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Little Klickitat River Basin Fish Habitat Analysis Using the Instream Flow Incremental Methodology

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Little Klickitat River Basin
Fish Habitat Analysis
Using the Instream Flow Incremental Methodology

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ABSTRACT

The Washington State Department of Ecology, Water Resources Program conducted an instream flow study in the Little Klickitat River basin using the Instream Flow Incremental Methodology. The study provides fish habitat versus streamflow relationships that Ecology can use in developing minimum instream flows for the Little Klickitat River basin.

Two study sites, involving nine transects, were chosen to represent 11 miles of the Little Klickitat River. Five other creeks: Blockhouse, Bloodgood, Bowman, Mill, and Springs Creeks, each had one study site involving four transects apiece. Habitat and streamflow measurements for the hydraulic models were collected at three or four different flows.

The Little Klickitat River, Lower Site model has habitat peaking for spawning chinook at a flow of 260 cubic feet per second (cfs), spawning coho at 120 cfs, spawning rainbow at 280 cfs, spawning steelhead at 240 cfs, juvenile chinook and coho rearing at 100 cfs, juvenile rainbow rearing at 110 cfs, juvenile steelhead rearing at 90 cfs, adult chinook holding at 360 cfs, adult rainbow holding at 200 cfs, and adult steelhead holding at 280 cfs. The range of flows modeled was 7 to 363 cfs.

The Little Klickitat River, Upper Site model has habitat peaking for spawning chinook at a flow of 1000 cfs, spawning coho at 60 cfs, spawning rainbow at 120 cfs, spawning steelhead at 120 cfs, juvenile chinook and coho rearing at 70 cfs, juvenile rainbow rearing at 60 cfs, juvenile steelhead rearing at 80 cfs, adult chinook holding at 220 cfs, and adult rainbow holding at 150 cfs, and adult steelhead holding at 70 cfs. The range of flows modeled was 2 to 210 cfs.

The Blockhouse Creek model has habitat peaking for spawning rainbow at 20 cfs, juvenile rainbow rearing at 17 cfs, and adult rainbow holding at 22 cfs. The range of flows modeled was 0.36 to 23 cfs.

The Bloodgood Creek model has habitat peaking for spawning rainbow trout at a flow of 19 cfs, juvenile rainbow rearing at 22 cfs, and adult rainbow holding at 22 cfs. The range of flows modeled was 3 to 22 cfs.

The Bowman Creek model has habitat peaking for spawning coho at a flow of 9 cfs, spawning rainbow at 30 cfs, spawning steelhead at 42 cfs, juvenile coho rearing at 12 cfs, juvenile rainbow rearing at 9 cfs, juvenile steelhead rearing at 12 cfs, adult rainbow holding at 30 cfs, and adult steelhead holding at 18 cfs. The range of flows modeled was 0.7 to 66 cfs.

The Mill Creek model has habitat peaking for spawning coho at a flow of 21 cfs, spawning rainbow at 51 cfs, spawning steelhead at 36 cfs, juvenile coho rearing at 57 cfs, juvenile rainbow rearing at 57 cfs, juvenile steelhead rearing at 57 cfs, adult rainbow holding at 57 cfs, and adult steelhead holding at 51 cfs. The range of flows modeled was 1 to 57 cfs.

The Spring Creek model has habitat peaking for spawning coho at a flow of 20 cfs, spawning rainbow at 32 cfs, spawning steelhead at 32 cfs, juvenile coho rearing at 28 cfs, juvenile rainbow rearing at 32 cfs, juvenile steelhead rearing at 32 cfs, adult rainbow holding at 32 cfs, and adult steelhead holding at 32 cfs. The range of flows modeled was 2 to 32 cfs.

PREFACE

This publication provides fish habitat versus streamflow relationships for various streams in the Little Klickitat River basin. These habitat relationships can be used to determine how to manage the flows in the river and streams in the Little Klickitat River basin. There is no one flow that will provide peak habitat for all the fish species that use the Little Klickitat basin streams. Different fish species and life stages exist simultaneously in the river and streams and each has a different flow requirement. Setting an instream flow requires prioritizing river reaches, fish species, and life stages. No attempt was made to prioritize in this report because a consensus on fishery management is needed from several state and federal natural resource agencies and the Yakima Indian Tribe.

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LIST OF ACRONYMS

cfs	cubic feet per second
Ecology	Washington Department of Ecology
fps	feet per second
HABTAT	Instream Flow Group's habitat model
IFG4	Instream Flow Group's hydraulic model
IFIM	Instream Flow Incremental Methodology
IRPP	Instream Resource Protection Program
NMFS	National Marine Fisheries Service
PHABSIM	Physical Habitat Simulation computer model
RM	river mile
VAFS	Velocity Adjustment Factor
WAC	Washington Administrative Code
WDF	Washington Department of Fisheries
WDW	Washington Department of Wildlife
WUA	Weighted Usable Area
USFWS	U.S. Fish and Wildlife Service
YIN	Yakima Indian Nation

I. PROJECT BACKGROUND

Study Objectives

The Washington State Department of Ecology (Ecology) has conducted Instream Flow Incremental Methodology (IFIM) studies since 1983 for use in determining minimum instream flows. This study serves two objectives.

1. To provide Ecology with instream flow information to determine the impact of new water right appropriation on fish habitat, and

2. To provide Ecology with instream flow information to determine minimum instream flows in an Instream Resource Protection Program (IRPP).

Participants

Project participants included the Washington State Department of Fisheries (WDF), Washington State Department of Wildlife (WDW), National Marine Fisheries Service (NMFS), and the Yakima Indian Nation (YIN).

Basin Description

The Little Klickitat River basin is located in north-central Klickitat County in Washington State. The basin is approximately 280 square miles in area and drains the southern flanks of the Simco Mountains. The confluence of the West Prong and East Prong Little Klickitat River marks the start of the Little Klickitat River at river mile (RM) 25.7. The river flows southwesterly across the Munson Prairie and encounters the eastern edge of the town of Goldendale at RM 16.3. The river continues westerly entering the canyon area at RM 8.3. Principle tributaries above the canyon area are Jenkins Creek at RM 20.2, Bloodgood Creek at RM 14.9, and Spring Creek at RM 8.6.

The river continues westerly through the canyon area for approximately 4.5 miles and bends northwesterly, flowing to its confluence with the Klickitat River (RM 19.8) north of Wahkiacus. Principle tributaries to the Little Klickitat River downstream of Spring Creek are Blockhouse Creek at RM 6.3, Mill Creek at RM 3.6, and Bowman Creek at RM 1.2.

Within the canyon reach, the steep canyon walls are often next to the river and the river channel bottom is mostly exposed bedrock. A series to two- to three-foot bedrock-shelf drops in the canyon reach may block upstream migration of fish at flows of less than 20 cfs. A 15-foot waterfall just downstream from Blockhouse Creek at RM 6.1 is probably an anadromous fish barrier. In the lower 4.2 miles of the river, the canyon walls are set back from the river.

The Little Klickitat River can be divided into three reaches on the basis of river gradient. The lower reach, RM 0.0 to RM 4.5, has an average gradient of 1.3 percent. The middle reach of the Little Klickitat River is the canyon area, RM 4.5 to RM 8.7, and has an average gradient of 2.0 percent. The upper reach, RM 8.7 to RM 25.7, has an average gradient of 0.9 percent.

Each of the tributaries assessed in this study originates in the foothills of the Simco Mountains, flows southwesterly across a prairie, and drops into an incised canyon to join the Little Klickitat River.

Blockhouse Creek joins the Little Klickitat River at RM 6.3 on the right bank. Blockhouse has a total stream length of 11.0 miles and a drainage basin of 10.0 square miles. Blockhouse Creek canyon extends upstream from the mouth a distance of 1.8 miles. The average gradient of the canyon reach is 5.0 percent, but there is a 56-foot waterfall at RM 0.2. The average gradient of the reach upstream from the canyon is approximately 1.3 percent.

Bloodgood Creek joins the Little Klickitat River at RM 14.9 on the right bank. There are 6.5 miles of mainstem and a drainage area of approximately 5.8 square miles. The average gradient of the creek is approximately 2.2 percent.

Bowman Creek's confluence with the Little Klickitat River is on the right bank at RM 1.2. Bowman Creek has a drainage area of 23.0 square miles and 17.3 miles of mainstem with the canyon running from the mouth to RM 2.6. The average gradient of the canyon reach is 5.0 percent. Upstream of the canyon reach the average stream gradient is 3.4 percent.

Mill Creek joins the Little Klickitat River on the right bank at RM 3.8. The creek has approximately 16 miles of mainstem and nearly 30 square miles of drainage area. The Mill Creek canyon extends from the mouth to RM 2.6. The average gradient of the canyon reach is 5.2 percent. Upstream of the canyon reach, Mill Creek has an average stream gradient of 4.1 percent.

Spring Creek joins the Little Klickitat River at RM 9.0 on the right bank. Spring Creek is 8.3 miles long and has approximately 18 square miles of drainage area fed primarily by a spring. Spring Creek does not have a canyon reach per se, but there are several 3- to 4-foot cascades between RM 0.1 and RM 0.2. The average gradient of Spring Creek is 1.1 percent over its length.

Hydrology

The Little Klickitat River is fed by snow melt, surface runoff, and ground water. The Little Klickitat River 50 percent exceedence flow near Wahkiacus (USGS gage 14112500 at RM 0.4) ranges from 70 to 120 cfs from December through May and is about 14 cfs during August, the normal low flow month (Figure 1). The 50 percent exceedence flow for the Little Klickitat River near Goldendale at Ecology's upper IFIM site ranges from 20 to 100 cfs from December through May and is about 4 cfs during August, the normal low flow month (Figure 1).

The 50 percent exceedence flow for Blockhouse Creek at RM 2.5 ranges from 6 to 8 cfs from December through May and is less than 1 cfs during August, the normal low flow monthly (Figure 2).

Flows for Bloodgood Creek at RM 0.5 are estimated to range from 5 to 11 cfs year round (Figure 2).

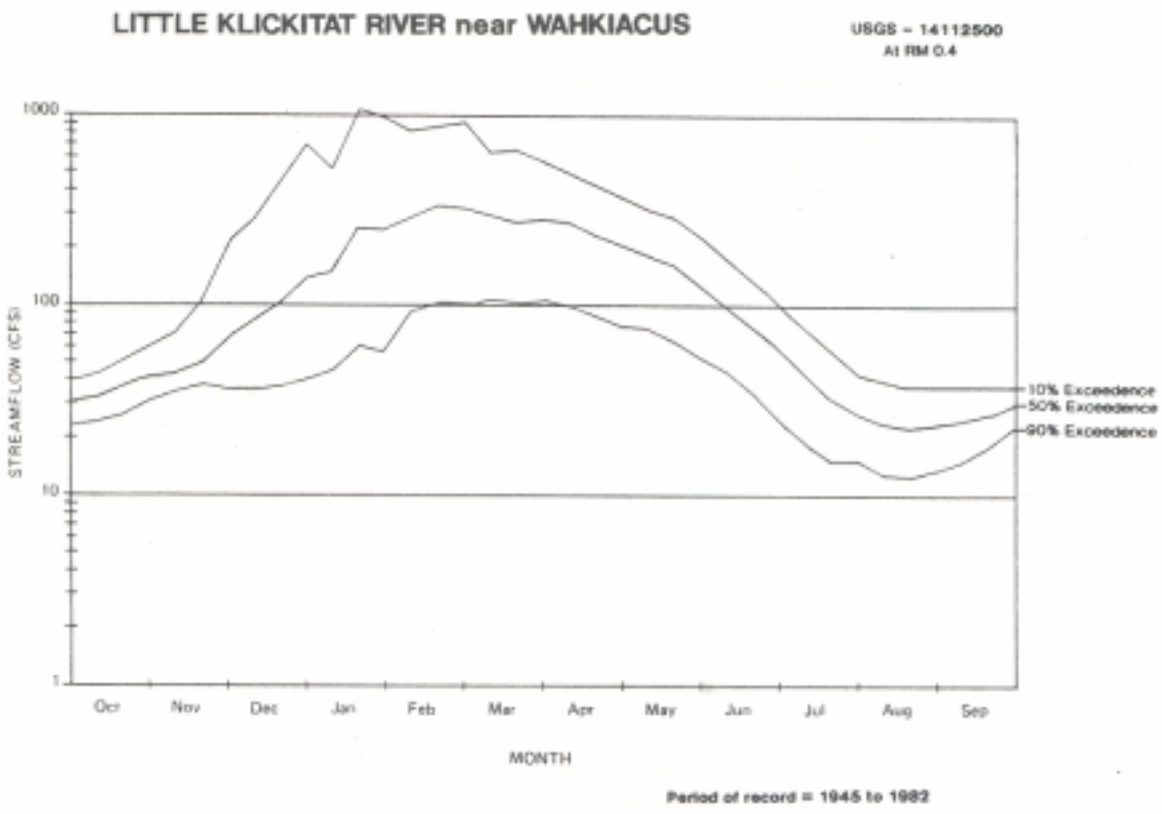
The 50 percent exceedence flow for Bowman Creek at RM 3.5 ranges from 11 to 15 cfs from December through May and is approximately 2 cfs during August, the normal low flow month (Figure 3).

The 50 percent exceedence flow for Mill Creek near Blockhouse (USGS gage 14112400 at RM 3.0) ranges from 8 to 30 cfs from December through May and is 2 to 3 cfs during August, the normal low flow month (Figure 3).

The 50 percent exceedence flow for Spring Creek near Blockhouse at RM 0.7 ranges from 9 to 13 cfs (Figure 4).

A description of how the hydrographs for each IFIM site were made is in Appendix K.

Appendix L contains a table of the water temperatures measured during site visits.



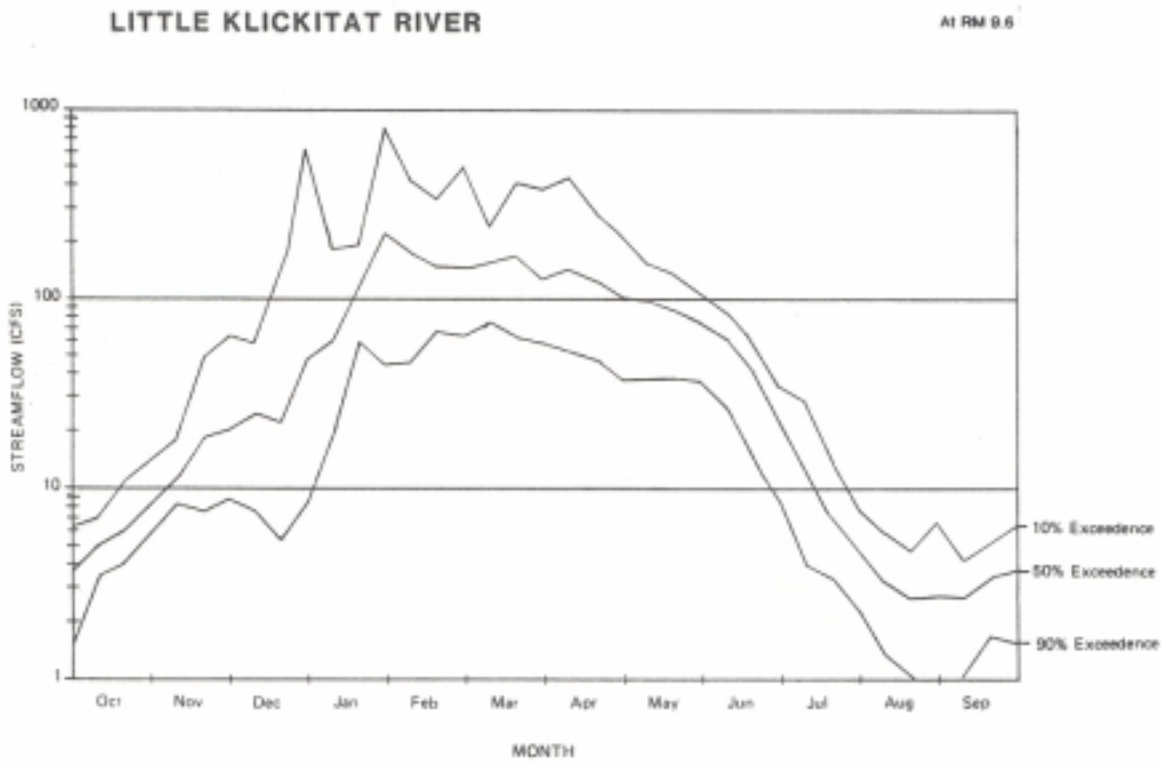


Figure 1. Exceedence-frequency hydrographs of the Little Klickitat River

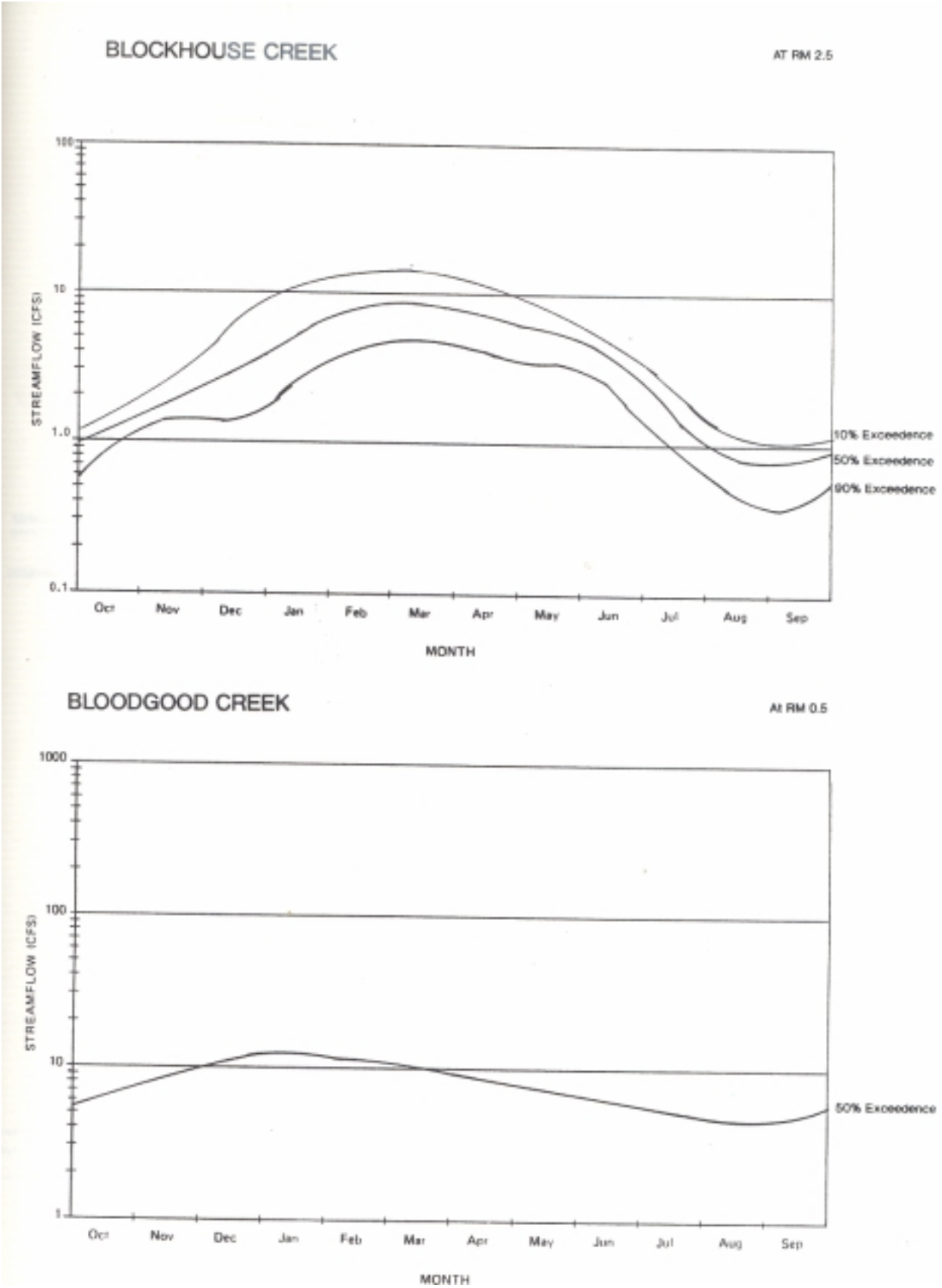
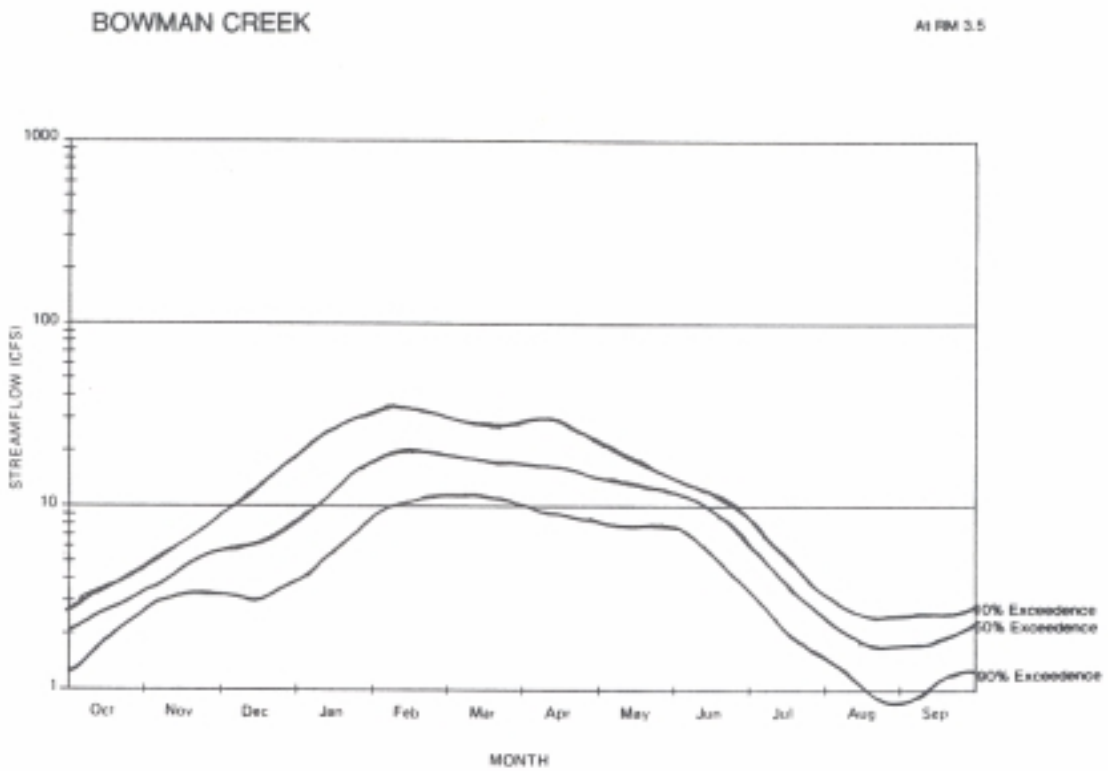


Figure 2. Exceedence-frequency hydrographs of Blockhouse & Bloodgood Creeks.



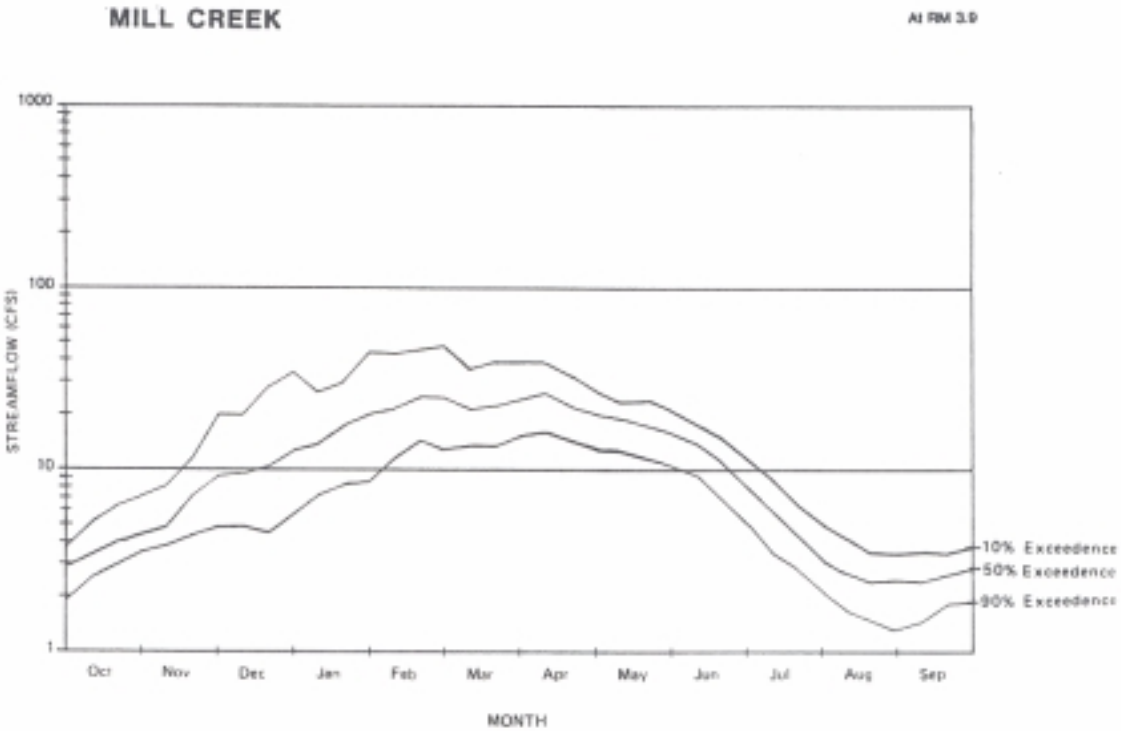


Figure 3. Exceedence-frequency hydrographs of Bowman and Mill Creeks.

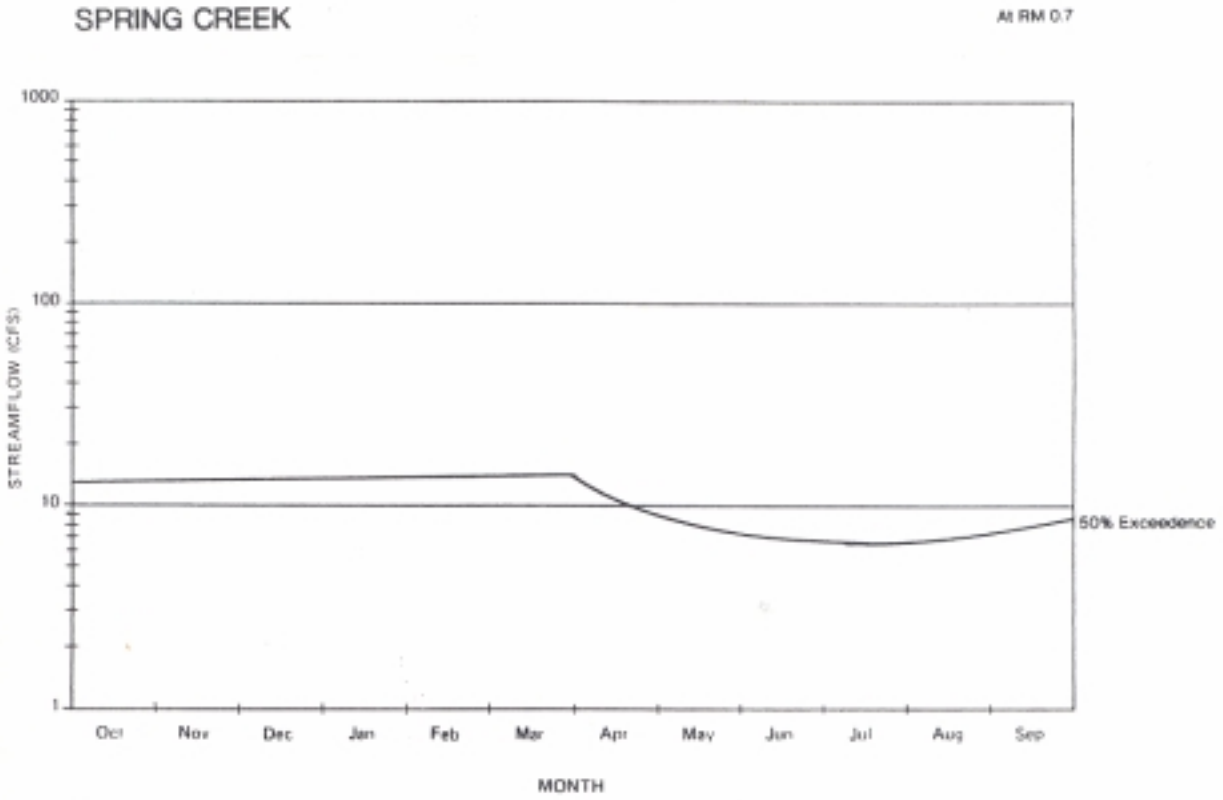


Figure 4. Exceedence-frequency hydrograph of Spring Creek.

Figure 4. Exceedence-frequency hydrograph of Spring Creek.

Present and Future Fish Habitat Use

The Department of Wildlife has found rainbow trout throughout the Little Klickitat River and its tributaries in spot checks in recent years. Bill Sharp with the Yakima Indian Nation electroshocked the Little Klickitat River, Bowman Creek, and Mill Creek in July and August of 1989. He found juvenile steelhead and/or rainbow trout, chinook, and coho salmon in the sites listed above along with non-game fishes. This is the first verification that salmon are spawning in the Klickitat River at RM 6.1 are probably a block to anadromous fish (though rumor has it that a couple of steelhead have passed the falls).

Bowman Creek probably has a block to anadromous fish upstream of the Highway 142 crossing. Mill Creek has no anadromous block according to the Bureau of Reclamation. Blockhouse Creek has a 56-foot waterfall about 0.1 mile upstream from its mouth. Bloodgood and Spring Creeks have no anadromous fish blocks, although they are upstream of the waterfall on the Little Klickitat River. Approximately half of the water in the Little Klickitat River comes from Spring Creek and Bloodgood Creek during the summer and fall. These tributaries contain excellent spawning gravel and have very high potential for steelhead, coho, and, possibly, late run chinook salmon production if the falls are laddered.

II. METHODS OF STUDY

IFIM was selected for this study as the best available methodology for predicting how fish habitat responds to incremental changes in streamflow.

Description of the Instream Flow Incremental Methodology

IFIM, as described by Bovee (1982), was developed by the U.S. Fish and Wildlife Service's Instream Flow Group in the late 1970's. Their main achievement was advancing the state-of-the-art in calculating fish-habitat-versus-flow relationships for multiple flows. Previous methods often used only a single transect to describe depths and velocities along a cross section of a river and lacked the ability to extrapolate the results to higher or lower flows of interest.

PHABSIM (Physical Habitat Simulation) is a collection of computer models used in IFIM (Milhous et al, 1984). The most commonly used hydraulic model in PHABSIM is IFG4. IFG4 uses multiple transects to predict the depths and velocities in a river over a range of flows (Figure 5).

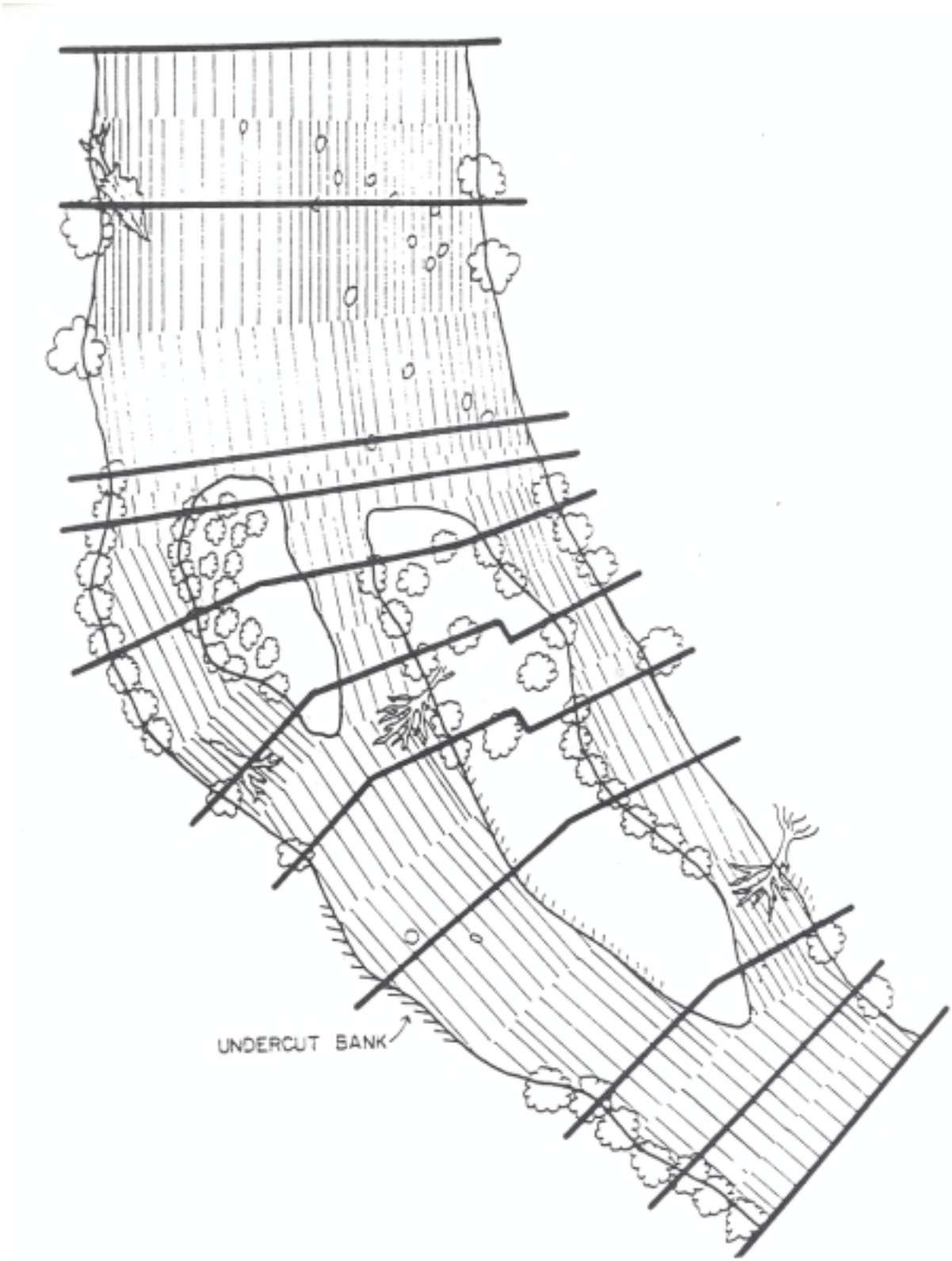


Figure 5. Top view looking down on placement of transects and measurement verticals used to define the distribution of aquatic habitat in an IFIM site (from Bovee, 1982).

IFG4 creates a cell for each measured point along the transect or cross-section. Each cell has an average water depth and water velocity associated with a type of substrate or cover for a particular flow. The cell's area is measured in square feet. Fish habitat is defined in the computer model by the variables of velocity, depth, substrate, and/or cover. These are important habitat variables that can be measured, quantified, and predicted.

The IFIM is used nationwide and is accepted by most resource managers as the best available tool for determining fish habitat versus flow relationships. However, the methodology only uses four variables in hydraulic simulation, and at certain flows, such as extreme low flows, other variables such as fish passage, food supply (aquatic insects), competition between fish species, and predation (birds, larger fish, etc.) may be of overriding importance. The IFIM approach encompasses more than just the PHABSIM model, it includes reviewing water quality, sediment, channel stability, temperature, hydrology, and other variables that affect a river's fish production. These additional variables are not analyzed in this report.

After the hydraulic model (IFG4) is calibrated and run, a computer model called HABTAT combines IFG4 output with a biological model. The biological model is composed of fish preference curves describing the preference each fish species has for each of the four variables (depth, velocity, substrate, and cover). The fish species are defined further by particular life stages: adult spawning, juvenile rearing, and adult holding.

Weighted Usable Area (WUA) is an index of fish habitat. The preference factor for each variable at a cell is multiplied by the other variables to arrive at a composite, weighted preference factor for that cell. For example, a velocity preference of 1.0 multiplied by a depth preference of 0.9 multiplied by a substrate preference of 0.8 equals a composite-preference factor of 0.72 for that cell. This composite-preference factor is multiplied by the number of square feet of area in that cell. This gives the number of square feet of habitat in that cell. A summation of all the transects' cell areas gives the total number of square feet of preferred habitat at a specified flow. This total square feet of habitat is normalized to 1,000 feet of stream. The final model result is a listing of fish habitat values called WUA in units of square feet per 1,000 feet of stream. WUA is listed with its corresponding flow or discharge in cfs.

Interagency Participation in Scope-of-Work

A meeting was held March 12, 1987, to discuss the use of IFIM in the Little Klickitat River basin. Attending the meeting were representatives of WDF, WDW, and Ecology. For the small streams in the basin it was agreed that a one-flow-high-flow IFG4 hydraulic model using four transects would be appropriate. For the main stem Little Klickitat River the group agreed that a three-flow IFG4 hydraulic model would be appropriate with two study reaches. Because of distinct differences in channel morphology and stream flow upstream and downstream of the Little Klickitat River canyon, study sites were located upstream and downstream of the canyon.

Study Site and Transect Selection

Preliminary study sites were selected for the IFIM study by reviewing topographic maps. Actual site selection was done during field visits.

After tentative study sites and transects were selected, all interested state and federal agencies and the YIN were invited for a ground tour to ensure agreement on site and transect selection.

Figures 6 through 9 show the study site locations. Each small creek had one study site while the Little Klickitat River had two study sites. Each study site modeled a representative reach of the creek or river.

Field Procedures

IFIM measurements began in April 1987 for the seven sites:

1. Little Klickitat River, Lower site
2. Little Klickitat River, Upper site
3. Blockhouse Creek
4. Bloodgood Creek
5. Bowman Creek
6. Mill Creek
7. Spring Creek

Measurements of water depth, water velocity, substrate composition, and cover were made at various intervals along each transect. A temporary gage at each site was used to verify that streamflow at each transect remained steady during measurement. Transects were marked using fence posts and or survey hubs and flagging. Water velocity was measured using standard USGS methods with a calibrated Swoffer velocity meter mounted on a top-set wading rod.

Water-surface elevations and stream-bank profiles were surveyed with a survey level and stadia rod. These points were referenced to an arbitrary, fixed benchmark. Substrate composition and cover were assessed by visually estimating the percent of the two main particle size classes and type of cover according to a scale recommended by WDF and WDW (Appendix I). Any reference to a right or left bank in this report is determined by looking downstream.

The four small creeks had one complete set of velocity data collected during the initial field visit. Subsequent data collection was limited to one transect measurement for discharge calculation and collection of water surface elevations for all transects.

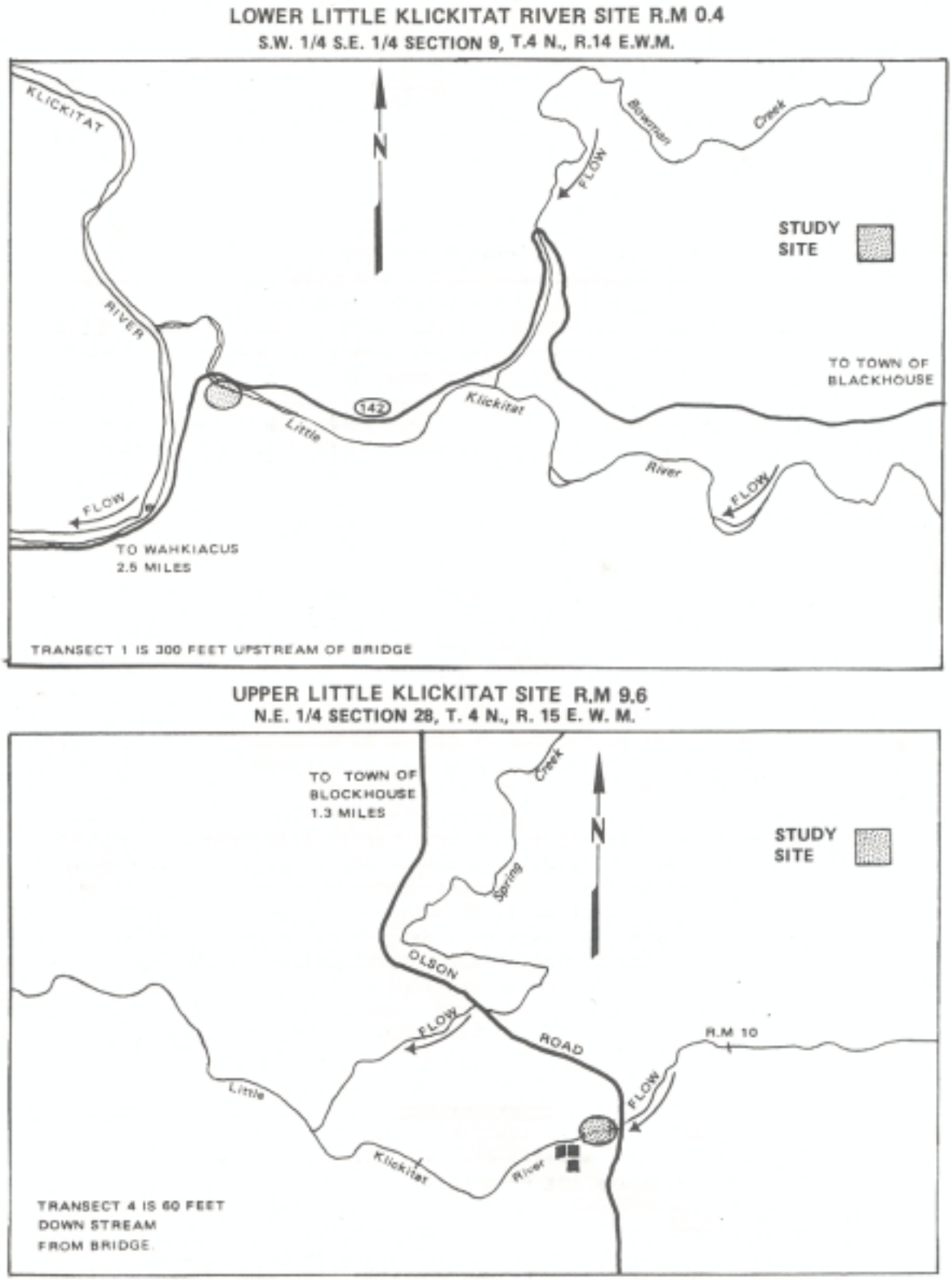


Figure 6. Site maps for Lower and Upper Little Klickitat IFIM sites.

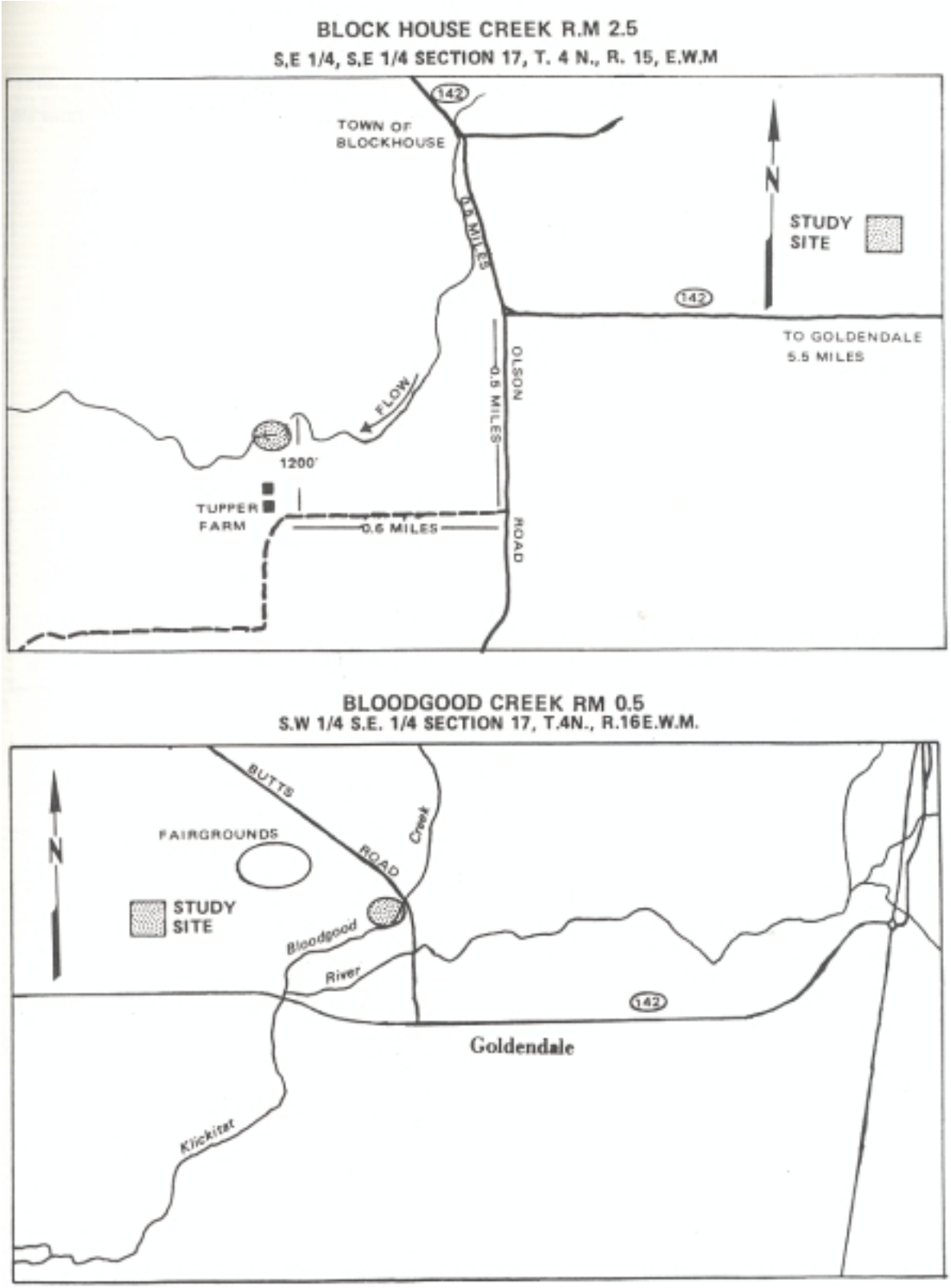
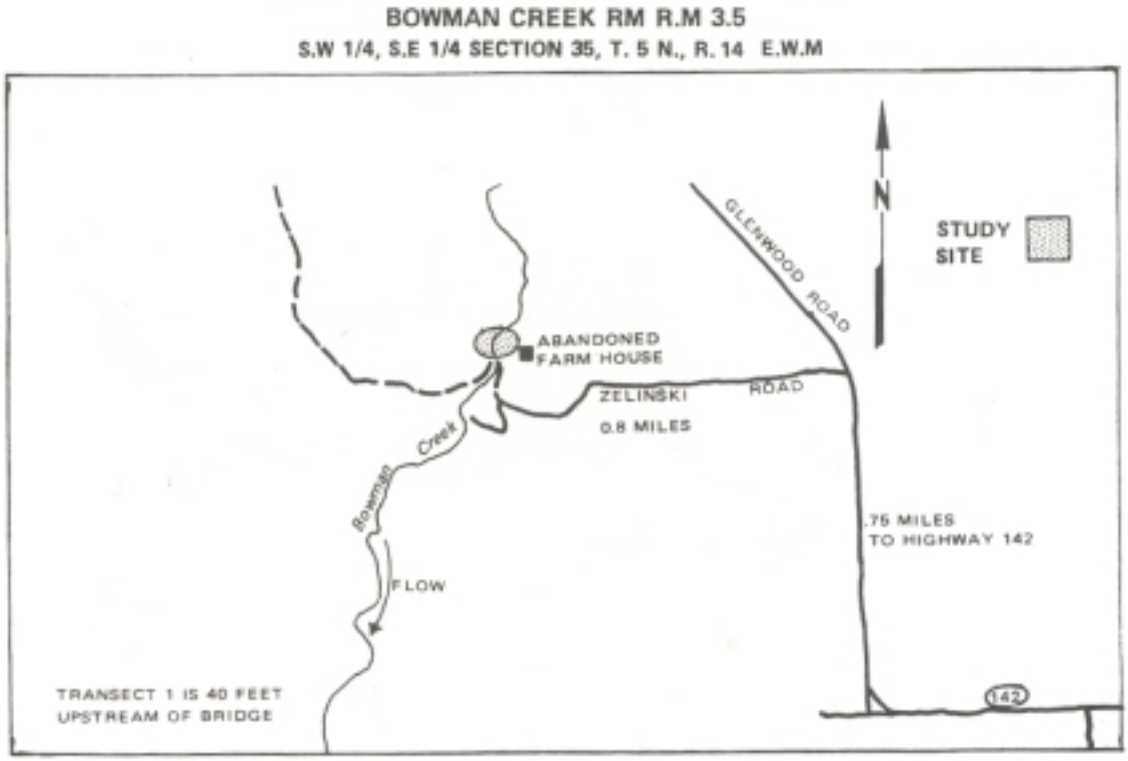


Figure 7. Site maps for Blockhouse & Bloodgood Creek IFIM sites.



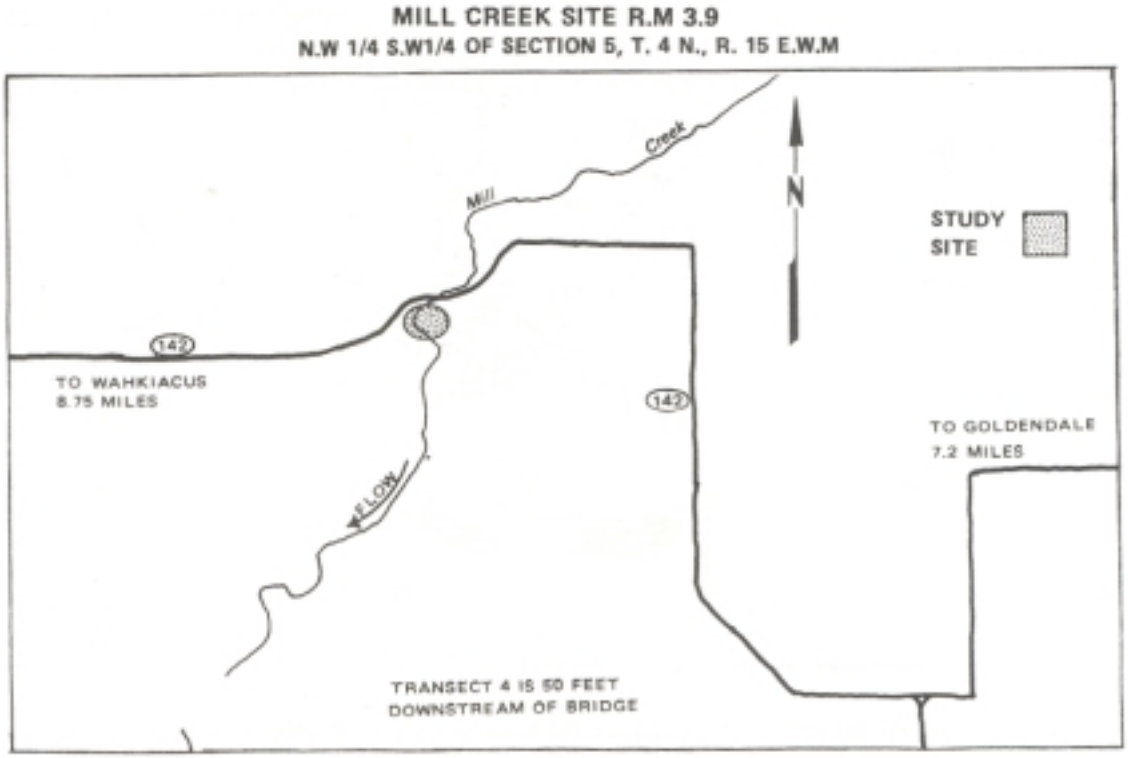


Figure 8. Site maps for Bowman & Mill Creek IFIM sites.

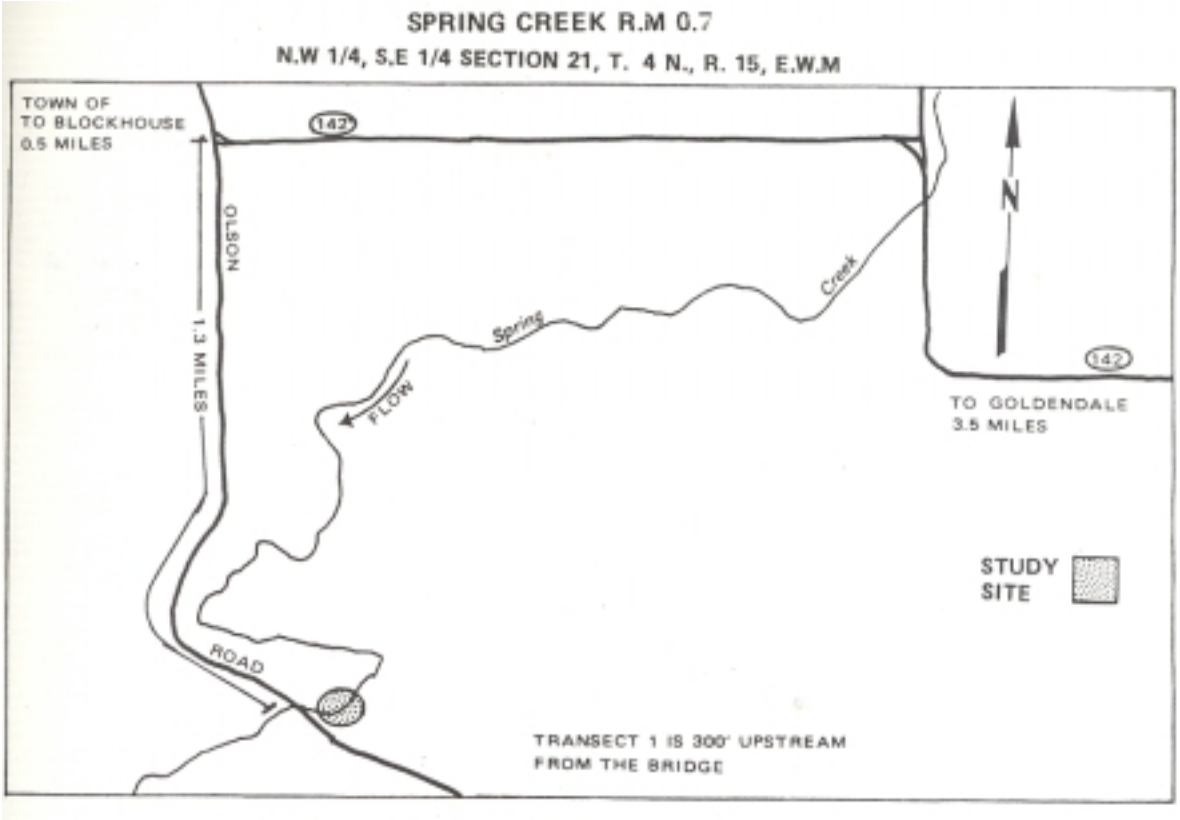


Figure 9. Site map for Spring Creek IFIM site.

Site Descriptions and Conditions during Measurement

Little Klickitat River Lower Site

The Little Klickitat River, Lower Site represents the river from RM 0.0 through RM 4.5. The study site is located at RM 0.4. The river gradient in this reach is approximately 1.3 percent. The river is about 70 feet wide, and, generally, has a cobble bottom with some boulders. The dominant habitat in this lower reach is pool/glide habitat. Six transects represent the Lower Site: transect 1 is a riffle, transects 2 is a shallow glide, transect 3 is a glide, transect 3.5 is a pool, transect 4 is a shallow riffle, and transect 5 is a deeper pool.

Field measurements were collected at flows of 145 cfs on 4-06-87, 81 cfs on 5-14-87, 32 cfs on 6-17-87, and 16 cfs on 7-15-87. The four flows were well spaced for calibrating the hydraulic model. The flows were steady during measurement. No observable bed shifts occurred between flow measurements on the six transects.

Little Klickitat River, Upper Site

The Upper Site represents the river from RM 8.7 through RM 14.9 and is located at RM 9.6. The average gradient in this reach is about 0.8 percent. The Upper Site is about 25- to 30-feet wide, with gravel and cobble substrate. There are sporadic, bedrock outcrops in the river channel in this reach. Four transects represent the river in the upper area. Transect 1 is a riffle, transects 2 is a glide, transect 3 is a riffle and transect 4 is a pool.

Field measurements were collected at flows of 87 cfs on 4-7-87, 40 cfs on 5-14-87, 12 cfs on 6-16-87 and 4 cfs on 7-14-87. The flows were steady during measurement and were well spaced for calibrating the model. No observable bed shifts occurred between the flow measurements at this site.

Blockhouse Creek

The Blockhouse Creek site represents the creek from RM 1.75 on upstream. The site is located at RM 2.5, above the Blockhouse Creek canyon. Blockhouse Creek is characterized by large cobble substrate, in a channel generally 10- to 12-feet wide. Four transects represent this reach: transects 1 through 3 are riffles, and transect 4 is a pool.

Field measurements were collected at flows of 9 cfs on 4-6-87, 0.4 cfs on 5-13-87, and 0.5 cfs on 6-16-87. The flows were steady during measurement. The flow range was limited due to extensive irrigation withdrawals upstream.

Bloodgood Creek

The Bloodgood Creek site is at RM 0.5 and represents the lower 2.2 miles of the creek. Bloodgood Creek is generally 10- to 12-feet wide with sand and gravel substrate. The stream has stable banks and heavy riparian vegetation. Four transects represent the stream: transect 1 is a glide, transect 2 is a riffle, transect 3 is a deep glide, and transect 4 is a glide.

Field measurements were collected at flows of 8.8 cfs of 4-2-87 and 7.2 cfs on 5-13-87. The flows were steady during measurement. The range of stream flows measured was limited because the flow was fairly constant over the spring, summer, and fall.

Bowman Creek

The Bowman Creek site is located at RM 3.5 and represents the creek upstream of the canyon area. Bowman Creek is generally 8-feet wide with lots of boulder substrate. The stream banks are gently sloped and have thick riparian vegetation. Four transects represent the creek. Transect 1 is glide, transect 2 is a cascade, transect 3 is a shallow glide, and transect 4 is a narrow chute.

Field measurements were collected at flows of 27 cfs on 4-3-87, 14 cfs on 5-13-87, 5 cfs on 6-16-87, and 0.7 cfs on 7-14-87. The four flows measured covered an adequate range of flows. The flows were steady during measurement, and no observable bed shifts occurred between the flow measurements.

Mill Creek

The Mill Creek site is at RM 3.9 just downstream of the Highway 142 bridge, where the highway crosses Mill Creek. The site represents Mill Creek upstream of the Mill Creek canyon. Mill creek is generally a narrow creek with steep banks and sand/cobble bottom. Four transects represent the creek: transect 1 is a glide, transects 2 and 3 are pools, and transect 4 is a shallow riffle.

Field measurements were collected at flows of 22 cfs on 4-2-87, 12 cfs on 5-13-87, 7 cfs on 6-16-87, and 3 cfs on 7-14-87. The flows were steady during measurement. No observable bed shifts occurred between the flow measurements. The four flows measured covered an adequate range of flows.

Spring Creek

The Spring Creek site is at RM 0.7 and represents Spring Creek upstream of RM 0.2. Spring creek has a gravel and mud substrate with thick riparian vegetation. Four transects represent the creek: transect 1 is a shallow riffle, transect 2 is a shallow glide and transects 3 and 4 are glides.

Field measurements were collected at flows of 13 cfs on 4-6-87, 9 cfs on 5-13-87, and 7 cfs on 6-16-87. The flows were steady during measurement. No observable bed shifts occurred between or during the flow measurements. The flow range available for measuring was limited because the streamflow was fairly constant over the spring, summer, and fall.

III. HYDRAULIC MODEL

Calibration Philosophy

Calibration of the hydraulic model involved checking the velocities and depths predicted by the model against velocities and depths measured in the field. This included examining indicators of the model's accuracy such as mean error and Velocity Adjustment Factor (VAF).

The calibration philosophy was to change data or to manipulate data using a computer calibration option only when doing so would improve the model's ability to extrapolate without reducing the accuracy of predicted depths and velocities at the measured calibration flows. Calibration of the IFG4 model was done cell by cell for each transect to decide whether the predicted cell velocities adequately represented measured velocities. Generally, if the predicted cell velocity at the calibration flow was within 0.2 feet per second (fps) of the measured cell velocity, the predicted velocity was considered adequate. Any change to a calibration velocity was limited to a change of 0.2 fps. The 0.2 fps was thought to be reasonable considering the normal range of velocity measurement error. All cell velocities were reviewed at the highest and lowest extrapolated flows to ensure that extreme cell velocities were not predicted.

Indicators of Model Accuracy

Two indicators of the IFG4 model's accuracy in predicting depths and velocities are the mean error and the Velocity Adjustment Factor (VAF).

The mean error is the ratio of the calculated discharge (from depths and velocities at the measured flows) to the predicted discharge (from depth and velocity regressions). As a rule of thumb, the mean error for the calculated discharge should be less than 10 percent.

The Velocity Adjustment Factor (VAF) for a three-flow IFG4 hydraulic model indicates whether the flow predicted from the velocity/discharge regressions matches the flow predicted from the stage/discharge regressions. The velocities predicted from the velocity/discharge regressions for a transect are all multiplied by the same VAF to achieve the flow predicted from the stage/ discharge regression. Calculating and comparing the flows predicted from two different regressions gives an indication as to whether or not some of the model's assumptions are being met.

A range in the VAF value of 0.9 to 1.1 is considered good, 0.85 to 0.9 and 1.1 to 1.15 fair, 0.8 to 0.85 and 1.15 to 1.20 marginal, and less than 0.8 and more than 1.2 poor (Milhous, et al., 1984). The standard extrapolation range is 0.4 times the low calibration flow and 2.5 times the high calibration flow. The extrapolation range of the model is usually limited when two or more transects have VAFs which fall below 0.8 or above 1.2.

The VAFs for the one-flow IFG4 model do not have the same meaning as the three-flow IFG4 model. In a one-flow model the cell velocities are predicted from Manning's equation. All velocities on a transect are multiplied by the same VAF to achieve the flow predicted from the stage/discharge regression. The VAF range listed above does not apply to one-flow model VAFs. Instead of predicting velocities from a velocity/discharge regression (three-flow IFG4), the velocities are predicted from Manning's equation using a constant roughness factor (N).

The bottom roughness factor is highest at low flow and becomes progressively lower as flow increases. Because the N value calculated by the computer is constant, the N value used to predict higher flow velocities is usually too high. The VAF corrects this problem by changing the velocities predicted to arrive at the flow on the stage/discharge regression. The VAF will be nearly one at the measured flow, usually less than one at lower flows, and more than one at higher flows.

Normal empirical values for bottom roughness do not apply to these Manning's Ns. These Ns are used only for calibrating velocities in the IFG4 hydraulic model.

Options in IFG4 Model

Several options are available in the IFG4 hydraulic model (see Milhous et al, 1984). Ecology' standard method is to set all the options to zero except for option eight which is set at two. The standard options were used for all models.

Site Specific Calibration

Little Klickitat River, Lower Site

A four-flow IFG4 model was run for this site. The IFG4 input file, a summary of the calibration details, data changes, and the VAFs are included as Appendix B. The mean errors of the stage/ discharge regressions range from 0.18 to 7.05 percent, all less than the 10 percent rule of thumb. At 7 cfs this model has one VAF of 0.83, and at 363 cfs the worst VAF is 0.85, actually quite good. Overall, this IFG4 model is good and could be extrapolated beyond the standard extrapolation range of 7 to 363 cfs.

Little Klickitat River, Upper Site

A four-flow IFG4 model was run for this site. The IFG4 input file, a summary of the calibration details, data changes, and VAFs are in Appendix C. The mean errors of the stage/discharge relationships range from 5.13 to 10.60 percent. The worst VAFs are 0.69 at 2 cfs and 0.93 at 210 cfs. The model is adequate for the standard extrapolation range of 2 to 210 cfs and could be extended higher if necessary.

Blockhouse Creek

A one-flow IFG4 model was run for this site. The IFG4 input file, a summary of calibration details, and VAFs are in Appendix D. The mean errors of the stage/discharge relationships range from 2.62 to 6.13 percent and are all less than the 10 percent guideline. The VAFs range from 0.17 at 0.3 cfs to 1.58 at 22 cfs. The model is adequate for extrapolation from 0.3 to 23 cfs.

Bloodgood Creek

A one-flow IFG4 model was run for this site. The IFG4 input file, a summary of calibration details, and VAFs are in Appendix E. There are no mean errors for the stage/discharge relationship because only two flows were measured. The VAFs range from 0.3 at 3 cfs to 1.7 at 22 cfs. The VAFs for transect four are unusual because no velocities were used to calibrate transect four because of measurement error during collection of the data. The model is adequate for an extrapolation range from 3.0 to 22 cfs.

Bowman Creek

A one-flow IFG4 model was run for this site. The IFG4 input file, a summary of calibration details, and VAFs are in Appendix F. The mean errors of the stage/discharge relationships range from 5.44 to 15.77 percent. The VAFs range from 0.17 at 0.7 cfs to 1.7 at 66 cfs. The model is adequate for an extrapolation range of 0.7 to 66 cfs.

Mill Creek

A one-flow IFG4 model was run for this site. The IFG4 input file, a summary of calibration details, and VAFs are in Appendix G. The mean errors of the stage/discharge relationships range from 6.01 to 16.17 percent. The VAFs range from 12.1 at 1.0 cfs to 1.46 at 57 cfs. The model is adequate for an extrapolation range of 2.0 cfs to 57 cfs.

Spring Creek

A one-flow IFG4 model was run for this site. The IFG4 input file, a summary of calibration details, and VAFs are in Appendix H. The mean errors of the stage/discharge relationships range from 0.05 to 2.0. The VAFs range from 30.1 at 2 cfs to 0.3 at 32 cfs. The model is adequate for an extrapolation range of 2 cfs to 32 cfs.

Transect Weighing

Appendix I lists the percent weighing each transect received relative to the whole site. Transect weighing is determined one of two ways, either the model automatically determines weighing for each transect by using the distance between the transects or transect weight is set to predetermined levels by specifying distances between transects (this is composite weighing). Composite weighing is done when the transects are located far apart and the distances between the transects would create incorrect weighing, or the researcher wants to increase the weight of a particular type of fish habitat for that site. Transect weighing for the Little Klickitat River, Lower Site transect was determined using distances between transects, while the rest of the study sites had composite weighing.

Agency and Tribal Approval of the Hydraulic Model

A meeting was held November 3, 1988, by Ecology to discuss and achieve a consensus on the adequacy of the Little Klickitat River basin hydraulic models. Those in attendance were Ken Bruya (WDF), and Steve Hirschey and Brad Caldwell (Ecology). Also invited to the meeting were Hal Beecher (WDW), Estyn Head (USFWS), Bob Tuck and Larry Wasserman (YIN), and Einar Wold (NMFS). Consensus was achieved that the hydraulic models were calibrated adequately. Agreement was reached that there was no problem using a normal extrapolation range of 0.4 times the low calibration flow and 2.5 times the high calibration flow. Attendees also agreed that natural transect weighing would be used for the Little Klickitat River, Lower Site and composite weighing for the rest of the sites.

IV. HABTAT MODEL

Options Used In HABTAT MODEL

The HABTAT Program combines the depths and velocities predicted from the IFG4 hydraulic model with the depths, velocities, cover, and substrate preferences from the habitat-use curves. The HABTAT program calculates WUA for each flow modeled. The IOC options used in HABTAT were 10000001010000.

Selection of Habitat-use Curves Used in HABTAT

Habitat-use curves for salmon used were WDF's and Ecology's standard set of river and stream curves. Habitat-use curves used for trout were WDW's standard curves.

For the Little Klickitat River, Lower Site habitat-use curves were run for steelhead and rainbow trout. Salmon curves were run for chinook and coho salmon. Habitat-use curves run for the Little Klickitat River, Upper Site were steelhead, rainbow trout, and coho salmon. Curves run for Spring, Mill, and Bowman Creeks were steelhead, rainbow trout, and coho salmon. Rainbow trout curves were run for Blockhouse and Bloodgood Creeks. The depth and velocity habitat-use curves and the substrate/cover codes used are in Appendices J1 and J2, respectively.

Agency and Tribal Approval of Habitat-Use Curves

A meeting was held November 3, 1988, by Ecology to discuss and achieve a consensus on the adequacy of the habitat-use curves for use in this study. In attendance were Ken Bruya (WDF), and Steve Hirschey and Brad Caldwell (Ecology). Also invited to the meeting were Hal Beecher (WDW), Estyn Mead (USFWS), Bob Tuck and Larry Wasserman (YIN), and Einar Wold (NMFS). Agreement was reached to use the standard river curves for the Little Klickitat River, Lower Site and stream curves for the rest of the sites. Agreement was also reached to use the standard trout curves.

V. RESULTS AND DISCUSSION

The habitat versus flow results are presented in Appendix A. The figures are grouped by site; the Little Klickitat River, Lower Site first followed by the Little Klickitat River, Upper Site. The small creeks are in alphabetical order. The figures are ordered by area, and then by fish species.

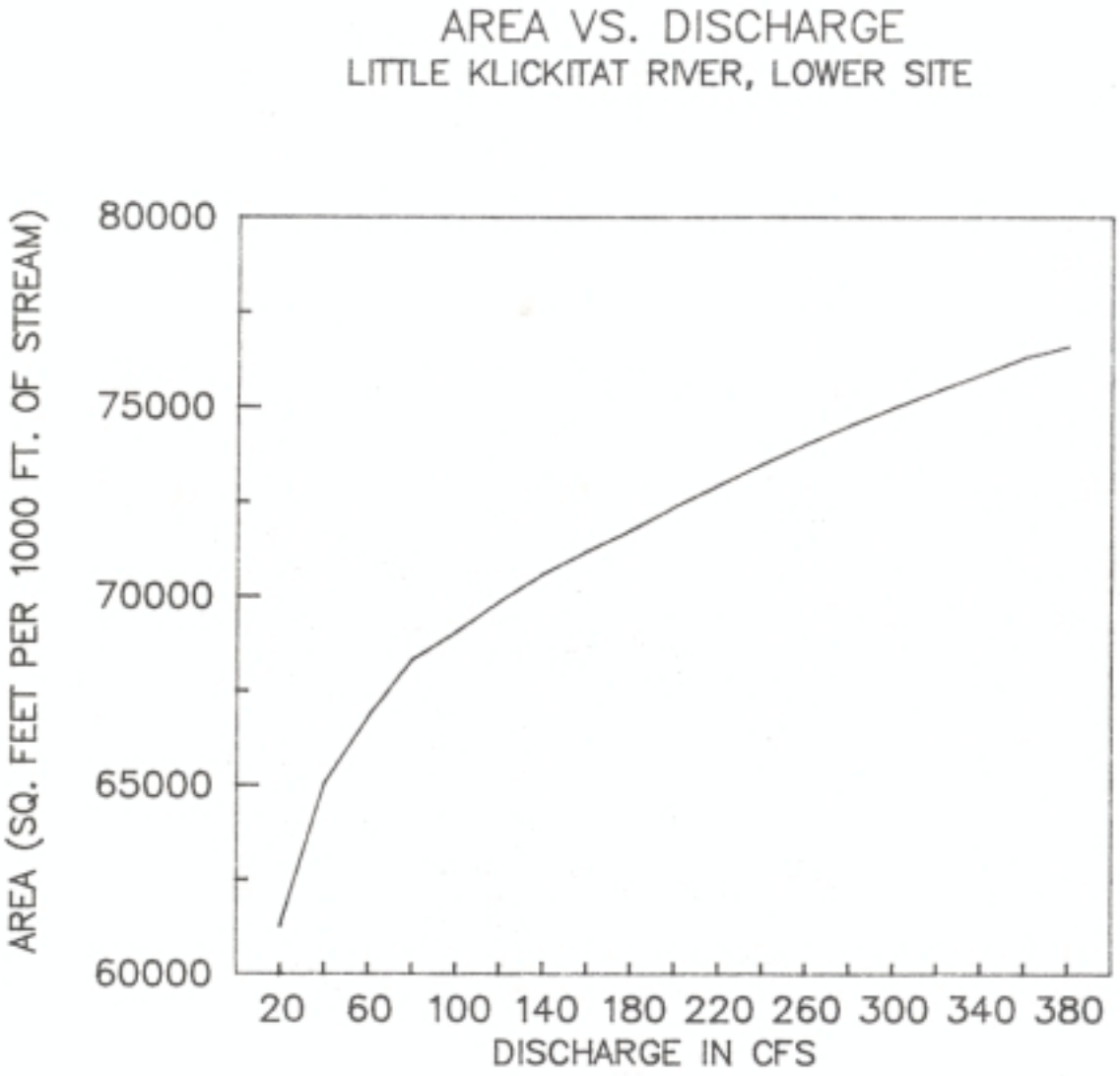
Recommendation for Use of WUA Results to Set Minimum Instream Flows

Determining a minimum instream flow for a river or stream in the Little Klickitat River basin requires more thought than choosing the peak WUA flow from the IFIM study. Setting a minimum instream flow for a river or stream in the basin requires ranking the importance of each fish species and life stage. This ranking requires a consensus on long-range management plans for the fishery resources from the state and federal natural resource agencies and the Yakima Indian Nation.

In addition, minimum instream flows must include flows necessary for incubation of fish eggs, smolt out-migration, fish passage to spawning grounds, and prevention of stranding of fry and juveniles. Other variables which have to be considered include water temperature, water quality, and sediment load.

Appendix A

WUA VS FLOW GRAPHS

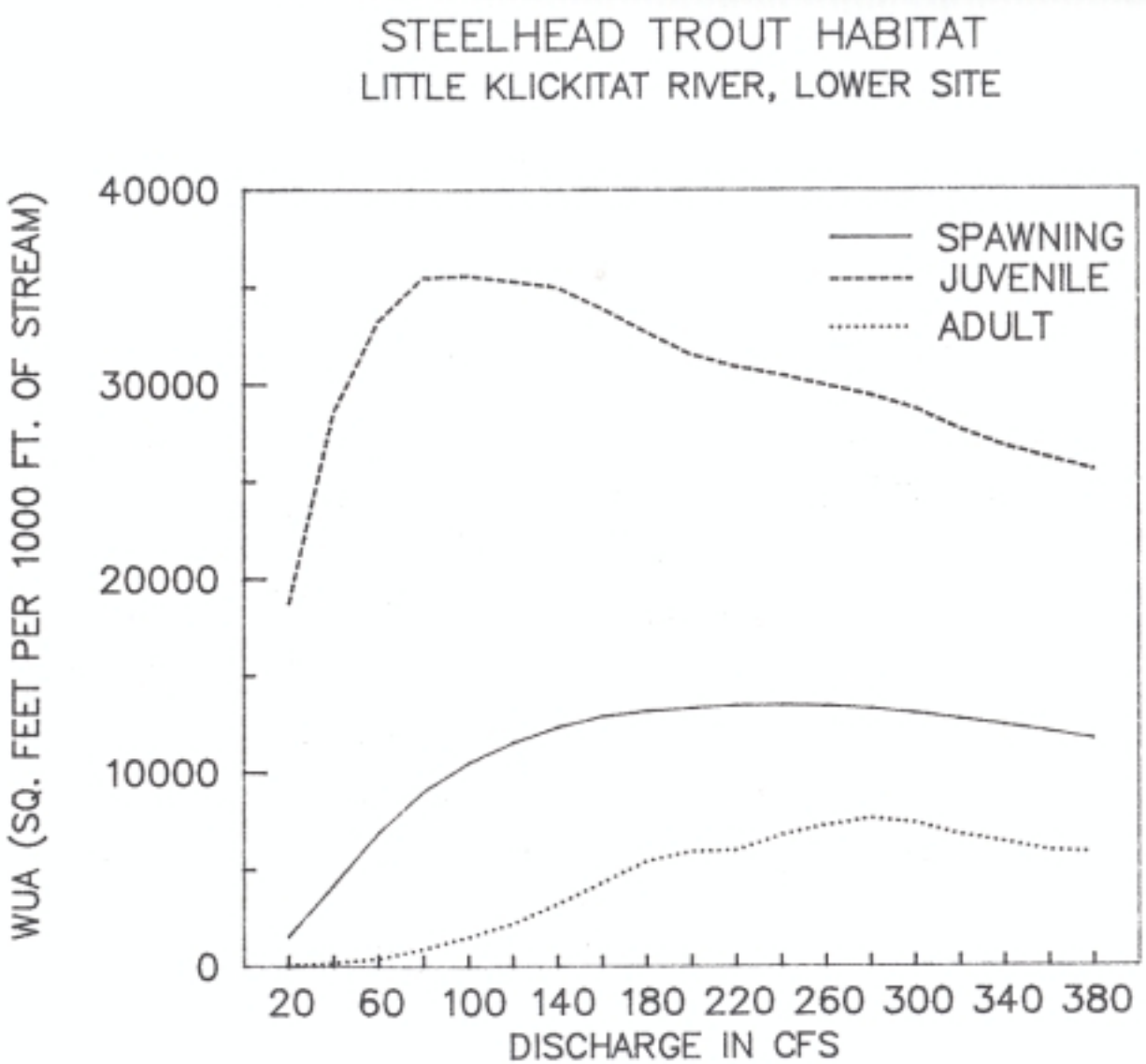


W.R.I.A. 30 RM. 0.4

DATE AND FLOW MEASURED

04-16-87	145 cfs
05-14-87	81 cfs
06-17-87	32 cfs
07-15-87	16 cfs

FLOW	AREA
15	59620
20	61272
25	62529
30	63879
35	64481
40	65027
45	65517
50	65967
55	66385
60	66801
70	67381
80	68314
90	68692
100	69040
110	69427
120	69849
130	70244
140	70583
160	71178
180	71732
200	72358
220	72936
240	73490
260	74014
280	74510
300	74980
320	75428
340	75855
360	76301

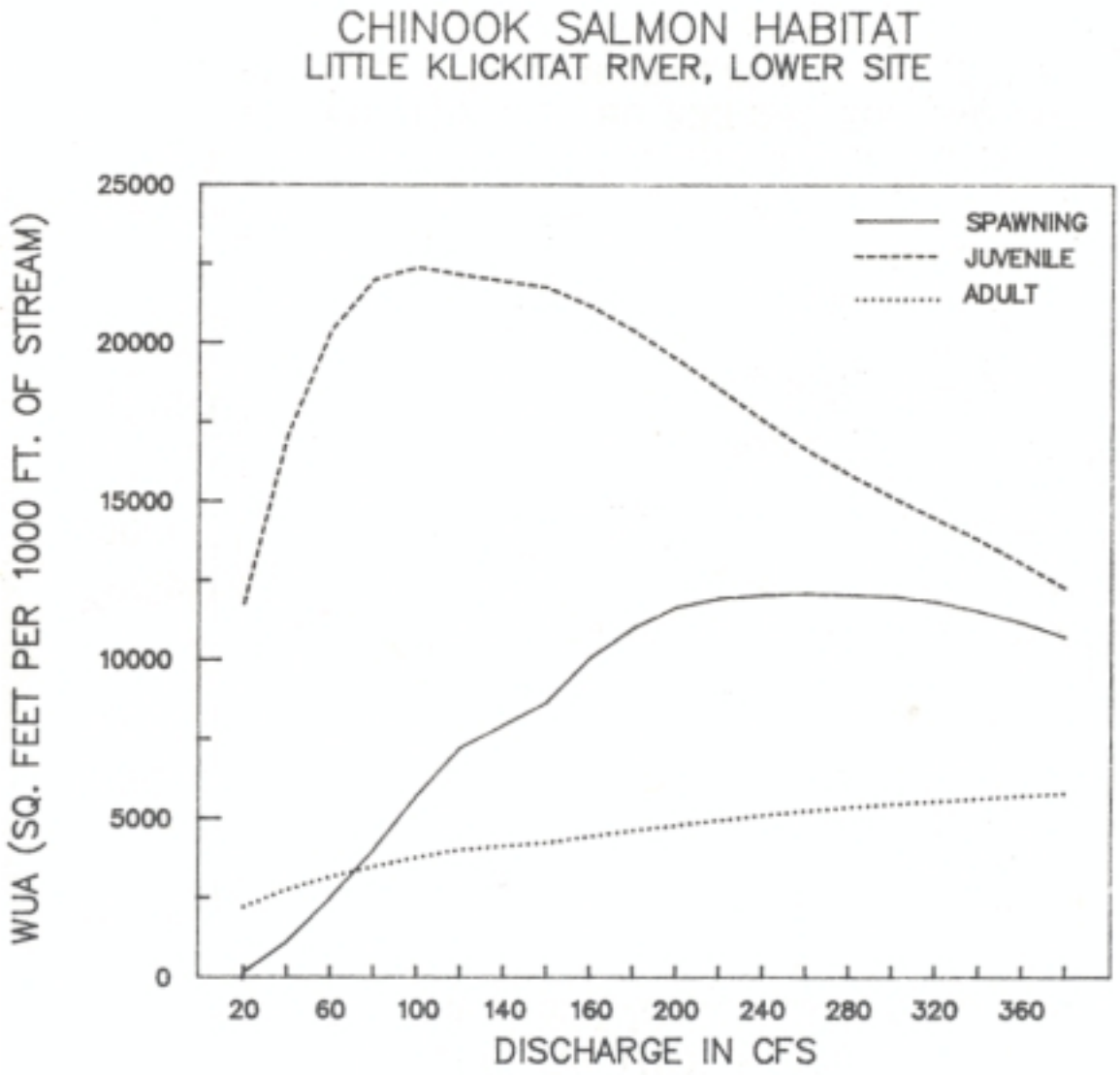


W.R.I.A. 30 RM. 0.4

DATE AND FLOW MEASURED

04-16-87 145 cfs
05-14-87 81 cfs
06-17-87 32 cfs
07-15-87 16 cfs

FLOW	SPAWNING	JUVENILE	ADULT
15	1071	14983	39
20	1553	18748	54
25	2112	21776	69
30	2754	24318	89
35	3473	26588	114
40	4185	28514	149
45	4898	30085	197
50	5602	31384	245
55	6263	32375	311
60	6886	33257	380
70	8044	34628	567
80	9010	35480	898
90	9813	35599	1245
100	10478	35597	1520
110	11049	35386	1793
120	11529	35291	2201
130	11951	35269	2600
140	12329	34985	3204
160	12892	33900	4304
180	13157	32681	5419
200	13324	31522	5903
220	13458	30904	5966
240	13470	30465	6762
260	13416	29941	7244
280	13277	29428	7620
300	13032	28738	7362
320	12723	27655	6736
340	12406	26801	6363
360	12048	26172	5930

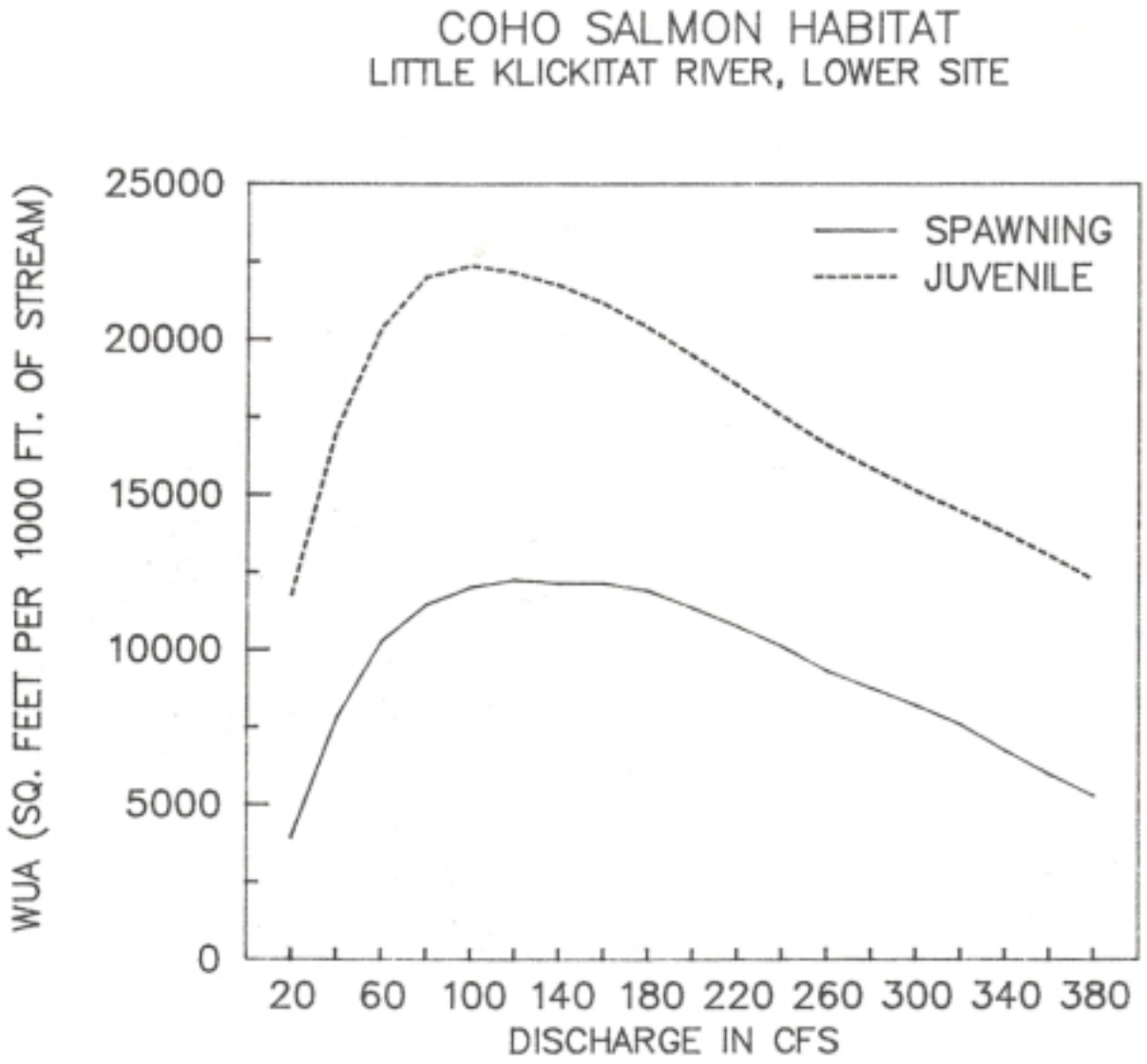


W.R.I.A. 30 RM. 0.4

DATE AND FLOW MEASURED

04-16-87	145 cfs
05-14-87	81 cfs
06-17-87	32 cfs
07-15-87	16 cfs

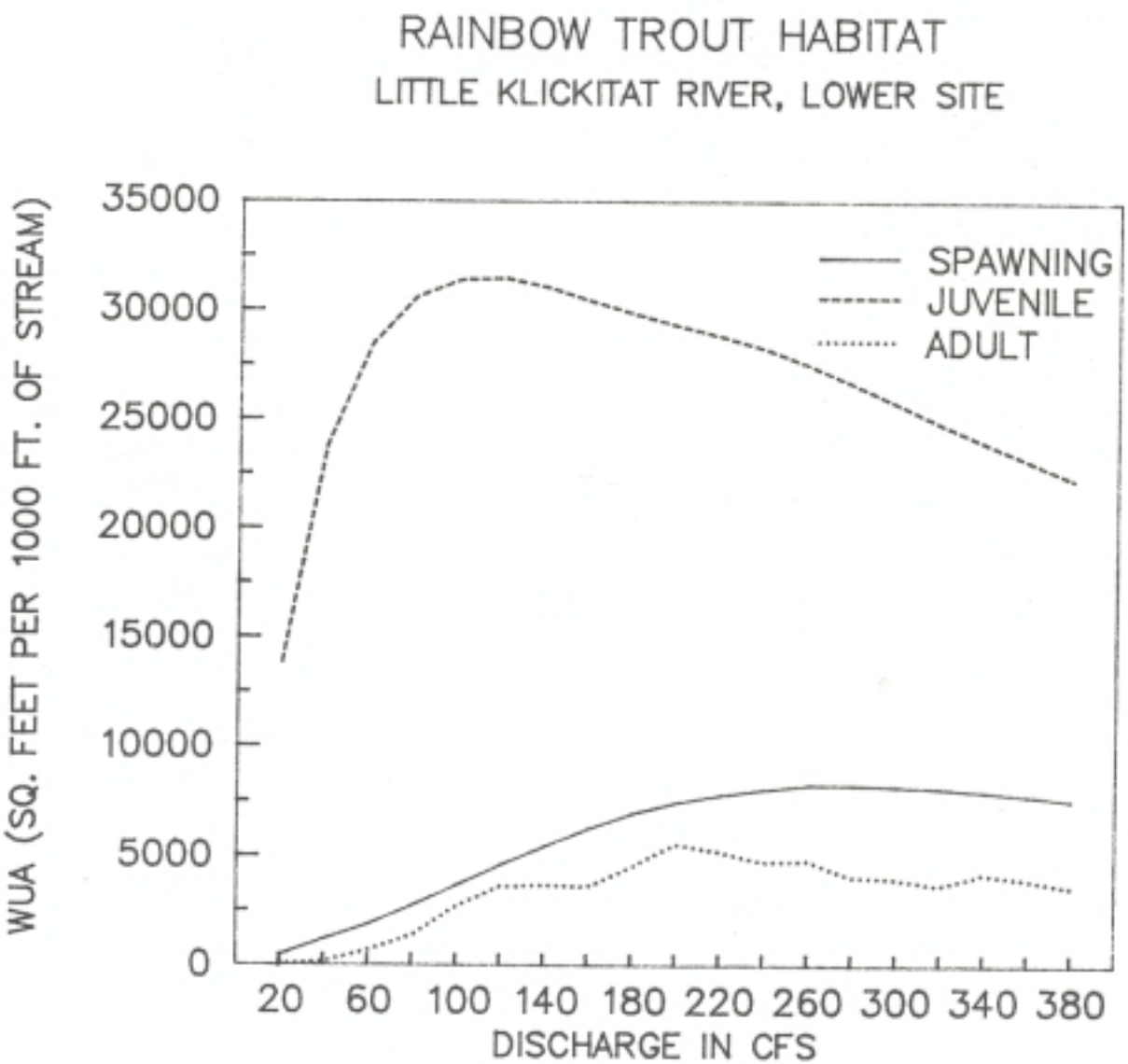
FLOW	SPAWNING	JUVENILE	ADULT
15	56	9647	2018
20	152	11767	2205
25	306	13454	2370
30	538	14801	2515
35	820	15998	2644
40	1118	17091	2762
45	1412	18034	2873
50	1739	18913	2974
55	2087	19675	3069
60	2466	20367	3158
70	3218	21342	3324
80	3994	22005	3478
90	4785	22280	3622
100	5697	22380	3759
110	6485	22305	3890
120	7224	22138	4014
130	7923	21930	4129
140	8644	21728	4237
160	10040	21142	4431
180	10985	20364	4609
200	11654	19468	4773
220	11934	18523	4932
240	12036	17534	5087
260	12089	16615	5226
280	12035	15843	5341
300	11994	15119	5440
320	11833	14450	5530
340	11521	13775	5614
360	11160	13027	5701



W.R.I.A. 30 RM. 0.4

DATE AND FLOW MEASURED	
04-16-87	145 cfs
05-14-87	81 cfs
06-17-87	32 cfs
07-15-87	16 cfs

FLOW	SPAWNING	JUVENILE
15	2478	9647
20	3941	11767
25	5152	13454
30	6295	14801
35	7072	15998
40	7754	17091
45	8497	18034
50	9160	18913
55	9755	19675
60	10266	20367
70	10967	21342
80	11445	22005
90	11781	22280
100	12012	22380
110	12178	22305
120	12253	22138
130	12176	21930
140	12141	21728
160	12137	21142
180	11894	20364
200	11340	19468
220	10752	18523
240	10109	17534
260	9323	16615
280	8767	15843
300	8216	15119
320	7590	14450
340	6747	13775
360	5988	13027



W.R.I.A. 30 RM. 0.4

DATE AND FLOW MEASURED

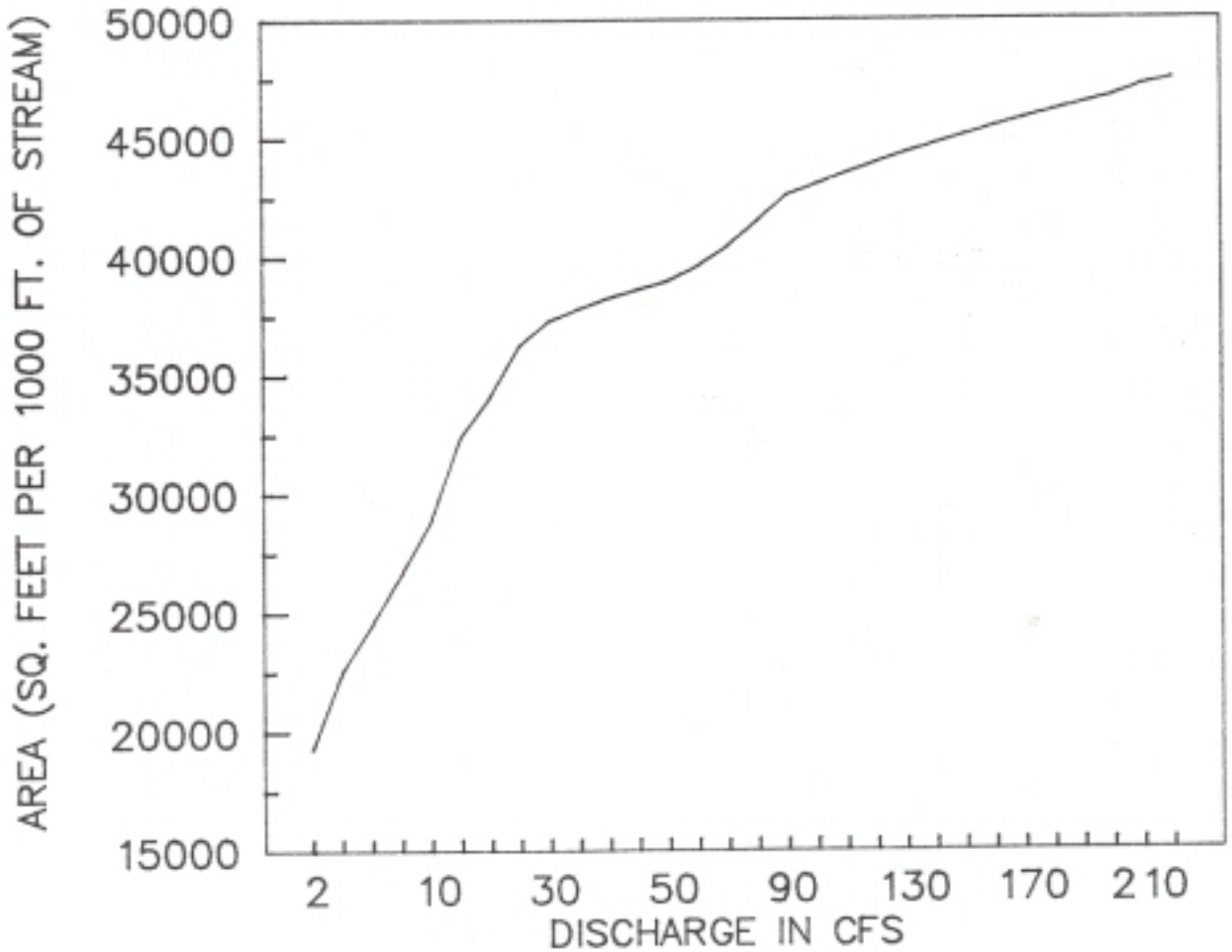
04-16-87	145 cfs
05-14-87	81 cfs
06-17-87	32 cfs
07-15-87	16 cfs

FLOW	SPAWNING	JUVENILE	ADULT
15	268	10216	0
20	449	13839	0
25	631	16964	0
30	814	19631	26
35	1007	21912	67
40	1179	23818	120
45	1330	25318	130
50	1498	26596	320
55	1677	27613	398
60	1855	28462	659
70	2275	29715	992
80	2717	30613	1352
90	3172	31082	1728
100	3635	31389	2680
110	4103	31531	3438
120	4562	31461	3581
130	4997	31280	3720
140	5409	31023	3661
160	6222	30388	3585
180	6921	29801	4491
200	7430	29263	5542
220	7784	28773	5188
240	8055	28198	4712
260	8255	27430	4762
280	8259	26590	4028
300	8182	25683	3959
320	8088	24745	3650
340	7941	23897	4193
360	7769	23081	3945

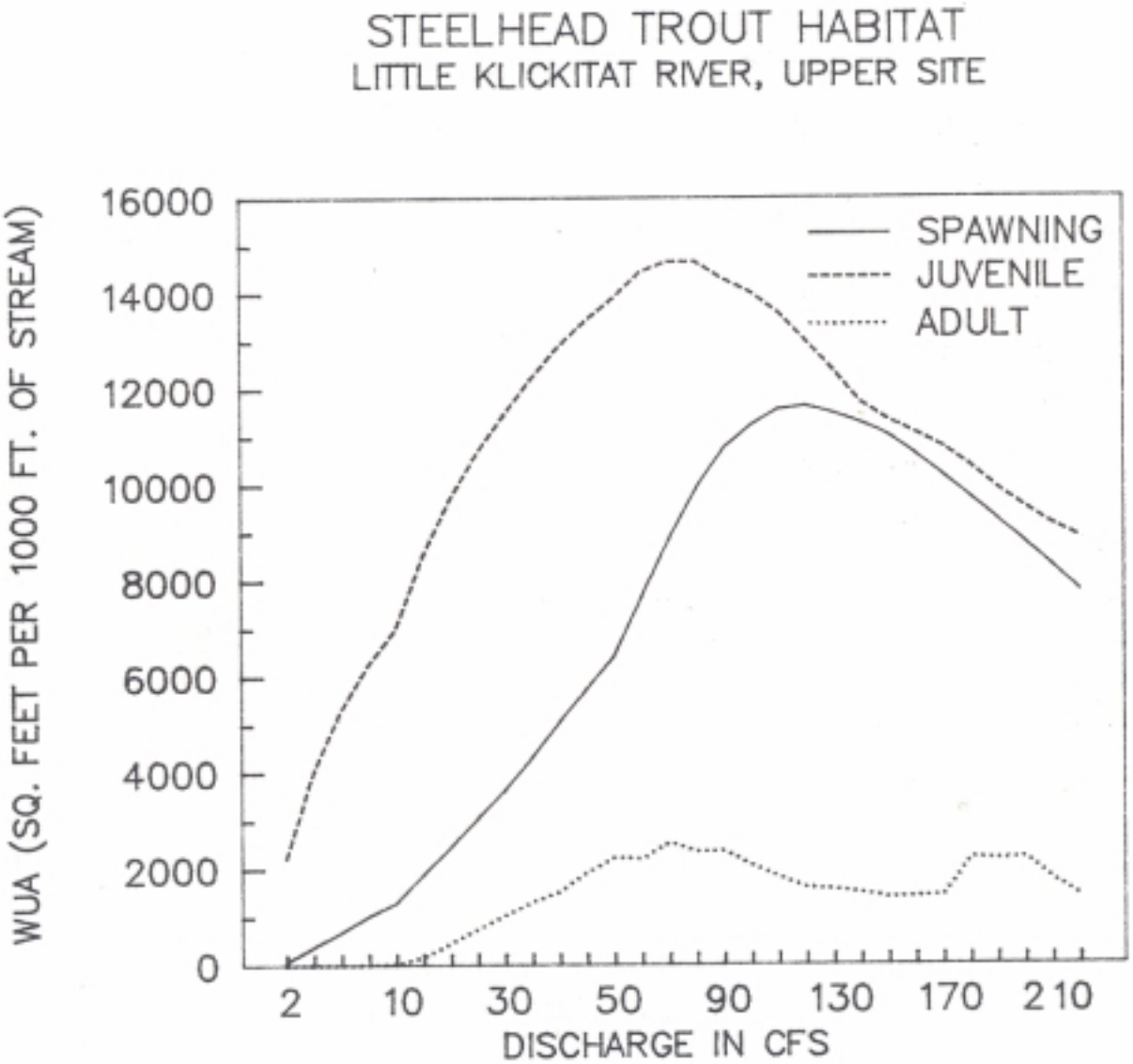
W.R.I.A. 30 RM. 9.6

DATE AND FLOW MEASURED

04-07-87	87 cfs
05-14-87	40 cfs
06-16-87	12 cfs
07-14-87	4 cfs



FLOW	AREA
2	19320
4	22530
6	24530
8	26656
10	28880
15	32368
20	34079
25	36246
30	37278
35	37798
40	38241
45	38604
50	38956
60	39576
70	40392
80	41445
90	42555
100	43016
110	43479
120	43913
130	44322
140	44709
150	45077
160	45429
170	45765
180	46087
190	46397
200	46694
210	47166

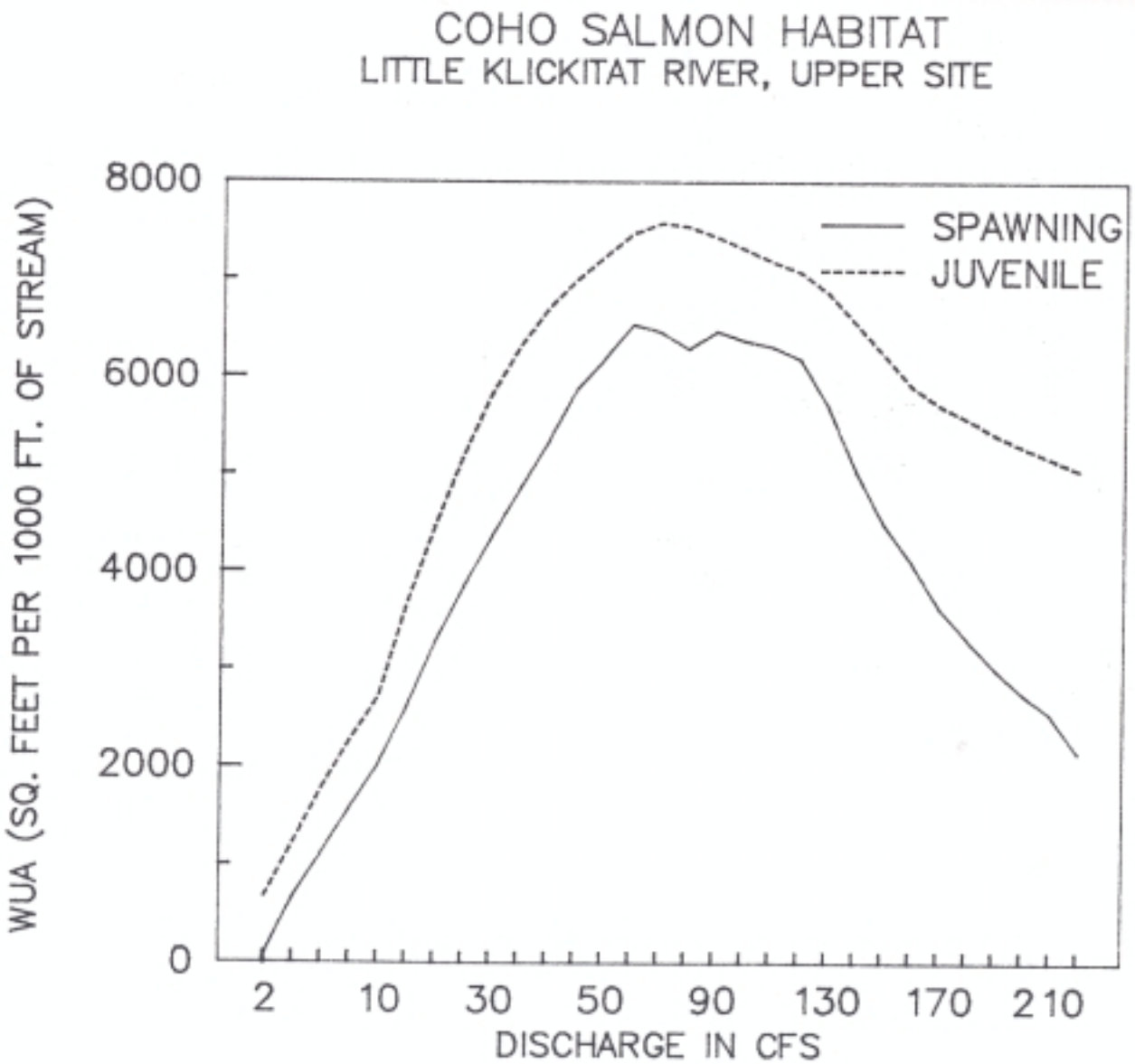


W.R.I.A. 30 RM. 9.6

DATE AND FLOW MEASURED

04-07-87	87 cfs
05-14-87	40 cfs
06-16-87	12 cfs
07-14-87	4 cfs

FLOW	SPAWNING	JUVENILE	ADULT
2	79	2237	0
4	394	4038	0
6	701	5307	0
8	1028	6251	1
10	1299	6995	18
15	1886	8507	167
20	2457	9698	464
25	3045	10653	757
30	3635	11450	1038
35	4307	12210	1305
40	5044	12872	1521
45	5726	13417	1914
50	6414	13891	2221
60	7644	14442	2195
70	8831	14664	2532
80	9899	14665	2335
90	10733	14297	2343
100	11217	14017	2045
110	11559	13601	1794
120	11637	13008	1582
130	11482	12398	1557
140	11284	11720	1477
150	11031	11354	1375
160	10630	11075	1395
170	10187	10779	1431
180	9727	10389	2215
190	9251	9912	2173
200	8774	9511	2210
210	8284	9152	1744

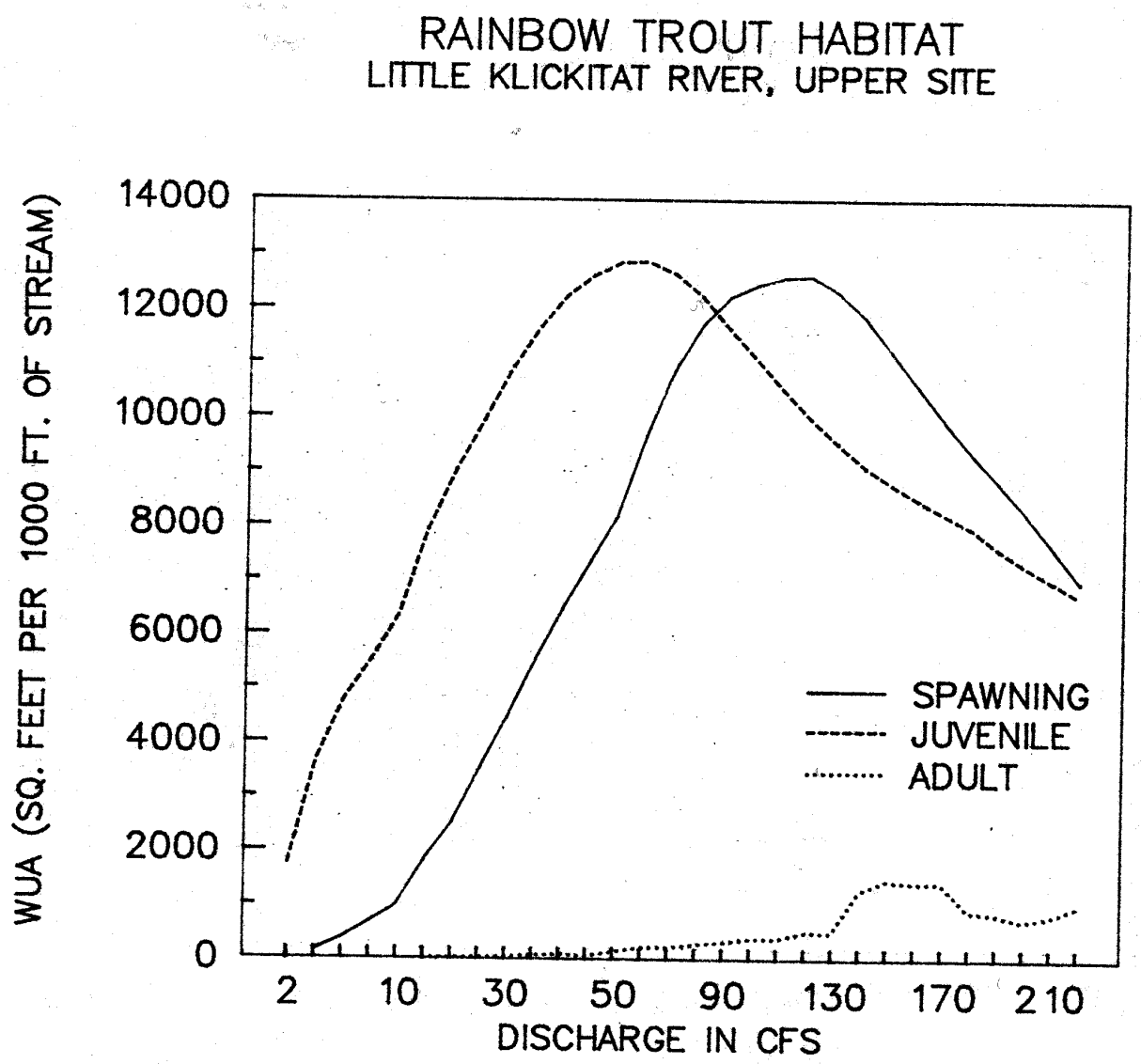


W.R.I.A. 30 RM. 9.6

DATE AND FLOW MEASURED

04-07-87	87 cfs
05-14-87	40 cfs
06-16-87	12 cfs
07-14-87	4 cfs

FLOW	SPAWNING	JUVENILE
2	71	667
4	652	1217
6	1102	1770
8	1561	2265
10	2010	2708
15	2601	3669
20	3269	4478
25	3834	5202
30	4351	5828
35	4836	6311
40	5330	6705
45	5862	6989
50	6179	7232
60	6533	7469
70	6456	7573
80	6281	7540
90	6465	7430
100	6367	7306
110	6305	7177
120	6177	7068
130	5695	6850
140	5033	6536
150	4495	6219
160	4106	5901
170	3637	5706
180	3318	5565
190	3017	5408
200	2758	5277
210	2547	5161



W.R.I.A. 30 RM. 9.6

DATE AND FLOW MEASURED

04–07–87 87 cfs
05–14–87 40 cfs
06–16–87 12 cfs
07–14–87 4 cfs

FLOW	SPAWNING	JUVENILE	ADULT
2	0	1750	0
4	148	3650	0
6	374	4781	0
8	670	5518	0
10	966	6353	0
15	1826	7910	0
20	2512	9004	7
25	3515	9918	22
30	4478	10861	30
35	5516	11618	67
40	6470	12227	80
45	7332	12601	58
50	8189	12848	139
60	9643	12867	222
70	10848	12638	222
80	11691	12220	281
90	12217	11640	319
100	12445	11089	384
110	12576	10529	389
120	12604	9996	505
130	12304	9535	497
140	11848	9110	1262
150	11204	8781	1462
160	10558	8485	1415
170	9904	8216	1419
180	9311	7951	895
190	8778	7575	842
200	8219	7259	724
210	7600	6981	808

AREA VS. DISCHARGE

BLOCKHOUSE CREEK, TRIBUTARY TO THE LITTLE KLICKITAT RIVER

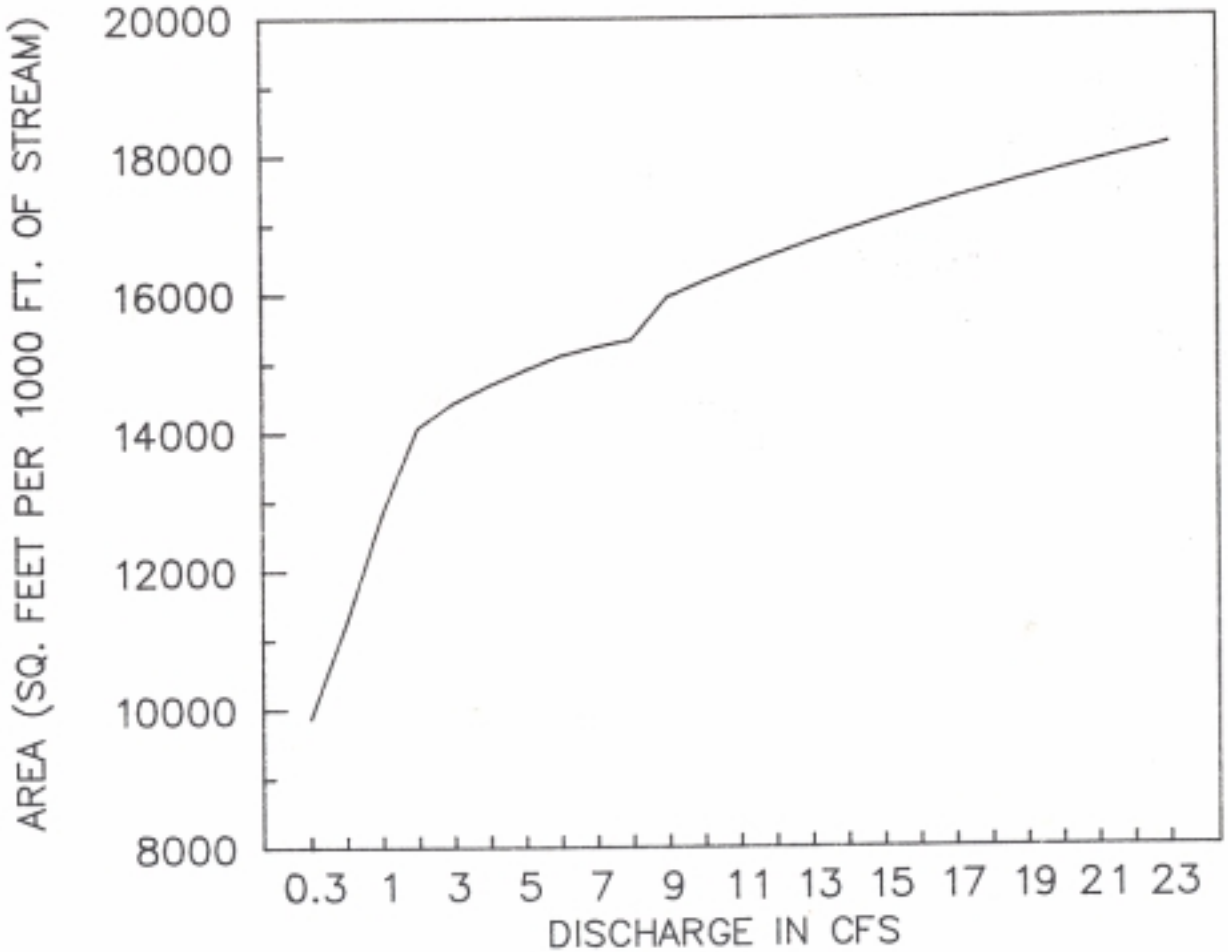
W.R.I.A. 30 RM. 2.5

DATE AND FLOW MEASURED

04-06-87 9 cfs

05-13-87 .4 cfs

06-16-87 .5 cfs

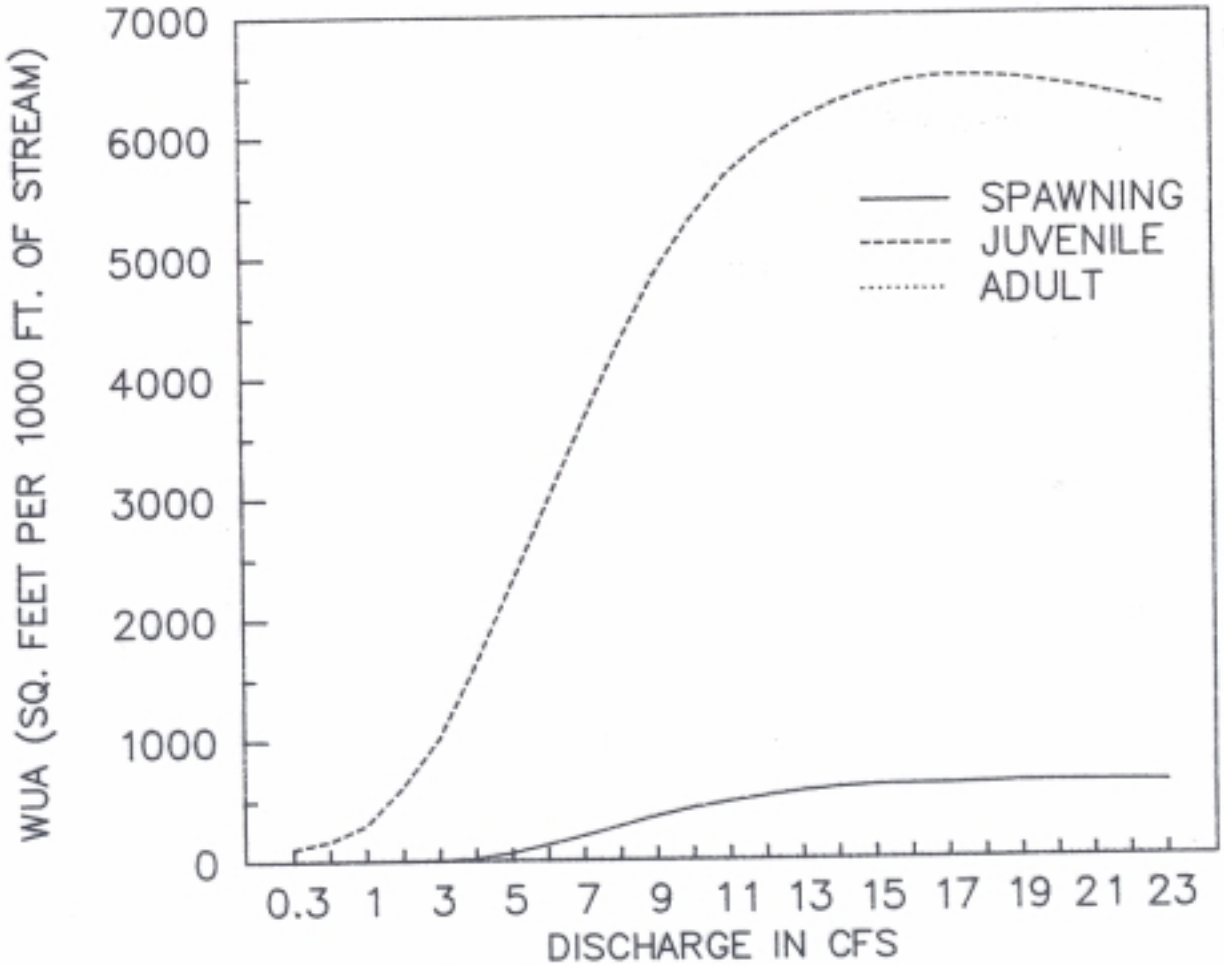


FLOW	AREA
.3	9882
.5	11257
1	12814
2	14072
3	14433
4	14688
5	14905
6	15113
7	15240
8	15342
9	15955
10	16172
11	16375
12	16565
13	16744
14	16913
15	17074
16	17228
17	17375
18	17516
19	17651
20	17782
21	17908
22	18030
23	18148

RAINBOW TROUT HABITAT

BLOCKHOUSE CREEK, TRIBUTARY TO THE LITTLE KLICKITAT RIVER

W.R.I.A. 30 RM. 2.5
DATE AND FLOW MEASURED
04-06-87 9 cfs
05-13-87 .4 cfs
06-16-87 .5 cfs

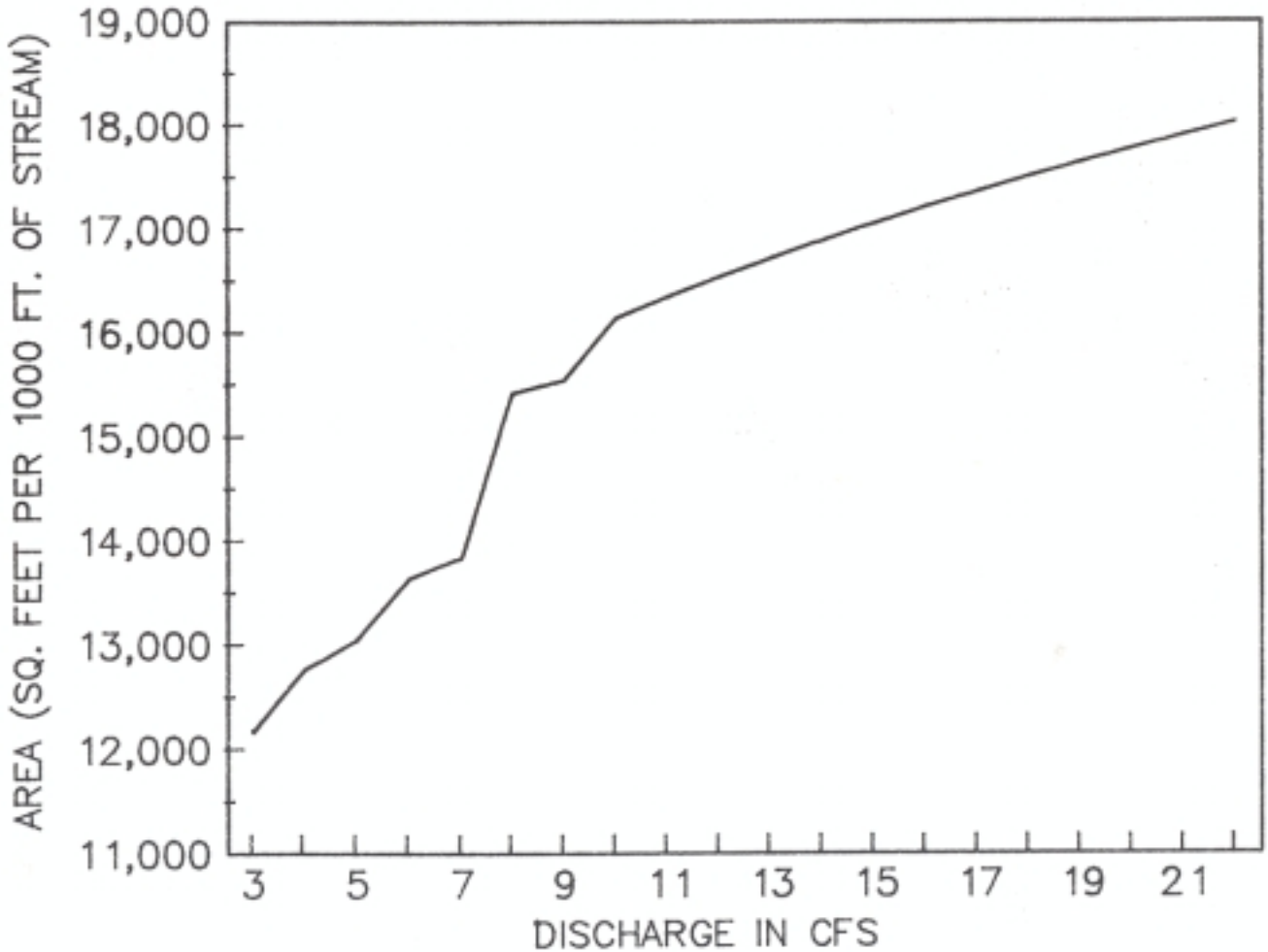


FLOW	SPAWNING	JUVENILE	ADULT
.3	0	104	0
.5	0	166	0
1	0	302	0
2	0	613	0
3	1	1011	0
4	16	1607	0
5	66	2273	0
6	132	2942	0
7	205	3607	0
8	284	4261	0
9	363	4843	0
10	427	5300	0
11	477	5670	0
12	521	5928	0
13	560	6122	0
14	586	6266	0
15	603	6374	0
16	610	6450	0
17	612	6484	0
18	618	6482	0
19	625	6463	1
20	630	6417	4
21	628	6363	4
22	626	6300	5
23	619	6233	4

AREA VS. DISCHARGE

BLOODGOOD CREEK, TRIBUTARY TO THE LITTLE KLICKITAT RIVER

W.R.I.A. 30 RM. 0.5
DATE AND FLOW MEASURED
04-02-87 8.8 cfs
05-13-87 7.2 cfs

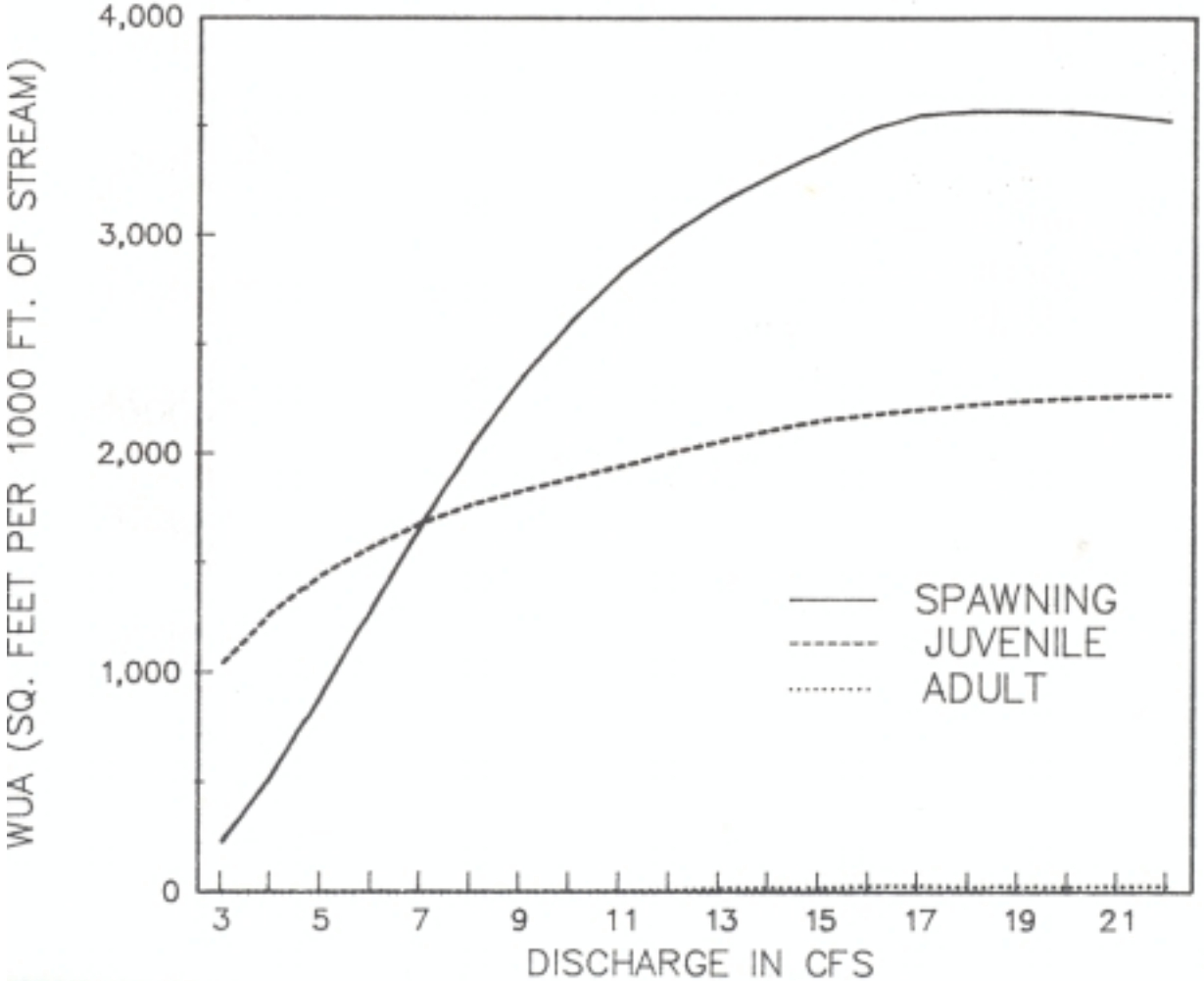


FLOW	AREA
3	12174
4	12766
5	13051
6	13641
7	13841
8	15421
9	15546
10	16141
11	16345
12	16537
13	16718
14	16889
15	17052
16	17208
17	17357
18	17500
19	17638
20	17770
21	17898
22	18022

RAINBOW TROUT HABITAT

BLOODGOOD CREEK, TRIBUTARY TO THE LITTLE KLICKITAT RIVER

W.R.I.A. 30 RM. 0.5
DATE AND FLOW MEASURED
04-02-87 8.8 cfs
05-13-87 7.2 cfs



FLOW	SPAWNING	JUVENILE	ADULT
3	235	1046	0
4	533	1276	0
5	904	1450	0
6	1298	1576	0
7	1677	1685	0
8	2041	1769	1
9	2348	1832	1
10	2612	1891	2
11	2835	1945	3
12	3013	2007	5
13	3159	2062	16
14	3276	2110	18
15	3386	2156	18
16	3493	2184	28
17	3555	2206	29
18	3572	2228	23
19	3573	2245	26
20	3570	2258	24
21	3552	2267	26
22	3528	2273	28

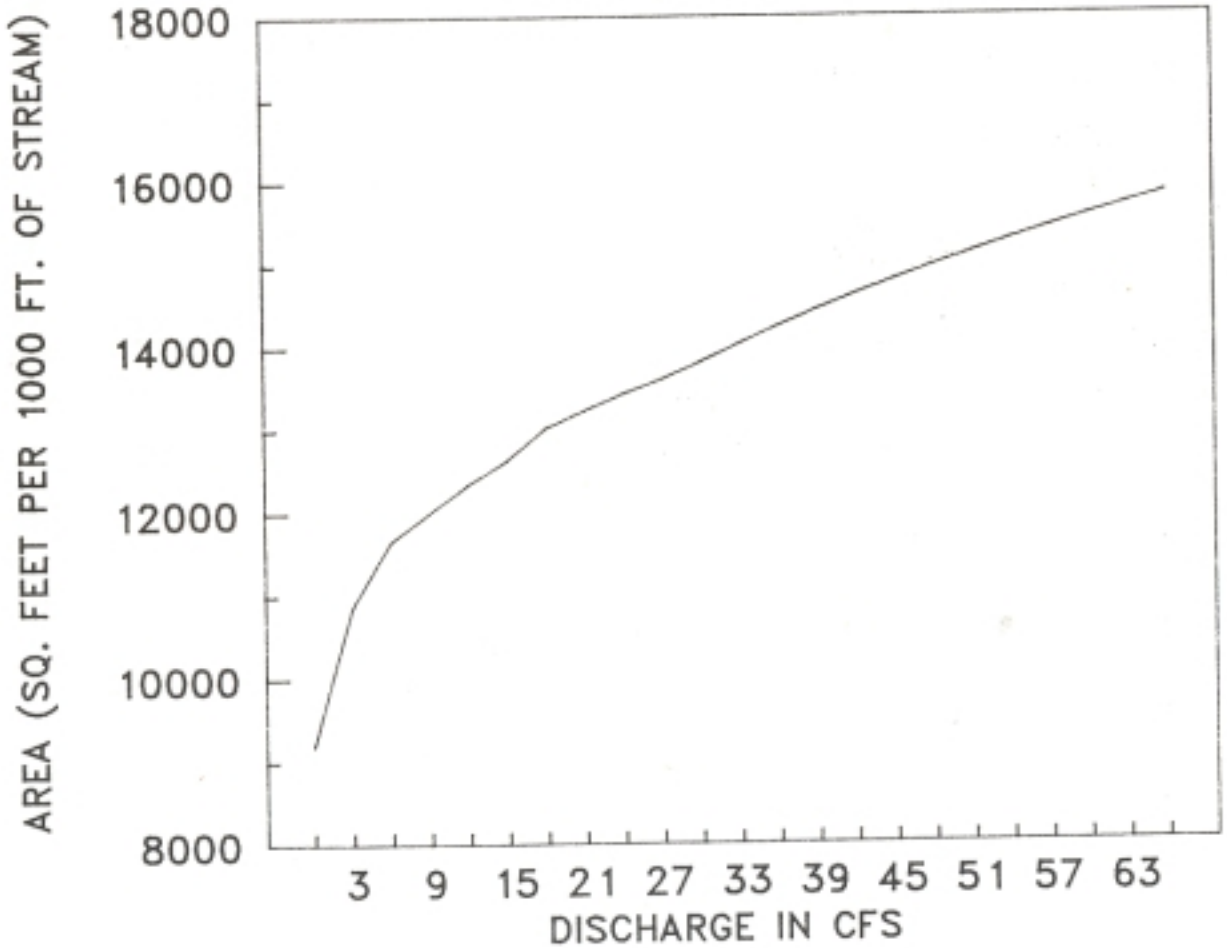
W.R.I.A. 30 RM. 3.5

DATE AND FLOW MEASURED

04-03-87	28 cfs
05-13-87	14 cfs
06-16-87	5 cfs
07-14-87	.7 cfs

AREA VS. DISCHARGE

BOWMAN CREEK, TRIBUTARY TO THE LITTLE KLICKITAT RIVER

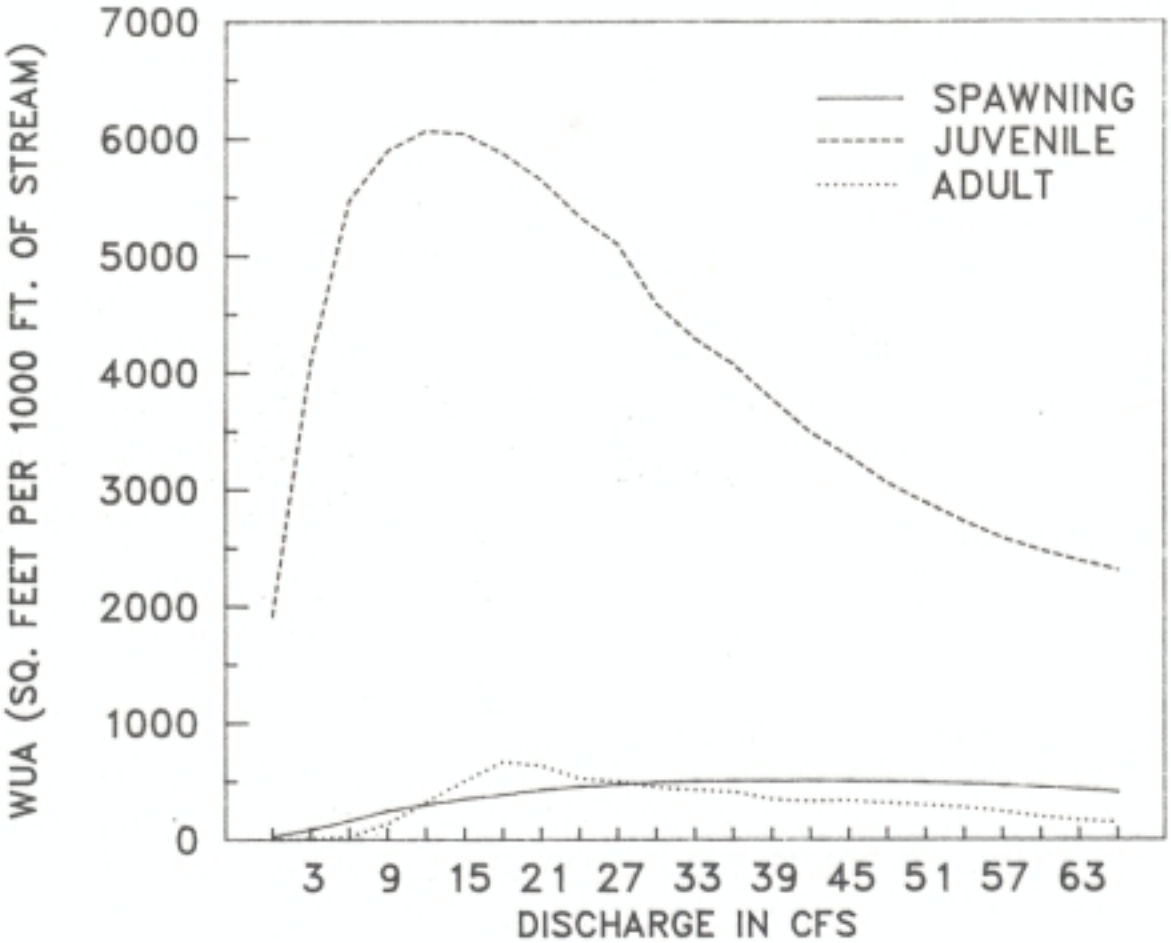


FLOW	AREA
1	9197
3	10853
6	11649
9	11995
12	12336
15	12622
18	13013
21	13226
24	13427
27	13595
30	13804
33	14021
36	14232
39	14429
42	14615
45	14791
48	14958
51	15117
54	15270
57	15415
60	15555
63	15690
66	15820

W.R.I.A. 30 RM. 3.5
DATE AND FLOW MEASURED
04-03-87 28 cfs
05-13-87 14 cfs
06-16-87 5 cfs
07-14-87 .7 cfs

STEELHEAD TROUT HABITAT

BOWMAN CREEK, TRIBUTARY TO THE LITTLE KLICKITAT RIVER



FLOW	SPAWNING	JUVENILE	ADULT
1	21	1917	0
3	86	4095	2
6	164	5474	22
9	247	5901	140
12	302	6068	322
15	352	6041	506
18	387	5871	667
21	427	5645	632
24	455	5332	522
27	474	5092	493
30	489	4587	442
33	500	4286	423
36	504	4071	406
39	504	3772	345
42	507	3486	326
45	502	3285	330
48	498	3054	311
51	491	2886	295
54	481	2726	274
57	465	2585	241
60	450	2479	196
63	432	2390	165
66	410	2311	151

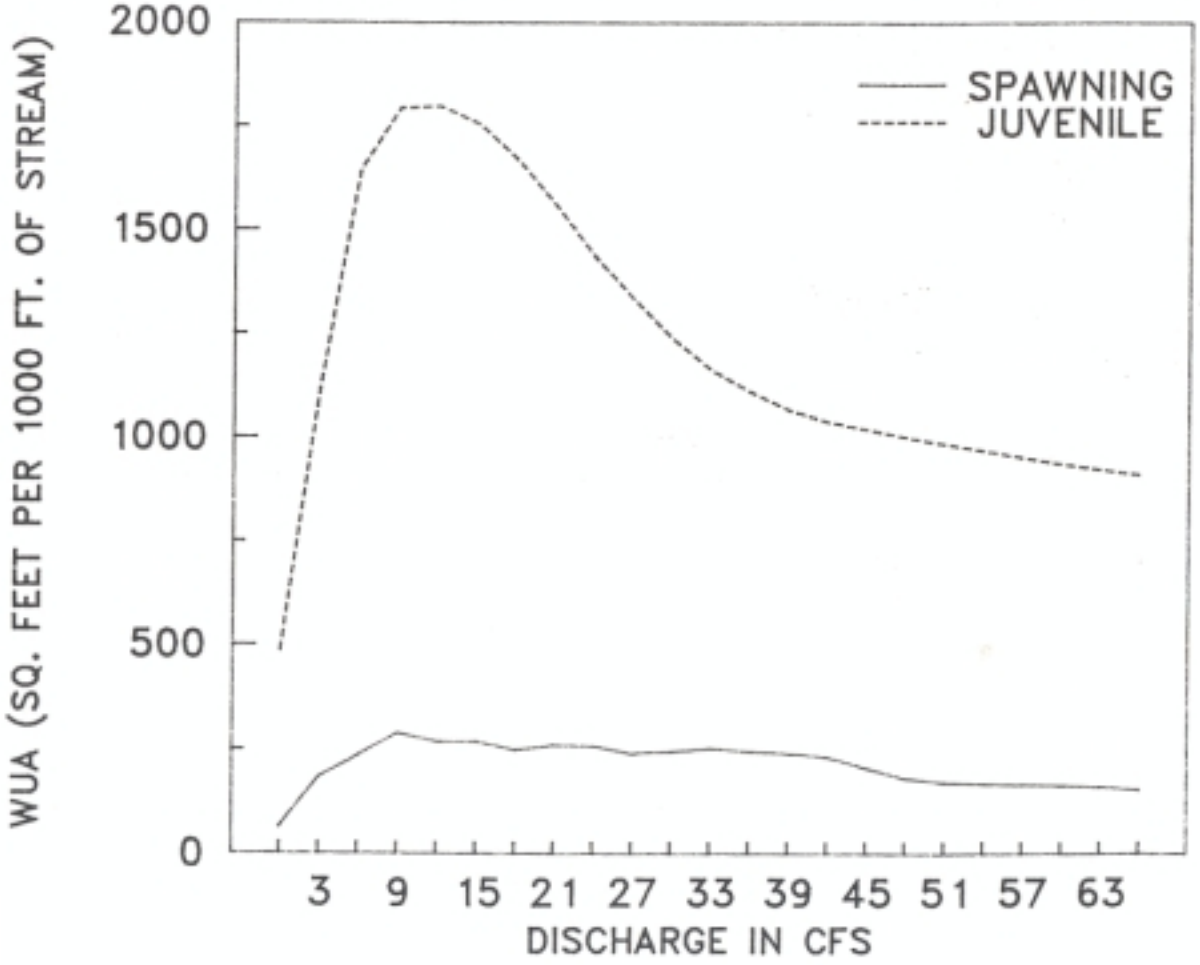
COHO SALMON HABITAT

BOWMAN CREEK, TRIBUTARY TO THE LITTLE KLICKITAT RIVER

W.R.I.A. 30 RM. 3.5

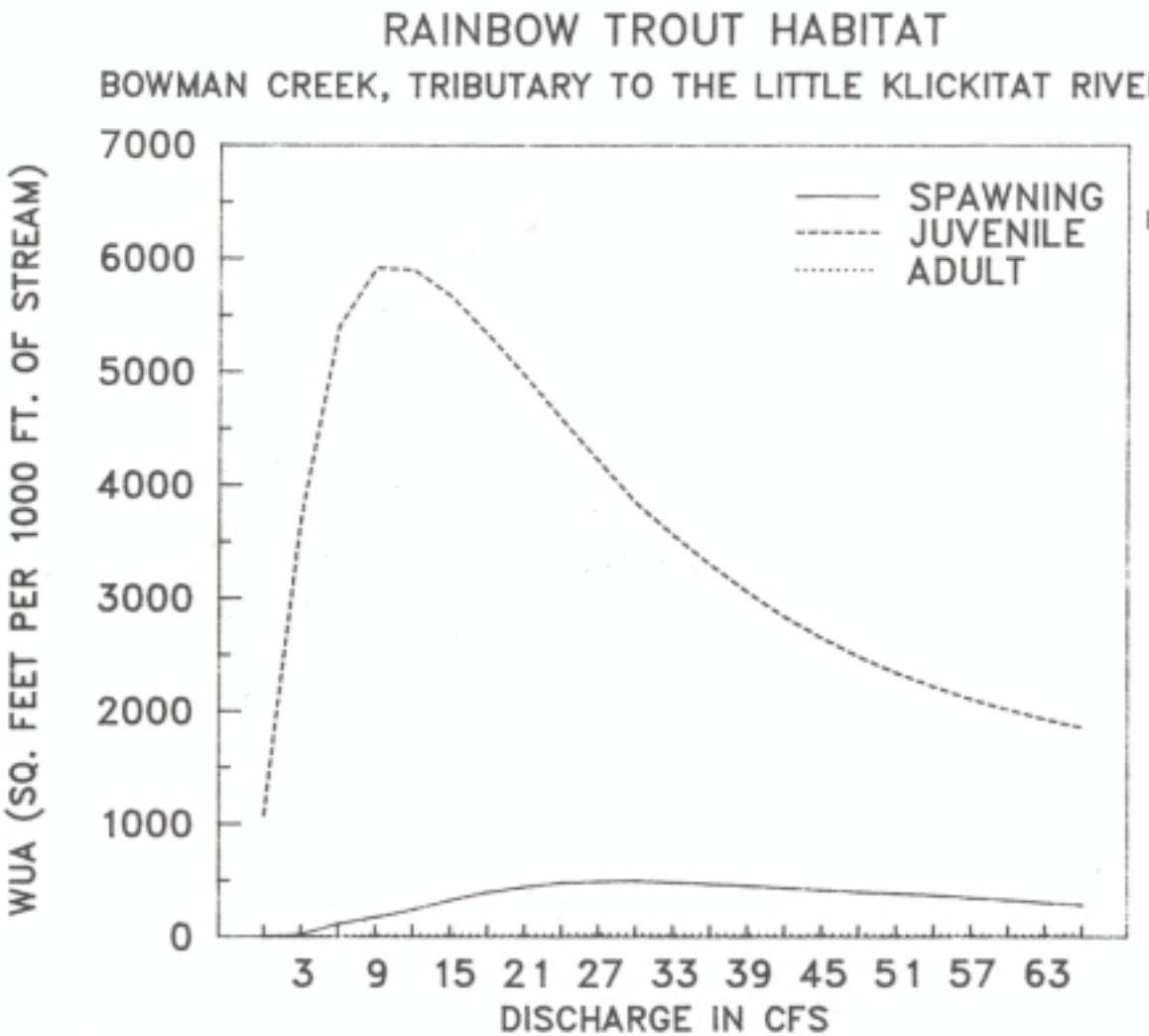
DATE AND FLOW MEASURED

04-03-87	28 cfs
05-13-87	14 cfs
06-16-87	5 cfs
07-14-87	.7 cfs



FLOW	SPAWNING	JUVENILE
1	64	487
3	183	1125
6	235	1644
9	288	1793
12	268	1798
15	268	1755
18	248	1669
21	259	1558
24	258	1435
27	239	1333
30	244	1238
33	253	1162
36	245	1110
39	240	1066
42	232	1038
45	206	1019
48	181	1001
51	171	984
54	167	968
57	165	951
60	163	935
63	159	921
66	153	909

W.R.I.A. 30 RM. 3.5
DATE AND FLOW MEASURED
04-03-87 28 cfs
05-13-87 14 cfs
06-16-87 5 cfs
07-14-87 .7 cfs



FLOW	SPAWNING	JUVENILE	ADULT
1	0	1076	0
3	16	3712	0
6	113	5396	4
9	174	5917	10
12	239	5896	9
15	322	5660	13
18	396	5320	13
21	441	4960	15
24	480	4576	20
27	492	4211	21
30	497	3842	22
33	483	3555	18
36	467	3297	19
39	449	3052	17
42	431	2834	16
45	415	2648	18
48	398	2482	17
51	381	2336	15
54	368	2213	15
57	345	2102	12
60	322	2009	13
63	299	1925	13
66	278	1851	23

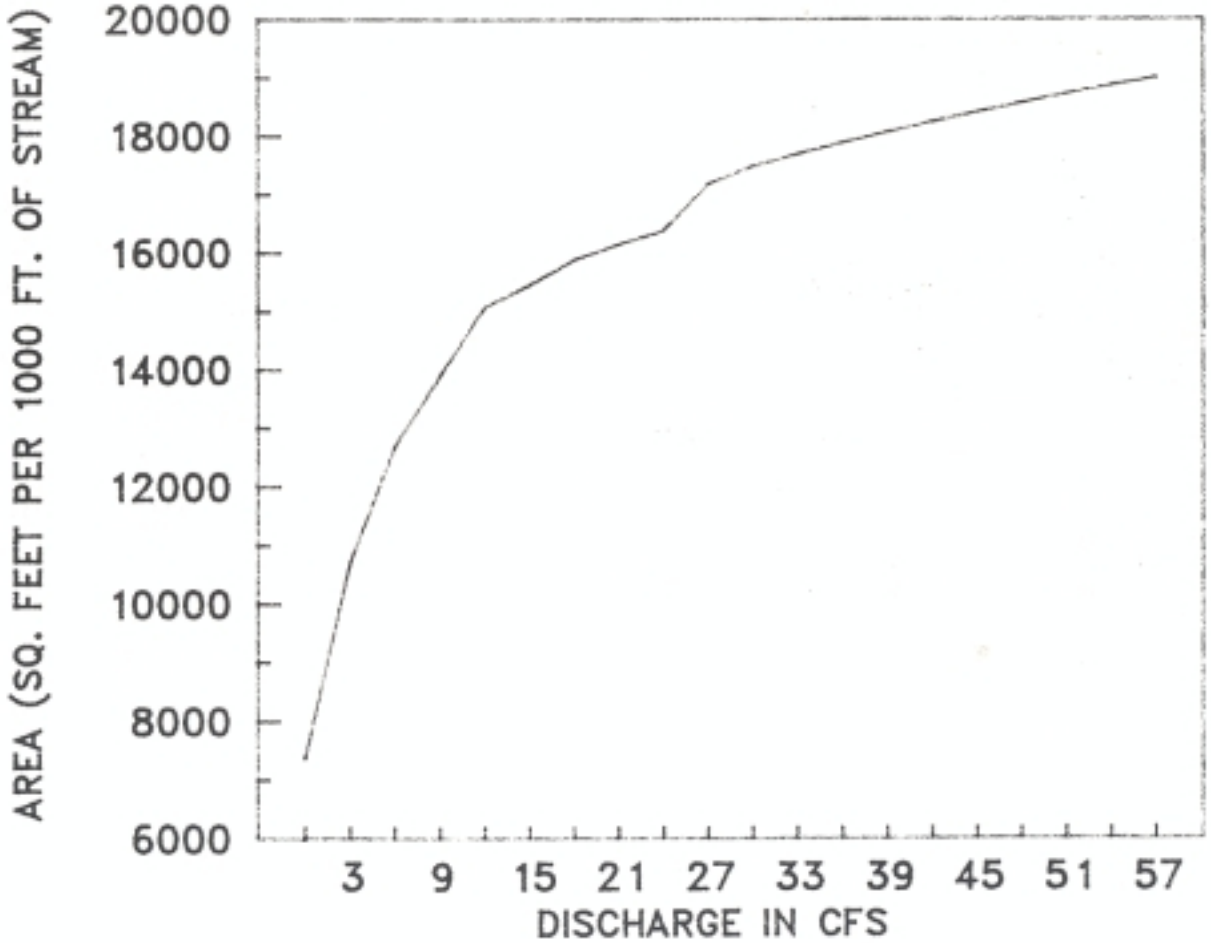
AREA VS. DISCHARGE

MILL CREEK, TRIBUTARY TO THE LITTLE KLICKITAT RIVER

W.R.I.A. 30 RM. 3.9

DATE AND FLOW MEASURED

04-02-87	22 cfs
05-13-87	12 cfs
06-16-87	7 cfs
07-14-87	3 cfs



FLOW	AREA
1	7367
3	10710
6	12684
9	13890
12	15069
15	15446
18	15879
21	16140
24	16378
27	17174
30	17481
33	17688
36	17882
39	18066
42	18240
45	18405
48	18564
51	18715
54	18861
57	19001

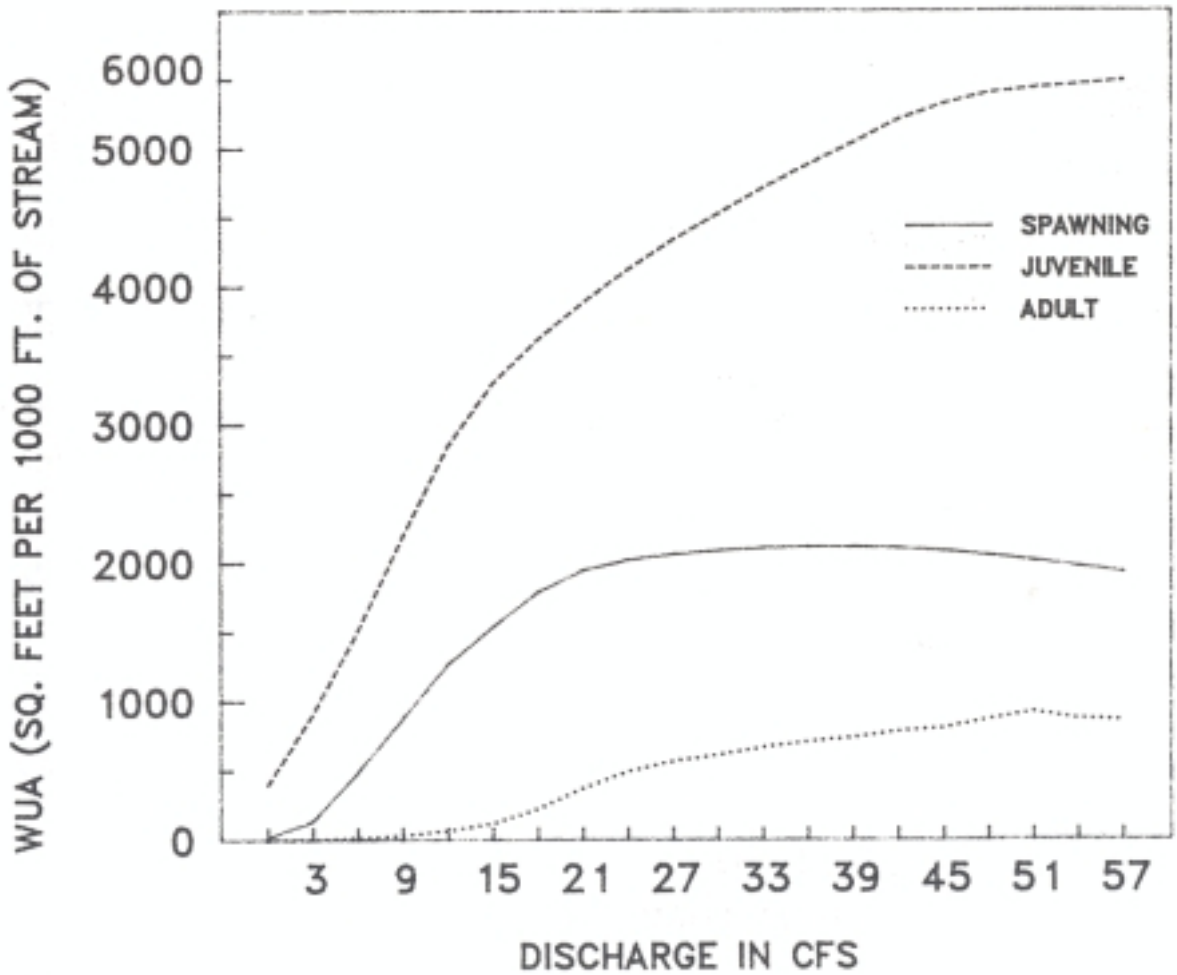
W.R.I.A. 30 RM. 3.9

DATE AND FLOW MEASURED

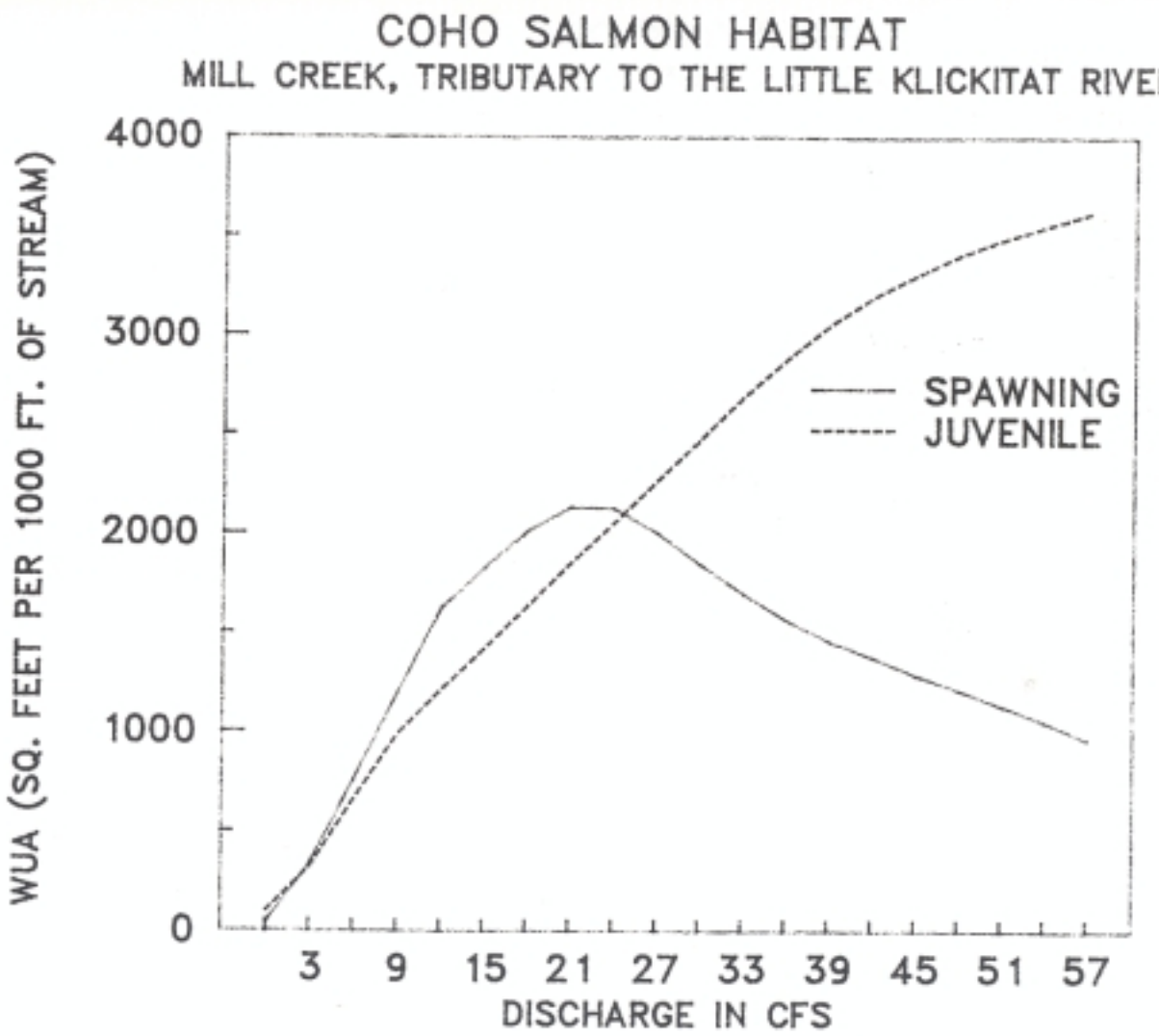
04-02-87	22 cfs
05-13-87	12 cfs
06-16-87	7 cfs
07-14-87	3 cfs

STEELHEAD TROUT HABITAT

MILL CREEK, TRIBUTARY TO THE LITTLE KLICKITAT RIVER



FLOW	SPAWNING	JUVENILE	ADULT
1	17	399	0
3	136	910	0
6	488	1507	10
9	875	2195	31
12	1266	2846	64
15	1535	3301	117
18	1786	3617	224
21	1945	3884	373
24	2023	4125	492
27	2062	4340	566
30	2088	4528	611
33	2105	4712	665
36	2115	4880	706
39	2114	5042	737
42	2102	5209	781
45	2080	5324	803
48	2049	5403	865
51	2010	5438	919
54	1969	5464	869
57	1928	5491	860

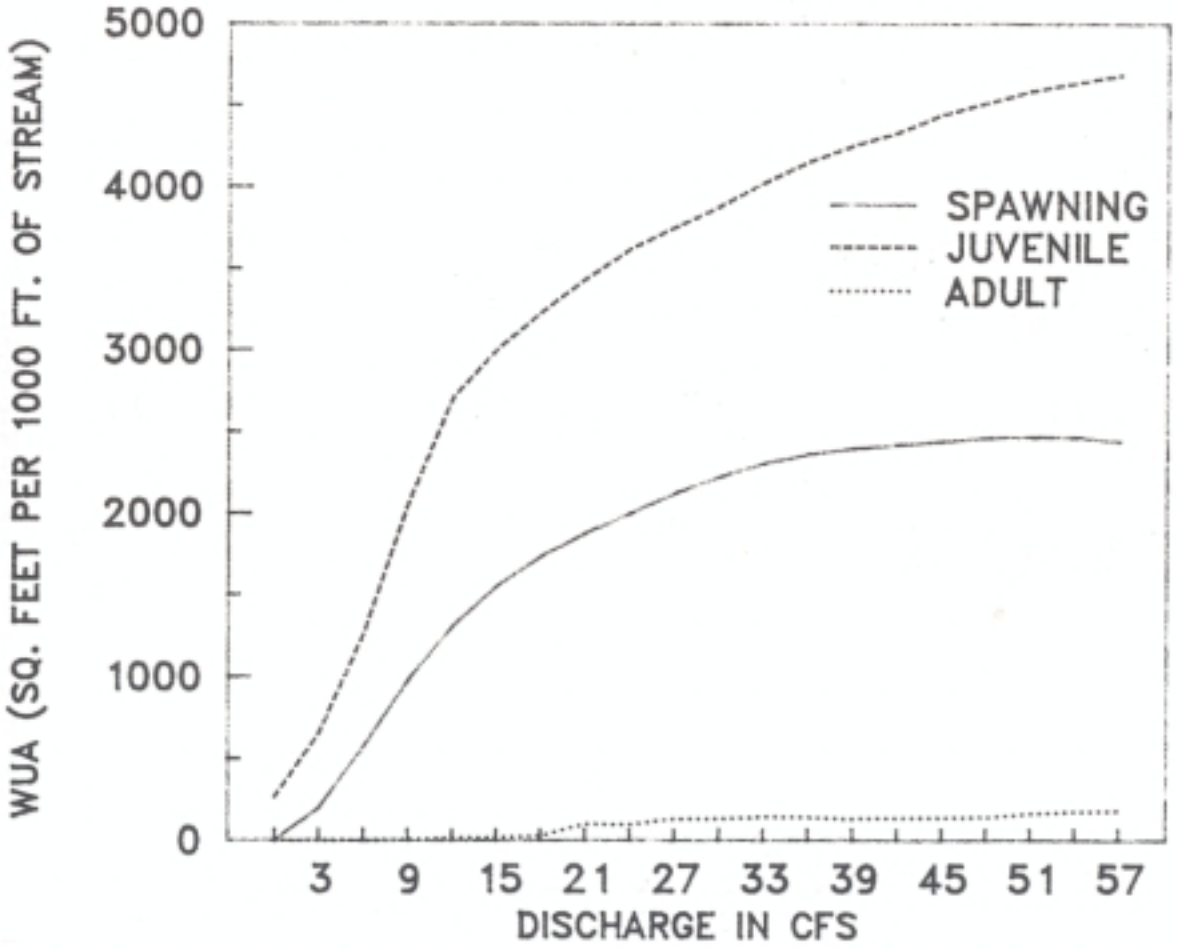


W.R.I.A. 30 RM. 3.9

DATE AND FLOW MEASURED

04-02-87	22 cfs
05-13-87	12 cfs
06-16-87	7 cfs
07-14-87	3 cfs

FLOW	SPAWNING	JUVENILE
1	38	95
3	333	316
6	756	657
9	1194	987
12	1621	1209
15	1826	1416
18	2010	1630
21	2133	1848
24	2126	2053
27	2003	2266
30	1845	2476
33	1697	2692
36	1565	2882
39	1459	3058
42	1378	3198
45	1288	3308
48	1214	3410
51	1133	3489
54	1055	3555
57	966	3619



W.R.I.A. 30 RM. 3.9

DATE AND FLOW MEASURED

04-02-87	22 cfs
05-13-87	12 cfs
06-16-87	7 cfs
07-14-87	3 cfs

FLOW	SPAWNING	JUVENILE	ADULT
1	0	266	0
3	201	659	0
6	572	1261	0
9	980	2064	3
12	1308	2707	14
15	1556	3006	15
18	1737	3233	26
21	1881	3440	101
24	2001	3624	100
27	2125	3755	131
30	2223	3883	134
33	2304	4028	146
36	2362	4157	144
39	2397	4256	131
42	2420	4336	138
45	2441	4444	141
48	2462	4517	144
51	2469	4589	166
54	2467	4638	178
57	2439	4685	182

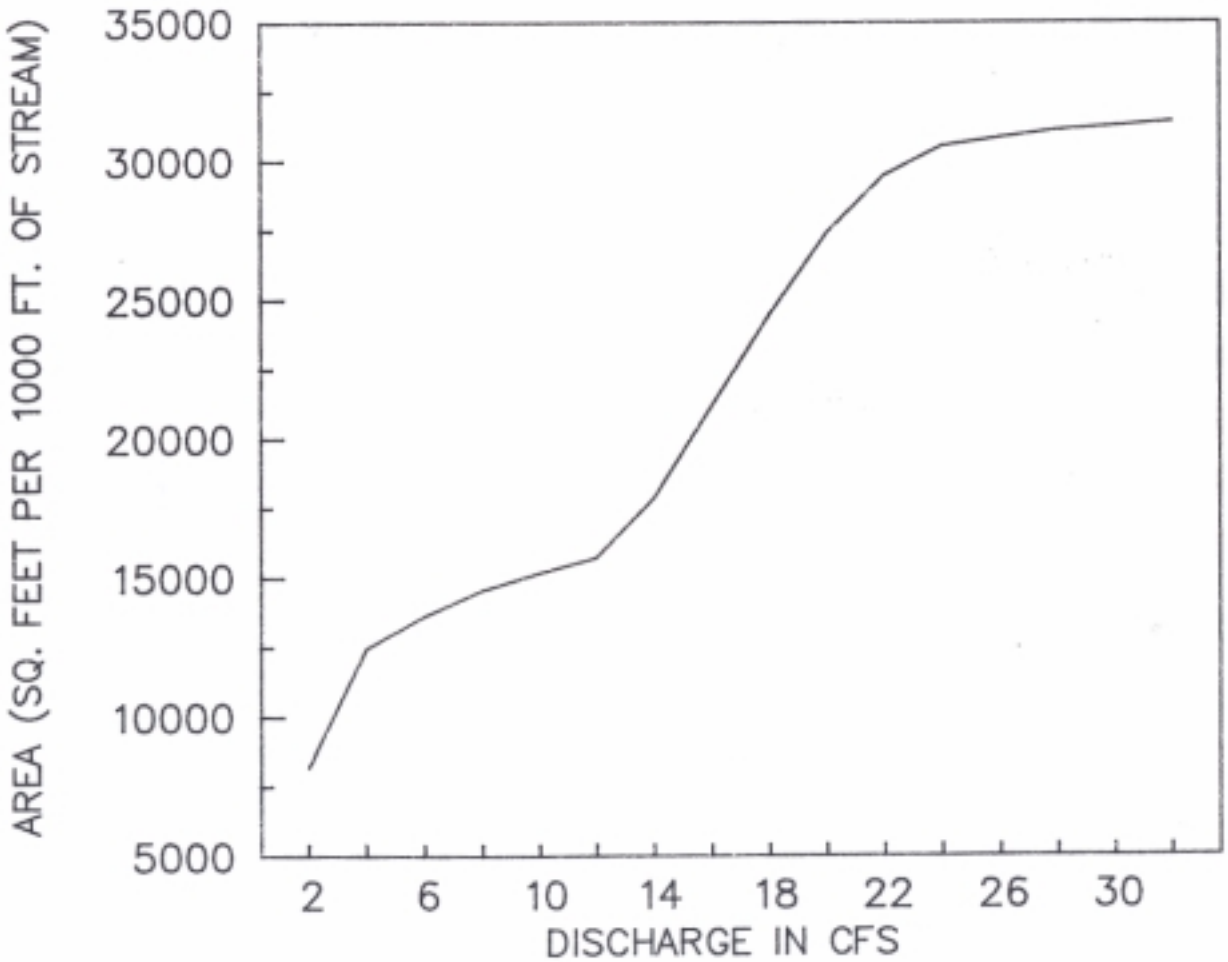
W.R.I.A. 30 RM. 0.6

DATE AND FLOW MEASURED

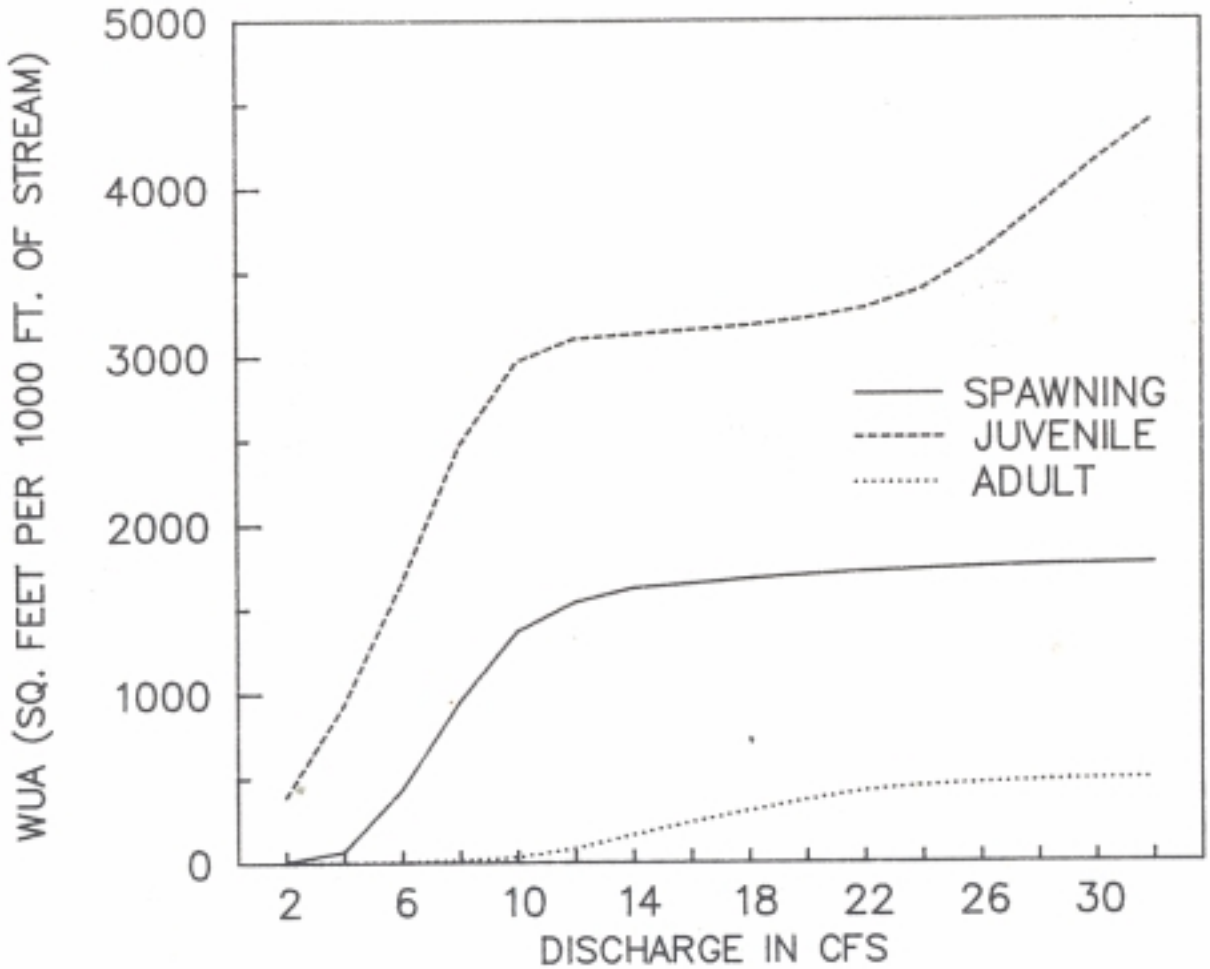
04-06-87	13 cfs
05-13-87	9 cfs
06-16-87	7 cfs

AREA VS. DISCHARGE

SPRING CREEK, TRIBUTARY TO THE LITTLE KLICKITAT RIVER



FLOW	AREA
2	8221
4	12467
6	13631
8	14553
10	15165
12	15709
14	17842
16	21162
18	24439
20	27390
22	29465
24	30528
26	30830
28	31095
30	31244
32	31391

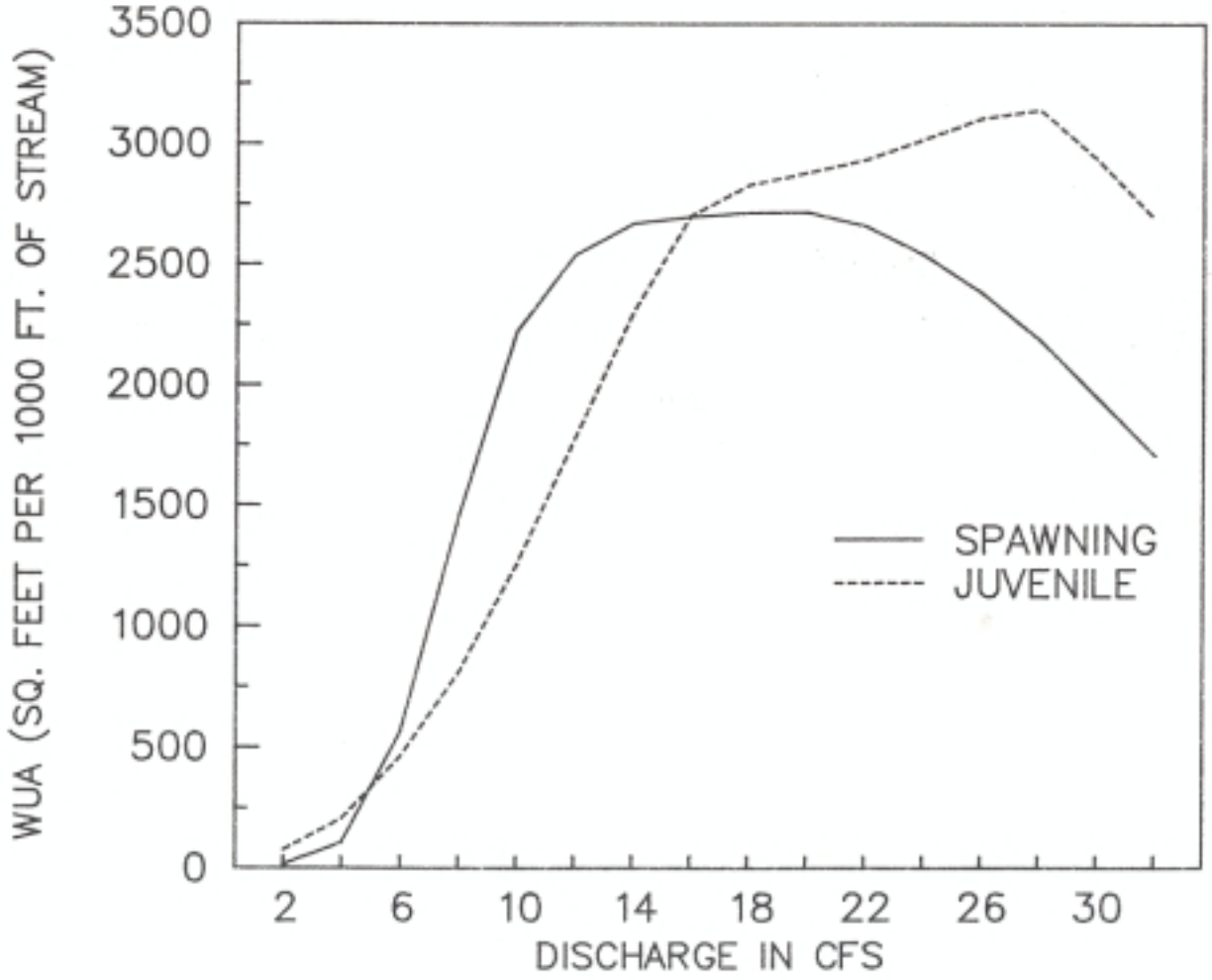


W.R.I.A. 30 RM. 0.6

DATE AND FLOW MEASURED

04-06-87	13 cfs
05-13-87	9 cfs
06-16-87	7 cfs

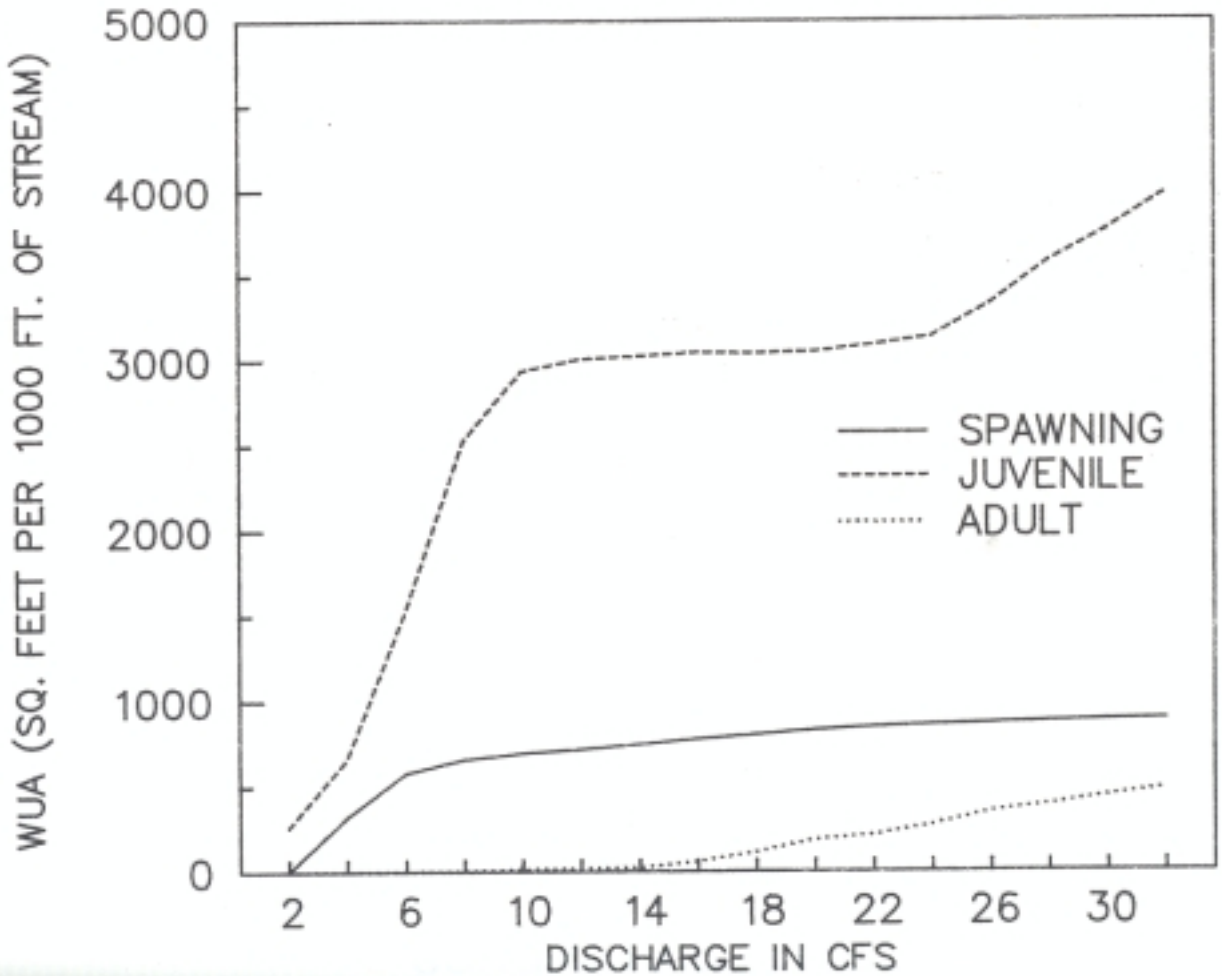
FLOW	SPAWNING	JUVENILE	ADULT
2	7	392	0
4	69	933	0
6	437	1659	2
8	954	2475	12
10	1369	2971	33
12	1540	3106	83
14	1624	3132	165
16	1649	3158	238
18	1677	3182	304
20	1700	3223	368
22	1718	3284	422
24	1731	3397	451
26	1744	3605	467
28	1754	3875	478
30	1760	4156	487
32	1767	4405	494



W.R.I.A. 30 RM. 0.6

DATE AND FLOW MEASURED	
04-06-87	13 cfs
05-13-87	9 cfs
06-16-87	7 cfs

FLOW	SPAWNING	JUVENILE
2	14	75
4	105	204
6	564	461
8	1453	806
10	2221	1253
12	2538	1772
14	2670	2299
16	2698	2702
18	2714	2829
20	2717	2880
22	2659	2934
24	2538	3019
26	2382	3108
28	2188	3142
30	1948	2933
32	1707	2686



W.R.I.A. 30 RM. 0.6

DATE AND FLOW MEASURED

04-06-87	13 cfs
05-13-87	9 cfs
06-16-87	7 cfs

FLOW	SPAWNING	JUVENILE	ADULT
2	5	262	0
4	323	662	0
6	579	1529	0
8	659	2529	1
10	694	2935	13
12	717	3006	16
14	746	3024	23
16	775	3045	57
18	801	3041	113
20	825	3049	186
22	844	3088	214
24	855	3135	271
26	865	3328	350
28	874	3577	389
30	883	3763	440
32	890	3977	486

APPENDIX B

LITTLE KLICKITAT RIVER, LOWER SITE CALIBRATION INFORMATION

Appendix B1 IFG4 Input File Little Klickitat River, Lower Site

```
Little Klickitat River, Lower Site at RM 0.4
Q\Date Measured 145 cfs 4-6-87;81 cfs 5-14-87;32 cfs 6-17-87;16 cfs 7-15-87
IOC          0000000200000000000000
QARD       7.0
QARD      16.0
QARD      32.0
QARD      81.0
QARD     145.0
QARD     363.0
XSEC       1.0              0.0      .50     94.9      0.00000
           1.0-10.098.37          0.097.32          6.096.72      9.5    96.2    14.5    96.2    15.0      96.1
           1.0    17.5    95.3    20.0     95.2    22.5    95.3    25.0    95.2    27.5    95.1    30.0      95.2
           1.0    32.5    95.4    35.0     95.0    37.5    95.1    40.0    94.9    42.5    95.0    45.0      95.1
           1.0    47.5    95.3    50.0     95.1    52.5    95.1    55.0    95.3    57.5    95.2    60.0      95.1
           1.0    62.5    95.0    65.0     95.4    67.5    95.4    70.0    95.5    71.7    96.2    72.0      96.1
           1.0    75.0    96.5    84.2     97.0    92.2    96.6
NS         1 0     0.00     .80     0.00      .80     0.00     .80     0.00     .80     0.00     .80     0.00      .80
NS         1.0     0.00     .20     0.0068.60        0.0068.60        0.0068.60        0.0078.50        0.0078.50
NS         1.0     0.0078.50        0.0068.50        0.0068.50        0.0068.70        0.0068.70        0.0068.70
NS         1.0     0.0067.50        0.0067.50        0.0078.70        0.0078.70        0.0068.50        0.0068.50
NS         1.0     0.0068.50        0.0068.50        0.0068.50        0.00     .20     0.00     .80     0.00      .80
NS         1.0     0.00     .80     0.00      .80     0.00     .80
CAL1       1.0            96.52            145.00
VEL1       1.0                              .05      .05      .05     1.85    2.67    2.21    1.37    2.45      2.84
VEL1       1.0     1.36    3.05     3.18     2.56     3.31     2.86     2.74    2.69    2.01    2.34    2.68      2.36
VEL1       1.0     2.25    1.80     1.80      .81      .05     0.00
CAL2       1. 0    9 6.21           81.00
VEL2       1. 0                                      0.00     1.37    1.66    1.50     .28    1.34      1.89
VEL2       1.0     2.02    1.39     2.12     1.87     2.24     2.03     1.93    1.59    1.13    2.47    1.71      1.51
VEL2       1.0     1.54     .41     1.32      .24
CAL3       1.0            95.90            32.00
VEL3       1.0                                               .89     .98     .63     .11     .86      1.26
VEL3       1.0     1.21    1.21     1.87     1.56     1.66     1.25     1.41    1 23     .65    1.34     .64      1.02
VEL3       1.0      .40     .11      .33      .32
CAL4       0 1            95.73            16.00
VEL4       1.0                                               .25     .54     .35     .06     .49      .88
VEL4       1.0     1.01     .74     1.39     1.04     1.04      .53      .83     .75     .35     .90     .30      .58
VEL4       1.0      .34     .40      .23     0.00
XSEC       2.0            100.0      .50              94.9      0.00000
           2.0-15.099.68   0.0100.3                  12.0     99.8     20.0    97.4    30.0    95.7    35.0      95.1
           2.0    40.0    95.2    45.0     94.9    50.0    95.0    55.0    95.2    60.0    95.0    65.0      95.1
           2.0    67.5    95.1    70.0     95.1    72.5    95.0    75.0    94.9    77.5    94.9    80.0      94.8
           2.0    82.5    94.7    85.0     94.7    87.5    94.5    90.0    94.5    92.5    94.6    95.0      94.7
           2.0    97.5    95.2100.0        95.5102.5        96.0104.5        96.5106.5        97.7107.5        98.8
           2.0110.5100.0
NS         2.0     0.00     .80     0.00      .80     0.00     .80     0.00     .80     0.00     .60     0.00      .60
NS         2.0     0.0075.70        0.00      .60     0.00     .60     0.0051.80        0.0051.80        0.0061.80
NS         2.0     0.0076.80        0.0071.80        0.0056.50        0.0056.50        0.0067.80        0.0056.50
NS         2.0     0.0067.80        0.0078.80        0.0087.60        0.0087.60        0.0087.60        0.0087.60
NS         2.0     0.00     .60     0.0017.50        0.00     .20     0.00     .80     0.00     .80     0.00      .80
```

```
NS        2.0     0.00    .80
CAL1      2.0             96.91           145.00
VEL1      2.0                                     .53     .63     .81     .83     .92    1.11     .93    1.41
VEL1      2.0     1.15    1.20    1.00    1.23    1.54    1.56    1.44    1.35    1.20     .99    1.34    1.04
VEL1      2.0     .47     .71     .37
CAL2      2.0             96.52           81.00
VEL2      2.0                                     .00     .41     .55     .61     .57     .77     .68     .81
VEL2      2.0     .69     .68     .82.    .87     .87     .83     .85     .86     .89     .55     .73     .66
VEL2      2.0     .49     .40     .23
CAL3      2.0             96.17           32.00
VEL3      2.0                                     0.00    0.00    .33     .23     .28     .36     .24     .49
VEL3      2.0     .37     .39     .35     .54     .54     .66     .58     .58     .47     .26     .46     .37
VEL3      2.0     .17     .17     0.00
CAL4      2.0     .       95.96           16.00
VEL4      2.0                                     0.00    0.00    0.00    0.00    .10     .22     .23     .30
VEL4      2.0     .36     .27     .29     .37     .47     .27    :44     .25     .25     .35     .12     .09
VEL4      2.0     .10     .05
XSEC      3.0             70.0    .50     94.9    0.00000
          3.0-10.0100.4   0.0     98.4    10.0    95.5    15.0    95.3    20.0    95.5    25.0    95.6
          3.0     30.0    95.5    35.0    95.5    40.0    94.8    42.5    95.1    45.0    95.0    47.5    94.7
          3.0     50.0    94.7    52.5    94.6    55.0    94.6    57.5    94.4    60.0    94.1    62.5    94.0
          3.0     65.0    94.0    67.5    93:9    70.0    93.9    72.5    94.0    75.0    94.1    77.5    94.4
          3.0     80.0    95.6    83.6    96.9    85.098.95       89.0100.1       99.0102.8
NS        3.0     0.00    .80     0.00    .80     0.00    .20     0.00    .60     0.00   :60     0.00    .60
NS        3.0     0.00    .60     0.00    .60     0.00    .60     0.00    .60     0.00    .60     0.00    57.50
NS        3.0     0.0057.50       0.0057.50       0.0057.50       0.0057.50       0.0067.60       0.0067.60
NS        3.0     0.0067.60       0.0071.80       0.0071.80       0.00    .60     0.00    .60     0.00    .20
NS        3.0     0.00    .20     0.00    .80     0.00    .80     0.00    .80     0.00    .80
CAL1      3.0             96.92           145.00
VEL1      3.0                     .10     .17     .29     .38     .44     .62     .75     .85     1.09    1:20
VEL1      3.0     1.20    1.40    1.42    1.50    1.76    1.73    1.86    1.78    1.38    1.28    .72     .79
VEL1      3.0     0.00
CAL2      3.0             96.53           81.00
VEL2      3.0                     0.00    .05     .07     .00     .21     .45     .39     .45     .75     .85
VEL2      3.0     .82     .90     1.01    .75     1.00    1.22    1.36    1.04    .90     .64     .37     .51
VEL2      3.0
CAD       3.0             96.18           32.00
VED       3.0                     0.00    0.00    0.00    0.00    .05     .18     .20     .20     .29     .46
VEL3      3.0     .40     .53     .48     .30     .40     .61     .63     .54     .50     .51     .41     .13
VEL3      3.0     .05
CAL4      3.0             95.97           16.00
VEL4      3.0                     0.00    0.00    0.00    0.00    0.00    .05     .05     .05     .05     .18
VEL4      3.0     .22     .27     .27     .26     .26     .42     .40     .34     .28     .21     .24     .10
VEL4      3.0     0.00
XSEC      3.5             70.0    .50             94.9    0.00000
          3.5     10.0    99.3    0.0     97.8    5.0     97.3    10.0    96.7    15.0    96.1    20.0    95.8
          3.5     25.0    95.9    30.0    95.8    32.5    95.6    35.0    95.6    37.5    95.3    40.0    95.2
          3.5     42.5    94.8    45.0    94.5    47.5    94.4    50.0    93.7    52.5    93.2    55.0    92.6
          3.5     57.5    92.3    60.0    92.5    62.5    92.6    65.0    94.2    67.5    94.7    70.0    96.8
          3.5     73.0    99.5
```

Appendix B1 IFG4 Input File Little Klickitat River, Lower Site Continued

```
NS      3.5     0.00    .80     0.00    .80     0.00    .80     0.00    .80     0.0071.90       0.0071.90
NS      3.5     0.00    .60     0.00    .60     0.00    .60     0.00    .60     0.0056.50       0.0056.50
NS      3.5     0.0056.50       0.0056.50       0.0056.50       0.0057.50       0.0057.50       0.0057.50
NS      3.5     0.0057.50       0.0057.50       0.0086.70       0.0086.70       0.0086.70       0.0086.70
NS      3.5     0.00    .80
CAL1    3.5             96.85           145.00
VEL1    3.5                             0.00    .01     .22     .29     .61     .54     .72     .61     1.04
VEL1    3.5     1.26    1.18    1.63    1.36    1.75    2.61    2.26    1.18    .59     .02     .11
VEL1    3.5
CAL2    3.5             96.54           81.00
VEL2    3.5                                     0.00    .00     .08     .77     .24     .45     .32     .41
VEL2    3.5     .72     .73     1.25    1.11    1.28    1.51    1.33    .98     .33     0.00    .05
VEL2    3.5
CAL3    3.5             96.18           32.00
VEL3    3.5                                     0.00    0.00    .05     .25     .05     .00     .05     .12
VEL3    3.5     .17     .24     .56     .74     .69     .71     .68     .38     .10     .05     .05
VEL3    3.5
CAL4    3.5             95.98           16.00
VEL4    3.5                                             0.00    0.00    0.00    .05     0.00    .05     .05
VEL4    3.5     .09     .18     .20     .28     .19     .38     .50     .23     0.00    0.00    0.00
VEL4    3.5
XSEC    4.0             100.0   .50     96.0    0.00000
        4.0-10.0101.4   0.098.76        10.097.66       11.7    97.2    12.5    97.0    15.0    96.9
        4.0     17.5    96.8    20.0    96.6    22.5    96.3    25.0    96.3    27.5    96.2    30.0    96.4
        4.0     32.5    96.2    35.0    96.3    37.5    96.2    40.0    96.4    42.5    96.3    45.0    96.3
        4.0     47.5    96.0    50.0    96.2    52.5    96.6    55.0    96.2    57.5    96.2    60.0    96.2
        4.0     62.5    96.1    65.0    96.4    67.5    96.5    70.0    96.4    72.5    96.5    75.0    96.7
        4.0     77.5    96.8    80.0    96.8    82.5    96.6    85.0    96.7    87.0    96.8    89.0    97.0
        4.0     91.598.05101.599.55
NS      4.0     0.00    .80     0.00    .80     0.00    .80     0.00    .80     0.00    .80     0.0087.70
NS      4.0     0.0087.70       0.0078.70       0.0078.70       0.0078.70       0.0078.70       0.0078.70
NS      4.0     0.0078.90       0.0078 90       0.0078.90       0.0078.90       0.0057.50       0.0057.50
NS      4.0     0.0078.60       0.0078.60       0.0087.60       0.0087.60       0.0087.60       0.0087.60
NS      4.0     0.0087.60       0.0078.60       0.0078.60       0.0078.80       0.0078.80       0.0078.80
NS      4.0     0.0078.80       0.0078.80       0.00    .20     0.00    .80     0.00    .80     0.00    .80
NS      4.0     0.00    .80     0.00    .80
CAL1    4.0             97.20           145.00
VEL1    4.0                                     1.21    .78     2.29    3.51    3.96    1.98    3.40    3.41
VEL1    4.0     3.01    3.83    3.83    3.99    4.22    4.61    3.57    1.68    2.49    2.50    1.71    3.29
VEL1    4.0     2.17    2.60    3.25    1.64    1.23    2.11    1.47    .40     .05     .45     .30     0.00
VEL1    4.0
CAL2    4.0             97.09           81.00
VEL2    4.0                                             .00     .00     2.26    2.14    1.62    2.20    2.49
VEL2    4.0     2.61    2.99    2.14    3.06    2.71    2.99    1.97    .92     3.59    1.58    2.56    2.26
VEL2    4.0     1.94    1.38    .10     2.06    1.43    2.73    .00     1.32    .12     0.00    0.00
VEL2    4.0
CAL3    4.0             96.86           32.00
VEL3    4.0                                             1.65    .99     .45     1.98    1.38
VEL3    4.0     1.35    1.85    1.93    .89     2.04    2.20    .59     .10     .10     1.55    .99     1.09
VEL3    4.0     1.49    .35     1.39    1.38    .54     .30             .10     0.00    .10
```

Appendix B1 IFC4 Input File Little Klickitat River, Lower Site Continued

```
VEL3      4.0
CAL4      4.0          96.71          16.00
VEL4      4.0                                                  0.00  1.37   .50  1.73  1.12
VEL4      4.0    .73 1.06    1.44    .00  1.67  1.99  1.16   .13   .20   .64   .59   .95
VEL4      4.0   1.24 1.12     .23    .23   .43                       .10
VEL4      4.0
XSEC      5.0         150.0    .50        96.0   0.00000
          5.0-10.0100.0        0.0   99.2   6.4   98.5   7.5  95.3  10.0  94.9  12.5  94.7
          5.0   15.0  94.5   17.5   94.8  20.0   94.4  22.5  94.6  25.0  94.6  27.5  94.6
          5.0   30.0  94.9   32.5   95.6  35.0   95.9  37.5  96.8  40.0  96.9  42.5  96.9
          5.0   45.0  97.1   47.5   97.5  50.0   97.7  52.5  98.0  55.0  98.4  57.9  98.5
          5.0   60.0  98.9   67.0   99.4
NS        5.0   0.00   .80   0.00    .80   0.00    .80   0.00   .80  0.0087.80   0.0087.80
NS        5.0   0.0087.80   0.0087.80   0.0087.80   0.0087.80   0.0087.80   0.0078.80
NS        5.0   0.0078.80   0.0067.60   0.00    .60   0.0058.80   0.0058.80   0.00    .60
NS        5 .0  0.00   .60   0.00    .60   0.00    .80   0.00   .80   0.00   .80   0.00   .80
NS        5.0   0.00   .80   0.00    .80
CAL1      5.0          98.53         145.00
VEL1      5.0                   .33   .69   .67  1.13  1.55  1.56  1.07   .92   .75
VEL1      5.0    .73   .62    .63    .84   .52   .55   .42   .48   .32   .31   .05
VEL1      5.0
CAL2      5.0          98.30          81.00
VEL2      5.0                   .41   .68   .67   .72   .98   .82   .88   .69   .65
VEL2      5.0    .45   .47    .44    .55   .36   .40   .19   .26   .15   .14
VEL2      5.0
CAD       5.0          97.98          32.00
VED       5.0                   .06   .28   .21   .36   .45   .33   .24   .32   .30
VEL3      5.0    .09   .14    .22    .10   .18   .10  0.00  0.00  0.00
VEL3      5.0
CAL4      5.0          97.77          16.00
VELA      5.0                         .15   .13   .24   .22   .20   .25   .18   .17
VEL4      5.0    .04   .13   0.00   0.00  0.00  0.00  0.00  0.00  0.00
VEL4      5.0
ENDJ
```

Appendix B2 Summary of Calibration Details Little Klickitat River, Lower Site

Little Klickitat, Lower Site Calibration Information for Calculated Discharge

Transect Number

1	2	3	3.5	4	5

Discharge

171.6	145.1	149.2	137.5	155.9	110.1
86.6	73.0	75.6	80.2	96.1	73.3
38.6	29.8	31.8	32.2	36.3	24.6
18.8	13.7	15.6	14.4	20.0	13.0

Stage

96.52	96.91	96.92	96.85	97.20	98.53
96.21	96.52	96.53	96.54	97.09	98.30
95.90	96.17	96.18	96.18	96.86	97.98
95.73	95.96	95.97	95.98	96.71	97.77

Plotting Stage

1.620	2.010	2.020	1.950	1.200	2.530
1.310	1.620	1.630	1.640	1.090	2.300
1.000	1.270	1.280	1.280	0.860	1.980
0.830	1.060	1.070	1.080	0.710	1.770

Ratio of measured versus predicted discharge

0.986	0.950	0.962	0.940	1.069	0.934
0.994	1.056	1.045	1.056	0.959	1.121
1.068	1.054	1.037	1.085	0.913	0.950
0.956	0.945	0.960	0.929	1.067	1.005

Mean error of stage/discharge relationship for calculated Q

3.25	5.36	4.01	6.80	6.64	5.88

Mean error of stage/discharge relationship for given Q

4.93	5.78	5.84	3.07	7.05	0.18

Stage/discharge relationship (S vs Q) S=A*Q**B+SZF

A =	.3321	.5115	.4883	.5231	.3346	1.168
B =	.3072	.2721	.2814	.2639	.2563	.1620
SZF =	94.90	94.90	94.90	94.90	96.00	96.00

B coefficient log/log discharge/stage relationship

3.255	3.674	3.553	3.789	3.901	6.172

Appendix B3 Data Changes Little Klickitat River, Lower Site

Transect	2	Vertical	5	VEL2	changed 0.10	to 0.0
Transect	3	Vertical	6	VEL2	changed 0.03	to 0.0
Transect	3.5	Vertical	6	VEL2	changed 0.05	to 0.0
Transect	3.5	Vertical	8	VEL3	changed 0.05	to .25
Transect	3.5	Vertical	10	VEL3	changed 0.02	to 0.0
Transect	4	Vertical	6	VEL2	changed 0.10	to 0.0
Transect	4	Vertical	7	VEL2	changed 0.36	to 0.0
Transect	4	Vertical	16	VEL4	changed 0.29	to 0.5
Transect	4	Vertical	21	VEL4	changed 0.00	to 0.2
Transect	4	Vertical	30	VEL3	changed 0.10	to 0.3
Transect	4	Vertical	31	VEL2	changed 0.10	to 0.0
Transect	4	Vertical	32	VEL3	changed 0.00	to 0:1
Transect	5	Vertical	21	VEL1	changed 0.52	to 0.32
Transect	5	Vertical	22	VEL1	changed 0.41	to 0.31

Appendix B4 Velocity Adjustment Factors Little Klickitat River, Lower Site

Transect	Discharge	VAF
1.00	7.0	.991
1.00	16.0	1.000
1.00	32.0	1.012
1.00	81.0	1.016
1.00	145.0	1.007
1.00	363.0	.966
2.00	7.0	.838
2.00	16.0	.892
2.00	32.0	.933
2.00	81.0	.980
2.00	145.0	1.001
2.00	363.0	1.016
3.00	7.0	.897
3.00	16.0	.962
3.00	32.0	.998
3.00	81.0	1.002
3.00	145.0	.971
3.00	363.0	.850
3.50	7.0	.829
3.50	16.0	.945
3.50	32.0	.994
3.50	81.0	1.011
3.50	145.0	.995
3.50	363.0	.927
4.00	7.0	.985
4.00	16.0	.998
4.00	32.0	1.022
4.00	81.0	1.027
4.00	145.0	1.009
4.00	363.0	.925
5.00	7.0	.864
5.00	16.0	.934
5.00	32.0	.981
5.00	81.0	1.013
5.00	145.0	1.002
5.00	363.0	.910

APPENDIX C

LITTLE KLICKITAT RIVER, UPPER SITE CALIBRATION INFORMATION

Appendix C1 IFG4 Input File Little Klickitat River, Upper Site

```
Little Klickitat River Upper Site at RM 9.6
Q\Date Measured 87 cfs 4-7-87; 40 cfs 5-14-87; 12 cfs 6-16-87; 4 cfs 7-14-87
IOC          00000002000000000000
QARD      2.0
QARD      4.0
QARD     12.0
QARD     40.0
QARD     87.0
QARD    210.0
XSEC      1.0          0.0     .50          90.6 0     .00000
          1.0    0.0  93.2    1.0    93.2    3.0   92.7    5.0   92.1    7.0   92.1    9.091.65
          1.0   11.0  91.6  13.091.65        15.0   91.9   17.0   92.0   19.0   92.0   21.091.95
           .1.0 23.0  91.9  25.091.68        27.0   91.7   29.0   91.7   31.091.35     33.0     91.2
          1.0   35.090.94   37.090.73        39.0   90.6   41.090.65     43.0   92.2   45.0     91.2
          1.0   47.0  91.8  49.092.55        49.5   92.7   53.293.96
NS        1.0    0.00   .80   0.00    .80    0.00    .80    0.00    .80    0.00    .80    0.00    35 80
NS        1.0    0.0036.50   0.0035.70      0.0035.70      0.0036.70      0.0036.70      0.0037.90
NS        1.0    0.0037.90   0.0047.80      0.0047.80      0.0067.70      0.0067.70      0.0056.70
NS        1.0    0.0057.50   0.0087.80      0.0087.80      0.0087.90      0.0088.50      0.0088.50
NS        1.0    0.00   .80   0.00    .80    0.00    .80    0.00    .80
CAL1      1.0          92.70          87.24
VEL1      1.0                    .55    1.58   1.87   1.94   2.30   2.46   2.84   2.60     2.18
VEL1      1.0     .34   1.73   1.64   2.64    2.40   2.37   1.59   2.12   2.02   1.97   2.68     2.12
VEL1      1.0     .97    .05
CAL2      1.0          92.20          40.00
VEL2      1.0                   0.00    0.00    .87    .80   1.27   1.22   2.27   2.36     2.60
VEL2      1.0    1.73   0.14   1.23   2.18     .76   2.16   1.52   1.35   2.12   3.67   0.00     1.98
VEL2      1.0    0.00
CAL3      1.0          91.73          12.45
VEL3      1.0                                  0.00   0.00   0.00   0.00
VEL3      1.0    0.10   0.05          0.00     .55   1.02   1.48   1 25   1.58   1.29            1.04
VEL3      1.0
CAL4      1.0          91.49           4.33
VEL4      1.0
VEL4      1.0                                   .36    .22    .57    .77   1.08    .21             .46
VEL4      1.0
XSEC      2.0          55.0     .50          90.6     0.00000
          2.0    0.0  94.2    1.0    94.2    8.092.89       10.0   91.3   12.090.65     14.090.53
          2.0   16.090.85   18.0    90.9   20.091.23      22.091.73      24.0   92.1   26.091.95
          2.0   28.0  91.8  30.091.45        32.0   91.5   34.092.05      36.0   91.5   38.0     91.1
          2.0   40.0  91.6  42.091.19        44.090.95      46.091.03      48.0   91.2   50.092.54
          2.0   50.992.89   54.094.86
NS        2.0    0.00   .80   0.00    .80    0.00    .80    0.00    .60    0.00    .60    0.00     .60
NS        2.0    0.00   .60   0.00    .60    0.00    .60    0.0056.80     0.0054.70      0.0046.60
NS        2.0    0.0065.60   0.0096.80      0.0098.90      0.0098.90      0.0098.90      0.0098.90
NS        2.0    0.0098.90   0.0098.90      0.0098.90      0.0099.50      0.00    .20    0.00     .80
NS        2.0    0.00   .80   0.00    .80
CAL1      2.0          92.89          87.24
VEL1      2.0                    .04     .38    .79    .30    .14    .16    .26   2.34     2.51
VEL1      2.0    2.80   2.68    .58   1.50    2.54   1.95   2.00   2.63   2.23   2.17   2.05      .47
```

Appendix C1 IFG4 Input File Little Klickitat River, Upper Site Continued

```
VEL1      2.0
CAL2      2.0          92.45          40.00
VEL2      2.0                           .05     .27     .20     .16     .05    0.00    1.17    2.14    1.72
VEL2      2.0    1.64    1.30     .57     .63    1.50    1.10    1.33    1.64    1.27    1.26    1.28
VEL2      2.0
CAD       2.0          92.01          12.45
VEL3      2.0                          0.00    0.00    0.00    0.00    0.00    0.00     .01
VEL3      2.0    1.15    1.25    1.09             .74    1.64    1.20    1.17     .94     .82     .98
VEL3      2.0
CAL4      2.0          91.72           4.33
VEL4      2.0                          0.00    0.00    0.00    0.00    0.00    0.00
VEL4      2.0             .40     .41             .00     .45     .91     .73     .70     .69     .55
VEL4      2.0
XSEC      3.0          42.0     .50            91.9   0.00000
          3.0   0.096.29      7.594.16        8.093.76      10.092.76      12.0    92.2    14.0    92.8
          3.0  16.092.15     18.092.45       20.093.16      22.0    92.0   24.091.95      26.0    91.9
          3.0  28.092.17     30.0    92.4    32.092.66      34.092.85      36.093.16      38.0    93.4
          3.0  40.093.61     42.093.86       44.094.06      46.094.06      48.093.91      49.694.16
          3.0  60.096.29
NS        3.0    0.00     .80    0.00     .80    0.00     .80   0.0011.50    0.00     .60   0.0088.50
NS        3.0   0.0058.50     0.0038.50       0.0085.80      0.0068.50      0.0058.60      0.0056.80
NS        3.0   0.0056.80     0.0056.90       0.0056.90      0.0056.90      0.0045.50      0.0045.50
NS        3.0   0.0045.50     0.0015.50       0.00     .80    0.00     .80    0.00     .80    0.00     .80
NS        3.0    0.00     .80
CAL1      3.0          94.16          87.24
VEL1      3.0                           .01     .01     .33     .83    1.01    2.12    2.27    2.14    2.12    2.33
VEL1      3.0    2.19    2.58    2.37    2.35    2.21    1.64    1.35     .58     .01     .01     .08
VEL1      3.0
CAL2      3.0          93.56          40.00
VEL2      3.0                          0.00     .10     .21     .82    1.21    1.45    1.85    1.79    2.10
VEL2      3.0    2.25    2.12    1.79    1.87    1.27     .67
VEL2      3.0
CAD       3.0          93.05          12.45
VEL3      3.0                          0.00     .05     .39     .21    0.00             .81    1.17    1.35
VEL3      3.0    1.27    1.22     .93
VEL3      3.0
CAL4      3.0          92.75           4.33
VEL4      3.0                                      .10            0.00    0.00             .64     .79    1.07
VEL4      3.0     .80     .62             .41
VEL4      3.0
XSEC      4.0          30.0     50             91.9   0.00000
          4.0    1.0    96.0    5.394.21        7.0    93.2     9.0    92.8    11.0    92.2   13.092.06
          4.0  15.091.95     17.091.64       19.092.22      21.0    92.0   23.091.73      25.091.75
          4.0  27.091.73     29.091.97       31.092.15      33.092.76      35.0    93.1    37.0    93.4
          4.0  39.0    93.3  40.0    93.6    41.093.86      42.094.21      58.297.82
NS        4.0    0.00     .80    0.00     .80    0.00     .80    0.00     .80    0.00     .60   0.0091.90
NS        4.0   0.0051.80     0.0059.50       0.0081.80      0.0081.80      0.0051.80      0.0051.80
NS        4.0   0.0091.80     0.0091.80       0.00     .60   0.0011.50    0.00     .60    0.00     .60
NS        4.0    0.00     .80    0.00     .80    0.00     .80    0.00     .80    0.00     .80    0.00     .80
CAL1      4.0          94.21          87.24
```

```
VEL1    4.0                     .23     .37     .83    1.07    1.16    1.48    2.02    1.63    1.46    1.66
VEL1    4.0    1.47    1.38    1.23    1.01     .44     .61     .35     .31     .12
CAL2    4.0            93.59           40.00
VEL2    4.0                    0.00    0.00     .64     .73     .62     .92    1.11    1.27    1.27    1.02
VEL2    4.0    1.04     .87    1.07    1.19     .99    0.00     .10
CAL3    4.0            93.07           12.45
VEL3    4.0                            0.00    .05-     .50     .34     .44     .68     .61     .65     .45
VEL3    4.0     .61     .53     .54     .25
CAL4    4.0            92.76            4.33
VEL4    4.0                                     .05     .09     .09     .10     .43     .31     .34     .29
VEL4    4.0     .36     .22     .10
ENDJ
```

Appendix C2 Summary of Calibration Details Little Klickitat River, Upper Site

Upper Little Klickitat Site Calibration Information for Calculated Discharge

Transect Number	1	2	3	4
Discharge				
	97.9	85.9	88.4	76.7
	43.2	36.0	42.9	37.5
	12.0	13.4	12.0	12.3
	4.0	4.2	4.9	4.0
Stage				
	92.70	92.89	94.16	94.21
	92.20	92.45	93.56	93.59
	91.73	92.01	93.05	93.07
	91.49	91.72	92.75	92.76
Plotting Stage				
	2.100	2.290	2.260	2.310
	1.600	1.850	1.660	1.690
	1.130	1.410	1.150	1.170
	0.890	1.120	0.850	0.860
Ratio of measured versus predicted discharge				
	0.913	0.971	0.926	0.898
	1.099	0.985	1.138	1.119
`	1.100	1.130	0.963	1.104
	0.906	0.925	0.985	0.902
Mean error of stage/discharge relationship for calculated Q				
	9.52	6.03	6.35	10.60
Mean error of stage/discharge relationship for given Q				
	9.80	5.13	7.39	7.26

Stage/discharge relationship (S vs Q) S=A*Q**B+SZF

A	=	.5917	.7755	.4956	.5222
B	=	.2709	.2416	.3328	.3343
SZF	=	90.06	90.60	91.90	91.90

B coefficient log/log discharge/stage relationship

3.690	4.139	3.004	2.991

Appendix C3 Data Changes Little Klickitat River, Upper Site

Transect	1	Vertical	13	VEL3	changed	0.0	to 0.10
Transect	1	Vertical	14	VEL1	changed	1.93	to 1.73
Transect	1	Vertical	14	VEL3	changed	0.0	to 0.05
Transect	2	Vertical	5	VEL1	changed	0.18	to 0.38
Transect	2	Vertical	5	VEL2	changed	0.37	to 0.27
Transect	3	Vertical	8	VEL3	changed	0.13	to 0.00
Transect	3	Vertical	15	VEL4	changed	0.05	to 0.00
Transect	3	Vertical	16	VEL3	changed	0.21	to 0.41
Transect	4	Vertical	16	VEL3	changed	0.05	to 0.25

Appendix C4 Velocity Adjustment Factors Little Klickitat River, Upper Site

Transect	Discharge	VAF
1.00	2.0	.694
1.00	4.0	.880
1.00	12.0	1.129
1.00	40.0	1.042
1.00	87.0	.970
1.00	210.0	.939
2.00	2.0	1.056
2.00	4.0	.919
2.00	12.0	.946
2.00	40.0	.963
2.00	87.0	1.027
2.00	210.0	1.062
3.00	2.0	.823
3.00	4.0	.904
3.00	12.0	.986
3.00	40.0	.998
3.00	87.0	1.002
3.00	210.0	.980
4.00	2.0	.959
4.00	4.0	1.008
4.00	12.0	1.035
4.00	40.0	.993
4.00	87.0	.979
4.00	210.0	.927

APPENDIX D

BLOCKHOUSE CREEK CALIBRATION INFORMATION

Appendix D1 IFG4 Input File Blockhouse Creek

```
Blockhouse Creek at RM 2.5
Q/Date Measured   8.55 cfs 4-6-87, .36 cfs 5-13-87, .5 cfs 6-16-87
IOC          0000000200000000000000
QARD         .36
QARD         .50
QARD        8.55
QARD       23.0
XSEC        1.0          0.0       .67          94.46       .000
            1.0     0.095.86     1.095.86        4.095.21     5.094.81     5.594.71     6.094.71
            1.0     6.594.86     7.094.56        7.594.61     8.094.56     8.594.86     9.094.61
            1.0     9.594.76    10.094.66       10.594.61    11.094.81    11.594.91    12.094.61
            1.0    12.594.56    13.094.71       13.594.71    14.094.81    14.594.71    15.094.66
            1.0    15.594.66    16.094.51       16.594.61    17.094.51    17.594.51    18.094.61
            1.0    18.594.61    19.094.56       19.594.66    20.094.86    20.594.71    21.094.46
            1.0    22.094.61    23.095.21       25.096.06
NS          1.0     0.00   .80   0.00    .80     0.00    .20   0.00   .20   0.00   .20   0.00   .20
NS          1.0     0.00   .20   0.0089.80       0.0089.80     0.0089.80     0.0089.80     0.0089.80
NS          1.0     0.0089.80    0.0089.80       0.0089.80     0.0089.80     0.0089.80     0.0089.80
NS          1.0     0.0089.80    0.0089.80       0.0089.80     0.0089.80     0.0081.70     0.0081.80
NS          1.0     0.0081.80    0.0081.80       0.0081.80     0.0081.80     0.0081.80     0.0081.80
NS          1.0     0.0081.80    0.0081.80       0.0081.80     0.00   .20   0.00   .20   0.00   .20
NS          1.0     0.00   .20   0.00    .80     0.00    .80
CAL1        1.0          95.21          8.55
VEL1        1.0                  0.00    .01      .16    .10    .49   .76    .34   .57    .66   .64
VEL1        1.0      .75   .49    .14    .03      .42    .41    .56  1.03   1.53  1.20   1.15  1.51
VEL1        1.0     2.06  1.04   1.74   2.33     1.51   1.15   1.01   .88    .69  1.80   1.24   .31
VEL1        1.0      .97  0.00
CAL2        1.0          94.72           .50              .50
VEL2        1.0
VEL2        1.0
VEL2        1.0
VEL2        1.0
CAL3        1.0          94.68           .36              .36
VEL3        1.0
VEL3        1.0
VEL3        1.0
VEL3        1.0
XSEC        2.0          15.0      .50  95.14          0.00000
            2.0     1.097.54     4.095.94        4.595.44     5.095.29     5.595.84     6.095.34
            2.0     6.595.29     7.095.34        7.595.49     8.095.44     8.595.39     9.095.54
            2.0     9.595.39    10.095.44       10.595.44    11.095.44    11.595.84    12.095.89
            2.0    12.595.64    13.095.39       13.595.24    14.095.29    14.595.29    15.095.44
            2.0    15.595.44    16.095.39       16.595.29    17.095.14    17.595.34    18.095.24
            2.0    18.595.24    19.095.29       19.595.94    23.5   97.6
NS          2.0     0.00   .80   0:00    .10     0.0081.80     0.0081.80     0.0081.80     0.0081.80
NS          2.0     0.0081.80    0.0081.80       0.0081.80     0.0083.70     0.0078.70     0.0078.50
NS          2.0     0.0078.50    0.0078.50       0.0078.50     0.0078.50     0.0078.50     0.0078.50
NS          2.0     0.0078.50    0.0078.50       0.0078.50     0.0078.50     0.0078.50     0.0078.50
NS          2.0     0.0078.50    0.0078.50       0.0078.50     0.0073.70     0.0073.70     0.0073.70
NS          2.0     0.00   .20   0.00    .20     0.00    .20           .80
```

Appendix D1 IFG4 Input File Blockhouse Creek Continued

```
CAL1      2.0          95.94          8.55
VEL1      2.0           0.00   2.08   1.13   1.92   1.67   1.34   2.68   2.27   2.13    .45   1.56
VEL1      2.0    .66    1.02    .23 1    .12    .64    .01   1.40    .91   1.09   1.14    .88    .65
VEL1      2.0    .38    .45    1.03    .83    .85   1.02    .46    .01   0.00
CAL2      2.0          95.59          .50          .50
VEL2      2.0
VEL2      2.0
VEL2      2.0
CAL3      2.0          95.55          .36          .36
VEL3      2.0
VEL3      2.0
VEL3      2.0
XSEC      3.0          10.0    .33   95.89   0.00000
          3.0   1.096.59    2.896.59    3.096.04    3.595.99    4.096.24    4.595.99
          3.0   5.095.99    5.595.99    6.095.94    6.595.89    7.095.94    7.595.89
          3.0   8.095.99    8.596.09    9.095.94    9.596.19   10.096.14   10.596.04
          3.0  11.096.19   11.596.19   12.096.29   12.596.39   13.096.59   16.097.11
NS        3.0   0.00    .80   0.00    .80   0.0074.80   0.0074.80   0.0074.80   0.0074.80
NS        3.0   0.0074.80   0.0078.70   0.0078.70   0.0078.70   0.0078.70   0.0078.70
NS        3.0   0.0078.70   0.0078.70   0.0078.70   0.0074.70   0.0074.70   0.0074.70
NS        3.0   0.0074.70   0.00    .80   0.00    .80   0.00    .80   0.00    .80   0.00    .80
CAL1      3.0          96.59          8.55
VEL1      3.0           0.00   1.56   2.02   1.40    .15    .86   1.43   2.77    .60   1.76   2.57
VEL1      3.0    2.56   2.55   2.82   3.02   2.52   2.43   2.01   1.45   1.14    .01   0.00
CAL2      3.0          96.10          .50          .50
VEL2      3.0
VEL2      3.0
CAL3      3.0          96.06          .36          .36
VEL3      3.0
VEL3      3.0
XSEC      4.0          15.0    .60   95.89   0.00000
          4.0   1.097.28    4.496.93    5.096.73    5.596.43    6.096.43    6.596.48
          4.0   7.096.23    7.596.13    8.096.13    8.595.98    9.095.93    9.595.88
          4.0  10.095.93   10.595.73   11.095.63   11.595.58   12.095.63   12.595.68
          4.0  13.095.83   13.595.83   14.095.78   14.596.13   15.095.88   15.595.73
          4.0  16.096.08   16.595.88   17.095.98   17.596.13   18.096.13   18.596.53
          4.0  19.096.58   19.596.23   20.096.48   20.596.58   21.096.73   21.296.93
          4.0  24.597.38
NS        4.0   0.00    .80   0.00    .80   0.00    .80   0.0085.60   0.0064.70   0.0064.70
NS        4.0   0.0071.60   0.0071.60   0.0018.80   0.0018.80   0.0018.80   0.0018.80
NS        4.0   0.0018.80   0.0018.80   0.0048.80   0.0048.80   0.0048.80   0.0048.80
NS        4.0   0.0048.80   0.0048.80   0.0048.80   0.0048.80   0.0078.70   0.0078.70
NS        4.0   0.0078.70   0.0078.70   0.0078.70   0.0078.70   0.0078.70   0.0078.70
NS        4.0   0.0078.70   0.0078.70   0.0018.90   0.00    .80   0.00    .80   0.00    .80
NS        4.0   0.00    .80
CAL1      4.0          96.93          8.55
VEL1      4.0                   .82   1.35   1.57   1.58   1.20    .86    .13    .25    .36   1.29
VEL1      4.0   1.10    .49    .25    .01    .07   1.07   1.17    .38    .06    .01    .25    .70
VEL1      4.0    .77    .75    .23    .12    .35    .35    .53    .80    .88    .81    .42   0.00
VEL1      4.0
```

```
CAL2      4.0     96.48     .50     .50
VEL2      4.0
VEL2      4.0
VEL2      4.0
VEL2      4.0
CAL3      4.0     96.43     .36     .36
VEL3      4.0
VEL3      4.0
VEL3      4.0
VEL3      4.0
ENDJ
```

Appendix D2 Summary of Calibration Details Blockhouse Creek

Blockhouse Creek Calibration Information For Calculated Discharge

Transect Number	1	2	3	4
Discharge				
	8.56	8.27	9.45	7.91
	0.50	0.50	0.50	0.50
	0.36	0.36	0.36	0.36
Stage				
	95.21	95.94	96.59	96.93
	94.72	95.59	96.10	96.48
	94.68	95.55	96.06	96.43
Plotting Stage				
	0.810	0.800	0.700	1.040
	0.320	0.450	0.210	0.590
	0.280	0.410.	0.170	0.540
Ratio of measured versus predicted discharge				
	1.005	1.009	1.014	1.007
	0.961	0.941	0.913	0.951
	1.035	1.054	1.081	1.045
Mean error of stage/discharge relationship for calculated Q				
	2.63	4.10	6.13	3.37
Mean error of stage/discharge relationship for given Q				
	2.62	4.28	5.55	3.77

Stage/discharge relationship (S vs Q) S=A*Q**B+SZF

A	=	.3976	.5139	.2712	.6751
B	=	.3321	.2103	.4248	.2096
SZF	=	94.40	95.14	95.89	95.89

B coefficient log/log discharge/stage relationship

3.011	4.755	2.3541	4.77

Appendix D3 Velocity Adjustment Factors Blockhouse Creek

Transect	Discharge	VAF
1.00	0.3	1.472
1.00	0.5	1.175
1.00	8.5	.995
1.00	22.0	1.229
2.00	0.3	.295
2.00	0.5	.338
2.00	8.5	.993
2.00	22.0	1.509
3.00	0.3	1.369
3.00	0.5	1.274
3.00	8.5	.987
3.00	22.0	1.068
4.00	0.3	.166
4.00	0.5	.226
4.00	8.5	.994
4.00	22.0	1.586

APPENDIX E

BLOODGOOD CREEK CALIBRATION INFORMATION

Appendix E1 IFG4 Input File Bloodgood Creek

```
Bloodgood Creek     WRIA 30 at RM 0.5
Flow measured at 8.8 cfs on 4-2-87 and 7.2 cfs on 5-13-87
IOC          00000002000000000000
QARD      3.0
QARD      7.2
QARD      8.8
QARD     22.0
XSEC      1.            .001.00            96.09      .00300
          1.     1.0    98.0    6.0    97.0    7.5    97.0    8.0    96.1    8.5    96.1    9.0    96.2
          1.     9.5    96.1   10.0    96.1   10.5    96.2   11.0    96.2   11.5    96.3   12.0    96.3
          1.    12.5    96.3   13.0    96.3   13.5    96.2   14.0    96.2   14.5    96.3   15.0    96.2
          1.    15.5    96.2   16.0    96.3   16.5    96.4   17.0    96.5   17.5    96.6   18.0    96.6
          1.    18.5    96.5   19.0    96.7   19.3    97.0   25.8    98.1
NS        1.     .00     .8     .00     .1     .00    52.8     .00    52.8     .00    52.8     .00    52.8
NS        1.     .00    52.8     .00   52.8     .00    52.8     .00    52.7     .00    52.7     .00    52.7
NS        1.     .00    52.7     .00   52.7     .00    52.7     .00    52.7     .00    52.6     .00    52.6
NS        1.     .00    52.6     .00   22.5     .00    22.5     .00    22.5     .00    22.5     .00    22.5
NS        1.     .00    22.5     .00   22.5     .00     .8      .00     .8
CAL1      1.            96.99            8.80            9.05
VEL1      1.     .00     .00     .00     .68    1.26    1.91    1.81    1.77    1.96    1.83    1.68    1.74
VEL1      1.    1.56    1.49    1.34    1.19     .90     .83     .56     .22     .02     .00     .05     .47
VEL1      1.     .62     .02     .00     .00
CAL2      1.            96.94            7.20            7.20
VEL2      1.     .00     .00     .00     .00    00      .00     .00     .00     .00     .00     .00     .00
VEL2      1.     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
VEL2      1.     .00     .00     .00     .00
XSEC      2.            10.001.00        96.09      .00300
          2.     1.0    98.5    5.0    97.0    5.5    96.4    6.0    95.9    6.5    95.9    7.0    95.9
          2.     7.5    96.0    8.0    96.0    8.5    96.0    9.0    96.0    9.5    96.0   10.0    96.1
          2.    10.5    96.3   11.0    96.3   11.5    96.4   12.0    96.5   12.5    96.6   13.0    96.5
          2.    13.5    96.5   14.0    96.6   14.5    96.8   15.0    96.7   15.5    96.6   16.0    96.8
          2.    16.5    96.7   17.0    96.8   17.5    96.8   18.0    96.7   18.5    96.8   20.3    97.0
          2.    26.0    97.0   27.0    98.4
NS        2.     .00     .2     .00     .1     .00     .1     .00     .2     .00    27.6     .00    27.6
NS        2.     .00    27.6     .00   27.6     .00    42.6     .00    42.6     .00    42.6     .00    42.6
NS        2.     .00    42.6     .00   42.6     .00    42.6     .00    42.6     .00    42.7     .00    42.7
NS        2.     .00    42.7     .00   42.7     .00    42.7     .00    42.7     .00    42.7     .00    42.7
NS        2.     .00    22.5     .00   22.5     .00    22.5     .00    22.5     .00    22.5     .00     .8
NS        2.     .00     .8      .00     .8
CAL1      2.            97.04            8.80            8.55
VEL1      2.     .00     .00     .48     .49     .42     .47     .50     .92    1.13    1.32    1.52    1.58
VEL1      2.    1.50    1.51    1.37    1.87    1.64    1.73    1.29    1.13     .91     .79     .69     .52
VEL1      2.     .42     .36     .31     .04     .05     .00     .00     .00
CAL2      2.            96.99            7.20            7.20
VEL2      2.     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
VEL2      2.     .00     .00     .00    :00      .00     .00     .00     .00     .00     .00     .00     .00
VEL2      2.     .00     .00     .00     .00     .00     .00     .00     .00
XSEC      3.            10.00     .50            96.09      .00300
          3.     1.0    97.6    4.6    97.1    5.0    97.0    5.5    96.8    6.0    96.8    6.5    96.7
          3.     7.0    96.7    7.5    96.8    8.0    96.8    8.5    96.6    9.0    96.5    9.5    96.4
```

```
        3.   10.0  96.4  10.5  96.8  11.0  96.2  11.5  96.2  12.0  96.0  12.5  96.0
        3.   13.0  96.0  13.5  96.0  14.0  96.1  14.5  96.1  15.0  95.9  15.5  95.8
        3.   16.0  95.8  16.5  95.7  17.0  95.8  17.5  95.8  18.0  95.7  18.5  95.7
        3.   19.0  96.3  19.5  97.1  21.0  98.9
NS      3.     .00    .8   .00    .1   .00    .2   .00    .2   .00  42.7   .00  42.7
NS      3.     .00  42.7   .00  23.8   .00  23.8   .00  23.8   .00  23.8   .00  42.7
NS      3.     .00  42.7   .00  42.7   .00  42.7   .00  42.7   .00  42.7   .00  42.7
NS      3.     .00  42.7   .00  42.7   .00  42.7   .00  52.7   .00  52.7   .00  52.7
NS      3.     .00  52.7   .00  52.7   .00  52.7   .00  52.7   .00  52.7   .00  52.7
NS      3.     .00  22.5   .00    .1   .00    .8
CAL1    3.          97.11         8.80         8.96
VEL1    3.     .00    .00   .27  2.43  2.38  2.52   .02    .00   .00   .00   .00   .05
VEL1    3.     .76   1.02   .58   .20   .44   .79   .85   1.34   .84  1.38  1.98  2.24
VEL1    3.    1.03    .36   .25   .04   .07   .10   .00    .00   .00
CAL2    3.          97.05         7.20         7.20
VEL2    3.     .00    .00   .00   .00   .00   .00   .00    .00   .00   .00   .00   .00
VEL2.   3.     .00    .00   .00   .00   .00   .00   .00    .00   .00   .00   .00   .00
VEL2    3.     .00    .00   .00   .00   .00   .00   .00    .00   .00
XSEC    4.          20.00   .00  96.09  .00300
        4.     1.0   98.5   3.8  97.3   4.5  96.4   5.0   96.4   5.5  95.4   6.0  95.5
        4.     6.5   95.6   7.0  95.7   7.5  95.8   8.0   95.8   8.5  95.8   9.0  95.9
        4.     9.5   96.0  10.0  96.2  10.5  96.3  11.0   96.4  11.5  96.5  12.0  96.6
        4.    12.5   96.7  13.0  96.8  13.5        96.814.0 96.9  14.5  96.9  15.0  97.0
        4.    15.5   97.0  16.0  97.1  16.5  97.1  17.0   97.1  17.5  97.1  18.0  97.3
        4.    21.0   98.5
NS      4.     .00    .8   .00    .8   .00    .2   .00    .2   .00    .2   .00  24.9
NS      4.     .00  24.9   .00  24.9   .00  23.6   .00  23.6   .00  23.6   .00  23.6
NS      4.     .00  23.6   .00  24.6   .00  24.6   .00  24.6   .00  24.6   .00  24.6
NS      4.     .00  24.6   .00  24.6   .00  42.6   .00  42.6   .00  42.6   .00  42.6
NS      4.     .00  42.6   .00  42.6   .00  42.6   .00  42.6   .00  42.6   .00  42.6
NS      4.     .00    .8
CAL1    4.          97.30         8.80         8.80
VEL1    4.     .00    .00   .00   .00   .00   .00   .00    .00   .00   .00   .00   .00
VEL1    4.     .00    .00   .00   .00   .00   .00   .00    .00   .00   .00   .00   .00
VEL1    4.     .00    .00   .00   .00   .00   .00   .00
CAL2    4.          97.22         7.20         7.20
VEL2    4.     .00    .00   .00   .00   .00   .00   .00    .00   .00   .00   .00   .00
VEL2    4.     .00    .00   .00   .00   .00   .00   .00    .00   .00   .00   .00   .00
VEL2    4.     .00    .00   .00   .00   .00   .00   .00
ENDJ
```

Appendix E2 Summary of Calibration Details Bloodgood Creek

Bloodgood Creek Calibration Information For Calculated Discharge

Transect Number	1	2	3	4
Discharge				
	9.04	8.80	8.95	8.80
	7.20	7.20	7.20	7.20
Stage				
	96.99	97.04	97.11	97.30
	96.94	96.99	97.05	97.72
Plotting Stage				
	0.900	0.950	1.020	1.210
	0.850	0.900	0.960	1.130

Stage/discharge relationship (S vs Q) S=A*Q**B+SZF

A	=	.5184	.5287	.5551	.5765
B	=	.2505	.2694	.2775	.3909
SZF	=	96.09	96.09	96.09	96.09

B coefficient log/log discharge/stage relationship

3.991	3.711	3.6031	2.993

Appendix E3 Velocity Adjustment Factors Bloodgood Creek

Transect	Discharge	VAF
1.00	3.0	.548
1.00	7.2	.891
1.00	8.8	1.000
1.00	22.0	1.685
2.00	3.0	.790
2.00	7.2	.956
2.00	8.8	.999
2.00	22.0	1.238
3.00	3.0	.587
3.00	7.2	.906
3.00	8.8	.993
3.00	22.0	1.489
4.00	3.0	.298
4.00	7.2	.442
4.00	8.8	.478
4.00	22.0	.662

APPENDIX F

BOWMAN CREEK CALIBRATION INFORMATION

Appendix F1 IFG4 Input File Bowman Creek

```
Bowman Creek at RM. 3.4
Q\Date Measured 27.4 cfs 4-3-87, 13.9 cfs 5-13-67, 5 cfs 6-16-87, .7 cfs 7-14-87
IOC        0000000200000000000
QARD     0.7
QARD     4.8
QARD    13.9
QARD    27.4
QARD    66.0
XSEC     1.0          0.0     .67          88.8     .00000
         1.0   1.092.78     5.090.45     5.589.95     6.089.55     6.589.45     7.0 89.3
         1.0   7.589.25     8.089.15     8.589.15     9.089.55     9.589.05    10.0 89.1
         1.0  10.588.85    11.0 89.0    11.589.05    12.0  88.9   12.5  88.9   13.088.95
         1.0  13.5  89.2   14.0  89.2   14.5  89.2   15.089.25    15.5  89.2   16.089.35
         1.0  16.589.35    17.089.35    17.589.45    18.0  89.6   18.5  89.6   19.090.45
         1.0  23.392.98
NS       1.0   0.00  .80    0.00  .80    0.00  .80    0.0081.90    0.0081.90    0.0081.90
NS       1.0   0.0081.90    0.0081.90    0 0081.90    0.0082.80    0.0082.80    0.0082.80
NS       1.0   0.0082.80    0.0082.80    0.0082.80    0.0082.80    0.0082.80    0.0082.80
NS       1.0   0.0082.80    0.0082.80    0.0088.50    0.00  .20    0.00  .20    0.00  .20
NS       1.0   0.00  .20    0.00  .20    0.00  .80    0.00  .80    0.00  .80    0.00  .80
NS       1.0   0.00  .80
CAL1     1.0        90.45        27.46
VEL1     1.0                     .28   .14   .04   .35   .55   .37  1.67  1.67  2.42
VEL1     1.0   1.78  2.03   2.27  3.39   3.32  2.41   2.24  2.43   2.98  2.76  2.39  2.06
VEL1     1.0   1.46  1.50   1.29   .59    .14
CAL2     1.0        90.20        13.90        13.90
VEL2     1.0
VEL2     1.0
VEL2     1.0
CAL3     1.0        89.92         4.80         4.80
VEL3     1.0
VEL3     1.0
VEL3     1.0
CAL4     1.0        89.48         0.71         0.71
VEL4     1.0
VEL4     1.0
VEL4     1.0
XSEC     2.0        15.0     .50    90.16     0.00000
         2.0   1.093.39     5.192.07     5.591.86     6.091.66     6.591.36     7.091.41
         2.0   7.591.21     8.091.31     8.591.51     9.091.41     9.591.41    10.091.26
         2.0  10.591.26    11.090.96    11.591.06    12.091.06    12.590.96    13.090.46
         2.0  13.590.16    14.090.66    14.590.26    15.090.26    15.590.36    16.091.36
         2.0  16.591.66    17.091.86    17.591.86    18.092.06    25.694.43
NS       2.0   0.00  .80    0.00  .80    0.00  .20    0.00  .20    0.0056.80    0.0056.80
NS       2.0   0.0056.80    0.0086.60    0.0086.60    0.0086.60    0.0086.60    0.0086.60
NS       2.0   0.0086.60    0.0086.60    0.0086.60    0.0086.60    0.0086.60    0.0086.60
NS       2.0   0.0086.60    0.0086.60    0.0086.60    0.0086.60    0.0088.50    0.00  .20
NS       2.0   0.00  .20    0.00  .80    0.00  .80    0.00  .80    0.00  .80
CAL1     2.0        92.06        27.46
VEL1     2.0              .01   .02   .83  2.03   1.50  1.59   1.69  1.98  3.63  1.06
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```
VEL1      2.0     3.19    2.64    5.05    3.98    3.72    3.29    1.02    1.90    2.62    2.88    1.09    4.12
VEL1      2.0     3.51     .70     .62
CAL2      2.0            91.80           13.90           13.90
VEL2      2.0
VEL2      2.0
VEL2      2.0
CAL3      2.0            91.57            4.80            4.80
VEL3      2.0
VEL3      2.0
VEL3      2.0
CAL4      2.0            91.19            0.71            0.71
VEL4      2.0
VEL4      2.0
VEL4      2.0
XSEC      3.0            10.0     .33   91.08    0.00000
          3.0    1.093.58        5.092.63        5.591.93        6.091.73        6.591.73        7.091.63
          3.0    7.591.58        8.091.53        8.591.58        9.091.28        9.591.48       10.091.28
          3.0   10.591.28       11.091.23       11.591.18       12.091.48       12.591.58       13.091.18
          3.0   13.591.18       14.091.08       14.591.38       15.091.23       15.591.33       16.091.53
          3.0   16.592.33       17.092.38       17.591.93       18.092.03       18.592.03       19.092.13
          3.0   19.592.48       20.092.58       20.292.63       28.394.47
NS        3.0    0.00     .80    0.00     .80    0.00     .20    0.0081.80       0.0081.80       0.0081.80
NS        3.0    0.0081.80       0.0081.80       0.0081.80       0.0081.80       0.0081.80       0.0081.80
NS        3.0    0.0081.80       0.0081.80       0.0081.80       0.0081.80       0.0081.80       0.0081.80
NS        3.0    0.0081.80       0.0081.80       0.0081.80       0.0081.80       0.0081.80       0.00     .50
NS        3.0    0.0011.50       0.0011.50       0.0011.50       0.00     .20    0.00     .20    0.00     .80
NS        3.0    0.00     .80    0.00     .80    0.00     .80    0.00     .80
CAL1      3.0            92.63           27.46
VEL1      3.0                     .68    1.17    1.21     .96    1.09    1.23    1.41    2.32    2.89    3.24
VEL1      3.0     3.04    2.82    2.48    2.79    2.60    1.92    2.34    1.97    1.49    1.32    1.18     .91
VEL1      3.0      .85     .54     .61     .74    1.09     .48     .15    0.00
CAL2      3.0            92.38           13.90           13.90
VEL2      3.0
VEL2      3.0
VEL2      3.0
CAL3      3.0            92.10            4.80            4.80
VEL3      3.0
VEL3      3.0
VEL3      3.0
CAL4      3.0            91.80            0.71            0.71
VEL4      3.0
VEL4      3.0
VEL4      3.0
XSEC      4.0            15.0     .60    91.4    0.00000
          4.0    1.095.39        8.593.12        9.093.02        9.592.92       10.092.87       10.592.72
          4.0   11.092.52       11.592.32       12.092.12       12.592.02       13.091.82       13.591.87
          4.0   14.091.72       14.591.52       15.091.62       15.591.47       16.091.62       16.591.67
          4.0   17.091.72       17.591.67       18.091.62       18.591.67       19.091.77       19.591.67
          4.0   20.091.82       20.592.02       21.092.07       21.293.12       24.894.24
NS        4.0    0.00     .80    0.00     .80    0.00     .80    0.00     .80    0.00     .80    0.0011.50
```

Appendix F1 IFG4 Input File Bowman Creek Continued

```
NS      4.0   0.0011.50   0.0011.50   0.0011.50   0.0019.50   0.0019.50   0.0027.50
NS      4.0   0.0092.60   0.0092.60   0.0092.60   0.0028.50   0.0028.50   0.0082.80
NS      4.0   0.0082.80   0.0082.80   0.0082.80   0.0082.80   0.0082.80   0.0082.80
NS      4.0   0.00   .80   0.00   .80   0.00   .80   0.00   .80   0.00   .08
CAL1    4.0         93.12         27.46
VEL1    4.0                .01    .01    .26    .25    .37    .46    .49    .62    .85    1.47
VEL1    4.0   1.72   2.08   2.59   2.75   3.85   4.07   3.36   3.50   3.21   2.48   2.34   1.71
VEL1    4.0    .64    .01    .01
CAL2    4.0         92.89         13.90         13.90
VEL2    4.0
VEL2    4.0
VEL2    4.0
CAL3    4.0         92.37          4.80          4.80
VEL3    4.0
VEL3    4.0
VEL3    4.0
CAL4    4.0         92.05          0.71          0.71
VEL4    4.0
VEL4    4.0
VEL4    4.0
ENDJ
```

Appendix F2 Summary of Calibration Details Bowman Creek

Bowman Creek Calibration Information For Calculated Discharge

Transect Number	1	2	3	4
Discharge				
	27.73	27.74	26.70	27.65
	13.90	13.90	13.90	13.90
	4.80	4.80	4.80	4.80
	0.71	0.71	0.71	0.71
Stage				
	90.45	92.06	92.63	93.12
	90.20	91.80	92.38	92.89
	89.92	91.57	92.10	92.37
	89.48	91.19	91.80	92.05
Plotting Stage				
	1.650	1.900	1.550	1.720
	1.400	1.640	1.300	1.490
	1.120	1.410	1.020	0.970
	0.680	1.030	0.720	0.650
Ratio of measured versus predicted discharge				
	1.040	0.921	0.887	1.010
	1.029	1.130	1.066	0.850
	0.895	0.980	1.167	1.369
	1.044	0.981	0.906	0.852
Mean error of stage/discharge relationship for calculated Q				
	5.66	6.04	10.92	15.77
Mean error of stage/discharge relationship for given Q				
	.54	6.25	10.09	15.64

Stage/discharge relationship. (S vs Q) S=A*Q**B+SZF

A	=	.7464	1.0861	.7578	.6836
B	=	.2416	.1642	.2102	.2787
SZF	=	8.80	90.16	91.08	91.40

B coefficient log/log discharge/stage relationship

4.139	6.089	4.757	3.588

Appendix F3 Velocity Adjustment Factors Bowman Greek

Transect	Discharge	VAF
1.00	.7	.220
1.00	4.8	.440
1.00	13.9	.705
1.00	27.4	.975
1.00	66.0	1.514
2.00	.7	.202
2.00	4.8	.483
2.00	13.9	.761
2.00	27.4	1.041
2.00	66.0	1.609
3.00	.7	.172
3.00	4.8	.432
3.00	13.9	.746
3.00	27.4	1.063
3.00	66.0	1.699
4.00	.7	.271
4.00	4.8	.487
4.00	13.9	.743
4.00	27.4	.992
4.00	66.0	1.468

APPENDIX G

MILL CREEK CALIBRATION INFORMATION

Appendix G1 IFG4 Input File Mill Creek

```
Mill Creek at RM. 3.7
Q/DateMeasured 22 cfs 4-2-87, 12 cfs 5-13-87, 7 cfs 6-16-87, 3 cfs 7/8 7
IOC          00000002000000000000
QARD      1.0
QARD      3.0
QARD      7.0
QARD     12.0
QARD     22.0
QARD     57.0
XSEC      1.0          0.0     .67    90.05          0.00000
          1.0    1.094.73     3.092.26       4.590.08       5.090.06       5.590.05       6.090.11
          1.0    6.59.0.14    7.090.15       8.090.24       9.090.33      10.090.58      11.090.74
          1.0   12.090.83    13.091.13      14.091.41      14.591.75      15.091.75      16.092.76
          1.0   16.392.26    19.593.41
NS        1.0    0.00   .80   0.00   .80    0.00   .10    0.0011.50      0.0011.50      0.0014.50
NS        1.0    0.0014.50    0.0014.80      0.0022.50      0.0022.50      0.0022.50      0.0022.50
NS        1.0    0.0022.50    0.00   .20    0.00   .20    0.00   .20    0.00   .20    0.00   .20
NS        1.0    0.00   .20   0.00   .80    0.00   .80    0.00   .80
CAL1      1.0          92.26          22.60
VEL1      1.0          0.00   1.39    .01    1.59   1.42   1.62   1.49   1.45   1.31   1.49   1.40
VEL1      1.0     .24   .31    .06    .09    .02   0.00   0.00
CAL2      1.0          91.74          11.70          11.70
VEL2      1.0
VEL2      1.0
CAL3      1.0          91.51           6.80           6.80
VEL3      1.0
VEL3      1. 0
CAL4      1.0          91.28           3.30           3.30
VEL4      1.0
VEL4      1.0
XSEC      2.0   15.0   .50          90.09    0.00000
          2.0    1.095.98     4.092.29       4.592.29       5.090.79       5.590.69       6.090.59
          2.0    6.590.54     7.090.39       7.590.29       8.090.29       8.590.19       9.090.09
          2.0    9.590.09    10.090.14      11.090.19      12.090.29      13.090.59      14.090.84
          2.0   15.091.09    16.091.19      17.091.09      18.091.59      19.092.24      19.392.29
          2.0   20.092.41
NS        2.0    0.00   .80   0.00   .80    0.00   .10    0.00   .20    0.00   .20    0.00   .20
NS        2.0    0.00   .20   0.0056.80      0.0056.80      0.0056.80      0.0056.80      0.0056.80
NS        2.0    0.0022.50    0.0022.50      0.0022.50      0.0022.50      0.0022.50      0.0022.50
NS        2.0    0.0022.50    0.00   .20    0.00   .20    0.00   .20    0.00   .20    0.00   .20
NS        2.0    0.00   .80
CAL1      2.0          92.29          22.60
VEL1      2.0          0.00   0.00   0.00    .01    .07    .04    .67    .94   1.33   1.27   1.23
VEL1      2.0    1.15   1.09   1.01   1.01   1.05   85     .51    .23    .14   0.00    .05   0.00
VEL1      2.0
CAL2      2.0          91.74          11.70          11.70
VEL2      2.0
VEL2      2.0
VEL2      2.0
CAL3      2.0          91.51           6.80           6.80
```

```
VEL3     2.0
VEL3     2.0
VEL3     2.0
CA14     2.0   91.28   3.30   3.30
VEL4     2.0
VEL4     2.0
VEL4     2.0
XSEC     3.0          10.0    .33          90.09   0.00000
         3.0   1.095.71     6.0   92.3   6.592.05        7.0   91.8    7.5   91.7   8.091.55
         3.0   8.5   90.9   9.0   90.5   9.590.25       10.0   90.2   10.5   90.1  11.090.05
         3.0  11.590.05    12.0   90.1   12.5   90.1    13.0   90.1  14.090.15     15.0     90.4
         3.0  16.090.65    17.090.08     18.091.05      19.0   91.4   20.0   91.8   21.0     92.0
         3.0  22.0   92.1  22.5   92.3   24.592.99
NS       3.0   0.00    .80   0.00    .80   0.0011.50      0.0011.50      0.0011.50      0.0011.50
NS       3.0   0.0011.50    0.0043.80     0.0043.80      0.0022.50      0.0022.50      0.0022.50
NS       3.0   0.0022.50    0.0022.50     0.0023.80      0.0023.80      0.0023.80      0.0022.50
NS       3.0   0.0022.50    0.0022.50     0.0011.50      0.0011.50      0.0011.50      0.00     .20
NS       3.0   0.00    .20   0.00    .20   0.00    .80
CAL1     3.0          92.30          22.60
VEL1     3.0                  .42    .82   1.01   1.34   1.49   1.55   1.77   1.95   1.59     1.67
VEL1     3.0   1.64   1.52   1.30   1.23   1.24   1.05    .89    .48    .17    .09    .40      .25
VEL1     3.0   0.00   0.00
CAL2     3.0          91.75          11.70          11.70
VEL2     3.0
VEL2     3.0
VEL2     3.0
CAL3     3.0          91.52           6.80           6.80
VEL3     3.0
VEL3     3.0
VEL3     3.0
CAL4     3.0          91.29           3.30           3.30
VEL4     3.0
VEL4     3.0
VEL4     3.0
XSEC     4.0          15.0    .60   90.09   0.00000
         4.0   1.094.94     5.0   92.3   6.3    92.3    7.0   91.0    8.0   91.3   9.0      91.2
         4.0   9.5   91.1  10.090.95     10.5   90.9   11.0   90.8   11.5   90.8  12.090.75
         4.0  12.5   90.8  13.0   90.8   13.5   90.9   14.0   91.1   14.5   91.3  15.091.25
         4.0  15.5   91.1  16.0   91.1   16.5   91.1   17.091.15     17.5   91.1  18.091.05
         4.0  19.091.05    20.0   91.4   21.0   91.3   22.091.75     23.0   91.7   24.0     91.5
         4.0  25.0   91.5  26.0   91.4   27.0   91.8   27.5   92.3   29.393.78
NS       4.0   0.00    .80   0.00    .80   0.00    .10   0.0011.50      0.0011.50      0.0013.80
NS       4.0   0.0013.80    0.0013.80     0.0041.80      0.0041.80      0.0041.80      0.0041.80
NS       4.0   0.0041.80    0.0041.80     0.0041.80      0.00    .60    0.0045.80      0.0045.80
NS       4.0   0.0045.80    0.0045.80     0.0045.80      0.0045.80      0.0045.80      0.00     .20
NS       4.0   0.00    .20   0.00    .20   0.00    .20   0.00    .20   0.00    .20    0.0011.50
NS       4.0   0.0011.50    0.0011.50     0.00    .10   0.00    .80   0.00    .80
CAL1     4.0          92.30          22.60
VEL1     4.0                          .59    .79    .99    .93    .96   1.09   1.48   1.76     2.19
VEL1     4.0   2.53   2.73   2.20   1.61   .92 1  .89   2.06   1.80   1.65   1.98   1.71     1.32
```

```
VEL1    4.0    1.07    .31    .14    .06    .20    .26    .31    .61    .53    0.00
CAL2    4.0           91.77          11.70          11.70
VEL2    4 . 0
VEL2    4.0
VEL2    4.0
CAL3    4.0           91.53           6.80           6.80
VEL3    4.0
VEL3    4.0
VEL3    4.0
CAL4    4.0           91.29           3.30           3.30
VEL4    4.0
VEL4    4.0
VEL4    4.0
ENDJ
```

Appendix G2 Summary of Calibration Details Mill Creek

Mill Creek Calibration Information for Calculated Discharge

Transect Number	1	2	3	4
Discharge				
	20.0	16.9	25.6	25.8
	11.7	11.7	11.7	11.7
	6.8	6.8	6.8	6.8
	3.3	3.3	3.3	3.3
Stage				
	92.26	92.29	92.30	92.30
	91.74	91.74	91.75	91.77
	91.51	91.51	91.52	91.53
	91.28	91.28	91.29	91.29
Plotting Stage				
	2.12	2.20	2.21	2.21
	1.69	1.65	1.66	1.68
	1.46	1.42	1.43	1.44
	1.23	1.19	1.20	1.20
Ratio of measured versus predicted discharge				
	.894	.860	.934	.947
	1.182	1.268	1.105	1.076
	1.074	1.091	1.055	1.048
	.880	.841	.918	.936
Mean error of stage/discharge relationship for calculated Q				
	11.95	16.17	7.68	6.01
Mean error of stage/discharge relationship for given Q				
	9.49	10.21	10.25	8.80

Stage/discharge relationship (S vs Q) S=A*Q**B+SZF

A	=	.7981	.7059	.8173	.8237
B	=	.3273	.3820	.3002	.2987
SZF	=	90.05	90.09	90.09	90.09

B coefficient log/log discharge/stage relationship

3.005	2.617	3.330	3.347

Appendix G3 Velocity Adjustment Factors Mill Creek

Transect	Discharge	VAF
1.00	1.0	.461
1.00	3.3	.618
1.00	6.8	.755
1.00	9.0	.819
1.00	11.7	.886
1.00	22.6	1.087
1.00	57.0	1.442
2.00	1.0	.668
2.00	3.3	.805
2.00	6.8	.906
2.00	9.0	.952
2.00	11.7	.998
2.00	22.6	1.137
2.00	57.0	1.376
3.00	1.0	.265
3.00	3.3	.447
3.00	6.8	.620
3.00	9.0	.702
3.00	11.7	.787
3.00	22.6	1.031
3.00	57.0	1.465
4.00	1.0 1	2.143
4.00	3.3	1.873
4.00	6.8	1.188
4.00	9.0	1.097
4.00	11.7	1.051
4.00	22.6	1.048
4.00	57.0	1.218

APPENDIX H

SPRING CREEK CALIBRATION INFORMATION

Appendix H1 IFG4 Input File Spring Creek

```
Spring Creek at RM. 0.6
Q/DATE MEASURED 12.9 cfs 4-6-87, 8.7 cfs 5-13-87, 6.7 cfs 6-16-87
IOC          0000000200000000000000
QARD      2.0
QARD      6.7
QARD      8.7
QARD     13.0
QARD     32.0
XSEC      1.0          0.0     .67          92.4     0.00000
          1.0   1.095.13     17.0    94.1    17.5    93.4    18.0    93.1    18.5    92.9    19.0    92.9
          1.0   19.5   92.9  20.092.85       20.592.75       21.0    92.7    21.5    92.8    22.0    92.8
          1.0   22.5   92.8  23.092.85       23.5    92.9    24.092.85       24.592.65       25.092.65
          1.0   25.5   92.7  26.0    92.7    26.5    92.5    27.0    92.4    27.592.55       28.0    92.6
          1.0   28.5   92.6  29.092.65       29.592.75       30.092.85       30.5    93.0    31.093.25
          1.0   32.0   93.7  33.0    94.1    36.295.12
NS        1.0    0.00    .80   0.00    .80   0.0011.50       0.0011.50       0.0011.50       0.0052.60
NS        1.0    0.0052.60     0.0052.60     0.0052.60       0.0052.60       0.0052.60       0.0052.60
NS        1.0    0.0052.60     0.0026.50     0.0026.50       0.0026.50       0.0026.50       0.0026.50
NS        1.0    0.0026.50     0.0026.50     0.0062.50       0.0062.50       0.0062.50       0.0065.50
NS        1.0    0.0065.50     0.0065.50     0.0028.50       0.0028.50       0.0028.50       0.0028.50
NS        1.0    0.0022.50     0.0022.50     0.00    .80
CAL1      1.0         94.10         12.97
VEL1      1.0          0.00     .01     .13     .34     .59     .76     .81     .75     .77     .80     .81
VEL1      1.0     .76     .80     .78     .78     .74     .86     .96     .91     .79     .73     .80     .77
VEL1      1.0     .71     .77     .72     .45     .15     .02    0.00    0.00
CAL2      1.0         93.66         8.70          8.70
VEL2      1.0
VEL2      1.0
VEL2      1.0
CAL3      1.0         93.40         6.70          6.70
VEL3      1.0
VEL3      1.0
VEL3      1.0
XSEC      2.0   15.0     .50         92.85   0.00000
          2.0   1.094.88      10.8    94.1    11.593.65       12.0    93.5    12.593.35       13.0    93.3
          2.0   13.5   93.2  14.093.15       14.5    93.2    15.0    93.1    15.5    93.1    16.093.05
          2.0   16.593.05     17.0    93.1    17.5    93.0    18.092.95       18.5    92.9    19.0    92.9
          2.0   19.5   92.9  20.092.95       20.5    92.9    21.0    92.9    21.5    92.9    22.092.92
          2.0   22.5   92.9  23.0    92.9    23.5    92.9    24.0    93.0    24.5    92.9    25.0    93.0
          2.0   25.5   93.0  26.092.95       26.592.85       27.0    92.9    27.5    92.9    28.0    92.9
          2.0   28.5   92.9  29.092.97       30.093.07       31.093.05       32.093.15       33.093.42
          2.0   34.093.42    35.093.67       36.0    93.9            36.5    94.1            40.094.97
NS        2.0    0.00    .80   0.00    .80   0.00    .20   0.0022.50       0.0022.50       0.0022.50
NS        2.0    0.0062.60     0.0062.60     0.0062.60       0.0025.60       0.0025.60       0.0025.60
NS        2.0    0.0025.60     0.0025.60     0.0026.60       0.0026.60       0.0026.60       0.0026.60
NS        2.0    0.0026.60     0.0026.60     0.0026.60       0.0026.60       0.0026.60       0.0026.60
NS        2.0    0.0026.60     0.0026.60     0.0025.60       0.0025.60       0.0025.60       0.0026.60
NS        2.0    0.0026.60     0.0026.60     0.0026.60       0.0026.60       0.0026.60       0.0025.60
NS        2.0    0.0022.50     0.0022.50     0.0022.50       0.0022.50       0.0022.50       0.0022.50
NS        2.0    0.0022.50     0.0022.50     0.0022.50       0.00    .80     0.00    .80
```

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CAL1    2.0        94.10        12.97
VEL1    2.0                0.00     .01     .04     .26     .45     .74     .89     .61     .53     .68
VEL1    2.0    .63     .61     .54     .45     .30     .29     .31     .36     .57     .70     .67     .66
VEL1    2.0    .80     .98     .78     .80     .96    1.16     .85     .82     .93     .98     .90     .58
VEL1    2.0    .10     .01    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
CAL2    2.0        93.67        8.70        8.70
VEL2    2.0
VEL2    2.0
VEL2    2.0
VEL2    2.0
CAL3    2.0        93.42        6.70        6.70
VEL3    2.0
VEL3    2.0
VEL3    2.0
VEL3    2.0
XSEC    3.0        10.0     .33        92.85    0.00000
        3.0    1.095.22    5.594.17    6.093.47    6.593.47    7.093.27    7.592.92
        3.0    8.092.67    8.592.57    9.092.57    9.592.57   10.092.42   10.592.32
        3.0   11.092.32   11.592.52   12.092.47   12.592.47   13.092.67   13.592.67
        3.0   14.092.82   14.592.77   15.093.02   15.594.12   16.094.17    25.6    94.9
NS      3.0    0.00    .80    0.00    .80    0.0022.50    0.0022.50    0.0022.50    0.0022.50
NS      3.0    0.00    .20    0.0062.50    0.0062.50    0.0062.50    0.0062.50    0.0062.50
NS      3.0    0.0062.50    0.0062.50    0.0062.50    0.0062.60    0.0062.60    0.0062.60
NS      3.0    0.0062.60    0.0062.60    0.0062.60    0.0062.60    0.0062.60    0.00    .80
CAL1    3.0        94.17        12.97
VEL1    3.0            0.00    0.00     .01     .04     .37     .87    1.11    1.34    1.51    1.44    1.17
VEL1    3.0    1.12    1.27    1.17    1.22    1.27    1.09     .89     .80     .68    0.00    0.00
CAL2    3.0        93.80        8.70        8.70
VEL2    3.0
VEL2    3.0
CAL3    3.0        93.64        6.70        6.70
VEL3    3.0
VEL3    3.0
XSEC    4.0        15.0     .60        92.85    0.00000
        4.0    1.095.62    8.094.18    8.593.18    9.092.88    9.592.88   10.092..98
        4.0   10.593.13   11.092.88   11.592.88   12.093.08   12.592.88   13.092..83
        4.0   13.592.98   14.092.93   14.593.13   15.093.33   15.593.13   16.093.08
        4.0   16.593.28   17.093.38   17.593.33   18.093.13   18.593.18   19.093.18
        4.0   19.593.18   20.094.18   28.794.78
NS      4.0    0.00    .80    0.00    .20    0.0052.60    0.0052.60    0.0052.60    0.0052.60
NS      4.0    0.0052.60    0.0052.60    0.0052.60    0.0052.60    0.0052.60    0.0052.60
NS      4.0    0.0052.60    0.0054.60    0.0054.60    0.0054.60    0.0025.60    0.0025.60
NS      4.0    0.0025.60    0.0025.60    0.0025.60    0.0025.60    0.0025.60    0.0025.60
NS      4.0    0.0025.60    0.00    .80    0.00    .80
CAL1    4.0        94.18        12.97
VEL1    4.0            0.00     .63    1.02     .98    1.02    1.08    1.04     .96     .77    1.06     .88
VEL1    4.0    1.22    1.72    1.83    1.94    1.75    1.02    1.77    1.42    1.15     .83     .84     .49
VEL1    4.0     .36    0.00
CAL2    4.0        93.82        8.70        8.70
VEL2    4.0
```

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VEL2    4.0
VEL2    4.0
CAL3    4.0          93.67          6.70          6.70
VEL3    4.0
VEL3    4.0
VEL3    4.0
ENDJ
```

Appendix H2 Summary of Calibration Details Spring Creek

Spring Creek Calibration Information For Calculated Discharge

Transect Number	1	2	3	4
Discharge				
	12.48	11.75	13.73	13.90
	8.70	8.70	8.70	8.70
	6.70	6.70	6.70	6.70
Stage				
	94.10	94.10	94.17	94.18
	93.66	93.67	93.80	93.82
	93.40	93.42	93.64	93.67
Plotting Stage				
	1.700	1.250	1.320	1.330
	1.260	0.820	0.950	0.970
	1.000	0.570	0.790	0.820
Ratio of measured versus predicted discharge				
	1.003	1.000	0.999	0.998
	0.994	1.001	1.002	1.005
	1.004	1.000	0.994	0.997
Mean error of stage/discharge relationship for calculated Q				
	0.43	0.05	0.15	0.33
Mean error of stage/discharge relationship for given Q				
	1.17	1.99	1.03	1.37

Stage/discharge relationship (S vs Q) S=A*Q**B+SZF

A	=	.1986	.0398	.2021	.2314
B	=	.8516	1.398	0.716	.6639
SZF	=	92.40	92.85	92.85	92.85

B coefficient log/log discharge/stage relationship

1.174	0.715	1.396	1.506

Appendix H3 Velocity Adjustment Factors Spring Creek

Transect	Discharge	VAF
1.00	2.0	11.720
1.00	6.7	1.745
1.00	8.7	1.361
1.00	13.0	.990
1.00	32.0	.562
2.00	2.0	30.072
2.00	6.7	2.602
2.00	8.7	1.728
2.00	13.0	.975
2.00	32.0	.309
3.00	2.0	.685
3.00	6.7	.958
3.00	8.7	.985
3.00	13.0	1.000
3.00	32.0	.815
4.00	2.0	3.636
4.00	6.7	1.400
4.00	8.7	1.207
4.00	13.0	1.004
4.00	32.0	.686

APPENDIX I

TRANSECT WEIGHTING

Appendix I Transect Weighting

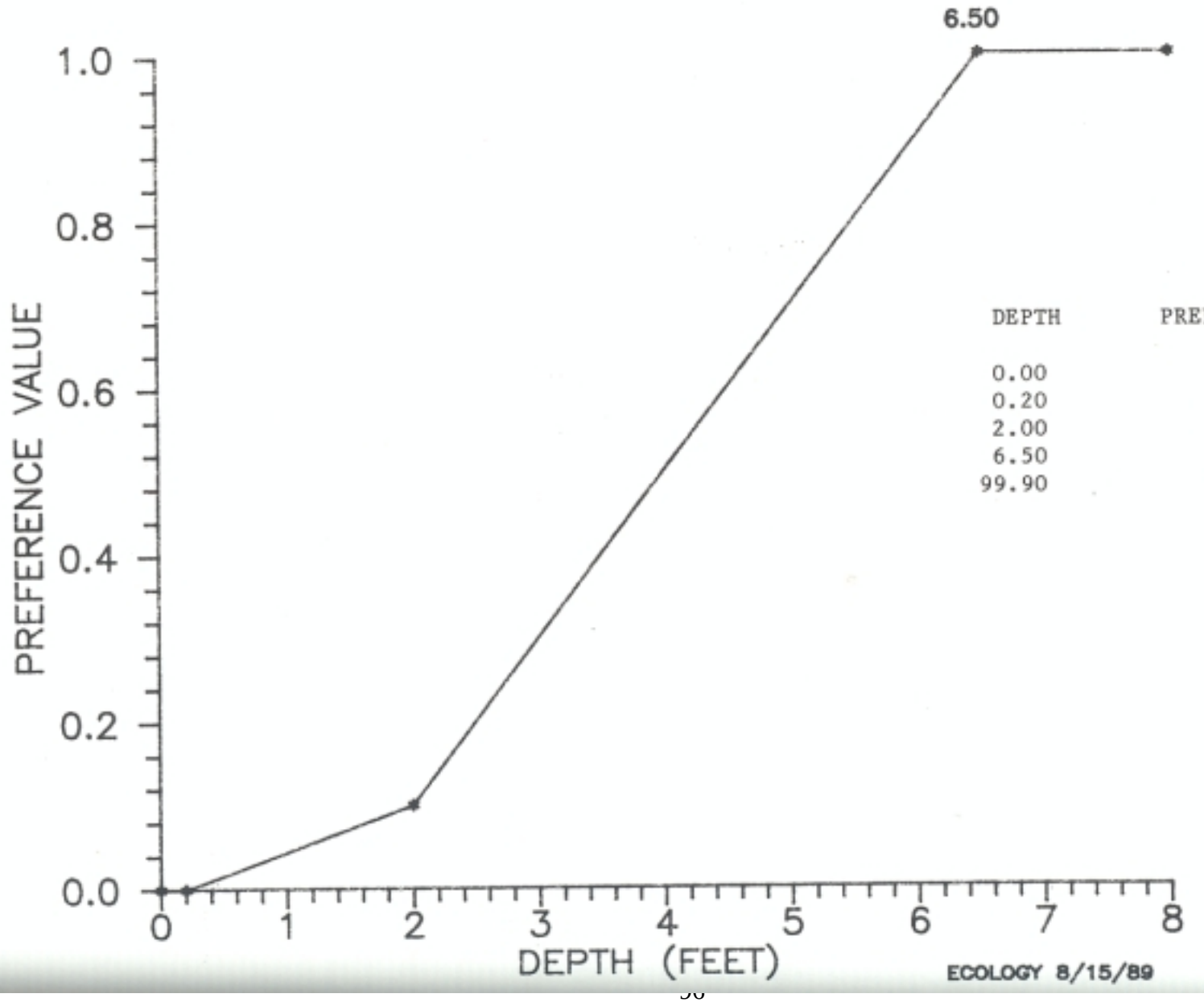
Transect Weighting As A Percent of Total Reach

	Transect Number					
Site	1	2	3	3.5	4	5
Lower L. Klickitat	10.2	17.3	14.3	17.3	25.5	15.3
Upper L. Klickitat	21.7	38.2	28.3	11.8		
Blockhouse Creek	25.1	24.9	24.9	25.1		
Bloodgood Creek	25.0	25.0	25.0	25.0		
Bowman Creek	25.1	24.9	24.9	25.1		
Mill Creek	25.1	24.9	24.9	25.1		
Spring Creek	25.1	24.9	24.9	25.1		

APPENDIX J

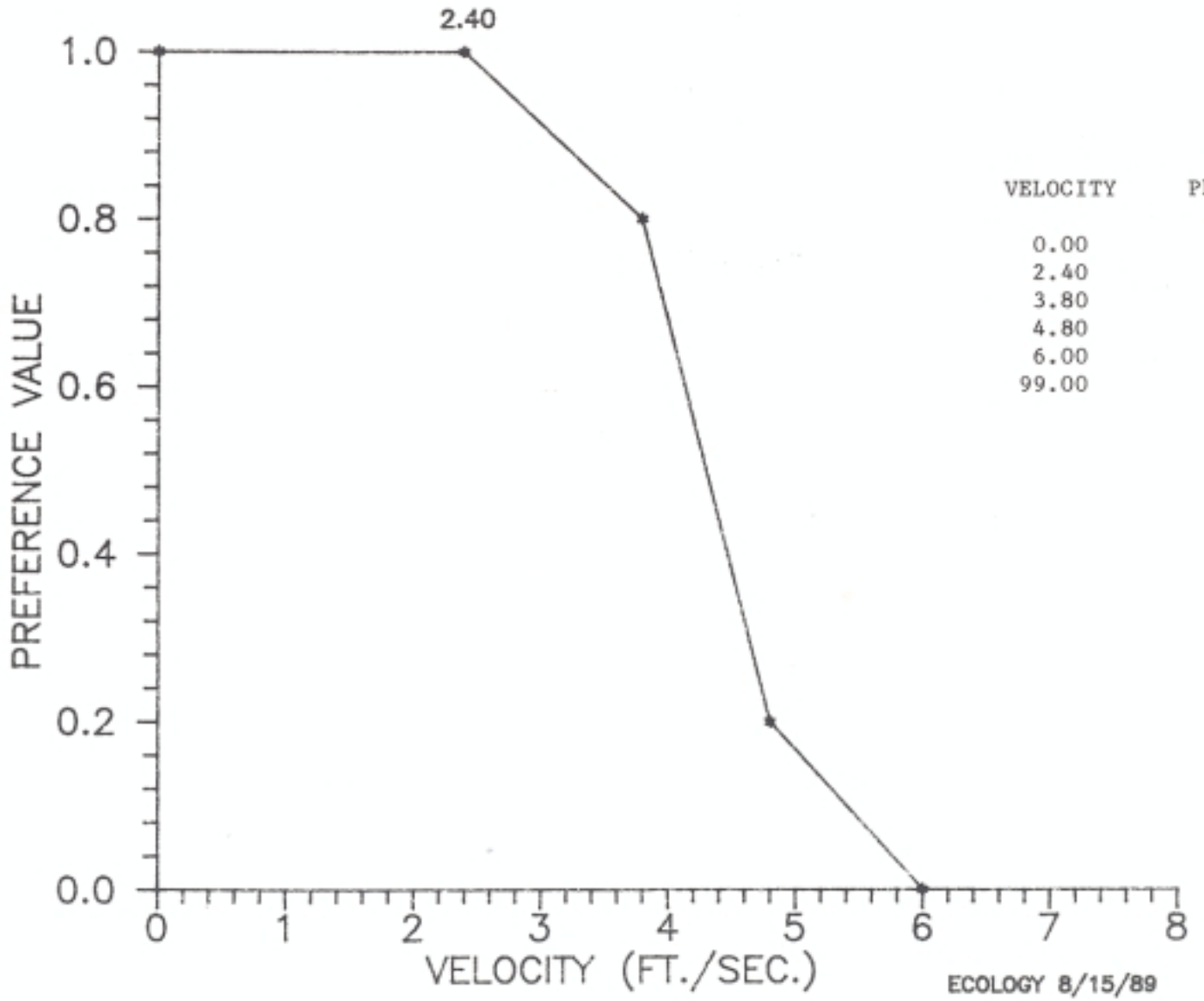
HABITAT-USE CURVES

CHINOOK SALMON ADULT HOLDING – RIVER

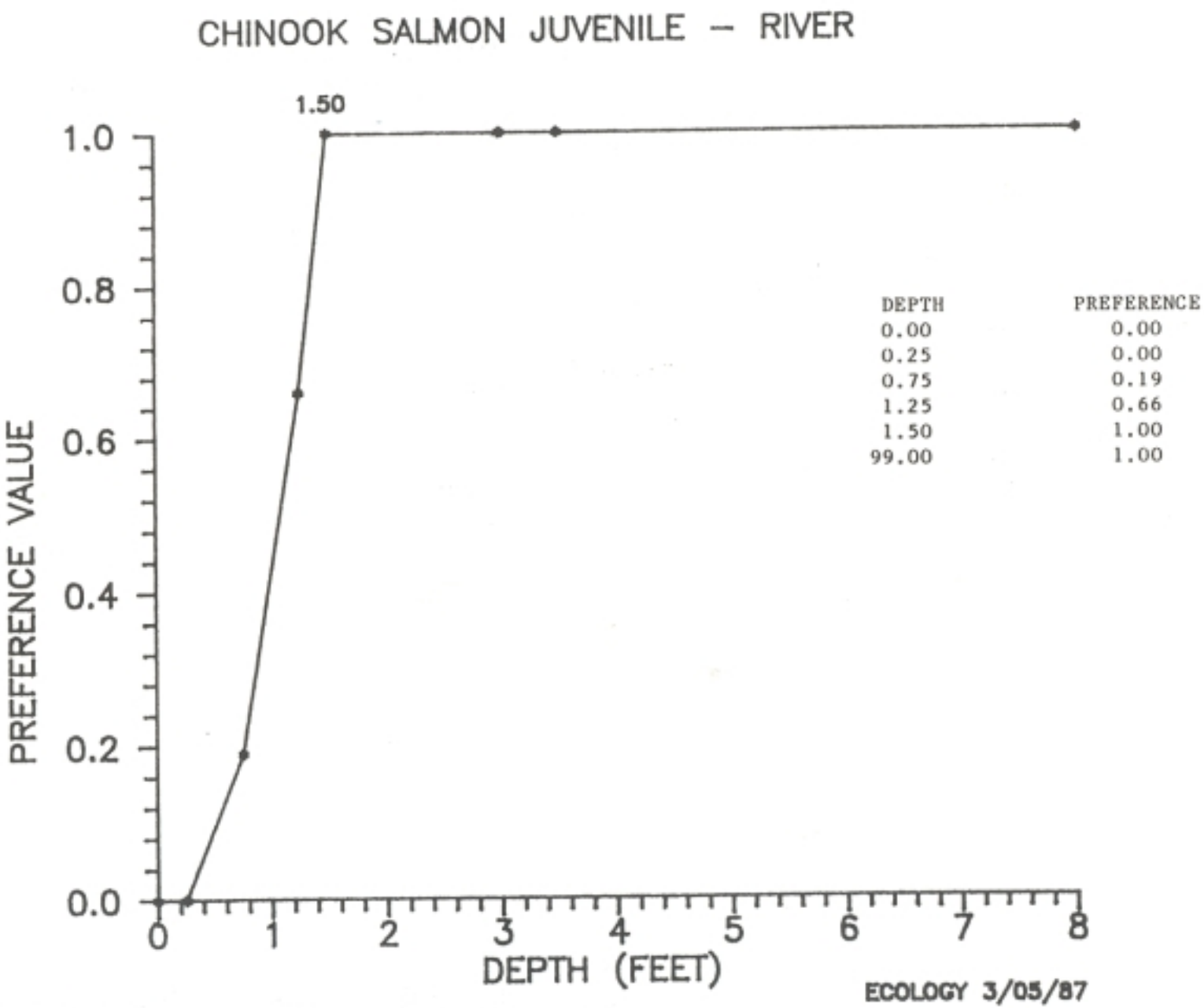


DEPTH	PREFERENCE
0.00	0.00
0.20	0.00
2.00	0.10
6.50	1.00
99.90	1.00

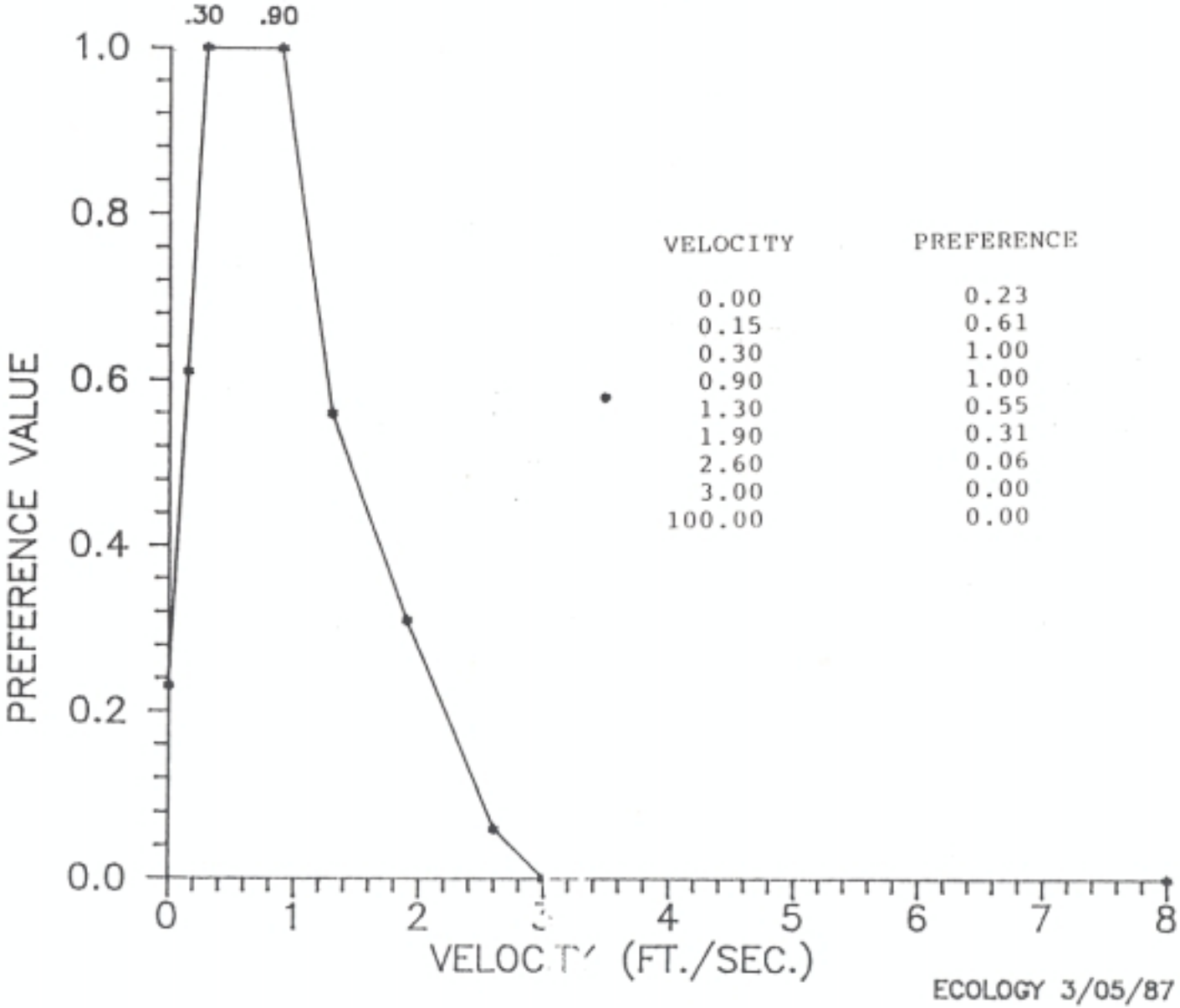
CHINOOK SALMON ADULT HOLDING – RIVER



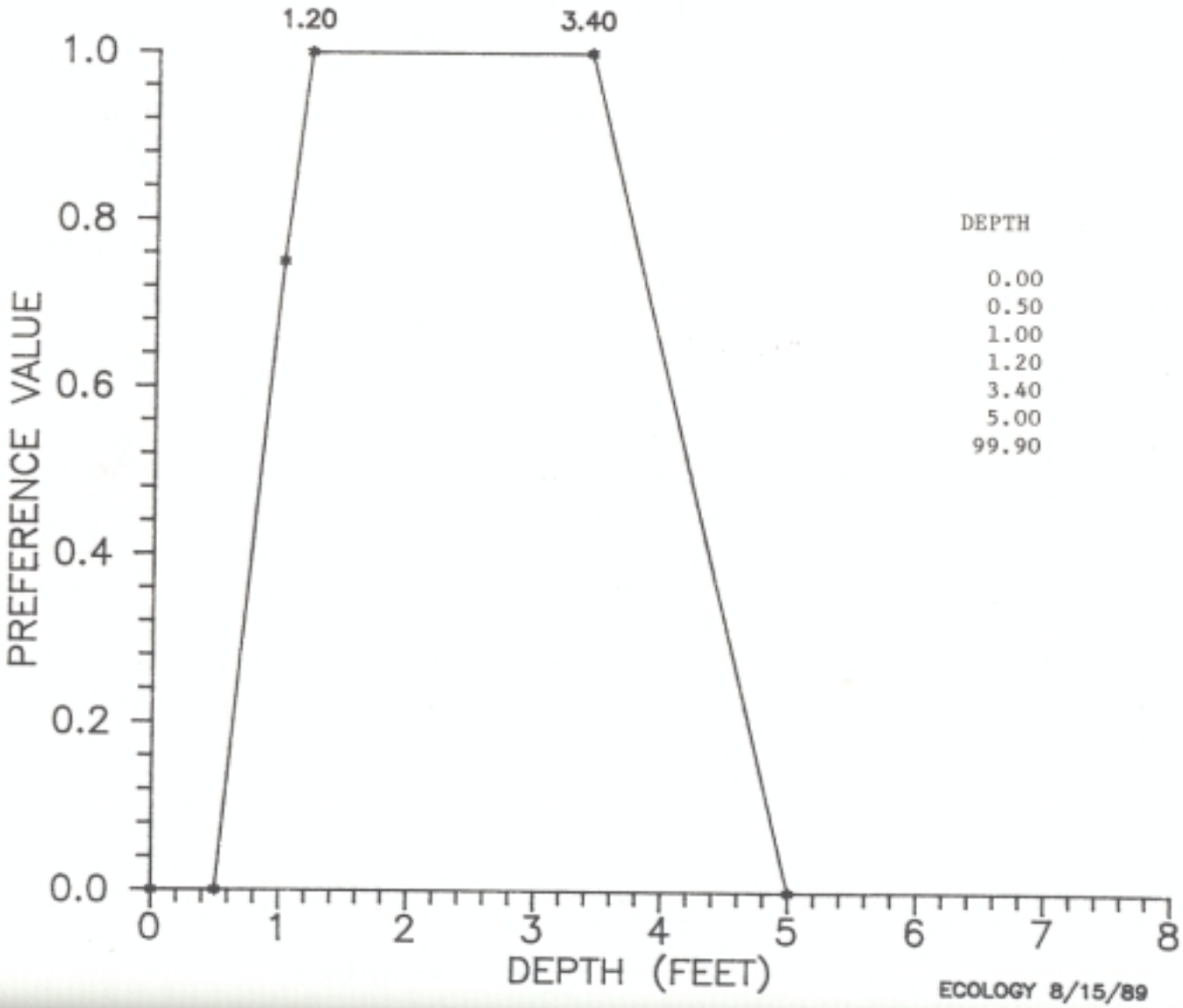
VELOCITY	PREFERENCE
0.00	1.00
2.40	1.00
3.80	0.80
4.80	0.20
6.00	0.00
99.00	0.00



DEPTH	PREFERENCE
0.00	0.00
0.25	0.00
0.75	0.19
1.25	0.66
1.50	1.00
99.00	1.00

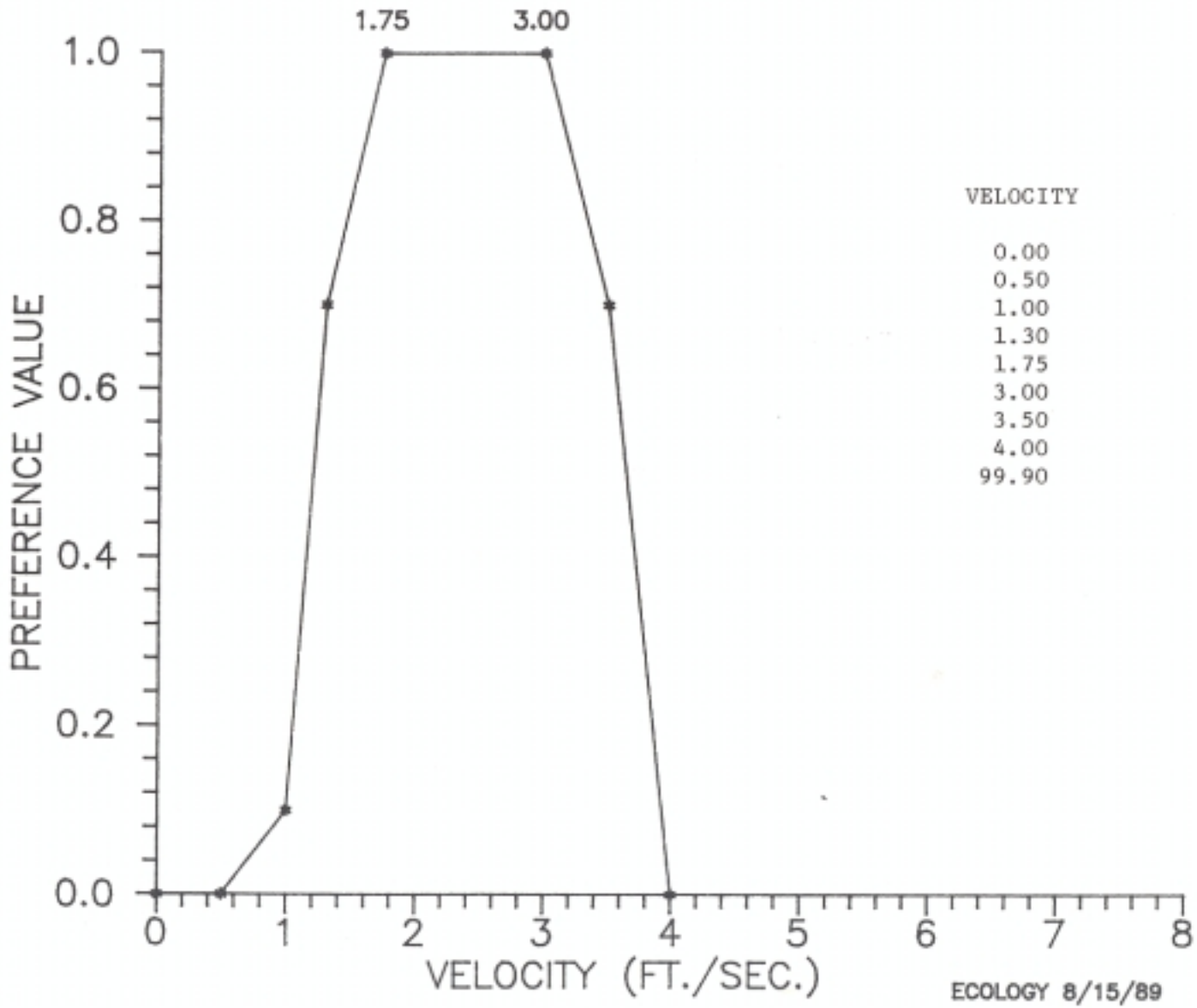


VELOCITY	PREFERENCE
0.00	0.23
0.15	0.61
0.30	1.00
0.90	1.00
1.30	0.55
1.90	0.31
2.60	0.06
3.00	0.00
100.00	0.00

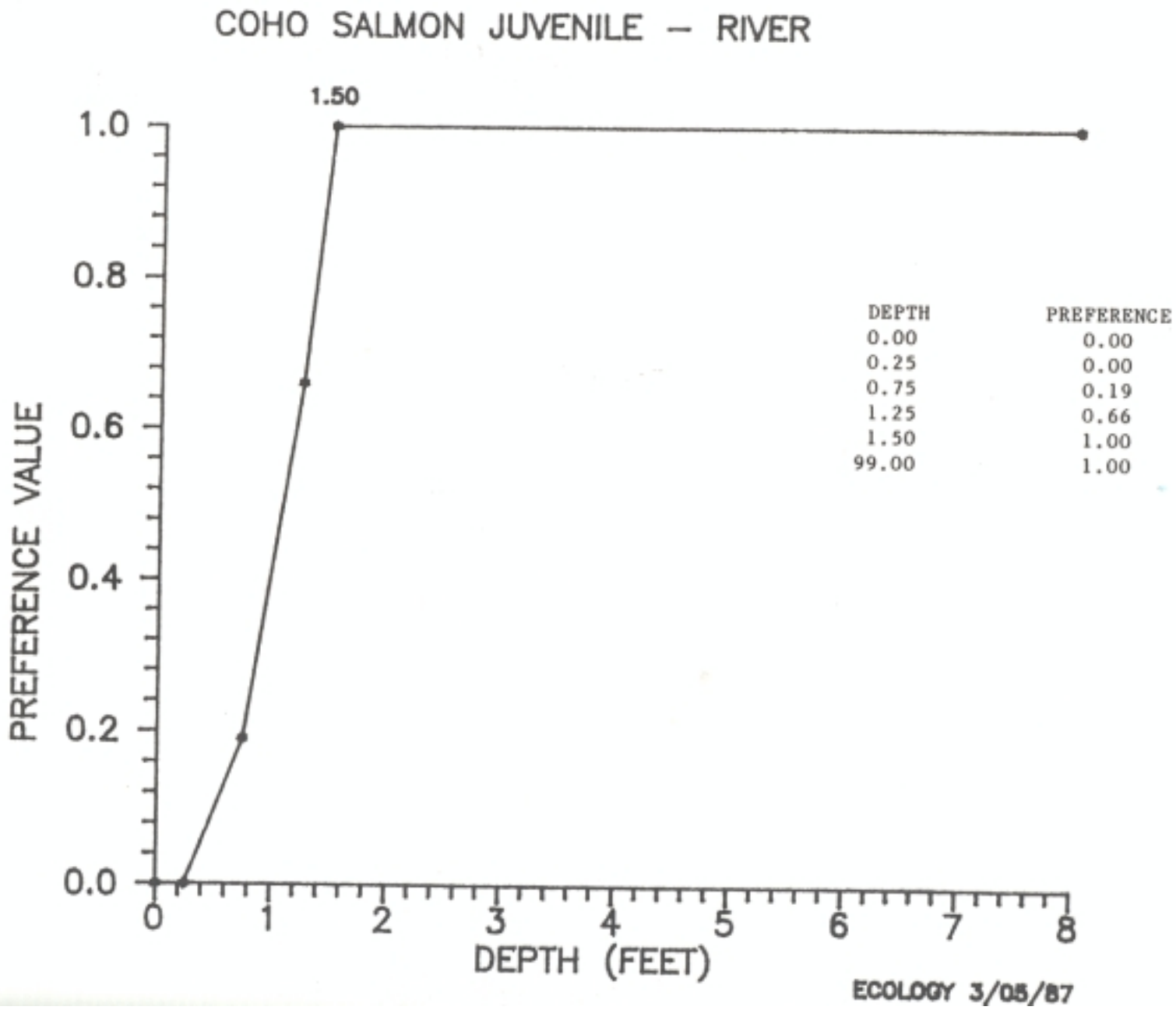


DEPTH	PREFERENCE
0.00	0.00
0.50	0.00
1.00	0.75
1.20	1.00
3.40	1.00
5.00	0.00
99.90	0.00

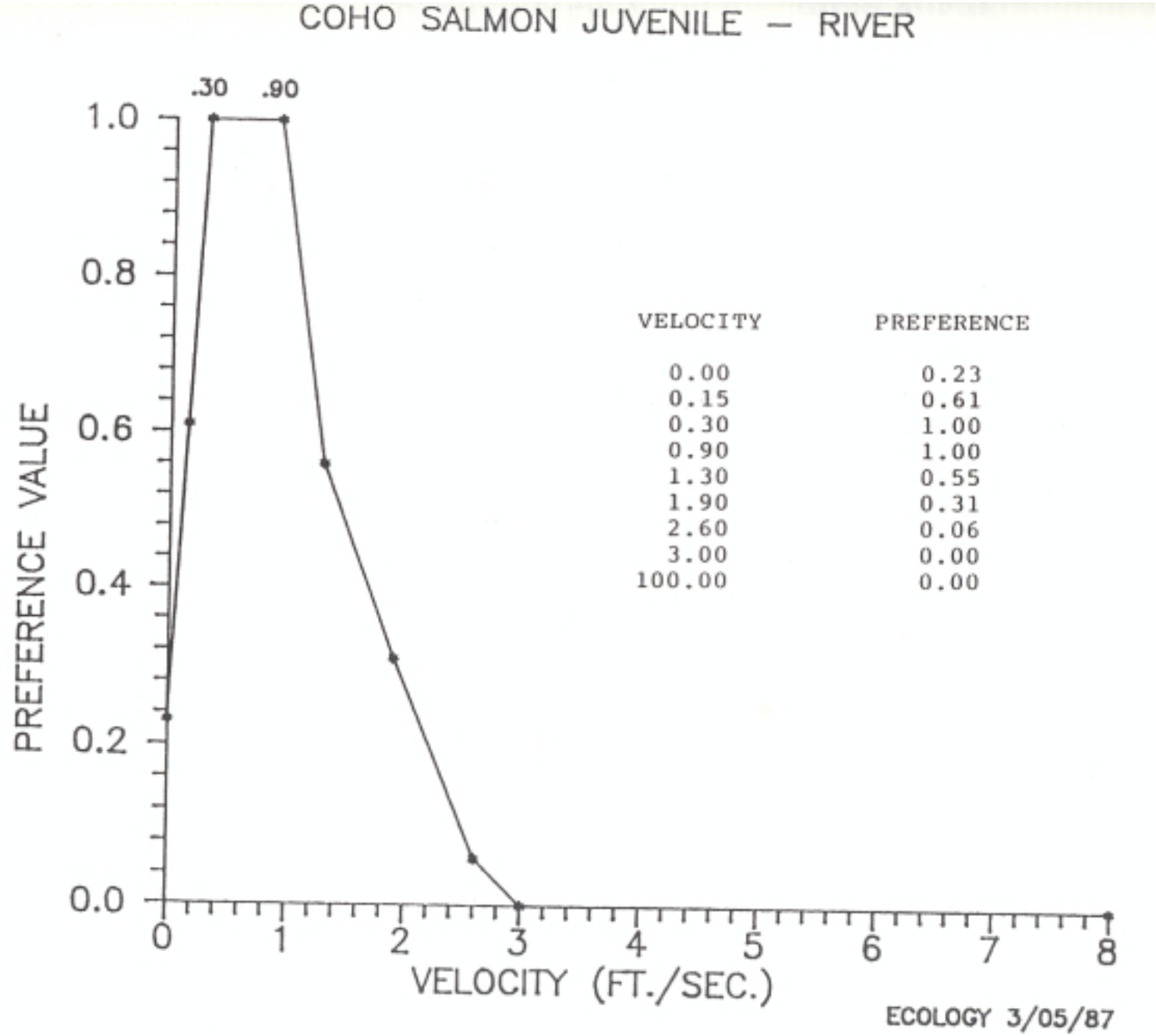
CHINOOK SALMON SPAWNING – RIVER



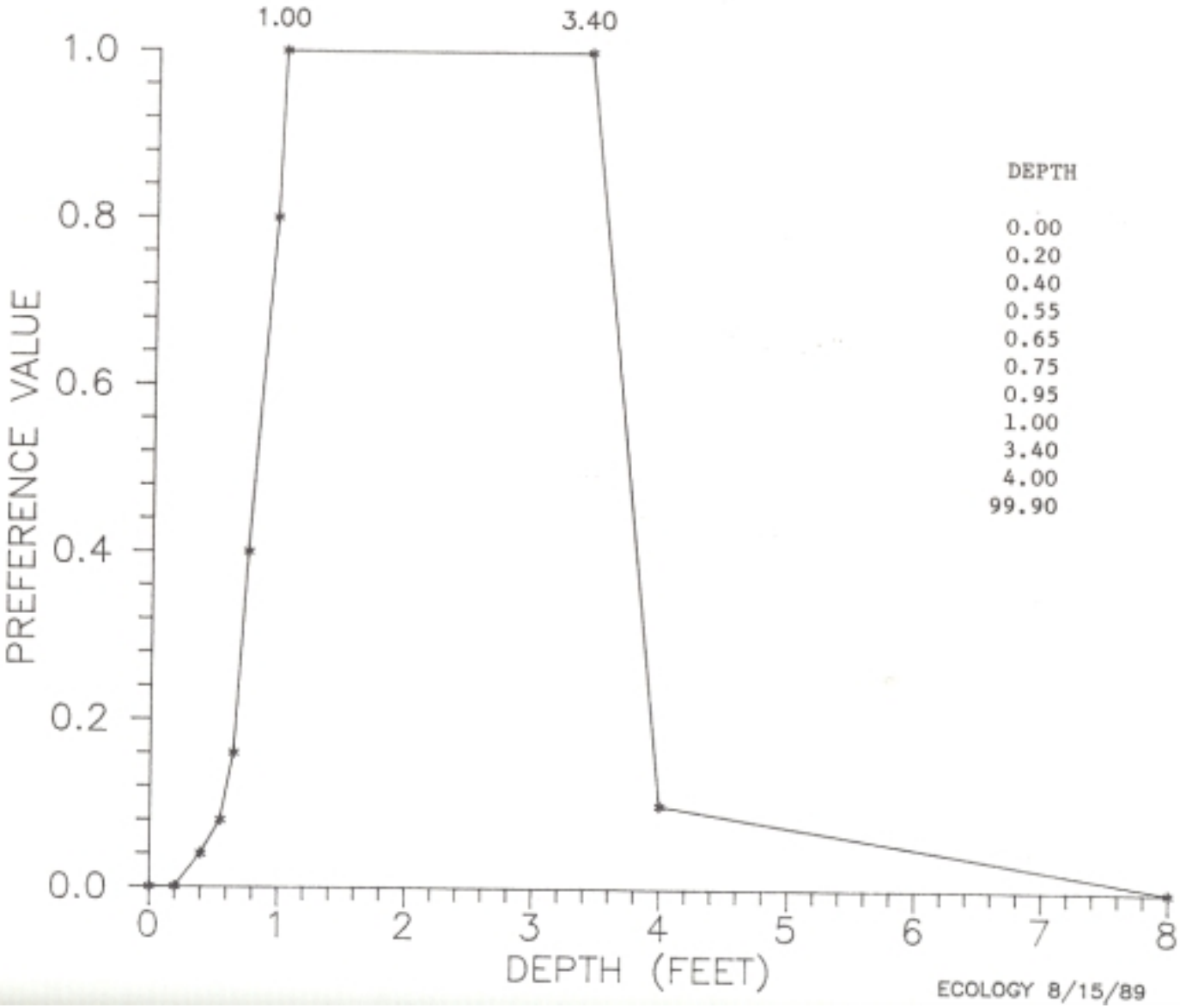
VELOCITY	PREFERENCE
0.00	0.00
0.50	0.00
1.00	0.10
1.30	0.70
1.75	1.00
3.00	1.00
3.50	0.70
4.00	0.00
99.90	0.00



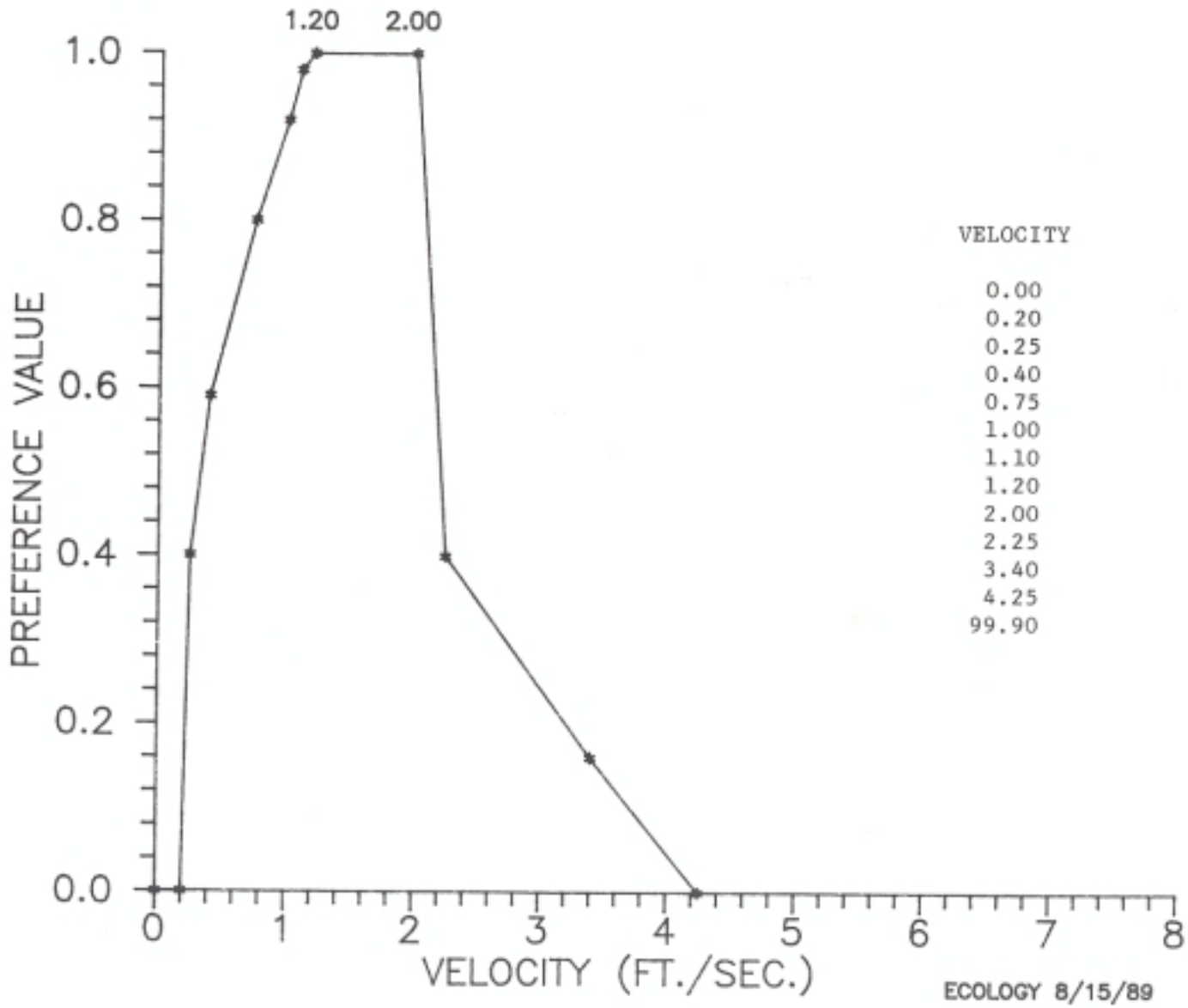
DEPTH	PREFERENCE
0.00	0.00
0.25	0.00
0.75	0.19
1.25	0.66
1.50	1.00
99.00	1.00



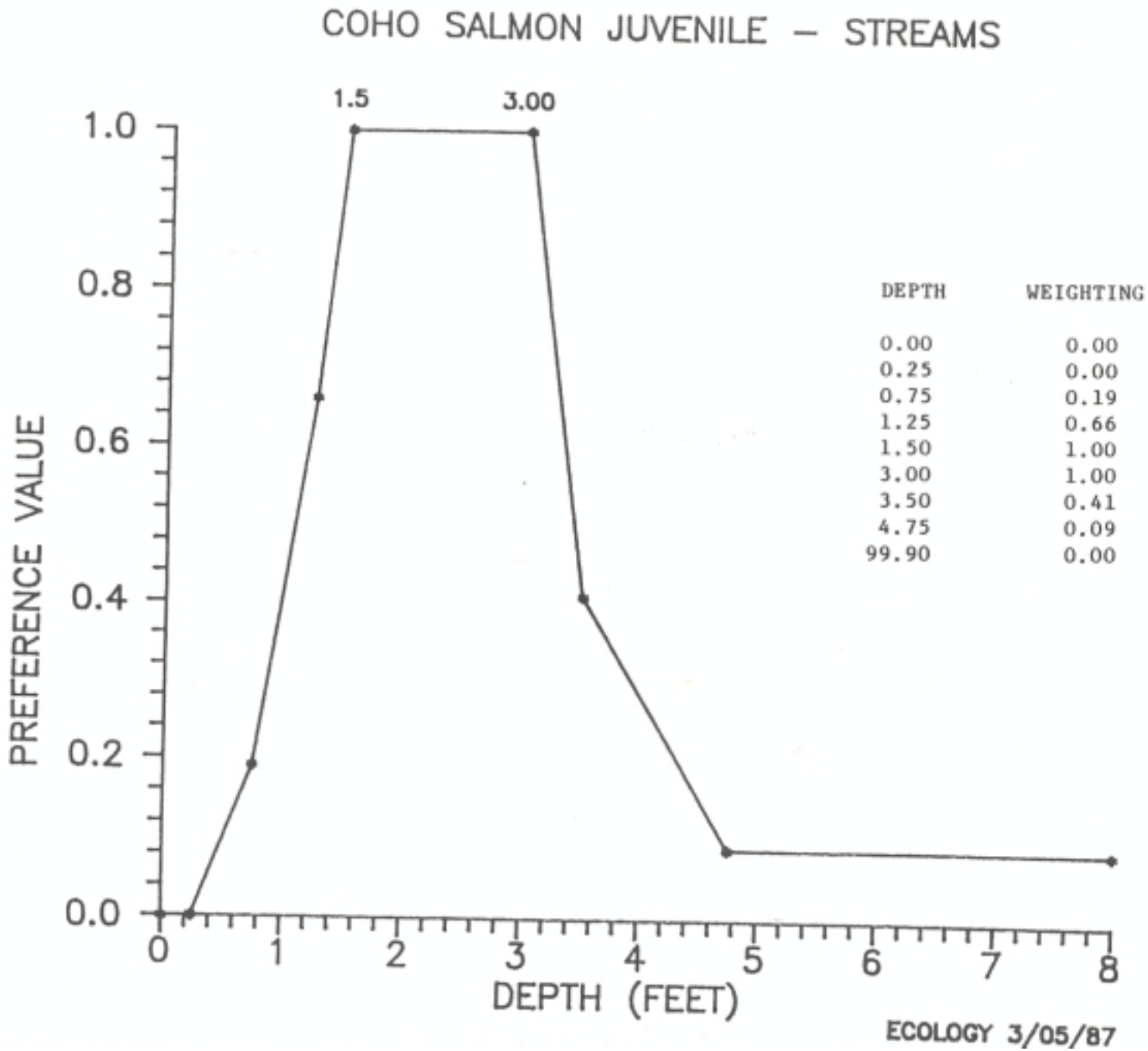
VELOCITY	PREFERENCE
0.00	0.23
0.15	0.61
0.30	1.00
0.90	1.00
1.30	0.55
1.90	0.31
2.60	0.06
3.00	0.00
100.00	0.00



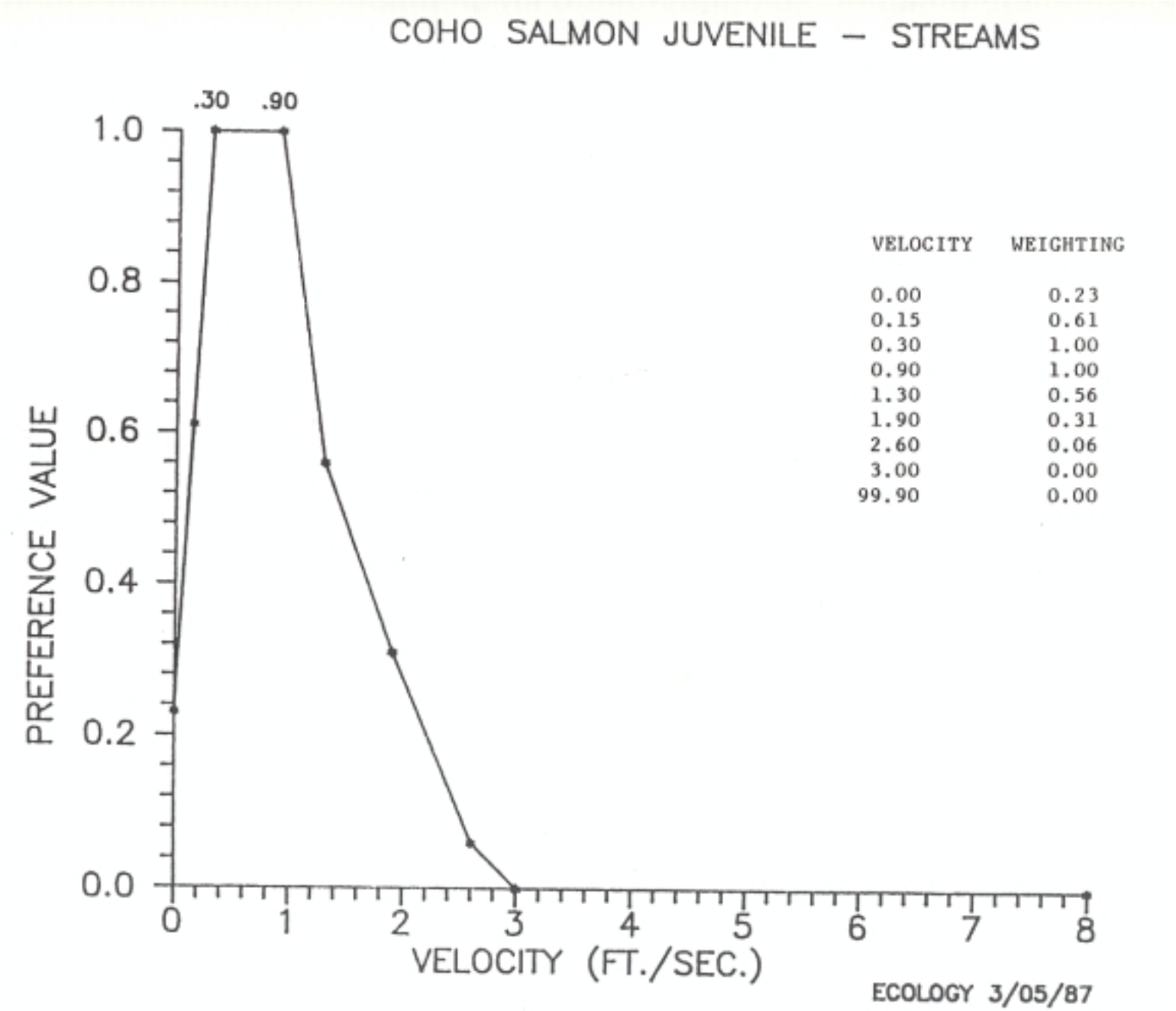
DEPTH	PREFERENCE
0.00	0.00
0.20	0.00
0.40	0.04
0.55	0.08
0.65	0.16
0.75	0.40
0.95	0.80
1.00	1.00
3.40	1.00
4.00	0.10
99.90	0.00



VELOCITY	PREFERENCE
0.00	0.00
0.20	0.00
0.25	0.40
0.40	0.59
0.75	0.80
1.00	0.92
1.10	0.98
1.20	1.00
2.00	1.00
2.25	0.40
3.40	0.16
4.25	0.00
99.90	0.00

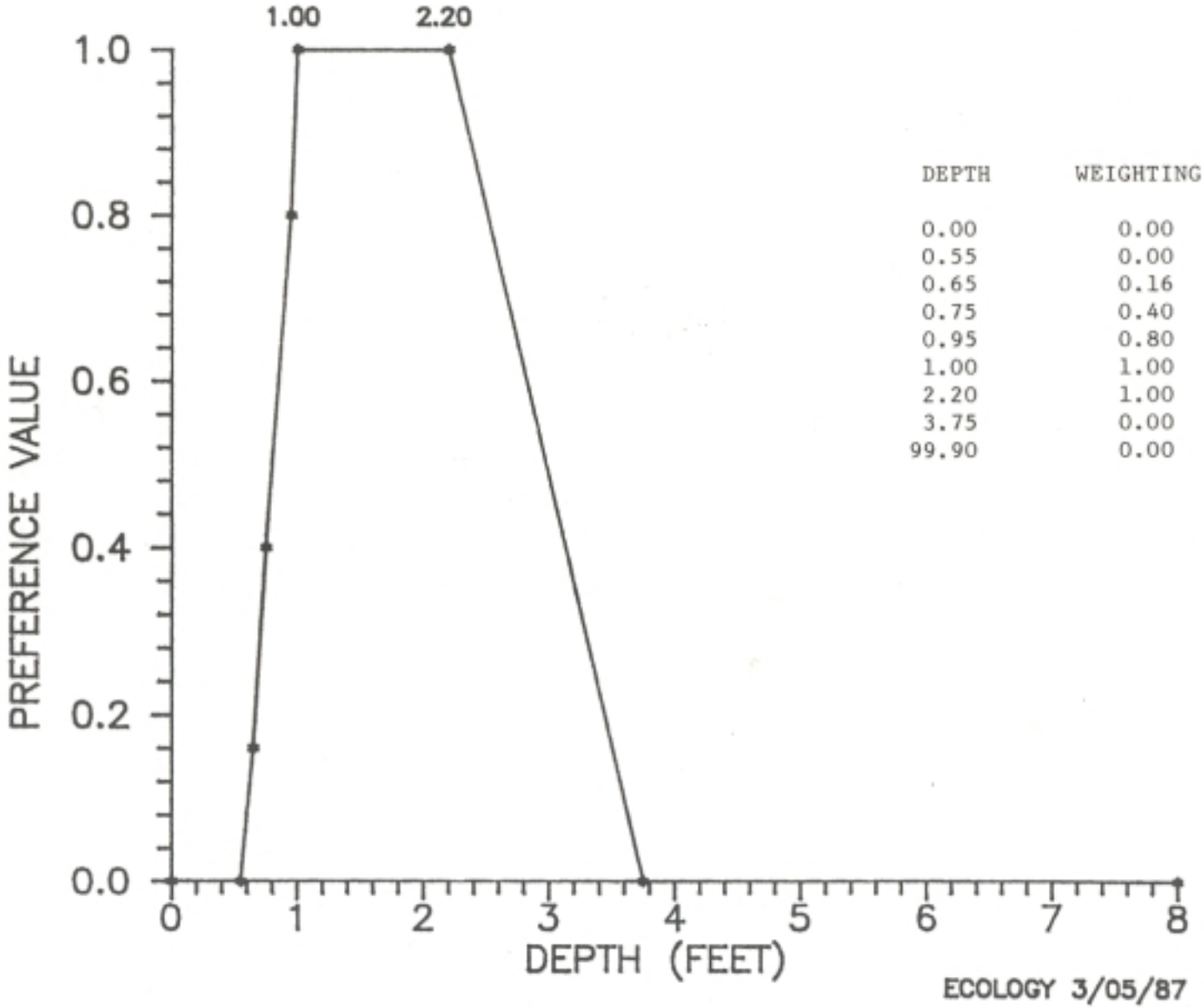


DEPTH	WEIGHTING
0.00	0.00
0.25	0.00
0.75	0.19
1.25	0.66
1.50	1.00
3.00	1.00
3.50	0.41
4.75	0.09
99.90	0.00



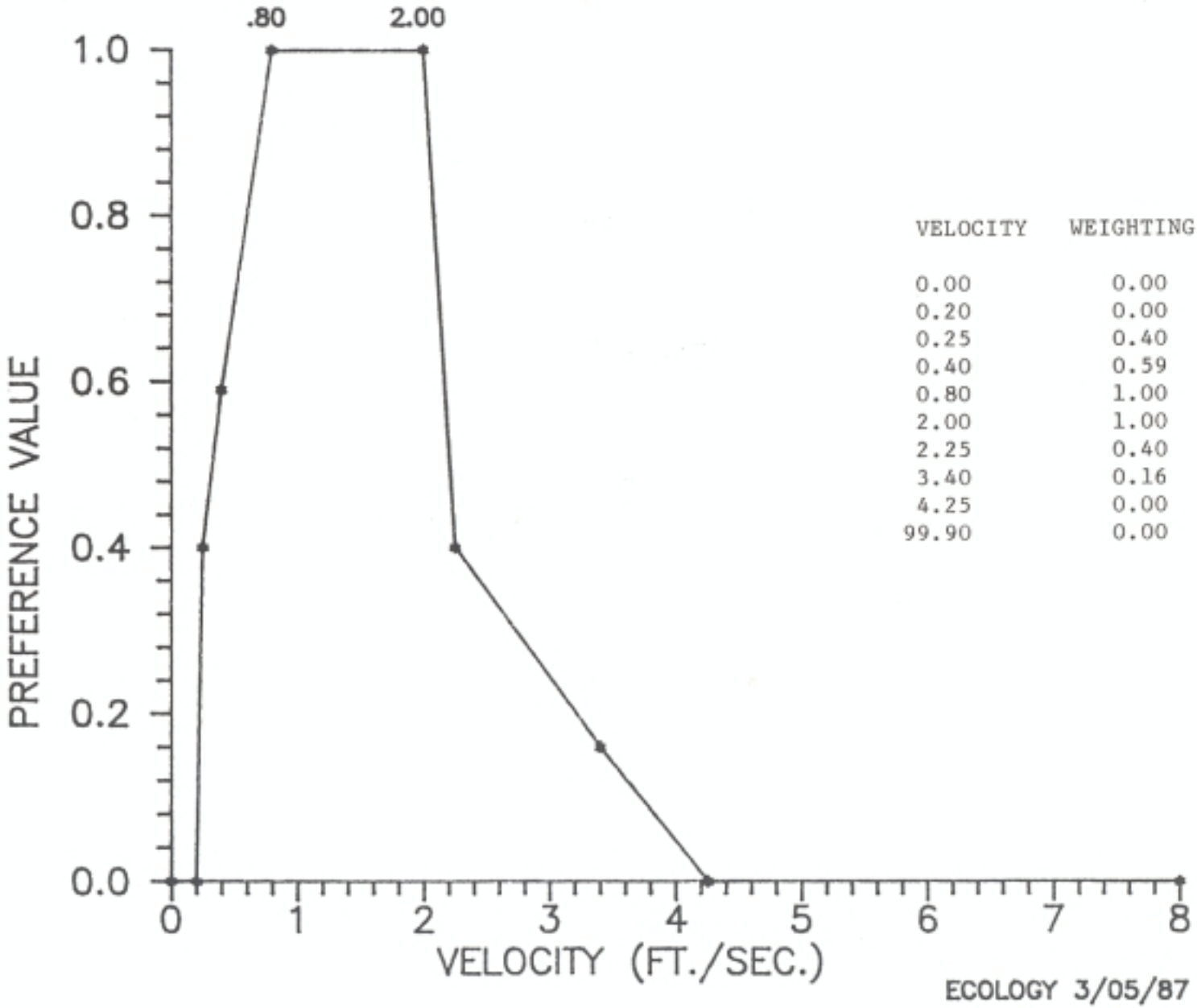
VELOCITY	WEIGHTING
0.00	0.23
0.15	0.61
0.30	1.00
0.90	1.00
1.30	0.56
1.90	0.31
2.60	0.06
3.00	0.00
99.90	0.00

COHO SALMON SPAWNING – STREAMS

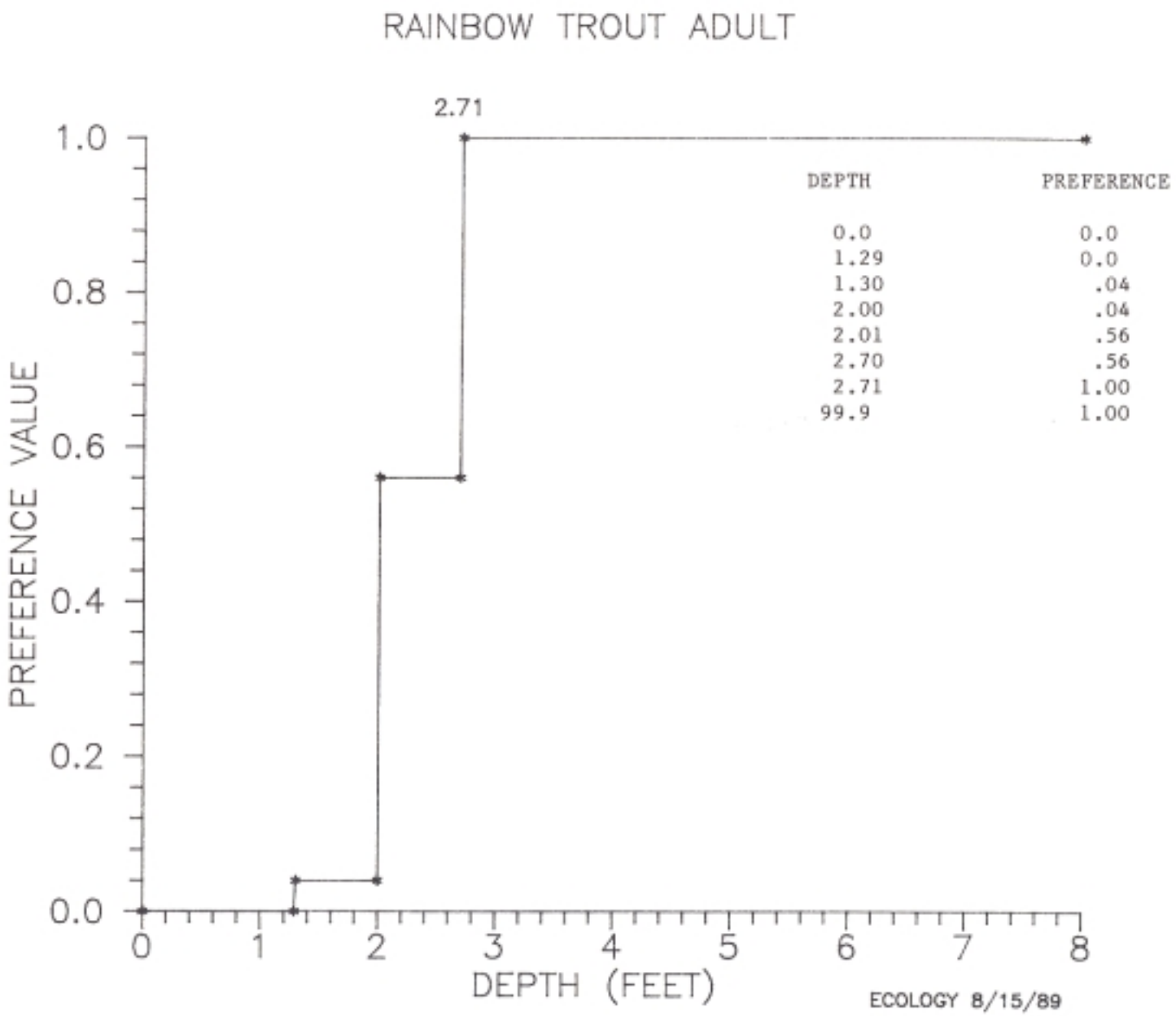


DEPTH	WEIGHTING
0.00	0.00
0.55	0.00
0.65	0.16
0.75	0.40
0.95	0.80
1.00	1.00
2.20	1.00
3.75	0.00
99.90	0.00

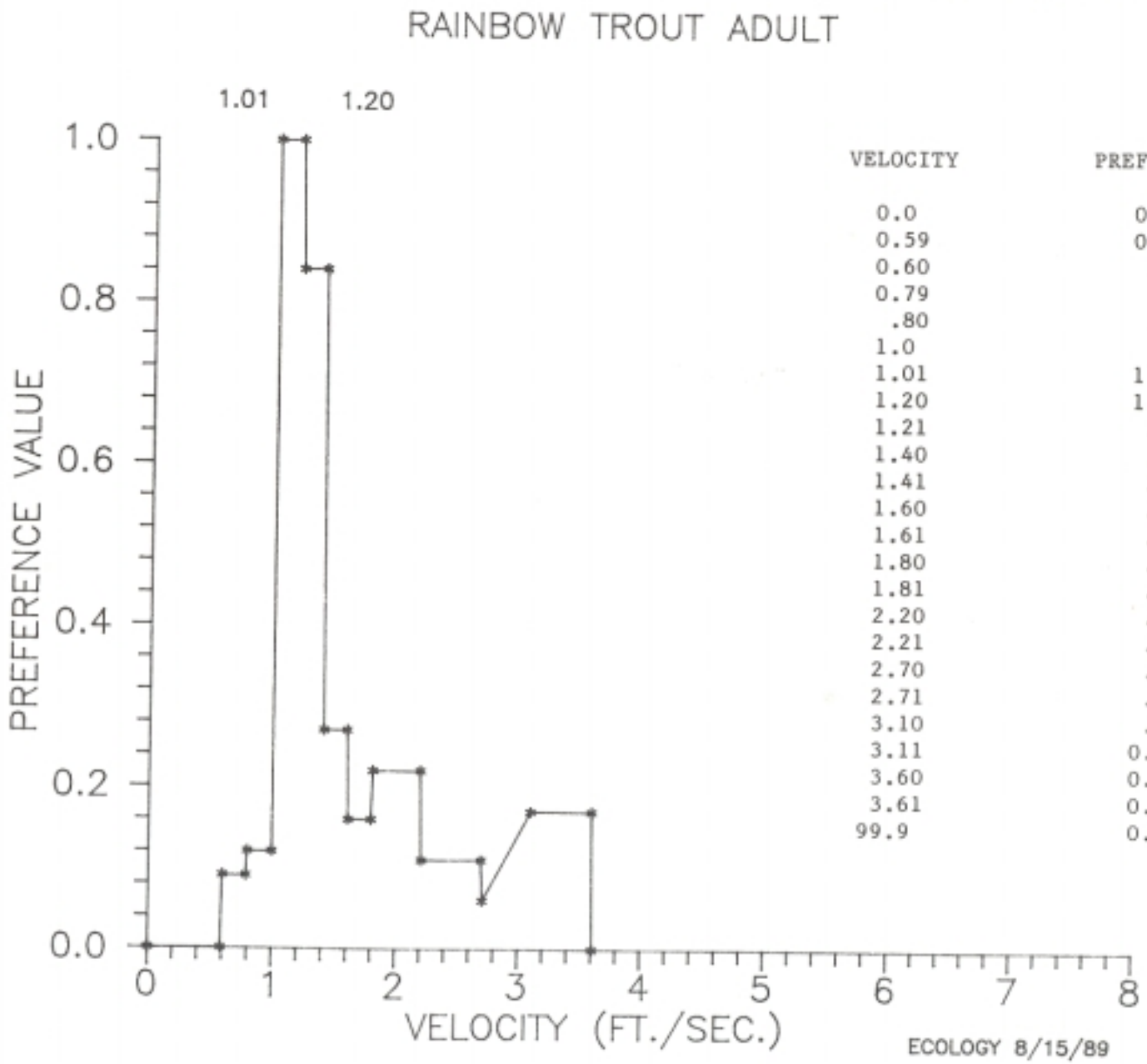
COHO SALMON SPAWNING — STREAMS



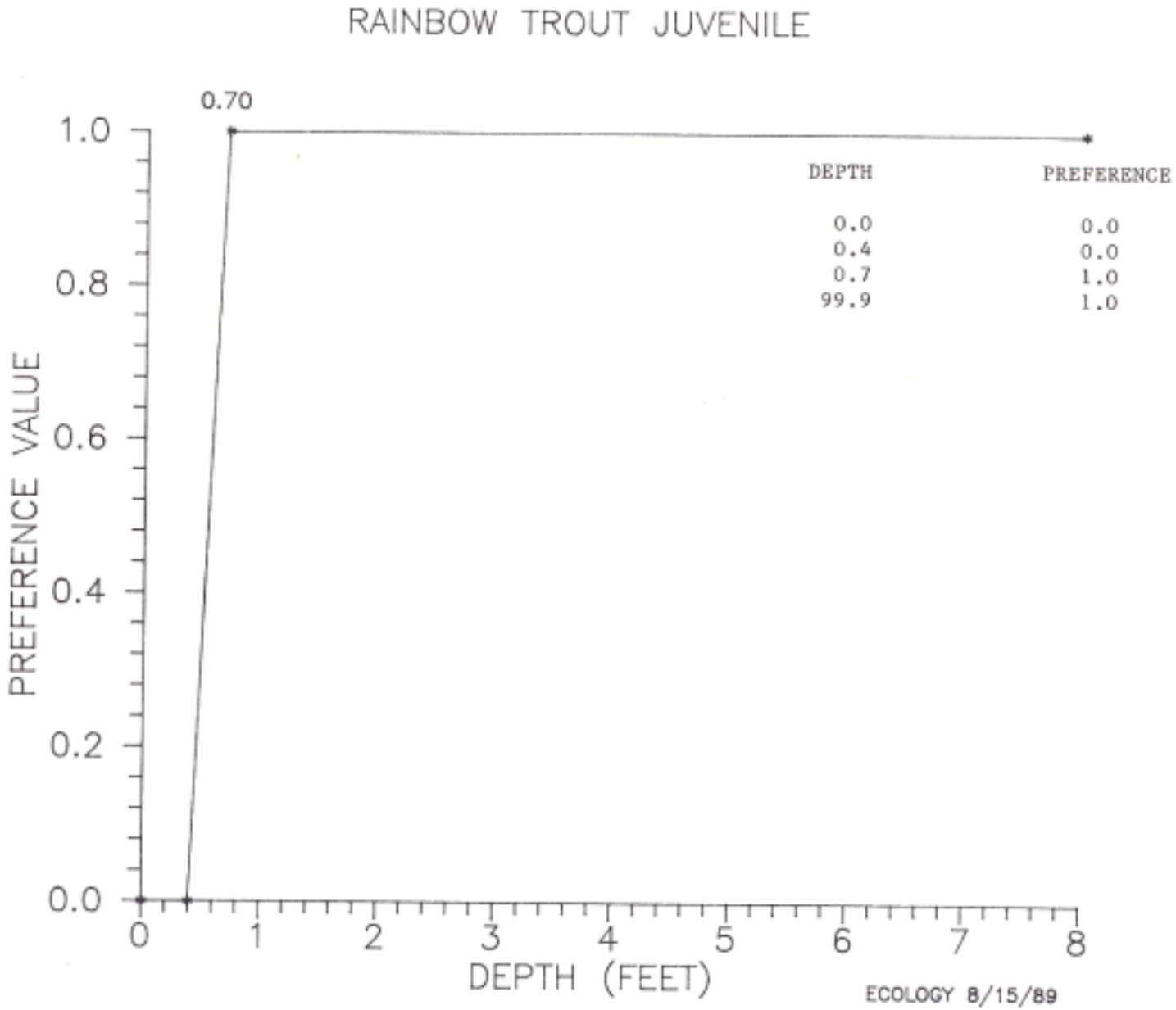
VELOCITY	WEIGHTING
0.00	0.00
0.20	0.00
0.25	0.40
0.40	0.59
0.80	1.00
2.00	1.00
2.25	0.40
3.40	0.16
4.25	0.00
99.90	0.00

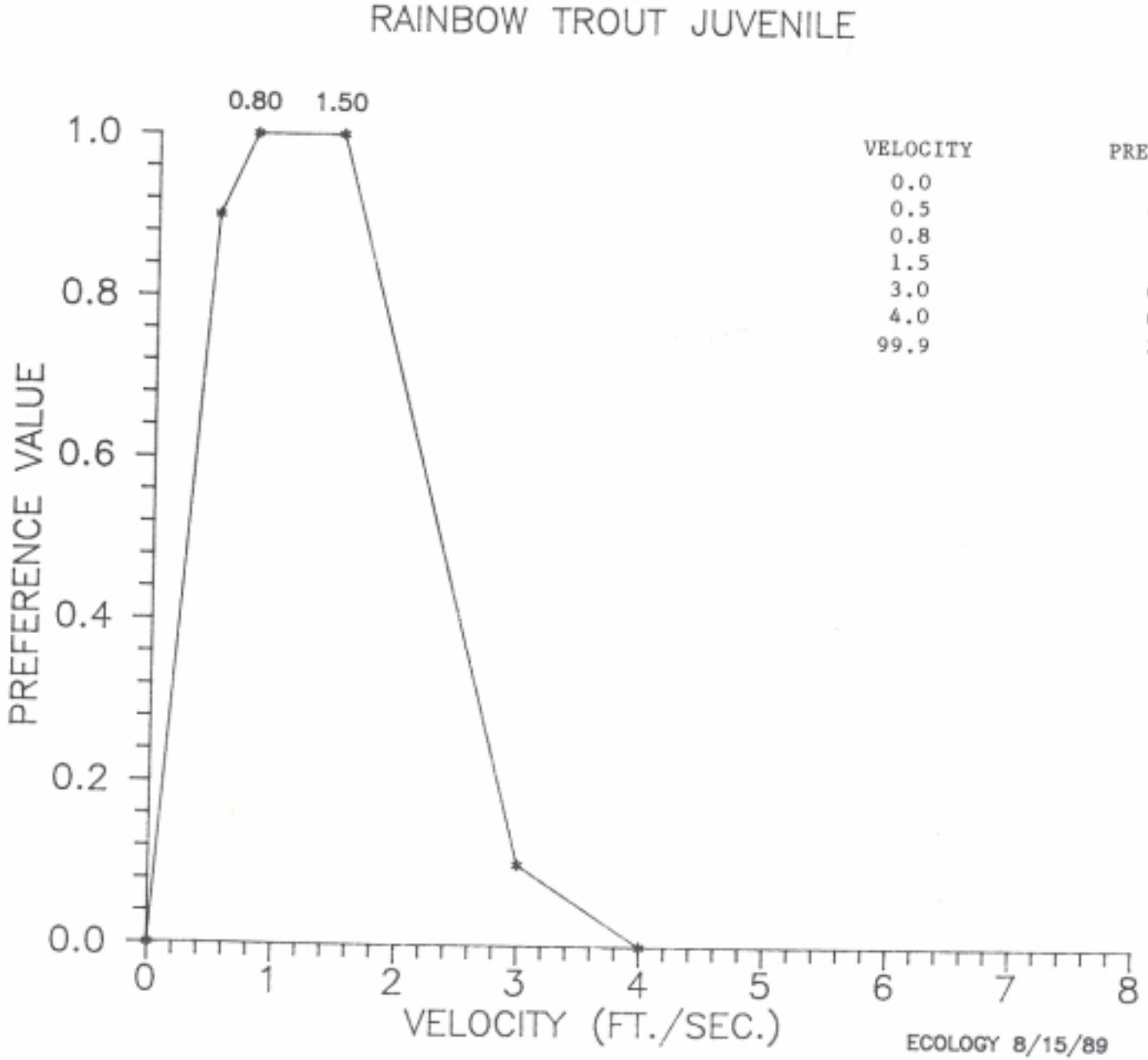


DEPTH	PREFERENCE
0.0	0.0
1.29	0.0
1.30	.04
2.00	.04
2.01	.56
2.70	.56
2.71	1.00
99.9	1.00

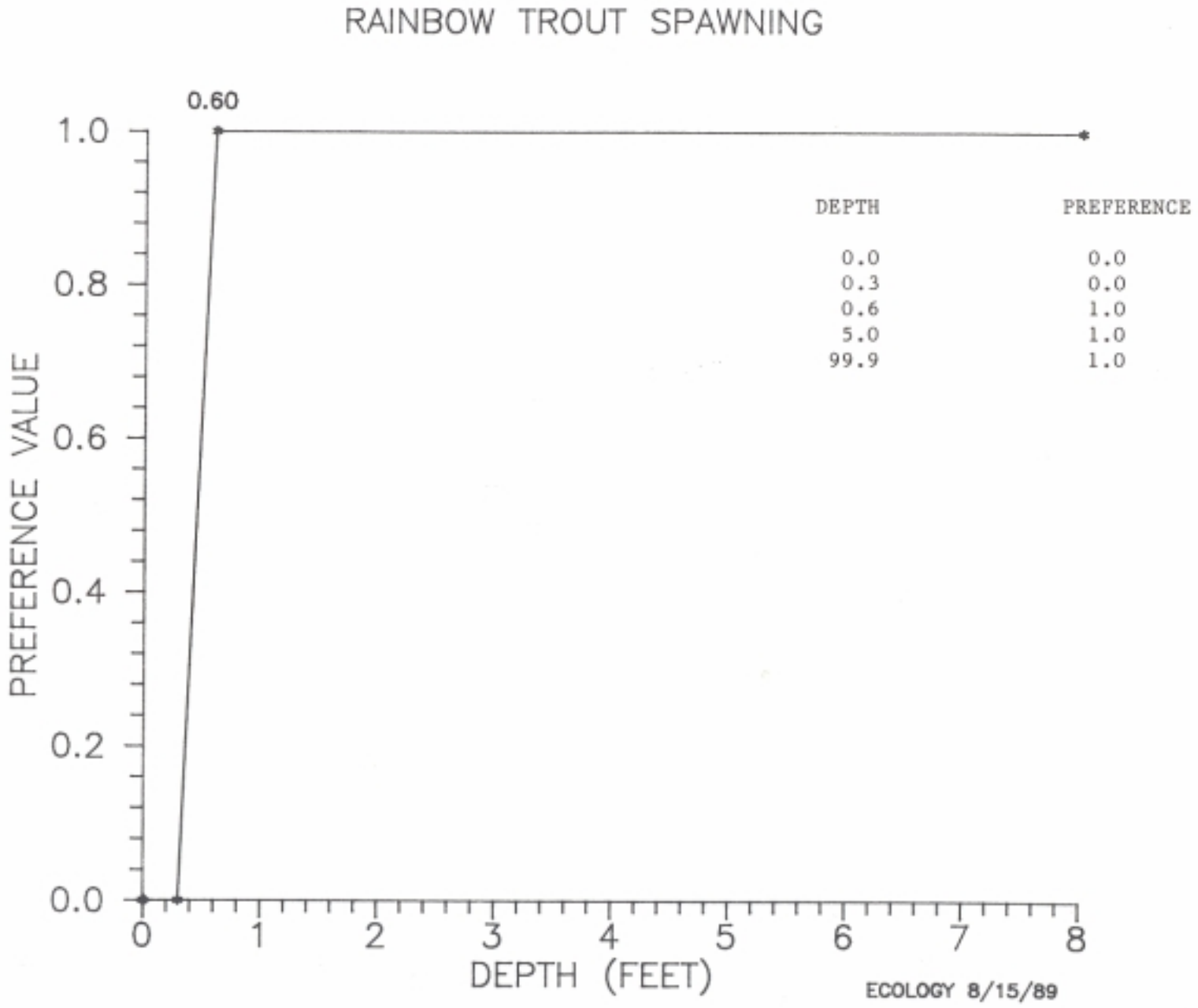


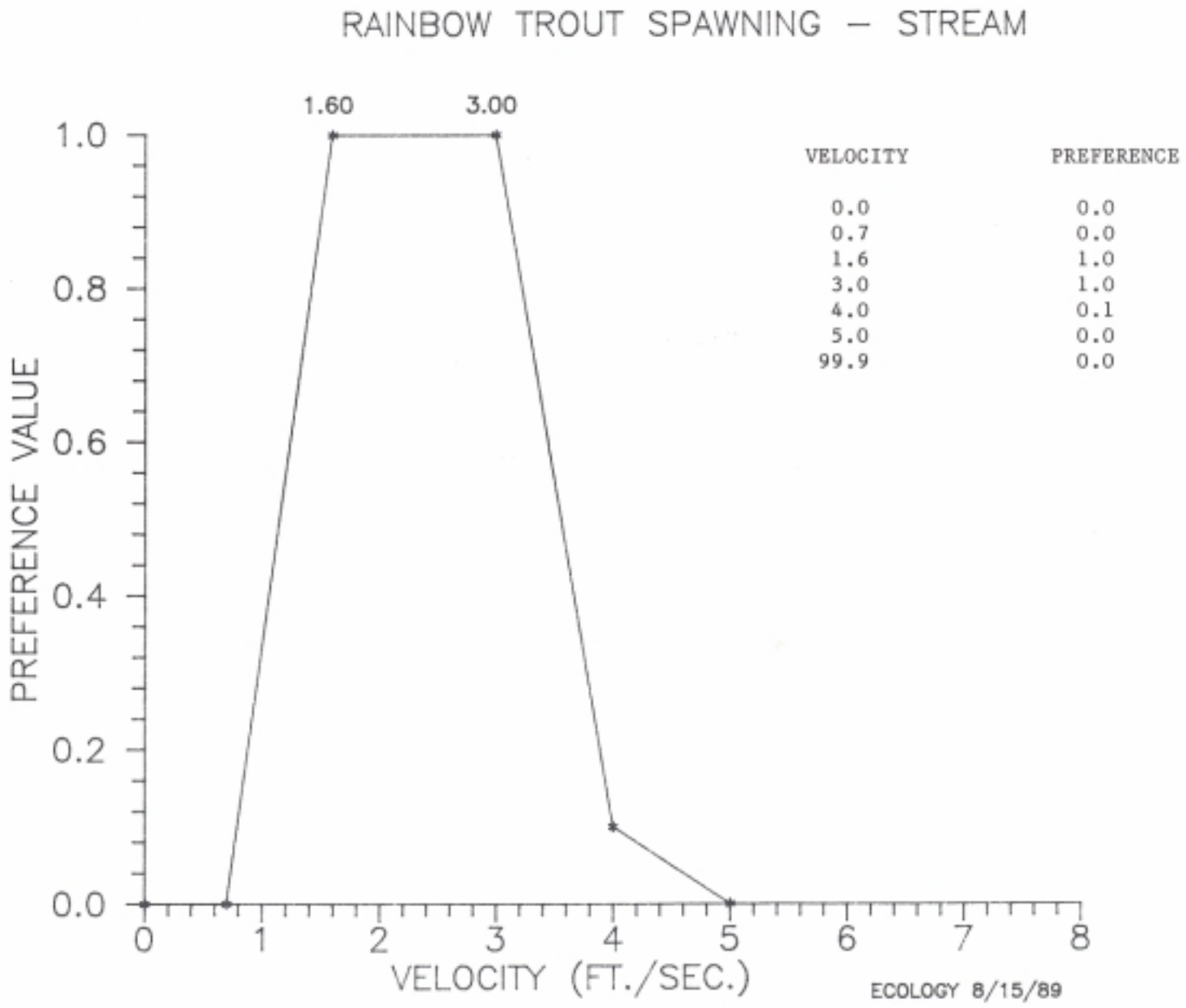
VELOCITY	PREFERENCE
0.0	0.0
0.59	0.0
0.60	.09
0.79	.09
.80	.12
1.0	.12
1.01	1.00
1.20	1.00
1.21	.84
1.40	.84
1.41	.27
1.60	.27
1.61	.16
1.80	.16
1.81	.22
2.20	.22
2.21	.11
2.70	.11
2.71	.06
3.10	.06
3.11	0.17
3.60	0.17
3.61	0.0
99.9	0.0


RAINBOW TROUT JUVENILE
0.70
1.0
0.8
0.6
0.4
0.2
0.0
PREFERENCE VALUE
0
1
2
3
4
5
6
7
8
DEPTH (FEET)
DEPTH PREFERENCE
0.0 0.0
0.4 0.0
0.7 1.0
99.9 1.0
ECOLOGY 8/15/89

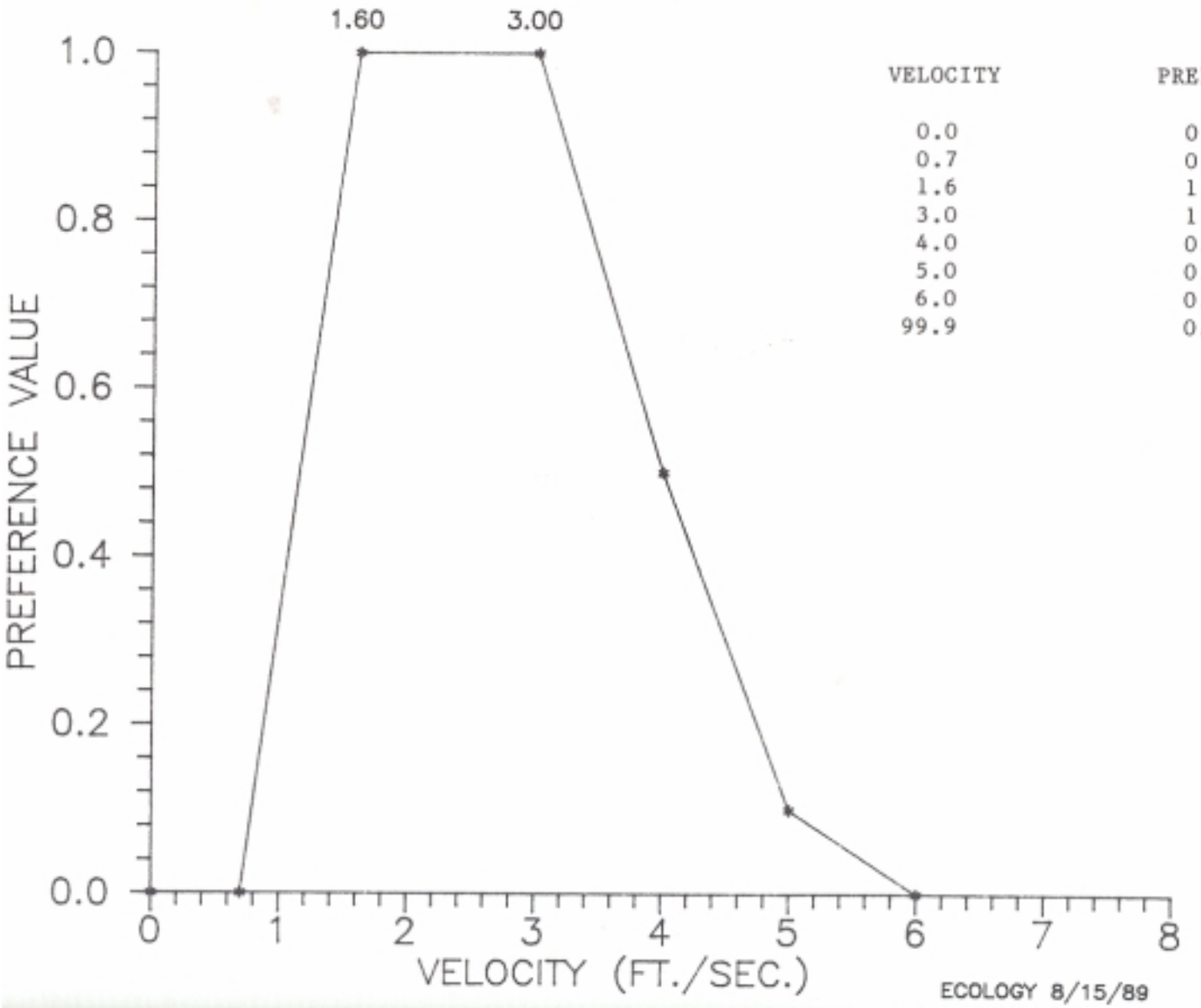


VELOCITY	PREFERENCE
0.0	0.1
0.5	0.9
0.8	1.0
1.5	1.0
3.0	0.1
4.0	0.0
99.9	2.0

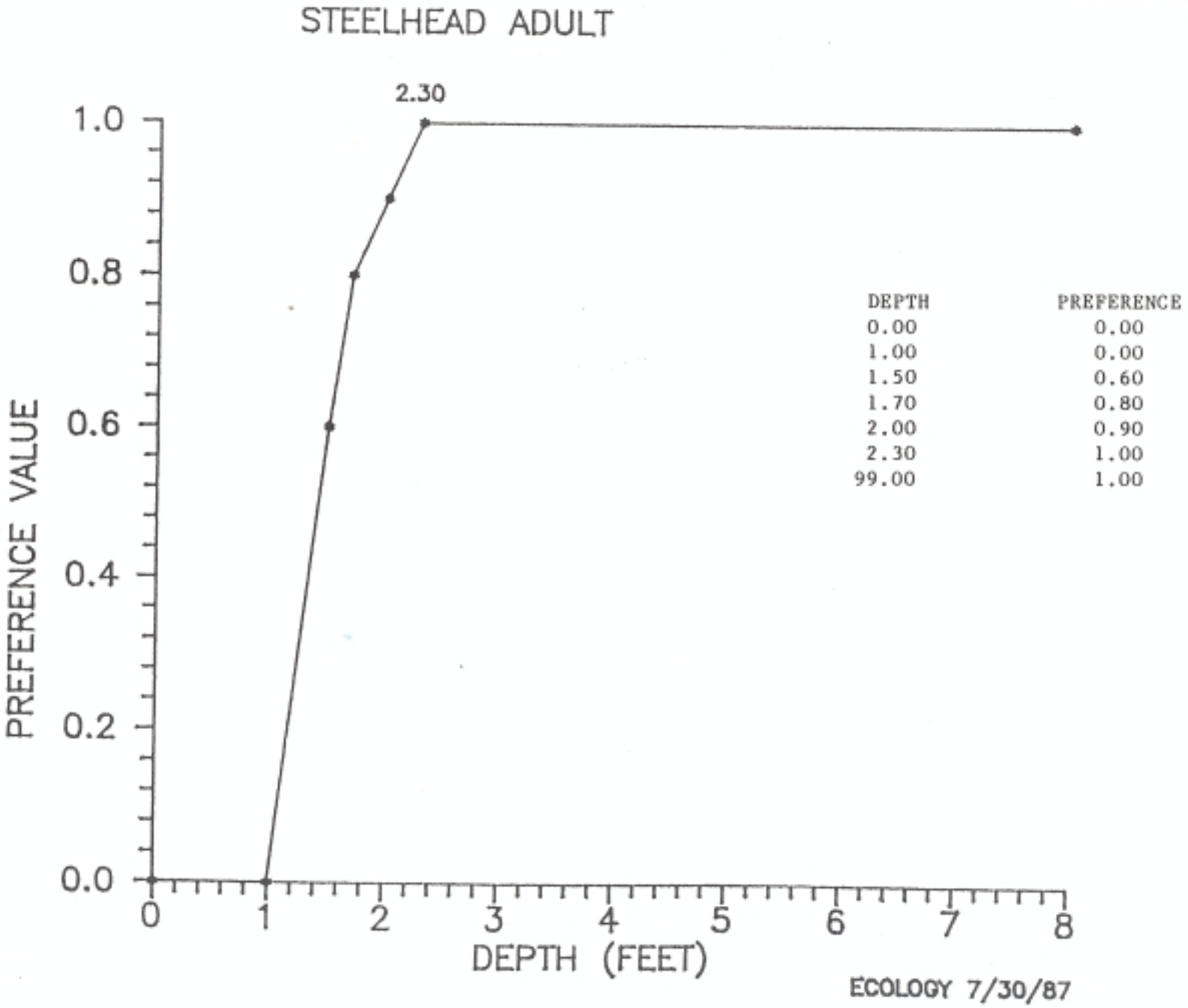

RAINBOW TROUT SPAWNING
0.60
1.0
0.8
0.6
0.4
0.2
0.0
PREFERENCE VALUE
0
1
2
3
4
5
6
7
8
DEPTH (FEET)
DEPTH PREFERENCE
0.0 0.0
0.3 0.0
0.6 1.0
5.0 1.0
99.9 1.0
ECOLOGY 8/15/89



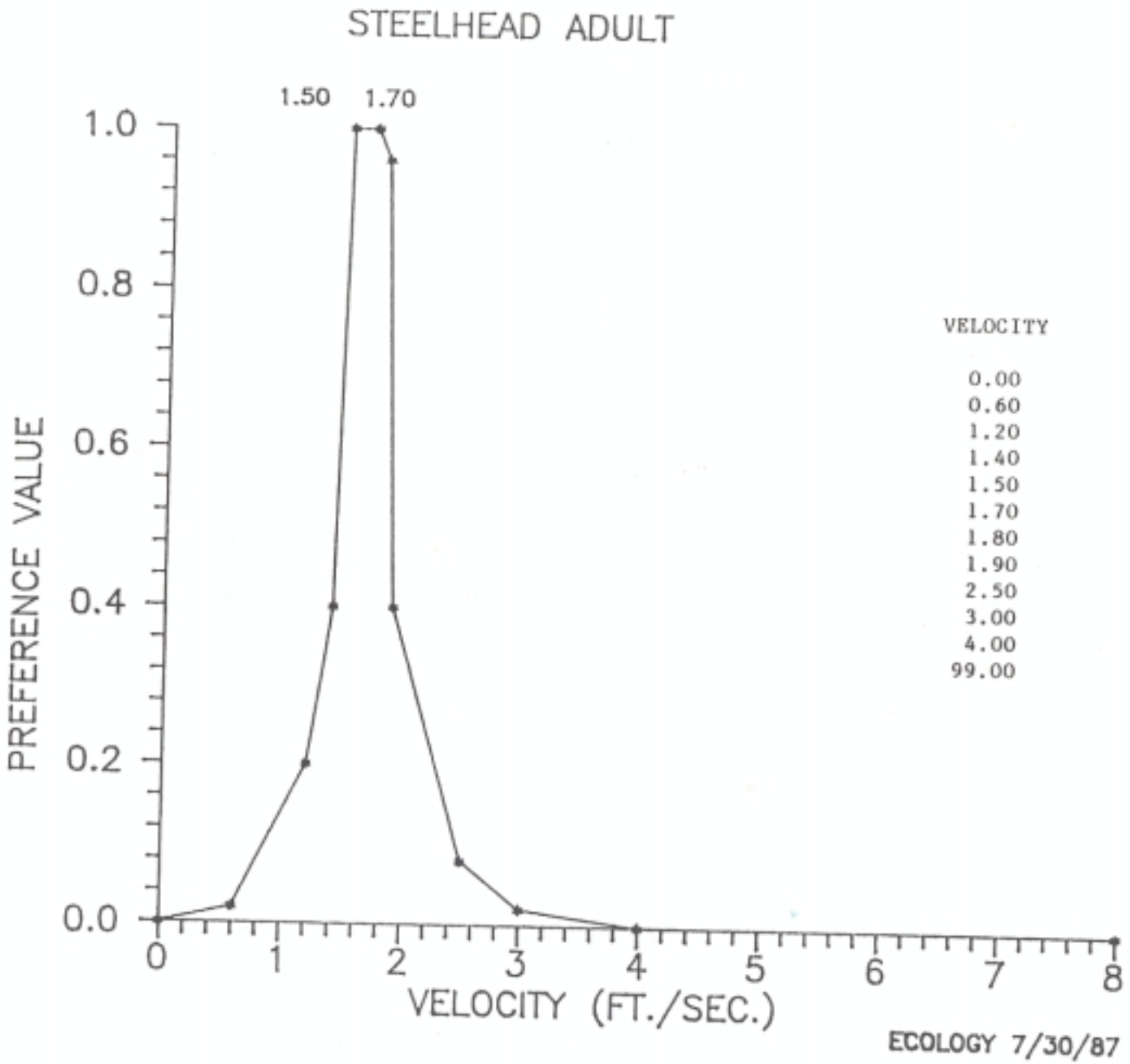
VELOCITY	PREFERENCE
0.0	0.0
0.7	0.0
1.6	1.0
3.0	1.0
4.0	0.1
5.0	0.0
99.9	0.0



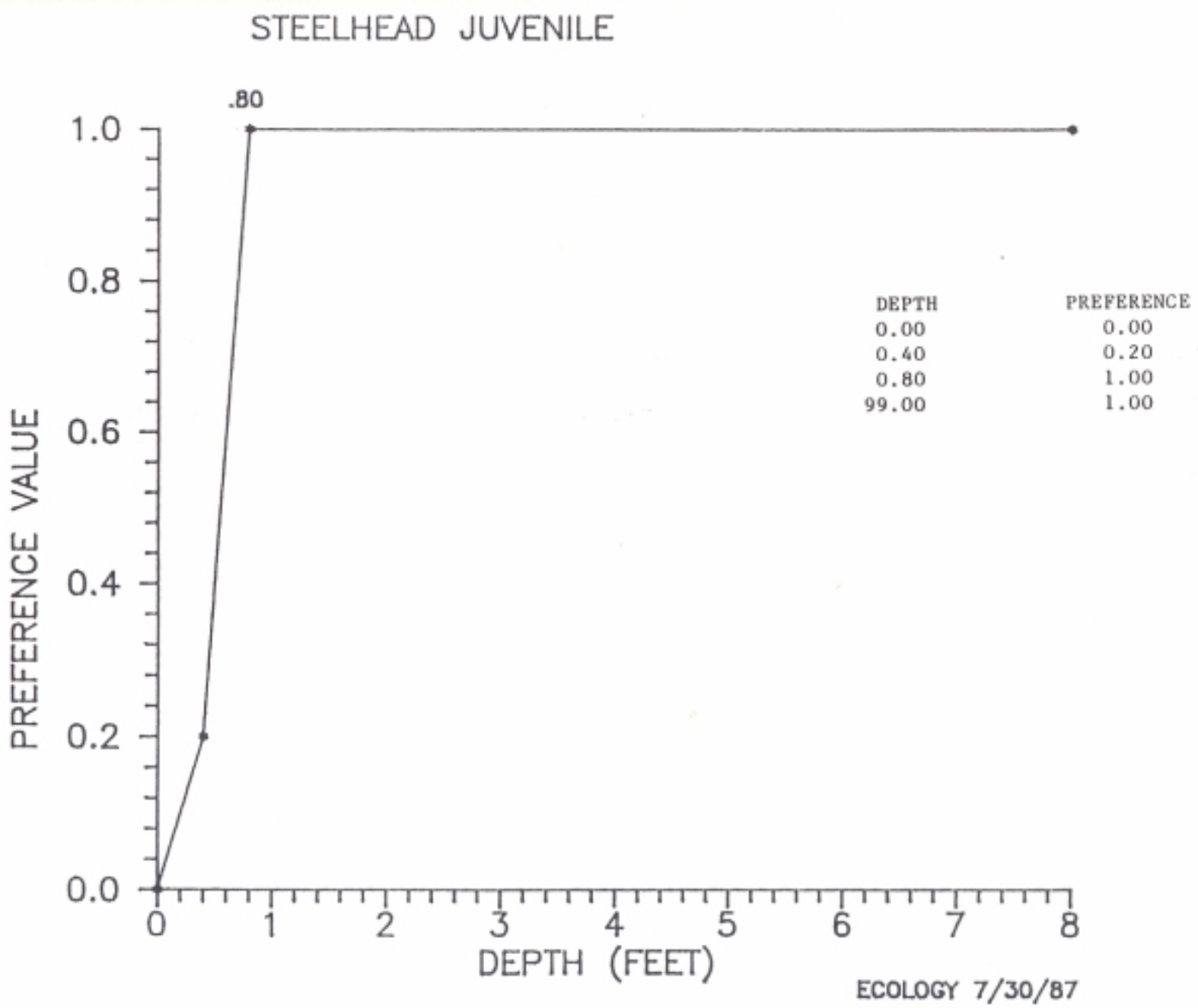
VELOCITY	PREFERENCE
0.0	0.0
0.7	0.0
1.6	1.0
3.0	1.0
4.0	0.5
5.0	0.1
6.0	0.0
99.9	0.0

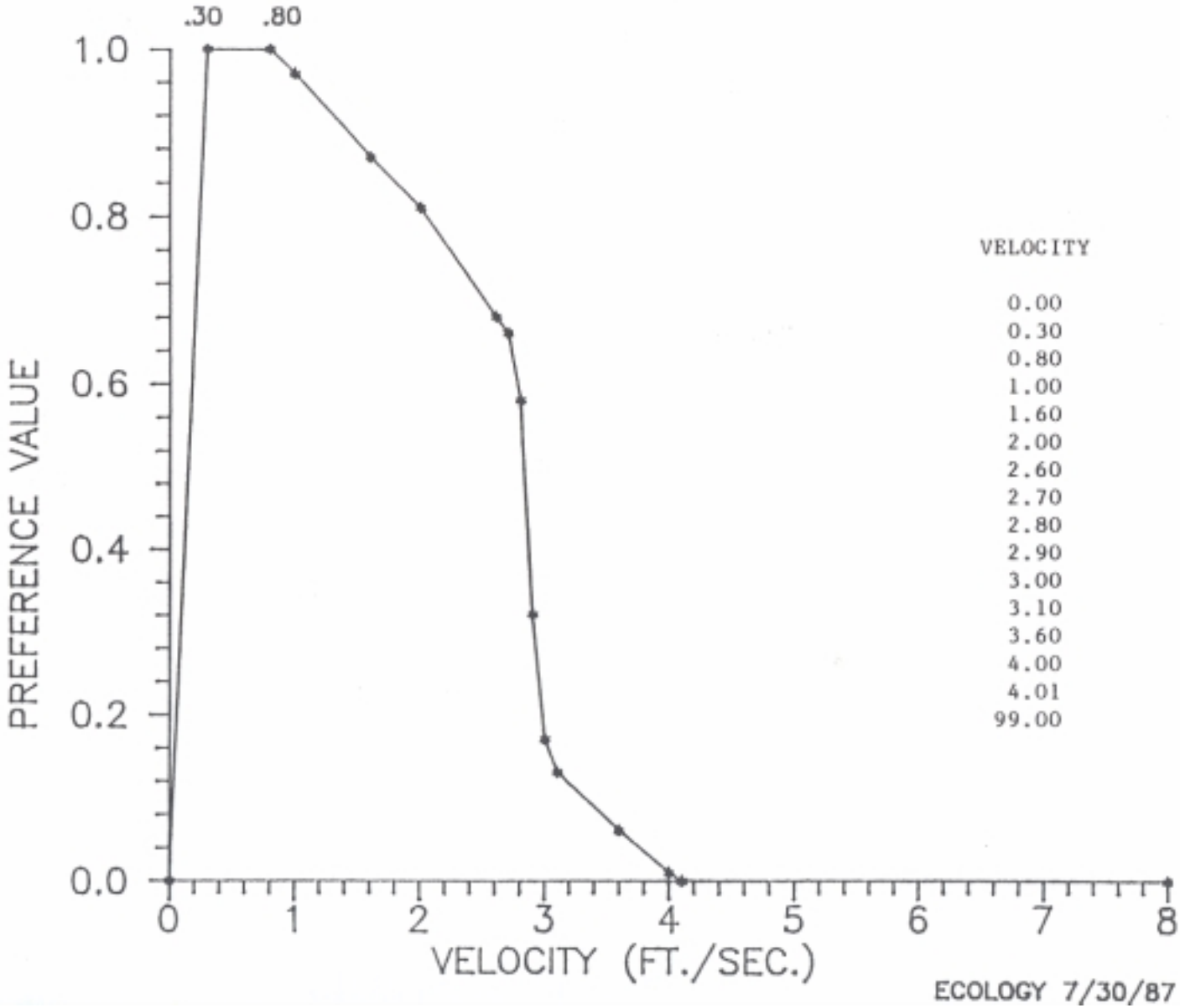


DEPTH	PREFERENCE
0.00	0.00
1.00	0.00
1.50	0.60
1.70	0.80
2.00	0.90
2.30	1.00
99.00	1.00

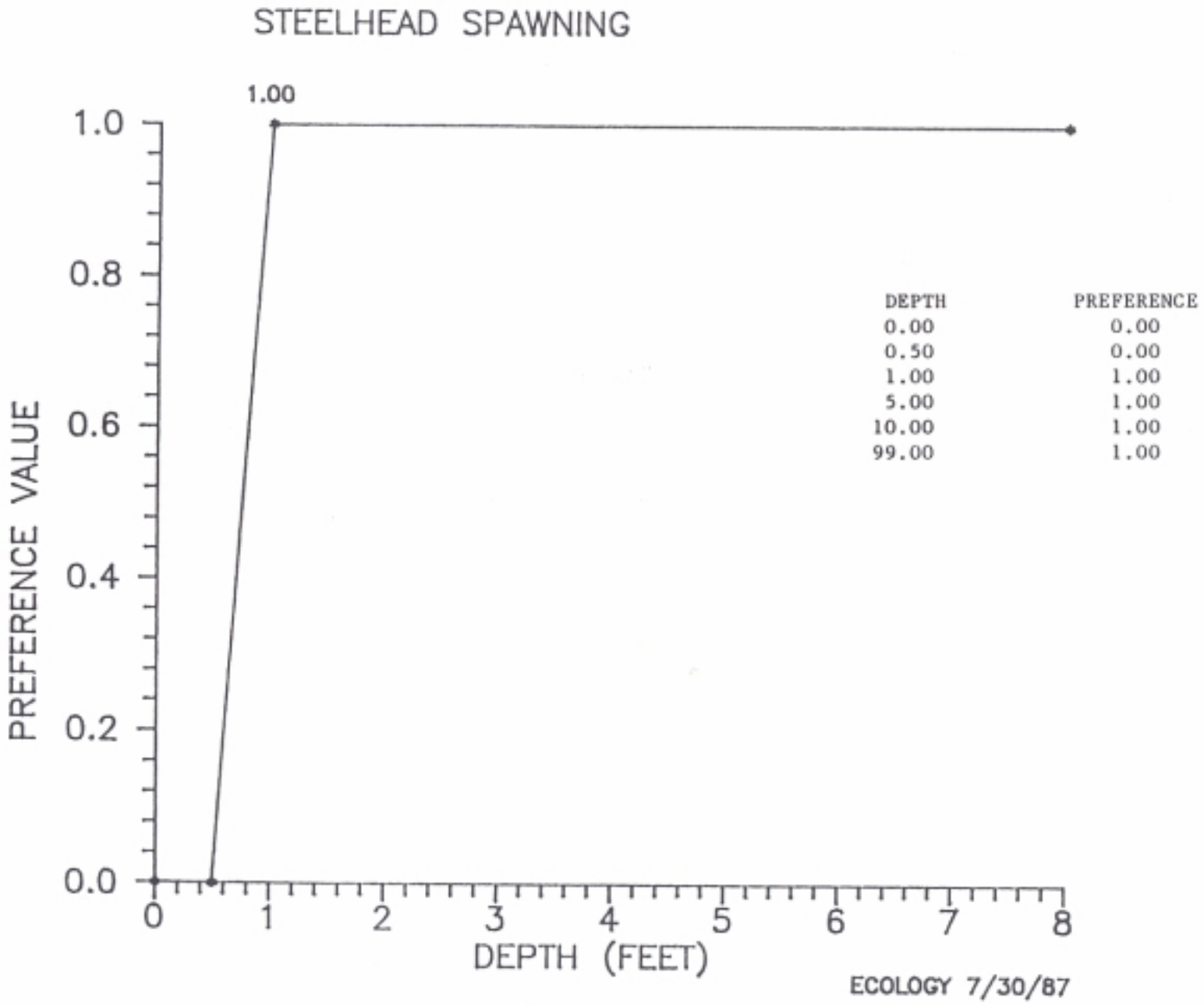


VELOCITY	PREFERENCE
0.00	0.00
0.60	0.02
1.20	0.20
1.40	0.40
1.50	1.00
1.70	1.00
1.80	0.96
1.90	0.40
2.50	0.08
3.00	0.02
4.00	0.00
99.00	0.00

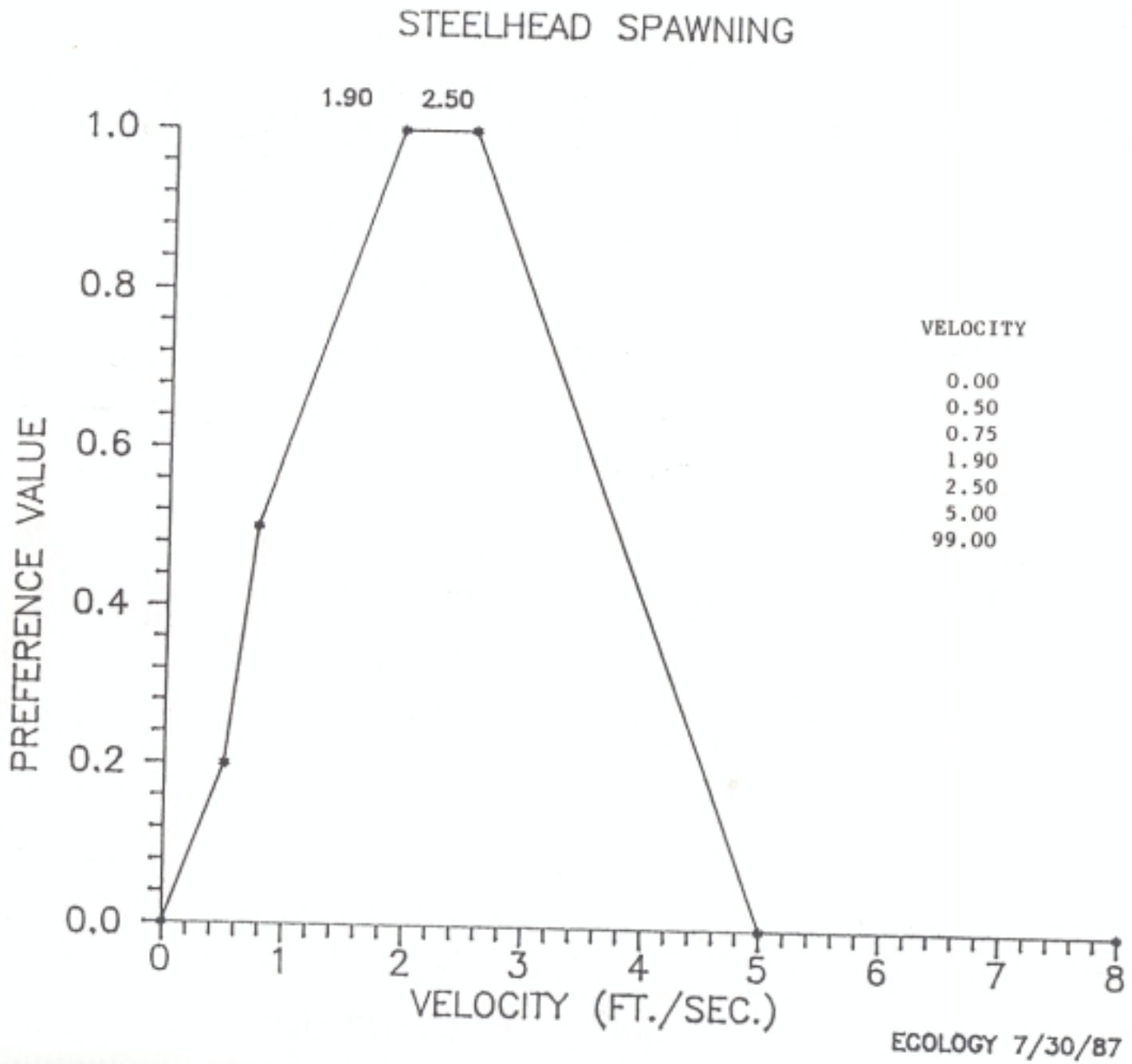

STEELHEAD JUVENILE
.80
1.0
0.8
0.6
0.4
0.2
0.0
PREFERENCE VALUE
0
1
2
3
4
5
6
7
8
DEPTH (FEET)
DEPTH PREFERENCE
0.00 0.00
0.40 0.20
0.80 1.00
99.00 1.00
ECOLOGY 7/30/87



VELOCITY	PREFERENCE
0.00	0.00
0.30	1.00
0.80	1.00
1.00	0.97
1.60	0.87
2.00	0.81
2.60	0.68
2.70	0.66
2.80	0.58
2.90	0.32
3.00	0.17
3.10	0.13
3.60	0.06
4.00	0.01
4.01	0.00
99.00	0.00



DEPTH	PREFERENCE
0.00	0.00
0.50	0.00
1.00	1.00
5.00	1.00
10.00	1.00
99.00	1.00



VELOCITY	PREFERENCE
0.00	0.00
0.50	0.20
0.75	0.50
1.90	1.00
2.50	1.00
5.00	0.00
99.00	0.00

DEPARTMENTS OF FISHERIES & WILDLIFE
INSTREAM FLOW STUDIES SUBSTRATE AND COVER CODE APPLICATION 11/23/87

The tree-digit code used describes the dominant substrate (the first number), the subdominant substrate (the second number), and the percent of only the dominant substrate (the third number). The percent of the subdominant substrate can be determined by subtraction. Dominant substrate is determined by the largest quantity of a certain substrate, not by the size of the substrate. The sum of the percent dominant and the percent subdominant will total 100 percent. The coding will not allow the dominant percent to be less than 50 percent, or greater than 90 percent. All other preference values are determined by using weighted averages. The value of the dominant substrate is multiplied by the percent of the dominant substrate, and the product is added to the product of the subdominant substrate times the percent of subdominant substrate. The sum of all the codes observed times their preference value will be a value between 0.0 and 1.0. The coding should also give a preference value of zero for the entire substrate observation when the code is class zero, one, or two, and is 50 percent or more of the observation. Where there is a situation where addition of two values could equal more than 1.0, the value will default to 1.0. Overhanging vegetation should be counted as cover if it is within 3 to 4 feet of the water surface. Cover values should be incorporated with the substrate values for both salmon and steelhead juvenile life stages and for chinook and steelhead adult holding.

LIFE STAGES AND VALUE OF SUBSTRATE

		SALMON			STEELHEAD & TROUT			
					Spawning		Rearing/Holding	
Code	Substrate Size in inches	Juvenile Rearing	Spawning	Adult Holding	Steelhead	Trout	Juvenile & Adult	Steelhead Adult
0 Detritus		.1	0	.1	0	0	.1	.1
1 Silt, Clay		.1	0	.1	0	0	.1	.1
2 Sand		.1	0	.1	0	0	.1	.1
3 Small Gravel	.1 - 0.5	.1	.3	.1	.5	1	.1	.1
4 Medium Gravel	.5 - 1.5	.3	1	.3	1.0	1	.3	.3
5 Large Gravel	1.5 - 3.0	.3	1	.3	1.0	1	.3	.3
6 Small Cobble	3.0 - 6.0	.5	1	.3	1.0	.5	.5	.3
7 Large Cobble	6.0 - 12.0	.7	.3	.3	.3	0	.7	.3
8 Boulder		1.0	0	1.0	0	0	1.0	1.0
9 Bedrock		.3	0	.3	0	0	.3	.3
0.1 Undercut bank		1.0	0	1.0	0	0	1.0	1.0
0.2 Overhanging Vegetation		1.0	0	1.0	0	0	1.0	1.0
0.3 Root Wad		1.0	0	1.0	0	0	1.0	1.0
0.4 Log Jam		1.0	0	1.0	0	0	1.0	1.0
0.5 Log Instream		.8	0	.8	0	0	.8	.8
0.6 Submerged Vegetation		1.0	0	.8	0	0	1.0	.8
0.8 Grass/Bushes Up on Bank		.1	0	.1	0	0	.1	.1
0.9 Fine Organic Substrate		.1	0	.1	0	0	.1	.1

(* 0.6 for chinook spawning can be used, depending on river size)

APPENDIX K
EXCEEDENCE HYDROGRAPHS

The exceedence hydrographs for the Ecology IFIM sites (Figures 1-4) were estimated from USGS streamflow data. The first step was generation of a long-term record of daily streamflow for each site. The 10 percent, 50 percent, and 90 percent exceedence flows were calculated assuming a Log-Pearson Type III distribution. Pearson k-values were computed by an equation generally considered reliable for the skew coefficients between 1.0 and -1.0. The k-values were based on the standard normal deviates, not the Pearson k-tables.

Little Klickitat River, Lower Site

The long-term record of daily stream flow for this site uses USGS data from the Little Klickitat River at Wahkiacus (period of record 1945 - 1982).

Little Klickitat River, Upper Site

The long-term streamflow for the Ecology Little Klickitat River, Upper site was estimated by proportioning the streamflow at Goldendale based on the ratio of the watershed area above the Ecology site to the watershed area above the USGS Goldendale gage. The equation used was: Little Klickitat River, Upper Site = 130/84 of Little Klickitat near Goldendale.

Blockhouse Creek

Long-term streamflows for Blockhouse Creek were estimated based on a simple proportioning of Blockhouse Creek's watershed area compared to Mill Creek's watershed. The equation used was: Blockhouse Creek = 10/30 of Mill Creek.

Bloodgood Creek

The hydrograph for Bloodgood Creek is for one year only and is based on data that Ecology collected.

Bowman Creek

Streamflows for Bowman Creek were estimated based on a simple proportioning of Bowman Creek's watershed area compared to Mill Creek's watershed. The equation used was: Bowman Creek = 23/30 of Mill Creek.

Mill & Spring Creeks

The long-term record of daily streamflow for each site was made by correlating existing USGS streamflow data on these streams (Spring Creek near Blockhouse, 14112300, 1964-1968 and Mill Creek near Blockhouse, 14112400, 1964-1973) with the long-term records available for the Little Klickitat River at Wahkiacus was used to estimate streamflow of Spring Creek. The regression equations and related statistics are:

Spring Creek

number of observations = 1341
correlation coefficient = 0.97
coefficient of determination = 0.5
equation: Spring Creek = exp(2.437+0.037*1n(Little Klickitat))

The Spring Creek estimations were modified during the spring and summer to reflect irrigation diversions above the study site. An estimate of irrigation diversions was obtained the study site. An estimate of irrigation diversions was obtained from Ecology water right records. Because the stream is primarily spring fed, the 10 percent, 50 percent, and 90 percent exceedence flows were similar. Only the 50 percent exceedence flow is shown in the hydrograph in Figure 4.

Mill Creek

number of observations = 2252
correlation coefficient = 0.98
coefficient of determination = 0.95
equation: Mill Creek = exp(0.483+0.5721*1n(Little Klickitat))

APPENDIX L
TEMPERATURE DATA

Date	Discharge	Water Temperature	Time of Day
Lower Little Klickitat River			
4-16-87	151.0 cfs	55° F	11:30 A.M.
5-14-87	76.0 cfs	58° F	10:19 A.M.
6-17-87	31.0 cfs	55° F	9:58 A.M.
7-15-87	15.0 cfs	67° F	8:14 A.M.
10-1-87		54° F	1:00 P.M.
Upper Little Klickitat River			
4-07-87	90.0 cfs	52°F	
5-14-87	41.0 cfs	64°F	3:00 P.M.
6-16-87	14.0 cfs	63°F	3:00 P.M.
7-14-87	5.0 cfs	87°F	2:38 P.M.
Bloodgood Creek			
4-02-87	3.8 cfs	55°F	
5-13-87	7.0 cfs	54°F	12:32 P.M.
6-16-87	7.0 cfs	52°F	12:06 P.M.
7-14-87	3.8 cfs	59°F	12:57 P.M.
9-30-87	5.1 cfs	54°F	1:30 P.M.
Blockhouse Creek			
4-6-87	8.4 cfs	52°F	
5-13-87	0.4 cfs		
6-16-87	0.5 cfs	58°F	3:32 P.M.
7-14-87	0.2 cfs	73°F	3:49 P.M.
9-30-87	0.3 cfs		
Mill Creek			
4-2-87	21.0 cfs	54°F	
5-13-87	11.6 cfs	54°F	4:00 P.M.
6-16-87	6.8 cfs	58°F	4:27 P.M.
7-14-87	3.3 cfs	70°F	4:46 P.M.
9-30-87	4.3 cfs	54°F	4:00 P.M.
Bowman Creek			
4-3-87	27.4 cfs	50°F	
5-13-87	13.3 cfs	56°F	5:15 P.M.
6-16-87	5.0 cfs	56°F	5:16 P.M.
7-14-87	1.5 cfs	78°F	5:31 P.M.
9-30-87	0.5 cfs	58°F	4:45 P.M.

Date	Discharge	Water Temperature	Time of Day
Spring Creek			
5-13-87	12.9 cfs	54o F	2:11 A.M.
6-16-87	8.7 cfs	56o F	1:12 A.M.
7-14-87	6.7 cfs	66o F	1:44 A.M.
9-30-87	4.3 cfs	52o F	2:15 A.M.

APPENDIX M
LITERATURE CITED

Bovee, K. D., 1982. A Guide to Stream Habitat Analysis using the Instream Flow Incremental Methodology. Instream Flow Paper 12. U.S. Fish and Wildlife Service, Fort Collins, Colorado. FWS/OBS-82/26.

Milhous, R. T., et. al. 1984. User's Guide to the Physical Habitat Simulation System. Instream Flow Paper 11. U.S. Gish and Wildlife Service, Fort Collins, Colorado. FWS/OBS-81/43 Revised.

OUR MISSION

WASHINGTON STATE DEPARTMENT OF ECOLOGY

The mission of the Department of Ecology is to protect, preserve and enhance Washington's environment and promote the wise management of our air, land and water for the benefit of current and future generations.

To accomplish this mission, Ecology will:

- Recognize its most valuable asset is its dedicated and committed employees and it will provide necessary support, training and professional development.
- Promote prevention and conservation as the most effective ways to preserve our natural resources and protect the environment.
- Enforce environmental laws and regulations in a fair and firm manner.
- Provide public, education programs to promote wise use of our natural resources and encourage environmental protection.
- Offer information, technical and financial assistance to help the public, governments, businesses and industries comply with environmental laws and regulations.
- Promote the recognition that compliance with environmental laws and regulations is compatible with a sound economy.
- Promote meaningful public involvement in the development of rules, regulations and new initiatives.
- Provide leadership in addressing emerging problems and strive to bring public agencies and diverse interest groups together to address environmental issues.
- Use an integrated approach to resolve environmental issues.
- Place special emphasis on educating and working with youths to create a strong environmental ethic.
- Help state agencies set an example in environmental protection.
- Work with the executive and legislative branches to promote sound environmental policy.

WASHINGTON STATE DEPARTMENT OF ECOLOGY