WYOMING GAME AND FISH DEPARTMENT

FISH DIVISION

ADMINISTRATIVE REPORT

TITLE: North Platte River Below Glendo Reservoir Instream Flow Report

PROJECT: IF-5591-07-9101

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INTRODUCTION

Background

The North Platte River (NPR) flows northward from Colorado and enters Wyoming in Albany County in southeastern Wyoming. The river flows in a northerly direction to the city of Casper, where it turns east, eventually exiting Wyoming and entering Nebraska (Figure 1). In Wyoming, the NPR flows approximately 436 miles, loses nearly 4,000 feet in elevation, and drains 20,588 square miles. Within Wyoming, the NPR is a highly developed river system. The reach of river from Interstate 80 downstream to the town of Guernsey, a distance of 274 miles, contains eight dams, seven of which are operated by the Bureau of Reclamation (BOR). The eighth dam is located just downstream of Glenrock and is owned and operated by Pacific Power and Light. Of the seven BOR dams, five of are located upstream of Casper, while two (Glendo and Guernsey) are located downstream.

Glendo Dam is located on the NPR 4.5 miles southeast of the town of Glendo. The dam was completed in 1958, and when full, creates a reservoir 14 miles long and has a storage capacity of 795,196 acre-feet. The Glendo powerplant is located approximately 1.5 miles downstream of the dam and has a capacity of 24.0 MW. Downstream of the dam, the NPR flows for 20 miles before entering Guernsey Reservoir.

Due to the operation of Glendo Dam, this 20 mile stretch of river has a totally modified, non-typical flow regime. Flows remain high through the summer months to meet downstream irrigation demands, and then are essentially "turned off" (releases equal zero) during the fall and winter to allow Glendo Reservoir to fill. As a result of this annual flow pattern, the biotic community of the NPR downstream of Glendo Dam has been severely suppressed for over 30 years.

Presently, the river between Glendo and Guernsey reservoirs is rated as a Class 3 trout stream (fisheries of regional importance) by the WGFD. However, this stretch may have the potential to be a Class 1 trout stream (fisheries of national importance) with a better flow regime.

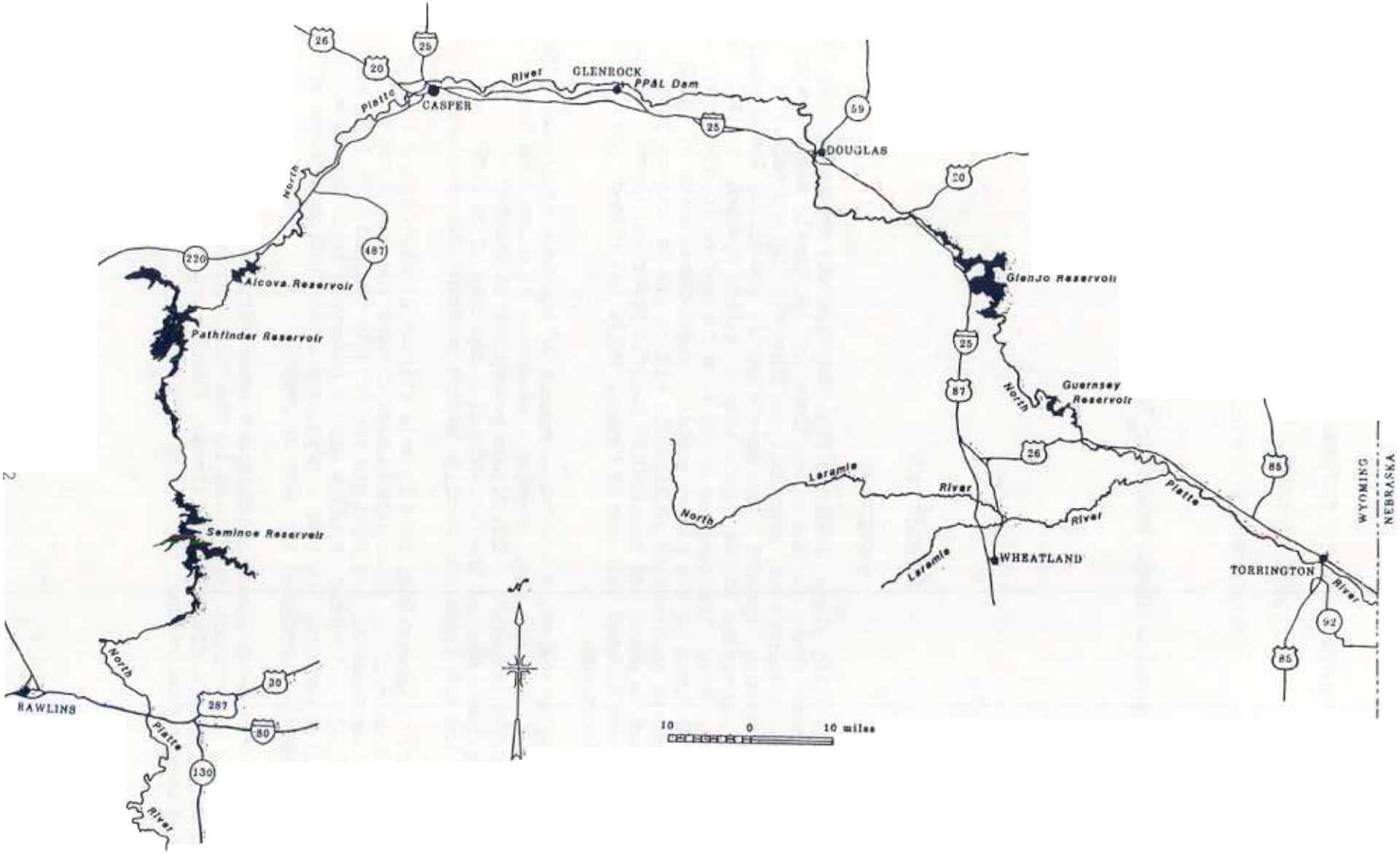


Figure 1. The lower North Platte River system in Wyoming.

Three prior instream flow/habitat analyses have been conducted by the WGFD within this stream reach. Work performed in 1983 determined that a minimum flow of about 125 cfs was necessary to maintain the adult brown trout (Salmo trutta) population in the stretch of river just downstream of the Glendo powerplant. A second study, completed in 1987, recommended a minimum flow release of 290 cfs. This analysis was performed using a riffle habitat retention method (Nehring 1979), using criteria set for use on Wyoming streams by the WGFD. Binns et al. (1980) used the Habitat Quality Index (HQI) (Binns and Eiserman 1979, Binns 1982) to evaluate habitat conditions at three locations on the NPR between Glendo Dam and Guernsey Reservoir. Binns et al. (1980) determined that a minimum flow release from Glendo Reservoir of 133 cfs would improve fish habitat conditions in the downstream reach of the NPR.

Study Objectives

Beginning in late 1992, the BOR will modify the flow release schedule by allowing a minimum flow of 25 cfs at all times of the year. This study, termed the NPR/GLENDO study, was undertaken in part, to evaluate the possible fishery benefits of this discharge This evaluation was based on predicted changes in trout habitat quantity and quality with the changes in flow conditions.

There were three primary objectives of this study:

1. Evaluate the potential changes/benefits in fish habitat of the NPR study reach given a year round minimum release of 25 cfs;

2. Determine the level of discharge required to meet a minimum and a preferred instream flow for trout;

3 Perform a limiting factor analysis for the study reach.

Description of Study Area

The stretch of the NPR between Glendo Dam and Guernsey Reservoir has three distinct sub-reaches based on channel morphology. The reach of river extending from the dam downstream to the powerplant is unique in that it has not received flows of any significant magnitude and/or duration since the dam was closed. The area has become severly encroached by riparian vegetation and is now ponded by two road crossings/dikes which cross the historic channel. Instream flow/habitat work completed on downstream reaches is not applicable to this reach.

The 12 miles of river from the powerplant to the top end of Wendover Canyon is low gradient and meandering, with a relatively wide channel. The river is characterized by having long stretches of deep run/glide habitats, with short riffle sections between them. The surrounding lands are primarily used for grazing and hay production.

The lower section of the NPR flows through Wendover Canyon. Here the river channel is narrower, with increased gradient. Habitat type is dominated by a balance of pool/riffle combinations, with a increased amount of instream structure (i.e. boulders) than is present in the upper section.

Two perennial streams enter the NPR within the study reach. Horseshoe Creek enters the NPR from the west, 4.5 miles downstream of Glendo Dam. This creek has a mean annual discharge of 28.0 cfs (USGS Gage #066533.00), with an average winter time flow of only 1 to 2 cfs. Big Cottonwood Creek enters the NPR at the downstream end of the canyon, near the town of Wendover. This stream is ungaged, but with a much smaller watershed than Horseshoe Creek, it should have a smaller total water yield.

The mean monthly hydrograph and a flow duration curve for the NPR in the study reach is shown in Figure 2. These are based on data collected at USGS Gage #066528.00 (WY1981-WY1990). This gage is located 3.1 miles downstream from Glendo Dam and has a period of record (POR) of October 1957 to present. At this gage, the NPR has a drainage area of 15,548 square miles and is at an elevation of 4,489 feet above mean sea level. The mean daily discharge for the POR is 1,646 cfs, with maximum and minimum extremes of 10,300 cfs and 0.0 cfs, respectively.

The primary fish species inhabiting the NPR between Glendo and Guernsey Reservoirs include; rainbow trout (Oncorhynchus mykiss), brown trout, Snake River cutthroat trout (O. clarki), walleye (Stizostedion vitreum), yellow perch (Perca flavescens), white sucker (Catostomus commersoni), longnose sucker (C. catostomus) carp (Cyprinus carpio), and quillback (Carpiodes cyprinus).

The river section is managed as a basic yield fishery for rainbow, brown and cutthroat trout, and is stocked with advanced fingerlings (4 inches) of each of these species.

METHODS

This section describes the field and data analysis techniques used during this study. All field work for this study was performed from July through September 1991.

Study Site Selection

In June 1991, the North Platte River from Glendo Dam downstream to Wendover was floated to view the river and select a study site. The study site used represented the major habitat types found in the upper reach of river. This habitat type is characterized by a short riffle followed by a long slow glide/run immediately upstream. Site selection was based on from the representative reach approach described by Bovee (1982).

This study site was located approximately 7 miles downstream of Glendo Dam, and 1 mile downstream of Cassa Bridge. The site is in Platte County, R67W, T28N, S7, SE1/4. It was estimated that during normal winter months, flow from dam leakage, tributaries and gains at this reach of river averaged approximately 10 cfs. This site appeared to be very similar to the majority of the upper river section in that it contained a short riffle/run habitat type on the downstream end, with a much longer stretch of deep, glide type of water on the upstream. No study was established in the lower stretch of river (Wendover Canyon) because it was assumed that flow recommendations made in the upper stretch would satisfy habitat needs for the lower section as well. The total length of the study site was approximately 1,500 feet.

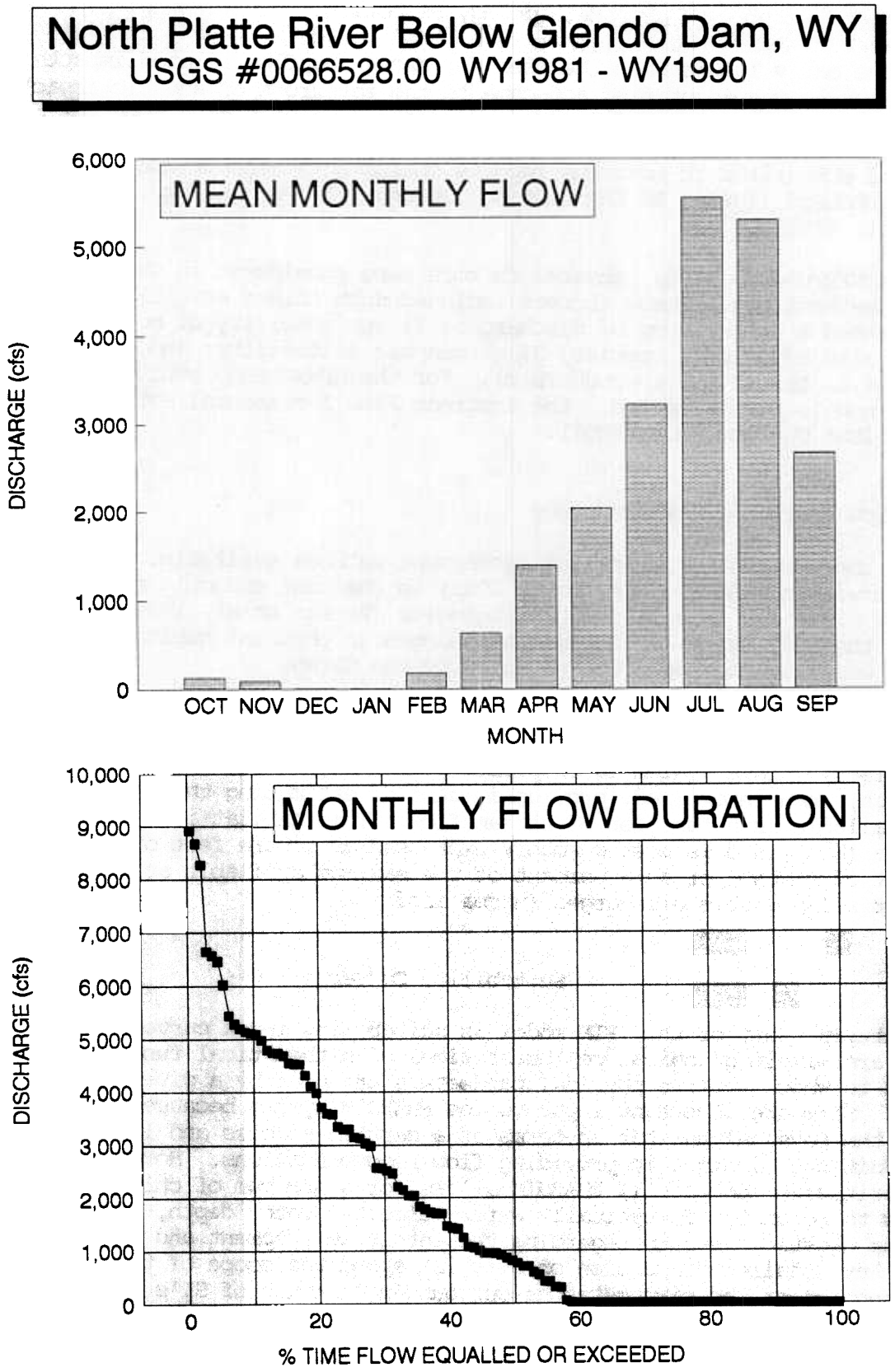


Figure 2. Mean monthly flow and flow duration for the North Platte River below Glendo Dam, Wyoming (USGS #0066528.00).

Methodology Selection

Since the early 1970's when the need for assessing flow related impacts on aquatic resources was identified and came to the forefront of aquatic impact analysis, a multitude of methodologies and models have been developed for quantifying habitat and/or formulating instream flow recommendations. These models have been reviewed and summarized in numerous reports including Stalnaker and Arnette (1976), Wesche and Rechard (1980), EA Engineering, Science, and Technology, Inc. (1986), and Fausch et al. (1988).

For the NPR/Glendo study, several factors were considered in the selection of an evaluation methodology. These factors included such things as: 1) providing the means to assess a large range of discharges; 2) applicability of model primarily for trout, but also additional species; 3) geographic suitability; and, 4) biological soundness (i.e. tested and reproducible). For the NPR/Glendo study, two habitat assessment models were selected; the Instream Flow Incremental Methodology (IFIM), and the Habitat Quality Index (HQI).

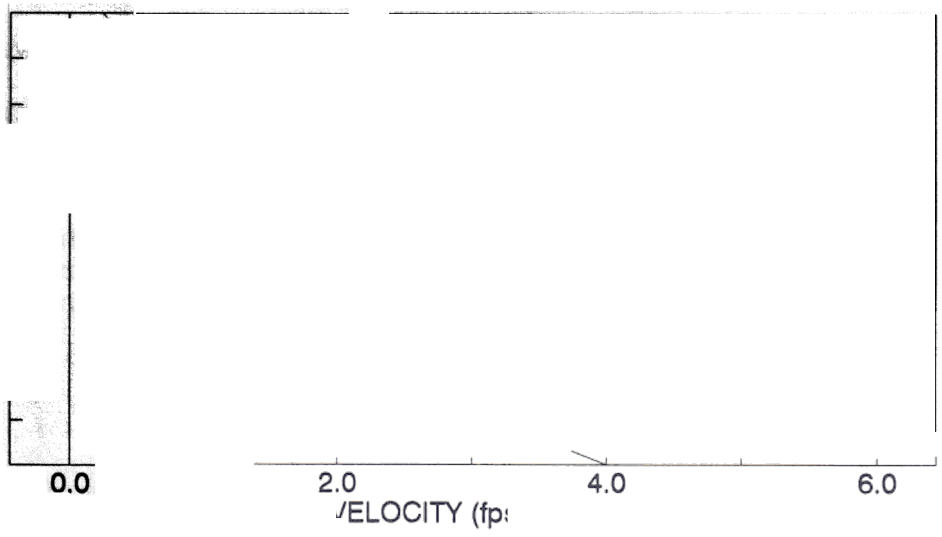
Instream Flow Incremental Methodology

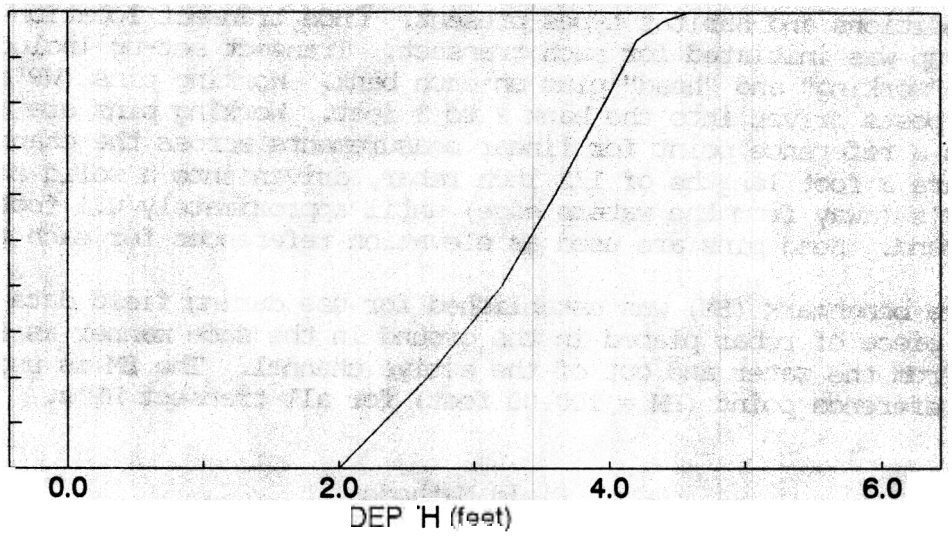
Of all the instream flow/habitat assessment methods available, the U.S. Fish and Wildlife Service's (USFWS) IFIM (Bovee 1982) is the most commonly applied and widely accepted by state and federal resource agencies (Reiser et al. 1989). The model allows for the evaluation of incremental changes in physical habitat with changes in flows, and was also developed and promoted by the USFWS.

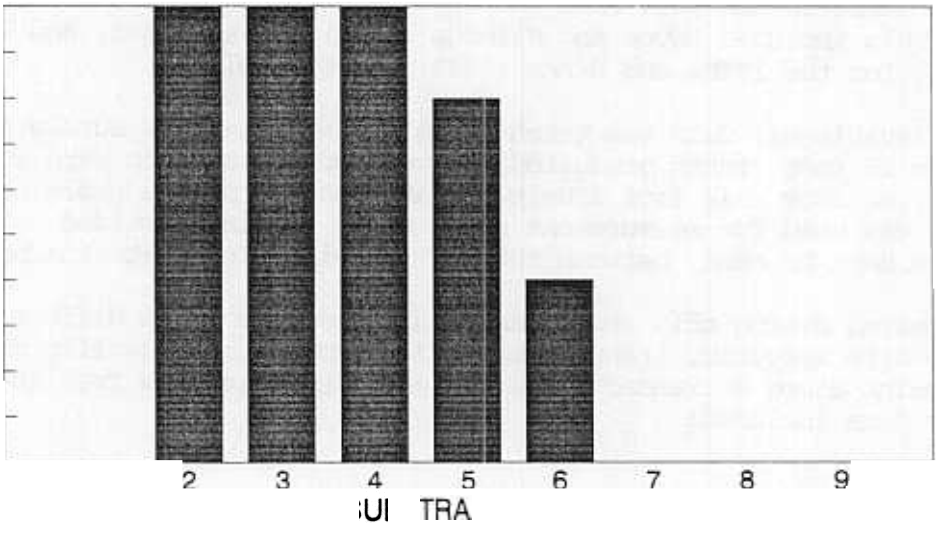
The primary analysis component of the IFIM is the computer software package collectively known as the Physical Habitat Simulation System (PHABSIM) (Milhous et al. 1984, 1989). This system is comprised of both hydraulic and habitat simulation models which, when interfaced, provide a means of estimating the quantity of physical habitat available as a function of stream flow. This habitat is termed Weighted Usable Area (WUA), and is most commonly expressed as square feet of habitat per 1,000 linear feet of stream, or as a percent of the maximum available at any single location at all possible discharges (normalized).

Suitability Curves

One integral part of the IFIM model is suitability index curves (SI's) (Figure 3). SI's are simple graphical representations of mathematical functions which define the limits to which various physical parameters are used by a given fish species and lifestage. SI's are important input to the PHABSIM system because they define for the model the physical habitat in terms of a certain species and lifestage, which can provide additional insight in providing flow recommendations. However, SI,s are also commonly criticized because 1) PHABSIM allows for a maximum of only three physical parameters to be analyzed (typically water velocity, water depth, and substrate) and 2) numerous questions remain regarding the entire development and application process of SI's. Any detailed discussion on SI's is beyond the scope of this report, however, mention of the circumstances surrounding the use of SI's is important to establish the limits within which results may be interpreted.







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Habitat Quality Index

A second model used for this analysis was the HQI. The HQI was developed by the WGFD for use on Wyoming streams, and is the department's standard trout habitat evaluation procedure. The HQI was developed and tested on 36 study streams of various sizes located throughout Wyoming. The HQI model is one of the most widely applied models in the western U.S.

The HQI procedures involve the measurement and rating of nine physical and chemical variables for a given stream reach. The rated variables are then used as input into a power function equation, with the resultant output being in a unitless index termed Habitat Units (HU's).

Transect Selection and Setup

Five cross-channel transects were established within the study site (Figure 4) for use with both models. Locations of these transects were based on specific hydraulic conditions and habitat types present. Once transect locations were marked, transect set-up was initiated for each transect. Transect set-up included the placement of "working" and "head" pins on each bank. Working pins (WP's) are 5-foot fence posts driven into the bank 2 to 3 feet. Working pins are used to secure cables and as a reference point for linear measurements across the channel. Head pins (HP's) are 3 foot lengths of 1/2 inch rebar, driven into a solid substrate behind the WP's (away from the waters edge) until approximately 0.1 foot remains above the ground. Head pins are used as elevation references for each transect.

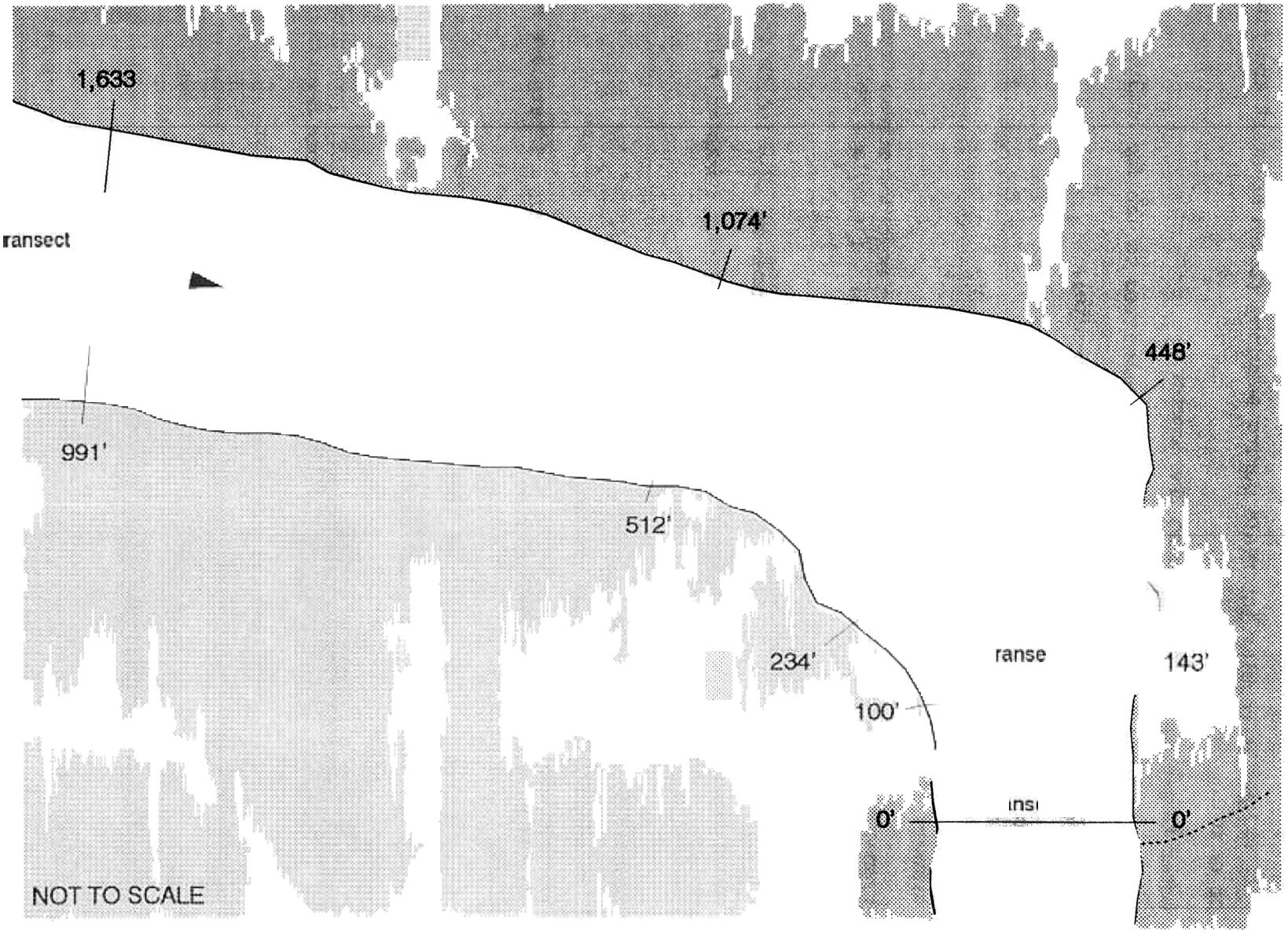
A relative benchmark (BM) was established for use during field data collection. The BM was a piece of rebar placed in the ground in the same manner as HP's, but placed away from the water and out of the active channel. The BM is used as an elevational reference point (BM = 100.00 feet) for all transect HP's.

Field Methods

All field measurements were made in strict accordance with outlined and accepted procedures. This included Bovee and Milhous (1978), Bovee (1982) and Trihey and Wegner (1981), for the IFIM; and Binns (1982) for the HQI.

Survey (elevational) data was taken using a PENTAX B-1 32x autolevel and a standard 14 or 25 foot (tenth graduated) survey rod. Transects were measured by either wading, or from a 14 foot aluminum boat with a standard cable and reel set-up. When the boat was used for measurement purposes, a 1/8 inch braided, steel cable was stretched from bank to bank, between the working pins, for boat attachment.

Data collected during this study can be grouped into three different types. These include site specific, transect specific, and station specific data. A station is a single point along a transect which is a defined distance from the left bank WP. Site specific data included: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discharge at time of sampling (calculated);

gage height at regular intervals during sampling (taken at start and finish of each transect);

water temperature (using pocket thermometer);

nitrate-nitrogen (water sample taken and submitted to lab for analysis);

length of eroding banks present (measured on-site);

photographs (taken at several photo points).

Transect-specific data included (Figure 5):

transect number;

transect location (distance in feet upstream from next downstream transect as measured on both the left and right banks with a fiberglass reel tape);

sampling time (begin and end);

elevation of left and right head pins (as referenced to BM = 100.00 feet);

water surface elevation (taken near both right and left banks as referenced to BM = 100.00 feet);

photograph looking along transect (across channel);

Station-specific data included (Figure 5):

distance from left working pin (in feet as measured with a fiberglass reel tape);

bank/stream bed elevation (as referenced to BM = 100.00 feet);

water depth (read from a wading rod or reading taken off cable and reel - in feet);

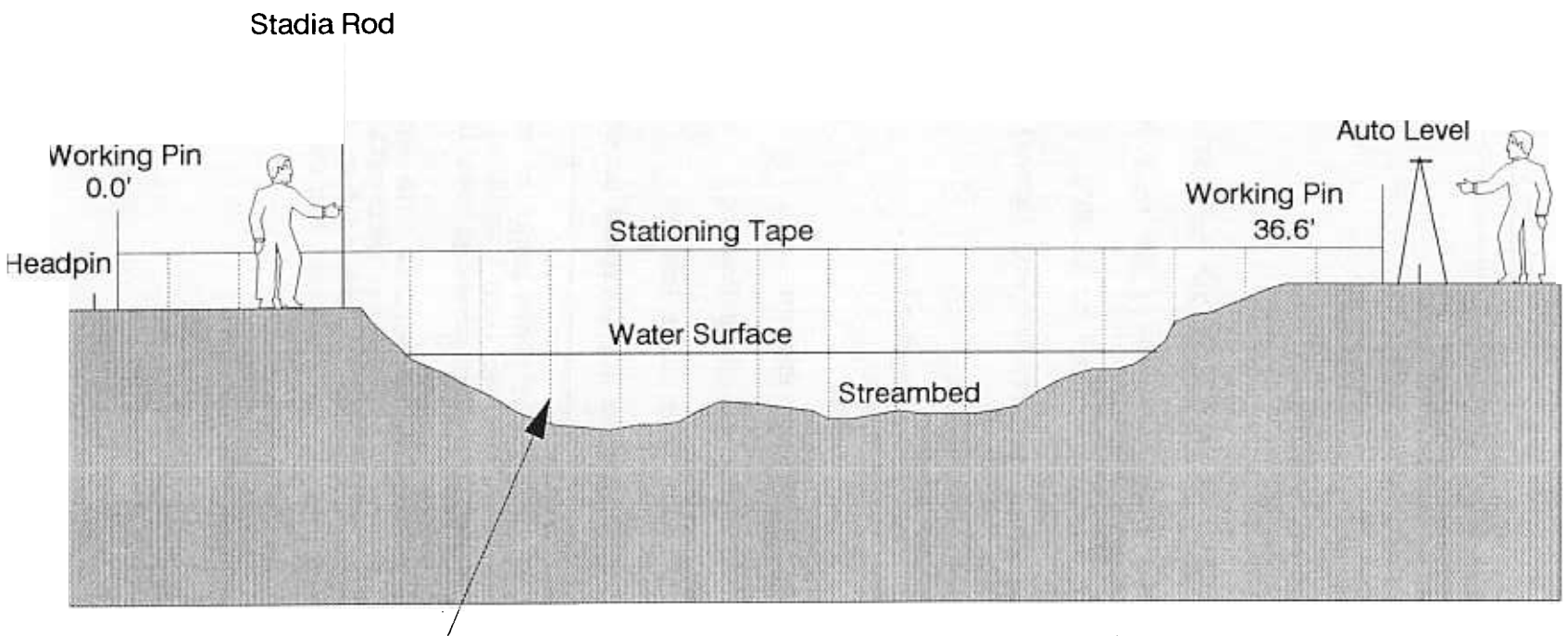
mean column velocity as defined by Buchanan and Somers (1968) (measured using a Marsh-McBirney brand 201 velocity meter - in feet per second);

substrate class (% dominant and subdominant - see Table 1 for classification);

percent embeddedness (as defined by Platts et al. (1983));

cover type present (see Table 1 for classification).

EXAMPLE CROSS CHANNEL TRANSECT



STATION 14.0' - Measurements Taken Include:

- Distance from working pin
- Streambed elevation
- Water depth
- Water velocity
- Substrate
- Embeddedness
- Cover

Figure 5. Example of cross-channel transect, and measurements taken during field data collection for use in the Physical Habitat Simulation System.

Table 1. Description of substrate and cover codes and classification used in the NPR/Glendo study.

Code	Classification
	Substrate
1	Organics/Sod
2	Silt/Clay
3	Sand
4	Fine Gravel (0.25" to 0.99")
5	Coarse Gravel (1.00" to 2.99")
6	Rubble (3.00" to 11.99")
7	Boulder (12.00" and larger)
8	Bedrock
9	Aquatic Vegetation
	Cover
1	No Cover Present
2	Instream Cover Present
3	Overhead Cover Present
4	Instream and Overhead Cover Present

All data were recorded in bound waterproof field books or on "write-in-the-rain" data sheets. Upon returning to the office after each completed field sampling effort, all field notes were photocopied and originals placed in the project files.

At each discharge sampled, either a full or partial data set was collected. A full data set included all site, transect and station information; while a partial data set included only site and transect data. A crew of four individuals was used to collect full data sets, while a crew of two was used for collecting partial sets

Selection of Target Species and Suitability Curves

One of the most important steps in any instream flow analysis using PHABSIM is the selection of target species, and the selection of suitability curves used to represent them.

Target species typically are those species which are generally considered to be those with primary importance (i.e. game fish). However, target species may include any fish species or guild, and can also be macroinvertebrates. For the NPR/Glendo study the two principal game fish inhabiting the reach, rainbow trout and brown trout, were selected as target species. Life stages included adult, juvenile, fry and spawning. Rainbow trout SI's used in PHABSIM were from Raleigh et al. (1984). This set of curves is considered a very generalized curve set and used often in PHABSIM studies. Adult, juvenile and spawning brown trout curves were from Wolff (1989). These curves were developed from several data sources collected on brown trout habitat utilization in mid-sized rivers in Wyoming and Montana. Brown trout fry curves came from Nehring (1986), and were collected on the South Platte and Gunnison rivers in Colorado. Curves used can be seen in Appendix A.

Data Analysis Procedures

Once all field data had been collected, data analysis procedures were initiated. Data analysis efforts were split between PHABSIM and HQI models. The majority of analysis routines were performed on a IBM-type microcomputer.

Physical Habitat Simulation System

Hydraulic and physical habitat simulations were completed using the methods and procedures described by Milhous et al. (1984, 1989). The primary hydraulic simulation model used was the one flow IFG-4A model. This model is a modification of the multiple flow IFG-4 model and is now the recommended procedure for most simulations (Milhous and Schneider 1985); Milhous (1984) found the IFG-4A model to be more reliable in its velocity predictions than was the IFG-4 model.

Hydraulic simulation using IFG-4A was completed individually for each transect; and on a low, mid, and high range deck for each transect. The differences in the flow range decks were in calibration. Each deck was calibrated to better simulate flow conditions in a given range of discharges (Table 2). These resulted in a total of 15 data decks used in the analysis.

Table 2. Range of simulated discharges used in HABTAT simulation for low, mid high flow calibrated IFG4 data decks.

	Discharge Range Simulated (cfs)
Low Range	10 to 100
Mid Range	> 100 to 1,000
High Range	> 1,000 to 10,000

After hydraulic simulation was completed, output data were used along with the selected SI's and processed through the HABTAT model of PHABSIM. Output from the HABTAT model provided physical habitat values (as WUA) for each transect at flows from 10 to 10,000 cfs. Data from each transect were used to compute mean physical habitat values for the study reach at each simulated flow. Mean physical habitat values were normalized; calculated as a percent of the maximum possible for that simulation range.

Substrates were not used in the habitat simulation portion of the analyses because the classification of substrates within our study site was difficult due to deep and turbid water, and algal mats on the streambed. Since the substrate component is a "static" parameter (does not change as a function of flow), the resultant physical habitat curves will primarily differ in magnitude, not function.

The final step performed during the PHABSIM analysis sequence was that of time series. This is simply taking the developed physical habitat versus discharge curves, and comparing it to a given flow regime, historic or proposed. The result is a graphic output of physical habitat versus time. The entire IFIM simulation sequence can be seen in Figure 6.

Habitat Quality Index

Variable rating and score calculation for the HQI was done according to Binns (1982), as modified by Annear (T. Annear, Wyoming Game and Fish Department, personal communication). The critical period used for rating flow dependent variables (X1 and X2) was 1 October to 31 March instead of the normal late summer period as is typically used. This was because the winter flow regime is assumed to be the limiting flow period for this stretch of river. All other variables were rated based on conditions present from August 1 to September 15, as suggested by Binns (1982). The mean discharge for this period was 4,843 cfs. A list of the nine variables used in computing the HQI score, along with the source of measured values is in Table 3.

HQI scores were computed based on 1) the current flow regime (10 cfs winter-time flow), 2) the proposed new flow regime with a 25 cfs minimum flow release, and 3) at an incremental set of discharges to attempt to make estimates for a maintenance and an optimum flow release. To compute HQI scores at unmeasured flows, all variables were held constant except X1 (critical period flow), and X2 (annual stream flow variation); as per Annear.

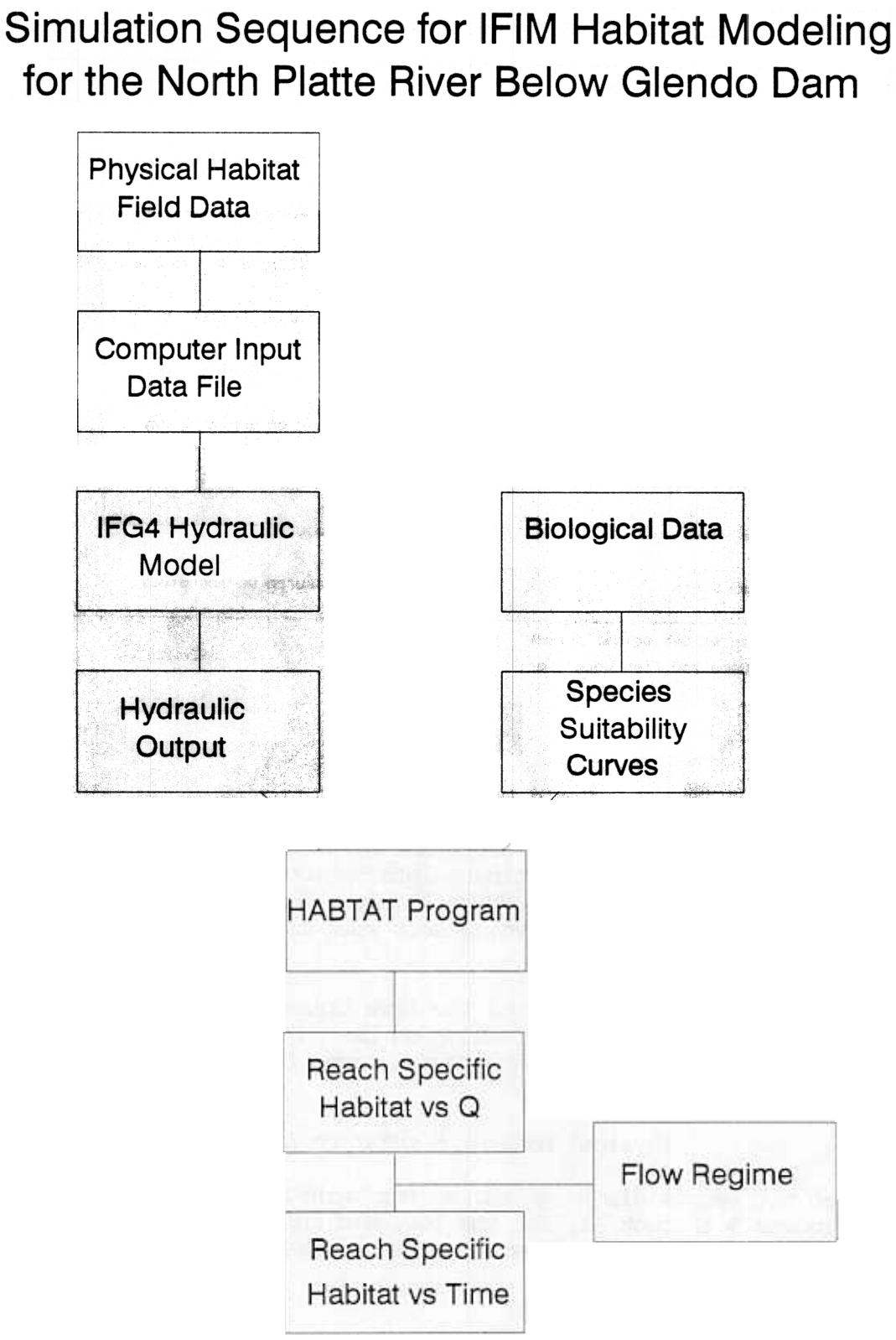


Figure 6. Sequence of modeling steps used with the Physical Habitat Simulation System.

Table 3. List of variables used in the Habitat Quality Index model, and sources where measured values were obtained for this study. See Binns (1982) for a detailed description of each variable.

Variable Data*	Variable	Source of Symbol	Description
X1	Critical Period Flow	USGS Gage #066528.00	(WY1981-WY1990)
X2	Annual Stream Flow Variation	USGS Gage #066528.00	(WY1981-WY1990)
X3	Maximum Summer Stream Temperature	USGS Gage #066528.00	(WY1960-WY1983)
X4	Nitrate-Nitrogen	WGFD Water Quality Data Base	
X7	Cover	Field Measured During Study	
X8	Eroding Stream Banks	Field Measured During Study	
X9	Substrate Condition	Field Measured During Study	
X10	Water Velocity	Field Measured During Study	
X11	Stream Width	Field Measured During Study	

USGS = United States Geological Survey
WGFD = Wyoming Game and Fish Department

RESULTS

Field Data Collection

Field data were collected on five different dates between 26 July and 30 September 1991. Table 4 presents pertinent information regarding each sampling time. Flows sampled ranged from over 7,000 cfs to 25 cfs. Full data sets were collected at the three middle flows, while only partial sets were collected at the high and low discharges.

Cross-sectional profiles for each of the five transects are shown in Figures 7 and 8. Table 5 presents summary information on the physical and hydraulic characteristics of each transect at each of the three fully measured discharges.

Physical Habitat Simulation System

Physical habitat versus discharge curves for rainbow trout (all life stages) are presented in Figures 9 through 11, for the low, mid and high flow ranges, respectively. Similar graphs for brown trout are presented in Figures 12 through 14.

Table 4. Pertinent information of individual sampling efforts for the NPR/Glendo study during 1991.

Date Sampled	Discharge Sampled (cfs)	Data Set Collected*
July 26	7,420	Partial
September 4	3,971	
September 23	773	
September 27	268,206**	
September 30	25	Partial

* - All site, transect and station specific data collected for full sample set; only site and transect specific data collected for partial data set.

** - Discharge at Transect 1 at time of sampling was 268 cfs; Discharge at Transects 2-5 at time of sampling was 206 cfs.

Table 5. Physical and hydraulic characteristics at measured discharges for individual transects at NPR/Glendo study site.

Transect	Discharge (cfs)	Top Width (ft)	Wetted Perimeter (ft)	Hydraulic Depth (ft)	Mean Velocity (fps)	X-Sec Area (ft2)
	3,971	299	300	3.01	4.40	901
	773	231	231	2.10	1.59	485
	268	187	187	1.79	0.80	334
2	3,971	324	325	3.56	3.44	1,154
	773	279	279	2.28	1.22	636
	206	235	235	1.66	0.53	391
3	3,971	423	424	3.43	2.74	1,451
	773	363	363	1.86	1.14	675
	206	326	326	1.04	0.61	338
4	3,971	328	330	4.17	2.91	1,367
	773	303	304	2.81	0.91	851
	206	266	266	2.19	0.35	582
5	3,971	259	260	5.16	2.97	1,336
	773	233	234	3.82	0.87	891
	206	210	211	3.19	0.31	670

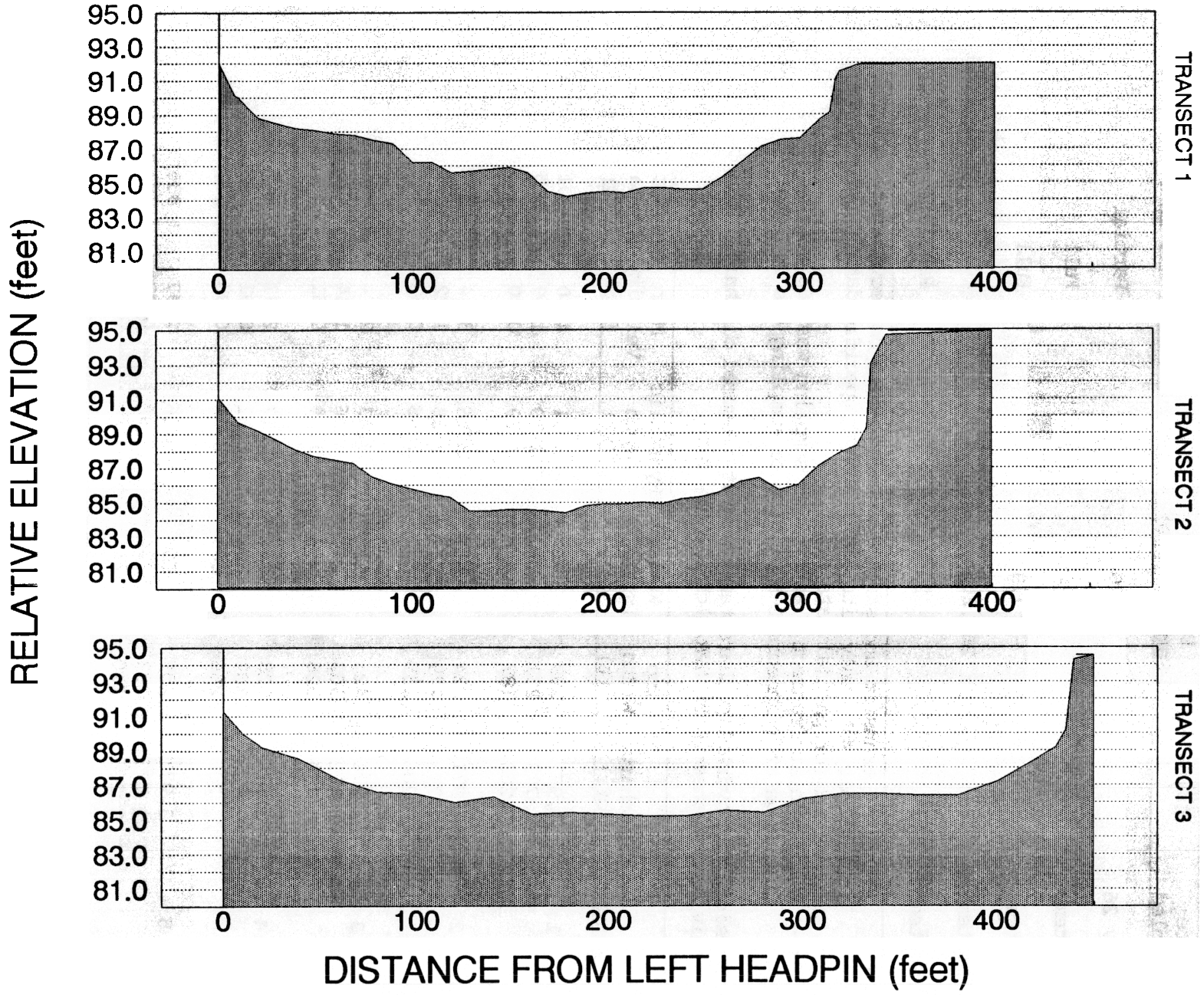


Figure 7. Cross-sectional profiles for transects 1 to 3 used during the NPR/Glendo instream flow study.

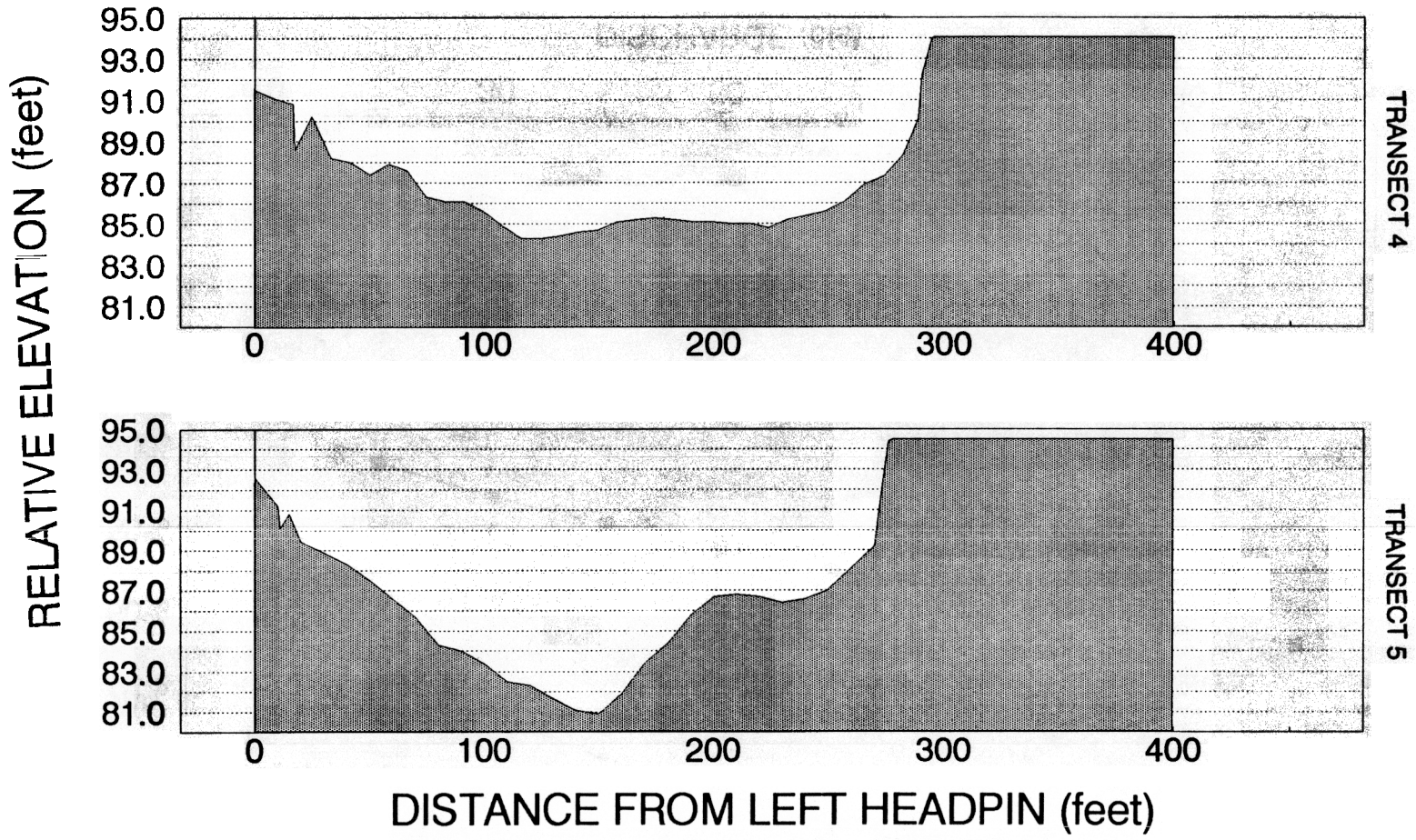
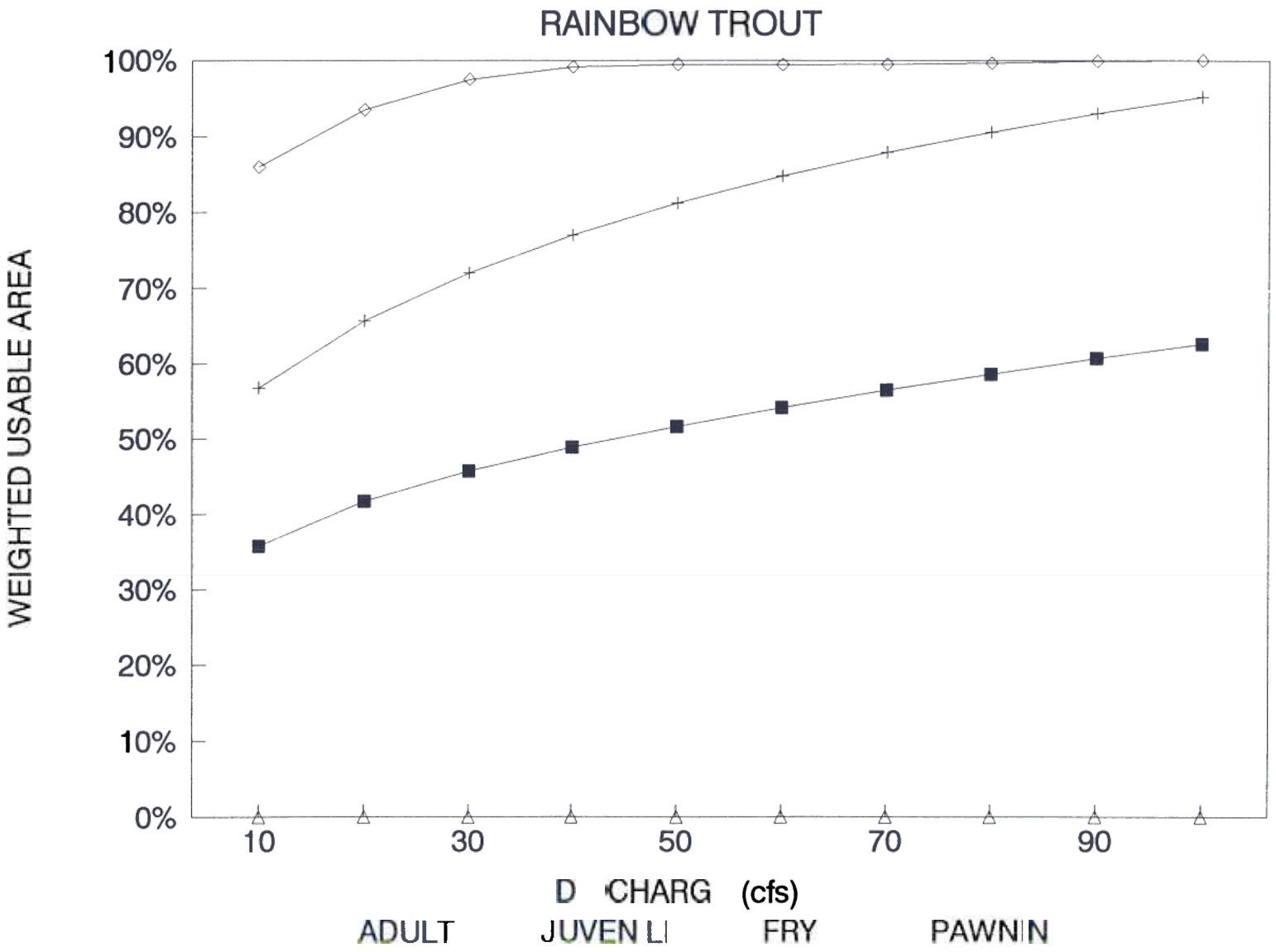


Figure 8. Cross-sectional profiles for transects 4 and 5 used during the NPR/Glendo instream flow study.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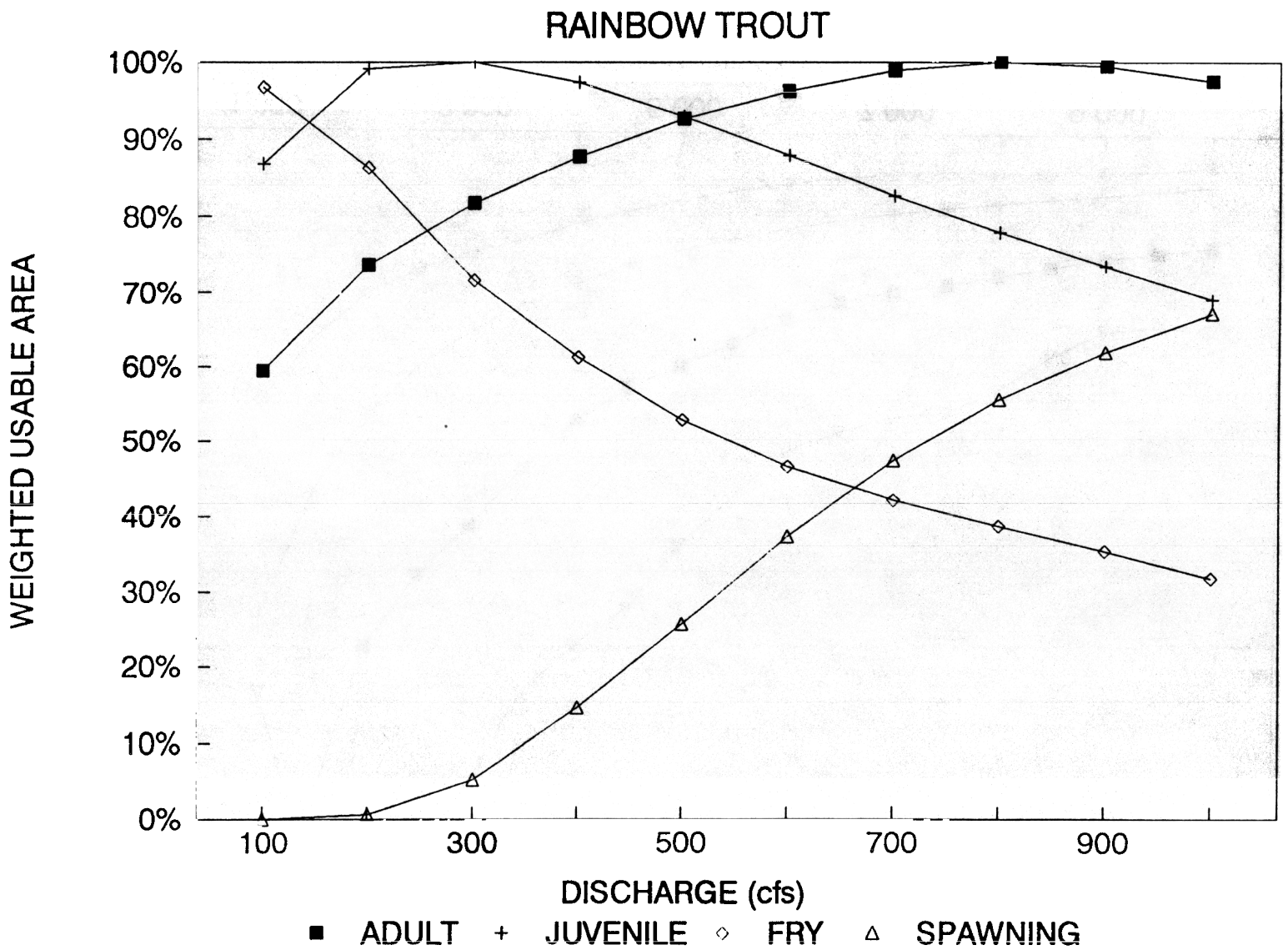


Figure 10. Habitat:discharge relationship for rainbow trout at flows from 100 cfs to 1,000 cfs.

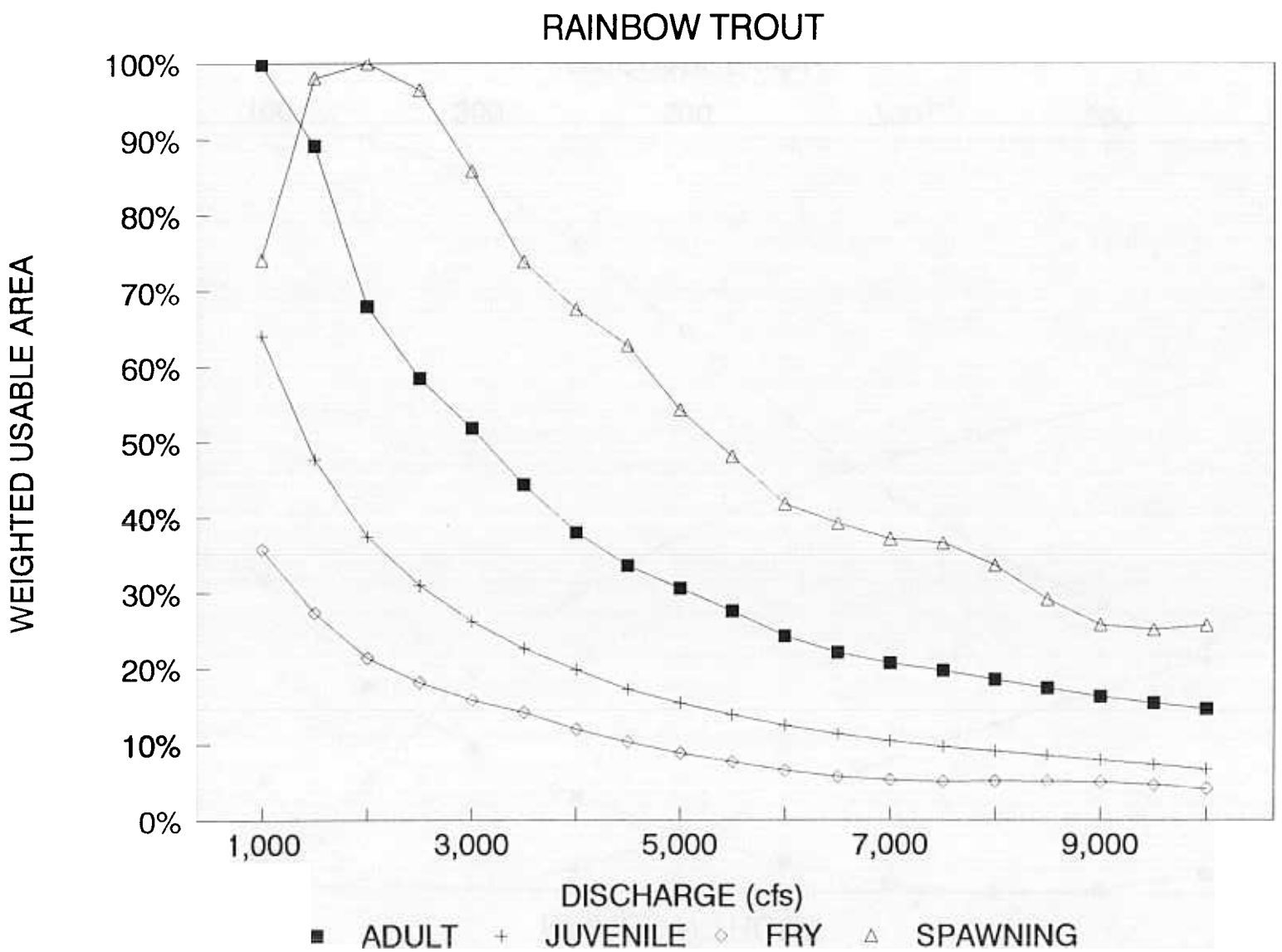


Figure 11. Habitat:discarge relationship for rainbow trout at flows from 1,000 cfs to 10,000 cfs.

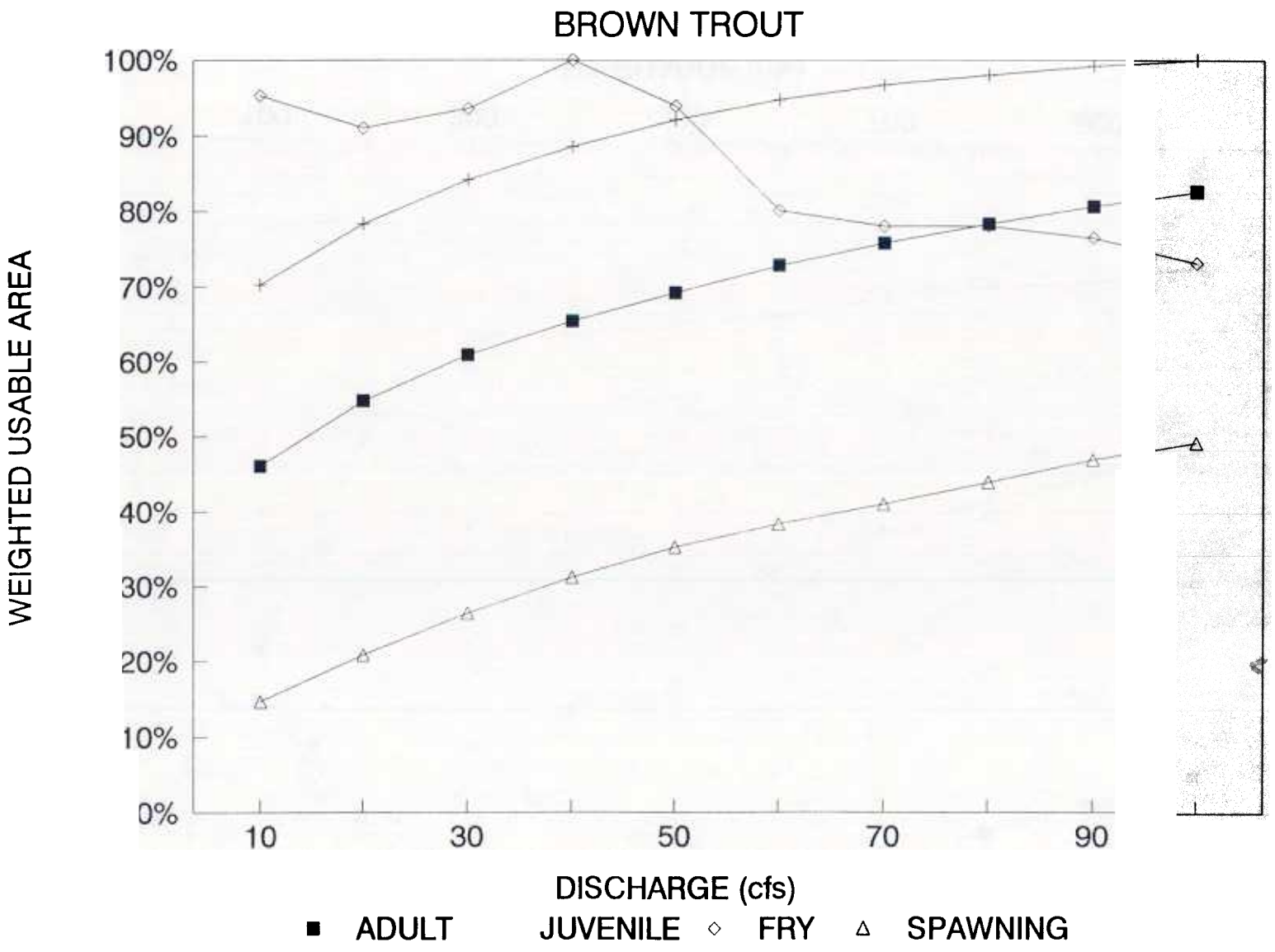


Figure 12. Habitat:discharge relationship for brown trout at flows from 10 cfs to 100 cfs.

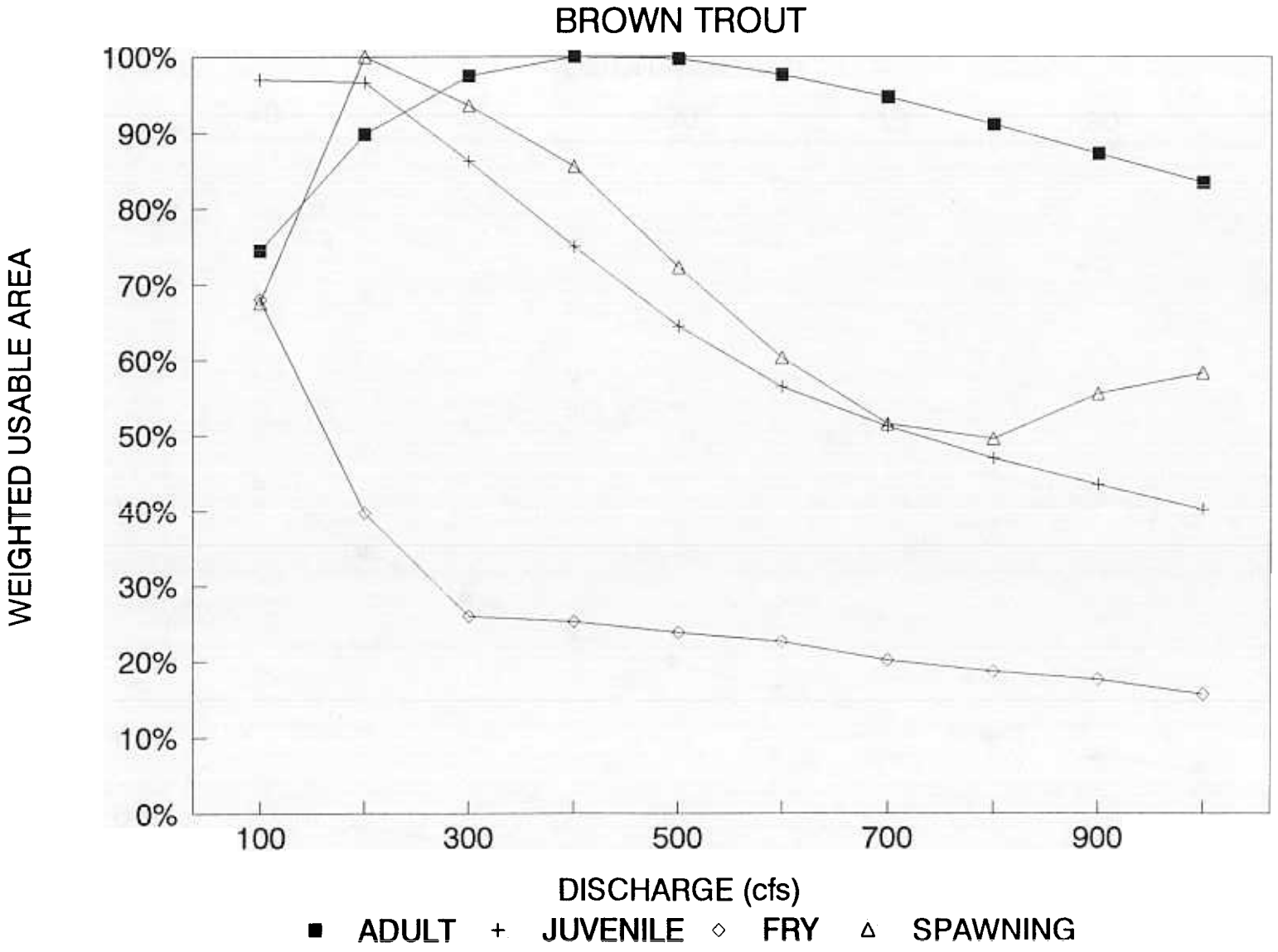


Figure 13. Habitat:discharge relationship for brown trout at flows from 100 cfs to 1,000 cfs.

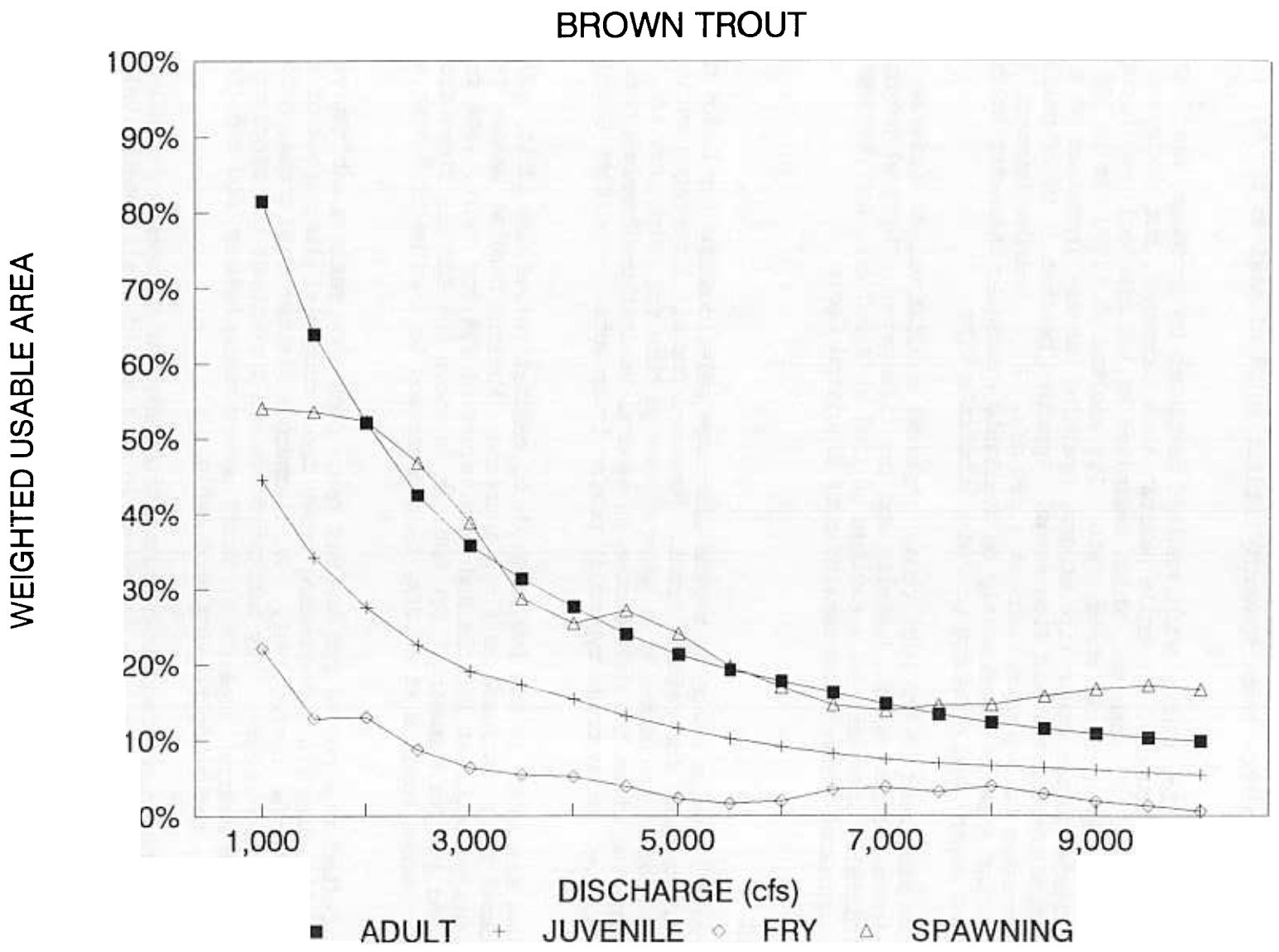


Figure 14. Habitat:discharge relationship for brown trout at flows from 1,000 cfs to 10,000 cfs.

Rainbow Trout

Physical habitat values for rainbow trout in the low flow range steadily increase as flows increase for the adult, juvenile, and fry lifestages. At 100 cfs, adult habitat is at 63% of maximum, juvenile habitat is 95% of maximum, and fry habitat is 100% of maximum. Rainbow trout spawning habitat is 0% of maximum for all flows in the low flow range.

Within the mid flow range, adult habitat continues to increase, until it reaches 100% of maximum at 800 cfs. Juvenile habitat also increases, but maximizes at 300 cfs, then declines. Fry habitat, which maximized at 100 cfs declines through the entire flow range at a fairly steady rate. Fry habitat at 1,000 cfs is 32% of maximum. Inverse to the other life stages, spawning habitat increases at a each successive flow through the mid flow range. Spawning habitat is 0% of maximum at 100 cfs, and increases to 67% of maximum at 1,000 cfs. As a reminder however, this spawning habitat area is based solely on available hydraulic characteristics (velocity and depth) and does not consider substrate type.

At flows simulated in the high range, physical habitat values decrease as discharge increases for adult, juvenile and fry lifestages. Physical habitat for spawning initially increases to a maximum of 100% at 2,000 cfs, and decreases as discharge increases through the remainder of simulated flows.

Brown Trout

In general, physical habitat versus discharge relationships for brown trout are very similar to those for rainbow trout. However, for all lifestages evaluated, brown trout habitat maximizes at a lower discharge than for rainbow trout. This would be expected given the differences in general habitat preferences between the two species (i.e. brown trout typically prefer lower water velocities than rainbow trout).

At flows simulated in the low range deck, habitat values for adult, juvenile and spawning brown trout increase as flows increase. Maximum habitat values for all three lifestages occur at 100 cfs and have values of 83% for adult, 100% for juvenile, and 49% for spawning. Fry habitat is above 90% for all flows from 10 cfs to 30 cfs, reaches maximum at 40 cfs, then decreases to a value of 73% at a discharge of 100 cfs.

Habitat-discharge curves for the mid range deck show maximum habitat values of 100% for adult, juvenile and spawning brown trout occurs at discharges of 400 cfs, 100 cfs, and 200 cfs, respectively. At discharges greater than these, habitat values decrease as flows increase. Fry habitat decreases throughout the range of simulated flows. Spawning habitat does take a small upward swing between 800 cfs (50%) and 1,000 cfs (59%), before decreasing once again.

For the higher simulated flows, brown trout habitat decreases for all life stages as flows increase. By the time discharge is at 2,000 cfs, all habitat values are at or below 50% of maximum, and once discharge is above 5,500 cfs all habitat values are below 20% of maximum.

Time Series

Results of the time series analyses (for adult lifestage only) are shown in Figure 15 for rainbow and brown trout. The hydrology data used as input was the mean monthly flows for the period of WY1981 to WY1990.

Habitat Quality Index

Measured and rated values for each of the nine HQI attributes for the study site under present conditions are shown in Table 6. Using this variable set, the HQI score is computed as 1.0 available HU's. This low rating occurs because three of the variables, X1 (critical period flow), X2 (annual stream flow variation) and X11 (stream width), have rated values of 0 given conditions present at the study site under the current flow regime. X11 will always be equal to zero based on the HQI rating system and data collected at the study site used which showed that the NPR will always have a mean width exceeding 150 feet. This is because of the areas of the NPR which hold water year-round are the slow, wide, glide sections.

Table 6. Measured and rated values for the present condition for the nine variables used in the Habitat Quality Index.

Rated Variable	Measured Value	Value
X1 - Critical Period Flow	0.4%	0
X2 - Annual Stream Flow Variation	8,072	0
X3 - Maximum Summer Stream Temperature	76o F	1
X4 - Nitrate-Nitrogen	0.18 mg/l	4
X7 - Cover	1%	0
X8 - Eroding Stream Banks	32%	2
X9 - Substrate Condition	N/A	4
X10 - Water Velocity	3.61 fps	1
X11 - Stream Width	166 feet	0

To assess how habitat in the NPR might change when there is a minimum winter time flow of 25 cfs, the two "active" flow dependent variables (X1, X2) were adjusted to represent this change (Table 7). However, only variable X2 changed with this corresponding change in discharge, going from a rated value of 0 to 1. This changed the predicted HU's only slightly, increasing from 1.0 to 2.0.

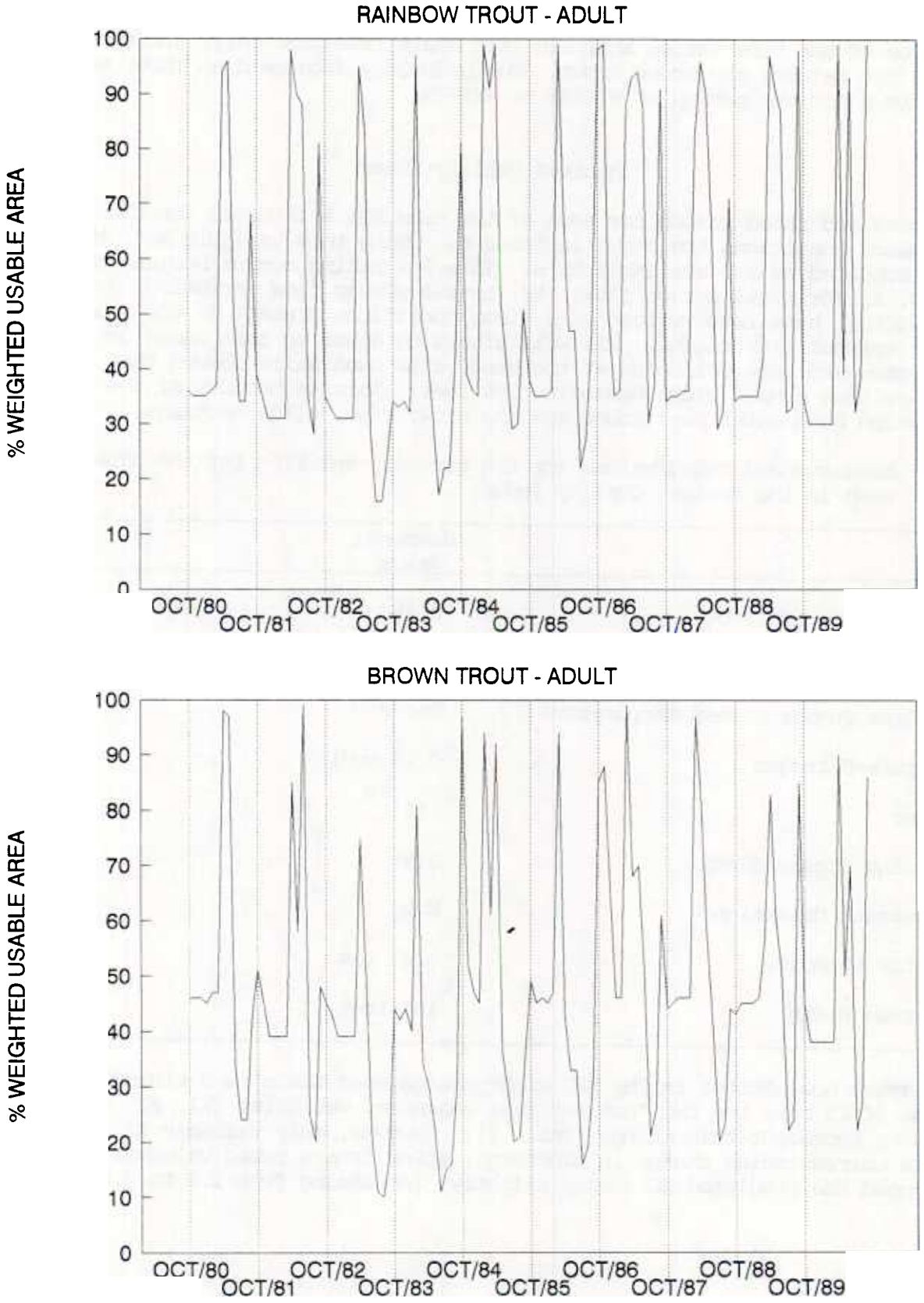


Figure 15. Habitat:time series for adult rainbow trout and brown trout at the NPR/Glendo study site, WY1981-WY1990.

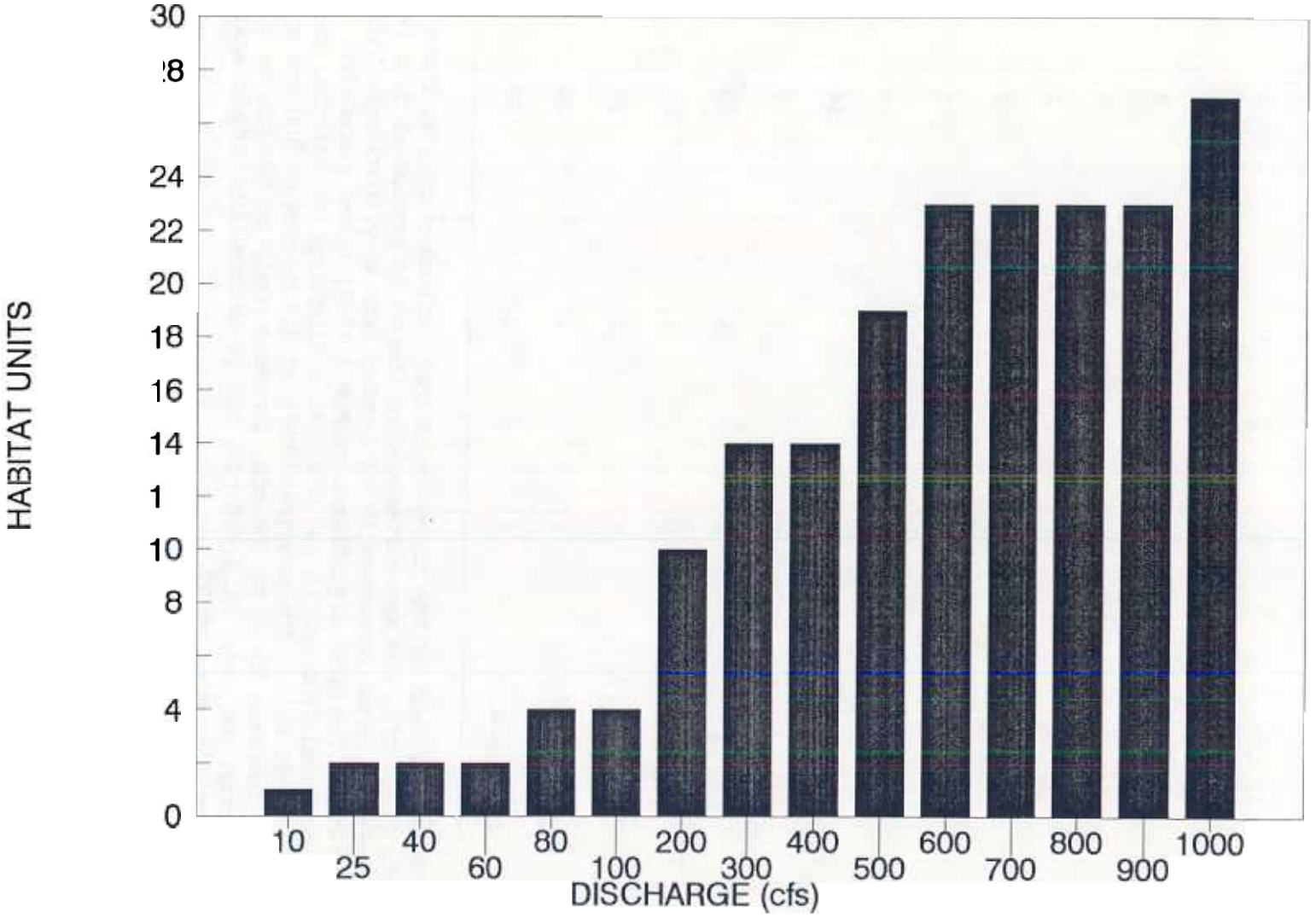
Table 7. Habitat Quality Index ratings for flow dependent variables, and score (Habitat Units) at varying discharges.

Discharge	Variable Ratings X1	X2	Habitat Units
10 cfs	0	0	1
25 cfs	0	1	2
40 cfs	0	1	2
60 cfs	0	1	2
80 cfs	0	2	4
100 cfs	0	2	4
200 cfs	1	3	10
300 cfs	2	3	14
400 cfs	2	3	14
500 cfs	3	3	19
600 cfs	3	4	23
700 cfs	3	4	23
800 cfs	3	4	23
900 cfs	3	4	23
1,000 cfs	4	4	27

Table 7 shows how each of the three variables' ratings change as flows increase up to 1,000 cfs, and the corresponding change in predicted HU's (Figure 16). As can be seen, some increases in HU's occur from when discharge increases from 10 to 100 cfs. The most significant change (+150%) takes place when discharge is increased from 100 to 200 cfs. At a discharge of 200 cfs, the HQI score increases to 10 HU's. The predicted HU's at discharges of 300 cfs and 400 cfs is 14. HU's increase to 19 at 500 cfs, increase again at 600 cfs to 23, and remain at 23 through 900 cfs. At 1,000 cfs, the predicted HU's obtain maximum possible value for this site at 27.

HABITAT QUALITY INDEX

North Platte River below endo Dam



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DISCUSSION

Using output from each of the two models, evaluations were made to address three flow scenarios. These scenarios included 1) the current flow regime, 2) the proposed modified flow regime with a 25 cfs minimum flow release, and 3) assessment of the discharge which would satisfy a typical fisheries maintenance and/or preferred flow condition. These discussions are primarily based on "holding habitat", or only the habitat necessary to sustain adult and juvenile fish. Although not documented, it is assumed there is some natural recruitment to this fishery, but the majority of fish present come from WGFD plants of fingerling fish. Additionally, a short discussion is presented concerning additional factors which could be limiting the fishery in the NPR/Glendo study area.

Present Condition

In reviewing model output, habitat conditions in the NPR below Glendo under the present flow regime are very poor. These conditions are caused not only by low (non-existent) winter flows, but also by high, sustained summer flows. Mean summer flows exceed 2,000 cfs during all months (May through September), and are typically greater than 5,000 cfs during July and August. Physical habitat for trout decreases rapidly at flows above approximately 1,000 cfs.

The time-series analysis (Figure 15) reveals how the amount of available physical habitat consistently fluctuates from near 100% of maximum, to less than 50%. The low points in these fluctuations occur on an biannual basis, corresponding to the summer and winter flows. The peaks generally only occur during brief periods of transition between the two flow periods when flows "pass through" the discharges which maximize physical habitat values. At high flows, the HQI had similar habitat predictions, showing habitat decreasing when flows exceed 1,500 cfs.

Available physical habitat for brown trout appears to be impacted to a greater degree at higher flows than is rainbow trout habitat, usually dropping below 20% of maximum during the summer months. This is due to the more restrictive velocity criteria in the brown trout suitability curves than was used for rainbow trout. Even though this difference in velocity preference between the two species is probably accurate, model output may not accurately simulate actual habitat availability for the study reach. The model is using the mean column velocity as a standard to compare to the velocity criteria. Given the large amount of area in the NPR/Glendo study reach which consists of long, deep glides, there is in all probability a large amount of area within those habitats which have suitable velocities at or near the stream bed, even though the mean column velocity may not reflect that condition.

Two facts concerning high flows in this reach of river need to be put forth. The first, even though sustained, high summer flows probably impact the available fishery to some extent, these are not the flows that limit the fish populations or survival. And secondly, given that the reason there are high summer flows is to provide water for downstream irrigators, this part of the system operations cannot be changed significantly. Based on these two facts, the remainder of the discussion in this report will concentrate on the winter flow regime.

Based on the PHABSIM model, mean adult and juvenile physical habitat availability during the winter months, under present dam operations (mean discharge at the study site, 10 cfs), is less than 50% for both rainbow and brown trout. However, given that 10 cfs at this site is less than 1% of the mean daily flow, the fact that there is any available habitat at all is very unusual. Again, this is due to the amount of long, deep glides which exist in this study reach. These glides act as small ponds which hold water throughout the year, regardless of measurable discharge. Transect hydraulic data, even at zero discharge, show average depths at transects 4 and 5 of 1.5 and 2.9 feet, with wetted top widths of 228 and 148 feet. Even under a winter flow condition, there is physical habitat available.

This does not consider, however, other factors such has oxygen or food availability. The extent to which these type of factors may reduce or completely negate the available habitat is not known, and very difficult to address. Still, these factors undoubtedly play a significant role in determining the overall habitat quality of the system. Also, the impact of winter flows on over-wintering habitat for eggs/alevins or young-of-the-year fish, which typically occurs in riffle sections, is not addressed but is undoubtedly very high. This will be discussed further in the section that addresses Limiting Factors.

Results from the HQI model at present low flow conditions revealed different results than did the PHABSIM model. The 1.0 HU predicted for the present flow regime appears to be more inline to what would be expected under such severe flow conditions.

Modified Flow Regime

Under the proposed modified flow regime, a minimum of 25 cfs would be released from Glendo Dam during all months. This would provide an estimated flow of about 30 cfs at the NPR study site. With this discharge, trout habitat would increase only a small amount based on both PHABSIM and HQI predictions.

However, such a minimum flow could very well provide for a better quality of holding habitat by affecting the factors mentioned above; including better oxygen and food availability, as well as increased survival of eggs and alevins. The flow of water through these "ponded" stream areas is important to maintain sufficient oxygen and nutrient cycling through the system for the survival and growth of trout. Also, the importance in maintaining riffle habitats in streams has long been recognized. Riffles are the primary production areas for aquatic macroinvertebrates (food base), and as habitat for spawning, and egg and alevin incubation.

Ultimately, even though the proposed minimum flow releases do not appear to provide for any large increase in holding habitat, the potential secondary benefits could be more important in benefiting trout populations as a whole than a simple increase in the amount of available physical habitat.

Minimum/Preferred Flow Conditions

Results from both of the habitat models used in this study were evaluated to determine at what discharge standard instream flow criteria would be met for a minimum flow (80% level) and for a preferred flow. This is based on habitat requirements for adult and juvenile fish only.

To assess instream flow regimes, standard criteria were applied to the PHABSIM results. Minimum flow requirements were considered met at the lowest discharge where normalized habitat values for both adult and juvenile lifestages equalled or exceeded 80%. Preferred flows were set at the discharge where the cumulative normalized habitat value for adult and juveniles was maximized.

Physical habitat-discharge curves from the PHABSIM output for rainbow trout indicate that a minimum flow requirement would be met at a discharge of 300 cfs, and a preferred flow requirement at a discharge of 500 cfs. For brown trout, the minimum flow requirement would be obtained at a discharge of 200 cfs, while a discharge of 300 cfs would meet preferred flow requirements.

From a subjective evaluation, the preferred flows may be lower than would be expected (and believed). This is probably because of the limiting effect the juvenile velocity curve for both rainbow and brown trout has on the physical habitat versus discharge curves.

Based on the predicted HU's from the HQI model, a minimum flow of 200 cfs would be requested for the NPR below Glendo Dam. This discharge was selected because it represents the inflection point on the habitat:discharge curve constructed from the HQI output. As far as a preferred flow is concerned, once discharge reaches 600 cfs, HU's are greater than 80% of maximum, so 600 cfs would be requested for a preferred flow.

Based on the information presented above, a minimum flow recommendation of 200 cfs would be requested for release at Glendo Dam on a year-round basis to provide the habitat necessary to maintain trout populations in the downstream river reach.

Identifying a specific target for a preferred flow is not as easy. The possible flow recommendations based on the presented information range from 300 cfs (PHABSIM - adult and juvenile brown trout) to 1,000 cfs (HQI - maximum attainable HU's). Using the transect channel morphology and hydraulic data, a habitat retention analysis was conducted in hopes of better quantifying a preferred flow. For this the WGFD's standard criteria on depth, velocity and wetted perimeter were used (Vogt 1991). All three criteria were met at a discharge of 600 cfs. This flow is equal to the suggested preferred flow from the HQI, and would therefore be the recommended preferred flow for the NPR below Glendo Dam.

Limiting Factors

So far, the basis of this report has been the relation between discharge and habitat in the NPR/Glendo study area. However, there are several other "factors" which may limit the productivity of the fishery; spatially, temporally or otherwise. Provided below is a brief discussion on a few of the more obvious factors.

One observation made at the study site and throughout the NPR/Glendo study area concerns the poor quality of streambed gravels. This is of particular importance in riffle areas where food production and spawning/incubation take place. Although there are gravels present, they are heavily imbedded with fine sediments and sand. With the regulation of the downstream river by Glendo Dam, the typical peak flows which would normally flush the sediment build-up from the gravel bed no longer occurs. The consequence has been that the riffle areas are much less able to provide habitat for food production and reproduction than could be possible with a regular flushing event. However, it should be noted that historically the North Platte River in this area was a very silty, warm river; and would not have supported a cold-water fishery.

Along these same lines is the reduction in side channel and backwater habitats along the NPR. This is evident in touring the river and from old aerial photos and maps. The reason is the same as discussed above; sediment loading due to the removal of peak flows from the hydrograph. This has allowed encroachment processes to take place and reduce or eliminate available side channel and backwater areas. The result is a loss in the amount of habitat typically important to fry, young-of-the-year, and certain species of forage fish.

Temperature may also limit trout production in this stretch of river. Limited temperature data indicate that summer temperatures approach levels intolerable, and at times lethal, to trout. The overall extent of this problem and role it may play in limiting trout production is not known. However, it must be considered when evaluating trout habitat.

CONCLUSIONS

Following is an abbreviated list of study conclusions and perceived additional data needs for the NPR/Glendo study.

1. Under the present flow regime, both winter and summer flows limit trout production.

2. Any significant modification of the summer flow regime to enhance fisheries can not be expected due to downstream water demands.

3. With the modified flow regime of a minimum release of 25 cfs during the winter months, a negligible increase in adult/juvenile habitat will occur.

4. Secondary benefits (i.e. food production, over wintering) from the increased winter flows may provide a benefit to the aquatic system.

5. A discharge of 200 cfs is needed before significant benefits in terms of physical adult trout habitat will occur.

6. Additional transect data should be collected at a minimum of two riffle habitats to better define habitat-discharge relationships at low flows.

7. A study should be initiated to assess and quantify flushing flow and dominant flow needs for the NPR/Glendo study reach.

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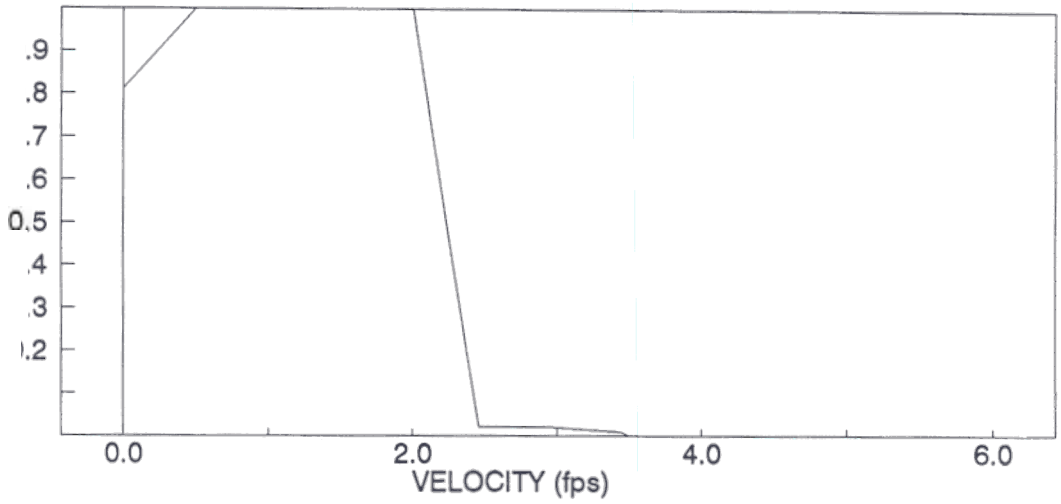
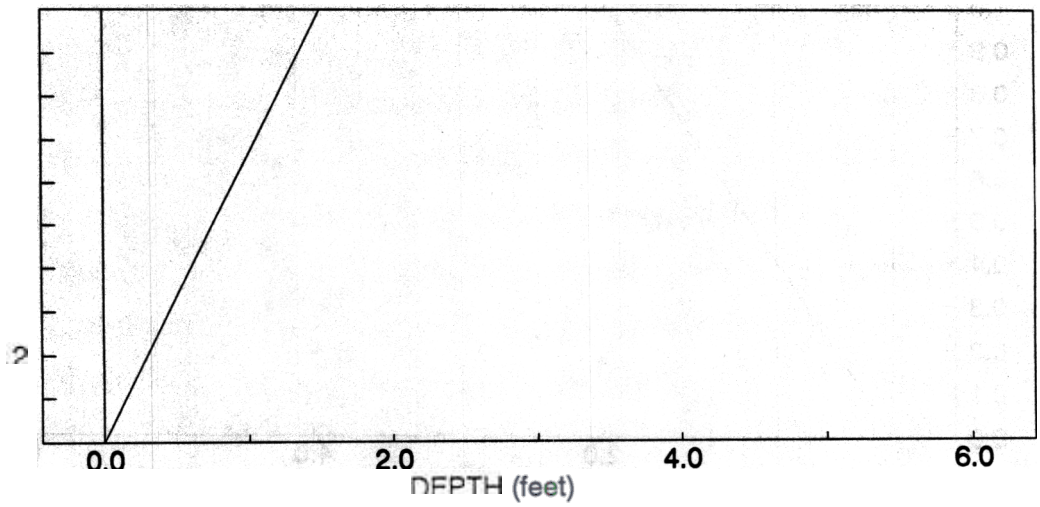
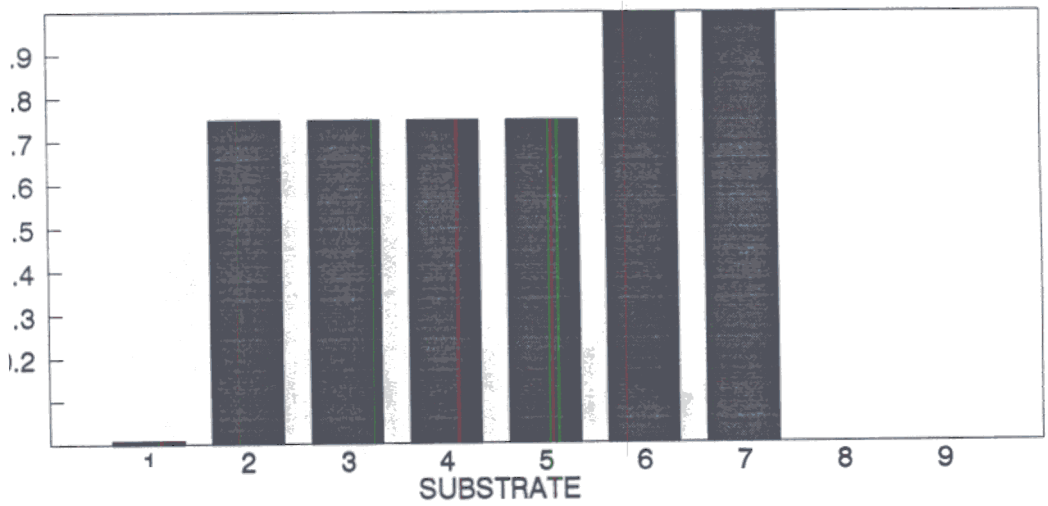
Appendix A

Suitability Curve Sets Used in the Physical Habitat Simulation

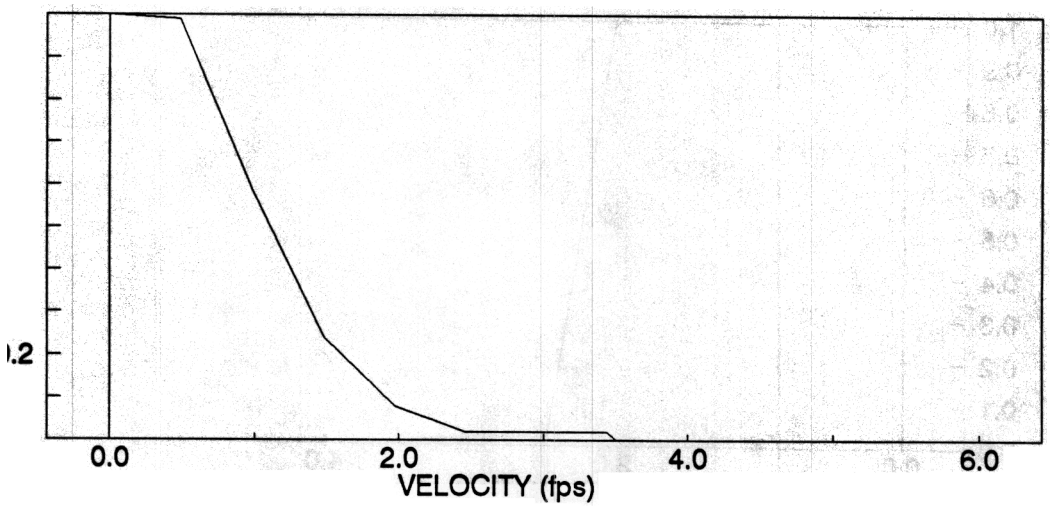
RAINBOW TROUT Adu

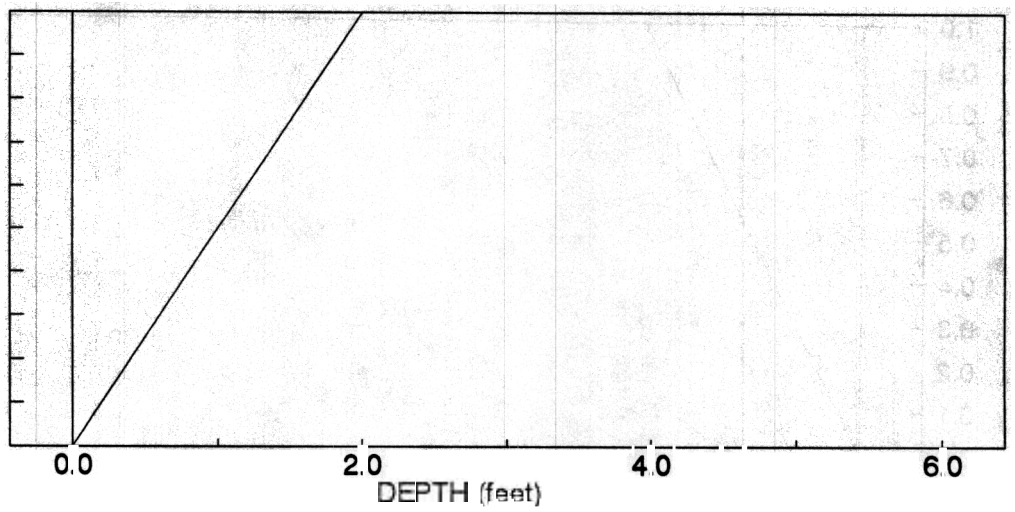


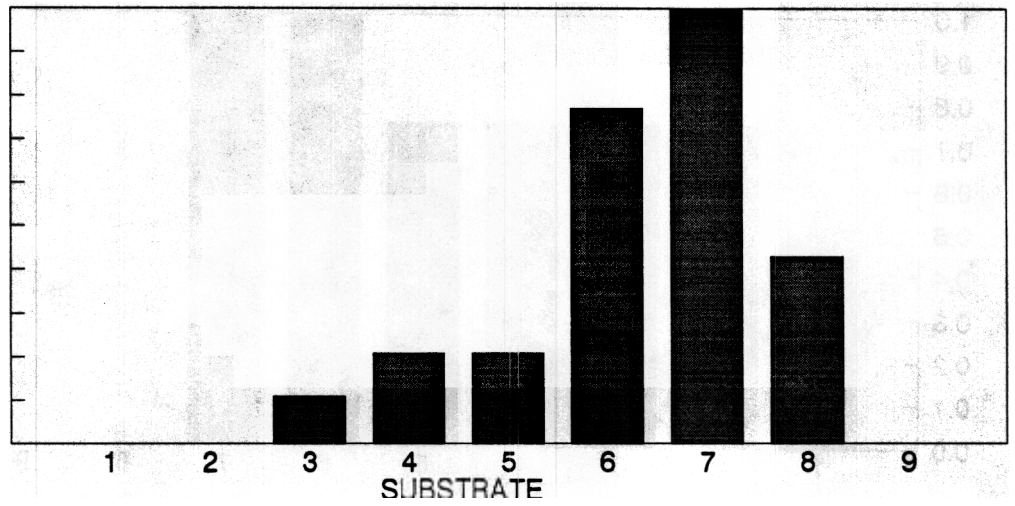




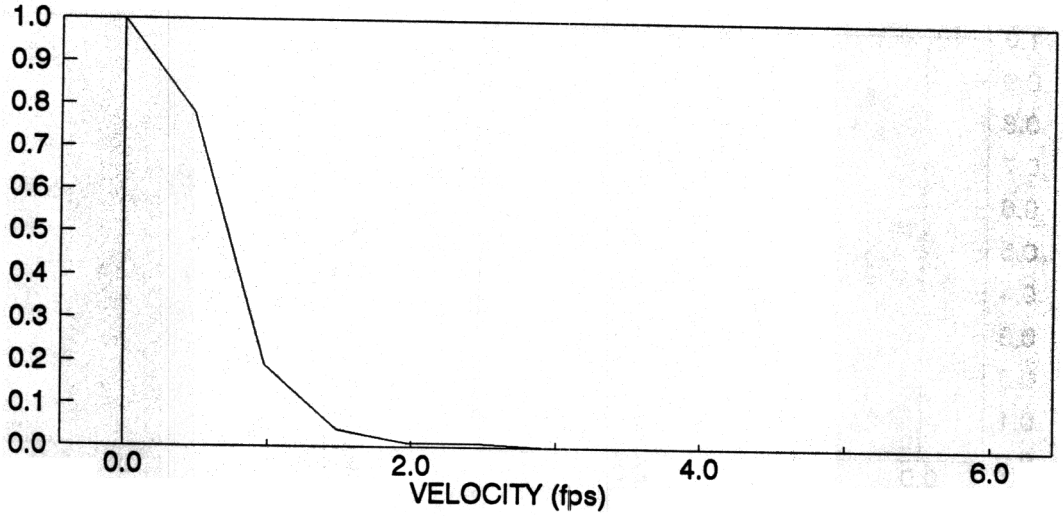
RAINBOW TROUT Juven

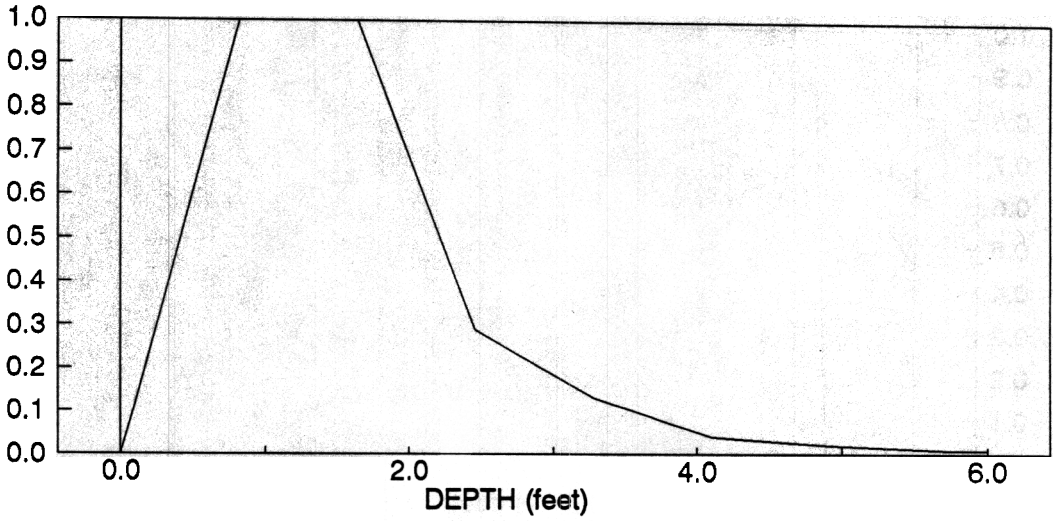


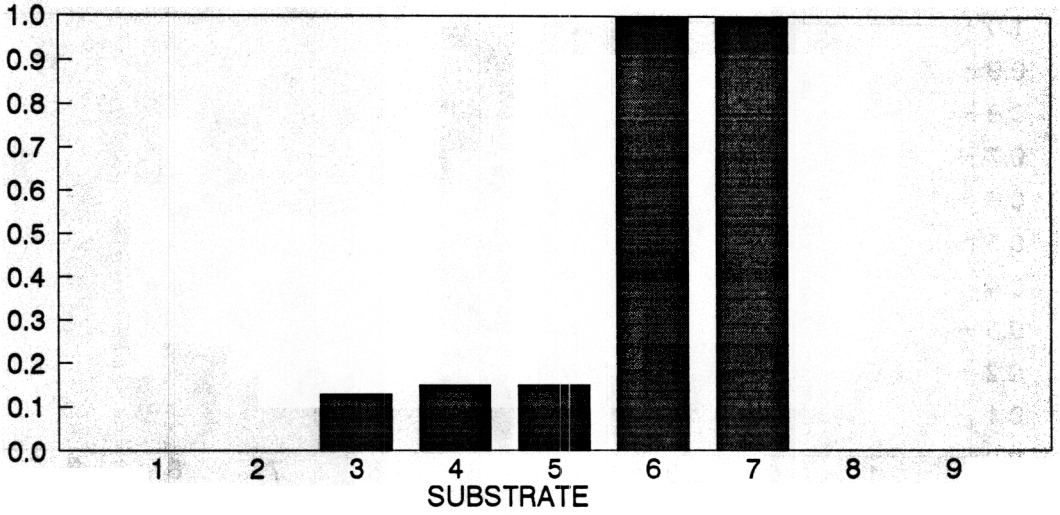




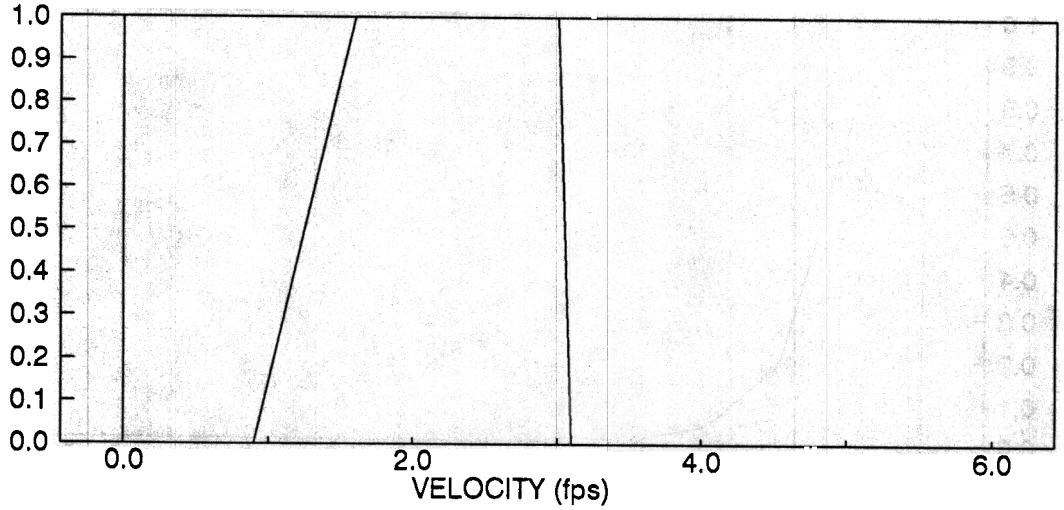
RAINBOW TROUT - Fry

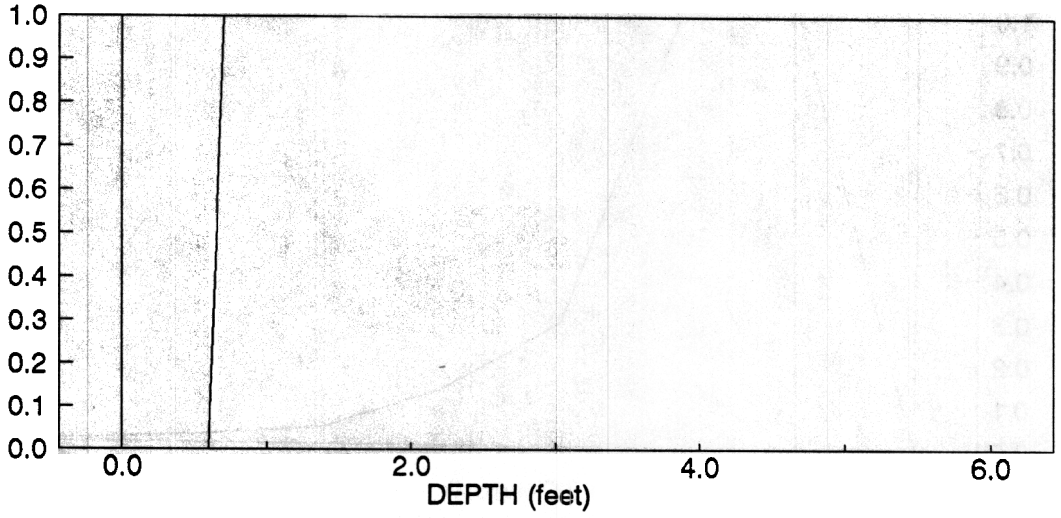


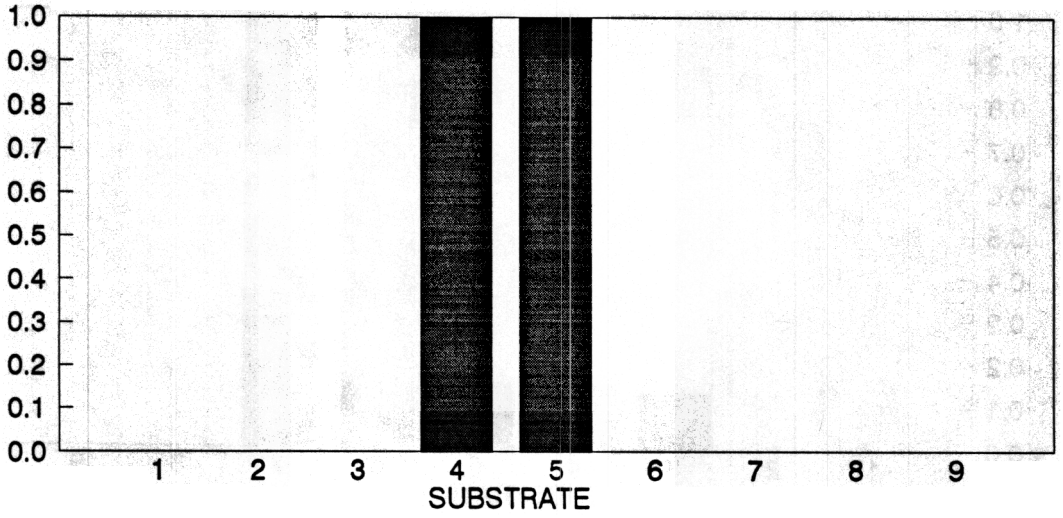




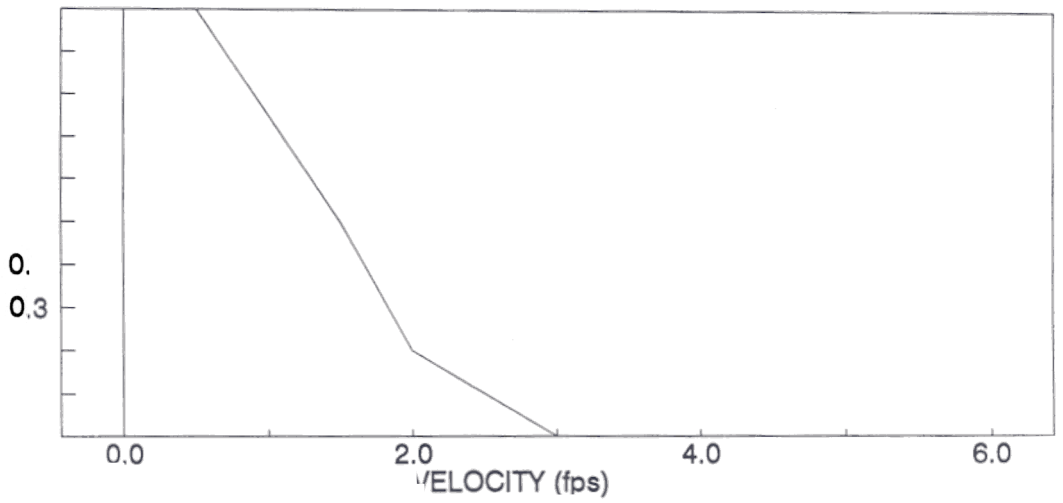
RAINBOW TROUT - Spawning

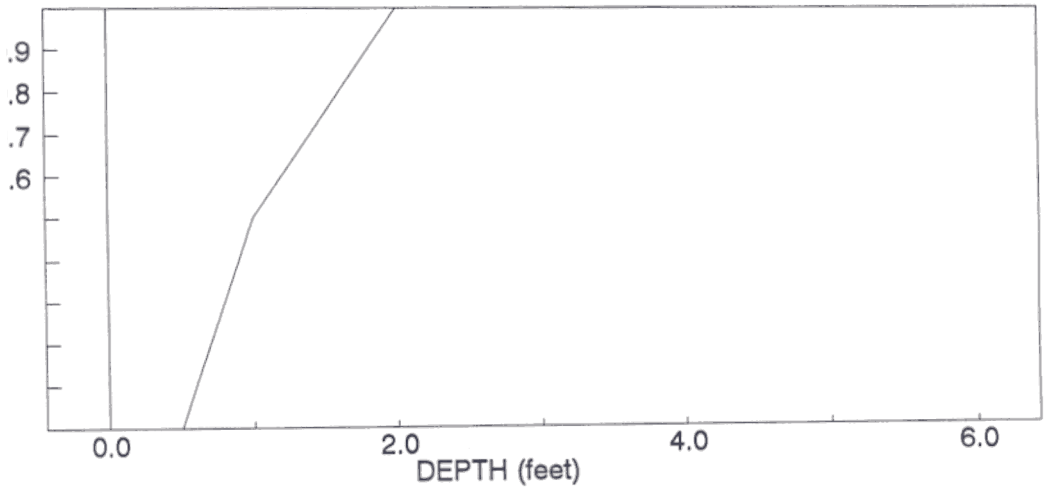


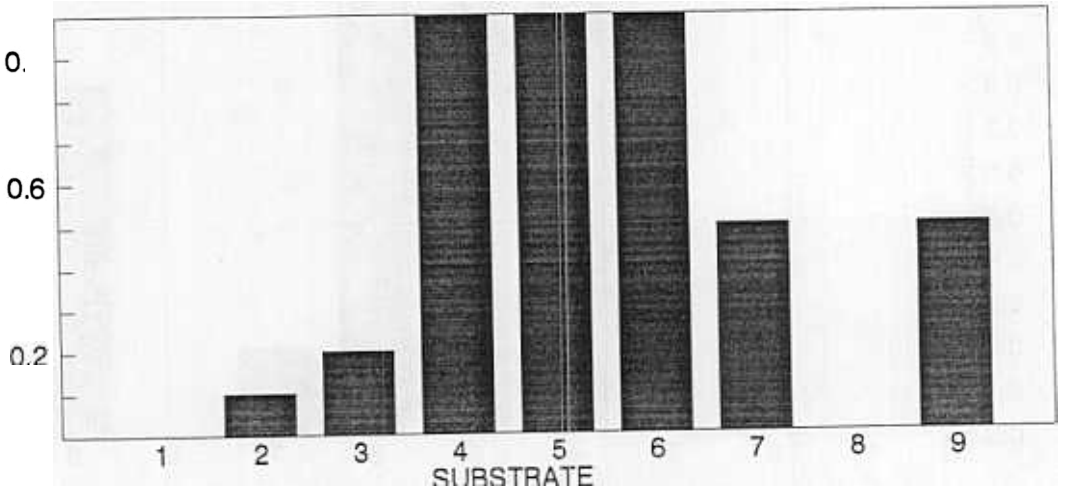




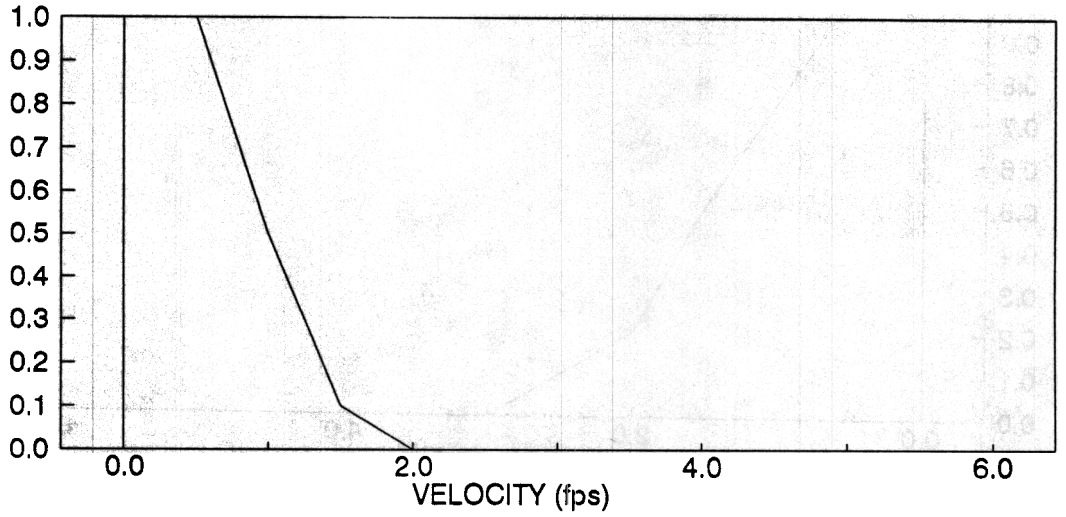
BROWN TROUT Adult

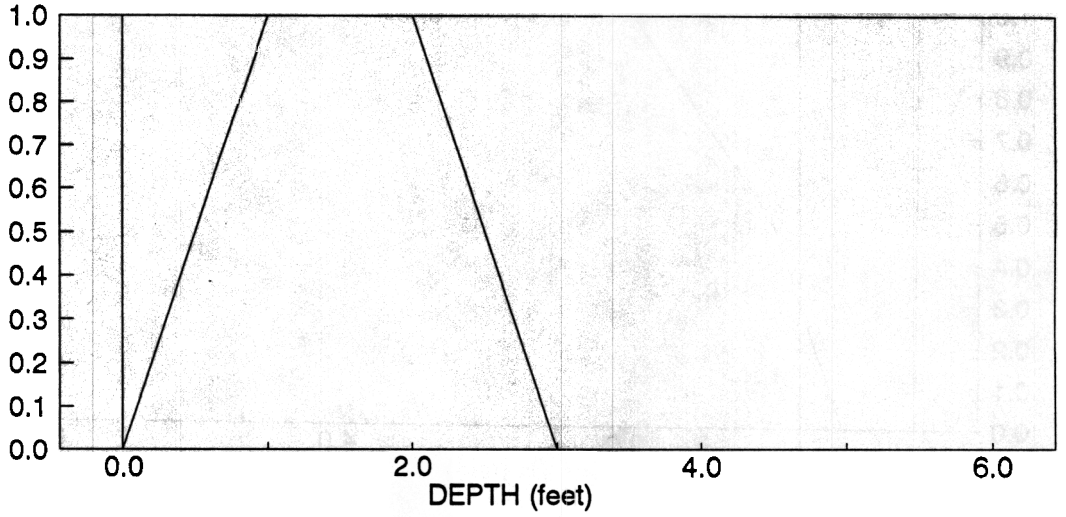


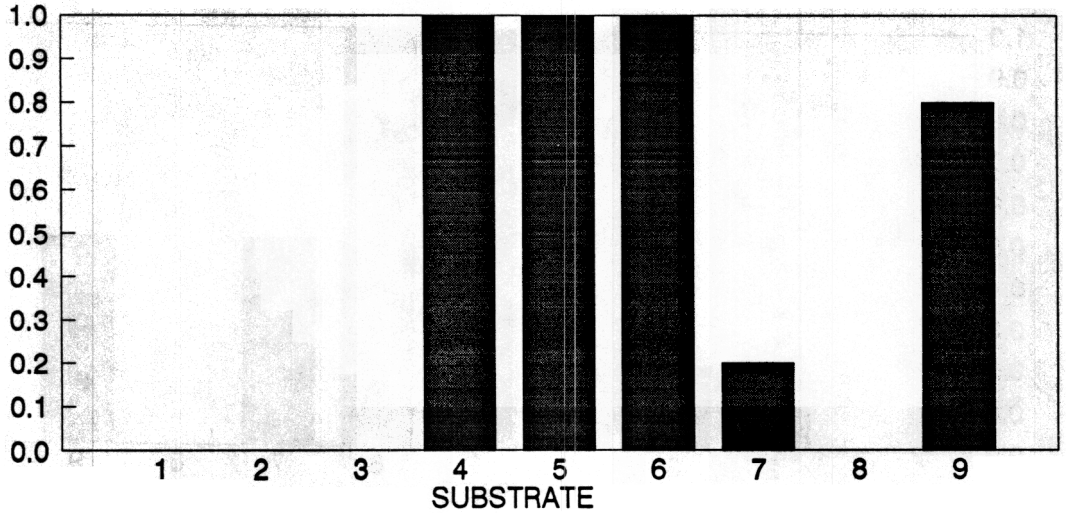




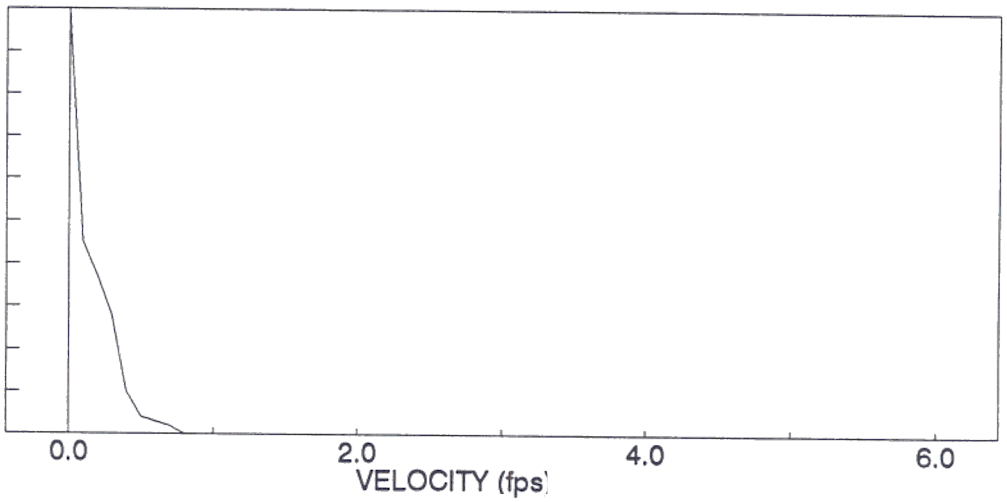
BROWN TROUT - Juvenile

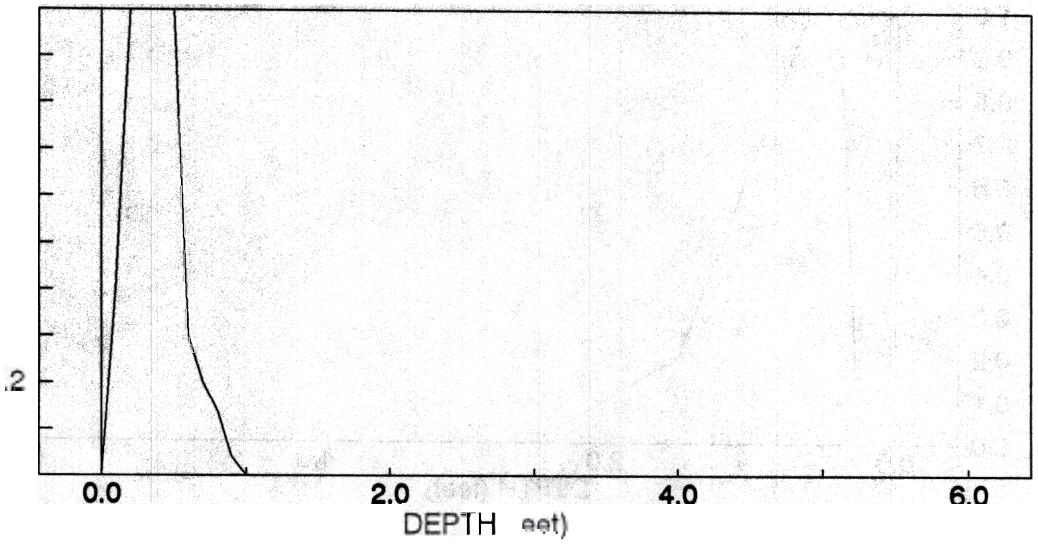


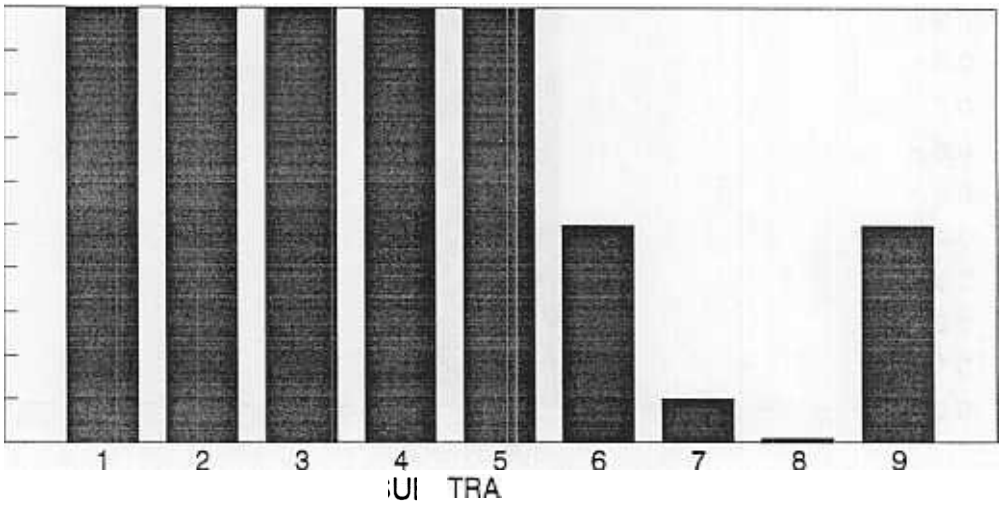
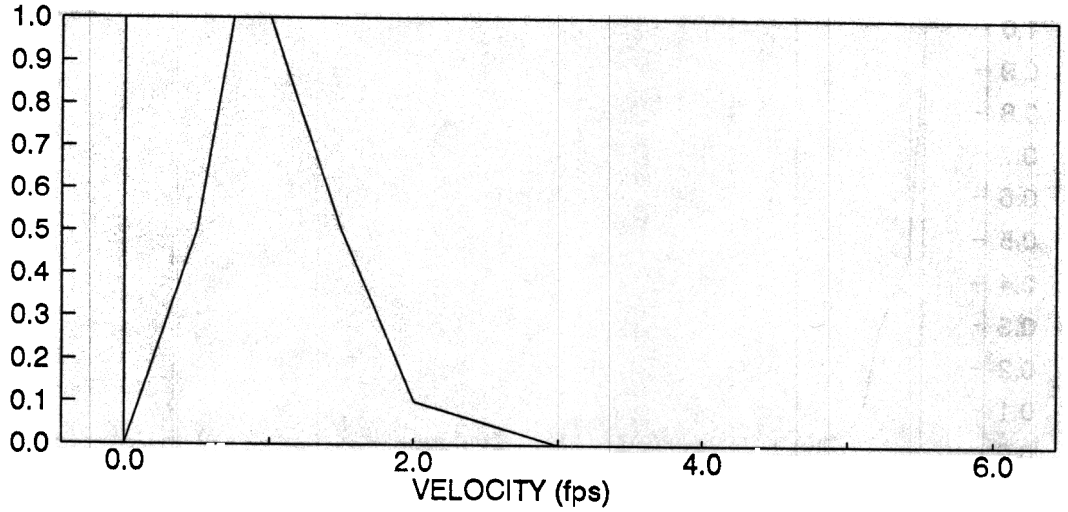
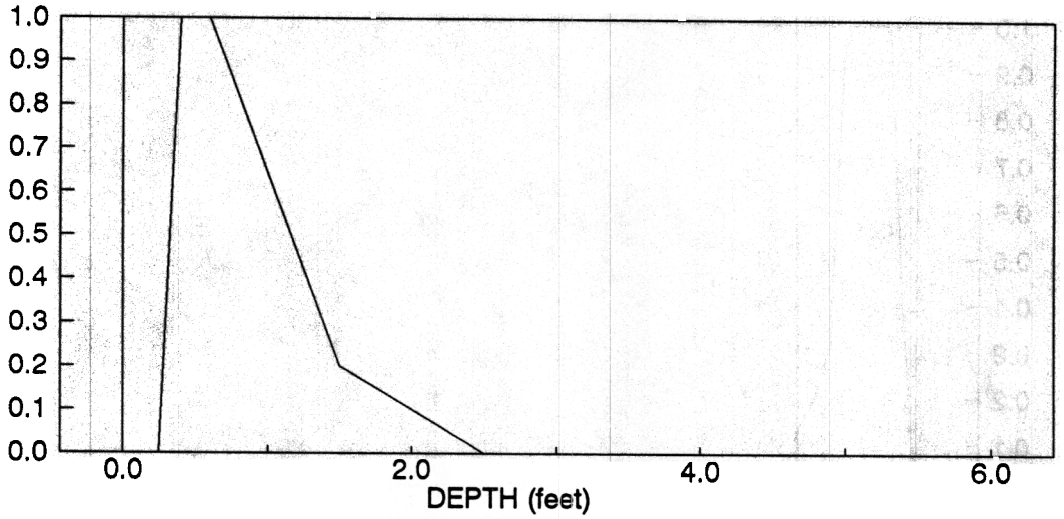
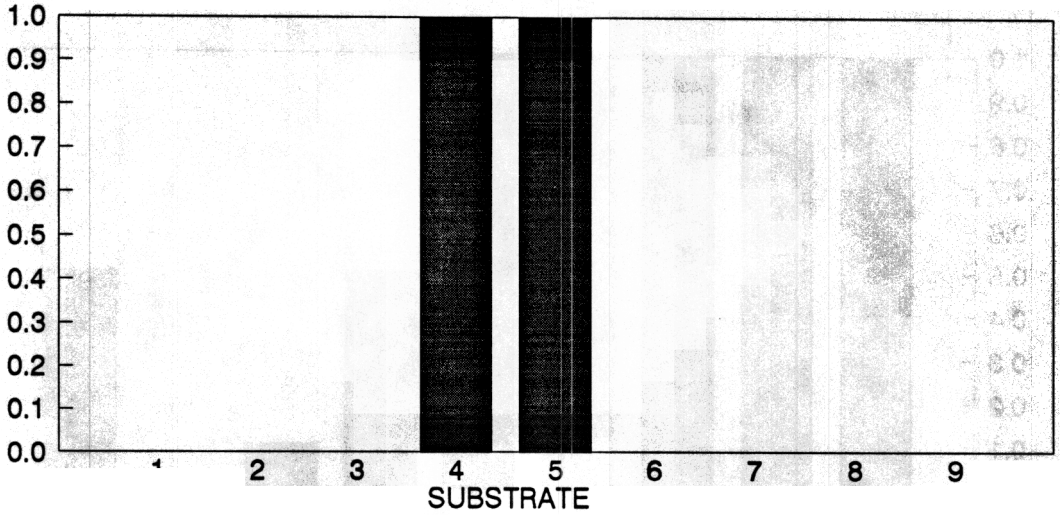




BROWN TROUT Fry







BROWN TROUT - Spawning