

TOLT RIVER FISHERIES
AND
INSTREAM FLOW ANALYSIS

by

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1.0 ABSTRACT

The proposed South Fork Tolt River hydroelectric project will generate electrical energy with water diverted from the existing Seattle Water Department Tolt River Reservoir. Water is presently stored and diverted for municipal and industrial supply. The purpose of this study was to determine baseline data on the composition and abundance of anadromous salmonids, resident fishes and macroinvertebrates in the Tolt River system. An instream flow analysis of salmonid habitat was conducted to establish the requirements for instream resource protection.

The predominant species of salmonids in the Tolt River is the steelhead trout followed by small numbers of coho salmon and cutthroat trout. The instream flow analysis utilized the incremental IFG methodology. Procedures for the establishment of instream flow recommendations based on weighted useable area and the peak habitat efficiency were developed to provide a range of flows from which to begin negotiations.

2.0 ACKNOWLEDGMENTS

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Dr. Robert Milhous, U.S. Fish and Wildlife Service-Fort Collins, provided updated (1981 version) computer programs of the instream flow models and much valuable advice. Mr. Dell Simmons of the U.S.F.W.S.-Vancouver, Washington, provided advice on the application and calibration of the IFG-4 and HABITAT models. Mr. Woody Trihey and Ms. Jean Baldrige of the Arctic Environmental Information and Data Center provided general assistance in interpreting computer output of WUA indices. Mr. Bill Wiggins of the U.S. Geological Survey provided recent hydrologic data for the Tolt River system.

The Seattle Water Department personnel aided in access to the watershed and the transport of equipment to study reaches. Mr. Doug Schaad, an avid and long-time Tolt River sports fisherman, provided valuable information on the timing and distribution of salmon and trout species in the river. The support of members and agencies represented on the Tolt River Fisheries Study Advisory Committee has been instrumental in the progress of this research. Finally, we wish to acknowledge the contribution of numerous field workers, in particular Mr. Ai-nu Ly, who provided both laboratory and field assistance.

3.0 INTRODUCTION

Development of the South Fork Tolt River hydroelectric project has been proposed by Seattle City Light to generate electrical energy from an undeveloped renewable source. This project would utilize water from the existing Seattle Water Department Tolt River Reservoir which is presently used to store and divert water from the South Fork Tolt River for municipal and industrial water supply. The primary purpose of the reservoir will continue to be for municipal and industrial water supply, and electrical energy will be generated from existing operating procedures.

The preferred design includes a 69 inch diameter five-mile long diversion pipeline from the reservoir to a powerhouse located southeast of an existing water supply regulating basin. A water return conduit from the powerhouse will be designed so that water will flow to the regulating basin for municipal and industrial water supply or during periods of reduced demand be returned to the South Fork Tolt River. The maximum hydraulic capacity of the turbine is 245 cfs. Excess water for power generation will occur primarily during the winter from November to March, while municipal and industrial water supply will be the predominant requirement during the summer months.

The purpose of this study was to determine baseline data on the composition and abundance of anadromous salmonids, associated resident fishes, and macroinvertebrates in the Tolt River system. An instream flow analysis of salmonid habitat requirements during the pre- and post-dam construction periods was conducted, and an evaluation of the potential impacts on instream flow needs following development of the South Fork

Tolt River Hydroelectric Project was made. Specific study objectives on the South Fork, North Fork, and mainstem Tolt River were to

1. characterize the physical habitat including discharge, temperature, suspended sediment, and substrate;
2. develop baseline descriptions of the macroinvertebrate benthos and drift components and utilization by salmonids;
3. conduct a baseline census of the existing spawning and rearing populations of salmonids and resident fishes;
4. conduct a quantitative analysis of the instream flow habitat requirements for each salmonid species and life history stage to predict present and future impacts of water diversion and flow regulation;
5. develop post-project instream flow alternatives for normal and critical water years to sustain the salmonid populations in the Tolt River system.

The establishment of instream flow requirements is needed to regulate the amount of water within the Tolt River system to protect instream resources. Ideally, the allocation of water within a stream should provide for a combination of instream values, including fish and wildlife populations, aesthetics, hydropower generation, recreation, water quality, and navigation. To this list may be added flows necessary for "ecosystem maintenance," as suggested by Bayha (1978) and Wassenberg et al. (1979), which includes freshwater inflow to estuarine areas, riparian vegetation, and floodplains. The value of these instream resources must frequently compete with various offstream water requirements, notably agricultural, industrial, and domestic needs.

The long-standing efforts of fisheries biologists to assess the impact

of human activities on fish populations and their habitat have received fresh impetus from the recent recognition of instream resources within the legal and institutional framework (Dewsnup 1976, Bradley 1976). Methodologies have been developed and refined to identify instream flow requirements, primarily those of economically important fish species, as a means of assessing the effects of flow regulation on the aquatic community. The methods are numerous and varied (see reviews by Prewitt and Carlson 1979, Stalnaker and Arnette 1976, Wesche and Recharad 1980, Loar and Sale 1981); however, most seek to provide a biologically sound basis for the recommendation and adoption of acceptable instream flow requirements.

An incremental simulation approach relating stream flows and habitat structure to the carrying capacity of streams has recently been developed by the Cooperative Instream Flow Service Group (IFG) of the U.S. Fish and Wildlife Service. This methodology was specifically designed to quantify the impact of alternative flow regimes upon fishery habitat potential, expressing the effects through changes in a habitat index value for each species, life stage, and stream discharge of interest. The results of the IFG analysis conducted in this study are intended for use as a decision-making tool in negotiating water allocations and proposed stream flow alterations in the Tolt River.

4.0 DESCRIPTION OF STUDY AREA

The Tolt River watershed lies approximately 40 miles east of Seattle on the west slope of the Cascade Mountain range in north central King County. The lower Tolt River from the confluence with the Snoqualmie River to the confluence of the north and south forks upstream extends for a distance of 8.81 miles (Williams et al. 1975). The average annual discharge for the mainstem Tolt River at USGS gage 12-1485 (Figure 1) is 599 cfs (USGS 1979). The entire mainstem Tolt River is accessible to anadromous salmonids. Stossel Creek is the principal tributary entering the mainstem Tolt River at river mile 8.3; however, eight additional smaller tributaries enter the mainstem, adding runoff to the lower river.

The river valley broadens from the forks downstream. The upper section of the streambed is comprised mostly of large rubble and boulders with limited areas of gravel and a fast riffle character. The lower five mile section is confined between setback levees which allow the river to meander. Channel splitting and overflow side channels occur along with increased gravel deposition in the lower reaches.

The North Fork Tolt River is the larger of the forks with an average annual discharge at USGS gage 12-1475 (Figure 1) of 367 cfs (USGS 1979). This study was confined to the lower 4.59 miles of the North Fork at a waterfall which defined the upstream limit of anadromous fish access. This section of river is characterized by a steep gradient with numerous falls, cascades, and rapids in a deep ravine-canyon. The lower two miles exhibit pools and riffles with a boulder and large rubble substrate (Williams et al. 1975).

The South Fork Tolt River had an average annual discharge of 198 cfs (USGS

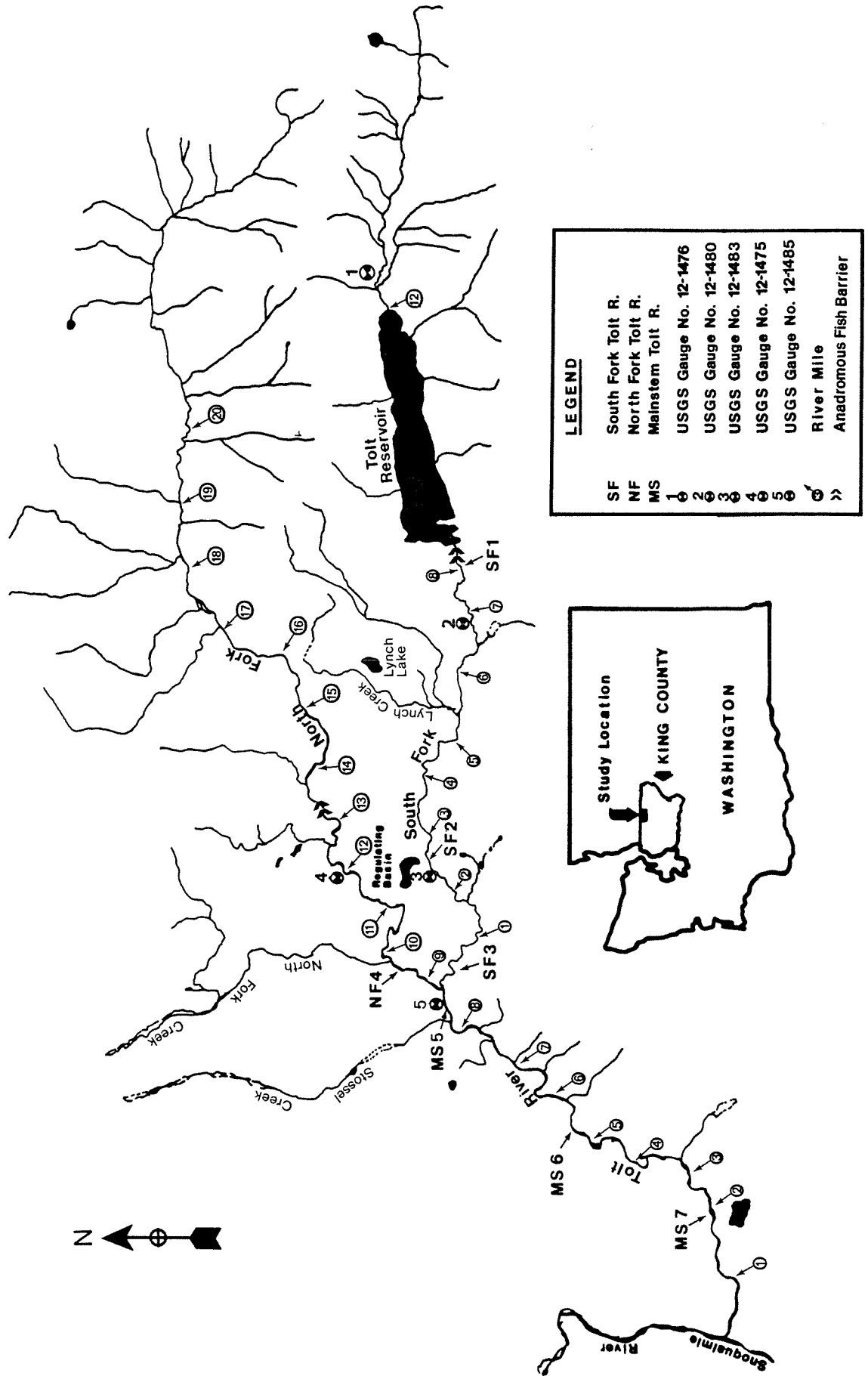


Figure 1. Tolt River study area showing sampling stations, river mile locations, and USGS gages.

1979) during the 11-year period 1953-63 prior to the construction of the Tolt Reservoir (capacity 57,830 acre-ft) by the Seattle Water Department. During 1979 the Seattle Water Department diverted an average daily discharge of about 83 cfs from the South Fork above gage 12-1480 (Fig. 1) to a regulating basin downstream for municipal and industrial water supply.

The South Fork considered in this study extended 7.95 miles from the forks to a large waterfall a short distance below the Tolt Dam. The stream is characterized by a moderately steep gradient, with fast riffles and some cascades (Williams et al. 1975). The river passes through a canyon between R.M. 2.5-3.5. The bottom is predominately rubble and boulders with limited patches of gravel.

During March 1976 a massive slide occurred on the South Fork at approximately R.M. 7.5 which temporarily occluded the stream channel. A study of slide impacts by Pfeifer and Fletcher (1976) found high sediment loads in spawning areas and reduction in macroinvertebrates and young-of-the-year salmonids. This slide continues to be a major potential source of sediment in the South Fork and mainstem along with other smaller instabilities along the valley walls. During high runoff, riverbed and bank erosion also contribute sediment to the river.

Seven river reaches were selected for this study. Three were located on the South Fork, one on the North Fork, and three on the mainstem. South Fork Station 1 was a reach extending 148 yds from the upper edge of the slide at RM 7.85. South Fork Station 2 (RM 2.50) included a reach 101 yds long located in the canyon at the proposed hydroelectric discharge site. South Fork Station 3 was a reach 134 yds long sited at RM 0.30 above the confluence with the North Fork. The single North Fork Station 4 was

located at RM 9.70, where the river entered a riffle-pool area below the canyon. This reach was 155 yds long. The three mainstem stations (5, 6, and 7) were located at RM 8.60, 5.40, and 2.50, and were 298, 326, and 246 yds in length, respectively.

n

The study reaches will be designated as SF1, SF2, SF3, NF4, MS5, MS6 and MS7 for South Fork Station 1, South Fork Station 2, South Fork Station 3, North Fork Station 4, Mainstem Station 5, Mainstem Station 6 and Mainstem Station 7 throughout the remainder of the text.

5.0 MATERIALS AND METHODS

5.1 Discharge, Temperature, and Suspended Sediment

Streamflows in the Tolt River system are continuously measured by the United States Geological Survey (USGS) at four permanent gaging stations (Figure 1). The inflow to the South Fork is monitored at gage 12-1476 above the reservoir. A second South Fork gaging station (12-1480) is located at RM 6.8, approximately 1.5 miles below the Tolt dam. The North Fork gage (12-1475) is positioned 3 miles upstream from the confluence with the South Fork. Mainstem Tolt River discharge is measured at gage 12-1485, located immediately downstream of the confluence of the two forks, and approximately 0.25 miles upstream of the mouth of Stossel Creek. Daily streamflow records from each of the above-mentioned gaging stations were obtained from the USGS WATSTORE system and analyzed for differences in the magnitude and timing of discharge fluctuations in the three river segments during the 1981 annual water year.

Stream temperatures were monitored in the South Fork, North Fork, and mainstem Tolt River over the duration of the project using continuously recording Ryan thermographs buried in the streambed at SF3, NF4, and MS5. The temperature record considered in this report includes data obtained during the first seven months of the project (June through December 1981). Exceptionally high streamflows in late December washed out the North Fork thermograph and the 4-foot-long steel bar to which it was secured; consequently, the data for the preceding three months were lost. Stream temperature records for the South Fork, North Fork, and mainstem Tolt River were analyzed for differences in diel and seasonal temperature fluctuations.

Suspended sediment samples were obtained from each of the river segments

on a seasonal basis to characterize the relationships between sediment concentrations, flow conditions, and sampling locations. Integrated suspended sediment samples were collected at 5 to 10 foot intervals along single transects at each station using a hand-held USGS DH-48 sampler. The sampler is designed to accumulate a water-sediment sample from each transect vertical by lowering and raising the sampler over the depth of the water column at a constant rate. Water depths and velocities (measured at 0.6 of the water depth) were recorded at each vertical immediately prior to sample collection. Water samples were stored in polyethylene containers and returned to the laboratory for analysis. The total non-filterable residue (TNFR), including organic and inorganic fractions, for each sample was determined by filtering a 200-ml subsample through a pre-dried and weighed 4.25 cm diameter glass filter. After drying and weighing the filter again, the difference between the two weights was multiplied by 5 to express the TNFR concentration in $\text{mg}\cdot\text{l}^{-1}$. In this study TNFR is considered synonymous with suspended sediment concentration.

The mean suspended sediment concentration determined for a given cross section was multiplied by the discharge at each transect to compute the suspended sediment discharge for the sampling location. Suspended sediment discharges were evaluated for differences between stations and sampling dates.

Stream discharge, temperature, and suspended sediment data will continue to be collected during the 1982 field season. A more complete description of the influence of these parameters on salmonid populations and their associated habitat in the Tolt River will be presented in the final report.

5.2 Substrate Composition

In order to assess the spatial and temporal variability in the quality of spawning substrate in the Tolt River system, gravel samples were obtained during the summer, autumn, and winter months at each station. Three replicate samples were taken per station on each date using a manually operated core sampler, shown in Figure 2, commonly known as a McNeil sampler (McNeil and Ahnell 1964). The locations from which gravel samples were taken were selected to represent the optimal spawning habitat found at each of the stations. All of the gravel sampling sites were subsequently observed to be utilized by spawning salmonids. The SF1 sampling site is probably used as a spawning area; however, this was not confirmed since spawner surveys did not include the uppermost reach of the South Fork.

Within the sampling area at each station, gravel samples were removed at approximately 1.0 meter intervals proceeding in an upstream direction. Water velocities and depths were measured at each sample location. Care was taken to avoid disturbing the streambed prior to sampling. The McNeil sampler is circular in cross-section and removes a core 15.24 cm in diameter and 20.32 cm deep. A plunger was used to capture suspended sediment in the tube after the coarse material had been removed by hand. All samples were collected by a single individual to avoid operator selectivity. Individual samples were placed in 5-gallon buckets lined with plastic bags and returned to the laboratory for analysis.

Laboratory procedures included sieving the samples through a graduated series of Tyler screens in order to separate particle size groups, and measuring the volumetric displacement of the material retained on each sieve,

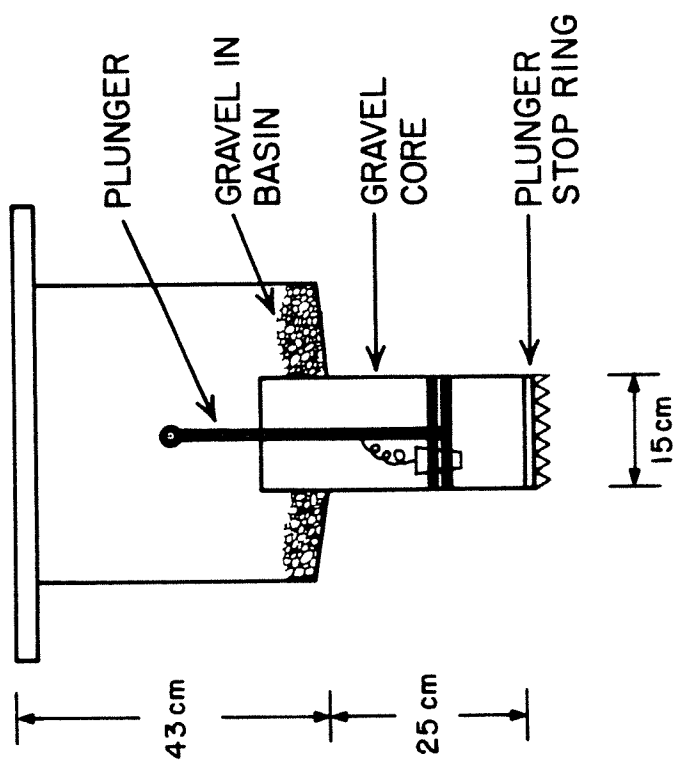
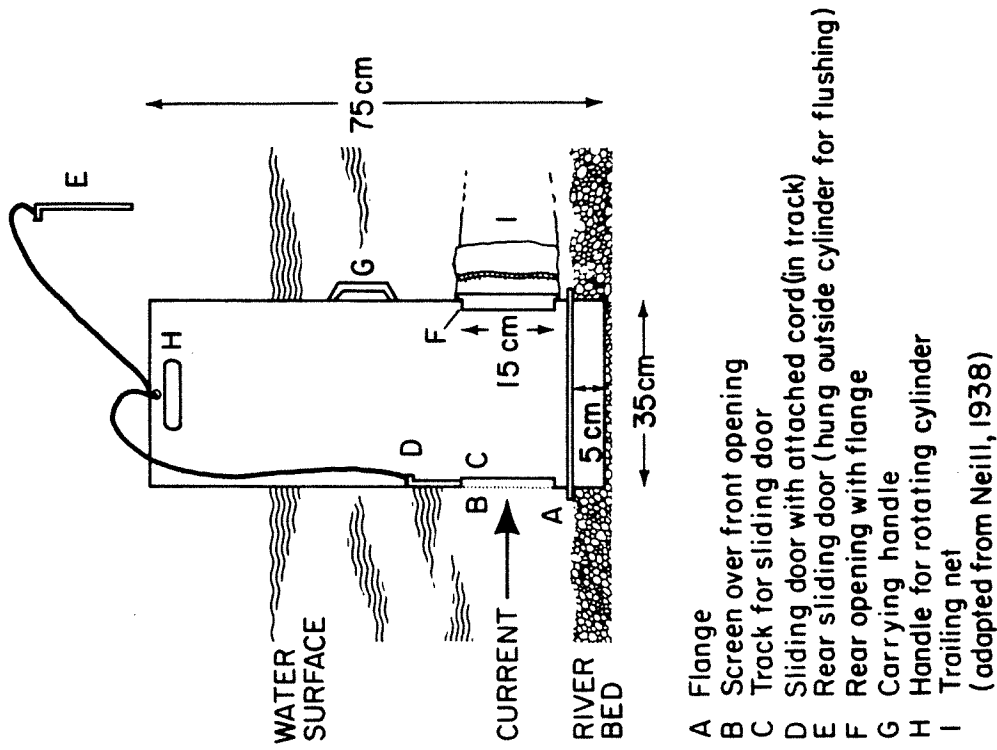


Figure 2. McNeil gravel sampler (left) and Neill cylinder (right) (from Cederholm et al. 1978).

as described in Scott et al. (1982). The data collected by the volumetric method were converted to dry weights and analyzed by least squares linear regression (Shirazi and Seim 1979) to obtain statistical parameters suitable for describing the textural composition of the gravel samples. The computer program SEDIMENT (FRG-367), written by Gales and Swanson (1980), was used to perform the regression analysis. The substrate statistics generated by SEDIMENT include the percentage of fine material less than 0.841 mm in diameter and the geometric mean (d_g) of the particle distribution for each sample. The percent fines and d_g statistics are related to the porosity and permeability characteristics of the gravel, which in turn directly influence the survival of salmonid embryos and alevins (Wickett 1958, Cooper 1965). Thus, these parameters are potentially adequate measures of substrate quality as it affects embryo survival.

The percentage of fines and d_g of the samples were analyzed for differences between stations and samples using analysis of variance techniques. Sampling depths and velocities were regressed against percent fines and d_g to determine if these variables influenced substrate composition.

5.3 Biological Components

5.3.1 Macroinvertebrates

5.3.1.1 Benthos

The benthos was sampled using a Neill cylinder (Neill 1938). The Neill cylinder was selected because it excludes most drift organisms and samples a uniform area. Artificial substrate samplers were rejected as too costly and labor-intensive. The Neill cylinder (Fig. 2) samples an area of $1,000 \text{ cm}^2$ at a maximum water depth of 70 cm. Its primary features include

a .25 mm mesh net secured to the downstream opening and a screened upstream opening which allows current to flow through into the net.

Benthic samples were taken at all seven stations during the three periods sampled. Three replicates were taken at each station on each date. Benthos was sampled adjacent to the spawning substrate sample sites for the following reasons: 1) water depths and velocities were suitable for sampling; 2) spawning gravel provided near-optimal invertebrate habitat due to high porosity and intragravel water flow; and 3) spawning substrate had a relatively uniform composition. The latter two probably resulted in a more uniform distribution of macroinvertebrates than in extremely heterogeneous habitats and may result in decreased sample variances.

The water depth and velocity was measured at each site immediately prior to sampling the benthos. The Neill cylinder was pushed 5 cm into the substrate with both apertures open to allow dislodged organisms to be carried into the net. The surface layer of the substrate within the sampler was washed free of organisms and removed for particle size analysis. The remaining substrate within the cylinder was then stirred to a depth of 10 cm with the outflow aperture closed to avoid introducing excessive substrate into the net. The outflow aperture was opened after the coarse sand had settled. The stirring process was repeated twice, followed by flushing. The benthos sample was then removed and preserved in 95 percent ethyl alcohol.

Invertebrates were sorted from debris in the laboratory. All insects were identified to family. Members of the orders of Ephemeroptera, Plecoptera, and Trichoptera were identified to genus. Length measurements of all insects were made to calculate weights from length/weight relationships.

Brillouin's Diversity Index (H) was calculated for each sample at the family level using the following equation (Brillouin 1962):

$$H = \frac{1}{N} \ln \frac{N!}{N_1! N_2! \dots N_i!}$$

where N = the total number of individuals in the sample

N_i = the number of individuals in taxon i

This index was chosen over others because it calculates the exact diversity of the sample (Kaesler and Herricks 1977) instead of estimating the population diversity. Other indices involve the estimation of population parameters which require unreasonably large sample sizes.

5.3.1.2 Drift and Salmonid Food Habits

Drift organisms were sampled to study the correlation between drift rates and salmonid diets. Drift samples were taken for 24 hours preceding electrofishing using a modified Miller sampler. Salmonid diets were sampled by stomach flushing with a syringe equipped with a large blunt needle. The analysis of drift and diet samples is incomplete and will appear in the final report.

5.3.2 Historical Records

Records of hatchery plants, catch estimates, and spawner surveys pertaining to the Tolt River system were obtained from the Washington Department of Fisheries (WDF) and the Washington Department of Game (WDG). These data were compiled to elucidate the historical fisheries management information on the system.

5.3.3 Spawner Surveys

Periodic spawner surveys were conducted on the South Fork, North Fork, and mainstem Tolt River commencing in May, 1981. Mainstem surveys were conducted by boat while both forks were surveyed on foot. Skin diving of the deeper pools of the mainstem and South Fork in the summer and autumn months greatly increased survey effectiveness. The data collected on each survey included 1) a description of weather and visibility conditions; 2) number, location, and species of adult salmonids observed; 3) number, location, and age of redds observed; and 4) incidental information (e.g., condition and sex of live and dead spawners, when possible).

The entire mainstem Tolt River was surveyed on each float trip. The lower 150 meters of Stossel Creek were walked on several occasions to document spawner use of this tributary. River sections containing representative amounts of holding and spawning habitat were chosen as index survey areas on the North and South Forks. The North Fork was surveyed from the USGS gage at RM 11.4 (immediately upstream of an apparent anadromous fish barrier) to RM 9.4, where it entered a small canyon area .7 RM above the confluence. The South Fork was surveyed from the bridge at RM 6.3 to RM 3.7, where the South Fork canyon starts. Occasional surveys were made outside of the index areas to document the usage of these areas by spawning steelhead and salmon.

5.3.4 Fish Population Assessment

Fish populations were sampled at all study sites in July and September 1981. Fish collection was accomplished with the simultaneous use of two Smith-Root backpack electroshockers at SF1, SF2, SF3, and NF4. Because the

mainstem stations were too deep to sample with backpack shockers, a model VVP-15 Coeffelt Electronics boat electrofisher was used. When streamflows permitted, block nets were used to eliminate emigration and immigration within the study area. High flows in July caused the nets to clog with debris and wash-out before sampling was completed. To reduce set-up time a natural fish barrier (e.g., the downstream end of a riffle) was utilized as the upstream terminus of the sampling area. Two or three electrofishing passes were made at each site as time allowed.

Following each pass, the captured fish were identified to species. Scale samples were obtained from a subsample of each species. Fork length measurements were taken on all fish to the nearest millimeter. Wet weights were measured to the nearest 0.1 gram using a triple-beam balance.

The removal method (Zippin 1956) was used to estimate the population size of each species. Separate estimates were made for the three juvenile steelhead age classes present. The following catch-effort formulae were used, depending on the number of passes made:

Two-pass method (Seber and LeCren 1967):

$$N_E = \frac{n_1^2}{(n_1 - n_2)}$$

where n_1 = catch on first pass
 n_2 = catch on second pass.

Three-pass method (Junge and Libosvářský 1965):

$$\hat{N}_E = \frac{6x^2 - 3xy - y^2 + y(y^2 + 6xy - 3x^2)^{\frac{1}{2}}}{18(x - y)}$$

with

$$x = 2n_1 + n_2$$

$$y = n_1 + n_2 + n_3$$

Length-weight regressions were calculated for each species to estimate mean weights. Separate regressions were required for July and September data due to seasonal changes in the relationship of length and weight. These equations were applied to fish for which weights were not obtained. The biomass of a given species/age group was calculated by adding the total wet weight for the collected fish in the species/age group to the estimated wet weight of uncollected fish. The mean weight of the species or age group was used to estimate the wet weight of uncollected fish. The biomass estimates for the three age classes of steelhead trout were summed to give total population estimates for each station. All other species were treated as a single cohort. Numerical and biomass estimates for the various species and steelhead age classes were divided by the surface area measurement of the station for which they were calculated to arrive at density ($N \cdot m^{-2}$) and standing crop ($g \cdot m^{-2}$) estimates. The total stream surface area electrofished at low flow for each station was determined from surveying data which had been analyzed by synagraphic mapping (SYMAP computer program) techniques.

5.3.5 Angler Surveys

Five questionnaire boxes were constructed and placed at various fishing access points in the Tolt River drainage (Appendix A, Fig. 1). A map of the river was mounted on the face of each box along with a brief description of

the Tolt River Study objectives and instructions (Appendix A, Fig. 2) for completing each questionnaire. The map was divided into six localities to enable anglers to identify the area fished.

The boxes were in place by June 19, 1981. Two of the boxes, located at the confluence of the two forks and at the end of the Tolt River Road, have accounted for most of the returns. The angler survey was used to supplement data from creel census and spawner surveys to arrive at seasonal estimates of total use and catch by species in the different reaches of the river. A request for scale samples from successful anglers was included with modified instructions last fall. Coin envelopes were made available in each box for the placement of scales identified by species, date, fish length, and location caught.

5.4 Instream Flow Analysis

5.4.1 Methodology

The IFG incremental methodology of instream flow assessment uses several computer programs, collectively called PHABSIM (Physical HABitat SIMulation system) to model various elements of open channel hydraulics and fish behavior. A discussion of the theory and applicability of PHABSIM is found in Milhous (1979). The basic assessment process consists of several steps: 1) selection of study areas on the basis of the critical reach or representative reach concept; 2) field measurement of depth, velocity, and substrate composition along multiple transects within a study area; 3) hydraulic simulation of the spatial distribution of combinations of these parameters; 4) application of species-specific suitability functions (i.e., habitat suitability criteria) which give the likelihood of a given species/

life stage being found in association with a particular flow or hydraulic condition; and 5) calculation of a Weighted Usable Area (WUA) value — an index of habitat availability, for each species/life stage and discharge of interest. The calculation of WUA roughly equates the area of suboptimal fish habitat within the study reach to an equivalent area of optimal habitat.

In applying the IFG analysis it is assumed that the stream channel remains unchanged while conveying the natural streamflows being simulated and during the time intervals between field sampling sessions. Further assumptions specifically related to this study are that the habitat parameters of depth, velocity, and substrate are the major determinants of fish distribution, that individuals of a species respond directly to changes in these parameters, and that the multivariate function used to calculate WUA correctly assumes that the effects of the parameters are independent of each other.

5.4.2 Study Site Selection

The study sites selected for instream flow analysis on the Tolt River included without exception the locations at which fish population estimates were obtained. For the sake of convenience, the station names designated earlier in this report will remain unchanged, although the study reaches sampled using the IFG method were 2-5 times longer than the electrofished sections of stream.

In regard to the instream flow study, the seven study sites depicted in Figure 1 were selected on the basis of accessibility, representativeness of the associated river segment, and sensitivity to existant and proposed alterations to the natural flow regime. The first criterion, accessibility,

was an important factor due to the remoteness and precipitous terrain of large stretches of the Tolt River. The scarcity of access points and the necessity of transporting unwieldy equipment to the study reaches precluded a strictly randomized approach to field sampling. Within this framework, however, study sites were chosen which reflected the hydraulic conditions and habitat types found in the associated river reach. Numerous foot, snorkel, boat, and plane surveys have confirmed the general representativeness of the selected study areas. From field survey notes and the inspection of large-scale aerial photographs, the actual linear distance represented by each station was calculated, allowing the extension of results obtained from the study reaches to all segments of the Tolt River used by anadromous fish.

From a consideration of the influence of the Tolt Reservoir operations and the potential impacts of the proposed hydroelectric project, a study reach (SF2) was established in the vicinity of the proposed powerhouse discharge site on the South Fork Tolt River. This study site also accurately reflects habitat conditions within the 1.75 mile-long canyon reach of the South Fork.

Only one study site was selected on the North Fork Tolt River, compared to three sites each on the South Fork and mainstem Tolt River. The North Fork is an unregulated stream, although its historical discharge has been altered by extensive timber removal in the upper areas of the watershed. The gross habitat features of NF4 are not entirely representative of the section of the North Fork used by anadromous fish since the station is located in a more open channel segment than is found within the canyon-walled sections of the river. Hence, the extrapolation of instream flow results to the entire North Fork should be undertaken with caution.

The location of the study reaches and the criteria used in their selection were collectively approved by FRI, Water Department, and City Light biologists prior to the initiation of field sampling.

5.4.3 Field Procedures

Application of the IFG-4 hydraulic simulation model requires positioning multiple transects within a study reach to adequately distinguish both its hydraulic and habitat features. The number of transects used in this study varied from 5 to 7 depending on the overall complexity of the sampling reach. Following procedures described in Bovee and Milhous (1978) and Trihey (1980), the transect located at the downstream end of each reach was positioned at a hydraulic control, defined as an inflection in the slope of the water surface indicating a stage-discharge relationship. Transects were placed at all of the hydraulic controls at each station with the exception of one control each at mainstem stations 5 and 7. The exceptions were made due to the foreseen hazard of sampling under high flow conditions. In these two instances the transects were moved slightly downstream into the head of the pool. The remaining cross-sections at each station were positioned to define the major habitat types prevailing within the study reach. Care was taken to ensure that all transects lay perpendicular to the direction of stream flow.

The endpoints of the transects were delimited by permanent wooden headstakes driven into the ground above the high water mark of the channel. Headstakes were referenced to a permanent benchmark using differential levelling and planimetric mapping techniques. The reach length between cross-sections was determined by averaging the distance between adjacent right and left stream banks (i.e., the intersection of transect with edge

of water) under low flow conditions. With respect to the benchmark established at each station, bed elevations were measured to the nearest 0.01 feet at 3-foot intervals from the right bank headstake.

The hydraulic information necessary to calibrate the IFG-4 model was collected from June through December, 1981, at relative low, intermediate, and high discharges. Water surface elevations were determined at the right and left stream margins of the cross sections at each of the calibration flows as prescribed by Bovee and Milhous (1978). If the elevations from both sides of a transect were unequal, an average value was calculated for the transect. Water velocities were measured in the stream channel at the same equidistant verticals for which bed elevations were obtained. The number of wetted data points varied between 9 and 56. A Marsh-McBirney Model 201 electromagnetic current meter and a six-foot top setting wading rod were used for velocity measurements. The accuracy of the current meter was periodically checked during the field season against known velocities in an experimental flume at the Harris Hydraulics Laboratory of the University of Washington. All velocity measurements were taken at 0.6 times the total depth of the associated vertical.

Wading conditions were generally unsafe at intermediate and high discharges at the North Fork and mainstem Tolt River stations, necessitating the use of a six-man capacity raft to traverse the river. The raft was attached by a rope and pulley system to a 1/4-inch steel cable which was winch-tightened immediately upstream and parallel to the transect tape. While one operator stabilized the raft in a position slightly downstream and to the side of the vertical being measured, a second individual obtained the requisite water velocity measurement beneath the transect tape.

It is imperative that the river stage does not change significantly while collecting data at a study reach for a given calibration flow. For this reason, a permanent staff gage made of 1 1/4 inch PVC pipe was installed at each study site. The water surface elevation measured by the staff gage was checked regularly to verify that the discharge remained constant during data collection. On two occasions a complete set of hydraulic measurements could not be collected in a single day. In these cases, the remaining data were obtained at the earliest opportunity at an identical river stage.

The manner of assessing the substrate composition at the study reach transects differed slightly from standard procedure. At each vertical along a transect, including left and right bank headstake positions, the three most dominant particle size classes were classified using Bovee and Cochnauer's (1977) substrate scale (Table 1) and ranked in descending order. The streambed area evaluated for substrate extended halfway to the adjacent verticals and 3 feet up and downstream from the transect. The predominant particle size class within this imaginary cell was multiplied by a factor of 0.5 and the two less prevalent size classes were multiplied by 0.25. The sum of the three products was used as the substrate value for that vertical. Substrate characteristics were recorded during low-flow periods at all stations.

5.4.4 Hydraulic Simulation and the Prediction of WUA

The PHABSIM application of the IFG-4 model to a study reach requires two or more sets of transect data collected under distinctly different flow regimes in order to obtain a reliably calibrated model. In this study, three calibration discharges were sampled per station. The IFG-4 program uses

Table 1. Substrate classification criteria.

IFG index value		Modified Wentworth scale particle size (diameter)	
		Metric	English
9	Undefined	—	—
8	Bedrock	—	—
7	Boulder	250 mm and larger	9.8 in and larger
6	Large cobble	130 to 250 mm	5 to 9.8 in
6	Small cobble	64 to 130 mm	2.5 to 5.1 in
5	Coarse gravel	32 to 64 mm	1.3 to 2.5 in
5	Medium gravel	8 to 32 mm	0.25 to 1.3 in
5	Fine gravel	2 to 8 mm	0.08 to 0.3 in
4	Sand	0.062 to 2 mm	0.002 to 0.08 in
3/2	Silt/clay	< 0.062 mm	< 0.002 in
1	Detritus	Decaying vegetation material	—

the hydraulic data to calibrate individual stage-discharge and velocity-discharge relationships at each vertical along the transects in a study reach. The results are extrapolated to an imaginary cell extending midway to the nearest verticals (or to the adjacent stream bank) and a variable distance up and downstream depending on the hydraulic conditions represented by adjacent transects. The study reach, therefore, may be viewed as a matrix of rectangular cells, each having a particular combination of depth, velocity and substrate characteristics. The program then calculates transect discharges for each set of calibration measurements, indicating various measures of the reliability of the model in the printed output. When the model has been calibrated to give velocity adjustment factors in the range of 0.9 to 1.1, and relatively few velocity prediction errors, it is suitable for use as a predictive tool (Milhous et al. 1981).

The primary value of the calibrated IFG-4 model lies in its ability to predict discharges and associated hydraulic parameters outside the range of observed (calibration) flows. Bovee and Milhous (1978) recommend extrapolating no further than 0.4 times the minimum discharge measured and 2.5 times the maximum calibration flow. These guidelines were adopted in the present study.

A second computer program, HABTAT, computes the WUA values for each species-life stage over the range of discharges simulated using the depth, velocity, and substrate data predicted by the hydraulic model. The habitat simulation program accesses an information base in the form of habitat suitability functions (curves) for each of the physical parameters. Habitat suitability functions have been constructed for more than 50 fish species of up to 5 life stages each, numerous taxa of stream macroinvertebrates, and

for recreational activities such as swimming, fishing, and boating. The curves used in this study were accessed from a binary file of species criteria termed FISHFIL, which is maintained and supported by the U.S. Fish and Wildlife Service on the University of Washington CDC computer.

For a given discharge, the calculation of the WUA for a particular species/life stage in a study reach involves computing the composite habitat suitability (\hat{S}_i) for each rectangular cell using the equation

$$\hat{S}_i = D(S_d) \cdot V(S_v) \cdot S(S_s)$$

where D, V, S = predicted depth, velocity, and substrate values for the i^{th} cell

S_d, S_v, S_s = weighting factors obtained from the habitat suitability curves.

The composite habitat suitability is then multiplied by the total surface area of the associated cell (A_i), and all $S_i \cdot A_i$ products are summed for the study reach to give the WUA as shown by the following equation:

$$WUA = \sum_{i=1}^n \hat{S}_i \cdot A_i$$

where n = the total number of cells within the study reach.

Most evidence presented in the literature to date supports the validity of using the IFG-4 and HABTAT model combination to simulate habitat availability as a function of discharge. The WUA value, however, should not be interpreted as a direct measure of the carrying capacity of a stream since

it does not incorporate other important environmental factors which influence aquatic productivity. Water quality and food limitations, in particular, may be more important than physical habitat in controlling population densities under moderate flow conditions. In regard to the analyses performed in this study, changes in WUA are considered an index of the availability of physical habitat at varying streamflows.

5.4.5 Procedures to Derive Instream Flow Recommendations

The process used to develop instream flow recommendations for the Tolt River consisted of the following steps:

- 1) simulation of a range of discharges at each study site to determine WUA values for each species/life stage;
- 2) calculation of combined WUA indices for each species/life stage for the South Fork, North Fork, and mainstem Tolt River by extrapolating individual study reaches to the associated river segment;
- 3) identification of discharges for the various species/life stages on the basis of the peak habitat efficiency values (i.e., the discharge (Q_E) associated with the maximum percentage of WUA) and the maximum habitat availability values (i.e., the discharge (Q_M) resulting in the maximum WUA);
- 4) combination of Q_M and Q_E flow information and stochastic projections of monthly discharge based on historical records to determine minimum flow recommendations for each species/life stage during normal and critical water years;
- 5) selection of salmonid life stages and species to be given preferential consideration in the determination of instream flow recommendations; the preference assigned was based on criteria such as numerical abundance, sensitivity to habitat perturbation, and critical or limiting periods of

life history; and

6) recommendation of alternative minimum and critical water year instream flows for the South Fork, North Fork, and mainstem Tolt River utilizing the results of steps 1 through 5.

It should be noted that utilization of both interpretations of the method (Q_E and Q_M) will lead to a low set and a high set of instream flow recommendations for each river segment.

In order to calculate combined discharges for all of the species/life stages known to inhabit the South Fork and mainstem Tolt River, it was necessary to estimate the proportion of the entire river represented by each of the study reaches. The South Fork and mainstem Tolt River were each partitioned into three segments of varying length on the basis of habitat inventory surveys and aerial photograph analysis. The length of the river segments and their gross habitat characteristics are described in Table 2. The total distance in feet of each segment was divided by 1000 (WUA is expressed in units of $\text{ft}^2/1000$ linear feet of stream) to obtain an extrapolation factor for each study reach. For all simulated discharges determined for South Fork Stations 1-3 and mainstem Stations 5-7, the WUA's predicted for each station were multiplied by that station's extrapolation factor. The summation of these products indicated the combined WUA for the South Fork and mainstem Tolt River, as well as the Q_M for each species/life stage.

The peak habitat efficiency for a given species/life stage was determined from the relationship between WUA and gross surface area available at the simulated discharges. The Q_E for each life stage was identified by the discharge which provided the highest WUA to gross surface area ratio (i.e., the peak habitat efficiency) within the range of discharges evaluated.

Streamflow records for the Tolt River have been collected over the time

Table 2. Reach characteristics used to partition the South Fork, North Fork, and mainstem Tolt River for study area representation.

Study area	Length of reach represented (miles)	Extrapolation factor	Reach description
SF1	3.8 (RM 4.1 - RM 7.9)	20.3	Reach boundaries are large, impassable falls located 0.1 mile above SF1 and ravine/canyon terrain below. Moderate to steep gradient; large rock and cobble substrate with fair amount of patch gravel. Good pool: riffle ratio. Banks unstable, particularly in vicinity of a large landslide at RM 7.4. Lynch Creek, a major tributary, enters at lower end of reach.
SF2	1.8 (RM 2.4 - RM 4.1)	9.2	Precipitous terrain; bedrock canyon walls. Moderately steep to steep gradient with deep pools, cascades, and fast riffles. 1:1 pool to riffle ratio. Heavily shaded. Good spawning gravels at tail end of pools, but subject to displacement at high flows.
SF3	2.4 (RM 0.0 - RM 2.4)	12.4	Valley broadens slightly. Moderate to steep stream gradient. Cobble and boulder substrate predominate with patch strips of gravel. Banks stable except in lower 0.5 mile of reach, where clearcutting has occurred. Fallen trees and debris dams common. Some channel braiding in lower reach.
NF4	4.6 (RM 8.8 - RM 13.4)	24.8	Steep gradient in upper canyon section; moderate to steep gradient over lower two miles. Large falls at RM 13.4 denies fish passage; smaller falls at RM 10.8 restricts access. Deep pools and cascades prevail in reach above bridge and in lower 0.25 mile. Mid-reach contains good pool:riffle ratio and fair to good spawning habitat. Some natural bank instability occurs. North Creek enters at RM 9.7, 0.1 mile below NF4.

Table 2. Reach characteristics used to partition the South Fork, North Fork, and mainstem Tolt River for study area representation (continued).

Study area	Length of reach represented (miles)	Extrapolation factor	Reach description
MS5	1.3 (RM 7.5 - RM 8.8)	6.3	Deep pool at confluence but fast riffles and rapids predominate in reach. Localized spawning gravels near USGS gage and mouth of Stossel Creek (RM 8.6); patch gravels elsewhere. Moderate gradient with large rock and cobble substrate. Riparian vegetation changes from second-growth conifer/deciduous mix to mostly deciduous below. Banks stable.
MS6	3.2 (RM 4.3 - RM 7.5)	16.6	Similar to MS 5 reach but larger river characteristics prevail with increased tributary inflow. Moderate gradient; cobble and boulder substrate; gravels suitable for spawning along stream margins and at tails of three large pools in mid to lower section. Minor slide activity and channel splitting in localized areas. Single-family residential land use from RM 6.0 downstream; land development increasing.
MS7	4.3 RM 0.0 - 4.3)	23.0	River channel broadens; gradient and prevailing substrate size are reduced relative to MS6 reach. Cobble and gravel areas provide widely distributed areas suitable for spawning. Rapids confined to shorter sections, deep glides are common, pool habitat is less defined. Channel braiding and overflow channels are common, as are riprap and earthen levees in the lower reach. Land development includes residential, pasture land, and rural farming.

Table 3. Streamflow data used in the Tolt River Fisheries Study.

Gage No.	Gage name	Source	Period of record
12-1475	North Fork	USGS	Oct 1952 - Dec 1963 Nov 1967 - Present
12-1476	South Fork Index	USGS	Dec 1959 - Dec 1963 Nov 1967 - Present
12-1480	South Fork Carnation	USGS	Oct 1952 - Dec 1963 Jun 1969 - Present
		R.W. Beck Simulated	Oct 1928 - Sep 1952 Jan 1964 - May 1969
12-1485	Tolt River	USGS	Aug 1928 - Jan 1932 Sep 1937 - Present
		R.W. Beck Simulated	Feb 1932 - Aug 1937

periods shown in Table 3. Summary statistics of the discharge data for these time periods were provided by the USGS Water Resources Division office in Tacoma, Washington. The primary flow statistics considered in this study were monthly mean discharges and monthly mean discharge exceedance probabilities based on Log-Pearson III analysis. Streamflow data collected prior to the construction of the South Fork Tolt Reservoir dam (1952-1963) were analyzed separately from data collected in subsequent years (1969-1982).

The optimum flow determined for a given species/life stage is of interest only for the time interval that the life stage is present in the Tolt River. The spatial distribution and relative abundance of salmonids utilizing the Tolt River was ascertained from published and unpublished sources, and from information obtained from seasonal stream surveys and fish sampling activities. Of particular use was a phenology chart defining the timing of salmon and trout fresh-water life phases in the Snohomish Basin which was compiled by the Pacific Northwest River Basins Commission (1970). A general phenology chart for salmonid species (except for mountain whitefish) known to use the Tolt River is shown in Figure 3.

5.4.6 Post-Project Effects

The construction and operation of the proposed powerhouse on the South Fork Tolt River will result in an alteration of the flow regime both upstream and downstream of the proposed discharge site. Average and peak daily discharges in the diversion reach can be expected to decline, resulting in reduced but more stable streamflows. The segment of the South Fork below the discharge site will probably experience greater fluctuations in discharge on a daily basis when compared to existing conditions. This conclusion seems valid even though the powerhouse will not be operated as

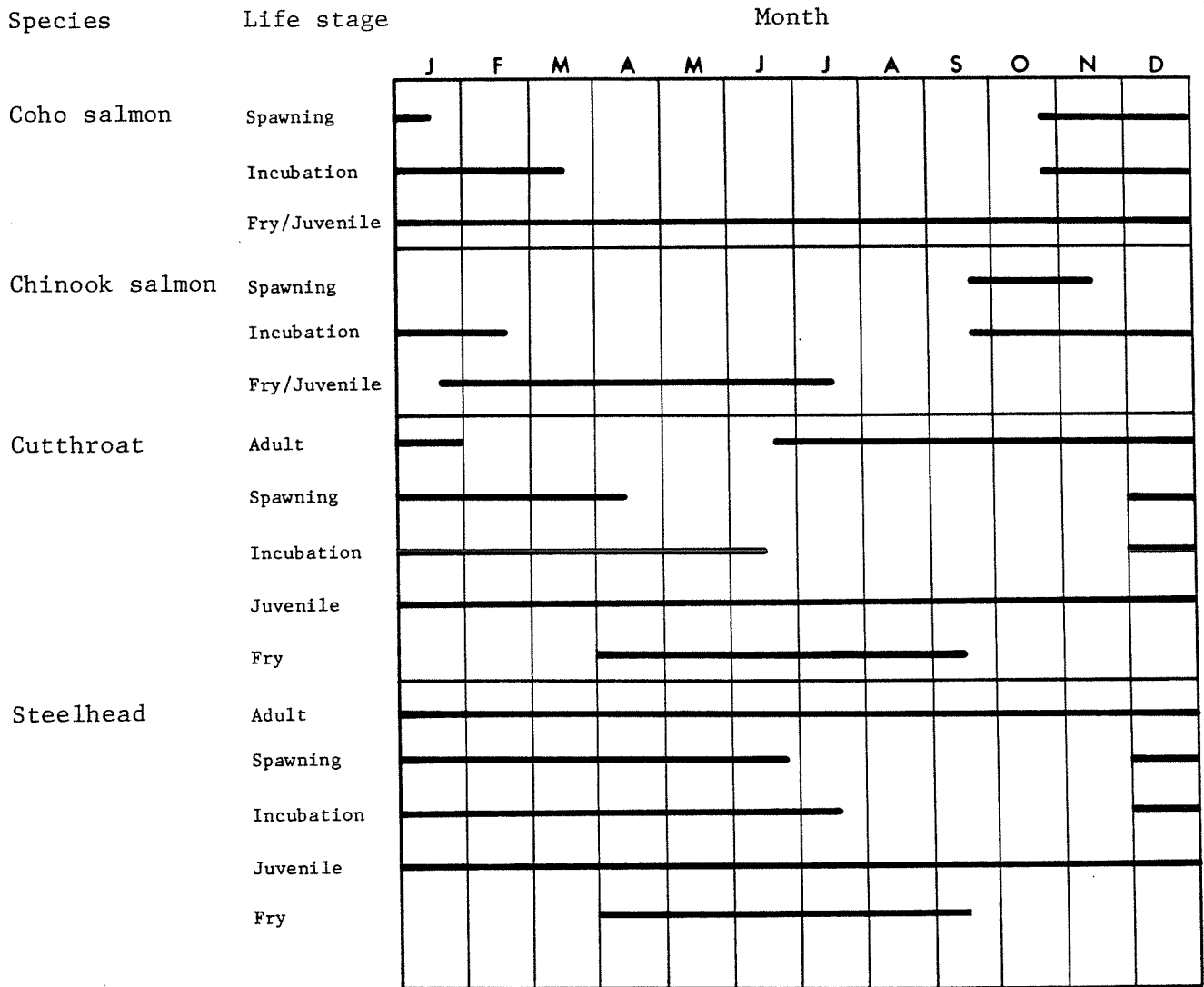


Figure 3. Phenology chart for salmonid species/life stages utilizing the Tolt River.

a peaking facility (Seattle City Light, Draft SEPA EIS, 1980). The overall volume of water delivered to the mainstem Tolt River by the South Fork will not change unless water diverted for municipal and industrial (M & I) supply is increased from present levels.

Alterations in the flow regime due to project operation will result in changes of the physical habitat in the upper and lower South Fork. The instream habitat response to prolonged periods of reduced stream flows in the river reach above the discharge site was investigated by comparing WUA values for monthly mean discharges calculated from pre- and post-dam construction streamflow data, and from discharge projected for the post-project period. The latter flows (Table 4) were generated by a computer simulation program developed by R. W. Beck and Associates (1980) which mathematically modeled the operation of the South Fork Tolt Reservoir system, including the proposed hydroelectric generation facility. Historical and reconstituted daily flows into the reservoir for the period October 1927 to September 1978 were used as the primary input. Several operating criteria, including monthly fishwater release requirements, served as constraints to the model. The rule to determine whether the normal or critical fishwater releases defined in the Water Department's existing diversion permit was based on reservoir water level. When the reservoir content was between the power rule curve and the critical rule curve, the normal instream flow requirements were met. A critical instream flow release was made when the reservoir content fell below the reservoir critical rule curve.

A modification of the existing instream flow requirements, as informally agreed to by the Water Department and the WDOE in 1980, was incorporated into the simulation model. The release of water to meet the WDOE

Table 4. Simulated monthly streamflows (cfs) for the South Fork Tolt River at USGS gage 12-1480 using post-project operating criteria. Data are from R. W. Beck (1980).

YEARS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	AVG
1928	60	97	83	116	77	69	73	80	38	35	35	44	67
1929	54	54	54	54	54	38	38	38	34	35	35	37	43
1930	38	38	47	49	52	54	54	54	35	35	30	30	43
1931	40	54	44	40	41	46	54	54	35	35	30	30	43
1932	41	54	54	60	56	126	83	83	83	61	35	44	65
1933	54	83	135	112	65	54	54	69	83	35	35	44	71
1934	70	142	172	621	96	69	77	60	35	35	35	43	121
1935	45	77	83	150	97	54	54	54	35	35	35	44	64
1936	54	54	54	54	54	54	54	78	83	35	35	44	54
1937	54	54	54	54	49	53	54	54	35	35	35	44	48
1938	54	70	83	83	63	54	54	54	35	35	35	44	55
1939	49	54	61	83	69	54	54	54	83	54	35	44	58
1940	54	75	83	67	60	71	56	37	35	35	35	44	55
1941	48	54	54	54	54	50	38	38	25	28	35	30	41
1942	52	54	66	58	54	54	54	40	34	35	35	44	48
1943	48	54	82	76	54	54	56	62	77	35	35	44	56
1944	54	54	76	74	54	54	54	54	35	35	35	44	57
1945	54	55	76	77	67	54	54	67	59	35	35	44	62
1946	56	83	83	83	55	54	54	73	85	42	35	44	62
1947	54	76	83	83	80	54	69	66	66	40	35	44	62
1948	60	89	106	89	61	54	54	76	69	36	35	44	89
1949	70	83	83	81	66	54	74	78	83	35	35	44	68
1950	60	79	83	83	189	63	54	54	35	35	35	44	68
1951	65	83	83	55	54	54	54	54	35	35	35	44	52
1952	53	70	83	55	54	54	54	54	35	35	35	44	55
1953	54	47	46	65	138	55	54	54	35	35	35	44	55
1954	54	61	104	84	83	55	54	54	45	58	35	44	61
1955	65	77	83	65	67	54	54	54	64	70	40	44	61
1956	65	124	107	83	59	54	54	65	83	54	35	44	69
1957	62	83	86	83	75	55	54	54	35	35	26	44	59
1958	54	54	63	83	83	55	54	54	35	35	35	44	52
1959	48	66	83	241	68	65	122	89	89	50	35	44	84
1960	107	222	247	74	74	54	54	89	59	35	35	44	88
1961	54	82	82	78	77	76	69	77	48	38	35	44	63
1962	54	79	77	110	69	54	48	39	25	27	35	44	55
1963	54	59	83	74	54	54	54	54	35	35	35	44	83
1964	54	54	80	83	60	54	54	55	131	66	40	44	65
1965	70	81	83	81	83	63	54	54	35	35	35	44	60
1966	54	54	54	73	55	54	54	54	61	55	35	44	54
1967	56	83	83	199	83	60	54	54	35	35	35	44	69
1968	54	71	83	83	83	65	59	65	53	35	35	44	61
1969	67	83	83	83	57	54	54	54	35	35	35	44	56
1970	65	76	74	74	74	73	54	54	35	35	35	44	63
1971	54	54	62	81	83	67	54	72	83	72	35	44	63
1972	57	83	83	83	83	207	70	83	81	66	35	44	81
1973	54	58	76	83	61	54	54	49	33	35	35	30	51
1974	43	54	68	80	83	68	83	83	122	73	35	44	70
1975	54	54	68	80	83	54	54	54	35	35	35	44	55
1976	57	83	232	148	80	54	54	61	65	54	35	44	81
1977	54	59	79	79	54	54	54	54	35	35	33	44	52
1978	54	54	81	72	54	54	54	52	34	29	25	34	50
56	73	85	95	70	58	60	54	42	34	42	34	42	61

requirements established in 1979 served as a criterion when power was being generated from water in excess of the City's M & I water supply needs. This situation occurred when the reservoir content was above the power rule curve.

Project impacts on the physical habitat in the section of the South Fork below the discharge site will depend in part on the rapidity and severity of streamflow fluctuations caused by powerhouse operations. City Light has stated that "most of the time the project would generate energy with a flow regime not significantly different from present operation" (DRAFT SEPA EIS 1980). Insufficient data exist, primarily with regard to ramping rates, to test the validity of this statement. No attempt was made in this study to analyze the effects of ramping rates on the physical habitat or aquatic community in the South Fork and mainstem Tolt River.

6.0 RESULTS

6.1 Discharge, Temperature, and Suspended Sediment

The South Fork, North Fork, and mainstem Tolt River hydrographs for the 1981 cycle year are shown in Figure 4. Peak runoff in the lower South Fork is dampened relative to the flow into the reservoir. On several occasions, particularly during the autumn months, the discharge measured at the upper gage exceeds streamflows recorded downstream of the dam. The maximum discharge recorded for the South Fork was 1130 cfs on April 29. The minimum flow measured at the upper gage was 2.7 cfs on August 16; the lowest daily discharge recorded at the lower gage was 29 cfs over a 5-day interval in late August.

Streamflows in the North Fork and mainstem Tolt River show identical patterns over the 12-month period. Peak flows occurred in February and April, with a maximum discharge of 3930 cfs recorded on April 29 at the mainstem Tolt River gage. Minimum flows occurred in mid-September in both rivers.

Stream temperature data, although incomplete for the North Fork, indicate substantially higher mean daily temperatures in the regulated stream (Figure 5). Average water temperatures in the mainstem Tolt River reflect the mixing of South and North Fork discharges. Diel fluctuations in water temperature are greatest in the South Fork and mainstem during the summer months. The North Fork daily range in temperature rarely exceeded 0.5°C; fluctuations of less than 0.2°C were frequently recorded.

Peak temperatures occurred in July in the South Fork, and in August in

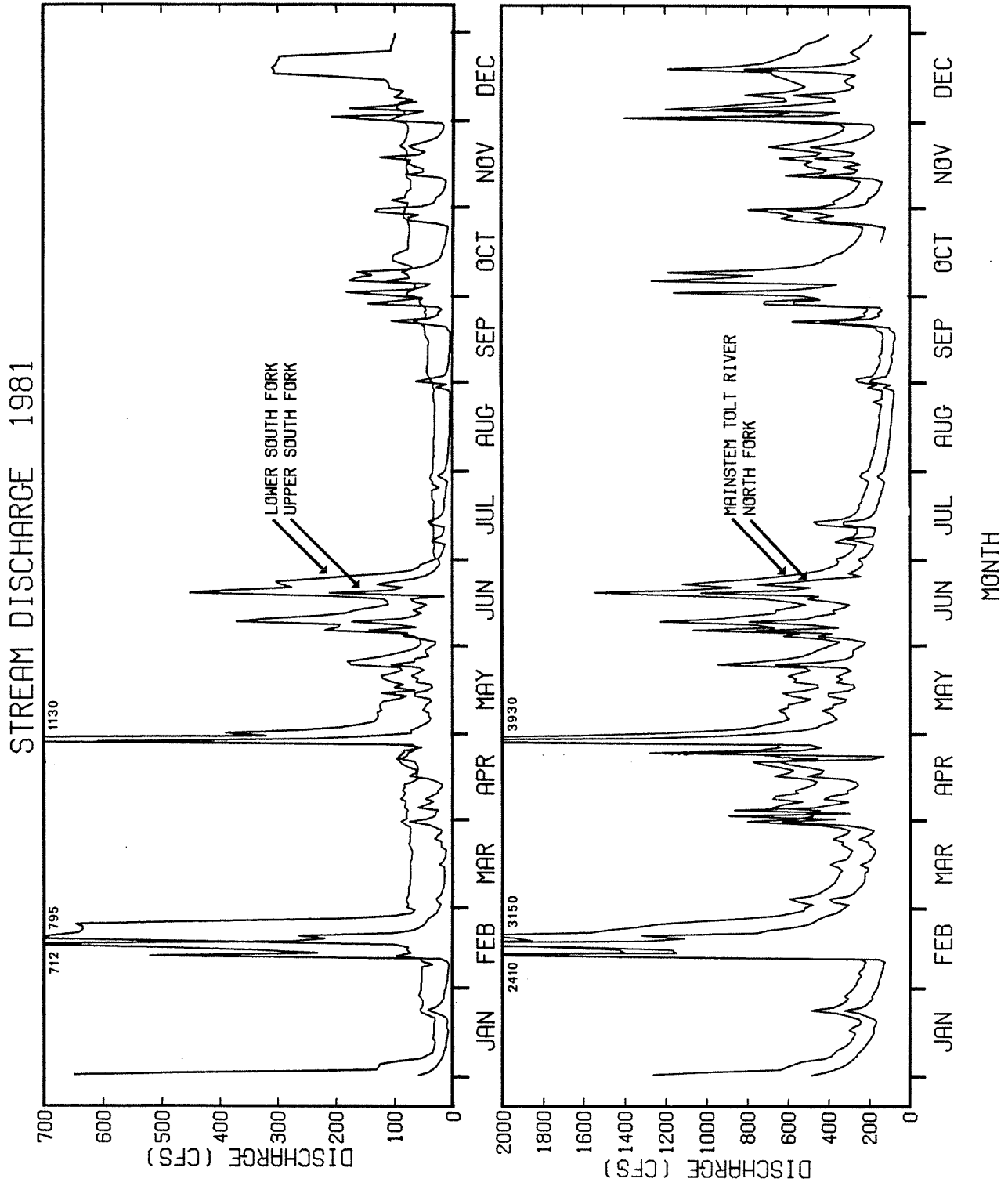


Figure 4. USGS recorded discharge at the upper South Fork (12-1476), lower South Fork (12-1480), North Fork (12-1475) and Tolt River (12-1485) gages during 1981.

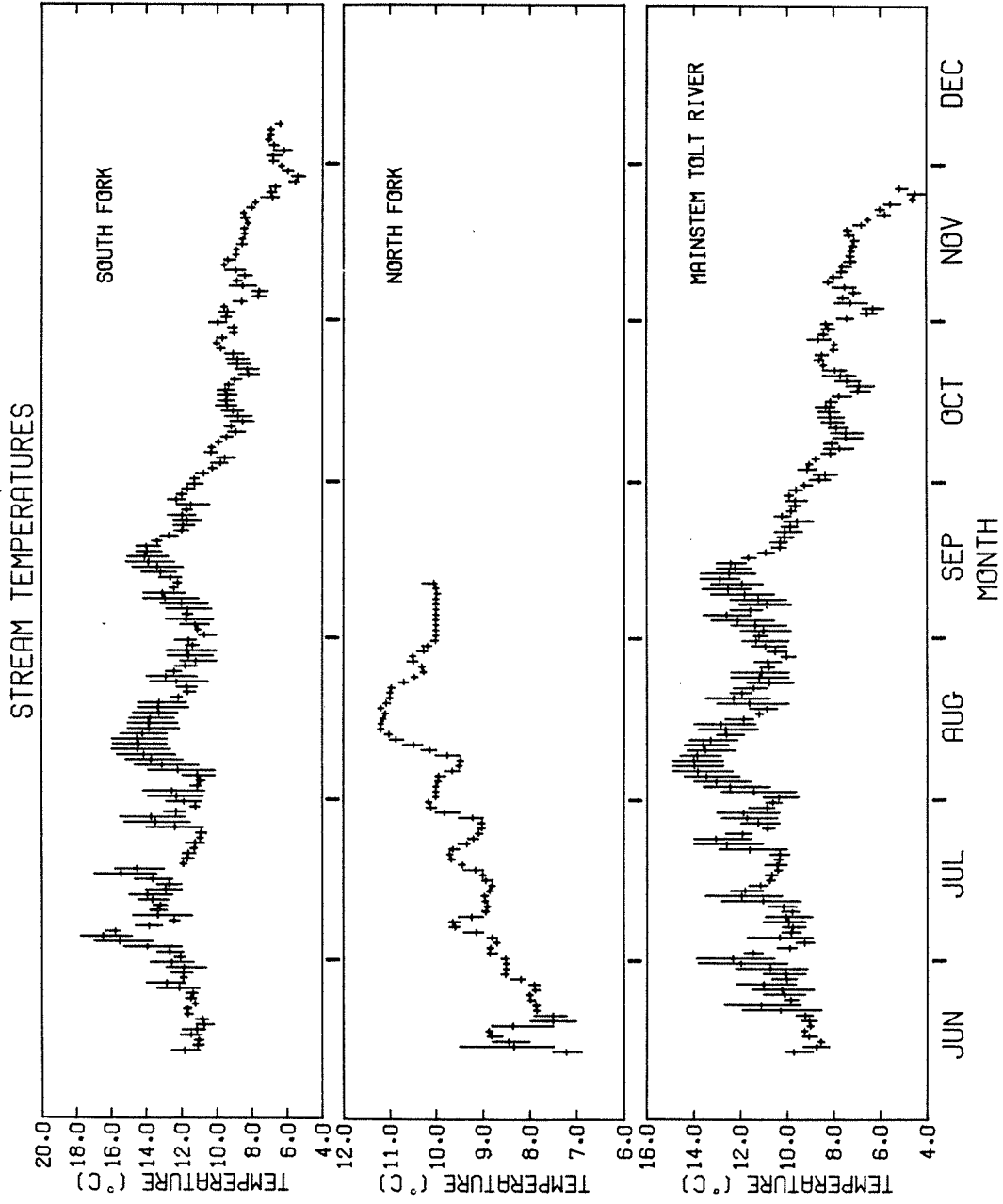


Figure 5. Daily ranges and means for stream temperatures recorded in the South Fork, North Fork, and mainstem Tolt River in 1981.

the North Fork and mainstem Tolt River. Temperature minima were measured in late November for the South Fork and mainstem; however, the annual minimum temperature probably occurs sometime during the winter months.

The average suspended sediment concentrations calculated for individual transects at the study areas for three sampling dates are tabulated in Table 5. Also listed are the streamflows measured at the transects and the instantaneous sediment discharges, expressed in terms of grams of suspended sediment per second. At low flows suspended sediment concentrations range from $1.01 \text{ mg} \cdot \text{l}^{-1}$ at MS6 to $3.48 \text{ mg} \cdot \text{l}^{-1}$ at SF1; there is no apparent pattern to the longitudinal distribution of suspended sediment concentrations in the Tolt River at reduced discharges. Samples obtained on July 13 were collected during the descending limb of a storm hydrograph. Suspended sediment concentrations increased relative to low-flow concentrations at all stations except SF1. During the winter high-flow periods, if the December samples are assumed to be typical, sediment concentrations increase at all stations. North Fork suspended sediment concentrations were generally higher than South Fork concentrations on all dates sampled. Suspended sediment at the mainstem stations did not necessarily reflect the combined contribution of sediment from the South and North Forks, suggesting that the processes of deposition and scouring are active within the system. The highest instantaneous sediment discharges were measured at the lower mainstem stations due to the observed increase in the volume of water conveyed through these reaches.

Table 5. Mean suspended sediment concentrations, instantaneous stream discharges, and sediment discharges measured at the Tolt River study areas on three dates.

	Sampling dates	Station						
		SF1	SF2	SF3	NF4	MS5	MS6	MS7
Suspended sediment concentration ($\text{mg}\cdot\text{l}^{-1}$)	7/01/81	3.48	1.14	1.27	1.72	1.06	1.01	2.71
	7/13/81	1.71	3.81	3.40	8.86	-	11.23	6.38
	12/05/81	-	4.46	5.53	14.25	-	15.68	14.45
Instantaneous discharge Q (cfs)	7/01/81	25.62	65.33	92.67	303.87	402.33	458.54	477.63
	7/13/81	38.32	97.11	124.18	389.89	-	489.11	510.04
	12/05/81	-	141.72	171.70	774.41	-	1021.64	1130.41
Sediment discharge ($\text{g}\cdot\text{s}^{-1}$)	7/01/81	2.55	2.20	3.36	14.93	12.18	13.23	36.98
	7/13/81	1.87	10.56	12.06	98.73	-	156.95	93.03
	12/05/81	-	18.06	27.13	315.36	-	456.69	466.70

6.2 Substrate Composition

The percentage of sediment less than 0.841 mm and the mean geometric diameter (d_g) are presented in Table 6 as mean values for the three replicate gravel samples obtained at each study area. Percent fines were calculated, both directly from the sieve data and by the regression method of Shirazi and Seim (1979). The former values represent volumetric data which have been corrected for water retention bias. The percentage of fine sediments calculated by the regression method is less than the corresponding estimate derived from the sieve data due to the predominance of larger rocks in the samples. The degree of underestimation by the regression technique is proportional to the extent that the particle size distribution is skewed toward larger particles. Although the assumption and results of the regression method are statistically valid, the percent fines computed from the sieve data will be used for comparisons between stations and sampling dates.

The percentages of fine sediment in the samples from the study areas are shown in Figure 6 for the July, September, and February sampling dates. Samples collected in February contained the highest percentage of fines at all stations except MS6. The percent fines in September were less than or equal to July values with the exception of NF4. Samples at the latter station contained the lowest percentage of fine materials of all stations. Only SF1 typically contained a lower percentage of fine materials than other South Fork and mainstem stations. SF1 had lower fines than NF4 on the September sampling date. The quality of the spawning substrate in the South Fork generally decreased in a downstream direction, as evidenced by

Table 6. Mean geometric diameters and percent fines of spawning gravels in the Tolt River system in July, September, and February, 1981-1982.

Mean d_g (mm) based on regression analysis							
	SF1	SF2	SF3	NF4	MS5	MS6	MS7
July	7.55	7.23	8.75	13.40	9.45	17.41	11.52
September	14.61	18.50	8.50	12.49	14.70	14.62	24.99
February	7.79	10.01	8.30	10.51	7.38	11.90	55.82
Mean percent fines < 0.841 mm based on regression analysis							
	SF1	SF2	SF3	NF4	MS5	MS6	MS7
July	6.26	6.99	7.46	4.89	7.07	5.89	6.78
September	5.69	5.33	8.14	6.91	6.79	5.62	6.11
February	7.13	6.15	6.62	5.47	7.71	6.63	5.19
Mean percent fines < 0.841 mm based on dry weights							
	SF1	SF2	SF3	NF4	MS5	MS6	MS7
July	8.1	9.9	10.4	5.5	14.6	10.0	9.8
September	6.3	7.5	10.4	7.5	12.7	7.8	9.8
February	10.4	11.5	13.5	9.3	16.1	9.4	11.7

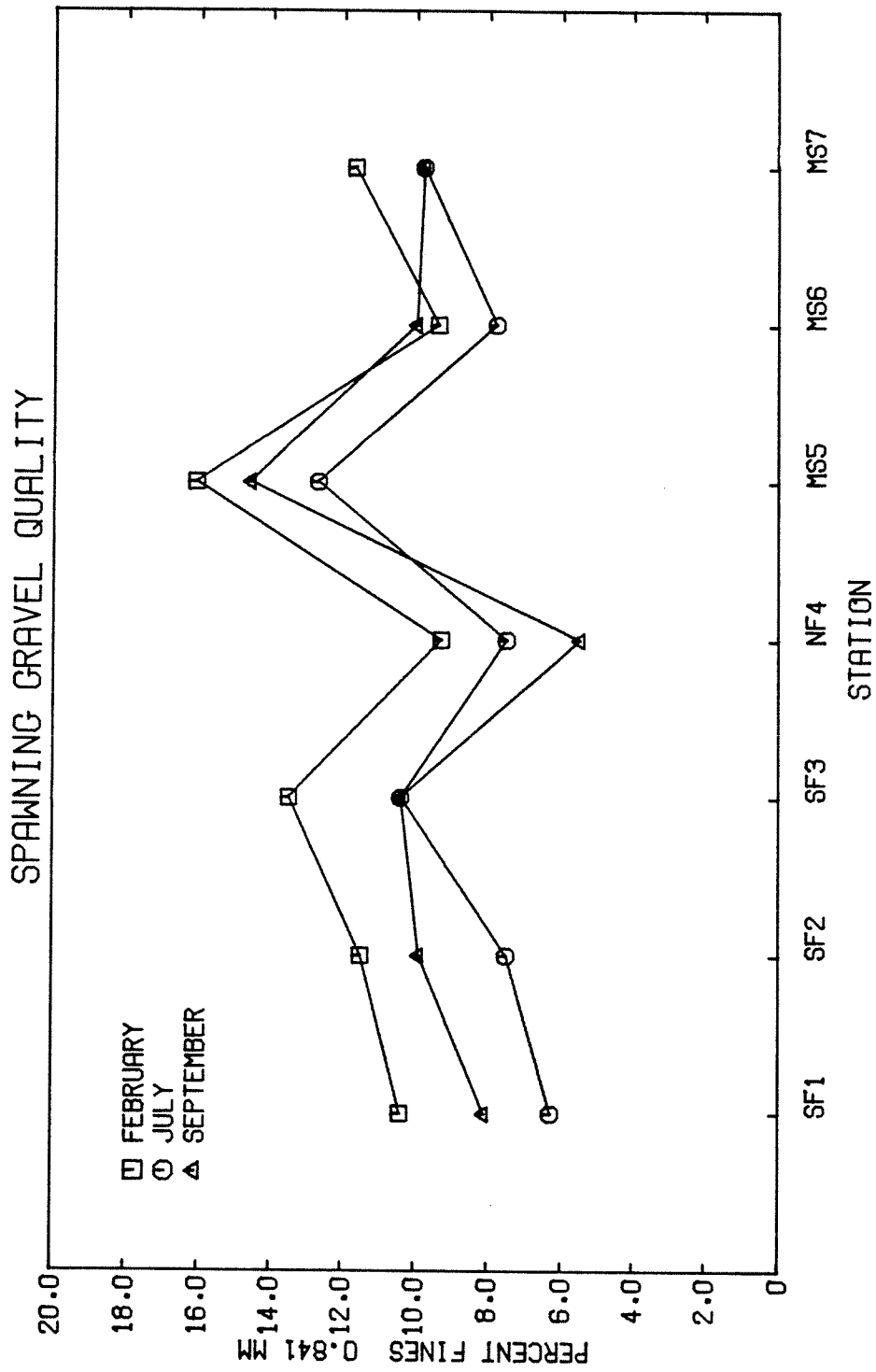


Figure 6. The percentage of fines < 0.841 mm in gravel samples collected during July and September 1981 and February 1982 at each station.

the order SF1 < SF2 < SF3 on all sampling dates. South Fork gravels compare favorably with mainstem Tolt River stations, primarily due to the large percentage of fines obtained at MS5. This station obtained the highest percent fines values on all sampling dates. Of the 63 samples analyzed in total, a maximum value of 17.9 percent (22.7 percent wet volume) was recorded at MS5 (replicate No. 3) in February. The minimum percentage of fine sediment in a sample was 5.1 percent (7.2 percent wet volume), obtained at the North Fork station in July.

Analysis of variance revealed significant differences between stations and sampling dates based on the percent fines. NF4 and MS5, as pointed out above, are the most divergent of stations. The pooled mean percent fines value for the South Fork stations is significantly different from the means of the North Fork ($\alpha < 0.01$) and combined mainstem Tolt River stations ($\alpha < 0.02$). A comparison between the North Fork and mainstem stations also concluded significant differences between sample means on all sampling dates ($\alpha < 0.01$). ANOVA results indicated a significant difference between July

ANOVA results indicated a significant difference between July and February, and September and February, in terms of the level of fine sediments in the gravel samples. A difference between the percent fines in July and September samples was not detected.

Both sample velocity and depth were positively correlated with the percentage of fine sediments present in the gravel samples. The two variables combined accounted for 42 percent of the variation in the level of fines within the substrate.

6.3 Biological Components

6.3.1 Benthic Macroinvertebrates

Thirty-four taxa were identified in the benthos (Table 7). The most abundant taxa for all dates sampled were Chironomidae > Baetidae > Oligochaeta > Chloroperlidae > Heptageniidae. The mean benthos diversity, biomass, and density by station and sampling period are plotted in Figure 7. The numerical values are presented in Table 8.

Statistical comparisons were made between sampling months and stations, and tests for correlation between sample parameters and environmental variables were performed. Due to the high sample variances typical of benthic samples, most tests yielded insignificant results. Increased numbers of samples would improve results at the cost of considerable additional laboratory work.

The biomass and number of organisms per sample (density) were analyzed after natural log (ln) transformation to enable the use of parametric statistics (Elliot 1977). Two-way analyses of variance were performed on density, biomass, and diversity using station and sampling month as factors. Station, date, and interaction effects were significant for all three variables except for density by station, which would probably also show significance given enough samples. The presence of significant interaction effects indicates that the benthos of different stations do not respond to changes in season in a similar manner. This interaction necessitates using data from only one level of one factor when comparing levels of the other factor (i.e., each month's data must be analyzed separately when comparing diversity between stations). Tukey's and Student-Neuman-Keuls tests ($\alpha = .05$) were used to determine differences between

Table 7. Rhithron invertebrates collected from the Tolt River, Washington.

	Total number collected			
	Feb	Jul	Sep	All dates
Arthropoda				
Insecta				
Ephemeroptera				
Ephemerellidae				
<u>Ephemerella</u> sp.	289	40	82	411
Heptageniidae				
<u>Epeorus</u> sp.	1	27	9	37
<u>Cinygmula</u> sp.	51	119	6	189
<u>Rithrogena</u> sp.	585	15	453	1,053
Baetidae				
<u>Baetis</u> sp.	140	1,000	485	1,625
Leptophlebiidae				
<u>Paraleptophlebia</u> sp.	6	107	22	135
Plecoptera				
Nemouridae				
<u>Nemoura</u> sp.	3	0	30	33
Taeniopterygidae				
<u>Brachyptera</u> sp.	19	1	121	141
Capniidae				
<u>Eucapnosis</u> sp.	4	0	0	4
Perlidae				
<u>Acroneuria</u> sp.	4	17	7	28
Perlodidae				
<u>Isogenus</u> sp.	20	26	85	131
<u>Isoperla</u> sp.	0	0	3	3
Chloroperlidae				
<u>Paraperla</u> sp.				
<u>Alloperla</u> sp.	164	502	474	1,140
Trichoptera				
Rhyacophilidae				
<u>Rhyacophila</u> sp.	29	42	15	86
Hydropsychidae				
<u>Arctopsyche</u> sp.	21	2	48	71
Brachycentridae				
<u>Brachycentrus</u> sp.	3	31	3	37
<u>Microesoma</u> sp.	0	3	9	12
Lepidostomatidae				
<u>Lepidostoma</u> sp.	19	20	15	54
Limnephilidae				
<u>Hesperophylax</u> sp.	0	2	0	2
<u>Neophylax</u> sp.	0	2	0	2

Table 7. Rhithron invertebrates collected from the Tolt River, Washington (continued).

	Total number collected			
	Feb	Jul	Sep	All dates
Psychomyiidae				
<u>Polycentropus</u> sp.	0	0	15	15
Glossomatidae				
<u>Glossoma</u> sp.				
Diptera				
Tipulidae	62	71	225	358
Tanyderidae	0	0	3	3
Deuterophlebiidae	0	3	0	3
Psychodidae	1	0	0	1
Simuliidae	6	15	3	24
Empididae	9	71	134	219
Ceratopogonidae	0	1	20	21
Blepharoceridae	0	1	0	1
Chironomidae	195	1,564	4,612	6,371
Coleoptera				
Elmidae	7	99	32	88
Dytiscidae	0	1	2	3
Arachnida				
Acarina	1	22	1	24
Crustacea				
Decapoda				
Astacidae	0	1	0	1
Annelida				
Oligochaeta	375	181	887	1,443

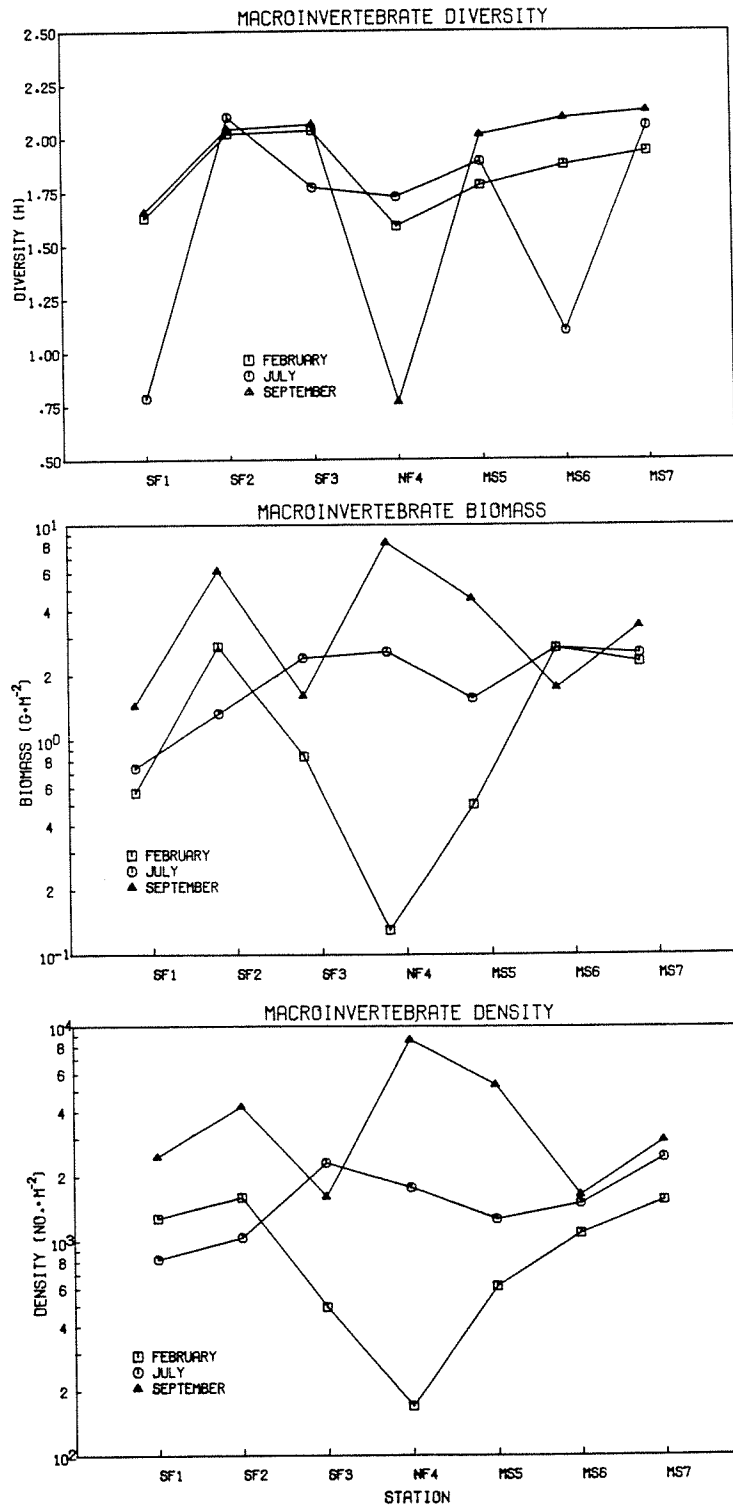


Figure 7. Benthic macroinvertebrate diversity, biomass, and density by station and date (July and September 1981 and February 1982).

Table 8. Macroinvertebrate biomass and density estimates and Brillouin's diversity index values (H) for all stations and sampling periods.

Station	Month	Brillouin's H	Biomass (g·m ⁻²)	Density (g·m ⁻²)
SF1	February	1.24	0.57	1,277
SF1	July	0.63	0.74	823
SF1	September	1.27	1.44	2,473
SF2	February	1.70	2.72	1,600
SF2	July	1.81	1.33	1,037
SF2	September	1.73	6.13	4,233
SF3	February	1.72	0.84	493
SF3	July	1.39	2.41	2,317
SF3	September	1.76	1.61	1,613
NF4	February	1.20	0.13	170
NF4	July	1.34	2.57	1,777
NF4	September	0.62	8.26	8,627
MS5	February	1.40	0.50	617
MS5	July	1.53	1.56	1,267
MS5	September	1.69	4.54	5,336
MS6	February	1.51	2.67	1,090
MS6	July	0.81	2.67	1,503
MS6	September	1.80	1.74	1,643
MS7	February	1.59	2.30	1,557
MS7	July	1.75	2.52	2,463
MS7	September	1.86	3.37	2,947
Average		1.4455	2.4100	2,136

stations and sampling months.

No significant differences in benthic density or biomass were found between sampling months except at SF2, where density was higher in July, and at MS5, where density and biomass were higher in September than in February. Insect density was significantly lower in July than in September and February at SF1 and MS6. At NF4, diversity was lower in September than in the other sampling months.

Differences in all parameters between stations were most pronounced in July. No stations were isolated from all other stations in regard to density and biomass, but several differences were found in the sample means for individual stations. Diversity was lowest at SF1 and MS6 in July, while in September, SF1, NF4, and MS5 were lowest. No significant differences between stations were found for density or biomass in July, or for diversity in February.

Multiple regression analysis was utilized to assess the importance of water depth, velocity, and the mean geometric diameter (d_g) of the substrate on the density, biomass, and diversity of invertebrates. Separate regression equations were determined for each sampling period to avoid the effects of temporally-related biological factors (e.g., recruitment, pupation, and emergence). Regression results are presented in Table 9. Significant correlations were found for depth and velocity but not for mean geometric diameter of the substrate.

Table 9. Results of stepwise multiple regression for Tolt River macro-invertebrates.

Month	Dependent variable	Variable entered	Multiple R ²	Overall significance	Correlation
January	Density	—	—	—	—
July	Density	Velocity	0.19044	0.048	(+)
September	Density	1) Velocity	0.61123	0.003	(-)
September	Density	2) Depth	0.79827	0.001	(-)
January	Biomass	Velocity	0.20600	0.039	(-)
July	Biomass	—	—	—	—
September	Biomass	Velocity	0.26488	0.017	(-)
January	Diversity	1) Depth	0.23369	0.026	(+)
January	Diversity	2) Velocity	0.39846	0.010	(-)
July	Diversity	Depth	0.38125	0.003	(+)
September	Diversity	—	—	—	—

6.3.2 Historical Records

6.3.2.1 Sport Catch

Washington Department of Game steelhead punch card catch estimates from 1962-1980 are shown in Figure 8. Marked fluctuations are indicated in the sport catch of both summer and winter-run steelhead. Summer steelhead catch estimates range from 4 fish in 1962 to 422 fish in 1972, averaging 155 fish annually. Winter steelhead catch estimates are substantially higher, ranging from 173 fish caught in 1970 to 985 fish in 1977. An average of 506 winter-run fish were caught each year. The mean number of winter steelhead caught during the years 1970-80 has decreased by 0.6 percent in comparison with the average number caught between 1962-69. The mean catch of summer-run steelhead, however, has increased 41.1 percent in 1970-80 compared to 1962-69. The average number of winter-run steelhead caught since the 1974 Boldt decision took effect has increased by 26.4 percent over previous years (1962-1974).

Salmon catch estimates from 1964-1980 for the Tolt River are presented in Table 10. The total salmon sport catch reported by the Washington Department of Fisheries has varied from 0 to 57 fish, averaging 14.4 salmon caught per year. Although no strong trend is evidenced for this time period, it is interesting to note that the highest sport catch was recorded in 1978, with 27 chinook, 23 coho, and 7 jacks reported caught. The high variability of the salmon catch estimate suggests that they may be unreliable measures of abundance.

6.3.2.2 Stocking Data

Washington Department of Game planting records for 1956-1981 are presented in Figure 9. Both summer and winter-run steelhead presmolts have

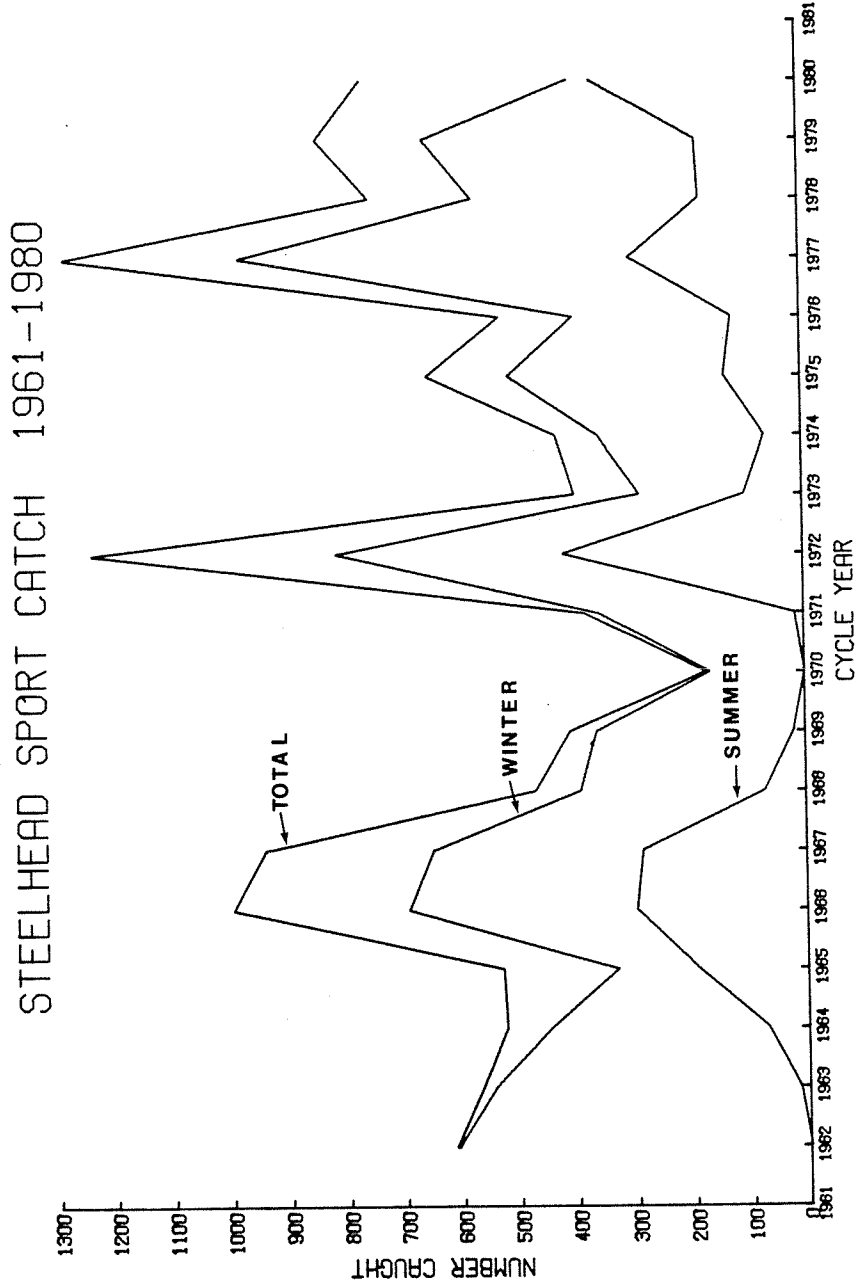


Figure 8. Total, winter-run and summer-run steelhead sport catch for the Tolt River, 1962-1980. Data are derived from Washington Department of Game punch card returns.

Table 10. Tolt River salmon sports catch from punch card returns, 1964-1980.

Species	Year																
	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Chinook										0				0	27	0	0
Coho										2				3	23	0	1
Pink										0	Only total catch reported for 1964-1973		No data	0	0	8	0
Jack										3	1975-1976		13	7	0	2	
Total ¹	0	3	18	23	5	16	16	2	13	28	5		19 ¹	57	8	3	

¹ Total for 1977 includes 3 "other."

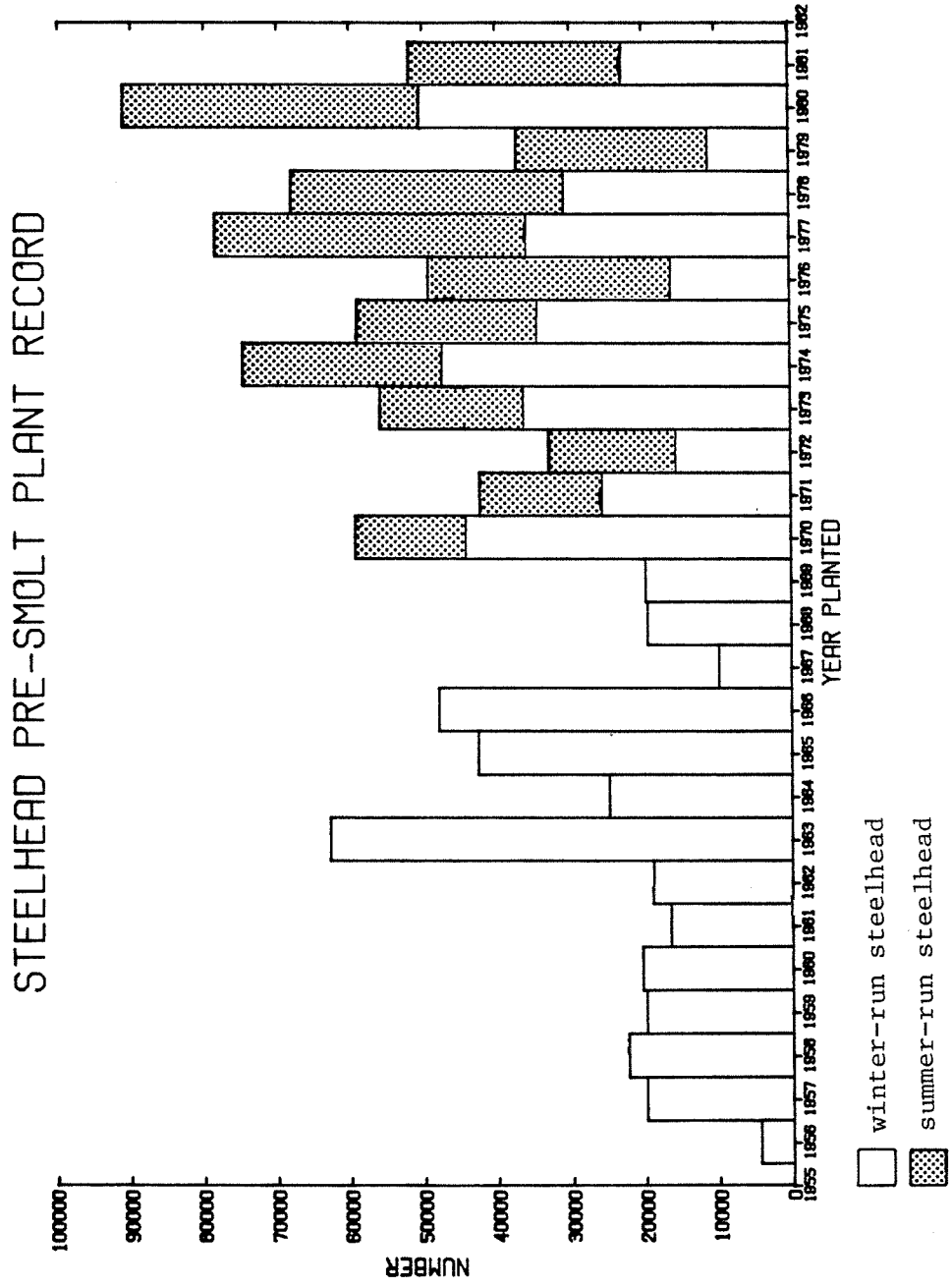


Figure 9. Washington Department of Game summer and winter-run steelhead pre-smolt plant record for the Tolt River, 1956-1981.

been stocked on an annual basis in the Tolt River. Stocking levels have been relatively consistent from year to year, averaging 30,000 summer steelhead and 16,500 winter steelhead annually. Most of the presmolts were raised in the Skykomish, South Tacoma, and Tokul Creek hatcheries. Regardless of hatchery origin, the planted summer steelhead are of Washugal stock and the winter steelhead are of Chambers Creek stock. At present the relative contribution of hatchery-reared fish to the total steelhead escapement in the Tolt River is unknown (Bob Pfeifer, WDG, pers. comm.).

Coho and fall chinook have been planted in the Tolt River by the Washington Department of Fisheries. The fall chinook releases total 1,361,000 fry and 304,000 fingerlings for 4 years in the period 1957 to 1974. Coho have been stocked almost yearly from 1952 to 1972, averaging 69,000 fry, 5,000 fingerlings, and 40,000 yearlings. The racial origin of these plants has not yet been determined.

6.3.2.3 WDF Spawner Surveys

WDF has conducted spawner surveys of the mainstem Tolt River since 1945. Figure 10 illustrates the changes in chinook, coho, and pink salmon spawner abundance over time. Pink counts decreased precipitously in 1955 and have not recovered. Pink counts averaged 272 fish/mile through 1959, decreasing to .1 fish/mile for 1961-1971, with no subsequent sightings. Chum salmon were reported by WEF in 1976 only and sited again by anglers in 1980. Coho counts have remained moderately high in Stossel Creek; however, abundance appears to have declined in the late 1940's. Chinook salmon counts averaged 17.1 fish/mile for 1947-1958, 1.8 fish/mile for 1960-1965, and 0 fish/mile in annual surveys since 1965 (Figure 11). The decline of this species has been most dramatic.

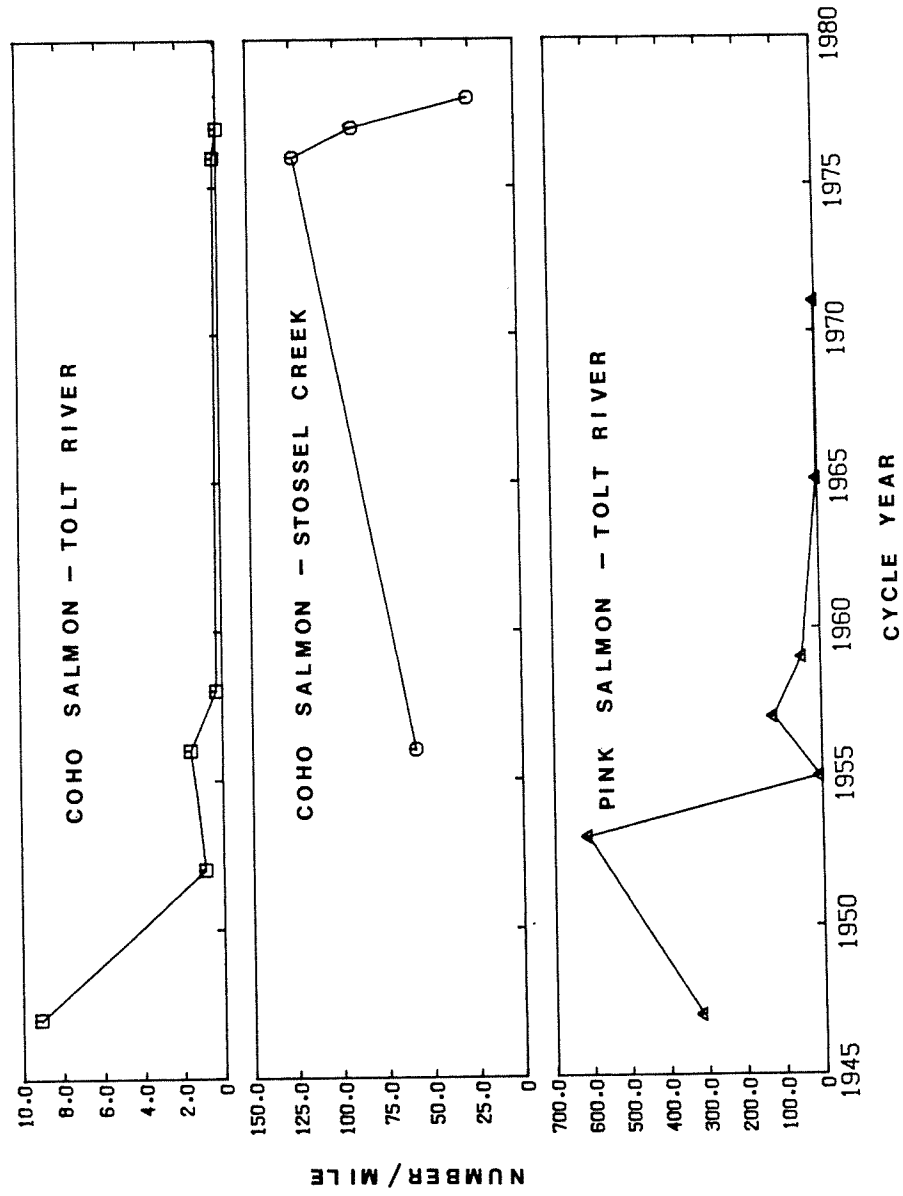


Figure 10. Washington Department of Fisheries coho and pink salmon spawner counts for the Tolt River and Stossel Creek, 1947-1978.

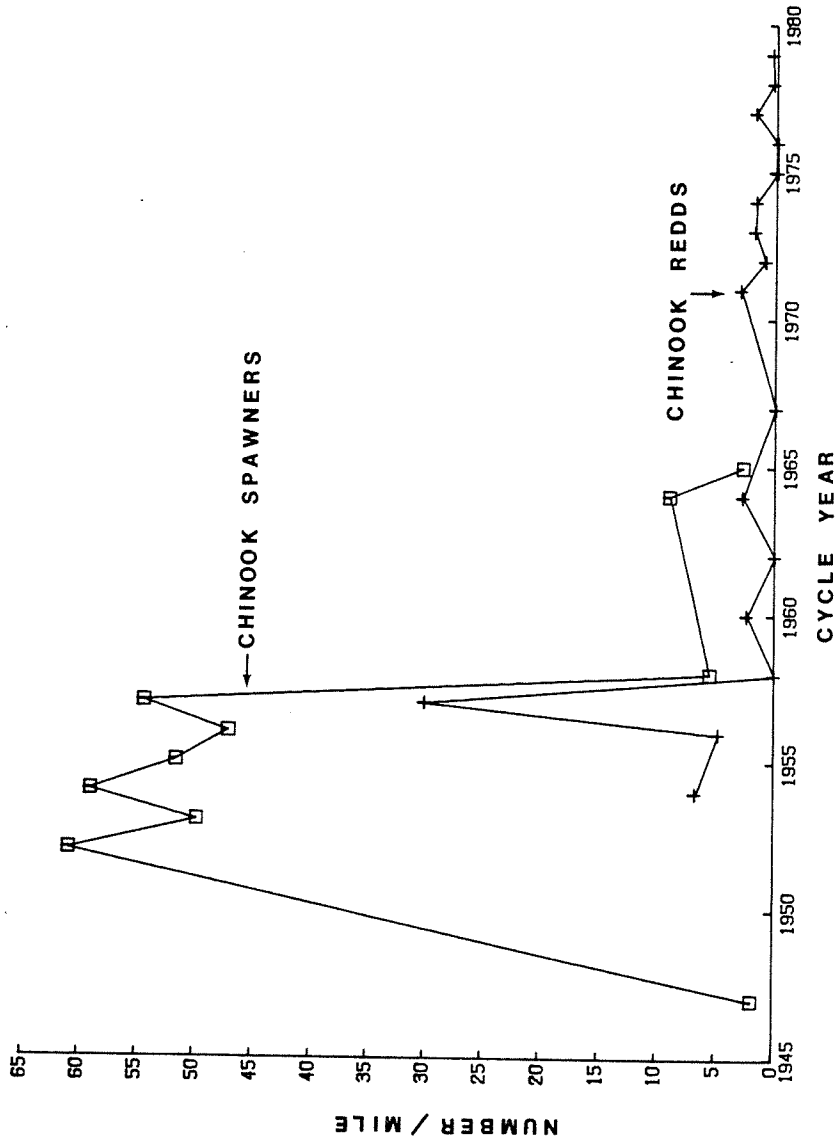


Figure 11. Washington Department of Fisheries chinook salmon spawner and redd counts for the Tolt River, 1947-1978.

6.3.3 Spawner Surveys

Adult steelhead trout were present in the Tolt River during the entire year. Summer-run fish enter the system near the end of the spawning period of the previous year's winter-run population. Survey results for the South Fork, North Fork, and mainstem Tolt River are presented in Tables 11, 12, and 13. The highest numbers of adult steelhead trout were observed in August with the aid of mask and snorkel. Lower counts were obtained during the period of October through February, largely due to decreases in water clarity. The highest number of adult steelhead counted per mile was obtained for the South Fork; however, deep pools in the North Fork and mainstem Tolt River probably contained many more fish than were actually seen. Steelhead spawning peaked in late April on the South Fork, as indicated by the relative number of redds counted in the surveys. Peak spawning activity in the North Fork and mainstem Tolt River apparently occurs later, probably around mid-May. More frequent surveys would be required to identify the peak spawning date more accurately for each river segment.

Coho salmon were observed from September to January, with peak numbers occurring in November. The greatest number of observations were made in the vicinity of the USGS gaging station on the mainstem Tolt River. Coho salmon adults were most frequently found in the North Fork index area.

Adult chinook salmon were seen on only two occasions. On October 11, 13 adults and three redds were counted on the mainstem Tolt River. Two chinook adults were also observed in the lower South Fork (non-index area) in September. Sockeye salmon were observed spawning near the tail of a deep pool on the mainstem, located approximately at RM 6.1. This species normally requires a lake downstream of the spawning grounds which serves as

Table 11. South Fork spawner surveys: 1981-1982.

Month	Day	Reach surveyed (RM)		Steelhead count	Steelhead redds	Other species	Comments
		Start	Finish				
Aug	3	8.0	0	16			1 of the steelhead was < 20"
Aug	19	8.0	0	13			
Sep	18	5.0	3.7	12			2 of the steelhead were < 20"
Sep	30	2.5	0	1		2 coho, 2 chinook	
Oct	20	6.3	3.7	12			
Nov	5	5.0	3.7	0			
Jan	7	6.3	3.7	2			1 steelhead carcass
Feb	26	6.3	3.7	7	1		
Mar	8	6.3	3.7	2	4		
Mar	25	6.3	3.7	8	2		
Apr	10	5.0	3.7	1	4		
Apr	22	6.3	3.7	2	10		
Apr	23	0.5	0.0	1	2		
Apr	23	7.8	6.3	0	2		
May	8	6.3	3.7	1	3		

Table 12. North Fork spawner surveys: 1981-1982.

Month	Day	Reach surveyed (RM)			Steelhead count	Steelhead redds	Other species	Comments
		Start	Finish	Miles				
Aug	4	11.7	8.7	3.0	14			
Aug	20	11.7	8.7	3.0	11			
Oct	14	11.7	8.7	3.0	2	11 coho		
Oct	21	11.7	8.7	3.0	5		1 coho redd	
Nov	6	11.7	8.7	3.0	8	10 coho		
Dec	24	11.7	8.7	3.0	0	4 coho	6 coho redds, 1 coho carcass	
Feb	27	11.7	8.7	3.0	0		1	
Mar	15	11.7	8.7	3.0	8			
May	1	11.7	8.7	3.0	25			

Table 13. Mainstem Tolt River spawner surveys: 1981-1982.

Month	Day	Reach surveyed (RM)			Steelhead count	Steelhead redds	Other species	Comments
		Start	Finish	Miles				
May	28	8.6	0	8.6	2	26		
Jun	26	8.6	0	8.6				
Jul	28	8.6	0	8.6	13	10 sockeye		
Aug	14	8.6	0	8.6	27	13 sockeye	18 of the steelhead were < 20"	
Aug	21	8.6	0	8.6	41		5 of the steelhead were < 20"	
Sep	18	8.6	5.4	3.2	14		3 chinook redds, 10 of the chum were in Stossel Cr.	
Oct	11	8.6	0	8.6		13 chinook, 11 chum		
Nov	8	8.6	0	8.6		34 coho	1 chinook carcass was found	
Jan	9	8.6	0	8.6		4 coho	4 coho carcasses, 1 redd	
Mar	7	8.6	0	8.6	2			
Apr	24	8.6	0	8.6	6	6		
May	2	8.6	0	8.6	6	31		

a nursery area for fry and juveniles. Since the mainstem Snohomish River system below the mouth of the Tolt River contains no lakes, the sockeye sighted in the mainstem are believed to have strayed from another river basin.

6.3.4 Fish Population Assessment

The fish species collected from the Tolt River, in decreasing order of abundance were: 1) steelhead trout (Salmo gairdneri), torrent sculpin (Cottus rhotheus), coho salmon (Oncorhynchus kisutch), longnose dace (Rhynchichthys cataractae), mountain whitefish (Prosopium williamsoni), cutthroat trout (Salmo clarki), chinook salmon (Oncorhynchus tshawytscha), redbside shiner (Richardsonius balteatus), and the eastern brook trout (Salvelinus fontinalis).

Steelhead trout and sculpins were abundant at all stations. Coho salmon were present at all stations except SF1 and were most numerous in decreasing order of abundance at MS7, NF4, SF3, and MS5. Chinook salmon juveniles were present in the catch only at MS7 in September. Cutthroat trout were found only in the North and South Forks, although several adult migrants were caught by anglers in the mainstem Tolt River. Whitefish were captured at all stations except SF1 and were most abundant at MS7. Dace were present at all mainstem stations and at SF3. Their distribution may be restricted by the high gradient reaches in the North Fork and lower South Fork. Brook trout and redbside shiner were found only at MS5. They were both considered to be strays. Redside shiners are typically found in slow-moving waters or lakes. The brook trout may have strayed from the beaver ponds on Stossel Creek, where they were planted in 1956 and 1957.

Mean density and standing crop estimates for the seven most abundant

species are presented in Table 14. Salmonid density estimates were lower for July than for September. The true salmonid densities probably show the opposite trend, as steelhead and cutthroat trout fry emergence is complete by July and population densities typically decrease by attrition over the summer. This suggests that the density estimates for all species in July may be low, probably due to low sampling efficiency caused by high flows. Nevertheless, the relative species composition was similar for both sampling months. Sculpin had the highest mean standing crop estimate, followed by steelhead, whitefish, and coho. The order of abundance given above is also consistent between months, varying only in the order of the less abundant species.

Density estimates for steelhead by age group for each station in September are shown in Figure 12. Age 0 fish were estimated to comprise 91.3 and 48.1 percent of the steelhead density and standing crop, respectively. Steelhead density at NF4 was 430 percent higher than the mean for other stations. The age 0 : age 1 steelhead ratio (.96) was also highest at NF4. The South Fork and mainstem stations had comparable steelhead densities,

September standing crop estimates for each station are depicted in Figure 13. Biomass estimates for steelhead trout, total salmonids, and all fish species combined are presented for each station. The highest total standing crop was found at MS7, NF4, and SF3. Sculpins contributed a high proportion of the biomass at these three stations, second only to steelhead at NF4. The high total salmonid biomass at MS7 was largely due to high whitefish numbers. Care should be taken not to include whitefish biomass when considering productivity at individual stations. Whitefish have been found to undergo extensive spawning migrations (Pettit and Wallace 1975), so they may best be considered as transients.

Table 14. Fish density and standing crop estimates averaged over all stations.

	Density ($N \cdot m^{-2}$)		Standing crop ($g \cdot m^{-2}$)	
	July	Sept.	July	Sept.
Steelhead Age 0	.1286	.1932	.0505	.3724
Age 1	.0122	.0165	.2127	.3320
Age 2	.0013	.0019	.0580	.0702
Steelhead total	.1421	.2116	.3212	.7746
Coho salmon	.0141	.0238	.0290	.1097
Chinook salmon	0	.0006	0	.0045
Cutthroat trout	.0002	.0007	.0089	.0181
Whitefish	.0016	.0028	.1424	.3663
Salmonid total	.1580	.2395	.5015	1.2732
Dace	.0005	.0093	.0038	.1066
Sculpin	.0764	.1594	.6167	.7499
Non-salmonid total	.2349	.4082	1.1220	2.1297
Total (all species)	.2349	.4082	1.1220	2.1297

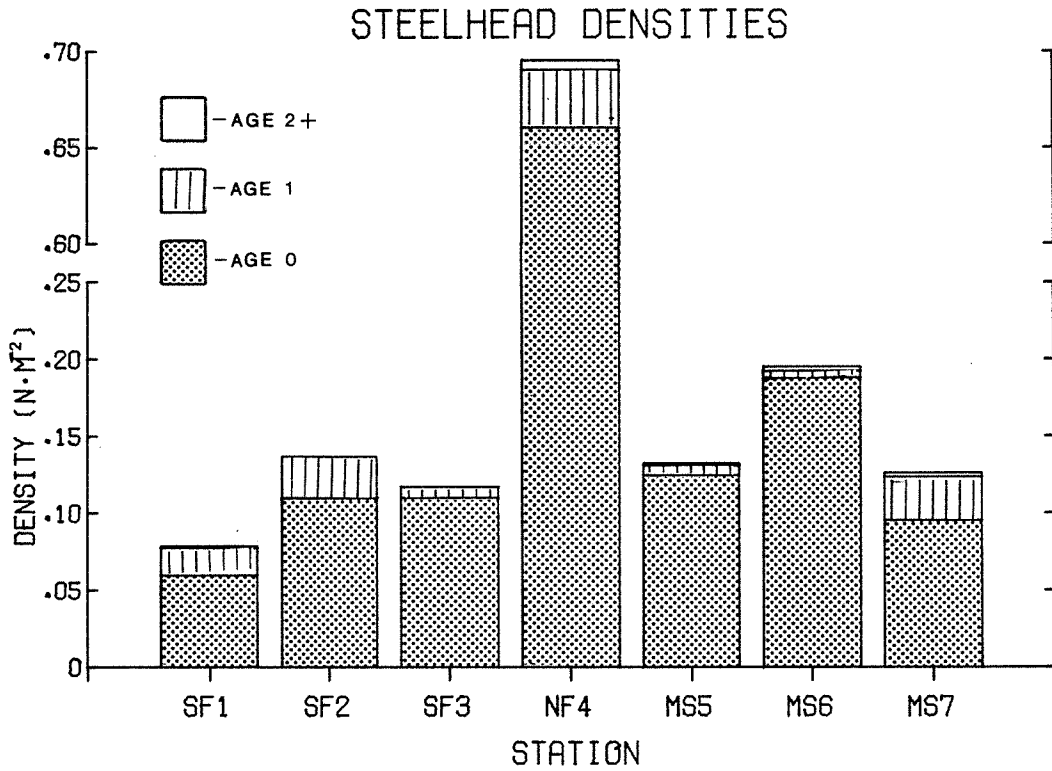


Figure 12. Estimated densities ($n \cdot m^{-2}$) of steelhead trout age classes in the Tolt River study areas during September 1981.

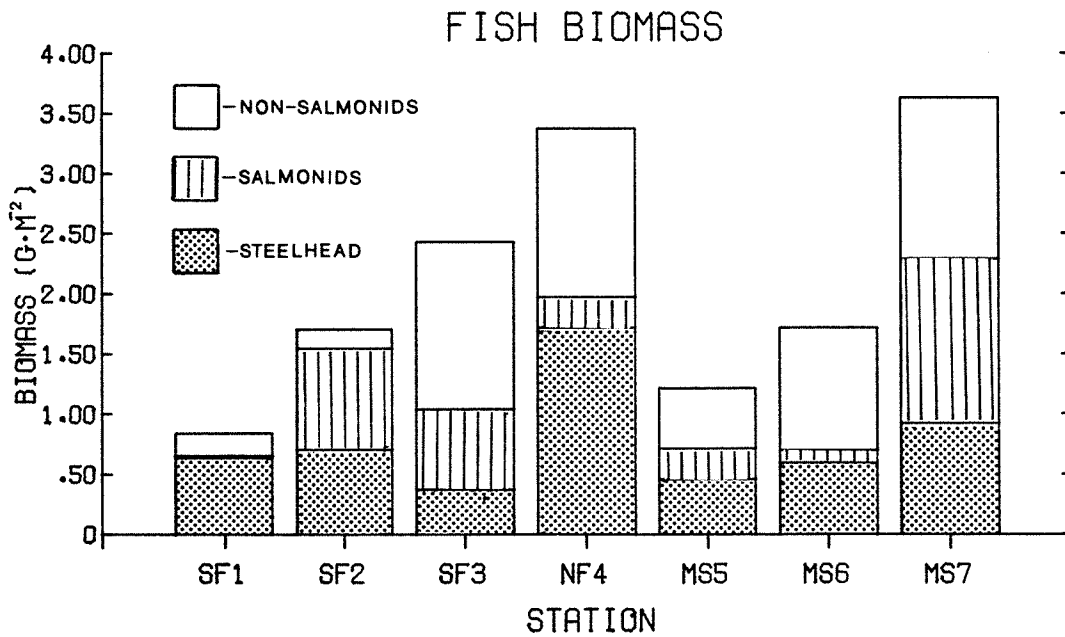


Figure 13. Steelhead trout, total salmonid, and total fish biomass ($g \cdot m^{-2}$) estimated for the Tolt River study areas during September 1981.

except that SF1 was below and MS6 was higher than the mean for these stations stations.

Mean lengths and weights for age 0 steelhead and coho are given in Table 15. July and September estimates are shown for the South Fork, North Fork, and mainstem Tolt River. Instantaneous growth rates were calculated for the period between sampling sessions to demonstrate differences in summer growth rates between river sections. Age 0 steelhead and coho were chosen because of their high abundance and their reliability of age class determination. Age 0 steelhead growth was greatest in the mainstem and lowest in the North Fork, as indicated by both mean lengths and weights attained by July, and by the growth rates calculated for the summer months. Coho mean length and weight in July was highest in the South Fork and lowest in the North Fork. Although summer growth of coho was slowest in the South Fork, they remain larger than North Fork and mainstem fish in September. The coho in the North Fork showed the greatest growth rate over the summer months, but were still the smallest overall in September. The indicated trend is that coho size differences in early life due to emergence timing or early growth conditions decrease over time, so that smolt size may approach uniformity.

6.3.5 Angler Survey

Table 16 summarizes the recreational catch data collected in 1981-82 for the Tolt River. The information should be qualified by the observation that successful anglers are more apt to respond to questionnaires than are unsuccessful fishermen. The greatest number of hours fished per month occurred in September, August and February, respectively. The highest catch per unit

Table 15. Mean lengths, weights, and growth rates of age 0 steelhead and coho salmon by river reach.

Species	Month	South Fork			North Fork			Mainstem Toit River		
		Mean length	Mean weight	n	Mean length	Mean weight	n	Mean length	Mean weight	n
Steelhead age 0	July	38.4	.496	72	35.4	.293	230	38.9	.473	204
	Sept.	56.5	2.178	221	49.5	1.488	265	59.1	2.345	417
	I.G.R.*	.337	.031		.294	.025		.346	.032	
Coho	July	63.1	2.960	13	52.9	1.616	16	54.2	1.966	47
	Sept.	75.7	5.361	22	70.7	4.416	18	73.5	4.425	45
	I.G.R.*	.252	.048		.371	.058		.292	.044	

* Instantaneous Growth Rate.

Table 16. Tolt River recreational catch data from questionnaire responses for 1981-1982.

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Hours fished		48.3	65.0	99.5	56.5	41.0	27.0	11.0	63.1			
Reported steelhead catch		10	2	20	6	1	3	3	13			
Avg. length (inches)		28.5	29.9	26.9	28.2	21	30.4	25.5	25.7			
Std. deviation		4.7	3.5	3.9	3.9		4.5	2.1	2.3			
CPUE	NO	.207	.026	.201	.106	.024	.111	.273	.206			
Steelhead/hour	DATA											SEASON CLOSED
Other species												
Juvenile steelhead		4		18								
Cutthroat trout ¹		5	27	19	18							
Whitefish		2		5	1							
Coho						2						
Chinook ²				1		2						

¹ Low population estimates for cutthroat trout indicate that most fish reported in the catch may be misidentified juvenile steelhead.

² The 3 chinook reported in the catch are likely to be misidentified coho because of the relative scarcity of chinook salmon in 1981.

Table 17. Length data for adult steelhead caught from the Tolt River in 1981-1982.

Area	Mainstem		South Fork		North Fork	
Avg. length (inches)	27.4		26.4		30.3	
Range	16.0 - 35.0		19.7 - 29.2		25.0 - 36.0	
Std. deviation	4.0		2.8		5.4	
Sample size	29		15		6	

effort was recorded in January during the winter steelhead angling season. Comparatively high numbers of adult steelhead were caught in February and July. The fish caught in the latter month were undoubtedly steelhead summer runs. The average length of steelhead caught in December exceeded the lengths recorded for all other months.

Adult steelhead in the North Fork attain a markedly larger body size than those in the South Fork and mainstem Tolt River (Table 17). It is suspected that the North Fork spawning population consists of a larger proportion of native and/or older fish in comparison to the other river segments. Further scale analysis should substantiate or refute this hypothesis.

6.4 Instream Flow Analysis

6.4.1 Study Reach Characteristics

Average instantaneous discharges calculated for the calibration flows sampled in the instream flow study are listed by station and date in Table 18. Field measured discharges may be compared to those recorded at USGS gages operated on the South Fork, North Fork and mainstem Tolt River. Streamflows at SF1 averaged 83 percent of the discharges measured at the South Fork gage, located approximately 1.3 miles downstream from the study reach. The low flow instantaneous discharges calculated from the seven transects at SF1 were higher than expected, averaging 3 cfs more than the USGS recorded datum for the same date. The total contribution of water from several spring sources entering the South Fork between SF1 and the gage is known to exceed 5 cfs (Pheifer and Fletcher 1976), suggesting a discrepancy either in field measurement procedures or in the USGS data.

Table 18. Average calibration flows determined for Tolt River study reaches. The daily discharges measured on the sampling dates are presented for comparison. Flow description: L = low, M = intermediate, H = high.

Study reach	Dates sampled	Flow description	Average discharge (cfs)	Standard deviation	USGS gaging station	USGS discharge (cfs)
SF1	8/29/81	L	40	3.0	12-1480	37
	12/10/81	M	105	5.2		114
	6/10/81	H	241	4.5		314
SF2	9/13/81	L	60	6.8	12-1480	42
	5/14/81	M	139	9.5		78
	12/10/81	H	188	5.3		90
SF3	9/12/81	L	66	3.3	12-1480	42
	12/08/81	M	166	8.2		69
	5/12/81	H	180	9.0		118
NF4	8/07/81	L	119	18.7	12-1475	112
	12/14/81	M	327	33.1		318
	6/24/81	H	486	49.3		426
MS5	8/20/81	L	156	11.7	12-1485	155
	12/12/81	M	545	15.7		552
	12/16/81	H	713	12.1		627
MS6	8/09/81	L	197	7.9	12-1485	174
	9/23/81	M	342	28.0		283
	11/21/81	H	643	22.7		562
MS7	8/26/81	L	142	4.0	12-1485	138
	9/25/81	M	326	7.1		230
	12/01/81	H	767	7.1		723

Instantaneous discharges averaged for SF2 calibration flows were 84 percent higher than USGS discharges recorded on the same dates. SF2 is located at the proposed powerhouse discharge site, approximately 4 miles downstream from the South Fork gaging station. The major tributary to the South Fork below the reservoir is Lynch Creek which enters upstream from SF2 and augments the amount of water conveyed through the station. Streamflows measured at SF2 may be overestimated when the measurements obtained for SF3 are considered. A slightly lower proportion (77 percent) of flows were passed by the latter station when compared to USGS data, indicating both the absence of significant inflow between SF2 and SF3 and the inherent variability of instantaneous discharges determined from cross-sectional data.

Discharge measured at NF4 during the field sessions were 9 percent higher than USGS recorded streamflows. Several sources of inflow enter the North Fork between the gage and the study area, a distance of about 1.9 miles; the overall contribution, however, is negligible. North Creek, a major tributary to the lower North Fork, joins the river 525 yards below the study site.

The highest discharge measured at MS5, located immediately downstream of the confluence of the two forks, was 86 cfs greater than the discharge calculated simultaneously at the USGS gage on the mainstem Tolt River. The two flow estimates should agree more closely, as they do at the low and intermediate calibration discharge levels, since the gage is bracketed by the study reach.

Calibration flows measured at mainstem stations 6 and 7 averaged 16 and 13 percent, respectively, higher than the daily discharges calculated from

USGS gage data. A side channel which seasonally diverts 10 to 40 cubic feet per second of water around MS7 was responsible for the lower proportional flow measurements obtained at the study reach. The side channel was not considered in the instream flow analysis of MS7.

Two general trends are noteworthy in the calibration flow data. The first is a tendency for the variation in discharge measurements between transects at a study reach to increase at higher flows. This reflects the difficulties and potential for measurement errors encountered while sampling under high runoff conditions. The second trend is an increase in the disparity between gage-recorded and field measured discharges as streamflows increase. The most likely explanation for this is an increase in the relative contribution of tributary inflow due to precipitation.

6.4.2 Calibration and Model Performance

Tests of reliability indicated that the hydraulic simulation models developed for the study reaches were suitable for predictive purposes. The ratios of field measured discharges to those predicted by the stage-discharge relationship ranged from 0.94 to 1.05, with corresponding mean error statistics less than 5.0. Velocity correlation coefficients and adjustment factors were within acceptable limits. Further indication of the model performance was provided by velocity prediction error analyses for each of the stations. The percent error in velocity predictions was calculated by

$$\text{Percent Error} = \left| \frac{V_{\text{meas}} - V_{\text{pre}}}{V_{\text{meas}}} \right| \times 100 \quad ,$$

where V_{meas} = the velocity measured at a given vertical and calibration flow,

and V_{pre} = the velocity predicted by the model at the same vertical and calibration flow.

The number of predicted velocities within the 0-5, 5-10, 10-15, etc., percent error intervals and the cumulative percent of predicted velocities within the same error intervals are listed in Table 19.

In a study conducted on a large prairie (alluvial) river which addressed the question of model reliability, it was concluded that the IFG-4 model could predict velocities with less than 10 percent error 90 percent of the time (Bovee et al. 1977). This level of velocity prediction error is considered "good" under the general guidelines presented for model calibration by Milhous (1981). Model prediction errors of less than 15 percent 90 percent of the time are described as "fair," but are still acceptable in a fully calibrated model. The velocity prediction errors determined for the seven hydraulic models developed in this study were acceptable for model application. It should be noted that high-gradient, boulder-strewn streams are usually less amenable to hydraulic modelling than are alluvial-type rivers, primarily due to the influence of streambed materials on local velocity distributions. For example, the water velocities measured between two boulders occasionally decreased at moderate flows, impairing the velocity-discharge relationships determined for those verticals. Similarly, the percent error in velocity predictions obtained for points near the bank were generally higher than errors calculated for mid-channel verticals. This may also be due in part to the application of Manning's equation in the model to fringe cells where less than two measurements exist. This equation is an effective predictor of discharge,

Table 19. Velocity prediction error analysis for IFG-4 model number and percent of predicted velocities within error intervals when compared to measured velocities for all Tolt River stations.

$$\text{Percent Error} = \left| \frac{V_{\text{MEAS}} - V_{\text{PRE}}}{V_{\text{MEAS}}} \right| \times 100$$

Percent error	Number of predicted velocities within error interval							
	SF1	SF2	SF3	NF4	MS5	MS6	MS7	Total
0-5	120	117	85	142	180	215	187	1,046
5-10	44	31	35	35	66	92	60	363
10-15	23	8	9	24	11	32	43	150
15-20	14	1	6	9	5	14	9	58
20-25	2	4	3	6	4	6	5	30
25-30	4	—	—	4	3	5	4	20
>30	—	—	—	3	1	2	1	8
Total	207	162	138	223	270	366	309	1,675

Percent error	Cumulative percent of predicted velocities within error interval							
	SF1	SF2	SF3	NF4	MS5	MS6	MS7	Total
0-5	58	73	62	64	67	59	61	62
5-10	79	92	87	79	91	84	80	84
10-15	90	97	93	90	95	93	94	93
15-20	97	98	98	94	97	96	97	97
20-25	98	100	100	97	98	98	98	98
25-30	100	100	100	99	99	99	99	99
>30	100	100	100	100	100	100	100	100

Qualitative* description	SF1	SF2	SF3	NF4	MS5	MS6	MS7	Total
	FAIR	GOOD	FAIR	FAIR	GOOD	FAIR	FAIR	FAIR

* Model predicts velocities with less than x% error, 90% or more of the time.

<u>x</u>	<u>Quality</u>
10%	GOOD
15%	FAIR
20%	MARGINAL
25%	POOR
>30%	VERY POOR

velocity, channel roughness, hydraulic radius, and energy slope under uniform flow conditions. The greater the deviation from uniform flow within a cell, however, the greater the potential for velocity prediction errors.

6.4.3 Weighted Usable Area Predictions

The hydraulic models developed for the South Fork Tolt River stations were used to simulate depths and velocities at a range of streamflows between 15 and 500 cfs. WUA was simulated at 5 cfs increments up to 100 cfs and at increasingly larger discharge intervals up to 500 cfs. WUA versus stream discharge for the life stages of coho and chinook salmon, cutthroat and steelhead trout and mountain whitefish are plotted in Appendix B, Figures 1, 2, 3, 4, and 5 respectively for each South Fork study reach. The variance between reaches for any given species/life stage is apparent and expected due to the different characteristics of each reach. A proportional extrapolation of each study reach to the entire South Fork was conducted to yield combined WUA curves plotted in Appendix B, Figures 6, 7, 8, 9 and 10 for coho, chinook, cutthroat, steelhead and mountain whitefish life stages, respectively. Also shown are the habitat efficiency curves for the different life stages, which are WUA values expressed as a percentage of the total stream surface area available.

From a consideration of the separate station WUA curves, it may be inferred that SF1 provides a greater amount of habitat for the fry stage of most species than do SF2 and SF3. The outstanding feature of SF1 is its diversity of habitat types; the large boulder, high gradient characteristics provide the shallow depth and low velocity areas preferred by most salmonid fry, even at moderate to high discharges.

SF1 also appears to be a more favorable habitat for mountain whitefish than are the other stations. For all whitefish life phases analyzed, the ranking of the stations is SF1 > SF2 > SF3, in terms of maximum WUA available. This conclusion was unanticipated in view of the fish sampling results, which found whitefish in greater abundance in lower reaches of the stream. Streamflows identified for whitefish life stages are generally higher than those determined for other species/life stages, suggesting a preference for higher water column velocities.

Maximum spawning WUA's for all species except whitefish were recorded for SF2. This result was expected since one of the transects (T3) at SF2 defined an excellent spawning area lying at the tail of a pool. At least three separate salmon and steelhead redds were observed at this cross-section during subsequent visits to the station. The combination of depths and velocities suitable for spawning at SF2 are available only for a narrow range of streamflows, typically at lower discharge levels, due to the steep canyon walls which confine the stream channel in the study reach.

Habitat available for salmon and trout incubation in the South Fork exceeds the WUA maxima calculated for all other life stages. This has important consequences in the analysis of instream flow requirements and will be discussed in a later section. WUA values for spawning habitat are lower than all other life stage WUA's of coho and chinook salmon and steelhead trout. The area calculated for chinook spawning, in particular, is the lowest WUA recorded for all life stages. It seems likely that chinook spawning habitat is adversely affected by the hydraulic equilibria which develop at higher flows in the South Fork. An increase in the volume of water passing through the channel increases the quality of the habitat in terms of depth, but the concomitant increase in water velocities

diminishes the overall suitability of the stream for chinook spawning. Other species/life stages whose WUA imply that a specific type of habitat may be limiting, even at near-optimal flows, are coho salmon spawning, mountain whitefish fry, and steelhead trout spawning. Clearly, spawning habitat availability is of prime concern to South Fork salmonid populations.

Of the life stages considered in the South Fork reach analysis, steelhead trout fry, juveniles, and incubation habitat were more abundant than the same habitat available for corresponding life-stages of other salmonid species. This finding correlates well with the relative species abundances determined from electrofishing sessions. Adult and spawning WUA's for cutthroat trout are higher than index values calculated for the same life-stages of other species.

Habitat availability in the South Fork is generally low in comparison to the total wetted surface area of stream. This is particularly true of spawning habitat, which averages less than 5 percent of the gross area. In contrast to this is the proportion of the total stream available as incubation habitat. Maximum incubation WUA's range between 30 and 50 percent of the gross area of the South Fork.

WUA values calculated for coho, chinook, cutthroat, steelhead and whitefish, based on the instream flow analysis for a single station in the North Fork, are illustrated in Appendix Figures C1, C2, C3, C4 and C5, respectively. These values have been extrapolated to the 4.7 miles of the North Fork accessible to migrating fish, with the caveat that some of the canyon areas of the North Fork may be underrepresented. Streamflows simulated by the NF4 hydraulic model were varied from 20 to 500 cfs, the highest resolution was in the range of 20 to 200 cfs.

The total area available for salmon and trout spawning habitat in the North Fork, even allowing for the shorter length of stream represented, is less than that found in the South Fork. The ratio of spawning habitat to total stream surface area (Appendix Figures C1 through C5) is slightly lower for most species in the North Fork in comparison to South Fork salmonids. The habitat available for spawning chinook salmon is less than the WUA for other spawning species. It is important to note that optimum discharges identified for spawning area are usually higher for the North Fork than for South Fork populations. This is due primarily to the hydraulic geometry resulting from the higher flow regime of the North Fork and the recruitment of suitable spawning areas near the margins of the stream as flows increase.

Further comparisons of the two streams indicate typically greater WUA discharges for species/life stages in the North Fork. Juvenile and incubation habitat is consistently high for all species of salmonids. Steelhead trout fry, juvenile, spawning, and incubation habitat availability is greater than it is for the corresponding life stages of other salmon and trout species. The WUA values for mountain whitefish, with the exception of fry habitat, also rank high among the species considered, although very few individuals of this species have been observed in the North Fork.

It may be inferred from the WUA curves of the mainstem Tolt River study reaches illustrated in Appendix Figures D1, D2, D3, D4, D5 and D6 for life stages of coho, chinook, cutthroat, steelhead and mountain whitefish, respectively, that MS5, located immediately downstream of the confluence of the North and South Forks, generally provides the greatest amount of fry and juvenile habitat. Spawning habitat is maximal for all species at MS6, largely

due to the influence of the uppermost transect located within this study reach. The cross-section was positioned at the transition zone of a large pool and the riffle at its base. During the summer low-flow period, the transect overlay a well-defined hydraulic control. At higher flows the left bank gravel bar was gradually inundated, providing an extensive area suitable for spawning. Although no salmon species were observed to use this area, over a dozen steelhead redds have been recorded in this location during the 1981 and 1982 spawning seasons.

Anticipating higher optimum flows for the various species/life stages in the mainstem Tolt River, the hydraulic characteristics of the mainstem study reaches were simulated at discharges ranging from 50 to 1500 cfs. Increments of 10 cfs were simulated up to 200 cfs, and increasingly larger interval discharges used up to 1500 cfs. In answering the question of which life stages are afforded more habitat than others under a range of flow conditions, the results are similar to those found for the North and South Forks. Incubation habitat is well-provided for by the regime of discharges identified, while spawning WUA values are generally quite low for the mainstem Tolt River. A comparison of WUA values expressed as a percent of the gross surface area for coho, chinook, cutthroat, steelhead and mountain whitefish shown in Appendix Figures D6, D7, D8, D9 and D10, respectively, reveal that incubation habitat comprises a relatively large percentage (greater than 40 percent for all species) of the available surface area. Spawning habitat averages less than 3 percent for coho, chinook, and cutthroat, 12 percent for steelhead, and 31 percent for mountain whitefish. Steelhead trout and mountain whitefish are the two most abundant species known to spawn in the mainstem Tolt River.

Of the salmon and trout species considered, steelhead trout habitat exceeds the area available for the corresponding life stages of other species, with the exception of adult habitat. The WUA associated with the latter steelhead category is lower than WUA's recorded for adult cutthroat trout and mountain whitefish for the mainstem Tolt River. Nevertheless, it appears that the relative abundance of all steelhead trout life stages correlates well with WUA values generated in the instream flow study.

The maximum WUA and associated discharge (Q_M) values for each species/life stage were obtained from the hydraulic models for the South Fork, North Fork and mainstem Tolt River (Table 20). This interpretation yielded the highest stream discharge (Q_M) requirements by species/life stage. The associated curves which express these data for each species/life stage for the South Fork, North Fork and mainstem Tolt River as a percentage of the total wetted surface area available was used to define the peak habitat efficiency. The peak habitat efficiency WUA values identified discharges (Q_E) which resulted in generally lower requirements (Table 21).

Selection of discharges on the basis of peak habitat efficiency rather than on the maximum WUA value (i.e., the peak of the WUA versus discharge curve) resulted in an average reduction of about 28 percent in the discharge with a corresponding loss in WUA of only about 4 percent for all species considered (Table 22).

A major reason for the substantial differences observed between discharges indicated by the peak habitat efficiency and maximal WUA methods is the tendency for WUA curves, notably those for the incubation life stage, to exhibit an inflection point at discharge levels well below the WUA maxima. The peak habitat efficiency generally coincided with the inflection

Table 20. Stream discharges (Q_M) resulting from the maximal habitat availability (WUA) for different species/life stages in the South Fork, North Fork, and mainstem Tolt River. Q = cfs; WUA = $\text{ft}^2 \times 10^5$ per total length of stream represented (SF = 7.95 mi., NR = 4.70 mi., MS = 8.7 mi.).

		South Fork		North Fork		Mainstem	
		Q	WUA	Q	WUA	Q	WUA
Coho							
	Fry	25	1.09	50	2.50	50	3.15
	Spawning	35	0.89	100	0.63	500	1.56
	Incubation	140	6.19	160	6.44	190	17.49
Chinook							
	Juvenile	40	3.57	65	6.00	60	8.31
	Spawning	70	0.84	140	0.42	600	1.49
	Incubation	175	7.31	350	7.90	450	20.84
Cutthroat							
	Fry	65	1.38	40	3.39	50	4.19
	Juveniles	130	2.61	85	4.71	100	6.53
	Adults	140	3.96	140	6.71	170	7.80
	Spawning	200	0.54	80	0.58	450	1.43
	Incubation	175	6.10	250	6.18	250	15.77
(Winter)							
Steelhead							
	Fry	30	3.20	25	3.93	50	10.06
	Juveniles	65	4.99	85	6.19	100	11.76
	Adults	175	1.38	120	1.96	180	3.06
	Spawning	150	1.17	200	0.91	180	3.84
	Incubation	250	9.14	400	9.67	600	26.61
Whitefish							
	Fry	70	0.92	120	1.88	50	2.31
	Juveniles	80	3.86	100	6.41	120	11.43
	Adults	500	2.94	225	4.95	225	6.94
	Spawning	150	3.08	140	4.60	140	10.05
Fishing/Wading		95	8.46	120	11.35	130	18.18

Table 21. Stream discharges (Q_E) resulting from the peak habitat efficiencies for different species/life stages in the South Fork, North Fork, and mainstem Tolt River. Q = cfs; WUA = ft $\times 10^5$ per total length of stream represented (SF = 7.95 mi., NR = 4.70 mi., MS = 8.7 mi.).

		South Fork		North Fork		Mainstem	
		Q	WUA	Q	WUA	Q	WUA
Coho							
	Fry	25	1.09	50	2.50	50	3.15
	Spawning	35	0.89	100	0.63	80	1.32
	Incubation	130	6.14	85	6.10	110	16.90
Chinook							
	Juveniles	30	3.52	55	5.99	50	8.22
	Spawning	60	0.82	120	0.41	100	1.36
	Incubation	140	7.13	85	6.19	140	18.64
Cutthroat							
	Fry	25	1.27	30	3.24	50	4.19
	Juveniles	50	2.28	60	4.59	80	6.49
	Adults	70	3.41	95	6.41	120	7.48
	Spawning	35	0.51	75	0.58	50	0.94
	Incubation	150	6.02	180	6.03	140	14.56
(Winter)							
Steelhead							
	Fry	25	3.17	25	3.93	50	10.06
	Juveniles	50	4.88	55	6.06	100	11.76
	Adults	80	1.35	120	1.96	180	3.06
	Spawning	90	0.98	200	0.91	170	3.84
	Incubation	175	8.84	180	7.85	350	24.80
Whitefish							
	Fry	45	0.88	85	1.80	50	2.31
	Juveniles	65	3.74	85	6.32	90	11.21
	Adults	140	2.69	225	4.95	200	6.89
	Spawning	85	2.94	120	4.59	120	9.95
Fishing/Wading							

Table 22. Percent reduction ($Q_M - Q_E$) in river discharge (Q_R) and habitat (WUA) between maximum WUA curves and peak habitat efficiency curves for different species/life stages in the South Fork (7.95 mi.), North Fork (4.7 mi.), and mainstem Tolt River (8.7 mi.).

		Percent reduction					
		<u>South Fork</u>		<u>North Fork</u>		<u>Mainstem</u>	
		Q_R	WUA	Q_R	WUA	Q_R	WUA
Coho							
	Fry	0	0	0	0	0	0
	Spawning	0	0	0	0	84	15
	Incubation	7	1	47	5	42	3
Chinook							
	Juveniles	25	1	15	<1	17	1
	Spawning	14	2	14	2	83	9
	Incubation	20	2	76	22	69	11
Cutthroat							
	Fry	62	8	25	4	0	0
	Juveniles	62	13	29	3	20	1
	Adults	50	14	32	4	29	4
	Spawning	83	6	6	0	89	34
	Incubation	14	1	28	2	44	8
Steelhead (Winter)							
	Fry	17	1	0	0	0	0
	Juveniles	23	2	35	2	0	0
	Adults	54	2	0	0	0	0
	Spawning	40	16	0	0	6	0
	Incubation	30	3	55	19	42	7
Whitefish							
	Fry	36	4	29	4	0	0
	Juveniles	19	3	15	1	25	2
	Adults	65	9	0	0	11	1
	Spawning	39	5	14	<1	17	1
	Mean	33	4.65	21	3.5	29	4.85

point of a given curve. In other cases, the discharge associated with the peak habitat efficiency was equivalent to or slightly less than the discharge at which WUA was highest.

6.4.4 Stochastic Flows and WUA

Mean monthly 10, 50, and 90 percentile flows were obtained from USGS records for 1953-1963 and 1970-1979 (pre- and post-dam construction periods) for the South Fork, 1953-1979 for the North Fork, and 1929-1979 for the mainstem Tolt River. The monthly mean discharge exceedance probabilities are based on Log-Pearson III analysis and correspond to streamflows equalled or exceeded in 1 out of 10, 1 out of 2, and 9 out of 10 years, respectively. The 10 percentile flow may be considered a wet water year, the 50 percentile a median water year, and the 90 percentile a dry water year.

The Q_E and Q_M discharges determined for each species/life stage were analyzed in relation to the stochastic flows defined above in order to identify periods of life history which are susceptible to reduction of instream habitat caused either by drought conditions or by M & I water diversion. The relationship between life stage Q_E values and streamflows during dry, medium, and wet years are illustrated for coho, chinook, cutthroat and steelhead in Figures 14, 15, 16 and 17, respectively for the South Fork under pre-dam conditions (1953-1963). Similar South Fork Tolt River discharges during a post-dam period (1970-1979) for the life stages of coho, chinook, cutthroat and steelhead are illustrated in Figures 18, 19, 20 and 21, respectively. Q_E values and projected 10, 50 and 90 percentile discharges were illustrated for the North Fork Tolt River in Figures 22, 23, 24 and 25 for the life stages of coho, chinook, cutthroat

SOUTH FORK TOLT RIVER 1953-1963

Mean monthly discharges for three equivalent flow years, flows not exceeded:

Flow Year	J	F	M	A	M	J	J	A	S	O	N	D
(9 in 10 years) ·····	513	348	240	360	329	330	228	113	183	327	462	477
(1 in 2 years) ———	223	224	145	243	237	172	97	52	69	180	302	304
(1 in 10 years) ---	101	122	82	110	156	86	40	23	38	51	100	165

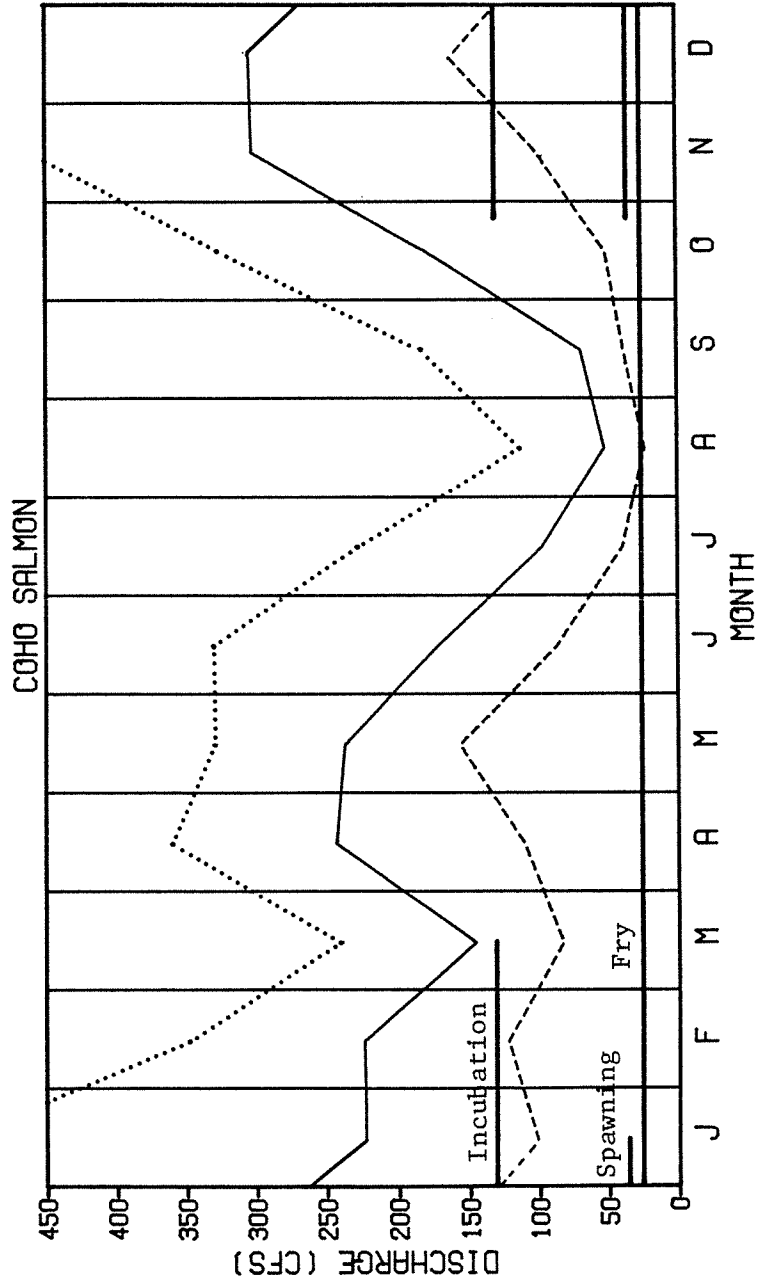


Figure 14. The relationship between Q_E discharges for coho salmon life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the South Fork during pre-dam construction years (1953-1963).

SOUTH FORK TOLT RIVER 1953-1963

Mean monthly discharges for three equivalent flow years, flows not exceeded:

(9 in 10 years) ·····	513	348	240	360	329	330	228	113	183	327	462	477
(1 in 2 years) ———	223	224	145	243	237	172	97	52	69	180	302	304
(1 in 10 years) ---	101	122	82	110	156	86	40	23	38	51	100	165

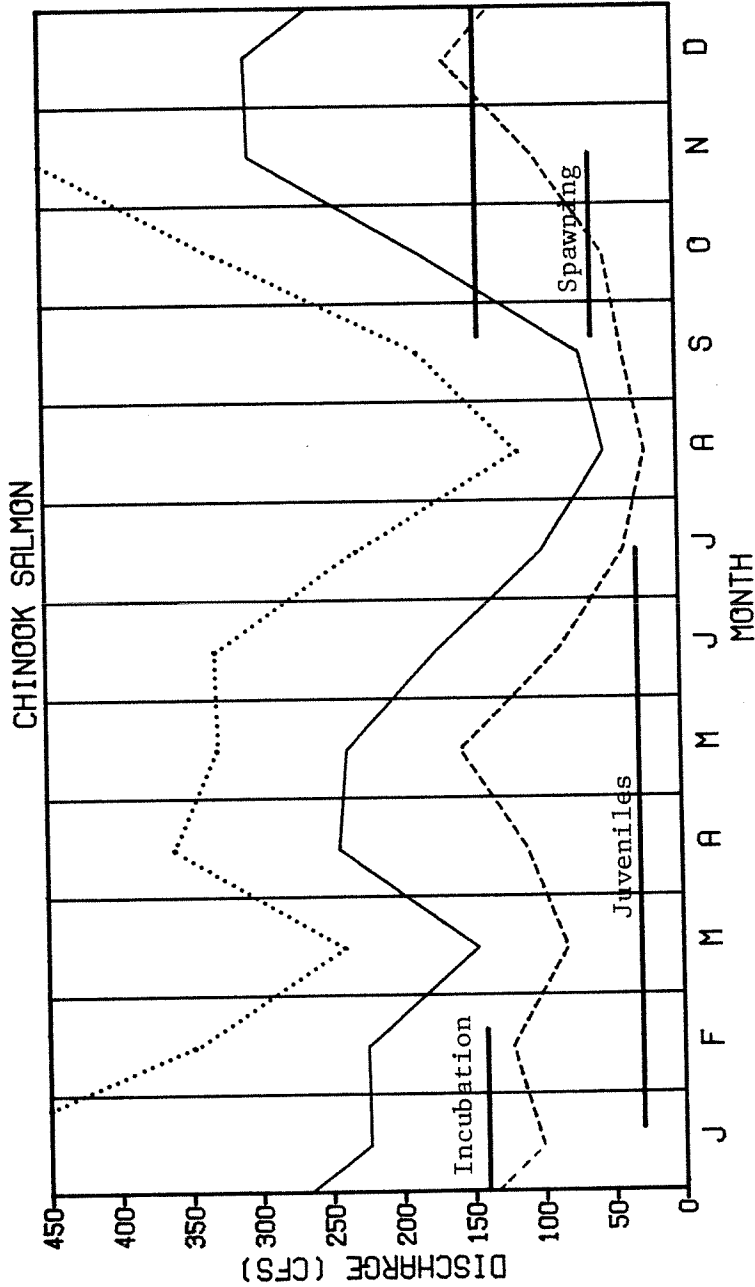


Figure 15. The relationship between Q_E discharges for chinook salmon life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the South Fork during pre-dam construction years (1953-1963).

SOUTH FORK TOLT RIVER 1953-1963

Mean monthly discharges for three equivalent flow years, flows not exceeded:

(9 in 10 years)	513	348	240	360	329	330	228	113	183	327	462	477
(1 in 2 years) ——	223	224	145	243	237	172	97	52	69	180	302	304
(1 in 10 years) ----	101	122	82	110	156	86	40	23	38	51	100	165

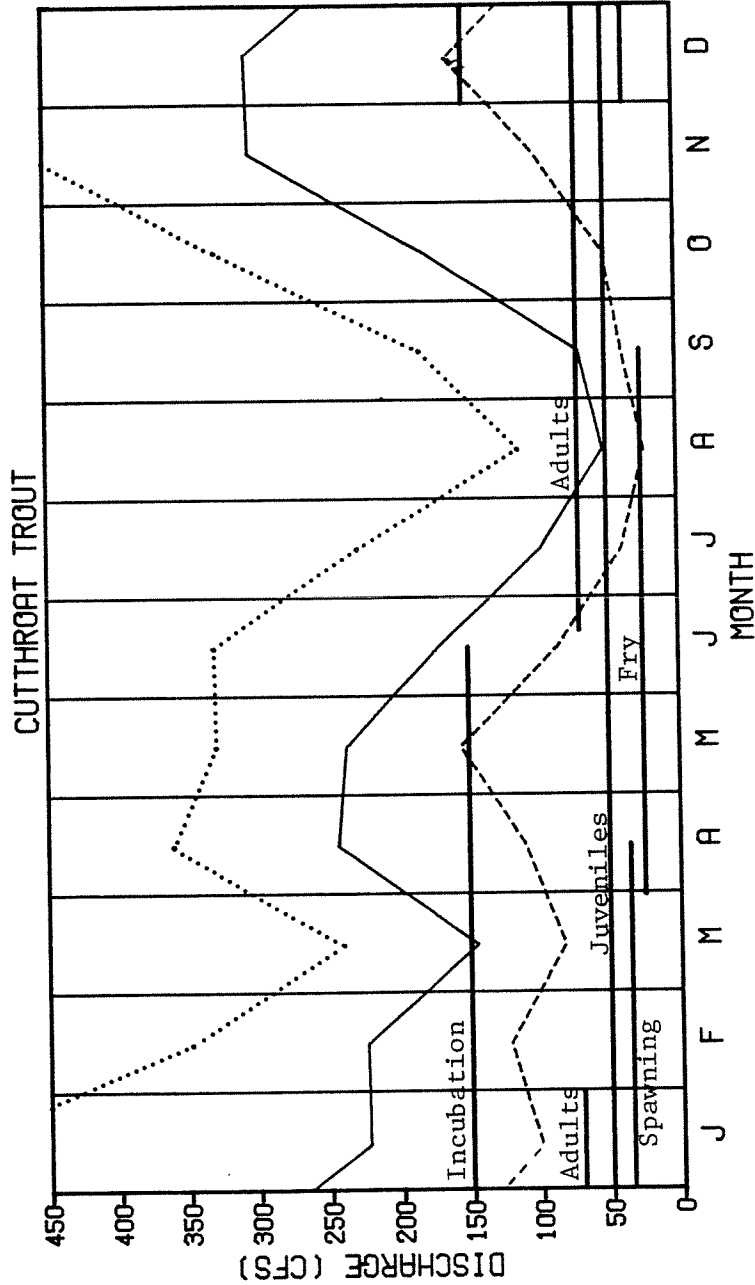


Figure 16. The relationship between Q_E discharges for cutthroat trout life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the South Fork during pre-dam construction years (1953-1963).

SOUTH FORK TOLT RIVER 1953-1963

Mean monthly discharges for three equivalent flow years, flows not exceeded:

Flow Year	J	F	M	A	M	J	J	A	S	O	N	D
(9 in 10 years) 513	348	240	360	329	330	228	113	183	327	462	477	
(1 in 2 years) —— 223	224	145	243	237	172	97	52	69	180	302	304	
(1 in 10 years) --- 101	122	82	110	156	86	40	23	38	51	100	165	

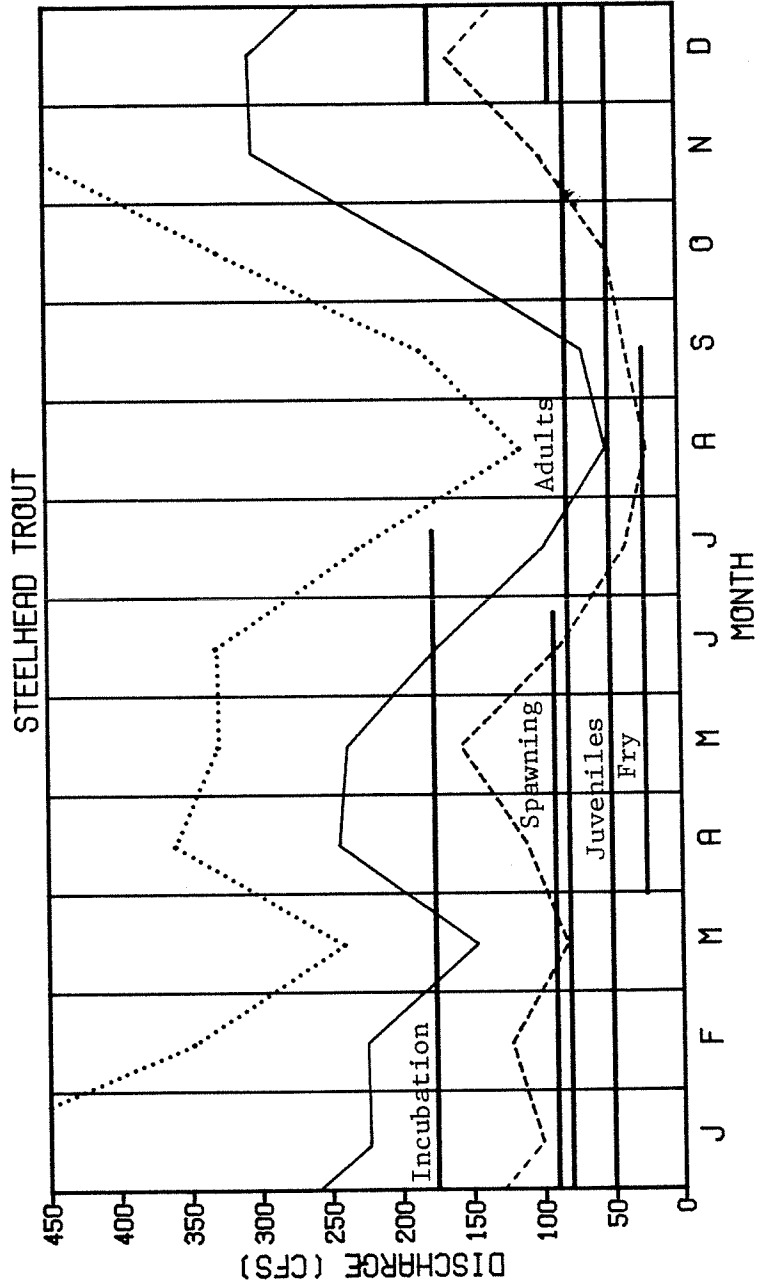


Figure 17. The relationship between Q_E discharges for steelhead trout life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the South Fork during pre-dam construction years (1953-1963).

SOUTH FORK TOLT RIVER 1970-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

(9 in 10 years)	.....	388	276	179	122	191	198	114	50	138	136	298	381
(1 in 2 years)	---	173	113	68	77	85	68	55	39	61	84	112	145
(1 in 10 years)	---	65	47	38	43	49	33	31	31	35	53	51	64

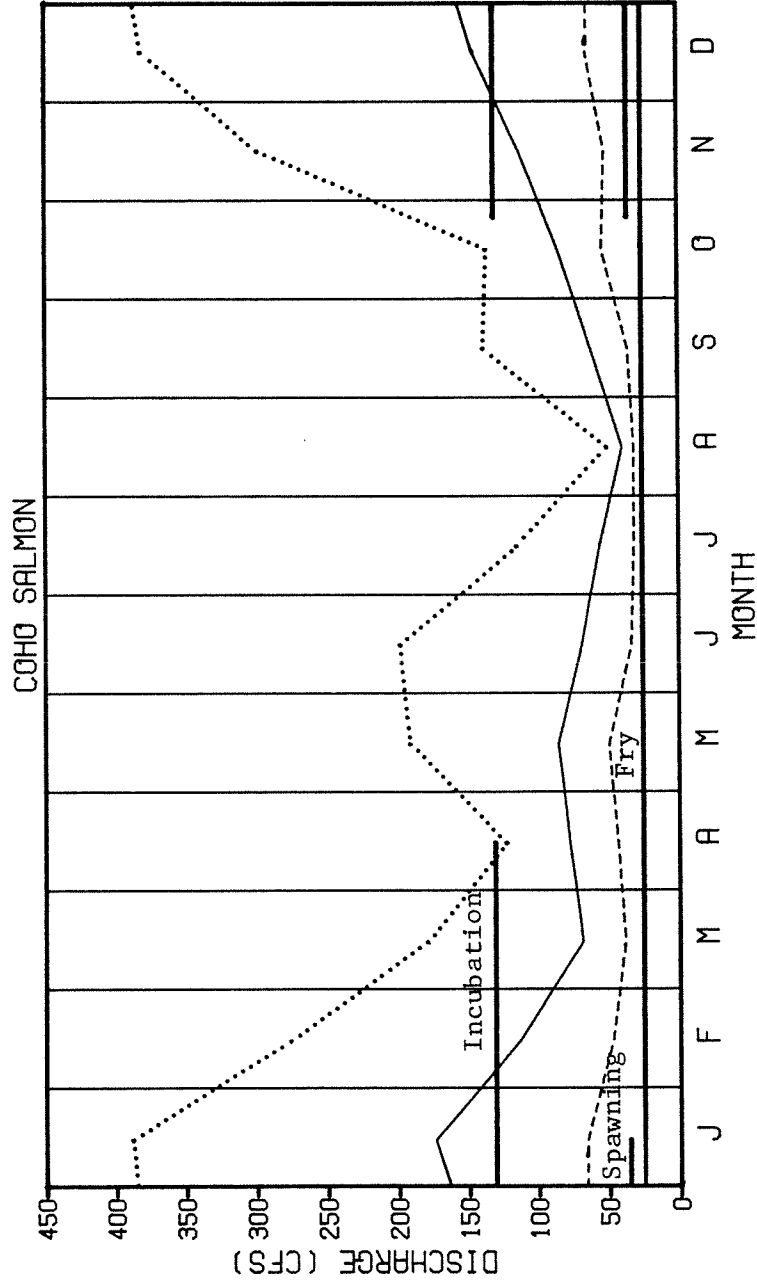


Figure 18. The relationship between Q_E discharges for coho salmon life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the South Fork during post-dam construction years (1970-1979).

SOUTH FORK TOLT RIVER 1970-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

(9 in 10 years)	.....	388	276	179	122	191	198	114	50	138	136	298	381
(1 in 2 years)	---	173	113	68	77	85	68	55	39	61	84	112	145
(1 in 10 years)	---	65	47	38	43	49	33	31	31	35	53	51	64

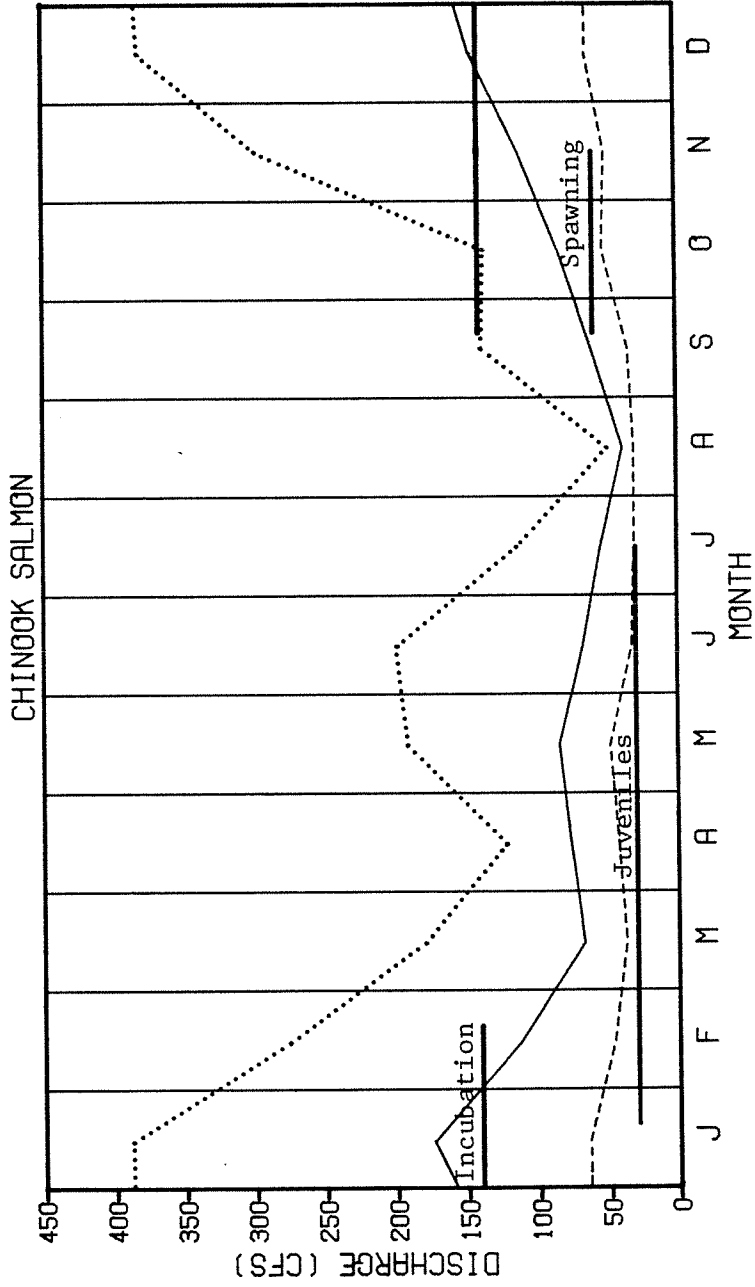


Figure 19. The relationship between Q_E discharges for chinook salmon life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the South Fork during post-dam construction years (1970-1979).

SOUTH FORK TOLT RIVER 1970-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

(9 in 10 years)	.....	388	276	179	122	191	198	114	50	138	136	298	381
(1 in 2 years)	---	173	113	68	77	85	68	55	39	61	84	112	145
(1 in 10 years)	---	65	47	38	43	49	33	31	31	35	53	51	64

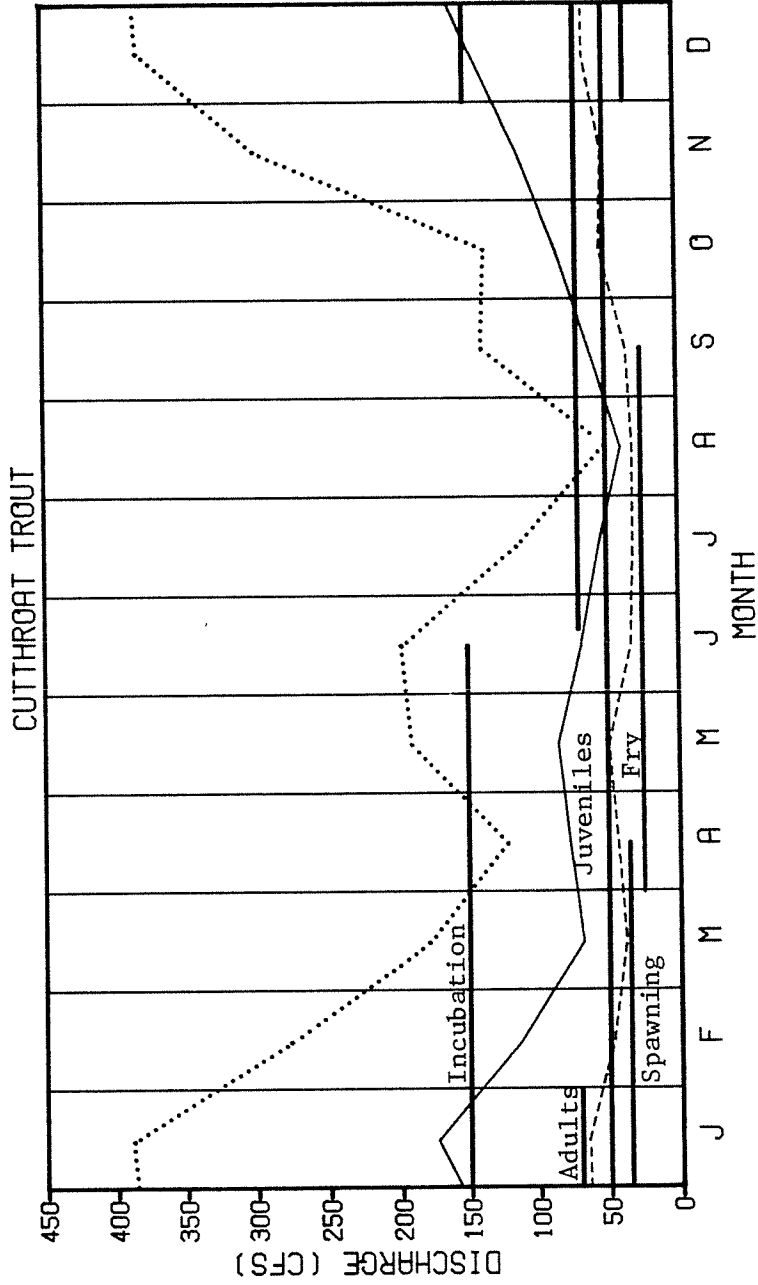


Figure 20. The relationship between Q_E discharges for cutthroat trout life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the South Fork during post-dam construction years (1970-1979).

SOUTH FORK TOLT RIVER 1970-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

Flow Year	J	F	M	A	M	J	J	A	S	O	N	D
(9 in 10 years)	388	276	179	122	191	198	114	50	138	136	298	381
(1 in 2 years)	173	113	68	77	85	68	55	39	61	84	112	145
(1 in 10 years)	65	47	38	43	49	33	31	31	35	53	51	64

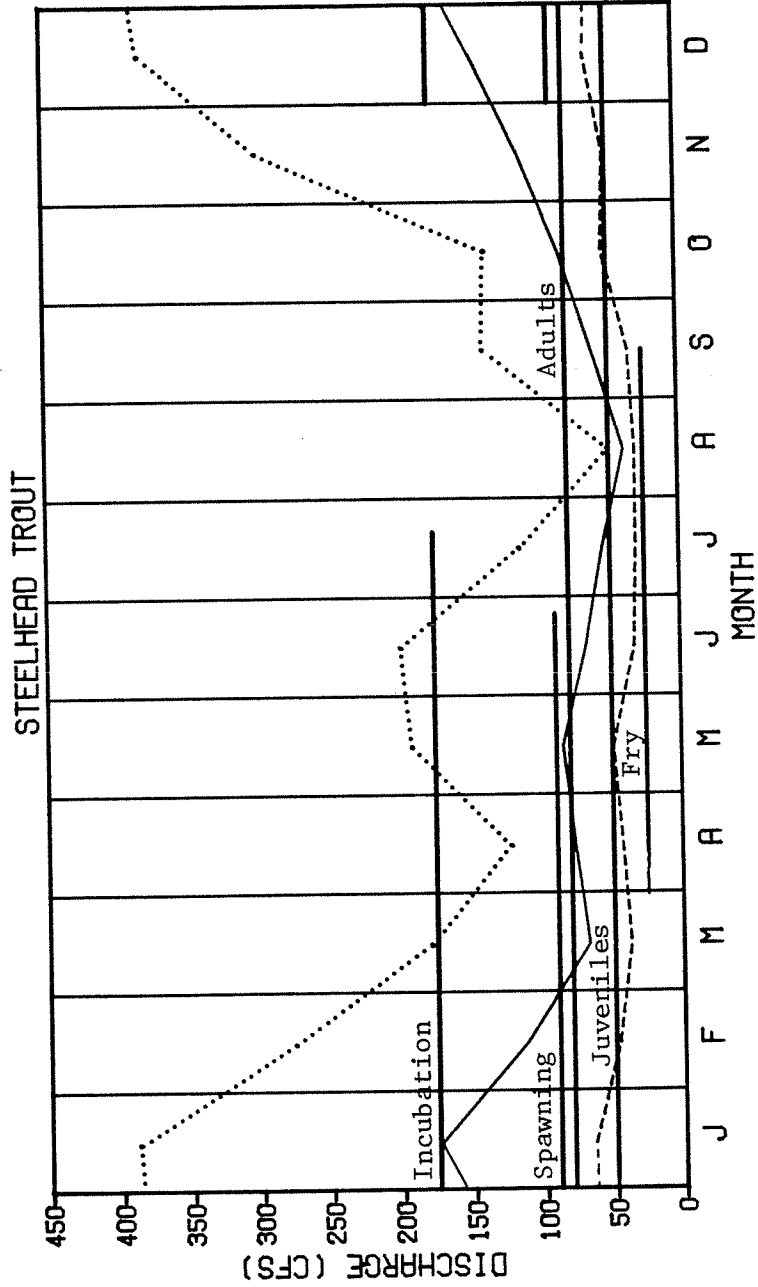


Figure 21. The relationship between Q_E discharges for steelhead trout life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the South Fork during post-dam construction years (1970-1979).

NORTH FORK TOLT RIVER 1953-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

Flow Year	J	F	M	A	M	J	J	A	S	O	N	D
(9 in 10 years)	863	660	534	561	615	578	347	198	309	470	681	850
(1 in 2 years) ——	515	422	322	421	449	354	192	122	146	250	489	538
(1 in 10 years) ---	294	242	231	303	309	210	112	68	81	95	211	326

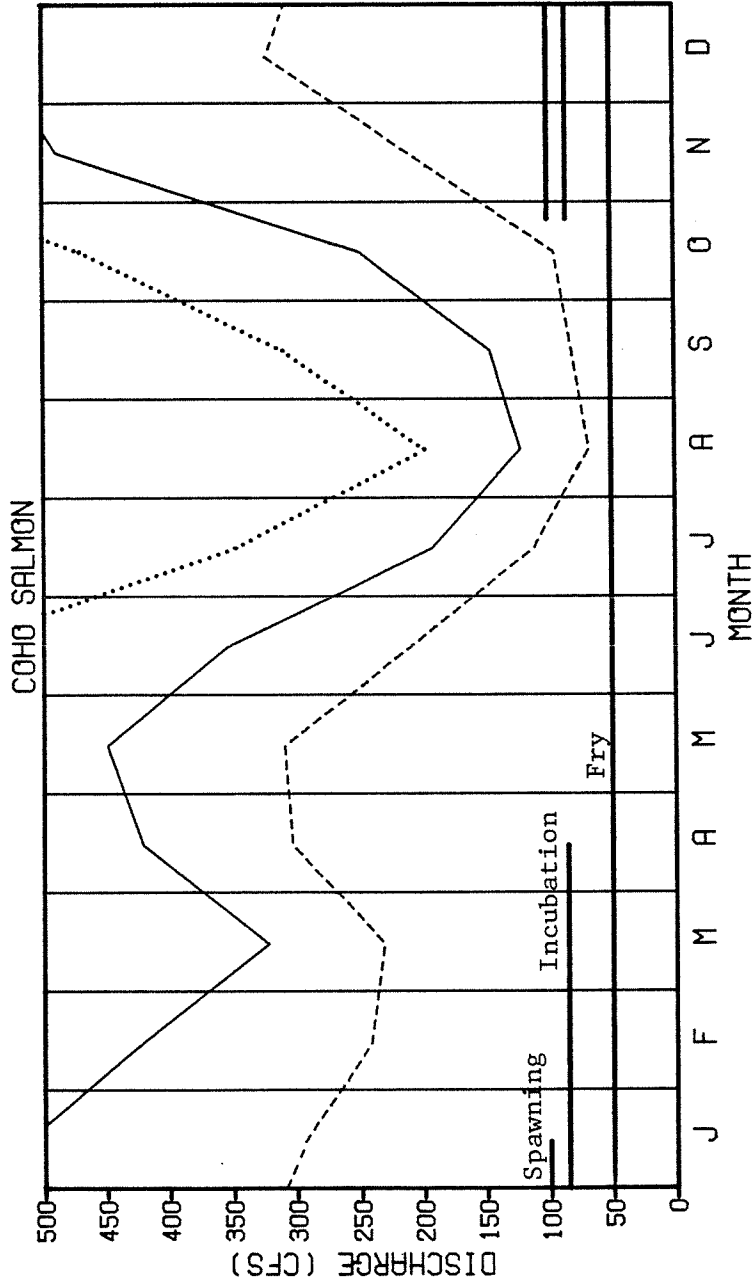


Figure 22. The relationship between Q_E discharges for coho salmon life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the North Fork (1953-1979).

NORTH FORK TOLT RIVER 1953-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

(9 in 10 years)	.....	863	660	534	561	615	578	347	198	309	470	681	850
(1 in 2 years)	—	515	422	322	421	449	354	192	122	146	250	489	538
(1 in 10 years)	---	294	242	231	303	309	210	112	68	81	95	211	326

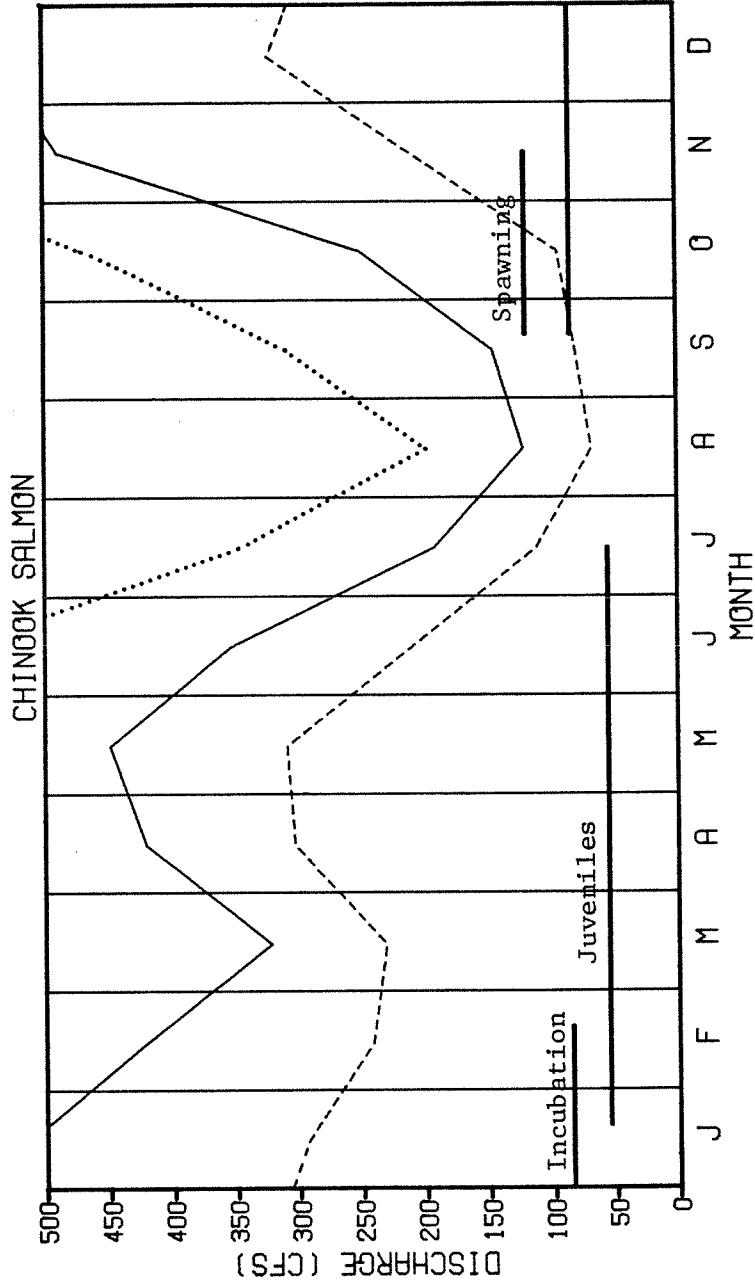


Figure 23. The relationship between Q_E discharges for chinook salmon life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the North Fork (1953-1979).

NORTH FORK TOLT RIVER 1953-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

(9 in 10 years)	.....	863	660	534	561	615	578	347	198	309	470	681	850
(1 in 2 years)	---	515	422	322	421	449	354	192	122	146	250	489	538
(1 in 10 years)	---	294	242	231	303	309	210	112	68	81	95	211	326

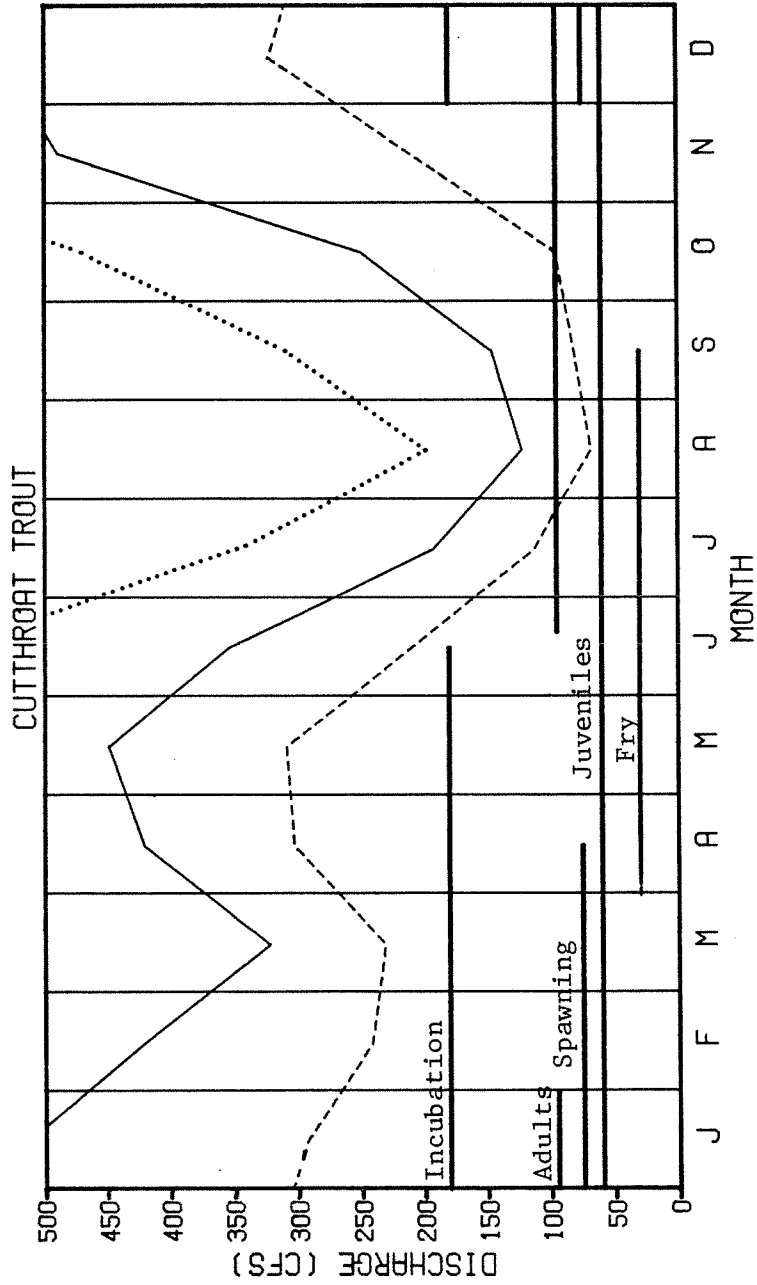


Figure 24. The relationship between Q_E discharges for cutthroat trout life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the North Fork (1953-1979).

NORTH FORK TOLT RIVER 1953-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

Flow Year	J	F	M	A	M	J	J	A	S	O	N	D
(9 in 10 years)	863	660	534	561	615	578	347	198	309	470	681	850
(1 in 2 years) ——	515	422	322	421	449	354	192	122	146	250	489	538
(1 in 10 years) ----	294	242	231	303	309	210	112	68	81	95	211	326

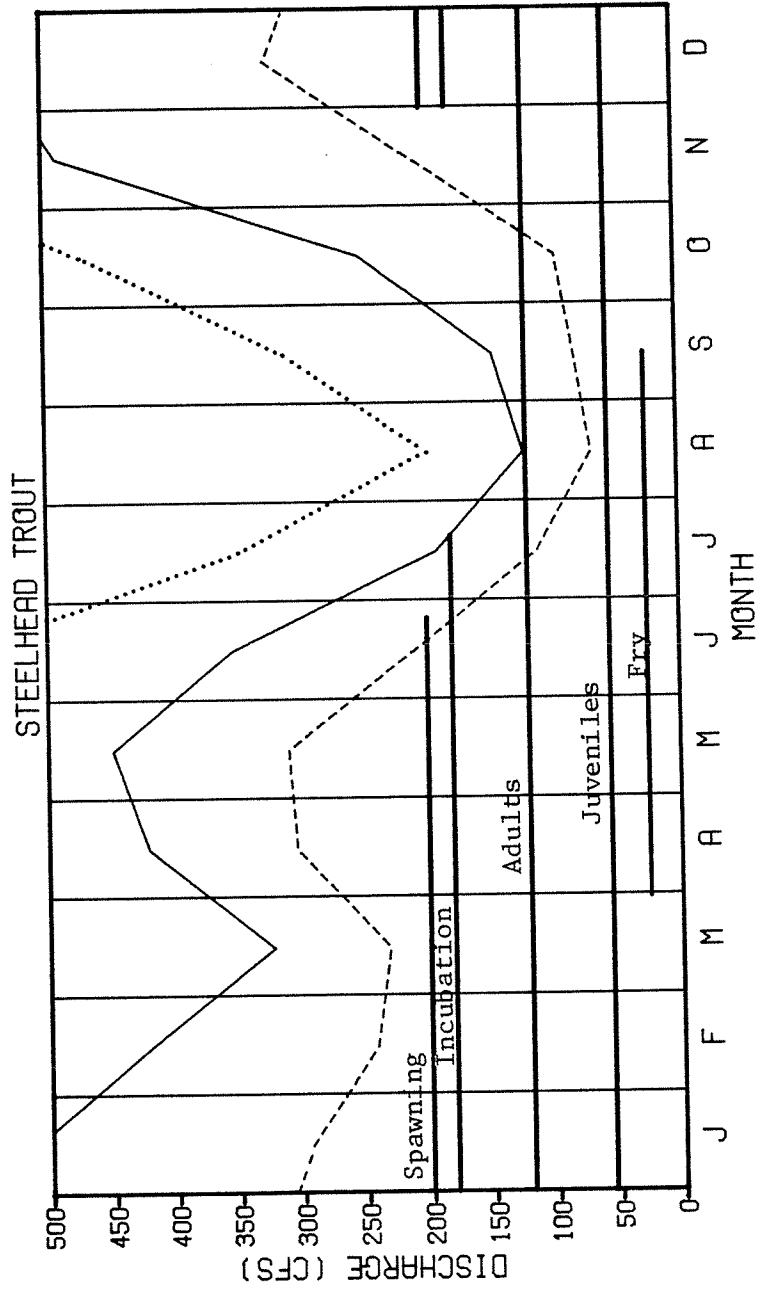


Figure 25. The relationship between Q_E discharges for steelhead trout life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the North Fork (1953-1979).

and steelhead, respectively. Q_E values and mainstem discharges for coho, chinook, cutthroat and steelhead are illustrated in Figures 26, 27, 28 and 29, respectively. Q_M discharges for the different life stages are not shown, but these values may be obtained from Table 20 for comparison with the plotted Q_E values.

In all river segments, Q_E discharges for each life stage are usually less than the associated monthly mean 50 percentile flow, with the exception of discharges determined for salmonid adult and incubation habitat under post-dam conditions (Figures 18, 19, 20 and 21). This observation was also true for streamflows at which maximum WUA values were obtained, suggesting that salmonids in the Tolt River are generally adapted to streamflows which occur less frequently than the median annual flow. Prior to dam construction on the South Fork, the WUA for incubation habitat at Q_E and Q_M flows was not provided for by dry water year streamflows for any of the species considered. Following construction, i.e., under present conditions, incubation habitat is generally unavailable during median water years. This was also found to be true for adult cutthroat and steelhead trout habitat under pre- and post-dam discharge conditions. Rearing and spawning habitat Q_E streamflows in the South Fork are usually exceeded by median and dry water year mean monthly discharges under both pre-dam and post-dam flow regimes.

Q_E and Q_M discharges identified for species/life stages known to reside in the North Fork and mainstem Tolt River are both low relative to streamflows available in median and dry water years. Incubation habitat, the life stage for which maximum Q_E and Q_M discharges were obtained for each species, is affected only during dry years, and usually at the end of the incubation period. The Q_E flows for trout adult habitat exceed dry water year discharges

MAINSTEM TOLT RIVER 1928-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

(9 in 10 years)	.....	1391	1167	885	934	1020	948	516	309	489	775	1233	1394
(1 in 2 years)	---	795	719	570	683	700	542	274	164	212	471	785	880
(1 in 10 years)	---	420	371	398	451	474	304	148	94	100	215	348	526

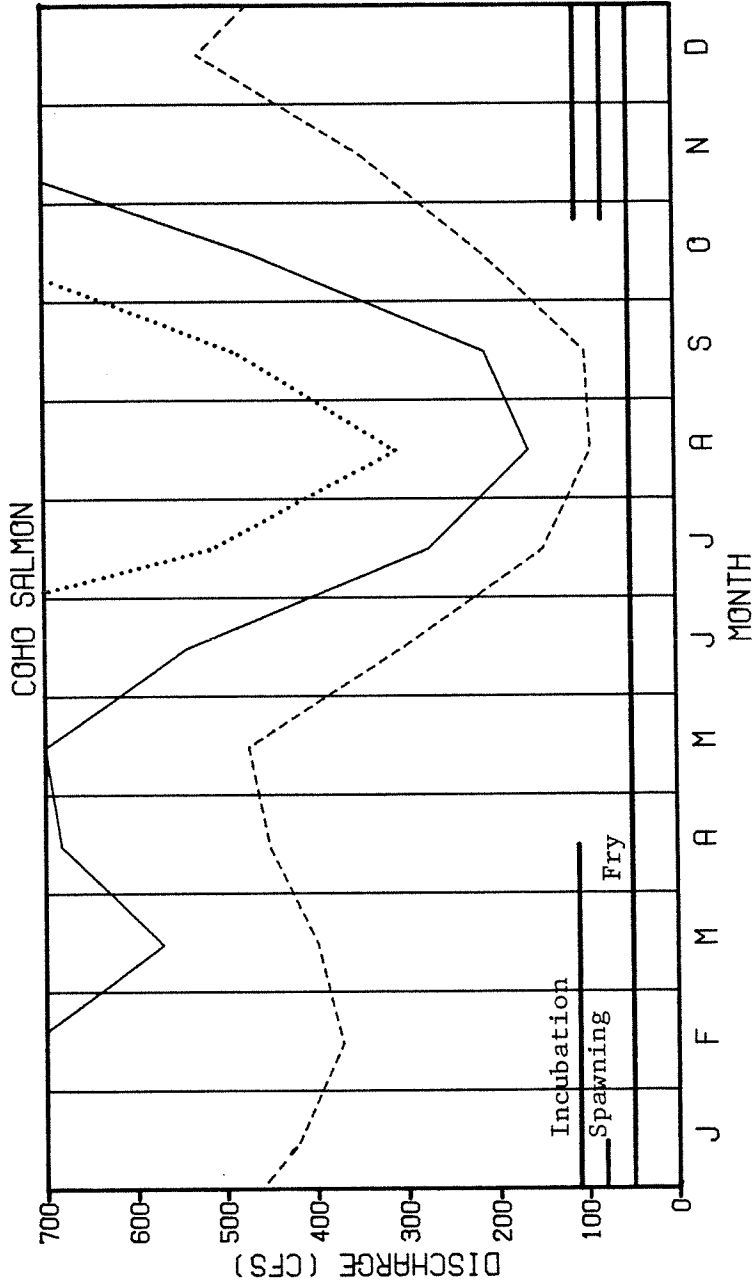


Figure 26. The relationship between Q_E discharges for coho salmon life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the mainstem Tolt River (1928-1979).

MAINSTEM TOLT RIVER 1928-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

(9 in 10 years)	.....	1391	1167	885	934	1020	948	516	309	489	775	1233	1394
(1 in 2 years)	---	795	719	570	683	700	542	274	164	212	471	785	880
(1 in 10 years)	---	420	371	398	451	474	304	148	94	100	215	348	526

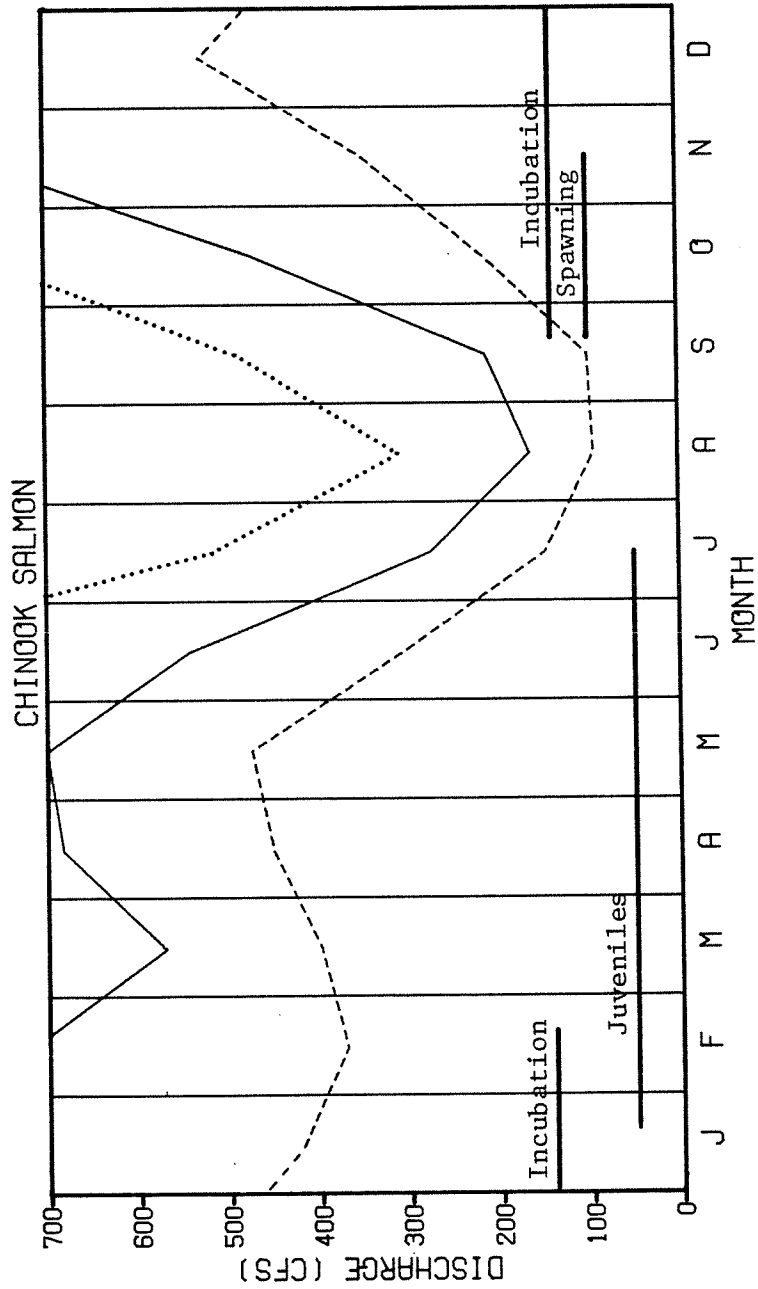


Figure 27. The relationship between Q_E discharges for chinook salmon life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the mainstem Tolt River (1928-1979).

MAINSTEM TOLT RIVER 1928-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

(9 in 10 years)	.....	1391	1167	885	934	1020	948	516	309	489	775	1233	1394
(1 in 2 years)	---	795	719	570	683	700	542	274	164	212	471	785	880
(1 in 10 years)	---	420	371	398	451	474	304	148	94	100	215	348	526

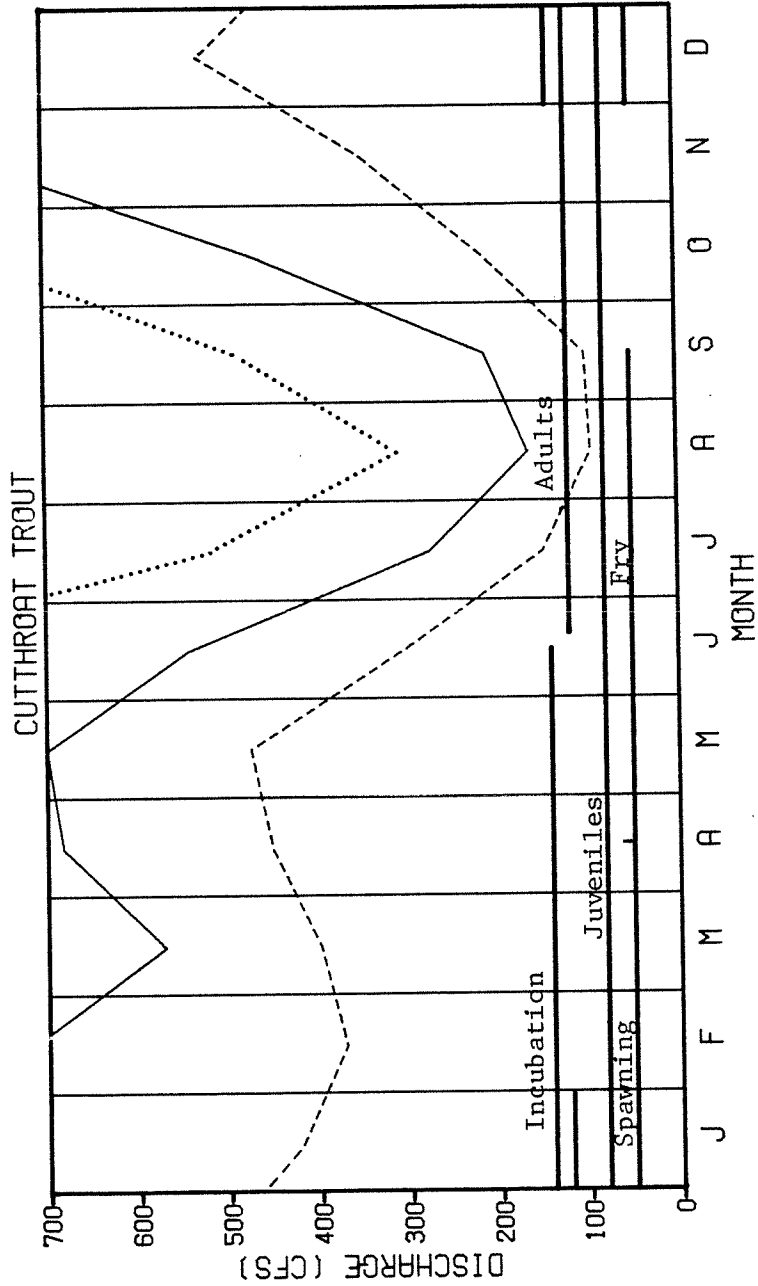


Figure 28. The relationship between Q_E discharges for cutthroat trout life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the mainstem Tolt River (1928-1979).

MAINSTEM TOLT RIVER 1928-1979

Mean monthly discharges for three equivalent flow years, flows not exceeded:

(9 in 10 years)	.....	1391	1167	885	934	1020	948	516	309	489	775	1233	1394
(1 in 2 years)	---	795	719	570	683	700	542	274	164	212	471	785	880
(1 in 10 years)	---	420	371	398	451	474	304	148	94	100	215	348	526

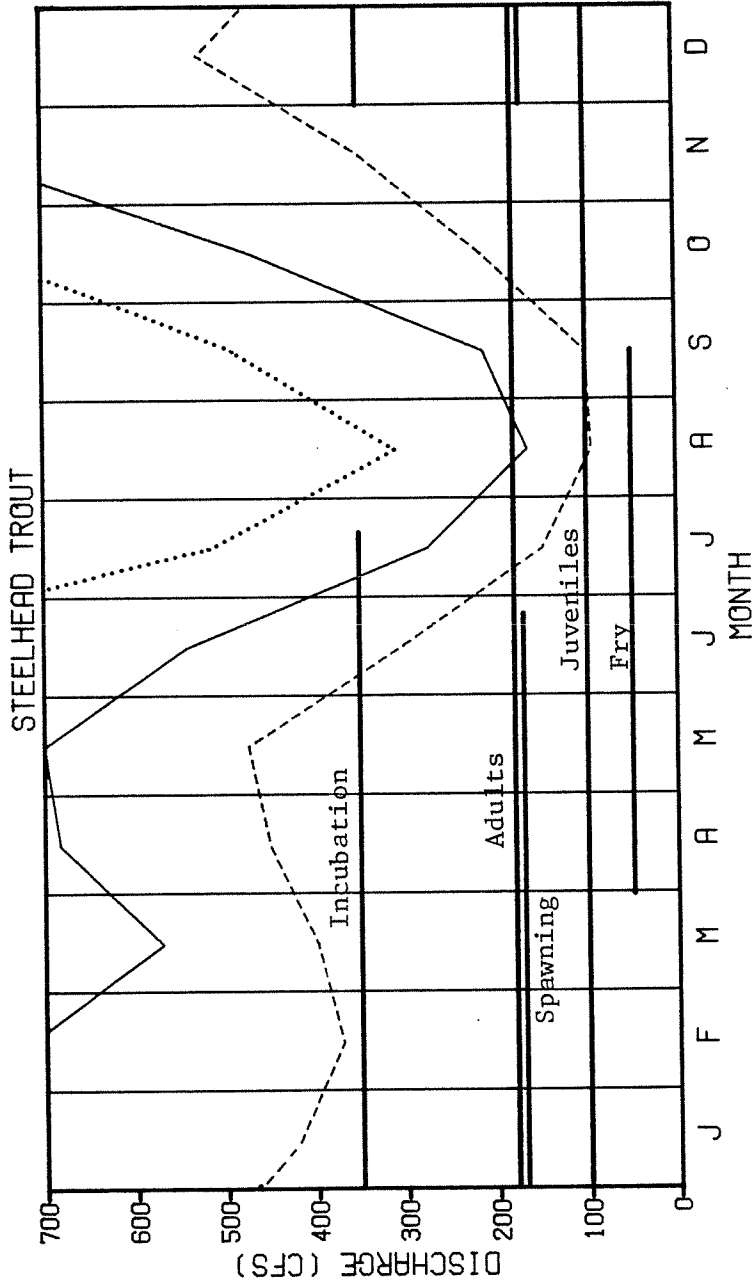


Figure 29. The relationship between Q_E discharges for steelhead trout life stages and mean monthly discharges at 10, 50, and 90 percentile exceedance probability levels for the mainstem Tolt River (1928-1979).

only during the summer months. It is apparent that moderate to dry water years on the Tolt River provide more habitat area for the various species/life stages than do years of high runoff.

6.4.5 Instream Flow Recommendations

The instream flow recommendations for the life stages of the various salmonid species were calculated for normal and critical water years using a combination of hydrological data and the Q_M flows specific to the life stages. The Q_M flows were identified as those discharges resulting in the maximum WUA for each species/life stage. For a given life stage, the recommended flow for a normal water year is equivalent to the discharge level less than or equal to the monthly median flow which results in the smallest reduction in habitat area relative to the WUA available at Q_M . Tables 23, 25, and 27 indicate the recommended monthly minimum instream flows for a normal water year for each life stage in the South Fork, North Fork, and mainstem Tolt River, respectively. The median monthly flow, obtained from USGS statistical records, corresponds to the expected monthly discharge in 1 out of 2 water years. Taken together, the median monthly flows indicated at the top of Tables 23, 25, and 27 are the equivalent of median flow years in the three river segments.

For those months that the median monthly flow exceeded the Q_M determined for a particular life stage, the recommended flow is identical to the Q_M . This situation occurred for most life stages, in spite of the higher Q_M flows.

A higher percentage of the discharges recommended for critical water years (Tables 24, 26, and 28) was less than the Q_M for the life stages in the three river segments. A critical water year is defined by the

occurrence of 90 percentile monthly flows or equivalently, the monthly discharge levels which are exceeded 9 in 10 years based on stochastic analysis of USGS discharge records. Streamflows less than the 90 percentile flows presented in Tables 24, 26, and 28 may be considered critical to the instream resources of the Tolt River.

An alternate method of determining instream flow recommendations for the life stages of the various salmonid species utilized normal and critical water years with a combination of hydrological data and peak habitat efficiency discharges (Q_E) specific to the life stages. The Q_E discharges resulted in an average reduction of 28 percent from the Q_M . For a given life stage, the recommended flow for a normal water year is equivalent to the discharge level less than or equal to the monthly median flow which results in the smallest reduction in habitat area relative to the WUA available at the Q_E flow. Tables 29, 31, and 33 indicate the recommended monthly minimum instream flows for a normal water year for each life stage in the South Fork, North Fork, and mainstem Tolt River, respectively. The median monthly flow, obtained from USGS statistical records, corresponds to the expected monthly discharge in 1 out of 2 water years. Taken together, the median monthly flows indicated at the top of Tables 29, 31, and 33 are the equivalent of median flow years in the three river segments.

For those months that the median monthly flow exceeded the Q_E flow determined for a particular life stage, the recommended flow is identical to the Q_E flow. This situation occurs for all life stages in the North Fork and mainstem Tolt River, in spite of Q_E flows as high as 200 and 350 cfs, respectively, in the two streams. In the South Fork, where the highest optimum flow was 175 cfs (steelhead trout incubation), recommended

flows were equivalent to the median monthly flows 7 percent of the time, primarily for adult and incubation life stages.

A much higher percentage of the discharges recommended for critical water years (Tables 30, 32, and 34) were less than the associated Q_E flows for the life stages in the three river segments. A critical water year is defined by the occurrence of 90 percentile monthly flows or, equivalently, the monthly discharge levels which are exceeded 9 years in 10 based on stochastic analysis of USGS discharge records. Streamflows less than the 90 percentile flows presented in Tables 30, 32, and 34 may be considered critical to the instream resources of the Tolt River.

Under critical water year conditions recommended flows are reduced relative to Q_E flows most frequently for adult and incubation life stages. In the South Fork, steelhead incubation flows are less than the optimum flow for the duration of the seven-month incubation period. Chinook salmon spawning and incubation habitat is also significantly affected by a decrease in monthly streamflows.

The weighting factors assigned to the physical habitat requirements of the salmon and trout species/life stages known to inhabit the Tolt River are listed in Table 35. The weight ascribed to each life stage is the average of three independent evaluations of the relative importance of the various habitat types which are utilized in the Tolt River system during successive months of the year. A value of 1.0 is assigned to a particular habitat type if only one life stage is present during the month in question. An example of this is chinook juvenile habitat in June when neither spawning nor incubation habitat for this species is utilized. For those months when multiple life stages of a species are present, the habitat types were

Table 35. Month-specific weighting factors (mean of three independent evaluations) derived for salmonid species/life stages known to inhabit the Tolt River system.

Species	Life stage	Month											
		J	F	M	A	M	J	J	A	S	O	N	D
Coho	Fry	0.133	0.333	0.367	0.633	1.000	1.000	1.000	1.000	1.000	0.300	0.133	0.100
	Spawning	0.367									0.567	0.700	0.633
	Incubation	0.500	0.667	0.633	0.367						0.133	0.167	0.267
Chinook	Juveniles	0.333	0.500	1.000	1.000	1.000	1.000	1.000					
	Spawning								0.833	0.767	0.466		
	Incubation	0.667	0.500						0.167	0.233	0.533	1.000	
Cutthroat	Fry				0.167	0.300	0.333	0.500	0.533	0.367			
	Juveniles	0.233	0.200	0.167	0.200	0.267	0.333	0.400	0.367	0.500	0.667	0.533	0.300
	Adults	0.167					0.100	0.100	0.100	0.133	0.333	0.467	0.330
	Spawning	0.433	0.600	0.500	0.233								0.367
	Incubation	0.167	0.200	0.333	0.400	0.433	0.233						0.100
Steelhead	Fry				0.167	0.200	0.333	0.433	0.467	0.300			
	Juveniles	0.233	0.133	0.133	0.100	0.100	0.300	0.433	0.400	0.533	0.700	0.677	0.300
	Adults	0.233	0.200	0.133	0.100	0.100	0.100	0.133	0.133	0.167	0.300	0.333	0.333
	Spawning	0.433	0.500	0.533	0.400	0.267							0.267
	Incubation	0.100	0.167	0.200	0.233	0.333	0.267						0.100

given weighting factors ranging from 0.1 to 0.9; the sum of the weighting factors equalled 1.0 for each species for any given month. For example, chinook spawning and incubation habitat is critical during October and receive weights on the basis of their relative importance to the species at this time of year. It is assumed that weighting factors developed for the various species/life stages were equally suited for South Fork, North Fork, and mainstem Tolt River populations.

Weighting factors for rearing habitat are generally high in comparison to adult habitat during the summer months. Spawning habitat becomes important during the fall months for salmon species and during the winter and early spring for trout species. The importance of incubation habitat is negligible until the peak spawning period for the individual species has passed. Adult habitat is most significant during the months immediately prior to spawning, and is weighted accordingly.

Monthly recommended flows for each species were determined by multiplying the recommended flows for each life stage obtained from Tables 23 through 28 for Q_M by the appropriate weighting factor and adding the products. The same procedure was followed using the recommended flows in Tables 29 through 34 for Q_E . Normal and critical water year recommended flows are presented in Table 36 based on Q_M and Table 37 based on Q_E for the separate species for the two forks and mainstem Tolt River.

The relative proportions of salmon and trout species captured during the early and late summer electrofishing sessions on the Tolt River are given in Table 38. Separate estimates were derived for the South Fork, North Fork, and mainstem Tolt River. Mountain whitefish, although observed in all three river segments, were not included in the analysis for reasons

Table 36. Minimum instream flow recommendations based on Q_m values for salmon and trout species for normal and critical water years for the South Fork, North Fork, and mainstem Tolt River.

	J	F	M	A	M	J	J	A	S	O	N	D
<u>South Fork</u>												
Coho	86	102	98	67	25	25	25	25	25	46	52	63
	67	90	61	56	25	25	25	25	25	34	45	62
Normal												
Critical												
Chinook	130	108	40	40	40	40	40	—	69	94	126	175
	81	81	40	40	40	40	40	—	38	51	86	165
Normal												
Critical												
Cutthroat	170	181	125	123	130	129	81	52	68	133	135	177
	96	116	82	96	122	77	40	23	38	51	89	142
Normal												
Critical												
Steelhead	135	149	134	142	145	89	52	42	55	88	91	131
	88	106	79	89	119	60	36	23	36	51	71	123
Normal												
Critical												
<u>North Fork</u>												
Coho	123	124	120	90	50	50	50	50	50	93	103	111
	123	123	120	90	50	50	50	50	50	82	103	111
Normal												
Critical												
Chinook	255	208	65	65	65	65	65	—	141	166	252	350
	218	154	65	65	65	65	65	—	81	95	178	326
Normal												
Critical												
Cutthroat	120	115	137	142	143	114	68	65	76	103	111	126
	120	113	131	142	143	105	65	58	66	88	111	116
Normal												
Critical												
Steelhead	174	202	198	198	212	140	64	62	73	96	97	159
	164	176	180	175	182	102	63	48	64	88	97	151
Normal												
Critical												
<u>Mainstem Tolt River</u>												
Coho	285	143	139	101	50	50	50	50	50	307	388	372
	256	143	139	101	50	50	50	50	50	85	94	372
Normal												
Critical												
Chinook	320	255	60	60	60	60	60	—	119	189	519	450
	300	215	60	60	60	60	60	—	100	134	237	450
Normal												
Critical												
Cutthroat	288	320	325	233	150	125	82	80	91	123	133	277
	275	293	299	233	150	125	80	71	82	123	133	277
Normal												
Critical												
Steelhead	203	240	247	248	286	209	89	85	98	124	128	198
	185	201	213	213	244	149	85	73	85	124	128	191
Normal												
Critical												

Table 38. Relative proportions of salmonid species inhabiting the South Fork, North Fork, and mainstem Tolt River based on electrofishing sessions in early and late summer, 1981.

Species	Percent numerical abundance		
	South Fork	North Fork	Mainstem
Coho salmon	0.088	0.046	0.180
Chinook salmon	0	0	0.005
Cutthroat trout	0.013	0.002	0.001
Steelhead trout	0.899	0.952	0.814

discussed above. Chinook salmon juveniles were captured only at MS7 and thus were excluded from the South Fork and North Fork analyses. In light of the spawner survey evidence of chinook spawning in the lower South Fork, it is highly probable that both tributaries are used to some extent by this species.

The monthly recommended flows calculated for each species were multiplied by their respective numerical proportions to arrive at composite normal and critical water year minimum instream flow curves for the Tolt River system. Recommended flows are identified on a monthly basis for the South Fork, North Fork, and mainstem Tolt River in Table 39 based on Q_M flows and in Table 40 based on Q_E flows.

It is apparent that the instream flow curves (Tables 39 and 40) developed in this study generally parallel the natural flow regimes of the three river segments. The recommended streamflows are greater during the winter and spring high runoff periods, decrease to seasonal low flows by late summer, and gradually increase during the autumn months. Relatively constant monthly discharges provide for steelhead spawning and incubation habitat needs, near-optimal summer rearing flows are attained during normal water years, and salmon spawning flows are incrementally increased as more water becomes available later in the year.

The Q_M -based instream flow recommendations (Table 39) indicate the maximum interpretation of fish flow requirements from the method for the South Fork, North Fork, and mainstem Tolt River. The winter discharge requirements based on Q_M are substantially higher during the winter-spring period when the steelhead spawning and incubation occur. This also coincides with the timing of maximum power demand. The minimum summer low

Table 39. South Fork, North Fork, and mainstem Tolt River normal and critical water year instream flow recommendations based on Q_M streamflows identified by WUA maxima for each species/life stage.

	J	F	M	A	M	J	J	A	S	O	N	D
<u>South Fork</u>												
Normal	131	145	130	135	134	84	50	40	53	84	88	126
Critical	86	105	78	86	110	58	35	23	35	50	69	118
<u>North Fork</u>												
Normal	172	198	195	193	205	136	63	61	72	95	97	157
Critical	162	173	177	171	176	100	62	48	64	84	97	150
<u>Mainstem</u>												
Normal	218	222	227	221	242	180	81	78	102	157	176	231
Critical	198	191	199	192	208	131	78	69	79	117	122	224

Table 40. South Fork, North Fork, and mainstem Tolt River normal and critical water year instream flow recommendations based on Q_E streamflows identified by peak habitat efficiency values for each species/life stage.

	J	F	M	A	M	J	J	A	S	O	N	D
<u>South Fork</u>												
Normal	85	95	93	91	92	72	41	37	43	57	58	80
Critical	77	87	75	76	87	51	32	23	33	48	58	79
<u>North Fork</u>												
Normal	144	160	165	144	138	88	51	50	57	75	77	128
Critical	144	160	165	144	138	88	50	43	48	68	77	128
<u>Mainstem Tolt River</u>												
Normal	158	173	177	164	172	138	82	76	90	115	119	155
Critical	158	173	177	164	172	128	78	69	79	115	119	155

flows closely approximate the minimums developed by either method, although the Q_M -based summer low flows are slightly higher than the Q_E -based flows.

Minimum instream flow recommendations for normal and critical water periods are identical for eight months of the year in the North Fork and mainstem Tolt River due to the interaction between Q_E flows and streamflows projected at the 50 and 90 percent exceedance probability levels (Table 40). If the Q_E flows identified for all species/life stages are less than the 1 in 2 and 1 in 10 year flows for a given month, then the normal and critical minimum flows are the same.

A final point to be made is that the recommendations for the two forks are generally higher in total than the discharges specified for the mainstem Tolt River. The greatest disparity occurs during the months of January through April, when the combined flows recommended for the tributaries range between 56 and 82 cfs higher than mainstem Tolt River flows (Table 40). This discrepancy is chiefly due to differences in steelhead spawning habitat Q_E flows determined for the North Fork and mainstem Tolt River. The Q_E flow for this life stage in the tributary is 200 cfs, as opposed to 170 cfs for the mainstem river. Furthermore, the proportional weighting of steelhead trout is greater in the North Fork than it is in the mainstem Tolt River. Since the 50 and 90 percentile flows are not limiting during the steelhead spawning season, the net result is higher recommended flows relative to the water available during median and critical water years in the North Fork.

6.4.6 Post-Project Effects

One of the objectives of this portion of the study was to determine the relationship between Q_E flows developed for the various salmonid species/ life stages and the average monthly discharges under pre-dam, post-dam, and post-project conditions. It was decided to use average rather than median monthly streamflows for the periods preceding and following reservoir construction since the simulated post-project discharges are only available as monthly averages (Table 4). The simulated flows were generated by R. W. Beck under specific constraints (e.g., existing minimum flow requirements) which are subject to change prior to project approval. Nevertheless, the flows which resulted from the feasibility study of the hydroelectric project represent the best estimates of monthly discharges for the South Fork below the Tolt Dam under post-project conditions, and are used herein to evaluate the effects of modifying the flow regime on the fishery resources in the river.

Q_E flows were determined from hydraulic and habitat modelling results for SF1 and SF2, which are located within the proposed diversion reach of the South Fork. The extrapolation factor for SF2 was adjusted downward to reflect the reduction in the length of stream represented by the study reach. Combined WUA indices were calculated for the 5.5 mile long diversion reach. The Q_E flows, identified by peak habitat efficiencies, and their associated WUA's for the upper South Fork (Table 41) are similar to those determined for the entire river (Table 21). The Q_E flows for salmon incubation habitat, however, are notably lower for the diversion reach. The relationship between Q_E flows and the historical/projected streamflows under pre- and post-dam and post-project conditions are illustrated for

Table 41. Combined WUA and associated Q_E flows resulting in peak habitat efficiencies for different species/life stages in the South Fork between the barrier falls (RM 8.0) and proposed discharge site (RM 2.5). Estimates were derived from HABTAT model results for South Fork stations 1 and 2.

		Optimum Q	WUA
Coho	Fry	50	82830
	Spawning	35	81221
	Incubation	70	431220
Chinook	Juveniles	35	261170
	Spawning	55	78771
	Incubation	80	473179
Cutthroat	Fry	40	100981
	Juveniles	70	174915
	Adults	65	225689
	Spawning	35	43888
	Incubation	140	441641
Steelhead	Fry	30	268041
	Juveniles	50	376504
	Adults	80	88570
	Spawning	100	92005
	Incubation	175	663874
Whitefish	Fry	60	63876
	Juveniles	75	264437
	Adults	500	278553
	Spawning	85	228235

coho, chinook, cutthroat, and steelhead in Figures 30, 31, 32, and 33, respectively.

Virtually all of the species/life stage Q_E flows are less than the average monthly flows calculated from pre-dam construction discharge records. The Q_E flow for steelhead incubation (175 cfs) is the lone exception to this observation; the Q_E flow exceeds the average pre-dam discharge in the months of March, June, and July. The remaining life stages have Q_E values which are generally equal or less than post-dam average monthly discharges. The only period of the year that this does not apply is August, the month with the lowest average flow. The primary life stages affected are coho fry, and adults and juveniles of the trout species. The average monthly streamflows simulated for the post-project period are greater than the optimum flows identified for several species/life stages. These include fry of all species, juvenile steelhead and chinook and coho and cutthroat spawning.

A second objective in analyzing the effects of post-project flows on instream salmonid habitat in the South Fork was to quantitatively describe the percent change in WUA as a function of past, present, and future modifications to the flow regime in the river. The percentage gain or loss in WUA for life stages of coho, chinook, cutthroat, and steelhead with pre-dam construction discharges compared to post-dam discharges are presented in Part A of Figures 34, 35, 36, and 37, respectively. The comparisons are made only for the periods of time that the species/life stages are known to inhabit the upper South Fork. The net effect of the reduction in average monthly streamflows caused by reservoir storage and water diversion has been beneficial: the WUA indices for most life stages

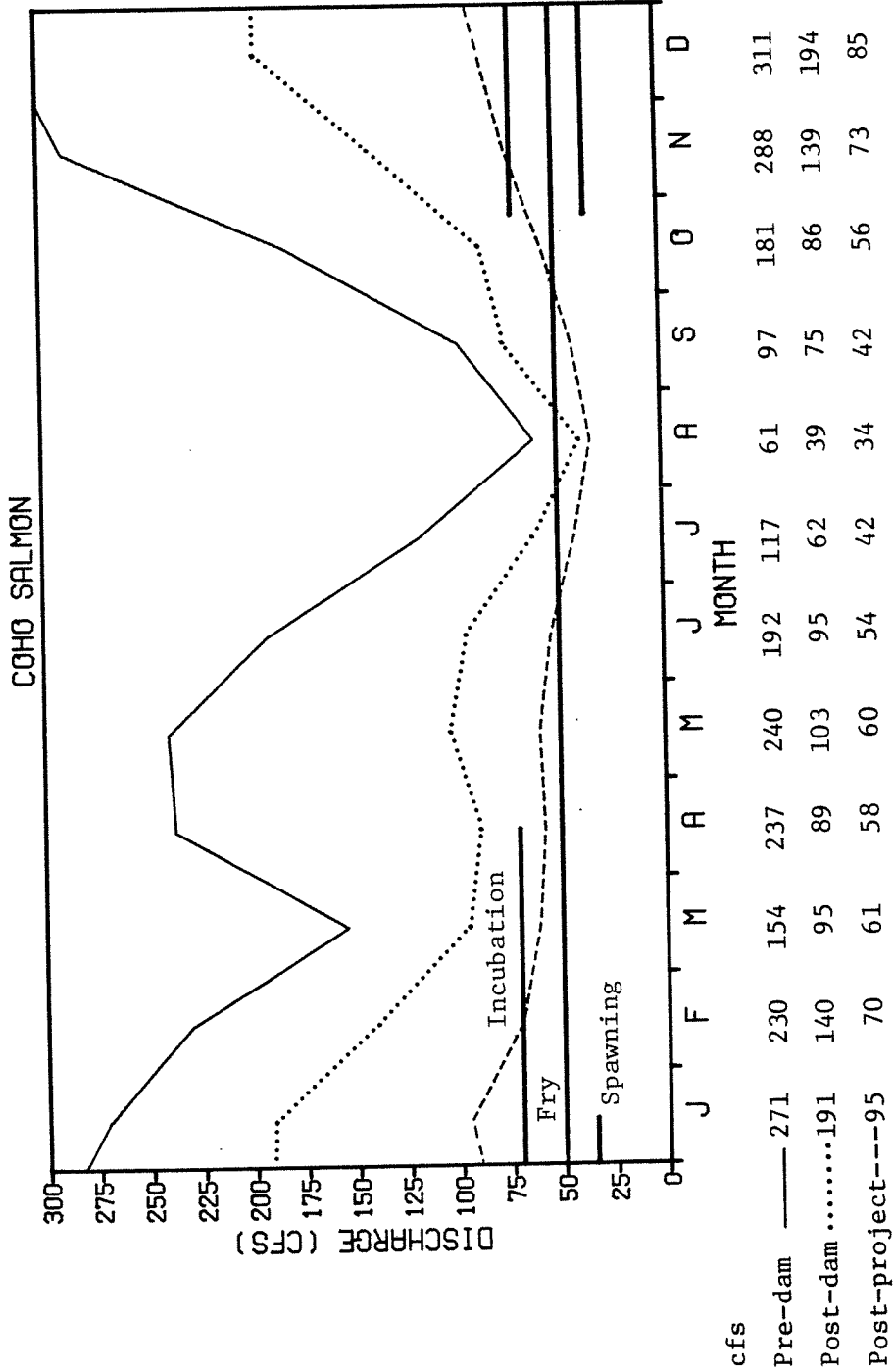


Figure 30. Relationship between Q_E discharges determined for different coho salmon life stages and average monthly streamflows during pre- and post-dam, and post-project construction periods for the South Fork Tolt River.

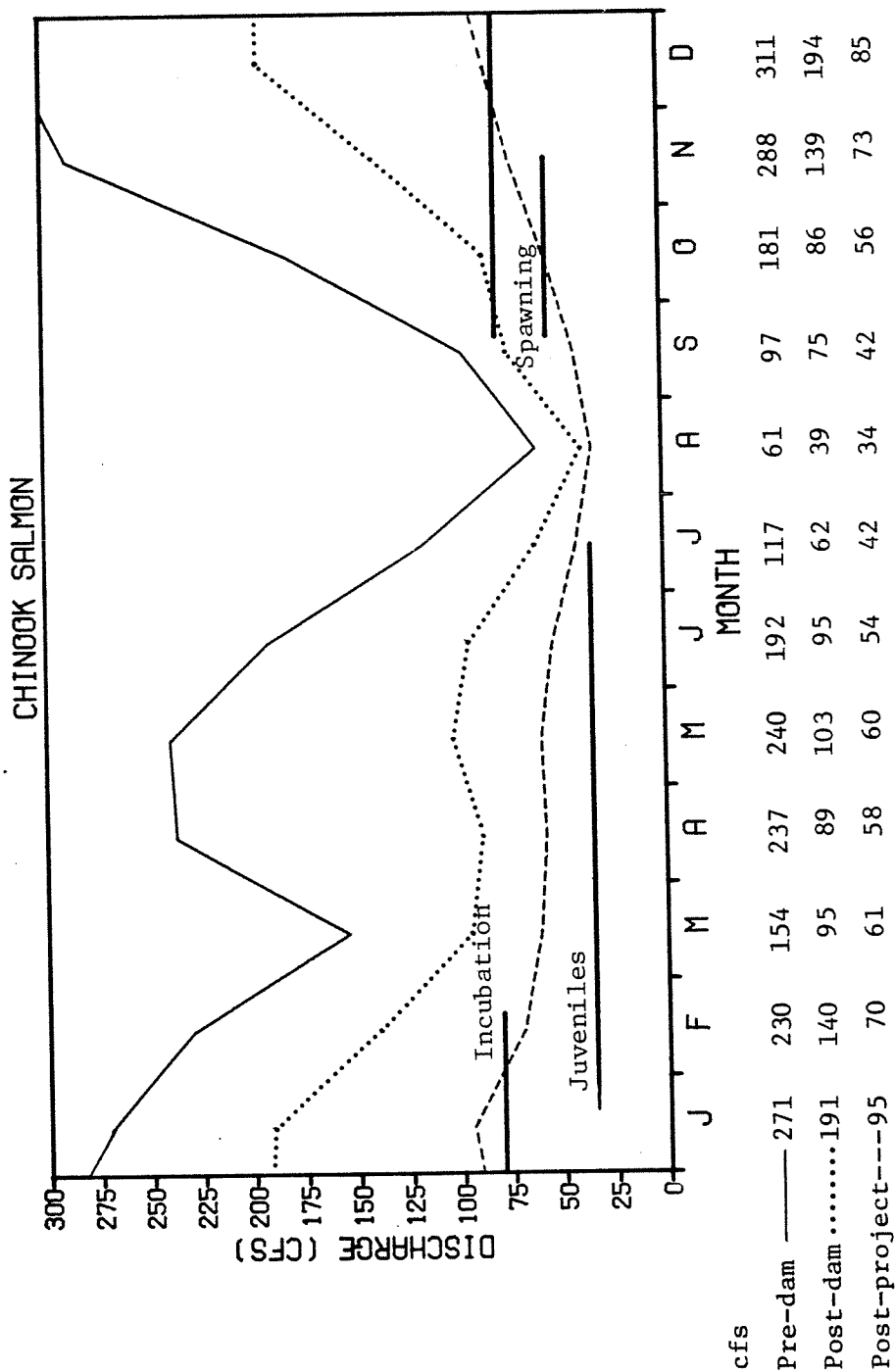


Figure 31. Relationship between Q_E discharges determined for different chinook salmon life stages and average monthly streamflows during pre- and post-dam, and post-project construction periods for the South Fork Tolt River.

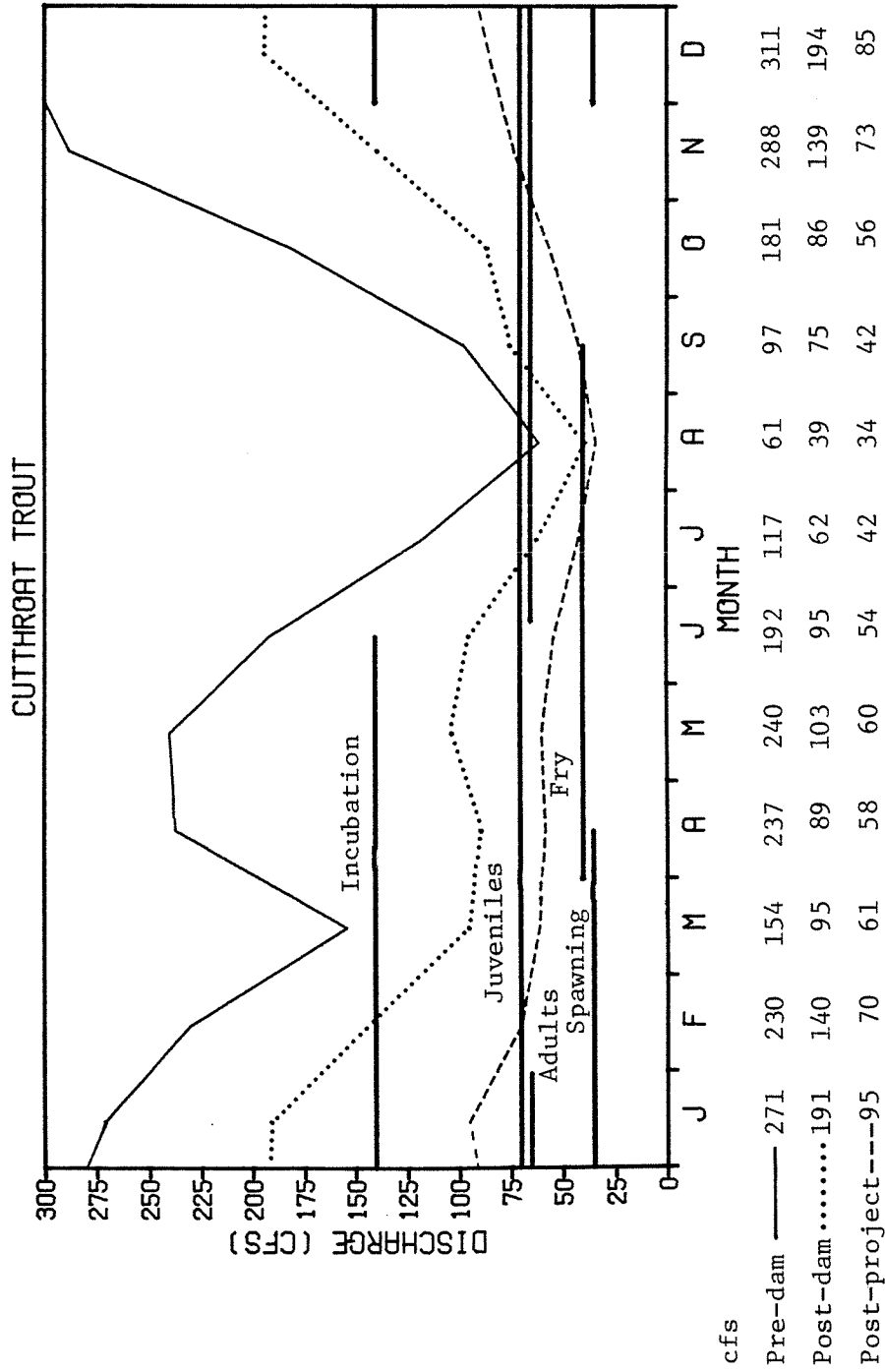


Figure 32. Relationship between Q_E discharges determined for different cutthroat trout life stages and average monthly streamflows during pre- and post-dam, and post-project construction periods for the South Fork Tolt River.

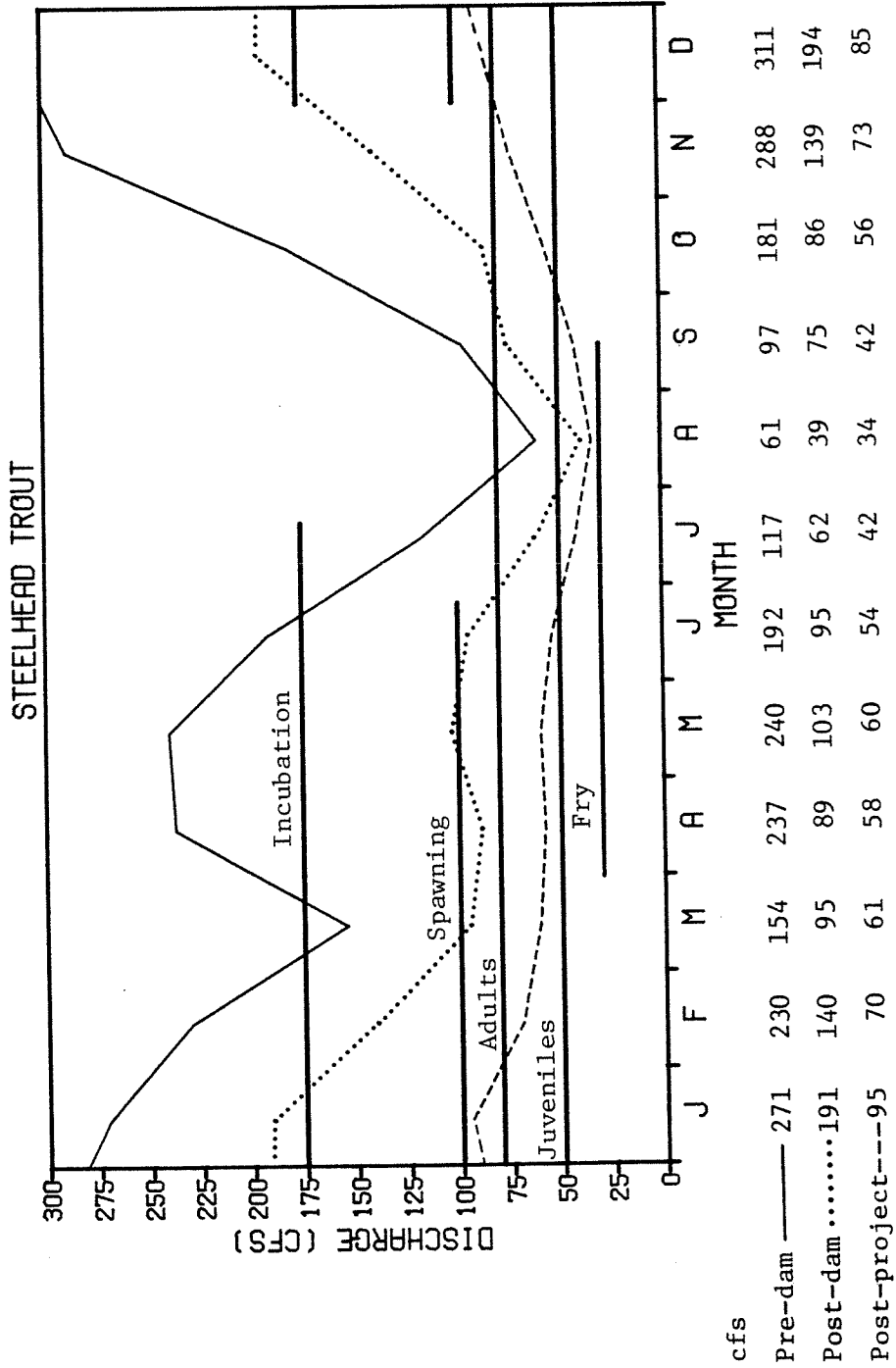
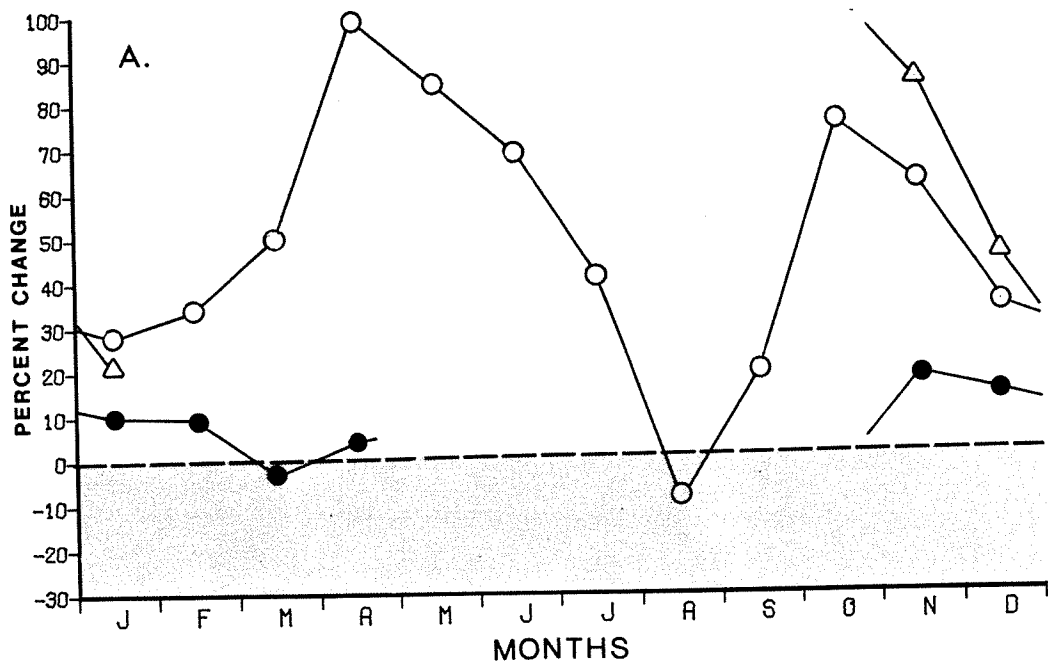
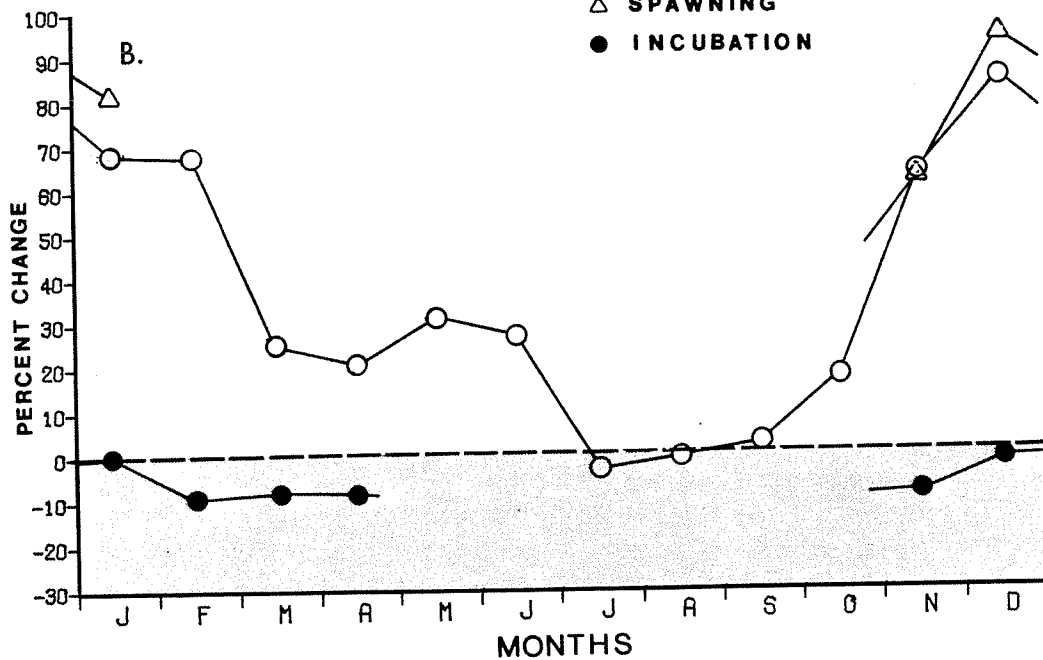


Figure 33. Relationship between Q_E discharges determined for different steelhead trout life stages and average monthly streamflows during pre- and post-dam, and post-project construction periods for the South Fork Tolt River.

COHO SALMON



○ FRY
 △ SPAWNING
 ● INCUBATION

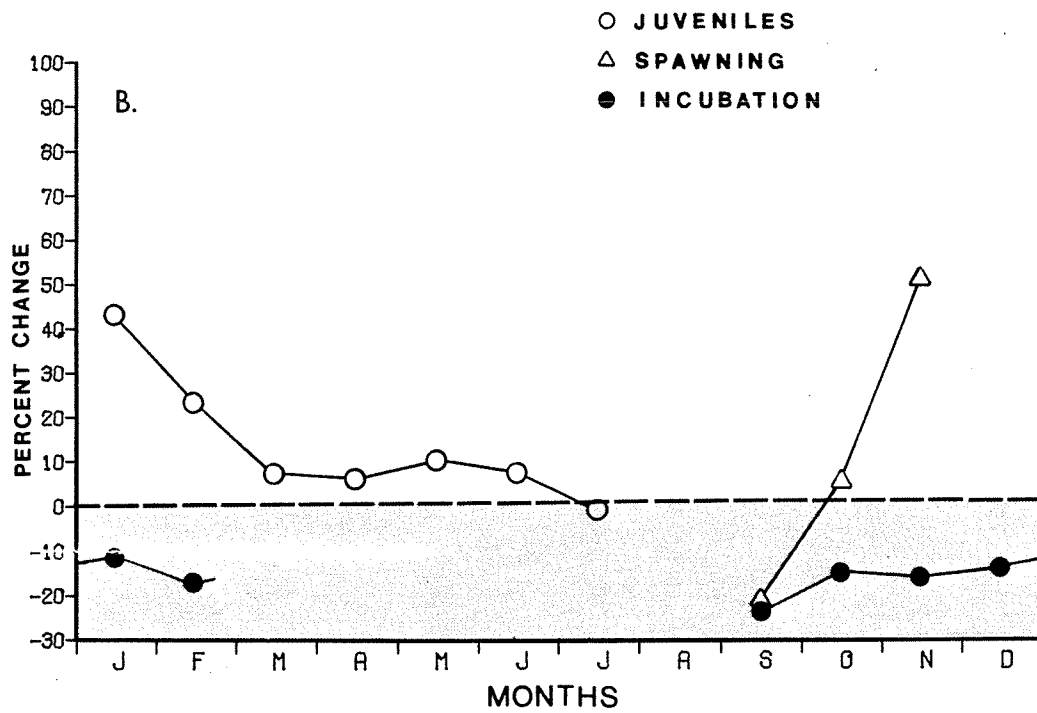
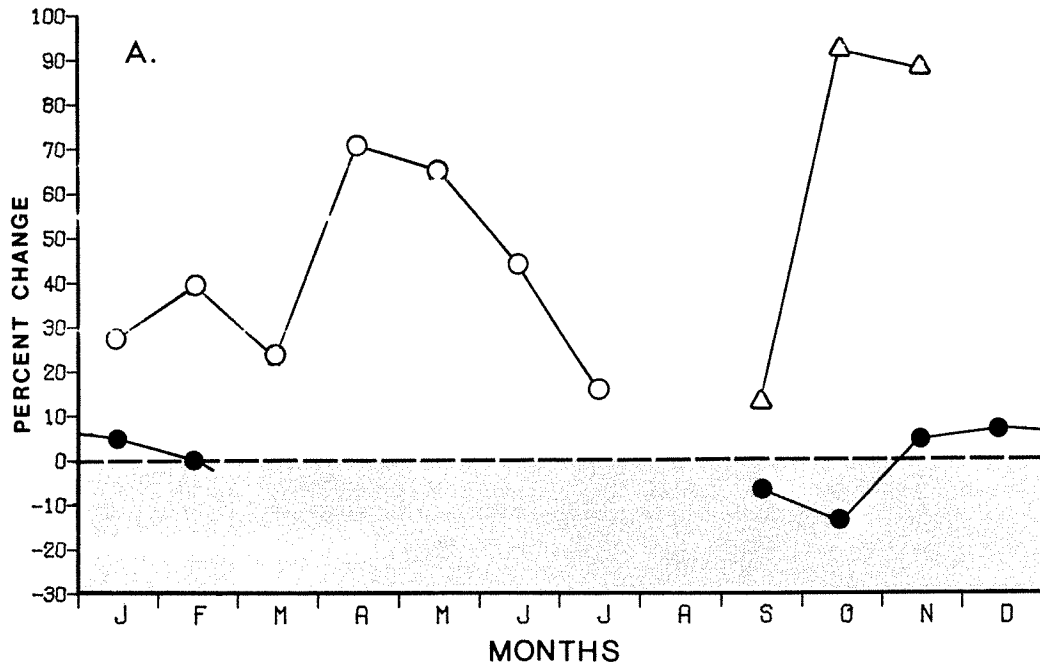


cfs

Pre-dam	271	230	154	237	240	192	117	61	97	181	288	311
Post-dam	191	140	95	89	103	95	62	39	75	86	139	194
Post-project	95	70	61	58	60	54	42	34	42	56	73	85

Figure 34. The percent change in WUA for coho salmon life stages in the South Fork when comparing A) pre-dam versus post-dam monthly discharges, and B) post-dam versus post-project mean monthly discharges.

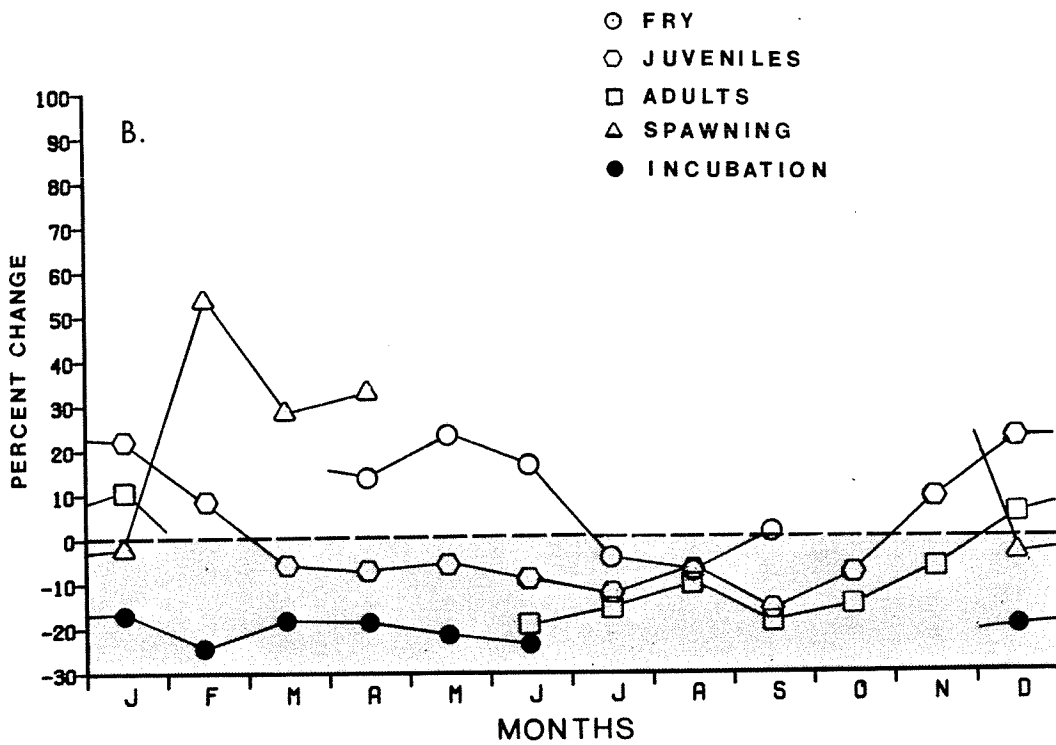
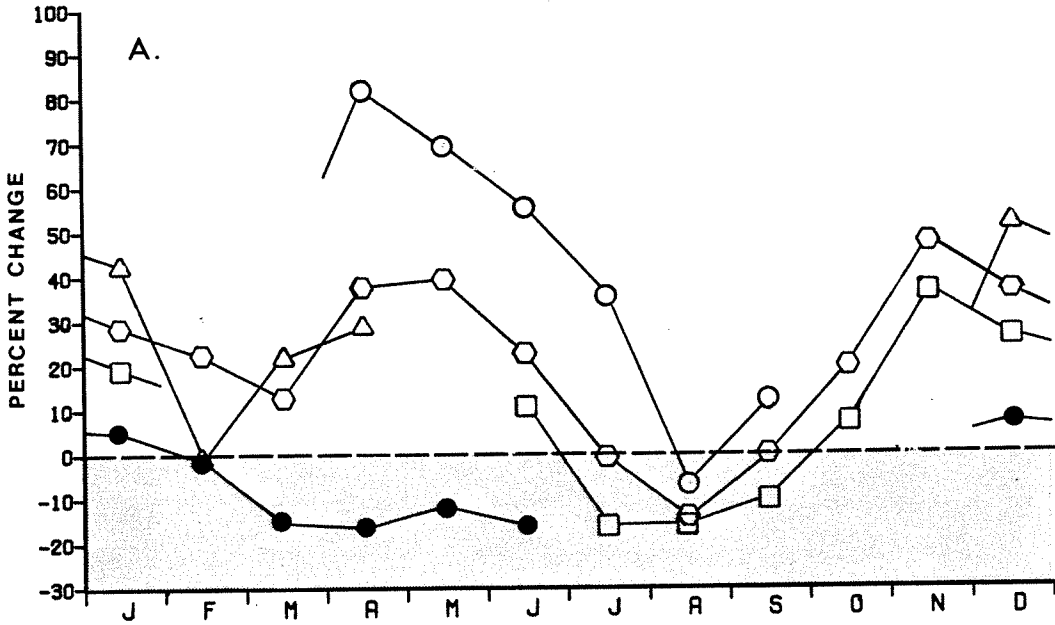
CHINOOK SALMON



cfs	J	F	M	A	M	J	J	A	S	O	N	D
Pre-dam	271	230	154	237	240	192	117	61	97	181	288	311
Post-dam	191	140	95	89	103	95	62	39	75	86	139	194
Post-project	95	70	61	58	60	54	42	34	42	56	73	85

Figure 35. The percent change in WUA for chinook salmon life stages in the South Fork when comparing A) pre-dam versus post-dam monthly discharges, and B) post-dam versus post-project mean monthly discharges.

CUTTHROAT TROUT

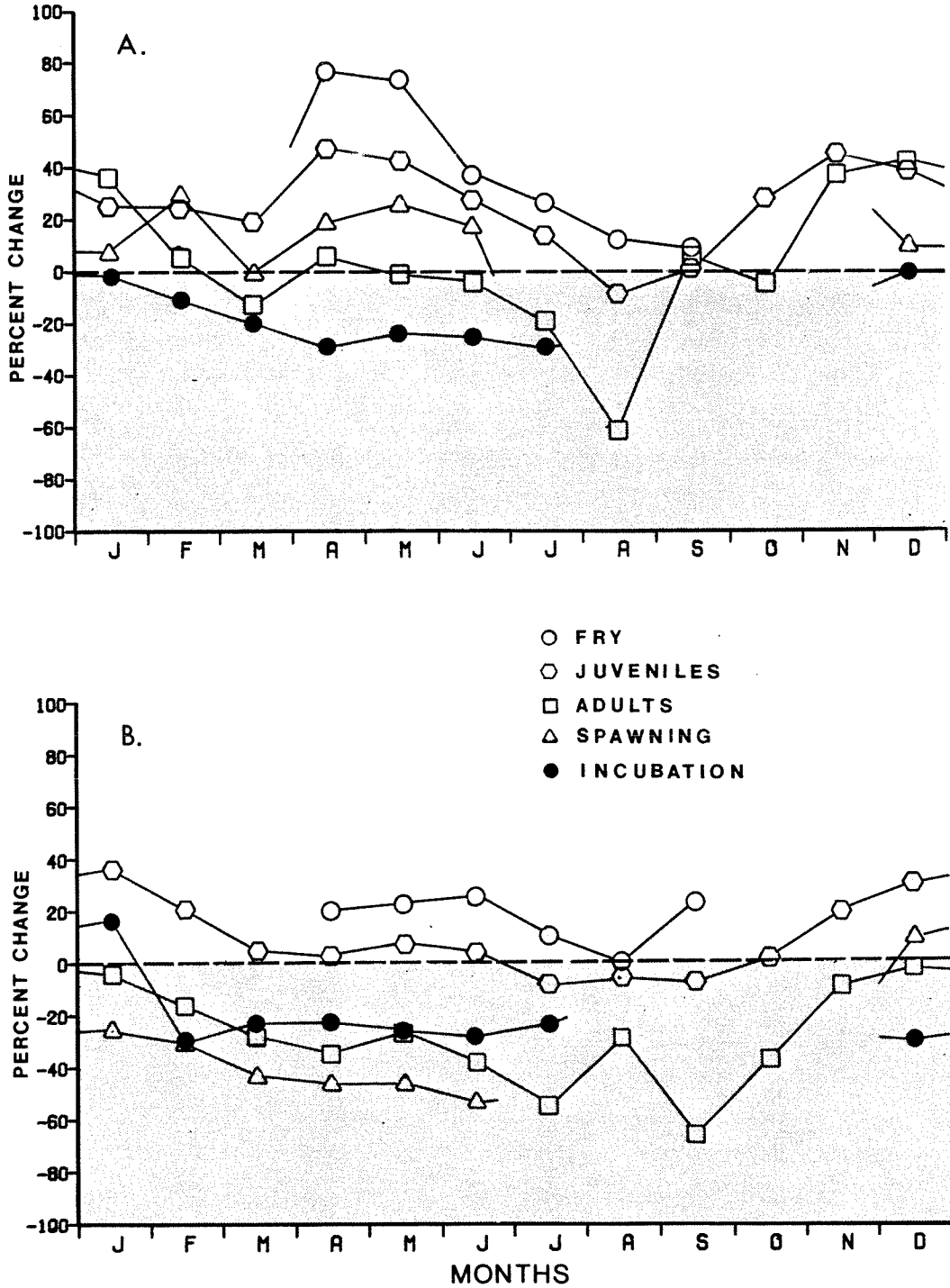


cfs

Pre-dam	271	230	154	237	240	192	117	61	97	181	288	311
Post-dam	191	140	95	89	103	95	62	39	75	86	139	194
Post-project	95	70	61	58	60	54	42	34	42	56	73	85

Figure 36. The percent change in WUA for cutthroat trout life stages in the South Fork when comparing A) pre-dam versus post-dam monthly discharges, and B) post-dam versus post-project mean monthly discharges.

STEELHEAD TROUT



cfs

Pre-dam	271	230	154	237	240	192	117	61	97	181	288	311
Post-dam	191	140	95	89	103	95	62	39	75	86	139	194
Post-project	95	70	61	58	60	54	42	34	42	56	73	85

Figure 37. The percent change in WUA for steelhead trout life stages in the South Fork when comparing A) pre-dam versus post-dam monthly discharges, and B) post-dam versus post-project mean monthly discharges.

increased by varying amounts relative to pre-dam indices. The largest positive response was observed for the fry and juvenile life stages of most species, particularly during the winter months. Low flows during the month of August, however, currently provide less rearing habitat than was available before the reservoir was completed. Spawning habitat has been enhanced under present conditions for all salmonid species, as evidenced by the positive percent change values. Incubation WUA's, on the other hand, have decreased for all species except coho following the transition from unregulated to regulated streamflows. This life stage also appears to be the most adversely affected by the further reduction in streamflows which will result from powerhouse operation.

The expected changes in physical habitat availability when present streamflows are compared to post-project simulated discharges on a monthly basis are presented for coho, chinook, cutthroat, and steelhead in Part B of Figures 34, 35, 36, and 37, respectively. Some benefit will accrue in terms of rearing and spawning habitat; however, rearing habitat will be negatively affected during the summer months. In addition to incubation habitat losses, adult cutthroat and steelhead habitat will decrease under post-project conditions. An even greater decrease, averaging 40 percent, can be expected in steelhead spawning habitat during the late winter and spring.

7.0 DISCUSSION

7.1 Physical

The discharge regime of the North Fork and mainstem Tolt River is fairly typical of streams draining the west slope of the Cascade Mountains. High flows coincide with periods of increased precipitation and snow melt in the winter and spring months. Low-flow periods generally extend through the months of August and September.

The effect of logging and road construction activities in the upper North Fork watershed may have produced some decrease in the lag time between the center of a storm mass and the center of the resultant hydrograph mass, and a concomitant increase in flood peaks measured in the lower river sections. The North Fork hydrograph appears to have a greater influence on the mainstem Tolt River flow regime than does South Fork discharge.

The necessity of recharging the South Fork reservoir following the summer high water demand period results in a reduction of peak flows below the dam relative to inflow into the reservoir during the autumn months. Fish release requirements augment the minimum flows present in the lower South Fork during the summer low-flow period. Streamflows in this reach probably would have declined below the minimum flow recorded (29 cfs) under unregulated conditions.

Stream temperature data indicate greater diel fluctuations and higher maxima in the South Fork due to the thermal regime of the reservoir and the level of release. Nevertheless, temperatures in the South Fork during the summer months are well below the critical temperature threshold for salmonids. The net effect of elevated temperature in the regulated stream

is probably beneficial in terms of increased growth rates and productivity within the aquatic community.

Suspended sediment concentrations appear to be of negligible concern in the Tolt River system. Although North Fork concentrations generally exceed those measured simultaneously in the South Fork, suspended sediment concentrations in both streams are well below levels at which lethal and sublethal effects have been observed for juvenile salmonids. A review of the behavioral, physiological, and lethal effects of suspended sediments on salmonids by Noggle (1978) indicates that sediment concentration in the Tolt River would have to increase on the order of 10 to 100 times present levels before the functional and structural characteristics of the aquatic community would be affected.

The measurement of the particle size distribution of spawning bed materials is a commonly used method of evaluating the quality of the intragravel environment for developing salmonid eggs and embryos. Studies conducted in Pacific Northwest streams in relatively undisturbed watersheds have found fine sediment levels ranging from 3.1 to 20.6 percent (wet volume) in spawning gravels, as shown in Table 42. The percentage of fine sediments recorded for the study areas from the Tolt River system vary between 7.2 and 22.7 percent, averaging 31.1 percent for the South Fork, 10.4 percent for the North Fork, and 15.6 percent for the mainstem Tolt River. Only MS5 approaches the upper limit of the range of values presented in Table 42, suggesting that spawning habitat in the Tolt River has not been seriously affected by human activities.

Streambed composition in the Tolt River system is highly variable in both time and space. The textural composition of spawning beds is affected

Table 42. Percentage of fine sediment (wet volume) in streambed core samples from Pacific Northwest streams not impacted by development (Source: Scott et al. 1981).

Stream (state)	Number of samples	Cutoff point	Percent fines	Source
Upstream Harris R. (AK)	25	<.833	13.9	McNeil and Ahnell (1960)
Anan Cr. (AK)	5	<.833	5.7	"
Upper Clearwater R. (WA)	27	<.850	8.3	Cederholm and Salo (1979)
S. Fork Hoh R. Trib. (WA)	6	<.850	3.1	"
S. Fork Hoh R. (WA)	19	<.850	8.3	"
Tshlecthy Cr. (WA)	6	<.850	6.0	"
Bob Cr. (WA)	6	<.850	4.9	"
Harlow Cr. (WA)	5	<.850	9.6	"
Stequaleho Cr. No. 1 (WA)	43	<.850	6.9	"
Sollocks R. Nos. 1-3	91	<.850	7.9	"
Little Lost Man Cr. (CA)	20	<.833	16.3	Woods (1980)
Bummer Lake Cr. (CA)	21	<.800	10.2	Burns (1972)
S. Fork Yager Cr. (CA)	10	<.800	16.4	"
Little N. Fork Noyo R. (CA)	27	<.800	20.0	"
S. Fork Casper Cr. (CA)	20	<.800	20.6	"
			Mean 11.1	

by a combination of biological and physical factors. Since gravel samples were not obtained from active redd sites, the influence of salmonid digging activity on the level of fine sediments in the samples is probably minimal. Stream discharge and sediment loading appear to be the primary processes affecting bed composition. The fact that February samples contain higher amounts of fines than do July and September samples suggests that the comparatively large sediment loads being delivered to the stream are incompletely flushed by peak flows during the winter months. The supply of fine materials introduced into the system at this time by erosion and overland flow apparently exceeds the sediment transport capacity of the stream, resulting in surface deposition and intrusion of fine sediments into gravel interstices. It is hypothesized that the percentage of fines in the Tolt River streambed is lowest in the late spring and early summer months following the snowmelt runoff period.

In regard to differences in percent fines between stations, the North Fork station consistently ranks lower than South Fork and mainstem Tolt River stations, implying that the quality of spawning gravel is better in the unregulated stream. The level of fine sediments in spawning gravel in the South Fork increased in a downstream direction, indicating an accumulation of sediment from erosional sources. Within the Tolt River watershed, bank failures caused by logging, road building, and construction activities are the primary source of sedimentation. It should also be pointed out that these same erosional sources supply spawning sediment-sized particles to the stream, compensating in part for the interception by the reservoir of gravel recruited from the upper watershed.

7.2 Biological

Although statistical analysis yielded few significant results, some trends and differences in benthos mean density, biomass, and diversity values are worthy of discussion. The large changes in benthic density and biomass at NF4 and MS5 are of particular interest. These differences were not significant due to high sample variances, indicating a strongly clustered (contagious) distribution within the substratum. The overall highest and lowest density and biomass values occur at NF4 in September and February, respectively. The lowest overall diversity value also occurred at NF4 in September. The low invertebrate density in February may reflect the depletion of benthos caused by scouring. The rapid increase to a high density level in September accompanied by a sharp drop in species diversity indicates rapid colonization and population growth by relatively few species. MS5, the uppermost mainstem station, is influenced by North Fork discharge and shows a similar strong depletion and recovery pattern, although higher diversity values were found. The other South Fork and mainstem stations exhibit less dramatic changes in standing crop yet all except SF3 attained peak density and biomass values in September. Exceptionally low diversity values were also found at SF1 and MS5 in July due to the dominance of chironomids in the samples. The chironomid population at SF1 may have been enhanced by the presence of a dense layer of periphyton on the substrate.

The peak standing crop level measured at NF4, although not statistically significant, is high enough to warrant speculation about benthic habitat quality in comparison to other stations. This is especially relevant

because of the high salmonid density estimates calculated, which is further evidence that a true difference in food (invertebrate) levels may exist. The North Fork station has some advantages due to its general bed morphology. The area sampled is wide and shallow and appears to receive greater solar insolation than most other stations, which probably benefits periphyton and macroinvertebrate grazers. The substrate is broken up by small boulders, creating a range of local water velocities at any given stage.

Results of the correlation and regression analyses of environmental variables are difficult to interpret. Other researchers have found that the substrate composition is highly correlated with the diversity (DeMarch 1976) and abundance (Williams and Mundie 1978) of lotic invertebrates. No significant correlations were found between density, biomass or diversity and substrate size for any of the sampling dates. Water depth and velocity showed both positive and negative significant correlations. Regression analysis of invertebrate density in September showed negative correlations with both depth and velocity. Both variables together explained 80 percent of the variability in the data.

A comparison of standing crop estimates derived in this study with those determined for other western Washington rivers is limited by differences in sampling techniques. Catch efficiency, depth of sample and sample bias differ between benthic samplers and preclude a comparison of quantitative data obtained with different samplers. Martin (1976) used the Neill cylinder and very similar methodology in his study of siltation effects on macroinvertebrates in four tributaries to the Clearwater River on the Olympic Peninsula. Averaging data from the four tributaries for the months that the Tolt River

was sampled, density and biomass estimates were obtained for comparison. Average density and biomass estimates for the Tolt River were 71 percent and 83 percent, respectively of the corresponding estimates for the Clearwater River tributaries. These findings may indicate that the Tolt River is less productive than other western Washington streams, primarily due to its high gradient and low nutrient levels.

Steelhead are the dominant salmonids in the Tolt River. Population estimates for September provide the most useful comparisons between stations due to the sampling problems experienced in July. Steelhead fry density was much higher at NF4 than at all other stations. The high steelhead redd counts in the North Fork (1981-1982 season) indicate that high fry densities may be expected in 1982. Age 1 steelhead density at NF4 was higher than at all stations except MS7, but the ratio of Age 1 to Age 0 fish (.04) was lower than at all other stations. Several reasons may account for this imbalance: 1) low survival of fry to age 1, 2) greater fry recruitment in 1981 than in 1980, 3) migration of fry or juveniles, and/or 4) sampling bias. Mortality estimates based on data from one year can be misleading because of variation in year class strength. If high mortality was occurring at NF4, it could indicate the operation of density-dependent factors (i.e., the carrying capacity had been reached). Similarly, migration from the station may be a response to overcrowding. The low Age 0 growth rates found in the North Fork may be indicative of competition for food. The macroinvertebrate results presented earlier indicate that food is abundant at NF4 in the summer and fall but becomes scarce by mid-winter. It is possible that the decreased macroinvertebrate levels and high winter flows stimulate downstream migration to areas of slower current

and higher food availability. Inaccurate estimation of Age 1 and Age 2 fish could also be responsible for the results, as the larger juveniles were more difficult to capture and tended to aggregate in favorable areas. The presence of one exceptional juvenile holding location in a study area often doubled the catch of Age 1 and Age 2+ steelhead in the sample.

The low steelhead density found at SF1 may be due to underseeding. No redds or adult steelhead were seen within .5 miles of this station; however, spawner surveys were not conducted regularly this far upriver. The highest steelhead density of the mainstem stations was found at MS6, which is a wide slow-moving run situated below a heavily spawned area. Steelhead fry may move downstream into MS6 after emergence, which offers the closest suitable rearing area. Aside from SF1 and MS6, the steelhead density estimates for the South Fork and mainstem stations are comparable, implying that flow reduction and moderation in the South Fork has not been detrimental to juvenile steelhead populations. However, pre-dam fish population level in the South Fork may have been higher, similar to that found in the North Fork.

Sculpins have often been accused of being deleterious to steelhead populations through predation and competition. No evidence to substantiate this belief is present in these results. The stations with low sculpin populations show similarly low steelhead levels. It is apparent from the standing crop estimates that conditions which favor one species are also of benefit to the other.

High coho densities at SF3 and NF4 indicate that the lower reaches

of both forks are utilized by this species. The highest density was found at MS7, which is downstream of a side channel in which coho were seen spawning in 1981. The sighting of large numbers of coho fry emigrating from Stossel Creek in May indicate that the mainstem area below MS5 rears large numbers of coho juveniles.

Standing crop estimates from selected steelhead rivers in Washington and California are presented in Table 43. The standing crop estimates derived for the Tolt River are considerably lower than those for other streams in nearly every case. This is true not only for steelhead, but for total salmonid and total teleost standing crop as well. These findings, in conjunction with the low macroinvertebrate population estimates, indicate that the aquatic productivity in the Tolt River is low at all trophic levels.

The North Fork and mainstem Tolt River appear to be used more heavily than the South Fork by spawning steelhead. Lower redd counts for the South Fork index area may be attributable to the relative scarcity of spawning habitat available in the stream and to the depressed numbers of returning adults. The early peak in spawning activity observed for the South Fork suggests that there may be a higher proportion of summer-run and/or hatchery fish returning as compared to the North Fork and mainstem Tolt River steelhead populations. Higher mean water temperatures in the South Fork may also be conducive to a change in spawning time. It should be noted that the early to mid-May peak in spawning activity documented for the North Fork and mainstem Tolt River is appreciably later than the mid-April peak observed in the Snoqualmie River by the Washington Department of Game in 1981 (WDG unpublished data 1981).

Coho salmon were found to spawn in low numbers in the North and South

Table 43. Standing crop estimates for some steelhead rivers in Washington and northern California.

Author	Stream	Location	Month	Standing crop ($\text{g}\cdot\text{m}^{-2}$)				
				Steelhead trout	Coho salmon	Total salmonids	Non-salmonids	Total teleosts
Chilcote et al. (1981)	Gobar Creek	Washington	Fall	3.10	0.08	3.64	—	—
Eddie (1975)	Sollek River	Washington	Aug. + Sept.	1.06	—	3.38	5.15	8.53
Eddie (1975)	Stequaleho Creek	Washington	Aug. + Sept.	.96	—	2.16	6.18	8.33
Casne (1975)	Cedar River	Washington	Sept.	—	—	2.50	—	—
Burns (1971)	S. Fk. Yager Cr.	California	Aug.	4.39	0	4.39	0.12	4.51
Burns (1971)	N. Fk. James Cr.	California	Oct.	6.50	0	6.50	1.12	7.62
Burns (1971)	Little N. Fk. Noyo R.	California	Oct.	0.37	2.10	2.47	0.17	1.02
Burns (1971)	Caspar River (North and South Fork)	California	June	1.65	0.88	2.53	0.01	2.54

Forks and in side channels of the mainstem Tolt River. The majority of the coho adults observed in the mainstem were probably en route to Stossel Creek, a tributary of the Tolt River which is heavily used by this species. A small number of chum salmon were also observed spawning in Stossel Creek.

The low numbers of chinook and chum salmon seen in the Tolt River system are consistent with the results of surveys conducted by the Washington Department of Fisheries in recent years. The gradual reduction in spawner numbers over the past two decades suggests that these species may be threatened with extinction from the Tolt River system.

7.3 Instream Flow Analysis

The procedures used to develop formal instream flow recommendations from the application of the IFG method have not yet become a standardized part of the procedure. The primary reasons for this lack of consensus among fisheries biologists are the relative newness of the method and the scarcity of literature which adequately describes the steps necessary to generate flow recommendations. Stalnaker (1979) and Loar and Sale (1981) discuss the decision-making process in general terms, but both references are incomplete in their instructions for arriving at final recommendations.

In this study, we have followed in part the directions offered by Loar and Sale (1981). Their suggestion, which they attribute to Ken Bovee of the IFG, is to examine the relative change in WUA from optimal conditions with respect to discharge. Using this approach, the instream flow requirement for each species/life stage is identified as the streamflow between the monthly median flow and the 90 percentile monthly flow resulting in the smallest reduction in WUA relative to the optimum. This process

is repeated for all life species/life stages of interest for each month of the year. The minimum flow recommended for a given month is the discharge which results in the lowest relative change for all species and life stages.

The initial problem encountered in the interpretation of WUA output for the Tolt River study areas was the selection of criteria used to define optimum flows for the various salmonid life stages. The use of WUA maxima was an obvious choice and was subsequently incorporated as the basis of Q_M derived flow recommendations. It is also apparent from an inspection of Figures in Appendices B, C, and D that the slope of the WUA curve frequently decreases in the vicinity of the WUA maxima. In several cases, this decrease is great enough to define an inflection point at a discharge which is less than the flow associated with the WUA maxima. The consequence of a flattened WUA curve is a disproportionate increase in discharge relative to the habitat area recruited as the WUA maxima are approached. It was found that the peak of the habitat efficiency curves generally identified inflection points on the WUA curves. Furthermore, the streamflow associated with the peak habitat efficiency value is that discharge which provides the maximum amount of physical habitat relative to the total stream surface area available for the range of streamflows considered. Streamflows determined in this manner were termed Q_E discharges and served as an alternative to Q_M discharges in the process of deriving instream flow recommendations. Using Q_E discharges for the various life stages resulted in an average decrease in instream flow of 28 percent relative to Q_M , yet only an average 4.5 reduction in WUA was observed.

No reference is made by Loar and Sale (1981) or Stalnaker (1979) as to the method of selecting target fish species or life stages to be given preferential consideration in the instream flow analysis. Presumably, the decision would be based on criteria such as numerical abundance, limiting or critical life stages, and economic or recreational value. In this study, all of the salmonid species/life stages for which phenological and habitat suitability data were available were included in the instream flow analysis. The preference accorded to each species was determined by their relative abundances in the different river sections during the early summer and autumn months. This method of weighting individual species appears justified despite the inevitable misrepresentation of some species due to sampling bias (i.e., location, time, and number of samples) and it avoids most of the subjectivity inherent in other methods.

Species-specific recommended flows were also based in part on the monthly weighting factors assigned to the various life stages present in the river. To make the selection of weighting factors as objective as possible, the three FRI fisheries biologists involved in the project individually assessed the importance of each life stage relative to other life stages of the same species present during successive months of the year. The independently derived weighting factors were summed and averaged in order to arrive at the values presented in Table 35. This technique minimized the subjective elements of the selection process.

The variability in streamflow which occurs naturally on a seasonal and annual basis in the Tolt River was incorporated in the instream flow analysis by using stochastic flow projections based on historical discharge

data. Loar and Sale (1981) implicitly acknowledged this requirement in their suggestion of using the monthly median and 90 percentile flows as constraints in the derivation of minimum flow recommendations. However, these authors did not identify a method for determining flow requirements under normal and critical water year conditions. In the present study normal water year minimum flow recommendations were developed which attempted to define mean monthly streamflows necessary to maintain existing fish habitat and related levels of fish production under average water year conditions. Critical water year flow recommendations, on the other hand, are viewed as streamflows which will eventually result in the degradation of habitat and associated fish production if applied on a long-term basis. The establishment of normal and critical water year recommendations was based on the influence of the 50 and 90 percentile mean monthly flows, respectively, on the Q_E and Q_M values derived for the different species/life stages. The alternative minimum flow recommendations for normal and critical water years for the South Fork, North Fork, and mainstem Tolt River are shown in Figures 38, 39, and 40, respectively. During months of high runoff, when the projected monthly discharges exceeded the Q_E and Q_M values of all life stages, the normal and critical water year flow recommendations were identical. This result suggests that a higher exceedance probability level (e.g., the 95 percentile flow) might be more appropriate for deriving flow recommendations for critical water years.

It should also be noted that streamflow requirements necessary to flush sediments, transport bed material, and generally maintain the morphological integrity of the stream channel were not developed in this study due to the difficulty of modelling hydraulic/streambed interactions.

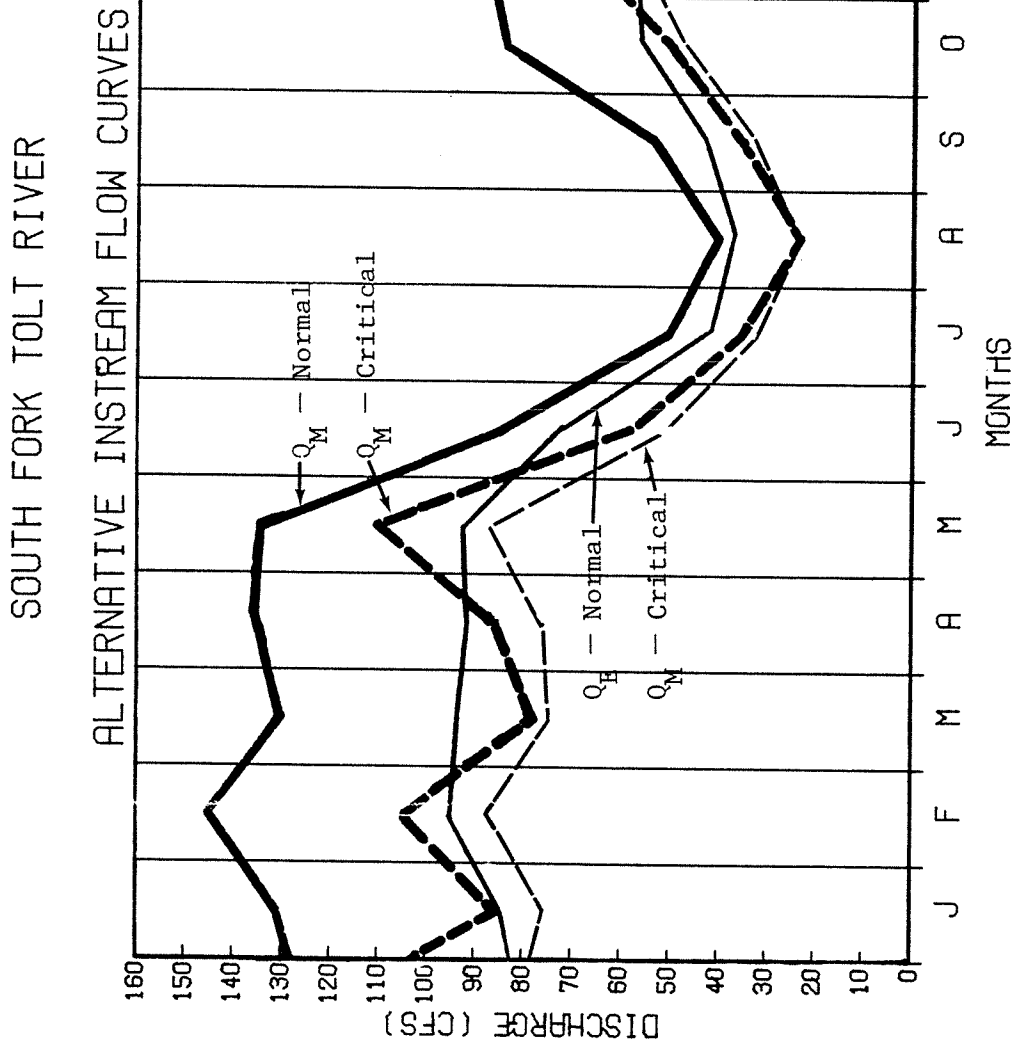


Figure 38. Minimum instream flow recommendations based on Q_M and Q_E flows for normal and critical water years for the South Fork Tolt River.

NORTH FORK TOLT RIVER

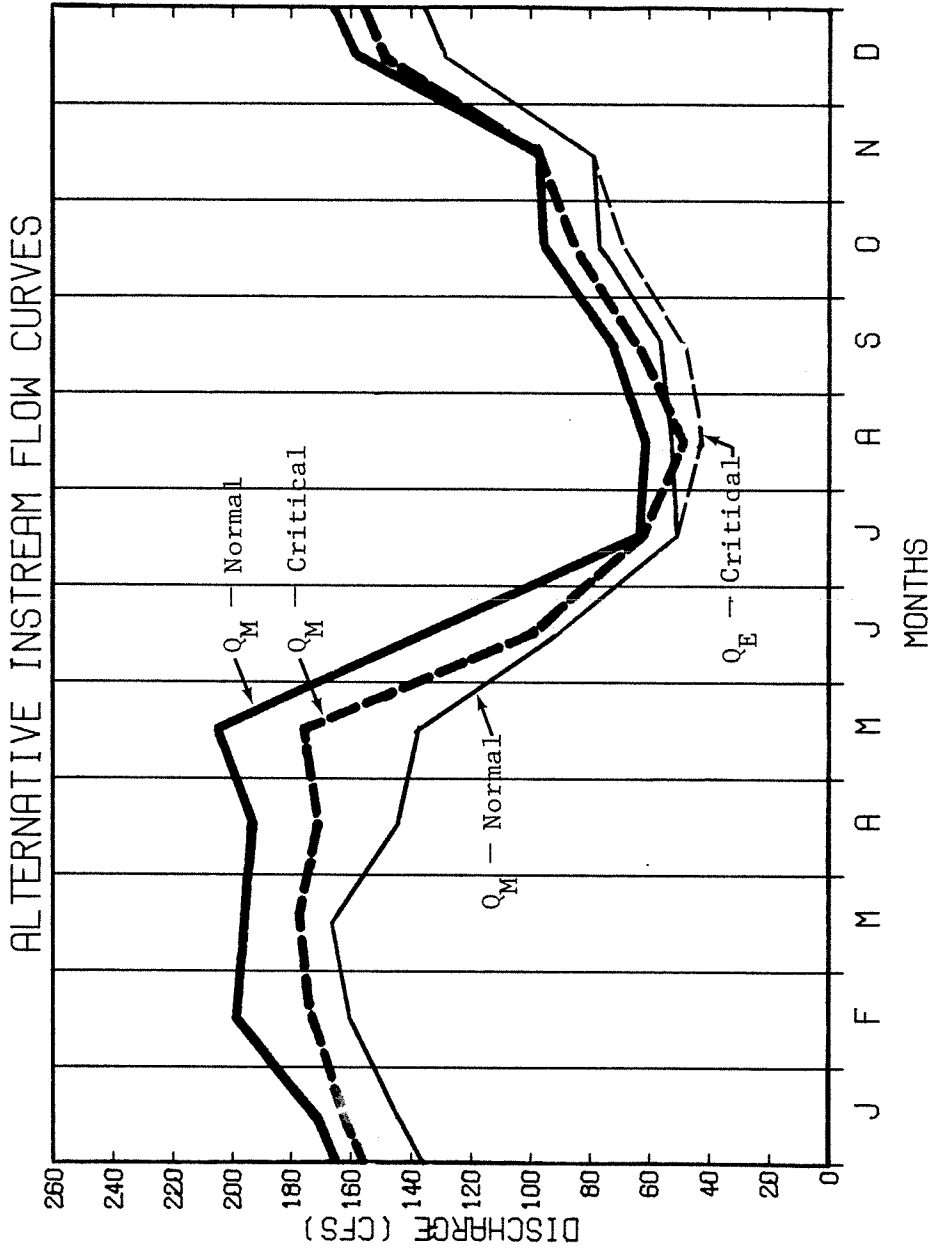


Figure 39. Minimum instream flow recommendations based on Q_M and Q_E flows for normal and critical water years for the North Fork Tolt River.

MAINSTEM TOLT RIVER

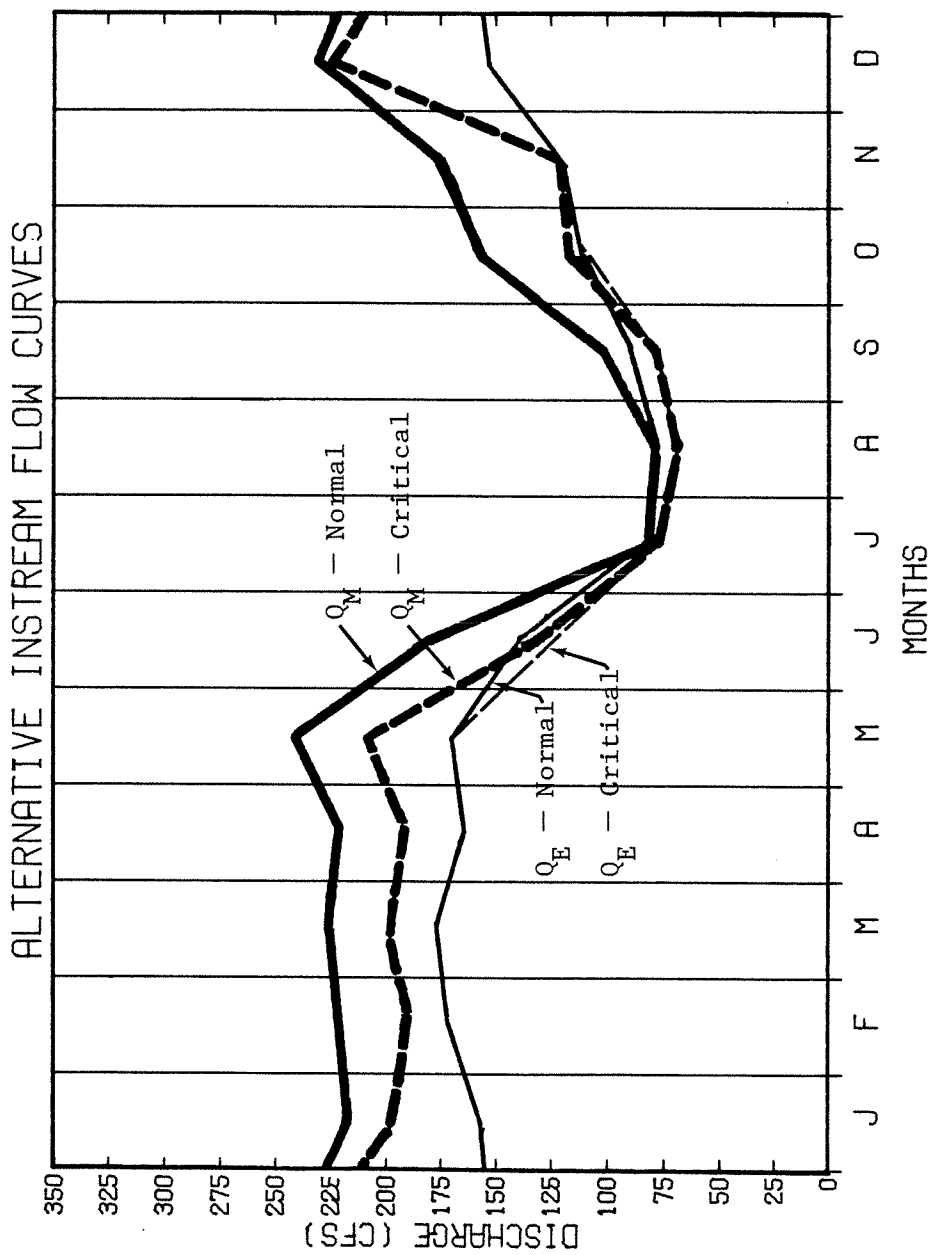


Figure 40. Minimum instream flow recommendations based on Q_M and Q_E flows for normal and critical water years for the mainstem Tolt River.

The importance of these natural processes in maintaining desirable habitat structure probably should be reflected in the establishment of a third level of minimum flow recommendations which would apply in wet water years.

From the foregoing discussion it may be concluded that the IFG method and the steps taken to generate flow recommendations represent a logical process for establishing minimum flow requirements for the South Fork, North Fork, and mainstem Tolt River. The overall method takes into account 1) biological information in the form of habitat suitability criteria, timing of occurrence, and relative abundance estimates for the salmonid species/life stages known to inhabit the Tolt River system; 2) hydraulic information consisting of field measurements of depth and velocity distributions within several study reaches, and the application of these data to predict physical habitat parameters for a range of simulated discharges; and 3) hydrologic information characterizing the variability in streamflow which occurs naturally both within and between annual cycles. The net result of the instream flow analysis performed in this study is the establishment of a regimen of minimum flow recommendations that will protect complete life cycles of salmonids utilizing the Tolt River.

The analysis of project-related effects on the physical habitat in the upper South Fork and the minimum instream flow recommendations are intended to aid in negotiations between the Water/Light Departments and the various federal and state regulatory agencies. It is apparent in the analysis conducted on the existing WDOE instream flow curves presented in Appendix E that new flows are needed. The instream flows established in the past were inconsistent and were not based on biological, hydrological,

or hydraulic criteria which this assessment includes. We have attempted to identify those fish species/life stages which should be protected in the Tolt River and weighted them accordingly in the analysis. We have also defined separate minimum flow recommendations for the South Fork, North Fork, and mainstem Tolt River, each representing segments of the Tolt River system. The questions of which set of flow recommendations should be adopted, where these flows are to be monitored, and when normal and critical water year recommendations apply must be addressed in the negotiation process.

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9.0 APPENDICES

TOLT RIVER FISHERIES

DATE: _____ AREA (SEE MAP)

1 2 3 4 5 6 STOSSEL CR.

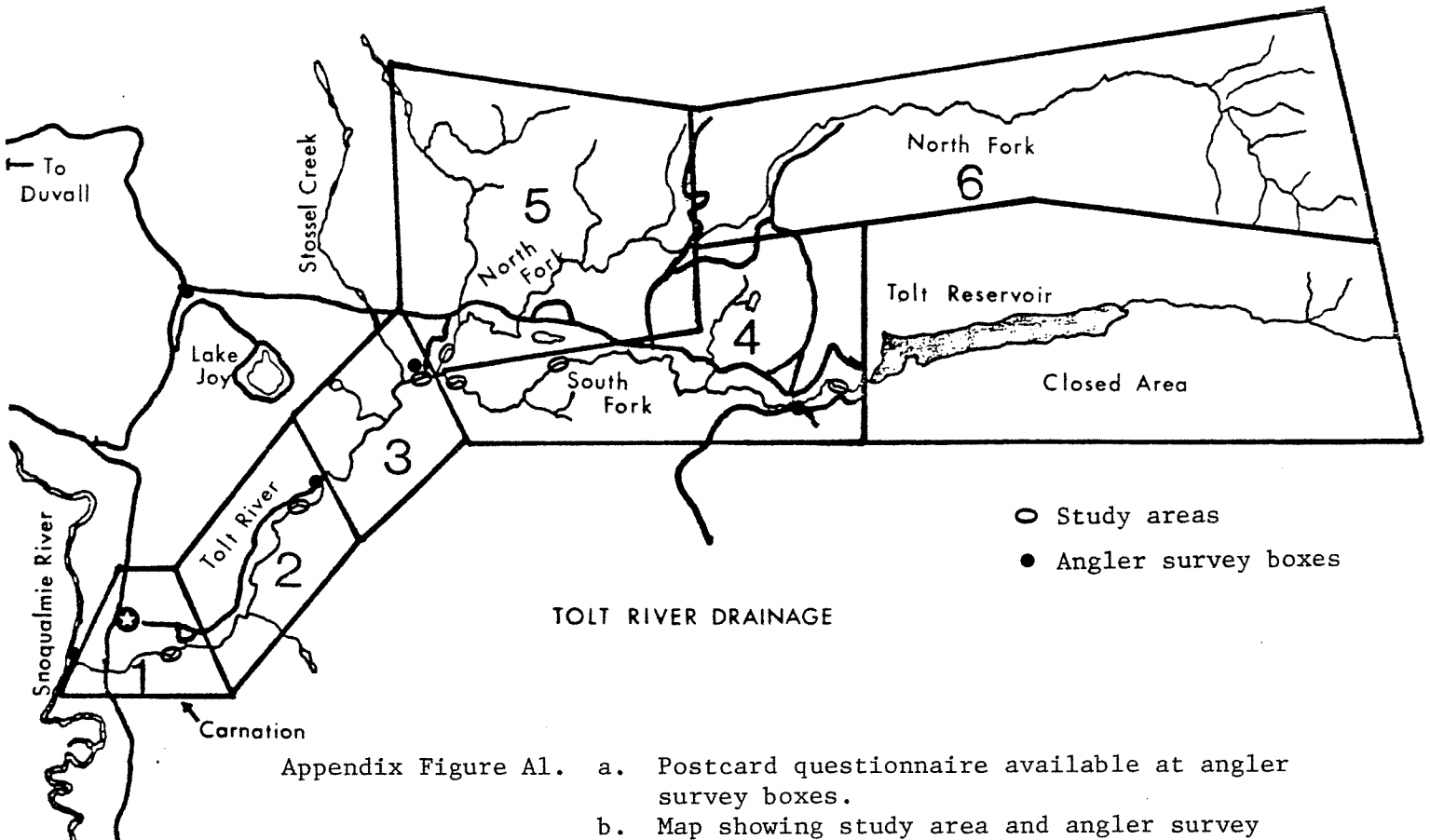
SPECIES CAUGHT (INDICATE NUMBER, REGARDLESS OF SIZE)

	<u>KEPT</u>	<u>RETURNED</u>	<u>FORK LENGTH(S)</u>	<u>SEX</u>
STEELHEAD	___	___	_____	___
CHINOOK	___	___	_____	___
COHO	___	___	_____	___
CUTTHROAT	___	___	_____	___
WHITEFISH	___	___	_____	___
OTHER	___	___	_____	___

TOTAL HOURS SPENT FISHING (IF MORE THAN ONE AREA WAS FISHED, PLEASE ESTIMATE TIME SPENT IN EACH AREA)

COMMENTS: _____

THANK YOU



Appendix Figure A1. a. Postcard questionnaire available at angler survey boxes.
 b. Map showing study area and angler survey box locations in the Tolt River drainage.

ATTENTION FISHERMEN

THE FISHERIES RESEARCH INSTITUTE OF THE UNIVERSITY OF WASHINGTON IS CONDUCTING A STUDY* OF THE SALMON AND STEELHEAD RESOURCES OF THE TOLT RIVER AND ITS TRIBUTARIES. INFORMATION CONCERNING THE NUMBER AND TYPE OF FISH CAUGHT AND THE HOURS SPENT ANGLING BY SPORTS FISHERMEN WILL HELP US IN OUR EFFORTS TO UPGRADE THE QUALITY OF THE TOLT RIVER FISHERIES.

IMPORTANT:

1. PLEASE READ AND FILL OUT ONE OF THE POST CARDS BELOW AFTER EACH FISHING TRIP, REGARDLESS OF WHETHER ANY FISH WERE CAUGHT OR NOT. PLACE COMPLETED CARD IN SLOT AT TOP OF BOX.
2. A SCALE IS PROVIDED ON THE SIDE OF THE BOX FOR LENGTH MEASUREMENTS. HOLD THE TIP OF THE FISH AT THE TOP OF THE SCALE AND MEASURE TO THE FORK OF THE TAIL.
3. CONSULT THE MAP BELOW TO IDENTIFY THE GENERAL LOCALITY IN WHICH YOU FISHED.
4. IF YOU HAVE ANY QUESTIONS ABOUT OUR WORK FEEL FREE TO CALL OR WRITE:

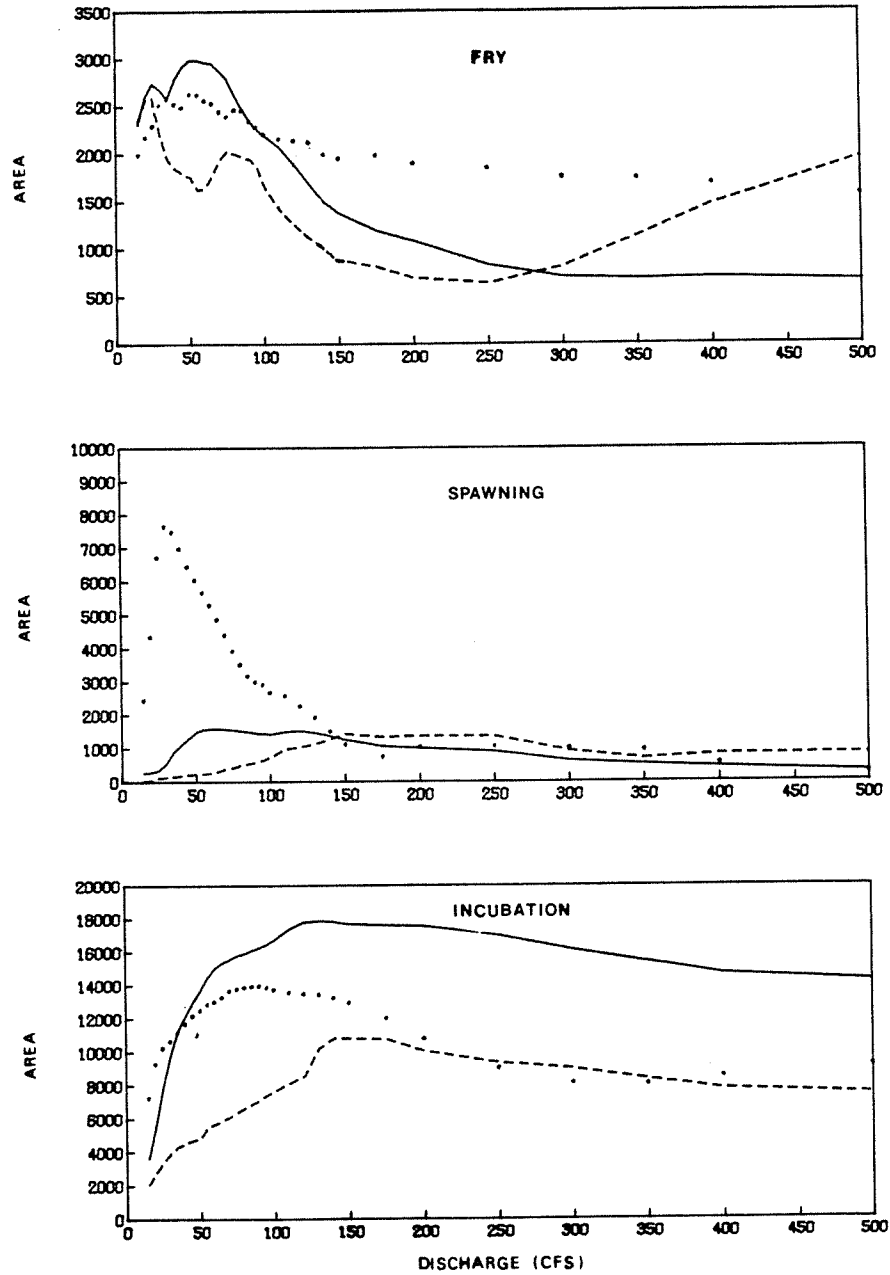
CLEVE STEWARD
 PHONE: 206-543-7537
 FISHERIES RESEARCH INSTITUTE
 UNIVERSITY OF WASHINGTON
 SEATTLE, WA 98195

THANK YOU

* SPONSORED BY CITY OF SEATTLE LIGHT AND WATER DEPARTMENTS.

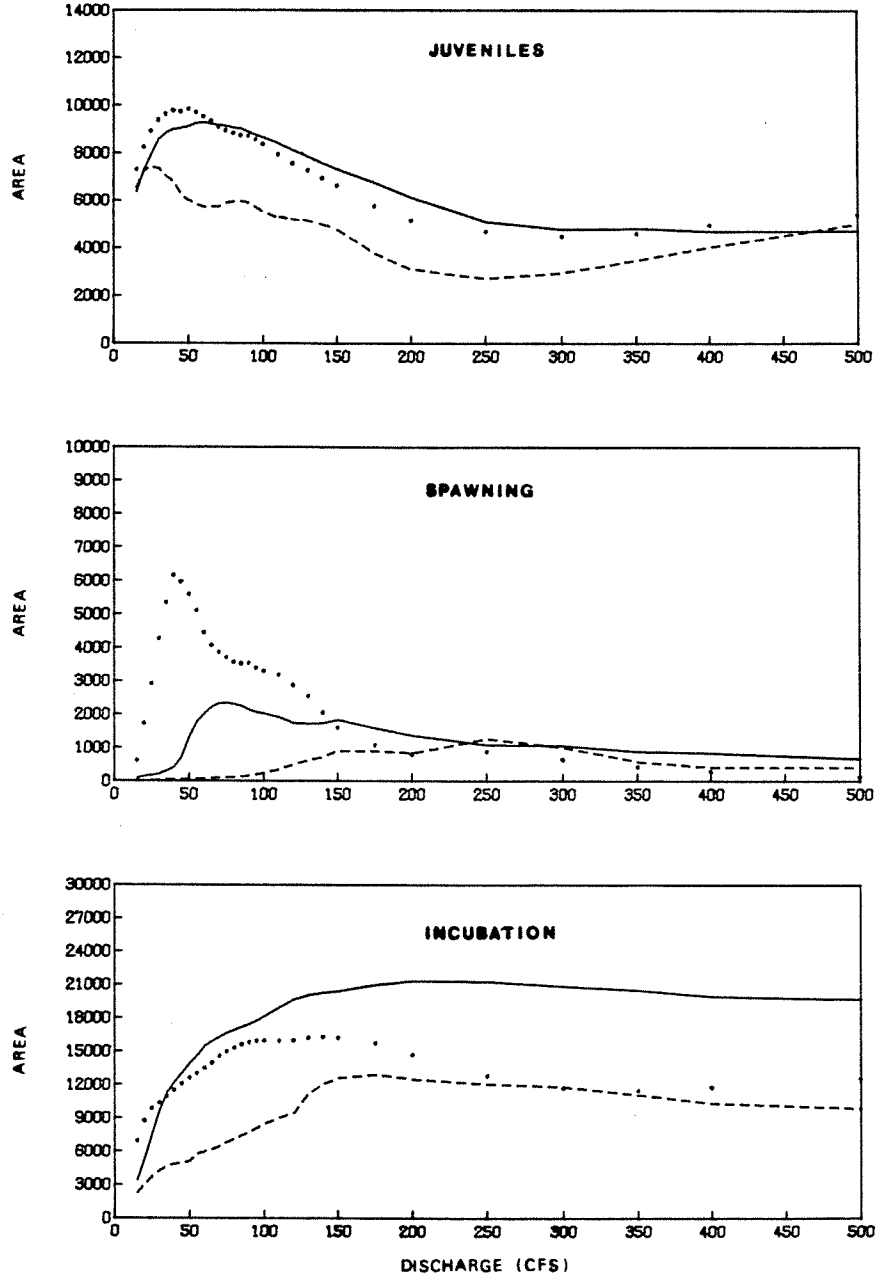
Appendix Figure A2. Public notice of research objectives and instructions for completing questionnaires posted on each angler survey box.

COHO SALMON

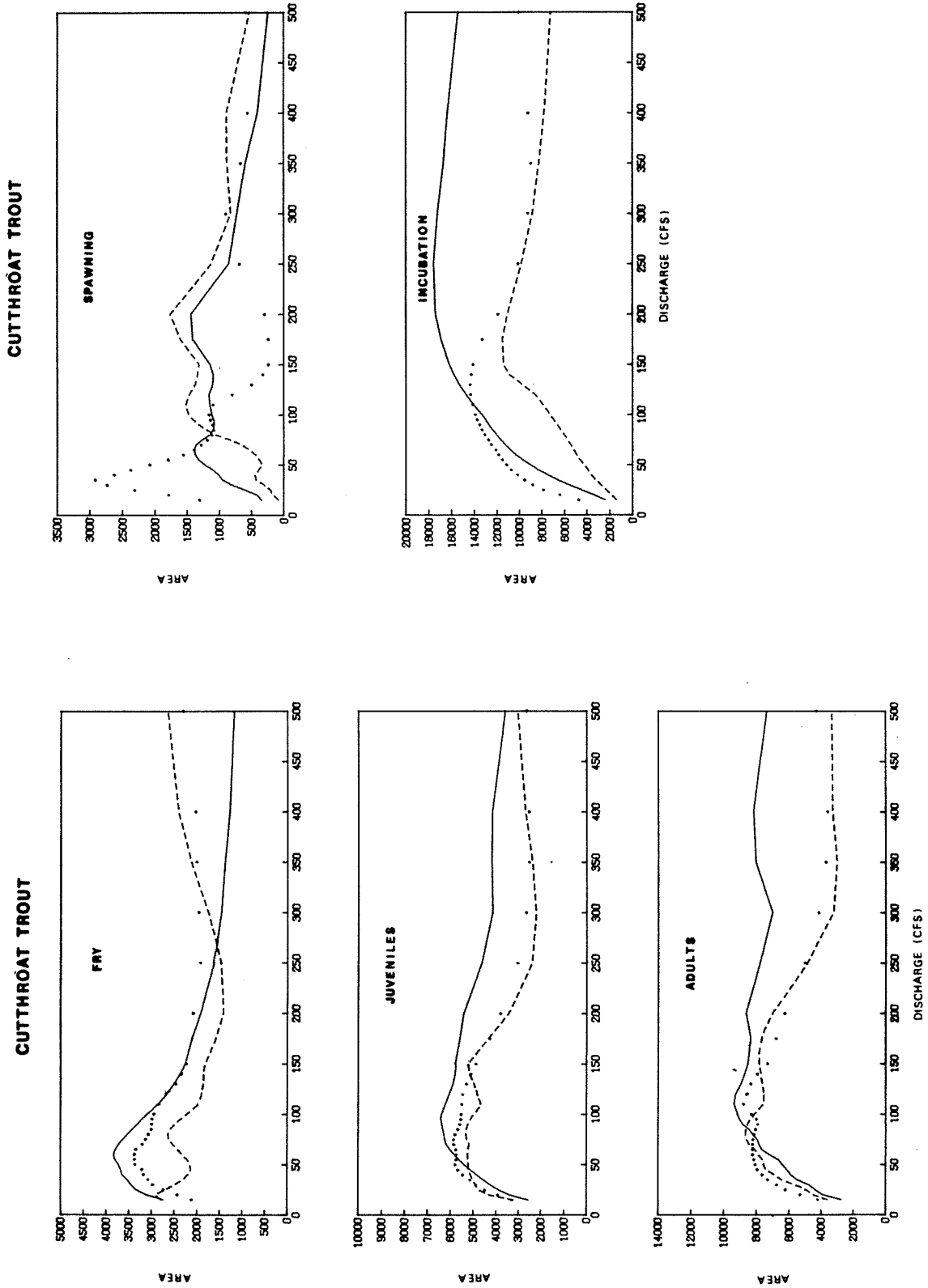


Appendix Figure B1. WUA (ft²) as a function of discharge (cfs) for coho salmon life stages at South Fork stations 1, 2, and 3.

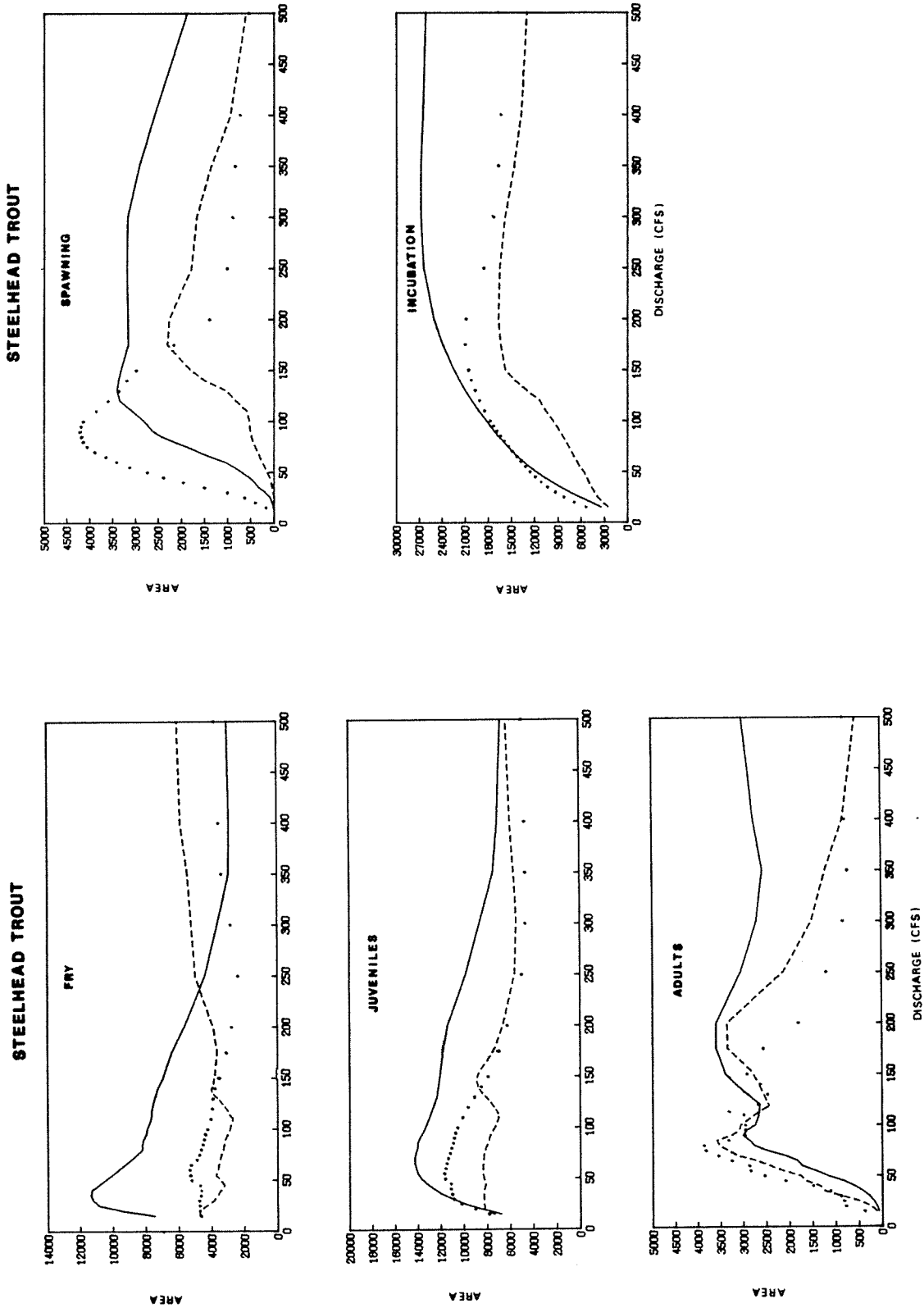
CHINOOK SALMON



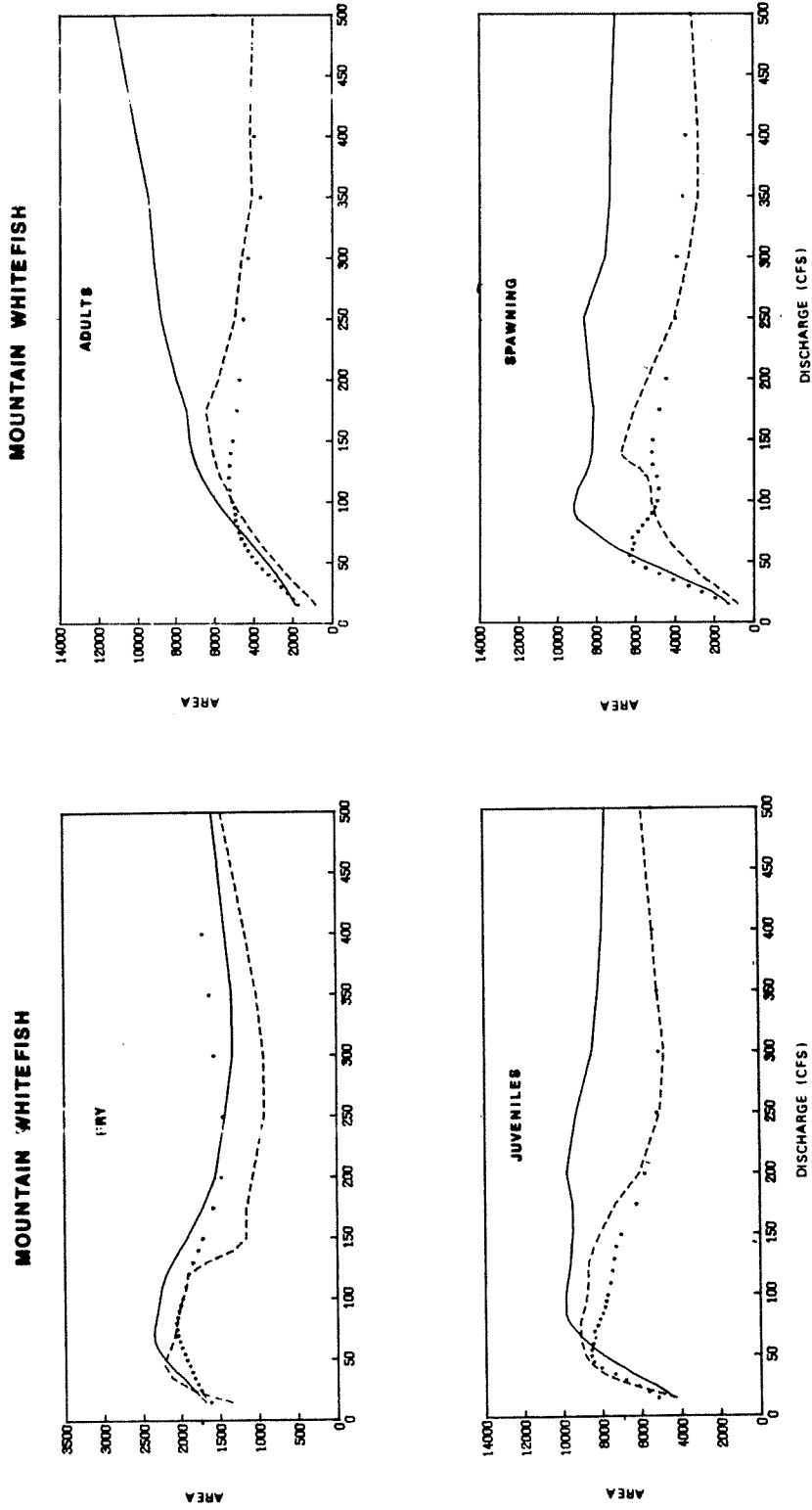
Appendix Figure B2. WUA (ft²) as a function of discharge (cfs) for chinook salmon life stages at South Fork stations 1, 2, and 3.



Appendix Figure B3. WUA (ft²) as a function of discharge (cfs) for cutthroat trout life stages at South Fork stations 1, 2, and 3.

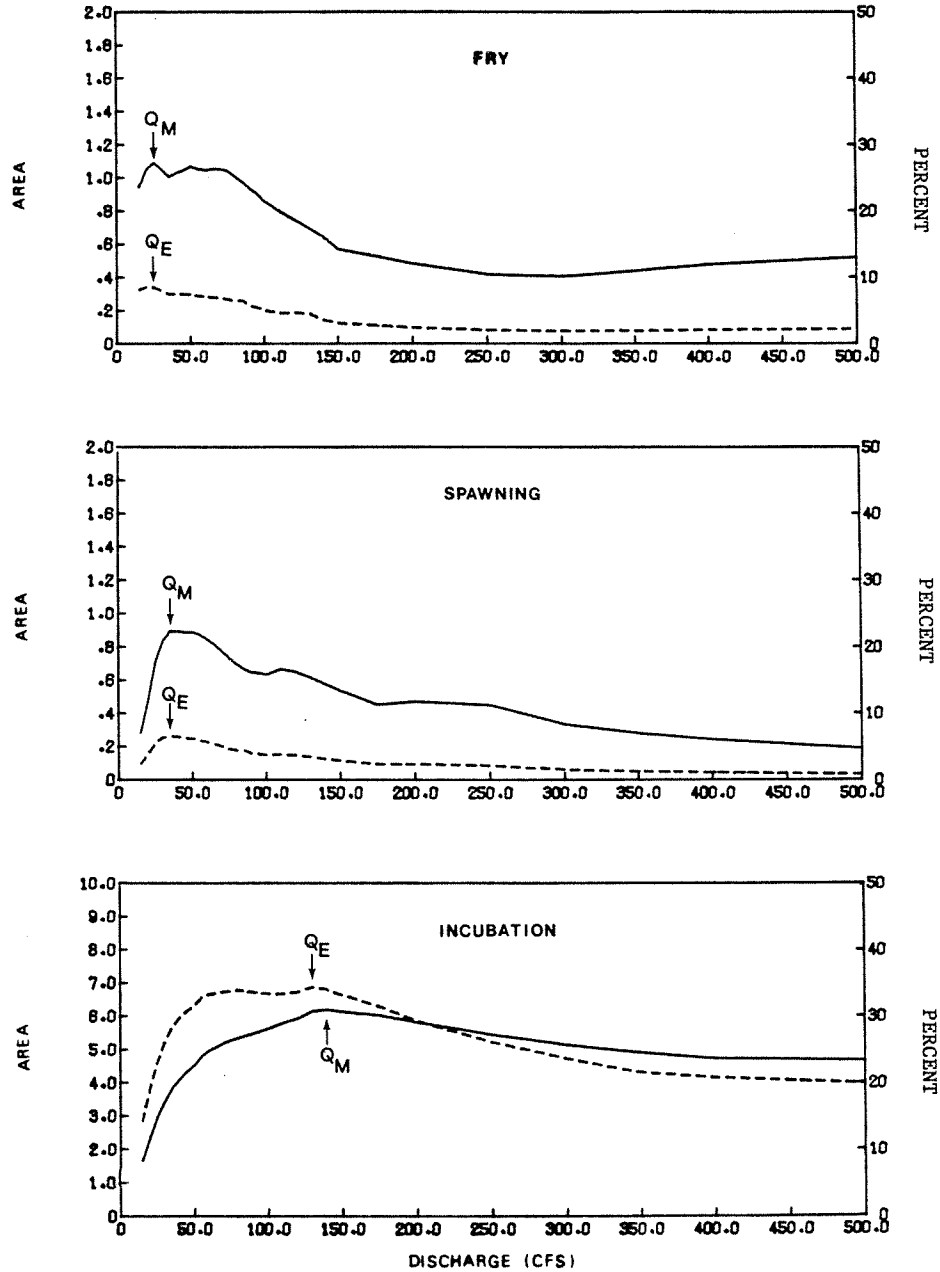


Appendix Figure B4. WUA (ft²) as a function of discharge (cfs) for steelhead trout life stages at South Fork stations 1, 2, and 3.



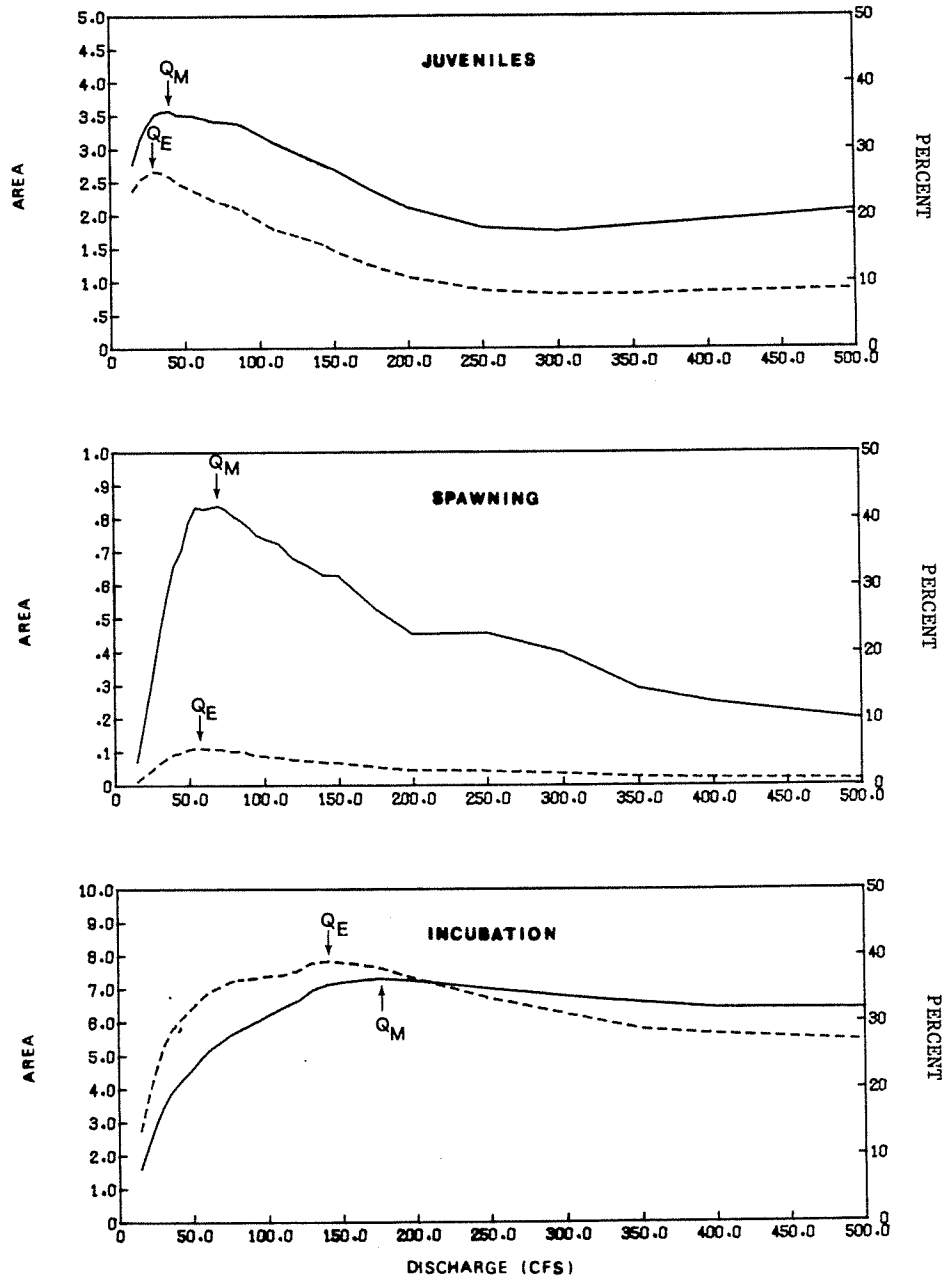
Appendix Figure B5. WUA (ft²) as a function of discharge (cfs) for mountain whitefish life stages at South Fork stations 1, 2, and 3.

COHO SALMON

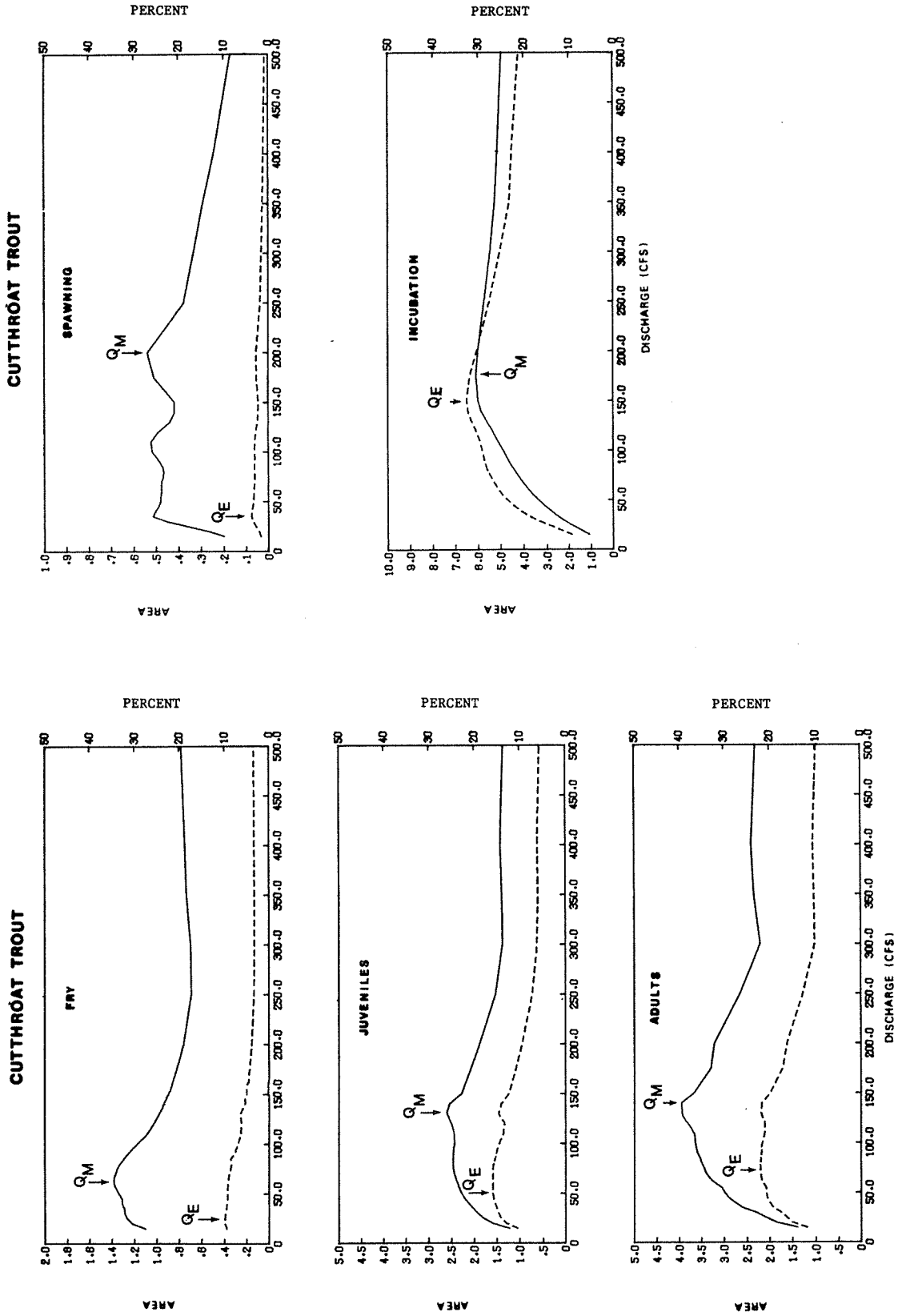


Appendix Figure B6. Combined WUA (solid line) and habitat efficiency (dashed line) values for coho salmon at different discharges for the South Fork. For a given flow, the habitat efficiency is the WUA expressed as a percentage of the total stream surface area. The discharges at which Q_M and Q_E values were obtained are indicated by arrows.

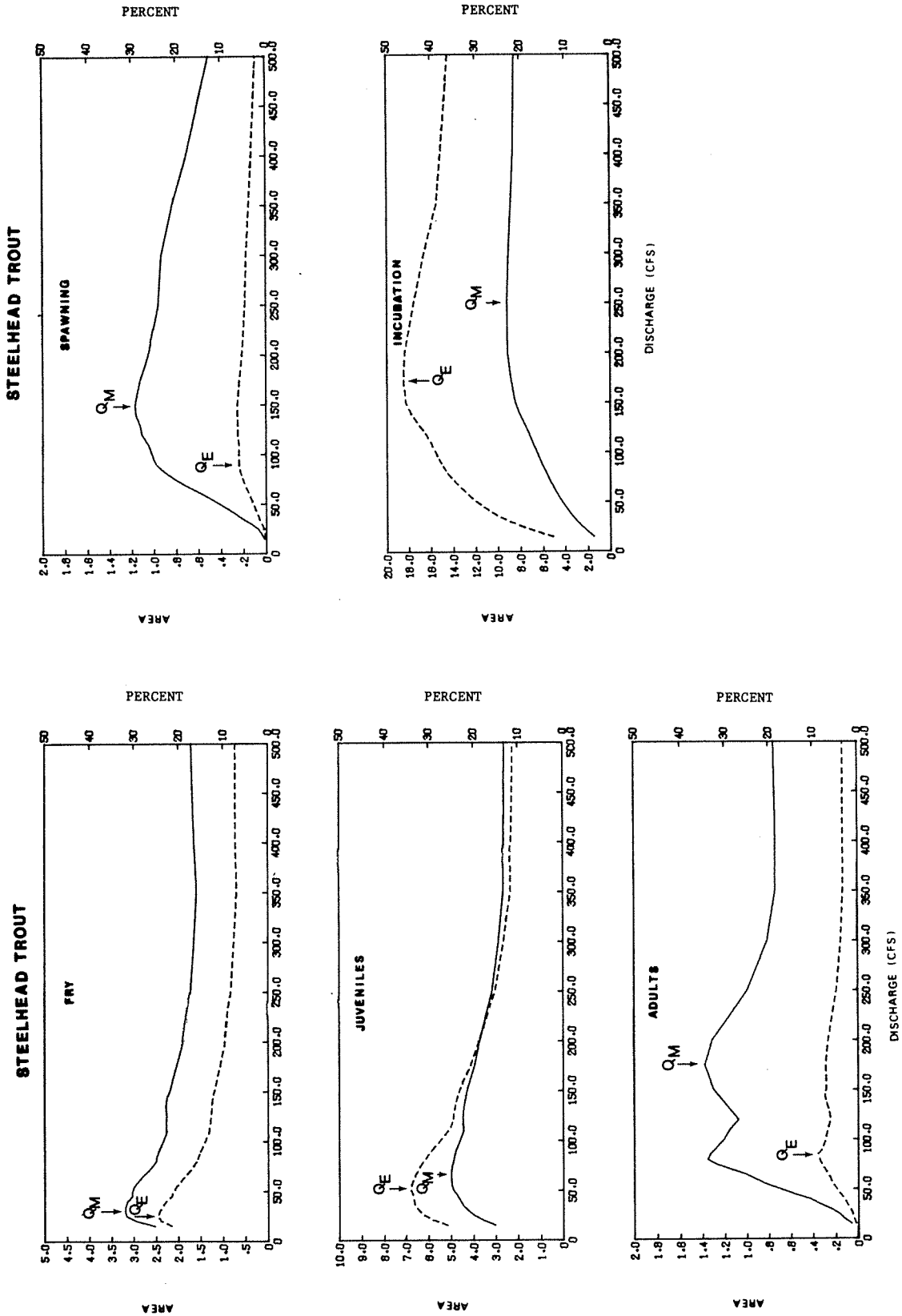
CHINOOK SALMON



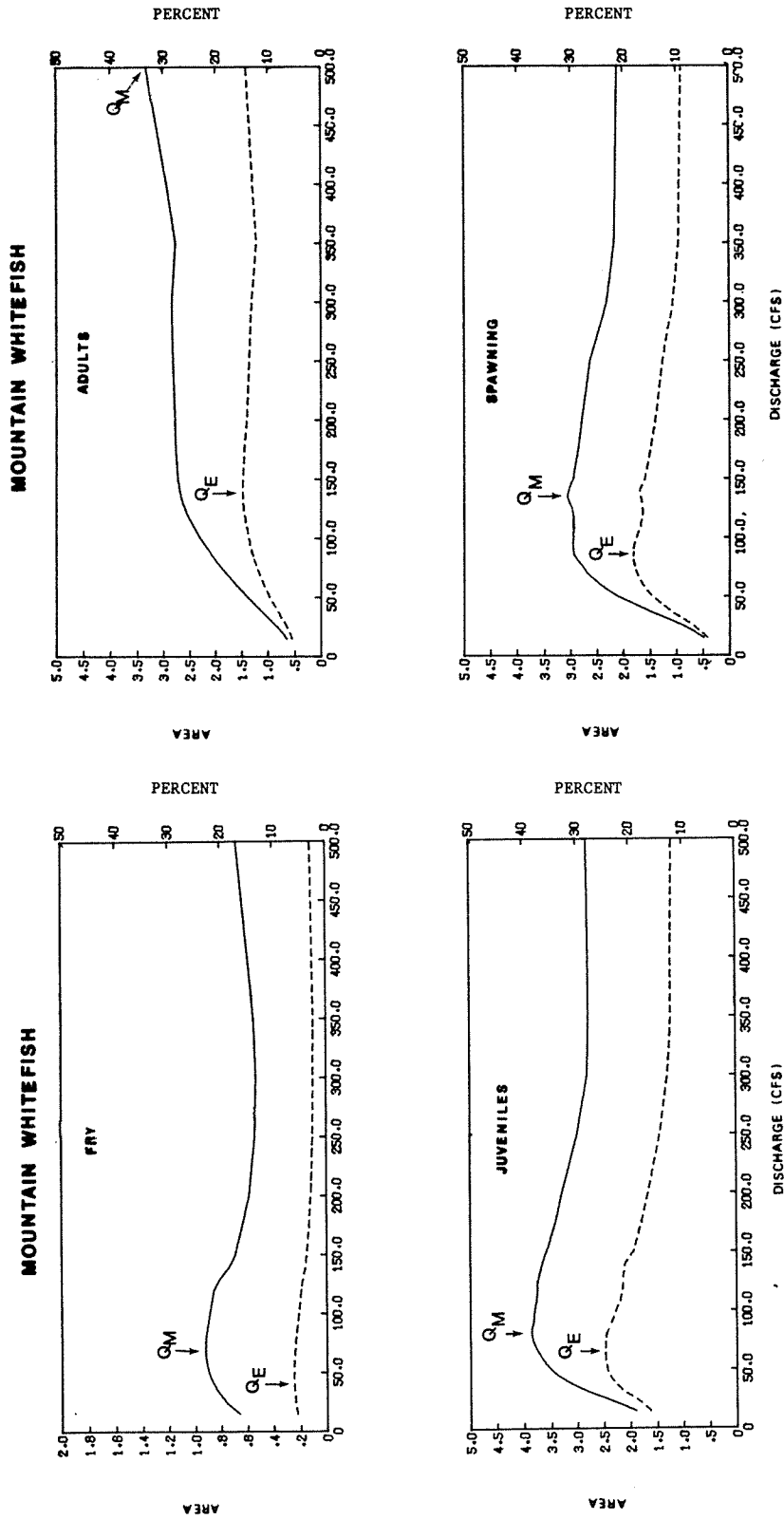
Appendix Figure B7. Combined WUA (solid line) and habitat efficiency (dashed line) values for chinook salmon at different discharges for the South Fork. For a given flow, the habitat efficiency is the WUA expressed as a percentage of the total stream surface area. The discharges at which Q_M and Q_E values were obtained are indicated by arrows.



Appendix Figure B8. Combined WUA (solid line) and habitat efficiency (dashed line) values for cutthroat trout at different discharges for the South Fork. For a given flow, the habitat efficiency is the WUA expressed as a percentage of the total stream surface area. The discharges at which Q_M and Q_E values were obtained are indicated by arrows.

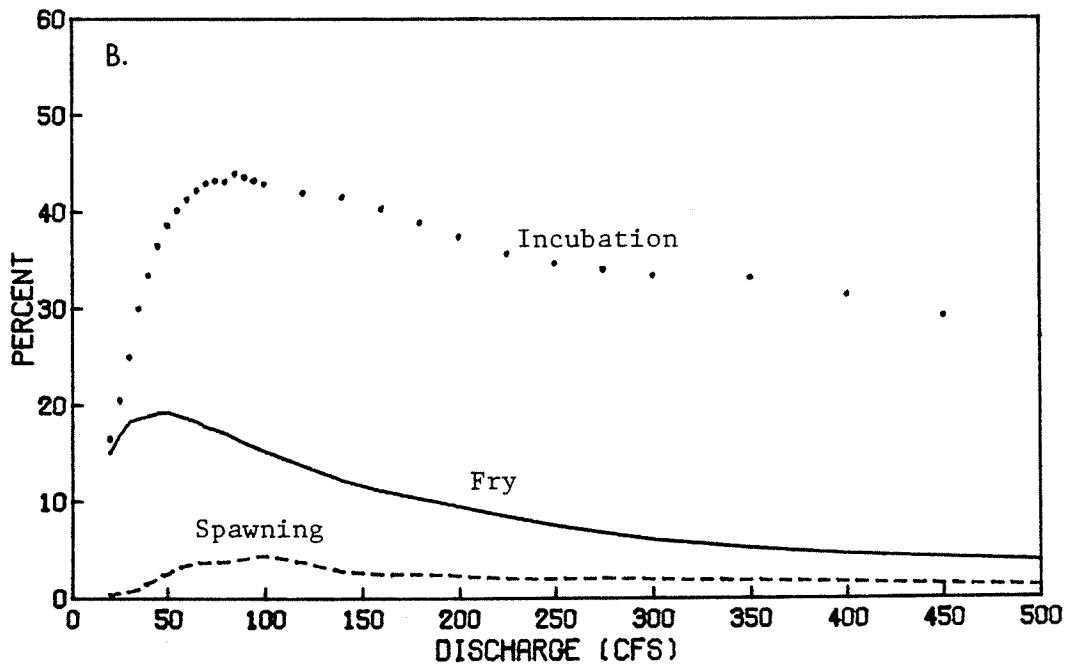
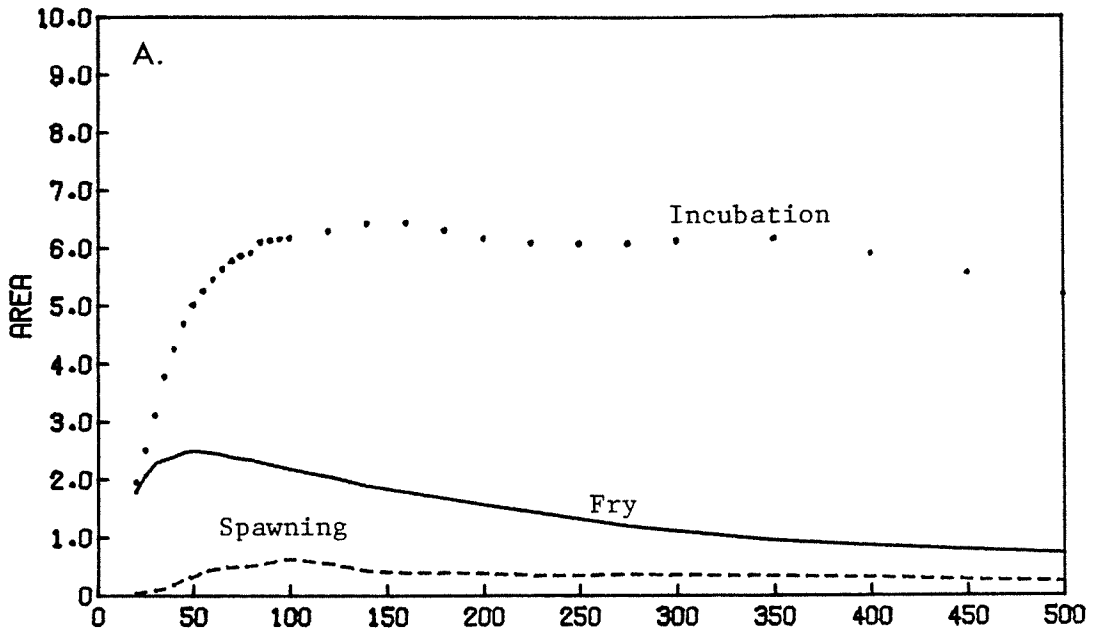


Appendix Figure B9. Combined WUA (solid line) and habitat efficiency (dashed line) values for steelhead trout at different discharges for the South Fork. For a given flow, the habitat efficiency is the WUA expressed as a percentage of the total stream surface area. The discharges at which Q_M and Q_E values were obtained are indicated by arrows.



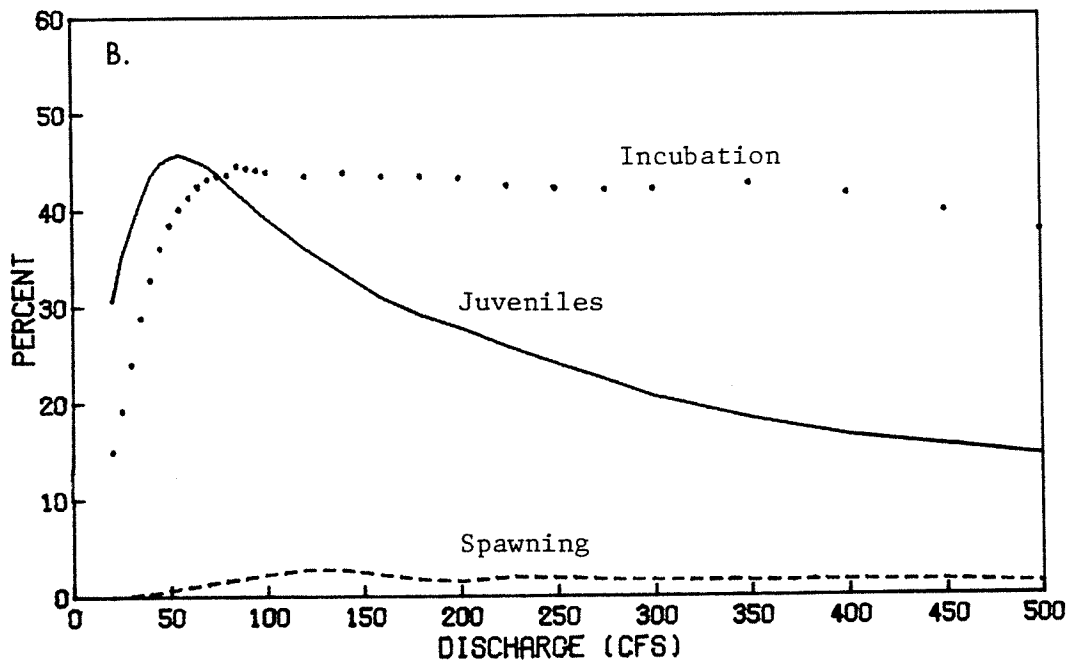
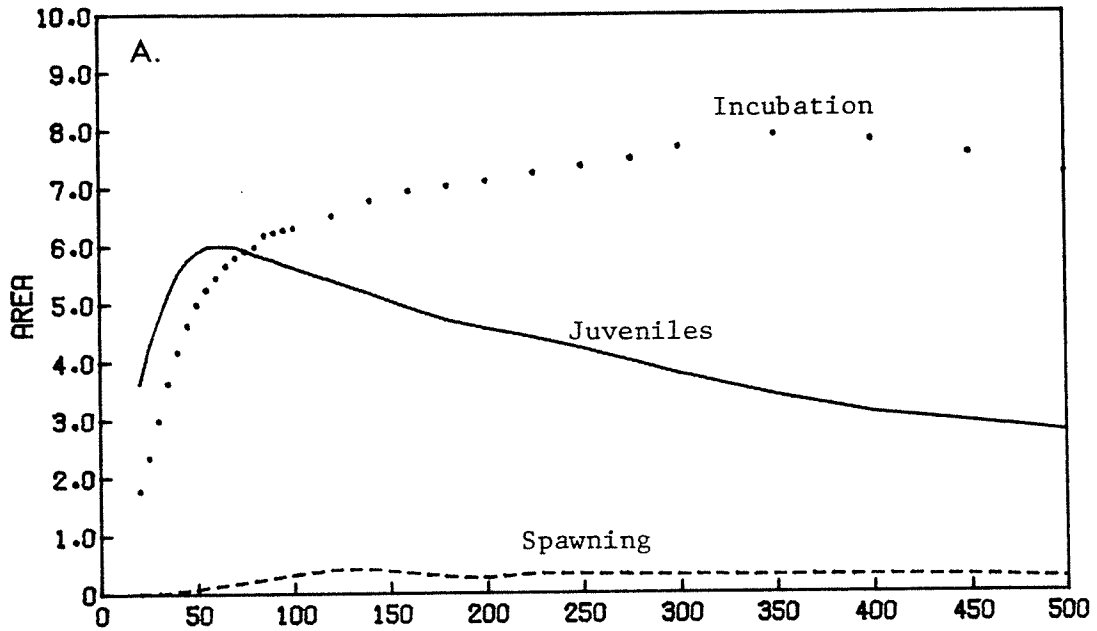
Appendix Figure B10. Combined WUA (solid line) and habitat efficiency (dashed line) values for mountain whitefish at different discharges for the South Fork. For a given flow, the habitat efficiency is the WUA expressed as a percentage of the total stream surface area. The discharges at which Q_M and Q_E values were obtained are indicated by arrows.

COHO SALMON



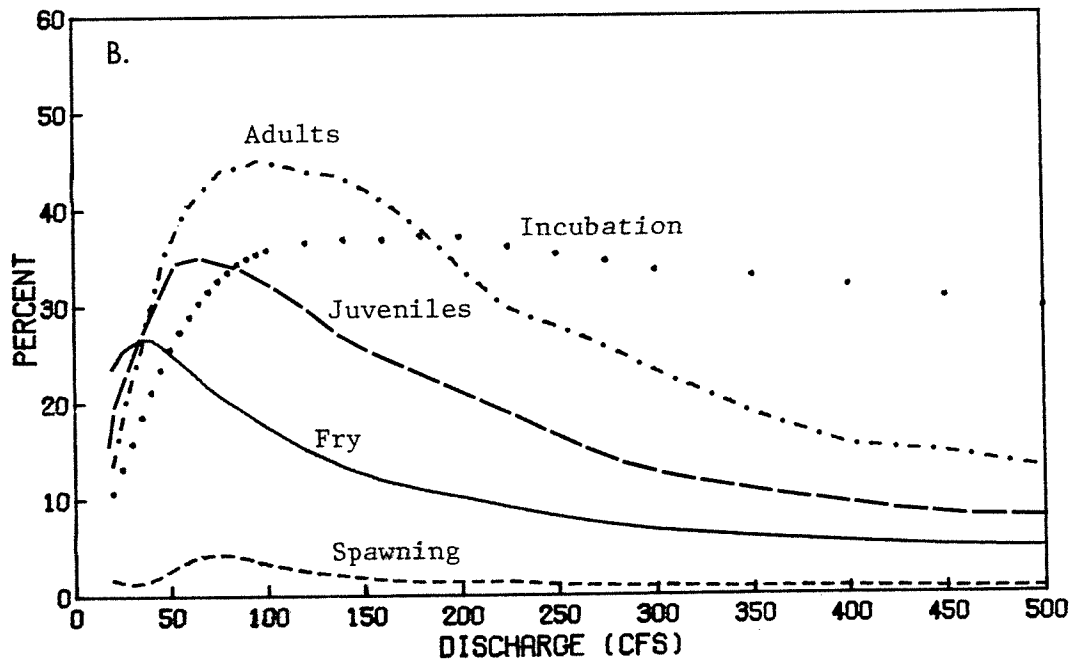
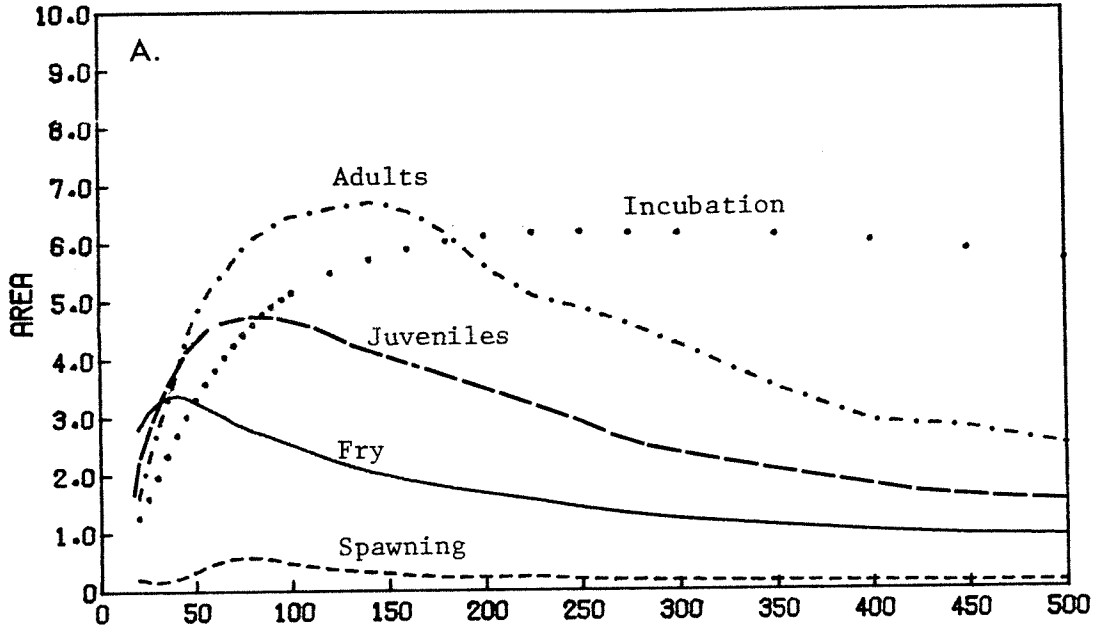
Appendix Figure C1. A. WUA ($\text{ft}^2 \times 10^5$) as a function of discharge (cfs) for coho salmon life stages in the North Fork. B. Habitat efficiency curves for coho life stages in the North Fork.

CHINOOK SALMON



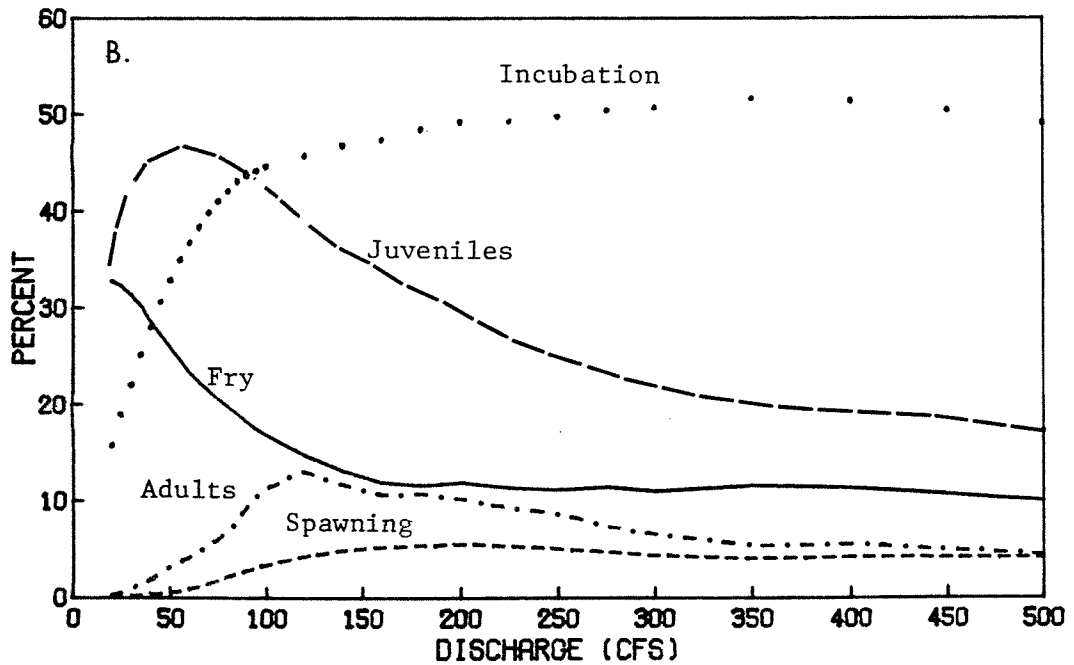
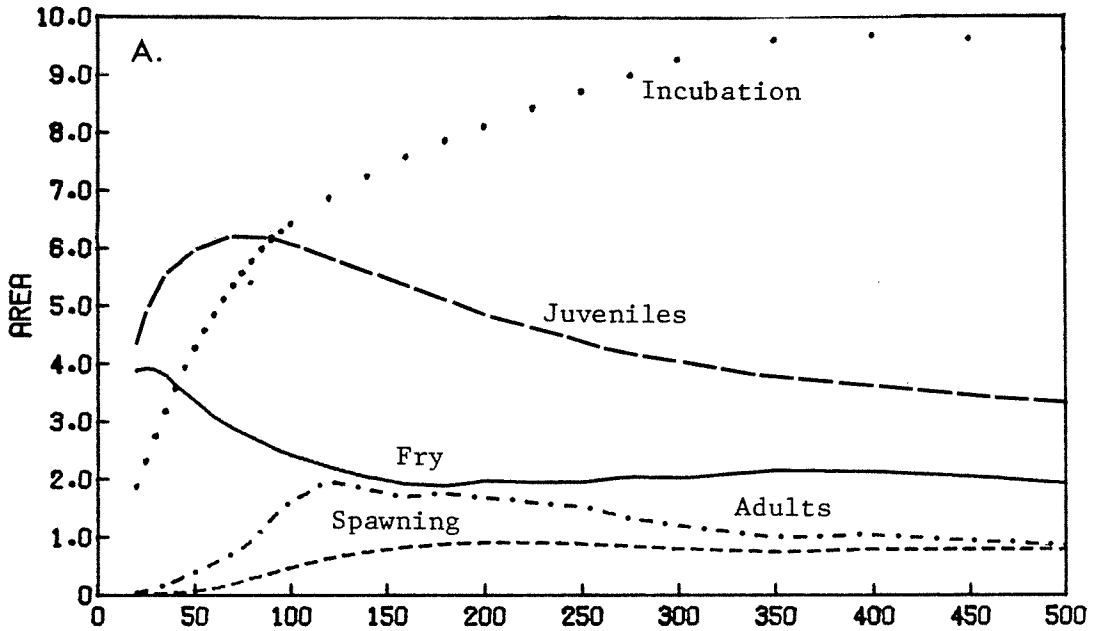
Appendix Figure C2. A. WUA (ft² x 10⁵) as a function of discharge (cfs) for chinook salmon life stages in the North Fork. B. Habitat efficiency curves for chinook life stages in the North Fork.

CUTTHROAT TROUT

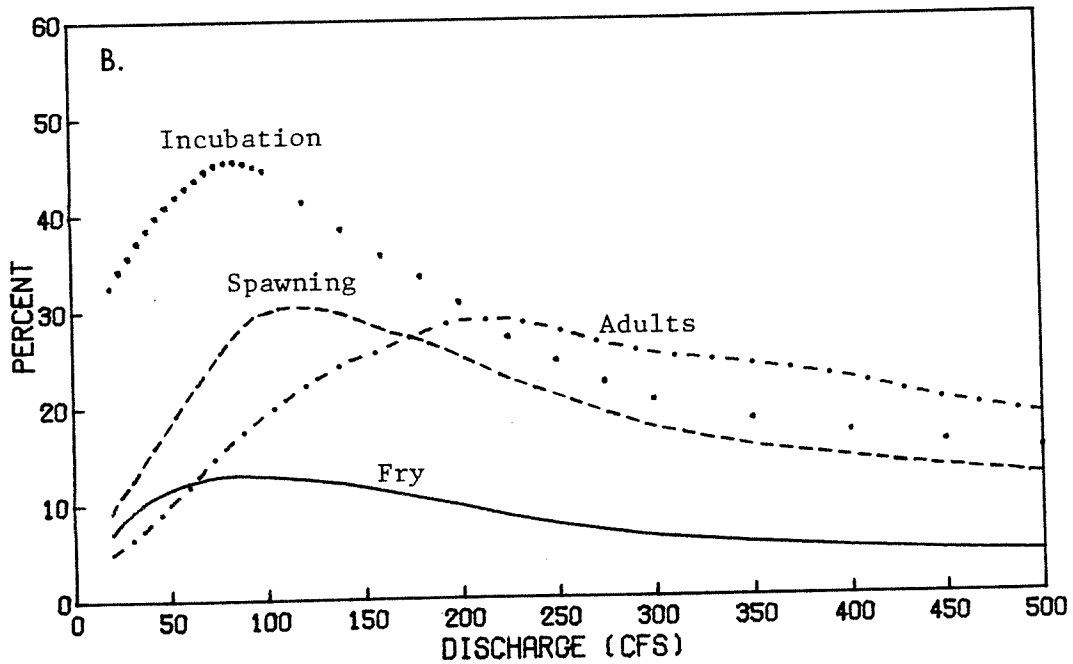
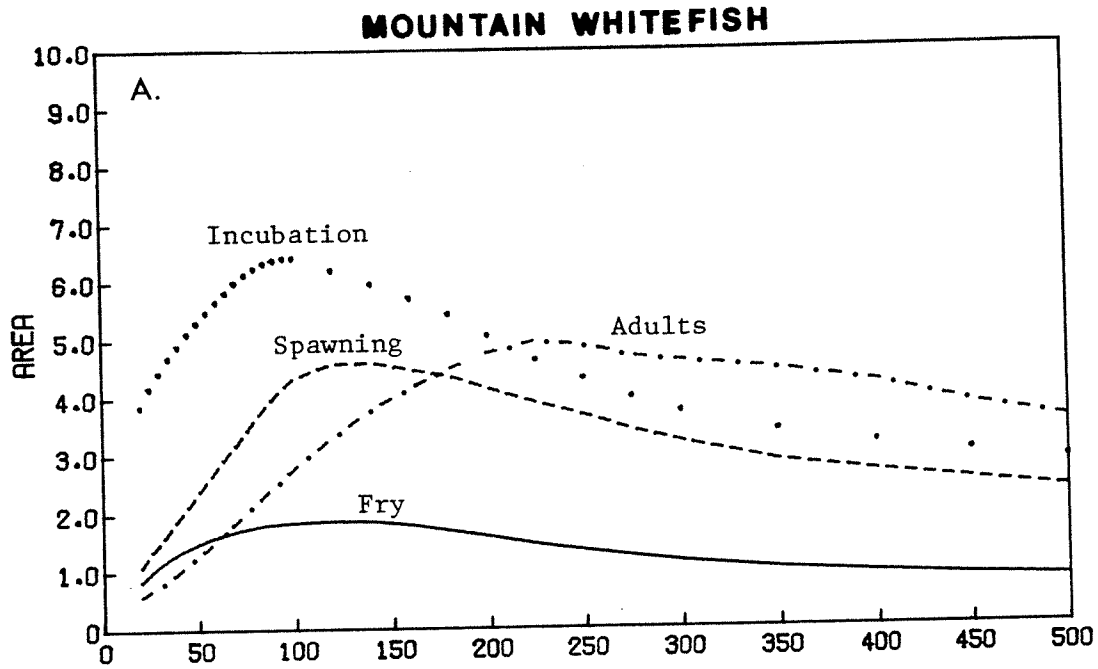


Appendix Figure C3. A. WUA (ft² x 10⁵) as a function of discharge (cfs) for cutthroat trout life stages in the North Fork. B. Habitat efficiency curves for cutthroat life stages in the North Fork.

STEELHEAD TROUT

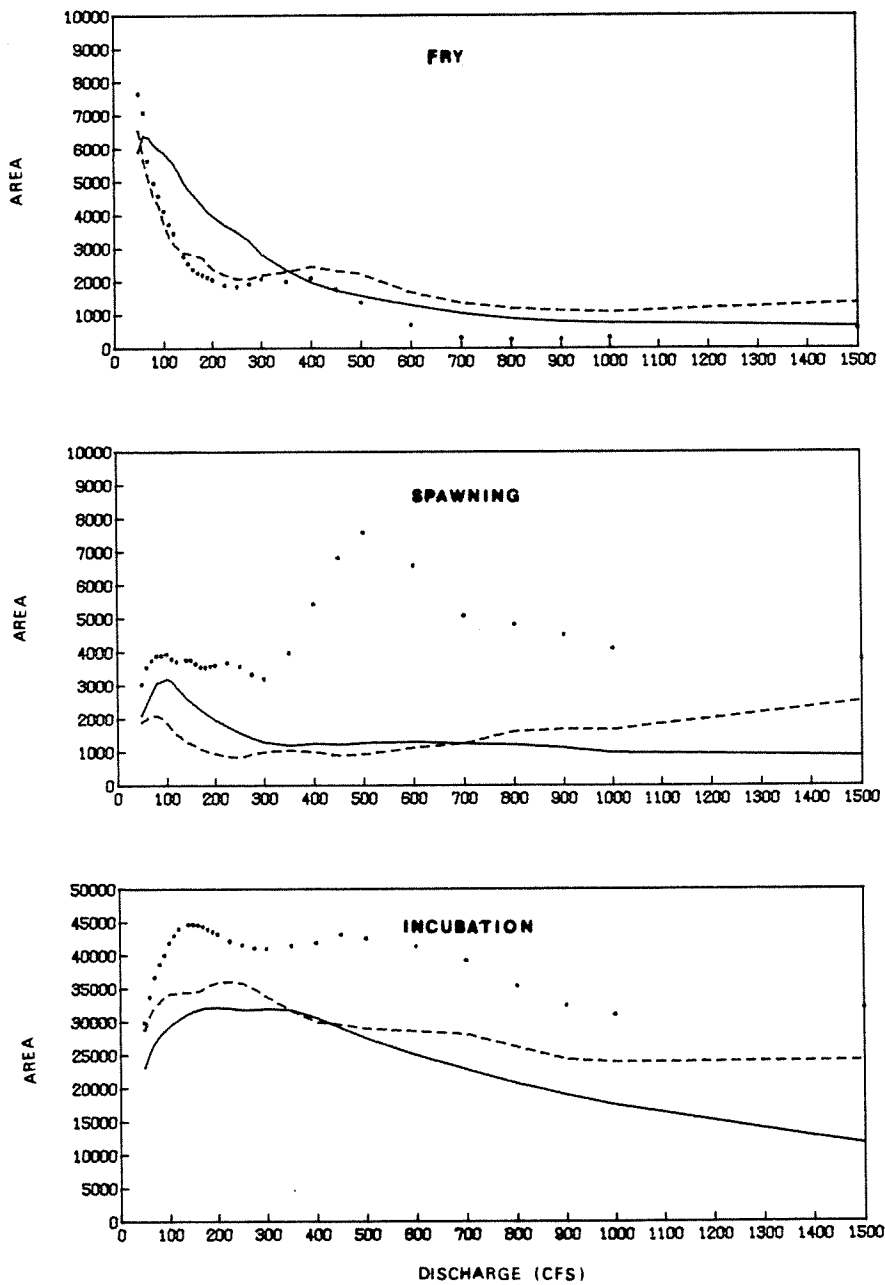


Appendix Figure C4. A. WUA ($\text{ft}^2 \times 10^5$) as a function of discharge (cfs) for steelhead trout life stages in the North Fork. B. Habitat efficiency curves for steelhead life stages in the North Fork.



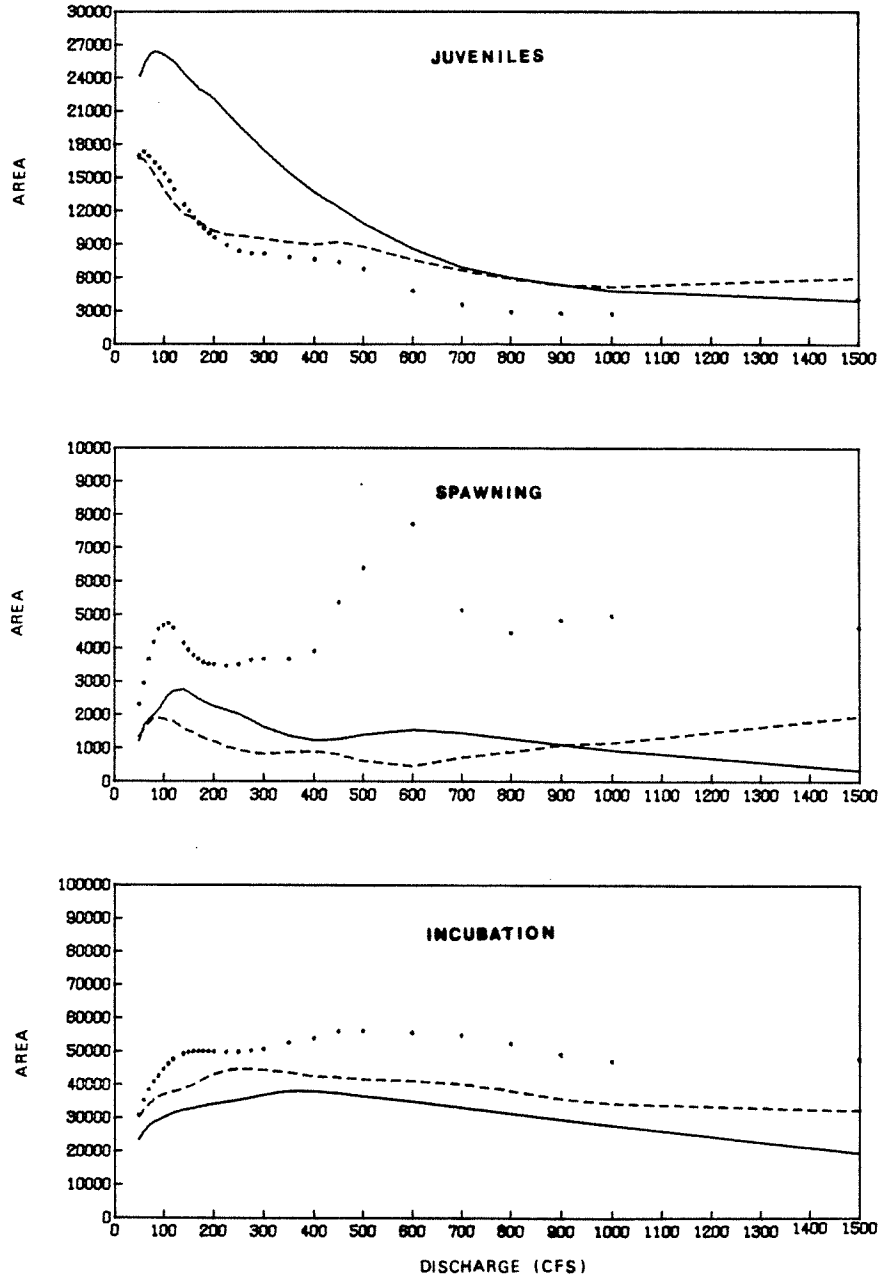
Appendix Figure C5. A. WUA (ft² x 10⁵) as a function of discharge (cfs) for mountain whitefish life stages in the North Fork. B. Habitat efficiency curves for mountain whitefish life stages in the North Fork.

COHO SALMON

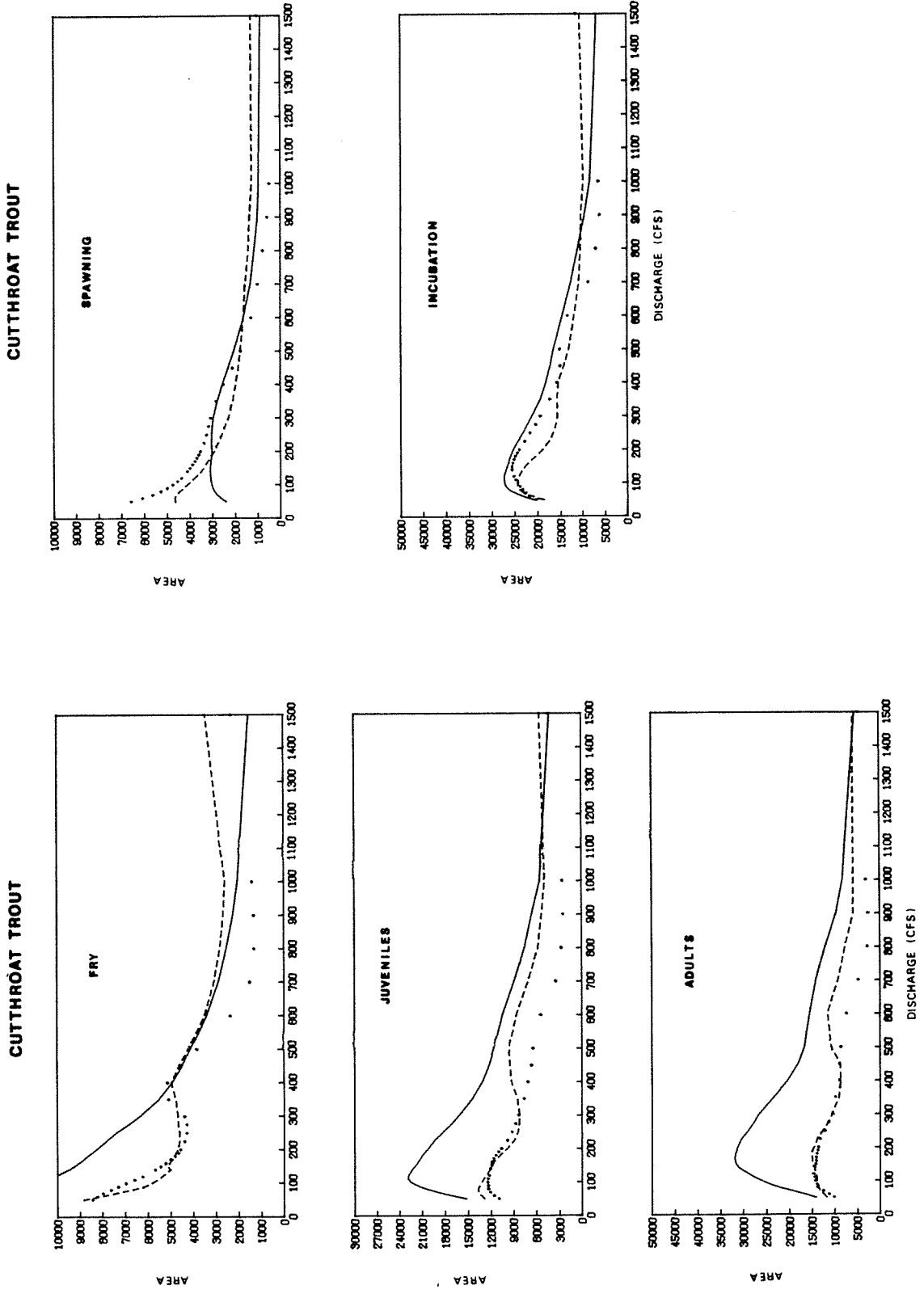


Appendix Figure D1. WUA (ft²) as a function of discharge (cfs) for coho salmon life stages at Tolt River stations 5, 6, and 7.

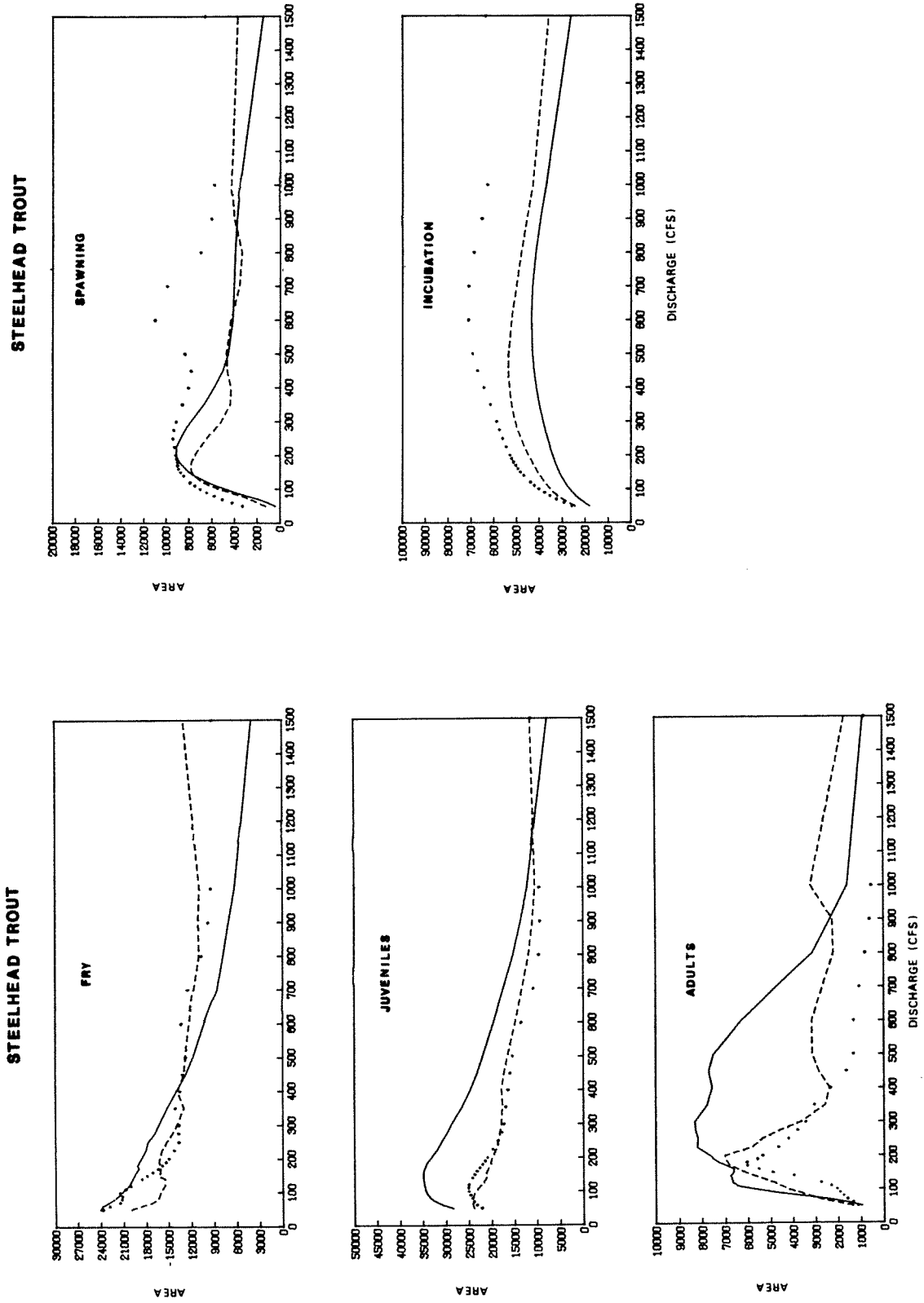
CHINOOK SALMON



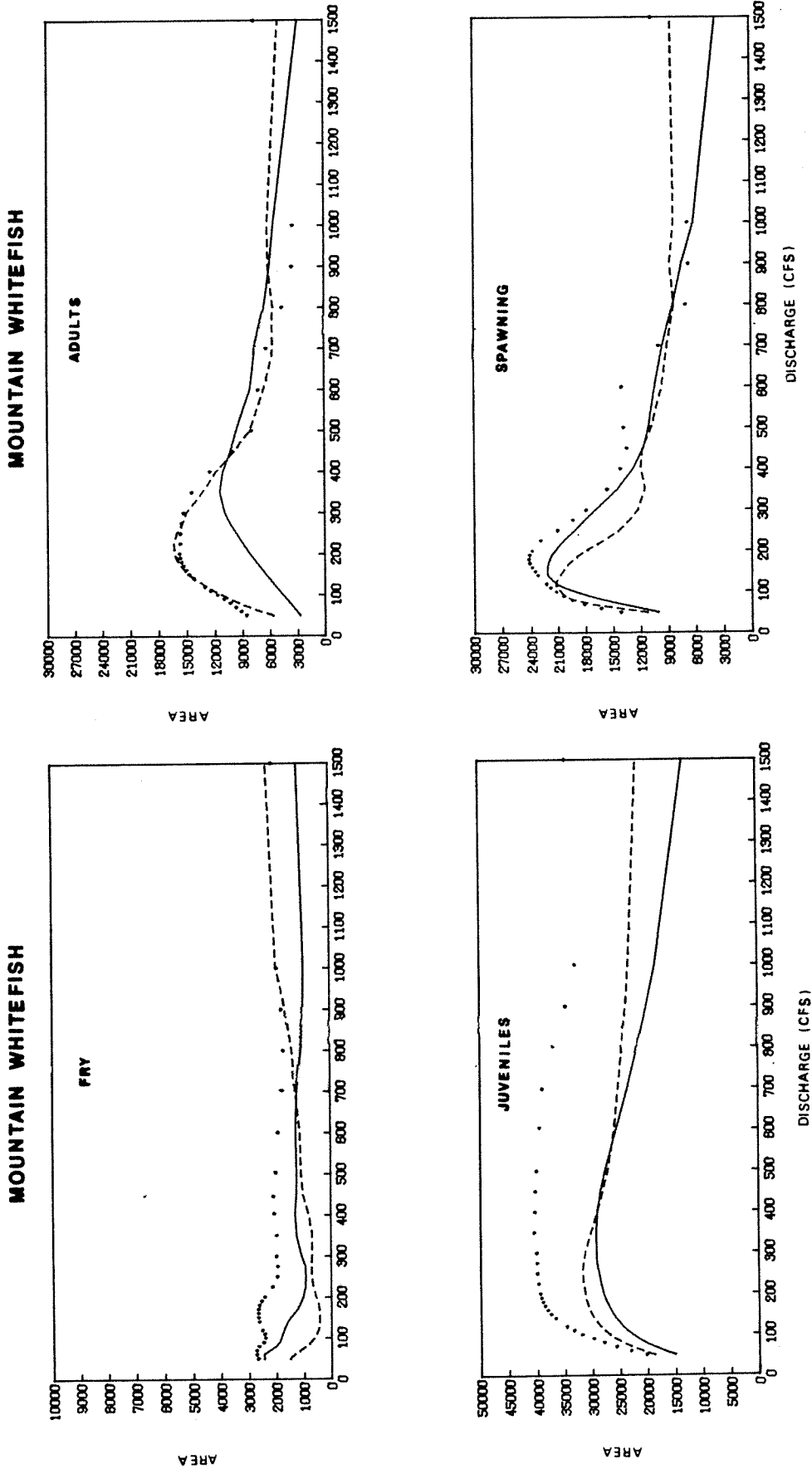
Appendix Figure D2. WUA (ft^2) as a function of discharge (cfs) for chinook salmon life stages at Tolt River stations 5, 6, and 7.



Appendix Figure D3. WUA (ft²) as a function of discharge (cfs) for cutthroat trout life stages at Tolt River stations 5, 6, and 7.

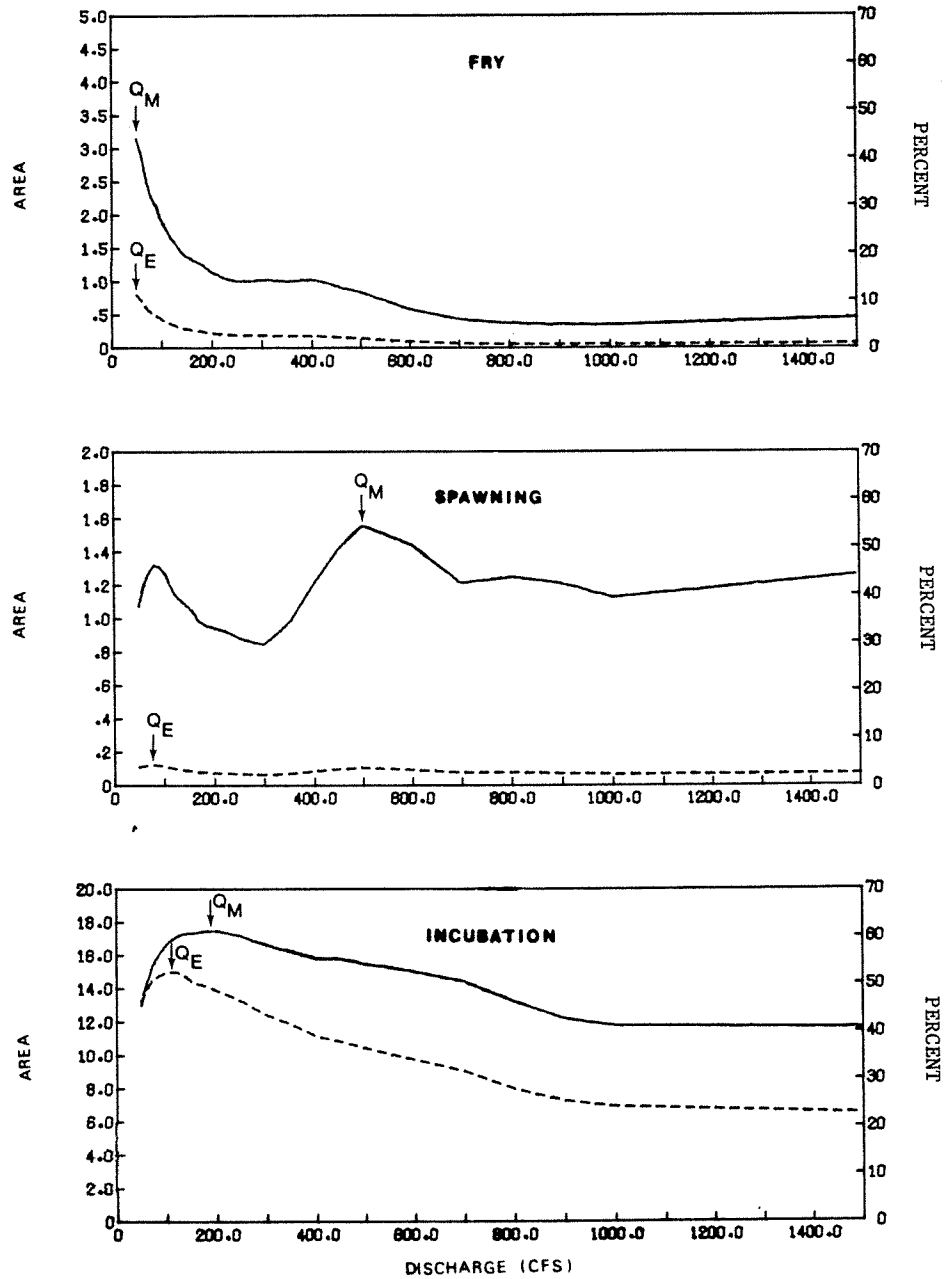


Appendix Figure D4. WUA (ft²) as a function of discharge (cfs) for steelhead trout life stages at Tolt River stations 5, 6, and 7.



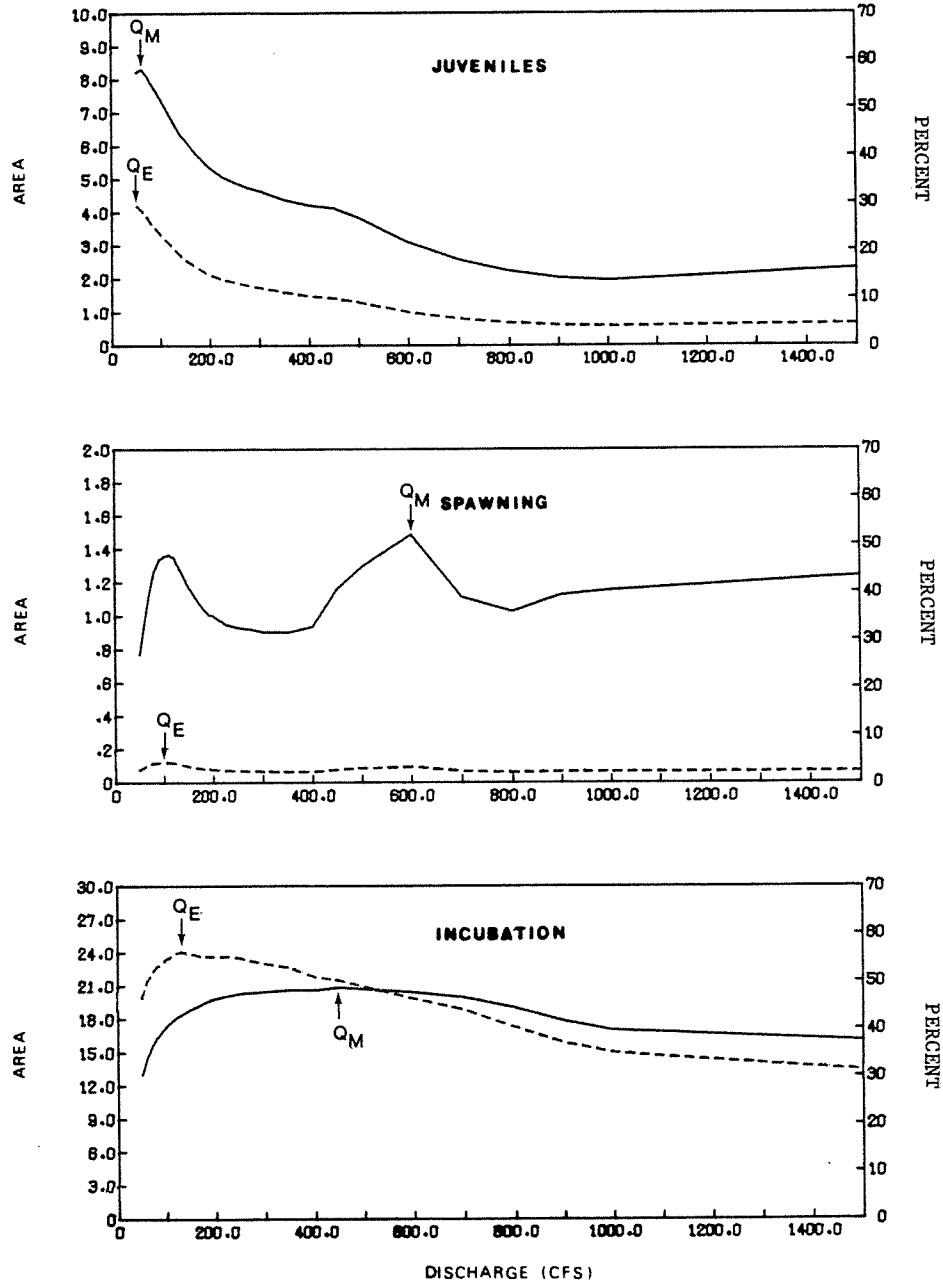
Appendix Figure D5. WUA (ft²) as a function of discharge (cfs) for mountain whitefish life stages at Tolt River stations 5, 6, and 7.

COHO SALMON

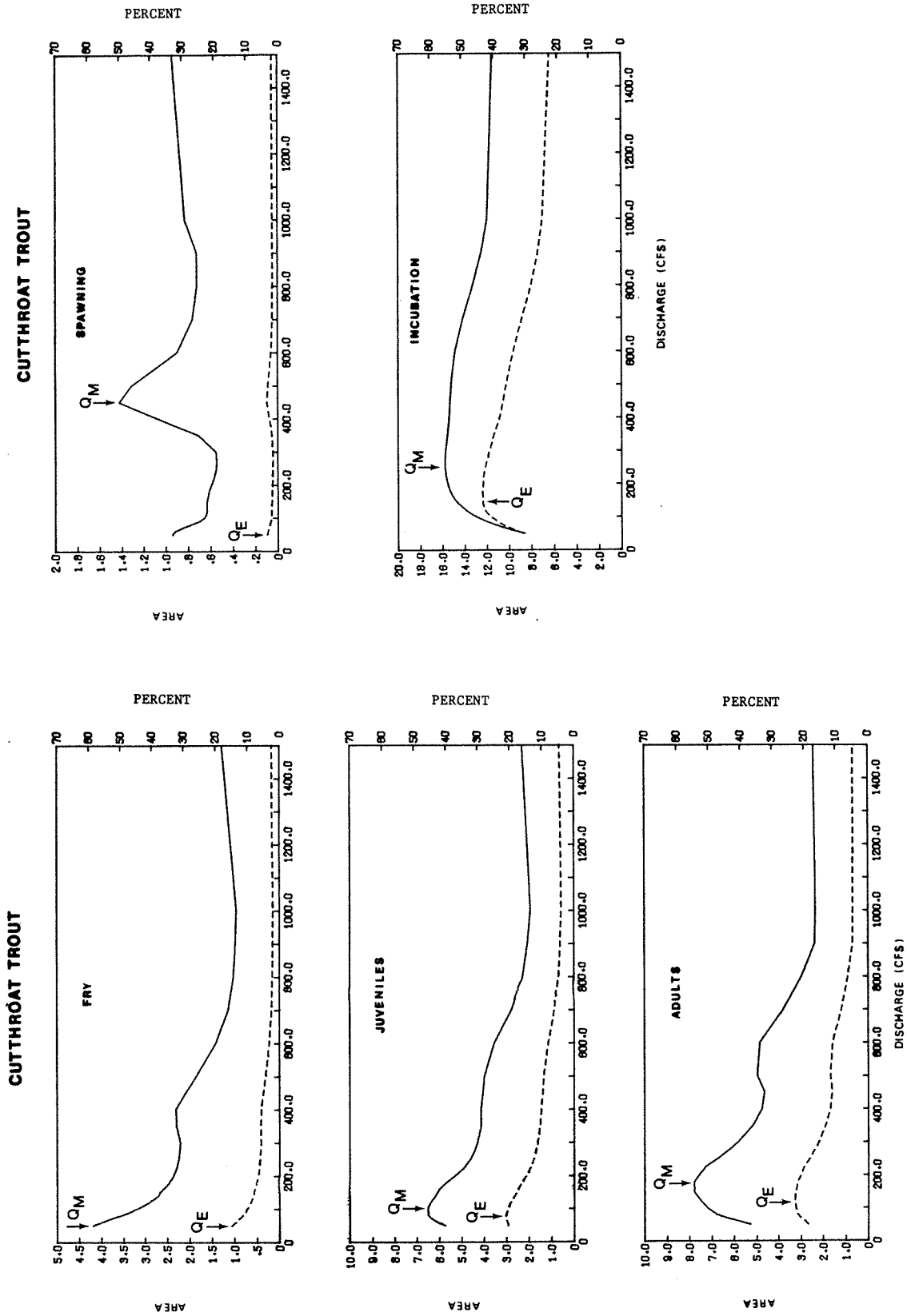


Appendix Figure D6. Combined WUA (solid line) and habitat efficiency (dashed line) values for coho salmon at different discharges for the mainstem Tolt River. For a given flow, the habitat efficiency is the WUA expressed as a percentage of the total stream surface area. The discharges at which Q_M and Q_E values were obtained are indicated by arrows.

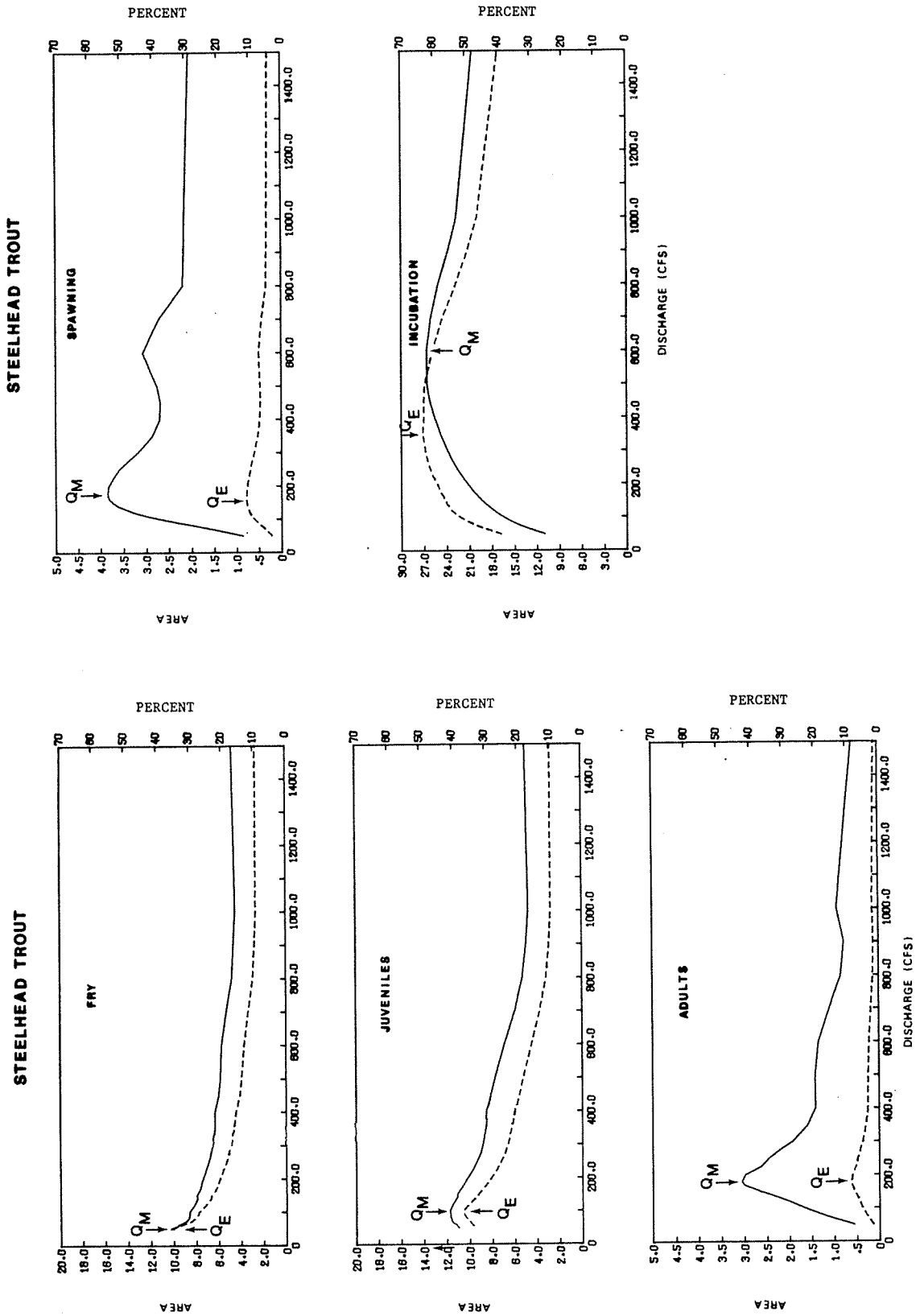
CHINOOK SALMON



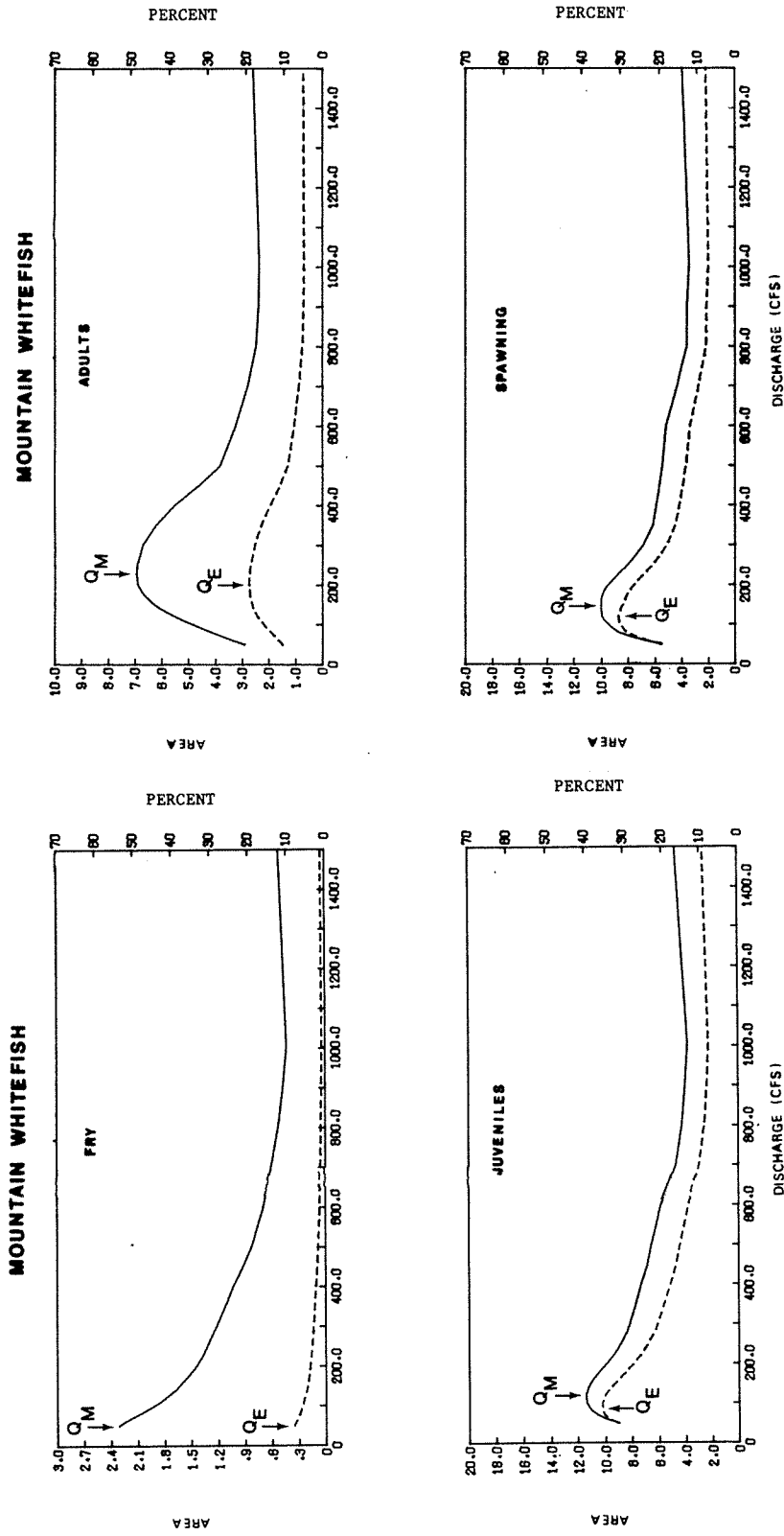
Appendix Figure D7. Combined WUA (solid line) and habitat efficiency (dashed line) values for chinook salmon at different discharges for the mainstem Tolt River. For a given flow, the habitat efficiency is the WUA expressed as a percentage of the total stream surface area. The discharges at which Q_M and Q_E values were obtained are indicated by arrows.



Appendix Figure D8. Combined WUA (solid line) and habitat efficiency (dashed line) values for cutthroat trout at different discharges for the mainstem Tolt River. For a given flow, the habitat efficiency is the WUA expressed as a percentage of the total stream surface area. The discharges at which Q_M and Q_E values were obtained are indicated by arrows.



Appendix Figure D9. Combined WUA (solid line) and habitat efficiency (dashed line) values for steelhead trout at different discharges for the mainstem Tolt River. For a given flow, the habitat efficiency is the WUA expressed as a percentage of the total stream surface area. The discharges at which Q_M and Q_E values were obtained are indicated by arrows.



Appendix Figure D10. Combined WUA (solid line) and habitat efficiency (dashed line) values for mountain whitefish at different discharges for the mainstem Tolt River. For a given flow, the habitat efficiency is the WUA expressed as a percentage of the total stream surface area. The discharges at which Q_M and Q_E values were obtained are indicated by arrows.

APPENDIX E. WDOE INSTREAM FLOW REQUIREMENTS

The efficacy of various fish release requirements for the Tolt River established by the Washington Department of Ecology (WDOE) in 1956 and 1979 was investigated as part of the instream flow analysis. The Seattle Water Department is presently obligated to meet minimum flows specified in 1956 under the terms of the Water Department's water right permit for the South Fork Tolt River. In addition to the minimum water releases determined for the South Fork, the Washington Departments of Fisheries and Game (Biggs 1956) recommended minimum flows for normal and critical water years for the North Fork and mainstem Tolt River (Table E1). The recommended water releases for normal water years were based on the judgement and consensus of fisheries biologists familiar with the Tolt River and on an analysis of the 1928-1956 discharge record from the USGS gage (12-1485) on the mainstem Tolt River. Fish release requirements during critical years allow a reduction of 30 percent from the normal minimum flows. Although there is no formal stipulation dictating when the critical minimum releases apply, Mancinelli (pers. comm.) asserts that the critical flow curve is in effect when natural stream flows fall below those specified by the normal flow curve. Water is presently released from the South Fork Tolt Reservoir to provide the required minimum flows at USGS gage 12-1480, located approximately two miles downstream from the Tolt dam.

The WDOE recently identified new instream flow criteria, shown in Table E1, under the Instream Resources Protection Program for the Snohomish River Basin (WDOE 1979). Minimum flow requirements were derived from basin hydrological characteristics and an interagency assessment of instream

Appendix Table E1. Summary of instream flow requirements and recommendations for the South Fork, North Fork, and mainstem Tolt River.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<u>South Fork</u>												
WDOE 1956												
Normal	54	54	54	54	54	35	35	35	44	54	54	54
Critical	37.8	37.8	37.8	37.8	37.8	24.5	24.5	24.5	30.8	37.8	37.8	37.8
WDOE 1979												
Normal	83	83	83	83	83	83	77	43	44	69.5	83	83
WDF&G (recommended)	160	160	160	160	115	65	65	65	160	160	160	160
<u>North Fork</u>												
WDOE 1956												
Normal	109	109	109	109	109	75	75	75	92	109	109	109
Critical	76.3	76.3	76.3	76.3	76.3	52.5	52.5	52.5	64.4	76.3	76.3	76.3
<u>Mainstem Tolt</u>												
WDOE 1956												
Normal*	200	200	200	200	200	125	125	125	125/200	200	200	200
WDOE 1979												
Normal	280	280	280	280	280	280	280/240	170/120	120	190/280	280	280
Critical	190	190	190	190	190	190/165	140/120	120	120	185/190	190	190

* Flows include Stossel Creek discharge.

resource values. For each stream, the annual hydrograph was separated into high and low flow periods depending on whether the discharge at the 50 percent exceedance probability level was greater or less than the median daily flow. During high flow periods the discharge at the 95 percent exceedance probability level (calculated for the entire high flow time interval) is equivalent to the minimum flow requirement. Under low flow conditions the exceedance probability statistic is dependent upon the rating assigned to the individual streams. For the Tolt River the probability statistic is equal to 72 percent, corresponding to a discharge of 120 cfs. A secondary set of flows is provided to apply to dry-year conditions; however, no explanation is given of either the method used to derive critical minimum flows or the specific rules indicating when the critical flow requirements apply.

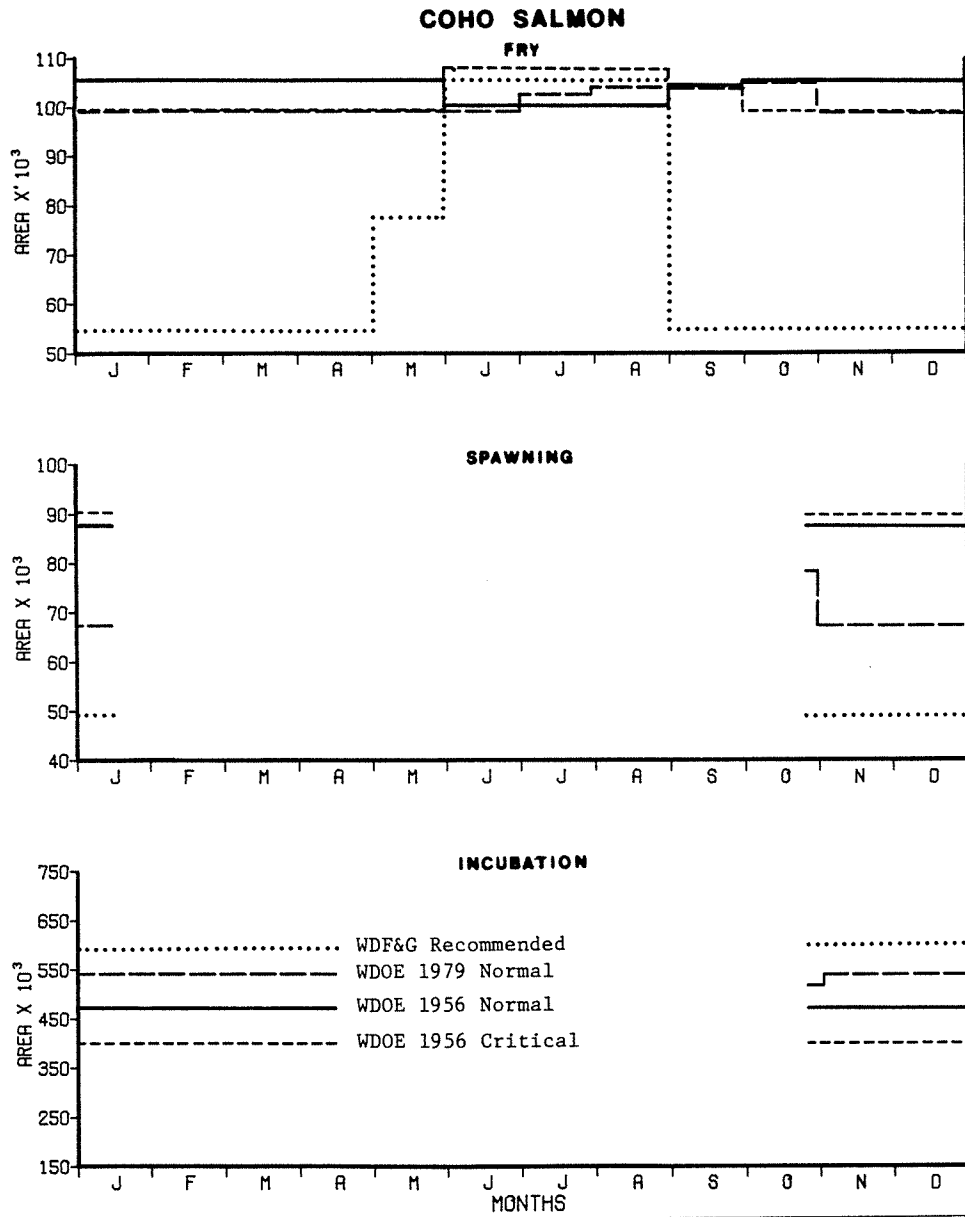
Representatives of the WDOE and Seattle City Light met in January 1980 to discuss the application of the new instream flow requirements vis-a-vis the Water Department's existing operation and the proposed hydroelectric project. The result was an informal agreement between the two groups that the Water Department would modify existing fishwater releases to accommodate state regulations when there was water available for power generation in excess of the City's municipal and industrial water supply needs.

Minimum flow requirements were specified by the Washington Department of Ecology in 1956 under the terms of the water permit granted to the Water Department for the South Fork, and in 1979 as part of a comprehensive Instream Resources Protection Program (Table E1). Minimum flows were identified on both occasions for the South Fork and mainstem Tolt River. Normal and

critical water releases were determined for the three river segments only in 1956. Minimum flow requirements established in 1979 included normal and critical water year releases for the mainstem Tolt River and normal year flows for the South Fork, but did not indicate instream flow requirements for the North Fork. In addition to the WDOE flow minima, the Washington Departments of Fisheries and Game submitted independent instream flow recommendations for the South Fork in 1979 (WDOE 1979).

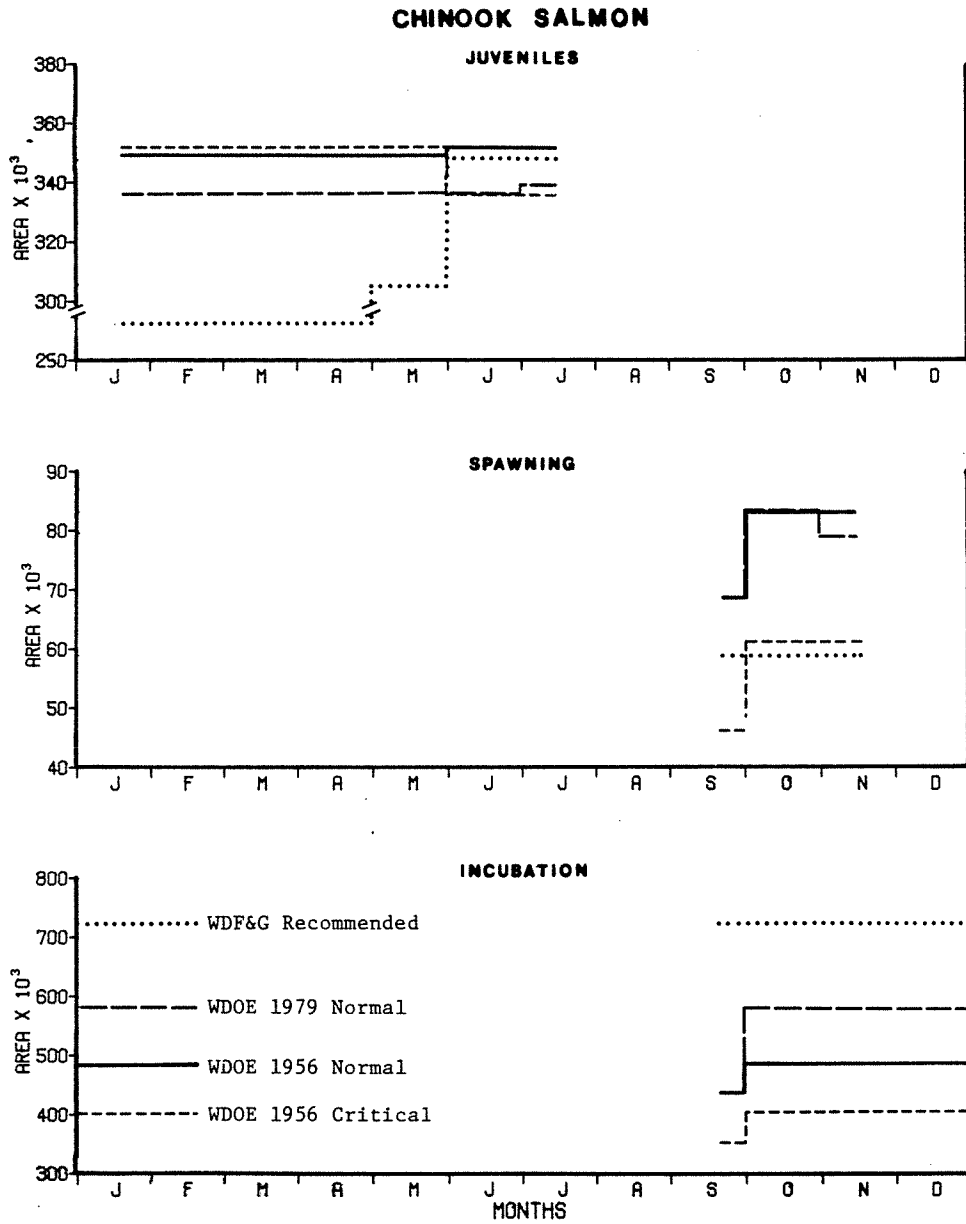
The WUA available at the specific discharges set forth by the instream flow requirements and recommendations mentioned above were compared for each species/life stage for the two forks and mainstem Tolt River. The WUA's provided by the specified flows are based on the combined proportional representation of each study reach in the separate river segments. Comparisons between different minimum flows for a particular life stage were confined to the period of the year that the life stage was present in the river. Mountain whitefish life stages were not included in the present analysis due to the uncertainty of the timing of their occurrence in the Tolt River system.

The primary purpose of the comparative analysis was to assess the efficacy of various minimum flow requirements in providing for the physical habitat needs of salmonids residing in the Tolt River system. The results of this analysis are presented in Figures E1, E2, E3, and E4 for coho, chinook, cutthroat, and steelhead, respectively, by life stage for the South Fork Tolt River. The WDOE 1956 normal and critical and the 1979 normal and WDF&G 1979 flow curves are compared. Comparisons for coho, chinook, cutthroat, and steelhead by life stage are presented in Figures



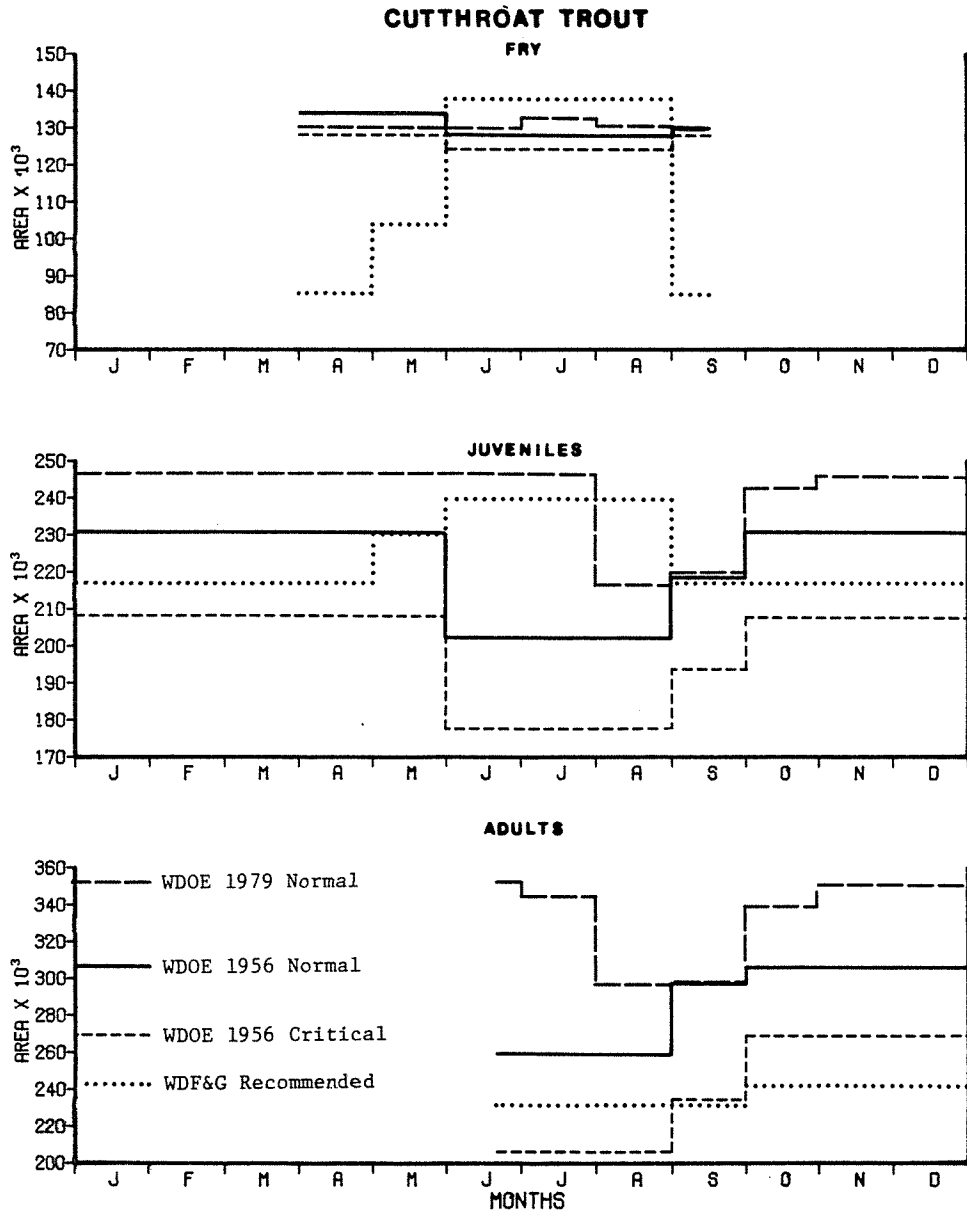
WDOE 1956 Normal	56	35	44	54		
WDOE 1956 Critical	37.8	24.5	30.8	37.8		
WDOE 1979 Normal	83	77	43	44	69.5	83
WDF&G 1979	160	115	65	160		

Appendix Figure E1. Coho salmon WUA available at discharges specified by various instream flow curves (fish releases) for the South Fork Tolt River.



WDOE 1956 Normal	56	35	44	54		
WDOE 1956 Critical	37.8	24.5	30.8	37.8		
WDOE 1979 Normal	83	77	43	44	69.5	83
WDF&G 1979	160	115	65	160		

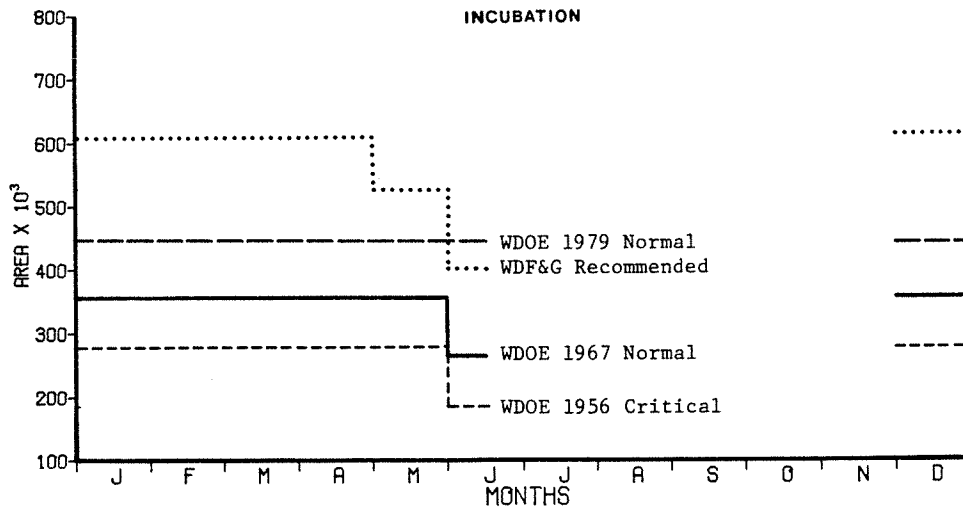
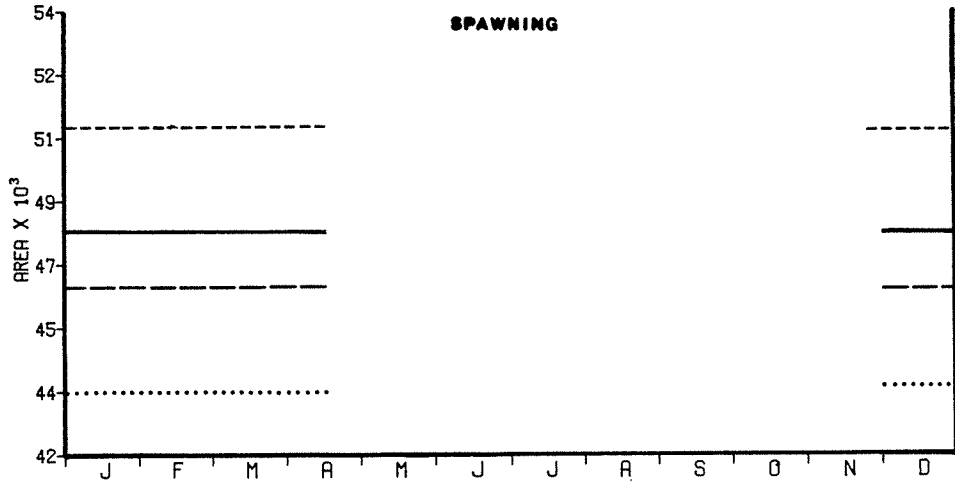
Appendix Figure E2. Chinook salmon WUA available at discharges specified by various instream flow curves (fish releases) for the South Fork Tolt River.



WDOE 1956 Normal	56	35	44	54		
WDOE 1956 Critical	37.8	24.5	30.8	37.8		
WDOE 1979 Normal	83	77	43	44	69.5	83
WDF&G 1979	160	115	65	160		

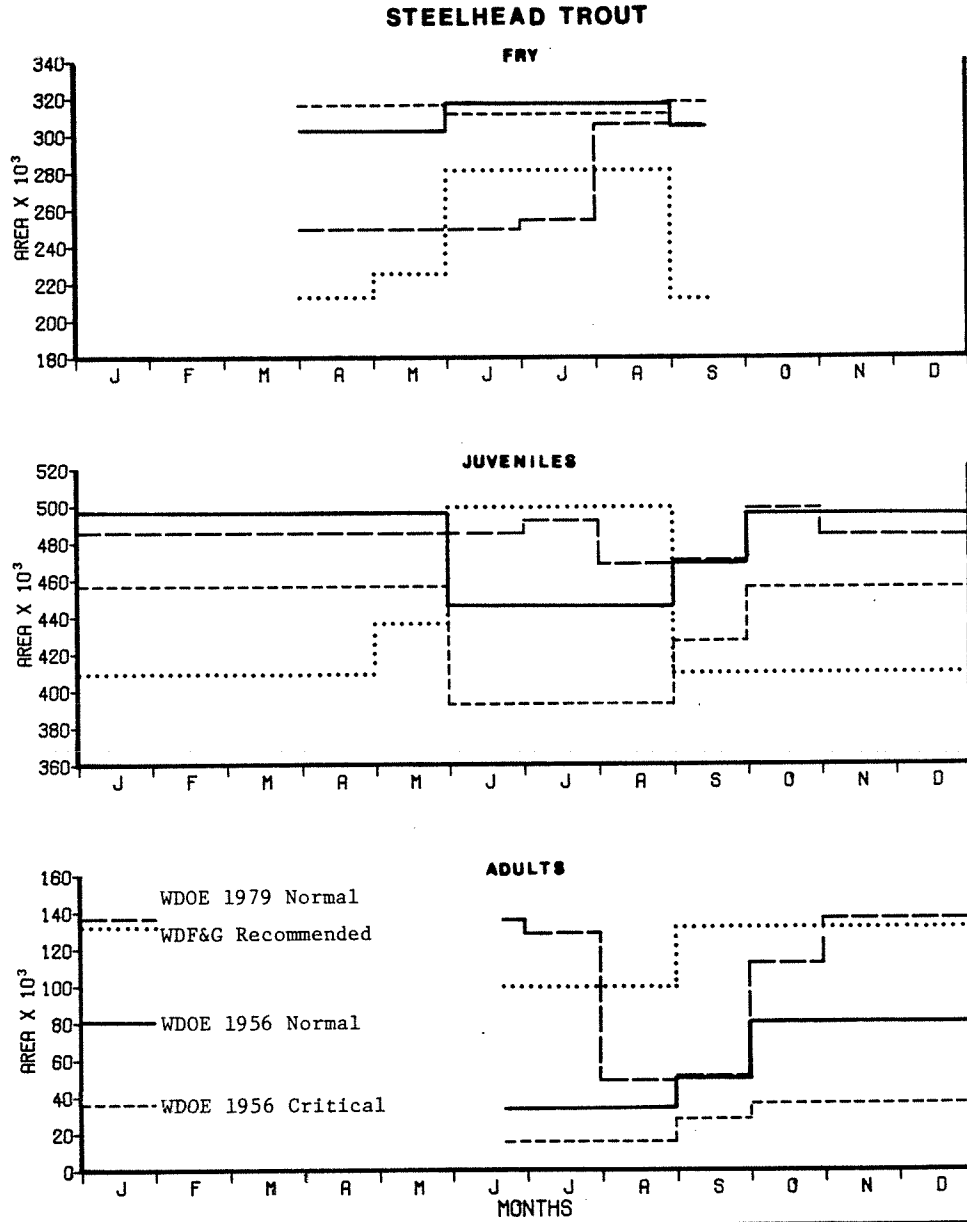
Appendix Figure E3. Cutthroat trout WUA available at discharges specified by various instream flow curves (fish releases) for the South Fork Tolt River.

CUTTHROAT TROUT



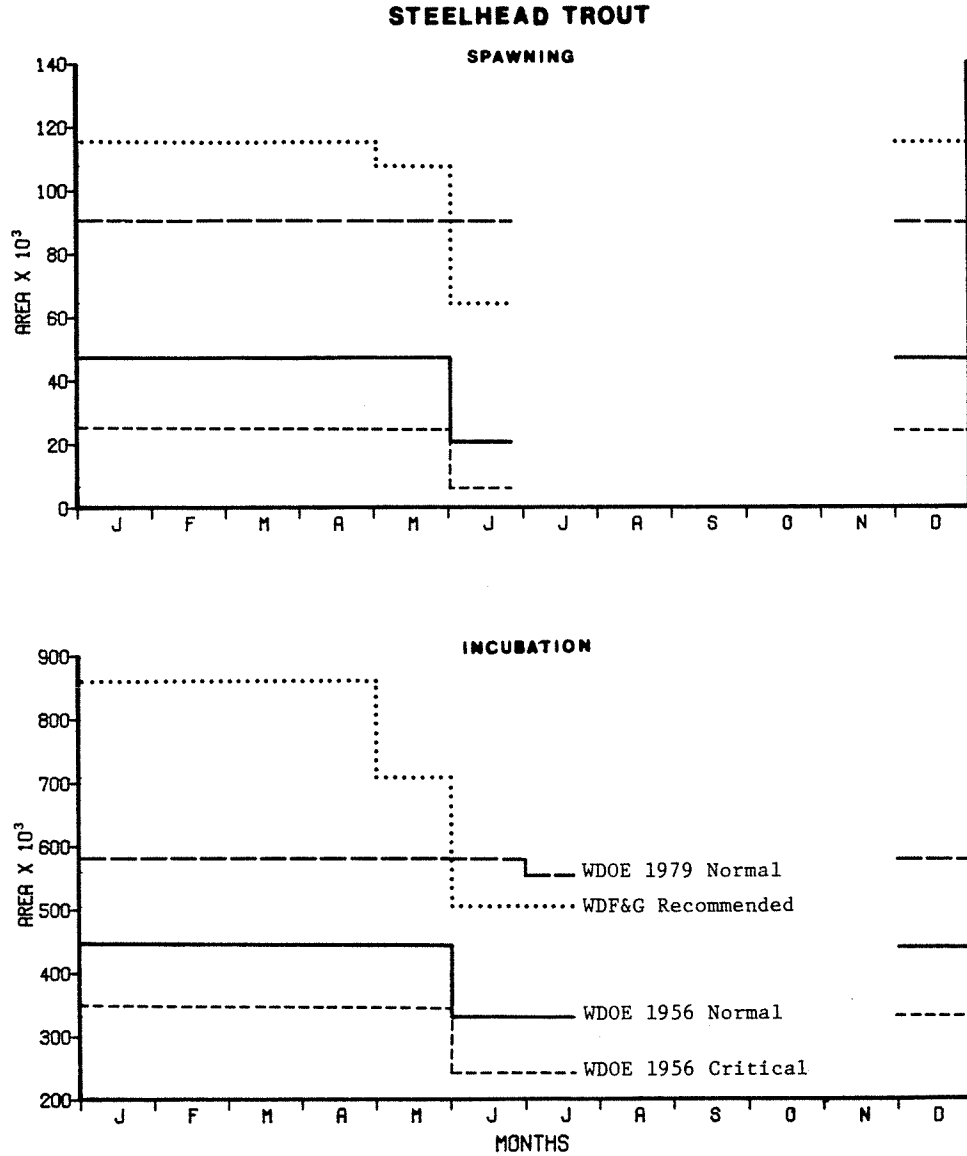
WDOE 1956 Normal	56	35	44	54		
WDOE 1956 Critical	37.8	24.5	30.8	37.8		
WDOE 1979 Normal	83	77	43	44	69.5	83
WDF&G 1979	160	115	65	160		

Appendix Figure E3. Cutthroat trout WUA available at discharges specified by various instream flow curves (fish releases) for the South Fork Tolt River (continued).



WDOE 1956 Normal	54	35	44	54		
WDOE 1956 Critical	37.8	24.5	30.8	37.8		
WDOE 1979 Normal	83	77	43	44	69.5	83
WDF&G 1979	160	115	65	160		

Appendix Figure E4. Steelhead trout WUA available at discharges specified by various instream flow curves (fish releases) for the South Fork Tolt River.



WDOE 1956 Normal	56	35	44	54		
WDOE 1956 Critical	37.8	24.5	30.8	37.8		
WDOE 1979 Normal	83	77	43	44	69.5	83
WDF&G 1979	160	115	65	160		

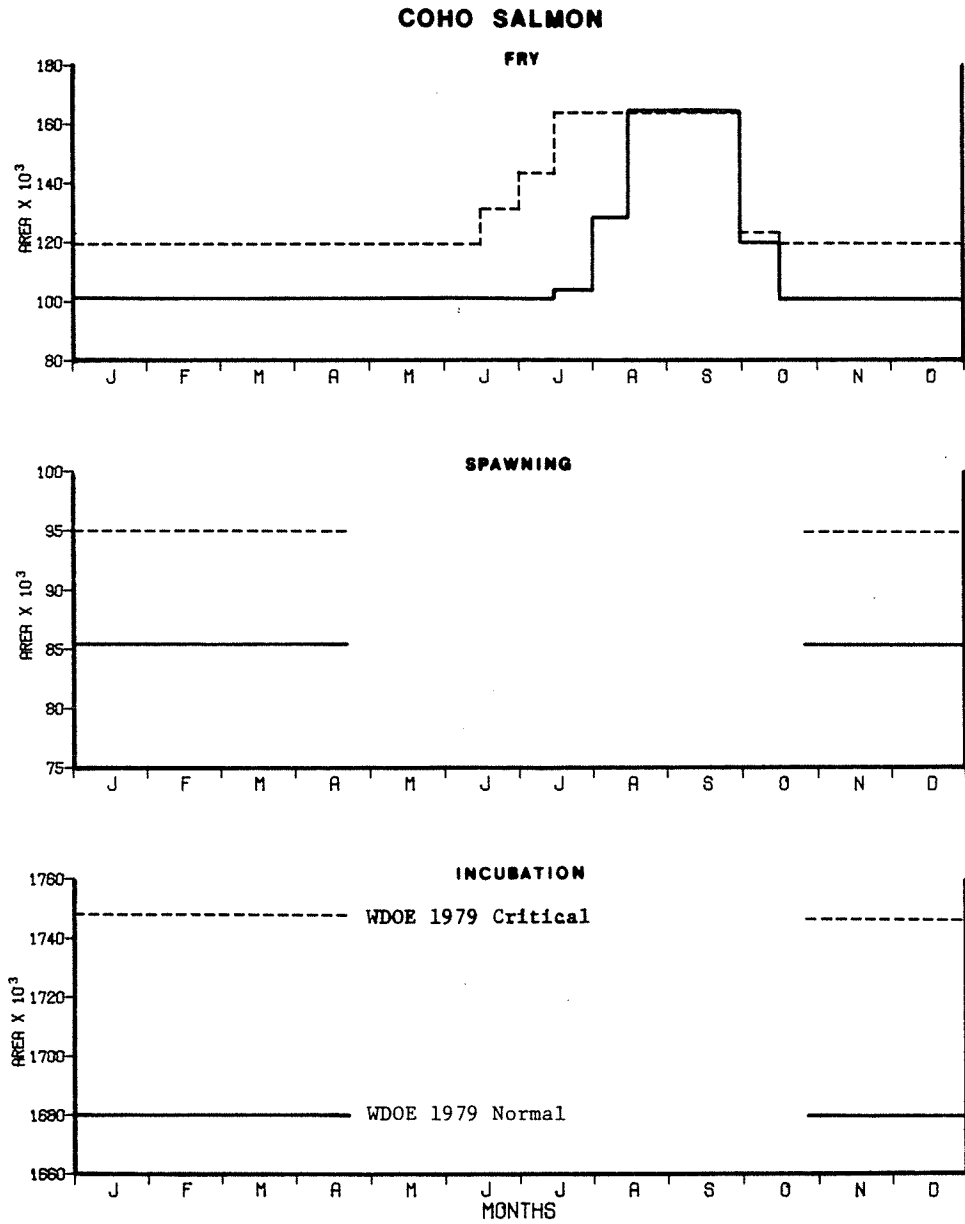
Appendix Figure E4. Steelhead trout WUA available at discharges specified by various instream flow curves (fish releases) for the South Fork Tolt River (continued).

E5, E6, E7, and E8, respectively, for the mainstem Tolt River. Only the WDOE 1979 normal and critical flow curves are compared for the mainstem since the 1956 requirements were specified for the river below Stossel Creek.

In most cases, the WDOE 1956 flow requirements for the South Fork resulted in the greatest amount of habitat area suitable for salmonid fry and juvenile rearing. Exceptions include cutthroat juvenile habitat during the high and low flow periods, and cutthroat fry and steelhead juvenile habitat under low flow conditions. The habitat criteria for these life phases, particularly the fry stage of salmon and trout, give more weight to areas of comparatively low velocity and shallow depth. Consequently, streamflows which provide these conditions generally enhance the quality of the stream as rearing habitat.

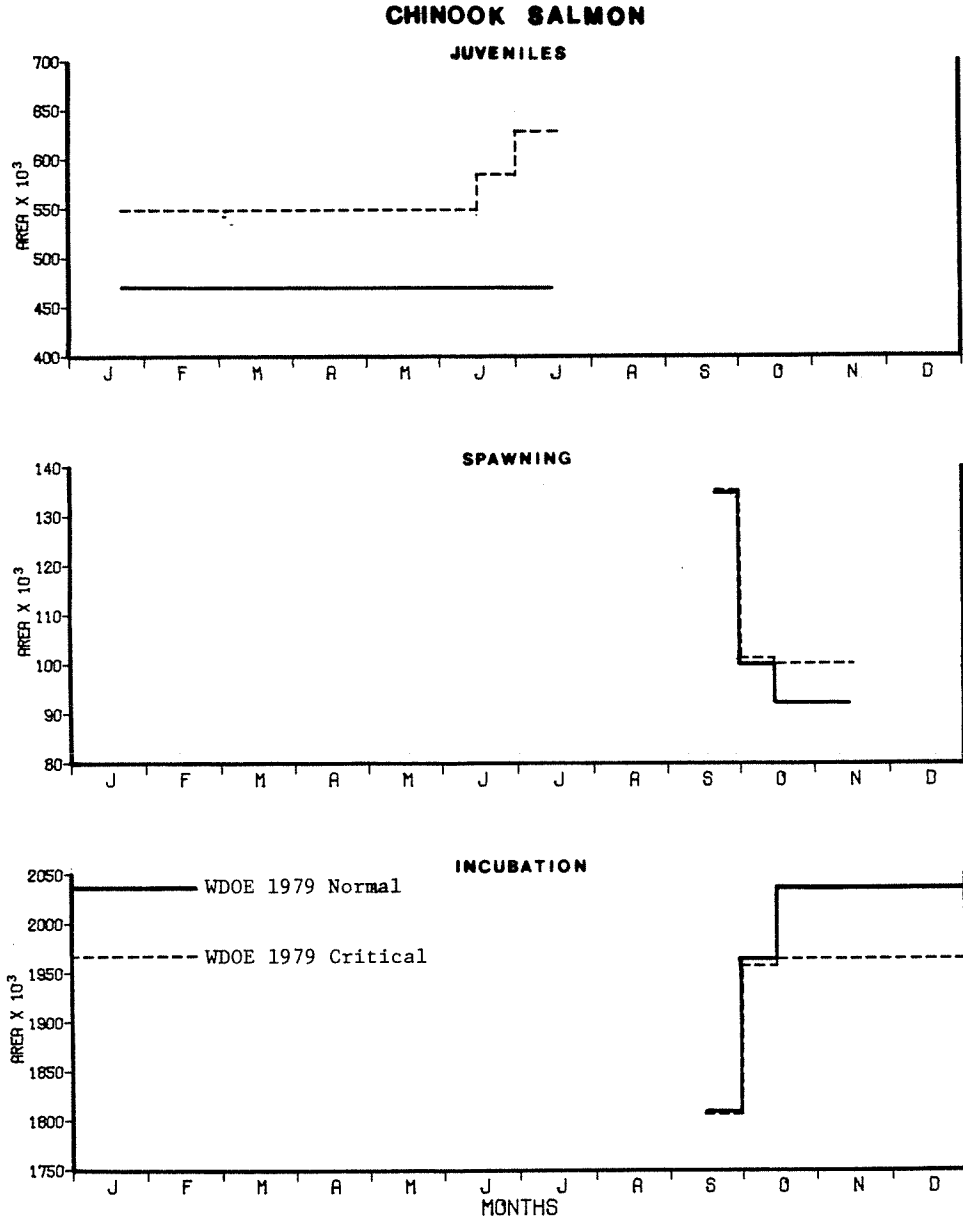
In contrast to the fry and juvenile life stages, spawning and incubation habitat availability is usually greater at the highest discharge specified by the various South Fork curves. This is true without exception for incubation habitat, which is greater at the WDF&G requirement of 160 cfs for high flow periods than it is at lower flows. Steelhead spawning WUA is over four times greater at 160 cfs than it is at the WDOE 1956 critical release requirement of 37.8 cfs. Coho and cutthroat spawning habitat, however, is actually more abundant at the latter discharge than at the other instream flow requirements.

It is apparent that a more appropriate minimum instream flow curve for the South Fork would combine elements of the various curves which have been considered in this analysis. For example, summer and fall minima might be taken from the WDOE 1956 normal and critical instream flow curve, and winter



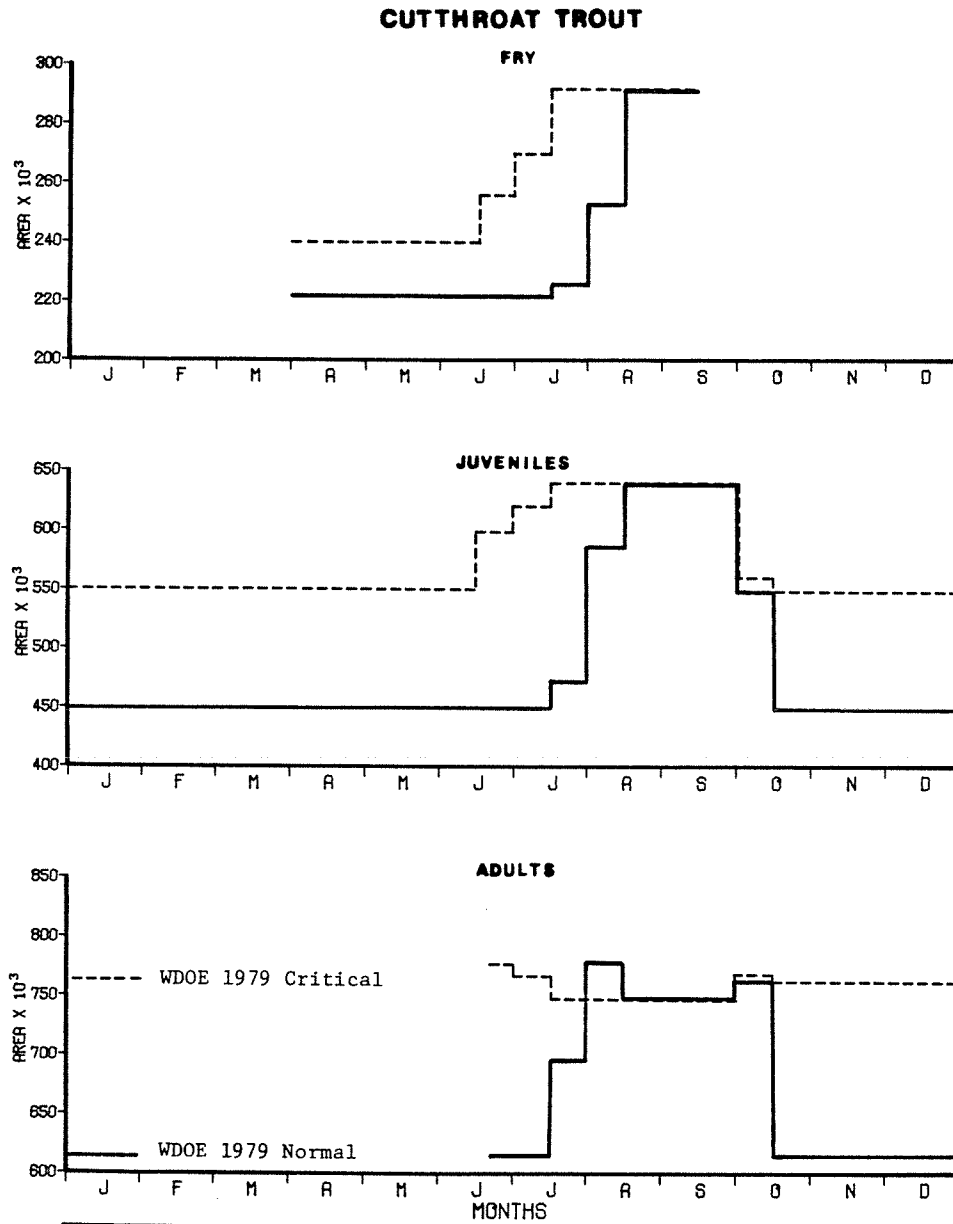
WDOE 1979 Normal	280	240	170	120	190	280
WDOE 1979 Critical	190	165	140	120	185	190

Appendix Figure E5. Coho salmon WUA available at discharges specified by WDOE (1979) as normal and critical water year instream flow requirements for the mainstem Tolt River.



WDOE 1979 Normal	280	[240|170]	120	[190]	280
WDOE 1979 Critical	190	[165|140]	120	[185]	190

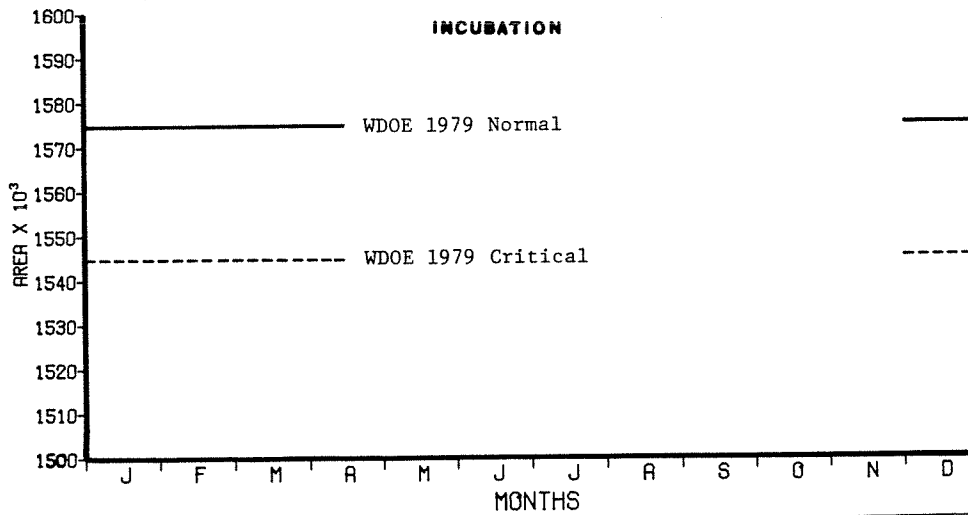
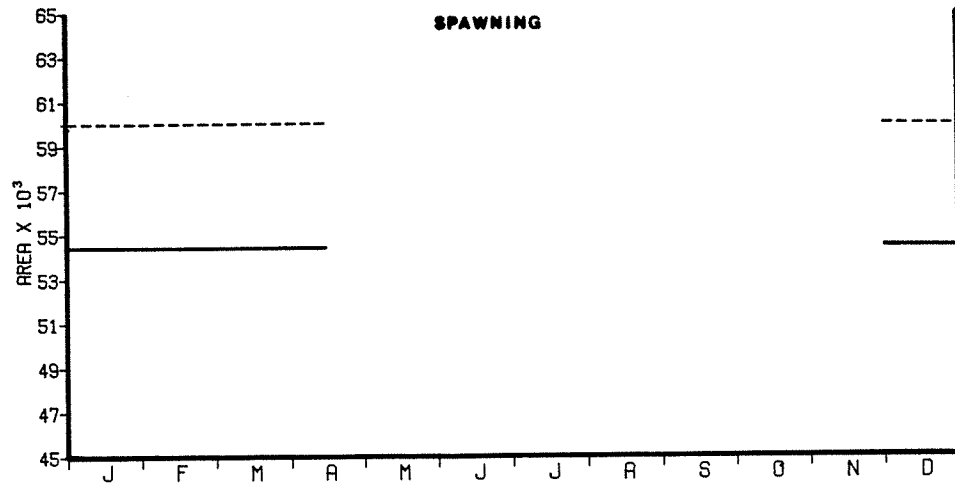
Appendix Figure E6. Chinook salmon WUA available at discharges specified by WDOE (1979) as normal and critical water year instream flow requirements for the mainstem Tolt River.



WDOE 1979 Normal	280	|240|170|	120	|190|	280
WDOE 1979 Critical	190	|165|140|	120	|185|	190

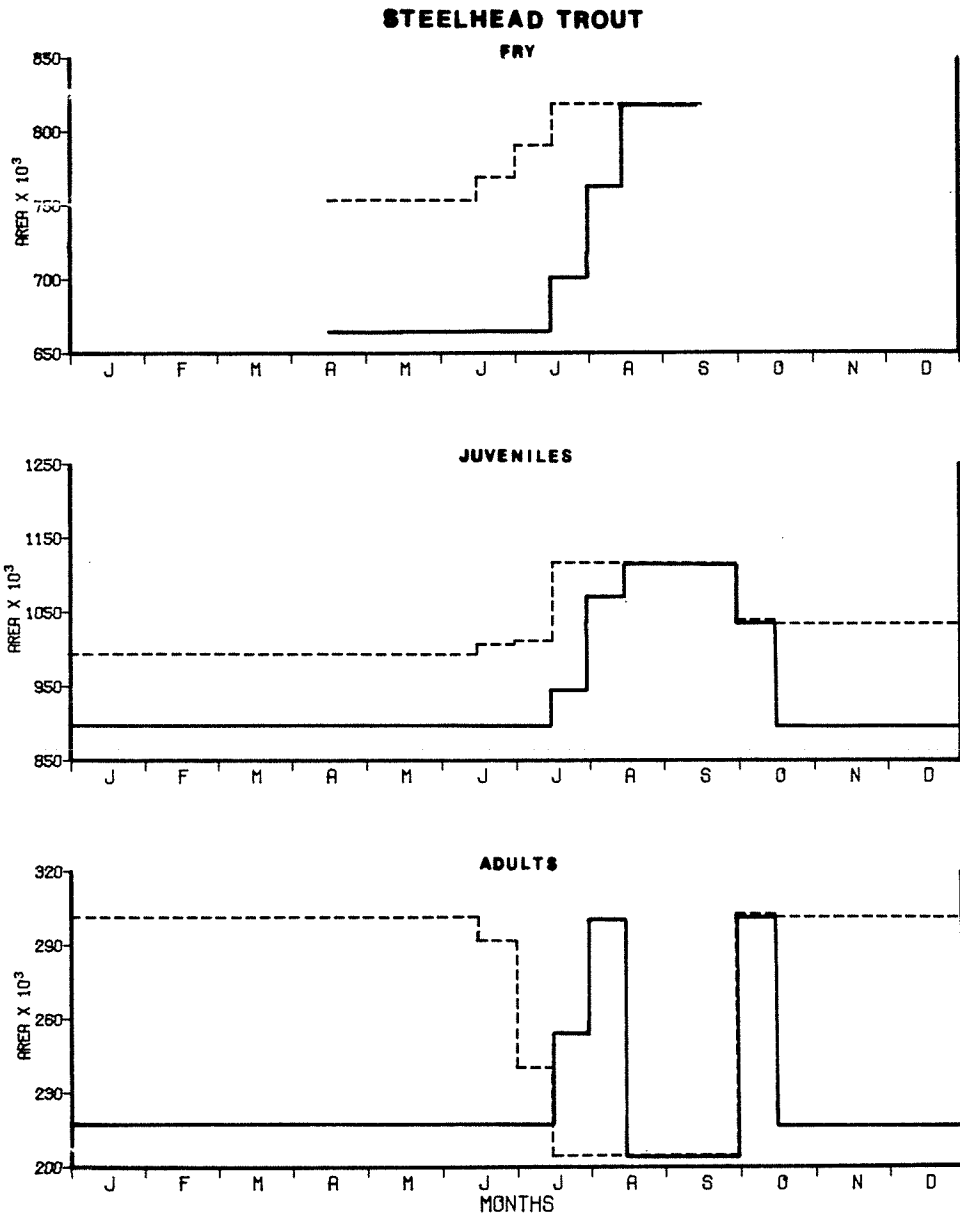
Appendix Figure E7. Cutthroat trout WUA available at discharges specified by WDOE (1979) as normal and critical water year instream flow requirements for the mainstem Tolt River.

CUTTHROAT TROUT



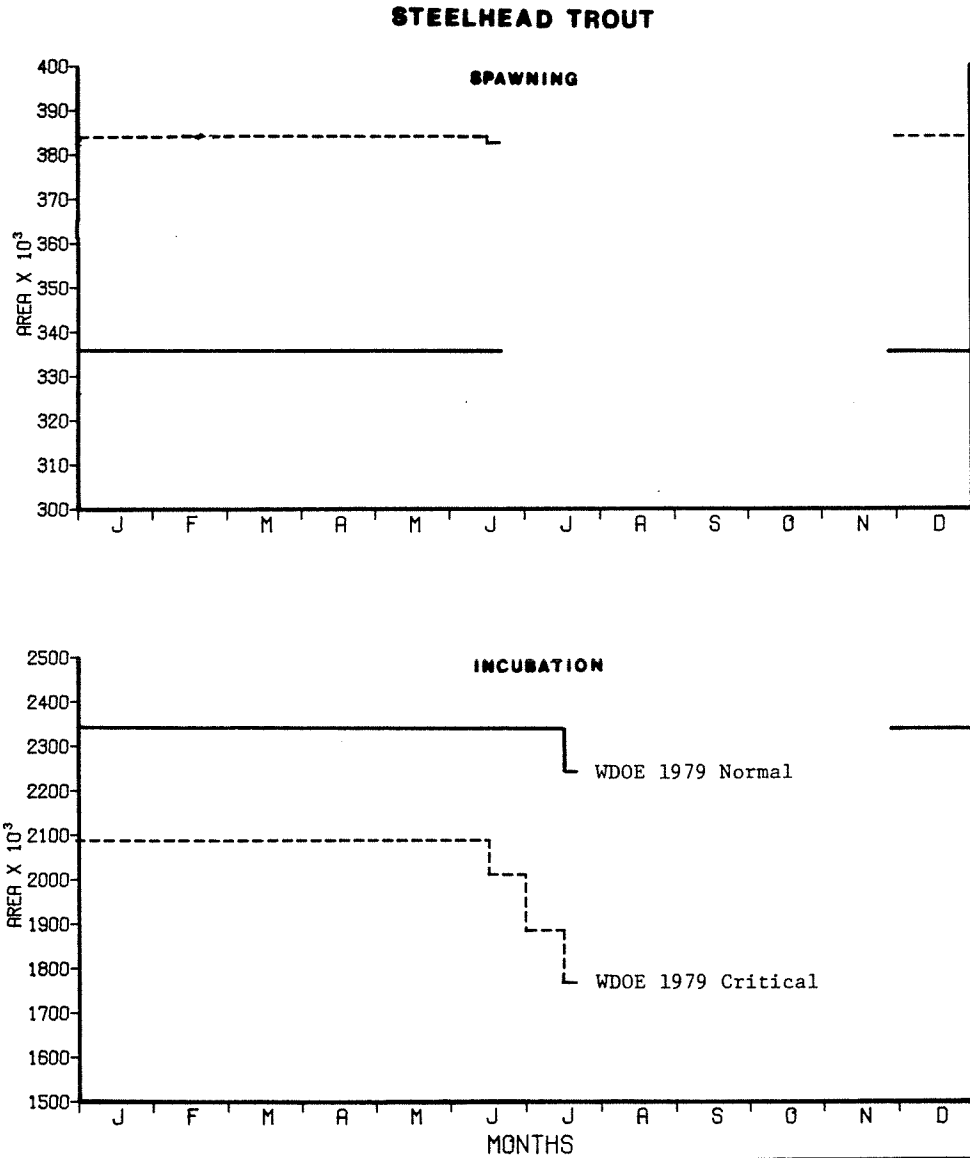
WDOE 1979 Normal	280	240	170	120	190	280
WDOE 1979 Critical	190	165	140	120	185	190

Appendix Figure E7. Cutthroat trout WUA available at discharges specified by WDOE (1979) as normal and critical water year instream flow requirements for the mainstem Tolt River (continued).



WDOE 1979 Normal	280	[240|170]	120	[190]	280
WDOE 1979 Critical	190	[165|140]	120	[185]	190

Appendix Figure E8. Steelhead trout WUA available at discharges specified by WDOE (1979) as normal and critical water year instream flow requirements for the mainstem Tolt River.



WDOE 1979 Normal	280	240	170	120	190	280
WDOE 1979 Critical	190	165	140	120	185	190

Appendix Figure E8. Steelhead trout WUA available at discharges specified by WDOE (1979) as normal and critical water year instream flow requirements for the mainstem Tolt River (continued).

and spring flow requirements set at WDF&G recommended discharges. This would provide greater amounts of rearing, spawning, and incubation habitat at the times of the year when they are critical.

Of the two instream flow curves proposed by WDOE in 1979 for the mainstem Tolt River, the critical water year releases result in higher WUA values for fry, juvenile, adult, and spawning life stages during the winter months. The availability of incubation habitat, however, is greater at normal flows for all species except coho salmon. During the low flow period, critical flows provide equivalent or higher WUA's than do normal water year releases for the fry and juvenile life stages of all species. Adult cutthroat and steelhead habitat, in contrast, was found to be greater at normal flows during the summer months. It may be concluded that critical flows are better suited for most life stages which inhabit the mainstem Tolt River. The quality of incubation habitat, however, is usually enhanced by the streamflows specified by the normal water year instream flow requirements.