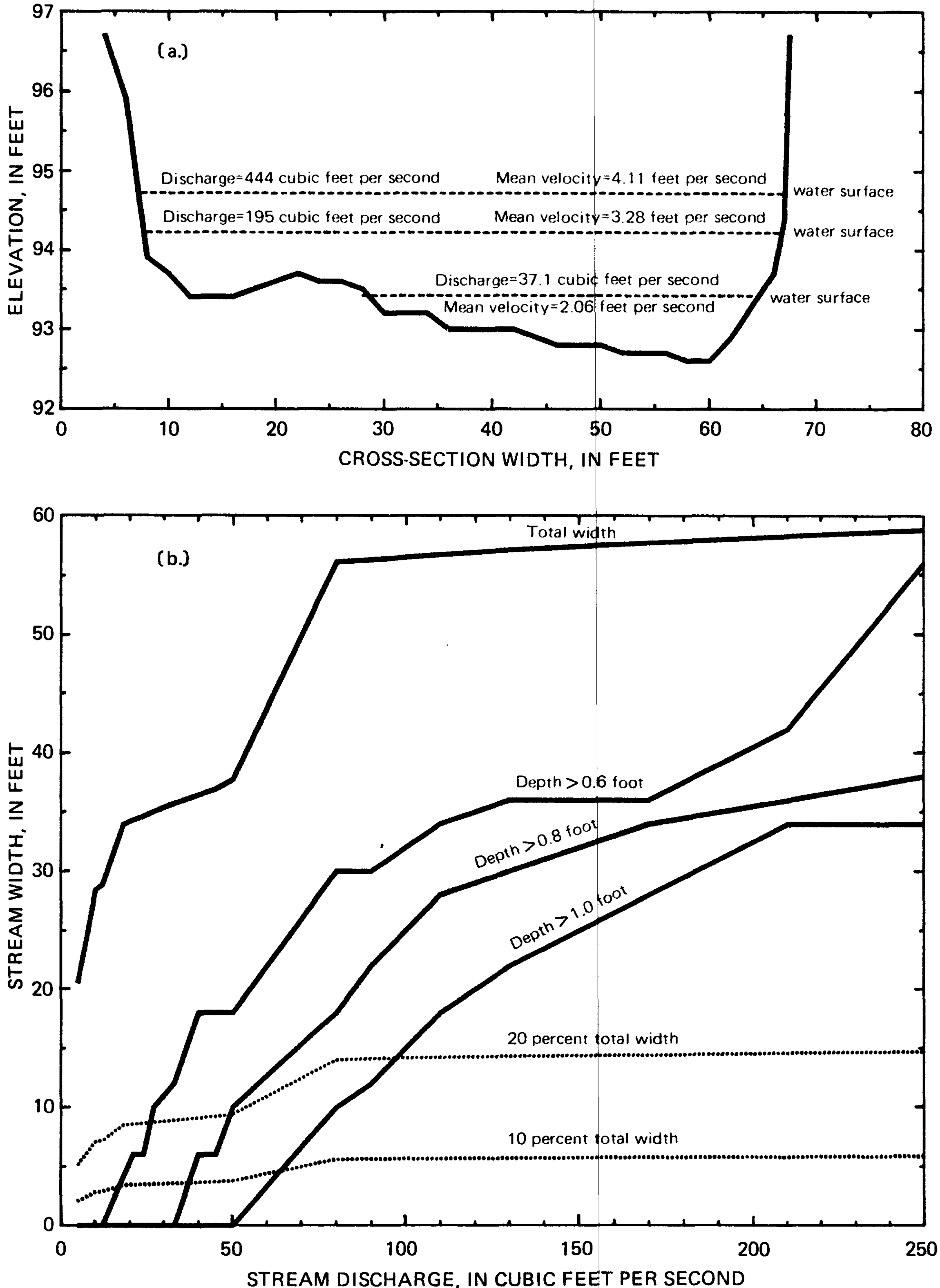


Figure 29.--Graph showing cross-section profile and water-surface elevations at three measured stream discharges, and relation of water depths and fish-passage widths to stream discharge at the Jim Creek Passage-Flow cross section.

An Example of a Time-Series Analysis

The North Fork Stillaguamish River at Wiersma Bar is located close enough (within 1 mile) to the U.S. Geological Survey gaging station 12167000 that it was used as an example of the application of the discharge-habitat relations in the time-series programs of PHABSIM. The 5-year period from 1979 to 1983 of mean monthly discharges was chosen for this example because it included the time period of this study. Time-series programs in PHABSIM compute a monthly habitat area associated with each mean monthly discharge for a particular species or life stage and then computes a statistical set of maximum, minimum, and mean annual values of monthly habitat area. These summary statistics (mean, maximum, and minimum habitat area) are based on a 12-month period and are stored in a computer output file in both tabular and graphic forms by PHABSIM.

In this example, the final graphs and tables of monthly habitat included in this report show values only for the months that correspond with the timing of freshwater use appropriate to each life stage at the Wiersma Bar site (see figure 6). Table 33 lists mean monthly and annual discharges and the computed associated habitat, and the graphs in figure 30 show the variation in the amount of monthly habitat corresponding to the historical streamflow record supplied to the time-series program. In general, maximum values of monthly habitat from one year to the next were similar; the same is true for the minimum values of habitat. Variation among monthly habitat values within each year is generally greater than the variation in maximum and minimum values among the years. The analysis also indicates more or less habitat available to a particular life stage during certain years than in others. For example, less habitat was available for chinook fry and coho juveniles in 1979 and 1982 (calendar years) than in the other 3 years.

Table 33.--Time-series values of mean monthly stream discharge (U.S. Geological Survey station, 12167000) and monthly habitat available for different life stages of steelhead trout and salmon at the North Fork Stillaguamish River at Wiersma Bar

Mean monthly discharge, in cubic feet per second

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	MEAN ANNUAL
1979	659	1966	1742	860	2556	2907	2140	1968	1507	905	278	497	1490
1980	1011	634	6177	1641	2769	1996	2681	1268	1072	637	451	1104	1780
1981	480	4100	4860	1330	3760	1360	3590	1390	2590	838	500	679	2100
1982	2580	2210	3210	3300	5630	2270	2070	2360	1940	1450	754	561	2340
1983	1040	1840	3280	4700	2710	2180	1310	1220	1590	1980	516	846	1930

Steelhead, adult, monthly habitat area, in square feet per thousand feet

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	MEAN ANNUAL
1979	---	42130	47870	61140	31620	26860	38840	42090	---	---	---	---	40510
1980	---	50360	9860	51350	28650	41560	29710	63950	---	---	---	---	39350
1981	---	15040	11960	62100	16990	61200	18610	60310	---	---	---	---	35170
1982	---	37510	22480	21420	10630	36470	40160	34950	---	---	---	---	29090
1983	---	44950	21610	12490	29360	38080	62700	65380	---	---	---	---	39220

Steelhead, spawning, monthly habitat area, in square feet per thousand feet

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	MEAN ANNUAL
1979	---	---	---	61690	33060	28510	40900	44470	51540	---	---	---	42760
1980	---	---	---	49690	30040	43890	31050	55110	58420	---	---	---	41730
1981	---	---	---	54160	20770	53710	22360	53200	32490	---	---	---	34840
1982	---	---	---	25140	12600	38290	42400	36710	45070	---	---	---	31090
1983	---	---	---	15260	30710	40180	54500	55790	50440	---	---	---	40630

Steelhead, fry, monthly habitat area, in square feet per thousand feet

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	MEAN ANNUAL
1979	28230	14220	15890	24610	9950	8440	12930	14200	18630	24680	51410	35500	21660
1980	25230	29100	10900	16950	8840	13990	9190	22520	25260	29000	38250	25240	21290
1981	36520	11590	11520	21340	11080	20770	10710	20130	9730	24600	35320	27530	20190
1982	9750	12390	8020	10070	11180	11970	13460	11360	14410	19360	25590	32250	14980
1983	25240	15170	10030	11530	9080	12670	21760	23380	17650	14130	34520	24600	18370

Steelhead, juvenile, monthly habitat area, in square feet per thousand feet

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	MEAN ANNUAL
1979	97390	46140	51310	91150	34910	28270	42400	46100	56940	89960	90890	101340	64990
1980	85470	98110	20050	53730	30630	45500	32570	66300	80780	98020	100770	78260	66040
1981	101130	20030	19740	63140	22120	61640	23610	59930	34380	91700	101360	96810	58390
1982	34430	40830	25170	26190	19880	39790	43950	38310	46720	58330	94290	99980	47410
1983	83320	49060	26350	19810	31930	41650	64280	68580	55050	45890	101010	91500	56630

Table 33.--Continued.

Chinook, spawning, monthly habitat area, in square feet per thousand feet

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	MEAN ANNUAL[1]
1979	17190	---	---	---	---	---	---	---	---	---	---	7240	---
1980	25450	---	---	---	---	---	---	---	---	---	---	26430	---
1981	6250	---	---	---	---	---	---	---	---	---	---	18060	---
1982	9420	---	---	---	---	---	---	---	---	---	---	11790	---
1983	25740	---	---	---	---	---	---	---	---	---	---	22750	---

Chinook, fry, monthly habitat area, in square feet per thousand feet

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	MEAN ANNUAL
1979	---	---	---	---	34080	29200	42570	46890	---	---	---	---	38180
1980	---	---	---	---	30810	45770	31880	66990	---	---	---	---	43860
1981	---	---	---	---	25270	64650	25280	63790	---	---	---	---	38430
1982	---	---	---	---	27030	39810	44120	28070	---	---	---	---	34760
1983	---	---	---	---	31530	41820	65980	68140	---	---	---	---	51870

Coho, juvenile, monthly habitat area, in square feet per thousand feet

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	MEAN ANNUAL[1]
1979	---	---	---	---	---	---	36690	39760	---	---	---	---	---
1980	---	---	---	---	---	---	29870	61310	---	---	---	---	---
1981	---	---	---	---	---	---	28760	55660	---	---	---	---	---
1982	---	---	---	---	---	---	37970	33590	---	---	---	---	---
1983	---	---	---	---	---	---	59520	63330	---	---	---	---	---

Pink, spawning, monthly habitat area, in square feet per thousand feet

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	MEAN ANNUAL[1]
1979	11290	3920	---	---	---	---	---	---	---	---	---	14550	---
1980	6840	11790	---	---	---	---	---	---	---	---	---	6450	---
1981	14890	1980	---	---	---	---	---	---	---	---	---	10900	---
1982	2550	3010	---	---	---	---	---	---	---	---	---	13250	---
1983	6720	4440	---	---	---	---	---	---	---	---	---	8350	---

Chum, spawning, monthly habitat area, in square feet per thousand feet

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	MEAN ANNUAL[1]
1979	8270	3980	5110	---	---	---	---	---	---	---	---	---	---
1980	4820	8710	2820	---	---	---	---	---	---	---	---	---	---
1981	12550	1600	3260	---	---	---	---	---	---	---	---	---	---
1982	2250	2940	1420	---	---	---	---	---	---	---	---	---	---
1983	4850	4600	1370	---	---	---	---	---	---	---	---	---	---

[1] Mean value not computed when number of months is less than 4.

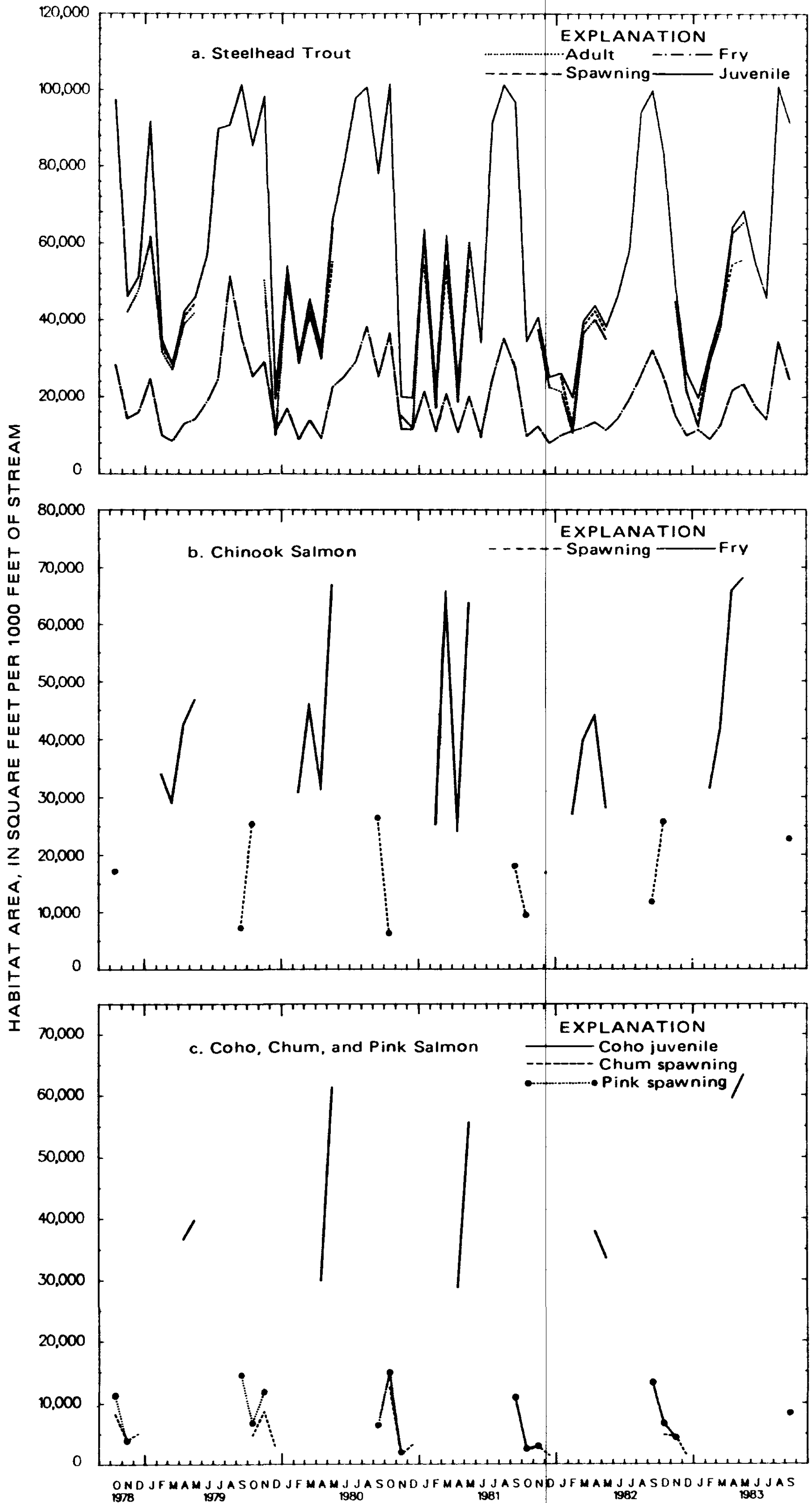


Figure 30.--Graph showing the monthly habitat area available for different life stages of steelhead trout and salmon corresponding to monthly mean discharge from October 1978 to September 1983 in the North Fork Stillaguamish River at Wiersma Bar.

WATER QUALITY

Water-quality conditions in the Stillaguamish River basin generally are rated by the WDOE (1977) as excellent (Class A) in the lower reaches of the basin's streams and as extraordinary (Class AA) in upper reaches such as the North Fork Stillaguamish River above its confluence with Squire Creek. The South Fork Stillaguamish River is rated as extraordinary above its confluence with Canyon Creek. However, in the lower reaches of some of the basin's streams, total coliform bacteria occasionally exceed state or federal standards and high water temperatures have been noted during the summer (Snohomish County, 1974). Water-quality information collected previous to this study is available for the Stillaguamish River basin from the Washington State Department of Ecology and the U.S. Geological Survey. The water samples collected for chemical analyses (nutrients, major ions, and metals) at the 11 sites (sites 20-30) in this study confirm the generally excellent quality of the water in the basin's streams (table 34).

Suspended-sediment concentrations in samples from all the sites were less than 30 mg/L (milligrams per liter) except during storm runoff. The greatest suspended-sediment concentrations measured during a rainstorm on July 14, 1983, were 410 mg/L in the North Fork Stillaguamish River near Oso and 620 mg/L in Squire Creek.

Water temperature measurements made in mid-channel at the time of sample collection were mostly within or below the ranges of water temperatures indicated in table 35 to be preferred by steelhead trout and salmon for certain life-stage activities. Water temperatures in late August exceeded the ranges of temperatures preferred by some species for migration and by all for spawning and rearing at five study sites: 17 $^{\circ}$C at site 20 (Stillaguamish River at Arlington), 17.5 $^{\circ}$C at site 21 (Pilchuck Creek), 17 $^{\circ}$C at site 26 (South Fork Stillaguamish River at Arlington), 14.5 $^{\circ}$C at site 27 (South Fork Stillaguamish River near Verlot), and 16 $^{\circ}$C at site 29 (Jim Creek).

Bell (1973) states that anadromous salmon and trout may die unspawned if subjected to long periods in excessively warm water, and that adult fish have been known to cease migrating when subjected to water temperatures approaching 21 $^{\circ}$C. Growth of young cold-water fish generally ceases at temperatures above 20 $^{\circ}$C because of increased metabolic rate. No water temperatures this high were measured during this study; however, excessively warm temperatures have been noted in small tributaries of the Stillaguamish River. Thermograph records and summary statistics of monthly means, maximums, and average mid-monthly temperatures for selected streams in the Stillaguamish River basin (Higgins and Hill, 1973) indicate a history of excessive temperature in Pilchuck Creek and Jim Creek. In Pilchuck Creek from 1954 to 1967, monthly mean temperatures that equalled or exceeded 20 $^{\circ}$C were recorded for July 1958, August 1958, and August 1961. In 1958, maximum monthly temperatures exceeded 20 $^{\circ}$C from May through September; maximum monthly temperatures above 20 $^{\circ}$C were recorded for every July and August for 1958 through 1961 and 1965 through 1967. At Jim Creek near Arlington the monthly mean temperature exceeded 14 $^{\circ}$C for every August during 1953 to 1956. The maximum monthly temperatures recorded during this period exceeded 20 $^{\circ}$C during July 1953, July 1956, and August 1956.

Table 34.--Physical and chemical characterisics of water at selected sites in 1983 in the Stillaguamish River basin.

[deg. C, degrees Celsius; NTU, nephelometric turbidity units; mg/L, milligrams per liter; ug/L, micrograms per liter; uS/cm, microsiemens per centimeter at 25° Celsius]

12167400 - STILLAGUAMISH RIVER AT ARLINGTON, WASH. (SITE 20)

Date	Time	Temperature (deg C)	Specific conductance (uS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
Jul 27[1]	1130	14.0	54	7.6	10.2	99	4.1	26	0	7.1	2.0	1.9
Aug 31[2]	1530	17.0	73	7.3	9.9	107	3.5	31	0	8.5	2.4	2.3

Date	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L as P)
Jul 27	13	.2	.50	27	4.3	1.6	7.7	36	41	.20	.40	.020
Aug 31	14	.2	.60	32	5.0	1.9	7.7	50	48	.10	.70	.020

Date	Phosphorus, ortho, dissolved (mg/L as P)	Arsenic dissolved (ug/L as As)	Cadmium dissolved (ug/L as Cd)	Chromium, dissolved (ug/L as Cr)	Copper, dissolved (ug/L as Cu)	Iron, dissolved (ug/L as Fe)	Lead, dissolved (ug/L as Pb)	Manganese, dissolved (ug/L as Mn)	Mercury dissolved (ug/L as Hg)	Selenium, dissolved (ug/L as Se)	Zinc, dissolved (ug/L as Zn)	Sediment, suspended (mg/L)
Jul 27	<.010	1	<1	<10	3	66	<1	5	<.1	<1	8	26
Aug 31	<.010	1	<1	<10	<1	95	<1	9	<.1	<1	6	23

Table 34--(Continued).

12168600 - PILCHUCK CREEK NEAR SILVANA, WASH. (SITE 21)

Date	Time	Temperature (deg C)	Specific conductance (uS/cm)	pH (standard units)	Oxygen, dis solved (mg/L)	Oxygen, dissolved (percent saturation)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
Jul 27[1]	1400	15.5	52	7.3	10.1	101	1.2	21	0	4.1	2.7	2.5
Aug 31[2]	1700	17.5	67	7.0	9.3	98	1.9	27	0	5.0	3.6	2.9

Date	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, totel (mg/L as P)
Jul 27	20	.2	.40	21	6.5	1.8	7.8	37	39	.40	.50	.020
Aug 31	18	.2	.60	27	8.9	2.6	8.7	46	49	.20	.40	.010

Date	Phosphorus, ortho, dissolved (mg/L as P)	Arsenic dissolved (ug/L as As)	Cadmium dissolved (ug/L as Cd)	Chromium, dissolved (ug/L as Cr)	Copper, dissolved (ug/L as Cu)	Iron, dissolved (ug/L as Fe)	Llead dissolved (ug/L as Pb)	Manganese, dissolved (ug/L as Mn)	Mercury dissolved (ug/L as Hg)	Selenium, dissolved (ug/L as Se)	Zinc, dissolved (ug/L as Zn)	Sediment, suspended (mg/L)
Jul 27	<.010	<1	<1	<10	4	140	<1	12	<.1	<1	14	8
Aug 31...	<.010	1	<1	<10	3	5	2	18	<.1	<1	9	2

Table 34--(Continued).

12167000 - N.F. STILLAGUAMISH R. NR. ARLINGTON, WASH. (SITE 22)

Date	Time	Temperature (deg C)	Specific conductance (uS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium dissolved (mg/L as Ca)
Jul 15[3]	1015	10.0	35	7.0	11.0	97	70	15	0	4.0
25[1]	1700	14.0	65	7.6	10.4	102	3.6	28	0	7.5
Oct 12[2]	1400	8.0	97	7.6	12.2	104	.80	41	0	11

Date	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
Jul 15	1.3	1.0	12	.1	.30	17	4.1	.80	5.2
25	2.3	1.9	13	.2	.50	30	3.8	1.5	8.5
Oct 12	3.4	3.2	14	.2	.80	43	4.4	2.6	11

Date	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Phosphate, ortho, dissolved (mg/L as PO_4)	Arsenic dissolved (ug/L as As)	Cadmium dissolved (ug/L as Cd)
Jul 15	18	27	.20	.40	.020	<.010	--	<1	<1
25	27	44	--	--	--	--	--	1	<1
Oct 12	56	62	.20	.60	.010	.020	.06	<1	<1

Date	Chromium, dissolved (ug/L as Cr)	Copper, dissolved (ug/L as Cu)	Iron, dissolved (ug/L as Fe)	Lead, dissolved (ug/L as Pb)	Manganese, dissolved (ug/L as Mn)	Mercury dissolved (ug/L as Hg)	Selenium, dissolved (ug/L as Se)	Zinc, dissolved (ug/L as Zn)	Sediment, suspended (mg/L)
Jul 15	<10	3	94	<1	9	.2	<1	5	363
25	10	1	58	<1	7	<.1	<1	10	9
Oct 12	10	1	73	<1	13	<.1	<1	<3	1

Table 34--(Continued).

12166300 - N F STILLAGUAMISH R NR OSO (SITE 23)

Date	Time	Temperature (deg C)	Specific conductance (uS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium dissolved (mg/L as Ca)
Jul 14[3]	1345	10.0	37	6.9	11.1	99	90	17	0	4.7
25[1]	1430	13.0	60	7.5	10.6	101	3.3	27	0	7.7
Oct 13[2]	0830	8.0	90	7.3	11.2	94	.90	41	0	12

Date	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
Jul 14	1.2	1.0	11	.1	.40	18	3.7	.80	5.1
25	1.8	1.5	11	.1	.50	28	3.5	.90	8.1
Oct 13	2.8	2.3	11	.2	.80	42	3.7	1.2	11

Date	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Phosphate, ortho, dissolved (mg/L as PO_4)	Arsenic dissolved (ug/L as As)	Cadmium dissolved (ug/L as Cd)
Jul 14	30	28	.20	.40	.050	<.010	--	1	<1
25	38	41	.20	.70	.020	<.010	--	<1	<1
Oct 13	57	59	.20	.60	<.010	.010	.03	1	<1

Date	Chromium, dissolved (ug/L as Cr)	Copper, dissolved (ug/L as Cu)	Iron, dissolved (ug/L as Fe)	Lead, dissolved (ug/L as Pb)	Manganese, dissolved (ug/L as Mn)	Mercury dissolved (ug/L as Hg)	Selenium, dissolved (ug/L as Se)	Zinc, dissolved (ug/L as Zn)	Sediment, suspended (mg/L)
Jul 14	<10	3	120	<1	15	.1	<1	5	410
25	<10	2	34	<1	6	<.1	<1	7	14
Oct 13	<10	1	51	1	13	<.1	<1	3	2

Table 34--(Continued).

12165500 - N F STILLAGUAMISH R NR DARRINGTON, WASH. (SITE 24)

Date	Time	Temper-ature (deg C)	Spe-cific con-duct-ance (uS/cm)	pH (stand-ard units)	Oxygen, dis-solved (mg/L)	Oxygen, dis-solved (per-cent satur-ation)	Tur-bid-ity (NTU)	Hard-ness (mg/L as $CaCO_3$)	Hard-ness, noncar-bonate (mg/L $CaCO_3$)	Calcium dis-solved (mg/L as Ca)
Jul 14[3]	1015	9.5	29	6.6	11.1	99	27	13	0	3.7
25[1]	1325	12.5	48	7.3	10.4	99	1.0	21	0	6.3
Oct 12[2]	1230	8.0	78	7.1	11.8	101	.70	34	0	10

Date	Mange-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Percent sodium	Sodium ad-sorp-tion ratio	Potas-sium, dis-solved (mg/L as K)	Alka-linity lab (mg/L as $CaCO_3$)	Sulfate dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Silica, dis-solved (mg/L as SiO_2)
Jul 14	.80	.80	12	.1	.40	15	3.5	.50	4.3
25	1.3	1.2	11	.1	.50	23	3.5	.60	6.7
Oct 12	2.1	2.0	11	.2	.70	36	3.7	1.1	9.7

Date	Solids, residue at 180 deg. C dis-solved (mg/L)	Solids, sum of consti-tuents, dis-solved (mg/L)	Nitro-gen, NO_2+NO_3 total (mg/L as N)	Nitro-gen, am-monia + organic total (mg/L as N)	Phos-phorus, total (mg/L as P)	Phos-phorus, ortho, dis-solved (mg/L as P)	Phos-phate, ortho, dis-solved (mg/L as PO_4)	Arsenic dis-solved (ug/L as As)	Cadmium dis-solved (ug/L as Cd)
Jul 14	22	23	.10	.40	.070	<.010	--	<1	<1
25	32	34	.10	.30	.020	<.010	--	<1	<1
Oct 12	47	51	.10	.70	<.010	.010	.03	1	<1

Date	Chro-mium, dis-solved (ug/L as Cr)	Copper, dis-solved (ug/L as Cu)	Iron, dis-solved (ug/L as Fe)	Lead, dis-solved (ug/L as Pb)	Manga-nese, dis-solved (ug/L as Mn)	Mercury dis-solved (ug/L as Hg)	Sele-nium, dis-solved (ug/L as Se)	Zinc, dis-solved (ug/L as Zn)	Sedi-ment, sus-pended (mg/L)
Jul 14	<10	3	77	1	7	.1	<1	8	124
25	10	3	63	<1	2	<.1	<1	4	2
Oct 12	<10	2	24	3	4	<.1	<1	<3	1

Table 34--(Continued).

12165000 - SQUIRE CREEK NEAR DARRINGTON, WASH. (SITE 25)

Date	Time	Temperature (deg C)	Specific conductance (uS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium dissolved (mg/L as Ca)
Jul 13[3]	1200	10.5	10	6.4	10.7	99	15	3	0	.78
25[1]	1045	11.0	19	6.7	10.7	98	.50	7	0	1.9
Oct 12[2]	1000	7.0	31	6.8	11.4	95	.80	12	0	3.0

Date	Mangesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
Jul 13	.37	.40	18	.0	.30	7.0	2.8	.30	2.2
25	.63	.70	16	.1	.50	10	1.7	1.3	4.8
Oct 12	1.0	1.1	16	.1	.50	14	2.3	.70	7.1

Date	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Phosphate, ortho, dissolved (mg/L as PO_4)	Arsenic dissolved (ug/L as As)	Cadmium dissolved (ug/L as Cd)
Jul 13	12	11	<.10	.50	.020	<.010	--	<1	<1
25	13	18	.10	.40	.020	<.010	--	<1	<1
Oct 12	22	24	.20	.40	<.010	.010	.03	<1	<1

Date	Chromium, dissolved (ug/L as Cr)	Copper, dissolved (ug/L as Cu)	Iron, dissolved (ug/L as Fe)	Lead, dissolved (ug/L as Pb)	Manganese, dissolved (ug/L as Mn)	Mercury dissolved (ug/L as Hg)	Selenium, dissolved (ug/L as Se)	Zinc, dissolved (ug/L as Zn)	Sediment, suspended (mg/L)
Jul 13	<10	3	33	3	4	.2	<1	7	620
25	<10	3	18	<1	2	<.1	<1	3	2
Oct 12	<10	1	20	2	4	<.1	<1	5	1

Table 34--(Continued).

12164510 - S F STILLAGUAMISH R AT ARLINGTON (SITE 26)

Date	Time	Temperature (deg C)	Specific conductance (uS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium dissolved (mg/L as Ca)
Jul 27[1]	0900	14.0	51	7.5	10.1	98	4.0	22	0	6.5
Aug 31[2]	1330	17.0	64	7.0	9.6	100	6.5	27	0	7.9

Date	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
Jul 27	1.5	1.6	13	.2	.50	24	4.5	1.3	6.5
Aug 31	1.8	2.0	14	.2	.50	28	5.2	1.6	6.4

Date	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Phosphate, ortho, dissolved (mg/L as PO_4)	Arsenic dissolved (ug/L as As)	Cadmium dissolved (ug/L as Cd)
Jul 27	35	37	.20	.40	.030	<.010	--	<1	<1
Aug 31	40	42	.10	.30	.020	<.010	--	1	<1

Date	Chromium, dissolved (ug/L as Cr)	Copper, dissolved (ug/L as Cu)	Iron, dissolved (ug/L as Fe)	Lead, dissolved (ug/L as Pb)	Manganese, dissolved (ug/L as Mn)	Mercury dissolved (ug/L as Hg)	Selenium, dissolved (ug/L as Se)	Zinc, dissolved (ug/L as Zn)	Sediment, suspended (mg/L)
Jul 27	<10	2	85	<1	4	<.1	<1	8	3
Aug 31	<10	1	51	1	6	<.1	<1	5	10

Table 34--(Continued).

12160400 - S.F.STILLAGUAMISH R. NR. VERLOT, WASH. (SITE 27)

Date	Time	Temperature (deg C)	Specific conductance (uS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
Jul 26[1]	1000	11.5	34	7.5	10.6	100	8.9	15	0	4.5	.89	1.0
Aug 30[2]	1630	14.5	42	7.2	9.6	98	8.0	19	0	5.7	1.1	1.3

Date	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L as P)
Jul 26	12	.1	.30	17	3.5	.60	4.8	24	26	<.10	.30	.020
Aug 30	13	.1	.40	20	4.2	.80	5.3	24	31	<.10	.20	.010

Date	Phosphorus, ortho, dissolved (mg/L as P)	Arsenic dissolved (ug/L as As)	Cadmium dissolved (ug/L as Cd)	Chromium, dissolved (ug/L as Cr)	Copper, dissolved (ug/L as Cu)	Iron, dissolved (ug/L as Fe)	Lead, dissolved (ug/L as Pb)	Manganese, dissolved (ug/L as Mn)	Mercury dissolved (ug/L as Hg)	Selenium, dissolved (ug/L as Se)	Zinc, dissolved (ug/L as Zn)	Sediment, suspended (mg/L)
Jul 26	<.010	1	<1	<10	2	54	<1	4	<.1	<1	9	18
Aug 30	<.010	1	<1	<10	<1	58	1	7	<.1	<1	<3	9

Table 34--(Continued).

12158500 - S F STILLAGUAMISH R AT SILVERTON WASH (SITE 28)

Date	Time	Temperature (deg C)	Specific conductance (uS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium dissolved (mg/L as Ca)
Jul 26[1]	0730	9.0	28	7.1	11.0	100	.90	13	0	4.1
Aug 30[2]	1330	11.5	31	7.3	10.1	99	1.4	13	0	4.1

Date	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
Jul 26	.58	.80	12	.1	.20	15	2.1	.50	4.1
Aug 30	.63	1.0	14	.1	.30	15	2.9	.70	4.0

Date	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Phosphate, ortho, dissolved (mg/L as PO_4)	Arsenic dissolved (ug/L as As)	Cadmium dissolved (ug/L as Cd)
Jul 26	13	21	<.10	.50	.030	.010	.03	1	<1
Aug 30	20	23	<.10	<.20	.010	<.010	--	1	<1

Date	Chromium, dissolved (ug/L as Cr)	Copper, dissolved (ug/L as Cu)	Iron, dissolved (ug/L as Fe)	Lead, dissolved (ug/L as Pb)	Manganese, dissolved (ug/L as Mn)	Mercury dissolved (ug/L as Hg)	Selenium, dissolved (ug/L as Se)	Zinc, dissolved (ug/L as Zn)	Sediment, suspended (mg/L)
Jul 26	<10	1	40	<1	3	<.1	<1	13	4
Aug 30	<10	1	27	1	1	<.1	<1	<3	1

Table 34--(Continued).

12164000 - JIM CREEK NEAR ARLINGTON, WASH. (SITE 29)

Date	Time	Temperature (deg C)	Specific conductance (uS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium dissolved (mg/L as Ca)
Jul 26[1]	1600	16.0	69	7.5	10.1	102	.80	30	0	8.5
Aug 31[2]	1100	16.0	83	7.0	9.9	101	1.5	35	2	9.7

Date	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
Jul 26	2.1	2.1	13	.2	.50	29	6.7	1.5	7.6
Aug 31	2.5	2.6	14	.2	.60	33	6.8	1.9	7.6

Date	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Phosphate, ortho, dissolved (mg/L as PO_4)	Arsenic dissolved (ug/L as As)	Cadmium dissolved (ug/L as Cd)
Jul 26	42	47	.30	.40	.020	.010	.03	<1	<1
Aug 31	33	52	.30	.20	.020	<.010	--	1	<1

Date	Chromium, dissolved (ug/L as Cr)	Copper, dissolved (ug/L as Cu)	Iron, dissolved (ug/L as Fe)	Lead, dissolved (ug/L as Pb)	Manganese, dissolved (ug/L as Mn)	Mercury dissolved (ug/L as Hg)	Selenium, dissolved (ug/L as Se)	Zinc, dissolved (ug/L as Zn)	Sediment, suspended (mg/L)
Jul 26	<10	2	72	<1	5	<.1	<1	10	3
Aug 31	<10	2	69	1	4	<.1	<1	5	1

Table 34--(Continued).

12161400 - CANYON CR. AT MASONIC PARK NR GRANITE FALLS, WA. (SITE 30)

Date	Time	Temperature (deg C)	Specific conductance (uS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Turbidity (NTU)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium dissolved (mg/L as Ca)
Jul 26[1]	1230	12.5	45	7.4	10.5	100	2.0	18	0	5.5
Aug 31[2]	1000	13.0	57	7.2	10.3	100	1.4	24	0	7.0

Date	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
Jul 26	1.1	1.3	13	.1	.40	20	4.2	1.0	5.8
Aug 31	1.5	1.7	13	.2	.40	24	5.2	1.2	6.3

Date	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Phosphate, ortho, dissolved (mg/L as PO_4)	Arsenic dissolved (ug/L as As)	Cadmium dissolved (ug/L as Cd)
Jul 26	28	31	.10	.30	.030	.010	.03	--	--
Aug 31	40	38	.10	<.20	.010	<.010	--	2	<1

Date	Chromium, dissolved (ug/L as Cr)	Copper, dissolved (ug/L as Cu)	Iron, dissolved (ug/L as Fe)	Lead, dissolved (ug/L as Pb)	Manganese, dissolved (ug/L as Mn)	Mercury dissolved (ug/L as Hg)	Selenium, dissolved (ug/L as Se)	Zinc, dissolved (ug/L as Zn)	Sediment, suspended (mg/L)
Jul 26	--	--	35	--	--	--	--	--	3
Aug 31	<10	1	81	2	4	<.1	<1	4	6

[1] medium-low streamflow
[2] low streamflow typical of late summer conditions
[3] medium to medium-high streamflow during a rainfall period

Table 35.--Preferred ranges of water temperatures for steelhead trout and salmon.

Life stage	Species	Preferred range[1], in degrees Celsius	Preferred range[2], in degrees Celsius	Maximum average weekly temperature[3] in degrees Celsius
Migration[1]	Steelhead	10.0 - 12.8	---------	------
	Chinook	9.4 - 14.2[4]	---------	------
	Coho	7.2 - 15.6	---------	------
	Pink	7.2 - 15.6	---------	------
	Chum	8.3 - 18.3	---------	------
Spawning	Steelhead	3.9 - 9.4	---------	8.0 (Rainbow Trout)
	Chinook	5.6 - 13.9	4.4-8.6(fall); 15.5-16.7(spring)	------
	Coho	4.4 - 9.4	4.4 - 8.3	10.0
	Pink	7.2 - 12.8	---------	------
	Chum	7.2 - 12.8	---------	------
Incubation	Steelhead	10.0	10.0 - 11.7	------
	Chinook	4.4 - 13.3	---------	------
	Coho	4.4 - 13.3	8.9 - 11.1	------
	Pink	4.4 - 13.3	---------	------
	Chum	4.4 - 13.3	---------	------
Rearing	Steelhead	12.0 - 14.0	14.4 - 15.5	19.0 (Rainbow Trout)
	Chinook	12.0 - 14.0	12.8 - 14.4	------
	Coho	12.0 - 14.0	12.8 - 14.4	18.0
	Pink	12.0 - 14.0	---------	------
	Chum	12.0 - 14.0	---------	------

[1] Bell, M.C., 1973
[2] U.S. Environmental Protection Agency, 1972
[3] U.S. Environmental Protection Agency, 1976
[4] Migration delayed at 21° C (70° F); Bell, M.C., 1973

SUMMARY

The objective of this study was to determine relations of streamflow to the habitat available for anadromous fish in the Stillaguamish River basin. The techniques of IFIM (Instream Flow Incremental Methodology) were used to determine the habitat area available at different streamflows for several life stages of steelhead trout and as many as 4 species of salmon at 14 study sites in the basin. Conditions for passage during upstream migration of adults were examined at the mouth of Jim Creek and at Pilchuck Creek. The IFG-4 hydraulic simulation model of IFIM was used to develop the hydraulic data required by the HABTAT program to simulate the habitat area available for a given life stage of fish.

The discharge-habitat relations developed by HABTAT were used to identify streamflows most favorable for different fish at each study site. The maximum amount of habitat available for each life stage at each study site and its corresponding streamflow vary throughout the Stillaguamish River basin because each discharge-habitat relation is unique. With some exceptions, the discharge that provides maximum habitat (optimum discharge) for spawning and rearing increases as stream size increases. Optimum discharges for spawning and rearing in this study were lowest at Pilchuck Creek, Squire Creek, and the South Fork Stillaguamish River at Marten Creek. Optimum discharges determined with IFIM techniques for spawning by salmon and steelhead trout generally are higher than optimum discharges based on depth-velocity criteria reported in previous studies.

The mainstem of the Stillaguamish River is used primarily as a migration route by anadromous fish; but, it is also used by chinook salmon, coho salmon, and steelhead trout for rearing. The mainstem is also used by steelhead adults and pink spawning. Optimum discharges at the one study site on the mainstem were determined to be 600 ft^3/s for chinook fry, 1,000 ft^3/s for steelhead juveniles, 400 ft^3/s for coho juveniles, 800 ft^3/s for pink spawning, and 2,000 ft^3/s for steelhead adults.

The North Fork Stillaguamish River is used for spawning and rearing by all the study species. At four study sites, optimum discharges for chinook ranged from 500 to 1,300 ft^3/s for spawning and from 150 to 400 ft^3/s for fry. Optimum discharges for coho ranged from 500 to 700 ft^3/s for spawning, and from 50 to 200 ft^3/s for juveniles and fry. For steelhead the ranges were from 500 to 1,170 ft^3/s for adults, 800 to 900 ft^3/s for spawning, 50 to 140 ft^3/s for fry, and from 300 to 500 ft^3/s for juveniles. The range for chum spawning was from 200 to 600 ft^3/s, and for pink spawning it was from 300 to 600 ft^3/s.

All the study species spawn and rear in the South Fork Stillaguamish River; however coho spawning and the rearing of fry occur only at the most upstream study site, and chum spawning occurs only at the most downstream site. At four sites on the South Fork, optimum discharges ranged from 300 to 900 ft^3/s for chinook spawning, and from 70 to 300 ft^3/s for chinook fry. For

coho juveniles, the range was from 50 to 100 ft^3/s. The ranges for steelhead were from 300 to 900 ft^3/s for adults, 250 to 1,200 ft^3/s for spawning, 45 to 1,600 ft^3/s for fry, and from 200 to 500 ft^3/s for juveniles. For pink spawning, the range was from 100 to 1,200 ft^3/s. Optimum discharges for coho spawning and fry were 140 and 50 ft^3/s, respectively; for chum spawning, the discharge was 100 ft^3/s.

Four tributary streams, represented by five sites, are used by all species, except that Pilchuck and Canyon Creeks are not used by chum salmon. Optimum discharges for all tributary streams ranged from 170 to 750 ft^3/s for chinook spawning, and from 50 to 170 ft^3/s for chinook fry. For coho salmon, the ranges were from 90 to 350 ft^3/s for spawning, 20 to 80 ft^3/s for fry, and from 35 to 130 ft^3/s for juveniles. Ranges of optimum discharges for steelhead were from 170 to 500 ft^3/s for adults, 130 to 400 ft^3/s for spawning, 20 to 70 ft^3/s for fry, and from 70 to 350 ft^3/s for juveniles. For pink spawning the range was from 70 to 300 ft^3/s, and for chum spawning in Squire Creek and Jim Creek it was from 70 to 450 ft^3/s.

Analysis of passage-flow conditions for adult fish at the mouth of Jim Creek showed that a discharge of about 18 ft^3/s provides a minimum 10-percent streamwidth for the passage of pink, coho, and chum salmon, and steelhead trout. A discharge of 37 ft^3/s provides the minimum 10-percent streamwidth for chinook salmon. Discharges that provide a minimum 25-percent streamwidth were 50 ft^3/s for chinook and 25 ft^3/s for the other species.

Time-series analysis is one application of the discharge-habitat relations to a record of streamflow. An example of this analysis is given in this report using the habitat results at the North Fork Stillaguamish River at Wiersma Bar and the streamflow record for the period 1978 to 1983 from a nearby Geological Survey gaging station. The time-series analysis shows that there was some habitat available for all species and life stages during each of the five years and that generally there was less variation in the maximum monthly habitat from year to year than the habitat among months within each year, at least at this particular site.

Water samples collected for chemical analyses at the 11 study sites in the Stillaguamish River basin indicated the quality of the water to be within state and federal guidelines as reported by Snohomish County (1974) and WDOE's classification system (1977). Sediment concentrations were found in this study to be less than 30 mg/L, except during one rainstorm when as much as 620 mg/L was measured at one site. Water temperatures measured in late summer at Pilchuck Creek (17.5°C), Jim Creek (16.0°C), the mainstem Stillaguamish River (17.0°C), and the South Fork Stillaguamish River at Arlington (17.0°C) and near Verlot (14.5°C) all exceeded the ranges of temperatures preferred by different life stages for certain activities. No water temperatures measured in this study exceeded 20°C, above which the migration of adults and growth of young fish may be inhibited; however, temperatures exceeding 20°C have previously been noted in Pilchuck Creek and Jim Creek.

REFERENCES

Arctic Environmental Information and Data Center (AEIDC), 1981, An assessment of environmental effects of construction and operation of the proposed Terror Lake hydroelectric facility, Kodiak Alaska, Instream Flow Studies, final report, Anchorage, Alaska, 419 p.

Bell, M. C., 1973, Fisheries handbook of engineering requirements and biological criteria: Fisheries-engineering research program, Army Corps of Engineers, North Pacific Division, Portland, Oregon, (34 chapters).

Bovee, K. D., 1978, Hydraulic simulation in instream flow studies: Theory and technique: Instream Flow Information Paper no. 5, U.S. Department of the Interior, Fish and Wildlife Service, Washington D.C., FWS/OBS-78/33, 131 p.

_____, 1982, A guide to stream habitat analyses using the Instream Flow Incremental Methodology: Instream Flow Information Paper no. 12, U.S. Department of the Interior, Fish and Wildlife Service, Washington D. C., FWS/OBS-82/26, 248 p.

Bovee, K. D., and Cochnauer, T., 1977, Development and evaluation of weighted criteria, probability-of-use curves for instream-flow assessments: Fisheries: Instream Flow Information Paper no. 3, U.S. Department of the Interior, Fish and Wildlife Service, Washington D.C., FWS/OBS-77/63, 39 p.

Guy, H. P., and Norman, V. W., 1970, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, chapter C2, 59 p.

Higgins, G. T., and Hill, G. W., 1973, Analyses and summary of temperatures of streams in Washington prior to 1968: State of Washington Department of Ecology Miscellaneous Report No. 73-003, 139 p.

Milhous, R. T., Wegner, D. L., Waddle, Terry, 1984, User's guide to the physical habitat simulation system (PHABSIM): Instream Flow Information Paper no. 11 (B edition), U.S. Department of the Interior, Fish and Wildlife Service, Washington D.C., FWS/OBS-81/43 Revised.

Rantz, S. E., and others, 1982, Measurement and computation of streamflow: volume 1. Measurement of stage and discharge; volume 2. Computation of discharge: U. S. Geological Survey Water-Supply Paper 2175, 631 p.

Skougstad, M. W., Fishman, M. J., Friedman, L. C., Erdmann, D. E., and Duncan, S. S., editors, 1979, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, chapter A1, 626 p.

Snohomish County, 1974, Water quality management plan for the Stillaguamish River basin, Volume II: 136 p.

Stillaguamish Tribe, 1981, Fisheries management annual report: Bureau of Indian Affairs, contract no. POOC14206596 FY81, 121 p.

Swift, C. H., III, 1976, Estimation of stream discharges preferred by steelhead trout for spawning and rearing in western Washington: U.S. Geological Survey Open-File Report 75-155, 50 p.

_____, 1979, Preferred stream discharges for salmon spawning and rearing in Washington: U.S. Geological Survey Open-File Report 77-422, 51 p.

Thompson, K., 1972, Determining streamflows for fish life: In a transcript of proceedings: Pacific Northwest River Basins Commissions, Instream Flow Requirement Workshop, Portland, Oregon, March 15-16, 1972, pages 31-46.

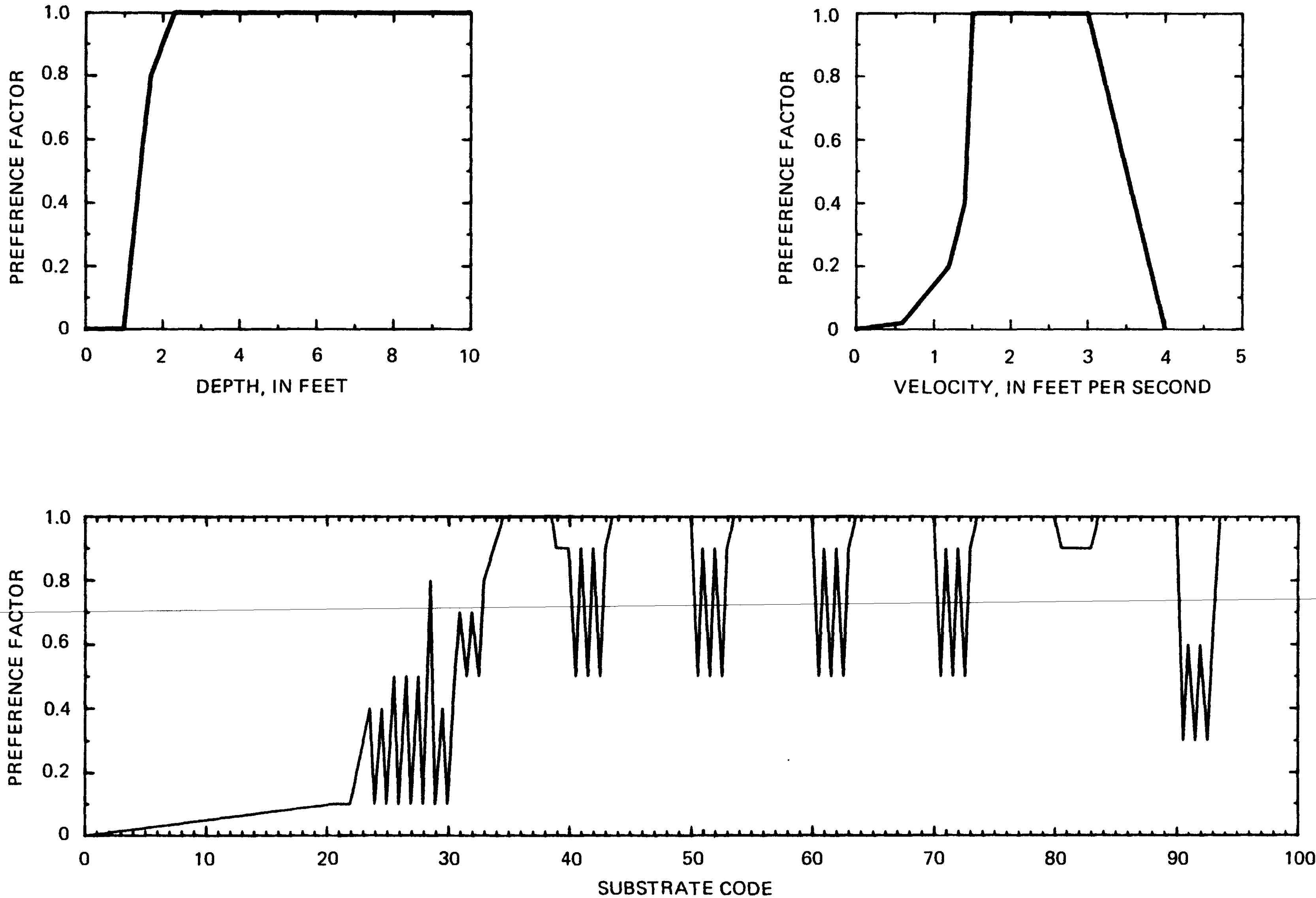
Trihey, W. E., and Wegner, D. L., 1981, Field data collection procedures for use with the Physical Habitat Simulation System of the Instream Flow Group: Cooperative Instream Flow Service Group, Fort Collins, Colorado, draft with partial revision, February 1983, 131 p.

_____, 1976, Quality criteria for water: Washington D.C., 256 p.

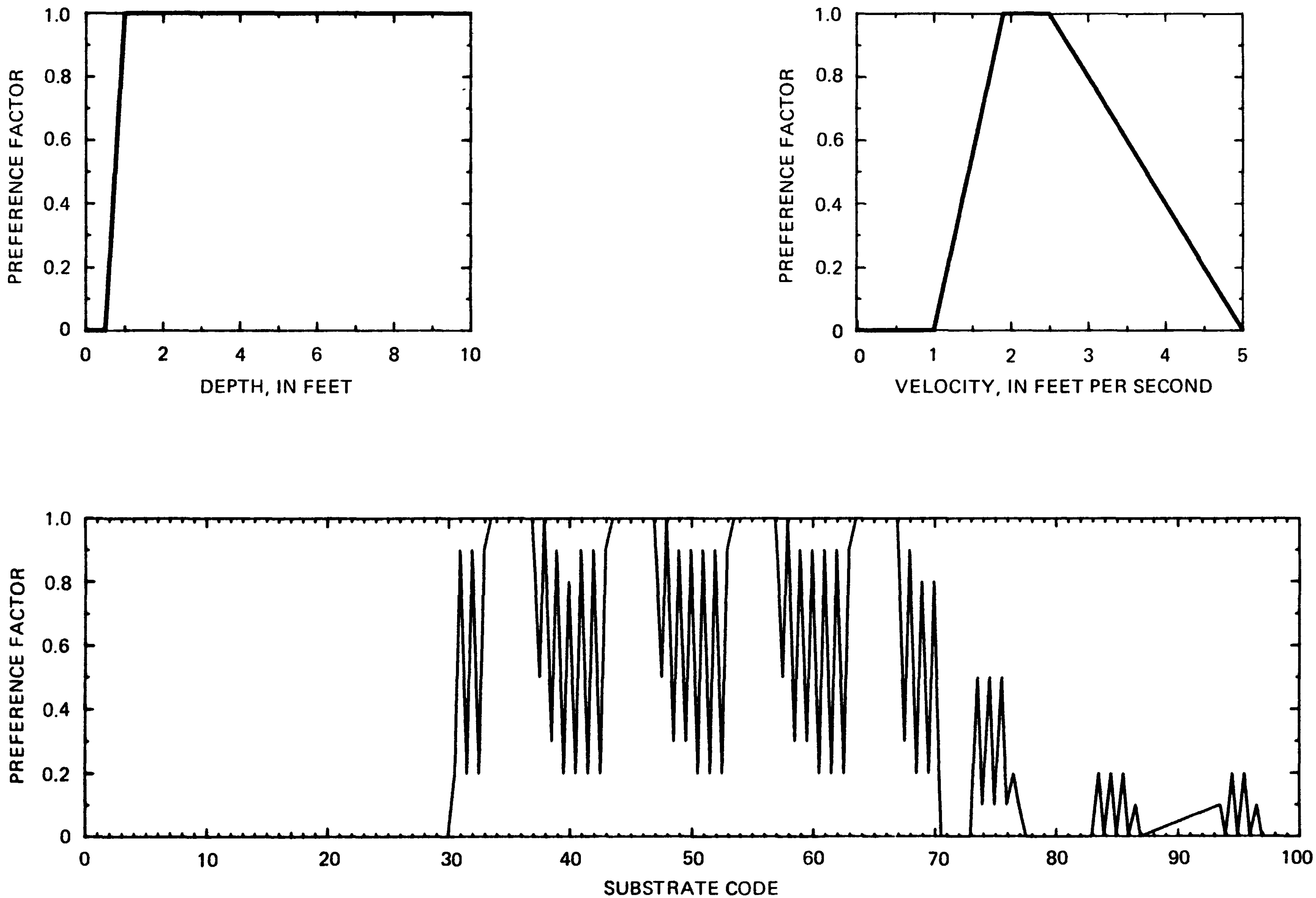
Washington Department of Ecology, Office of Water Programs, 1983, Kennedy-Goldsborough instream resources protection program including proposed administrative rules WAC 173-514 (Water Resource Inventory Area 14): Olympia, Washington, 38 p.

_____, 1977, Washington State water quality standards: Olympia, Washington, 33 p.

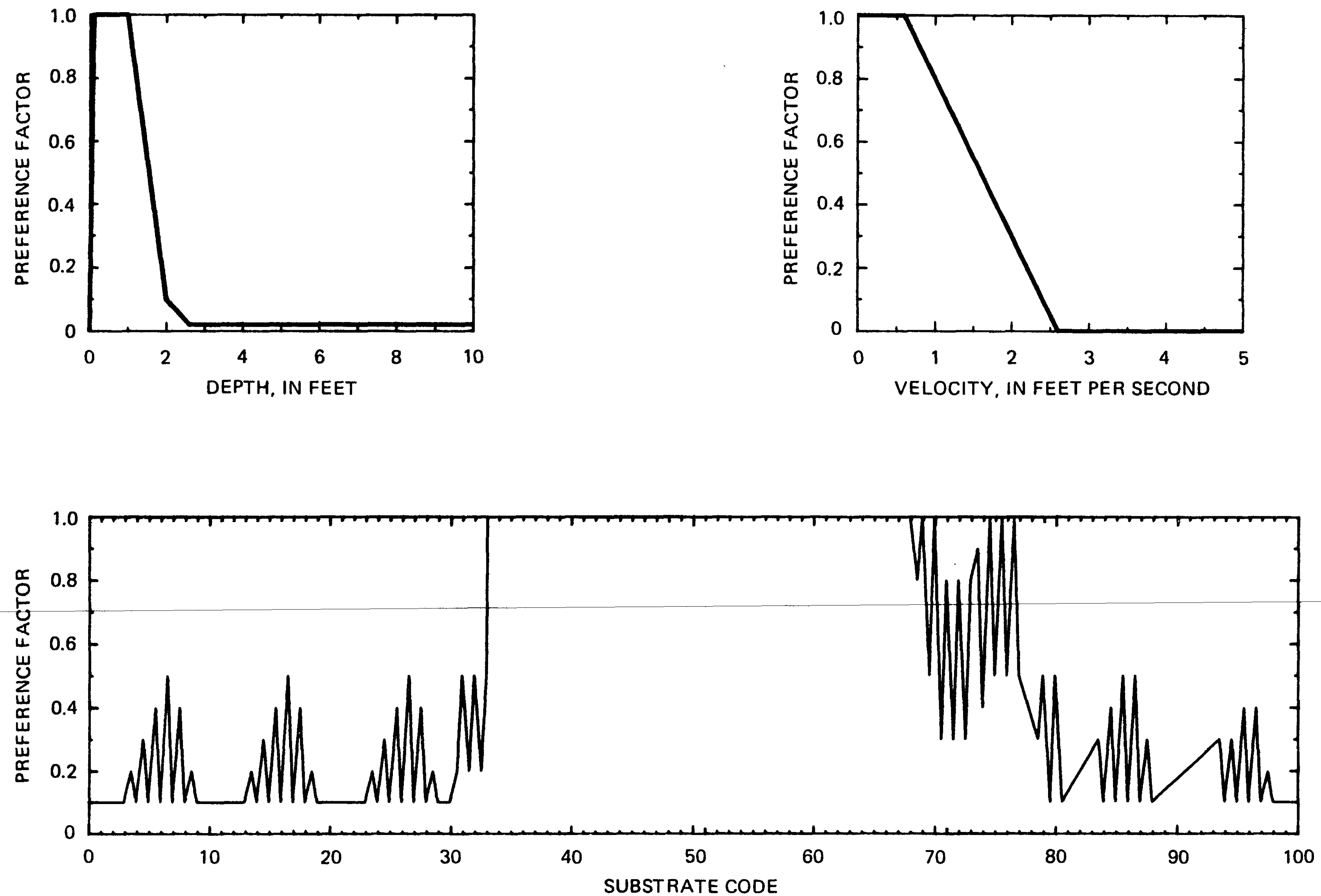
Williams, R. W., Laramie, R. M., Ames, J. J., 1975, A catalog of Washington streams and salmon utilization, Volume 1., Puget Sound Region: Washington State Department of Fisheries, Olympia, Washington, 19 chapters.



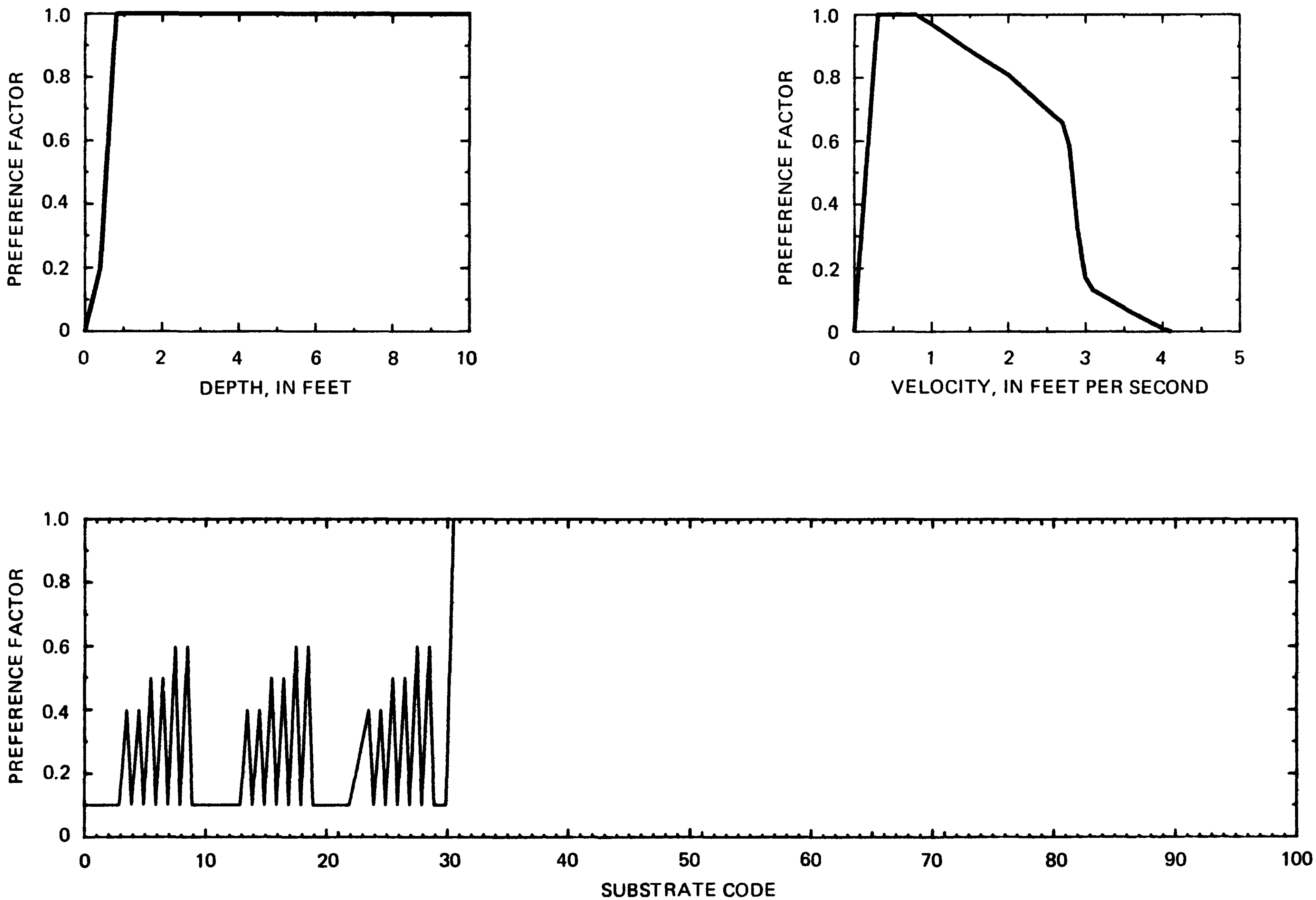
Appendix A.1.--Steelhead trout adult preference-factor curves (code 11002); written communication from State of Washington Department of Game, 1983; depth, State of Washington, Washington Department of Game, after Bovee and Cochnauer, 1977; velocity, after State of Washington Department of Game, after Bovee and Cochnauer, 1977; substrate, State of Washington Department of Game.



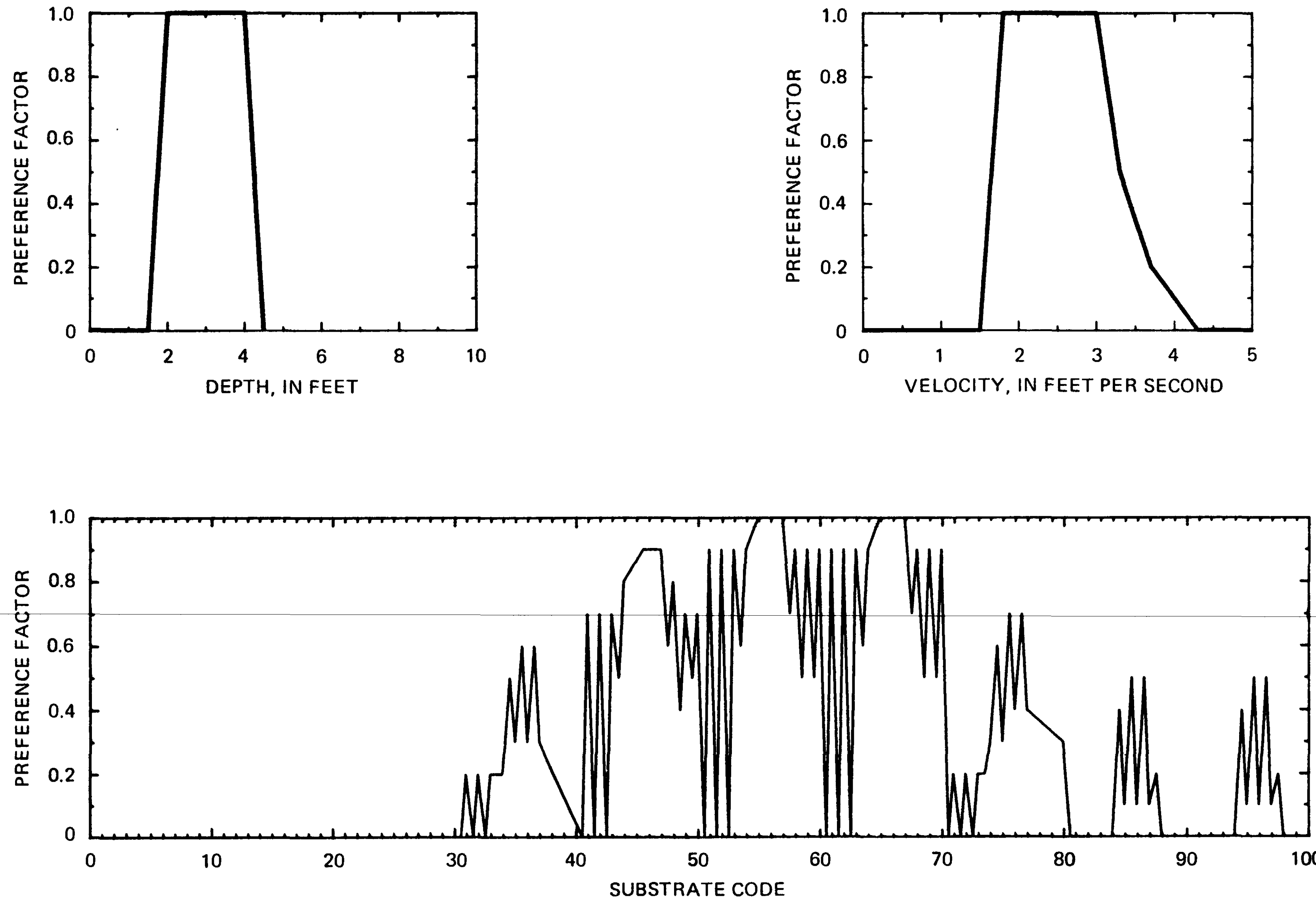
Appendix A.2.--Steelhead trout spawning preference-factor curves (code 11010); written communication from State of Washington Department of Game, 1983.



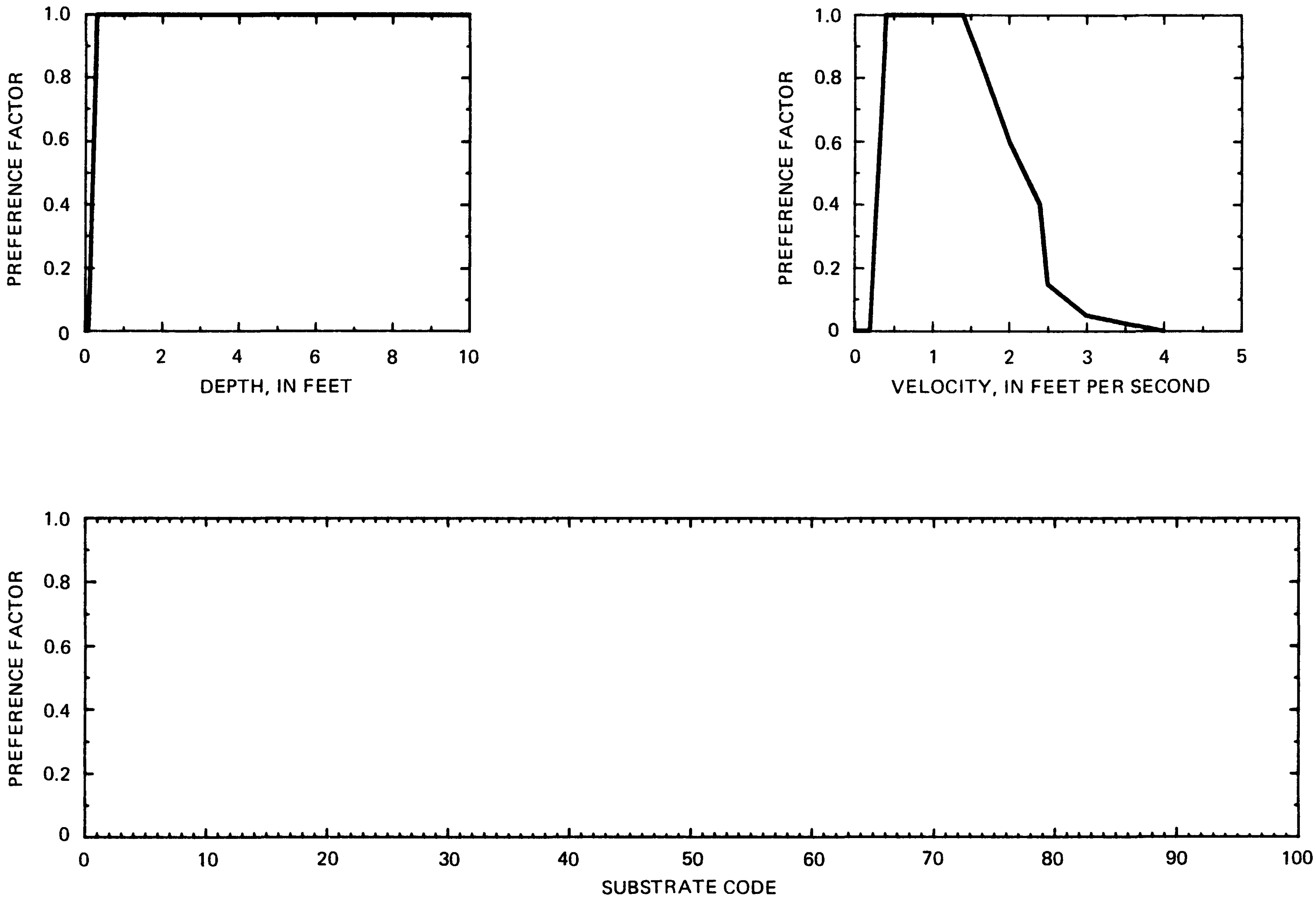
Appendix A.3.--Steelhead trout fry preference-factor curves (code 11000); written communication from State of Washington Department of Game, 1983.



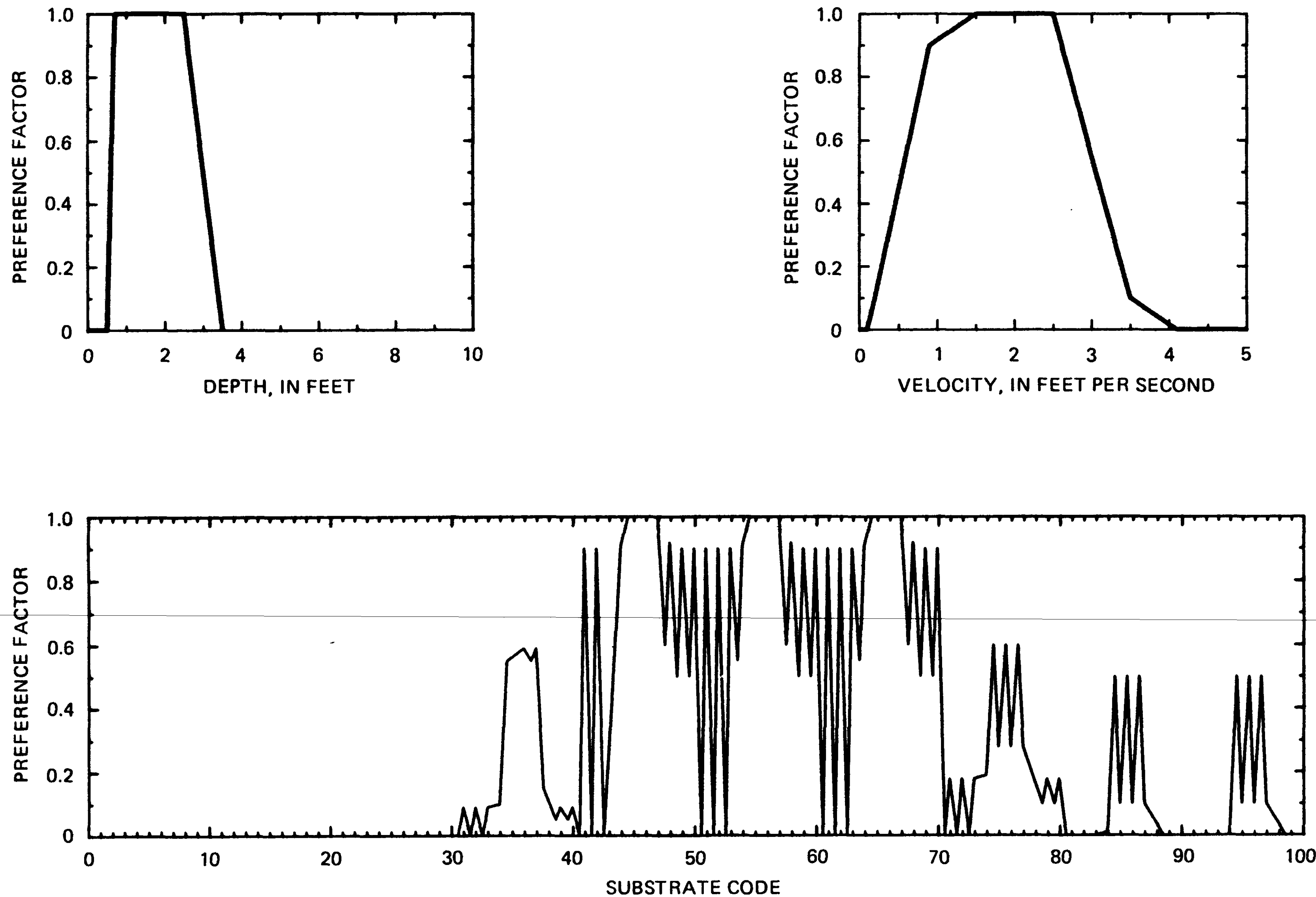
Appendix A.4.--Steelhead trout juvenile preference-factor curves (code 11001); written communication from State of Washington Department of Game, 1983.



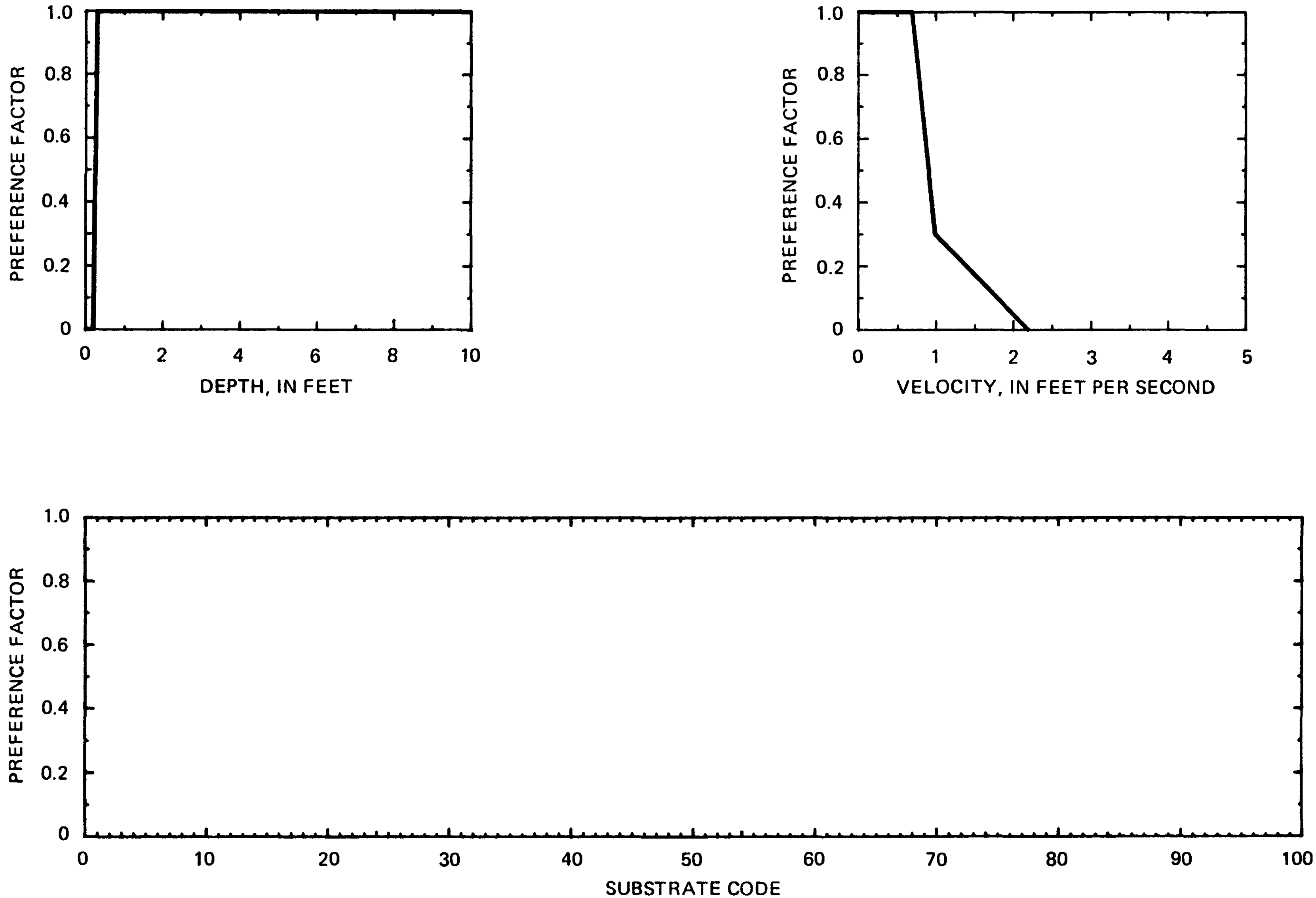
Appendix A.5.--Chinook salmon spawning preference-factor curves (code 10110); written communication from Dames and Moore Consultants, 1984; depth after Dames and Moore Consultants; velocity after U.S. Fish and Wildlife Service; substrate, Dames and Moore Consultants.



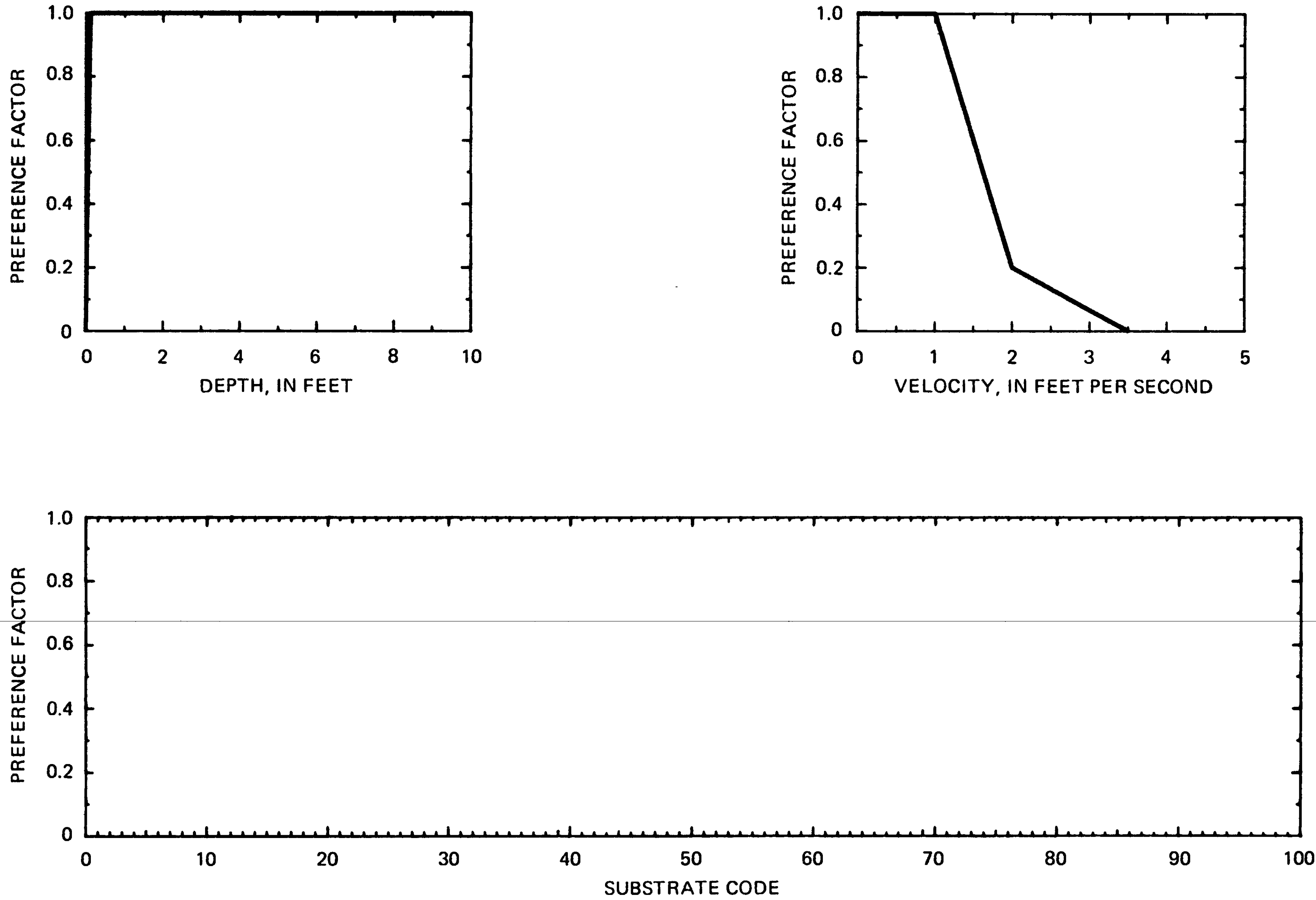
Appendix A.6.--Chinook salmon fry preference-factor curves (code 10100); written communication from Dames and Moore Consultants, 1984; depth after Dames and Moore Consultants.



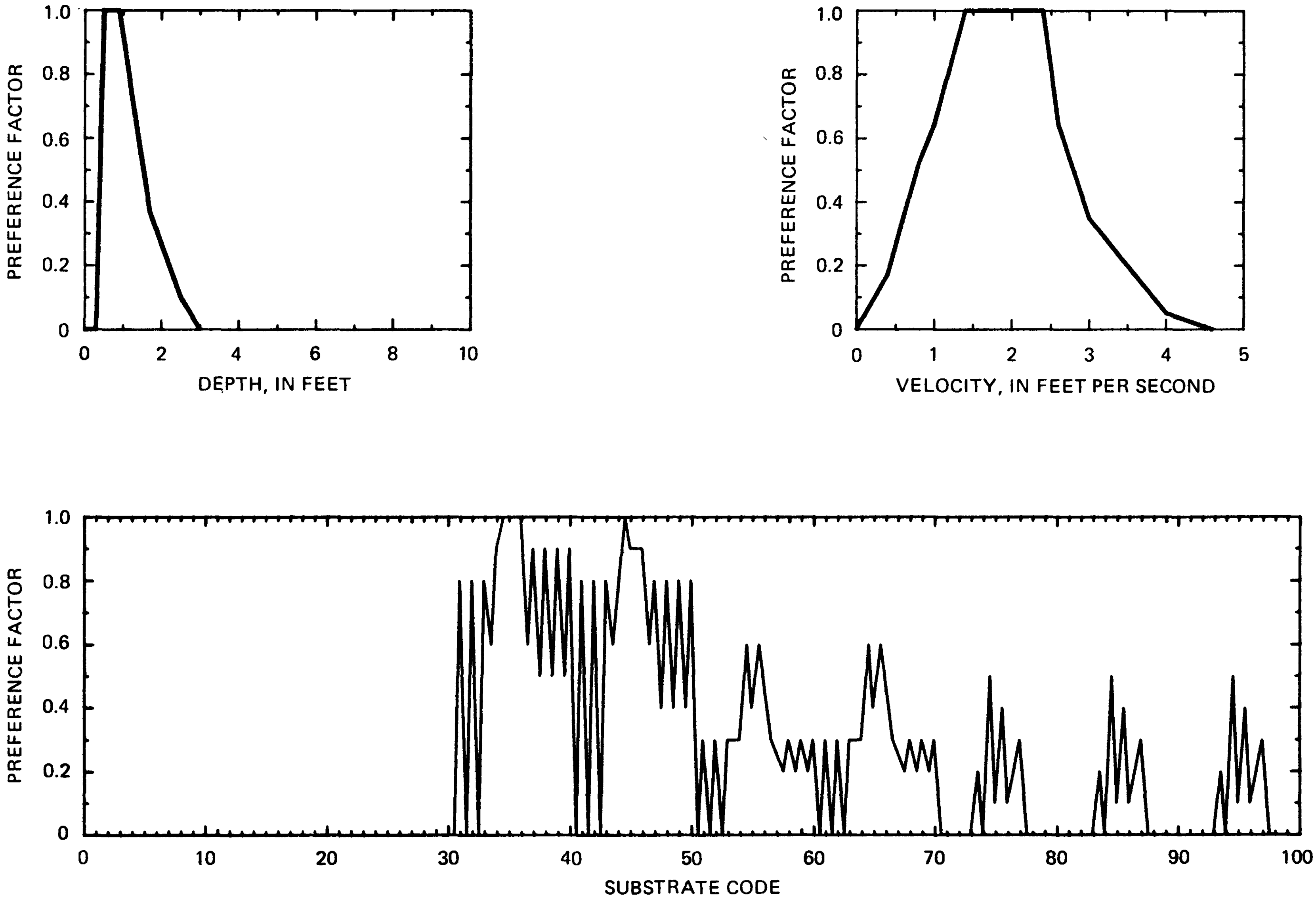
Appendix A.7.--Coho salmon spawning preference-factor curves (code 11110); depth after Arctic Environmental Information and Data Center (AEIDC), 1981?, appendix 3; velocity from AEIDC, 1981?, appendix 3; substrate, written communication from State of Washington Department of Fisheries, 1984.



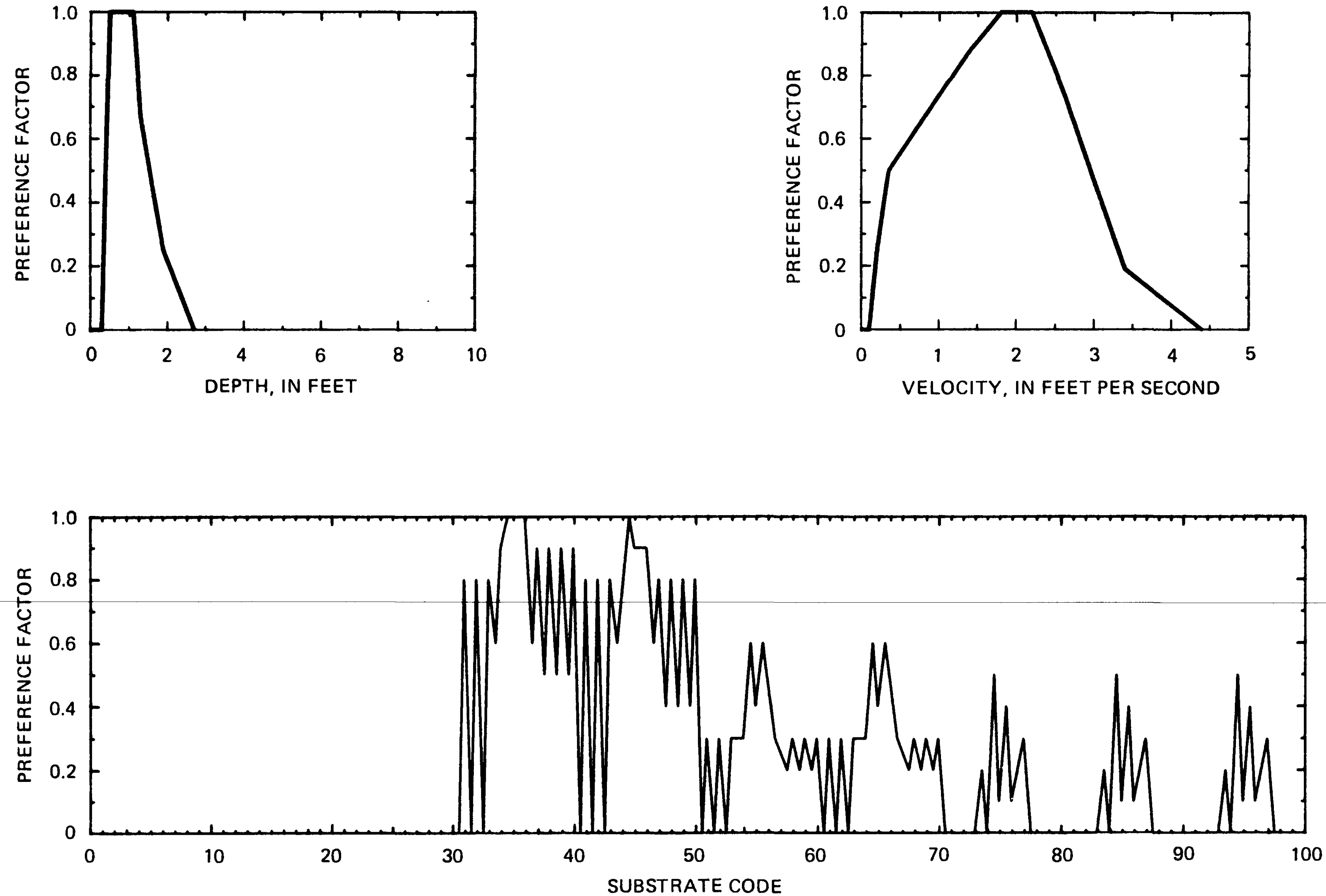
Appendix A.8.--Coho salmon fry preference-factor curves (code 11100); after written communication from Dames and Moore Consultants, 1984.



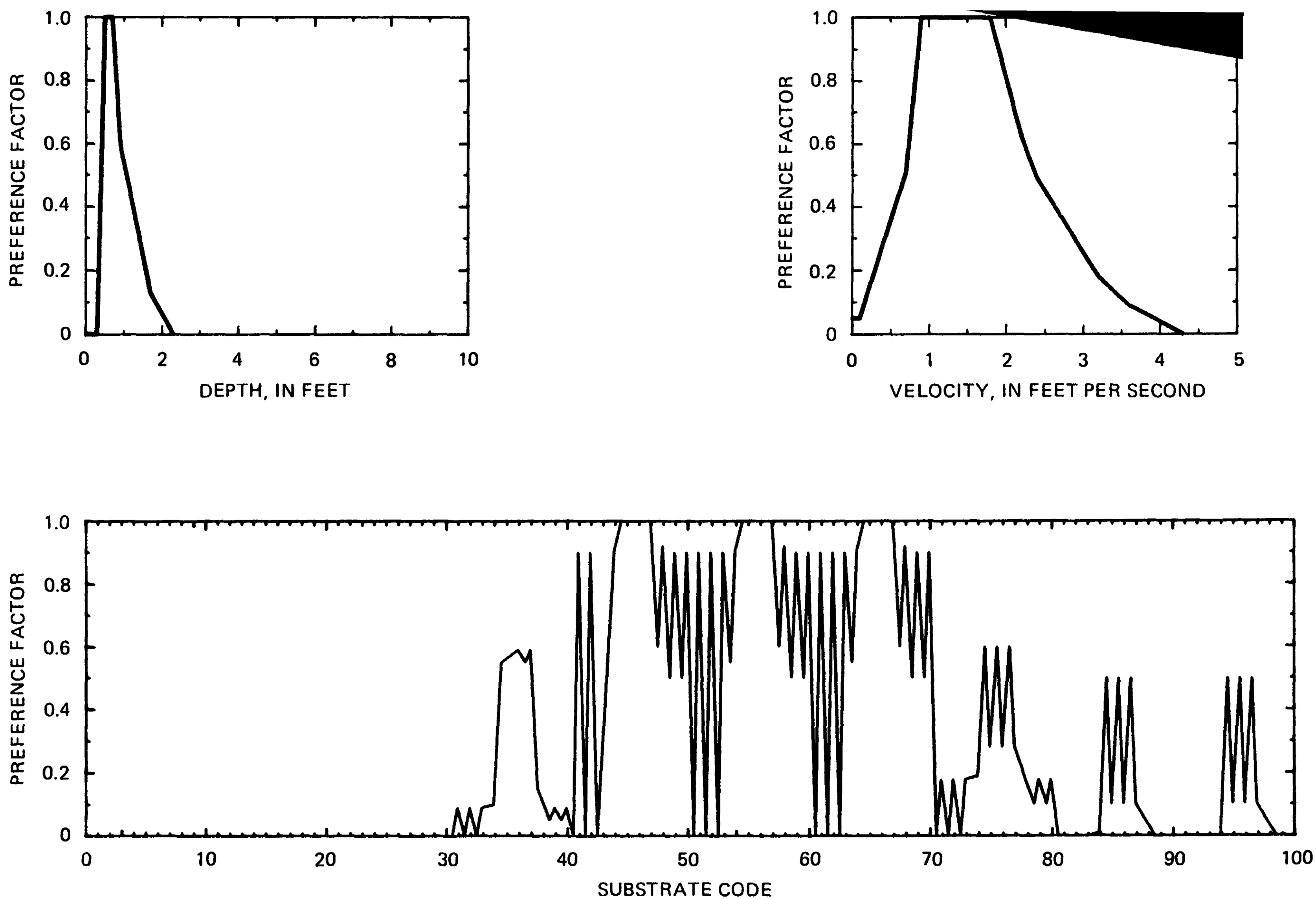
Appendix A.9.--Coho salmon juvenile preference-factor curves (code 11101); after written communication from Dames and Moore Consultants, 1984.



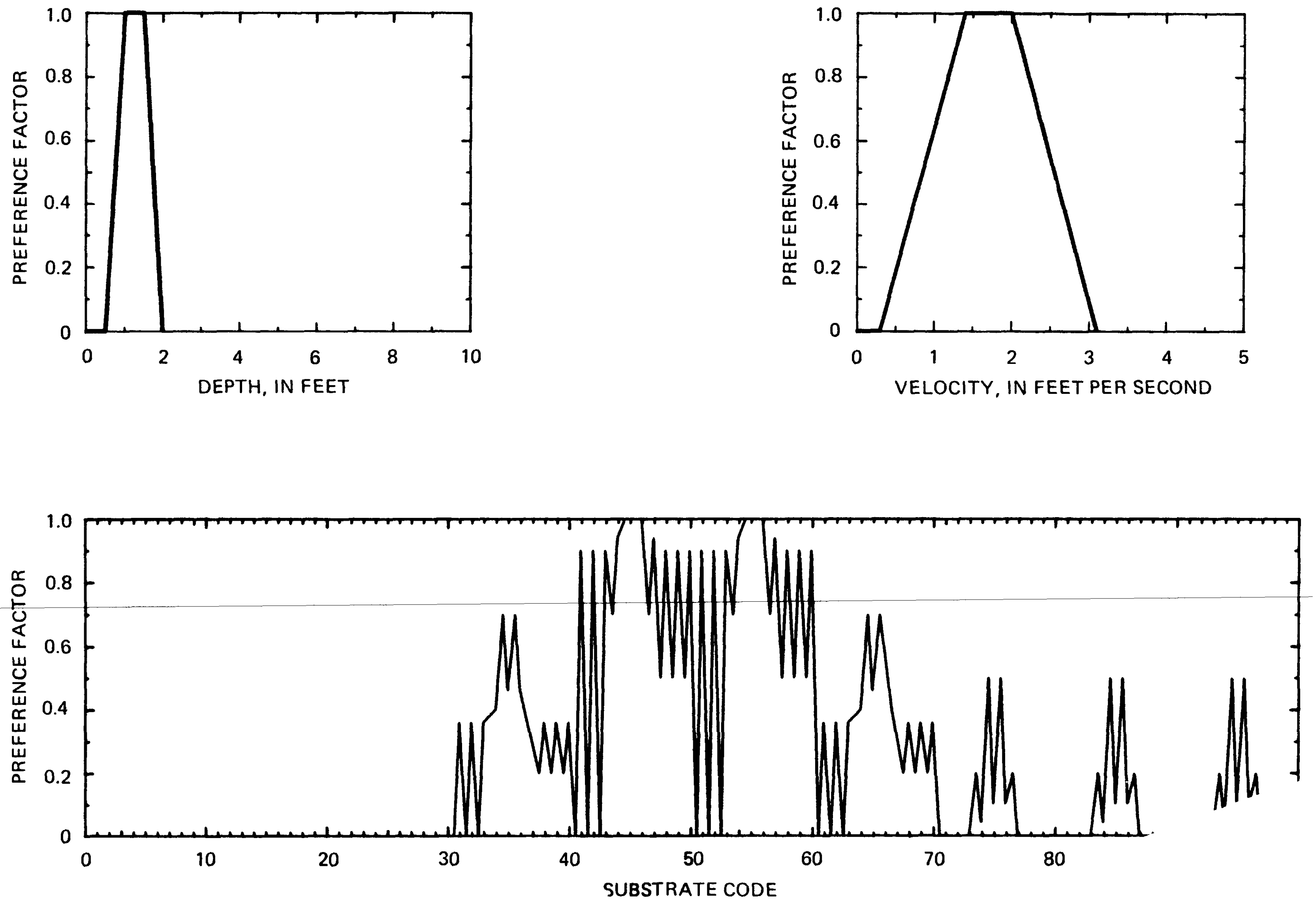
Appendix A.10.--Pink salmon spawning preference-factor curves (code 10410); after written communication from State of Washington Department of Fisheries, 1984.



Appendix A.11.--Pink salmon spawning preference-factor curves for small streams (code 10409); after written communication from the State of Washington Department of Fisheries, 1984.



Appendix A.12.--Chum salmon spawning preference-factor curves (code 10510); after written communication from State of Washington Department of Fisheries, 1984.



Appendix A.13.--Chum salmon spawning preference-factor curves for sm-
after written communication from State of Washington Departm-

APPENDIX B.--The size ranges of the substrate particles described by the substrate preference curves in Appendix A and the format of the substrate code as it is entered into the data files.

Substrate particle code number	Description	Diameter millimeters	inches[1]
0	organic detritus[2]		
1	silt, clay	<2	<0.1
2	sand[3]	<2	<0.1
3	small gravel	2 - 12	0.1 - 0.5
4	medium gravel	12 - 38	0.5 - 1.5
5	large gravel	38 - 76	1.5 - 3.0
6	small cobble	76 - 152	3.0 - 6.0
7	large cobble	152 - 305	6.0 - 12.0
8	boulder	>305	>12.0

[1]rounded to nearest 0.5 inch
[2]material smaller than that which will provide cover
[3]investigators use best judgement in the field to estimate whether small particles are sand or silt

The substrate code is a 3-digit code as follows:

AB.C

where, A = dominant substrate particle code (from percent abundance),
B = subdominant substrate particle code (from percent abundance), and
C = percent of dominant particle (rounded to nearest 10 percent and last zero dropped).

Example: 53.9 where
5 = large gravel
3 = small gravel
0.9 = 90 percent large gravel

The substrate preference curves are constructed using the steps listed below.

1. The substrate coding will give a preference value for the substrate equal to zero when the subdominant code is a zero, one, or a two, and is 50 percent or more of the substrate. For example, 40.5 = zero preference, as does 41.5 and 14.6.

2. All other preference values are determined by using weighted averages. The value of the dominant substrate is multiplied by the percent of the dominant substrate, and that product is added to the product of the subdominant substrate times the percent of subdominant substrate.

Substrate Preference Value = [(Dominant Value) x (% Dominant)] +

[(Subdominant Value) x (% Subdominant)]

For example: the preference for Large Gravel (code 5) is assigned a value of 1.0 and Small Gravel (code 3) is assigned a value of .10 for a Chinook salmon spawning curve. If the 3-digit code is 53.9 the Substrate Preference Value is computed as follows:

Substrate Preference Value = [(1.0) x (.90)] + [(.20) x (.10)] = .92 = .9

The coordinate values for the plotting points entered into the computer are generally the 50 and 90 percent (AB.5 and AB.9) breaks in the preference value computations.

APPENDIX C.--Note on the calibrations of the IFG-4 model

1. Limitation of the Beta coefficients

The Instream Flow Group considered the Beta coefficient (B) of the velocity regression equations good if it ranged from about 0.3 to 0.8 (K.D. Bovee, U. S. Fish and Wildlife Service, oral commun., 1983). An upper limit of 1.10 for B was chosen for this study after a review of the simulation results showing the difference between measured and predicted velocities. A lower limit of 0.3 for B was also chosen.

The maximum B is controlled by an option within the model; however, the minimum B is controlled by recomputing the given discharge using an equation with a B of 0.3 and reentering the controlled velocities into the model. The equations used to recompute the velocities and limited by the minimum B are:

a. $\bar{V} = \sqrt[3]{V_1 V_2 V_3}$ where V_1 = measured velocity at low flow
V_2 = measured velocity at medium flow
V_3 = measured velocity at high flow

b. $\bar{Q} = \sqrt[3]{Q_1 Q_2 Q_3}$ where Q_1 = IFG-4 computed low-flow discharge
Q_2 = IFG-4 computed medium-flow discharge
Q_3 = IFG-4 computed high-flow discharge

c. $a = \dfrac{\bar{V}}{Q^{0.3}}$ where a = alpha coefficient

d. $Va = aQ_1^{0.3}$

$Vb = aQ_2^{0.3}$

$Vc = aQ_3^{0.3}$ where Va = new low-flow velocity limited by B=0.3
Vb = new medium-flow velocity limited by B=0.3
Vc = new high-flow velocity limited by B=0.3

Three restrictions of the recomputation of minimum Beta were based on the correlation coefficients for the measured velocities.

A. If a 3-point correlation coefficient was less than .9 and Beta was less than 0.3, new velocities were computed.

B. If a 3-point correlation coefficient was less than .9 but the Beta coefficient was greater than 0.3, the velocities were not recomputed.

C. If the vertical had velocities measured at only two discharges and the Beta was less than 0.3, the velocities were recomputed.

2. The discharge given the model for calibration was generally an average of the discharge measured at all the cross sections in a study site. At some sites, certain discharges at cross sections were excluded from the average in favor of discharges measured at cross sections providing conditions for the best estimate of discharge.

3. Cross sections that covered a divided channel or a side channel were adjusted to a single, average water-surface elevation by adjusting the bed elevation of the channel with a lower water-surface elevation to the channel with the higher water-surface elevation.

4. Recommendations for the limits of extrapolation of the IFG-4 model are given by the Instream Flow Group (Bovee, 1978 and 1982). If three discharges are used in the model, the limits are 0.4 times the lowest discharge and 2.5 times the highest discharge. If 2 discharges are used, the limits are 0.77 times the lowest discharge and 1.3 times the highest. These guidelines were followed for most of the ranges of discharges used in the habitat analyses. Discharges exceeding these limits and occasionally less than these limits were included for some study sites after reviewing the hydraulic simulations. The decision to accept or reject certain flow simulations was determined mostly by how the model distributed velocities within the cross section.

5. Poor simulation of cross section 7 at Jim Creek at mouth at Arlington is the result of incompleted high-flow measurements. The difference in the computation of habitat with and without cross section 7 did not appear so large as to require deletion of the cross section from the data set.

6. Four discharges were used in the complete calibration of Canyon Creek near Granite Falls, but were available for each cross section as follows: calibration flows of 114 and 338 cubic feet per second were used for all 5 cross sections; 756 cubic feet per second was used for cross sections 1 and 2; and 453 cubic feet per second was used for cross sections 3, 4, and 5.

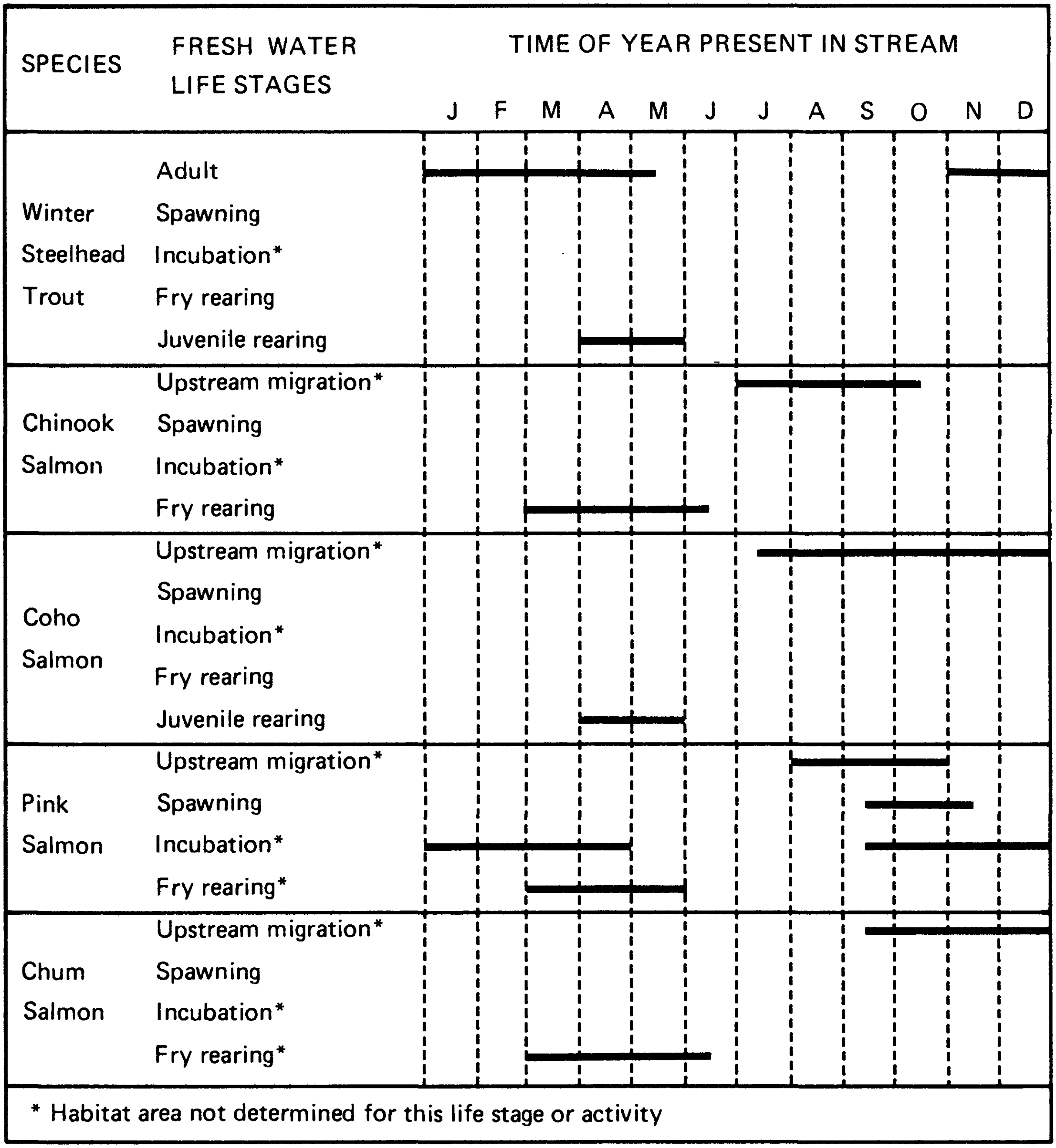


Figure 2.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 1, Mainstem Stillaguamish River at Arlington.

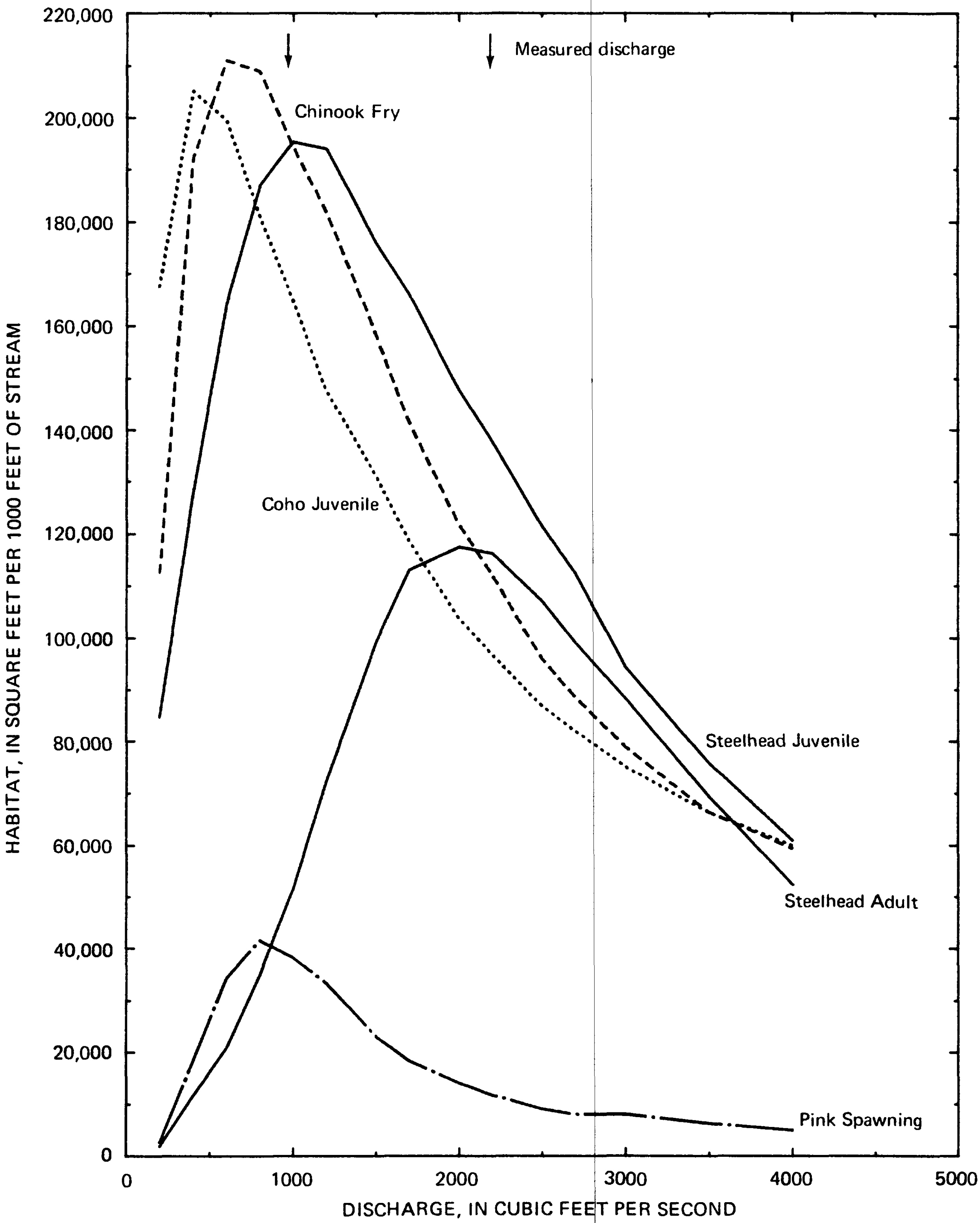


Figure 3.--Graph showing relations between stream discharge and habitat at site 1, Mainstem Stillaguamish River at Arlington.

Table 3.--Total surface area and habitat area according to stream discharge, species, and life stage for the mainstem Stillaguamish River at Arlington

[Calibration discharges = 971 and 2,190 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 750 to 2,850 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet				
		STEELHEAD		CHINOOK	COHO	PINK
		ADULT	JUVENILE	FRY	JUVENILE	SPAWNING
200	191,080	1,860	84,720	112,650	176,490	2,650
400	246,610	11,660	127,730	192,270	205,160	18,360
600	264,980	20,810	164,370	211,060	199,560	34,440
800	275,430	35,070	187,000	209,020	181,100	41,640
1,000	283,050	51,630	195,400	194,460	165,000	38,390
1,200	289,920	72,410	194,080	181,940	147,610	33,380
1,500	301,280	99,370	175,990	158,530	131,210	23,080
1,700	306,710	113,120	166,190	141,560	118,650	18,400
2,000	311,750	117,470	147,800	121,820	103,860	14,130
2,200	314,620	116,280	137,720	112,140	96,780	11,780
2,500	317,570	107,120	121,440	96,010	86,870	9,090
2,700	319,140	99,170	112,550	88,680	82,120	8,060
3,000	321,150	88,320	94,410	78,970	75,130	8,080
3,500	324,000	69,360	75,770	66,400	66,340	6,310
4,000	326,360	52,430	61,030	59,470	60,030	4,980

Table 4.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 1, Mainstem Stillaguamish River at Arlington

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha[2] coefficient	Beta[2] coefficient
1	pool	971		0.964	----	1.82	1.75	85.84	85.84	71.70	0.106E-07	9.528
		2,190		1.03	----	3.40	3.50	87.10	87.10	D.O.	D.O.	D.O.
			200	.796	----	---	---	---	---	D.O.	D.O.	D.O.
			485	.900	----	---	1.12	---	84.85	D.O.	D.O.	D.O.
			4,000	1.04	----	---	---	---	---	D.O.	D.O.	D.O.
			4,380	1.08	----	---	6.31	---	88.26	D.O.	D.O.	D.O.
2	pool	971		.997	----	3.53	2.85	86.98	86.98	84.70	64.6	3.287
	riffle	2,190		1.01	----	4.37	4.39	87.62	87.62	D.O.	D.O.	D.O.
	transition		200	1.29	----	---	---	---	---	D.O.	D.O.	D.O.
			485	1.04	----	---	2.45	---	86.55	D.O.	D.O.	D.O.
			4,000	1.03	----	---	---	---	---	D.O.	D.O.	D.O.
			4,380	1.01	----	---	8.11	---	88.31	D.O.	D.O.	D.O.
3	mid-	971		.999	----	2.58	2.58	87.68	87.68	84.70	57.5	2.589
	riffle	2,190		1.00	----	3.96	3.97	88.78	88.78	D.O.	D.O.	D.O.
			200	1.07	----	---	---	---	---	D.O.	D.O.	D.O.
			485	1.01	----	---	1.91	---	86.98	D.O.	D.O.	D.O.
			4,000	1.01	----	---	---	---	---	D.O.	D.O.	D.O.
			4,380	1.01	----	---	6.02	---	90.03	D.O.	D.O.	D.O.
4	control	971		.999	----	1.88	1.88	88.16	88.16	85.00	38.2	2.812
		2,190		1.01	----	3.05	3.07	89.22	89.22	D.O.	D.O.	D.O.
			200	1.03	----	---	---	---	---	D.O.	D.O.	D.O.
			485	1.00	----	---	1.29	---	87.47	D.O.	D.O.	D.O.
			4,000	1.00	----	---	---	---	---	D.O.	D.O.	D.O.
			4,380	.998	----	---	6.05	---	90.40	D.O.	D.O.	D.O.
5	run	971		.986	----	1.48	1.46	88.30	88.30	80.40	.000728	6.824
		2,190		1.02	----	2.42	2.46	89.30	89.30	D.O.	D.O.	D.O.
			200	.854	----	---	---	---	---	D.O.	D.O.	D.O.
			485	.937	----	---	.96	---	87.54	D.O.	D.O.	D.O.
			4,000	1.02	----	---	---	---	---	D.O.	D.O.	D.O.
			4,380	1.02	----	---	4.31	---	90.25	D.O.	D.O.	D.O.
6	run-	971		.981	----	1.42	1.39	88.32	88.32	79.10	.810E-04	7.343
	riffle	2,190		1.02	----	2.72	2.78	89.40	89.40	D.O.	D.O.	D.O.
	transition		200	.847	----	---	---	---	---	D.O.	D.O.	D.O.
			485	.931	----	---	.87	---	87.49	D.O.	D.O.	D.O.
			4,000	1.04	----	---	---	---	---	D.O.	D.O.	D.O.
			4,380	1.04	----	---	5.33	---	90.42	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2] from the stage-discharge relation for given discharges.

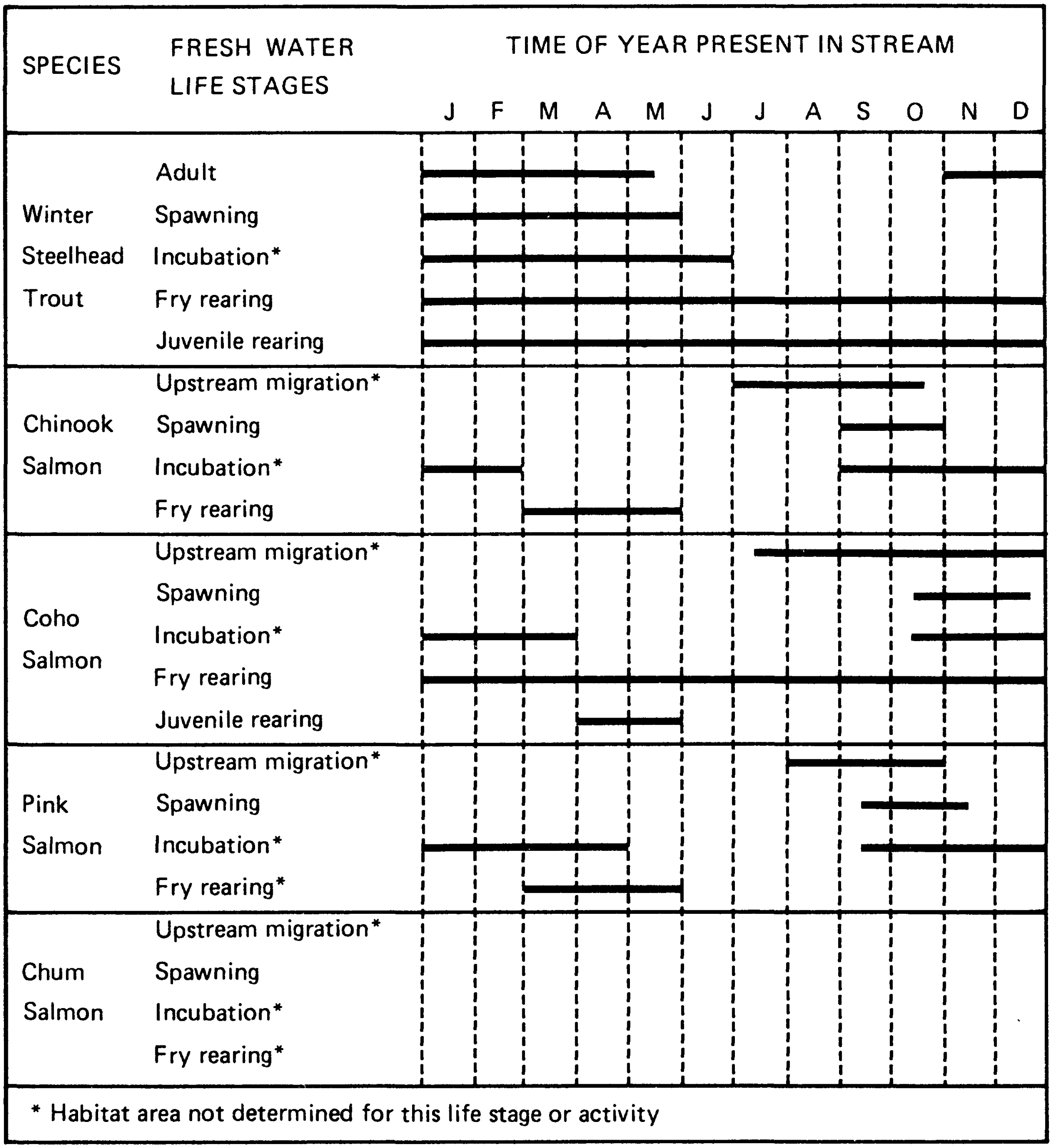


Figure 4.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 2, Pilchuck Creek near Arlington.

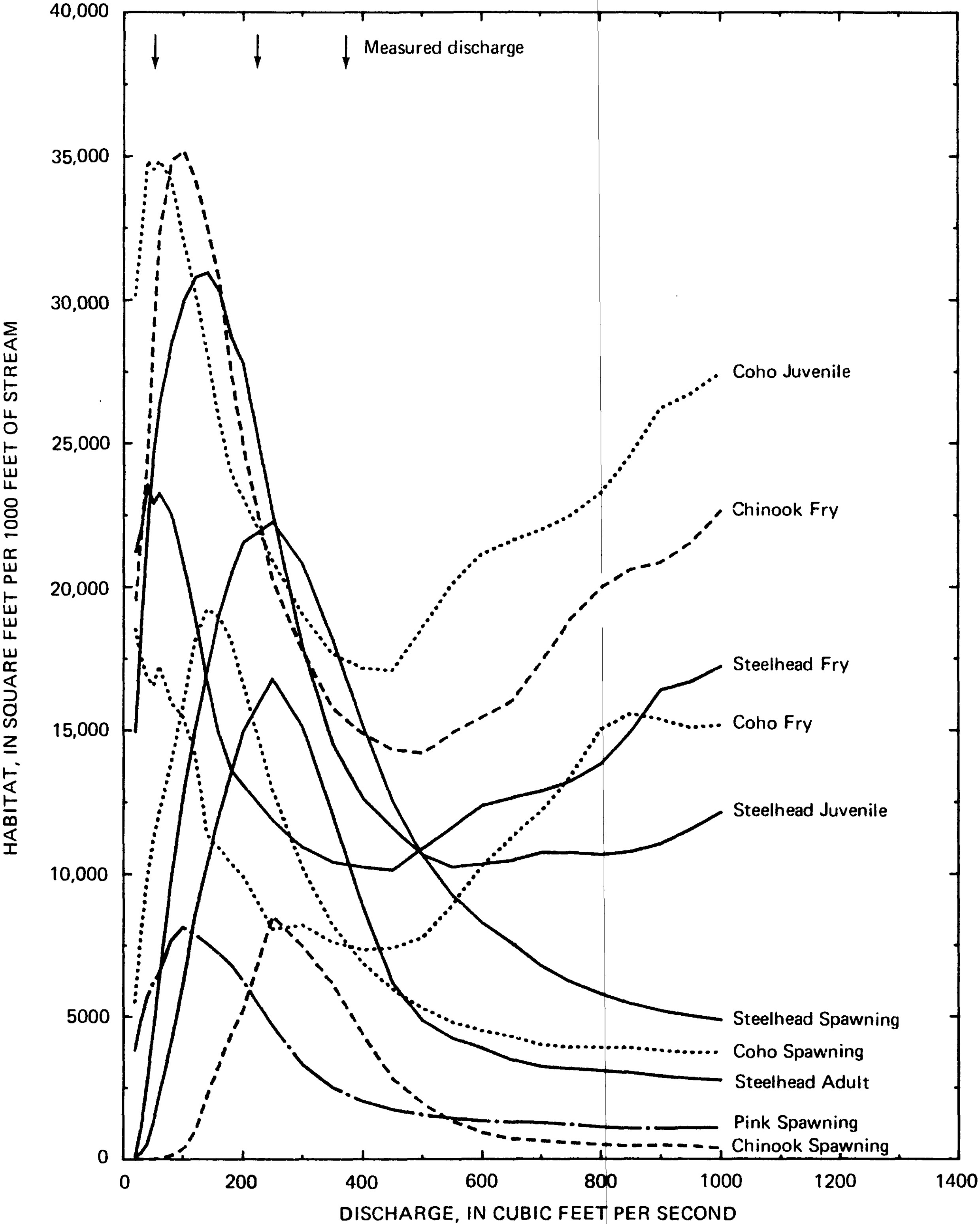


Figure 5.--Graph showing relations between stream discharge and habitat at site 2, Pilchuck Creek near Arlington.

Table 5.--Total surface area and habitat area according to stream discharge, fish species, and life stage for Pilchuck Creek near Arlington

[Calibration discharges = 52, 224, and 373 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 21 and 930 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet									
		STEELHEAD				CHINOOK		COHO			PINK
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	SPAWNING	FRY	JUVENILE	SPAWNING
20	32,420	97	102	21,200	14,930	0	19,550	5,530	18,540	30,140	3,820
30	39,270	205	1,120	22,090	18,780	0	21,890	7,900	17,550	32,260	4,880
40	43,580	518	2,680	23,540	21,970	0	24,560	9,820	16,860	34,850	5,650
50	47,070	1,260	4,440	22,910	24,620	0	28,940	11,140	16,560	34,550	6,160
60	49,290	2,230	6,310	23,270	26,400	34	32,360	12,100	17,260	34,850	6,540
80	52,530	4,040	9,800	22,550	28,510	137	34,860	13,870	15,960	34,120	7,660
100	54,750	6,150	12,730	20,840	29,970	361	35,210	15,880	15,490	32,040	8,150
120	56,470	8,560	15,010	18,920	30,800	1,000	34,140	18,160	14,160	30,250	7,890
140	57,340	10,330	17,080	16,670	30,950	2,270	32,520	19,240	11,390	28,070	7,590
160	58,280	12,050	19,040	14,850	30,310	3,370	30,660	18,990	10,920	25,800	7,230
180	60,130	13,490	20,460	13,640	28,720	4,380	27,440	18,140	10,390	23,970	6,850
200	61,860	14,930	21,540	13,100	27,750	5,260	24,940	16,660	9,940	23,120	6,290
250	63,910	16,800	22,270	11,880	22,590	8,530	20,230	12,940	8,080	20,950	4,700
300	65,270	15,140	20,820	10,930	17,930	7,480	17,810	10,240	8,220	19,070	3,340
350	66,860	12,070	18,160	10,410	14,520	6,160	15,800	8,220	7,630	17,680	2,530
400	68,250	8,830	15,150	10,230	12,630	4,370	14,900	6,900	7,360	17,180	2,050
450	70,980	6,200	12,530	10,130	11,620	2,840	14,340	5,980	7,420	17,090	1,760
500	73,990	4,870	10,650	10,880	10,670	1,970	14,210	5,310	7,760	18,560	1,570
550	75,670	4,250	9,260	11,620	10,230	1,340	14,910	4,820	8,900	20,100	1,450
600	77,220	3,890	8,290	12,380	10,340	935	15,470	4,520	10,280	21,150	1,350
650	78,510	3,480	7,580	12,650	10,460	723	16,010	4,320	11,290	21,590	1,300
700	79,860	3,250	6,790	12,880	10,740	649	17,360	4,020	12,180	21,990	1,280
750	81,220	3,170	6,210	13,220	10,730	575	18,880	3,930	13,390	22,480	1,210
800	82,660	3,100	5,800	13,830	10,670	513	19,980	3,920	15,030	23,280	1,120
850	84,140	3,030	5,450	14,950	10,770	477	20,620	3,910	15,590	24,570	1,080
900	85,550	2,920	5,200	16,420	11,060	488	20,860	3,820	15,390	26,230	1,080
950	87,200	2,830	5,020	16,690	11,550	466	21,540	3,740	15,100	26,730	1,090
1,000	88,880	2,780	4,880	17,230	12,150	389	22,660	3,750	15,190	27,480	1,100

Table 6.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 2, Pilchuck Creek near Arlington

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha coefficient[2]	Beta coefficient[2]
1	not used	---	---	---	---	---	---	---	---	---	---	---
2	riffle	52	---	0.981	0.098	3.28	2.83	91.42	91.42	90.50	64.5	2.71.
		224	---	.984	---	4.03	4.05	92.20	---	D.O.	D.O.	D.O.
		373	---	1.03	---	5.32	5.14	92.29	---	D.O.	D.O.	D.O.
			20	1.05	---	---	2.59	---	91.15	D.O.	D.O.	D.O.
			930	1.08	---	---	13.54	---	93.18	D.O.	D.O.	D.O.
3	riffle-run transition	52	---	.987	.103	1.80	1.81	91.94	91.94	90.64	21.1	3.421
		224	---	1.00	---	4.26	3.90	92.65	92.63	D.O.	D.O.	D.O.
		373	---	1.00	---	5.32	5.39	92.94	92.95	D.O.	D.O.	D.O.
			20	.958	---	---	1.10	---	91.62	D.O.	D.O.	D.O.
			930	.982	---	---	10.03	---	93.66	D.O.	D.O.	D.O.
4	pool-run transition	52	---	.725	.383	1.72	2.15	92.06	92.06	87.93	.00029	8.532
		224	---	.951	---	3.23	2.70	92.83	92.83	D.O.	D.O.	D.O.
		373	---	.998	---	3.99	4.14	93.13	93.13	D.O.	D.O.	D.O.
			20	.558	---	---	1.43	---	91.62	D.O.	D.O.	D.O.
			930	1.02	---	---	10.13	---	93.72	D.O.	D.O.	D.O.
5	run	52	---	1.00	.111	1.89	1.94	92.28	92.28	91.13	35.7	2.662
		224	---	1.01	---	3.89	3.41	93.15	93.12	D.O.	D.O.	D.O.
		373	---	1.01	---	3.72	4.51	93.52	93.54	D.O.	D.O.	D.O.
			20	1.08	---	---	1.40	---	91.93	D.O.	D.O.	D.O.
			930	.996	---	---	12.90	---	94.54	D.O.	D.O.	D.O.
6	pool	52	---	.855	.188	.84	.73	92.35	92.34	86.30	.141E-05	9.685
		224	---	1.02	---	2.00	1.98	93.31	93.33	D.O.	D.O.	D.O.
		373	---	1.05	---	2.86	2.99	93.72	93.71	D.O.	D.O.	D.O.
			20	.728	---	---	.51	---	91.78	D.O.	D.O.	D.O.
			930	1.02	---	---	11.62	---	94.44	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2] from the stage-discharge relationship for given discharges.

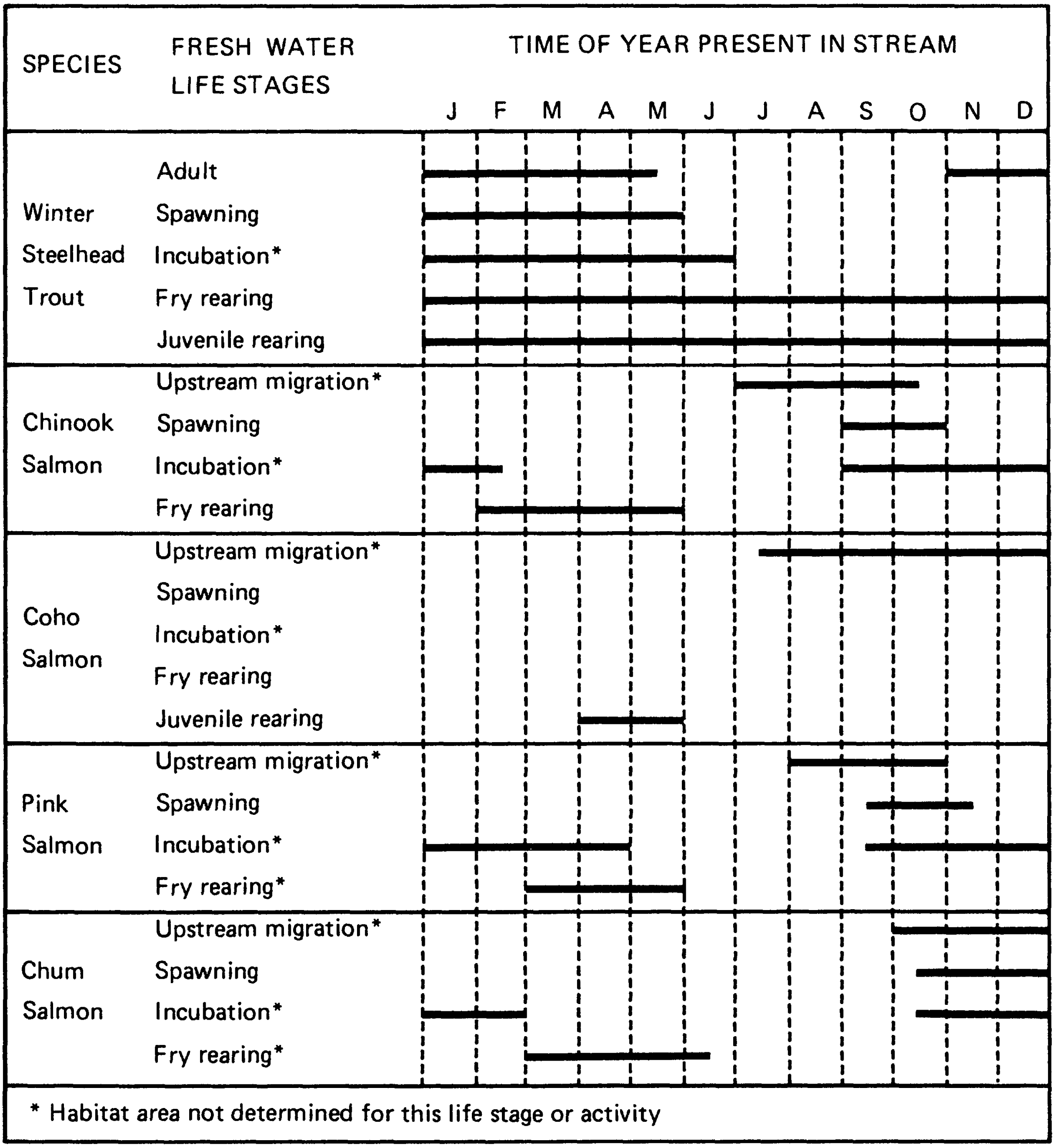


Figure 6.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 4, North Fork Stillaguamish River at Wiersma Bar.

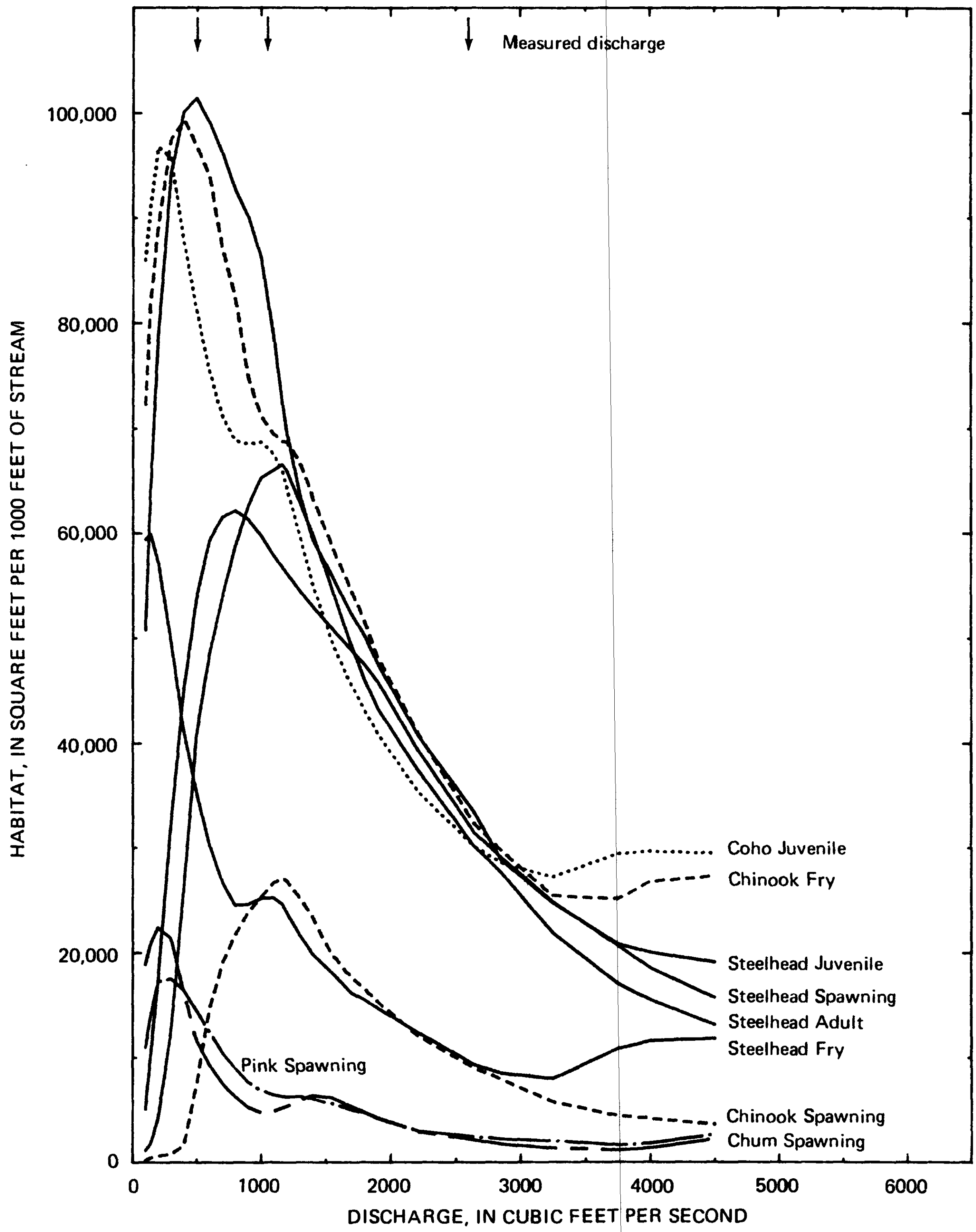


Figure 7.--Graph showing relations between stream discharge and habitat at site 4, North Fork Stillaguamish River at Wiersma Bar.

Table 7.--Total surface area and habitat area according to stream discharge, fish species, and life stage for North Fork Stillaguamish River at Wiersma Bar near Arlington

[Calibration discharges = 503, 1,050, and 2,600 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 200 and 6,500 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet								
		STEELHEAD				CHINOOK		COHO	PINK	CHUM
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	JUVENILE	SPAWNING	SPAWNING
100	126,950	1,120	5,070	59,410	50,790	206	72,280	85,980	10,980	18,860
140	136,220	1,740	9,870	59,940	63,920	424	82,120	90,930	13,920	20,800
200	148,910	4,180	17,420	57,310	78,800	628	89,170	96,740	17,280	22,450
300	160,580	12,440	32,240	49,750	94,300	772	97,500	95,660	17,570	21,430
400	165,690	25,940	44,960	41,300	100,130	1,640	99,390	87,690	16,490	16,250
500	170,610	40,770	53,840	35,320	101,380	7,410	96,810	81,210	14,490	11,620
600	174,710	48,510	59,400	30,290	99,090	14,590	93,980	75,350	12,460	9,310
700	178,100	53,950	61,570	26,800	96,204	18,990	87,170	71,210	10,480	7,550
800	183,380	58,800	62,180	24,560	92,650	21,790	82,420	68,850	8,960	6,280
900	188,060	62,700	61,370	24,650	90,150	23,880	74,840	68,600	7,640	5,270
1,000	193,900	65,330	59,750	25,220	86,320	25,330	71,210	67,600	6,460	4,920
1,170	199,040	66,600	56,680	24,680	72,150	27,120	68,800	65,840	6,290	5,240
1,200	199,490	65,980	56,160	23,850	69,820	26,880	68,760	59,890	6,310	5,970
1,400	201,950	60,010	53,060	19,950	59,460	23,450	63,550	49,590	5,600	6,160
1,700	206,460	49,230	48,880	16,200	52,300	17,690	54,490	45,490	5,040	5,340
1,800	207,430	46,000	47,470	15,510	50,250	16,550	51,620	43,180	4,750	4,810
1,900	208,300	43,380	45,880	14,700	47,560	15,340	48,230	40,970	4,160	4,260
2,220	210,560	37,320	39,250	12,340	40,680	12,000	40,860	35,260	2,990	2,910
2,640	212,500	30,200	31,520	9,360	33,470	9,020	32,380	30,170	2,490	2,150
2,850	213,390	27,680	29,110	8,520	28,850	7,930	29,820	28,610	2,250	1,760
3,250	218,150	21,910	24,880	7,970	24,800	5,790	25,490	27,230	2,050	1,380
3,750	222,420	17,060	20,690	10,860	20,860	4,450	25,180	29,450	1,670	1,180
4,000	224,090	15,520	18,560	11,600	20,060	4,190	26,820	29,670	1,830	1,380
4,500	225,920	13,140	15,760	11,820	19,110	3,640	27,320	29,510	2,710	2,240

Table 8.--Selected calibration and simulation details for the IFG-4 model for site 4, North Fork Stillaguamish River at Wiersma Bar

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha[2] coefficient	Beta[2] coefficient
1	control	503		0.977	0.060	3.29	3.26	90.85	90.81	87.93	17.7	3.165
		1,050		.995	---	3.96	3.84	91.48	91.56	D.O.	D.O.	D.O
		2,600		1.00	---	5.58	5.72	92.81	92.77	D.O.	D.O.	D.O.
			200	1.02	---	---	2.89	---	90.08	D.O.	D.O.	D.O.
			5,200	1.01	---	---	8.95	---	93.95	D.O.	D.O.	D.O.
2	pool	503		.986	.521	1.77	1.66	91.10	91.00	84.06	.00268	6.269
		1,050		1.02	---	2.78	2.86	91.70	91.86	D.O.	D.O.	D.O.
		2,600		1.02	---	5.34	5.26	93.14	93.08	D.O.	D.O.	D.O.
			200	.929	---	---	.88	---	90.05	D.O.	D.O.	D.O.
			5,200	1.03	---	---	10.16	---	94.13	D.O.	D.O.	D.O.
3	pool-riffle transition	503		.986	.133	1.86	1.86	91.12	91.04	84.42	.0122	5.626
		1,050		1.01	---	3.08	3.02	91.82	91.96	D.O.	D.O.	D.O.
		2,600		1.03	---	5.27	5.62	93.34	93.28	D.O.	D.O.	D.O.
			200	.939	---	---	1.08	---	90.04	D.O.	D.O.	D.O.
			5,200	1.03	---	---	9.76	---	94.44	D.O.	D.O.	D.O.
4	riffle; log pile	503		.977	.230	5.00	3.94	91.40	91.36	86.50	1.21	3.812
		1,050		1.04	---	5.42	5.07	92.32	92.40	D.O.	D.O.	D.O.
		2,600		1.03	---	7.43	7.90	94.02	93.98	D.O.	D.O.	D.O.
			200	.854	---	---	2.73	---	90.32	D.O.	D.O.	D.O.
			5,200	.958	---	---	14.71	---	95.47	D.O.	D.O.	D.O.
5	control	503		.986	.044	3.72	3.68	93.50	93.50	91.76	114.0	2.670
		1,050		1.02	---	4.57	4.73	94.06	94.06	D.O.	D.O.	D.O.
		2,600		.987	---	6.60	6.20	94.89	94.98	D.O.	D.O.	D.O.
			200	.929	---	---	2.72	---	92.99	D.O.	D.O.	D.O.
			5,200	.918	---	---	9.32	---	95.94	D.O.	D.O.	D.O.
6	run	503		.987	.805	2.39	2.46	93.95	93.98	92.18	139.0	2.183
		1,050		.993	---	3.06	3.02	94.80	94.70	D.O.	D.O.	D.O.
		2,600		.983	---	4.41	4.36	95.93	96.00	D.O.	D.O.	D.O.
			200	1.03	---	---	2.07	---	93.36	D.O.	D.O.	D.O.
			5,200	.954	---	---	8.99	---	97.43	D.O.	D.O.	D.O.
7	riffle	503		.974	.095	3.34	3.25	94.34	94.36	92.38	88.2	2.555
		1,050		1.00	---	3.72	3.57	95.06	95.02	D.O.	D.O.	D.O.
		2,600		1.06	---	4.05	4.63	96.11	96.14	D.O.	D.O.	D.O.
			200	1.12	---	---	3.43	---	93.76	D.O.	D.O.	D.O.
			5,200	1.07	---	---	6.80	---	97.31	D.O.	D.O.	D.O.
8	upstream of riffle	503		.966	.063	2.61	2.56	95.31	95.31	93.49	81.5	3.031
		1,050		.999	---	3.48	3.31	95.82	95.81	D.O.	D.O.	D.O.
		2,600		1.01	---	4.90	5.36	96.62	96.62	D.O.	D.O.	D.O.
			200	.892	---	---	1.79	---	94.83	D.O.	D.O.	D.O.
			5,200	.990	---	---	8.46	---	97.43	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2] from the stage-discharge relationship for given discharges.

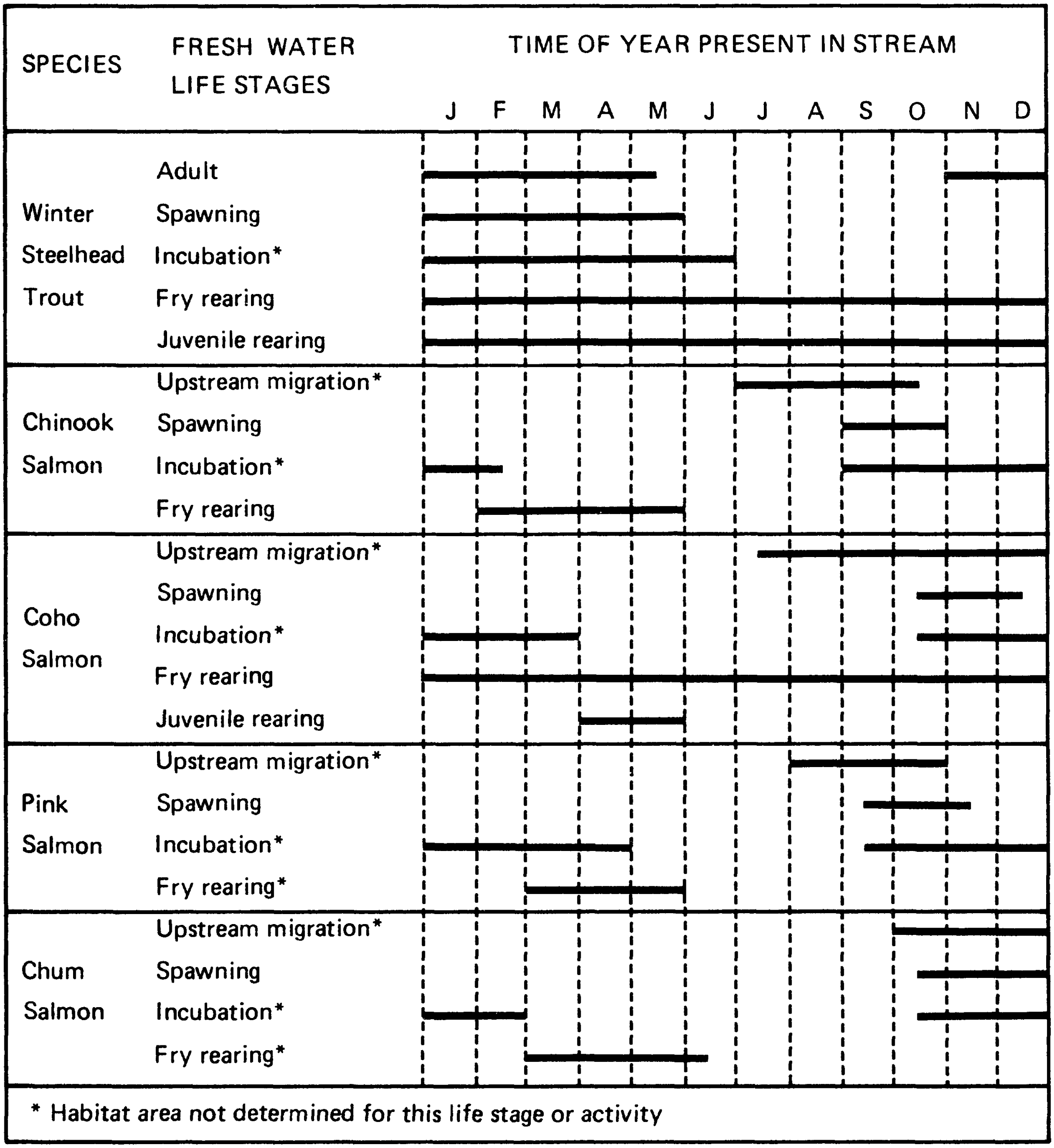


Figure 8.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 5 and site 6, North Fork Stillaguamish River near Oso and near Hazel.

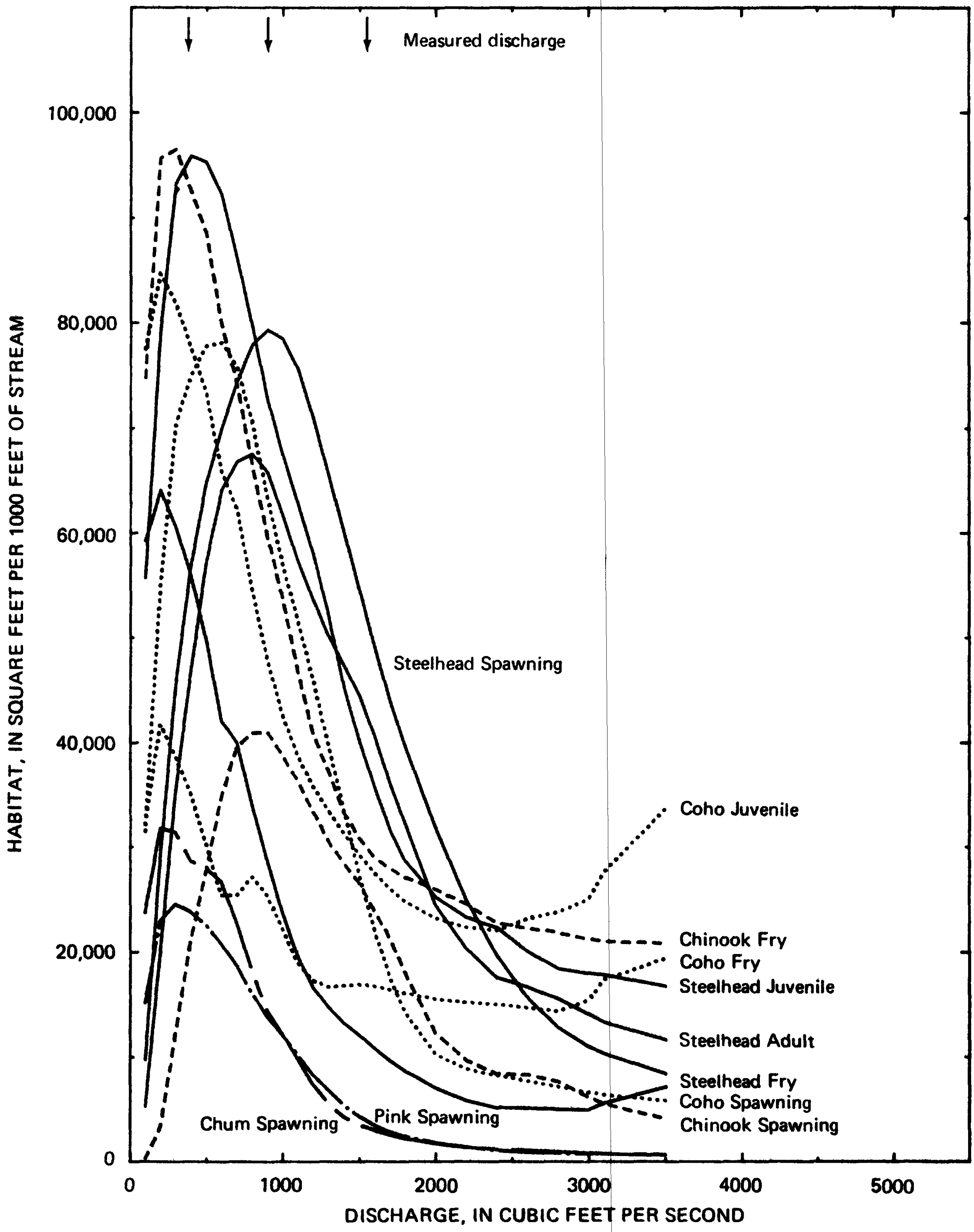


Figure 9.--Graph showing relations between stream discharge and habitat at site 5, North Fork Stillaguamish River near Oso.

Table 9.--Total surface area and habitat area according to stream discharge, fish species, and life stage for North Fork Stillaguamish River near Oso

[Calibration discharges = 382, 905, and 1,550 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 150 and 3,880 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet										
		STEELHEAD				CHINOOK		COHO			PINK	CHUM
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	SPAWNING	FRY	JUVENILE	SPAWNING	SPAWNING
100	99,210	5,230	9,710	59,250	55,700	276	74,750	31,500	32,170	77,470	15,180	23,840
200	125,300	20,100	29,240	64,080	79,380	3,340	95,770	54,930	41,760	84,760	23,020	31,860
300	138,800	35,510	45,510	60,580	93,280	12,410	96,560	70,380	38,760	81,880	24,670	31,490
400	150,300	46,810	56,930	55,920	95,950	21,250	92,680	74,940	35,150	77,690	23,910	28,720
500	155,680	57,330	64,930	49,710	95,370	27,950	88,610	77,790	30,300	73,410	22,620	28,020
600	159,870	64,150	69,970	42,070	92,210	35,040	79,830	78,090	25,450	65,930	20,860	26,760
700	165,420	66,850	74,410	40,020	88,180	39,690	74,230	75,820	25,450	62,350	18,770	22,800
800	166,750	67,610	77,900	33,960	79,640	40,980	66,570	70,650	27,240	54,560	16,100	18,320
900	167,540	65,890	79,300	28,640	72,750	41,040	59,800	63,580	25,510	47,950	13,890	14,480
1,000	168,040	81,730	78,460	23,750	87,550	38,750	53,760	57,100	22,370	42,710	12,130	12,250
1,100	168,450	57,320	75,620	19,650	62,840	36,370	46,950	51,720	19,050	38,810	10,250	9,860
1,200	168,840	53,600	70,980	16,680	58,000	33,390	40,930	48,120	17,360	35,900	8,350	7,420
1,300	169,210	50,150	65,560	14,740	52,080	30,540	37,320	39,850	16,730	33,520	6,830	5,570
1,400	169,560	47,390	60,100	13,270	45,270	28,450	33,380	33,620	16,880	31,380	5,470	4,310
1,500	169,890	44,490	54,550	12,080	40,140	26,550	30,900	27,390	16,970	29,350	4,350	3,540
1,600	170,210	40,580	49,040	10,790	35,700	23,850	29,040	22,080	16,800	27,540	3,530	3,010
1,700	170,510	36,090	44,010	9,840	31,830	21,380	28,000	17,700	16,480	28,110	2,910	2,600
1,800	170,800	32,230	39,690	8,660	28,700	18,060	27,180	14,310	18,150	24,880	2,460	2,240
2,000	171,350	24,450	31,780	6,990	25,280	12,290	26,050	10,280	15,530	23,290	1,880	1,780
2,200	171,860	20,380	25,050	5,830	23,350	9,690	24,670	8,890	15,250	22,420	1,470	1,420
2,400	173,350	17,570	19,680	5,140	22,340	8,410	22,860	8,230	15,050	22,100	1,120	1,230
2,600	174,940	16,710	15,650	5,130	20,090	8,320	22,320	7,720	14,730	23,280	979	1,130
2,800	176,620	15,560	12,810	5,010	18,450	7,640	21,950	7,160	14,390	23,920	892	996
3,000	181,000	14,070	10,960	4,980	17,990	6,110	21,290	6,630	15,470	25,130	830	880
3,100	185,410	13,290	10,300	5,590	17,850	5,520	21,090	6,400	17,440	27,740	800	815
3,500	188,530	11,630	8,410	7,120	16,790	4,110	20,910	5,850	19,450	33,700	711	631

Table 10.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 5, North Fork Stillaguamish River near Oso

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha coefficient[2]	Beta coefficient[2]
1	control	382		0.987	0.058	2.83	2.80	92.02	92.00	90.00	48.4	2.977
		905		1.01	---	3.75	3.77	92.62	92.67	D.O.	D.O.	D.O.
		1,550		1.01	---	4.44	4.49	93.24	93.20	D.O.	D.O.	D.O.
			100	.894	---	---	---	---	---	D.O.	D.O.	D.O.
			150	.924	---	---	1.94	---	91.46	D.O.	D.O.	D.O.
			3,880	.969	---	---	9.63	---	94.36	D.O.	D.O.	D.O.
2	riffle-pool transition	382		1.00	.040	2.37	2.42	92.20	92.18	90.06	41.2	2.964
		905		1.01	---	3.65	3.58	92.84	92.90	D.O.	D.O.	D.O.
		1,550		.997	---	4.85	4.84	93.50	93.46	D.O.	D.O.	D.O.
			100	.957	---	---	---	---	---	D.O.	D.O.	D.O.
			150	.971	---	---	1.77	---	91.61	D.O.	D.O.	D.O.
			3,880	.958	---	---	8.41	---	94.70	D.O.	D.O.	D.O.
3	deep run	382		1.00	.042	2.97	3.15	92.20	92.19	89.10	8.46	3.372
		905		.999	---	4.96	4.19	93.08	93.10	D.O.	D.O.	D.O.
		1,550		1.00	---	5.14	5.55	93.80	93.79	D.O.	D.O.	D.O.
			100	1.10	---	---	---	---	---	D.O.	D.O.	D.O.
			150	1.06	---	---	2.42	---	91.45	D.O.	D.O.	D.O.
			3,880	1.01	---	---	9.46	---	95.25	D.O.	D.O.	D.O.
4	run-riffle transition	382		.988	.071	4.24	3.74	93.68	93.68	90.84	13.8	3.189
		905		1.02	---	5.94	4.61	94.54	94.56	D.O.	D.O.	D.O.
		1,550		1.02	---	5.36	5.51	95.25	95.24	D.O.	D.O.	D.O.
			100	.808	---	---	---	---	---	D.O.	D.O.	D.O.
			150	.864	---	---	3.03	---	92.95	D.O.	D.O.	D.O.
			3,880	.917	---	---	10.17	---	96.71	D.O.	D.O.	D.O.
5	mid-riffle	382		.999	.141	3.79	3.11	93.72	93.70	90.20	2.90	3.898
		905		1.01	---	4.57	4.26	94.50	94.56	D.O.	D.O.	D.O.
		1,550		1.01	---	5.32	5.86	95.25	95.21	D.O.	D.O.	D.O.
			100	1.10	---	---	---	---	---	D.O.	D.O.	D.O.
			150	1.05	---	---	2.37	---	92.95	D.O.	D.O.	D.O.
			3,680	1.02	---	---	15.59	---	96.54	D.O.	D.O.	D.O.
6	control	382		.999	.042	1.92	1.96	94.76	94.76	92.28	18.0	3.359
		905		.994	---	3.13	2.99	95.50	95.49	D.O.	D.O.	D.O.
		1,550		1.01	---	3.89	4.02	96.04	96.05	D.O.	D.O.	D.O.
			100	1.17	---	---	---	---	---	D.O.	D.O.	D.O.
			150	1.08	---	---	1.38	---	94.16	D.O.	D.O.	D.O.
			3,660	1.04	---	---	6.65	---	97.23	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.

[2] from the stage-discharge relationship for given discharges.

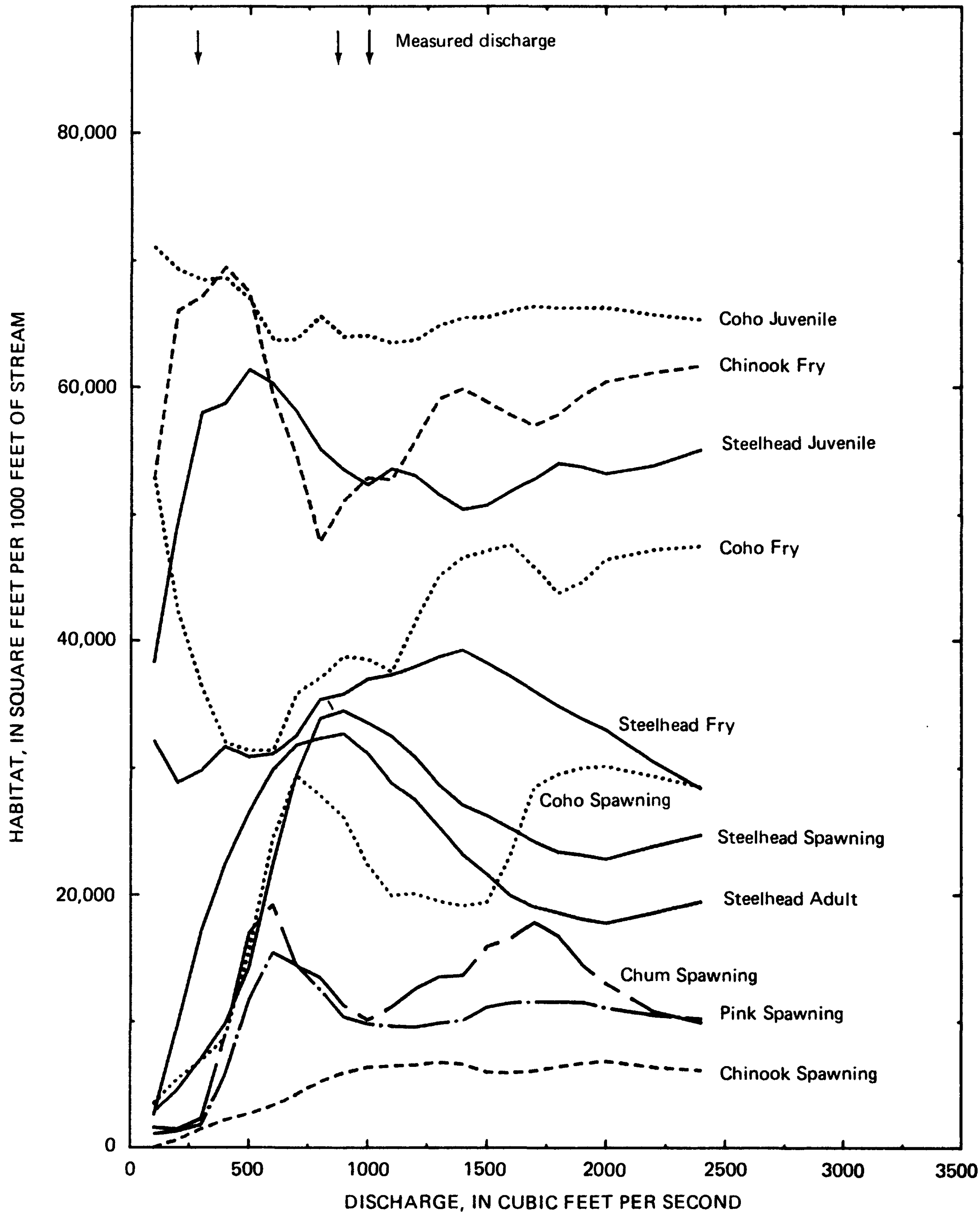


Figure 10.--Graph showing relations between stream discharge and habitat at site 6, North Fork Stillaguamish River near Hazel.

Table 11.--Total surface area and habitat area according to stream discharge, fish species, and life stage for North Fork Stillaguamish River near Hazel

[Calibration discharges = 278, 870, and 1,000 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 110 and 2,500 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet										
		STEELHEAD				CHINOOK		COHO			PINK	CHUM
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	SPAWNING	FRY	JUVENILE	SPAWNING	SPAWNING
100	82,250	2,590	2,800	32,170	38,360	5	52,830	3,490	52,900	71,050	1,080	1,590
200	98,180	9,710	4,590	28,840	49,460	614	66,030	5,430	42,300	69,310	1,300	1,460
300	111,400	17,150	7,070	29,800	57,990	1,470	67,130	6,860	36,400	68,450	1,810	2,310
400	126,140	22,350	9,810	31,730	58,740	2,180	69,470	8,640	32,020	68,650	5,740	8,830
500	133,850	26,470	14,250	30,880	61,380	2,670	67,490	15,450	31,370	66,920	11,750	17,000
600	139,690	29,660	22,330	31,110	60,270	3,290	59,230	24,330	31,400	63,690	15,450	19,180
700	149,360	31,660	29,480	32,600	58,120	4,240	54,620	29,390	35,850	63,790	14,460	14,390
800	155,290	32,360	33,940	35,430	55,180	5,230	47,810	27,620	37,060	65,610	12,460	13,490
900	159,650	32,740	34,530	35,840	53,550	5,910	51,070	26,060	38,760	63,980	10,340	11,270
1,000	162,940	31,160	33,610	37,000	52,340	6,370	52,890	22,340	36,560	64,070	9,790	10,120
1,100	166,020	26,840	32,540	37,340	53,640	6,490	52,730	19,910	37,570	63,480	9,640	11,130
1,200	170,530	27,490	30,670	37,990	53,090	6,560	55,660	20,050	41,510	63,740	9,550	12,560
1,300	173,440	25,380	28,710	36,760	51,590	6,800	59,060	19,450	45,130	64,660	9,680	13,540
1,400	176,200	23,160	27,070	39,290	50,420	6,640	59,850	19,060	46,580	65,490	10,060	13,640
1,500	178,300	21,620	26,260	36,290	50,770	6,020	58,860	19,350	47,130	65,540	11,140	15,930
1,600	180,190	19,920	25,230	37,200	51,870	5,950	57,640	23,140	47,580	66,050	11,460	16,590
1,700	181,990	19,030	24,200	36,070	52,620	6,130	57,030	26,490	45,640	66,390	11,540	17,840
1,800	183,250	16,570	23,370	34,930	54,060	6,450	57,840	29,500	43,770	66,250	11,540	16,760
1,900	184,410	16,060	23,130	33,930	53,790	6,710	59,300	30,000	44,640	66,270	11,510	14,470
2,000	185,540	17,760	22,600	33,060	53,260	6,900	60,420	30,110	46,410	66,310	11,070	12,970
2,200	187,670	16,570	23,820	30,500	53,680	6,400	61,140	29,350	47,210	65,740	10,500	10,800
2,400	189,690	19,460	24,710	26,420	55,110	6,160	61,650	26,480	47,470	65,330	10,240	9,930

Table 12.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 6, North Fork Stillaguamish River near Hazel

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha[2] coefficient	Beta[2] coefficient
1	control	278		1.00	0.099	1.72	1.74	90.02	89.99	86.80	0.384	5.670
		870		.998	---	3.88	3.39	90.60	90.71	D.O.	D.O.	D.O.
		1,000		.990	---	3.65	3.73	90.88	90.80	D.O.	D.O.	D.O.
			100	.979	---	---	.93	---	89.47	D.O.	D.O.	D.O.
			2,500	.949	---	---	7.01	---	91.50	D.O.	D.O.	D.O.
2	run; pool on right bank	278		.983	.095	2.04	2.01	90.06	90.06	87.00	4.18	3.758
		870		1.00	---	4.26	4.05	91.10	91.14	D.O.	D.O.	D.O.
		1,000		1.00	---	4.16	4.43	91.33	91.30	D.O.	D.O.	D.O.
			100	.940	---	---	1.10	---	89.33	D.O.	D.O.	D.O.
			2,500	.988	---	---	8.12	---	92.48	D.O.	D.O.	D.O.
3	riffle	278		.995	.046	3.31	2.74	90.24	90.24	88.00	34.6	2.588
		870		1.01	---	4.32	3.93	91.44	91.48	D.O.	D.O.	D.O.
		1,000		1.01	---	3.89	4.11	91.70	91.67	D.O.	D.O.	D.O.
			100	.931	---	---	1.94	---	89.51	D.O.	D.O.	D.O.
			2,500	.949	---	---	11.26	---	93.23	D.O.	D.O.	D.O.
4	upstream of riffle	278		.991	.050	1.88	1.87	90.46	90.46	88.20	31.5	2.671
		870		.997	---	3.38	3.35	91.65	91.66	D.O.	D.O.	D.O.
		1,000		1.00	---	3.76	3.87	91.86	91.85	D.O.	D.O.	D.O.
			100	1.06	---	---	1.39	---	89.74	D.O.	D.O.	D.O.
			2,500	1.07	---	---	6.79	---	93.34	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2] from the stage-discharge relationship for given discharges.

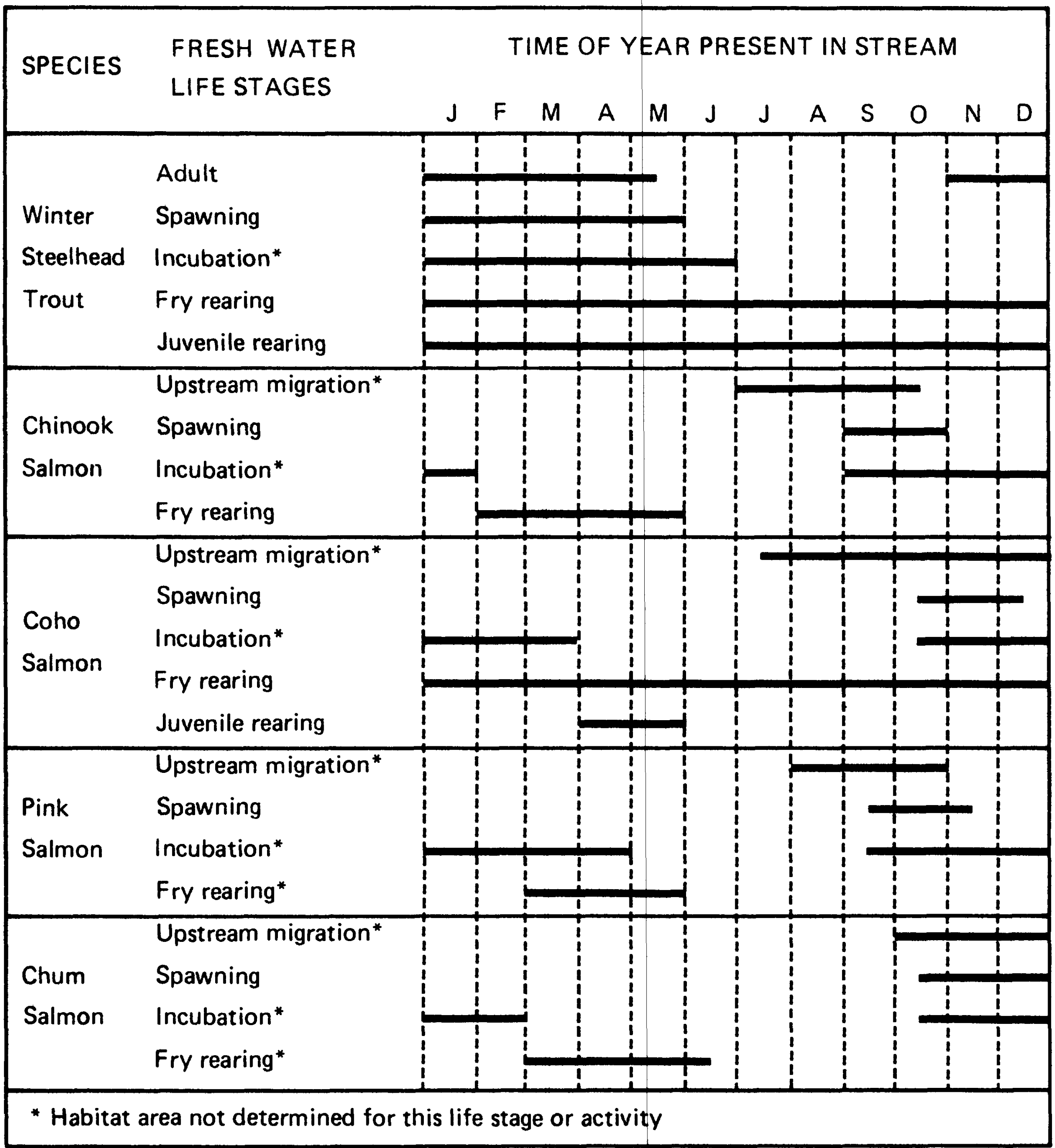


Figure 11.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 7, North Fork Stillaguamish River at Blue Slough.

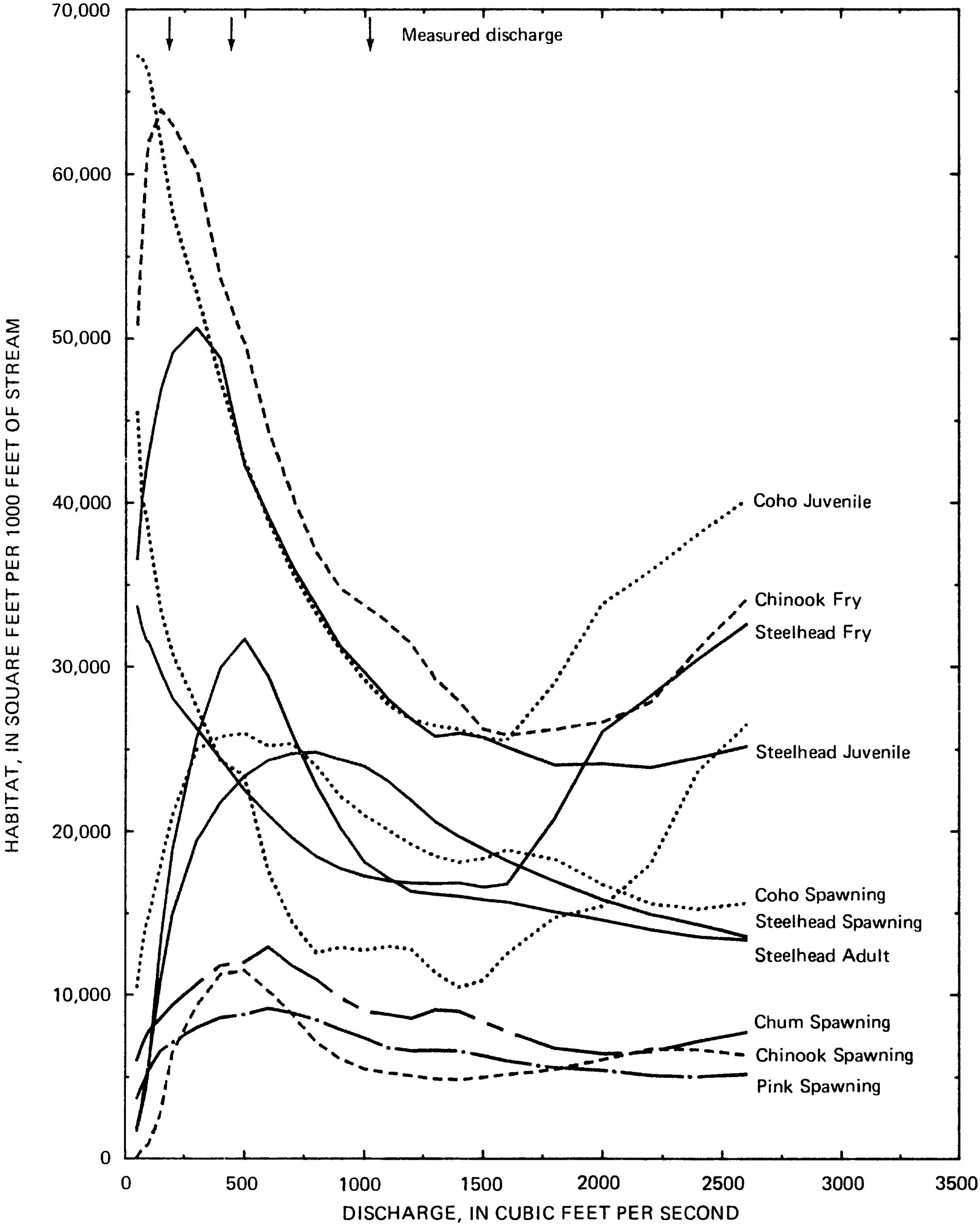


Figure 12.--Graph showing relations between stream discharge and habitat at site 7, North Fork Stillaguamish River at Blue Slough.

Table 13.--Total surface area and habitat area according to stream discharge, fish species, and life stage for North Fork Stillaguamish River at Blue Slough

[Calibration discharges = 182, 442, and 1,020 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 73 and 2,550 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet										
		STEELHEAD				CHINOOK		COHO			PINK	CHUM
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	SPAWNING	FRY	JUVENILE	SPAWNING	SPAWNING
50	71,960	1,720	1,870	33,680	36,590	71	50,860	10,500	45,510	67,160	3,710	6,030
70	76,070	2,850	3,180	32,430	39,950	487	56,210	12,710	40,310	67,100	4,410	6,860
90	79,270	4,300	4,820	31,600	42,160	782	60,920	14,350	39,140	66,380	5,030	7,520
100	80,780	5,550	5,720	31,480	43,070	910	62,050	14,850	38,020	66,000	5,390	7,810
150	86,710	13,200	10,750	29,710	46,870	2,730	63,920	17,990	33,530	61,920	6,580	8,550
200	91,200	18,820	14,920	26,100	49,160	6,450	62,950	20,980	30,760	57,550	7,100	9,350
300	97,940	25,670	19,390	26,280	50,640	9,310	60,230	24,960	27,610	52,760	8,000	10,660
400	101,290	29,930	21,730	24,440	48,810	11,280	53,550	25,780	24,310	47,380	8,620	11,820
500	104,040	31,700	23,350	22,500	42,270	11,520	49,670	25,960	23,390	42,550	8,810	12,010
600	106,290	29,410	24,320	20,980	39,150	10,270	44,370	25,220	17,580	38,920	9,200	12,970
700	108,410	25,940	24,760	19,610	36,170	8,870	40,410	25,350	14,460	35,790	8,930	11,800
800	110,310	22,800	24,840	16,490	33,720	7,130	36,950	23,980	12,600	33,250	8,500	10,970
900	112,130	20,230	24,360	17,740	31,250	6,130	34,780	22,130	12,930	31,070	7,920	9,850
1,000	113,980	18,120	23,960	17,280	29,660	5,500	33,730	20,930	12,760	29,200	7,390	9,020
1,100	115,560	17,150	23,050	16,980	28,040	5,270	32,700	20,080	13,010	27,710	6,800	8,810
1,200	117,010	16,330	21,840	16,850	26,810	5,080	31,360	19,180	12,810	26,820	6,600	8,580
1,300	118,390	16,160	20,570	16,810	25,780	4,890	29,240	18,470	11,400	26,460	6,640	9,100
1,400	119,660	16,030	19,660	16,840	25,980	4,840	27,860	18,110	10,500	26,220	6,600	9,010
1,500	120,920	15,830	18,920	16,600	25,720	5,000	26,230	18,320	10,940	25,680	6,300	8,380
1,600	122,180	15,680	18,200	16,780	25,140	5,160	25,860	18,860	12,550	25,590	5,990	7,790
1,800	131,200	15,080	16,950	20,760	24,040	5,480	26,220	18,280	14,720	29,010	5,580	6,760
2,000	134,450	14,560	15,820	26,090	24,110	6,070	26,660	16,740	15,440	33,660	5,420	6,430
2,200	139,170	13,980	14,940	28,230	23,890	6,720	27,850	15,590	18,000	35,860	5,100	6,550
2,400.	141,710	13,550	14,290	30,480	24,510	6,680	31,140	15,260	23,690	38,140	5,020	7,210
2,600.	144,250	13,360	13,580	32,610	25,190	6,360	34,110	15,610	26,500	40,190	5,160	7,750

Table 14.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 7, North Fork Stillaguamish River at Blue Slough

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha[2] coefficient	Beta[2] coefficient
1	mid-riffle	182		1.01	0.122	3.18	2.78	91.78	91.79	90.00	26.9	3.299
		442		1.01	---	3.28	3.45	92.35	92.34	D.O.	D.O.	D.O.
		1,020		1.01	---	4.85	4.89	93.00	93.01	D.O.	D.O.	D.O.
			50	1.03	---	---	---	---	---	D.O.	D.O.	D.O.
			70	1.03	---	---	2.38	---	91.34	D.O.	D.O.	D.O.
			2,550	.974	---	---	9.01	---	93.97	D.O.	D.O.	D.O.
2	upstream of riffle	182		.996	.231	2.29	2.38	92.12	92.10	90.40	27.7	3.565
		442		1.01	---	3.31	3.36	92.52	92.57	D.O.	D.O.	D.O.
		1,020		1.02	---	5.30	5.31	93.18	93.15	D.O.	D.O.	D.O.
			50	1.01	---	---	---	---	---	D.O.	D.O.	D.O.
			70	.988	---	---	1.84	---	91.70	D.O.	D.O.	D.O.
			2,550	1.00	---	---	10.03	---	93.98	D.O.	D.O.	D.O.
3	pool	182		.970	.113	1.82	1.80	92.25	92.25	86.20	.0299	8.234
		442		1.01	---	3.14	3.05	92.86	92.87	D.O.	D.O.	D.O.
		1,020		1.02	---	4.61	4.83	93.54	93.54	D.O.	D.O.	D.O.
			50	.854	---	---	---	---	---	D.O.	D.O.	D.O.
			70	.889	---	---	.99	---	91.87	D.O.	D.O.	D.O.
			2,550	.998	---	---	9.00	---	94.38	D.O.	D.O.	D.O.
4	pool-riffle transition	182		.960	.162	2.75	2.70	92.35	92.34	89.20	.719	4.832
		442		1.04	---	4.18	3.71	92.96	92.98	D.O.	D.O.	D.O.
		1,020		1.04	---	5.16	5.92	93.70	93.69	D.O.	D.O.	D.O.
			50	.766	---	---	---	---	---	D.O.	D.O.	D.O.
			70	.819	---	---	1.79	---	91.78	D.O.	D.O.	D.O.
			2,550	.963	---	---	10.29	---	94.63	D.O.	D.O.	D.O.
5	mid-riffle	182		.989	.192	2.99	2.79	92.98	92.92	90.70	5.23	4.481
		442		1.03	---	3.57	3.85	93.29	93.40	D.O.	D.O.	D.O.
		1,020		1.02	---	5.16	5.05	94.01	93.96	D.O.	D.O.	D.O.
			50	.889	---	---	---	---	---	D.O.	D.O.	D.O.
			70	.918	---	---	2.02	---	92.49	D.O.	D.O.	D.O.
			2,550	.965	---	---	9.13	---	94.71	D.O.	D.O.	D.O.
8	control	182		.991	.075	2.05	2.01	92.96	92.97	90.70	8.33	3.783
		442		1.01	---	3.46	3.20	93.80	93.57	D.O.	D.O.	D.O.
		1,020		1.00	---	5.56	5.01	94.27	94.29	D.O.	D.O.	D.O.
			50	.939	---	---	---	---	---	D.O.	D.O.	D.O.
			70	.954	---	---	1.24	---	92.46	D.O.	D.O.	D.O.
			2,550	.973	---	---	11.79	---	95.26	D.O.	D.O.	D.O.

Table 14.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 7, North Fork Stillaguamish River at Blue Slough--continued

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha coefficient[2]	Beta coefficient[2]
7	pool-run transition	182		0.993	0.101	1.84	1.87	93.02	93.00	89.60	0.555	4.732
		442		1.02	---	3.36	2.97	93.66	93.70	D.O.	D.O.	D.O.
		1,020		.998	---	4.32	4.80	94.52	94.50	D.O.	D.O.	D.O.
			50	.911	---	---	---	---	---	D.O.	D.O.	D.O.
			70	.936	---	---	1.10	---	92.38	D.O.	D.O.	D.O.
			2,550	.934	---	---	6.52	---	95.54	D.O.	D.O.	D.O.
8	pool	162		.979	.128	2.00	2.04	93.02	93.00	88.50	.0297	5.80
		442		1.02	---	3.46	3.23	93.69	93.74	D.O.	D.O.	D.O.
		1,020		1.02	---	4.75	4.91	94.56	94.55	D.O.	D.O.	D.O.
			50	.669	---	---	---	---	---	D.O.	D.O.	D.O.
			70	.900	---	---	1.21	---	92.31	D.O.	D.O.	D.O.
			2,550	.967	---	---	8.52	---	95.59	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2] from the stage-discharge relationship for given discharges.

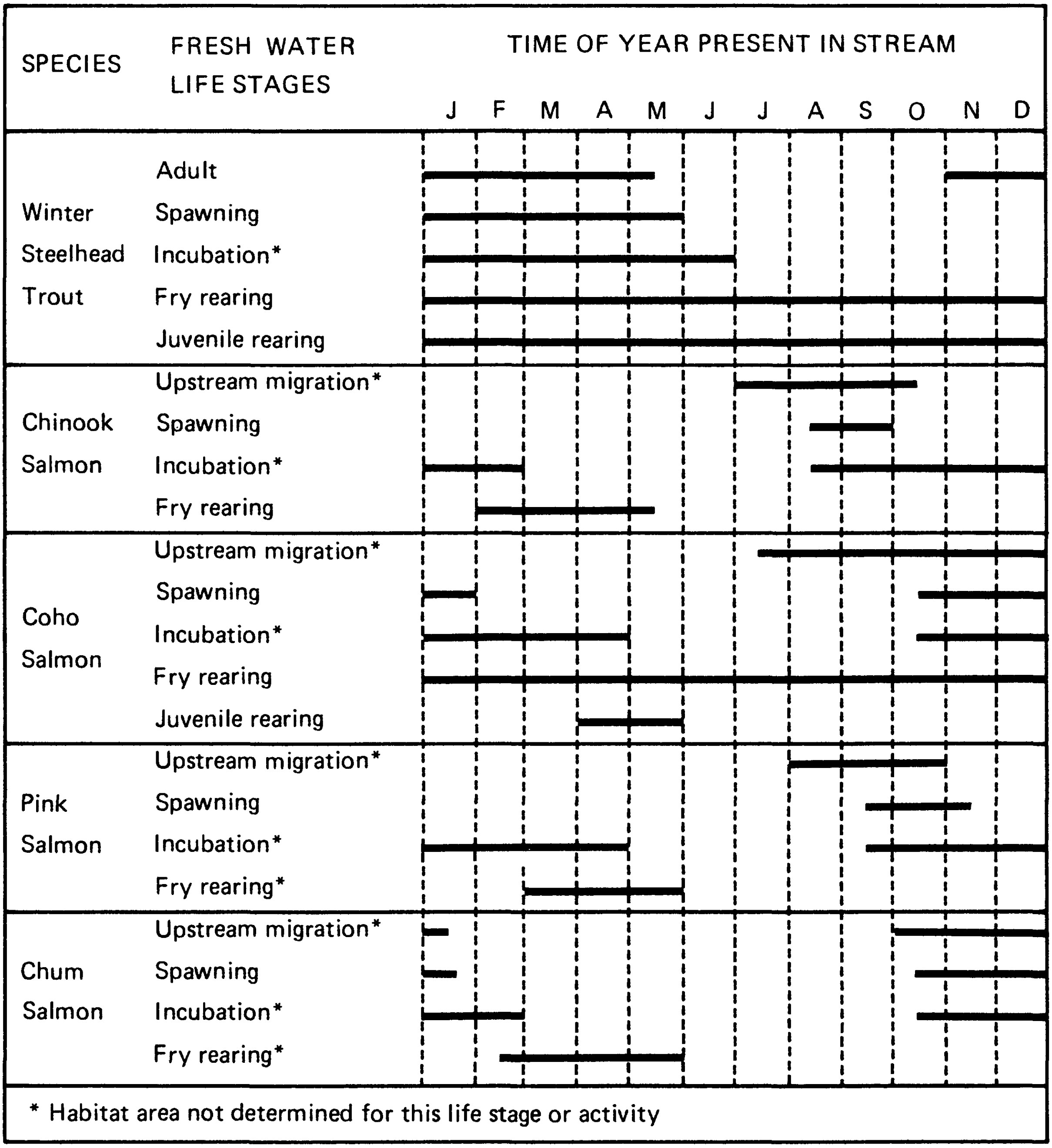


Figure 13.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 8, Squire Creek near mouth near Darrington.

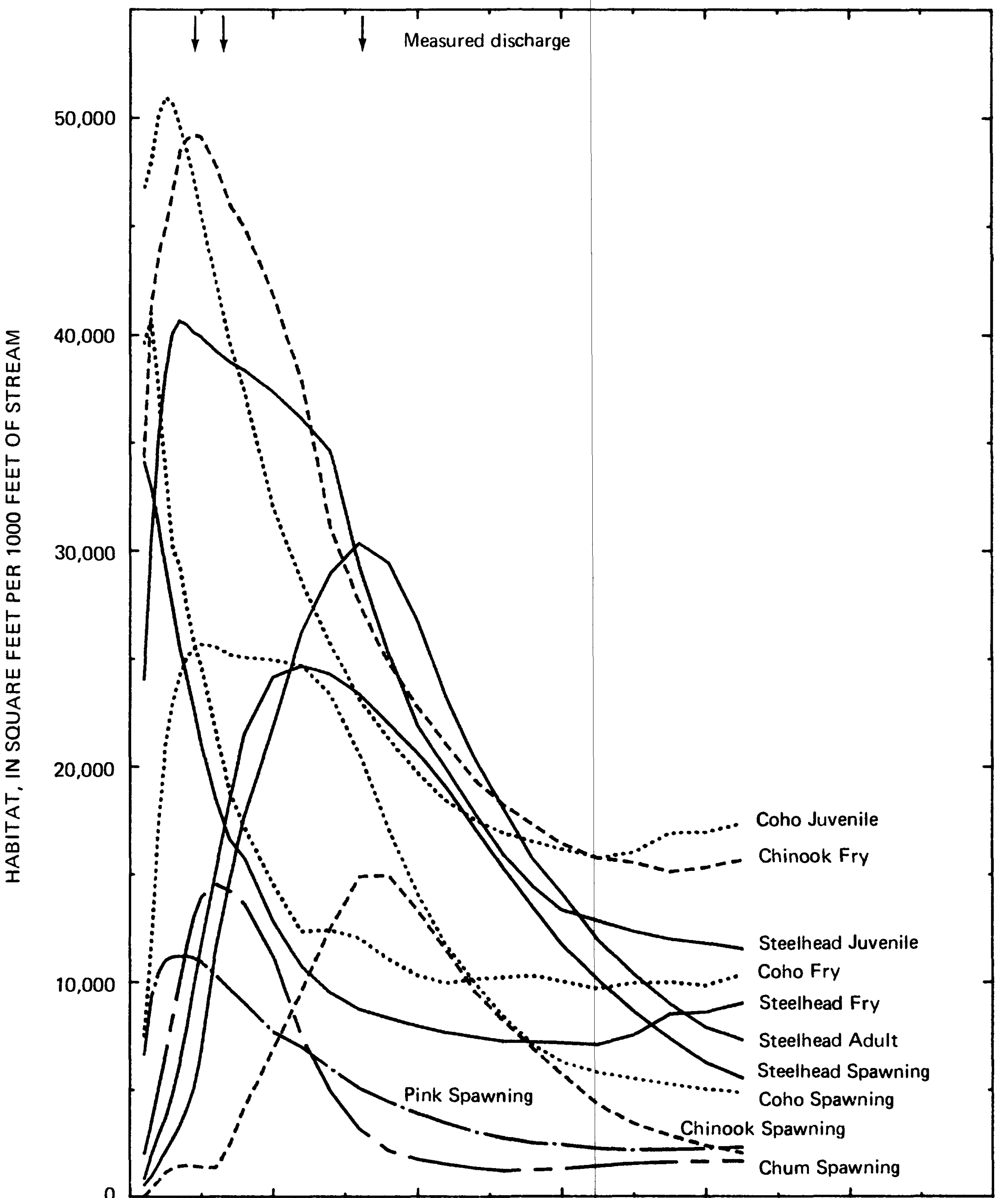


Figure 14.--Graph showing relations between stream discharge and habitat at site 8, Squire Creek near mouth near Darrington.

Table 15.--Total surface area and habitat area according to stream discharge, fish species, and life stage for Squire Creek near mouth near Darrington

[Calibration discharges = 91, 130, and 324 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 36 and 810 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet										
		STEELHEAD				CHINOOK		COHO			PINK	CHUM
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	SPAWNING	FRY	JUVENILE	SPAWNING	SPAWNING
20	49,430	549	852	34,100	24,030	19	34,350	7,460	39,580	46,760	6,640	2,030
30	52,430	948	1,920	32,900	30,380	380	41,260	11,690	40,720	48,100	9,330	3,480
40	54,580	1,540	2,850	31,300	35,010	742	43,630	17,170	37,370	50,130	10,470	5,130
50	56,250	2,130	3,670	29,270	38,220	1,140	44,940	21,030	33,550	50,950	11,010	6,700
60	56,960	2,700	4,820	27,450	40,060	1,350	46,620	22,980	30,150	50,620	11,160	8,390
70	57,550	3,320	6,240	25,570	40,660	1,450	48,450	24,290	29,250	49,550	11,190	10,110
80	58,530	4,110	7,910	24,090	40,480	1,480	49,020	25,120	27,370	48,410	11,210	11,700
90	58,980	5,070	9,610	22,740	40,130	1,450	49,210	25,450	25,800	47,110	11,110	13,050
100	59,470	6,710	11,620	21,120	39,940	1,400	49,130	25,670	24,620	45,450	10,940	13,970
120	60,410	11,450	15,090	18,530	39,280	1,370	47,810	25,540	21,700	42,450	10,310	14,560
140	62,790	14,810	18,450	16,630	38,740	2,450	45,960	25,180	18,780	39,600	9,650	14,240
160	63,500	17,690	21,500	15,790	38,370	4,200	44,940	25,060	17,210	37,340	9,020	13,630
200	64,510	21,810	24,140	12,850	37,360	6,830	41,870	24,950	14,540	32,000	7,690	11,210
240	65,350	26,240	24,680	10,730	36,130	9,600	37,910	24,690	12,350	28,580	6,980	7,470
280	66,050	28,970	24,270	9,510	34,620	12,460	31,080	23,300	12,390	25,690	5,990	4,930
320	66,520	30,360	23,360	8,730	29,240	14,920	27,560	20,570	12,030	23,090	5,070	3,190
360	66,960	29,450	22,020	8,340	25,280	14,960	24,810	17,100	11,050	21,310	4,460	2,180
400	67,360	26,770	20,640	7,950	21,900	13,320	22,750	14,070	10,300	19,690	3,910	1,750
440	67,730	23,220	19,050	7,640	19,910	11,460	21,050	11,700	9,940	18,410	3,450	1,530
480	68,100	20,340	17,130	7,420	17,830	9,530	19,350	9,910	10,130	17,530	3,040	1,350
520	68,510	18,010	15,240	7,230	15,690	8,170	18,200	8,350	10,220	16,920	2,750	1,230
560	68,890	15,720	13,450	7,200	14,430	6,900	17,300	7,070	10,280	16,530	2,520	1,260
600	69,280	14,120	11,740	7,150	13,330	5,710	16,430	6,260	10,020	16,180	2,430	1,300
650	70,100	11,960	10,110	7,070	12,830	4,320	15,760	5,780	9,680	15,780	2,260	1,450
700	71,190	10,360	8,630	7,510	12,320	3,420	15,540	5,500	9,940	16,020	2,170	1,560
750	72,210	8,980	7,370	8,500	11,970	2,860	15,120	5,230	9,980	16,910	2,210	1,620
800	73,120	7,890	6,250	8,600	11,760	2,400	15,330	5,010	9,820	16,960	2,250	1,660
850	73,980	7,290	5,540	9,000	11,520	2,040	15,660	4,830	10,330	17,360	2,320	1,670
900	74,650	6,920	5,040	9,430	11,540	1,760	16,290	4,910	11,090	17,870	2,300	1,730

Tabla 16.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 8, Squire Creek near mouth near Darrington

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha[2] coefficient	Beta[2] coefficient
1	control	91		0.997	0.036	1.54	1.46	88.85	88.87	87.02	9.51	3.666
		130		.991	---	1.88	1.77	89.10	89.06	D.O.	D.O.	D.O.
		324		.989	---	3.21	3.05	89.62	89.64	D.O.	D.O.	D.O.
			20	1.06	---	---	---	---	---	D.O.	D.O.	D.O.
			35	1.03	---	---	1.02	---	88.45	D.O.	D.O.	D.O.
			810	.995	---	---	6.97	---	90.38	D.O.	D.O.	D.O.
			900	.996	---	---	---	---	---	D.O.	D.O.	D.O.
2	pool	91		.998	.139	1.14	1.23	88.98	89.00	84.52	.00388	6.712
		130		1.00	---	1.76	1.61	89.31	89.24	D.O.	D.O.	D.O.
		324		1.01	---	2.80	3.40	89.90	89.93	D.O.	D.O.	D.O.
			20	.961	---	---	---	---	---	D.O.	D.O.	D.O.
			35	.977	---	---	.69	---	88.40	D.O.	D.O.	D.O.
			810	1.00	---	---	7.17	---	90.72	D.O.	D.O.	D.O.
			900	1.00	---	---	---	---	---	D.O.	D.O.	D.O.
3	pool-riffle transition	91		.993	.144	3.02	3.22	89.01	89.02	86.14	.800	4.473
		130		1.02	---	4.06	3.78	89.28	89.26	D.O.	D.O.	D.O.
		324		1.03	---	5.32	5.69	89.96	89.97	D.O.	D.O.	D.O.
			20	.832	---	---	---	---	---	D.O.	D.O.	D.O.
			35	.899	---	---	2.17	---	88.47	D.O.	D.O.	D.O.
			810	1.00	---	---	8.17	---	90.84	D.O.	D.O.	D.O.
			900	.995	---	---	---	---	---	D.O.	D.O.	D.O.
4	riffle	91		1.01	.092	3.43	3.37	89.44	89.49	87.90	23.9	2.885
		130		1.00	---	4.26	3.84	89.82	89.70	D.O.	D.O.	D.O.
		324		1.00	---	5.46	5.65	90.29	90.37	D.O.	D.O.	D.O.
			20	1.11	---	---	---	---	---	D.O.	D.O.	D.O.
			35	1.05	---	---	2.46	---	89.04	D.O.	D.O.	D.O.
			810	.984	---	---	9.49	---	91.29	D.O.	D.O.	D.O.
			900	.979	---	---	---	---	---	D.O.	D.O.	D.O.
5	riffle	91		.994	.215	3.74	3.38	90.90	90.94	89.28	15.3	3.519
		130		1.01	---	4.37	3.79	91.20	91.12	D.O.	D.O.	D.O.
		324		.965	---	5.74	5.15	91.61	91.66	D.O.	D.O.	D.O.
			20	.887	---	---	---	---	---	D.O.	D.O.	D.O.
			35	.921	---	---	2.41	---	90.54	D.O.	D.O.	D.O.
			810	.846	---	---	9.52	---	92.37	D.O.	D.O.	D.O.
			900	.841	---	---	---	---	---	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2] from the stage-discharge relationship for given discharges.

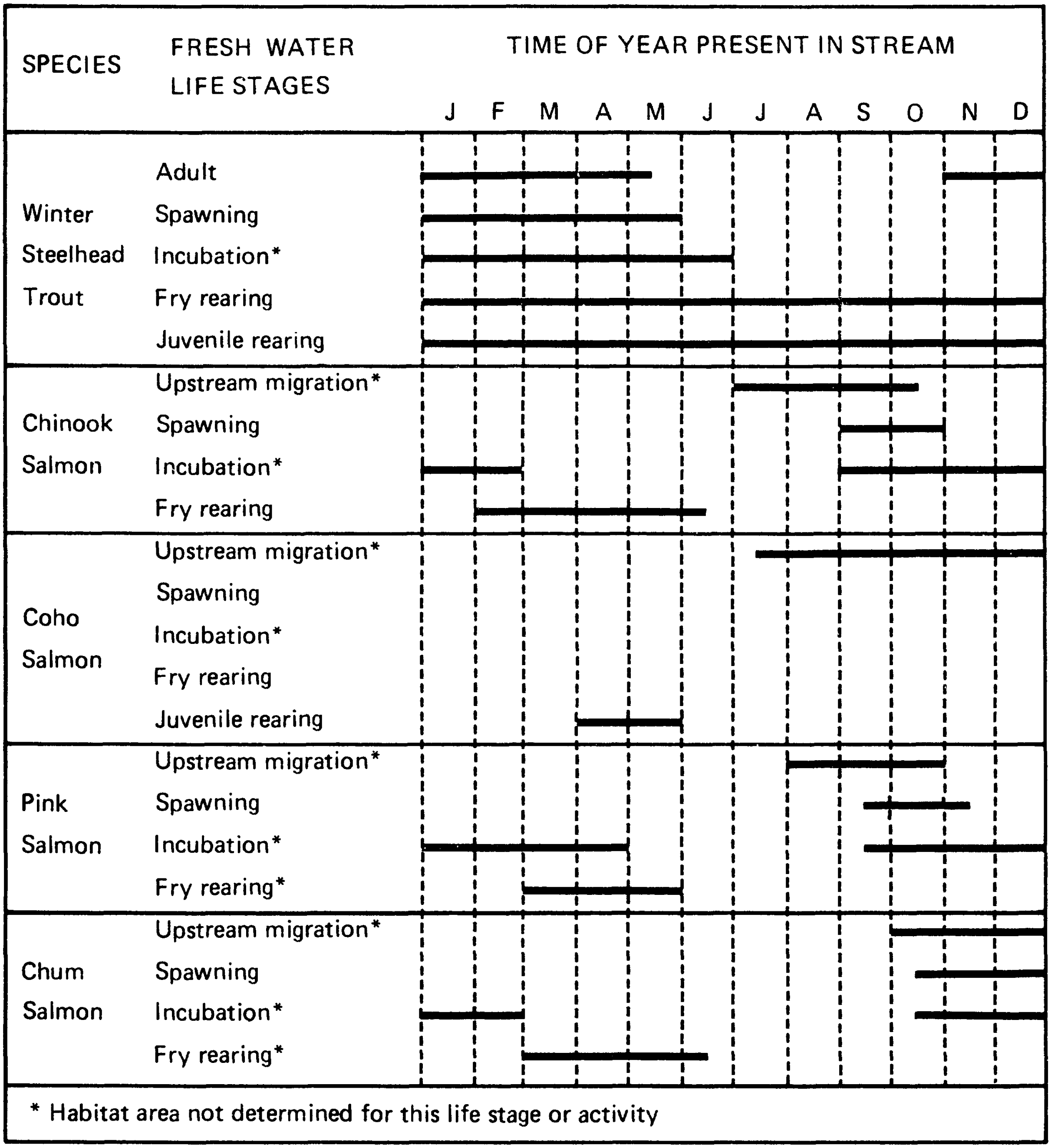


Figure 15.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 9, South Fork Stillaguamish River at Byle's Farm at Arlington.

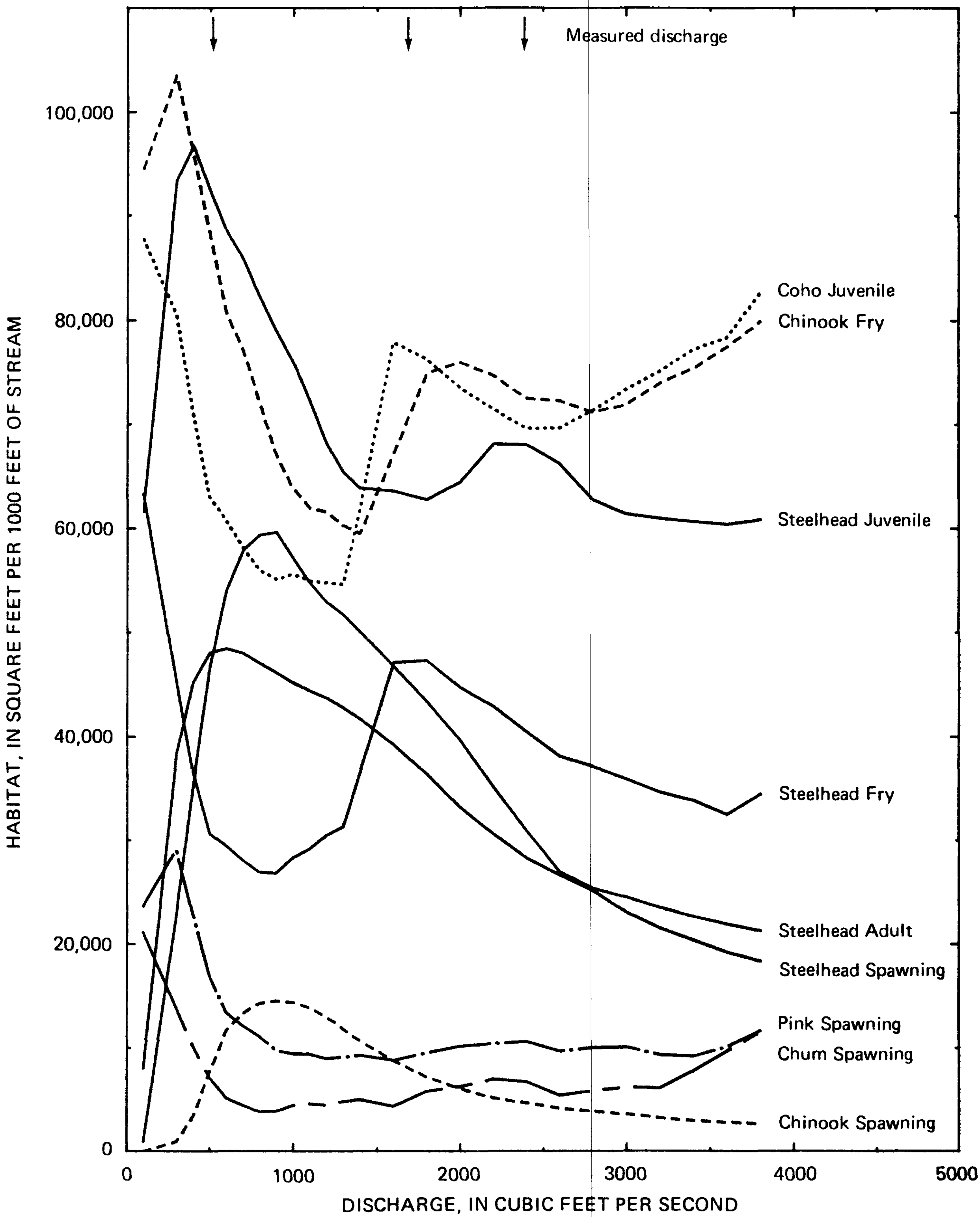


Figure 16.--Graph showing relations between stream discharge and habitat at site 9, South Fork Stillaguamish River at Byle's Farm at Arlington.

Table 17.--Total surface area and habitat area according to stream discharge, fish species, and life stage for South Fork Stillaguamish River at Byle's Farm at Arlington

[Calibration Discharges = 518, 1,690, and 2,390 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 210 and 5,980 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet								
		STEELHEAD				CHINOOK		COHO	PINK	CHUM
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	JUVENILE	SPAWNING	SPAWNING
100	111,330	902	8,050	63,290	61,560	0	94,540	87,770	23,570	21,110
300	143,140	22,850	38,280	45,170	93,400	935	103,550	80,480	29,090	13,860
400	148,240	35,250	45,180	36,530	96,760	3,370	95,840	70,890	22,860	10,140
500	152,120	46,540	48,010	30,700	92,470	7,760	88,180	63,040	16,970	7,140
600	163,140	54,040	48,420	29,490	88,500	11,700	80,590	60,730	13,380	5,150
700	167,240	57,930	47,960	28,090	85,860	13,320	77,060	58,130	12,120	4,450
800	173,140	59,380	46,990	26,930	82,160	14,280	71,890	56,020	11,080	3,810
900	177,460	59,640	46,110	26,860	78,960	14,510	67,000	55,110	9,730	3,850
1,000	185,210	57,170	45,130	28,340	75,980	14,370	63,880	55,640	9,430	4,430
1,100	189,560	54,810	44,380	29,190	72,250	13,850	61,990	54,970	9,400	4,610
1,200	194,260	52,980	43,710	30,540	68,190	13,020	61,620	54,840	8,980	4,500
1,300	200,900	51,720	42,760	31,400	65,460	11,830	60,320	54,670	9,140	4,850
1,400	212,100	50,040	41,680	36,650	63,870	10,690	59,500	61,860	9,270	5,010
1,600	233,630	46,710	39,240	47,100	63,600	8,760	67,160	77,870	8,800	4,360
1,800	237,460	43,340	36,400	47,290	62,770	7,210	74,920	76,290	9,530	5,820
2,000	239,820	39,700	33,240	44,700	64,440	6,080	76,010	73,490	10,150	6,270
2,200	242,050	35,140	30,650	42,900	68,130	5,180	74,700	71,450	10,410	6,980
2,400	244,410	30,960	28,300	40,470	68,070	4,720	72,480	69,620	10,590	6,720
2,600	247,200	27,000	26,670	38,150	66,240	4,210	72,270	69,660	9,680	5,410
2,800	253,050	25,380	25,150	37,150	62,770	3,890	71,190	71,350	10,020	5,860
3,000	255,470	24,490	23,040	35,940	61,410	3,610	71,890	73,340	10,080	6,210
3,200	260,940	23,510	21,520	34,710	61,000	3,250	73,960	75,120	9,340	6,120
3,400	263,240	22,620	20,380	33,900	60,690	2,970	75,430	77,210	9,220	7,800
3,600	267,320	21,900	19,230	32,550	60,440	2,810	77,490	78,350	10,100	9,690
3,800	275,920	21,250	18,350	34,530	60,890	2,670	79,900	82,630	11,630	11,500

Table 18.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 9, South Fork Stillaguamish River at Byle's Farm et Arlington

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha coefficient[2]	Beta coefficient[2]
1	riffle-run	518		0.998	0.033	2.86	2.85	82.35	82.34	80.03	52.8	2.723
	transition	1,690		1.00	---	4.50	4.43	83.56	83.60	D.O.	D.O.	D.O.
		2,390		1.00	---	5.57	5.41	84.12	84.09	D.O.	D.O.	D.O.
			100	1.05	---	---	---	---	---	D.O.	D.O.	D.O.
			200	1.01	---	---	2.04	---	81.66	D.O.	D.O.	D.O.
			4,000	.993	---	---	---	---	---	D.O.	D.O.	D.O.
			5,980	.979	---	---	10.04	---	85.71	D.O.	D.O.	D.O.
2	mid-	518		.995	.074	3.65	3.44	82.44	82.43	79.62	22.7	3.029
	riffle	1,690		1.01	---	5.58	4.92	83.72	83.77	D.O.	D.O.	D.O.
		2,390		1.01	---	5.78	5.59	84.32	84.28	D.O.	D.O.	D.O.
			100	1.00	---	---	---	---	---	D.O.	D.O.	D.O.
			200	.983	---	---	2.58	---	81.67	D.O.	D.O.	D.O.
			4,000	.989	---	---	---	---	---	D.O.	D.O.	D.O.
			5,980	.966	---	---	10.80	---	85.92	D.O.	D.O.	D.O.
3	control	518		1.00	.073	3.21	3.26	83.34	83.34	81.51	111.0	2.553
		1,690		1.00	---	5.94	5.08	84.42	84.42	D.O.	D.O.	D.O.
		2,390		.999	---	5.64	5.78	84.84	84.84	D.O.	D.O.	D.O.
			100	1.04	---	---	---	---	---	D.O.	D.O.	D.O.
			200	1.01	---	---	2.31	---	82.77	D.O.	D.O.	D.O.
			4,000	.971	---	---	---	---	---	D.O.	D.O.	D.O.
			5,980	.927	---	---	8.49	---	86.28	D.O.	D.O.	D.O.
4	run-pool	518		.991	.089	2.42	2.36	83.63	83.62	78.49	.344	4.475
	transition;	1,690		1.00	---	3.61	3.74	85.12	85.17	D.O.	D.O.	D.O.
	log pile	2,390		1.00	---	4.38	4.45	85.75	85.71	D.O.	D.O.	D.O.
			100	.908	---	---	---	---	---	D.O.	D.O.	D.O.
			200	.977	---	---	1.67	---	82.64	D.O.	D.O.	D.O.
			4,000	1.02	---	---	---	---	---	D.O.	D.O.	D.O.
			5,980	1.03	---	---	10.31	---	87.35	D.O.	D.O.	D.O.
5	pool	518		.992	.055	2.52	2.46	83.66	83.67	80.95	40.1	2.560
		1,690		1.01	---	3.24	3.59	85.34	85.26	D.O.	D.O.	D.O.
		2,390		.996	---	4.32	4.00	85.82	85.89	D.O.	D.O.	D.O.
			100	1.02	---	---	---	---	---	D.O.	D.O.	D.O.
			200	.969	---	---	1.82	---	82.82	D.O.	D.O.	D.O.
			4,000	.978	---	---	---	---	---	D.O.	D.O.	D.O.
			5,980	.958	---	---	9.68	---	88.02	D.O.	D.O.	D.O.
6	pool-	518		.991	.078	2.94	2.37	83.73	83.73	77.59	.150	4.490
	riffle	1,690		1.01	---	4.62	3.51	85.56	85.58	D.O.	D.O.	D.O.
	transition	2,390		1.00	---	3.56	4.46	88.23	86.22	D.O.	D.O.	D.O.
			100	.779	---	---	---	---	---	D.O.	D.O.	D.O.
			200	.905	---	---	1.73	---	82.56	D.O.	D.O.	D.O.
			4,000	.963	---	---	---	---	---	D.O.	D.O.	D.O.
			5,980	.891	---	---	7.70	---	88.17	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2] from the stage-discharge relationship for given discharges.

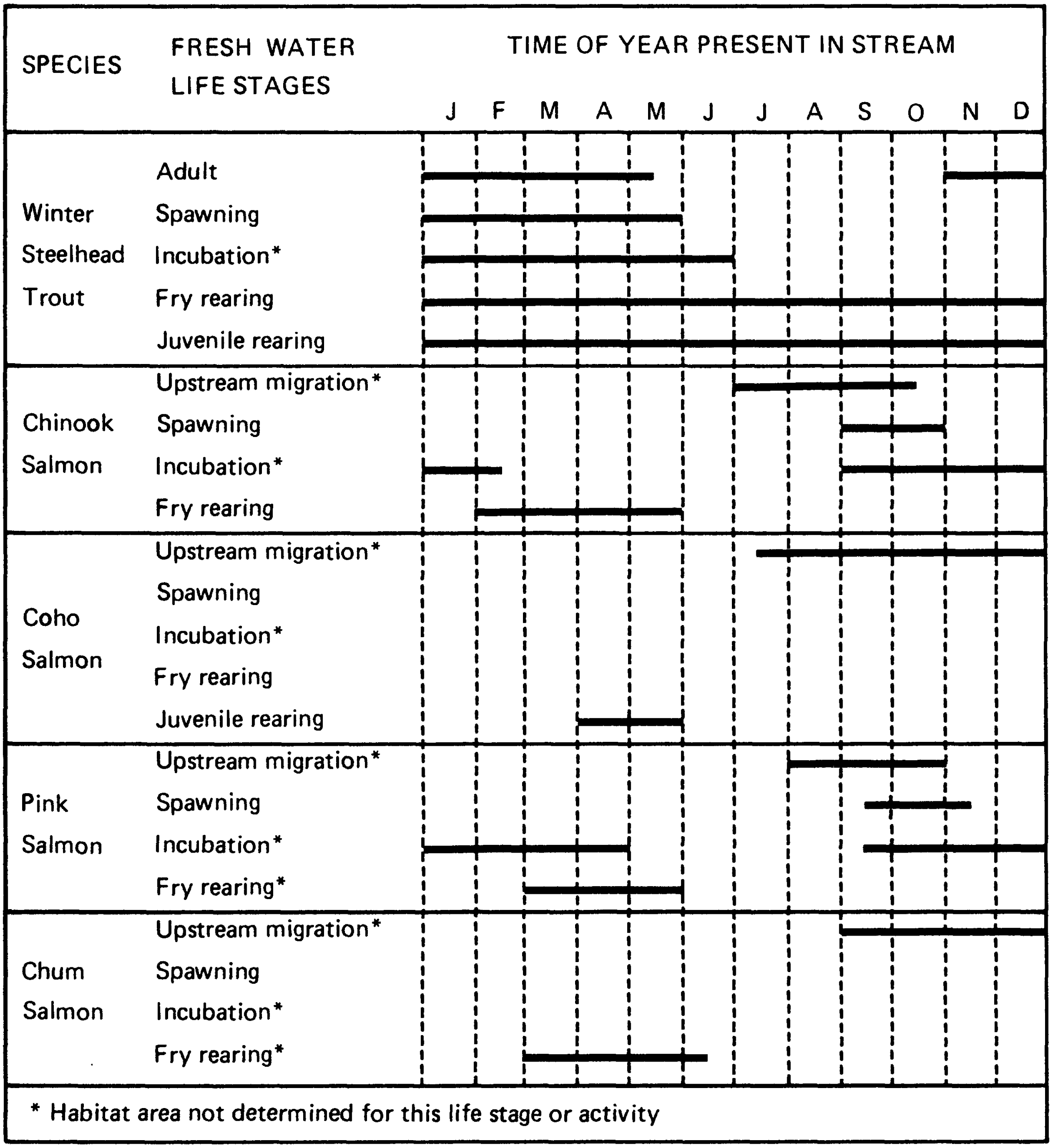


Figure 17.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 10, South Fork Stillaguamish River at Chappel Road near Granite Falls.

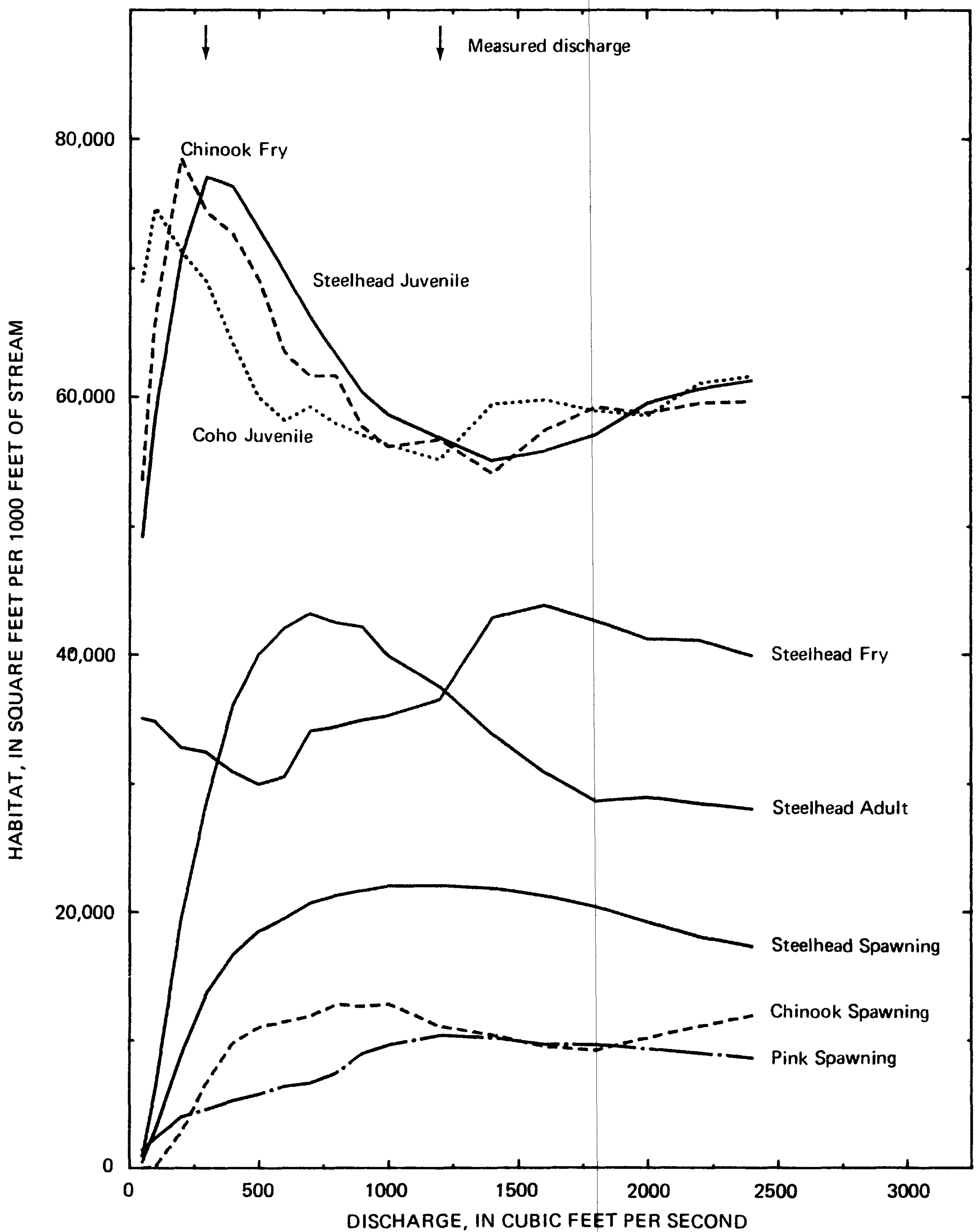


Figure 18.--Graph showing relations between stream discharge and habitat at site 10, South Fork Stillaguamish River at Chappel Road near Granite Falls.

Table 19.--Total surface area and habitat area according to stream discharge, fish species, and life stage for South Fork Stillaguamish River at Chappel Road near Granite Falls

[Calibration discharges = 292 and 1,200 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 220 and 2,120 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet							
		STEELHEAD				CHINOOK		COHO	PINK
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	JUVENILE	SPAWNING
50	70,680	967	465	35,050	49,140	0	53,590	68,960	1,400
100	85,260	6,210	3,000	34,840	58,560	110	66,340	74,640	2,280
200	101,060	19,430	8,850	32,830	70,860	2,810	78,480	71,270	4,000
300	112,280	28,750	13,710	32,460	77,080	6,780	74,280	68,940	4,590
400	119,220	36,100	16,660	30,940	76,300	9,790	72,640	64,200	5,260
500	125,290	40,070	18,470	29,960	73,060	11,000	69,220	59,950	5,750
600	132,610	42,130	19,490	30,540	69,740	11,440	63,520	58,150	6,390
700	140,620	43,250	20,690	34,100	66,320	11,880	61,660	59,240	6,650
800	145,300	42,510	21,280	34,410	63,310	12,810	61,660	57,930	7,420
900	149,650	42,200	21,670	34,940	60,390	12,650	57,710	57,070	8,950
1,000	155,090	39,910	22,040	35,260	58,620	12,830	56,150	56,280	9,590
1,200	161,300	37,500	22,060	36,510	56,850	11,060	56,690	55,100	10,350
1,400	172,760	33,850	21,860	42,900	55,040	10,410	54,050	59,410	10,160
1,600	176,110	30,890	21,230	43,880	55,800	9,500	57,380	59,740	9,650
1,800	178,700	28,640	20,380	42,640	57,090	9,200	59,190	58,880	9,620
2,000	181,600	28,930	19,180	41,230	59,510	10,190	58,740	58,520	9,280
2,200	185,460	28,460	18,010	41,140	60,600	11,050	59,480	61,020	8,940
2,400	187,650	28,040	17,270	39,920	61,280	11,910	59,640	61,600	8,570

Table 20.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 10, South Fork Stillaguamish River at Chappel Road near Granite Falls

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha coefficient[2]	Beta coefficient[2]
1	control	292		0.966	---	2.75	2.66	80.33	80.33	74.80	0.0116	5.924
		1,200		1.06	---	4.24	4.70	81.82	81.82	D.O.	D.O.	D.O.
			50	.634	---	---	---	---	---	D.O.	D.O.	D.O.
			150	.847	---	---	1.86	---	79.74	D.O.	D.O.	D.O.
			2,400	1.07	---	---	7.67	---	82.69	D.O.	D.O.	D.O.
2	run-riffle	292		.941	---	3.40	3.01	80.44	80.44	77.20	4.85	3.486
	transition	1,200		1.01	---	4.68	5.00	82.06	62.06	D.O.	D.O.	D.O.
			50	.800	---	---	---	---	---	D.O.	D.O.	D.O.
			150	.904	---	---	2.35	---	79.88	D.O.	D.O.	D.O.
			2,400	1.06	---	---	6.60	---	63.13	D.O.	D.O.	D.O.
3	downstream	292		1.00	---	2.48	2.42	80.69	80.89	77.00	.297	5.072
	of riffle	1,200		1.00	---	4.91	4.93	82.14	82.14	D.O.	D.O.	D.O.
			50	1.13	---	---	---	---	---	D.O.	D.O.	D.O.
			150	1.03	---	---	1.98	---	60.41	D.O.	D.O.	D.O.
			2,400	.992	---	---	8.37	---	62.89	D.O.	D.O.	D.O.
4	mid-	292		.979	---	3.06	2.99	82.64	62.64	80.40	4.19	5.263
	riffle	1,200		1.03	---	5.94	6.12	83.33	83.33	D.O	D.O.	D.O.
			50	.858	---	---	---	---	---	D.O	D.O	D.O.
			150	.937	---	---	2.31	---	82.37	D.O.	D.O.	D.O.
			2,400	1.04	---	---	8.88	---	83.74	D.O.	D.O.	D.O.
5	upstream	292		.996	---	3.10	3.09	82.98	82.98	80.80	30.9	2.882
	of riffle	1,200		1.02	---	5.40	5.48	84.36	84.36	D.O.	D.O.	D.O.
			50	.683	---	---	---	---	---	D.O.	D.O.	D.O.
			150	.959	---	---	2.29	---	82.53	D.O.	D.O	D.O.
			2,400	.993	---	---	7.04	---	85.33	D.O.	D.O.	D.O.
6	run	292		.997	---	2.47	2.46	83.28	83.28	80.10	5.29	3.468
		1,200		1.01	---	4.73	4.79	84.88	84.88	D.O.	D.O.	D.O.
			50	.832	---	---	---	---	---	D.O.	D.O.	D.O.
			150	.941	---	---	1.75	---	82.72	D.O.	D.O.	D.O.
			2,400	.970	---	---	6.58	---	85.94	D.O.	D.O.	D.O.
7	downstream	292		.984	---	2.12	2.12	83.87	83.87	81.20	14.1	3.087
	of riffle	1,200		1.03	---	4.21	4.35	85.42	85.42	E.O.	D.O.	D.O.
			50	.762	---	---	---	---	---	D.O.	D.O.	D.O.
			150	.912	---	---	1.54	---	83.35	D.O.	D.O.	D.O.
			2,400	1.00	---	---	7.76	---	86.48	D.O.	D.O.	D.O.

[1] from the stage-discharge relationship for given discharges.
[2] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.

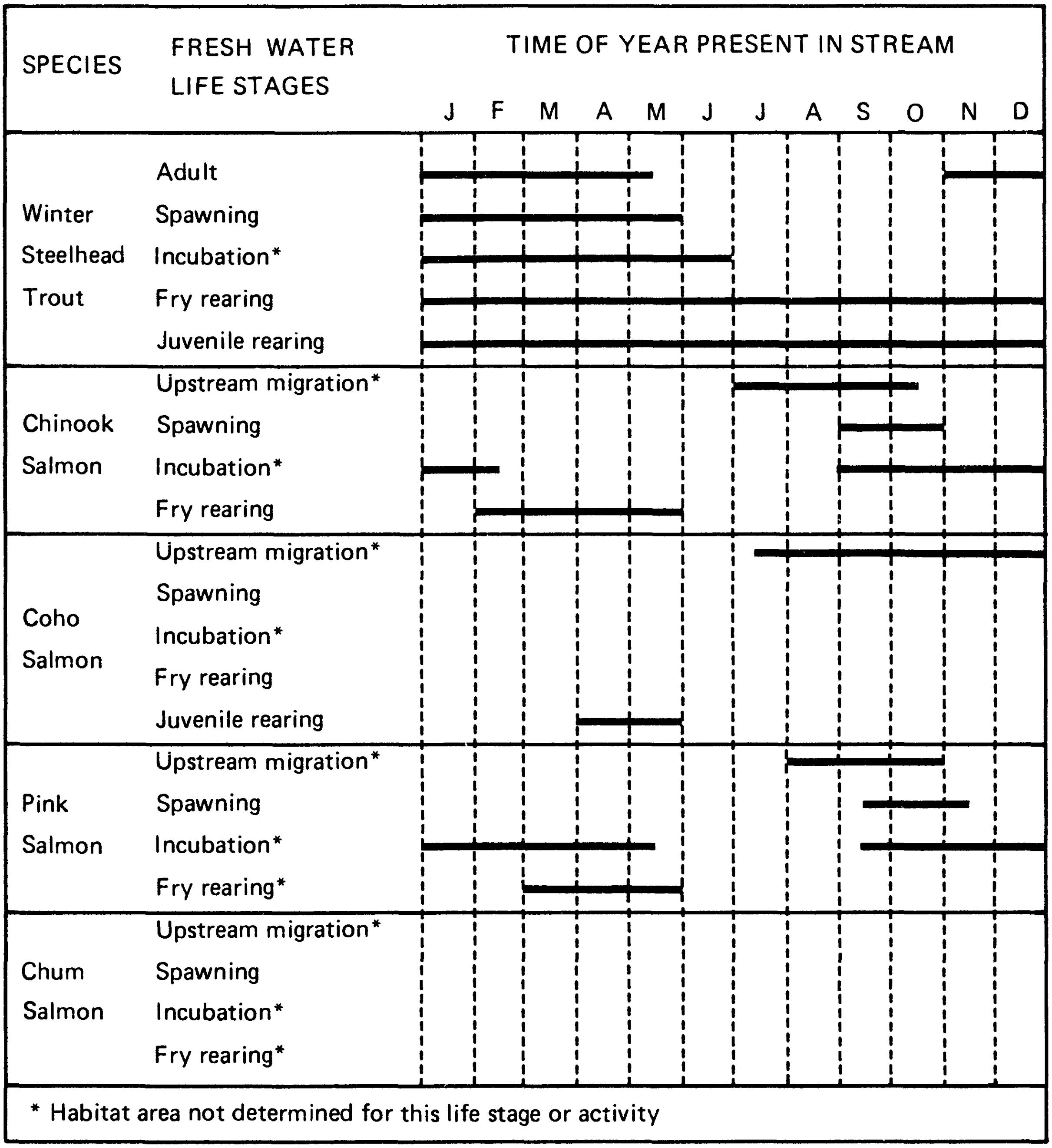


Figure 19.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 12, South Fork Stillaguamish River at Moore's Farm near Verlot.

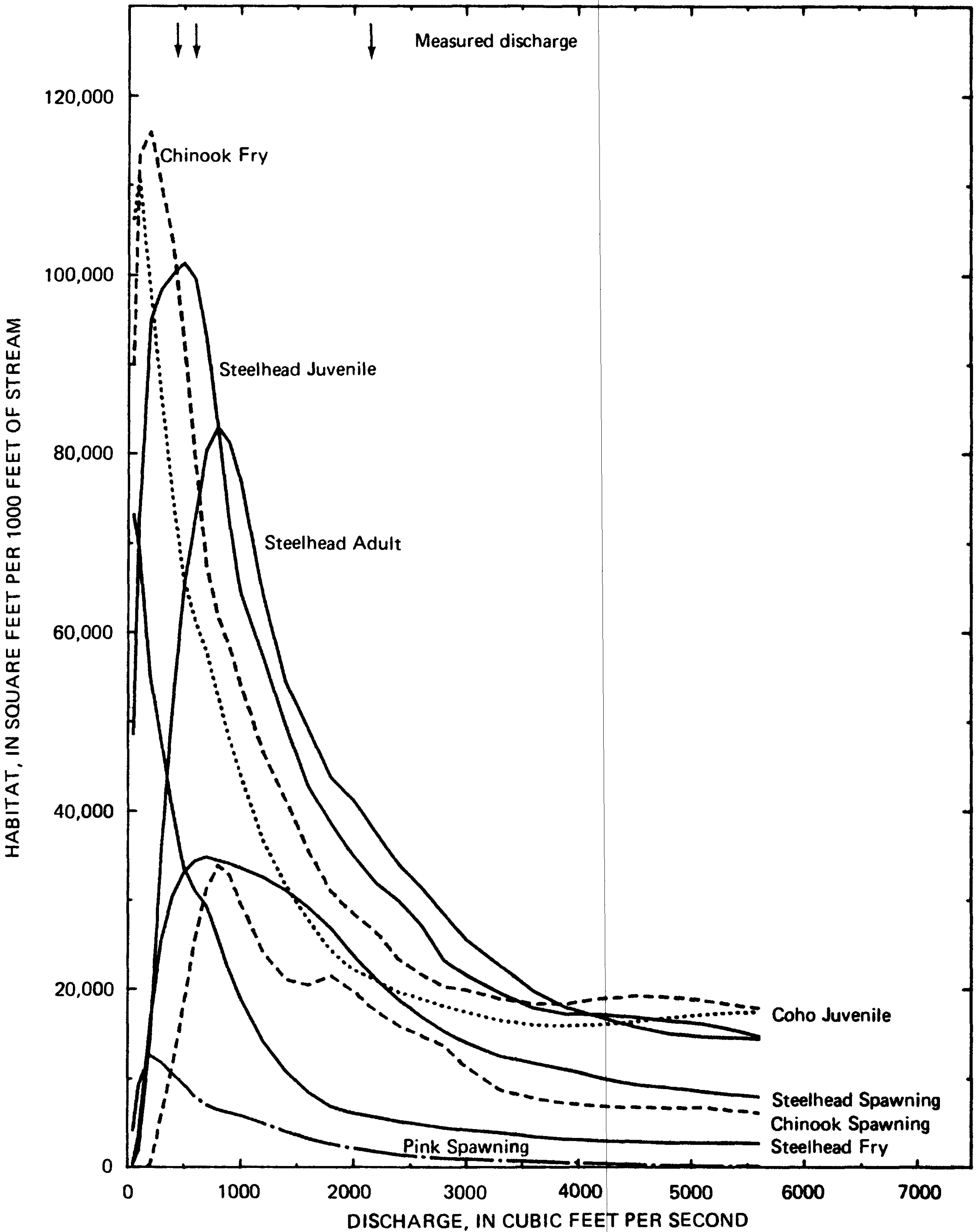


Figure 20.--Graph showing relations between stream discharge and habitat at site 12, South Fork Stillaguamish River at Moore's Farm near Verlot.

Table 21.--Total surface area and habitat area according to stream discharge, fish species, and life stage for South Fork Stillaguamish River at Moore's Farm near Verlot

[Calibration discharges = 434, 592, and 2,140 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 170 and 5,350 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet							
		STEELHEAD				CHINOOK		COHO	PINK
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	JUVENILE	SPAWNING
50	114,710	350	507	73,170	48,560	0	89,970	106,190	4,120
100	126,340	1,910	3,610	69,460	72,600	0	113,540	110,940	9,360
200	135,570	14,400	16,060	55,050	95,100	196	116,010	98,090	12,600
300	147,880	35,690	25,550	47,850	98,490	5,730	109,720	86,130	11,840
400	150,230	51,720	30,450	40,110	100,110	11,440	103,580	74,950	10,610
500	152,830	65,180	33,150	33,650	101,300	18,220	92,290	65,990	9,390
600	156,350	72,960	34,420	30,990	99,580	25,760	78,930	61,300	7,930
700	158,760	80,490	34,880	29,340	92,860	31,290	67,520	57,840	7,060
800	159,600	83,020	34,480	25,780	82,920	33,940	61,930	52,980	6,510
900	160,380	81,270	34,150	22,080	72,310	32,920	58,490	48,220	6,180
1,000	161,110	76,910	33,650	18,940	64,450	29,590	54,210	44,080	5,860
1,200	162,420	64,160	32,580	14,160	57,220	24,160	46,660	36,760	4,990
1,400	163,600	54,500	31,140	10,920	49,630	21,100	41,470	31,770	4,070
1,600	164,580	49,210	29,240	8,460	42,830	20,460	35,700	27,790	3,240
1,800	165,420	43,840	26,860	6,880	38,750	21,490	31,090	24,420	2,620
2,000	166,330	41,270	23,830	6,090	35,000	19,790	28,500	22,150	2,160
2,200	167,110	37,570	21,090	5,670	31,910	17,500	26,490	20,970	1,790
2,400	167,830	34,010	18,840	5,190	29,920	15,930	23,410	19,690	1,450
2,600	168,560	31,420	16,890	4,820	27,140	14,780	21,650	18,900	1,200
2,800	169,250	28,440	15,300	4,440	23,270	13,690	20,360	18,150	1,050
3,000	166,910	25,560	13,990	4,200	21,550	11,330	19,920	17,420	955
3,300	170,850	22,660	12,520	3,900	19,580	8,730	18,990	16,530	827
3,600	171,930	19,760	11,720	3,440	17,850	7,770	18,410	16,000	712
3,900	172,980	17,900	10,970	3,160	17,160	7,180	18,400	15,930	576
4,200	173,990	16,820	10,040	2,990	17,150	6,910	18,970	16,030	481
4,500	174,960	15,770	9,310	2,890	16,850	6,750	19,280	16,340	394
4,800	175,890	15,040	8,950	2,760	16,450	6,710	19,160	16,810	280
5,100	176,770	14,690	8,520	2,750	16,120	6,730	18,810	17,130	200
5,300	177,330	14,620	8,260	2,760	15,650	6,510	18,440	17,320	165
5,600	178,140	14,440	7,950	2,700	14,740	6,140	17,870	17,440	128

Table 22.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 12, South Fork Stillaguamish River at Moore's Farm near Verlot

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha[2] coefficient	Beta[2] coefficient
1	control	434		0.995	0.089	2.20	2.21	92.48	92.52	90.20	32.7	3.076
		592		1.00	---	2.55	2.61	92.82	82.78	D.O.	D.O.	D.O.
		2,140		1.02	---	5.30	5.27	94.07	94.09	D.O.	D.O.	D.O.
			50	.962	---	---	---	---	---	D.O.	D.O.	D.O.
			170	.973	---	---	1.36	---	91.91	D.O.	D.O.	D.O.
			5,350	1.01	---	---	10.45	---	95.44	D.O.	D.O.	D.O.
			5,600	1.01	---	---	---	---	---	D.O.	D.O.	D.O.
2	run-riffle transition	434		1.01	.051	2.50	2.38	92.60	92.60	89.70	11.7	3.397
		592		.998	---	2.58	2.67	92.88	92.88	D.O.	D.O.	D.O.
		2,140		.999	---	4.92	4.83	94.34	94.34	D.O.	D.O.	D.O.
			50	1.57	---	---	---	---	---	D.O.	D.O.	D.O.
			170	1.09	---	---	1.78	---	91.90	D.O.	D.O.	D.O.
			5,350	1.03	---	---	8.23	---	95.78	D.O.	D.O.	D.O.
			5,800	1.03	---	---	---	---	---	D.O.	D.O.	D.O.
3	mid-riffle	434		1.00	.048	2.81	2.79	93.00	93.00	90.90	88.9	2.518
		592		.998	---	3.06	3.10	93.28	93.28	D.O.	D.O.	D.O.
		2,140		1.00	---	5.70	5.54	94.86	94.88	D.O.	D.O.	D.O.
			50	1.42	---	---	---	---	---	D.O.	D.O.	D.O.
			170	1.07	---	---	2.13	---	92.35	D.O.	D.O.	D.O.
			5,350	1.03	---	---	9.75	---	98.60	D.O.	D.O.	D.O.
			5,600	1.03	---	---	---	---	---	D.O.	D.O.	D.O.
4	riffle-run transition	434		.995	.147	2.62	2.57	93.55	93.52	90.50	11.8	3.260
		592		1.01	---	3.10	2.99	93.79	93.82	D.O.	D.O.	D.O.
		2,140		1.02	---	5.56	5.89	95.44	95.43	D.O.	D.O.	D.O.
			50	.888	---	---	---	---	---	D.O.	D.O.	D.O.
			170	.949	---	---	1.70	---	92.77	D.O.	D.O.	D.O.
			5,350	.998	---	---	10.37	---	97.03	D.O.	D.O.	D.O.
			5,600	.996	---	---	---	---	---	D.O.	D.O.	D.O.
5	run	434		.998	.089	3.37	3.14	93.78	93.74	90.90	17.5	3.073
		592		1.00	---	3.60	3.41	94.00	94.05	D.O.	D.O.	D.O.
		2,140		1.01	---	5.63	5.54	95.69	95.88	D.O.	D.O.	D.O.
			50	.880	---	---	---	---	---	D.O.	D.O.	D.O.
			170	.972	---	---	2.41	---	93.00	D.O.	D.O.	D.O.
			5,350	.998	---	---	8.83	---	97.34	D.O.	D.O.	D.O.
			5,600	.998	---	---	---	---	---	D.O.	D.O.	D.O.

[1]Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2]from the stage-discharge relationship for given discharges.

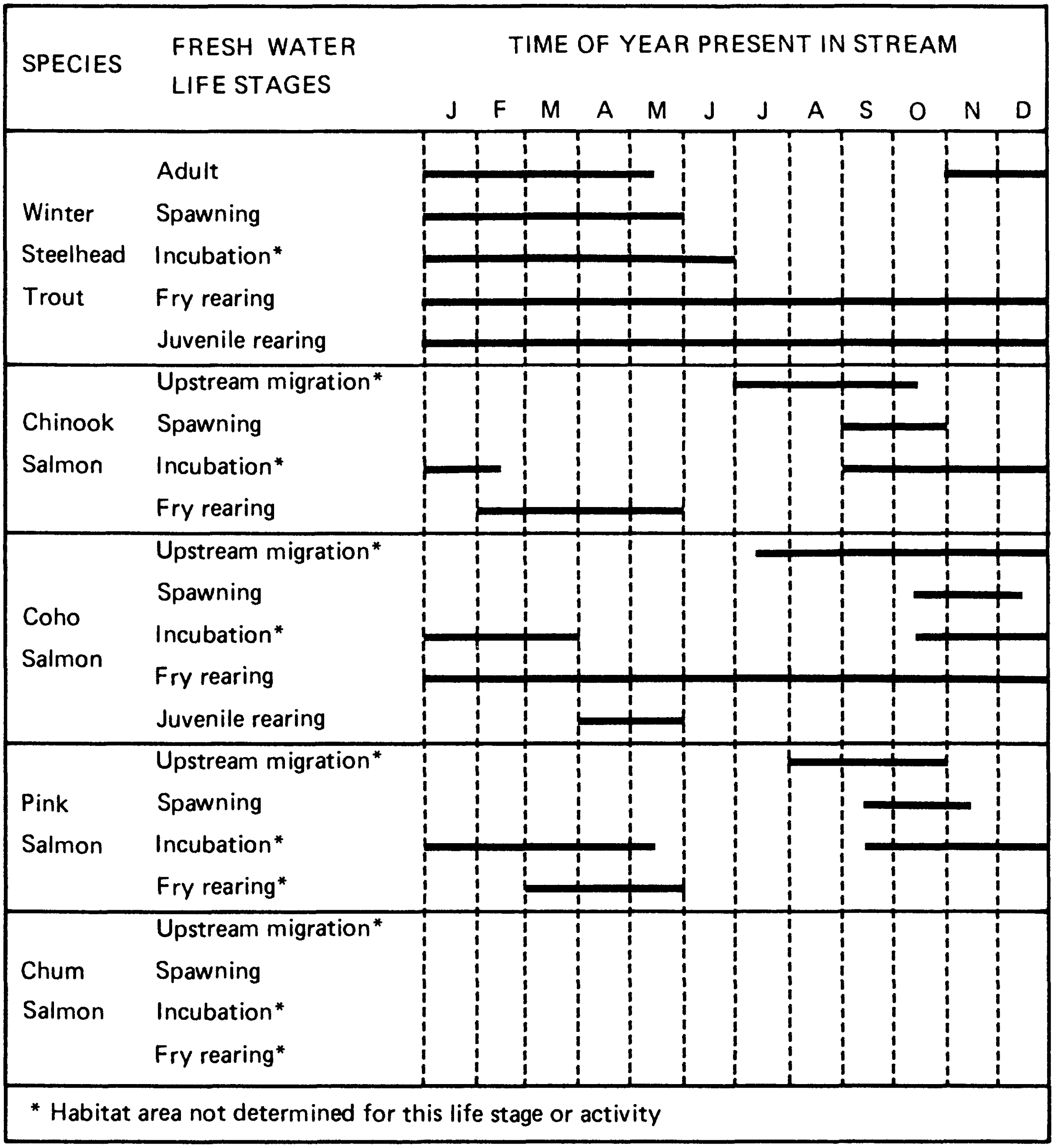


Figure 21.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 14, South Fork Stillaguamish River at Marten Creek near Silverton.

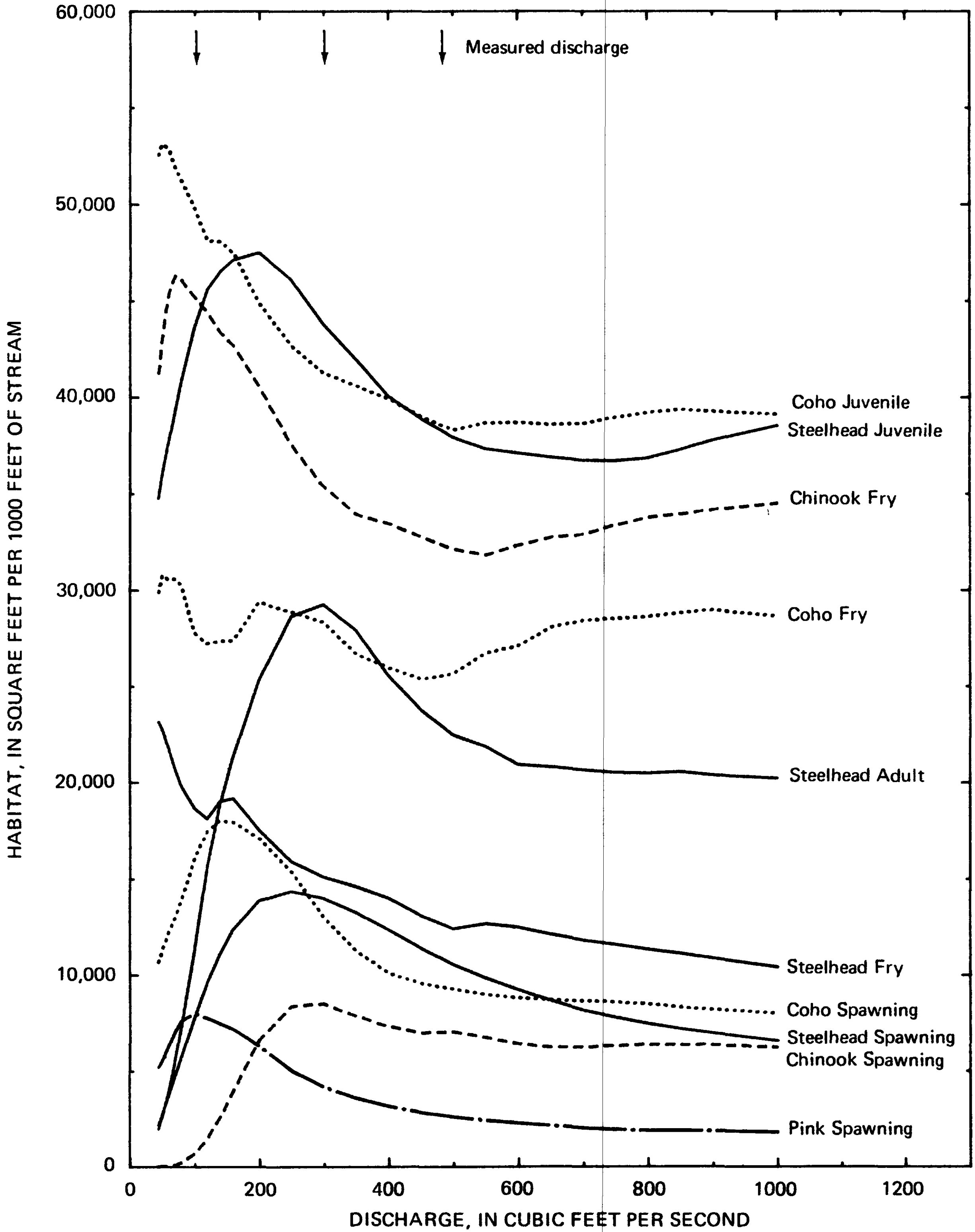


Figure 22.--Graph showing relations between stream discharge and habitat at site 14, South Fork Stillaguamish River at Marten Creek near Silverton.

Table 23.--Total surface area and habitat area according to stream discharge, fish species, and life stage for South Fork Stillaguamish River at Marten Creek near Silverton

[Calibration discharges = 102, 301, and 483 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 41 and 1,210 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet									
		STEELHEAD				CHINOOK		COHO			PINK
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	SPAWNING	FRY	JUVENILE	SPAWNING
45	59,920	1,970	2,170	23,170	34,770	10	41,240	10,670	29,880	52,550	5,200
50	60,580	2,560	2,660	22,830	35,890	24	43,000	11,270	30,800	53,140	5,480
60	61,710	3,850	3,660	21,880	37,600	45	45,320	12,230	30,540	52,920	6,250
70	62,960	5,400	4,650	20,770	39,190	101	46,330	12,990	30,610	51,950	7,010
80	64,720	7,240	5,660	19,840	40,840	220	46,120	13,920	30,250	51,240	7,590
100	66,730	11,170	7,700	18,670	43,580	693	45,230	16,100	27,780	49,850	7,990
120	70,070	15,640	9,600	18,110	45,570	1,470	44,400	17,500	27,260	48,130	7,770
140	72,800	18,870	11,120	19,010	46,540	2,590	43,370	18,030	27,380	48,120	7,470
160	74,910	21,360	12,370	19,170	47,140	3,950	42,710	17,960	27,410	47,510	7,190
200	76,580	25,370	13,890	17,540	47,510	6,620	40,560	17,100	29,410	44,900	6,310
250	78,840	28,650	14,370	15,900	46,120	6,390	37,560	15,360	28,870	42,680	5,050
300	81,000	29,260	14,020	15,110	43,780	8,520	35,420	13,040	28,380	41,270	4,170
350	83,050	27,930	13,280	14,600	41,990	7,860	33,960	11,280	26,680	40,610	3,600
400	84,160	25,560	12,370	14,020	40,060	7,340	33,470	10,100	25,990	39,920	3,180
450	85,110	23,800	11,430	13,120	38,920	7,000	32,780	9,590	25,410	39,010	2,850
500	67,010	22,490	10,560	12,420	37,950	7,050	32,130	9,290	25,670	38,330	2,610
550	88,890	21,890	9,850	12,680	37,330	6,750	31,830	9,000	26,750	38,690	2,430
600	90,030	20,930	9,230	12,490	37,110	6,420	32,330	8,810	27,100	38,710	2,280
650	91,180	20,810	8,650	12,120	36,900	6,240	32,730	8,680	28,080	38,610	2,150
700	92,300	20,640	8,150	11,810	36,740	6,240	32,900	8,650	28,430	38,650	2,000
750	93,700	20,510	7,770	11,590	36,710	6,300	33,370	8,590	28,540	36,970	1,930
800	94,480	20,480	7,450	11,340	36,850	6,380	33,790	8,490	28,640	39,220	1,900
850	95,230	20,550	7,190	11,130	37,280	6,380	33,960	8,330	28,830	39,370	1,900
900	95,940	20,390	6,960	10,870	37,790	6,370	34,200	8,210	28,990	39,280	1,880
1,000	97,240	20,230	6,560	10,410	38,550	6,240	34,520	8,010	28,670	39,150	1,820

Table 24.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 14, South Fork Stillaguamish River at Marten Creek near Silverton

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha[2] coefficient	Beta[2] coefficient
1	control	102		0.998	0.059	2.55	2.50	89.36	89.36	87.45	14.4	3.026
		301		1.01	---	3.89	3.49	90.19	90.18	D.O.	D.O.	D.O.
		483		.996	---	5.57	5.22	90.64	90.65	D.O.	D.O.	D.O.
			40	.960	---	---	1.82	---	88.85	D.O.	D.O.	D.O.
			1,000	.959	---	---	---	---	---	D.O.	D.O.	D.O.
			1,210	.945	---	---	11.36	---	91.78	D.O.	D.O.	D.O.
2	pool	102		.978	.030	1.46	1.45	89.48	89.48	86.37	.542	4.622
		301		.997	---	2.82	2.73	90.28	90.30	D.O.	D.O.	D.O.
		483		.991	---	3.58	3.56	90.73	90.72	D.O.	D.O.	D.O.
			40	.942	---	---	.87	---	88.91	D.O.	D.O.	D.O.
			1,000	.971	---	---	---	---	---	D.O.	D.O.	D.O.
			1,210	.962	---	---	6.97	---	91.67	D.O.	D.O.	D.O.
3	pool-riffle transition	102		1.00	.083	2.74	2.54	89.46	89.46	87.19	5.96	3.456
		301		1.01	---	3.89	3.79	90.32	90.30	D.O.	D.O.	D.O.
		483		1.00	---	4.96	4.52	90.74	90.76	D.O.	D.O.	D.O.
			40	.995	---	---	1.91	---	88.92	D.O.	D.O.	D.O.
			1,000	.986	---	---	---	---	---	D.O.	D.O.	D.O.
			1,210	.981	---	---	8.09	---	91.84	D.O.	D.O.	D.O.
4	mid-riffle	102		.999	.124	4.26	3.47	90.54	90.53	88.44	7.21	3.588
		301		1.01	---	5.20	4.86	91.24	91.27	D.O.	D.O.	D.O.
		483		1.00	---	5.95	5.62	91.89	91.67	D.O.	D.O.	D.O.
			40	1.08	---	---	2.80	---	90.05	D.O.	D.O.	D.O.
			1,000	.991	---	---	---	---	---	D.O.	D.O.	D.O.
			1,210	.987	---	---	13.06	---	92.61	D.O.	D.O.	D.O.
5	upstream of riffle	102		.997	.029	1.51	1.50	91.87	91.88	89.24	1.69	4.23
		301		1.00	---	2.78	2.83	92.68	92.65	D.O.	D.O.	D.O.
		483		.998	---	3.93	3.92	93.02	93.05	D.O.	D.O.	D.O.
			40	.974	---	---	.85	---	91.35	D.O.	D.O.	D.O.
			1,000	.963	---	---	---	---	---	D.O.	D.O.	D.O.
			1,210	.965	---	---	8.30	---	93.97	D.O.	D.O.	D.O.
6	pool	102		1.01	.398	1.80	1.82	91.89	91.89	86.36	.0000701	8.297
		301		1.00	---	3.69	3.33	92.66	92.66	D.O.	D.O.	D.O.
		483		1.01	---	4.72	4.92	93.03	93.03	D.O.	D.O.	D.O.
			40	1.23	---	---	1.25	---	91.30	D.O.	D.O.	D.O.
			1,000	1.01	---	---	---	---	---	D.O.	D.O.	D.O.
			1,210	1.01	---	---	11.65	---	93.81	D.O.	D.O.	D.O.

Table 24.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 14, South Fork Stillaguamish River at Marten Creek near Silverton--continued

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha[2] coefficient	Beta[2] coefficient
7	mid-riffle	102		0.996	0.054	3.29	3.32	92.81	92.82	91.33	37.1	2.552
	boulders	301		.990	---	4.53	4.29	93.64	93.60	D.O.	D.O.	D.O.
		483		1.00	---	5.40	5.54	94.03	94.06	D.O.	D.O.	D.O.
			40	1.13	---	---	3.00	---	92.36	D.O.	D.O.	D.O.
			1,000	1.03	---	---	---	---	---	D.O.	D.O.	D.O.
			1,210	1.04	---	---	15.37	---	95.25	D.O.	D.O.	D.O.
8	upstream	102		.961	.104	4.37	3.20	93.43	93.43	91.43	11.4	3.148
	of riffle	301		1.01	---	5.12	4.60	94.27	94.25	D.O.	D.O.	D.O.
		483		1.02	---	7.10	5.68	94.70	94.71	D.O.	D.O.	D.O.
			40	.939	---	---	2.37	---	92.92	D.O.	D.O.	D.O.
			1,000	1.03	---	---	---	---	---	D.O.	D.O.	D.O.
			1,210	1.03	---	---	15.30	---	95.82	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2] from the stage-discharge relationship for given discharges.

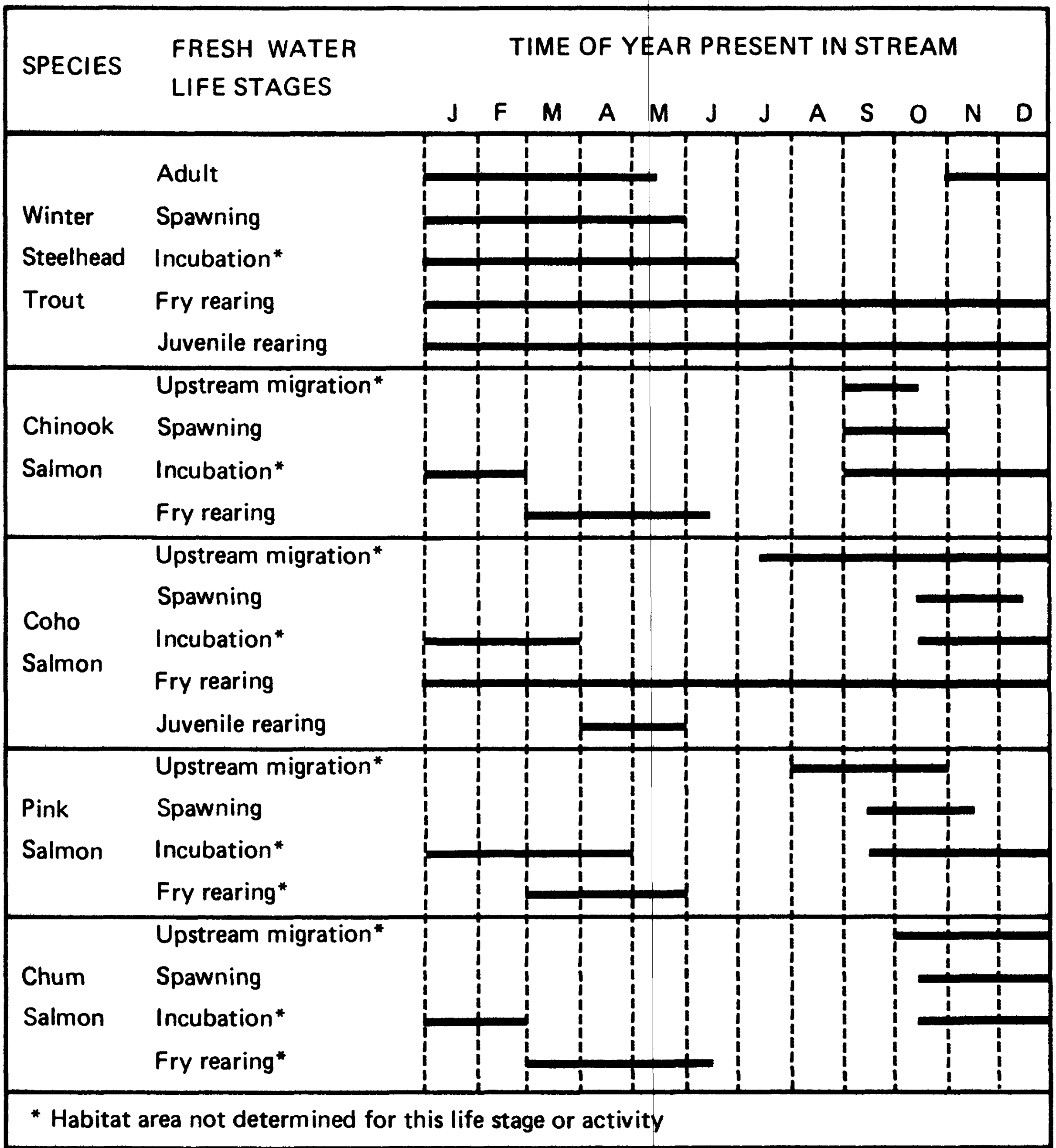


Figure 23.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 15 and site 17, Jim Creek at mouth at Arlington and below 4-mile bridge near Arlington.

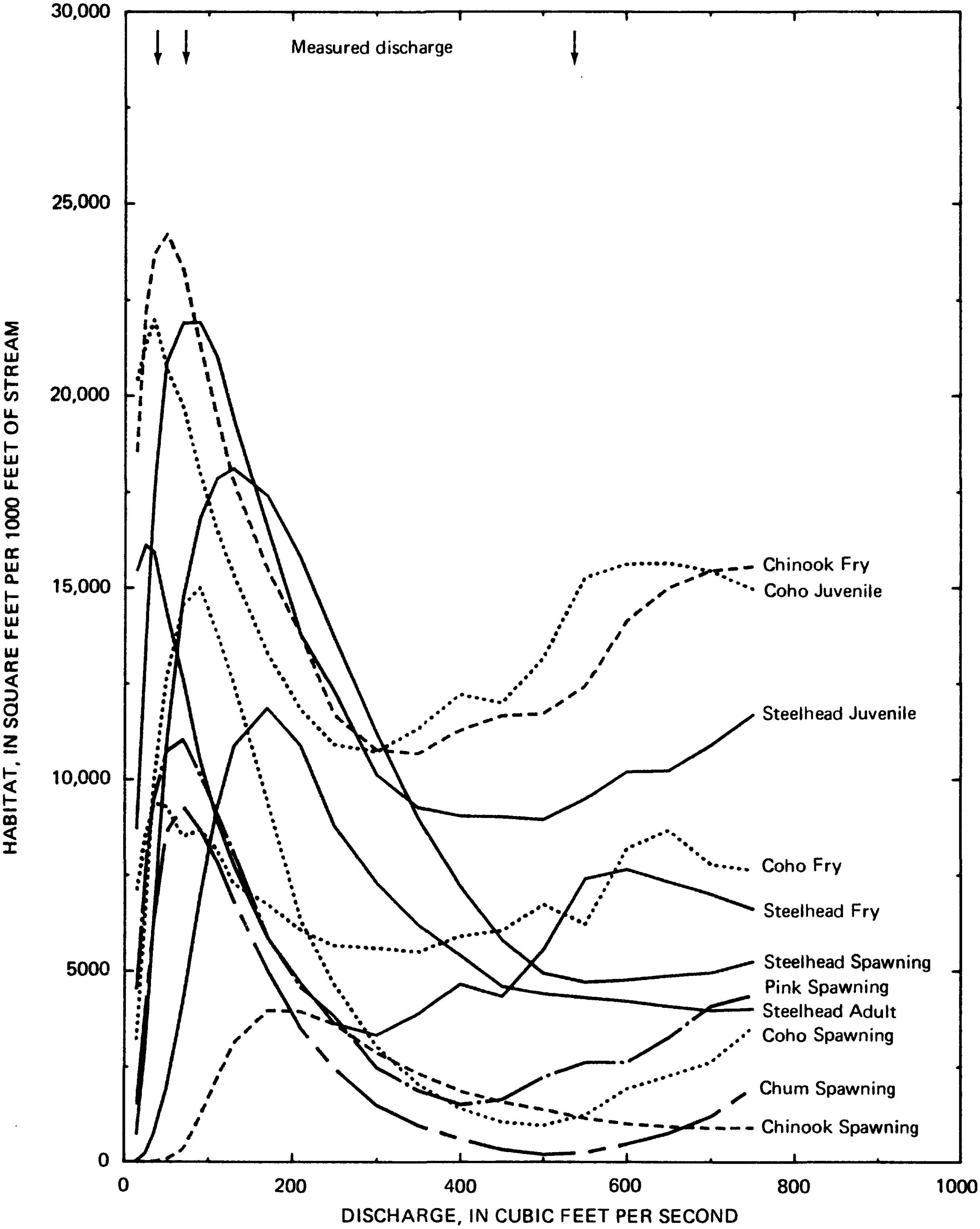


Figure 24.--Graph showing relations between stream discharge and habitat at site 15, Jim Creek at mouth at Arlington.

Table 25.--Total surface area and habitat area according to stream discharge, fish species, and life stage for Jim Creek at mouth at Arlington

[Calibration discharges = 38, 71, and 537 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 15 and 1,340 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet										
		STEELHEAD				CHINOOK		COHO			PINK	CHUM
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	SPAWNING	FRY	JUVENILE	SPAWNING	SPAWNING
15	28,680	23	730	15,460	8,720	0	18,570	3,220	7,110	20,410	4,530	1,520
25	32,430	212	3,060	16,110	13,420	0	22,240	6,600	8,510	21,340	7,640	4,040
35	35,460	735	6,370	15,940	17,460	10	23,690	9,920	9,370	21,970	9,490	6,320
50	37,700	1,930	10,910	14,370	20,880	68	24,240	12,670	9,290	20,680	10,740	8,530
70	39,610	4,200	14,750	12,590	21,910	319	23,800	14,540	8,500	19,700	11,040	9,290
90	40,600	6,920	16,840	10,520	21,920	1,170	21,820	15,000	8,680	17,920	10,110	8,680
110	41,320	9,220	17,860	8,960	21,030	2,170	19,470	13,820	8,160	16,450	9,110	7,830
130	42,240	10,880	18,120	7,750	19,400	3,120	17,750	12,500	7,260	15,290	8,080	6,800
170	43,370	11,870	17,410	5,880	16,570	3,960	15,480	9,450	6,730	13,280	5,880	5,010
210	44,350	10,900	15,790	4,710	13,790	3,950	13,800	6,330	6,070	11,820	4,580	3,500
250	45,340	8,800	13,710	3,630	12,310	3,620	11,700	4,660	5,660	10,910	3,820	2,460
300	46,830	7,300	11,240	3,330	10,140	2,880	10,790	3,040	5,600	10,730	2,470	1,480
350	49,770	6,200	8,990	3,890	9,270	2,330	10,690	2,040	5,500	11,340	1,860	945
400	52,670	5,410	7,210	4,660	9,050	1,860	11,300	1,400	5,900	12,210	1,500	594
450	54,640	4,600	5,820	4,330	9,030	1,580	11,670	1,040	6,050	11,990	1,630	313
500	56,930	4,400	4,940	5,560	8,950	1,370	11,720	949	6,730	13,150	2,220	184
550	60,890	4,300	4,710	7,400	9,490	1,140	12,430	1,220	6,210	15,260	2,610	232
600	61,830	4,210	4,770	7,650	10,210	1,000	14,130	1,920	8,180	15,610	2,610	471
650	62,650	4,080	4,880	7,330	10,240	934	15,010	2,260	8,660	15,640	3,270	753
700	63,410	3,970	4,960	7,010	10,910	893	15,450	2,620	7,760	15,430	4,080	1,190
750	64,260	4,010	5,250	6,630	11,700	898	15,550	3,520	7,610	14,950	4,360	1,950

Table 26.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 15, Jim Creek at mouth near Arlington

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha[2] coef-ficient	Beta[2] coef-ficient
1	run-riffle	38		1.01	0.083	2.03	2.08	92.62	92.70	91.80	47.5	2.083
	transition	71		.990	---	2.58	2.49	93.21	93.01	D.O.	D.O.	D.O.
		537		1.01	---	5.78	5.46	94.81	95.00	D.O.	D.O.	D.O.
			15	1.07	---	---	1.64	---	92.37	D.O.	D.O.	D.O.
			1,000	1.01	---	---	9.61	---	96.12	D.O.	D.O.	D.O.
2	mid-	38		1.06	.170	3.25	2.88	92.92	92.99	91.60	14.6	2.908
	riffle	71		1.00	---	2.86	3.27	93.46	93.32	D.O.	D.O.	D.O.
		537		.967	---	8.06	8.42	94.96	95.06	D.O.	D.O.	D.O.
			15	1.32	---	---	2.74	---	92.61	D.O.	D.O.	D.O.
			1,000	.939	---	---	15.77	---	95.88	D.O.	D.O.	D.O.
3	control	38		1.00	.065	1.92	1.95	93.22	93.33	92.10	22.9	2.466
		71		1.01	---	2.55	2.48	93.97	93.68	D.O.	D.O.	D.O.
		537		.982	---	5.87	8.04	95.42	95.69	D.O.	D.O.	D.O.
			15	1.01	---	---	1.38	---	92.94	D.O.	D.O.	D.O.
			1,000	.932	---	---	10.02	---	96.72	D.O.	D.O.	D.O.
4	pool	38		1.01	.079	2.00	1.87	93.30	93.40	91.49	4.30	3.379
		71		1.01	---	2.34	2.45	93.98	93.78	D.O.	D.O.	D.O.
		537		.979	---	6.35	6.25	95.53	95.68	D.O.	D.O.	D.O.
			15	1.02	---	---	1.26	---	92.94	D.O.	D.O.	D.O.
			1,000	.891	---	---	8.90	---	98.51	D.O.	D.O.	D.O.
5	pool-rif-	38		1.01	.095	3.28	2.80	93.63	93.69	92.39	19.2	2.806
	fle tran-	71		.993	---	3.13	3.31	94.16	94.04	D.O.	D.O.	D.O.
	sition	537		.995	---	6.32	6.24	95.90	95.98	D.O.	D.O.	D.O.
			15	1.17	---	---	2.48	---	93.30	D.O.	D.O.	D.O.
			1,000	.931	---	---	10.36	---	98.95	D.O.	D.O.	D.O.
6	mid-	38		.999	.140	2.61	2.77	94.06	94.07	93.03	34.8	2.318
	riffle	71		1.02	---	3.65	3.35	94.40	94.39	D.O.	D.O.	D.O.
		537		1.01	---	6.38	6.53	98.28	96.29	D.O.	D.O.	D.O.
			15	.989	---	---	2.13	---	93.73	D.O.	D.O.	D.O.
			1,000	.880	---	---	7.30	---	97.29	D.O.	D.O.	D.O.
7	control	38		.843	---	2.68	2.02	94.50	94.50	93.71	51.2	1.297
		71		.865	---	3.56	3.07	95.00	95.00	D.O.	D.O.	D.O.
		537		.809	---	---	49.04	---	99.84	D.O.	D.O.	D.O.
			15	.876	---	---	1.31	---	94.10	D.O.	D.O.	D.O.
			1,000	.805	---	---	128.0	---	103.61	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2] from the stage-discharge relationship for given discharges.

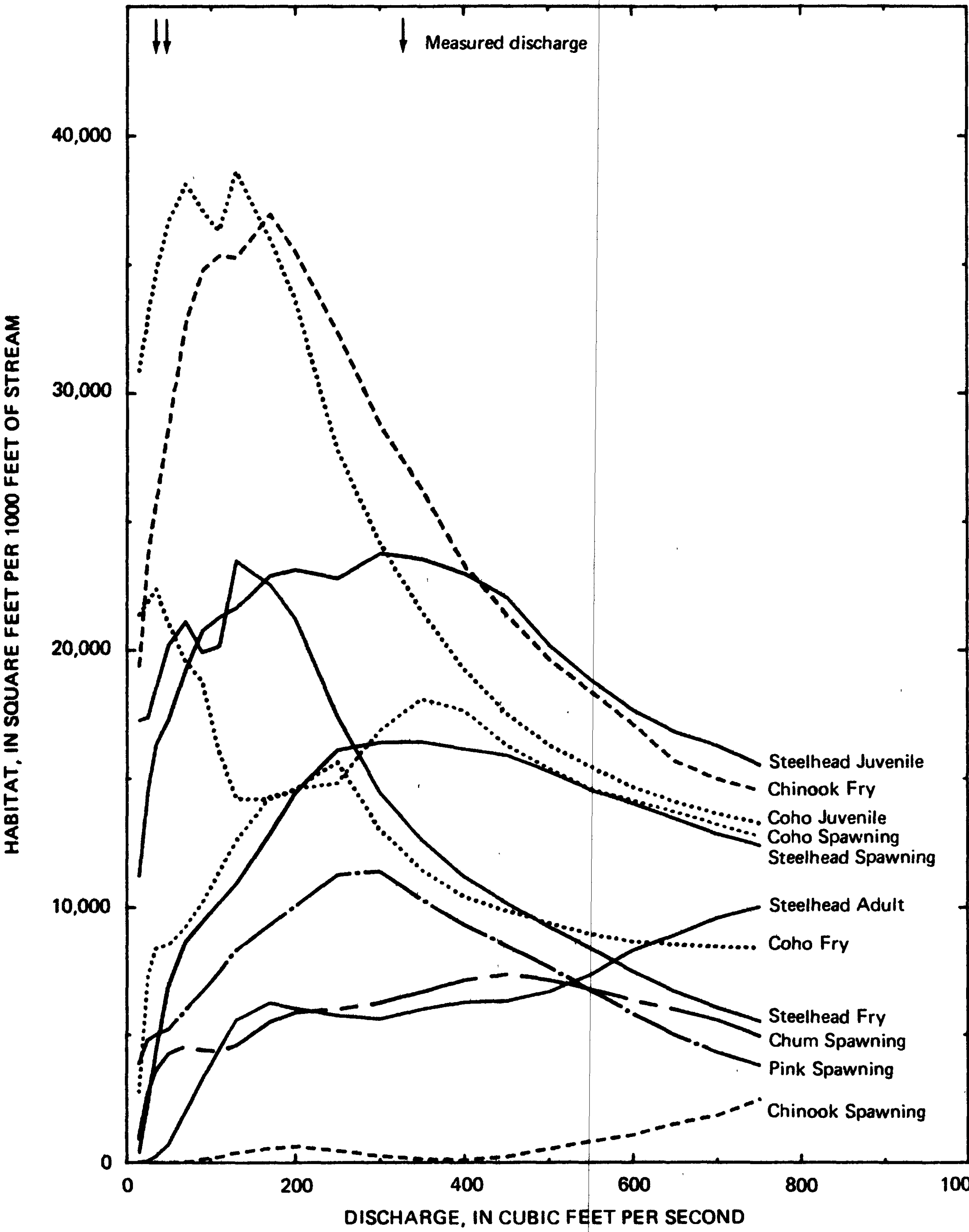


Figure 25.--Graph showing relations between stream discharge and habitat at site 17, Jim Creek below 4-mile bridge near Arlington.

Table 27.--Total surfsce area and habitat area according to stream discharge, fish species, and life stage for Jim Creek below 4-mile bridge nesr Arlington

[Calibrstion discharges = 34, 46, and 326 cubic feet per second; recommended range of extrapolation (Bovee, 1976) = 13 and 820 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet										
		STEELHEAD				CHINOOK		COHO			PINK	CHUM
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	SPAWNING	FRY	JUVENILE	SPAWNING	SPAWNING
15	35,200	15	394	17,260	11,200	0	19,410	2,760	21,370	30,860	3,880	933
25	40,190	59	2,320	17,370	14,460	0	23,730	7,270	21,850	32,890	4,790	2,660
35	43,750	252	4,380	18,540	16,320	0	25,860	8,430	22,400	34,800	5,010	3,610
50	48,660	719	6,960	20,220	17,340	0	28,810	8,580	21,040	36,670	5,210	4,260
70	52,830	1,980	6,640	21,100	19,230	9	32,740	9,240	19,590	38,120	5,960	4,540
90	55,470	3,250	9,410	19,910	20,770	134	34,800	10,210	16,780	37,110	8,880	4,400
110	63,660	4,420	10,160	20,150	21,260	253	35,360	11,360	16,040	36,330	7,460	4,360
130	65,750	5,570	10,890	23,460	21,620	398	35,270	12,580	14,220	38,810	8,330	4,570
170	71,320	6,240	12,830	22,540	22,890	580	36,960	14,310	14,200	38,010	9,310	5,500
200	72,200	6,020	14,440	21,230	23,130	858	35,500	14,800	14,580	33,820	10,060	5,660
250	72,590	5,750	18,110	17,390	22,780	489	32,370	14,840	15,650	27,810	11,260	6,000
300	72,930	5,610	18,400	14,430	23,780	288	28,810	16,890	13,010	24,200	11,390	6,250
350	73,200	5,990	16,410	12,550	23,530	122	28,260	18,110	11,430	21,510	10,290	6,670
400	73,430	6,260	16,140	11,160	22,970	83	23,330	17,860	10,410	19,280	9,310	7,140
450	73,630	6,310	15,890	10,140	22,040	239	21,390	16,320	9,880	17,540	6,500	7,370
500	73,820	6,670	15,250	9,210	20,200	557	19,670	15,390	9,370	16,330	7,860	7,120
550	74,030	7,350	14,530	8,360	18,820	829	18,370	14,590	8,940	15,450	6,710	6,760
600	74,230	8,300	14,000	7,450	17,650	1,090	17,150	14,130	8,660	14,700	5,820	6,330
650	74,420	8,890	13,420	8,670	18,800	1,530	15,680	13,720	8,540	14,100	5,000	5,980
700	74,600	9,560	12,610	6,030	18,270	1,850	15,000	13,220	8,470	13,640	4,320	5,570
750	74,780	10,000	12,360	5,510	15,510	2,480	14,550	12,740	8,410	13,270	3,820	4,950

Table 28.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 17, Jim Creek below 4-mile bridge near Arlington

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha coefficient[2]	Beta coefficient[2]
1	pool-riffle transition	34		0.991	0.084	0.69	0.77	93.02	93.06	89.90	0.00147	8.74
		46		.986	---	1.04	.92	93.22	93.17	D.O.	D.O.	D.O.
		328		1.03	---	3.48	3.61	93.98	93.99	D.O.	D.O.	D.O.
			13	1.06	---	---	.48	---	92.73	D.O.	D.O.	D.O.
			820	1.06	---	---	10.46	---	94.45	D.O.	D.O.	D.O.
2	pool transition	34		1.06	.245	.86	.82	93.02	93.07	87.00	.101E-09	14.726
		46		1.05	---	1.12	.97	93.25	93.19	D.O.	D.O.	D.O.
		328		1.01	---	3.50	3.89	94.06	94.07	D.O.	D.O.	D.O.
			13	1.12	---	---	.49	---	92.68	D.O.	D.O.	D.O.
			820	1.00	---	---	8.62	---	94.53	D.O.	D.O.	D.O.
3	pool-run transition	34		.956	.179	1.11	.99	93.02	93.06	90.55	.064	6.805
		46		.975	---	1.26	1.22	93.24	93.18	D.O.	D.O.	D.O.
		328		1.06	---	4.30	4.57	94.04	95.06	D.O.	D.O.	D.O.
			13	.878	---	---	.54	---	92.73	D.O.	D.O.	D.O.
			820	1.08	---	---	10.05	---	94.56	D.O.	D.O.	D.O.
4	run-riffle transition	34		.985	.080	2.00	1.89	93.09	93.12	91.98	21.1	3.642
		46		1.01	---	2.03	2.17	93.26	93.22	D.O.	D.O.	D.O.
		328		1.00	---	5.08	5.09	94.09	94.10	D.O.	D.O.	D.O.
			13	.882	---	---	1.18	---	92.86	D.O.	D.O.	D.O.
			820	.993	---	---	10.30	---	94.71	D.O.	D.O.	D.O.
5	mid-riffle	34		.930	.161	2.39	2.11	93.66	93.65	92.38	14.6	3.576
		46		.919	---	2.50	2.22	93.74	93.76	D.O.	D.O.	D.O.
		328		1.05	---	5.45	5.72	94.77	94.77	D.O.	D.O.	D.O.
			13	1.04	---	---	1.92	---	93.35	D.O.	D.O.	D.O.
			820	1.16	---	---	10.17	---	95.46	D.O.	D.O.	D.O.
6	riffle-run transition	34		.992	.158	3.57	3.24	94.16	94.19	93.28	43.7	2.595
		46		1.04	---	3.90	3.18	94.34	94.30	D.O.	D.O.	D.O.
		328		1.01	---	5.74	5.69	95.44	95.46	D.O.	D.O.	D.O.
			13	.828	---	---	2.22	---	93.91	D.O.	D.O.	D.O.
			820	.956	---	---	10.02	---	96.38	D.O.	D.O.	D.O.
7	run	34		1.00	.034	.72	.71	95.80	95.82	94.59	15.2	3.807
		46		.997	---	.88	.87	95.96	95.93	D.O.	D.O.	D.O.
		328		1.00	---	3.57	3.56	96.82	96.83	D.O.	D.O.	D.O.
			13	1.05	---	---	.39	---	95.55	D.O.	D.O.	D.O.
			820	1.03	---	---	7.93	---	97.44	D.O.	D.O.	D.O.

[1]Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2]from the stage-discharge relationship for given discharges.

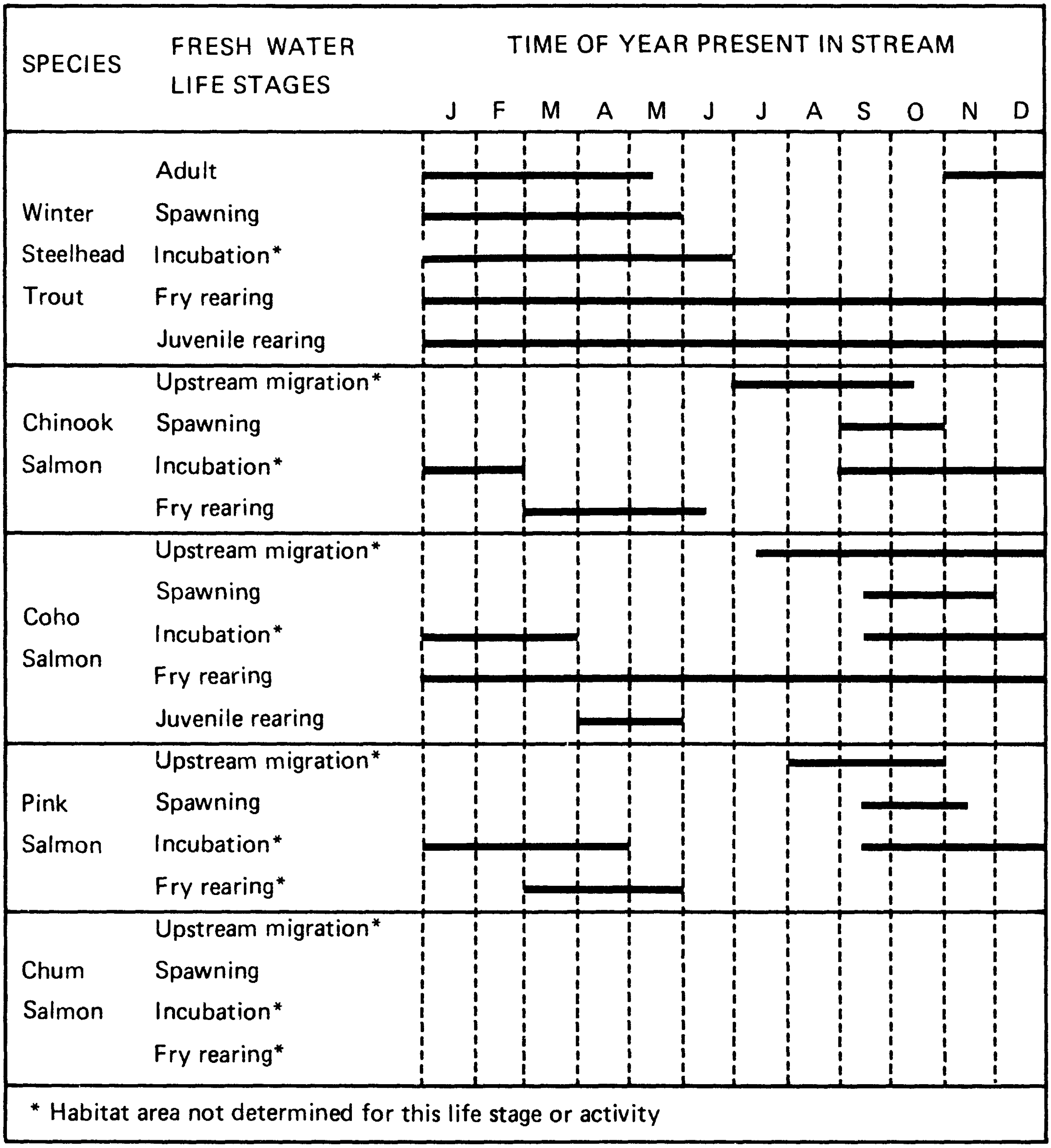


Figure 26.--Bar chart showing time of year that different life stages of steelhead trout and salmon typically are present at site 19, Canyon Creek near Granite Falls.

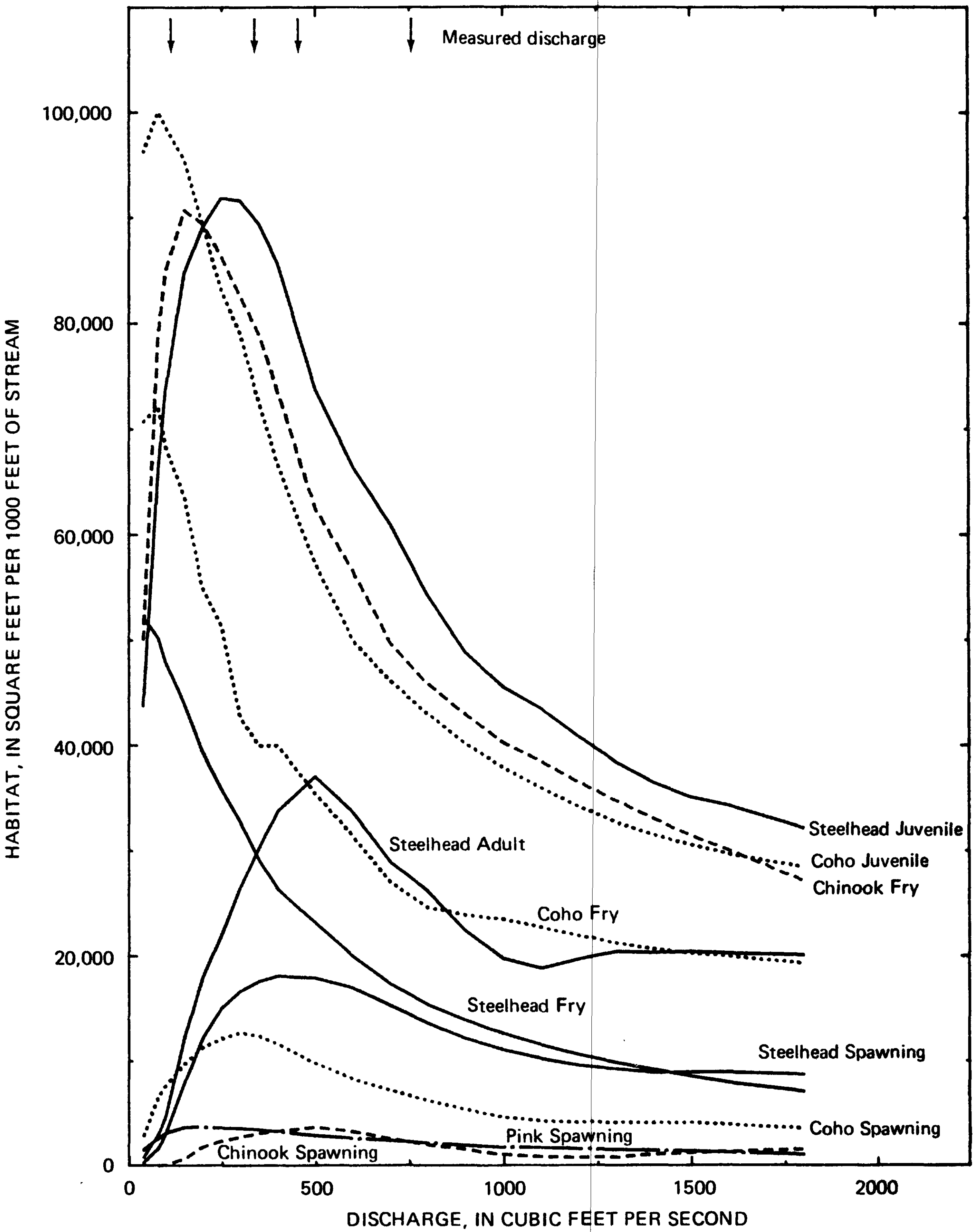


Figure 27.--Graph showing relations between stream discharge and habitat at site 19, Canyon Creek near Granite Falls.

Table 29.--Total surface area and habitat area according to stream discharge, fish species, and life stage for Canyon Creek near Granite Falls

[Calibration discharges = 114, 338, 453, and 756 cubic feet per second; recommended range of extrapolation (Bovee, 1978) = 46 and 1,890 cubic feet per second]

DISCHARGE, cubic feet per second	TOTAL SURFACE AREA (square feet per 1000 feet)	HABITAT AREA, in square feet per thousand feet									
		STEELHEAD				CHINOOK		COHO			PINK
		ADULT	SPAWNING	FRY	JUVENILE	SPAWNING	FRY	SPAWNING	FRY	JUVENILE	SPAWNING
40	97,460	746	270	52,040	43,760	0	50,090	2,840	70,700	96,190	1,510
80	106,250	3,050	1,620	50,230	65,930	0	78,830	6,560	72,100	100,060	2,650
100	108,720	4,740	3,070	47,980	73,500	56	84,910	7,670	68,460	98,870	3,100
150	116,690	12,260	7,850	44,050	84,760	663	90,770	9,720	63,660	95,560	3,660
200	120,950	18,000	12,200	39,340	89,120	1,810	89,420	11,320	54,970	89,350	3,690
250	125,500	22,030	15,070	35,880	91,850	2,380	86,390	12,190	51,310	83,190	3,640
300	127,990	26,570	16,660	32,750	91,630	2,760	82,590	12,720	42,710	79,110	3,600
350	129,220	30,320	17,610	29,120	89,410	3,080	79,050	12,400	39,970	72,500	3,470
400	130,430	33,790	18,100	26,380	85,660	3,300	73,630	11,610	39,970	66,710	3,240
500	132,460	37,070	17,920	23,200	73,860	3,660	62,530	9,830	35,460	57,250	2,890
600	133,510	33,650	16,950	19,980	66,430	3,250	56,580	8,250	31,410	49,950	2,630
700	134,380	28,890	15,270	17,340	60,970	2,550	49,740	7,190	26,990	46,150	2,420
800	135,140	26,150	13,610	15,340	54,190	1,970	45,900	6,210	24,630	43,020	2,170
900	135,810	22,370	12,140	13,900	48,860	1,530	42,970	5,350	23,900	40,190	1,960
1,000	136,410	19,780	11,060	12,620	45,560	1,030	40,300	4,600	23,520	37,910	1,800
1,100	136,940	18,820	10,220	11,540	43,540	831	38,490	4,230	22,740	36,020	1,730
1,200	137,440	19,690	9,560	10,600	40,860	768	36,550	4,110	21,950	34,260	1,600
1,300	137,910	20,400	9,180	9,820	38,380	815	34,780	4,080	21,230	32,760	1,510
1,400	138,340	20,290	8,840	9,140	36,460	1,050	33,100	4,050	20,660	31,540	1,460
1,500	138,750	20,400	8,910	8,480	35,090	1,220	31,480	4,050	20,220	30,590	1,390
1,600	139,140	20,260	8,900	7,910	34,330	1,340	30,100	3,880	19,980	29,740	1,280
1,800	139,870	20,080	8,680	7,060	32,190	1,540	27,160	3,520	19,330	28,500	1,060

Table 30.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 19, Canyon Creek near Granite Falls

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha[2] coefficient	Beta[2] coefficient
1	boulder riffle	114		1.01	0.283	1.88	1.98	94.33	94.32	92.60	10.1	4.463
		338		1.02	---	3.80	3.27	94.76	94.79	D.O.	D.O.	D.O.
		---	453	1.03	---	---	3.87	---	94.94	D.O.	D.O.	D.O.
		756		1.03	---	4.54	5.68	95.24	95.22	D.O.	D.O.	D.O.
			45	1.10	---	---	1.59	---	94.00	D.O.	D.O.	D.O.
			1,890	1.00	---	---	12.96	---	95.82	D.O.	D.O.	D.O.
2	upstream of riffle	114		.972	.206	3.13	2.66	94.50	94.47	92.79	16.6	3.697
		338		1.03	---	3.28	3.84	94.98	95.05	D.O.	D.O.	D.O.
		---	453	1.04	---	---	4.22	---	95.23	D.O.	D.O.	D.O.
		756		1.02	---	5.93	6.08	95.64	95.60	D.O.	D.O.	D.O.
			45	.866	---	---	1.82	---	94.10	D.O.	D.O.	D.O.
			1,890	.948	---	---	11.04	---	96.39	D.O.	D.O.	D.O.
3	boulders-pools	114		.978	.180	1.60	1.44	94.64	94.62	90.53	.00437	7.218
		338		1.01	---	3.28	3.18	95.22	95.29	D.O.	D.O.	D.O.
		453		1.01	---	4.62	3.96	95.53	95.46	D.O.	D.O.	D.O.
		---	756	.989	---	---	6.79	---	95.65	D.O.	D.O.	D.O.
			45	.902	---	---	.97	---	94.13	D.O.	D.O.	D.O.
			1,890	.924	---	---	17.20	---	96.57	D.O.	D.O.	D.O.
4	boulder-riffle	114		.964	.129	2.34	2.27	94.80	94.80	92.07	1.01	4.715
		338		1.02	---	3.43	3.67	95.48	95.50	D.O.	D.O.	D.O.
		453		1.02	---	4.46	4.41	95.74	95.72	D.O.	D.O.	D.O.
		---	756	1.01	---	---	5.93	---	96.14	D.O.	D.O.	D.O.
			45	.874	---	---	1.65	---	94.31	D.O.	D.O.	D.O.
			1,890	.926	---	---	11.43	---	97.01	D.O.	D.O.	D.O.
5	upstream of riffle	114		1.01	.069	3.06	2.44	94.78	94.79	92.86	22.6	2.471
		338		1.00	---	3.50	3.55	95.92	95.85	D.O.	D.O.	D.O.
		453		1.01	---	4.75	4.23	96.16	96.23	D.O.	D.O.	D.O.
		---	756	1.01	---	---	5.73	---	97.00	D.O.	D.O.	D.O.
			45	1.13	---	---	2.03	---	94.18	D.O.	D.O.	D.O.
			1,890	.987	---	---	11.24	---	96.86	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2] from the stage-discharge relationship for given discharges.

Table 31.--Selected calibration and simulation details for the IFG-4 hydraulic model for site 16, Jim Creek Passage Flow Cross Section

[Q, discharge; VAF, velocity adjustment factor; VPE, velocity prediction error]

Cross-section number	Cross-section type	Calibration Q	Simulation Q	VAF	Average VPE error[1]	Maximum measured velocity in feet per second	Maximum predicted velocity in feet per second	Measured water-surface elevation in feet	Predicted water-surface elevation in feet	Point of zero flow	Alpha[2] coefficient	Beta[2] coefficient
1	---	37		0.991	0.013	2.60	2.60	93.42	93.43	92.60	60.3	2.555
		194		1.02	---	4.16	4.06	94.22	94.16	D.O.	D.O.	D.O.
		431		.986	---	5.20	5.48	94.72	94.76	D.O.	D.O.	D.O.
			14	.903	---	---	2.23	---	93.16	D.O.	D.O.	D.O.
			1,080	.916	---	---	11.07	---	95.69	D.O.	D.O.	D.O.

[1] Velocity Prediction Error statistics are not computed on data sets with less than 3 measurements.
[2] from the stage-discharge relationship for given discharges.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1987— 7 9 5 - 2 0 1 / 6 0 1 8 3