SULTAN RIVER FLOW STUDY

A Report Prepared For The

Snohomish County P.U.D.

By

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INTRODUCTION

The Snohomish County Public Utility District is presently conducting a study to determine the feasibility of developing the Sultan River for hydroelectric power production. Part of the study must address water availability and allocation among present and potential uses. The salmon resource is currently an important water user downstream from the City of Everett diversion dam (RM 9.7). Therefore, it is imperative that the flow requirements of the fishery resource be considered in the allocation of flows and in the seasonal and daily operation of the proposed project.

In 1967, the Department of Fisheries conducted a flow study in the Sultan River mainly to determine fishery needs in the lower three miles of the river below the canyon area (Magee, 1967). The results of that study indicated that a minimum of 165 cfs and 200 cfs were needed for salmon rearing and spawning, respectively.

If the PUD decides to proceed with hydroelectric development, the Department of Fisheries will request that sufficient water be released, with minimal daily fluctuations, in order to maintain the salmon runs below the existing diversion dam. Consequently, the PUD asked the Department of Fisheries to provide minimum flow requirements for salmon spawning and rearing for both the lower river and the Sultan River canyon. The previously reported minimum rearing and spawning flows are acceptable in the lower 3.5 miles of river. However, the flow requirements for the canyon area were unknown when the PUD made the request for this information.

To fill this knowledge gap, Fisheries personnel conducted a study during the summer of 1978 to quantify the flow requirements for salmon spawning and rearing in the Sultan River canyon (RM 3.3-9.7). Higher than normal flows during the summer prevented the collection of all the data needed to determine adequate rearing flows for both fall chinook and coho salmon. Additional data will be collected in 1979 and rearing flows for the canyon area will be determined in a later report.

METHODOLOGY

The methodology we used to determine spawning flows for fall chinook and coho salmon in the Sultan River canyon is called "Usable Width" analysis. This method yields reliable spawning flow information and has been used by fishery biologists in Washington, Oregon, and Idaho for a number of years. (McKinley, 1956; Magee, 1967; Stalnaker and Arnette, 1976).

The basic procedure is as follows: (1) Several study stations are selected at representative spawning areas. If possible, the stations are selected with respect to the spatial distribution of the spawning population; (2) one or more transects are established across spawning areas within each station; (3) at each of several flows, evenly spaced depth and velocity measurements are made along the transects; (4) depth and velocity distribution curves are constructed for each transect at each flow; (5) the portion of each transect which at each flow falls within predetermined, species-specific velocity and depth spawning criteria is considered "usable width"; (6) usable width results from all transects are combined and an overall recommended spawning flow is determined for the entire river section.

We based our selection of representative study stations on two criteria: (1) suitability of the substrate for salmon spawning, and (2) accessibility. The steep-walled Sultan River canyon forced us to restrict the search for study sites to areas near the limited number of access points. Fortunately, we found three suitable sites in the upper and middle portions of the canyon (Figure 1).

Station 1 (RM 9.5), is located approximately 1/4 of a mile below the City of Everett diversion dam, adjacent to the site where the water diversion line tunnels underground headed for Lake Chaplain. Two transects, approximately 20 feet apart, were established across a gravel bed close to the left bank (looking downstream). Transect reference points were painted on boulders at the water's edge. Station 2 (RM 7.6), is located about 100 feet above the mouth of Marsh Creek across the tail of a large pool. One transect was established in the tailout which has a large amount of suitable spawning substrate. Station 3 (RM 5.7), is located downstream of the USGS gauge station below the mouth of Chaplain Creek. Three transects were established at this station - one in the tail of the pool below the gauge cable crossing and two in the riffle area immediately below the pool. Selection of the study stations was later supported by spawner utilization surveys conducted in October, 1978.

After reviewing the results of the 1967 flow study, we decided to make depth and velocity measurements at four different flows - approximately 200, 150, 100, and 50 cfs measured at the Chaplain Creek gauge. The results of the 1967 study indicated that the preferred spawning and rearing flows in the canyon should be bracketed by these study flows. City of Everett Water District staff assisted by notifying study personnel when river flows approximated the desired test flows.

We modified the field procedure by also considering the suitability of the substrate for spawning along each transect. Depth and velocity measurements were made only along the portion of the transect with acceptable spawning substrate. We considered gravel and small cobble (diameter 1/4 - 6 inches) suitable spawning material and classification across each transect was made by on-site inspection.

Depth and velocity measurements were made over the spawnable portions of each transect using a standard Gurley current meter, a graduated wading staff, stopwatch, and 100 foot cloth tape. Measurements were made at 4-foot intervals with one exception (5 foot intervals at Station 3, transect 1). The cloth tape and transect markers on opposite banks were used to align and locate the current meter for each set of measurements. At each measurement site, the depth was recorded to the nearest 0.1 feet and velocity[1/] was measured twice and averaged. The measurements were recorded on data forms along with the discharge at the Chaplain Creek gauge and any other pertinent observations (Figure 2).

Spawning Criteria

Fall Chinook Salmon

The spawning criteria used to evaluate the depth-velocity data for fall chinook were established after reviewing the pertinent literature. Chambers et. al. (1955) made depth and velocity measurements over 45 individual fall chinook redds in the Kalama and Coweman Rivers in south-western Washington. Using his frequency distributions for redd depth and velocities, we developed modal range criteria (most widely used depths and velocities) which we believe are applicable to the Sultan River canyon. The fall chinook depth criteria range from 1.00 - 2.25 feet and the velocity criteria range from 1.00 - 2.50 feet per second. Approximately 86 and 90 percent of the 45 measured fall chinook redds fell within these depth and velocity criteria, respectively.

1/ Velocity: average velocity 0.4 feet above the bottom. This depth represents the average location of fish above the substrate at the time of redd construction.

Coho Salmon

Chambers et. al. (1955) also measured depth and velocities over 277 individual coho salmon redds on eleven streams in Washington. Using his frequency distributions for redd depths and velocities, we developed modal range criteria that are realistic for evaluating coho salmon spawning flows. The depth criteria range from 0.50 - 2.00 feet and encompass about 80 percent of Chamber's observations. The velocity criteria range from 0.50 - 2.25 fps and include about 83 percent of the observations.

RESULTS

Figures 3 - 8 show the depth and velocity distributions (solid lines) at 205, 149, and 108 cfs for all six study transects. The fall chinook spawning criteria (dashed lines) are superimposed over the depth and velocity plots, thus allowing the reader to evaluate the ability of a certain flow to provide adequate depth and velocities. High summer runoff eliminated the possibility of taking measurements at flows less than 100 cfs. However, analysis of the data collected at higher discharges revealed that low flow measurements were not necessary to determine preferred spawning flows for both species.

All three study flows provide adequate velocities at Station 1, with the exception of a portion of transect 2 at 108 cfs (Figures 3 and 4). However, flows greater than 149 cfs result in depth becoming limiting, and at 205 cfs both transects are completely unsuitable for fall chinook spawning on the basis of the depth criteria.

The velocities at Station 2 were too low over the entire transect at 108 cfs, borderline at 149 cfs and acceptable over much of the gravel at 205 cfs (Figure 5). However, depths were most satisfactory at 108 cfs with progressively less suitable depth as discharge increases.

Station 3, transect 1, is located in an area deeper, wider and slower than the other five transects. Velocities are borderline at 205 cfs and flows of 108 and 149 cfs produce insufficient velocity for spawning fall chinook (Figure 6). In contrast, the two transects in the riffle at Station 3 (transects 2 and 3) are in a constricted area with relatively high velocities and shallow depths. Although 108 cfs yields the most usable width from a velocity standpoint, depths are too shallow over the majority of both transects (Figures 7 and 8). The minimum acceptable discharge from a depth standpoint is approximately 150 cfs.

Table 1 summarizes the results of the usable width analysis for fall chinook spawning habitat. Usable width at each flow is defined as that portion of the transect with both suitable velocities and depths. At Station 1, the optimum spawning discharge is 149 cfs as this flow yields 100 percent usable width for both transects. Close inspection of Figure 5 reveals that the best spawning flow at Station 2 is between 149 and 205 cfs. An intermediate flow maximizes usable width for both depth and velocity. By interpolating between 149 cfs and 205 cfs depth and velocity plots, 175 cfs curves can be approximated. We did this and estimated that 175 cfs would produce a peak usable width of 65.3 percent at Station 2. If you sum the usable widths and total widths for the three transects at Station 3, the highest combined percent usable width (29.8 percent) is obtained at 205 cfs. A discharge of 149 cfs only yields a combined percent usable width of 11.0 percent.

DISCUSSION

Unfortunately, it is impossible to simultaneously provide optimum spawning flows for fall chinook salmon at all three stations in the Sultan River canyon. A single flow is needed which will satisfy the spawning requirements for a majority of the fish utilizing the canyon. Table 2 combines the usable width results for all six transects which allows evaluation of the different flows on a canyon-wide basis. The results indicate that 149 cfs is the preferred spawning discharge if differences in the spatial distribution of spawners are not considered.

However, the spawning surveys conducted in the fall of 1978 did allow us to determine the areas most heavily utilized by the fish. This information should be considered in determining the most suitable spawning flow. Table 3 shows the estimated fall chinook escapement to the Sultan River canyon by section. Sections I and III have similar channel characteristics and are best represented by Stations 1 and 2. Section II encompasses and is best characterized by the three transects at Station 3. The survey indicates that about 70 percent of the fall chinook spawning in the canyon utilize the 2.5 miles of Section II, while the remaining 30 percent are distributed between Sections I and III.

Selection of 149 cfs as the recommended spawning flow would eliminate much of the preferred spawning habitat for the majority of the fish since 205 cfs and not 149 cfs is the optimum flow at Station 3 (and presumably in Section II). Recommending 205 cfs for the whole canyon would maximize spawning habitat at Station 3 (and in Section II). However, this is not desirable either since this flow essentially eliminates spawning in four miles of canyon utilized by 30 percent of the population. The evidence points to selecting an intermediate flow between 149 and 205 cfs.

Therefore, on the basis of this study, we have determined that 175 cfs is the optimum spawning flow for fall chinook salmon in the canyon. This flow provides some usable spawning area at Station 1, maximizes spawnable area at Station 2, and provides habitat for significant amounts of spawning in the heavily utilized area represented by Station 3.

Spawning fall chinook redds were first observed in the canyon in early October this year. These fish ascended the river in late September. Therefore, we recommend that commencing September 15 of each year, a minimum discharge of 150 cfs be maintained to provide transportation water for returning adults. Commencing October 1, we would recommend that discharge be increased to 175 cfs (measured at Chaplain gauge) to provide adequate spawning flows.

Coho Salmon

Table 4 summarizes the results of the usable width analysis for coho salmon spawning habitat. We completed this analysis using the same depth and velocity plots and techniques used to perform the fall chinook analysis. The only difference is that coho spawning criteria were substituted for fall chinook criteria in making the evalutions. The results clearly indicate that the overall optimum flow for coho salmon spawning in the canyon is 108 cfs. This finding leads to the conclusion that following completion of fall chinook spawning in October, discharge whould be lowered from 175 to 108 cfs, if possible, to accomodate coho. However, the well-being of the incubating chinook eggs must be considred before selecting this flow for coho. The depth and velocity plots (Figures 3 - 8) indicate that chinook redds constructed at the study stations at 175 cfs would be adequately covered with water at 108 cfs. However, additional surveys would be necessary to determine if chinook redds are adequately covered at 108 cfs in other areas of the canyon.

CONCLUSIONS

1) The recommended spawning discharge for fall chinook salmon in the Sultan River canyon is 175 cfs commencing October 1st of each year. Minimum transportation flows of 150 cfs should commence by September 15th of each year.
2) The preliminary spawning discharge for coho salmon is 108 cfs. This discharge is provisional and is subject to upward revision based on future investigations to determine coho utilization and whether reduced flows will adequately cover fall chinook redds. Coho utilization and time of spawning will be determined based on surveys to be conducted in November-December, 1978.
3) Additional field work will be conducted during the summer of 1979 to quantify rearing flows for coho and fall chinook salmon.

ACKNOWLEDGEMENTS

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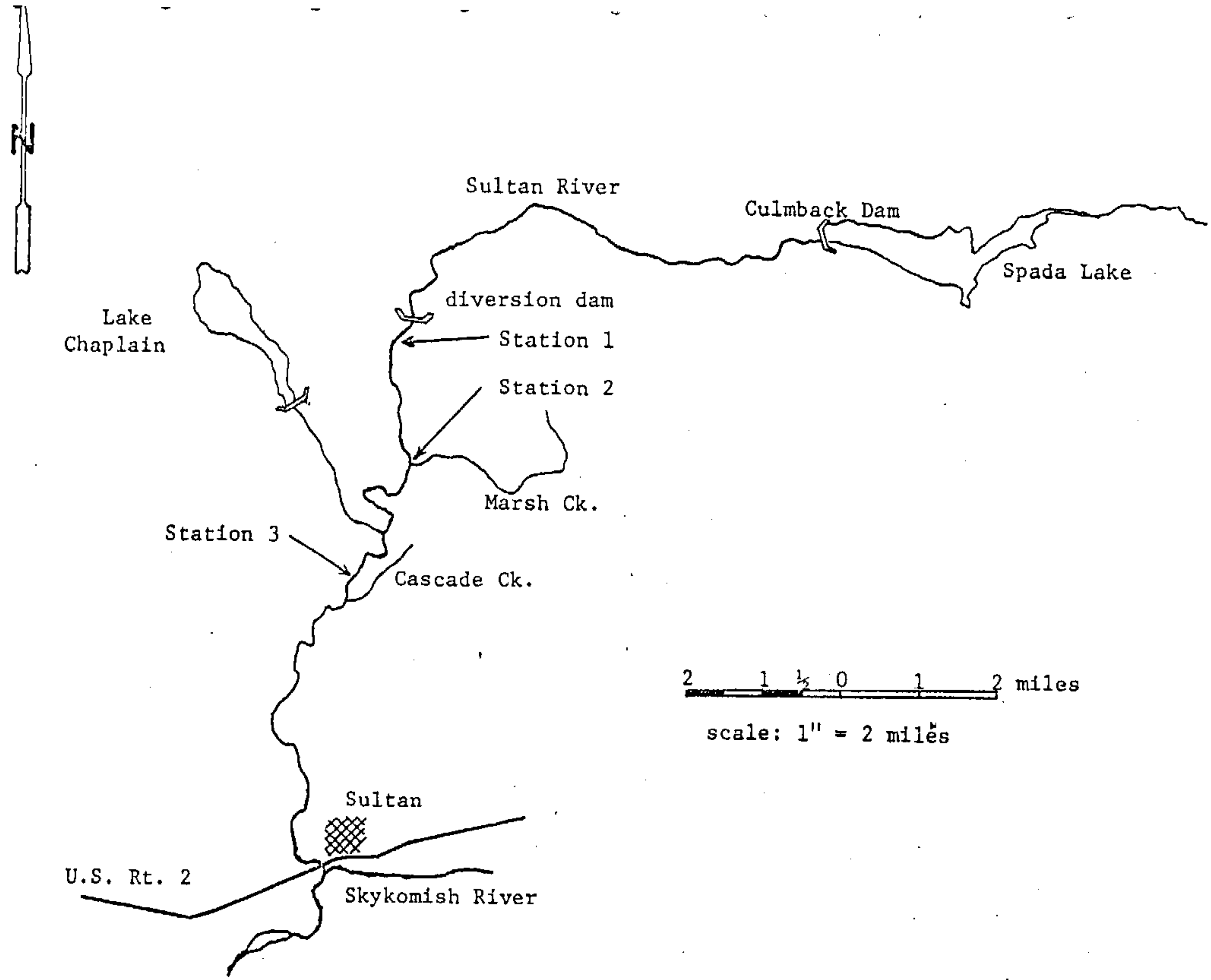

Figure 1. Map of the Sultan River showing location of flow study stations.

FLOW DATA   Rubble (6"-12"), Boulder (>12")

t. from . Pt.	Depth (ft.)	Rev #1	Rev #2	Mean Rev	Elapsed Time(sec)	Velocity (fps)	Total Width (ft.)	Substrate Rating						
								Sand	Gravel	Cobble	Rubble	Boulder	S	M
0-40	no depth or velocity measurements taken, substrate unsuitable							X			X	X		
40	2.6	10	11	10.5	40	0.63	87.5		X				X	
44	2.2	13	12	12.5	"	0.74			X				X	
48	1.9	13.5	14	13.75	"	0.81			X				X	
52	1.7	16	16	16	"	0.94			X				X	
56	1.7	15	15	15	"	0.88			X				X	
60	1.7	16	15	15.5	"	0.91			X				X	
64	1.6	14	14	14	"	0.82			X				X	
68	1.5	15	15	15	"	0.88			X				X	
72	1.5	12	12	12	"	0.71			X				X	
76	1.7	5.5	5	5.25	"	0.32			X				X	
80-87.5	substrate unsuitable (ledge)													

Legend:

S = suitable substrate

M = marginal substrate

U = unsuitable substrate

Figur .. Field data form with actual depth-velocity a collected at Station 2, Transect 1 at a flow of 108 cfs.

Washington Department of Fisheries

SULTAN RIVER FLOW STUDIES

FIELD DATA FORM

Date July 26, 1978 Personnel Gerke, Easterbrooks, Wert Time 16:10

Station # 2 Location Marsh Creek RM 7.6 Weather rainy, foggy, cool

Transect # 1 Description

Discharge @ USGS Gauge (Chaplin Ck) 108 @ 10:20 hrs. (cfs)

Meter 0.4 feet above bottom. Interval between measurements 4 (feet).

Equipment used and serial number Gurley meter # 29625 Ref. Pt.: L or/~~R~~/Bank (down)

NOTES: 1 adult steelhead observed, no steelhead fry

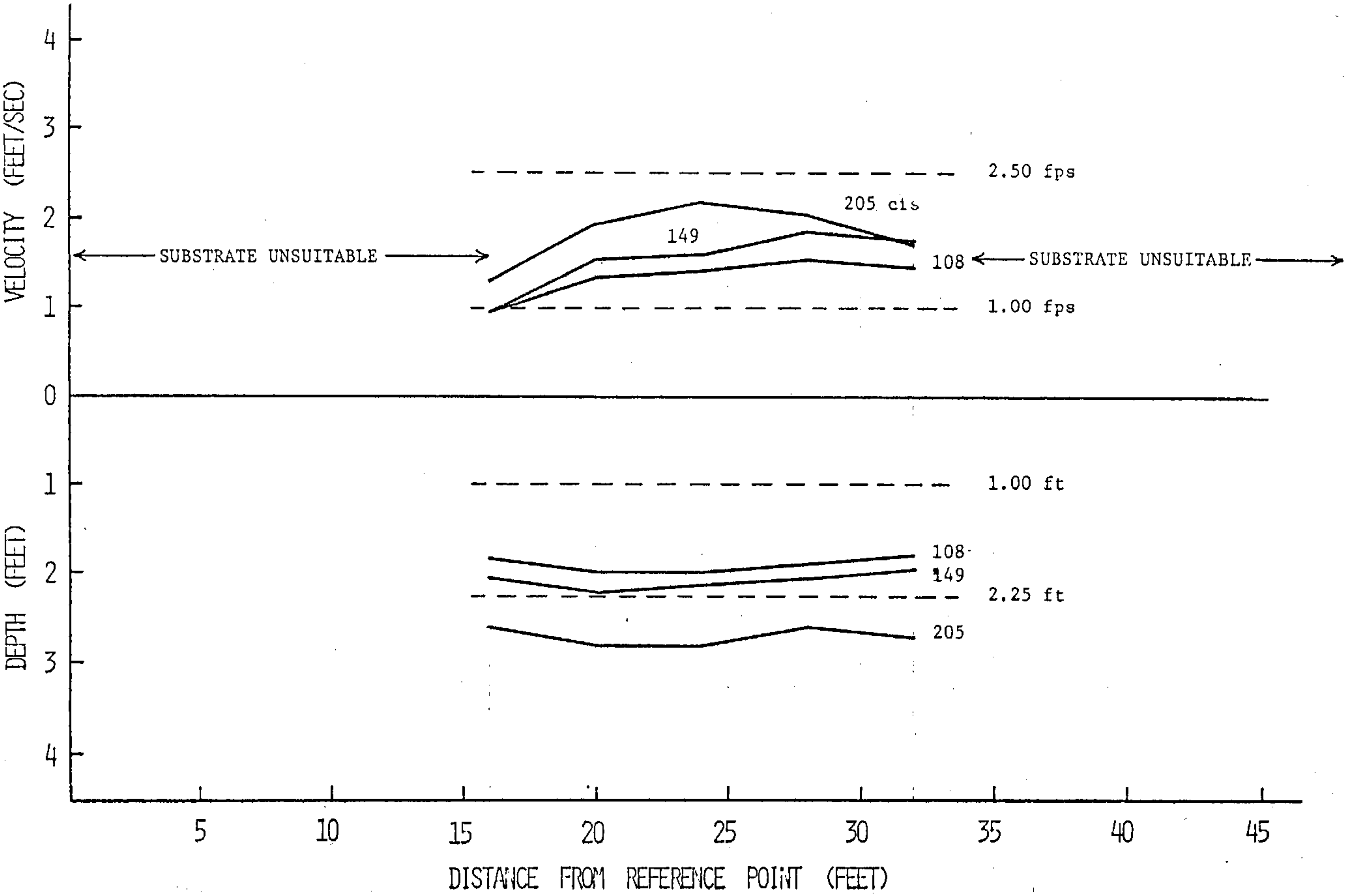

Figure 3. Velocities and depths at Station 1, Transect 1 with fall chinook salmon spawning criteria.

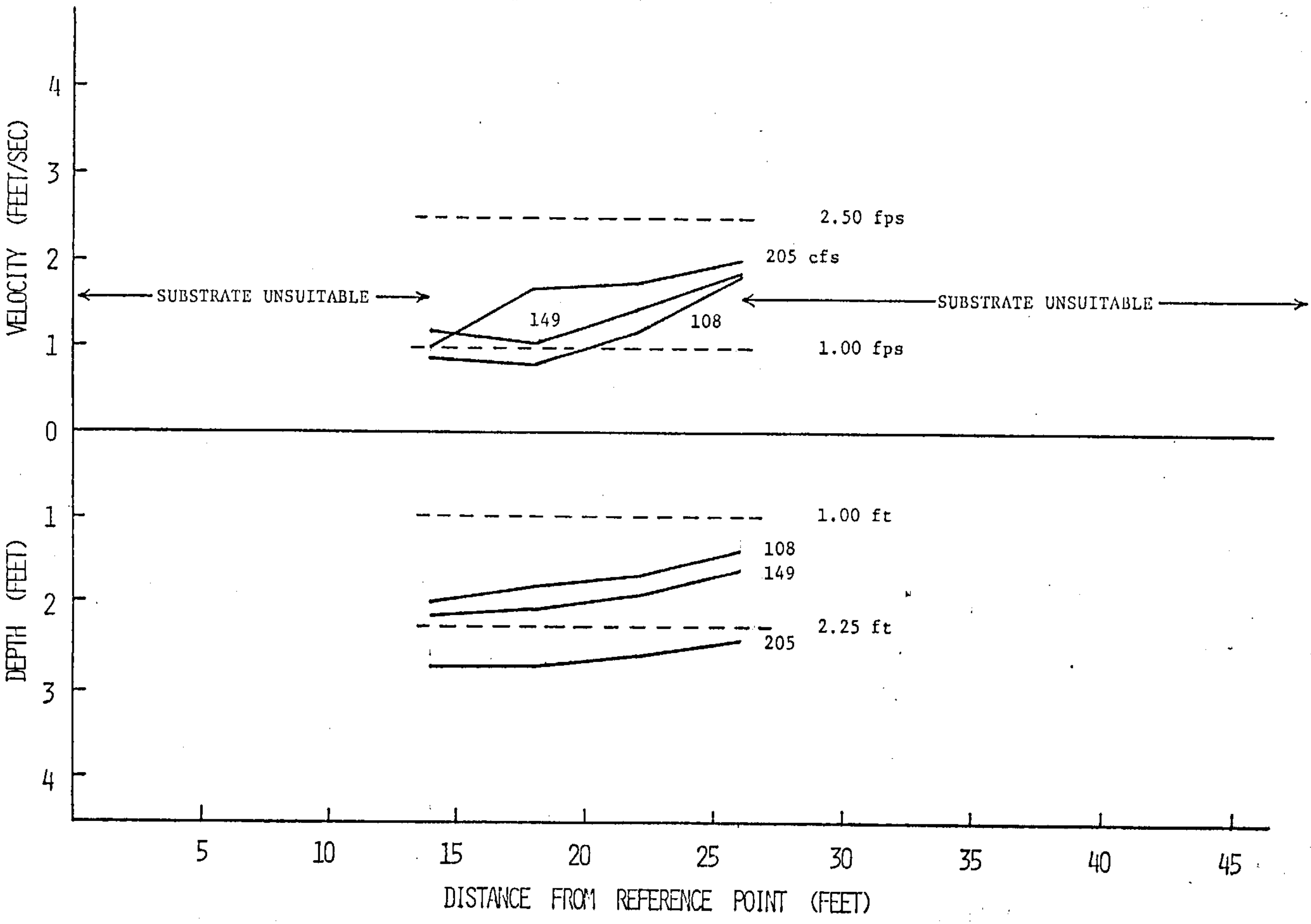

Figure 4. Velocities and depths at Station 1, Transect 2 with fall chinook salmon spawning criteria.

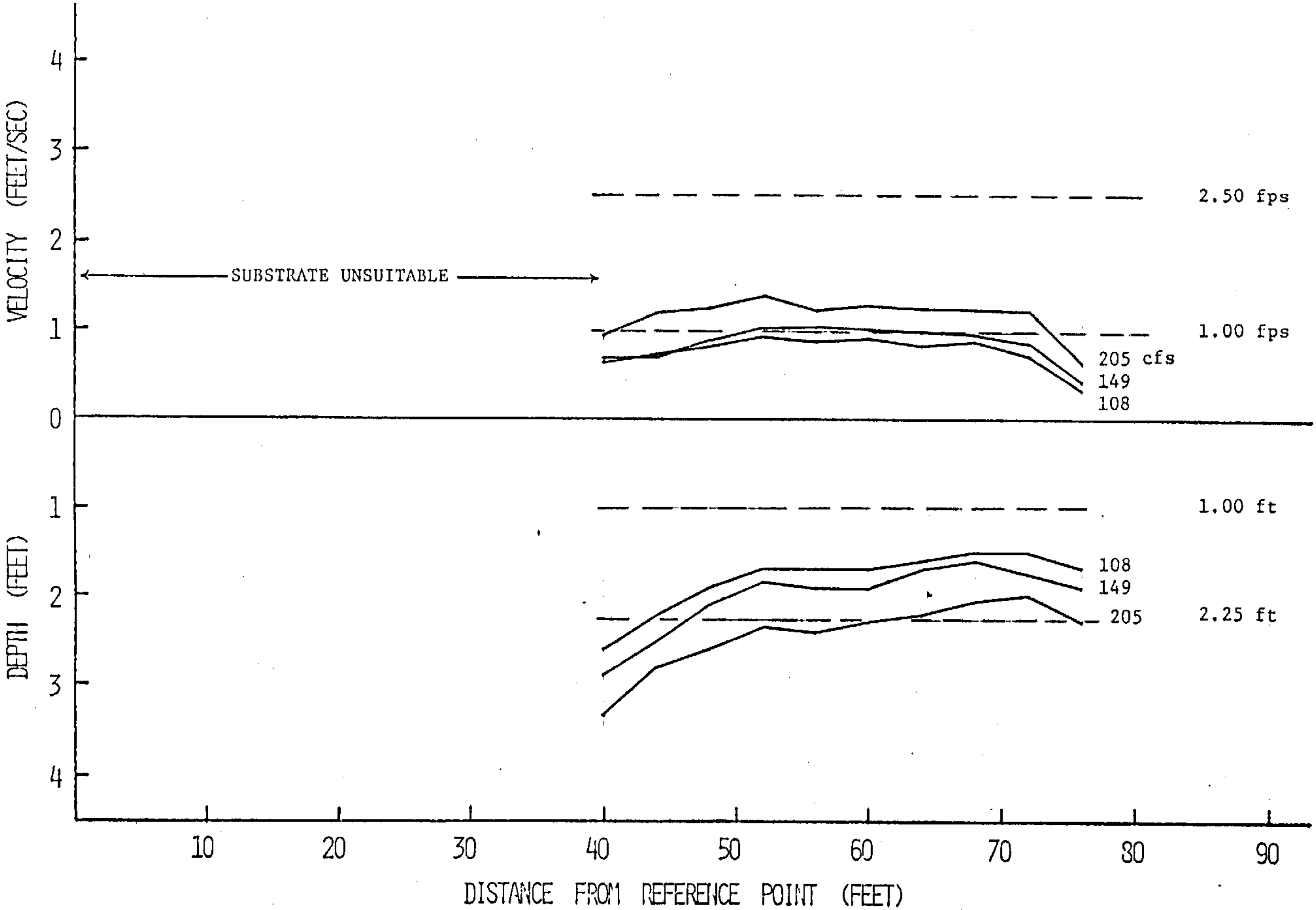

Figure 5. Velocities and depths at Station 2, Transect 1 with fall chinook salmon spawning criteria.

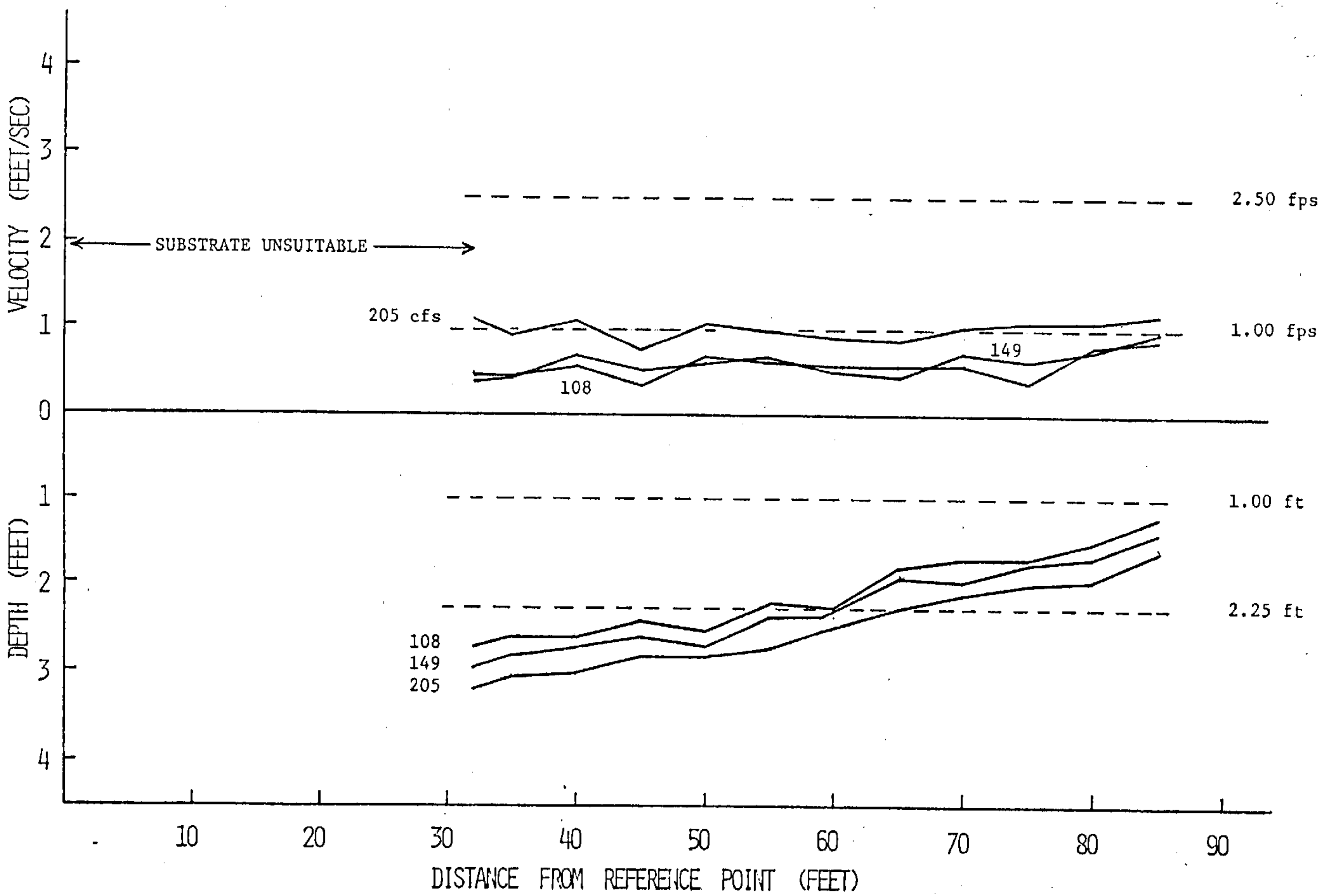

Figure 6. Velocities and depths at Station 3, Transect 1 with fall chinook salmon spawning criteria.

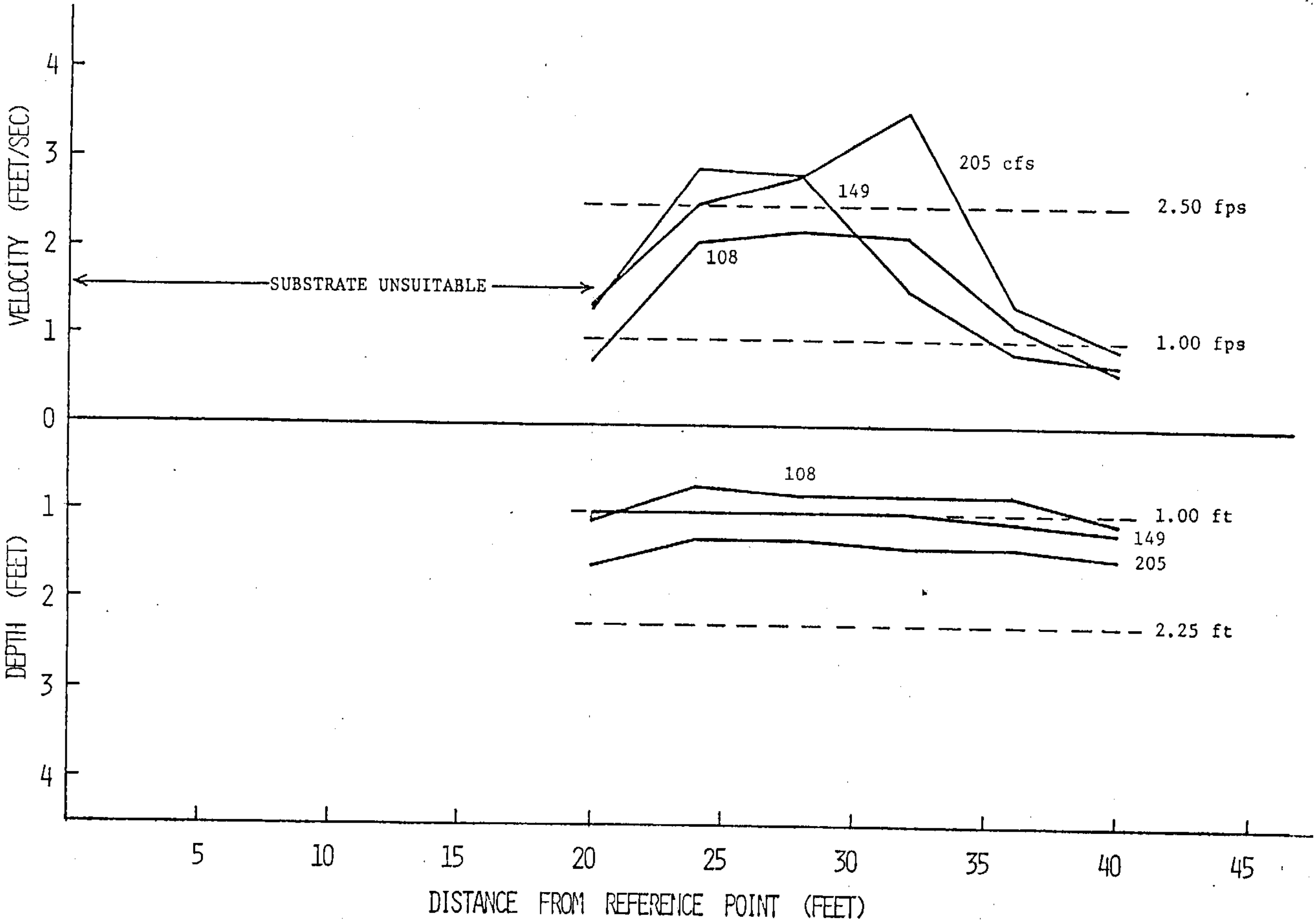

Figure 7. Velocities and depths at Station 3, Transect 2 with fall chinook salmon spawning criteria.

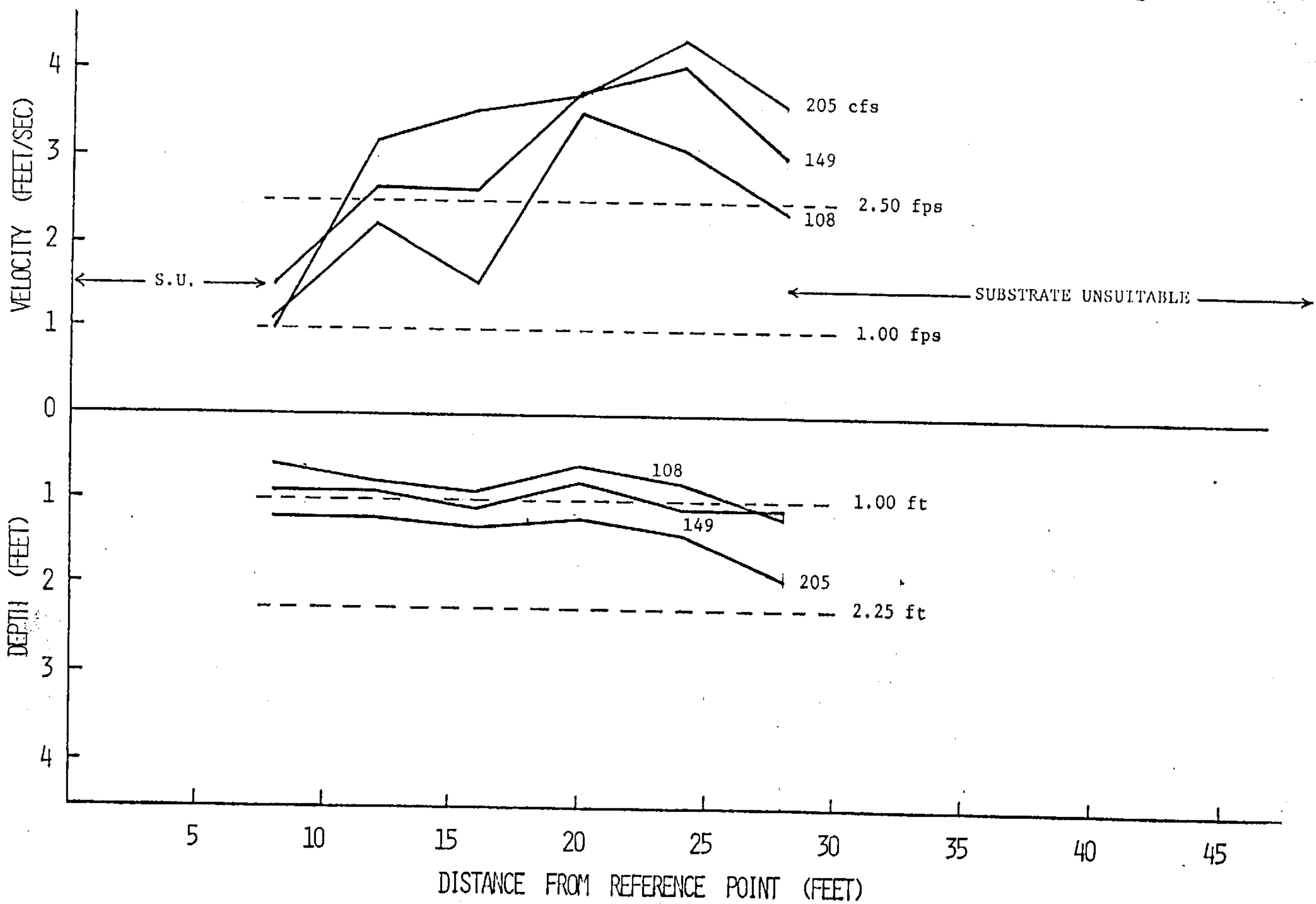

Figure 8. Velocities and depths at Station 3, Transect 3 with fall chinook salmon spawning criteria.

Table 2. Usable Width Analysis for Fall Chinook Salmon Spawning Habitat for all Transects Combined.

Discharge at Chaplain Creek	Usable Width (ft)	Total Width (ft)	% Usable Width
205	40.25	157	25.6
*175	42.50	157	27.1
149	50.25	157	32.0
108	22.75	157	14.5

* Determined through interpolation between 149 and 205 cfs

Table 1. Usable Width Analysis for Fall Chinook Salmon Spawning Habitat by Study Transect.

Location	Discharge at Chaplain Gauge	Usable Width (ft)	Total Width (ft) (Substrate Suitable)	% Usable Width
Station 1 Transect 1	205	0.00	16	0.0
	*175	0.00	16	0.0
	149	16.00	16	100.0
	108	16.00	16	100.0
Station 1 Transect 2	205	0.00	12	0.0
	*175	4.75	12	39.6
	149	12.00	12	100.0
	108	6.00	12	50.0
Station 2 Transect 1	205	12.50	36	34.7
	*175	23.50	36	65.3
	149	12.00	36	33.3
	108	0.00	36	0.0
Station 3 Transect 1	205	16.00	53	30.2
	*175	2.00	53	3.8
	149	0.00	53	0.0
	108	0.00	53	0.0
Station 3 Transect 2	205	9.00	20	45.0
	*175	9.25	20	46.2
	149	10.25	20	51.2
	108	0.25	20	1.2
Station 3 Transect 3	205	2.75	20	13.8
	*175	3.00	20	15.0
	149	0.00	20	0.0
	108	0.50	20	2.5

* Data at 175 cfs determined by interpolation between 149 and 205 cfs

Table 3. Estimated Fall Chinook Spawning Escapement in the Sultan River Canyon by Section.

Section		Fish/Mile	Length of Section (miles)	Escapement	% Escapement
I	RM 3.3 - 4.5 (Below Station 3)	25	1.2	30	9.2
II	RM 4.5 - 7.0 (Includes Station 3)	92	2.5	230	70.1
III	RM 7.0 - 9.7 (Includes Stations 1 & 2)	25	2.7	68	20.7
	TOTALS		6.4	328	100.0

Estimates based on peak spawning survey made on October 6, 1978

Table 4. Usable Width Analysis for Coho Salmon Spawning Habitat by Study Transect.

Location	Discharge at Chaplain Gauge	Usable Width (ft)	Total Width (ft) (Suitable Substrate)	% Usable Width
Station 1 Transect 1	205	0.00	16	0.0
	149	1.50	16	9.4
	108	16.00	16	100.0
Station 1 Transect 2	205	0.00	12	0.0
	149	6.00	12	50.0
	108	12.00	12	100.0
Station 2 Transect 1	205	1.00	36	2.8
	149	25.50	36	70.8
	108	27.50	36	76.4
Station 3 Transect 1	205	8.00	53	15.1
	149	18.50	53	34.9
	108	16.00	53	30.2
Station 3 Transect 2	205	7.75	20	38.7
	149	13.00	20	65.0
	108	20.00	20	100.0
Station 3 Transect 3	205	2.25	20	11.2
	149	2.50	20	12.5
	108	9.50	20	47.5