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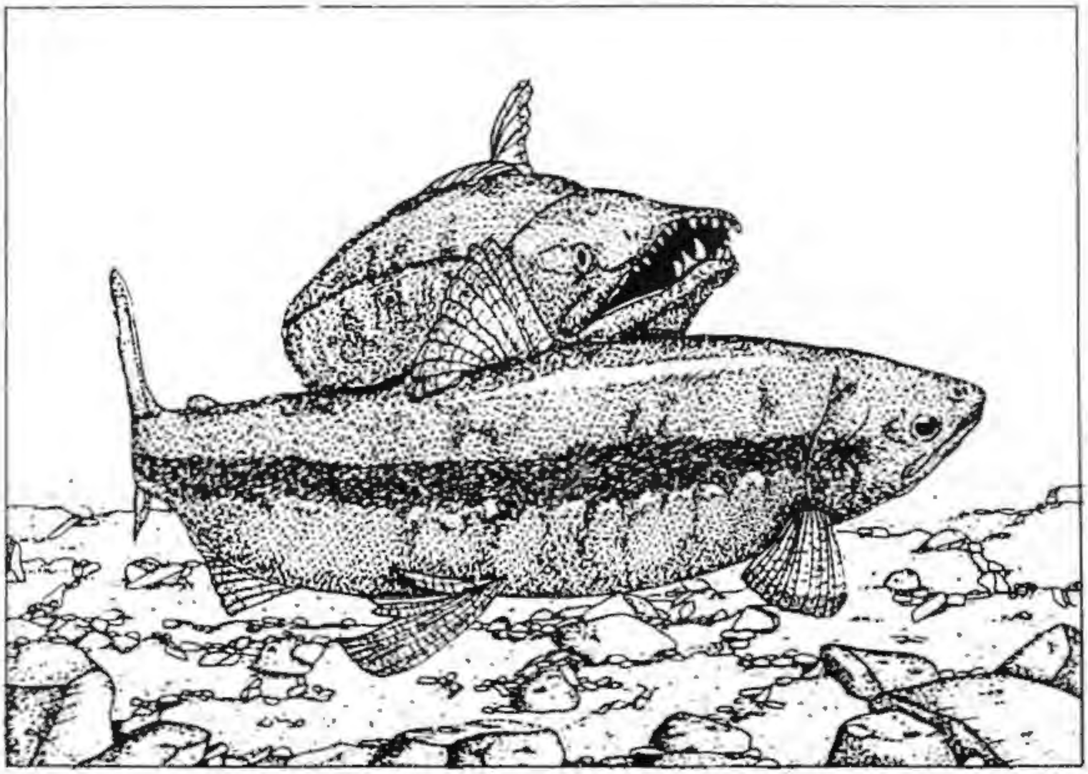

SUSITNA HYDRO AQUATIC STUDIES
PHASE II DRAFT REPORT

Volume I - Synopsis of the 1982 Aquatic Studies and Analysis of Fish and Habitat Relationships.

— APPENDICES —

by

ALASKA DEPARTMENT OF FISH AND GAME
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503

1983

PREFACE

This report is Volume One of a five volume presentation of the fisheries, aquatic habitat, and instream flow data collected by the Alaska Department of Fish and Game (ADF&G) Susitna Hydroelectric (Su Hydro) Feasibility Aqustic Studies Program during the 1981-82 (October-May) ice-covered and 1982 open water (May-October) seasons. It is one of a series of reporta prepared for the Alaska Power Authority (APA) by the ADF&G and other contractors to evaluate the feasibility of the proposed Susitna Hydroelectric Project. This draft report is intended for data transmittal to other Susitna Hydroelectric Feasibility Study participants.

This volume presents a synopsis of the information contained in the other four volumes. The topics discussed in Volumea Two through Five are illuatrated in Figure A. In addition to the synopsis, this report also includes the analysis of the pre-project fishery and habitat relationships derived from Volumes Two through Five and related reports prepared by other study participants. The final report will be submitted to the APA on June 30, 1983 for formal distribution to study participanta, atate and federal agencies, and the public. Also scheduled for completion on June 30, 1983 is the first draft of the ADF&G 1982-83 ice-covered sesson bssic data report. It will include a presentation of 1982-83 incubation and other fishery and habitat data.

These and other ADF&G reports (1974, 1976, 1977, 1978, 1979, 1981a, b, c, d, e, f, 1982) and information reported by others will be summarized and analyzed by the Arctic Environmental Information and Data Center (AEIDC) to evaluate post-project conditions within the overall study area of the proposed project (Figure B). Woodward Clyde Consultants will, in turn, use this information to support the

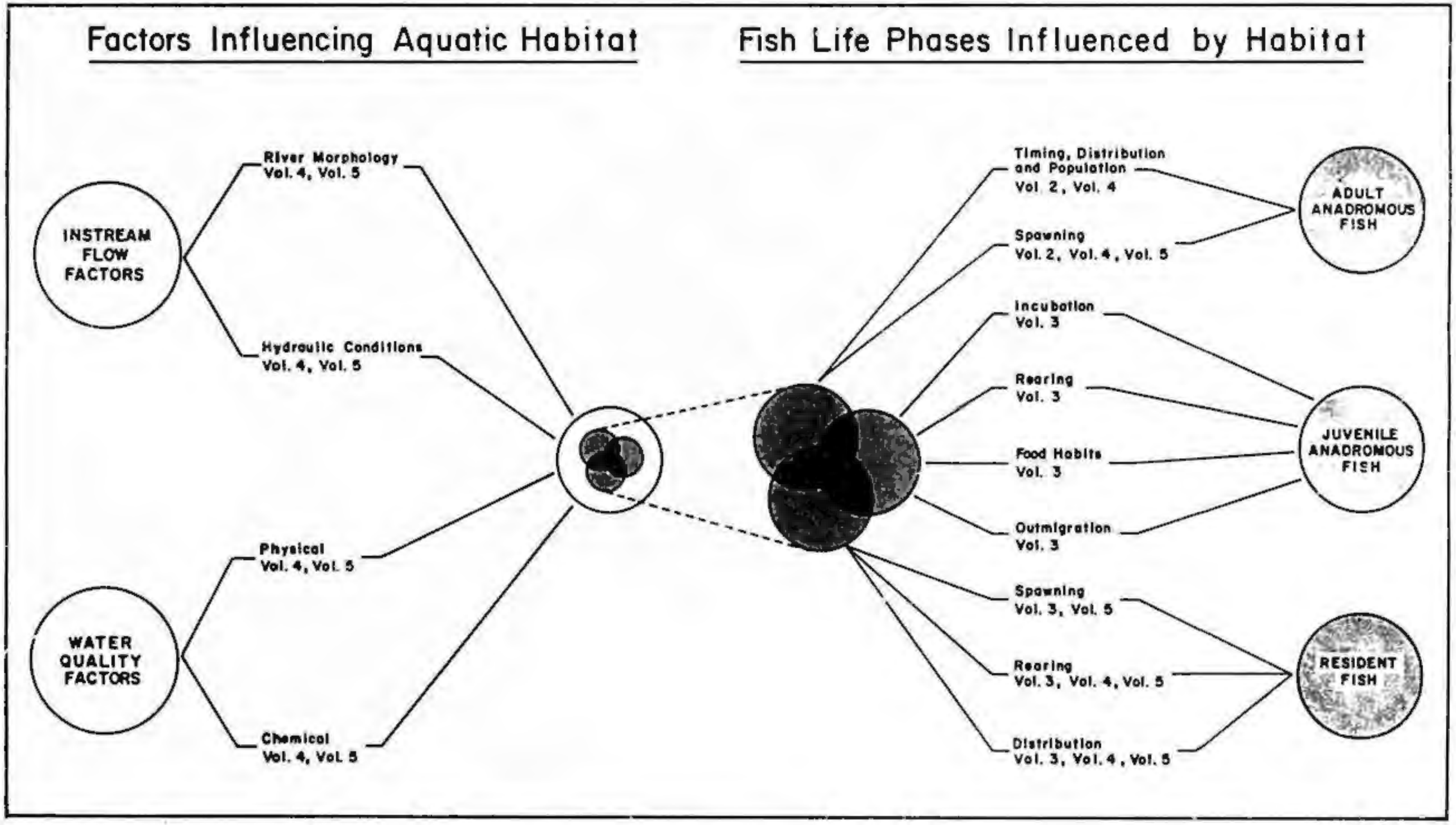

Figure A. Intregration of and relationships among program elements presented in Volumes II through IV.

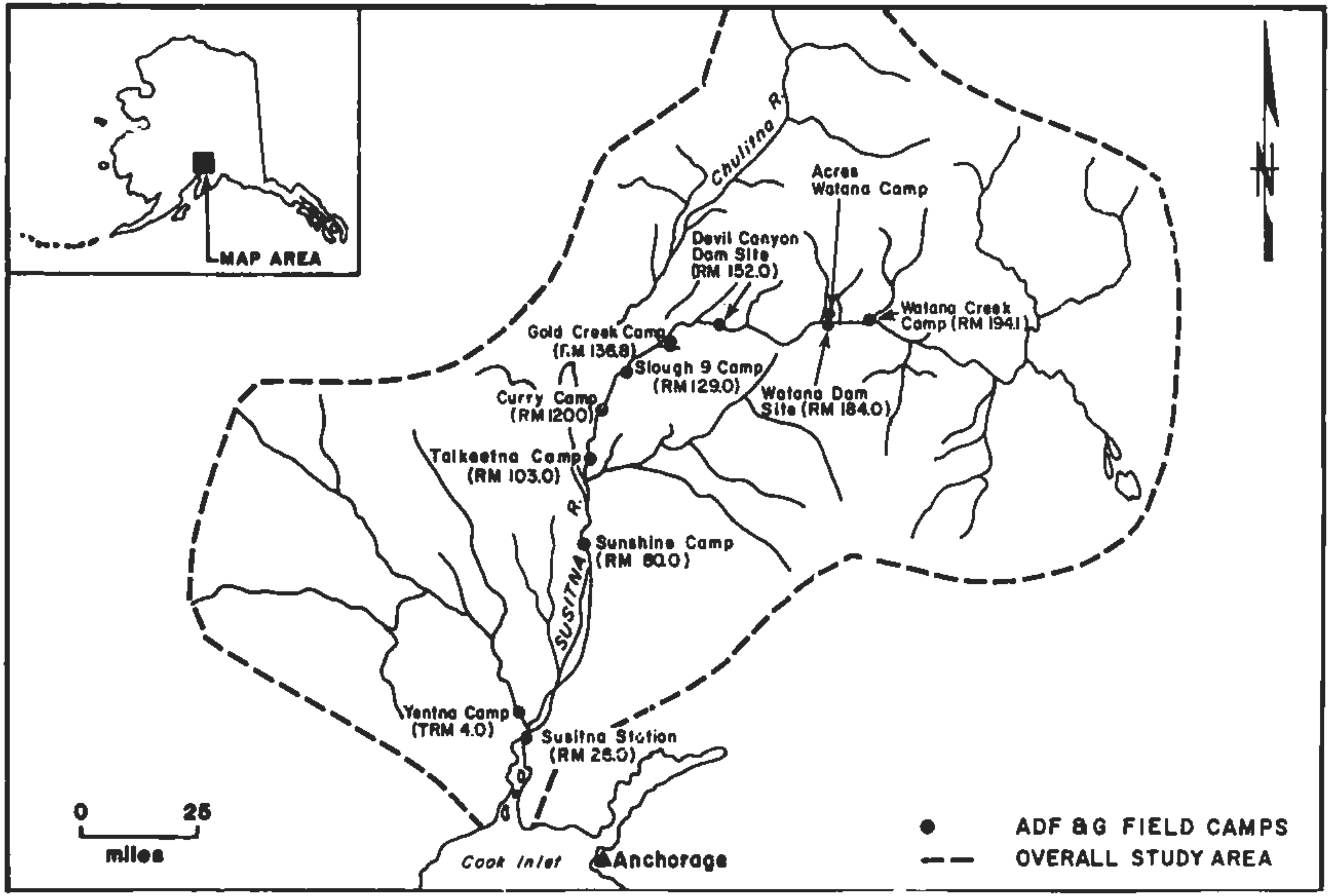

Figure B. Overall study area of the Susitna Hydroelectric Feasibility Study Program.

preparation of the Federal Energy Regulatory Commission License Application for Acres.

The five year (Acres 1980) ADF&G Su Hydro Aquatic Studies program was initiated in November 1980. It is subdivided into three study sections: Adult Anadromous Fish Studies (AA), Resident and Juvenile Anadromous Fish Studies (RJ), and Aquatic Habitat and Instream Flow Studies (AH).

Specific objectives of the three sections are:

1. AA - determine the seasonal distribution and relative abundance of adult anadromous fish populations produced within the study area (Figure B);

2. RJ - determine the seasonal distribution and relative abundance of selected resident and juvenile anadromous fish populations within the study area; and

3. AH - characterize the seasonal habitat requirements of selected anadromous and resident fish species within the study area and the relationship between the availability of these habitat conditions and the mainstem discharge of the Susitna River.

The 1981-82 ice-covered and 1982 open-water ADF&G study areas (Figures C and D) were limited to the mainstem Susitna River, associated sloughs and side channels, and the mouths of major tributaries. Portions of tributaries which will be inundated by the proposed Watana and Devil Canyon reservoirs were also evaluated. Descriptions of study sites are presented in each of these volumes including the ADF&G reports (ADF&G 1981a, b, c, d, e, f).

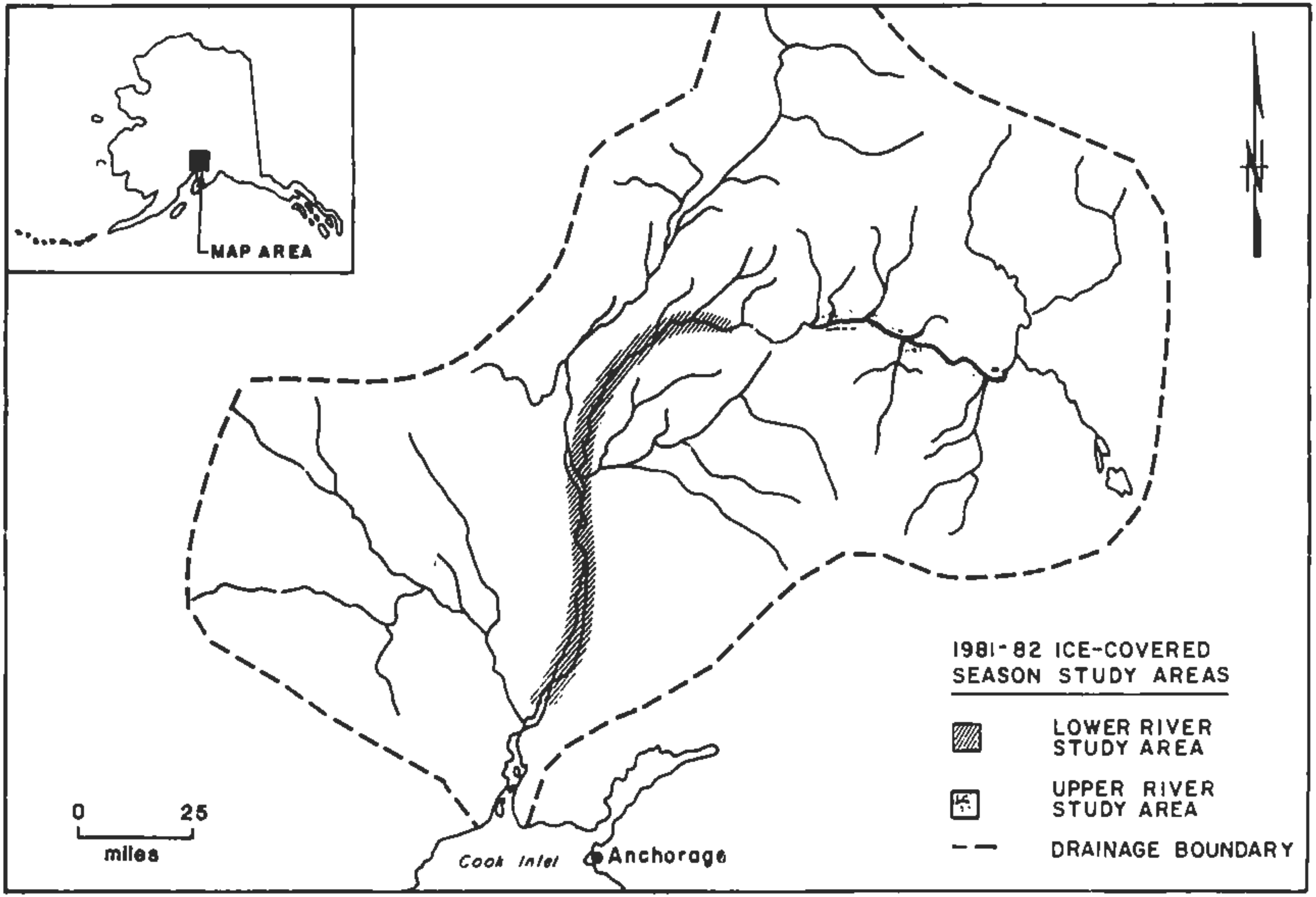

Figure D. 1981-82 ADF&G ice-covered season (October through May) study area.

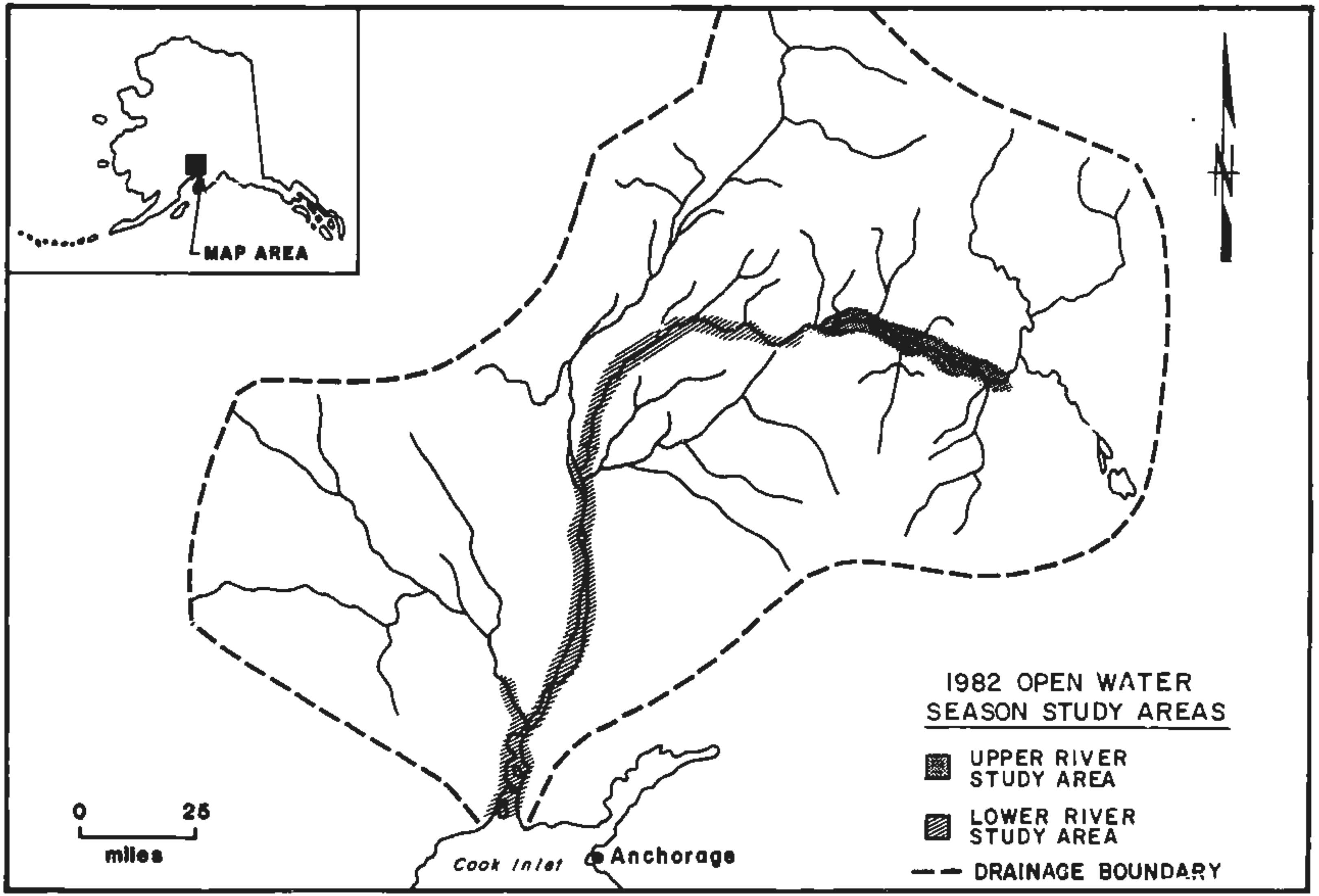

Figure C. 1982 ADF&G open water season (May through October) study area.

Questions concerning these reports should be directed to:

Thomas W. Trent
Aquatic Studies Coordinator
Alaska Department of Fish & Game
Su Hydro Aquatic Studies Program
2207 Spenard Road
Anchorage, Alaska 99503
Telephone (907) 274-7583

PREFACE REFERENCES

Acres American, Inc. (Acres) 1980. Susitna Hydroelectric Project Plan of Study. Prepared for the Alaska Power Authority. Anchorage, Alaska.

Alaska Department of Fish and Game (ADF&G). 1974. An assessment of the anadromous fish populations in the Upper Susitna River Watershed between Devil Canyon and the Chulitna River. Anchorage, Alaska.

______. 1976. Fish and Wildlife studies related to the Corps of Engineers Devil Canyon, Watana Reservoir Hydroelectric Project. ADF&G. Anchorage, Alaska.

______. 1977. Preauthorization assessment of the proposed Susitna Hydroelectric Projects: preliminary investigations of water quality and aquatic species composition. ADF&G. Anchorage, Alaska.

______. 1978. Preliminary environmental assessment of hydroelectric development on the Susitna River. Anchorage, Alaska.

______. 1979. Preliminary final plan of study fish and studies proposed by the ADF&G. ADF&G. Anchorage, Alaska.

______. 1981a. Aquatic studies procedures manual. Phase I. Final Draft. Subtask 7.10. Prepared for Acres American, Incorporated, by the Alaska Department of Fish and Game/Su Hydro. Anchorage, Alaska.

______. 1981b. Adult anadromous fisheries project. Phase I. Final Draft. Subtask 7.10. Prepared for Acres American, Incorporated, by the Alaska Department of Fish and Game/Su Hydro. Anchorage, Alaska.

PREFACE REFERENCES (Continued)

______. 1981c. Aquatic habitat and instream flow project. Phase I. Final Draft. Prepared for Acres American, Incorporated, by the Alaska Department of Fish and Game/Su Hydro. Anchorage, Alaska.

______. 1981d. Resident fish investigation on the lower Susitna River. Phase I. Final Draft. Prepared for Acres American, Incorporated by Alaska Department of Fish and Game/Su Hydro. Anchorage, Alaska.

______. 1981e. Resident fish investigations on the lower Susitna River. Phase I. Final Draft. ADF&G Su Hydro Aquatic Studies Program. Anchorage, Alaska.

______. 1981f. Resident fish investigations on the upper Susitna River. Phase I. Final Draft. ADF&G Su Hydro Aquatic Studies Program. Anchorage, Alasks.

______. 1982. Aquatic Studies Program. Phase I. Final Draft. Subtask 7.10. Prepared for Acres American, Incorporated by the Alaska Department of Fish and Game/Su Hydro. Anchorage, Alaska.

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APPENDIX A

Analysis of the species selectivity of fishwheels for the capture of adult salmon in the Susitna River.

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Introduction

Fishwheels have been used to intercept adult salmon for commercial and subsistence purposes for many years. They are usually most successful in glacial, turbid rivers such as the Susitna River. More recently, however, fishwheels have become a tool used by fishery biologists to manage salmon fisheries.

As with any capture gear used to manage a fisheries it becomes necessary to identify and, if possible, quantify any gear deficiencies or biases.

An inherent bias with fishwheels has been the species selectiveness in their capture of adult salmon. Meehan (1961) found that chinook and coho salmon in the Taku River were least susceptible to recapture by fishwheel while pink salmon were more susceptible to recapture. He also noted fishwheel selectivity within a species; the smaller "jack" chinook salmon were more readily captured than the larger, older chinook salmon. He felt that fishwheel selectivity was manageable when the data were used as a relative index of the escapement and not as a definitive measure of the escapement.

In relation to the present study, the Alaska Department of Fish and Game (ADF&G) Su Hydro, Adult Anadromous staff deployed fishwheels for tag/recapture programs at Sunshine, Talkeetna and Curry stations. Also side scan sonar units, with associated fishwheels to apportion the sonar counts, were operated at Susitna, Yentna, Sunshine and Talkeetna stations (Appendix Figure A-1). The equipment located at Susitna station was managed by ADF&G, Commercial Fisheries Division, Soldotna.

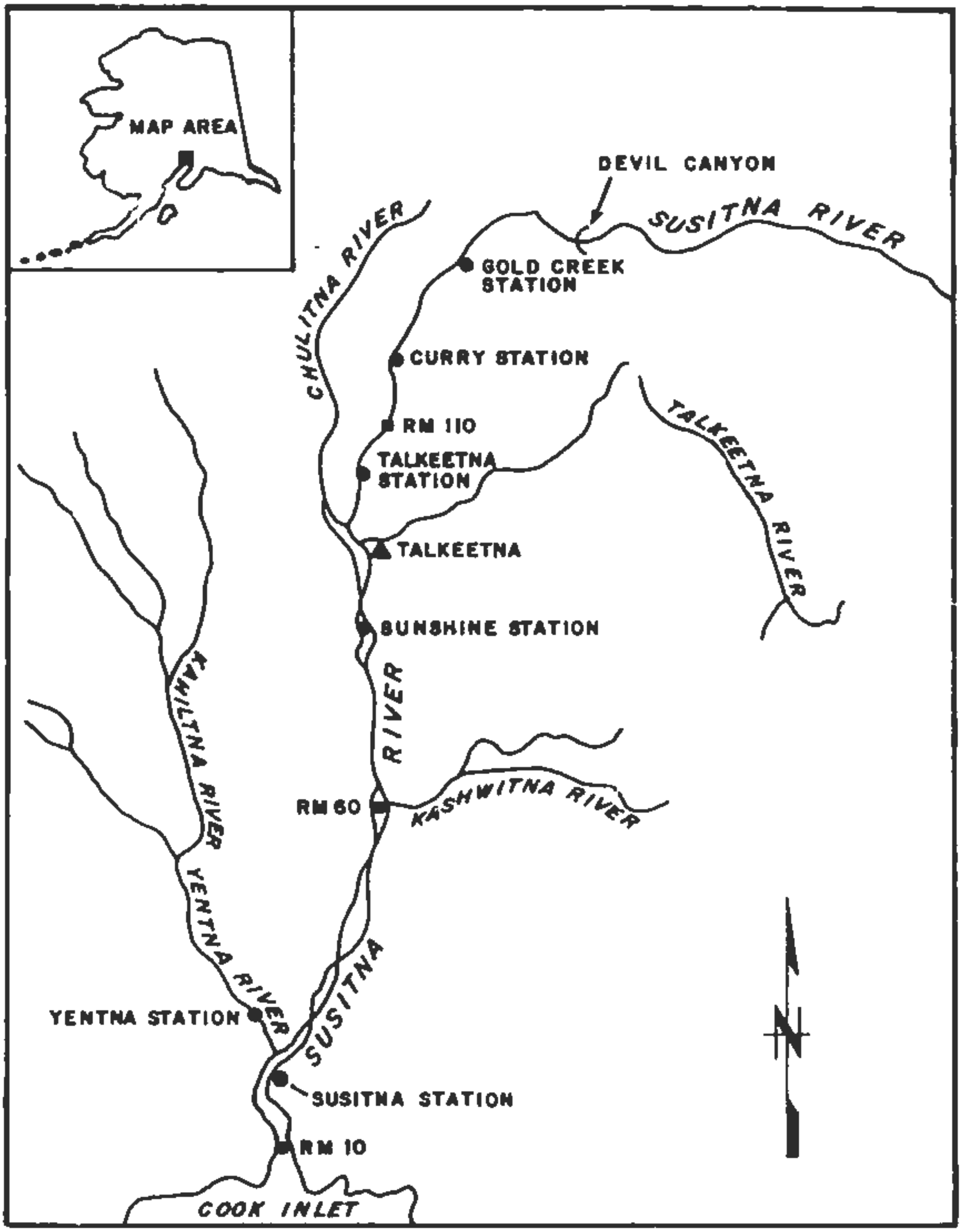
It is the purpose of this paper to ascertain whether or not fishwheels were selective in their capture of adult salmon in the Susitna River, and if so, discuss the implications of using fishwheels to apportion sonar counts.

Methods

Tagging Process

Fishwheels, designed and built by ADF&G/Su Hydro, Adult Anadromous staff, were used to intercept salmon for tag application at Sunshine, Talkeetna and Curry stations in 1981 and 1982. There were four fishwheels located at Sunshine and Talkeetna stations and two at Curry Station. Fishwheel specifications may be obtained by consulting the Phase I, ADF&G/Su Hydro, Adult Anadromous Report (1981).

Adult salmon were trapped in rotating fishwheel baskets and exited via a padded chute into a live box. A member of the tagging crew dipnetted salmon from the live box and placed them on a cushioned tagging platform. Next, a second crewmember inserted and secured either a floy FT-4 spaghetti tag or a Petersen disc beneath the dorsal fin and gently released the salmon. Both tag types were color coded and identifiable to station. The total time elapse of the tagging process, from dipnetting to release, was 10 to 15 seconds.



Appendix Figure A-1. Susitna River basin map showing field stations and major tributaries.

Tag Recovery

Marked salmon were recovered during repetitive surveys of streams and sloughs above the tagging sites. For each survey, surveyors recorded the number of tagged live salmon by tag type and color and the number of live untagged salmon by species. Results of the repetitive surveys were summed and provided the seasonal number of tagged salmon (r) and the number of salmon examined for marks (c), by species and station. Only those surveys with good to excellent visibility were used in computing the seasonal r/c proportions.

Tag loss

The percent tag loss was used to adjust the number of tags recovered (r) for each species tagged at stations with reported tag loss. The adjustment was made as follows with the results presented in Appendix Table A-1:

$$r_{adjusted} = (r_{observed} \text{ X percent tag loss}) + r_{observed}$$

Data Analysis

A chi square test of association was used to test the hypothesis that fishwheels were species non-selective in capturing adult salmon or:

$$H_o: \; r_1/c_1 = r_2/c_2 = \ldots r_i/c_i$$

Appendix Table A-1 Percent tag loss based on surveys conducted between Talkeetna Station and Devil Canyon in 1981 and 1982

Tag Type	Tagging Station	Year	No. tagged fish examined	No. shed tags	Percent tag loss
FT-4/Spaghetti	Talkeetna	1981	397	27	7.5
FT-4/Spaghetti	Talkeetna	1982	386	26	6.3
Petersen disc	Curry	1982	325	3	.9

Where r_i = total number of taggeo adult salmon for the i^{th} species

c_i = total number of the i^{th} species of adult salmon examined for tags

This test incorporated the following assumptions:

1) Fishwheels were not selective for stocks within a species (with the exception of chinook salmon $\leq$ 350 millimeters in length).

2) Tagged salmon mixed randomly with untagged salmon and exhibited essentially no behavioral differences.

3) Reported tag loss, by station and tag type, occurred at the same rate for all species.

4) Tagged and untagged salmon had no differential mortality.

5) Salmon passage during flood events was negligible in relation to total salmon passage (substantiated by sonar counts and electroshocking efforts).

Next, an expected value for r (E_r) not weighted by sample size was derived for each species. This was accomplished by calculating an arithmetic mean of the observed r/c proportions for all species at each station and multiplying this value by the total number of each species examined for marks (c). The resultant expected value, E_r, and the observed value for r (O_r) were expressed as the ratio $O_r:E_r$. Letting E_r (=1) define the base of comparison O_r then becomes a function of fishwheel selectivity herein referred to as the coefficient of selectivity (C.S.). O_r values less than one indicate fewer tagged salmon of that species were recovered than expected and conversely O_r values greater than one indicate more tagged salmon of that species were recovered than expected.

Finally, the percent deviation between observed r values (O_r) and expected r values (E_r) were determined for each species at each station. These values were derived by subtracting O_r from E_r and expressing this value as a percent of E_r. Using E_r as a base for comparison, the percent deviation, as with the coefficient of selectivity, may be greater than the expected (E_r) or less than expected (E_r) and when referred to will always be pre-fixed by the appropriate sign. The percent deviations, regardless of sign, were divided into three categories:

1) < 15% — low deviation from expected value

2) 15% to 30% — moderate deviation from expected value

3) > 30% — high deviation from expected value

RESULTS

The null hypothesis, H_0 the number of tagged (r) salmon per number salmon observed (c) is equal for all species, was tested for salmon tagged at Talkeetna and Curry stations in 1981 and 1982. Salmon tagged at Sunshine station were not included in the test as fishwheels there did not operate continuously and therefore had a disproportionate amount of capture effort expended for each species.

Results of the chi square test indicated a highly significant (p .001) difference between r/c proportions of sockeye, pink, chum and coho salmon tagged at Talkeetna and Curry stations in 1981 (Appendix Table A-2). Similarly, the results of the chi square test for data collected in 1982 also indicated a highly significant (p .001) difference between the r/c proportions for chinook, sockeye, pink, chum and coho tagged at Talkeetna stations and chinook, sockeye, chum and coho salmon tagged at Curry Station (Appendix Table A-3). Only fifty percent of the pink salmon captured at Curry Station in 1982 were tagged and subsequently they were not included in the analysis. Fishwheels operated at Talkeetna and Curry Stations in 1981 and 1982, based on the chi square test results, were selective in capturing adult salmon.

The unweighted mean value of the r/c proportions and subsequently derived expected r values provided a quantitive method to access the species selectivity of fishwheels located at Talkeetna and Curry Stations. The deviation of the observed number of tag recoveries, provided the assumptions previously described are true, reflects the

Appendix Table A-2 Chi square test results of observed versus expected number of recaptures at Talkeetna and Curry stations in 1981.

TALKEETNA STATION

Species	c[1]	Observed r[2]	Expected r	Cell X^2[3]	Significance DF=3
Sockeye	4,167	286	296	.37	N.S.
Pink	724	82	51	11.36	**
Chum	5,944	346	423	16.98	***
Coho	852	117	61	27.21	***
Total	11,687	831	831	91.39	***

CURRY STATION

Species	c	Observed r	Expected r	Cell X^2	Significance DF=3
Sockeye	3,040	403	324	15.55	***
Pink	69	12	7	1.80	N.S.
Chum	4,033	345	430	20.76	***
Coho	105	12	11	.05	N.S.
Total	7,247	772	772	43.67	***

[1] c = Total number of i^{th} species examined for marks.

[2] r = Total number of tags (adjusted) recovered

[3] X^2 = Chi square

Appendix Table A-3 Chi square test results of observed versus expected number of recaptures at Talkeetna and Curry stations in 1982.

TALKEETNA STATION

Species	c[1]	Observed r[2]	Expected r	Cell X^2[3]	Significance DF=4
Chinook	1,436	88	183	49.52	***
Sockeye	2,128	287	272	.88	N.S.
Pink	13,936	2,597	1,779	376.61	***
Chum	9,588	503	1,223	424.42	***
Coho	1,065	118	136	2.36	N.S.
Total	28,153	3,593	3,593	978.70	***

CURRY STATION

Species	c	Observed r	Expected r	Cell X^2	Significance DF=3
Chinook	642	35	35	.00	N.S.
Sockeye	1,970	171	108	36.67	***
Chum	7,802	361	428	10.46	*
Coho	398	26	22	.80	N.S.
Total	10,812	593	593	50.72	***

[1] c = Total number of i^{th} spec'.s examined for marks.

[2] r = Total number of tags (adjusted) recovered

[3] X^2 = Chi square

selectivity or non-selectivity of fishwheel captures for each species. Resu ts for each species are summarized below:

1) Chinook salmon

Chinook salmon were tagged at Talkeetna and Curry Station in 1982 only. Chinook salmon less than 351 mm were not tagged. The coefficient of selectivity was .56 at Talkeetna Station and .61 at Curry Stations. The present deviation between the number of tag recoveries observed and the number expected was high, less than 44.0 percent at Talkeetna Station and less than 34.0 percent at Curry Station (Appendix Table A-4).

2) Sockeye salmon

Fishwheels did not appear to selectively capture sockeye salmon in 1982. The percent deviation between observed and expected tag recoveries was greater than 10.5 percent at Talkeetna Station and less than 2.8 percent at Curry Station, both low values. In 1981 sockeye salmon were caught at less than the expected rate (moderate percent deviation of less than 28.1 percent) at Talkeetna Station while fishwheels at Curry Station did not appear to be selective in capture (low percent deviation of greater than 1.6 percent) (Appendix Table A-5 and A-6).

3) Pink salmon

Pink salmon tended to have consistently higher r values than expected. The coefficient of selectivity in 1981 was 1.19 and 1.50 at Talkeetna

Appendix Table A-4 Coefficient of selectivity and percent deviation for chinook, sockeye, pink, chum and coho salmon tagged at Talkeetna and Curry stations in 1982.

TALKEETNA STATION

Species	Observed Values c	Observed Values r	r/c	Expected Values r/c	Expected Values r	Coefficient of Selectivity	Percent Deviation
Chinook	1,436	88	.06	.11	157	.56	44.0
Sockeye	2,126	284	.13	.11	233	1.22	21.9
Pink	13,936	2,596	.19	.11	1,473	1.76	76.2
Chum	9,588	502	.05	.11	1,054	.48	47.6
Coho	1,065	117	.11	.11	117	1.0	0.0

CURRY STATION

Species	Observed Values c	Observed Values r	r/c	Expected Values r/c	Expected Values r	Coefficient of Selectivity	Percent Deviation
Chinook	642	35	.06	.09	57	.66	34.0
Sockeye	1970	171	.09	.09	177	1.05	4.9
Pink	4,470	726	.16	.09	371	1.96	95.7
Chum	7,802	359	.05	.09	647	.55	44.5
Coho	398	26	.07	.09	33	.79	21.2

Appendix Table A-5 Coefficient of selectivity and percent deviation for sockeye, pink, chum and coho salmon tagged at Talkeetna Stations in 1981 and 1982.

1981

Species	Observed Values c	Observed Values r	Observed Values r/c	Expected Values r/c	Expected Values r	Coefficient of Selectivity	Percent Deviation
Sockeye	4,167	299	.07	.10	416	.72	28.1
Pink	724	86	.12	.10	72	1.19	19.4
Chum	5,944	357	.06	.10	594	.60	39.9
Coho	852	125	.15	.10	85	1.47	47.1

1982

Species	Observed Values c	Observed Values r	Observed Values r/c	Expected Values r/c	Expected Values r	Coefficient of Selectivity	Percent Deviation
Sockeye	2,126	284	.13	.12	257	1.11	10.5
Pink	13,936	2,596	.19	.12	1,686	1.54	54.0
Chum	9,588	502	.05	.12	1,160	.43	56.7
Coho	1,065	117	.11	.12	128	.91	8.6

Appendix Table A-6 Coefficient of selectivity and percent deviation for sockeye, pink, chum and coho salmon tagged at Curry Station in 1981 and 1982.

1981

Species	Observed Values c	Observed Values r	Observed Values r/c	Expected Values r/c	Expected Values r	Coefficient of Selectivity	Percent Deviation
Sockeye	3,040	386	.13	.13	380	1.02	1.6
Pink	69	12	.17	.13	8	1.50	50.0
Chum	4,033	333	.08	.13	504	.66	33.9
Coho	105	12	.11	.13	13	.92	7.7

1982

Species	Observed Values c	Observed Values r	Observed Values r/c	Expected Values r/c	Expected Values r	Coefficient of Selectivity	Percent Deviation
Sockeye	1,970	172	.09	.09	177	.97	2.8
Pink	4,470	732	.16	.09	402	1.82	82.1
Chum	7,[illegible]02	362	.04	.09	702	.52	48.4
Coho	398	26	.07	.09	35	.74	27.7

and Curry Stations, respectively (Appendix Table A-5 and A-6). In 1982, the large number of pink salmon in the Susitna River drainage and manpower constraints allowed only 50 percent of the pink salmon to be tagged at Curry Station and number of observed tag recoveries was doubled to compensate.

The 1981 trend of larger observed r values than expected continued in 1982. The percent deviation was greater than 54.0 and greater than 82.1 percent at Talkeetna and Curry Stations, respectively (Appendix Table A-5 and A-6). Pink salmon appear to be captured by fishwheels at a rate that exceeds expectations regardless of the location.

4) Chum salmon

The number of chum salmon tag recoveries was lower than expected for fish tagged at Talkeetna and Curry Stations in both 1981 and 1982. In 1981 the coefficient of selectivity was .60 and .66 at Talkeetna and Curry Stations, respectively. In 1982 the coefficient of selectivity was lower, .43 and .52 in the above station order. The percent deviation remained high (greater than 30 percent at both Talkeetna and Curry Stations in 1981 and 1982 (Appendix Table A-5 and A-6).

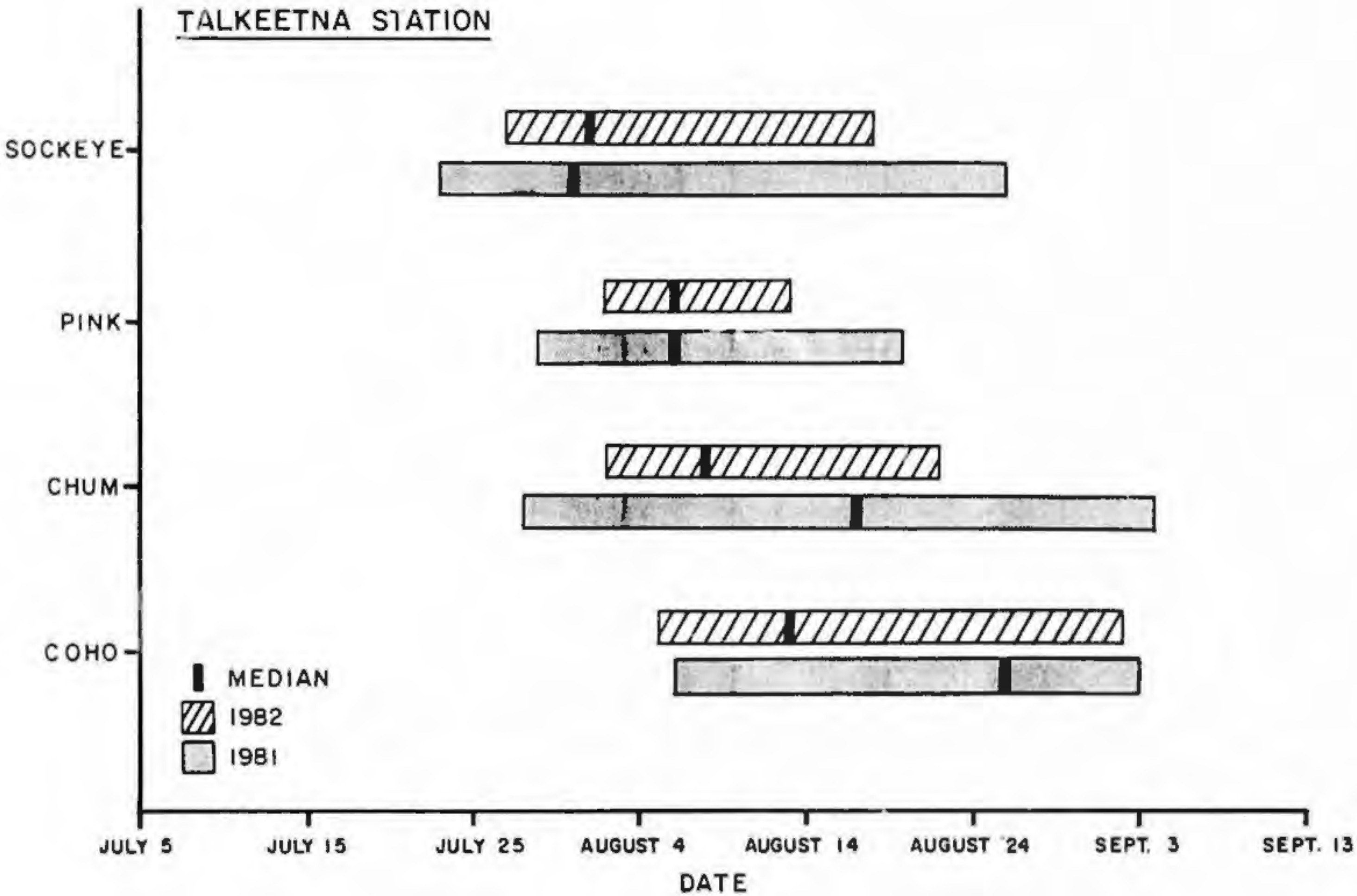
5) Coho salmon

Coho salmon observed tag recoveries and expected tag recoveries varied considerably between years and between sites. In 1981 the percent deviation at Talkeetna and Curry Stations were less than 47.1 and greater than 7.7 percents, respectively. In 1982 for the same stations the percent deviations were greater than 8.6 and greater than 27.7 percents, respectively (Appendix Table A-5 and A-6).

DISCUSSION

Fishwheel selectivity has been a frequently discussed subject. Selectivity can be a function of many parameters such as fishwheel site, channel configuration, water velocity, fish size and behavioral traits. These parameters have been considered intuitively but were difficult to quantify. The large number of fish tagged and the extensive random surveys pursuant to goals of this project provided the means to assess fishwheel selectivity in a quantitive manner. For reasons yet to be defined it appears that chinook and chum salmon generally tend to be undercaught by fishwheels while pink salmon are usually overcaught. Sockeye and coho salmon do not exhibit these general trends and are caught at different rates by fishwheels at Talkeetna and Curry Stations.

Having established fishwheel selectivity it becomes apparent that using fishwheels to apportion sonar counts in the Susitna River would bias the counts based on the fishwheel selectivity of the fishwheels at that site. This bias can change constantly, from no bias (one species present) to bias which severely impacts daily sonar estimates of the number of each species present (when two or more species temporarily overlap). This is graphically visualized in Appendix Figure A-2 where as many as four species temporarily overlap during passage by Talkeetna Station.



Appendix Figure A-2. Temporal timing of sockeye, pink, chum and coho salmon at Talkeetna station in 1981 and 1982.

LITERATURE CITED

Alaska Department of Fish and Game (AOF&G). 1981. Adult Anadromous Phase I final species/subject report. ADF&G/Su Hydro Aquatic Studies Program. Anchorage, Alaska.

Meehan, W.R. 1961. Use of a Fishwheel in Salmon Research Management. Trans. Amer. Fish. Sol. Vol. 90(4): 490-494.

APPENDIX B

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Timing and Access of Adult Salmon into Sloughs of the Susitna River Between Talkeetna and Devil Canyon

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I. INTRODUCTION

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This appendix discusses the effect of mainstem discharge on adult salmon timing and access into slough habitats of the Susitna River located between Talkeetna and Devil Canyon. It presents a summary of timing of passage through the mainstem and into the slough and tributaries and; an assessment of access conditions at sloughs 8A, 9, 11 and 21. A compilation of relevant field observations which describe access conditions at other sloughs is also included. The access portion addressed in this paper is an extension of the analysis of ADF&G data presented earlier for Slough 9 (Trihey 1982).

Five species of Pacific salmon (chinook, Oncorhynchus tshwayscha; coho O. kisutch; sockeye, O. nerka; chum, D. keta; and pink O. gorbushka) are known to utilize the various habitats associated with the Susitna River within the Cook Inlet (RM 0) to Devil Canyon (RM 157) reach. Hydraulic barriers within Devil Canyon prevents access of salmon to habitats above this reach (ADF&G 1981, 1983). The use of each habitat type varies for both life phase and species. Studies of salmon in the various habitats located in the Talkeetna to Oevil Canyon reach of the Susitna river indicate that mainstem and side channel habitats are used to a limited extent by chum salmon. The most intensively used spawning ares within the Talkeetna to Devil Canyon reach are located in tributaries and side sloughs. Tributaries are used most heavily for spawning by chinook, coho, chum and pink salmon, whereas side sloughs are used primarily by chum and sockeye salmon.

Timing of the four principle life stages must be evaluated for each salmon species: spawning, incubation, rearing and passage (Figure B-1). This presentation focuses on the timing of adult salmon passage to the slough habitats and the accessibility of these slough spawning habitats to adult salmon. At present, the data base necessary for a comprehensive assessment of the other habitat types and life phase is incomplete.

The reduced annual variation in flow resulting from construction, filling and operation of the proposed Susitna Hydroelectric facilities will affect anadromous fish populations. Present data indicate that the greatest changes in existing physical and chemical characteristics of anadromous fish habitat are expected to occur between Talkeetna and Devil Canyon. Therefore, the Susitna Hydro Aquatic Studies Program has focused its data collection program in this reach. These data document dynamics of fish populations at relatively undisturbed habitat conditions and will allow projection of responses of future runs to alternative project operational scenarios. They will also provide information for possible mitigation options.

Importance of timing

Adult salmon returning to spawn in Alaskan rivers and streams must arrive at the proper time and in good health if spawning is to be successful. Thus, migrating salmon must be able to reach their spawning area and complete spawning before adverse climatological, or physiological factors intervene, and at a time compatible with the hydraulic conditions allowing access. If factors such as unfavorable discharges,

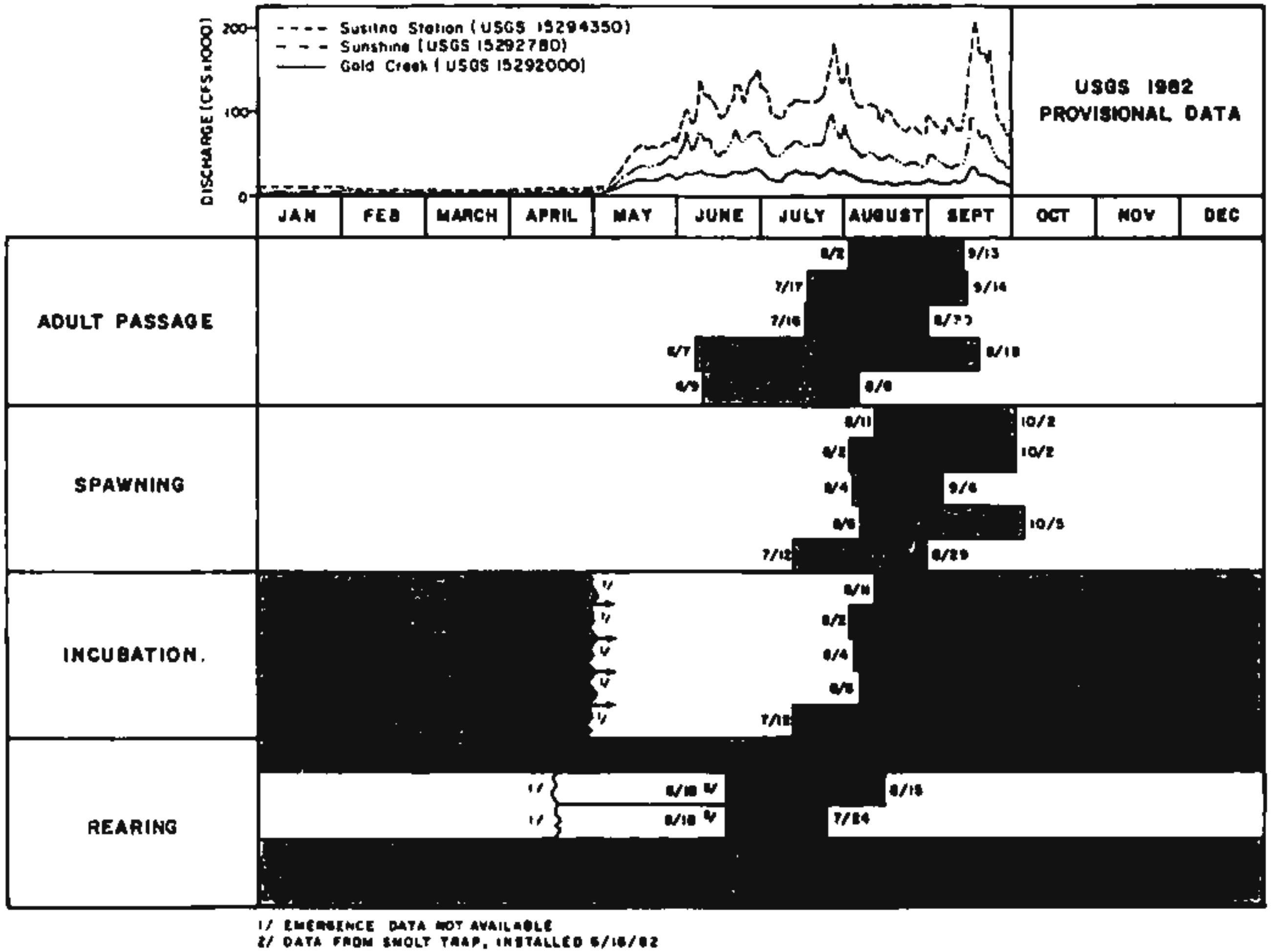

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Figure B-1. Timing of salmon migration, spawning, incubation and rearing in the Susitna River system above Talkeetna, and Susitna River discharge at Gold Creek, RM 136.6, #15292000 (USGS 1982b).

water temperatures, turbidity levels or water quality delay fish from completing their arrival to their natal spawning grounds it may reduce their chances for spawning to be successfully completed (Reiser and Bjornn 1979).

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Importance of Access

The proposed Susitna hydroelectric project will alter the existing streamflow, sediment, and thermal regimes of the Susitna River. The project would reduce streamflows during summer and increase them during winter (Acres 1982). Suspended sediment, turbidity, and water temperatures are expected to follow similar patterns. Natural flows for the Susitna River at the Gold Creek stream gage commonly range between 20,000 and 30,000 cfs during June, July, and August (R&M 1982). Average monthly postproject streamflows at Gold Creek are forecast to be in the range of 7,000 to 11,000 cfs during June, July, and early August with a proposed controlled flow of no less than 12,000 cfs from mid-August to mid-September (Acres 1982).

In general, when adult salmon migrate upstream they encounter progressively lower flows as they pass into smaller drainage basins. This too, is the case, under natural conditions within the Susitna River. However, reduction in flow and associated stage in the Susitna River system at the point where migrating salmon pass from the mainstem river and begin to ascend tributaries and side sloughs is pronounced. Therefore it is expected that under reduced post project flows, entrance conditions may reduce or prohibit salmon access into these spawning areas. If access were denied into a slough, all available upstream spawning habitat would be unavailable for use by adult salmon, eliminating reproduction in this habitat.

Although high velocities have been identified as blocking the upstream migration of spawning fish in some Alaskan rivers (Trihey 1982), field observations of entrance conditions at several side sloughs in the Talkeetna to Devil Canyon reach indicate that it is unlikely that velocity barriers will exist at these locations. Thus the ease with which adult salmon can enter the side sloughs from the mainstem Susitna is primarily a function of depth.

Depths of 0.3 ft for less than 100 ft in association with adjacent pools for holding (resting) were used by Trihey (1982) for evaluating access by adult chum salmon to slough 9. On the basis of ADF&G field observations the criteria suggested by Trihey appear reasonable, and are used as passage criteria for slough access in this report.

2. METHODS

Timing of upstream fish migration

Numbers of adult salmon were counted daily at fishwheels located at three sites on the Susitna River: Susitna Station (RM 26) from July 1 to September 5, 1982, Sunshine Station (RM 80) from June 4 to October 1, 1982 and Talkeetna camp (RM 103) from June 6 to September 18, 1982. These data were tabulated in Volume Two of the Basic Data Report (ADF&G 1983).

Daily surface water temperatures and daily discharges (USGS 1982a, b) were plotted against daily number of salmon captured in fishwheels. Susitna River discharge data were recorded daily at three USGS gaging stations (Susitna Station, RM 25.7; Sunshine Station, RM 83.9; Gold Creek, RM 136.7) located near fishwheels (Susitna Station, RM 26.0; Sunshine Station, RM 80.0; Talkeetna Station, RM 103). Discharge data for 1982 is provisional.

Surface water temperatures were also recorded daily at three locations near the fishwheels: above the confluence of the Yentna River (RM 29.5), at the Parks Highway Bridge (RM 83.9) and at Talkeetna Camp (RM 103). These data were tabulated Volume 4, of the 1982 Basic Data Report (ADF&G 1983).

Timing of Movement into sloughs and tributaries

To determine times of arrival of different salmon species into sloughs and tributaries, observers surveyed each slough or tributary approximately once each week. In sloughs, numbers of each species were censused at each visit, whereas in tributaries, numbers of each species were counted only in a portion (index area) of each tributary. In 1981, foot surveys to count chum, sockeye, pink and coho salmon began in late July and ended in early October. Surveys for chinook salmon were initiated in late July and terminated in mid August. Surveys for chinook salmon were performed by helicopter, fixed-wing aircraft, and in one instance, by foot. In 1982, surveys for all species were performed on foot, and began in mid July and ended in late October. A detailed discussion of methods is included in the 1981 and 1982 Basic Data Reports (ADF&G 1981, 1982). The 1982 data were compared with provisional discharge data from the Gold Creek gaging station (USGS 1982b).

<u>Access into sloughs</u>

Access conditions at the mouth of a slough are primarily determined by observations of fish, discharge in the mainstem, discharge of the slough and slough channel geometry.

Two approaches were used to evaluate access conditions for adult salmon into sloughs and are discussed below. Selection of the approach was dependent upon the level of detailed information available.

The first approach was applied to sloughs 8A, 9, 11 and 21. These were studied more intensively than other sloughs. In the fall of 1982, streambed profiles (thalweg) and water surface profiles were surveyed from the head of, to the mouth of, these sloughs. A section of this thalweg, both upstream and downstream of the slough mouth, was used as a basis for the analysis. In each case the critical passage reach (segment of slough where depth controls access) is located upstream from the slough mouth and the backwater control (streambed or water surface elevation in the river which controls depth in the passage reach) is located downstream from the slough mouth. Corresponding water surface elevations (WSEL) were determined from ADF&G and R&M staff gages near the mouth of the sloughs. Water surface elevations were matched with the average daily mainstem flow at the USGS Gold Creek gaging station for the date of the readings. This provided a tabulation of WSEL versus mainstem discharge for each of the sloughs being investigated. This information was plotted for each of the four sloughs, and a piecewise linear fit made through the data points. These graphs provide the basis for interpolating WSELS for unobserved mainstem flows. The WSELS derived from these graphs were compared to the streambed profiles near the mouths of the sloughs to determine what mainstem flows were necessary for access.

The second approach was applied to a study of sloughs 22, 20, 16B and Whiskers Creek Slough. Streambed and water surface profiles were not available for these sloughs. Cross sections which had been located at the mouth, mid-slough, and head of these sloughs were utilized instead. As with the sloughs for which streambed profiles were available, gage height observations from R&M and ADF&G staff gages at these cross sections were matched with corresponding mainstem discharges for the date of the observations. Field observations from ADF&G personnel were incorporated to present a more accurate evaluation of slough access at various discharges.

3. RESULTS

Timing of upstream migration

The upstream migration of salmon in the mainstem Susitna River in 1982 was characterized by temporal spacing between different species with periods of overlap (Figures B-2 to B-4). The dates when peak and median

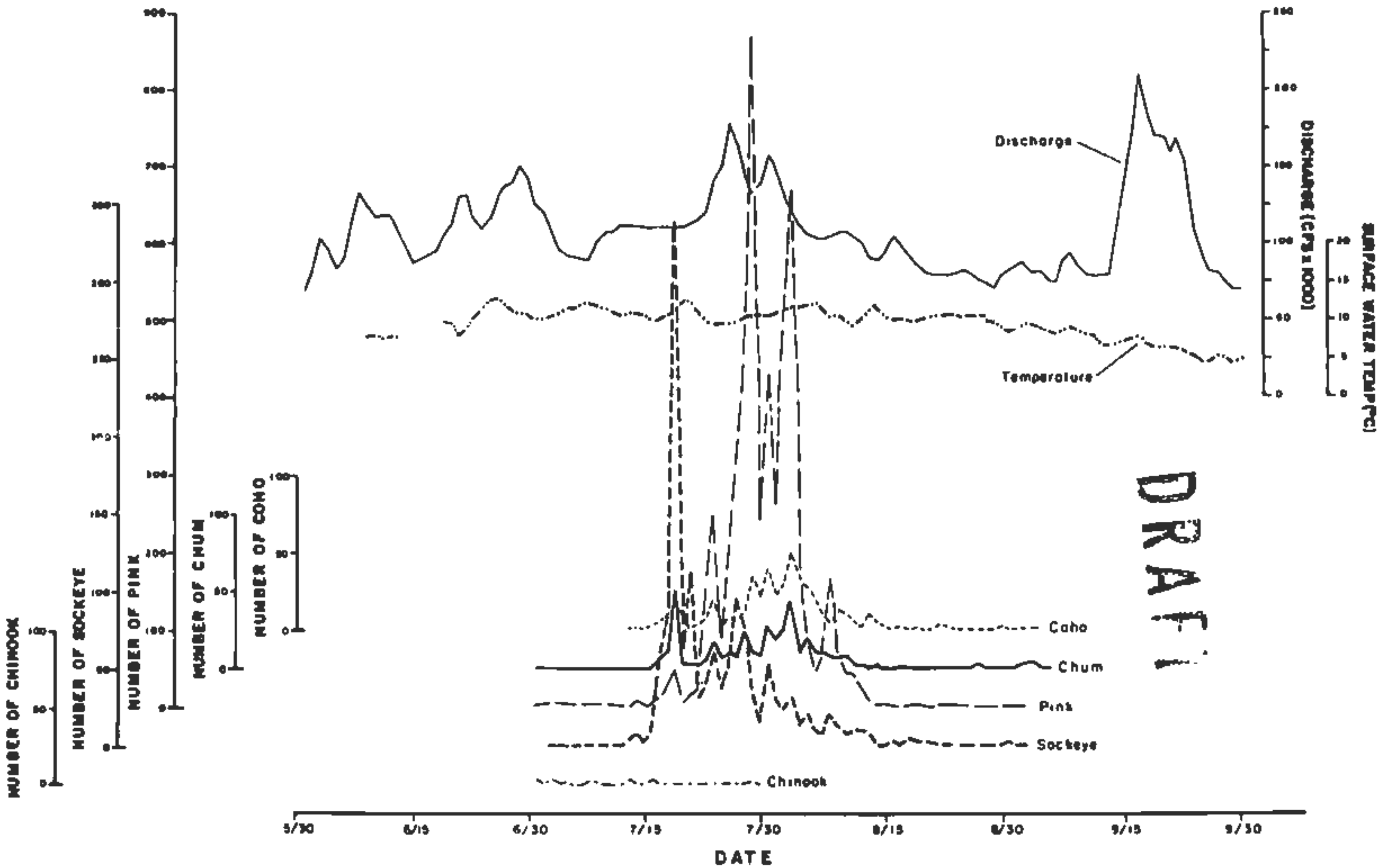

Figure B-2. Susitna River fishwheel catches for the five species of Pacific salmon at Susitna Station, RM 28 (ADF&G 1983), Susitna River discharge at Susitna Station, #15294350 (USGS 1982b provisional data) and Susitna River surface water temperature above the confluence of the Yentna River, RM 29.5 (ADF&G 1983).

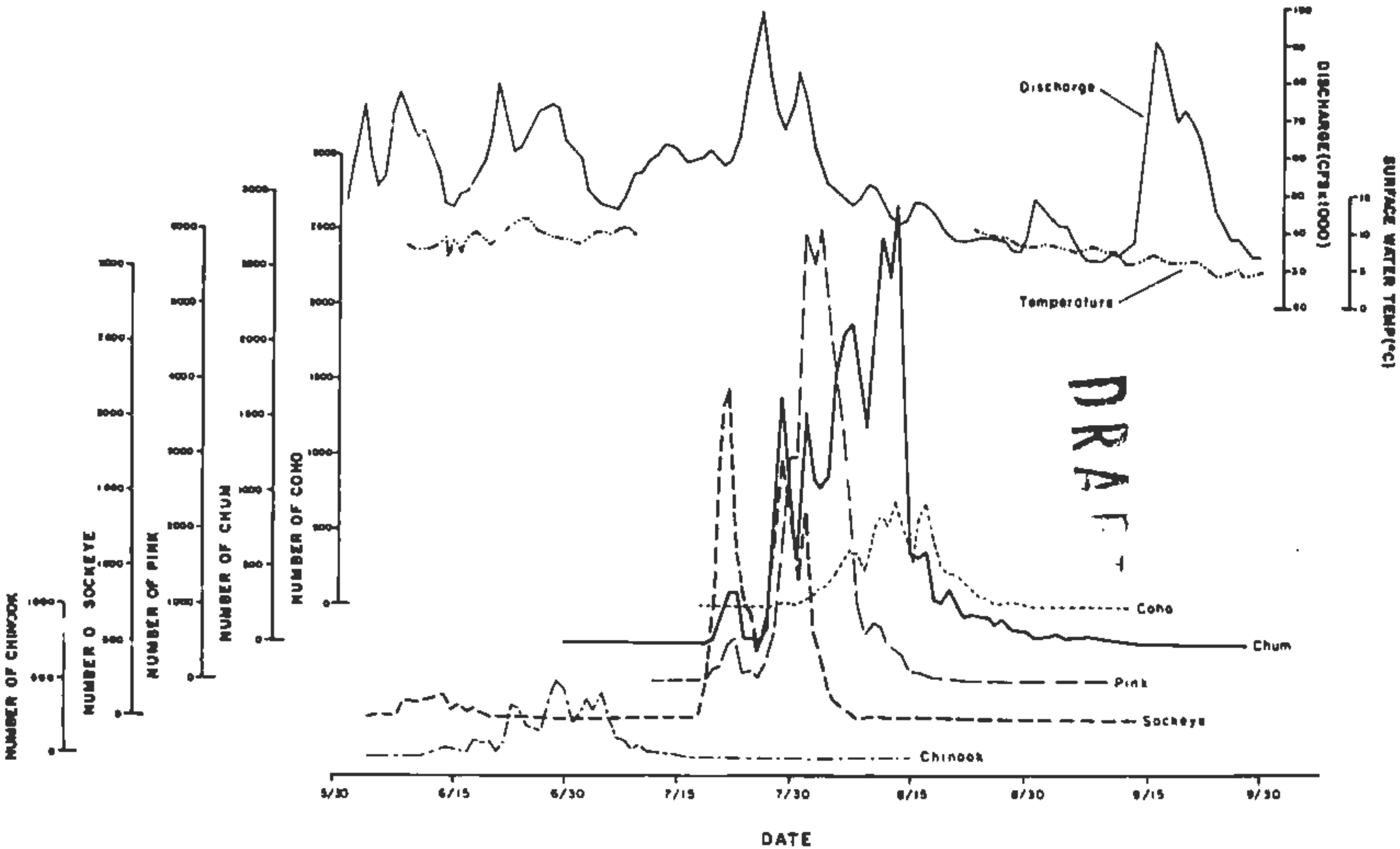

Figure B-3. Susitna River fishwheel catches for the five species of Pacific salmon at Sunshine Station, RM 80 (ADF&G 1983), Susitna River discharge at Sunshine Station, #5292780 (USGS 1982b provisional data) and Susitna River surface water temperature at the Parks Highway Bridge, RM 83.9 (ADF&G 1983).

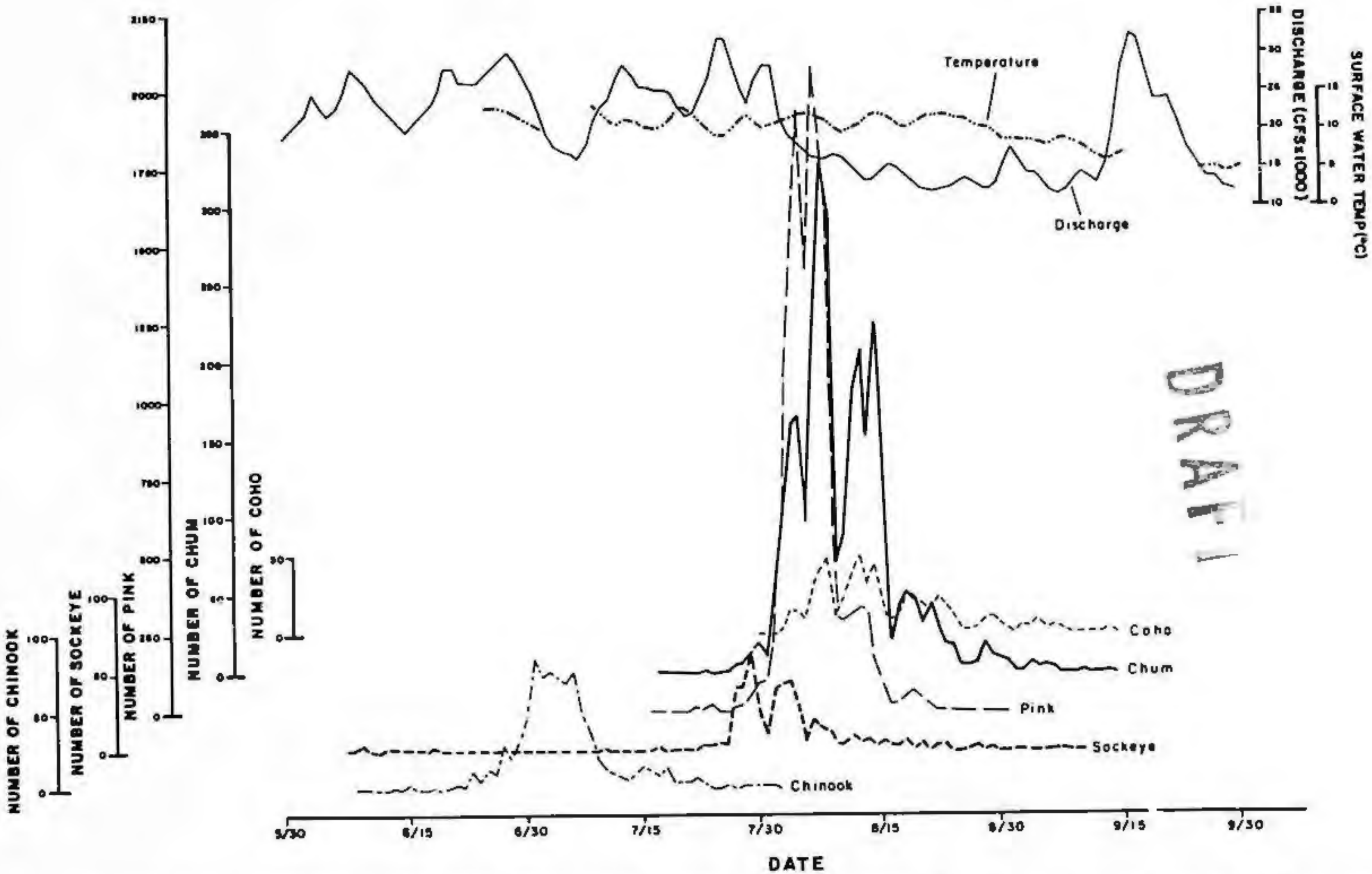

Figure B-4. Susitna River fishwheel catches for the five species of Pacific salmon at Talkeetna Station, RM 103 (ADF&G 1983), Susitna River discharge at Gold Creek, RM 136.6 #15292000 (USGS 1982b provisional data) and Susitna River surface water temperatures at Talkeetna fishwheel, RM 103.0 (ADF&G 1983).

numbers of each species migrated generally were distinct. Chinook salmon were the first species of salmon to immigrate into the Susitna system. Peak and median numbers of chinook salmon were followed by peak or median numbers of sockeye, pink, chum and coho salmon, in that order.

As fish moved upstream past the fishwheels at Susitna, Sunshine and Talkeetna Station, the number of migrating adults of each species peaked at successively later dates, with two exceptions. Numbers of coho and chum salmon recorded at the Susitna Station fishwheels (Figure B-2) peaked later than numbers recorded at the Talkeetna fishwheels (Figure 4). This discrepancy in timing suggests that many of the coho and chum salmon at Susitna Station actually migrated into the Chulitna and/or Talkeetna Rivers.

In 1982 all salmon species migrated up the Susitna River when surface water temperatures ranged between 7 and 12°C (Figures B-2 to B-4). However there was no obvious relationship between timing of fish movements and changes in water temperature.

Upstream movements of salmon in the Susitna River appear to be influenced by discharge. A major movement of sockeye salmon was sharply reduced on July 26 by a peak discharge of 99,300 cfs recorded at Sunshine Station (ADF&G 1983). Peak movements upstream seem to occur for all five species when discharge is not increasing (Figure B-5). It appears that fish tend to move upstream when discharge is falling rather than stable. This pattern is best illustrated by the peaks in Figure

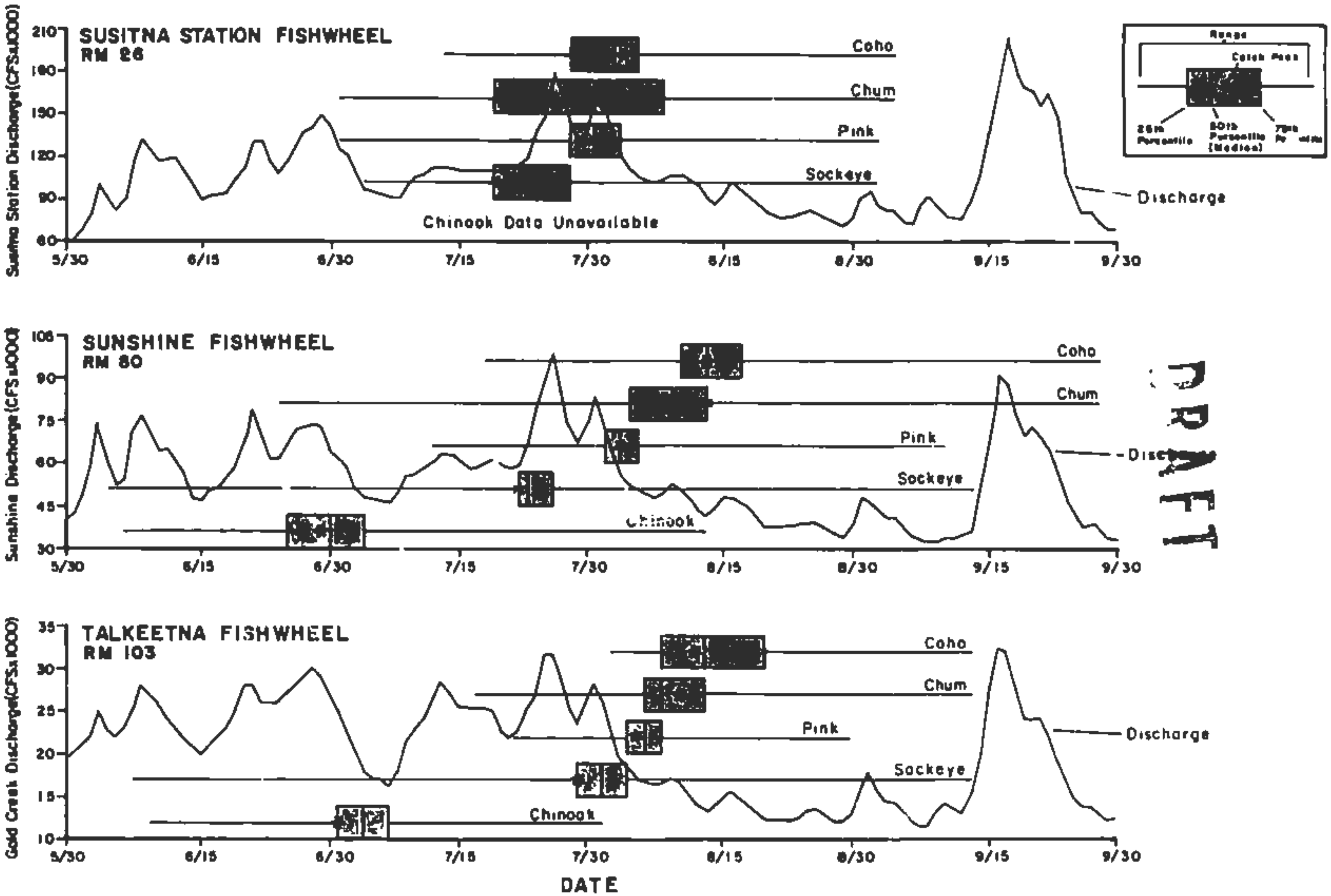

Figure B-5. Periodicity of salmon fishwheel catches and Susitna River discharge, 1982.

B-2 because of the large number of all species of salmon captured at the Sunshine fishwheels.

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Timing of movement into sloughs and tributaries

The order in which salmon species migrated up the mainstem Susitna River in 1981 and 1982 (chinook, sockeye, pink, chum, and coho salmon, respectively) differed from the order (Figures B-6 and B-7) in which they entered sloughs and/or tributaries (chinook, pink, chum, sockeye and coho salmon, respectively). The difference occurred in the relative position of sockeye movements and is probably not of significance in terms of differences in access to spawning habitat.

Although each species of salmon arrived a few days later in 1982. The median date of arrival for a species in sloughs and tributaries was similar in 1981 and 1982 (Figures B-6 and B-7). The largest difference in median arrival time between the two years was less than 10 days. This difference is relatively small in light of the large differences in mainstem discharges between years (Figures B-6 and B-7).

The difference between times when median numbers of each fish species passed Talkeetna fishwheels and times where median numbers of each species were observed in sloughs and/or tributaries differed between species.

In 1982 median numbers of pink salmon were observed in sloughs and tributaries (Figure B-7) less than 10 days after they were observed at

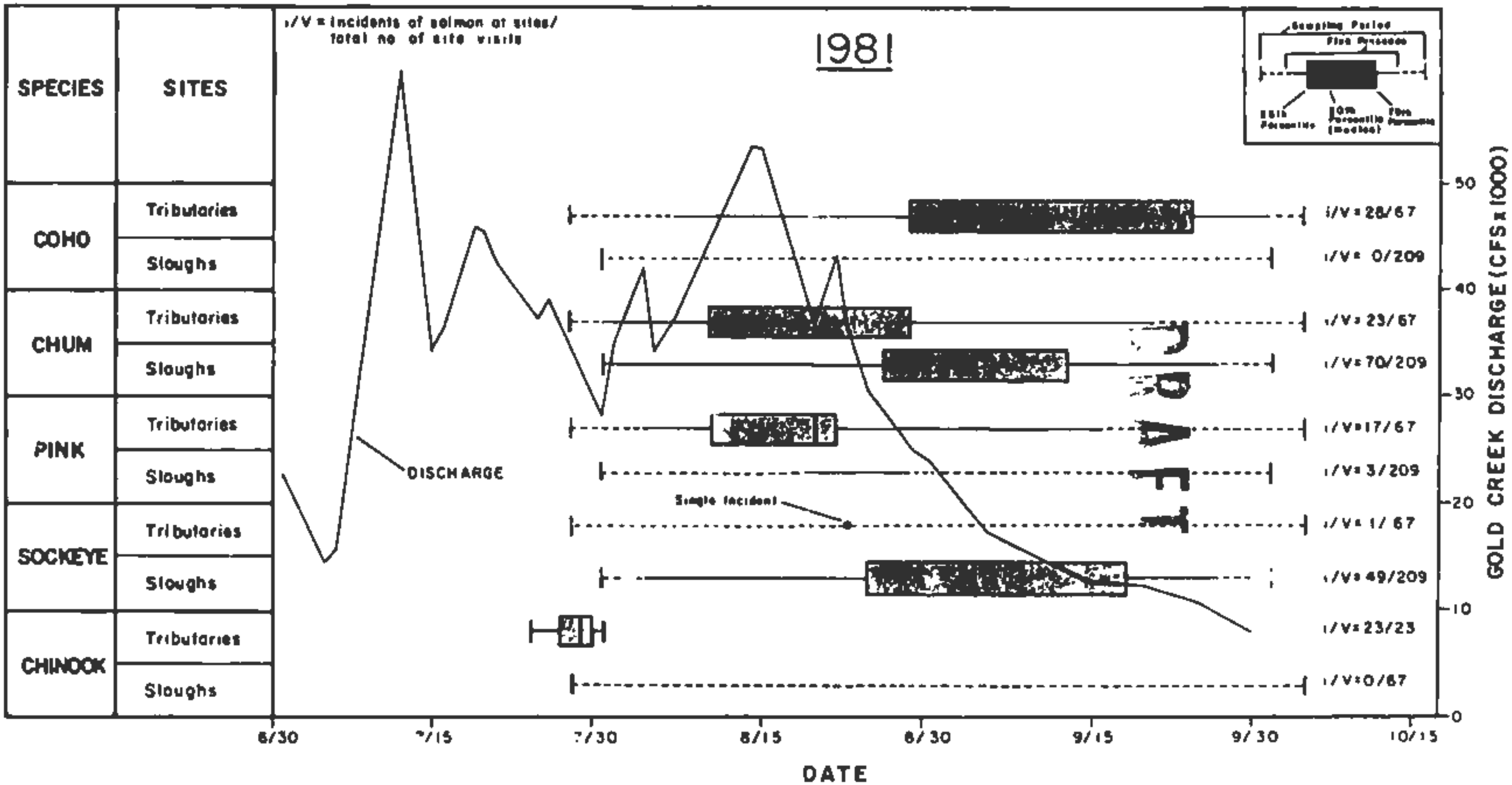

Figure B-6. Periodicity of live salmon in Susitna River tributaries, RM 101.0 through 113.6, and sloughs, RM 99.6 through 145.5 (ADF&G 1981), and Susitna River discharge at Gold Creek #15292000 (USGS 1982a, provisional data) 1981.

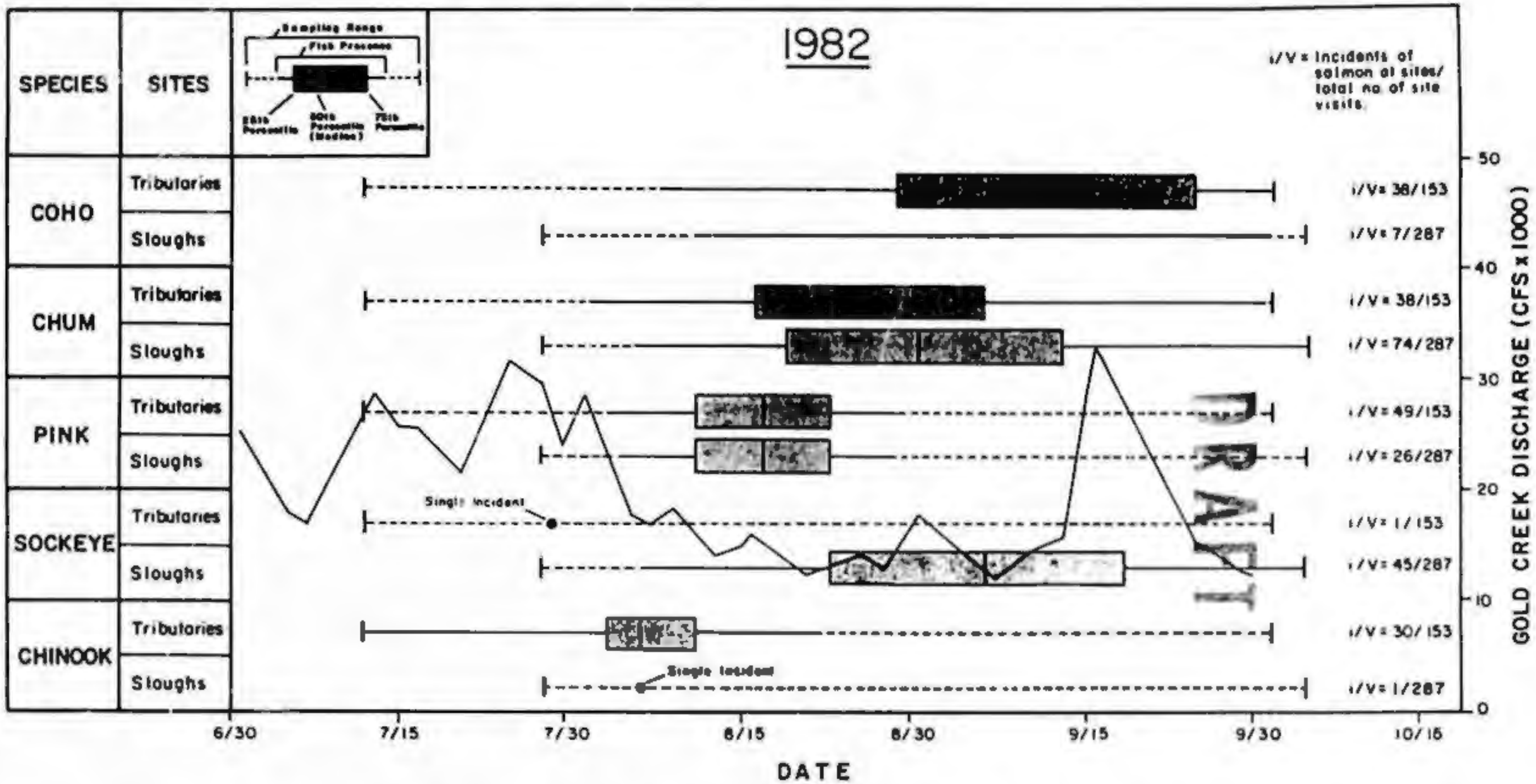

Figure B-7. Periodicity of live salmon in Susitna River tributaries, RM 101.4 through 161.0, and sloughs, RM 99.6 through 144.3 (ADF&G 1983) and Susitna River discharge at Gold Creek #15292000 (USGS 1982, provisional data) 1982.

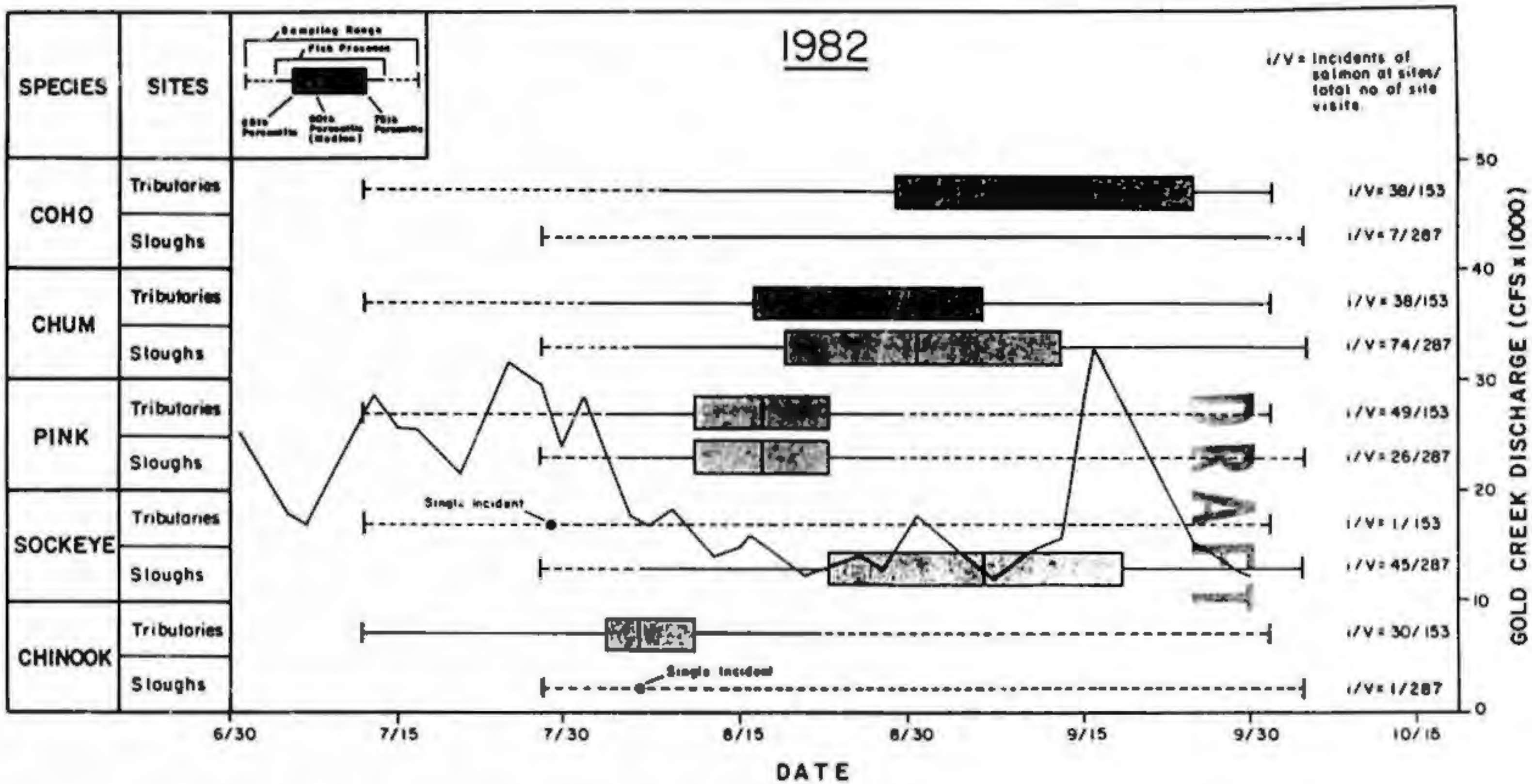

Figure B-7. Periodicity of live salmon in Susitna River tributaries, RM 101.4 through 161.0, and sloughs, RM 99.6 through 144.3 (ADF&G 1983) and Susitna River discharge at Gold Creek #15292000 (USGS 1982, provisional data) 1982.

Talkeetna fishwheels (Figure B-4). However, this time difference was approximately two weeks for chum salmon and a month or more for chinook, sockeye and coho salmon. Reasons for these differences may be related to variations in lengths of time that each species mill or hold near the mouth of tributaries or sloughs.

Access

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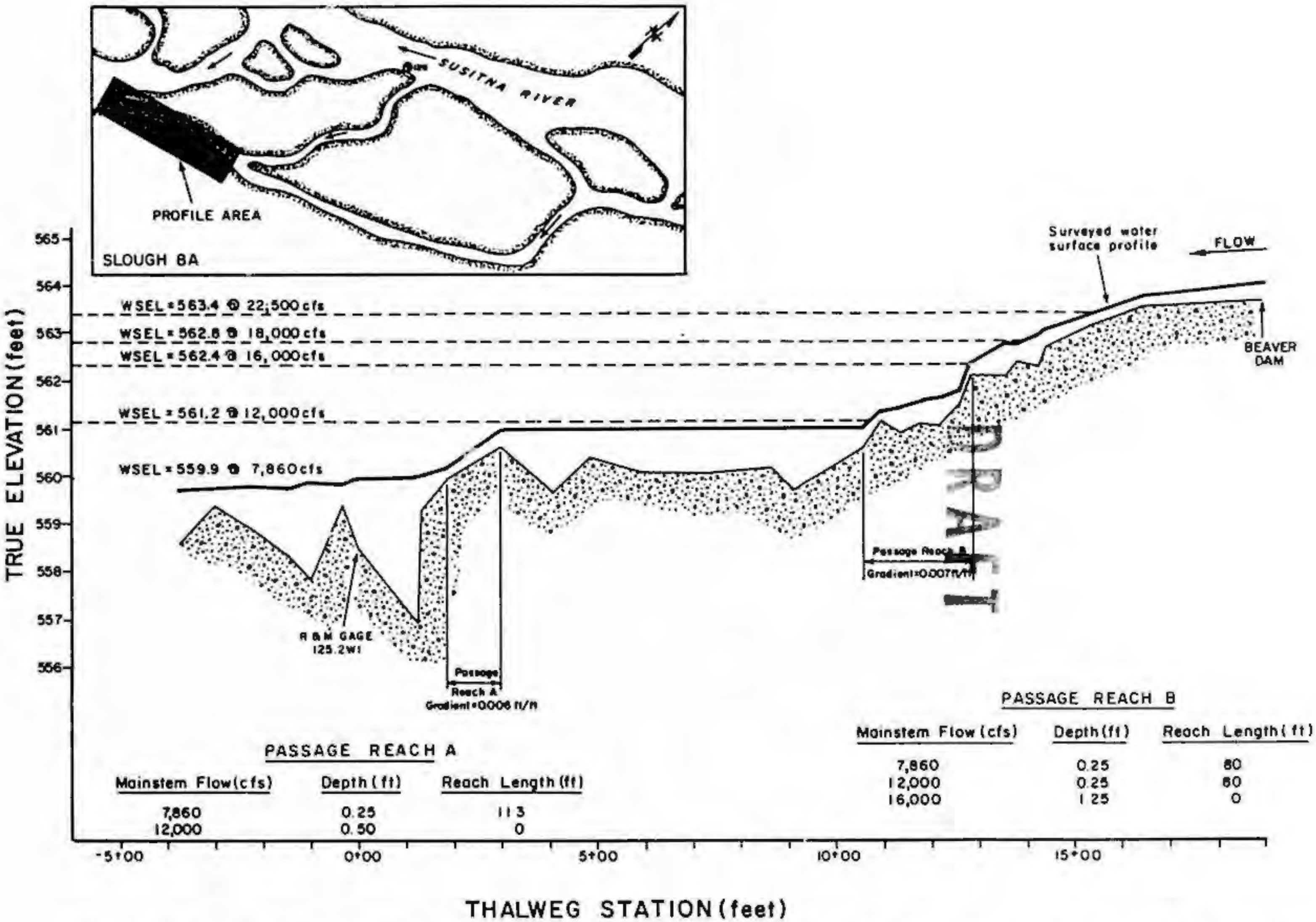
Slough 8A

The streambed and water surface profiles that define entrance conditions for Slough 8A on October 14, 1982 are presented in Figure B-8. The mainstem discharge at Gold Creek was 7860 cfs and flow in Slough 8A was approximately 7 cfs. Depth of flow was repeatedly measured from 0.2 to 0.4 ft in the deepest portions (thalweg) of the riffle areas. A large backwater pool which is generally present during summer months at the entrance to Slough 8A was notably reduced in size.

Gage height readings at the mouth of Slough 8A (gage #125.2W1) and water surface elevations for two independent cross section surveys at the mouth of Slough 8A (ADF&G 1982, R&M 1982) were used to define the relationship between mainstem discharge and the water surface elevation at the mouth of Slough 8A (Figure B-8). This relationship and the surveyed streambed profile for Slough 8A were the principal physical data used to evaluate access conditions. Water surface profiles were determined for a slough flow of approximately 7 cfs and various levels of mainstem discharge (Figure B-8). Entrance or passage conditions were



PASSAGE REACH A

Mainstem Flow (cfs)	Depth (ft)	Reach Length (ft)
7,860	0.25	113
12,000	0.50	0

PASSAGE REACH B

Mainstem Flow (cfs)	Depth (ft)	Reach Length (ft)
7,860	0.25	80
12,000	0.25	80
16,000	1.25	0

Figure B-8. Thalweg profile and water surface elevations in the lower reach of Slough 8A at various mainstem discharges. Passage reaches are those segments of the channel where water depth restricts access of adult salmon into the slough.

derived from field observations and interpretations of the data presented in Figure B-8.

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Passage problems are not anticipated for returning adult salmon in Slough 8A when mainstem discharge at Gold Creek equals or exceeds 12,000 cfs. When mainstem flows are less than 12,000 cfs access by adult salmon into Slough 8A is probably dependent upon base slough flow. Insufficient data are available at this time to indicate whether or not midsummer base slough flows are sufficient to provide access into Slough 8A when mainstem discharges are less than 12,000 cfs (Table B-1).

Table B-1. Flow measurements obtained in Slough 8A during unbreached conditions.

Date	Slough 8A Discharge (cfs)	Mainstem Discharge (cfs) Gold Creek
06/25/82	6.36	17,100
07/21/81	551.00	40,800
09/30/81	2.76	N/A
08/22/82*	3.84	13,600
09/07/82*	6.21	11,700
09/19/82*	22.28	24,100

* 1982 slough discharges are averages of several transect measurements.

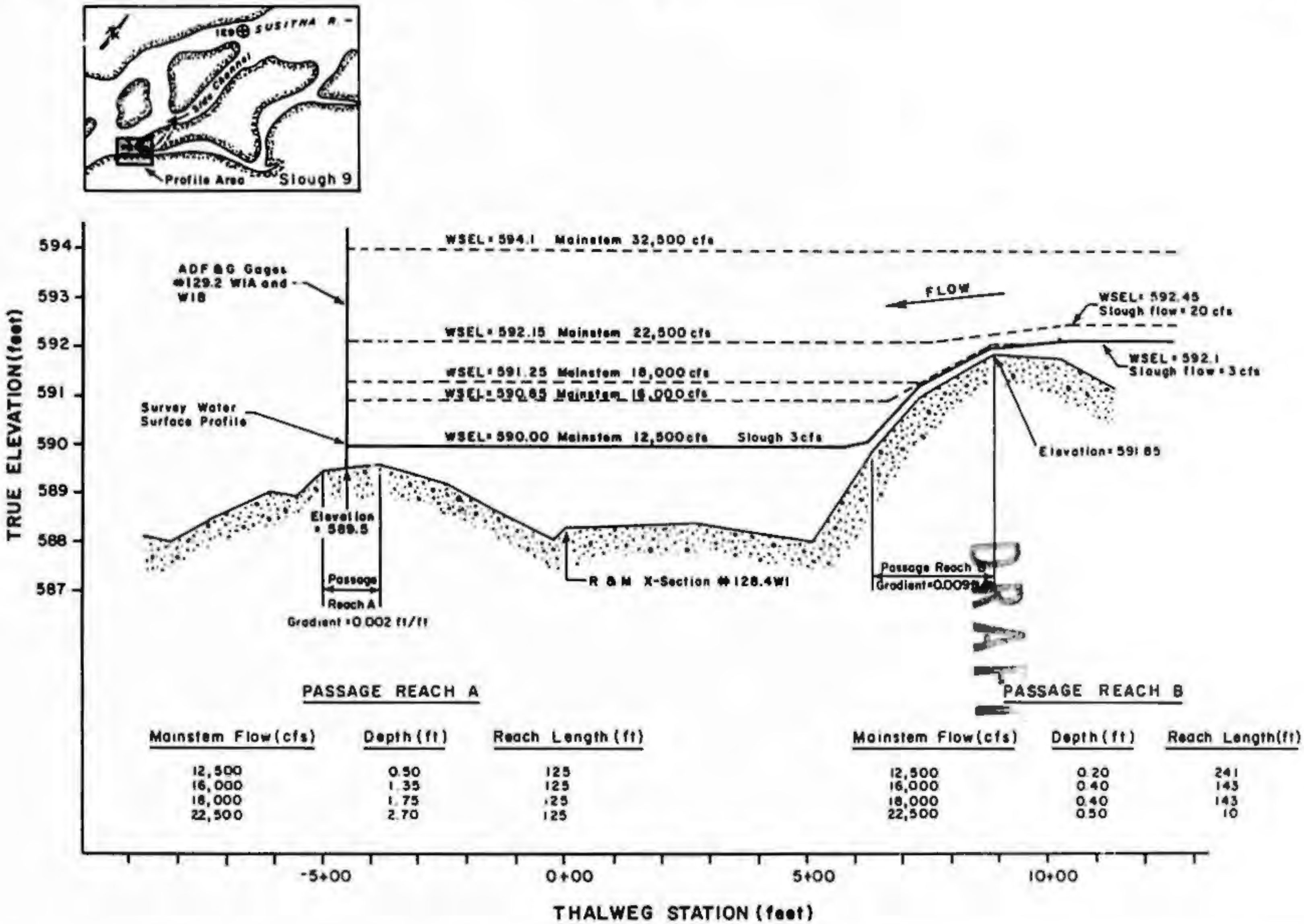
However, it is thought that precipitation events and the resulting local runoff will increase slough flow to about 30 to 40 cfs and mainstem flow by 2,000 to 3,000 cfs (Trihey 1983). Under these natural summer flow conditions passage into Slough 8A would probably not be restricted.

Slough 9

Streambed and water surface profiles surveyed on August 24, 1982 are illustrated in Figure B-9. The mainstem discharge at Gold Creek was 12,500 cfs and flow in Slough 9 was 3 cfs. The representative depth associated with this flow condition was 0.4 ft for passage reach A and 0.2 ft for passage reach B on the date of survey. A small pool existed upstream from passage reach A which provided depths of nearly 2.0 feet at the slough mouth. This pool appeared to result from changes in streambed elevation rather than from mainstem backwater effects.

Staff gages (gage #129.2W1A and gage #129.2W1B) were installed in passage reach A and numerous gage height readings were recorded throughout the open water field season. The staff gage was installed in the deepest water available within the reach to ensure that it would not dewater before the passage reach. These data were used to define the relationship between mainstem discharge and the water surface elevation at the mouth of Slough 9 (Figure B-9).

This relationship and the surveyed streambed profile provided the basic information to evaluate the physical aspects of access to Slough 9 by spawning salmon. Water surface profiles were extended up into the slough for various levels of mainstem flow and a slough flow of 3 cfs (Figure B-9). Access into Slough 9 by adult salmon was determined on the basis of the depth of flow, the length of passage reach B, and observations of fish passage.



PASSAGE REACH A

Mainstem Flow (cfs)	Depth (ft)	Reach Length (ft)
12,500	0.50	125
16,000	1.35	125
18,000	1.75	125
22,500	2.70	125

PASSAGE REACH B

Mainstem Flow (cfs)	Depth (ft)	Reach Length (ft)
12,500	0.20	241
16,000	0.40	143
18,000	0.40	143
22,500	0.50	10

Figure B-9. Thalweg profile and water surface elevations in the mouth of Slough 9 at various mainstem discharges of the Susitna River at Gold Creek. Passage reaches are those segments of the channel where water depth restricts access of adult salmon into the slough.

Upstream passage into Slough 9 by adult salmon does not appear to be restricted when mainstem flows are 18,000 cfs or higher. Upstream access becomes increasingly more difficult for salmon as mainstem discharges decrease and become acute at mainstem streamflows of 12,000 cfs and less.

It is thought that precipitation events and the resulting local runoff will increase slough flow to about 10 to 15 cfs and mainstem flow by 2,000 to 3,000 cfs (Trihey 1983). Under these natural summer flow conditions passage into Slough 9 would probably not be restricted.

Slough 11

Streambed and water surface profiles at Slo... were surveyed October 17, 1982 (Figure B-10). The mainstem disc... Gold Creek was 6,660 cfs while flow in Slough 11 was approximat... cfs. A depth of 0.5 feet was measured at several locations along the thalweg upstream of the backwater area under these flow conditions. The backwater zone at the downstream entrance to Slough 11 was about ten feet wide at the mouth (Station 0+00) and extended approximately 175 ft into the slough. Mid-summer observations indicate this backwater zone is generally 50 to 50 feet wide at the mouth and extends more than 500 ft into the slough (ADF&G 1983, Volume 3).

A staff gage was installed at the mouth of Slough 11 (gage #135.3W1) and in the side channel approximately 250 ft downstream from the mouth of the slough (gage #135.3M4A). Repetitive reading of these gages

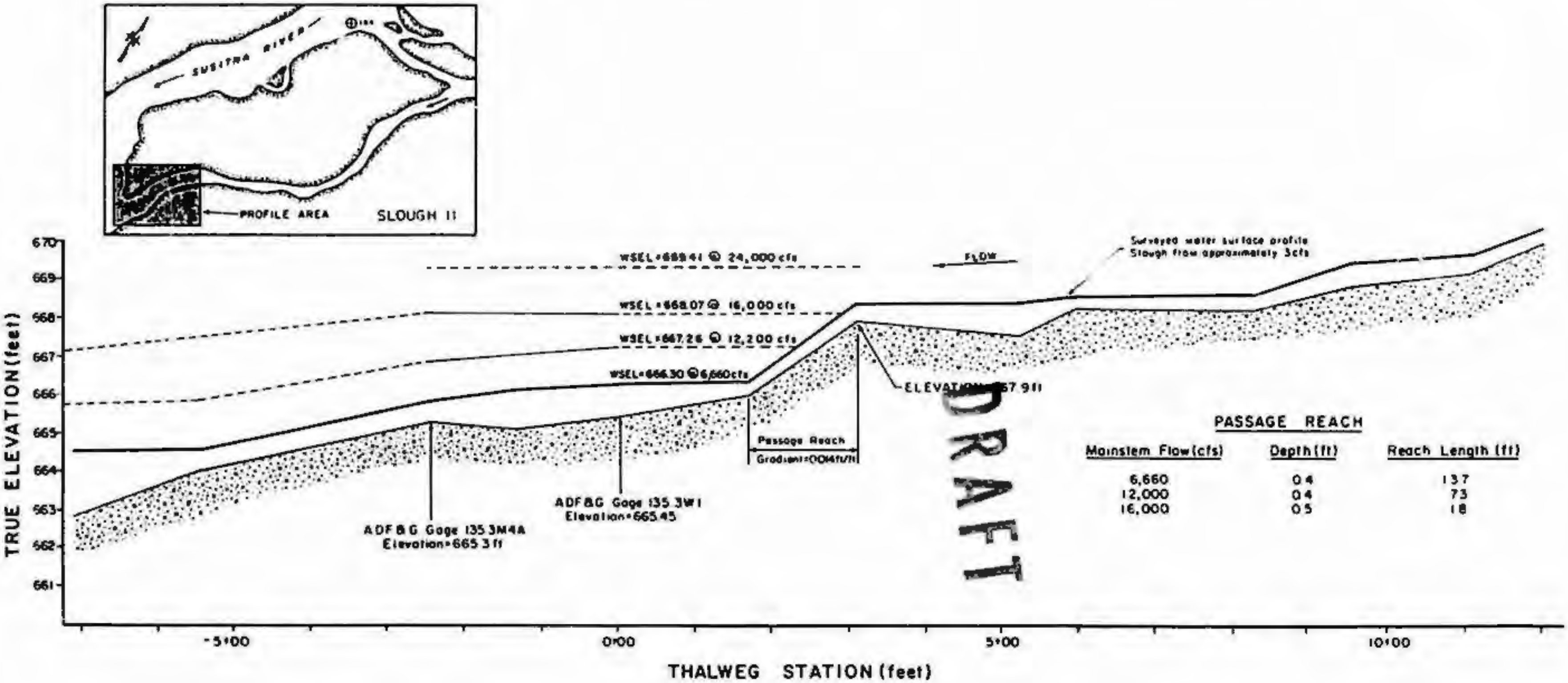


Figure B-10. Thalweg profile and water surface elevations in the lower reach of Slough 11 at various mainstem discharges. Passage reaches are those segments of the channel where water depths restricts access of adult salmon into the slough.

throughout the 1982 open water field season provided the data used to define the relationships between mainstem discharge and the water surface elevation at the entrance to Slough 11 (Figure B-10). These relationships combined with observations of salmon, and the surveyed streambed profile are the criteria used to evaluate access conditions for adult salmon.

When mainstem flow is 7,000 cfs or greater adequate depths for passage exist throughout the lower reach of Slough 11. In part this is attributable to the slough flow in the lower reach of Slough 11 being confined to a very narrow channel. Thus the naturally occurring flow from Slough 11 appears adequate to provide for fish passage provided the existing channel geometry of the slough is maintained.

Slough 21

The streambed and water surface profile for Slough 21 (Figure B-11) was surveyed October 14, 1982. The mainstem discharge on the date of the survey was 16,000 cfs with the flow in Slough 21 being less than 5 cfs. Depth of flow was less than 0.2 ft throughout much of a 200 ft reach between stations 5+50 and 7+50. These shallow depths were also observed throughout much of the 1982 spawning period (mid-August to mid-September) when mainstem flows were less than 22,500 cfs. A fairly large pool occurred at the mouth of Slough 21 due to the nature of the channel geometry in which most of the observed spawning occurred.

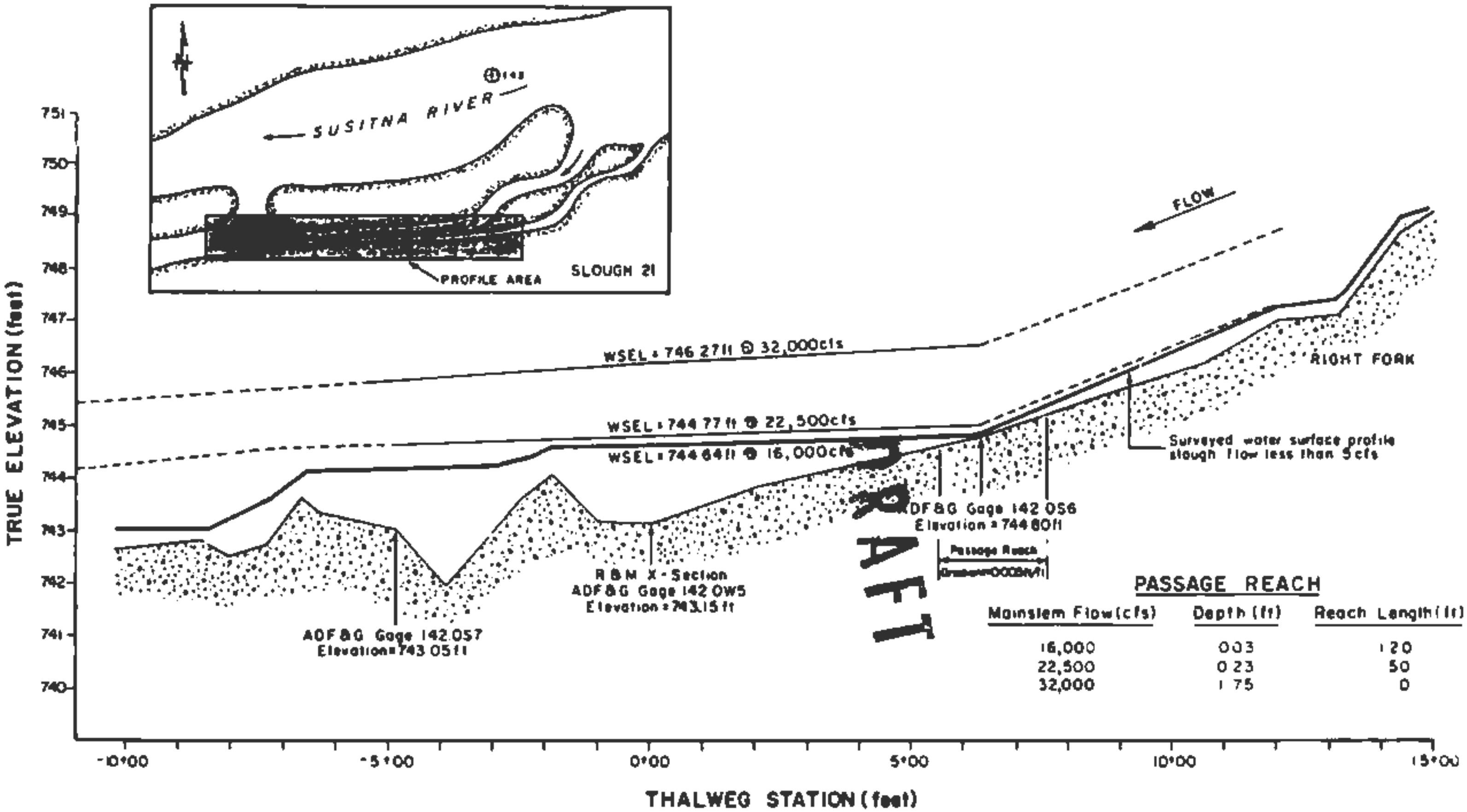


Figure B-11. Thalweg profile and water surface elevations in the lower reach of Slough 21 at various mainstem discharges. Passage reaches are those segments of the channel where water depth restricts access of adult salmon into the slough.

Staff gage (gage #142.0W5) was installed at the mouth of Slough 21 with two additional gages (gages #142.0S7 and #142.0S6) installed approximately 500 feet upstream and downstream of the slough mouth, respectively. Periodic observations of water surface elevations at these three staff gages provided the data base used to define the relationship between mainstem discharge and water surface elevations near the mouth of Slough 21 (Figure B-11).

Observations of salmon, this relationship and the surveyed streambed profile were used as the principal indicators of access conditions at the mouth of Slough 21. Water surface profiles were developed using the three staff gages for selected mainstem discharges between 16,000 and 32,000 cfs. Access into this slough by salmon is apparently limited or restricted until mainstem flows exceed 22,500 cfs and breach the upstream end of Slough 21. This breaching flow has been defined at 23,000 cfs (ADF&G 1983).

Other Sloughs

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Access to Whiskers Creek Slough and sloughs 6A, 16B, 20 and 22 was evaluated using cross sections and staff gage data. Streambed and water surface profiles were not surveyed at these locations. Based on field observations during the low flow period it was noted that the cross sections, which were established during a period of high flow, did not necessarily represent the most critical access conditions. Therefore the results from the direct comparison between mainstem discharge and depth at the mouths of these sloughs were adjusted by incorporating the professional judgement of field biologists familiar with these sites.

The results of the effects of mainstem discharge on access to the nine sloughs evaluated are summarized in Table B-2. The most significant finding of this assessment is the trend toward lower mainstem flow requirements for access by salmon into sloughs in a downstream direction from Devil Canyon toward Talkeetna. This analysis was substantiateo during helicopter flights. It appeared that access problems did not exist downstream of River Mile 140 (Slough 20) for mainstem flows of 20,000 cfs whereas, access conditions were questionable or absent upstream of RM 140 at this flow (sloughs 20, 21, 22 and 21A) (Trihey 1983).

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4. DISCUSSION

Fish passage in the Susitna River can be partitioned into three phases, each defined by district hydraulic conditions. In the first phase, adult salmon return to the Susitna River where passage conditions are primarily determined by the hydraulic conditions present in the mainstem river. The salmon progress upstream to their natal spawning areas in sloughs and tributaries, eventually reaching the mouth regions of these habitats. In their second phase they enter a hydraulic zone at the mouths of sloughs and tributaries defined by either slough and mainstem conditions tributary and mainstem. In this phase of their migration they often mill for various periods of time before entering into their natal habitat within the slough or tributary. In the third phase of

Table B-2. Access conditions at mouths of selected sloughs of the Talkeetna to Devil Canyon reach of the Susitna River at various mainstem Susitna discharges (USGS Gold Creek gage #15292000).

	Percent of Susitna River escapement past Talkeetna utilizing each slough				Access Condition		
Slough	Sockeye	Pink	Chum	Coho	Acute	Difficult	No Problem
22[b,c]					16,000	20,000	22,500
21[a]	9	13	33		20,000	22,000	25,000
20[b,c]		13			8,480	12,500	21,500
16B[b,c]					20,200	24,000	26,400
15		26			--	--	--
11[a]	75	26	21		6,660	12,200	16,000
9A			5		--	--	--
9[a]			13		12,000	16,000	18,000
8A[a]	11		15		7,860	10,000	16,000
6A[b,c]		7			--	--	8,440
B		6			--	--	--
Whiskers[b,c] Creek				28	7,950	8,440	23,000

[a]Determined from surveyed thalwegs and staff gage readings.

[b]Estimated from cross sections, staff gage readings and field observations.

[c]No problem was considered when the entire slough could be utilized.

their migration fish ascend above the influence of the mainstem river water into upper slough or tributary reaches where hydraulic conditions are primarily a function of the slough base flow and channel geometry, or tributary flows.

In this report we have focused on the slough habitat and the second phase of the upstream migration of salmon in the Susitna River; when salmon enter the mouth region of sloughs. The first phase of migration in the mainstem river has been limited to consideration of timing of upstream movements of fish relative to mainstem discharge and temperature. Consideration of a third phase of the salmon migration, when fish ascend above the influence of the mainstem river, has been limited to observations between distributions of spawning fish between 1981 and 1982 when slough base flows were significantly different, and observations of fish distributions before and after a high water event when slough heads were breached.

Mainstem River

In general there is a temporal separation in the timing of migration for different salmon species migrating in the mainstem Susitna River. This pattern is consistent at each of the ADF&G sampling stations in the mainstem (Figure 8-5) with chinook salmon migrating first, followed by sockeye, pink, chum and coho salmon respectively. The order of species migration in the mainstem differed slightly with the order in which fish entered sloughs and tributaries (Figures 8-7 and 8-8). Reasons for this difference in order are presently unknown.

Passage of adult salmon did not appear to be influenced by temperatures from 7 to 12°C measured in the Susitna River in 1981 and 1982. They were in the lower range of temperatures reported by Bell (1973) for species in other areas of North America: fall chinook salmon (10.6 - 19.4°C), chum salmon (8.3 - 15.6°C), coho salmon (7.2 - 15.6°C). pink salmon (7.2 - 15.6°C) and sockeye salmon (7.2 - 15.6°C). However it should be noted that abrupt changes from the normal temperature pattern could alter the timing of migration and adversely affect survival (Reiser and Bjornn 1979).

In contrast to temperature, variations of mainstem discharge and corresponding velocities influenced upstream movements of several salmon species, whereas reductions in discharge corresponded with increased numbers of fish being caught at fishwheels (Figures B-2 and B-4). Presumably, avoidance of migration at high discharges (water velocities) results in a reduction of energy cost to fish. Hynes (1970) and others have also discussed the relationship between discharge and fish migration.

Mouth of Sloughs

Although discharges in the mainstem Susitna River were different between 1981 and 1982, the time at which each species arrived at the sloughs each year were similar (Figures B-6 and B-7). The largest difference in median arrival time for any species was less than 10 days. Thus, it appears that fish may arrive at slough mouths at a uniform time every year, but many not be able to access areas within each slough due to variable difficulties in access conditions as evidenced in 1981 and 1982.

Difficulties in access conditions seem to follow a general downstream pattern from Devil Canyon to Talkeetna. In general lower mainstem flows are required to maintain suitable access conditions for salmon into sloughs (Table B-2) in a downstream direction than are required in the vicinity of Devil Canyon and a flow of 20,000 cfs will support the access of salmon into most sloughs.

Discharges of the mainstem Susitna River also influence the ability of salmon to access habitats within the slough after having entered the slough. Observations during 1982 suggest that if the timing of a peak mainstem flow (resulting in temporary breaching of sloughs 8A, 9, and 21) more closely coincided with peak numbers of live spawners, access to upper reaches of sloughs would have undoubtedly been facilitated. As it were many fish were restricted to lower quality spawning habitat in the lower reaches of the sloughs. Such an event, if properly timed would probably reduce many access problems near the mouth (e.g., Slough 9).

LITERATURE CITED

Acres American, Inc. 1982. Susitna Hydroelectric Project: FERC license application. Exhibit E. Volume 1, Chapter 2 (Draft Report). Prepared for Alaska Power Authority, Alaska Department of Commerce and Economic Development, Anchorage, Alaska.

Alaska Department of Fish and Game (ADF&G). 1980. Annual management report: Kuskokwim area. Commercial Fisheries Div. Juneau, AK.

______. 1981. Adult Anadromous Fisheries Project. Phase I. Final Draft. Subtask 7.10. Prepared for Acres American, Incorporated, by the Susitna Hydro Aquatic Studies. Anchorage, AK.

______. 1982. Phase I Final Draft Report. Subtask 7.10. Prepared for Acres American, Incorporated, by the Susitna Hydro Aquatic Studies. Anchorage, AK.

______. 1983. Susitna Hydro Aquatic Studies. Phase II Basic Data Report. Prepared for Acres American Inc. by Alaska Department of Fish and Game, Su Hydro Studies team. Anchorage, Alaska.

Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria: useful factors in life history of most common species. Unpubl. report. Submitted to Fish. Eng. Res. Program, U.S. Corps of Engineers, North Pacific Div. Portland, OR.

Hynes, H.B.N. 1970. Ecology of Running Waters. Univ. of Toronto Press, Toronto, Canada.

Mattson, C.R. and R.A. Hobart. 1962. Chum salmon studies in southeastern Alaska, 1961. U.S. Fish and Wildl. Service, Bureau of Commercial Fisheries Manuscript Report 62-5. Auke Bay, AK. 32 pp.

R&M. 1982. Provisional data from R&M Consultants, Inc.

Reiser, D.W. and T.C. 8jornn. 1979. Influences of forest and rangeland management on anadromous fish habitat in western North America: habitat requirements of anadromous salmonids. U.S. Forest Service Anadromous Fish Habitat Program, Pacific Northwest Forest and Range Experiment Station Gen. Tech. Report PNW-96. U.S. Dept. of Agriculture. Portland, OR. 54 pp.

Trihey, E.W. 1982. Preliminary assessment of access by spawning salmon to side slough habitat above Talkeetna. Draft Report. Prepared for Acres American, Inc., Anchorage, Alaska.

______. 1983 Personal communication.

U.S. Geological Survey (USGS). 1982a. Summary of water resources for Alaska. 1981. AK-81-1. Anchorage, AK.

______. 1982b. Provisional summary of 1982 water resources for Alaska.

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APPENDIX C

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Observations of Salmon Spawning Habitat in Susitna River Sloughs Located Within the Talkeetna to Devil Canyon Reach of the Susitna River.

APPENDIX C

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INTRODUCTION

This appendix addresses general habitat utilization in slough habitats once access is gained through the mouth of the slough. One of the major effects of the proposed hydroelectric project would be the change in flow regime. The slough habitats would be affected by these changes to a much greater extent than the tributaries.

In order to maximize use of finite resources, fish species have adapted to a variety of habitat conditions. In this way a species lessens competition for a scarce resource, such as food or spawning habitat, by selecting a particular range of acceptable conditions.

Adult salmon usually return to their natal waters to spawn (Hasler 1966). Access into these natal areas is the first critical obstacle to overcome and access depends on mainstem discharge, as is discussed in Appendix B. Once the adult salmon have gained access into sloughs and tributaries there are several environmental variables that determine their selection of spawning habitat.

Spawning habitat is a limited resource for all salmon species in the Susitna River between Talkeetna and Devil Canyon. Only a few salmon, primarily chum salmon, spawn in the mainstem or side channels. The primary spawning habitat for all five species of salmon are tributaries and side sloughs.

The habitat variables of substrate composition and areas of upwelling ground water, in a wide range of sloughs were evaluated with respect to their importance to the spawning preferences of the five salmon species.

METHODS

Distribution and abundance of adult salmon in 33 sloughs and 20 tributaries of the Susitna River between the Chulitna River and upper Devil Canyon were determined in 1981 and/or 1982. Survey methods and data are presented, in the Susitna Hydro Aquatic Studies FY82 and FY83 Basic Data Reports (ADF&G 1981a, 1983b). Procedures are further detailed in the 1981 and 1982 Procedures Manuals (ADF&G 1981b, 1983a). Peak numbers of live salmon in a slough were assumed to indicate the relative importance of a slough for spawning salmon.

Fourteen of these sloughs were evaluated during the open-water season for upwelling and seepage areas, substrate composition, and salmon spawning activity. During the ice-covered months, sloughs were observed for open leads in the ice cover. These open leads were used as an indicator of upwelling ground water or other warm water sources. During the open water season upwelling was detected by vents with ascending water currents in the substrate. Although these areas were easily visible in silt and sand substrate types they were difficult to detect visually in slough substrates with little or no sand or silt. Thus, the presence and extent of upwelling was difficult to quantify. Sloughs sampled included: Whiskers Creek Slough, Slough 6A, Lane Creek Slough (Slough 8), and sloughs 8A, 9, 9B, 9A, 10, 11, 16B, 19, 20, 21 and 22.

Observations during the open-water season were recorded and mapped during foot surveys along the sloughs. Observations were recorded on blue line aerial photographs of a scale 1" = 50'. These aerial photographs were taken during a medium-low water level (20,000 cfs at Gold Creek) on May 31, 1982. During the ice-covered season open leads were photographed and mapped from an altitude of 600 feet during two helicopter flights on November 18, 1982, and February 23, 1983. From the air it was difficult to determine differences between open leads and areas covered with clear ice unless a recent snow or wind left a layer of snow on the ice. Maps of open leads are included in Volume 4 of the Susitna Hydro Aquatic Studies FY 83 Basic Data Report (ADF&G 1983b).

During the open water season presence and extent of upwelling/seepage areas were rated on a scale of 0 to 3. A slough with no observed upwelling/seepage was assigned a value of 0. A slough where upwelling/seepage was infrequently observed was assigned a value of 1. A slough with several localized areas of strong upwelling/seepage or numerous areas of weak upwelling/seepage was assigned a value of 2. A slough with numerous areas of strong upwelling/seepage was assigned a value of 3.

Surface areas of substrate types during the open water season and open leads during the ice covered season were computed directly from the scaled blue line maps using a Numonics Digitizer. Surface areas of open leads and substrate types are expressed as percentage of total wetted surface area in the slough.

Access conditions were determined by observations of salmon moving into sloughs from the mainstem or by distribution of salmon within sloughs, or at slough mouths.

RESULTS

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The distribution and abundance of adult salmon differed between each slough, and tributary location. They also varied between years (1981 and 1982) for each location. Chinook salmon spawned exclusively in tributaries whereas sockeye salmon spawned only in sloughs (Tables C-1 to C-4). Chum, pink, and coho salmon spawned in both habitats.

Abundance of live salmon in tributaries is not comparable to abundance in the sloughs because entire tributaries were not surveyed. Relatively few sloughs contained large numbers of spawning salmon (Table C-5). Only sloughs 8A, 9, 9A, 11, 15, and 21 contained more than 100 salmon of a given species (ADF&G 1983b, Vol. 2).

Table C-6 summarizes the habitat variables of the sloughs studied. Field observations of open leads and areas of upwelling/seepage indicated that open leads occur immediately downstream from the point of upwelling/seepage. Correlations between these two characteristics were noted at Lane Creek Slough, and sloughs 9, 9A, 11, 21, and 22.

Several sloughs had many open leads yet little or no observed upwelling or seepage. In most of these instances open lead were due to presence of a nearby tributary or other source of moving water. This occurred at

Appendix Table C-1 Number of observations of salmon in Susitna River sloughs in the Talkeetna to Devil Canyon reach during 1981 (adapted from ADF&G 1981b).

Slough	River Mile	Total # of visits	Number of visits live salmon were observed in sloughs					Sampling Period
			Chinook	Sockeye	Pink	Chum	Coho	
1	99.6	6	-	0	0	1	-	8/21 - 10/2
2	100.2	7	-	0	0	3	-	8/2 - 10/2
3B	101.4	8	-	2	0	0	-	8/5 - 10/2
3A	101.9	8	-	4	1	0	-	8/4 - 10/2
4	105.2	8	-	0	0	0	-	8/4 - 10/2
5	107.2	5	-	0	0	0	-	8/7 - 9/22
6	108.2	5	-	0	0	0	-	8/2 - 9/22
6A	112.3	4	-	2	0	3	-	8/19 - 9/22
7	113.2	3	-	0	0	0	-	8/7 - 8/29
8	113.7	7	-	0	1	3	-	8/7 - 9/28
8D	121.8	4	-	0	0	0	-	8/1 - 8/27
8C	121.9	4	-	0	0	0	-	8/1 - 8/27
8B	122.2	4	-	0	0	1	-	8/1 - 8/27
Moose	123.5	5	-	0	0	5	-	8/27 - 9/27
A'	124.6	4	-	0	0	4	-	8/27 - 9/21
A	124.7	7	-	0	1	4	-	8/7 - 9/24
8A	125.1	7	-	4	0	4	-	8/7 - 9/27
9	128.3	8	-	3	0	4	-	8/7 - 9/27
9B	129.2	7	-	7	0	6	-	8/11 - 9/27
9A	133.3	8	-	3	0	5	-	7/31 - 9/27
10	133.8	5	-	0	0	0	-	7/31 - 9/20
11	135.3	10	-	8	0	7	-	7/31 - 9/26
12	135.4	7	-	8	0	0	-	7/31 - 9/26
13	135.7	8	-	0	0	2	-	7/31 - 9/26
14	135.9	7	-	0	0	0	-	7/31 - 9/26
15	137.2	7	-	0	0	1	-	7/31 - 9/19
16B	137.3	7	-	0	0	0	-	8/6 - 9/26
17	138.9	8	-	4	0	7	-	8/6 - 9/26
18	139.1	5	-	0	0	0	-	8/6 - 9/3
19	139.7	8	-	6	0	1	-	8/6 - 9/26
20	140.0	7	-	1	0	2	-	8/6 - 9/19
21	141.1	8	-	5	0	4	-	8/6 - 9/26
21A	144.3	3	-	0	0	3	-	8/26 - 9/11
TOTAL		209		49	3	70		

Appendix Table C-2 Number of observations of salmon in Susitna River sloughs in the Talkeetna to Devil Canyon reach during 1982 (adapted from ADF&G 1983b, Vol. 2).

Slough	River Mile	Total # of visits	Number of visits live salmon were observed in sloughs: Chinook	Sockeye	Pink	Chum	Coho	Sampling Period
1	99.6	6	0	0	0	0	0	8/8 - 9/29
2	100.2	6	0	0	0	0	0	8/8 - 9/29
3B	101.4	7	0	0	0	0	0	8/8 - 9/29
3A	101.9	6	0	0	0	0	0	8/8 - 9/21
4	105.2	7	0	0	0	0	0	8/13 - 9/29
5	107.2	7	0	0	0	1	0	8/7 - 9/21
6	108.2	6	0	0	0	0	0	8/13 - 9/21
6A	112.3	9	0	0	1	2	2	8/7 - 9/27
7	113.2	8	0	0	0	0	0	8/8 - 9/27
8	113.7	10	0	0	0	0	0	7/28 - 9/21
8D	121.8	8	0	0	0	1	0	8/6 - 9/25
8C	121.9	7	0	2	0	3	0	8/6 - 9/25
8B	122.2	10	0	4	0	6	0	8/6 - 9/25
Moose	123.5	8	1[a]	2	2	7	0	8/6 - 9/25
A'	124.6	9	0	0	0	0	0	7/29 - 9/19
A	124.7	9	0	0	0	0	0	7/29 - 9/19
8A	125.1	10	0	9	3	10	3	8/6 - 10/2
B	126.3	9	0	4	2	6	0	8/12 - 10/2
9	128.3	8	0	4	3	6	0	8/6 - 9/25
9B	129.2	3	0	1	0	1	0	8/6 - 9/25
9A	133.3	11	0	1	0	3	0	8/6 - 10/1
10	133.8	9	0	0	0	2	0	8/6 - 9/25
11	135.3	12	0	11	4	10	0	8/2 - 10/5
12	135.4	10	0	0	0	0	0	8/2 - 9/25
13	135.7	10	0	0	0	0	0	8/6 - 9/25
14	135.9	10	0	0	0	0	0	8/6 - 9/25
15	137.2	9	0	0	3	1	2	8/4 - 9/25
16B	137.3	9	0	0	0	0	0	8/4 - 9/25
17	138.9	10	0	0	0	3	0	8/4 - 9/30
18	139.1	10	0	0	0	0	0	8/4 - 9/30
19	139.7	10	0	0	1	0	0	8/4 - 9/30
20	140.0	10	0	0	4	4	0	8/4 - 9/30
21	141.1	10	0	7	3	8	0	8/4 - 9/30
21A	144.3	4	0	0	0	0	0	8/4 - 9/23
TOTAL		287	1	45	26	74	7	

[a]Single chinook salmon observed in Moose Slough.

Appendix Table C-3 Number of observations of salmon in Susitna River tributaries in the Talkeetna to Devil Canyon reach, 1981 (adapted from ADF&G 1981a).

Tributary	River Mile	Total # of visits	Number of visits live salmon were observed in sloughs					Sampling Period
			Chinook	Sockeye	Pink	Chum	Coho	
Whiskers Creek	101.4	8	-	0	0	0	7	8/5 - 10/2
Chase Creek	106.9	9	-	0	2	1	7	8/4 - 10/2
Gash Creek	111.6	2	-	0	0	0	2	9/23 - 9/28
Lane Creek	113.6	7	-	0	3	6	2	8/19 - 9/28
L. Mckenzie Creek	116.2	6	-	1	0	2	4	8/23 - 9/28
McKenzie Creek	116.7	2	-	0	0	0	0	8/11 - 8/23
Deadhorse	120.9	2	-	0	0	0	0	8/11 - 9/25
5th of July	123.7	1	-	0	1	0	0	8/11
Skull Creek	124.7	3	-	0	2	1	0	8/20 - 9/19
Sherman Creek	130.8	6	-	0	3	4	0	7/31 - 9/25
4th of July Creek	131.0	6	-	0	4	4	2	7/31 - 9/25
Gold Creek	136.7	1	-	0	0	0	0	8/25
Indian River	138.6	8	-	0	1	5	3	8/6 - 9/26
Jack Long Creek	144.5	3	-	0	1	0	0	8/21 - 9/24
Portage Creek	148.9	3	-	0	0	0	1	8/21 - 9/24
TOTAL		67	-	1	17	23	28	

Appendix Table C-4 Number of observations of salmon in Susitna River Tributaries in the Talkeetna to Devil Canyon reach, 1982.

Tributary	River Mile	Total # of visits	Number of visits live salmon were observed in Sloughs: Chinook	Sockeye	Pink	Chum	Coho	Sampling Period
Whiskers Creek	101.4	6	0	0	4	0	5	8/8 - 9/24
Chase Creek	106.9	8	1	0	4	0	3	8/8 - 9/27
L. Gash Creek	111.2	1	0	0	0	0	1	9/21
Gash Creek	111.6	7	0	0	0	0	3	8/7 - 10/2
Lane Creek	113.6	11	4	0	5	8	4	7/12 - 9/21
L. Mckenzie Creek	116.2	10	0	0	2	[illegible]	[illegible]	8/7 - 10/2
Mckenzie Cr	116.7	10	0	0	1	0	0	8/7 - 10/2
L. Portage Creek	117.7	10	0	0	4	3	3	8/7 - 10/2
5th of July Creek	123.7	8	1	0	4	1	0	8/6 - 9/20
Skull Creek	124.7	8	0	0	3	1	0	8/6 - 9/19
Sherman Cr	130.8	8	1	0	3	0	0	8/6 - 10/1
4th of July	131.0	11	3	0	4	9	3	8/28 - 10/1
Gold Creek	136.7	5	1	0	2	0	1	8/3 - 8/30
Indian River	138.6	13	6	0	6	9	7	7/21 - 9/30
Jack Long Creek	144.5	9	2	0	3	1	1	8/4 - 9/30
Portage Cr	148.9	12	4	1	4	6	3	7/21 - 9/30
Cheechako Creek	152.5	8	4	0	0	0	0	8/5 - 9/24
Chinook Cr	156.8	4	3	0	0	0	0	8/6 - 8/22
Devil Cr	161.4	4	0	0	0	0	0	8/6 - 8/22
TOTAL		153	30	1	49	38	38	

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Appendix Table C-5 Abundance of adult salmon in the Susitna River sloughs during peak observations in 1982. Highs (H) 100, Medium (M) 50-100, Low (L) 50, none observed (-).

Slough	River Mile	Chinook	Sockeye	Pink	Chum	Coho
1-4	99.6-105.2	-	-	-	-	-
5	107.2	-	-	-	L	-
6	108.2	-	-	-	-	-
6A	112.3	-	-	L	L	L
7	113.2	-	-	-	-	-
8	113.7	-	-	-	-	-
8D	121.8	-	-	-	L	-
8C	121.9	-	L	-	L	-
88	122.2	-	L	-	M	-
Moose	123.5	L[a]	L	L	L	-
A'	124.6	-	-	-	-	-
A	124.7	-	-	-	-	-
8A	125.1	-	M	L	H	L
B	126.3	-	L	L	L	-
9	128.3	-	L	L	H	-
9B	129.2	-	L	-	L	-
9A	133.3	-	L	-	H	-
10	133.8	-	-	-	L	-
11	135.3	-	H	H	H	-
12	135.4	-	-	-	-	-
13	135.7	-	-	-	-	-
14	135.9	-	-	-	-	-
15	137.2	-	-	H	L	L
168	137.3	-	-	-	-	-
17	138.9	-	-	-	L	-
18	139.1	-	-	-	-	-
19	139.7	-	-	L	-	-
20	140.0	-	-	M	L	-
21	141.1	-	L	M	H	-
21A	144.3	-	-	-	-	-

[a]Single chinook salmon observed milling in slough.

Appendix Table C-6 Comparison of upwelling, substrate and distribution of spawning salmon among some Susitna river sloughs.

Slough	Open lead in ice-cover %	Open water upwelling seepage	Substrate Type*	Substrate (ft^2)%	Spawning** 1981	Spawning** 1982
Whiskers Creek Slough	52	1	GRRUCO SISA	98 2		p coho
Slough 6A	33	0	SICO SI	4 96	s,c	p,c coho
Lane Creek Slough	59	2	CORU SISA	44 56		p,c
Slough 8A	10	3	GRRUCO SISA	91 9	c,s	c,p,s coho
Slough 9	24	2	GRRUCO SISA	[illegible] [illegible]	c,s	c,p, s
Slough 9B	8		CORU SISA	1 99	c,s	c,s
Slough 9A	52	2	RUCO SISA	95 5	c,s	c,s
Slough 10	19	0	RUCO SISA	58 42		c
Slough 11	48	2	GRRUCO GROSI	60 40	c s	c,p s
Slough 16B	8	0	GRRUCO SA	96 4		
Slough 19	11	2	RUCO SI	45 55	s	
Slough 20	6	1	GRRUCO SI	67 33	c,s	p,c
Slough 21	70	3	RUCO SISA	64 36	c,s	c,p,s
Slough 22	15	[illegible]	RUCO SI	65 35	c	

* SI - silt
SA - sand
GR - gravel
RU - rubble
CO - cobble
BO - boulder

** C - chum salmon
S - sockeye salmon
P - pink salmon
Coho - coho salmon

Whiskers Creek Slough, sloughs 6A, 10 and 20. Slough 19 has a concentrated upwelling area yet very few open leads, none near the upwelling. Open leads were present in Slough 16B yet no upwelling/seepage was observed (perhaps due to rubble-cobble substrate) and no tributaries are present (Table C-6).

Substrate in sloughs varied from silt to cobble and boulders. In most sloughs the substrate included a thin layer of silt that was easily fanned away. However, Sloughs 6A, 10 and 19 contained more silt and/or sand than the larger substrate types. Very few fish were observed in these areas. In substrate other than silt or sand it was difficult to note upwelling or seepage. The majority of salmon spawning in the sloughs were observed utilizing a combination of gravel, rubble, and/or cobble (Table C-6).

DISCUSSION

<u>Chum Salmon</u>

Most chum spawning occurred in or near areas of upwelling/seepage. The spawning substrate consisted of a rubble-cobble mixture with a top layer of silt which was fanned away by the spawning female. Such habitat is abundant in sloughs 8A, 9, 9A, 9B, 11, 20, 21 and Lane Creek Slough. Some sloughs with substantial upwelling/seepage, such as Lane Creek Slough and sloughs 19 and 22 did not attract spawning chum salmon, perhaps due to limited access, variable velocities or unacceptable substrates.

Pink Salmon

Pink salmon apparently select tributary-like areas for spawning within the sloughs. In sloughs 8A, 9, 11, 20 and 21 they were found spawning in shallow riffle zones containing gravel-rubble-cobble substrate. Pink salmon also spawned in the cobbled riffle zones just below the confluence of Waterfall Creek in Slough 20.

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Sockeye Salmon

Sockeye salmon apparently select the slower deeper pool type areas with a rubble-cobble substrate such as those in sloughs 8A, 9 (near the 90° bend), 11, 19 (1981 only), 20 (in the upper tributary) and 21.

Coho Salmon

Coho salmon are not nearly as abundant in the sloughs as chum, pink and sockeye salmon. Coho salmon usually prefer to spawn in the tributaries but were observed in Whiskers Creek Slough in 1981 and observed to spawn in the upper reaches of Slough 8A during both 1981 and 1982. Coho salmon were not observed in upper Slough 8A until after the water level rose in mid September 1982. Coho also arrived in Slough 8A during the same time in 1981 although water level had been high and turbid during most of summer.

Chinook Salmon

Chinook salmon spawned exclusively in tributaries.

LITERATURE CITED

Alaska Department of Fish and Game. 1981a. Adult anadromous phase I final species/subject report. ADF&G Su Hydro Aquatic Studies Program. Anchorage, Alaska.

______. 1981b. Aquatic Studies Procedures Manual. Phase I. Prepared for Acres American Incorporated, by the Alaska Department of Fish and Game/Su Hydro Studies team. Anchorage, Alaska.

______. 1983a. Aquatic Studies Procedures Manual. Phase II. Prepared for Acres American Inc. by the Alaska Department of Fish and Game, Su Hydro Studies team. Anchorage, Alaska.

______. 1983b. Susitna Hydro Aquatic Studies Phase II Basic Data Report (Vols. 1-5). Prepared for Acres American Inc. by the Alaska Department of Fish and Game, Su Hydro Studies team. Anchorage, Alaska.

Hasler, A.D. 1966. Underwater guideposts: homing of salmon. Univ. Wisconsin Press, Madison. 155 pp.

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APPENDIX D

Hydraulic and Habitat Modeling of Chum Salmon Spawning Habitat in Side Sloughs of the Susitna River

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INTRODUCTION

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This appendix presents an analysis of the velocity, depth and substrate spawning habitat characteristics utilized by chum salmon in side sloughs located within the Talkeetna to Devil Canyon reach of the Susitna River.

Hydraulic conditions that comprise aquatic habitats can be favorable or unfavorable to a particular species and life phase of fish depending upon their magnitude or character.

The Alaska Department of Fish and Game (ADF&G) began a hydraulic and spawning habitat modeling study of four side sloughs of the Susitna River in August of 1982. The study was initiated to evaluate fish habitat in the side sloughs. Particular attention was to be given to the range of discharge levels, particularly those that may occur as a result of the operation of the proposed hydroelectric facility. The hydraulic model is calibrated using observed hydraulic conditions at a range of discharges and is used to predict the available hydraulic conditions at various discharges within the calibration range. The modeling study underway will eventually simulate hydraulic conditions for slough flows from 5 to 500 cfs.

In developing a habitat model for the evaluation of fish habitat, which is combined with the hydraulic model to evaluate the availability of habitat at various flows, the following assumptions are made. Fish will generally not be found in unfavorable habitats. They will instead be distributed among favorable habitats. Furthermore, they will be most abundant in the most favorable habitats. Thus the importance of a particular habitat variable can be determined by comparing the proportion of the population found within increments of the habitat variable available.

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Spawning is a critical period in the life cycle of any fish, particularly anadromous fish such as salmon. In the Susitna River basin salmon often spawn in sloughs. Water levels in the sloughs are affected by water levels in the mainstem. Low mainstem discharge often limits access to spawning areas in sloughs. Medium levels in the mainstem provide back water areas near the mouth of the slough which can facilitate access to lower reaches. High mainstem discharges overtop the heads of sloughs and allow fish passage throughout the slough. Identifying the specific mainstem discharge at which these transitions occur will define the relationship between flow and access to spawning areas. The quality of the spawning habitat is dependent upon the environmental factors within the sloughs, some of which are flow dependent. Modeling hydraulic conditions at representative spawning areas in the sloughs and comparing the forecast conditions to measurements obtained over active redds can aid in assessing the influence of flow on the quality and availability of habitat.

Chum salmon were the most abundant spawning salmon in the sloughs studied in 1982. Consequently, their spawning requirements were selected for detailed analysis. Chum salmon redds were examined with respect to available water depths, water velocities, substrate composition and intragravel water temperatures. These habitat variables were chosen as being the most critical to the selection of adequate spawning sites. An analysis of intragravel temperatures is not included in this appendix.

METHODS

Site Selection and Field Data Collection

Five sloughs (8A, 9, 21, Rabideux Slough and Chum Channel) were selected to evaluate salmon spawning habitat in sloughs in the Susitna River (RM 76.0 to 141.0). Rational for selecting these study sloughs is discussed in Volume 4 of the Basic Data Report (ADF&G 1983) and the Procedures Manual (ADF&G 1982).

Study sites within each slough were reaches selected to represent the habitat conditions throughout that portion of the slough not influenced by mainstem backwater affects. These reaches were selected to encompass areas known to support chum salmon spawning during 1981. Transects within the study sites were selected to represent each type and proportion of habitat present (i.e., pool, riffle, or run). Detailed description of the site selection process and physical habitat data collection methods are described in the 1982 Aquatic Studies Procedures Manual (ADF&G 1982). Chum, pink and sockeye salmon redds were sampled in sloughs between August 25 and September 6, 1982. Basic site selection and field data collection techniques are based on those developed by the instream flow group (Bovee 1982 and Bovee and Milhouse 1978). Sufficient numbers of salmon redds were to be sampled to be analyzed statistically. Bovee (1978) recommends a minimum of 200. However hydraulic conditions during 1982 limited the anticipated utilization of this habitat and measurements were limited to 37 chum salmon redds in Slough 9 and 33 in Slough 21. Water depths, velocities and substrate composition were measured at active redds only at slough flows (4-8 cfs).

Low flows in the Susitna River prevented access to 1981 spawning areas; thus no chum salmon redds were found in Chum Channel or Rabideux Slough. Original data are tabulated ~~in the basic data report (ADF&G 1983; Appendix B).~~ Site descriptions, including maps, are given in the Susitna Hydro Aquatic Studies Phase II Basic Data Report (ADF&G 1983).

Data Analysis

Predicting Hydraulic Conditions

Field data were reduced according to the procedures developed by Trihey (1980), the hydraulic conditions in the sloughs were simulated by a computer model developed by Milhous et al. (1981). The model, IFG-4, was designed for use by fisheries biologists to predict hydraulic conditions for a wide range of discharges.

Because each study site was selected to represent a larger portion of the slough, the depth, velocity and substrate data collected at transects within each site were used to predict characteristic physical habitat parameters for the ~~entire~~ slough ~~segment~~ being represented. Hydraulic data and substrate type at each measuring point along a transect were used to represent the area halfway between adjacent transects at that point, this is referred to as a slough segment. Dimensions of each segment were calculated using procedures outlined in the ADF&G Su Hydro Aquatic Studies Procedures Manual (ADF&G 1982).

Observed water depths, velocities, water surface elevations and slough flows were used to calibrate the hydraulic models. Calibrating the IFG-4 model, as described by Milhous et al. (1981), involved slight adjustments to observed depths, velocities and water surface elevations within the range of accuracy of the field measurements. Adjustments rarely exceeded 0.1 ft in depth, 0.1 ft/sec in velocity or 0.01 ft in water surface elevation. Predicted depth and velocity values were accepted as "calibrated" by a final comparison with actual field measurements at known flows. Observed water surface elevations and discharges were compared with predicted water surface elevations and discharges at each transect in sloughs 8A, 9, 21 and Chum Channel. During the calibration process the model adjusts velocities at each transect by a constant (the velocity adjustment factor), which is a ratio between the calibration and calculated discharge. The velocity adjustment factor in a calibrated model must be between 0.9 and 1.1 in order for the model to accurately simulate natural conditions.

The computer program generates roughness coefficients ("Manning's n" values) needed to predict flows. Computer generated roughness coefficients were altered when necessary to better approximate known velocities. Values for most roughness coefficients were assigned within an acceptable range of potential values (Trihey 1980).

Once calibrated the IFG-4 program can predict hydraulic conditions at any discharge within the calibration range. Depending on how accurately the model fits observed values, the upper boundary of predicted flows can be up to 250 percent of the highest measured flow (Bovee and Milhous 1978). Measured depth and velocity data for study sites in the sloughs were not directly comparable because they were collected at different discharges. Discharges ranging between 4 and 8 cfs were measured at sloughs 8A, 9, 21 and Chum Channel when salmon were spawning; thus, 5 cfs was selected as a common predicted low flow. The maximum predictable flow within the calibration range of the model for Slough 8A was 50 cfs. Therefore this was selected as an intermediate predicted flow common to all four study areas. ~~The highest predictable~~ A high predicted flow for Chum Channel, 150 cfs, was also selected as an intermediate predicted flow ~~also~~ for sloughs 9 and 21. The maximum predictable flow in Slough 21 was approximately 300 cfs; therefore, this was selected as the highest predicted flow in Slough 9 as well. Observed discharges in Slough 8A were not sufficient to predict hydraulic conditions at intermediate and high flows (150 and 300 cfs). Data collected at Rabideux sloughs were insufficient for model calibration. Salmon were not observed spawning at intermediate and high flows.

Ultimately, the purpose of predicting these hydraulic conditions from the calibrated model is to qualify and quantify the habitat that would be available to a particular life phase of fish at a variety of discharges. At the present stage of development of the model and the available data base, the available habitat values for substrate composition are based on observed conditions as opposed to predicted values.*

Predicting Usable Proportion of Available Habitat

In order to determine whether a particular type of habitat is important for a particular species and life phase of fish, the habitat being utilized by the species and life phase of interest (spawning chum salmon) must be compared to the total amount and types of habitat available. The IFG-4 program can ~~only~~ predict hydraulic conditions at various discharges. The area available for use by fish of a particular species and life stage must therefore be determined by linking the IFG-4 model to a habitat model. This type of linkage to determine weighted usable area has been applied in other Alaskan river systems (Estes et al. 1981, Wilson et al. 1981). Aquatic habitat modeling provides a good index of available fish habitat to stream flow. Unfortunately, it cannot be calculated without knowing the range of acceptable and optimal habitat conditions required by the life stage of the fish.

An insufficient number of chum salmon redds were sampled this year to develop habitat suitability indices for water depths, velocities or substrate required for habitat modeling. In addition, insufficient intermediate and high discharges, needed to ~~properly~~ calibrate the

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* One of the assumptions of the IFG-4 model is that substrate composition will not vary with changes in discharge. Rather, the proportion of a particular substrate type to the total water surface area associated with a particular discharge is a function of a change in the wetted perimeter associated with that discharge (i.e. the area of substrate covered by water).

hydraulic models, were collected due to low water conditions during 1982.

Habitat criteria for the same species that was collected in other systems should not be used unless their applicability to the system is validated (Estes et al. 1981, Wilson et al. 1981). Therefore, the physical habitat modeling cannot be used to predict usable surface areas for Susitna River sloughs at this time.

For the reasons above a less rigorous analysis was performed and the relationship between flow and chum salmon spawning habitat (expressed as total water surface area) was determined in five steps. First, the range of habitat available was determined using the hydraulic model discussed above. Second, spawning habitat was categorized into four ranks (unacceptable, utilized, preferred and optimal) based upon distribution of habitats where redds were established, within the range of habitat available (Figure D-1).

> Unacceptable spawning habitat conditions in a slough are defined as those increments of the available habitat where no active redds were observed.
>
> Utilized spawning habitat conditions in a slough are defined as the combination of all increments of a particular habitat (i.e. depth, velocity, substrate) where active redds were observed. Utilized spawning habitats included those that were also preferred and optimal.
>
> Preferred spawning habitat conditions in a slough are defined as the combination of all increments of a particular habitat type where the proportion of active redds exceeded the proportion of wetted surface area. Preferred spawning habitats included optimal habitat.
>
> Optimal spawning habitat conditions in a slough are defined as the preferred increment or combination of increments of a particular habitat type in which the largest proportions (mode) of redds occurred.

Third, the rankings of each habitat type within a segment were compared. If all habitat types within a segment were of the same rank the entire segment was assigned that rank. If different ranks were assigned to the habitat types within a segment, the lowest rank was assigned to that segment.

Fourth, the surface area of all segments were summed. The final step in the analysis was accomplished by dividing the surface area of each rank by the total water surface area of the slough to calculate the percent of total water surface area for each rank within the slough.

Water depth, velocity, substrate composition and intragravel water temperature data are presented in Volume 4 of the Basic Data Report (ADF&G 1983: Appendix B). In order to determine if a particular habitat type could be used to calculate usable spawning habitat the cumulative frequencies of utilized water depths, velocities and substrate types were tested for significant difference in distribution ~~from those that were available~~ with a Kolmogorov-Smirnov two sample test (Conover 1971).

RESULTS

<u>Accuracy and Precision of Models</u>

The IFG-4 model must be calibrated to meet required standards of precision (Milhous et al. 1981). The IFG-4 models for hydraulic simulation in sloughs 8A, 9, 21 and Chum Channel predicted the water surface elevation and discharge at each transect. Seventy-three percent of the predicted water surface elevations were within 0.05 foot of observed water surface elevations (Tables D-1 to D-4). Overall, predicted water surface elevations were highly correlated with observed values ($r = 0.999$). Eight-two percent of the predicted discharges at each transect differed from mean observed discharges for each slough by no more than 1 percent. Only one transect (transect 5 of Chum Channel at 7.1 cfs) predicted discharge deviated by more than 5 percent from observed mean discharge of 6.7 cfs. Overall, predicted discharges at each transect were highly correlated with mean slough discharges ($r = 0.999$). Forty-seven percent of the velocity adjustment factors were 1.00 ± 0.01. All but one velocity adjustment factor (VAF) was considered "good" ($0.9 \leq VAF \leq 1.1$) That one was the velocity adjustment factor for Slough 21 Transect 6 (at 10 cfs) which was considered "fair" ($0.8 \leq VAF \leq 1.2$).

Precision standards also recommend keeping predicted water depths and velocities in each segment within 0.1 ft and 0.2 ft/sec of the measured depths and velocities (Milhous et al. 1981). A representative example of a transect at two discharges where the fit was not good (Table D-5) and another where the fit was good (Table D-6) are provided. Correlation coefficients may be somewhat misleading at the discharge level at which the models were calibrated. At such shallow depths and low velocities differences of 0.1 ft or ft/sec can appear disproportionally large.

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Predicting Hydraulic Conditions

Water depths, velocities or substrate types were not measured at redds when slough flows exceeded 8 cfs. However, the predicted proportions of depths and velocities are presented for slough flows of 5 and 50 cfs for all four sloughs; 150 cfs for sloughs 9, 21 and Chum Channel and 300 cfs for sloughs 9 and 21 (Figures D-2 to D-9) for comparative purposes.

Hydraulic conditions in a slough depend on whether or not the slough head is breached by water from the mainstem. Sloughs 8A, 9, 21 and Chum Channel were breached at mainstem flows of 32,000 cfs, 20,000 cfs, 25,000 cfs and 53,000 cfs, respectively (ADF&G 1983). When the sloughs were not breached, their discharges were generally less than 20 cfs. As breaching occurred, slough flows increased rapidly. Conversely, slough flows decreased rapidly when mainstem stage fell below the breaching point. Therefore, in these three sloughs discharges of 50 cfs (and perhaps as high as 150 cfs) were transitory.

Predicting Useable Proportion of Available Habitat

Available water depths, velocities and substrate types were compared with those found in chum salmon redds (Figures D-10 and D-11). Depths and substrate types at chum salmon redds in every slough (at 5 cfs) were significantly different ($P < 0.05$) from those available. Velocities measured at active redds (Figure D-12) were determined not to differ significantly ~~different~~ from available velocities at predictable slough flows of 5 cfs based on the Kolmogrov-Smirnov test. Therefore, water depth and substrate were selected as critical variables determining salmon habitat preference. Gaps in the range of utilized water depths can probably be attributed to the low sample size of redds rather than actual avoidance of those depths.

In Slough 8A, at 5 cfs, the water depths used by spawning chum salmon were 0.2 - 1.6 and 1.8 - 2.0 ft. Gravel-rubble and rubble-cobble substrates were used. Preferred water depths were 0.2 - 1.2 ft and the preferred substrate was gravel-rubble. Optimal water depths were 0.4 - 0.6 ft and the optimal substrate was gravel-rubble. The Slough 8A study area was comprised of 30.5 percent usable spawning area. Only 6.0 percent of the total water surface area was preferred and 1.0 percent was optimal for spawning.

In Slough 9, at 5 cfs, the water depths used by spawning chum salmon were 0.2 - 2.4 ft. Gravel-rubble, rubble-cobble and cobble-boulder substrates were used. Preferred water depths were 0.8 - 2.2 ft and the preferred substrates were gravel-rubble and rubble-cobble. Optimal water depths were 1.2 - 1.4 ft and optimal substrates were gravel-rubble and rubble-cobble. The Slough 9 study area was comprised of 24.4 percent usable spawning area. Only 0.8 percent of the total water surface area was preferred and 0.3 percent was optimal for spawning.

In Slough 21, at 5 cfs, the water depths used by spawning chum salmon were 0.2 - 2.0 and 2.4 - 2.6 ft. Substrate types used for spawning ranged from gravel to cobble-boulder. Preferred water depths were 0.4 - 1.2 and 1.4 - 2.0 ft. The preferred substrates ranged from gravel to rubble-cobble and cobble-boulder. Optimal water depths were 1.0 - 1.2 ft and optimal substrates were gravel-rubble and rubble-cobble. The Slough 21 study area was comprised of 21.4 percent usable spawning area. Only 8.2 percent of the total water surface area was preferred and 1.5 percent was optimal for spawning.

DISCUSSION

Spawning in the sloughs was restricted to water depths greater than 0.2 ft. The upper range of depths used for spawning was probably not reached because of low flows in August and September 1982. Water depths used for spawning in all three sloughs were within the range of depths (0.16 - 3.9 ft) reported for chum salmon redds in the Chena River (Kogl 1965). Similarly, water depths in the sloughs were within the range of depths (0.25 - 3.5 ft) reported for chum salmon redds in the Terror and Kizhuyak Rivers on Kodiak Island (Wilson et al. 1981).

The frequency distributions of water velocities in the three sloughs were not significantly different ($P > 0.05$) at each predicted flow. As with depths, the upper limit of velocities used for spawning was probably not observed because of low flows in August and September 1982. Water velocities used for spawning in all three sloughs were within the range of velocities (0.0 - 2.0 ft/sec) reported at chum salmon redds in the Chena River (Kogl 1965). Velocities reported at chum salmon redds in the Terror and Kizhuyak rivers (0.0 - 3.9 ft/sec) were even higher (Wilson et al. 1981). Chum salmon, like other salmonids, require moving water in redds to assure aeration of eggs (Wesche and Rechard 1980, Hale

1981). When redds were located in velocities of 0.0 - 0.2 ft/sec, upwelling ground water was frequently observed. Chum salmon were found to prefer areas of upwelling ground water in the Alaskan interior (Kogl 1965, Francisco 1977) and on Kodiak Island (Wilson et al. 1981). Upwelling ground water, which is warmer in winter than surface water, also prevents substrate freezing in shallow water and in slow currents (Levanidov 1954, Kogl 1965, Sano 1966, Francisco 1977).

For several reasons an increase in slough flow may not result in a proportional increase in spawning habitat. As flows increase in the slough so does the water surface area. But velocities will also increase with increased slough discharge. If velocities associated with higher discharges were to increase beyond the range utilized by the species of interest a reduction in the proportion of habitat acceptable for spawning would result. Thus the surface area that is usable by spawning salmon may decrease at high discharges (Hooper 1973). Secondly, salmon eggs and alevin remain in the gravel of redds for months and require a long term supply of water. Peaks in the Susitna River flow that are large enough to breach sloughs are generally short term. Spawning on this ephemeral habitat would result in unsuccessful incubation due to dewatering. Unless intragravel water sources (upwelling) were sufficient to support the entire incubation and alevin life phases.

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* A pilot program to collect intragravel water temperatures in sloughs was initiated in 1982 and will be continued in 1983. An analysis of these data and their influence on spawning utilization in sloughs will be presented in the FY84 ADF&G report.

This relationship of slough flow and spawning in no way reduces the necessity for seasonally timed high discharges in the mainstem. High water and breaching in sloughs is critically important to access and movement into upper reaches of the slough (where upwelling ground water may be sufficient to prevent complete dewatering at low flow), as well as flushing of fine material from spawning substrate. The hydraulic pressure of high mainstem flows may also contribute to upwelling in the sloughs.

Ranges of utilized particle sizes is noteworthy. Redds were not found in substrate smaller than gravel, including the combination of sand-gravel. Substrate composition in these three Susitna River sloughs differs from that found in other Alaskan chum salmon spawning areas. Most other studies found gravel (2 - 76 mm) substrate to be most used (Francisco 1976, Morrow 1980, Wilson et al. 1981). Rubble substrates, with particles as large as 127 mm, were also used on the Delta River (Francisco 1976).

Water depths, velocities and substrate types at chum salmon redds in sloughs are comparable with spawning sites in the Susitna River under a much wider range of environmental conditions. Chum salmon spawn infrequently in side channels of the Susitna River. Of 23 samples collected at 8 spawning sites between September 4-14, 1982 (ADF&G 1983), water depths at all but one site ranged from 0.5 - 2.5 ft. A depth of 4 ft was measured at one site. These are all within the range of depths at chum salmon redds in sloughs. Water velocities measured at all but one spawning site in the Susitna River ranged from 0 - 0.3 ft/sec. The same site with 4 ft depth had a velocity of 1.0 ft/sec. Thus, water velocities at the limited number of spawning sites located within these peripheral areas of the mainstem Susitna River were similar to those observed in sloughs. Substrate composition at 6 of the 8 samples was 60 - 90 percent gravel, rubble and/or cobble. Eight of the mainstem sites had a substrate composition of 0 - 30 percent gravel, rubble and/or cobble.

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Plans for data collection during the 1983 field season are based on the data in this report and other ADF&G reports. Additional data from chum salmon redds in sloughs are required to develop fish suitability curves for a habitat model. Additional hydraulic data must also be collected at intermediate and high flows in order to complete calibration of hydraulic models. Plans for 1983 also include the hydraulic simulation of two side channels of the Susitna River between Talkeetna and Devil Canyon. An attempt will also be made to collect enough data from pink and sockeye salmon redds to include these species in the habitat model. Intragravel water temperatures will be collected at transects while the salmon are spawning to compare available temperatures with those observed at redds.

LITERATURE CITED

Alaska Department of Fish and Game (ADF&G). 1982. Aquatic studies procedures manual. Phase II. Prepared for Acres American, Incorporated, by the Alaska Department of Fish and Game/Su Hydro Anchorage, Alaska.

______. 1983. Susitna Hydro Aquatic Studies. Phase II. Basic data report. Volume 4. Aquatic habitat and instream flow studies, 1983. Prepared for Harza-Ebasco Susitna Joint Venture. Anchorage, Alaska.

Bovee, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Instream Flow Information Paper No. 12. ~~U.S.F.W.S. Ft. Collins.~~ Coop. Instream Flow Service Group, U.S. Fish and Wildlife Service, Ft. Collins, Co.

______ and R. Milhous. 1978. Hydraulic simulation in instream flow studies theory and techniques. Instream Flow Information Paper No. 5. Coop. Instream Flow Service Group, U.S. Fish and Wildlife Service, Ft Collins, Co. 130 pp.

Conover, W.J. 1971. Practical nonparametric statistics. John Wiley and Sons, Inc. NY. 462 pp.

Estes, C., K. Hepler and A. Hoffmann 1981. Willow and Deception creeks instream flow demonstration study. Vol. 1. Alaska Department of Fish and Game, Habitat Protection and Sport Fish Divisions. Prepared for the U.S. Department of Agriculture, Soil Conservation Service, Interagency Coop. Susitna River Basin Study. 134 pp.

Francisco, K. 1976. First interim report of the Commercial Fish-Technical Evaluation Study. Joint State/Federal Fish and Wildlife Advisory Team. Special Report No. 4. Anchorage, Alaska. 85 pp.

_____. 1977. Second interim report of the Commercial Fish-Technical Evaluation Study. Joint State/Federal Fish and Wildlife Advisory Team. Special Report No. 9. Anchorage, Alaska. 46 pp.

Hale, S.S. 1981. Freshwater habitat relationships: chum salmon Oncorhynchus keta). Alaska Department of Fish and Game, Habitat Division, Resource Assessment Branch. Anchorage, Alaska. 94 pp.

Hooper, D.R. 1973. Evaluation of the effects of flows on trout stream ecology. Dept. Eng. Res., Pacific Gas and Electric Co. Emeryville, CA. 97 pp.

Kogl, D. R. 1965. Springs and ground-water as factors affecting survival of chum salmon spawn in a sub-arctic stream. M.S. thesis, Univ. of Alaska, Fairbanks. 59 pp.

Levanidov, V.Y. 1954. Ways of increasing the reproduction of Amer chum salmon. (Transl. from Russian). Akademiya. Nauk SSSR, Ikhtiologicheskaya Komissya, Trudy Soveschanii, No. 4:120-128. Israel Program for Scientific Translations. Cat. No. 8. Office of Tech. Service, U.S. Dept. Of Commerce, Washington, D.C. 12 pp.

DRAFT

Milhous, R.T., D.L. Wegner and T. Waddle. 1981. User's guide to the physical habitat simulation system. Instream Flow Information Paper No. 11. Coop. Instream Flow Service Group, U.S. Fish and Wildlife Services. Ft. Collins, Co.

Morrow, J.E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Co. Anchorage, Alaska. 248 pp.

Reiser, D.W. and T.C Bjounn. 1979. Influence of forest and rangeland management of anadromous fish habitat in Western North America: habitat requirements of anadromous salmonids. USDA Forest Service Anadromous Fish Habitat Program. Gen. Tech. Rpt. PNW-96. Pacific Northwest Forest and Range Experiment Station. Portland, OR. 54 pp.

Sano, S. 1966. Salmon of the North Pacific Ocean - Part III. A review of the life history of North Pacific salmon. 3. Chum salmon in the Far East. International North Pacific Fisheries Commission Bull. No. 18. Vancouver, B.C. pp. 41-57.

Trihey, E. W. 1980. Field reduction and coding procedures for use with the IFG-2 and IFG-4 hydraulic simulation models. Coop. Instream Flow Service Group. U.S. Fish and Wildlife Service Ft. Collins, Co. Draft.

DRAFT

Wesche, T.A. and P.A. Rechard. 1980. A summary of instream flow methods for fisheries and related research needs. Eisenhower Consortium Bull. No. 9. Water Resources Research Institute. Univ. Wyoming. Laramie. 122 pp.

Wilson, W.J., E.W. Trihey, J.E. Baldrige, C.D. Evans, J.G. Thiele and D.E. Trudgen. 1981. An assessment of environmental effects of construction and operation of the proposed terror lake hydroelectric facility, Kodiak, Alaska. Instream flow studies final report. Arctic environmental information and data center, Univ. of Alaska. 419 pp.

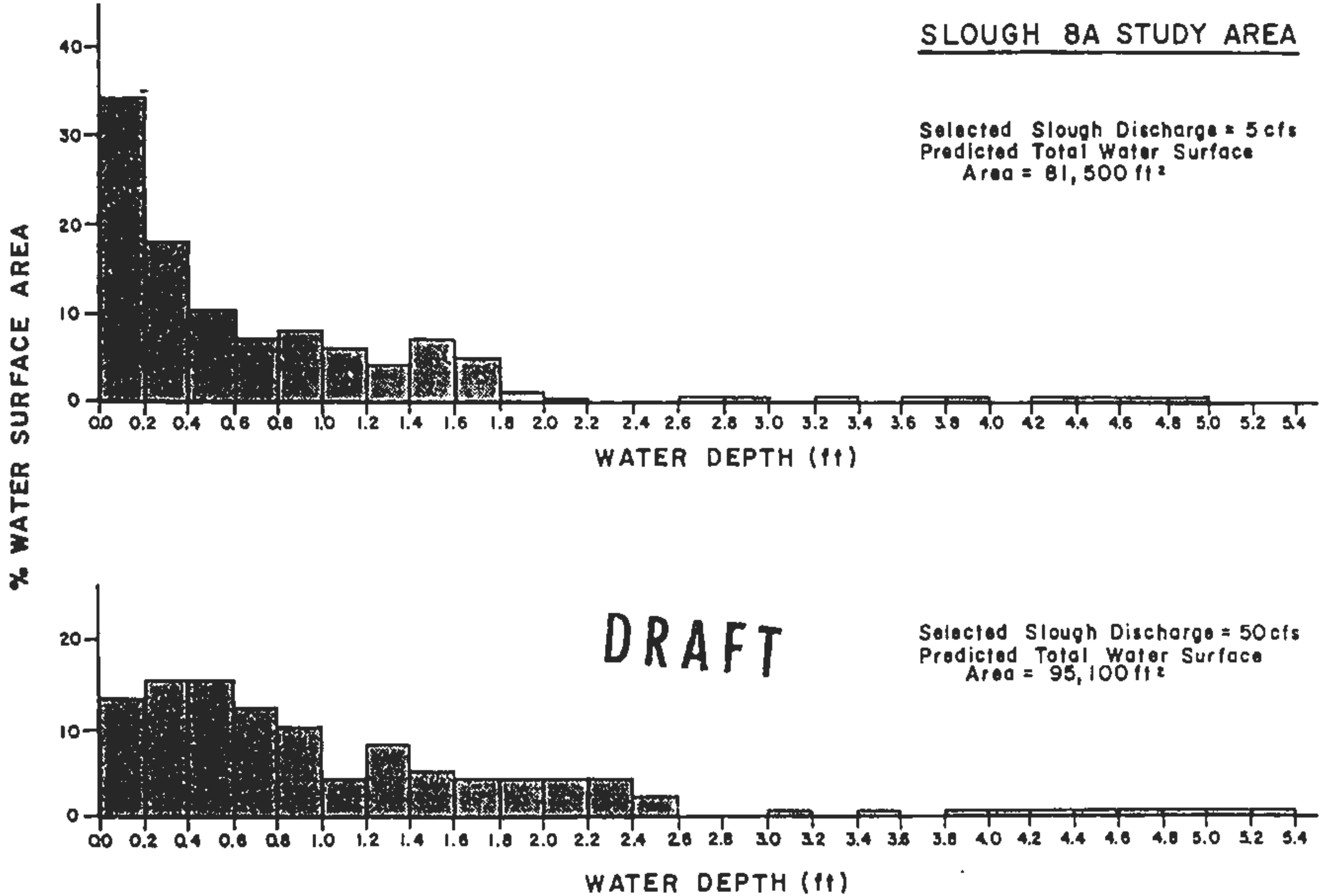

Figure D-2. Model-predicted frequency distribution of the water surface area of Slough 8A having associated water depths at two selected discharges. Water column depth is expressed in 0.2 ft increments.

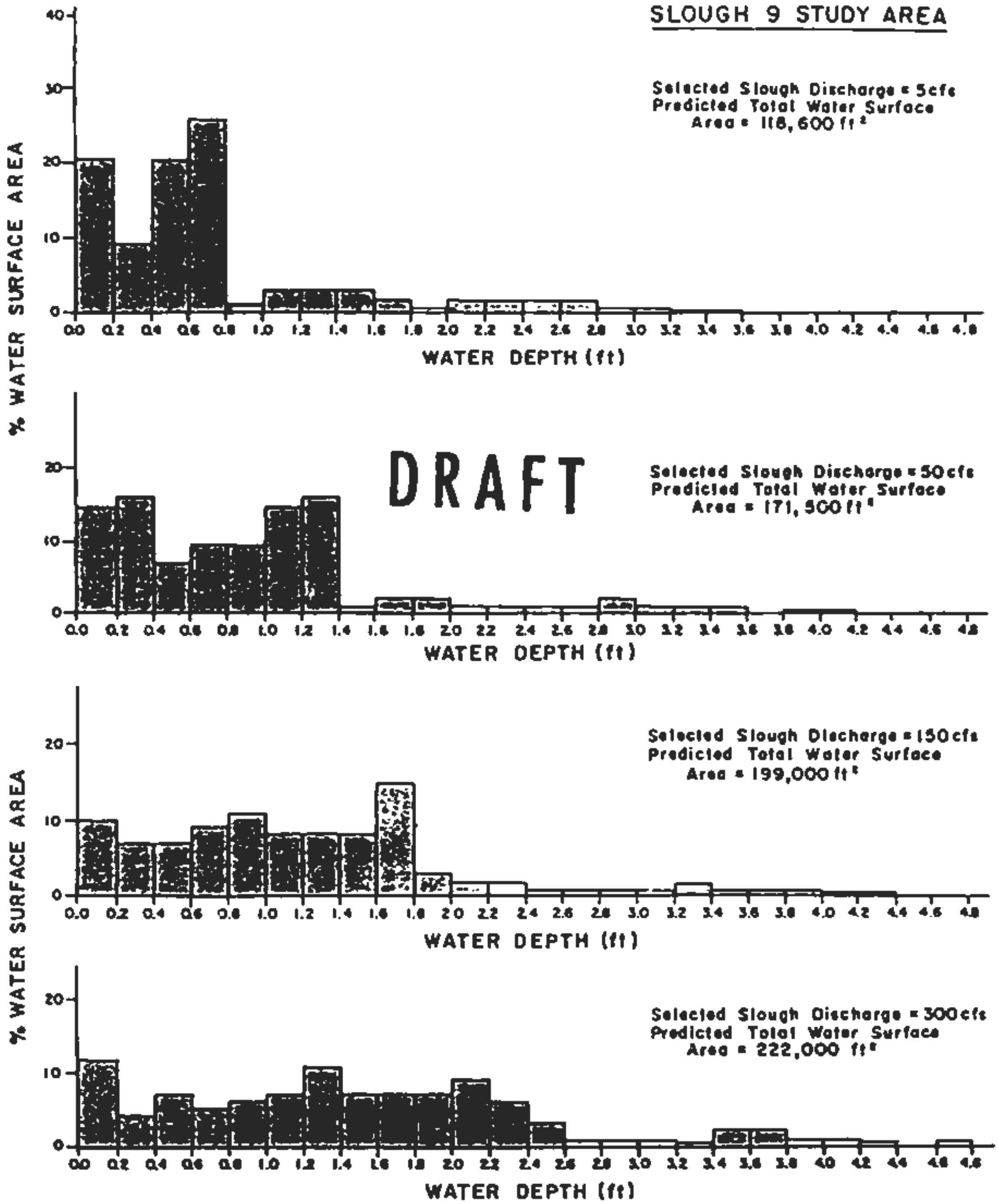

Figure D-3. Model-predicted frequency distribution of the water surface area of Slough 9 having associated water depths at four selected discharges. Water depth is expressed in 0.2 ft increments.

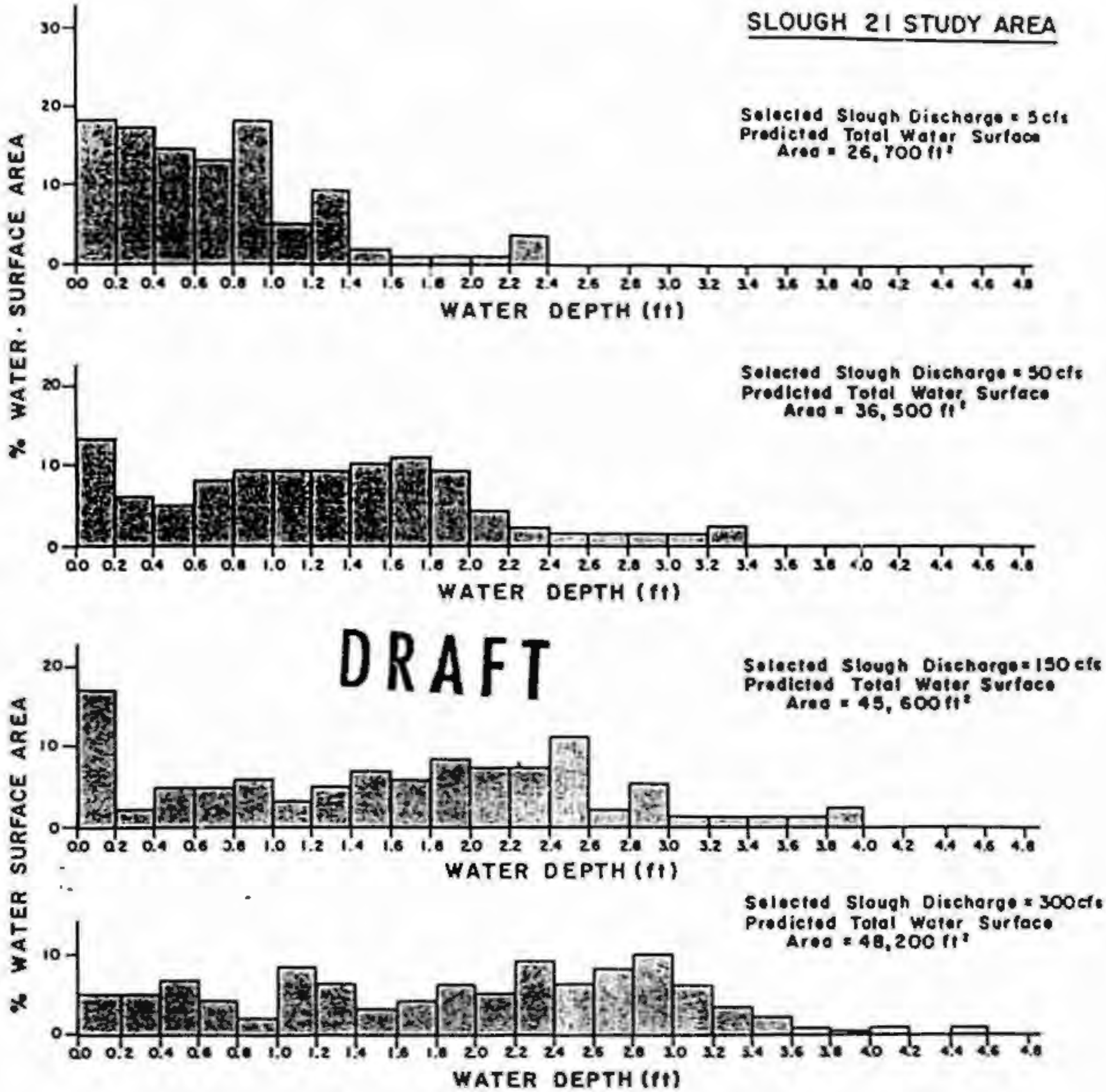

Figure D-4. Model-predicted frequency distribution of the water surface area of Slough 21 having associated water depths at four selected discharges. Water depth is expressed in 0.2 ft increments.

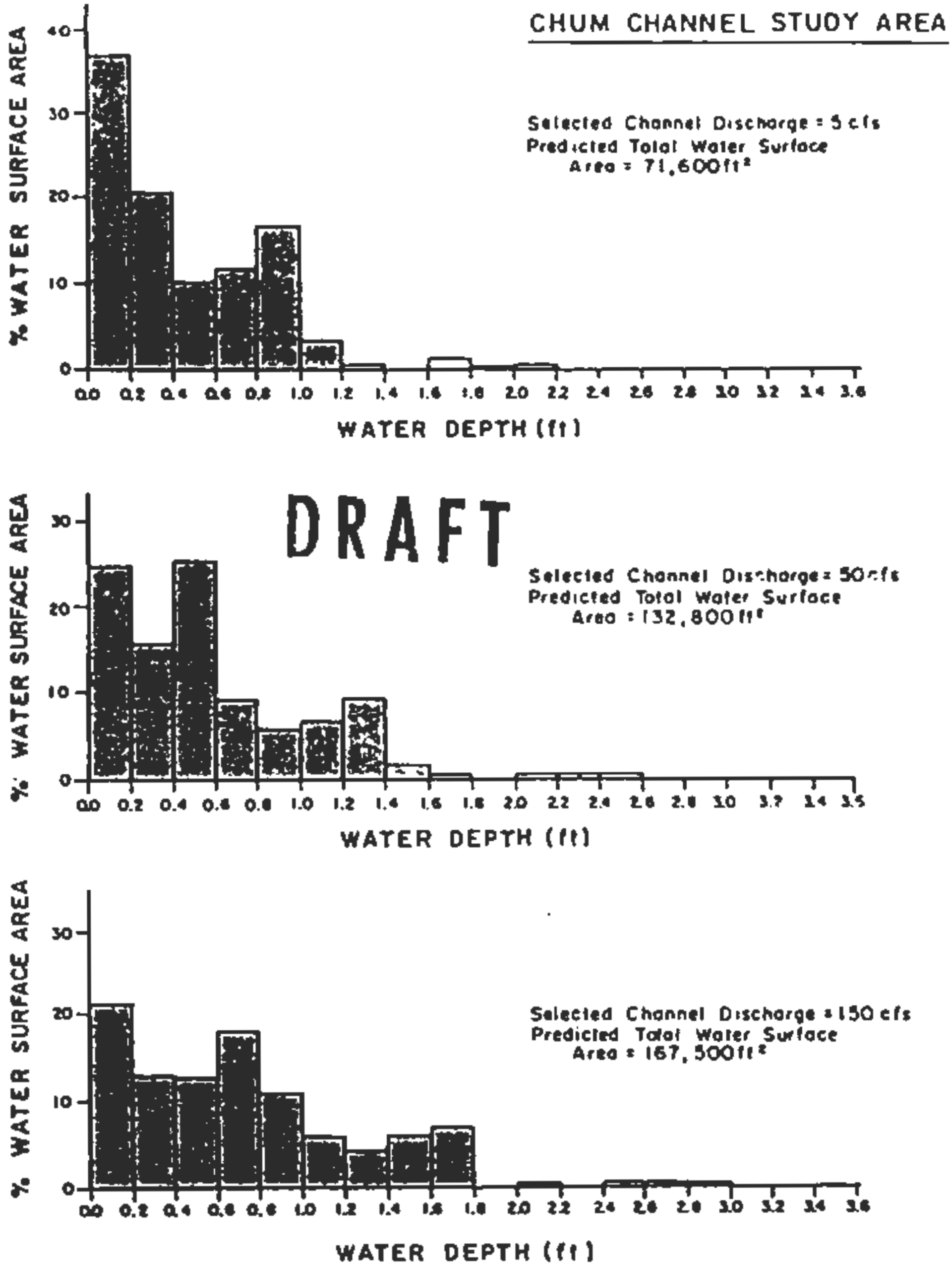

Figure D-5. Model-predicted frequency distribution of the water surface area of Chum Channel having associated water depths at three selected discharges. Water depth is expressed in 0.2 ft increments.

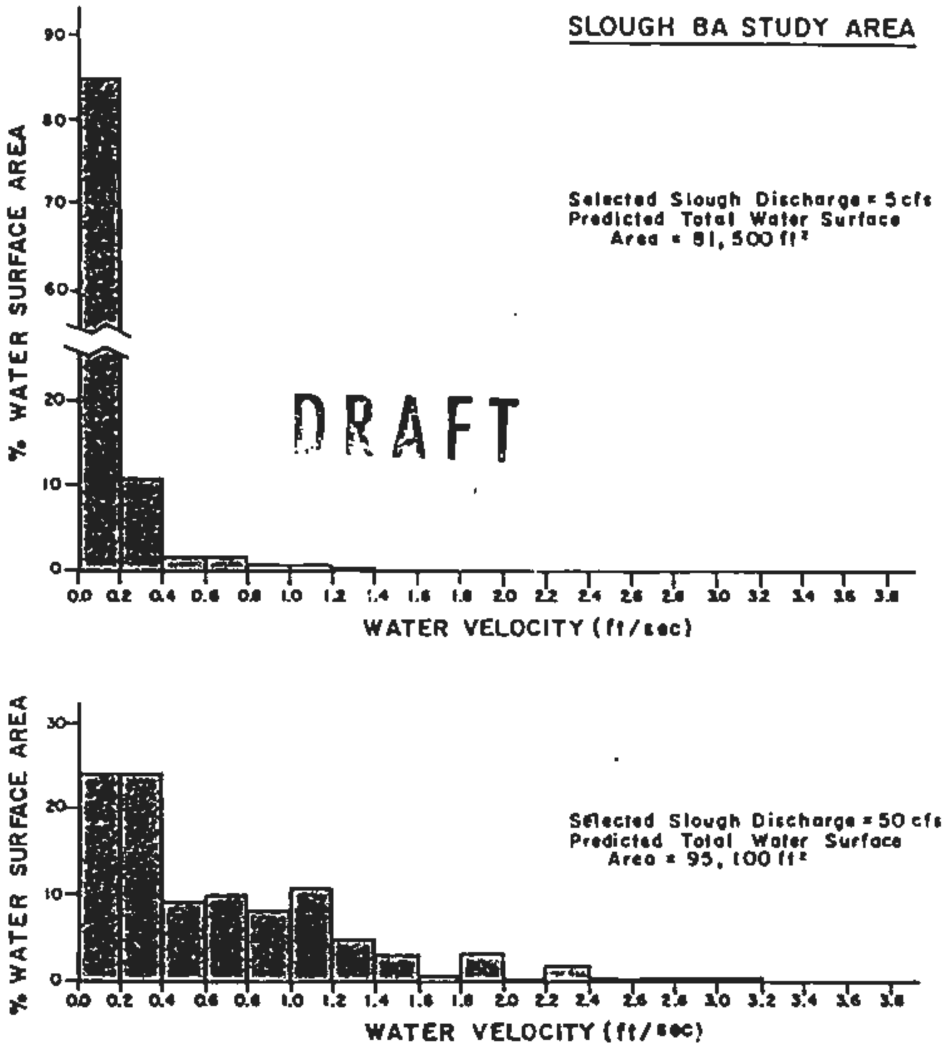

Figure D-6. Model-predicted frequency distribution of the water surface area of Slough 8A having associated water velocities at two selected discharges. Water velocity is expressed in 0.2 ft/sec increments.

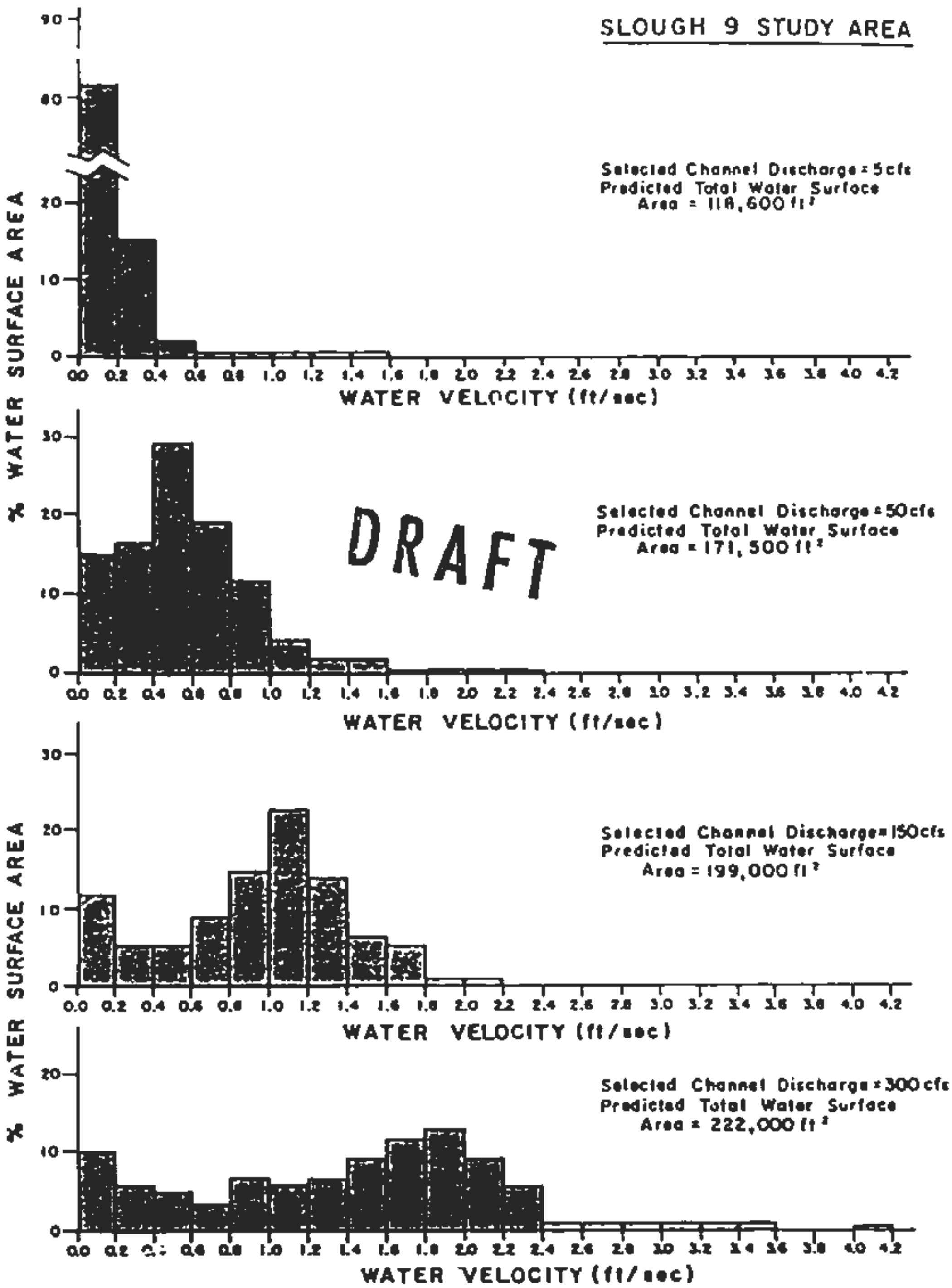

Figure D-7. Model-predicted frequency distribution of the water surface area of Slough 9 having associated water velocities at four selected discharges. Water velocity is expressed in 0.2 ft/sec increments.

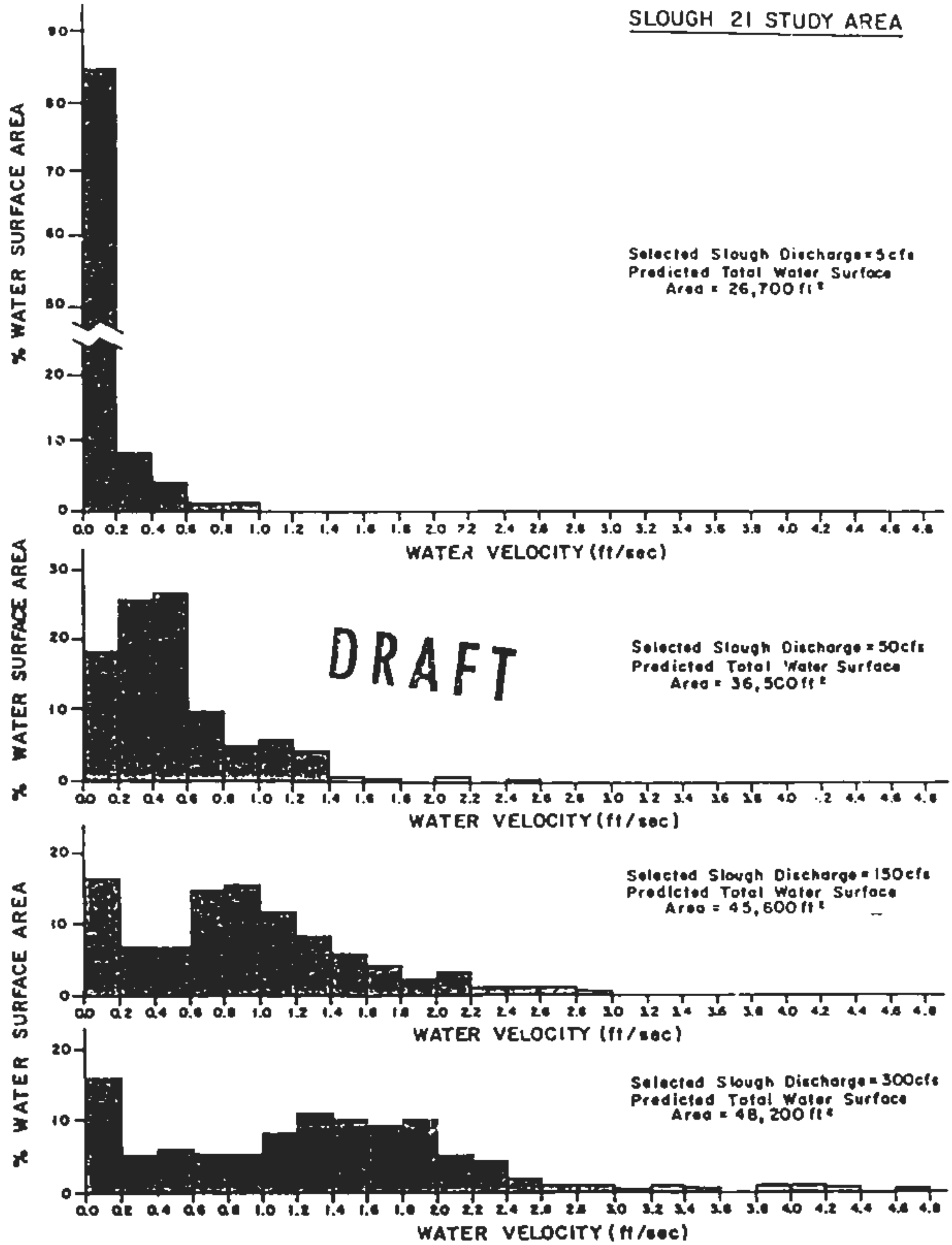

Figure D-8. Model-predicted frequency distribution of the water surface area of Slough 21 having associated water velocities at four selected discharges. Water velocity is expressed in 0.2 ft/sec increments.

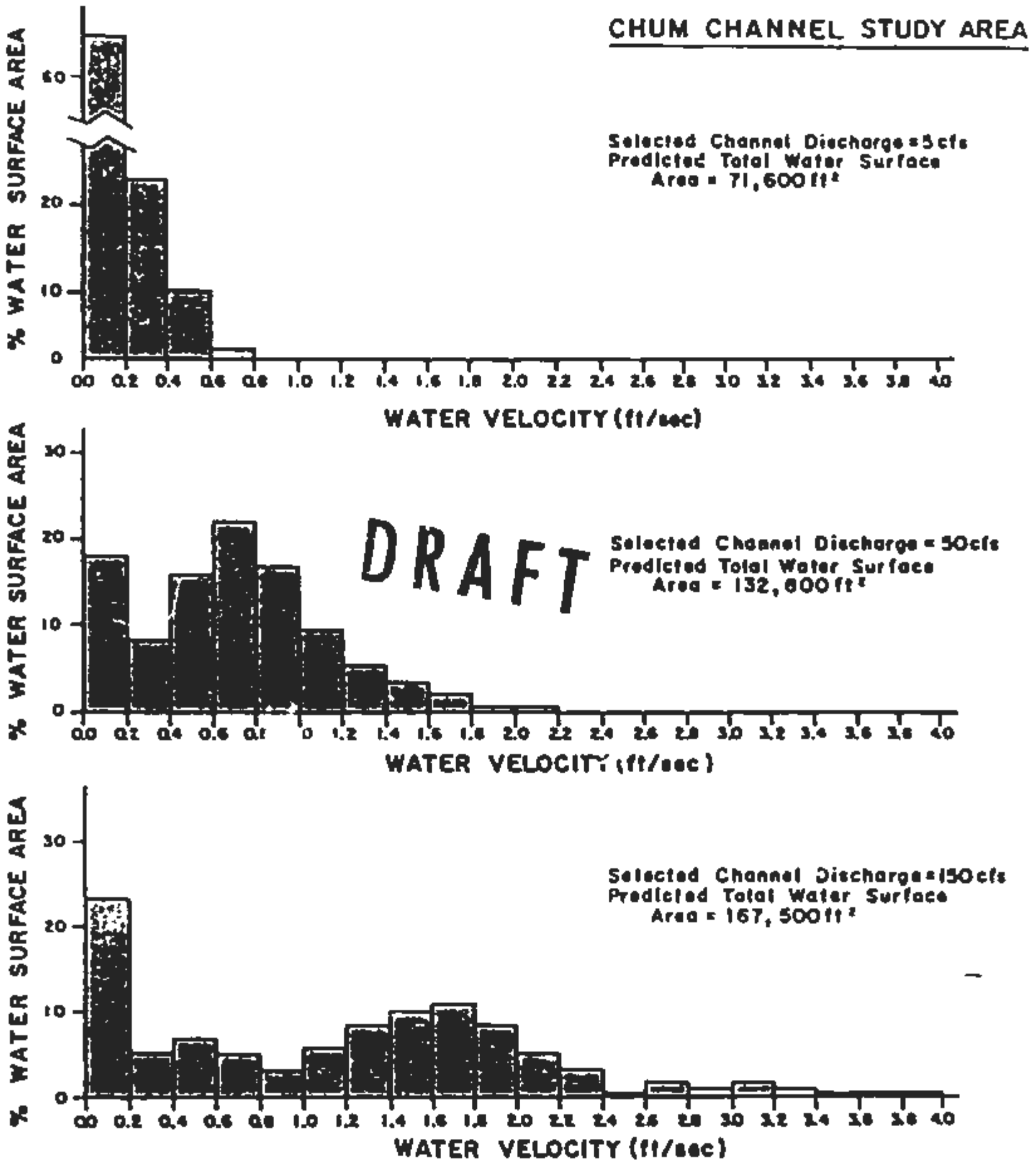

Figure D-9. Model-predicted frequency distribution of the surface water area of Chum Channel having associated water velocities at three selected discharges. Water velocity is expressed in 0.2 ft/sec increments.

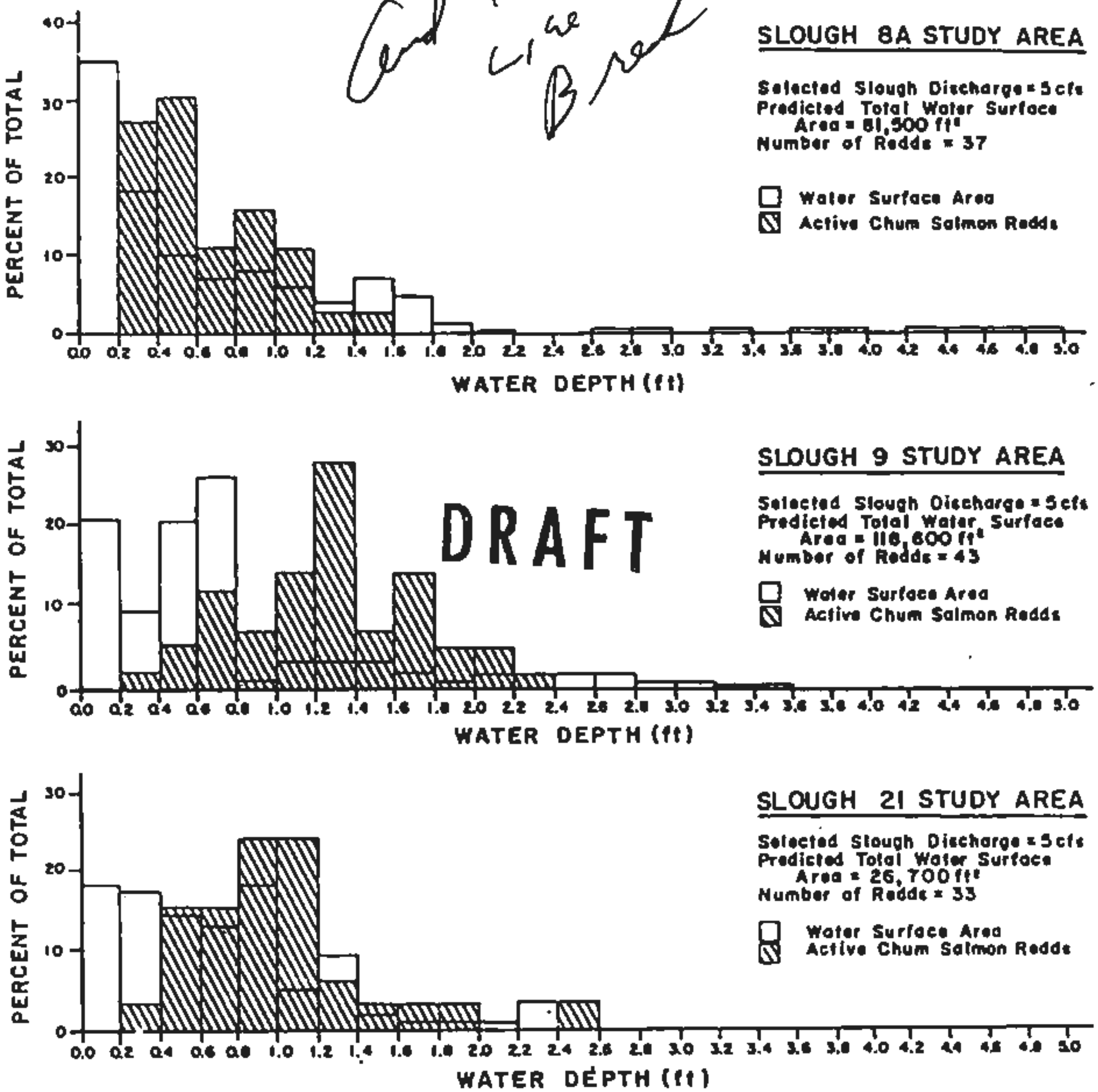

Figure D-10. Comparisons of the model-predicted water surface area at associated water depth frequency destribution with the frequency distribution of observed chum salmon redds versus their associated water depths for Slough 8A, 9 and 21.

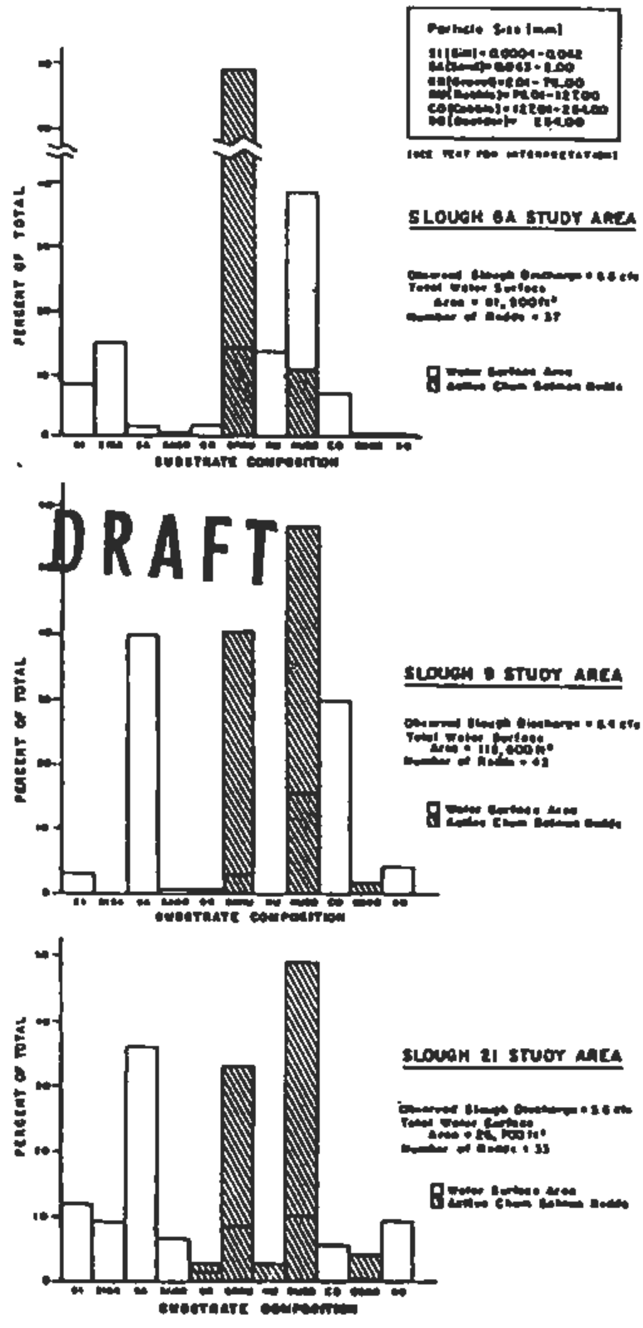

Figure D-11. Comparison of the observed water surface area versus associated substrate frequency distribution with the frequency distribution of observed chum salmon redds versus substrate composition for sloughs 8A, 9 and 21.

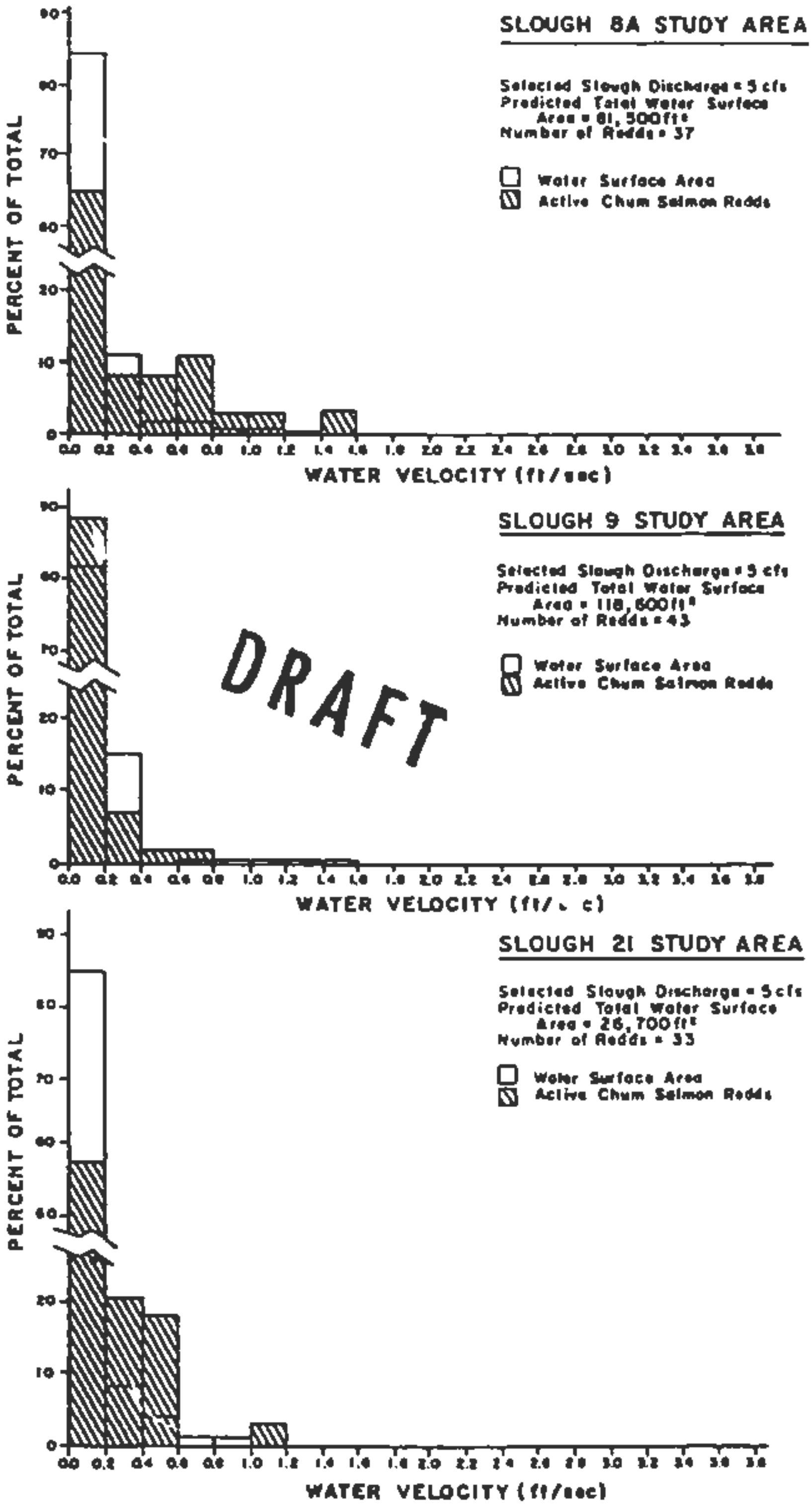

Figure D-12. Comparisons of the model-predicted water surface area versus associated water velocity with the frequency distribution of observed chum salmon redds versus their

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Table D-1. Calibration of water surface elevations and discharges at two flows for transects in Chum Channel.

Transect	Water Surface Elevation (ft)		Discharge (cfs)			Velocity Adjustment Factor
	Observed	Predicted	$\bar{X}$ Observed	Predicted	% Diff	
1	172.10	172.10	6.7	6.5	-3	1.0000
2	172.28	172.28	6.7	6.8	+1	1.0000
3	172.32	172.32	6.7	6.8	+1	.9995
4	172.32	172.32	6.7	6.7	0	.9862
5	172.35	172.35	6.7	7.1	+6	.9746
6	172.35	172.35	6.7	6.5	+3	.9977
7	172.50	172.50	6.7	6.8	+1	1.0000
8	172.66	172.66	6.7	6.5	-3	.9484
1	172.45	172.45	90.0	88.3	-2	.9879
2	172.72	172.72	90.0	90.8	+1	.9968
3	177.79	172.79	90.0	90.9	+1	.9960
4	172.81	172.81	90.0	89.0	-1	.9873
5	172.93	172.93	90.0	93.9	+4	1.0035
6	172.02	172.02	90.0	91.4	+2	.9992
7	173.10	173.10	90.0	92.1	+2	.9658
8	173.13	173.13	90.0	89.6	-1	.9971

Table D-2. Calibration of water surface elevations and discharges at three flows for transects in Slough 8A.

Transect	Water Surface Elevation (ft)		Discharge (cfs)			Velocity Adjustment Factor
	Observed	Predicted	$\bar{X}$ Observed	Predicted	% Diff	
1	565.47	565.50	4.0	4.1	+3	.9539
2	565.48	565.51	4.0	4.0	0	.9288
3	565.52	565.55	4.0	4.0	0	.9344
4	565.84	565.87	4.0	4.0	0	1.0043
5	566.01	566.02	4.0	4.0	0	.9124
6	566.05	566.06	4.0	4.1	+3	1.0036
7	566.31	566.32	4.0	4.0	0	1.0108
8	566.62	566.63	4.0	4.0	0	1.0060
9	567.20	567.21	4.0	4.0	0	.9866
10	567.20	567.21	4.0	4.0	0	.9851
11	567.20	567.21	4.0	4.0	0	.9884
1	565.65	565.60	7.00	7.1	+1	.9895
2	565.66	565.61	7.00	7.1	+1	.9746
3	565.69	565.64	7.00	7.1	+1	.9617
4	566.05	566.03	7.00	7.0	0	1.0076
5	566.13	566.13	7.00	7.0	0	.9740
6	566.15	566.15	7.00	7.1	+1	1.0146
7	566.37	566.37	7.00	7.0	0	.9833
8	566.68	566.68	7.00	7.0	0	1.0350
9	567.28	567.28	7.00	7.0	0	.9991
10	567.29	567.29	7.00	7.0	0	.9955
11	567.29	567.29	7.00	7.0	0	1.0107
1	565.76	565.80	20.05	20.1	+1	1.0206
2	565.77	565.81	20.05	20.1	+1	1.0082
3	565.80	565.84	20.05	20.1	+1	1.0086
4	566.37	566.38	20.05	20.2	+1	.9898
5	566.36	566.36	20.05	19.9	-1	1.0198
6	566.37	566.37	20.05	20.1	+1	.9867
7	566.48	566.48	20.05	20.0	0	1.0103
8	566.79	566.79	20.05	19.8	-1	1.0009
9	567.44	567.44	20.05	20.0	0	1.0048
10	567.46	567.46	20.05	20.0	0	1.0052
11	567.45	567.45	20.05	20.1	+1	.9920

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Table D-3. Calibration of water surface elevations and discharges at three flows for transects in Slough 9.

Transect	Water Surface Elevation (ft)		Discharge (cfs)			Velocity Adjustment Factor
	Observed	Predicted	X̄ Observed	Predicted	% Diff	
1	592.40	592.40	8.0	8.0	0	.9908
2	592.60	592.60	8.0	8.1	+1	1.0026
4	592.75	592.75	8.0	8.0	0	.9961
6	593.40	593.36	8.0	8.1	+1	1.0212
7	593.45	593.44	8.0	8.0	0	1.0117
8	593.40	593.39	8.0	7.9	-1	1.0054
9	593.50	593.50	8.0	8.2	+3	.9930
10	593.60	593.59	8.0	8.0	0	.9945
1	593.43	593.42	145.0	146.4	+1	1.0073
2	593.60	593.57	145.0	144.7	0	1.0148
4	593.60	593.65	145.0	145.3	0	1.0450
6	594.00	594.18	145.0	144.9	0	.9973
7	594.20	594.25	145.0	147.0	+1	1.0028
8	594.20	594.29	145.0	143.3	-1	1.0182
9	594.30	594.35	145.0	145.4	0	1.0221
10	594.30	594.37	145.0	144.7	0	1.0118
1	593.70	593.71	212.0	234.6	+1	.9903
2	593.80	593.83	212.0	231.0	0	.9987
4	594.00	593.94	212.0	212.6	0	.9848
6	594.50	594.36	232.0	231.4	0	.9621
7	594.50	594.45	123.0	235.9	+2	.9814
8	594.20	594.52	212.0	229.5	-1	.9798
9	594.60	594.56	212.0	231.8	0	.9920
10	594.60	594.54	212.0	231.4	0	.9893

Table D-4. Calibration of water surface elevations and discharges at three flows for transects in Slough 21.

Transect	Water Surface Elevation (ft)		Discharge (cfs)			Velocity Adjustment Factor
	Observed	Predicted	X̄ Observed	Predicted	% Diff	
3	744.23	744.28	5.0	5.0	0	1.0067
4	744.25	744.29	5.0	5.0	0	.9726
5	744.27	744.31	5.0	4.8	-4	1.0295
6	744.55	744.57	5.0	4.8	-4	.9952
7	744.74	744.77	5.0	5.0	0	.9655
3	744.60	744.50	10.0	10.0	0	.9951
4	744.59	744.51	10.0	10.0	0	.9990
5	744.61	744.51	10.0	9.7	-3	.9968
6	744.78	744.72	10.0	9.8	+2	1.1046
7	744.99	744.93	10.0	10.0	0	1.0641
3	745.84	745.90	157.0	156.8	0	.9906
4	745.85	745.90	157.0	156.2	-1	.9882
5	745.87	745.96	157.0	158.3	+1	.9562
6	745.89	745.94	157.0	157.8	+1	.9970
7	745.98	746.02	157.0	157.7	0	.9558

Table D-5. Comparison of observed and predicted water depths and velocities along Slough 8A Transect 1 at two slough flows: 4 and 20 cfs.[a]

	4 cfs				20 cfs			
	Depth (ft)		Velocity (ft/sec)		Depth (ft)		Velocity (ft/sec)	
Segment[b]	obs.	pred.	obs.	pred.	obs.	pred.	obs.	pred.
LWE 12	.40	.60	.00	.00	.70	.90	.05	.05
14	.80	.85	.00	.00	1.05	1.15	.05	.05
16	.90	.90	.10	.00	1.20	1.20	.10	.05
18	1.00	.95	.00	.00	1.20	1.25	.10	.05
20	1.00	1.00	.00	.00	1.30	1.30	.10	.05
22	1.00	1.00	.00	.02	1.30	1.30	.10	.11
24	1.05	1.10	.05	.02	1.40	1.40	.10	.11
26	1.20	1.25	.05	.04	1.40	1.55	.10	.12
28	1.30	1.35	.05	.04	1.50	1.65	.10	.12
30	1.45	1.40	.03	.04	1.70	1.70	.10	.12
32	1.40	1.40	.10	.03	1.70	1.70	.10	.11
34	1.50	1.45	.10	.04	1.65	1.75	.10	.13
36	1.60	1.50	.05	.04	1.80	1.80	.10	.12
38	1.55	1.55	.05	.04	1.80	1.85	.10	.12
40	1.60	1.60	.00	.06	1.90	1.90	.20	.18
42	1.65	1.60	.05	.06	1.80	1.90	.20	.18
44	1.60	1.60	.05	.06	1.85	1.90	.30	.30
46	1.60	1.60	.05	.06	1.90	1.90	.20	.25
48	1.60	1.55	.10	.08	1.90	1.85	.35	.32
50	1.55	1.50	.05	.07	1.80	1.80	.30	.32
52	1.50	1.50	.05	.10	1.80	1.80	.40	.32
54	1.50	1.50	.05	.10	1.70	1.80	.45	.37
56	1.50	1.45	.05	.07	1.75	1.75	.30	.32
58	1.40	1.35	.05	.06	1.65	1.65	.30	.30
60	1.25	1.20	.05	.06	1.50	1.50	.35	.35
62	1.10	1.05	.00	.06	1.35	1.35	.30	.30
64	1.00	.95	.00	.06	1.20	1.25	.25	.26
66	.95	.90	.05	.06	1.30	1.20	.20	.20
68	.95	.90	.00	.06	1.30	1.20	.20	.20
70	.95	.85	.00	.09	1.30	1.15	.20	.20
72	.85	.80	.00	.07	1.10	1.10	.20	.13
74	.90	.80	.00	.03	1.10	1.10	.20	.12
76	.80	.80	.00	.03	1.10	1.10	.15	.12
78	.85	.75	.00	.01	1.00	1.05	.15	.07
80	.80	.65	.00	.01	1.00	.95	.10	.07
82	.60	.60	.00	.01	.90	.90	.10	.07
84	.65	.55	.00	.01	1.00	.85	.10	.07
86	.50	.45	.00	.01	.80	.75	.10	.07
88	.45	.35	.00	.00	.65	.65	.05	.05
90	.30	.20	.00	.00	.60	.50	.00	.05
RWE 92	.10	.05	.00	.00	.40	.30	.00	.05
94					.20	.15	.00	.11
RWE 96					.00	.05	.00	.00
	r = .99		r = .35		r = .99		r = 1.00	

[b]Distance (ft) along transect from left bank head pin. LWE and RWE are left and right water's edge at the two discharges.

Table D-6. Comparison of observed and predicted water depths and velocities along Chum Channel Transect 5 at two slough flows: 6.7 and 90 cfs.[a]

	6.7 cfs				90 cfs			
	Depth (ft)		Velocity (ft/sec)		Depth (ft)		Velocity (ft/sec)	
Segment[b]	obs.	pred.	obs.	pred.	obs.	pred.	obs.	pred.
LWE 24					.00	.08	.00	.04
26					.10	18	.10	.10
28					.20	.28	.60	.51
30					.30	.38	.80	.81
32					.40	.48	1.30	1.29
34					.50	.53	1.30	1.32
LWE 35.2	.00		.00					
36		.08		.00	.60	.63	1.90	1.40
37	.10		.00					
38		.15		.58	.60	.73	1.90	1.73
39	.20		.20					
40		.25		.24	.80	.83	1.80	1.81
41	.30		.30					
42		.45		.29	1.00	1.03	2.10	2.11
43	.50		.30					
44		.60		.29	1.20	1.18	2.20	2.21
45	.50		.30					
46		.65		.39	1.30	1.23	2.20	2.21
47	.70		.50					
48		.75		.49	1.30	1.33	2.40	2.41
49	.70		.50					
50		.85		.44	1.40	1.43	2.50	2.51
51	.70		.40					
52		.85		.39	1.50	1.43	2.30	2.31
53	.70		.40					
54		.85		.39	1.50	1.43	2.30	2.31
55	.70		.40					
56		.80		.44	1.50	1.38	2.20	2.21
57	.70		.50					
58		.75		.44	1.40	1.33	2.20	2.21
59	.60		.40					
60		.70		.39	1.40	1.28	2.10	2.11
61	.50		.40					
62		.60		.34	1.20	1.18	2.20	2.21
63	.50		.30					
64		.50		.39	1.20	1.18	2.00	2.01
65	.40		.30					
66		.40		.24	1.10	.98	2.00	2.01
67	.30		.20					
68		.20		.24	1.00	.78	1.80	1.81
69	.10		.00					
70		.03		.26	.70	.58	1.30	1.57
RWE 71	.00		.00					
72		.00		.00	.50	.53	1.30	1.40
74					.50	.48	1.30	1.32
76					.40	.48	1.10	1.12
78					.50	.48	.90	.90
80					.40	.38	.70	.71
82					.30	.28	.50	.50
84					.20	.23	.40	.39
86					.20	.23	.50	.50
88					.20	.16	.40	.40
90					.10	.13	.20	.20
92					.10	.08	.20	.20
RWE 94					.00	.02	.00	.08
	r = .98		r = .57		r = .99		r = .99	

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[b]Distance (ft) along transect from left bank head pin. LWE and RWE are left and right water's edge at the two discharges.

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APPENDIX E

Effects of mainstem Susitna discharge on total wetted and backwater surface areas at selected study sites

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Introduction

This appendix provides additional information concerning the response of backwater surface areas to changes in mainstem discharge. Wetted surface areas which were larger than the backwater areas present at the slough and tributary locations sampled, are presented. These larger areas are referred to as the total wetted surface areas. A discussion concerning the relationship between the backwater and total wetted areas, and some data on the abundance of morphological pools at these study sites is also presented.

Methods

Fourteen slough and tributary mouths, between Susitna River miles 73.1 and 142.0, were visited twice monthly from the beginning of June to the end of September during 1982. Maps were drawn of the wetted surfaces present at each site, for each sampling. The total wetted and backwater surface areas represented on the maps were digitized after ensuring that the mapped boundaries were identical from trip to trip.

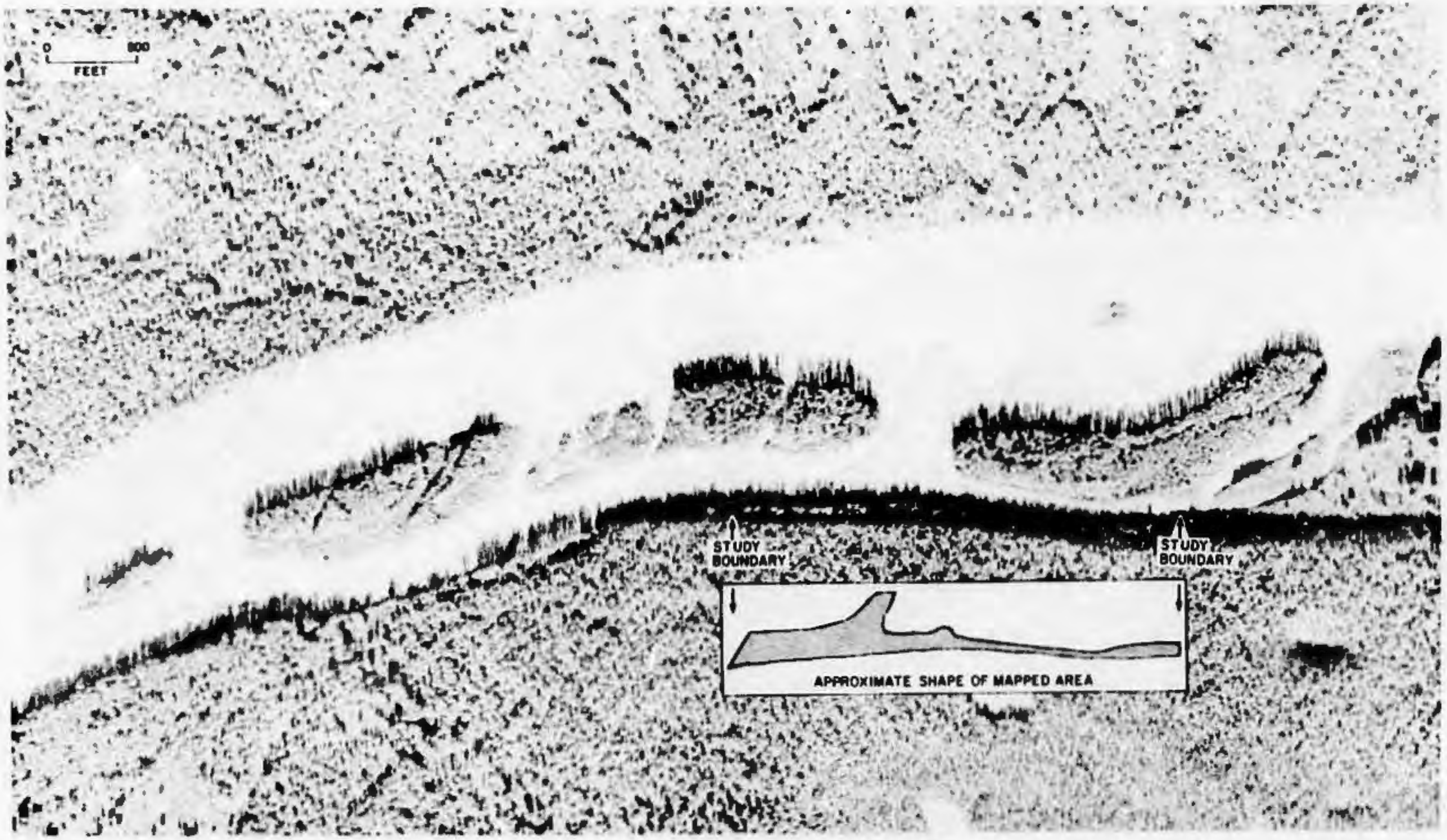
Details of the methodology are described in the Basic Data Report, Volume 4, Part I ADF&G, 1983. A detailed narrative describing each study site is available in Appendix F, Volume 4 of the Basic Data Report.

Aerial photographs of each of the study sites are presented as Appendix Plates E-1 to E-14. The sampling boundaries illustrated in these photographs bracket those reaches of each site where the surface area measurements were taken. The entire wetted surface found within this area during each sampling is termed the "total" wetted surface area. Inspection of the photographs will provide an indication of the level of abstraction involved if the reader associates the total wetted surface areas reported with the larger physical or hydraulic features of some of these habitat areas.

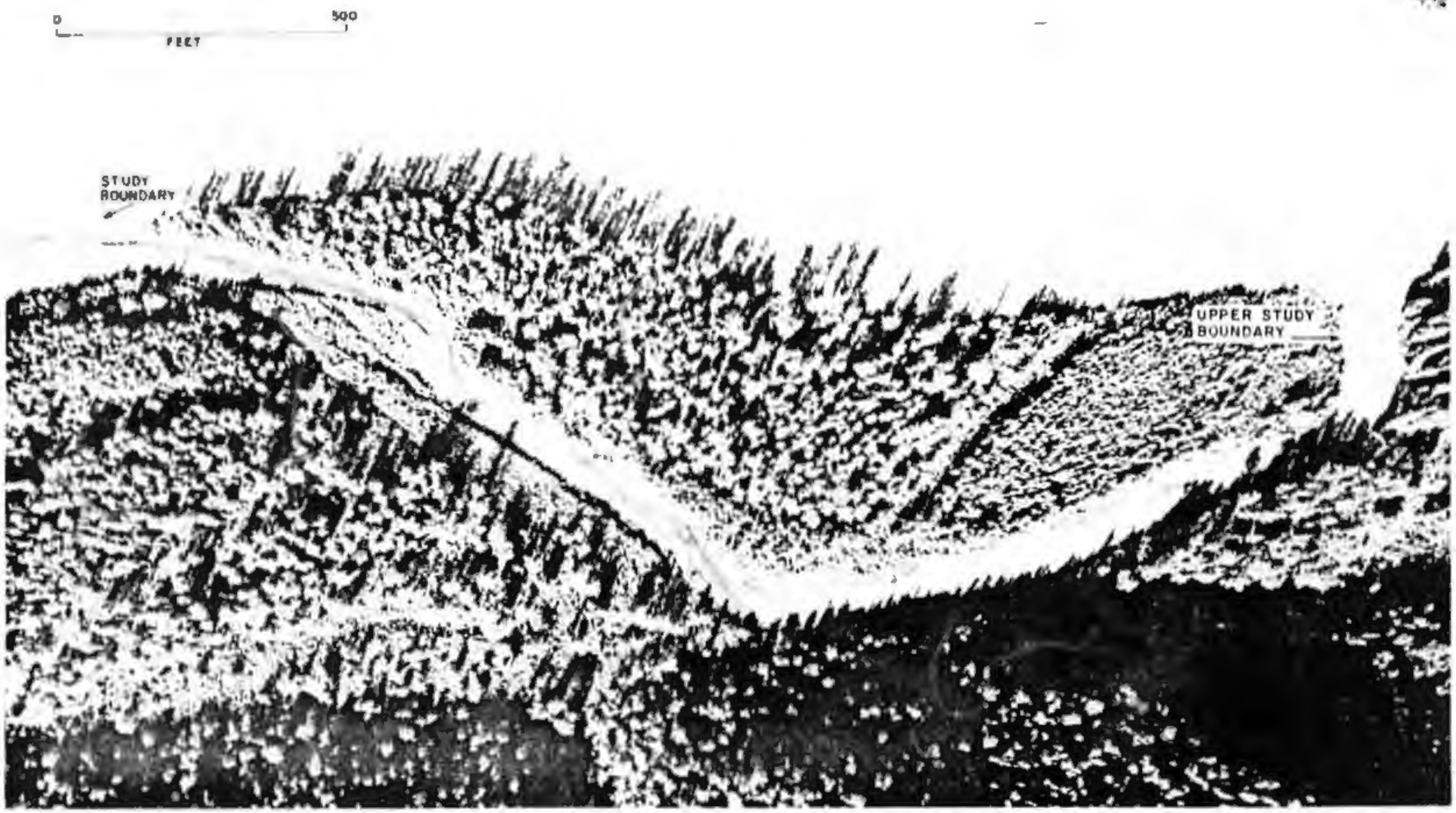
Some changes have been made in defining the "study" boundaries at the Sunshine Creek, Slough 9, Lane and Goose Creek sites from those defined in the Basic Data Report. At the Lane and Goose Creek sites, the creek portion of the sites has been omitted because mapping of this area was not always complete. At the Slough 9 location, maps of the upper half of the study area were not made during low water samplings. Thus, the upper half of the area was omitted from consideration.

At the Sunshine site, a section of the previously defined study area was also deleted due to inconsistent mapping of the uppermost reaches of the creek. As a result, 15,000 ft^2 at 60,100 cfs and 24,000 ft^2 at 82,400 cfs (of the true total) backwater area present during the July samplings was omitted in this study in order to obtain comparable total and backwater area measurements.

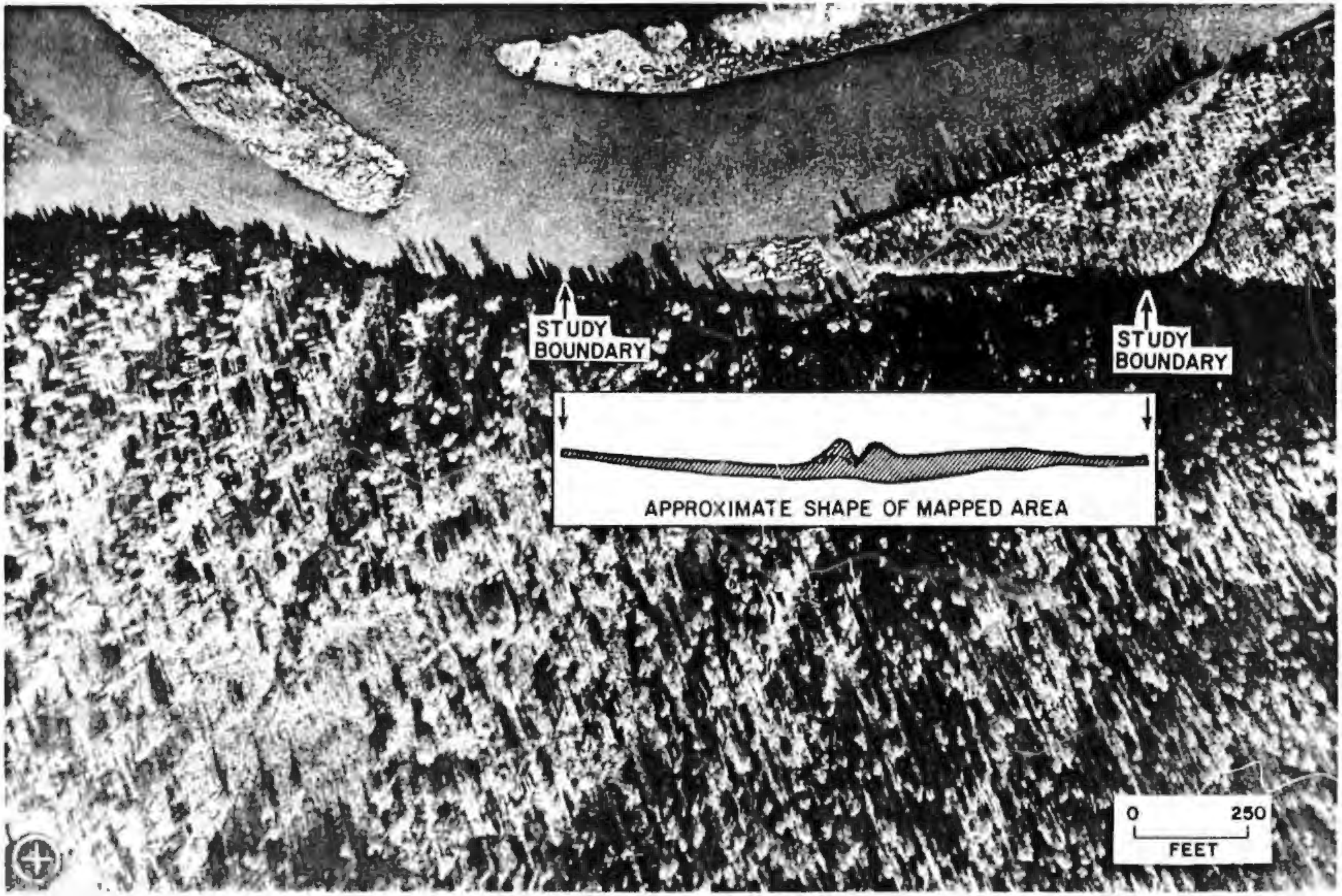
In general, the sampling boundaries at each site were chosen to encompass the backwater areas present over the range of flows sampled,



Appendix Plate E-1. August 1980 photograph of Slough 21 (RM 142.0). The surface area measurements reported are for the slough between the study boundaries shown.

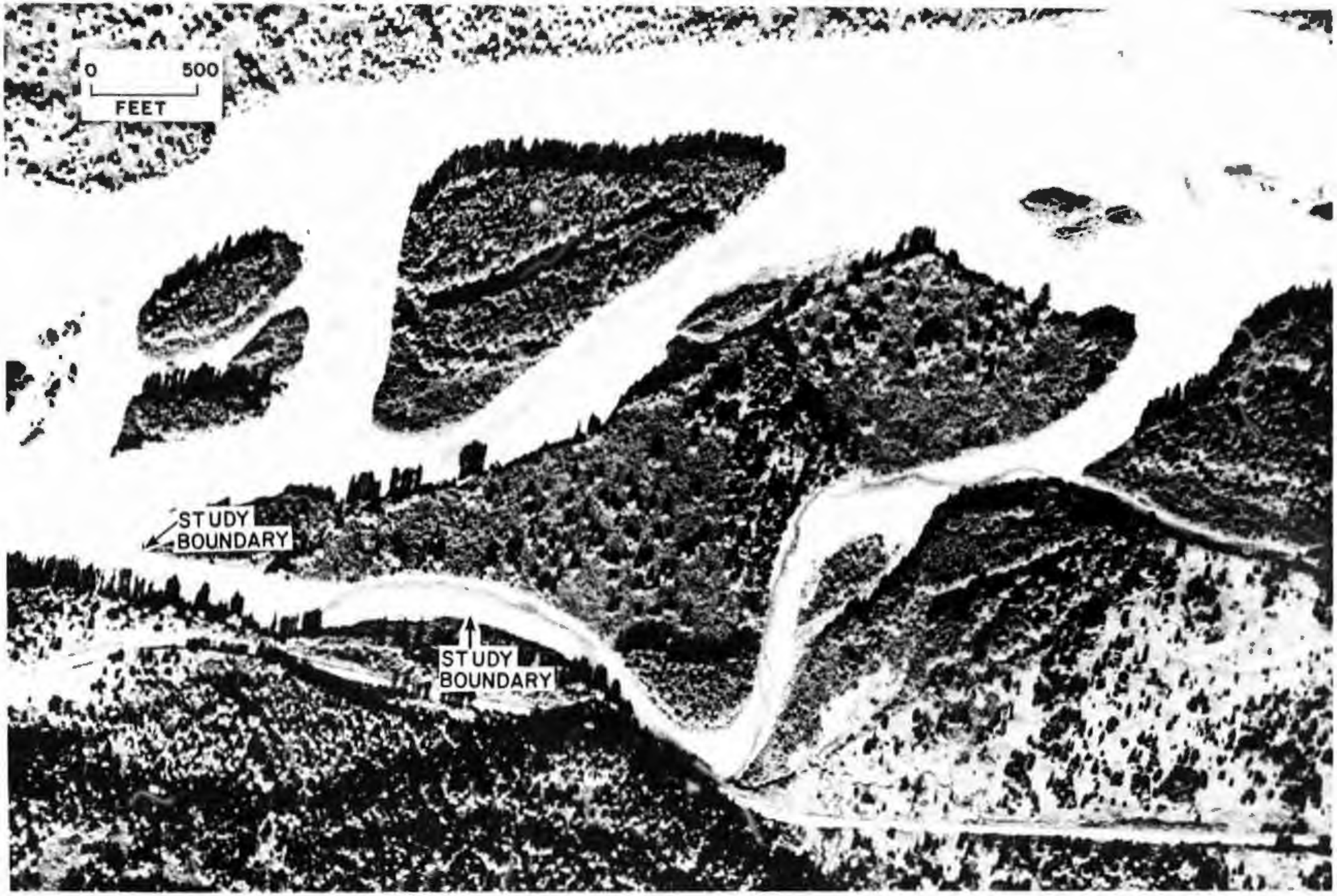


Appendix Plate E-2. August 1982 photograph of Slough 20 (RM 140.1). The surface area measurements reported are for the slough between the study boundaries shown.

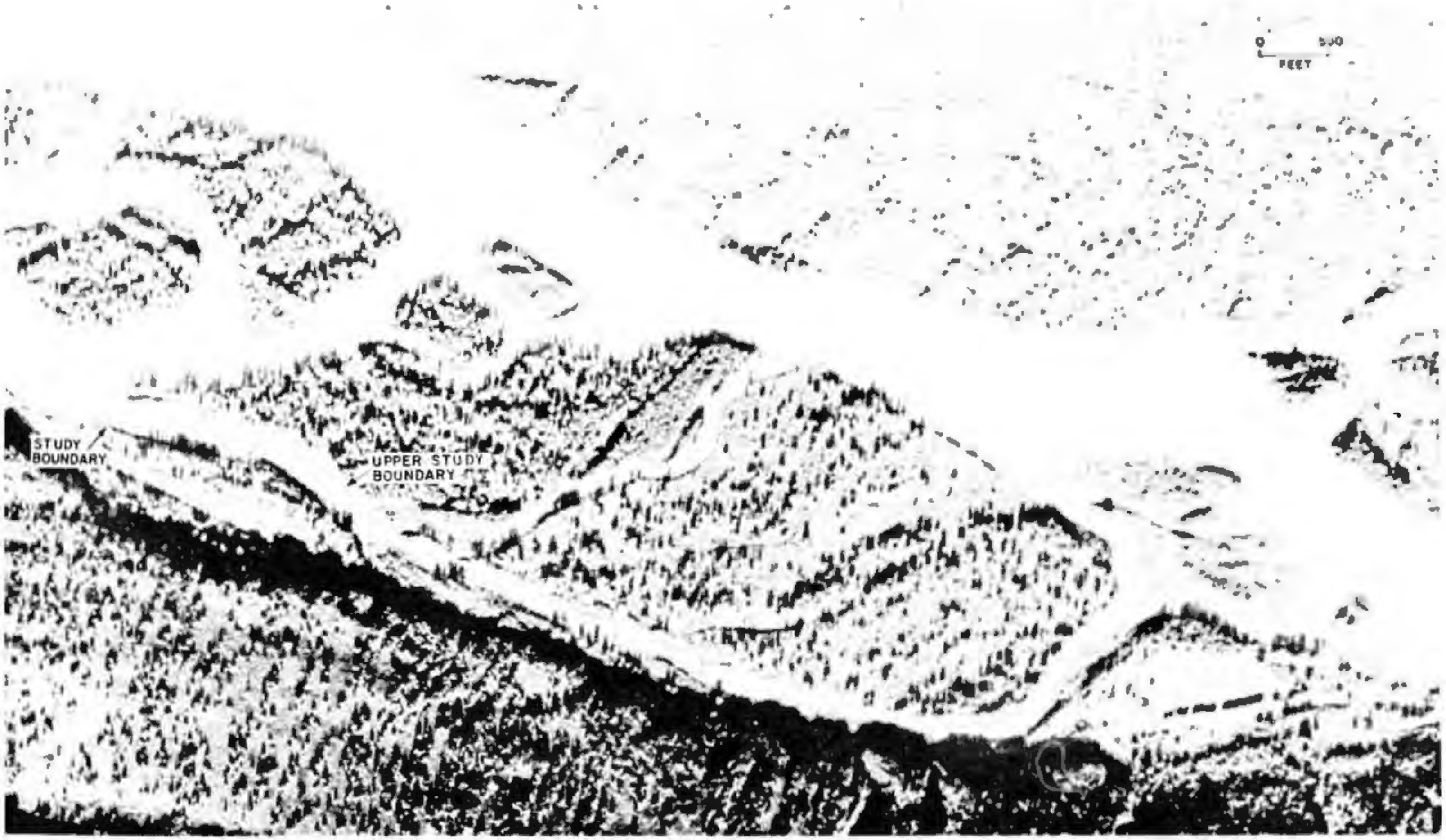


Appendix Plate E-3. May 1982 photograph of Slough 19 (RM 140.0). The surface area measurements reported are for the slough and its immediately downstream reach between the study boundaries shown.

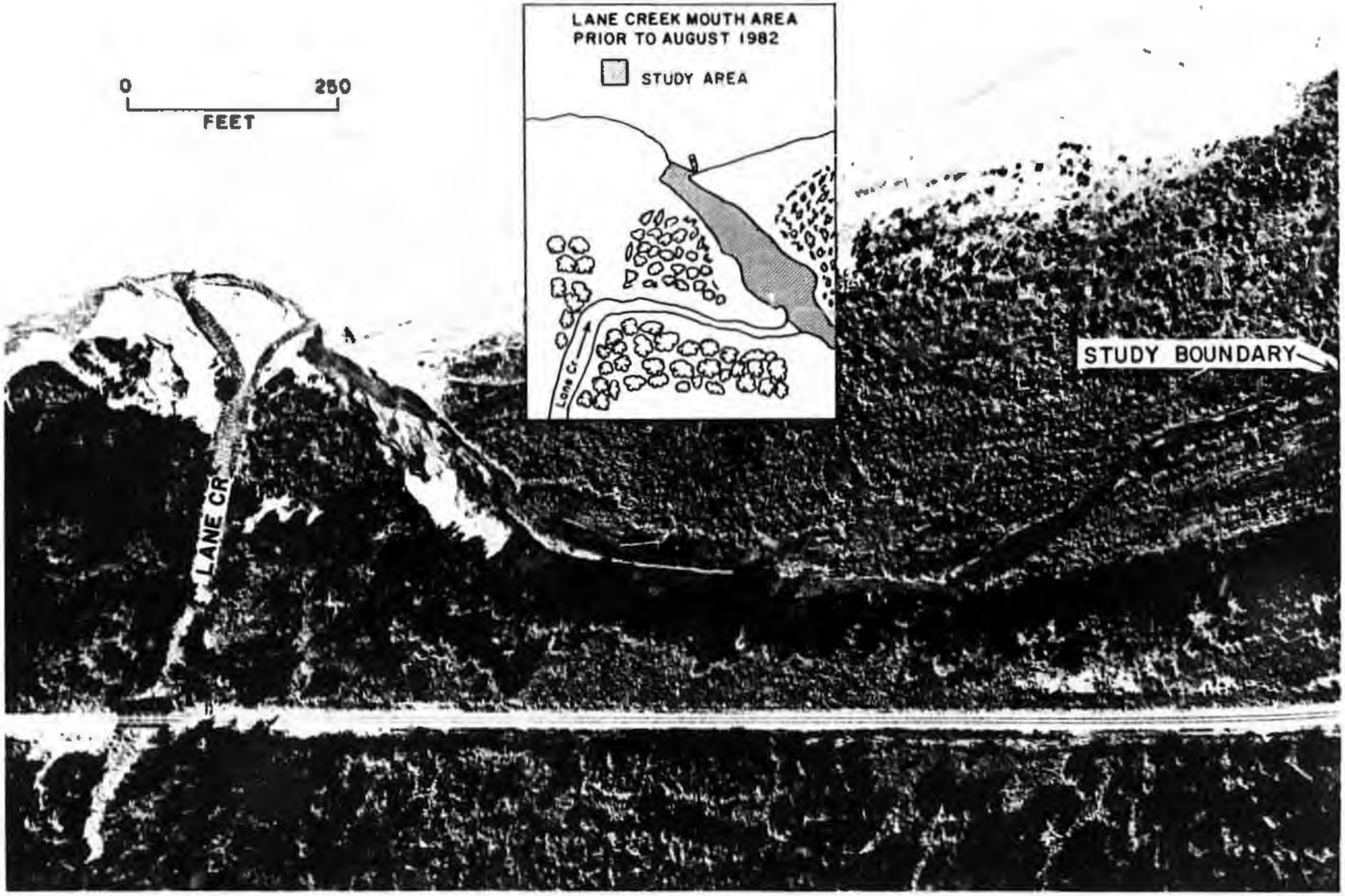
Appendix Plate E-4. August 1980 photograph of Slough 11 (RM 135.3). The surface area measurements reported are for the slough between the study boundaries shown.



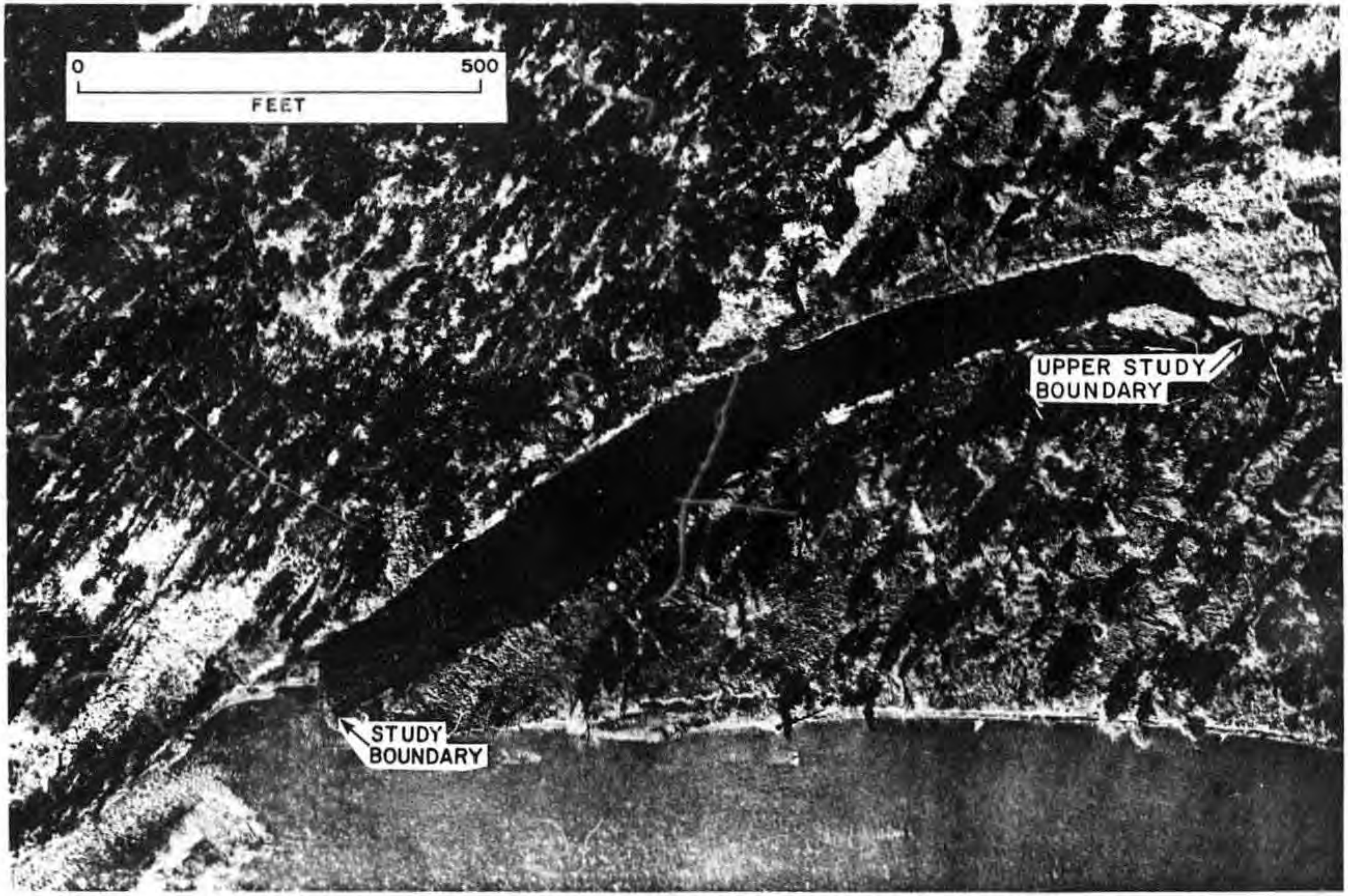
Appendix Plate E-5. August 1980 photograph of Slough 9 (RM 129.2). The surface area measurements reported are for the slough between the study boundaries shown.



Appendix Plate E-6. August 1980 photograph of Slough 8A (RM 125.3). The surface area measurements reported are for the slough between the study boundaries shown.

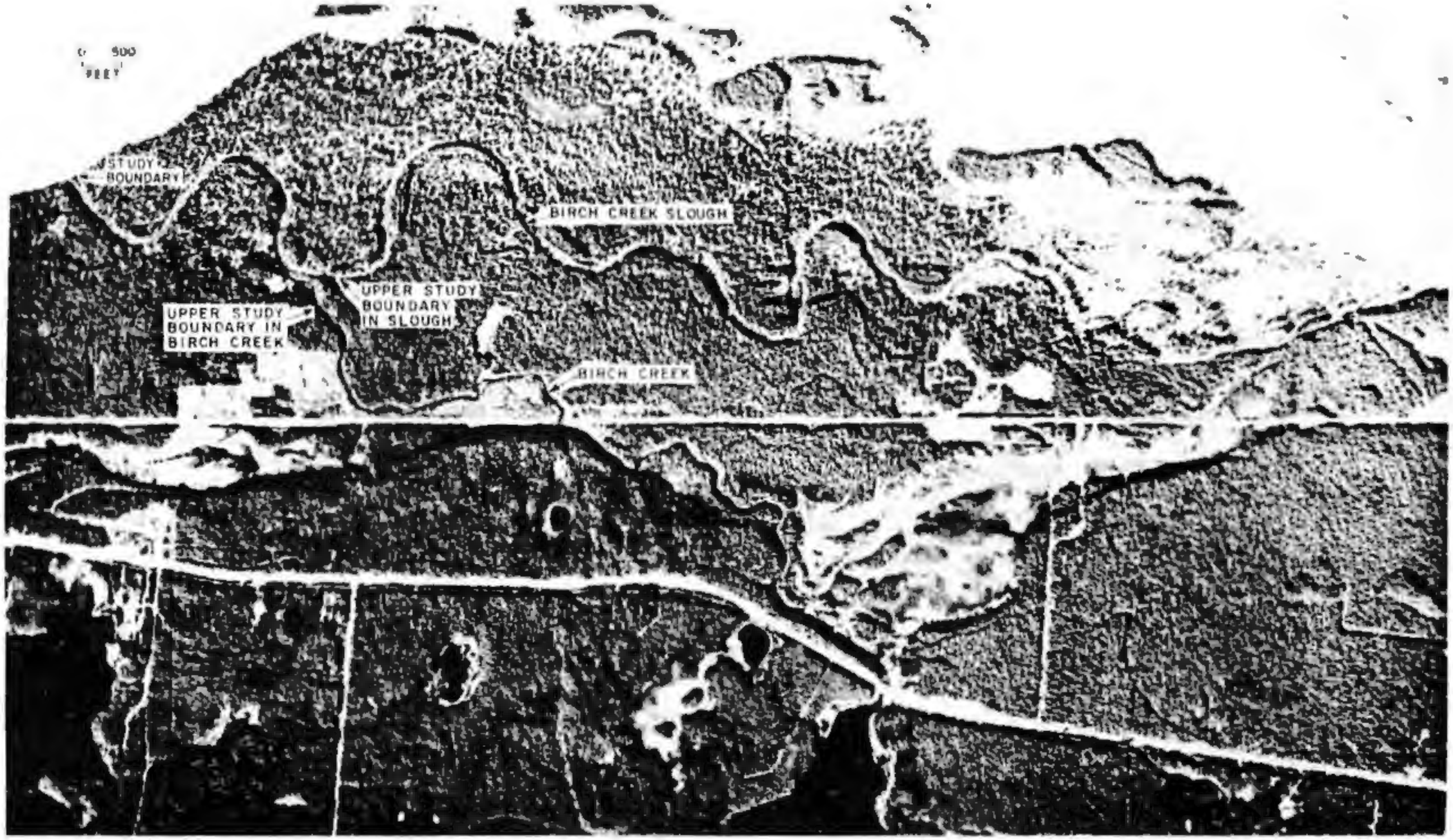


Appendix Plate E-7. August 1982 photograph of Lane Creek mouth and Slough 8 (RM 113.6). The surface area measurements reported are for the slough between its mouth (see inset) and the upper boundary shown.

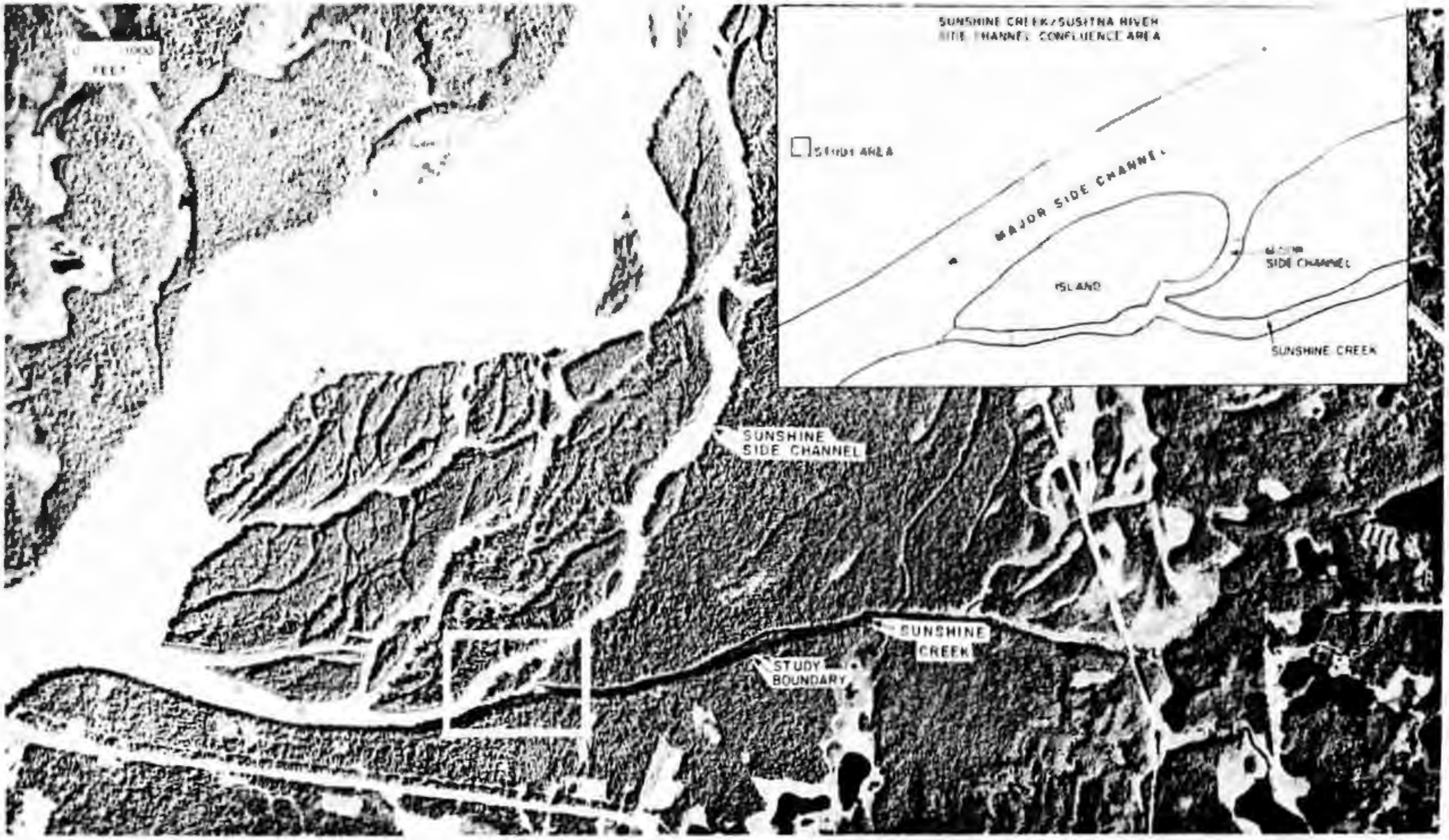


Appendix Plate E-8. May 1982 photograph of Slough 6A (RM 112.3). The surface area measurements reported are for the slough between the study boundaries shown.

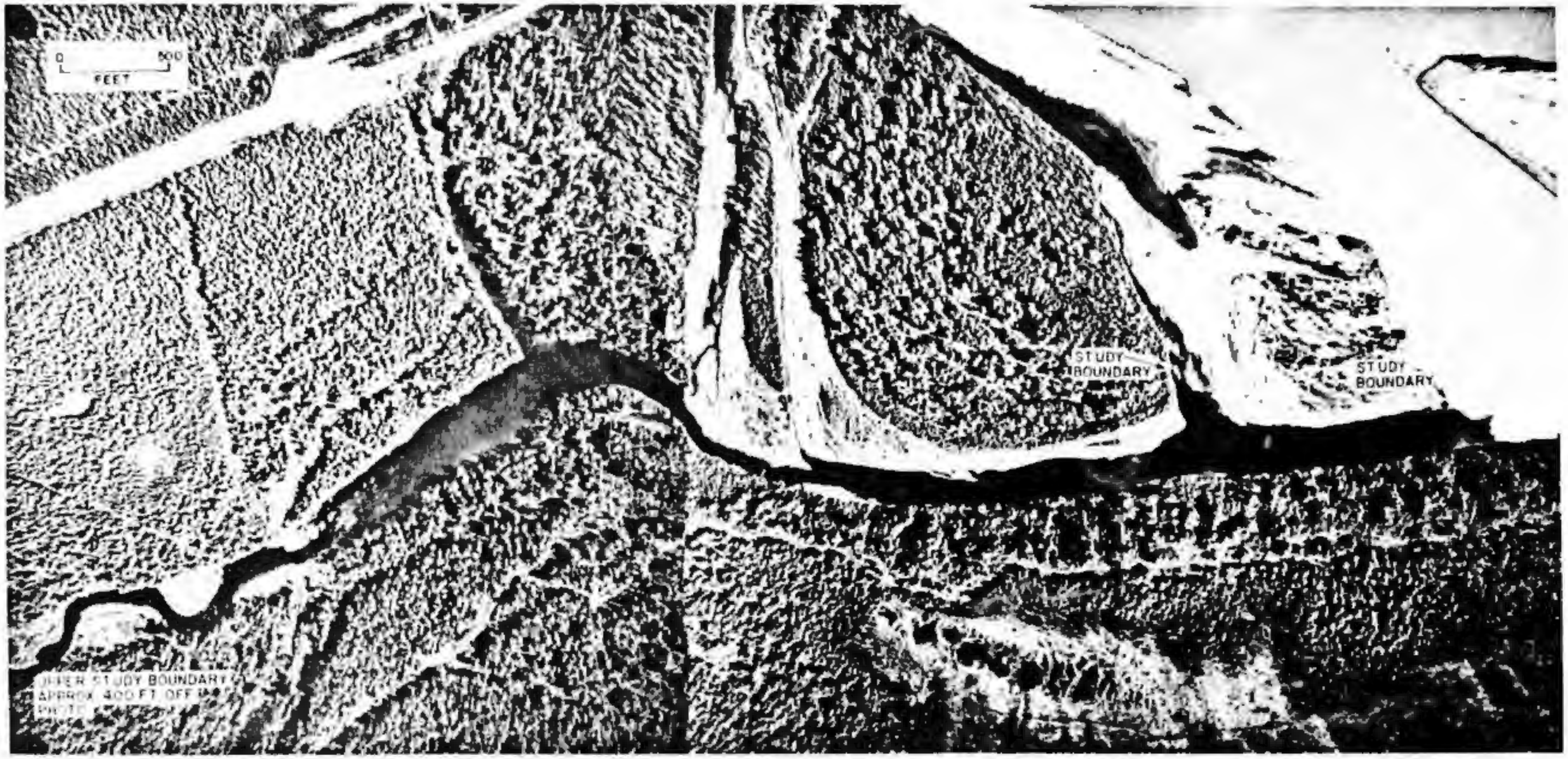
Appendix Plate E-9. May 1982 photograph of Whiskers Creek and Slough (RM 101.2). The surface area measurements reported are for the creek and slough between the study boundaries shown.



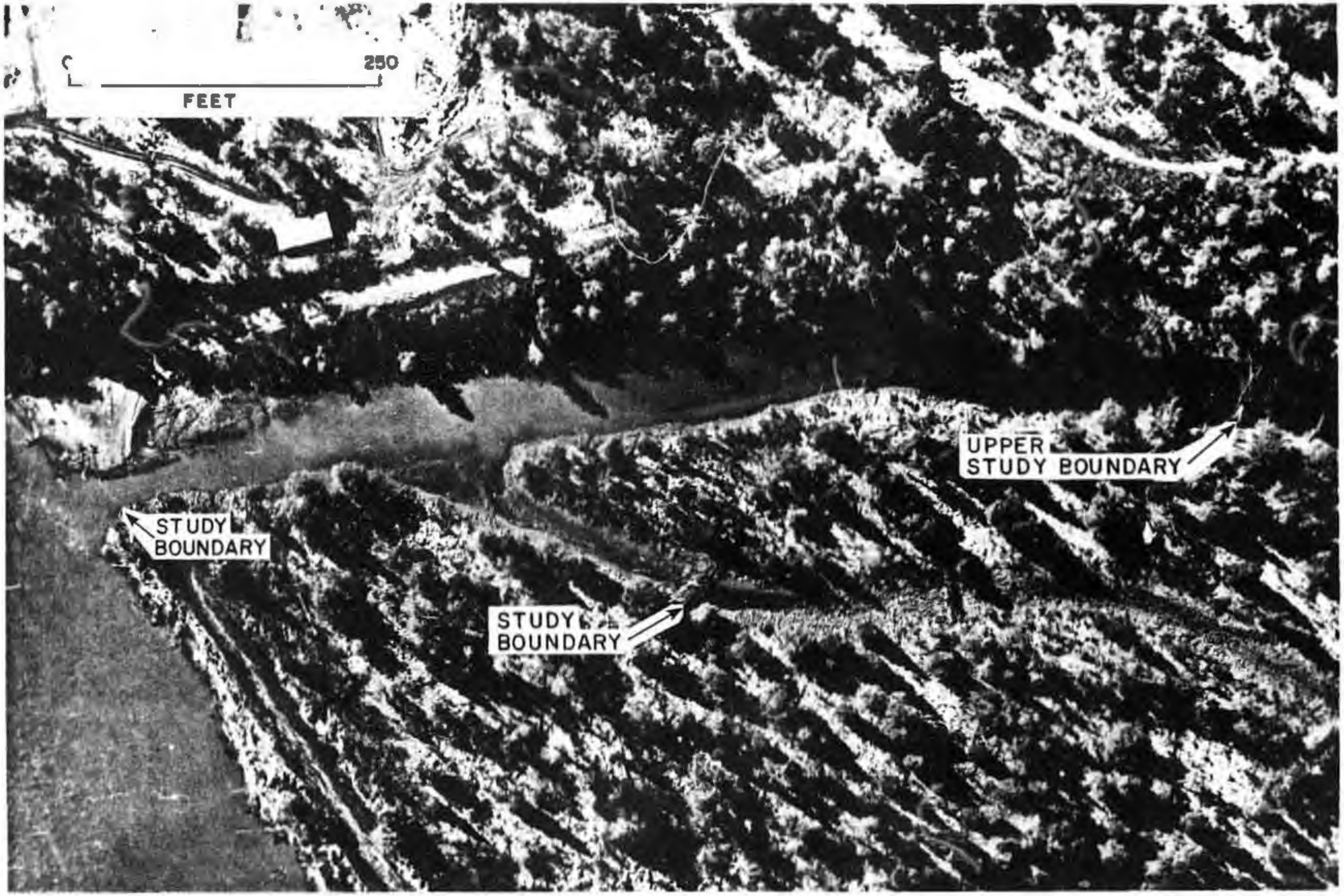
Appendix Plate E-10. August 1980 photograph of Birch Creek and Slough (RM 88.4). The surface area measurements reported are for the creek and slough between the study boundaries shown.



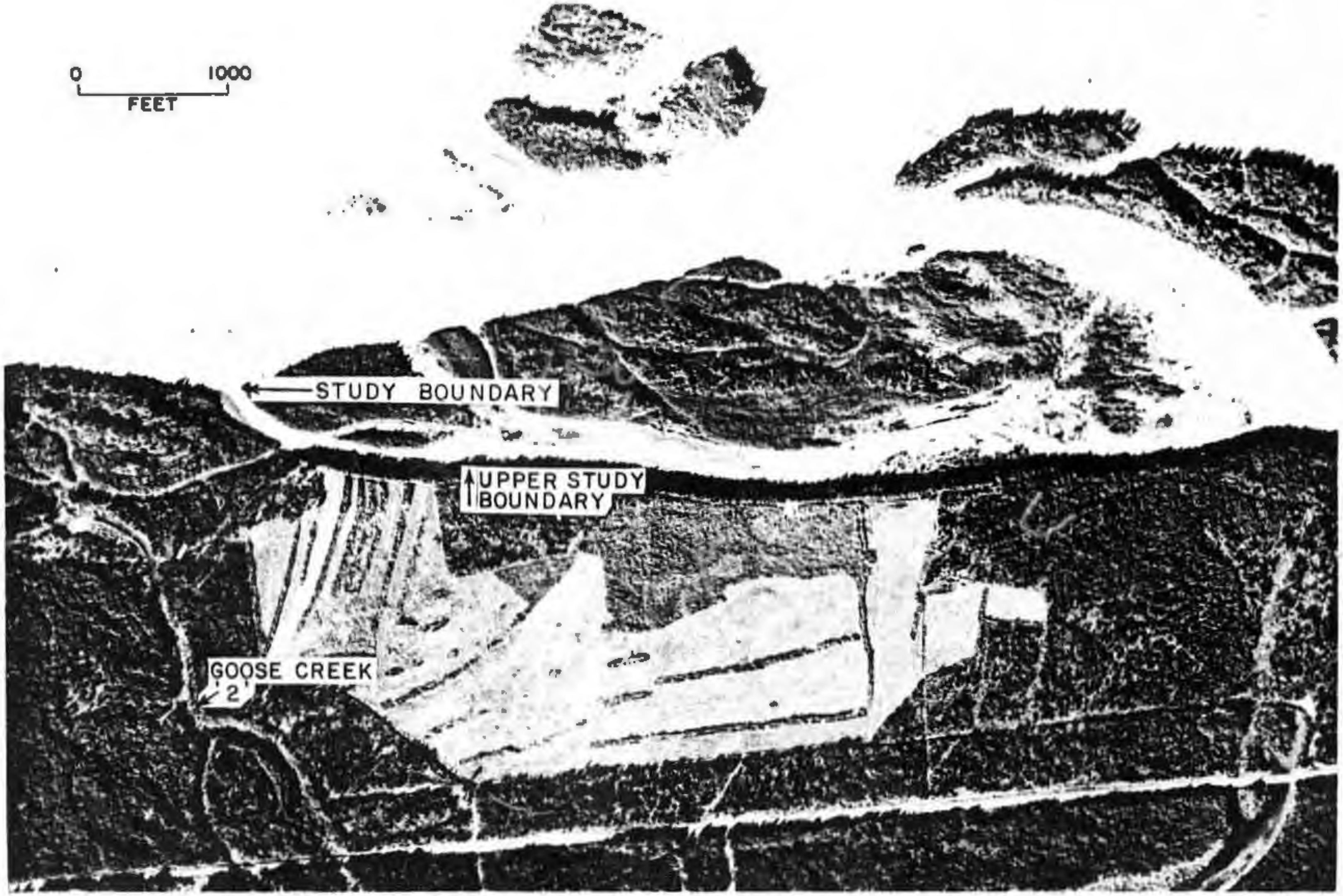
Appendix Plate E-11. August 1980 photograph of Sunshine Creek and Side Channel (RM 85.7). The surface area measurements reported are for the creek and slough areas shown in the inset and the creek above to the study boundary shown.



Appendix Plate E-12. August 1982 photograph of Rabideux Creek and Slough (RM 83.1). The surface area measurements reported are for the site between the study boundaries shown and a point on the creek about 400 ft. off the photograph.



Appendix Plate E-13. May 1982 photograph of Whitefish Slough (RM 78.7). The surface area measurements reported are for the slough between the study boundaries shown.



Appendix Plate E-14. August 1980 photograph of Goose Creek 2 and Side Channel (RM 73.1). The surface area measurements reported are for the slough between the study boundaries shown.

and as much additional free flowing slough or tributary water as was necessary for the fish collection aspect of the study.

Results

Appendix Table E-1 presents by two weeks intervals between June and September, 1982, the backwater and total wetted surface areas mapped within the boundaries at Designated Fish Habitat locations. Surface areas are tabulated with the corresponding mean daily discharge reported for the Gold Creek or Sunshine gaging station. Plots of the total wetted surface areas versus mainstem discharge are found as Appendix Figures E-1 to E-14. At most sites, the relationship between total wetted surface area and discharge was plotted by fitting least squares linear regressions to the data. For Whitefish Slough and Slough 21, a hand drawn curve was best fitted to the data. The relationship between backwater surface area and discharge is replotted in the manner developed previously (Volume 4, Part I, Basic Data Report) on a site by site basis.

Discussion

Even though sampling was centered around slough and tributary reaches where mainstem backwater zones were a dominant feature, a very diverse set of hydraulic and physical habitats were sampled. The total wetted surface areas measured decreased with decreasing mainstem discharges. The wetted surface areas of the upper portions of several sites were greatly reduced as flows declined, and the habitat (types) present in

Appendix Table E-1. Total wetted and aggregate type II (backwater) surface areas of selected regions of Designated Fish Habitat (DFH) sites, and mainstem Susitna River discharges[a], June through September, 1982.

DFH Site	Discharge cfs[a]	Date	Total Wetted Surface Area (Ft²)	Surface Area Type II (Ft²)
Slough 21[b]	31,900	7/25	316,000	72,800
	28,500[c]	6/19	203,000	16,300
	24,000	7/11	166,000	0
	17,000	8/09	160,000	73,600
	13,800	9/27	89,000	48,200
	12,500	8/20	96,000	47,300
	12,200	9/06	99,000	61,200
Slough 20	33,250[c]	6/20	139,000	20,600
	26,800	7/24	137,000	0
	23,000	6/04	115,000	0
	16,500	8/07	68,900	0
	14,400	9/04	68,900	500
	14,000	9/26	69,700	---[e]
	12,500	8/20	55,700	1,800
Slough 19	24,900	7/23	46,000	24,000
	22,000	6/17	30,000	10,000
	22,000	6/05	39,000	16,500
	16,800	8/06	29,000	12,300
	16,600	7/07	25,000	4,800
	15,000	9/25	20,000	0
	14,400	9/04	17,000	0
	13,300	8/19	15,000	4,200
Slough 11	33,250[c]	6/20	153,000	128,000
	27,300	7/14	135,000	92,800
	23,600	7/29	155,000	124,000
	23,000	6/04	132,000	95,000
	14,400	8/12	69,000	25,600
	12,400	9/29	50,000	19,300
	12,200	9/06	68,000	25,300
	12,200	8/22	53,000	23,700

[a]USGS provisional data at Gold Creek, 1982, 15292000.

[b]June 10, 1982, data for Slough 21 incomplete.

[c]Amended mainstem discharge at Gold Creek as determined from ADFG stage discharge curve.

[e]No backwater area mapped. A very small area probably existed.

Appendix Table E-1 (Contir ied).

DFH Site	Discharge cfs[a]	Date	Total Wetted Surface Area (Ft²)	Surface Area Type II (Ft²)
Slough 9	31,500	6/22	269,000	---[b]
	29,100	7/27	321,000	0
	28,400	7/13	305,000	0
	26,000	6/10	298,000	---[b]
	19,400	9/23	168,000	118,000
	16,700	8/10	185,000	133,000
	12,200	8/21	134,000	0
	11,700	9/07	172,000	0
Slough 8A	28,000	6/08	223,000	210,000
	26,500	7/12	218,000	202,000
	26,500[c]	6/23	223,000	210,000
	25,600	7/28	257,000	205,000
	17,100	9/24	169,000	143,000
	15,400	8/11	220,000	193,000
	12,200	8/21	185,000	158,000
	11,700	9/07	182,000	155,000
Lane Creek	28,500[c]	6/19	57,000	48,200
	25,000	6/07	61,000	45,000
	22,400	7/22	45,000	14,400
	18,100	7/08	54,000	14,700
	16,600	8/08	37,000	12,700
	15,000	9/25	32,000	8,000
	1[illegible],400	9/10	38,000	9,400
	12,500	8/20	36,000	6,100
Slough 6A	33,250[c]	6/20	138,000	138,000
	24,900	7/23	135,000	135,000
	23,000	6/06	131,000	131,000
	21,500	7/09	134,000	134,000
	16,600	8/08	131,000	131,000
	14,400	9/10	129,000	129,000
	14,000	9/26	131,000	131,000
	12,200	8/21	127,000	127,000

[a] USGS provisional data at Gold Creek, 1982, 15292000.

[b] June 10 and June 22 data for Slough 9 incomplete.

[c] Amended mainstem discharge at Gold Creek as determined from ADFG stage discharge curve.

Appendix Table E-1 (Continued).

DFH Site	Discharge cfs[a]	Date	Total Wetted Surface Area (Ft²)	Surface Area Type II (Ft²)
Whisker Creek and Slough	37,000[g]	6/21	217,000	76,000[b]
	31,900	7/25	236,000	56,000[b]
	25,000	6/03	217,000	160,000[c]
	23,000	7/10	213,000	83,900
	16,600	8/08	163,000	46,600
	13,800	9/27	190,000	---[d]
	13,400	9/0,	195,000	29,200
	12,200	8/22	150,000	28,500
Birch Creek and Slough	99,300	7/26	458,000	424,000
	61,600	6/23	388,000	354,000
	59,700	6/04	394,000	359,000
	58,400	7/11	422,000	398,000
	52,500	8/09	370,000	157,000
	38,000	8/23	362,000	147,000
	35,900	9/28	376,000	59,500
	33,800	9/11	363,000	81,900
Sunshine Creek and Sidechannel	82,400[e]	7/27	332,000	218,000[f]
	70,200	6/09	277,000	121,000
	62,700	6/24	275,000	134,000
	60,100	7/12	259,000	163,000[f]
	51,600	8/10	214,000	128,000
	38,700	8/24	180,000	46,300
	35,000	9/12	179,000	12,200
	33,400	9/30	154,000	25,300

[a]USGS provisional data at Gold Creek 15292000 (with Whisker Creek data).

[b]Surface area measurements for June 21 and July 25, 1982, are lower limits.

[c]Surface area measurement for June 3, 1982 is an upper limit.

[d]High tributary discharge this date eliminated zone 2 (see ADFG Basic Data Report, 1982).

[e]USGS provisional data at Sunshine 15292780.

[f]Differs from value in ADFG Basic Data Report, 1982 (see text).

[g]Amended mainstem discharge at Gold Creek as determined from ADFG stage discharge curve.

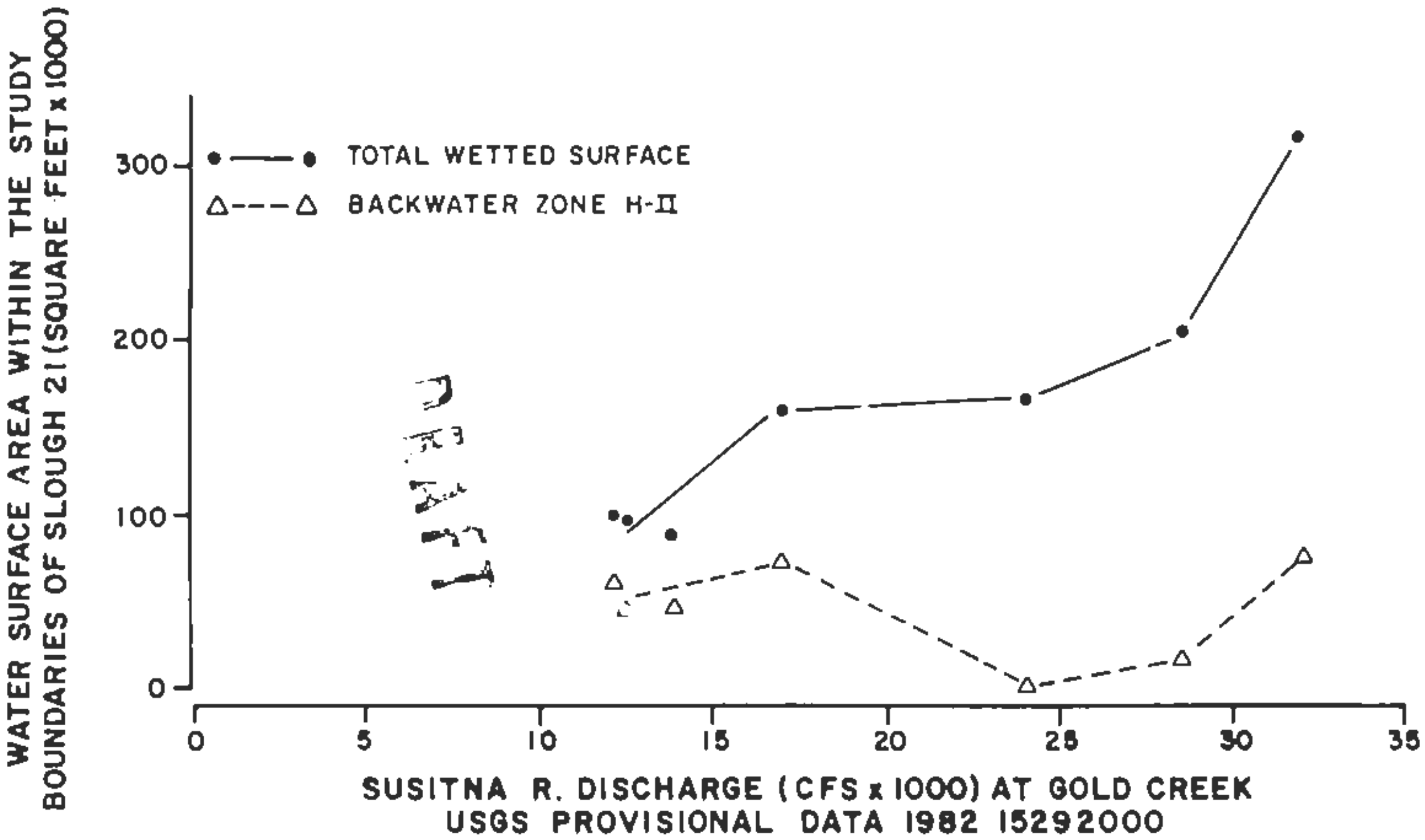
Appendix Table E-1 (Continued).

DFH Site	Discharge cfs[a]	Date	Total Wetted Surface Area (Ft²)	Surface Area Type II (Ft²)
Rabideux Creek and Slough[b]	71,700	6/26	1,170,000	1,160,000
	67,900	7/29	1,120,000	1,180,000
	53,000	9/14	1,220,000	965,000
	44,000	8/12	1,070,000	876,000
	38,700	8/25	1,080,000	836,000
	33,400	9/30	968,000	344,000
Whitefish Slough[c]	72,000	7/28	85,800	85,800
	66,700	6/25	75,000	75,000
	60,100	7/12	65,800	65,800
	53,000	9/14	71,000	71,000
	47,900	8/11	56,200	56,200
	38,700	8/25	32,200	32,200
	33,900	9/29	14,200	14,200
Goose Creek and Sidechannel	72,000	7/28	166,000	75,000
	66,700	6/25	170,000	83,000
	64,200	6/10	176,000	87,000
	63,000	7/13	158,000	74,400
	47,900	8/11	154,000	113,000
	38,700	8/25	148,000	122,000
	36,400	9/13	137,000	0
	33,900	9/29	134,000	0

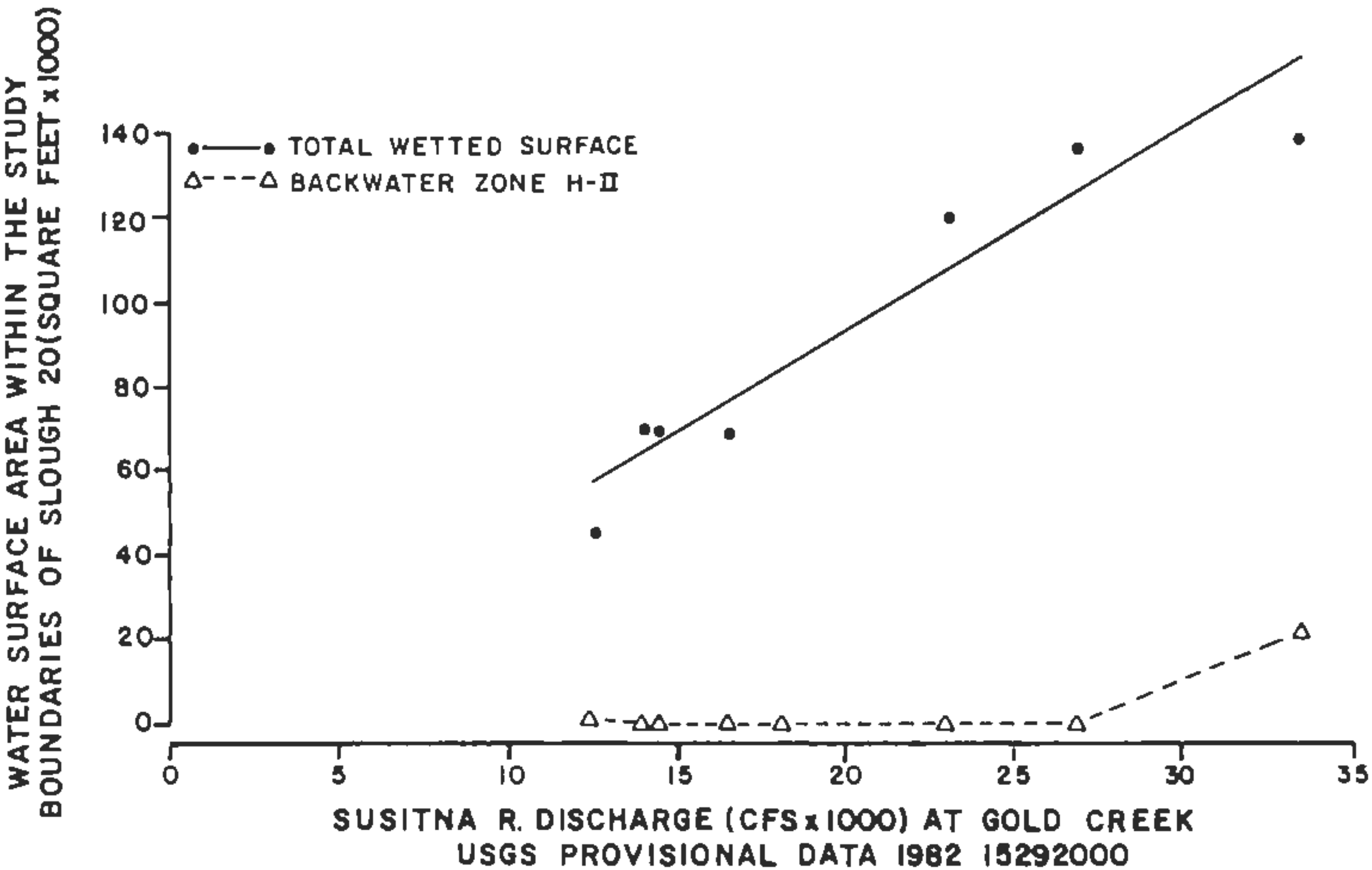
[a]USGS provisional data at Sunshine, 1982, 15292780.

[b]Not sampled in early June or in early July.

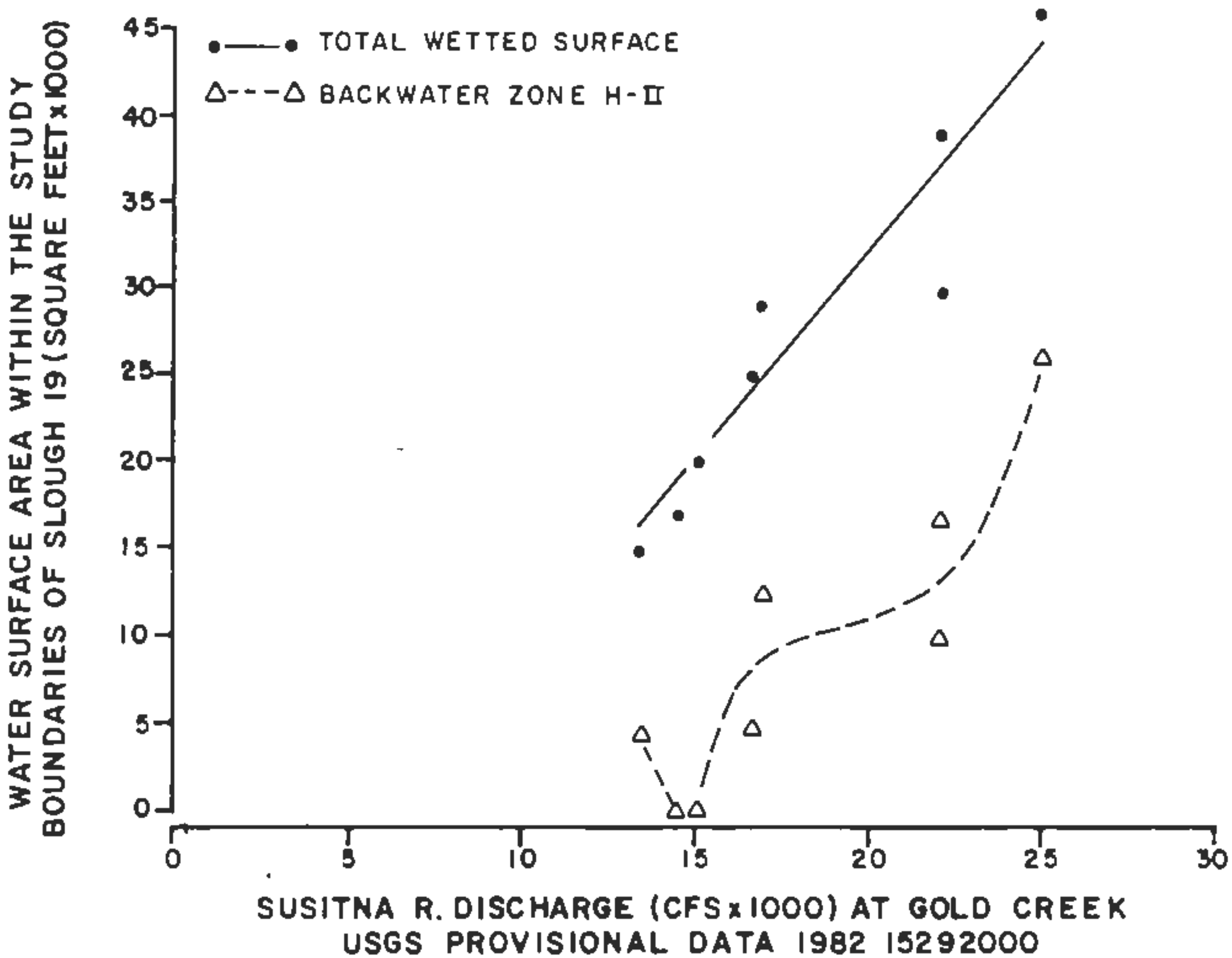
[c]Not sampled in early July.



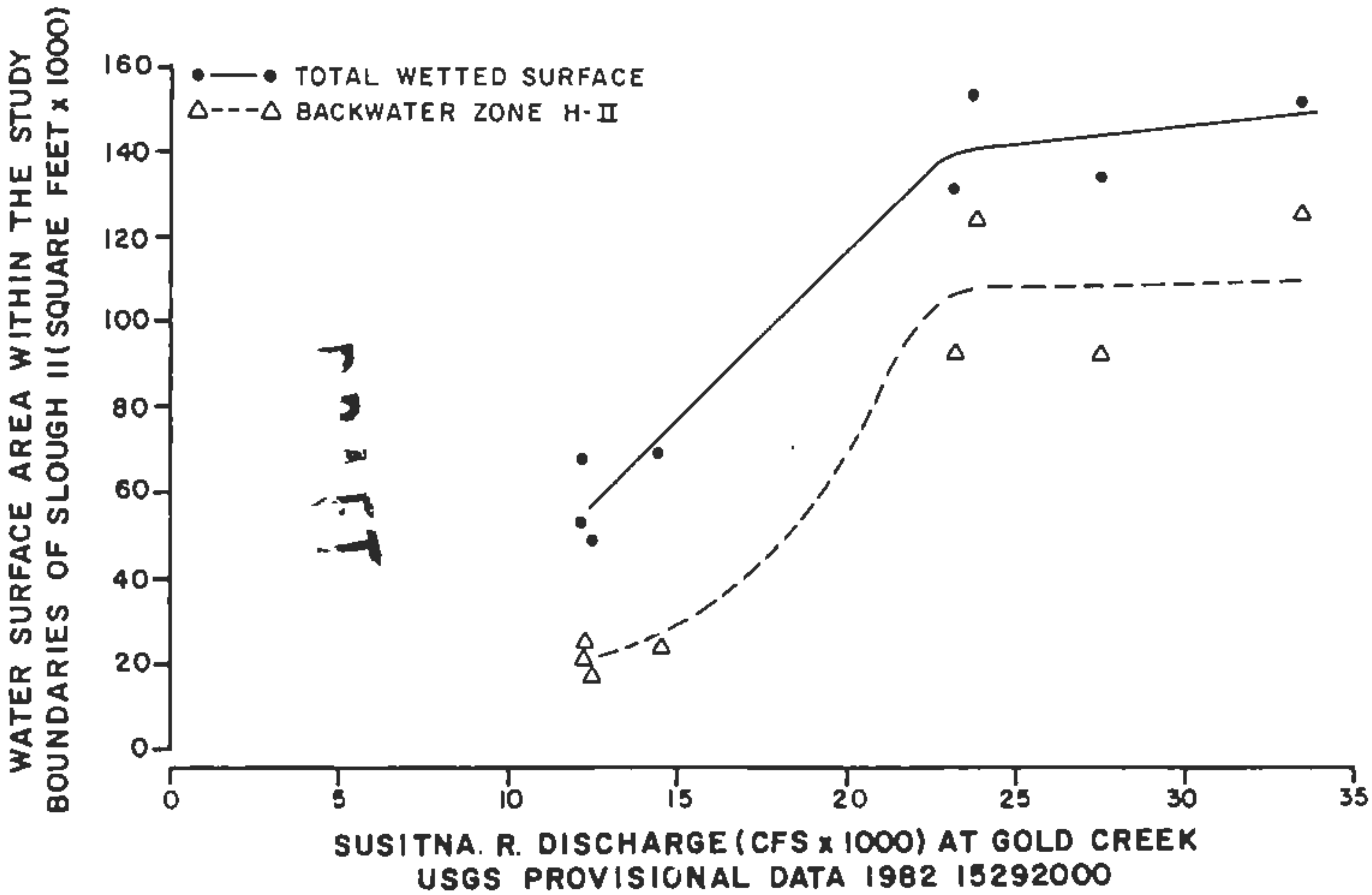
Appendix Figure E-1. Wetted surface area at Slough 21 versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-1.



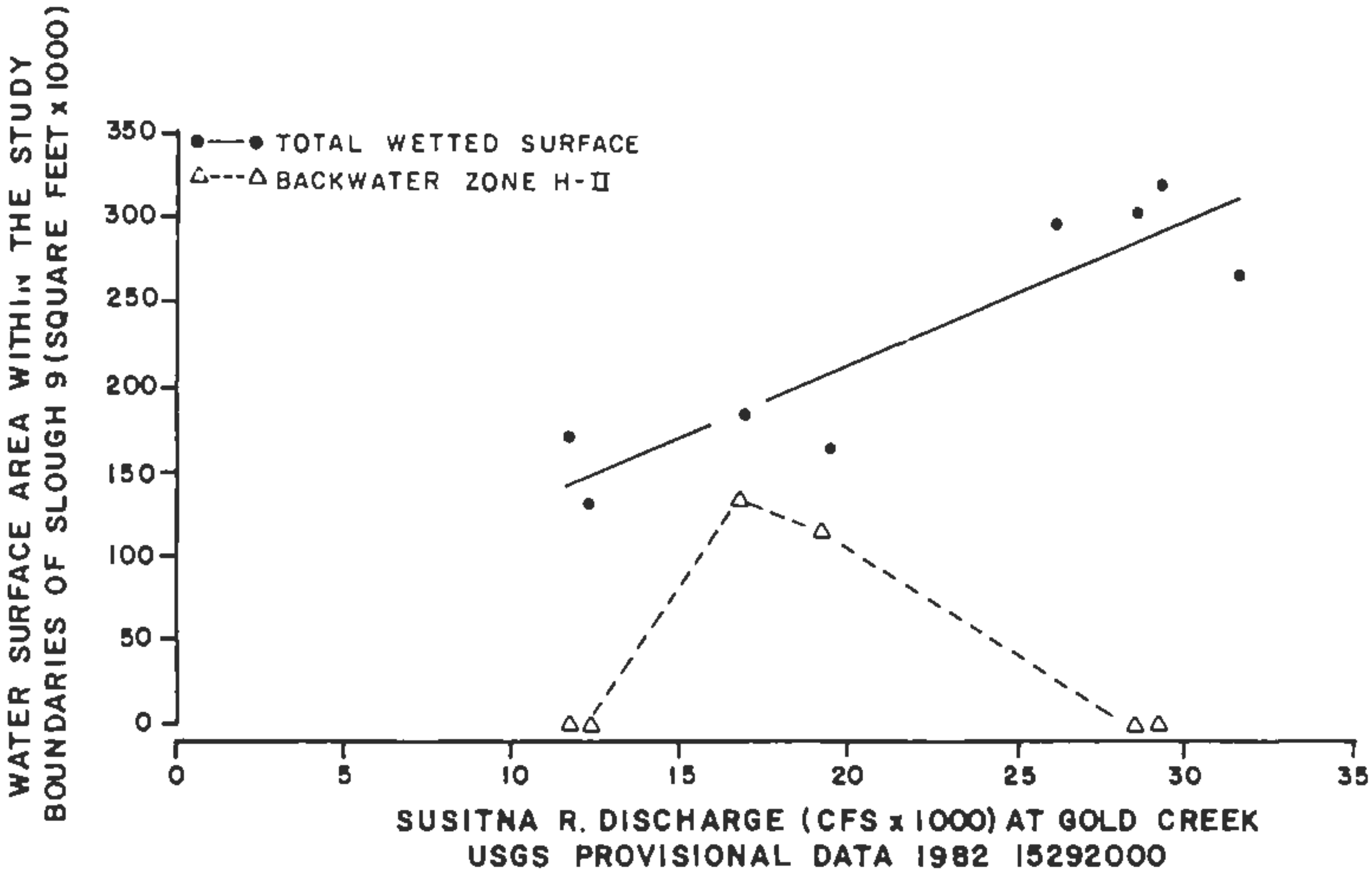
Appendix Figure E-2. Wetted surface area at Slough 20 versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-2.



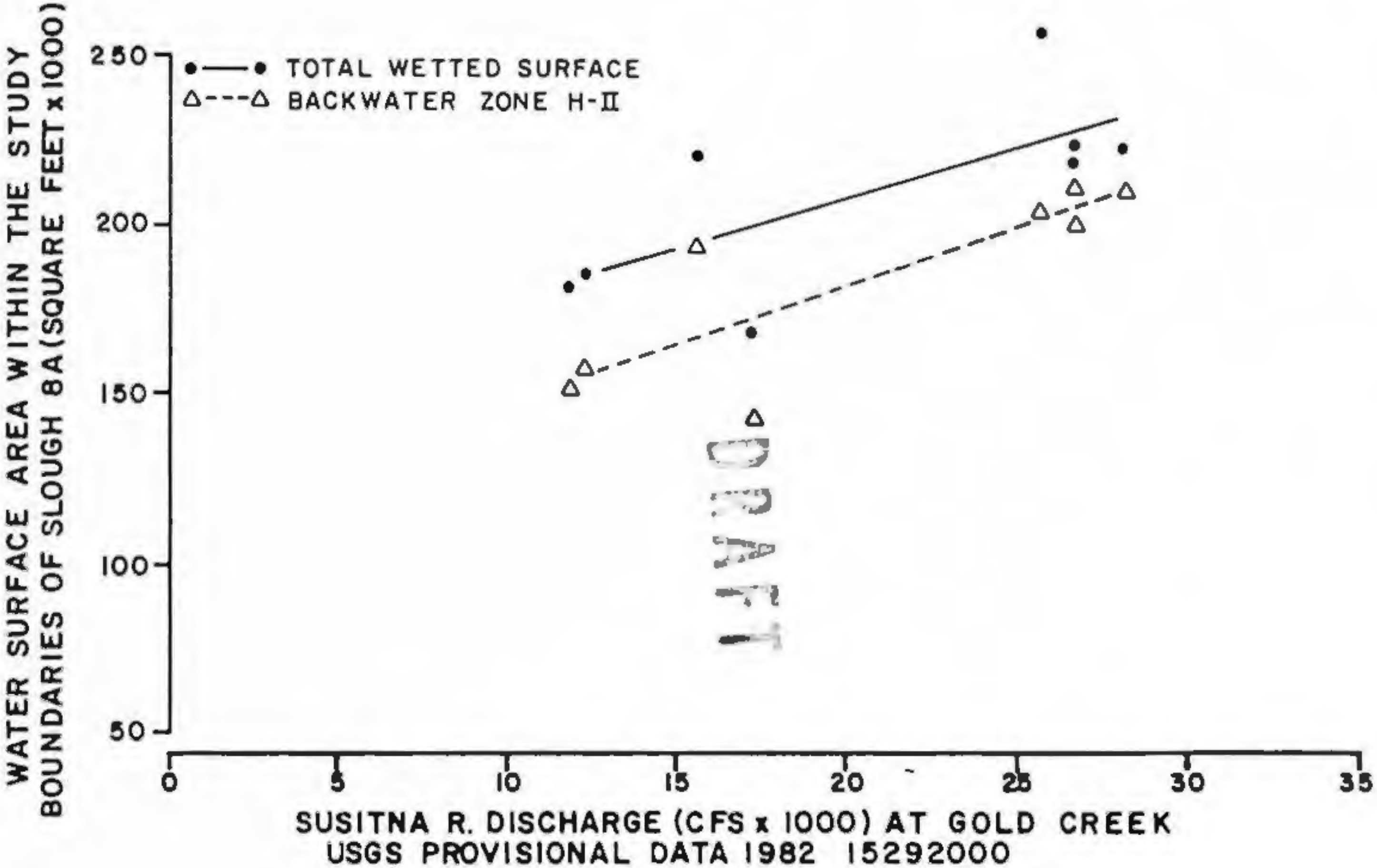
Appendix Figure E-3. Wetted surface area at Slough 19 versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-3.



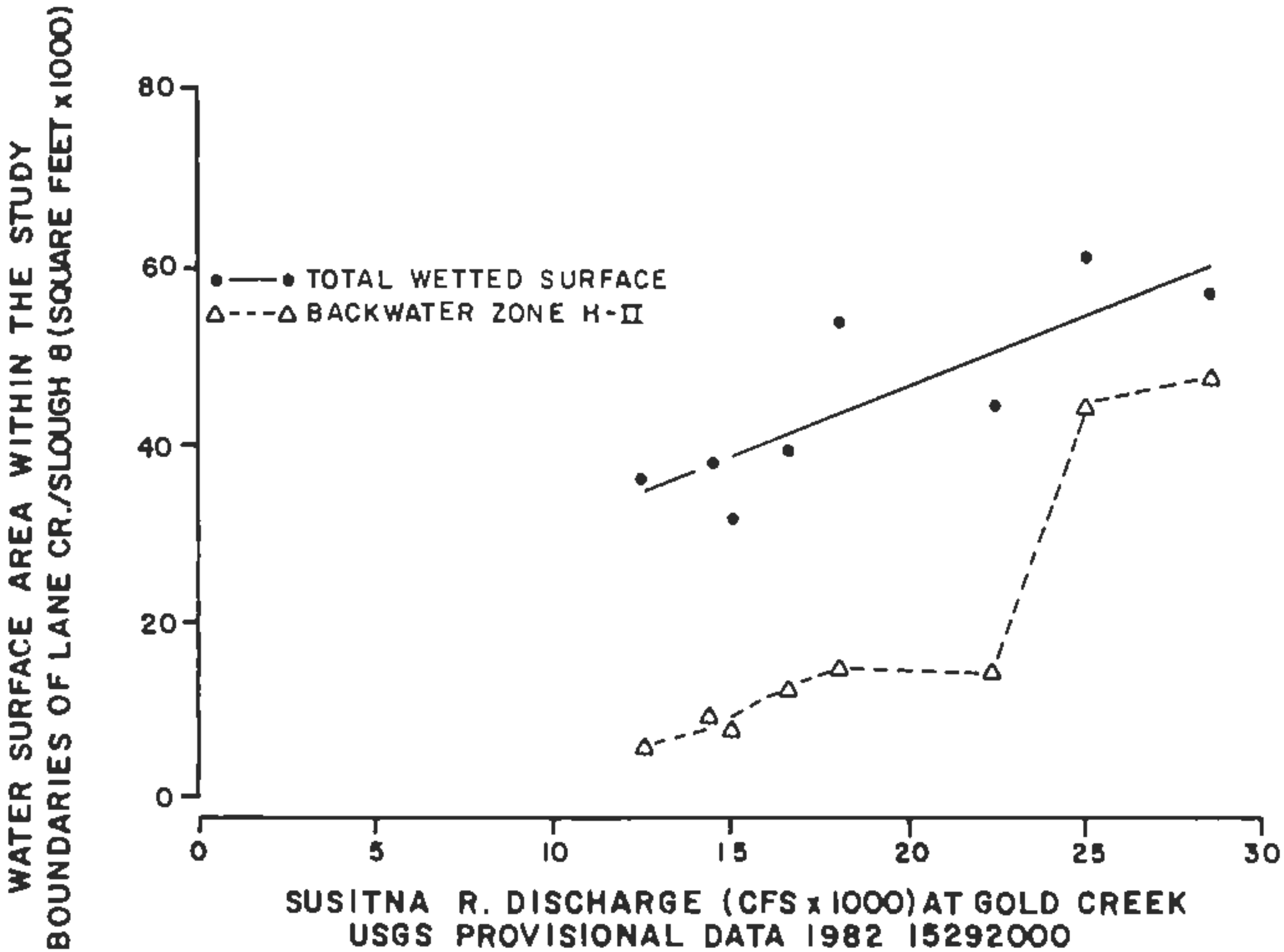
Appendix Figure E-4. Wetted surface area at Slough 11 versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-4.



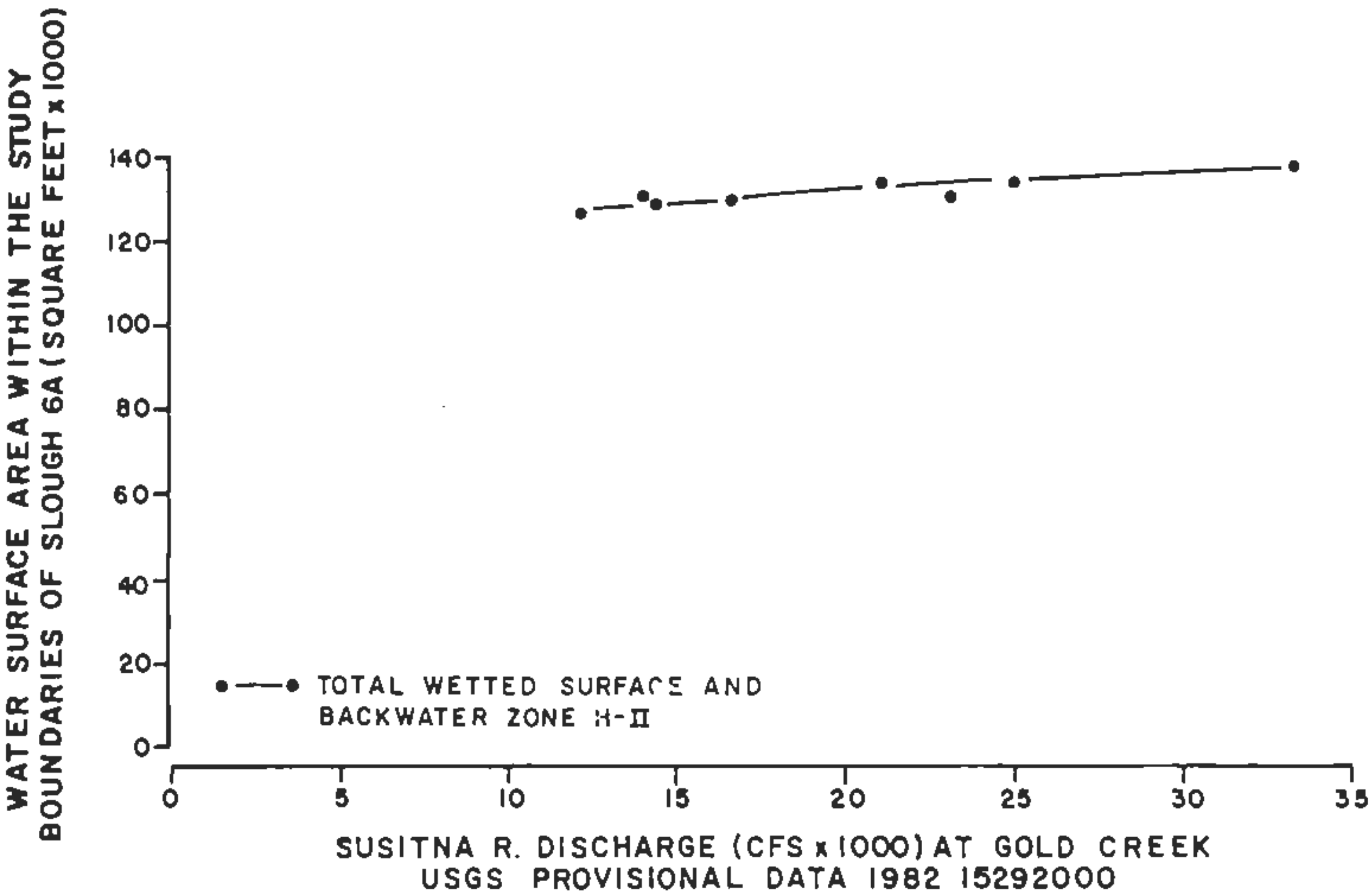
Appendix Figure E-5. Wetted surface area at Slough 9 versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-5.



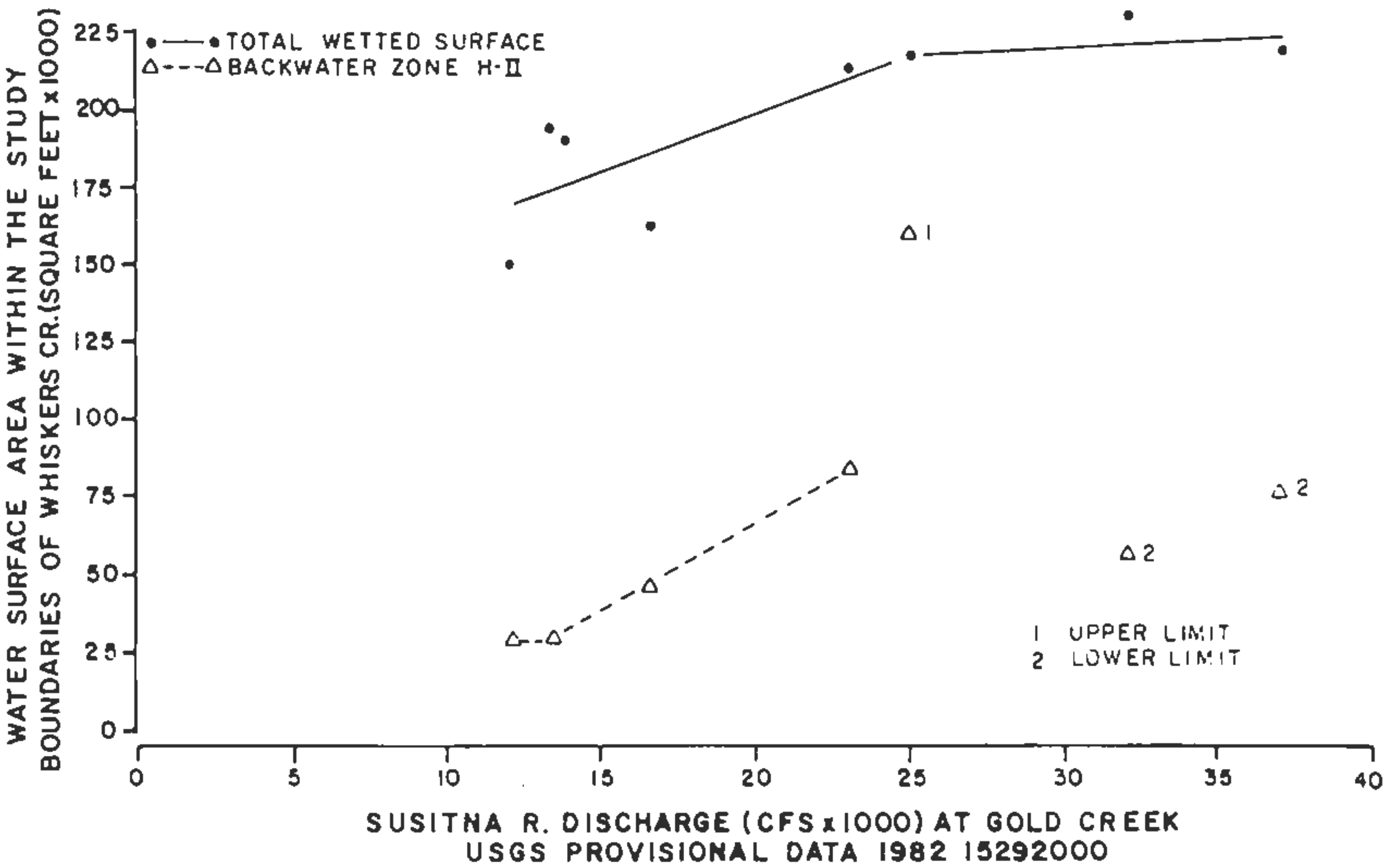
Appendix Figure E-6. Wetted surface area at Slough 8A versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-6.



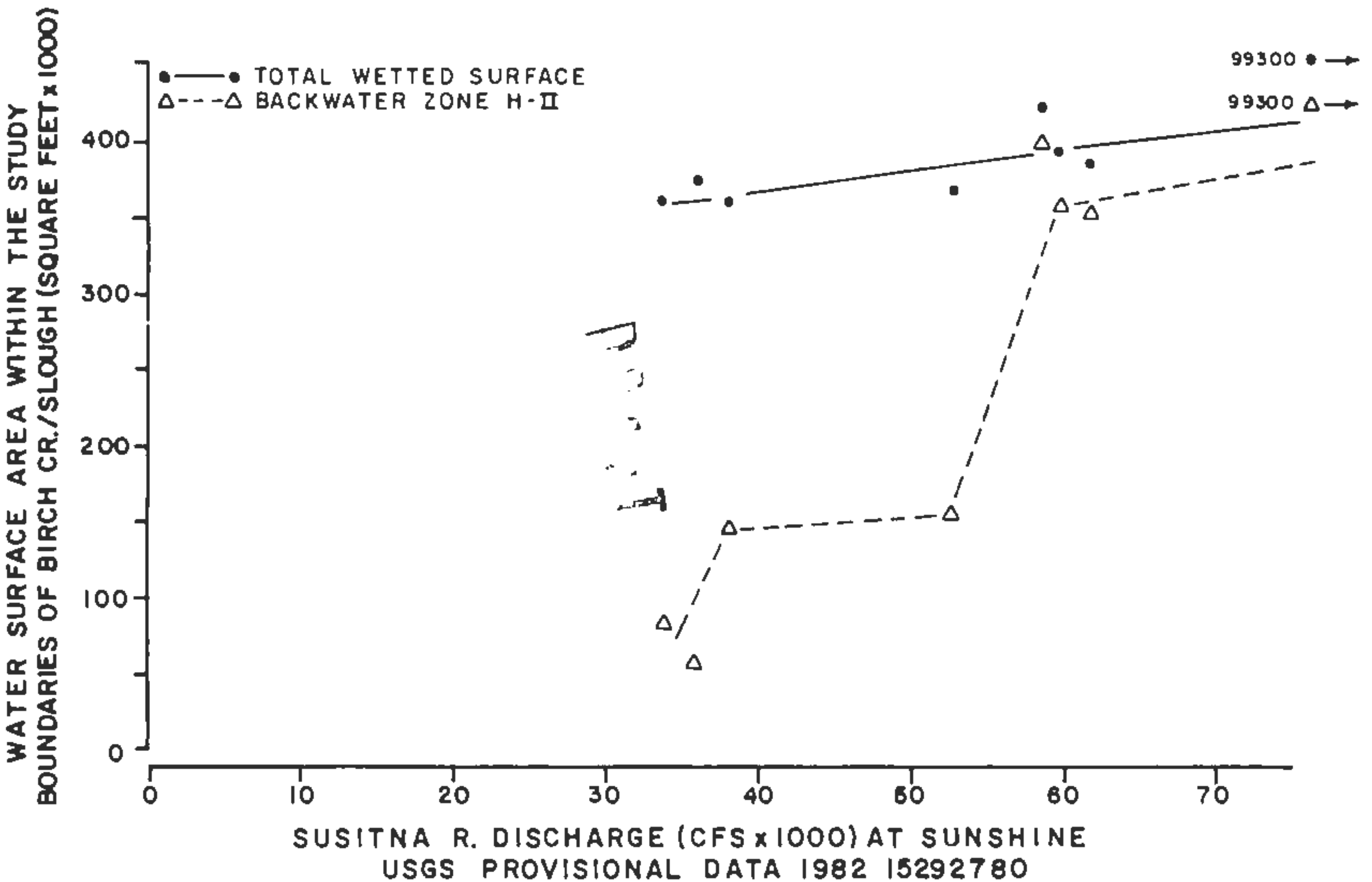
Appendix Figure E-7. Wetted surface area at Slough 8 / Lane Creek versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-7.



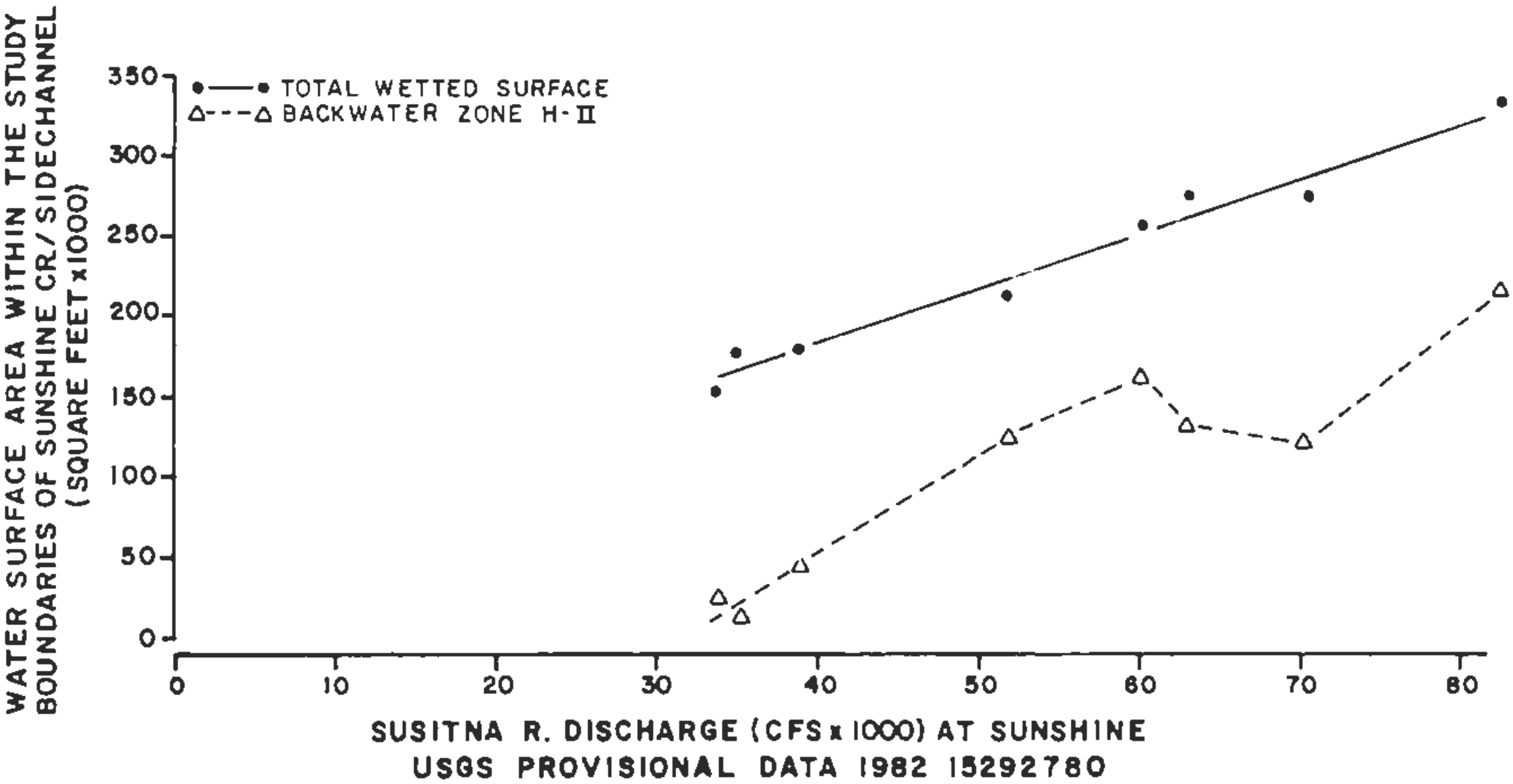
Appendix Figure E-8. Wetted surface area at Slough 6A versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-8.



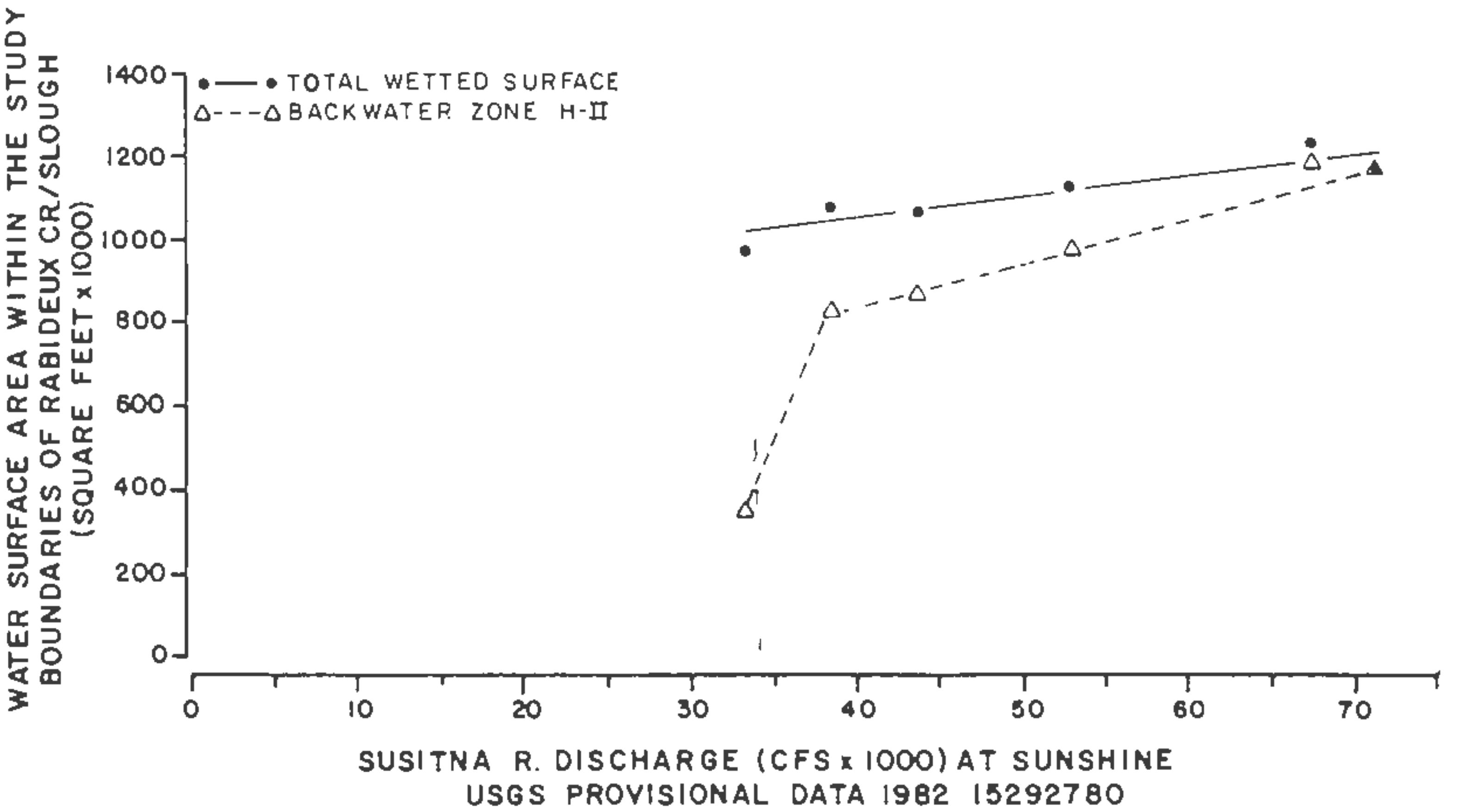
Appendix Figure E-9. Wetted surface area at Whiskers Creek / Slough versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-9.



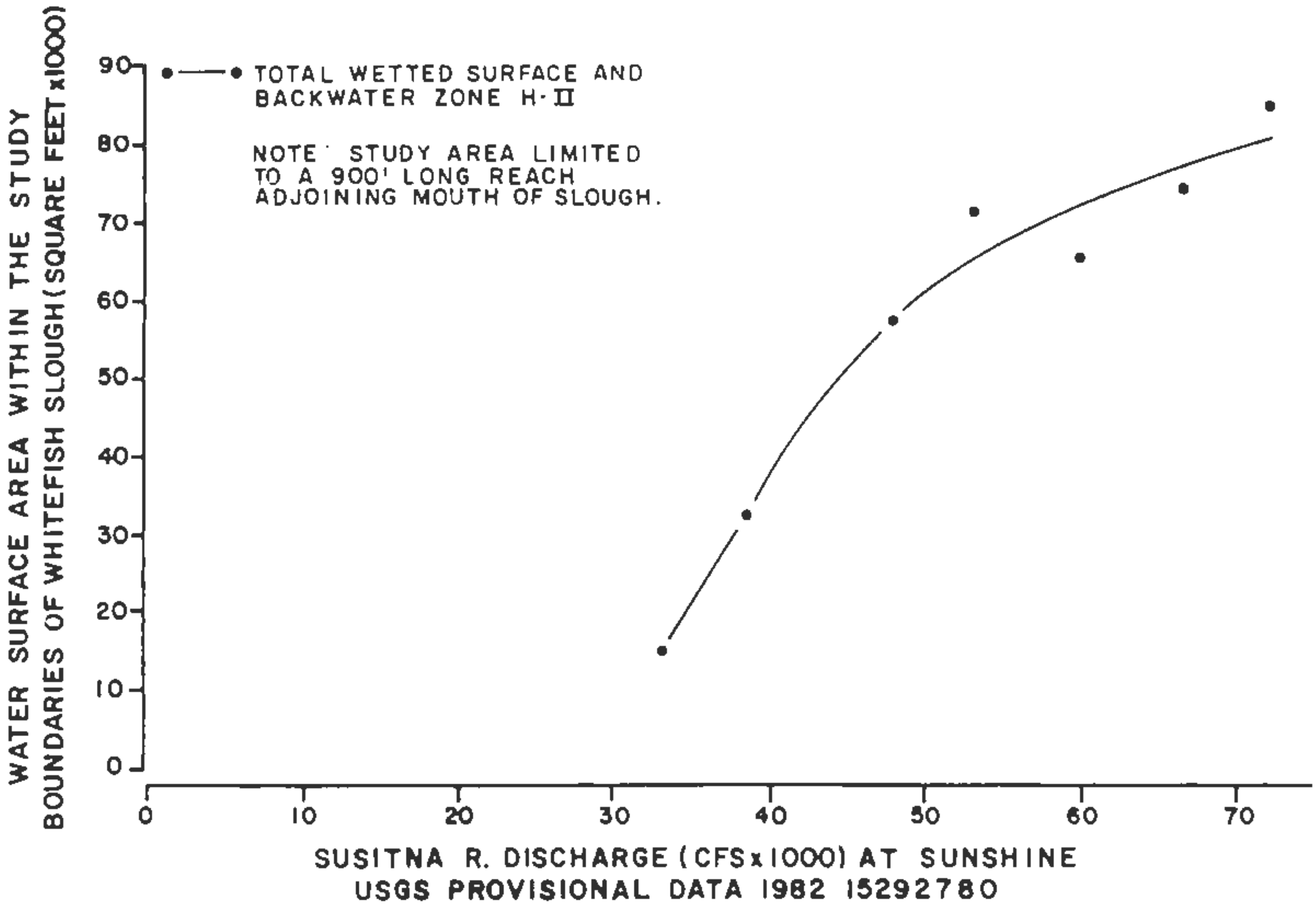
Appendix Figure E-10. Wetted surface area at Birch Creek / Slough versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-10.



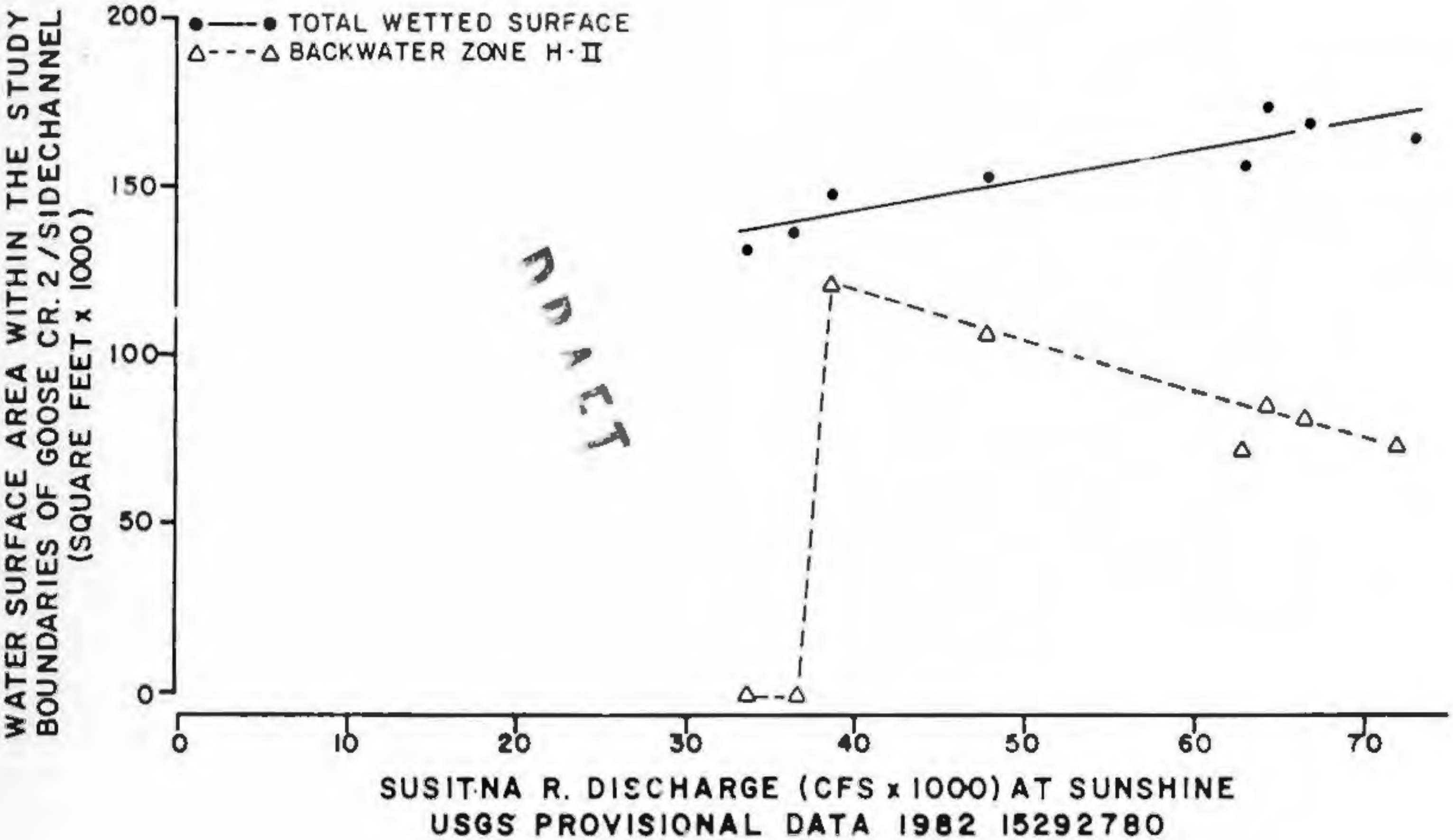
Appendix Figure E-11. Wetted surface area at Sunshine Creek versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-11.



Appendix Figure E-12. Wetted surface area at Rabideux Creek versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-12.



Appendix Figure E-13. Wetted surface area at Whitefish Slough versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-13.



Appendix Figure E-14. Wetted surface area at Goose Creek / Side Channel versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-14.

many of these areas changed considerably over the range of mainstem discharges observed. Total wetted surface area plots are typically represented by simple linear regressions. In contrast, backwater area plots are more complex. In part, this complexity is attributed to these areas moving, receding and reforming downstream as flow decreased (see Volume 4 for more discussion of this topic).

At Slough 6A and at Whitefish Slough, the total wetted and backwater surface areas are identical within the range of discharges observed.

The reaches of Sloughs 8A and 11 which were mapped consisted predominantly of backwater areas. At these and other habitat locations, except when zone 9 (calm water) pools were present (Appendix Table E-2), the difference between the total and backwater surface areas reported equals the surface area of water present in the study area which had appreciable velocity. Appreciable velocity was generally defined as a velocity of 0.5 ft/sec or greater (Volume 4, Part II). Conversely, the pool plus backwater surface area sum equals the low velocity (0.0 to 0.5 ft/sec) surface areas present within the boundaries mapped at a habitat site. Additional discussion relating surface areas to habitat is found in the Juvenile Anadromous Section of this volume.

A summation of the total wetted surface areas, within the boundaries of all upper and lower Susitna River study sites sampled, is shown in Appendix Tables E-3 and E-4, and in Appendix Figures E-15 and E-16. These values were obtained by determining the areas indicated at 2500

Appendix Table E-2. Surface areas of morphological pools[a] not regulated by mainstem Susitna River discharge at Designated Fish Habitat (DFH) sites, and mainstem Susitna River discharges, June through September, 1982.

DFH Site	Discharge cfs	Date	Zone 9 Surface Area
Goose Creek and Sidechannel	36,400	9/13	64,200
	33,900	9/29	77,400
Lane Creek/Slough 8	22,400	7/22	22,200
	18,100	7/08	23,100
	16,600	8/08	19,500
	15,000	9/25	18,800
	14,400	9/10	18,900
	12,500	8/20	18,700
Rabideux Creek and Slough	33,400	9/30	308,000
Slough 20	33,250	6/20	40,500
	26,800	7/24	54,800
	23,000	6/04	36,300
	18,100	7/08	11,500
	16,500	8/07	20,300
	14,400	9/04	18,100
	14,000	9/26	18,100
	12,500	8/20	15,900
Whisker Creek and Slough	37,000	8/21	41,400
	31,900	7/[illegible]5	8,400
	25,000	[illegible]/03	none
	23,000	7/10	55,200
	16,600	8/[illegible]	25,100
	13,800	9/27	23,500
	13,400	9/[illegible]	23,500
	12,200	8/22	19,500

[a] These areas were identified as zone 9 and occurred (as calm water morphologic pools) in free flowing tributary or ground water areas.

Appendix Table E-2. (Continued).

DFH Site	Discharge cfs	Date	Zone 9 Surface Area
Sunshine Creek and Sidechannel	35,000	9/12	8,400
	33,400	9/30	7,700
Birch Creek and Slough	38,000	8/23	33,900
	35,900	9/28	37,400
	33,800	9/11	37,400
Slough 19	15,500	9/25	5,500
	14,400	9/04	5,100
	13,300	8/19	4,600
Slough 8A			Approx 8,000[a]

[a]A small pool was located below the first beaver dam throughout most of the sampling year. This pool was not mapped as such but was the site of systematic fish captures.

Appendix Table E-3. Total wetted surface areas measured within the boundaries of nine study areas on the upper Susitna River, versus Gold Creek discharge[a], June through September, 1982.

	Surface Areas[b] (Square Feet x 1000) at Habitat Location, by Discharge						
Habitat Location	12,500	15,000	17,500	20,000	22,500	25,000	27,500
Slough 21	88.	129.	160.	161.	163.	173.	194.
Slough 20	57.	69.	82.	94.	106.	118.	130.
Slough 19	16.[c]	20.	26.	32.	38.	44.[d]	44.[d]
Slough 11	58.	77.	97.	116.	136.	143.	145.
Slough 9	150.	171.	193.	215.	237.	259.	280.
Slough 8A	186.	194.	201.	208.	215.	223.	230.
Lane Creek/Slough 8	35.	39.	43.	47.	51.	55.	59.
Slough 6A	128.	129.	131.	132.	134.	135.	137.
Whiskers Creek/Sidechannel	170.	179.	189.	198.	208.	217.	218.
Total by Discharge	888.	1007.	1122.	1203.	12[illegible]3.	1367.	1437.

[a]USGS Provisional data at Gold Creek, 1982, 15292000.

[b]Data compiled from Appendix Figures E-1 through E-9.

[c]Area measured at 13,300 cfs.

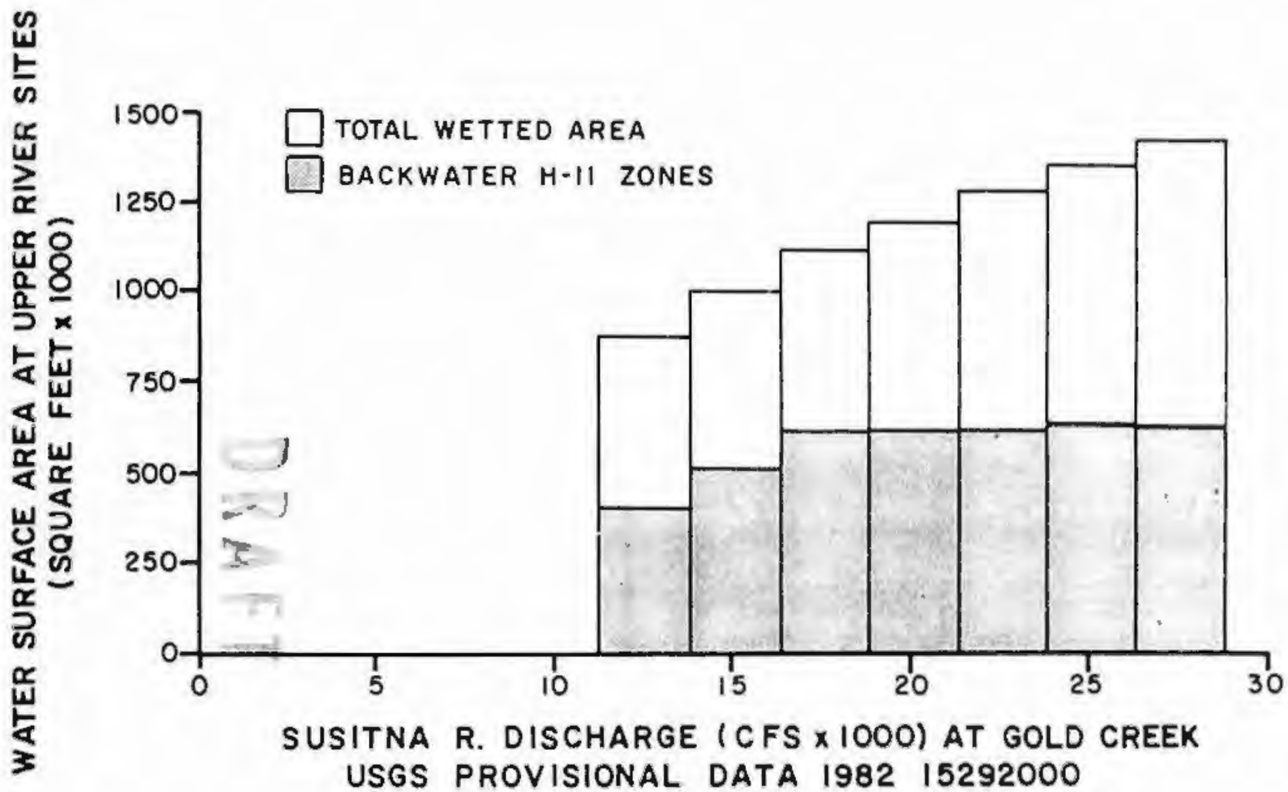
[d]Area measured at 24,900 cfs.

Appendix Table E-4. Total wetted surface areas measured within the boundaries of five study areas on the Lower Susitna River, versus Sunshine discharge[a], June through September, 1982.

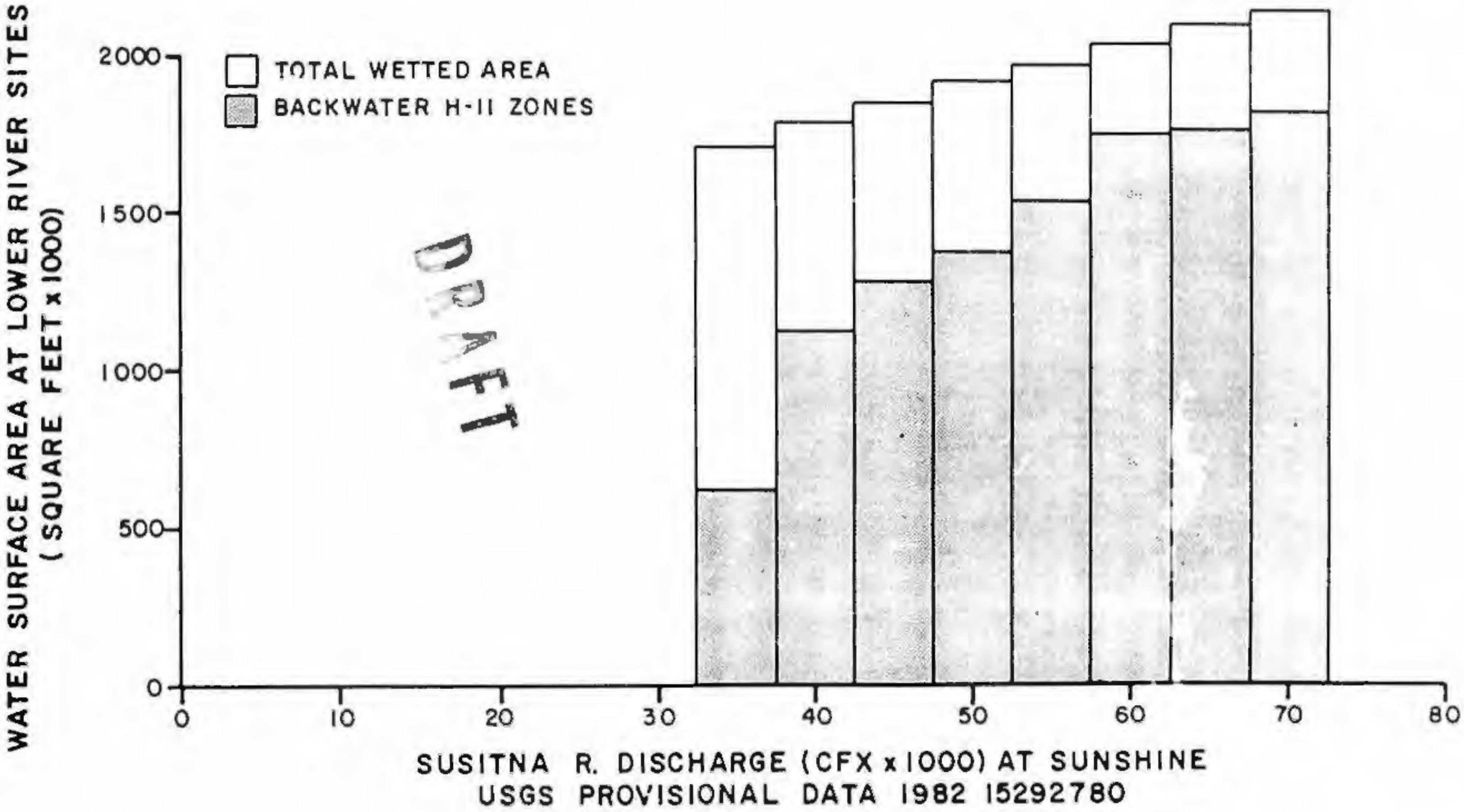
Habitat Location	Surface Areas[b] (Square Feet x 1000) at Habitat Location, by Discharge							
	35,000	40,000	45,000	50,000	55,000	60,000	65,000	70,000
Birch Creek	362.	368.	374.	380.	386.	394.	400.	406.
Sunshine Creek/Sidechannel	168.	185.	202.	219.	236.	253.	270.	287.
Rabideux Creek/Slough	1020.	1050.	1070.	1110.	1120.	1150.	1180.	1200.
Whitefish Slough	21.	37.	51.	61.	67.	72.	77.	80.
Goose Creek/Sidechannel	139.	143.	148.	152.	157.	161.	166.	170.
Total by Discharge	1710.	1783.	1845.	1922.	1966.	2030.	2093.	2143.

[a]USGS Provisional data at Sunshine, 1982, 15292780.

[b]Data compiled from Appendix Figures E-10 through E-14.



Appendix Figure E-15. Wetted surface area summations for the nine upper Susitna sites versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plates E-1 through E-9.



Appendix Figure E-16. Wetted surface area summations for the five lower Susitna sites versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in Appendix Plates E-10 through E-14.

and 5000 cfs discharge intervals from Appendix Figures E-1 to E-14. The upper river total wetted area versus Susitna River discharge plot indicates a small inflection in the relationship of areas to Gold Creek discharges above and below approximately 17,500 cfs.

The lower river plot indicates that a simple relationship between total wetted surface areas and Sunshine station discharge exists within the range of discharges observed.

Appendix Figures E-15 and E-16 also display the corresponding backwater surface data as adapted from Tables 4I-4-1 and 4I-4-2 of the Basic Oata Report. Comparison between the total wetted and backwater surface area plots requires careful interpretation. As noted above, the backwater areas occurring at each site were normally mapped in their entirety. The "total" wetted surfaces mapped were, however, selectively limited in area by study design and sampling logistics. Within the lower river slough and tributary areas sampled however, backwater surface areas decrease faster than do total wetted areas, at mainstem discharges below approximately 60,000 cfs. At mainstem discharges above 60,000 cfs, the total wetted areas increase faster than do backwater areas, yielding the highest proportion of backwater area near 60,000 cfs. At upper river sites, the inflection point near 17,500 cfs appears to be similar to the 60,000 cfs point in the lower river plot: above 17,500 cfs, the total wetted area increases faster than backwater area. Below 17,500 cfs (in the upper river plot), it is not clear that backwater surface areas decrease faster than do total wetted surfaces, as it appears in the lower river. Data at discharges of 10,000 cfs and below may show that this is the case in the upper river as well.

Use of this slough and tributary mouth wetted surface area data to model the total wetted surfaces of the Susitna River with decreasing flows should not be attempted. This data was not obtained from areas representative of the average mainstem environment, as the proportion of free flowing mainstem surfaces included represent an insignificantly small proportion of the Susitna River's total. There is however confidence for using the backwater data to represent true backwater surface area versus discharge relationship for larger reaches of the Susitna (as was done) as a significant percentage of these types of surfaces were actually measured. Thus, the total wetted surface areas presented are intended primarily to be illustrative of changes that occur within the slough environments.

This work illustrates that many difficulties might be involved in attempting discharge related assessments of available juvenile fish (slough and tributary) habitat based on overly simplified parameters, such as total wetted surface areas. Total backwater area relationships, which appear to be more complex, may be better indicators for selected species and life history stages. In addition, separating those backwater areas that reform downstream (in mainstem type environments during low mainstem flows) from the slough and tributary backwater habitats present at higher flows, would also contribute to a habitat analysis.

Both the total wetted and backwater surface area relationships presented should not be used to infer surface areas at mainstem discharges beyond those observed.

DRAFT

APPE F

Influence of Habitat Parameters on Di on and Relative Abundance of Juvenile Salmon and Resident Species

APPENDIX F

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A. INTRODUCTION

The physical and chemical parameters present in the Susitna River, such as discharge, surface area, water velocity and depth, temperature, and water quality have wide ranging spatial and temporal variations. Spatial variations range from micro-habitat (on the order of a few feet), to macro-habitat (such as tributary mouths or sloughs), to entire reaches. Temporal variations occur on a scale ranging from daily to annual to multi-year cycles. Fish and other organisms respond to these spatial and temporal variations and this response is reflected in the distribution and relative abundance of each species.

The distribution of juvenile fish in the Susitna present formidable difficulties in measuring the quantity of productive habitat with changing mainstem discharges. Although significant amounts of research have been conducted using hydraulic models to predict the availability of habitats over incrementally varying discharges, these studies have not been directed towards large and diverse glacial systems such as the Susitna River.

The broad geographical distribution of juvenile fish observed in 1981 provided an overall perspective and an indication of problems associated with evaluating the Susitna's juvenile salmon habitat on a very detailed level. These observations have also provided the basis for hypothesis of the factors which influence the distribution and abundance of the juvenile species at an intermediate level of resolution. Of these factors, those that were obviously influenced by mainstem discharge were selected as the focal point for the 1982 field study plan. A central thesis of this effort is that the highly varied habitats required collections at many sites to adequately represent the effects of changing mainstem flows on the habitat used by the majority of the fish.

The decision to examine a large number of habitats prevented the quantification of available micro-habitat conditions at the study sites. To monitor the physical habitat response to discharge without intensive data collection, a system of classifying the hydraulic conditions present at a study site into zones was developed. The zones were defined into a set of criteria that could be identified and easily mapped in the field using aerial photographs. The zones were measured for surface area under the variable flow conditions of the mainstem Susitna throughout the course of the summer and the distribution and relative abundance of fish were evaluated as a function of their distribution among zone types.

The analysis presented attempts to develop an estimate of habitat changes with discharge by combining the catch variations between zones with the changes in the surface area of the zones. The resulting index of habitat at the study sites is an approximation of the available habitat where the habitat is defined as the surface area multiplied times a weighting factor. The weighting factor is based on the value of a site as reflected by the relative abundance of the species among the zones sampled at each site. Changes in micro-habitat within the zones as a function of discharge were not evaluated in this years study. This work provides a logical step in the quantitative analysis of the available habitats over an incremental range of mainstem Susitna River discharges.

B. METHODS

Data were drawn from the 1982 open-water studies at the 17 Designated Fish Habitat (DFH) sites described in Volume 2 (Section 2.1.3) and Volume 4 (Section 2.1.3.1 of Part I and Section 2.2 and 2.3.2 of Part II) of the Basic Data Report (ADF&G, 1983). These sites included several different major habitat types located from Goose Creek (RM 73.1) to Portage Creek (RM 148.8). Two reaches were defined - the upper reach included twelve sites above the Chulitna River confluence (RM 98.5) and the lower reach included five sites below this point. These 17 sites were sampled twice per month in June, July, August, and September.

Assumptions

Each species of fish, during any particular sampling period was assumed to have a choice of available habitat types at a site and presumably would be found in greatest abundance in that habitat type which is most desirable to them. Recognizable habitat types at a site were categorized as "habitat zones" and are defined in Volume 4, Part II, Section 2.2. Criteria used in delineating habitat zones included water source, water velocity, and mainstem influence. Sampling at each site was standardized by zone.

A word model of the factors affecting juvenile salmon catch within a zone can be constructed as follows:

Catch = F (<u>abundance</u>, sampling effort, gear efficiency, and fish catchability)

Where:

<u>Abundance</u> = F (<u>Local habitat suitability</u>, time of season, success of previous fall's spawning and incubation survival, proximity to spawning grounds)

Where:

<u>Local habitat suitability</u> = F (temperature, water velocity, depth, substrate, turbidity, cover, food)

Some of these parameters are quantifiable and some are semi-quantifiable. For others, we have no data.

During data collection and subsequent analysis, however, we have attempted to eliminate the variables of sampling effort, gear efficiency, and fish catchability so that catch reflects abundance by using a constant effort with one type of gear that is most effective in catching the species of interest. The location of the site integrates such factors as proximity to spawning grounds and success of previous fall spawning and incubation survival. Local habitat suitability is integrated by hydraulic zone. Therefore we can simplify the model to catch = F (abundance) = F (time of season, site, and habitat zone within sampling site). Presumably higher catches reflect greater abundance and therefore we can proceed with a greatly simplified analysis.

1. Spatial and temporal variation in habitat variables and in relative abundance of fish.

Catch data were grouped by sampling site, habitat zone within sampling site, and sampling period. Analysis by sampling site and habitat zone address spatial variation and sampling period addresses seasonal variation. Sampling site takes into account macro-habitat variations including differences between reaches and differences between major habitat types such as tributary mouths versus upland sloughs. Habitat zone addresses a more narrowly defined habitat and considers the effect of habitat variables such as water temperature and velocity within a site. Habitat zone falls somewhere in between macro-habitat and micro-habitat (such as would be obtained by point-specific measurements).

Also, the catch and habitat data were sorted and pooled in various ways (as outlined in the results section) and mean values were tested for significant differences using a t test.

In order to increase sample sizes, habitat zones were pooled by aggregate zone types. Three different criteria were used to aggregate habitat zones - by the presence or absence of a mainstem backwater zone, by water source, and by water velocity. Details describing these aggregate zones were presented in Section 2.2, Part II, Volume 4 of the Basic Data Report (ADF&G, 1983). A summary follows:

	Criterion	Aggregate Zone	Description
1.	presence of mainstem backwater area	H-I	tributary or slough above mainstem backwater area
		H-II	mainstem backwater area
		H-III	mixing zone below mainstem backwater area
2.	water source	W-I	tributary water
		W-II	mainstem water
		W-III	mixing water
3.	water velocity	V-I	fast water
		V-II	slack water

2. Relationship of a habitat index and mainstem discharge

The value of a habitat type to a population of fish is a function both of the quality of the habitat and the amount available. In this section, we derive a quality index for each habitat zone and multiply the index by the surface area of that habitat zone available within the study boundaries at incremental levels of mainstem discharge.

The raw catch data from the fish habitat sites used to determine quality indices are contained in Appendices G and H of Volume 4 of the Basic Data Report. The surface area data are from Sections 3.1.3.1 and 4.1.3.1 of Volume 4, Part I, and from Appendix E of the present report.

First, the nine separate habitat zones were aggregated into three categories of hydraulic zone types. These zones are defined in Volume 4, Section 2.2, of the Basic Data Report (ADF&G, 1983). Briefly, the H-I aggregate zone consisted of all habitat zones which occurred above the influence of mainstem backwater areas. The H-II aggregate zone included all habitat zones which were backed up by a hydraulic barrier created by mainstem stage at the mouth of tributaries, sloughs, or side channels. The H-III aggregate zone was the mainstem itself, just below the H-II zone.

A catch ratio (r_c) was calculated for each hydraulic zone at each site during each sampling period. This was done for each species. The ratio took the form:

$$r_c = \frac{(CPUE)i}{\left(\sum_{j=1}^{n-1} (CPUE)j\right) / n-1}$$

where:
CPUE = catch per unit effort
n = total number of zones sampled
i = zone number of the zone in question
j = zone numbers of all other zones

This is simply the ratio of the CPUE of the zone in question to the mean of the CPUEs of all other zones. The ratio was calculated in this manner in accordance with the original assumption - that each species will concentrate in the zone that has the most desirable conditions. This ratio is also independent of the absolute numbers of fish at the site; if a particular zone is preferred, it could have the same ratio whether there were 50 fish or 500 fish present. A further advantage of the ratio is that it is independent of the number of zones sampled, which ranged from two to four. If less than ten fish of any one species were captured at a site during a particular sampling period, the case was dropped from the data set because of the small sample size.

Only minnow trap data were used to compile the CPUE for juvenile chinook and coho salmon. The CPUE was defined as catch/trap in a three hour set. Minnow traps were most effective in collecting these two species and were the most reproducible unit of gear between zones. The CPUE for juvenile sockeye and chum salmon were compiled from beach seining and backpack electrofishing data, which were the two methods most effective in capturing these species. Because of the difficulty in replicating effort among zones with these types of gear, a code was established using actual catch numbers:

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Number Captured	Code
0	0
1-10	1
11-25	2
more than 25	3

To be included in the analysis, at least two zones at any one site and sampling period had to have been sampled by the gear previously mentioned.

The catch ratio can vary from zero, if no fish were captured in the zone in question, to infinity, if all the fish at the site were captured in this zone. In order to transform this range into the range zero to one, which was desirable from the perspective of a habitat quality index, we derived the following equation:

$$ZQI = 1 - \frac{1}{r_c + 1}$$

where: ZQI = zone quality index
r_c = catch ratio

This asymptotic equation transforms catch ratios to a value ranging from zero to one. A value of zero means that none of the fish captured at the site were caught in the zone in question, a value of one means that all the fish were caught in this zone, and a value of 0.5 means that the fish caught at the site were equal to the average of all other zones. Further, if the catch/trap in zone X is twice as great as the catch/trap in zone Y, then the ZQI for zone X is twice as high as that for Zone Y. This zone quality index has the feature of being independent of mainstem discharge and surface area.

This zone quality index is unlike the quality index commonly used in habitat evaluation preference (HEP) curves in that it is a relative measure only - one zone relative to other zones. For example, if no fish of a certain species were captured at a site, a HEP quality index of zero would be indicated; in this case, a ZQI would not be calculated because there is no sample to compare one zone against another. The only way to obtain a ZQI of zero are the cases where the species was captured at the site, but none were captured in the zone in question.

ZQI's were calculated for each species, each site, each aggregate hydraulic zone, each period which met the criteria listed previously. For the present analysis, seasonal ZQI's for each site were calculated by taking the mean of all sampling periods at that site. This was performed after examination of the ratios between periods for time trends in the ratios. As no obvious trend over the periods of time that the fish were collected were observed, with the exception of early period chum salmon, the pooling of the data sets from the different collection periods appeared to be justified. This was done for each species for each of the three aggregate hydraulic zones. The assumption is that the value of each of the different zones relative to the other zones for a species was approximately constant over the period June through September.

Having obtained a site quality index for each zone for each species, the next procedure was to multiply these ZQI's by the total surface area of that zone which was present at a particular level of mainstem discharge. The surface area data used were those which were calculated for discharge increments of 2,500 cfs (upper reach) and 5,000 cfs (lower reach). The surface area values for the aggregate zone H-II were presented in Sections 3.1.3.1 and 4.1.3.1 of Volume 4, Part I, of the Basic Data Report. The values for the total wetted surface area are included in Appendix E of the present report. Values for the surface area of zones H-I and H-III were similarly obtained from the digitized maps, when this zone was present in the study area. The tributary sites (Portage, Indian and 4th of July) were excluded from the analysis at this point because none of them had a mainstem backwater (aggregate zone H-II area).

The product of zone quality index times surface area provides a habitat index (HI). This was calculated according to the following equation:

$$HI = \sum_{i=1}^{n} ZQI_i \times SA_i$$

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where:

ZQI = zone quality index for zone i

SA_i = surface area of zone i

n = number of zones

For the present analysis, this equation took the form:

$$HI = (ZQI_{H-I} \times SA_{H-I}) + (ZQI_{H-II} \times SA_{H-II})$$

where:

H-I = aggregate hydraulic zone H-I

H-II = aggregate hydraulic zone H-II

The surface area of the aggregate H-III zone is not included because it is assumed to be a constant - this type of habitat is always available to fish, regardless of the level of mainstem discharge, and is therefore not a factor. This habitat index (HI) is a product of habitat quality and habitat quantity and can be plotted as a function of mainstem discharge.

C. RESULTS

1. Spatial and temporal variation in habitat variables and spatial variation in relative abundance of fish

Habitat variables

Appendix Table F-1 is a matrix table of the habitat variables that were measured in each of the nine habitat zones. Some general results are as follows. The mainstem backwater zones (zones 2, 6, 7, and 8) were generally warmer than the other zones. There does not appear to be any real differences in dissolved oxygen levels that would matter to fish except that the levels in Zone 9 (morphological pools) was somewhat low. The pH of tributary water (zones 1 and 2) was lower than the other zones. As expected, the turbidity of tributary water was low and other zones are higher. Zone 9 has a low turbidity because this zone generally occurred within tributaries.

A habitat matrix table for the aggregate zones is presented in Appendix Table F-2. Slack water areas (zones H-II and V-II) were warmer than areas of a faster water velocity. This is illustrated by sampling period in Appendix Figure F-1. Slack water zones also had a lower dissolved oxygen level than other zones. Mainstem water zones (H-III and W-II) had a higher pH, conductivity, and turbidity than other zones. The mainstem backwater zone (H-II) and the low velocity zone (V-II) by definition had lower water velocities than the other zones. This is illustrated by sampling period in Appendix Figure F-2.

Appendix Table F-1 Matrix table of habitat conditions by zone. All sites, all dates, June through September, 1982.

Zone	Mean Water Temp(°C)	Mean DO (mg/l)	Mean pH	Mean Conductivity (umhos/cm)	Mean Turbidity NTU	Mean Water Velocity (ft/sec)
1	8.8	10.9	6.8	81	5	1
2	9.5	10.3	6.8	105	6	0
3	8.7	11.0	7.0	98	45	1
4	9.0	11.2	7.1	101	36	1
5	(6.6)	(12.3)	(7.1)	(75)	(17)	(1)
6	9.2	10.7	7.0	114	52	0
7	10.5	10.9	6.9	62	36	1
8	(15.5)	(9.1)	(7.4)	(82)	(85)	(1)
9	8.7	8.9	6.6	78	12	0

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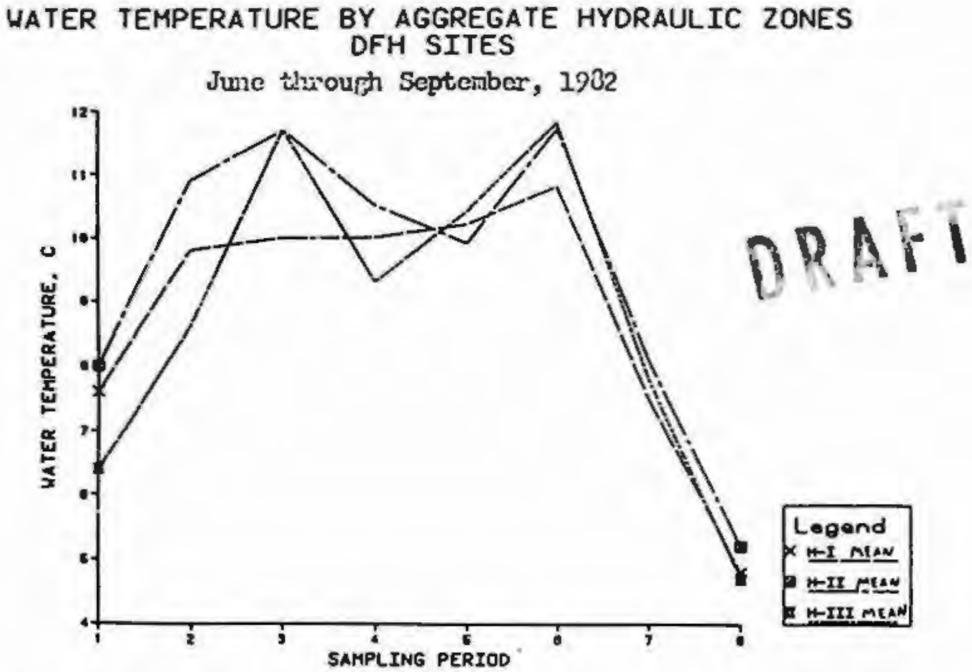
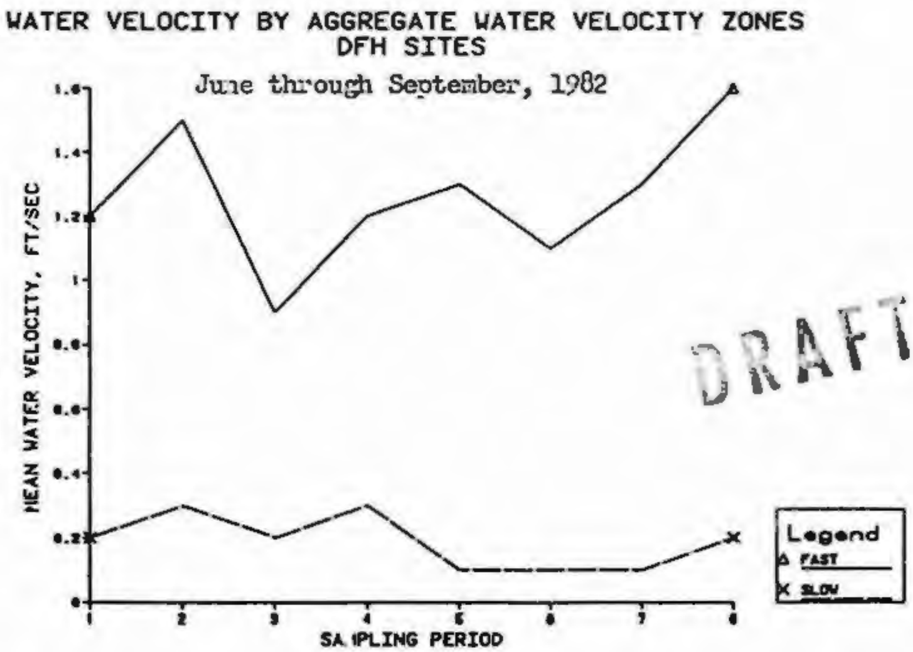
Appendix Table F-2 Matrix table of habitat conditions by aggregate zone. All sites, all dates, June through September, 1982.

Zone	Mean Water Temp(°C)	Mean DO (mg/l)	Mean pH	Mean Conductivity (umhos/cm)	Mean Turbidity NTU	Mean Water Velocity (ft/sec)
H-I	8.8	10.7	6.8	83	10	1.2
H-II	9.7	10.4	6.9	98	18	0.2
H-III	8.7	11.0	7.0	98	45	1.2
W-I	9.1	10.7	6.8	91	5	0.9
W-II	9.3	10.9	7.1	106	44	0.7
W-III	9.0	11.0	7.0	92	43	1.1
V-I	8.8	11.0	7.0	90	26	1.3
V-II	9.5	10.2	6.8	95	17	0.2



Appendix Figure F-1. Mean water temperature of the aggragate hydraulic zone types by sampling period.



Appendix Figure F-2. Mean water velocity of the aggragate velocity zones by sampling period.

The mean values of all 17 sites and all sampling periods for each of the three aggregate hydraulic zones for water temperature, water velocity, and turbidity were tested using a t test (Snedecor and Cochran 1967). These three variables were chosen for the analysis because they are the most important of the measured variables in influencing fish distribution. In all cases using these pooled data, the mean values of the three zones were significantly different ($P < 0.01$) as shown in the following table:

Pair	Water Temperature	Water Velocity	Turbidity
H-I/H-II	$P < 0.01$	$P < 0.01$	$P < 0.01$
H-I/H-III	$P < 0.01$	$P < 0.01$	$P < 0.01$
H-II/H-III	$P < 0.01$	$P < 0.01$	$P < 0.01$

Conducting the same analysis for each of the eight sampling periods showed that water temperature and water velocity of the three zones were significantly different ($P < 0.01$) during every period. Turbidity differences among the three zones were not significantly different in about one-half of the cases.

The above analysis establishes the uniqueness of the hydraulic zones with regard to these habitat variables. Therefore, it is valid to relate variation in catch to habitat variations among these zones.

Catch Data

The means of catch per unit effort data for four species of fish for all sites and sampling periods pooled are presented by habitat zone in

Appendix Tables F-3 to F-6. These four species and two gear types were chosen because the gear is efficient at capturing the species indicated and replicated observations enable statistical comparisons of means.

The highest catch rates for chinook salmon juveniles occurred in habitat zones 1 and 2 (tributary) and 7 (mainstem backwater zone below tributary mouth). Coho salmon catch rates were highest in the tributary habitat zones.

Rainbow trout were more broadly distributed among the habitat zones, but showed a preference for tributary zones (zones 1 and 2) over slough or mainstem zones. Burbot were caught most frequently in the mainstem mixing zone, followed by slough zones.

The results of taking these same data and aggregating them by zone, using three separate criteria, are presented in Appendix Tables F-7 to F-10. A t test was conducted for each pair of aggregate zones under each of the three zone aggregating categories for each of the four species. In all cases, these means representing pooled sites and sampling periods, showed highly significant differences ($P < 0.01$).

The catch rate for chinook salmon was about equally balanced between zone H-I and zone H-II, the rate for zone H-III was lower (Appendix Table F-7). Chinooks showed a slight preference for tributary water (W-I) over mainstem water. There was not a clear preference demonstrated for water velocity aggregates (V-I versus V-II).

Appendix Table F-3. Chinook juvenile catch per minnow trap by zone at selected DFH sites on the Susitna River below Devil Canyon, June through September, 1982.

Zone	Min	Max	Mean	n
1	0.0	6.9	0.4	15
2	0.0	5.8	0.2	13
3	0.0	1.0	0.1	17
4	0.0	0.2	0.0	7
5	0.0	0.0	0.0	2
6	0.0	0.7	0.1	5
7	0.0	13.0	0.9	6
8	0.0	0.0	0.0	1
9	0.0	0.4	0.0	5

Appendix Table F-4. Coho juvenile catch per minnow trap by zone at selected DFH sites on the Susitna River below Devil Canyon, June through September, 1982.

Zone	Min	Max	Mean	n
1	0.0	25.6	1.2	15
2	0.0	18.1	0.9	13
3	0.0	1.4	0.0	17
4	0.0	0.3	0.0	7
5	0.0	1.8	0.9	2
6	0.0	0.7	0.1	5
7	0.0	1.7	0.3	6
8	0.0	0.0	0.0	1
9	0.0	1.9	0.1	5

Like zone 1 best, then 2 and 5, then 7 (below trib).

Appendix Table F-5. Rainbow trout catch by trotline by zone at selected DFH sites on the Susitna River below Devil Canyon, June through September, 1982.

Zone	Min	Max	Mean	n
1	0.0	2.0	0.2	15
2	0.0	4.0	0.3	13
3	0.0	5.0	0.2	17
4	0.0	1.0	0.1	7
5	0.0	0.0	0.0	2
6	0.0	0.0	0.0	5
7	0.0	2.0	0.2	5
8	0.0	0.0	0.0	1
9	0.0	1.0	0.1	4

Like zone 2 best, then 3, 1, and 7.

Appendix Table F-6. Burbot catch by trotline by zone at selected DFH sites on the Susitna River below Devil Canyon, June through September, 1982.

Zone	Min	Max	Mean	n
1	0.0	2.0	0.0	15
2	0.0	5.0	0.3	13
3	0.0	4.0	0.7	17
4	0.0	2.0	0.6	7
5	0.0	0.0	0.0	2
6	0.0	2.0	0.6	5
7	0.0	2.0	0.5	5
8	0.0	0.0	0.0	1
9	0.0	2.0	0.3	4

Like zone 3 best, then 4 and 6 (above trib), 7 next.

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Appendix Table F-7. Chinook juvenile catch per minnow trap by aggregate zone at selected DFH sites on the Susitna River below Devil Canyon, June through September, 1982.

Aggregate Zone	n	Mean Catch/Trap
Hydraulic		
H-I	15	0.3
H-II	14	0.4
H-III	1[illegible]	0.1
Water Source		
W-I	17	0.3
W-II	8	0.1
W-III	17	0.2
Water Velocity		
V-I	17	0.2
V-II	15	0.3

Coho salmon preferred the area above the mainstem backwater zone over the backwater zone itself (Appendix Table F-8). The catch rate in the mixing zone (H-III was low). Cohos strongly preferred tributary water (W-I) over slough or mainstem water (W-II or W-III).

Rainbow trout did not show any strong separation by the aggregate zones (Appendix Table F-9). Burbot clearly demonstrated a preference for the mixing zone (H-III and W-III), mainstem water (W-II), and higher velocity water (V-I) (Appendix Table F-10).

2. <u>Relationship of the habitat index and mainstem discharge</u>

Zone quality indices

The calculated zone quality indices (ZQI) of the aggregate hydraulic zones for four species of juvenile salmon for each of the two reaches are presented in Appendix Table F-11. The mean shown is the mean of the seasonal ZQI's of all the sampling sites in the reach where the data from at least one sampling period met the previously defined criteria.

The mean ZQIs for chinook salmon are fairly evenly balanced between zone H-I and zone H-II in both reaches, with a slight preference shown for zone H-I. The ZQI for zone H-III is substantially smaller, although it is larger for chinook in the lower reach than for the other species.

Coho salmon show a strong preference for zone H-I over zone H-II in both reaches; there were very few caught in zone H-III. There was one site

Appendix Table F-8. Coho juvenile catch per minnow trap by aggregate zone at selected DFH sites on the Susitna River below Devil Canyon, June through September, 1982.

Aggregate Zone	n	Mean Catch/Trap
Hydraulic		
H-I	15	1.2
H-II	14	0.8
H-III	17	0.0
Water Source		
W-I	17	1.0
W-II	8	0.0
W-III	17	0.1
Water Velocity		
V-I	17	0.6
V-II	15	0.8

Appendix Table F-9. Rainbow trout catch per trotline by aggregate zone at selected DFH sites on the Susitna River below Devil Canyon, June through September, 1982.

Aggregate Zone	n	Mean Catch/Trap
Hydraulic		
H-I	15	0.2
H-II	[illegible]	0.3
H-III	17	0.2
Water Source		
W-I	17	0.3
W-II	8	0.1
W-III	17	0.2
Water Velocity		
V-I	17	0.2
V-II	14	0.3

Appendix Table F-10. Burbot catch per trotline by aggregate zone at selected DFH sites on the Susitna River below Devil Canyon, June through September, 1982.

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Aggregate Zone	n	Mean Catch/Trap
Hydraulic		
H-I	5	0.1
H-II	14	0.2
H-III	17	0.7
Water Source		
W-I	17	0.1
W-II	8	0.6
W-III	17	0.6
Water Velocity		
V-I	17	0.5
V-II	14	0.2

Appendix Table F-11. Range and mean zone quality indices (ZQI) for aggregate hydraulic zones by reach by species, June through September, 1982. The means are the mean of the seasonal ZQI's for all the sites in the reach. The sample size (n) equals the number of sites included in calculating the mean.

Lower reach

	Zone H-I				Zone H-II				Zone H-III			
Species	Min	Max	mean	n	Min	Max	mean	n	Min	Max	mean	n
Chinook	0.49	0.71	0.59	4	0.46	0.66	0.53	4	0.32	0.32	0.32	1
Coho	0.71	0.88	0.82	3	0.18	0.45	0.32	3	0.00	0.05	0.02	3
Sockeye	0.00	0.00	0.00	1	1.00	1.00	1.00	1	-	-	-	-
Chum	0.28	0.67	0.54	3	0.33	0.72	0.57	3	0.00	0.00	0.00	1

Upper reach

	Zone H-I				Zone H-II				Zone H-III			
Species	Min	Max	mean	n	Min	Max	mean	n	Min	Max	mean	n
Chinook	0.52	0.52	0.52	1	0.48	0.48	0.48	1	0.00	0.00	0.00	1
Coho	0.94	1.00	0.97	3	0.04	1.00	0.40	3	0.00	0.03	0.01	4
Sockeye	0.00	1.00	0.59	6	0.33	1.00	0.70	5	0.00	0.50	0.20	6
Chum	0.00	0.33	0.29	4	0.67	1.00	0.88	5	0.00	0.00	0.00	3

in the upper reach (Slough 6A) which never had a zone H-I present during the samplings. All the coho salmon caught at the site were in zone H-II; none were ever caught in zone H-III. This is the reason for the maximum ZQI of 1.00 for coho in the upper reach.

All of the sockeye salmon present at the one site in the lower reach which met the previously defined criteria were caught in zone H-II. In the upper reach, a preference for zone H-II is apparent. However, there was at least one site where all the sockeye present were in zone H-I, leading to the maximum value of 1.00 for that zone.

Chum salmon in the lower reach were approximately equally divided between zone H-I and zone H-II, with a slight preference shown for the latter. A strong preference for zone H-II was shown in the upper reach. Chum salmon were rarely caught in zone H-III.

Habitat Indices

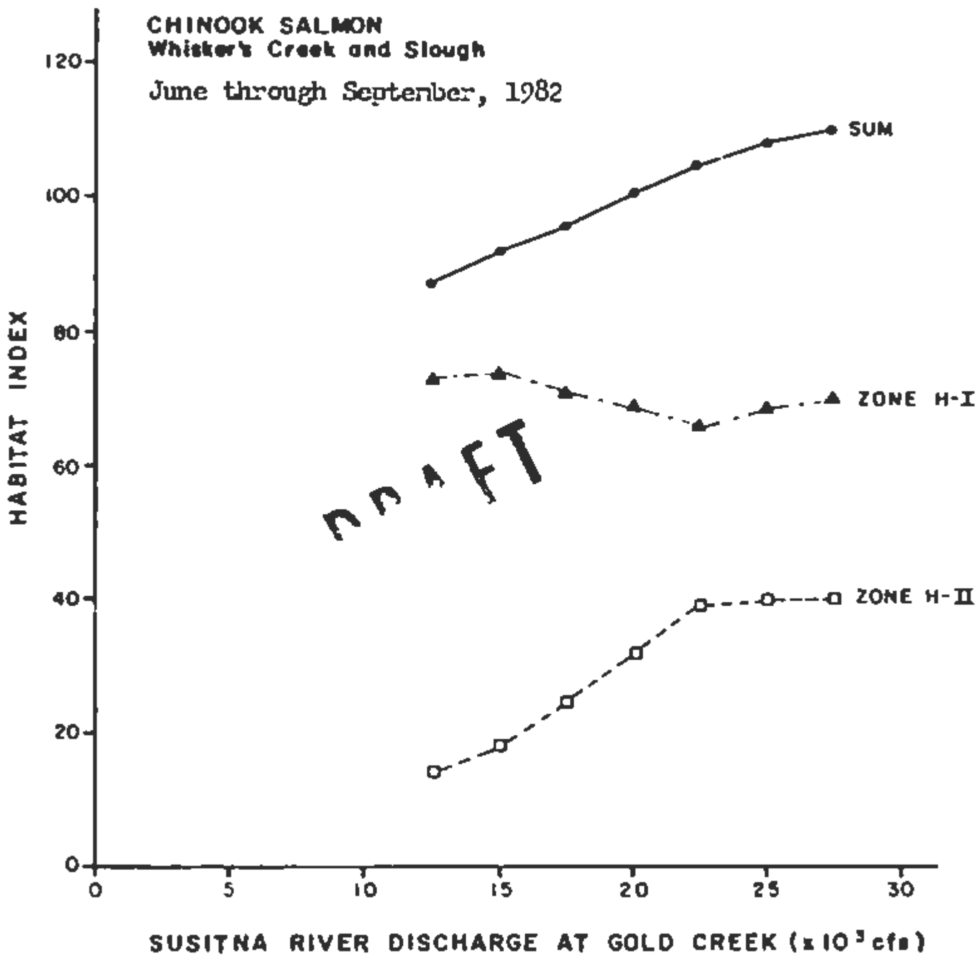
There are several possibilities for presenting the results of this analysis. There are four salmon species multiplied by 17 sampling sites. The sites could be pooled into the two reaches. Another combination could be produced by aggregating the nine habitat zones in a different manner than hydraulic aggregates; for example, habitat zones could be aggregated by water source. Rather than present the large number of graphs which could be generated, we have included in this report one graph for each of the four salmon species. One site was selected for each species. This site in each case was among those which had the highest catch for the species and which had zone quality indices which were typical for that species among the several sites in the reach. Together, the graphs include upland sloughs, side sloughs associated with a large tributary mouth, and side sloughs with no large tributary mouth; represent both reaches; and illustrate all the major points which result from this kind of analysis.

Juvenile Chinook Salmon

The site habitat index (sum of the habitat indices for each separate zone) for chinook salmon at the Whiskers Creek and slough site shows a steady increase with increasing discharge (Appendix Figure F-3). This results from summing the habitat indices of the two zones represented.

The shape of the habitat index curves for the individual zones is exactly the same as the shape of their surface area curves because the habitat index is a multiple of the surface area. The shape of the zone H-II curve is typical for sites in the reach - it shows a steady increase and then levels off at a discharge of approximately 22,500 cfs. The zone H-I surface area curve is relatively more constant. At the lower discharge levels, the linear extent of zone H-I increased downstream as the backwater zone (zone H-II) receded. However, at the same time, the width of zone H-I was decreasing. The result of the two was a slight increase in zone H-I surface area as discharge decreased.

Because the zone quality indices for the two zones at Whiskers Creek for chinook salmon were fairly similar (Appendix Table F-12), zone H-I and



Appendix Figure F-3. Habitat indices for chinook salmon juveniles at Whiskers Creek and Slough as a function of mainstem discharge.

Appendix Table F-12. Habitat indices for juvenile chinook salmon for aggregate hydraulic zones at Whiskers Creek and slough, June through September, 1982.

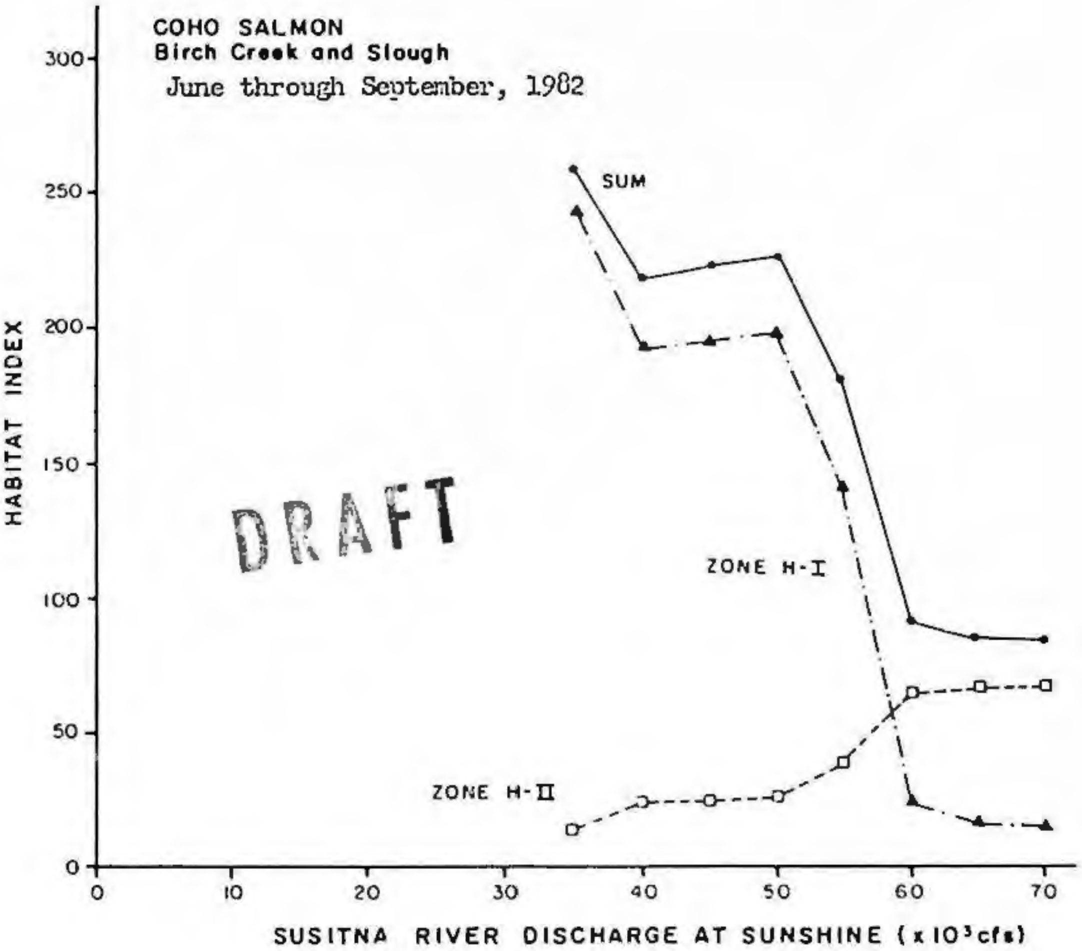
Susitna Discharge at Gold Creek (cfs)	Zone H-I (ZQI=0.52)	Zone H-II (ZQI=0.48)	Site habitat index (Σ HI)
12,500	73	14	87
15,000	74	18	92
17,500	71	25	96
20,000	69	32	101
22,500	66	39	105
25,000	69	40	109
27,500	70	40	110

zone H-II were given nearly equal weight in compiling the site habitat index. Zone H-I is slightly favored (ZQI = 0.52) over zone H-II (ZQI = 0.48). If the ZQI for each zone had been equal to 0.5, which means that chinook salmon were equally distributed between the two zones, then the site habitat index curve would exactly parallel the total wetted surface area.

Juvenile Coho Salmon

The shape of the surface area curves for zones H-I and H-II at the Birch Creek and Slough sampling site reflect a pattern which occurs at several of the study sites (Appendix Figure F-4); with increasing mainstem discharge, the surface area of zone H-I decreases. The zone H-I surface area decreases because the zone H-II (backwater area) encroaches upon it as the discharge level increases.

Because zone H-I was strongly preferred by coho salmon (Appendix Table F-13), the site habitat index curve is heavily weighted by the zone H-I habitat index and the two curves have a similar shape (Appendix Figure F-4). Basically, this means that a loss of zone H-I reflects an important loss of habitat for coho salmon at this site, because they may not have the capability of compensating for a decrease in this zone H-I surface area.



Appendix Figure F-4. Habitat indices for coho salmon juveniles at Birch Creek and Slough as a function of mainstem discharge.

Appendix Table F-13. Habitat indices for juvenile coho salmon for aggregate hydraulic zones at Birch Creek and Slough, June through September, 1982.

Susitna Discharge at Sunshine (cfs)	Zone H-I (ZQI=0.88)	Zone H-II (ZQI=0.18)	Site habitat index (≤ HI)
35,000	245	15	260
40,000	194	26	220
45,000	197	27	224
50,000	200	28	228
55,000	142	40	182
60,000	26	66	92
65,000	19	68	87
70,000	18	69	87

Juvenile Sockeye Salmon

Juvenile sockeye salmon preferred the zone H-II area (ZQI = 0.66) over the zone H-I area (ZQI = 0.55) (Appendix Table F-14). This, along with the fact that the surface area of the zone H-I area changed very little with variation in discharge, gave a site habitat index for Slough 8A for sockeye salmon which closely resembled the shape of the zone H-II habitat index (Appendix Figure F-5). This is opposite the situation for coho at Birch Creek, where the site habitat index was strongly influenced by the H-I zone. The flatness of the zone H-I curve at Slough 8A is in part due to the gradually sloping banks of the H-II zone at Slough 8A and because the gradient near the zone I/II interface is relatively steep.

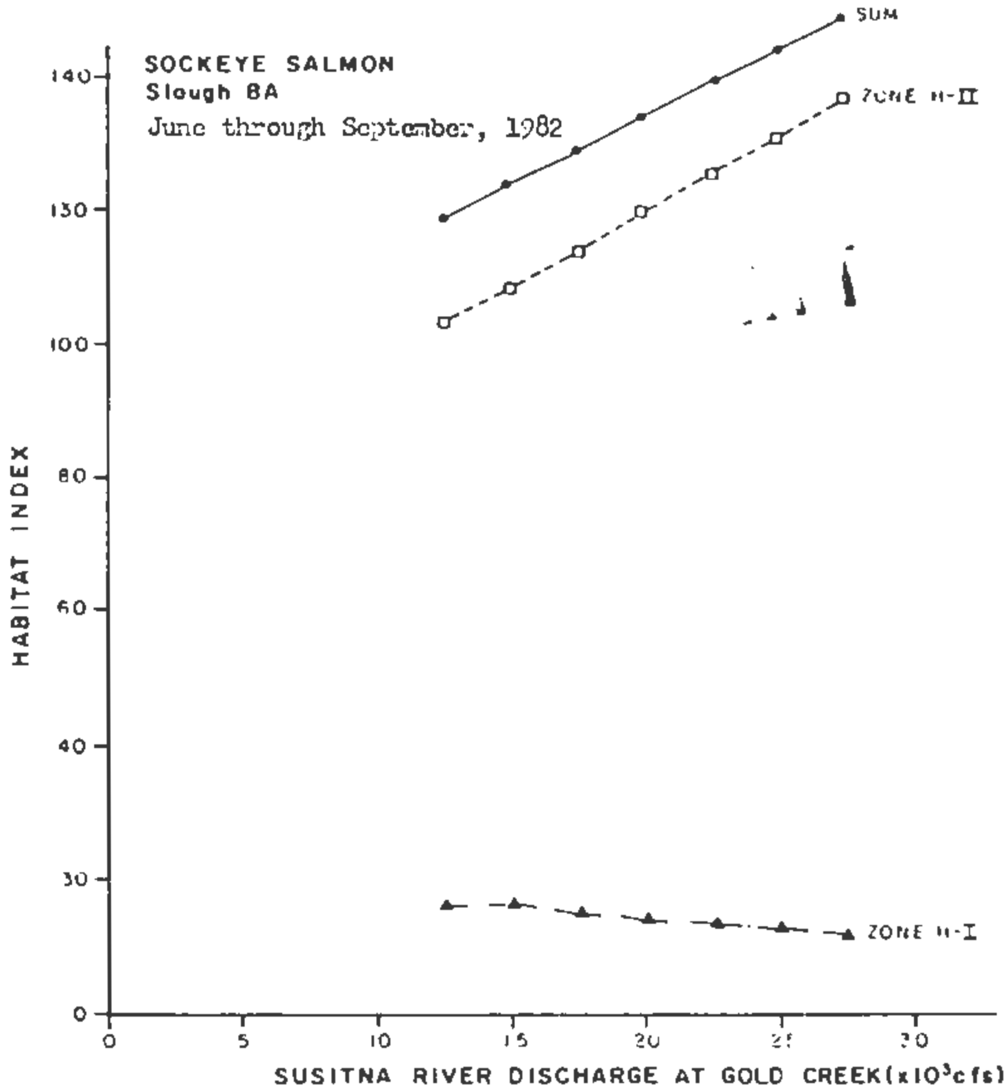
Juvenile Chum Salmon

Slough 6A was chosen as the site to depict habitat indices for chum salmon (Appendix Table F-15). The study boundary for this upland slough did not include an H-I zone. This slough has steep banks and a deep entrance channel, so the surface area of the slough showed only a small response to variations in mainstem discharge.

All of the chums present at this site were captured in the H-II zone, which gives that zone a ZQI of 1.00 and zone H-III a ZQI of 0.00. The net result of the above is that the site habitat index is exactly the same as the zone H-II habitat index and that this index did not vary much with variations in discharge (Appendix Figure F-6).

Appendix Table F-14. Habitat indices for juvenile sockeye salmon for aggregate hydraulic zones at Slough 8A, June through September, 1982.

Susitna Discharge at Gold Creek (cfs	Zone H-I (ZQI=0.55)	Zone H-II (ZQI=0.66)	Site habitat index (ΣHI)
12,500	16	103	119
15,000	16	108	124
17,500	15	114	129
20,000	14	120	134
22,500	14	125	139
25,000	13	131	144
27,500	12	137	149



Appendix Figure F-5. Habitat indices for sockeye salmon juveniles at Slough 8A as a function of mainstem discharge.

Appendix Table F-15. Habitat indices f^r juvenile chum salmon for aggregate hydraulic zones at Slough 6A, June through September, 1982.

Susitna Discharge at Gold Creek (cfs)	Zone H-I (ZQI = N/A)	Zone H-II (ZQI=1.00)	Site habitat index (Σ HI)
12,500	-	128	128
15,000	-	129	139
17,500	-	131	131
20,000	-	132	132
22,500	-	134	134
25,000	-	135	135
27,500	-	137	137

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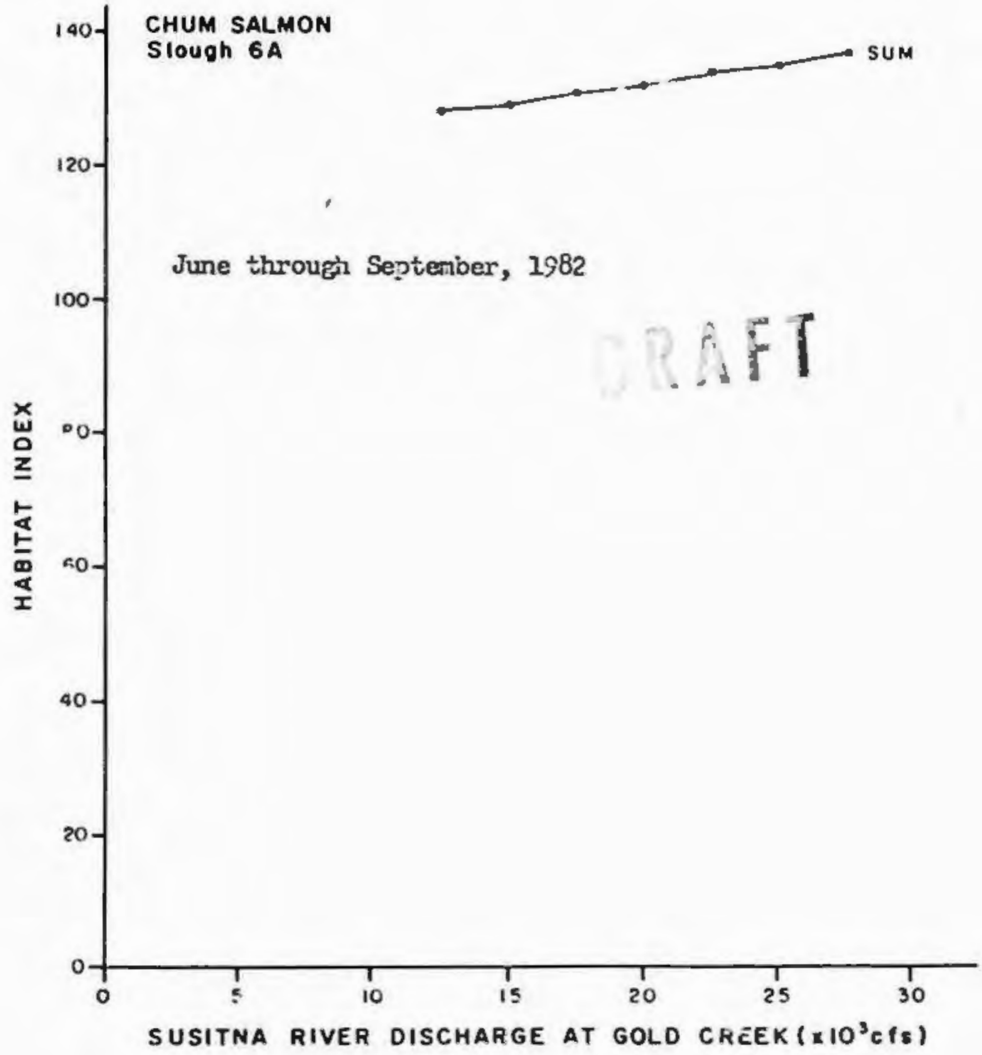

Appendix Figure F-6. Habitat indices for chum salmon juveniles at Slough 6A as a function of mainstem dishcarge.

D. DISCUSSION

1. Spatial and temporal variations in habitat variables and in relative abundance of fish

The validity of any type of analysis relating discharge to habitat would first establish if the fish species life stage in question can be demonstrated to respond to the variability of the habitat components being examined. The data presented suggests a significant difference in the key habitat indicators present in our defined areas and is maintained over time and over variations in mainstem discharge. The distribution of fish among the habitat zones is also established by the analysis present. That is, there are significant differences in the catch rates for the species between the zones sampled.

The calculation of the zone quality indices from these catch data is therefore demonstrated by the statistical validity of the differences in distribution observed.

2. Relationship of the habitat index and mainstem discharge

Zone Quality Indices

We believe the results show that the measure of habitat quality which was derived for this study, the zone quality index (ZQI), provides logical results which reflect juvenile salmon habitat preferences.

Chinook salmon apparently do not have strong preferences between the backwater areas (Zone H-II) and the free-flowing areas above the backwater zone (Zone H-I). They also show more association with the mixing zone (zone H-III) below the backwater area than other juvenile salmon species. These results suggest that chinook juveniles are associated with broader ranges of habitat parameters than the other species. Similar results were obtained when examining chinook distribution among the major habitat types (tributary mouths, upland sloughs, and so on) in Appendix G.

Coho salmon showed the strongest association of all the species for the area (zone H-I) above the backwater zone. This may be related to their preference for areas with tributary water. If the nine separate habitat zones had been aggregated using water source as a criterion rather than mainstem backup, a strong preference by coho for tributary water would have been evident. This kind of aggregation would separate the turbid H-I area of sloughs with a mainstem water source (called Zone 4) from the clear water H-I area of tributaries (called zone 1).

Sockeye and chum salmon juveniles both showed a marked preference for the mainstem backwater zone (Zone H-II). However, there were several cases where both these species were present in Zone H-I; thus, the ZQI for zone H-I is not insignificant. Field observations indicated that the sockeye present in zone H-I were often associated with the small calm water morphological pools present in these areas. This was the case in sites such as Slough 8A and Slough 19. If point-specific data were available for sockeye juveniles, it would probably show a very strong preference by sockeyes for low-velocity water. Two factors account for the presence of chum salmon juveniles in zone H-I. First, they were captured in this area during outmigration from tributary spawning grounds (at Goose Creek). Second, they were frequently present in sloughs above the backwater zones, having emerged from nearby redds (Slough 11) or having entered the slough head during outmigration (Birch Creek Slough). The examination of the distribution of this species over time also suggests that this may be the reason for their occurrence in zone H-I. Juvenile chums sampled shortly after emergence were found in a higher ratio in zone H-I than in later sampling periods when a higher ratio occurred in zone H-II. This presumably reflects their migration from natal areas in zone H-I to rearing areas in zone H-2.

Habitat Indices

The habitat indices which were presented in this report represent only one of the several possible approaches using this kind of analysis. The nine individual habitat zones could be treated separately or they could be aggregated using criteria other than the influence of the mainstem backwater. Other zone aggregations could be compiled using water velocity or water source as a criterion. However, the value of the approach has been demonstrated by what has been presented so far.

In interpreting the habitat index curves, one should be careful about extending the curves beyond the range of mainstem discharge which was observed, because the trends may not hold outside that range. Also, it very important to keep in mind that these curves reflect the situation only within the study boundaries. These boundaries usually included a tributary or slough mouth, some of the area above, and some of the mainstem mixing zone below. Just because the surface area of a preferred habitat diminished within the study boundary does not mean that the habitat was completely lost. For example, the coho salmon present in zone H-I at Birch Creek and Slough may be able to move further up the creek as a rising mainstem discharge causes the backwater zone to advance on zone H-I.

Similarly, decreasing areas of backwater zones may not have replacement habitat available, such as are used by sockeye and chum salmon. These study sites for this analysis were chosen in part because of their importance to the fish populations, and loss of surface area can correctly be interpreted as a habitat loss which will influence the populations.

The four site habitat index curves which were presented show all of the three possible relationships with an increase in mainstem discharge - they increase, decrease, or remain relatively constant. In practice, the curves showing a positive correlation with discharge are the norm. Only coho site habitat indices would be expected to decline with an increasing discharge. This relationship exists because of the strong association of cohos with zone H-I. The curve where there is little change in habitat index with a change in discharge (Slough 6A) is the exception. This occurs only at upland sloughs which are completely backed up by the mainstem, and extends only over the range at discharges sampled.

LITERATURE CITED

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods. The Iowa State University Press, Ames. 593 pp.

APPENDIX G

Use of Major Habitat Types by Juvenile Salmon and Resident Species

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1. Introduction

The preference of fish for a certain kind of habitat varies with species, life history stage, time of year, and other factors. This appendix is an analysis of preferences of resident fish and juvenile salmon during the open water season for six major habitat types occurring on the Susitna River between Cook Inlet and Devil Canyon. The six major habitat types were defined as tributary mouths, side channels with large tributary mouth, side sloughs with large tributary mouth, side sloughs with small tributary mouth or groundwater input, upland sloughs, and mainstem channels or side channels.

Methods

Two kinds of proportions were analyzed using chi square analysis (Snedecor and Cochran, 1974; Summers et al., 1981). The first kind was the distribution of a group of species among several different habitat types. The second was similar except that the distribution of a single species among these habitat types was tested. These tests were performed for both juvenile salmon (pink salmon not included because of low numbers captured) and resident species. A third kind of comparison which was conducted graphically but not with chi square analysis was the proportion of the four juvenile salmon species at one particular habitat type.

Statistical significance for all the chi square tests was set at the 95% confidence level. Continuity correction factors were calculated for all 2 X 2 contingency tables. Species, dates, or sites were pooled where necessary to keep the expected values greater than five.

Presence/absence data were extracted from (ADF&G 1983) and were collected by a number of gear types and methods (Appendix Table G-1). Appendix Table G-2 shows how the 17 Designated Fish Habitat (DFH) sites were grouped into five major habitat types along with sampling effort at each type.

3. RESULTS

Juvenile salmon

The presence/absence of the four species of juvenile salmon at the five major habitat types at DFH sites is shown in Appendix Table G-2. A 4 x 5 chi square test of the presence/absence of four species of juvenile salmon versus five major habitat types (Appendix Table G-3) showed that juvenile salmon did exhibit habitat preferences. A closer examination conducted by individual species revealed that cohos and sockeyes exhibited a significant preference for certain habitat types but no such preference by chinook and chums was demonstrated (Appendix Table G-3).

Appendix Table G-1. Summary of chi square analyses performed on 1982 presence/absence or species proportion data.

Method and Type of Data	Where Collected	Species	Chi Square Comparisons
All gear types[a] except boat electrofishing, presence/absence by species	17 DFH sites[b]	All juvenile salmon species	Among habitat types by all species
		Chinook salmon Coho salmon	Among habitat types by species
Beach seine or backpack electrofishing[c], presence/absence by species	17 DFH sites	Chum salmon Sockeye salmon Round whitefish Arctic grayling Longnose sucker Slimy sculpin	Among habitat types by species
Boat electrofishing, catch numbers	Cook Inlet to Devil Canyon	All resident species	Comparison of species proportions between habitat types and by season within mainstem and tributary types
Boat electrofishing, presence/absence by species	Above Chulitna River confluence (RM 98.5)	Round whitefish Arctic grayling Longnose sucker Burbot Humpback whitefish Rainbow trout Dolly varden	1) Among habitat type or pooled habitat type by species 2) Within habitat types by season by species

[a] Gear types include minnow traps, beach seines, and backpack electrofishing units.

[b] The 17 DFH (Designated Fish Habitat) sites ranged from Goose Creek (RM 73.1) to Portage Creek (RM 148.8).

[c] These methods were the only effective techniques for capturing these species at these sites.

Appendix Table G-2. Effort (number of sampling trips) and presence (number of trips that each species was present) of juvenile salmon at DFH sites. Includes catch by all gear types, June through September, 1982.

	Effort	Presence				Sub-Total
		Chinook	Coho	Chum	Sockeye	
Tributary mouths						
Fourth of July Creek	8	5	2	1	1	
Indian River	8	6	1	1	2	
Portage Creek	7	0	0	0	0	
sub-total	23	11	3	2	3	19
Upland sloughs						
Whitefish Slough	7	3	4	0	3	
Slough 6A	8	7	7	2	8	
Slough 19	8	3	0	1	6	
sub-total	23	13	11	3	17	44
Side sloughs w/large tribs						
Rabideux Creek	6	5	6	0	1	
Birch Creek	8	6	8	5	4	
Whiskers Creek	8	8	7	2	2	
Lane Creek	8	6	4	1	4	
Slough 20	8	5	1	1	3	
sub-total	38	30	26	9	14	79
Side sloughs w/small trib or groundwater						
Slough 8A	8	5	1	1	7	
Slough 9	8	7	1	3	4	
Slough 11	8	3	2	1	3	
Slough 21	8	5	1	2	4	
sub-total	32	20	5	7	18	50
Side channels w/trib						
Goose Creek	8	6	6	2	5	
Sunshine Creek	8	6	8	1	1	
sub-total	16	12	14	3	6	35
TOTAL	132	86	59	24	58	227

Appendix Table G-3. Summary of results of chi-square tests of association between juvenile salmon presence/absence and habitat type at DFH sites. Habitat types were tributary mouths, upland sloughs, side sloughs with large tributaries, side sloughs without large tributaries and side channels with large tributaries, June through September, 1982.

Species	Chi-square	Df	Probability
All four species of juvenile salmon[a]	22.8	12	p .05
Chinook[a]	7.8	4	NS[c]
Coho[a]	40.9	4	p .01
Chum[b]	0.0	1[d]	NS
Sockeye[b]	11.1	4	p .01

[a]All gear types

[b]Beach seining and electrofishing only

[c]NS = Not significant

[d]Habitat types were pooled into tributary sites and sloughs with no large tributaries.

Ratios of observed presence to expected presence show an association of coho salmon juveniles with upland sloughs, side sloughs with large tributary mouths, and side channels with large tributary mouths (Appendix Table G-4). Sockeye salmon juveniles were associated with upland sloughs and side sloughs without large tributary mouths. The distribution of each species among the major habitat types is illustrated in Appendix Figure G-1.

An examination of juvenile salmon species proportions at each of the five major habitat types (Appendix Figure G-2) shows that each habitat type had a rather distinctive community of juvenile salmon. Chi square tests were not performed on these proportions.

Resident Species

Boat electrofishing catch data were used to characterize species proportions of the resident fish community at five different habitat types of the Susitna River at sites both above and below the Chulitna River confluence (Appendix Table G-5). After less abundant species were pooled to increase sample sizes, species proportions between habitat types were tested, using actual numbers from catch data, with chi square analysis and found to be significantly different (Appendix Table G-6). The seasonal differences in species proportions at mainstem and tributary sites were also significantly different (Appendix Table G-6).

Appendix Table G-4. Ratios of observed to expected presence of coho and sockeye salmon juveniles at five different habitat types at DFH sites, June through September, 1982. Based on results presented in Appendix Table G-3.

Habitat type	Coho	Sockeye
Tributary	0.29	0.36
Upland Slough	1.07	1.46
Side Slough with large trib	1.53	0.78
Side Slough w/o large trib	0.35	1.25
Side channel with tributary	1.96	0.92

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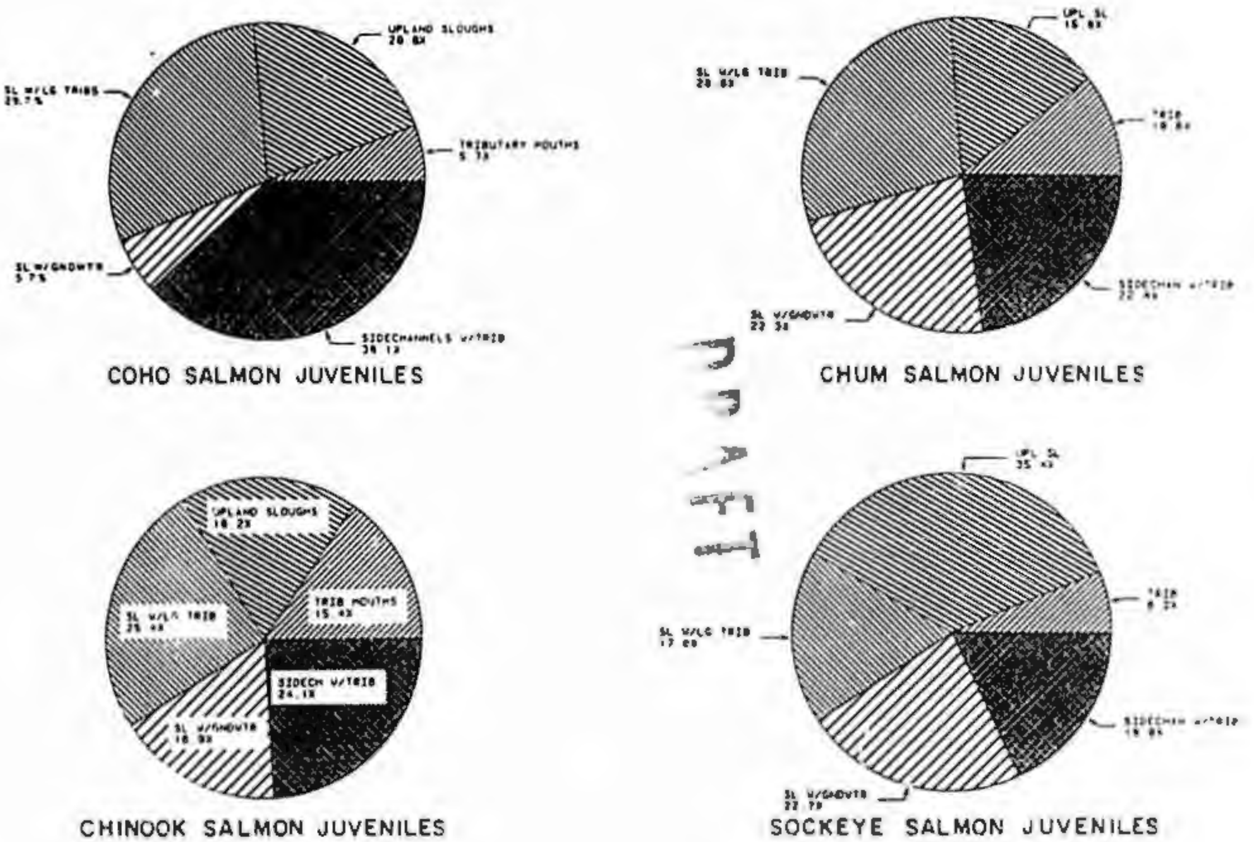
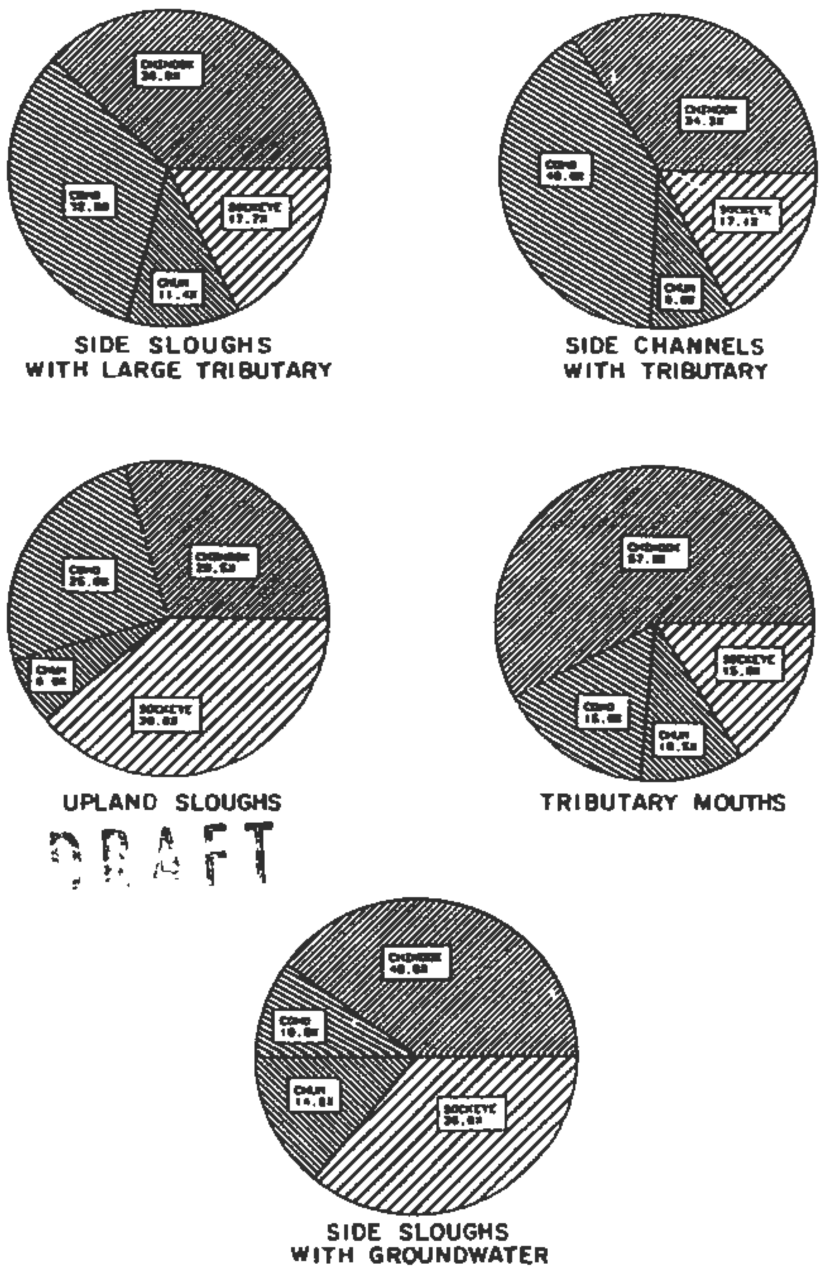


Appendix Figure G-1. Distribution of juvenile sal... species among the major habitat types at DFH sites, June th... ..., 1982. Based on the number of times the species was pres... ...centage of the total number of times the sites were sampled. E... ...ll gear types included. Percentages corrected for unequal sampling ... at the different habitat types.



Appendix Figure G-2. Proportions of juveniles of four species of salmon at each of five major habitat types located on the Susitna River, June through September, 1982. Based on the number of times the species was present as a percentage of the total number of times the sites were fished. Effort by all gear types included. Percentages corrected for unequal sampling effort at the different habitat types. Chum percentages are low because chums were not present in the Susitna system for the entire sampling season.

Appendix Table G-5. Resident species percentages by habitat type and by season within two habitat types at sites boat-electrofished between Cook Inlet and Devil Canyon, May through September 1982.

	No. of Resident Fish Captured	Percentage by Species						
		Rainbow	Arctic Grayling	Burbot	Round Whitefish	Humpback Whitefish	Longnose Sucker	Other
Habitat Type								
Mainstem	1057	2 4	20.2	7.2	30.9	3.3	30.7	5.2
Tributary mouths	1494	5.0	28.6	2.1	38.5	2.9	18.5	4.4
Upland sloughs	263	3.8	12.9	2.7	30.0	12.5	33.8	4.2
Side sloughs without trib	119	5.9	18.5	1.7	47.1	5.0	16.8	5.0
Side sloughs w/large tribs	377	5.6	19.4	2.1	19.4	2.4	47.5	3.7
Mainstem								
Month								
May-June	347	2.9	30.8	2.9	38.9	1.2	14.1	9.2
July-August	356	0.8	8.7	4.3	23.0	5.6	43.0	4.5
September	354	3.4	21.5	4.5	31.1	3.1	34.5	2.0
Tributary								
Month								
May-June	599	4.3	29.4	1.3	42.2	3.0	15.2	4.5
July-August	509	1.0	30.1	4.1	34.4	3.5	20.0	6.9
September	386	11.1	25.4	0.8	38.1	2.1	21.8	0.8

Appendix Table G-6. Comparison of species proportions of resident fish (rainbow trout, round whitefish, Arctic grayling, longnose sucker, and other) between habitat types and by season within each habitat type, May through September, 1982.

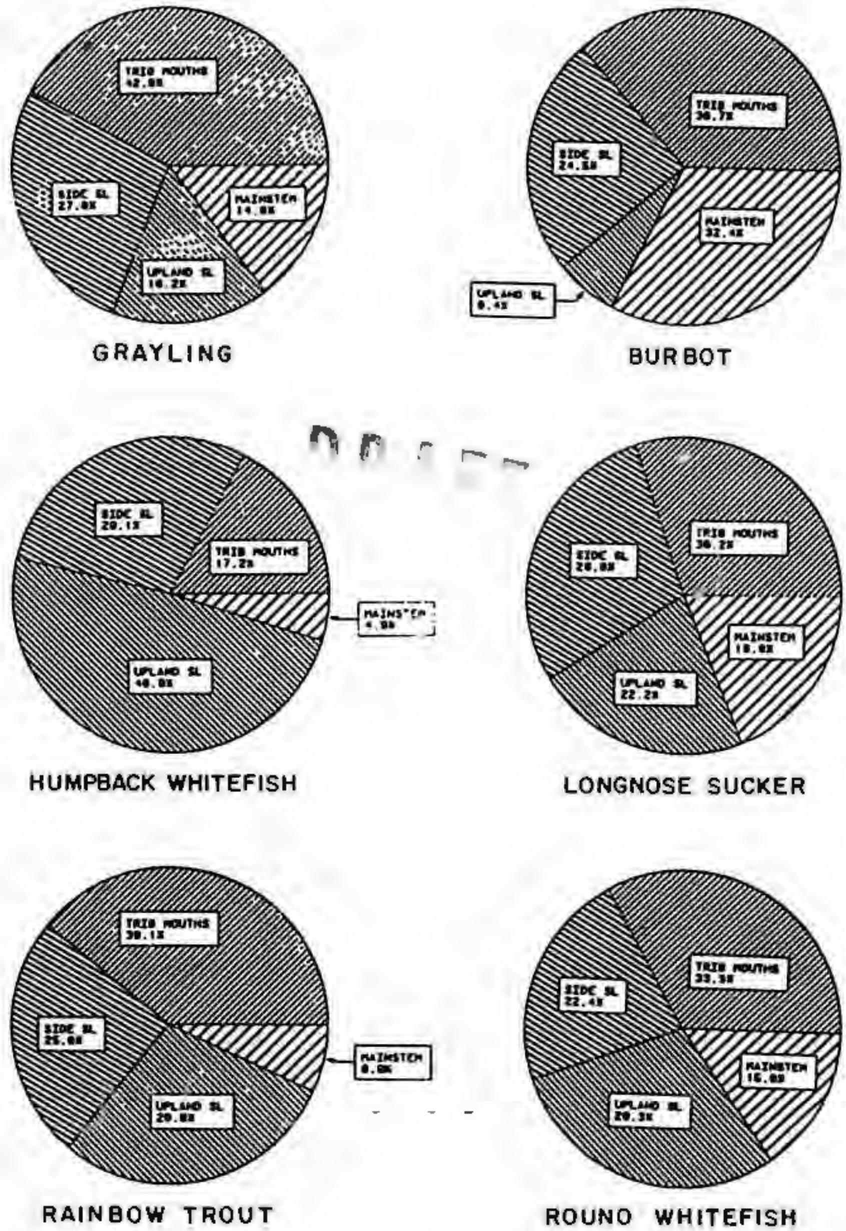
1 - Upland Sloughs
2 - Side Sloughs
3 - Mainstem
4 - Trib
5 - Slough/w/tributary

Comparison	Chi-square	df	Significance level
1 vs 2 vs 3 vs 4 vs 5	244.0	16	p .01
1 vs 2	20.4	4	p .01
4 vs 5	145.[illegible]	4	p .01
By season for mainstem sites:			
May-Jun vs Jul-Aug vs Sept	139.7	8	p .01
By season for Trib sites:			
May-Jun vs Jul-Aug vs Sept	87.3	8	p .01

Resident species proportions at tributary, side slough, upland slough, and mainstem sites above the Chulitna River confluence were further examined with presence/absence data collected with boat electrofishing gear for six species of resident fish. The relative distribution of each species among the four major habitat types is illustrated in Appendix Figure G-3.

Differences in species presence/absence at the four different habitat types above the confluence were tested for seven species of resident fish. If necessary, habitat types were pooled to increase sample sizes. Significant differences in habitat use were found for all except burbot (Appendix Table G-7). Ratios of observed to expected use of the various habitat types by species (only for those that were significantly different) are presented in Appendix Table G-8. A few seasonal differences in species use of a given habitat type were also significant (Appendix Table G-9). In July and August, use of a given habitat type was often lower than in May, June and September (Appendix Table G-10).

In another series of tests, resident fish distribution among five different habitat types at the 17 DFH sites were examined using catch data collected with beach seines and backpack electrofishing gear (Appendix Table G-11). Of the four species of resident fish examined, only Arctic grayling showed significant differences in their use of different habitat types. Arctic grayling were present at tributary sites relatively more than they were present at sloughs.



Appendix Figure G-3. Relative distribution of six resident species amount four major habitat types located above the Chulitna River confluence and sampled by boat electrofishing, May through September, 1982. Based on presence/absence data which were corrected for unequal effort at the different habitat types.

Appendix Table G-7. Chi-square tests of resident fish presence/absence associations among four major habitat types at sites above the Chulitna River confluence sampled by boat electrofishing. The four habitat types were tributaries, upland sloughs, side sloughs with no large tributaries, and mainstem sites, May through September, 1982.

Species	Chi-square	df	Probability
Round whitefish	38.5	3	p .01
Arctic grayling	46.0	3	p .01
Longnose sucker	9.5	3	p .05
Burbot	4.7	3	NS
Humpback whitefish	32.3	3	p .01
Rainbow trout[a]	31.5	2	p .01
Dolly varden[b]	7.5	1	p .01

[a] Upland and side sloughs were pooled due to small sample size
[b] Tributaries and mainstem only. No Dolly varden were captured in upland or side sloughs.

Appendix Table G-8. Ratios of observed to expected presence of resident fish by species at four different habitat types on the Susitna River between the Chulitna River and Devil Canyon, May through September, 1982. Only for those chi-square tests which were statistically significant.

	Round Whitefish	Arctic Grayling	Longnose Sucker	Humpback Whitefish
Tributaries	1.62	1.94	1.36	1.22
Side sloughs	1.08	1.25	1.30	2.04
Upland sloughs	1.42	0.75	1.00	3.45
Mainstem	0.73	0.69	0.85	0.50

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	Dolly Varden
Tributaries	2.42
Mainstem	0.52

	Rainbow
Tributaries	2.31
Upland & Side Sloughs (pooled)	1.61
Mainstem	0.41

(No Dolly Varden were captured in upland or side sloughs)

Appendix Table G-9. Chi-square tests of seasonal associations of resident fish presence within a major habitat type at sites above the Chulitna River confluence which were boat electrofished, May through September, 1982.

Species	Chi-square	df	Probability
Rainbow			
within tributaries: Spring (May, Jun) & Fall (Sep) vs Summer (Jul, Aug)	7.4	1	p .01
Grayling			
within tributaries: Spring & Fall vs Summer	0.5	1	NS
within side sloughs & upland sloughs: Spring & Fall vs Summer	3.3	1	NS
within mainstem sites: Spring & Fall vs Summer	14.6	1	p .01
Round Whitefish			
within tributaries: Spring & Fall vs Summer	0.1	1	NS
within side sloughs & upland sloughs: Spring & Fall vs Summer	0.7	1	NS
within mainstem sites: Spring vs Summer vs Fall	36.6	2	p .01
Longnose Sucker			
within tributaries: Spring & Fall vs Summer	1.2	1	NS
within side sloughs & upland sloughs: Spring & Fall vs Summer	0.1	1	NS
within mainstem sites: Spring vs Summer vs Fall	15.5	2	p .01
Burbot			
within tributaries: Spring & Summer vs Fall	0.0	1	NS
within mainstem sites: Spring & Summer vs Fall	0.0	1	NS

Appendix Table G-10. Ratios of observed to expected presence of resident fish by season at sites above the Chulitna River confluence which were boat-electrofished, May through September, 1982. Only those ratios from significant Chi-square tests are presented.

Species	Season	Obs/Exp
Rainbow Tributaries	Soring & Fall	1.5
	Summer	0.5
Grayling Mainstem	Spring & Fall	1.6
	Summer	0.6
Round Whitefish Mainstem	Spring	2.7
	Summer	0.6
	Fall	1.2
Longnose Sucker Mainstem	Spring	2.1
	Summer	0.7
	Fall	1.1

Appendix Table G-11. Chi-square tests of resident fish presence/absence associations among five major habitat types (the same as those used in Appendix Table G-3) at DFH sites, May through September, 1982. Only catch data from beach seining or backpack electrofishing were used.

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Species	Chi-square	df	Probability
Round whitefish	8.6	4	NS
Arctic grayling[a]	6.9	1	p 0.01
Longnose sucker[a]	0.4	1	NS
Slimy Sculpin	6.9	4	NS

[a] Sites were pooled into tributary mouths versus sloughs because of small sample size.

4. Discussion

Juvenile salmon

Chinook salmon juveniles appeared to be equally likely to be present at any of the five major habitat types defined. They apparently show less preference for particular major habitat types than the other species and are more broadly distributed.

No significant association of juvenile chum salmon with any of the five major habitat types was demonstrated, but this was probable a result of the relatively short time chum juveniles are present in the Susitna system. Because most chums have outmigrated by the end of July, there were only four or five possible sampling periods that they could have been present, as opposed to eight periods for the other species.

Coho salmon juveniles showed a definite preference for side sloughs with large tributary mouths and side channels with large tributary mouths. Sockeye salmon juveniles exhibited a strong preference for upland sloughs and side sloughs not associated with tributary mouths. Possibly many did not move from their natal areas (sloughs) to other habitat types.

The attractiveness of different major habitat types for juvenile salmon can be seen from examining Appendix Figure G-2. Sites that include large tributary mouths (both sloughs and side channels) attract chinook and coho salmon. Side sloughs without large tributary mouths attract chinook and sockeye.

Resident Species

Definite major habitat type preferences were demonstrated for all species except burbot. Burbot, in fact, have a strong preference for turbid water (see Appendix F), but this was not established with the present analysis because all of the sampling sites included areas of turbid water.

Of the six species examined, longnose suckers showed the least preference for certain habitat types (the chi square test for longnose sucker was significant at the 95% level, but not at the 99% level). Arctic grayling preferred tributary mouths and side sloughs over upland sloughs and the mainstem. Rainbow trout and Dolly Varden mainly used tributary mouths. Round whitefish were most likely to be found in tributary mouths and upland sloughs and humpback whitefish preferred sloughs.

Additionally, seasonal differences in habitat use were demonstrated for rainbow trout, Arctic grayling, round whitefish, and longnose suckers. Rainbow trout were more likely to be found at tributary mouths in the spring and fall than in the summer. This probably results from migration patterns into and out of tributaries.

Arctic grayling, round whitefish, and longnose suckers were all more likely to be found in the mainstem in the spring and fall than in the summer. These species apparently use tributaries and sloughs in the summer and the mainstem in the spring and fall during migrations and as over-wintering habitat.

Literature Cited

ADF&G, 1983. Volume 3, Resident and juvenile anadromous fish studies below Devil Canyon, 1982. Sus: na Hydro Aquatic Studies, Anchorage.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods. The Iowa State University Press, Ames. 593 pp.

Summers, G.W. W.S. Peters, and C.P. Armstrong. 1981. 8asic statistics in business and economics. Wadsworth Publishing Company, Belmont, CA. 594 pp.

APPENDIX H

Habitat Relationships of Juvenile Salmon Outmigration

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1. Introduction

This appendix is an analysis of the relationships between the outmigration timing of juvenile salmon and environmental variables for the Susitna River between the Chulitna River confluence and Devil Canyon. The purpose is to increase our understanding of how environmental factors influence the outmigration of juvenile salmon since the proposed hydroelectric project will change the timing and magnitude of several environmental parameters. If the effect of these changes on the outmigration of juvenile salmon can be predicted, subsequent effects on the production of juvenile salmon by this reach of river can be better analyzed.

2. Methods

Parameters examined included mainstem discharge, water temperature, turbidity and photoperiod. Time of season was another parameter used to integrate and sum other parameters such as photoperiod, water temperature and fish size. The variation in size (mean length) of the juvenile salmon species was also examined as a factor influencing outmigration. The catch data for this appendix came from an outmigrant trap located at river mile 103.0, 4.5 miles above the Chulitna River confluence. The trap was operated from June 18 to October 12, 1982. Details of the methods used to operate the trap and the results are outlined in the Basic Data Report (ADF&G, 1983a). Capture rates of juveniles of four species of salmon (chinook, coho, sockeye, and chum) were analyzed. Not enough juvenile pink salmon were captured to draw any conclusions about this species.

Discharges are from provisional data taken by the U.S. Geological Survey at the Gold Creek station. To obtain water temperatures representative of the area from which the juvenile salmon were migrating, most of the mainstem water temperature data were obtained from a continuous temperature recorder located at Curry (river mile 120.7), 17.7 miles above the outmigrant trap location (ADF&G, 1983b). Since this recorder was not operated for the entire season, other data were taken from recorders located at river miles 130.0 and 113.0 for the periods from June 24 to July 6 and from October 1 to 16 respectively. Data for June 18 to 24 were extracted from temperatures recorded by fish distribution crews at sites above the trap. Turbidities were taken at the trap location (ADF&G, 1983a) only from August 14 to the end of the season. Day length information was obtained from the National Weather Service. Time of season was computed as the number of days since the day (day 1) that the outmigrant trap began fishing.

Mean length for each species (age 0+ only) was calculated by summing the daily catches of fish until a sample size of at least 25 fish was obtained, and then taking the mean length of these fish. In some cases, it took only one day to get a sample size of at least 25, and in other cases, it took several days. The number of fish caught in this period was divided by the number of hours that the trap was fished to obtain an overall catch/hour. The median date during the period was used as the time marker.

Outmigration timing was examined using catch/hour data taken on a daily basis for each of the four species of juvenile salmon. Age classes were not separated. The relationship of these data to the habitat variables was examined through the use of linear regression using one or multiple independent (habitat) variables, correlation analysis, and analysis of variance (Snedecor and Cochran, 1967). Because the catch/hour data were quite variable from day to day, various data manipulations, including moving averages, exponential smoothing, time lags, and logarithmic transformations, were performed. We also used first-difference regressions, in which change in a dependent variable is regressed against the change in an independent variable (Summers et al., 1981). This has the advantage that any existing cause/effect relationships can be detected without problems caused by differences in relative magnitude.

3. Results

Habitat variables

The mean and range for the physicochemical variables are summarized in Appendix Table H-1. The pattern of water temperature was a mirror image of the discharge pattern (Appendix Figure H-1), during the middle part of the season, but during the early and late part of the season, water temperature more closely paralleled discharge. Turbidity fluctuations lagged discharge by two or three days. Day length (Appendix Table H-2) remained at 24 hours/day from the beginning of the sampling season until

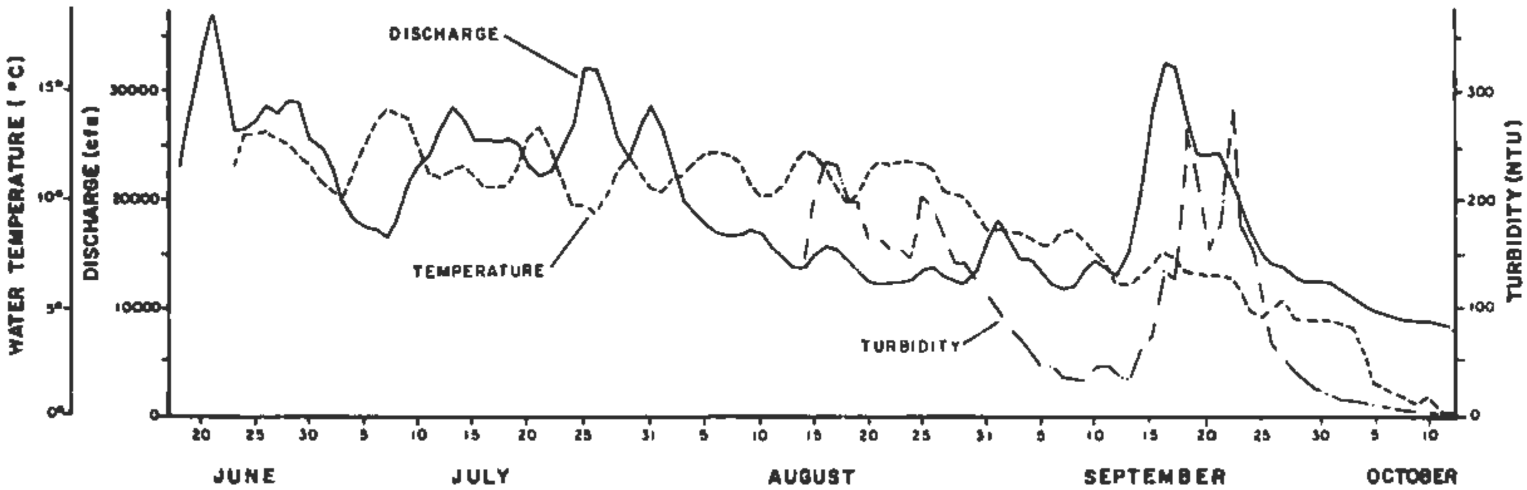
Appendix Table H-1. Range and mean for habitat variables and juvenile salmon catch/hour, outmigrant trap, June 18 - October 12, 1982.

	min	max	n	mean
Discharge (ft^3/sec)	7,950	37,000	104	19,225
Water temperature (°C)	0.5	14.1	104	9.2
Turbidity (NTU)[a]	8	284	51	103
Daylength (hrs)	11.8	24.0	104	18.4
Catch/hour				
chinook	0.0	1.2	104	0.2
coho	0.0	19.5	104	0.7
sockeye	0.0	16.2	104	1.2
chum[b]	0.0	10.0	55	0.6

DRAFT

[a] Aug 14 - Oct 12 only

[b] Jun 18 - Aug 15 only



Appendix Figure H-1. Variation of Susitna River mainstem environmental variables above the Chulitna River confluence from June 18 to October 12, 1982. See text for exact source of data.

Appendix Table H-2. Civil twilight at Talkeetna, Alaska
(Source: National Weather Service)

Date	Daylength (hours)	Date	Daylength (hours)	Date	Daylength (hours)
June 18	24.0	August 01	19.8	September 14	14.6
June 19	24.0	August 02	19.7	September 15	14.5
June 20	24.0	August 03	19.5	September 16	14.4
June 21	24.0	August 04	19.4	September 17	14.3
June 22	24.0	August 05	19.3	September 18	14.2
June 23	24.0	August 06	19.1	September 19	14.1
June 24	24.0	August 07	19.0	September 20	14.0
June 25	24.0	August 08	18.9	September 21	13.9
June 26	24.0	August 09	18.7	September 22	13.8
June 27	24.0	August 10	18.6	September 23	13.7
June 28	24.0	August 11	18.5	September 24	13.6
June 29	24.0	August 12	18.4	September 25	13.5
June 30	24.0	August 13	18.2	September 26	13.4
July 01	24.0	August 14	18.1	September 27	13.3
July 02	24.0	August 15	18.0	September 28	13.2
July 03	24.0	August 16	17.9	September 29	13.1
July 04	24.0	August 17	17.7	September 30	13.0
July 05	24.0	August 18	17.6	October 01	12.9
July 06	24.0	August 19	17.5	October 02	12.8
July 07	24.0	August 20	17.4	October 03	12.7
July 08	24.0	August 21	17.3	October 04	12.6
July 09	24.0	August 22	17.2	October 05	12.5
July 10	24.0	August 23	17.0	October 06	12.4
July 11	24.0	August 24	16.9	October 07	12.3
July 12	24.0	August 25	16.8	October 08	12.2
July 13	24.0	August 26	16.7	October 09	12.1
July 14	23.7	August 27	16.6	October 10	12.0
July 15	23.0	August 28	16.5	October 11	11.9
July 16	22.7	August 29	16.3	October 12	11.8
July 17	22.4	August 30	16.2		
July 18	22.2	August 31	16.1		
July 19	22.0	September 01	16.0		
July 20	21.8	September 02	15.9		
July 21	21.6	September 03	15.8		
July 22	21.4	September 04	15.7		
July 23	21.2	September 05	15.6		
July 24	21.0	September 06	15.5		
July 25	20.9	September 07	15.4		
July 26	20.7	September 08	15.3		
July 27	20.6	September 09	15.2		
July 28	20.4	September 10	15.0		
July 29	20.3	September 11	14.9		
July 30	20.1	September 12	14.8		
July 31	20.0	September 13	14.7		

mid-July, after which it steadily declined, usually by no more than 0.2 hr/day, to 11.8 hours/day on October 12.

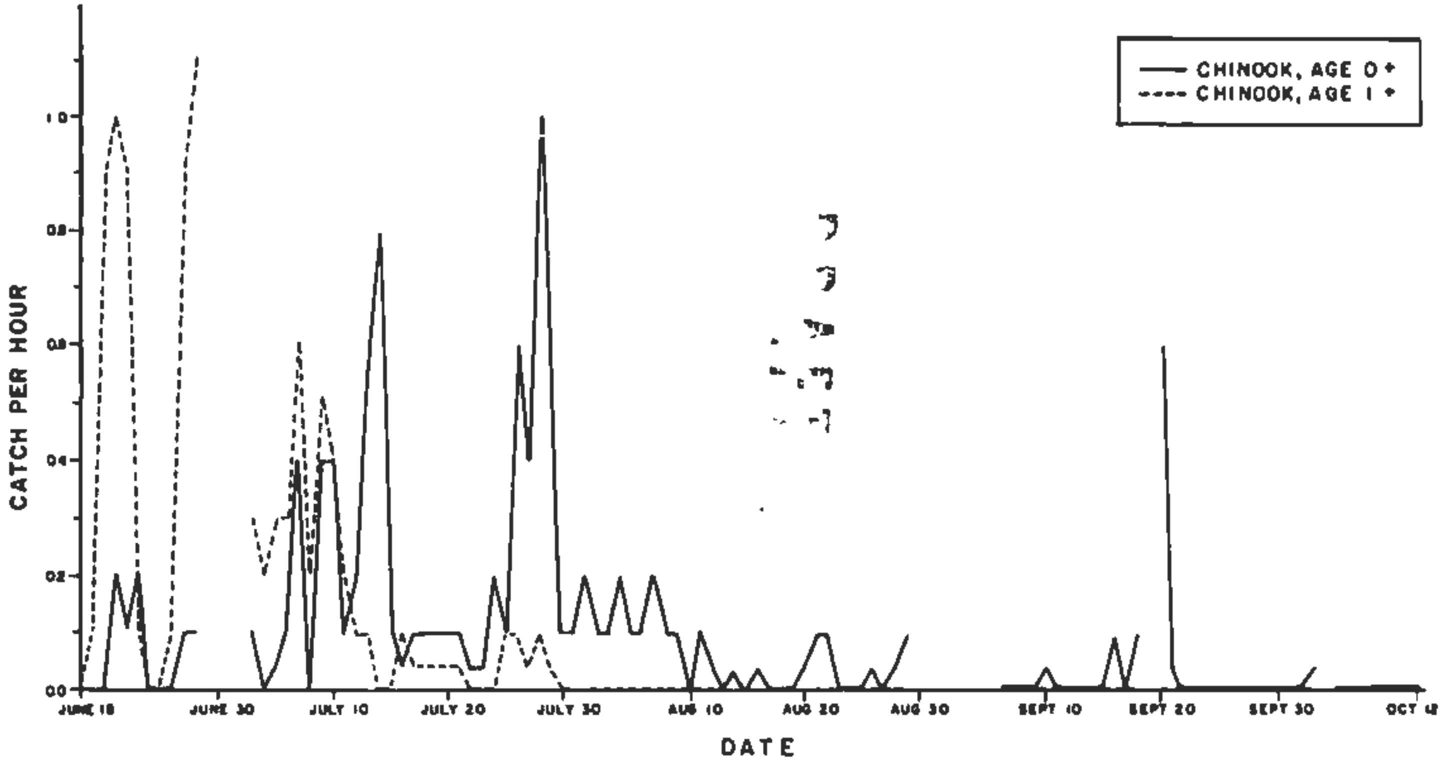
Except for a peak in mid-September, discharge generally declined over the course of the season. The correlation coefficient (r) between discharge and time of season was -0.65, $p < 0.01$. Temperature also generally decreased; with time of season ($r = -0.83$, $p < 0.01$). The correlation between discharge and water temperature was highly significant ($p < 0.01$) but relatively low ($r = 0.42$). This correlation was not improved by lagging water temperature one day behind discharge.

Juvenile salmon catch - all species

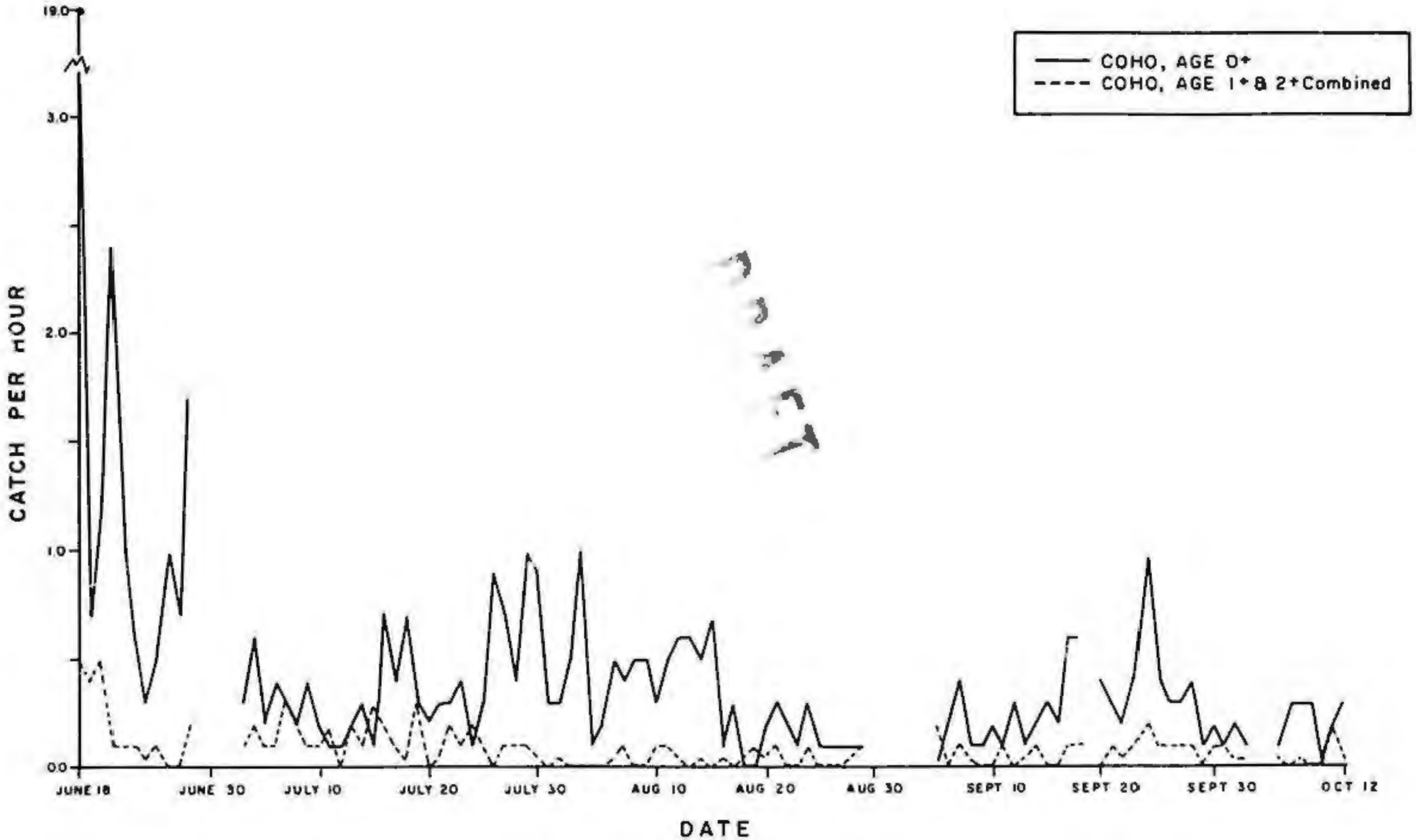
The catch/hour for juvenile salmon was initially relatively high and then declined over the course of the season (Appendix Figures H-2, H-3, and H-4). Appendix Table H-1 gives the range and mean catch/hour observed for each species.

Generally, a highly significant ($p < .01$) relationship was found between catch/hour for each individual species and the physical variables, but correlation coefficients were usually not very high.

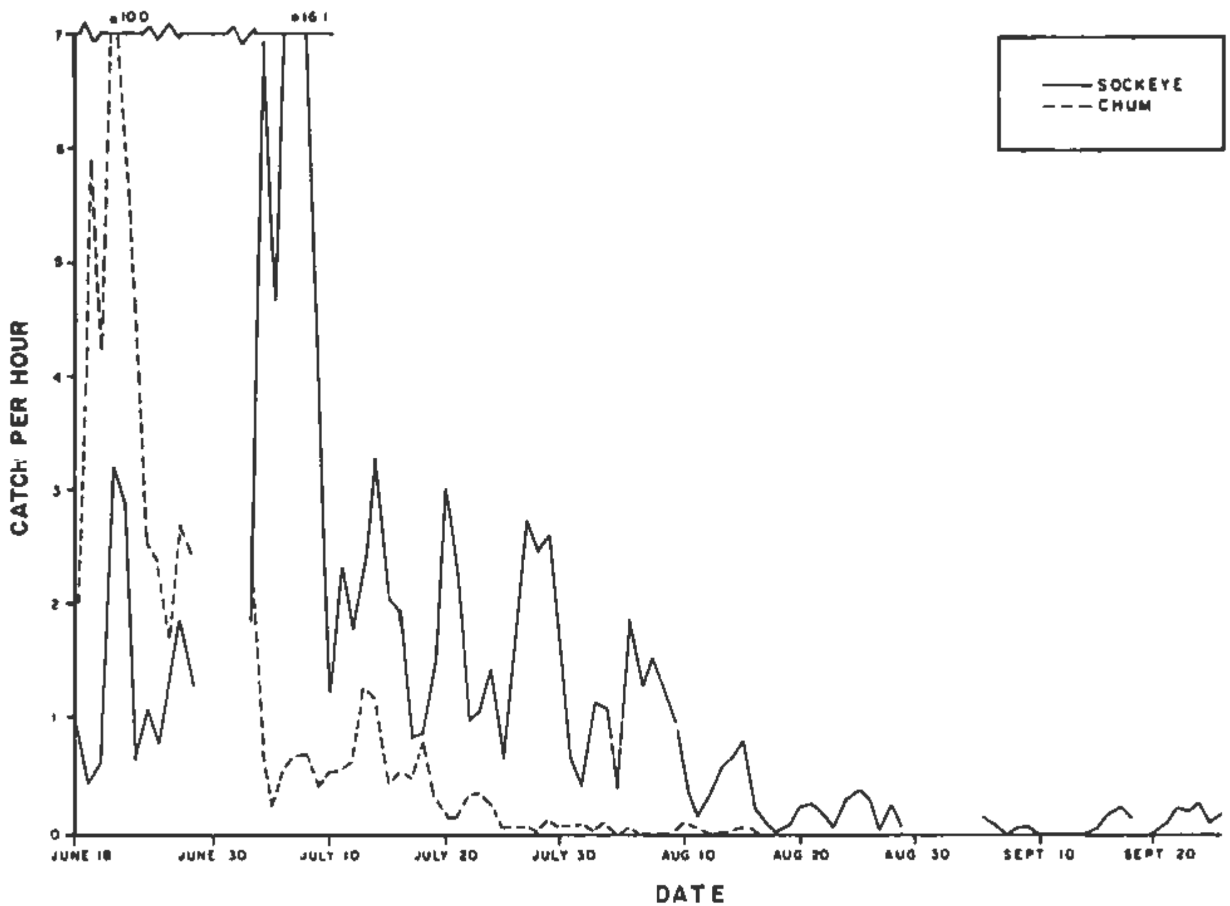
Correlations with turbidity were not calculated because turbidity data were available only after August 14. During this period, turbidity generally appeared to be closely related to discharge, so any correlation that existed between catch/hour and discharge would most likely also exist between catch/hour and turbidity.



Appendix Figure H-2. Catch per hour for Age 0+ and Age 1+ chinook salmon at the outmigrant trap, June 18 to October 12, 1982.



Appendix Figure H-3. Catch per hour for Age 0+ and Age 1+ and 2+ combined coho salmon at the outmigrant trap, June 18 to October 12, 1982.



Appendix Figure H-4. Catch per hour for juvenile sockeye and chum salmon at the outmigrant trap, June 18 to October 12, 1982.

The catch per hour for all species of salmon was summed to determine if there was a dominant factor influencing all species. This total was related to time of season (r = -.69) and to daylength (r = 0.67), but the correlations of total catch per hour with discharge and water temperature were low.

Juvenile chinook salmon

The majority of age 1+ chinook salmon outmigrated in June and early July (Appendix Figure H-2). The peak outmigration for age 0+ chinook occurred in July after the peak for the age 1+ fish.

There was a moderate correlation of juvenile chinook salmon catch/hour with discharge (r = 0.56). The correlation was not improved by lagging catch/hour one day behind discharge or by using a logarithmic transformation of both variables. A first-difference regression between catch/hour and discharge gave a poor correlation. The correlation of catch/hour with time of season was slightly higher than the one with discharge. The best coefficient of determination ($r^2 = 0.64$, $p < 0.01$) was obtained by regressing the three day moving average of catch/hour versus time of season and temperature. This equation took the form: moving average of catch/hour = 0.93 - 0.01 (time of season) - 0.03 (temperature). Most of the variation in moving average which was accounted for was explained by time of season.

Outmigrating age 0+ chinooks showed two pulses in catch/hour - one at a mean length of 50 mm and one at a mean length of 60 mm (Appendix Figure

H-5). The 60 mm pulse occurred prior to the 50 mm pulse. Relatively large numbers of 50 mm fish outmigrating near the end of July depressed the plot of mean length at that time.

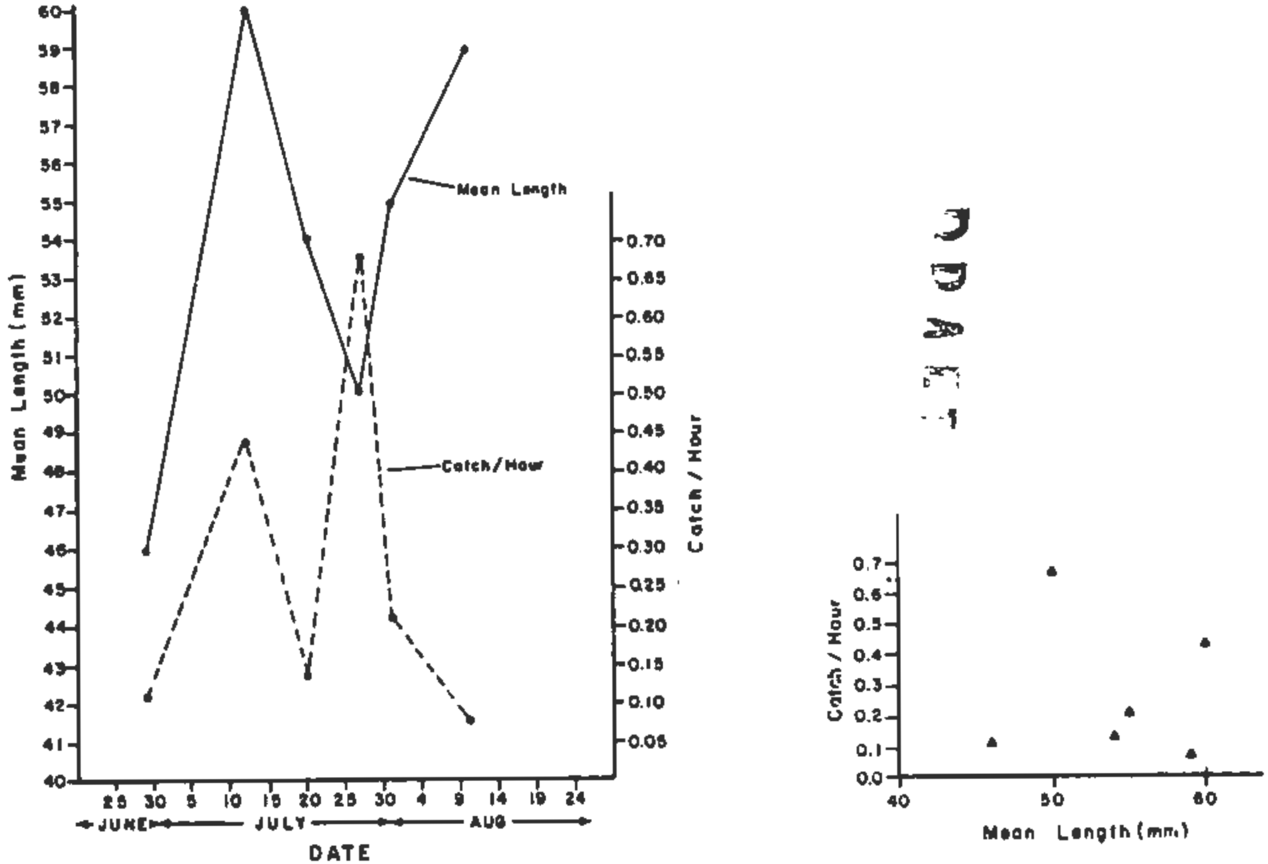
Juvenile coho salmon

Coho salmon outmigrated in a more consistent manner throughout the season than the other species (Appendix Figure H-3). This was especially true with the age 1+ and age 2+ cohos, which showed a marked contrast with the pattern of age 1+ chinook salmon.

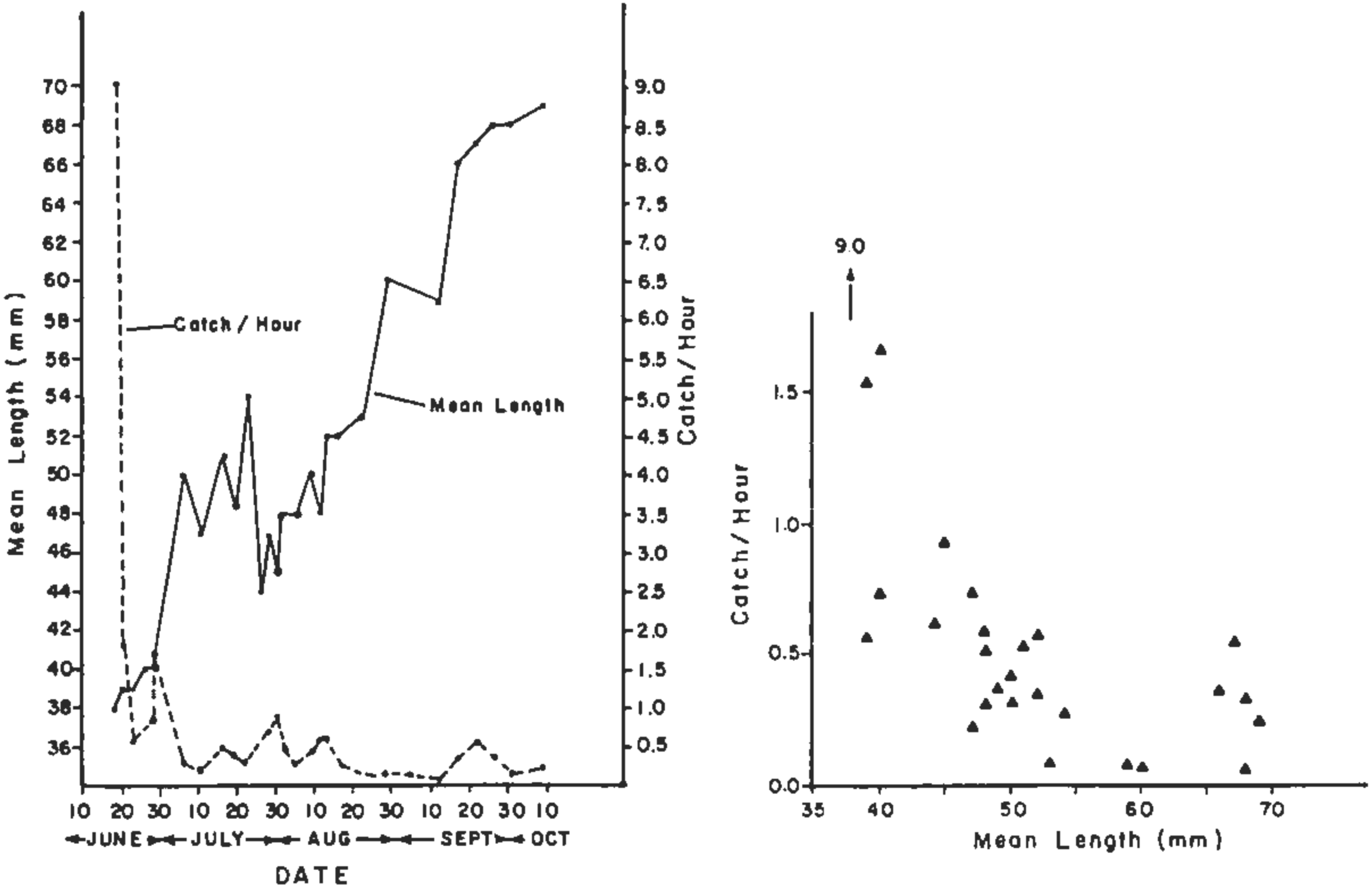
The relationships of juvenile coho salmon catch/hour with discharge and time of season were highly significant ($p < 0.01$), but the correlations were modest. These correlations were not improved by data lags or transformations. The first-difference regression between catch/hour and discharge yielded a poor relationship. The relationship of catch/hour with temperature was not significant. The highest catch/hour for age 0+ coho generally occurred at the smaller size classes (Appendix Figure H-6).

Juvenile sockeye salmon

The correlation of juvenile sockeye salmon with discharge was poor and was not improved by time lags, by using a moving average, or by performing a first-difference regression. There was a modest correlation with time of season. A logarithmic transformation of the catch/hour gave



Appendix Figure H-5. Relationship of mean length and catch per hour for ~~juvenile~~ age 0+ chinook salmon captured at the outmigrant trap.



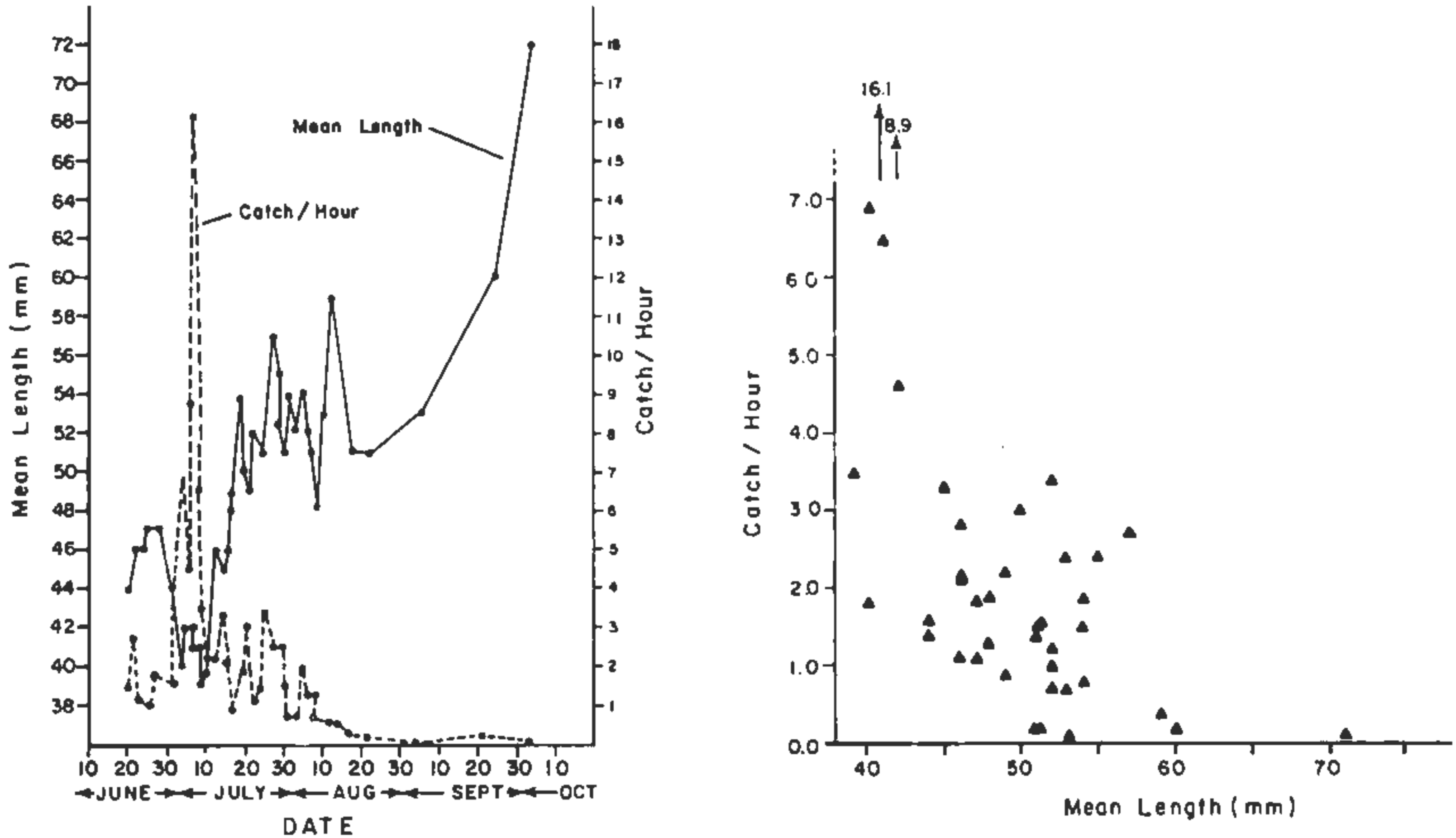
Appendix Figure H-6. Relationship of mean length and catch per hour for ~~juvenile~~ age 0+ coho salmon captured at the outmigrant trap.

fairly good correlations with time of season ($r = -0.82$) and temperature ($r = 0.71$).

The mean length/catch per hour relationship for age 0+ sockeye salmon is similar to that of age 0+ coho salmon (Appendix Figure H-7). The correlation coefficient between these two was $r = -0.53$. The highest catch/hour, occurring in early July, was related to a sharp decrease in the mean length.

Juvenile chum salmon

The last juvenile chum salmon was captured on August 15, so only those sampling days from June 18 to August 15 (55 cases) were included in the analysis. The strongest factor relating to catch/hour was time of season ($r = -0.71$). The relationship of catch/hour with discharge was modest and the relationship with temperature was poor. Logarithmic transformation of catch/hour provided no further insight. A first-difference regression of catch/hour with discharge gave inconclusive results. Using the three day moving average of catch/hour in a multiple regression against time of season and daily difference in discharge "explained" the most variation in catch/hour ($r^2 = 0.72$, $p < 0.01$). The equation for this regression is: moving average of chum catch/hour = 3.34 - 0.07 (time of season) + 1.30 (daily change in discharge/10^4). Most of the variation in the moving average was accounted for by time of season.

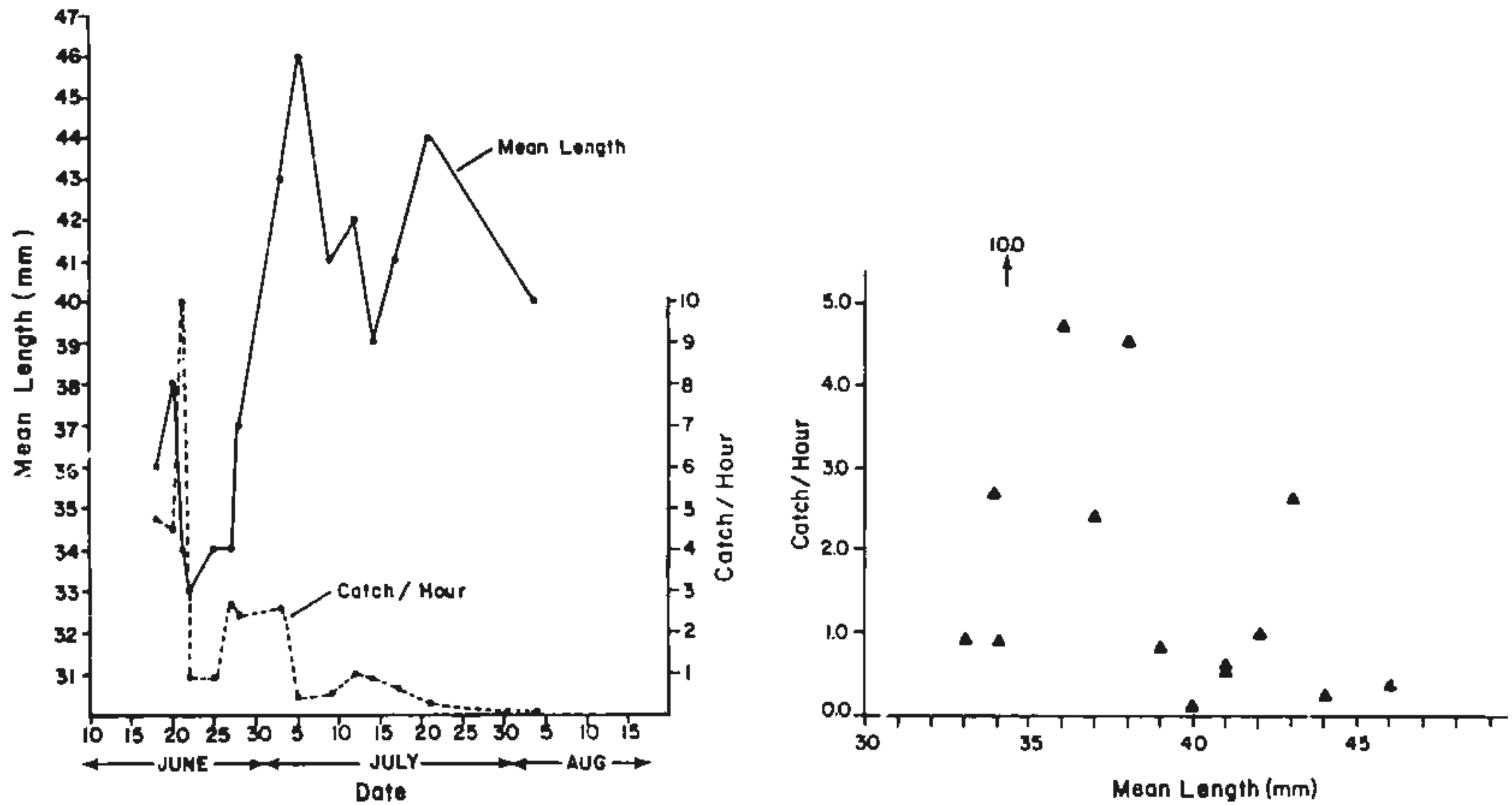


Appendix Figure H-7. Relationship of mean length and catch per hour for juvenile sockeye salmon captured at the outmigrant trap.

The pattern of catch/hour and mean length was not as clear for chum salmon as it was for the other species (Appendix Figure H-8), but generally, the highest catch/hour occurred early in the season when the mean length was low. When the largest fish were outmigrating, the catch/hour was low.

4. Discussion

It is apparent from the catch/hour plots over the course of the season (Appendix Figures H-2, H-3, H-4) that catch/hour for all species generally declined with time. Also apparent from Appendix Figure H-1 and Appendix Table H-2 is the fact that the levels of the environmental variables (discharge, water temperature, and daylength) also generally decreased over the course of the season. These two facts alone would probably lead to reasonable correlation coefficients between habitat variables and catch/hour. However, the real question is whether there is a cause-effect relationship between them or whether the correlation is simply coincidental. It may be that the fish are merely outmigrating in response to time of season. Many years of evolution have coded them to outmigrate when conditions (discharge, water temperature, timing of plankton blooms in the estuary, and so on) are most likely to be favorable. Given this, the objective of this study has been to determine if the fish respond to short-term fluctuations (on the order of days) in environmental variables and if changes in those variables, such as might be caused by the proposed hydroelectric project, would affect the timing of outmigration.



Appendix Figure H-8. Relationship of mean length and catch per hour for ~~juvenile~~ age 0+ chum salmon captured at the outmigrant trap.

Strength of correlations

Although the relationships examined were usually highly significant, the correlation coefficients calculated were generally moderate to low. At best, 72 percent of the variation in catch/hour was "explained" by variation in habitat variables. The relationships would probably be much stronger had catch/hour data been available for the entire period of outmigration. Outmigration probably begins some time in late April or early May, so at least one and a half months of data were not available. By the time the outmigrant trap began operation, the catch/hour for all species was already near the seasonal peak. Good data for outmigration occurring under the ice or during breakup (usually up until mid-May) will probably never be obtained because of sampling problems during this time of year.

Another factor leading to low correlations is that certain variables may have a strong influence on outmigration for a short period of time, but would not show a high correlation when calculated for the entire season. For example, the correlation of catch/hour and discharge was not very high for the whole season, but it can be seen from Appendix Figures H-1, H-2, and H-3 that the mid-September surge in discharge correlated very well with an increase in outmigration of chinooks and cohos.

Correlations could probably be improved if more habitat data were available. Mainstem water temperature was used in the calculations: slough and tributary water temperatures might be a better measure of the effect of temperature on outmigration. Also, other factors which may influence outmigration timing, such as rates of egg development, were not measured. Correlations for chinook and coho salmon might be improved by calculating the correlations for separate age classes, rather than for all age classes together.

Importance of the habitat variables

Before examining the relative importance of the different habitat variables, one should have a clear understanding of how these parameters interact with juvenile salmon: Discharge is important because an adequate flow may be necessary for the fish to outmigrate. Also, an adequate stage of river at the heads and mouths of sloughs and other areas may be necessary for the juveniles to gain access to the mainstem. A faster current requires less energy to outmigrate than a slower current. Turbidity is an important factor in providing cover to outmigrating salmon in a large river such as the Susitna. In relatively short non-turbid rivers, juvenile chum salmon outmigrate mainly at night (Neave, 1955). In the Susitna area, there is no true darkness during the time most of the juvenile salmon are outmigrating (Appendix Table H-2).

Water temperature is a regulator of metabolism and juvenile salmon show a preference for certain ranges (Reiser and Bjornn, 1979). Temperature can serve as an impetus for outmigration (Sano, 1966).

Day length regulates the biological clocks of juvenile salmon. For example, an increasing day length (photoperiod) affects the pituitary system of juvenile chum salmon, causing an increasing tolerance for salt water (Baggerman, 1960; Shelbourn, 1966).

The highest correlations were generally obtained between catch/hour and time of season. This was particularly true with chum salmon. As mentioned previously, time of season is an integrator of several variables. The correlation with discharge was modest with all species except sockeye, whose catch/hour was poorly correlated with discharge. The correlation with temperature was never strong for any species, but temperature contributed to explaining catch/hour variation in some of the multiple regressions. Daylength and turbidity correlations were not calculated for each species, but daylength correlated well with the total catch of all salmon species.

Correlations with habitat variables were generally the best with chum salmon catch/hour, which began high and then generally declined to zero in mid-August. Coho salmon correlations were the lowest. This species continued to outmigrate the entire season, whereas the others did not outmigrate in large numbers after the end of August.

Comments on methods

None of the first-difference regressions which were computed gave very good results. There are probably unpredictable time lags of one to three days which occur between the occurrence of an environmental event and the response of catch/hour at the outmigrant trap. If the time lags could be predicted, then a lag could be built into the calculation.

The daily catch/hour for all species is quite variable from day to day (Appendix Figures H-2, H-3 and H-4). The reasons for this variability are not evident at this time. The variability may be a result of juvenile salmon re-distributing themselves throughout the mainstem after migrating out of tributaries and sloughs. Small groups or individuals may hold for various lengths of time in the numerous small eddies, backwaters, and slack-water border areas. On any given day with this scenario, a more or less random number of individuals or groups of individuals migrates past the outmigrant trap. Regardless of the cause, the sharp fluctuations in numbers create problems in data analysis and probably require some sort of smoothing function. Stable results were obtained using a three day moving average. Some preliminary work using exponential smoothing also appeared to be promising. Further investigation with both of these techniques would probably be profitable, as would further calculations using different time lags. Mixed results were obtained using logarithmic transformations of one or two variables in a bivariate analysis.

Future work

The ultimate goal of this analysis, given the appropriate habitat data, is a prediction of the relative magnitude and timing of juvenile salmon outmigration. This goal was not met during the 1982 studies as the amount and types of data available did not allow for definitive relationships to be developed. In particular, more than one season of data is necessary in order to corroborate or expand on what only one year's data indicates. For example, a season in which discharge is low early in the season and then increases would be useful in determining whether this kind of discharge regime would override the effect of time of season on outmigration.

This report has provided some insight into the problem of habitat/ outmigration relationships and some direction for future work. During the 1983 studies, two outmigrant traps will be operated and they will begin operation in mid-May. Also, more complete habitat data will be obtained. Furthermore, coded wire tagging, in conjunction with habitat measurements, will be conducted in several sloughs above the outmigrant traps. These studies will contribute a great deal to a more powerful analysis of juvenile salmon outmigration.

LITERATURE CITED

ADF&G, 1983a. Volume 3, Resident and juvenile anadromous fish studies below Devil Canyon, 1982. Susitna Hydro Aquatic Studies, Anchorage.

______. 1983b. Volume 4, Aquatic habitat and instream flow studies, 1982. Parts I and II. Susitna Hydro Aquatic Studies, Anchorage.

Baggerman, Bertha. 1960. Salinity preference, thyroid activity and the seaward migration of four species of Pacific salmon (Oncorhynchus). J. Fish. Res. Bd. Can. 17(3):295-322.

Neave, Ferris. 1955. Notes on the seaward migration of pink and chum salmon fry. J. Fish. Res. Bd. Can. 12(3):369-374.

Reiser, D.W. and T.C. Bjornn. 1979. Influence of forest and rangeland management of anadromous fish habitat in the western United States and Canada. 1. Habitat requirements of anadromous salmonids. U.S. Dept. of Agricul., Forest Service. General Technical Report PNW - 96, Portland, Oregon. 54 pp.

Sano, S. 1966. Salmon of the North Pacific Ocean - Part III. A review of the life history of North Pacific salmon. 3. Chum salmon in the Far East. International North Pacific Fisheries Commission Bull. No. 18. Vancouver, B.C. pp. 41-57.

Shelbourn, J.E. 1966. Influence of temperature, salinity, and photoperiod on the aggregations of chum salmon fry (<u>Oncorhynchus keta</u>). J. Fish. Res. Bd. Can. 23(?):293-304.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods. Iowa State University Press, Ames, Iowa. 593 pp.

Summers, G.W., W.S. Peters, and C.P. Armstrong. 1981. Basic statistics in business and economics. Wadsworth Publishing Co., Calif 594 pp.

APPENDIX I

Population analysis of Arctic grayling above Devil Canyon

APPENDIX I

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Introduction

The opening of access roads into the proposed impoundment area can be expected to create a substantial grayling sport fishery in this previously seldom fished drainage. This study was initiated to examine the effects of increasing mortality rates (due to fishing pressure) on the age structure and populations in the clear water tributaries studied to date. The results of the analysis can suggest management strategies and should be useful in the impact analysis. Predicted increased access and fishing pressure can be used with this data set to predict the changes that may be expected in these unexploited populations of grayling.

Methods

Hook and line sampling methods were used to collect mark and recapture data over two open water seasons at eight major clear water tributaries in the proposed impoundment on the Susitna River. This data base is presented in ADF&G (1981) and ADF&G (1983). All field collection methods and data summaries are presented in those volumes and are not reported here. Because hook and line methods were used to collect the data, the effects of fishing pressure can be projected from these catch records and population estimates.

The theoretical analysis of the data was developed using equations described by Ricker (1975). The equations used show the relationships between mortality, population size and age structure. The Arctic grayling population structure in the proposed impoundment is presently assumed to be unexploited and with natural mortality rates in a state of equilibrium.

The following equations were used to project population changes:

(1) $N_{t+1} = N_t \times S_{tn}$ where: N_{t+1} = Population number of age class t plus one year.

N_t = Population number of age class t fish

S_{tn} = Natural survival rate of age t fish

N+ and N_{t+1} are known for each age class and give estimates for S_{tn} for each age class

in an exploited fishery then,

(2) $N_{t+1} = N_t X S_{tn+F}$ where: S_{tn+F} = Survival rate of age t fish due to combined natural and fishing mortalities.

The actual annual mortality rate, A, is related to S, as:

(3) $A_{tn+F} = 1 - S_{tn+F}$ and,

(4) $S_{tn+F} = e - Z_t$ and, where: Z_t = Instantaneous rate of total mortalities of age t fish.

(5) $Z_t = F_t + M_t$ and, where: F_t = Instantaneous rate of fishing mortality of age class t fish.

(6) $M_t = -\ln S_{tn}$ where: M_t = Instantaneous rate of natural mortalities of age class t fish.

Since M_t is available from N_t and N_{t+1} data, it is possible to substitute (model) values of F_t for a hypothetical fishery and predict the resulting age structure of the population with time. To do this, the following assumptions are made. (1) The rate of catch for each age class of fish per unit of fishing effort experienced by ADF&G will hold true for the general public. (2) Only grayling of age III and older are subject to increased mortality by (hook and line) fishing. (3) Recruitment of age II class fish is constant. The recruitment constancy was also examined briefly in a separate analysis.

In an exploited system then, F_t is viewed as

(7) $F_t = q_t \times f$ where: q_t = catchability of age class t; proportioned fish per unit time fished.

f = fishing effort, (98.25 hrs or 6.05 hrs/mile stream).

and q_t is estimated from

(8) $q_t = -\ln(1-u_t)$ using

(9) $u_t = \frac{R_t}{M_t}$ where: R_t = # of grayling marked in July that were recaptured in August 1982 by age class t.

M_t = # of grayling marked in July 1982, by age class t.

u_t is termed the rate of exploitation and is available from the mark-recapture fishing data found in Volume 5.

Calculation of A_{tn+F} (eq. 3) thus allows calculation of predicted catch at different levels of exploitation.

(10) $A_{tF} = A_{tn+F} - (1-S_{tn})$ $A_{tn} = 1-S_{tn}$

(11) $C_t = \sum_{t=III}^{t=VIII} AtF \times N_t$ C_t = total catch

A model of the maximum sustained yield of Arctic grayling at various levels of effort was constructed. (The analytical formula and data were manipulated using a microcomputer and a commercial spreadsheet software entitled SuperCalc^R).

Fishing pressure, f, and the exploitation coefficient $u_{(t)}$, were taken from R/M' data limited to the July and August 1982 samplings. This restriction most closely fulfills the "closed system assumption" (no in or outmigration), thus improving the level of certainty in the model.

Appendix Table I-1 summarizes the July catch and effort. The f value, which was varied to calculate C_t in the model, was taken as multiples of the 6.05 hrs/mile of effort reported during this period.

Results

Appendix Table I-2 presents the calculated maximum sustained catches resulting from differing levels of f. Appendix Figure I-1 graphically illustrates those calculations. The calculated rate of fishing pressure for maximum sustained catch (of all age classes greater than II) is less than 1,000 fish/year.

An additional calculation was made at this point to estimate the maximum sustained yield if catch (mortalities) are limited to individuals VI and older (roughly) 350 mm and greater in length). The maximum sustained yield under these conditions is very low (less than 100 fish). The total harvest of all size classes (>II) of fish is about 650 fish at the same level of f. This compares to the maximum sustained yield of 950 fish (which occurs at f=4.5) when maximizing the total number harvested of all age classes.

These values assume equal distribution of effort, and similar success levels, that ADF&G crews experienced in the field while collecting this data. If fisherman access is not limiting, the distribution of fishermen will probably parallel the relative densities of fish.

Appendix Table I-1. Summary of catch and effort made during the July 1982 proposed impoundment grayling tag and recapture sampling program. An f (fishing pressure) value of one (1.0) equals the 6.05 hrs/mile of effort expended by ADF&G during this time.

Impoundment River Fished	Miles of River Fished	Hours Fished	Catch	CPUE	Hours Fished Per Mile	Fish Per Mile
Oshetna	2.2	21.25	288	13.6	9.66	1103
Goose	1.2	6.75	91	13.5	5.63	791
Jay	3.5	12.00	130	10.8	3.43	455
Kosina	4.5	31.50	491	15.6	7.00	1232
Watana	4.0	18.00	175	9.7	4.50	324
Deadman	0.3	4.50	51	11.3	15.0	1835
Tsusena	0.4	3.00	29	9.7	7.5	
Fog	0.2	1.25	5	4.0	6.25	440
Total	16.3	98.25	1260	12.8	6.05	665

Appendix Table I-2. Results of age class and total population calculations at variable levels of fishing pressure.

	Relative fishing pressure (f) = .00							Total Population Age III and Older Fish	Population of Spawners (Age V+)	Spawners as a Percent of Total Population
	II	III	IV	V	VI	VII	VIII			
Natural Instantaneous Mortality (M)		.90	.46	.27	.77	.78	1.06			
Natural Survival (S)		.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.00	.00	.00	.00	.00	.00			
Mark/Recapture (M^1/R) Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		.90	.46	.17	.77	.78	1.06			
Total Actual Mortality (A_{F+N})		.59	.37	.15	.54	.54	.65			
Total Survival (S_{F+N})		.41	.63	.85	.46	.46	.35			
Year: 1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
1983	11363	4602	2904	2454	1134	521	180	11795	4289	36
1984	11363	4602	2904	2454	1134	521	180	11795	4289	36
1985	11363	4602	2904	2454	1134	521	180	11795	4289	36
1986	11363	4602	2904	2454	1134	521	180	11795	4289	36
1987	11363	4602	2904	2454	1134	521	180	11795	4289	36
1988	11363	4602	2904	2454	1134	521	180	11795	4289	36
1989	11363	4602	2904	2454	1134	521	180	11795	4289	36
1990	11363	4602	2904	2454	1134	521	180	11795	4289	36
1991	11363	4602	2904	2454	1134	521	180	11795	4289	36

Appendix Table I-2 (Continued).

	Relative fishing pressure (f) = .50							Total Population Age III and Older Fish	Population of Spawners (Age V+)	Spawners as a Percent of Total Population
	II	III	IV	V	VI	VII	VIII			
Natural Instantaneous Mortality (M)		.90	.46	.17	.77	.78	1.06			
Natural Survival (S)	.00	.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.02	.05	.07	.13	.11	.15			
Mark/Recapture (M^1/R) Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		.93	.51	.24	.91	.89	1.21			
Total Actual Mortality (A_{F+M})		.60	.40	.21	.60	.59	.70			
Total Survival (S_{F+M})		.40	.60	.79	.40	.41	.30			
Year: 1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
1983	11363	4500	2773	2280	992	467	155	11166	3893	35
1984	11363	4500	2712	2177	921	408	139	10857	3646	34
1985	11363	4500	2712	2129	880	379	122	10720	3509	33
1986	11363	4500	2712	2129	860	362	113	10675	3464	32
1987	11363	4500	2712	2129	860	354	108	10662	3451	32
1988	11363	4500	2712	2129	860	354	105	10660	3448	32
1989	11363	4500	2712	2129	860	354	105	10660	3448	32
1990	11363	4500	2712	2129	860	354	105	10660	3448	32
1991	11363	4500	2712	2129	860	354	105	10660	3448	32

Appendix Table I-2 (Continued).

	Relative fishing pressure (f) = 1.00							Total Population Age III and Older Fish	Population of Spawners (Age V+)	Spawners as a Percent of Total Population
	II	III	IV	V	VI	VII	VIII			
Natural Instantaneous Mortality (M)		.90	.46	.17	.77	.78	1.06			
Natural Survival (S)	.00	.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.04	.09	.15	.27	.22	.30			
Mark/Recapture (M^1/R) Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		.95	.55	.32	1.04	1.00	1.36			
Total Actual Mortality (A_{F+N})		.61	.42	.27	.65	.63	.74			
Total Survival (S_{F+N})		.39	.58	.73	.35	.37	.26			
Year: 1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
1983	11363	4400	2648	2118	868	418	134	10585	3537	33
1984	11363	4400	2532	1931	749	320	107	10038	3107	31
1985	11363	4400	2532	1846	683	276	82	9819	2887	79
1986	11363	4400	2532	1846	653	252	71	9753	2822	29
1987	11363	4400	2532	1846	653	241	65	9736	2804	29
1988	11363	4400	2532	1846	653	241	62	9733	2801	29
1989	11363	4400	2532	1846	653	241	62	9733	2801	29
1990	11363	4400	2532	1846	653	241	62	9733	2801	29
1991	11363	4400	2532	1846	653	241	62	9733	2801	29

Appendix Table I-2 (Continued).

	Relative fishing pressure (f) = 2.00							Total Population Age III and Older Fish	Population of Spawners (Age V+)	Spawners as a Percent of Total Population
	II	III	IV	V	VI	VII	VIII			
Natural Instantaneous Mortality (M)		.90	.46	.17	.77	.78	1.06			
Natural Survival (S)	.00	.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.09	.18	.29	.54	.44	.59			
Mark/Recapture (M^1/R) Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		.99	.64	46	1.31	1.22	1.66			
Total Actual Mortality (A_{F+M})		.63	.48	.37	.73	.70	.81			
Total Survival (S_{F+M})		.37	.52	.63	.27	.30	.19			
Year: 1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
1983	11363	4706	2415	1828	664	335	99	9547	2926	31
1984	11363	4206	2208	1520	494	196	64	8688	2274	26
1985	11363	4206	2208	1389	411	146	37	8397	1984	24
1986	11363	4206	2208	1389	376	121	28	8328	1914	23
1987	11363	4206	2208	1389	376	111	23	8313	1899	23
1988	11363	4206	2208	1389	376	111	21	8311	1897	23
1989	11363	4206	2208	1389	376	111	21	8311	1897	23
1990	11363	4206	2208	1389	376	111	21	8311	1897	23
1991	11363	4206	2208	1389	376	111	21	8311	1897	23

Appendix Table 1-2 (Continued).

	Relative fishing pressure (f) = 4.00							Total Population Age III and Older Fish	Population of Spawners (Age V+)	Spawners as a Percent of Total Population
	II	III	IV	V	VI	VII	VIII			
Natural Instantaneous Mortality (M)		.90	.46	.17	.77	.78	1.06			
Natural Survival (S)	.00	.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.18	.37	.59	1.07	.88	1.19			
Mark/Recapture (M^1/r) Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		1.08	.83	.76	1.84	1.66	2.25			
Total Actual Mortality (A_{F+M})		.66	.56	.53	.84	.81	.89			
Total Survival (S_{F+M})		.34	.44	.47	.16	.19	.11			
Year: 1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
1983	11363	3844	2009	1361	388	216	55	7873	2020	26
1984	11363	3844	1678	942	215	74	23	6776	1254	19
1985	11363	3844	1678	787	149	41	8	6506	984	15
1986	11363	3844	1678	787	124	28	4	6466	944	15
1987	11363	3844	1678	787	124	24	3	6460	938	15
1988	11363	3844	1678	787	124	24	2	6459	937	15
1989	11363	3844	1678	787	124	24	2	6459	937	15
1990	11363	3844	1678	787	124	24	2	6459	937	15
1991	11363	3844	1678	787	124	24	2	6459	937	15

Appendix Table I-2 (Continued).

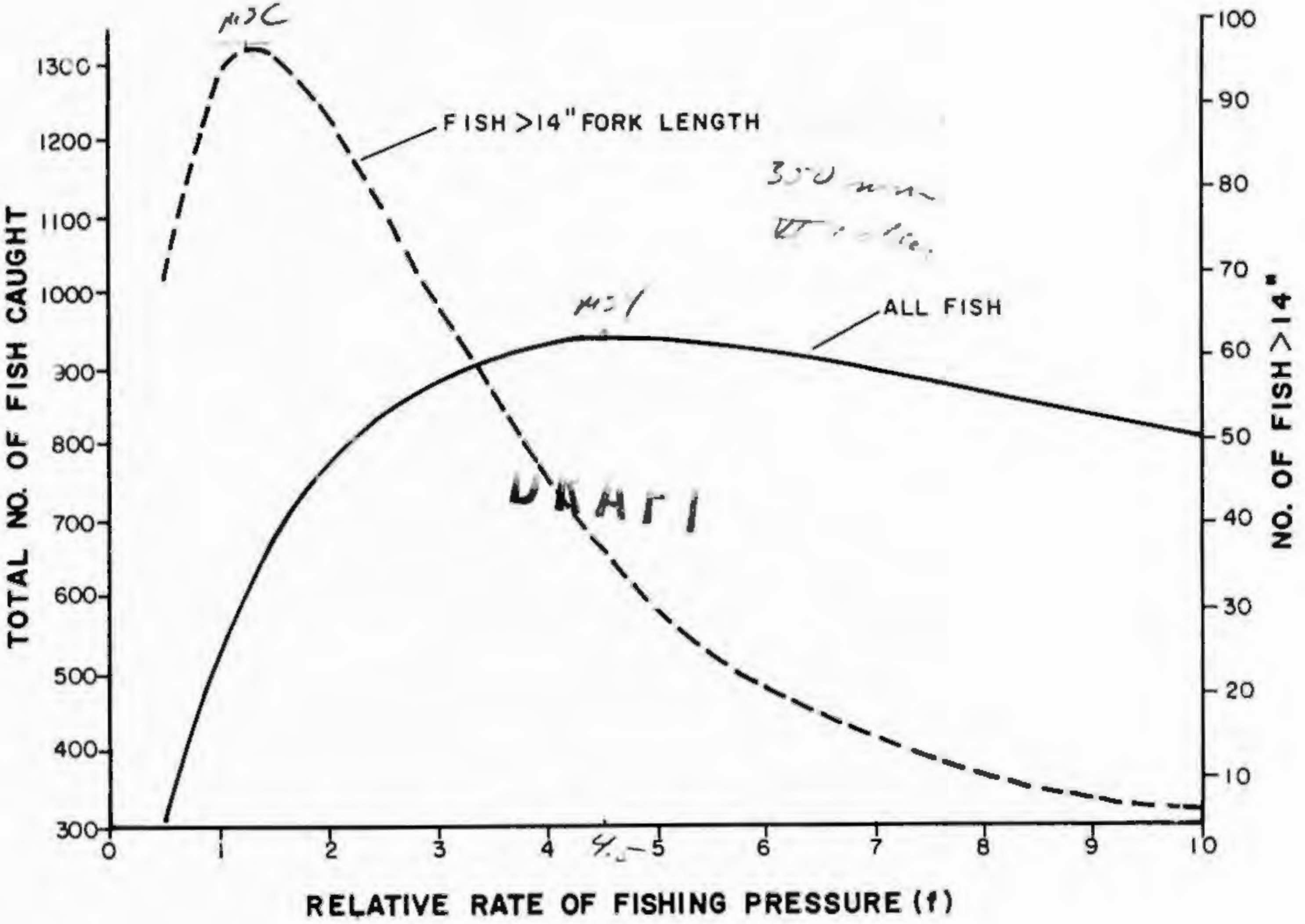
	Relative fishing pressure (f) = 6.00							Total Population Age III and Older Fish	Population of Spawners (Age V+)	Spawners as a Percent of Total Population
	II	III	IV	V	VI	VII	VIII			
Natural Instantaneous Mortality (M)		.90	.46	.17	.77	.78	1.06			
Natural Survival (S)	.00	.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.27	.55	.88	1.61	1.32	1.78			
Mark/Recapture (M^1/R) Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		1.17	1.01	1.05	2.38	2.10	2.85			
Total Actual Mortality (A_{F+M})		.69	.64	.65	.91	.88	.94			
Total Survival (S_{F+M})		.31	.36	.34	.09	.12	.06			
Year: 1982	11363	4602	2904	2454	1134	521	180	11795	4298	36
1983	11363	3513	1671	1014	227	139	30	6594	1410	21
1984	11363	3513	1276	583	94	28	8	5502	713	13
1985	11363	3513	1276	445	54	11	2	5301	512	10
1986	11363	3513	1276	445	41	7	1	5283	494	9
1987	11363	3513	1276	445	41	5	0	5281	492	9
1988	11363	3513	1276	445	41	5	0	5281	492	9
1989	11363	3513	1276	445	41	5	0	5281	492	9
1990	11363	3513	1276	445	41	5	0	5281	492	9
1991	11363	3513	1276	445	41	5	0	5281	492	9

Appendix Table 1-2 (Continued).

	Relative fishing pressure (f) = 8.00							Total Population Age III and Older Fish	Population of Spawners (Age V+)	Spawners as a Percent of Total Population
	II	III	IV	V	VI	VII	VIII			
Natural Instantaneous Mortality (M)		.90	.46	.17	.77	.78	1.06			
Natural Survival (S)	.00	.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.36	.74	1.18	2.14	1.77	2.38			
Mark/Recapture (M^1/R) Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		1.26	1.20	1.35	2.92	2.54	3.44			
Total Actual Mortality (A_{F+N})		.72	.70	.74	.95	.92	.97			
Total Survival (S_{F+N})		.28	.30	.26	.05	.08	.03			
Year: 1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
1983	11353	3211	1390	755	133	89	17	5595	994	18
1984	11363	3211	970	361	41	10	3	4596	416	9
1985	11363	3211	970	252	20	3	0	4456	275	6
1986	11363	3211	970	252	14	?	0	4448	267	6
1987	11363	3211	970	252	14	1	0	4447	267	6
1988	11363	3211	970	252	14	1	0	4447	267	6
1989	11363	3211	970	252	14	1	0	4447	267	6
1990	11363	3211	970	252	14	1	0	4447	267	6
1991	11363	3211	970	252	14	1	0	4447	267	6

Appendix Table I-2 (Continued).

	Relative fishing pressure (f) = 10.00							Total Population Age III and Older Fish	Population of Spawners (Age V+)	Spawners as a Percent of Total Population
	II	III	IV	V	VI	VII	VIII			
Natural Instantaneous Mortality (M)		.90	.46	.17	.77	.78	1.06			
Natural Survival (S)	.00	.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.45	.92	1.47	2.68	2.21	2.97			
Mark/Recapture (M^1/R) Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		1.35	1.38	1.64	3.45	2.98	4.03			
Total Actual Mortality (A_{F+N})		.74	.75	.81	.97	.95	.98			
Total Survival (S_{F+N})		.26	.25	.19	.03	.05	.02			
Year: 1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
1983	11363	2934	1156	562	78	57	9	4797	707	15
1984	11363	2934	737	224	18	4	1	3918	247	6
1985	11363	2934	737	143	7	1	0	3822	151	4
1986	11363	2934	737	143	5	0	0	3819	148	4
1987	11363	2934	737	143	5	0	0	3819	147	4
1988	11363	2934	737	143	5	0	0	3819	147	4
1989	11363	2934	737	143	5	0	0	3819	147	4
1990	11363	2934	737	143	5	0	0	3819	147	4
1991	11363	2934	737	143	5	0	0	3819	147	4



Appendix Figure I-1. Maximum sustained yield of Arctic grayling for different levels of fishing pressure. The f value represents multiples of 6.05 hrs per mile of hook and line sport fishing per year.

Possible effects of higher levels of exploitation on recruitment are also presented in Appendix Table I-3 and illustrated in Appendix Figure I-2. Under baseline conditions, the age III and older fish are composed of 36% spawners. At the higher rates of exploitation this number drops off rather rapidly. Although recruitment is probably in excess of what is required under the current conditions, the projected decreases of the spawners to the population at the high rates of exploitation is probably sufficient to effect recruitment. Using the assumptions of the model and assuming a linear decrease in recruitment following a decrease of spawning aged fish to 10% of the non-exploited population the number of fish caught annually rapidly decreases when f=78 (48.8 hrs/mile of river).

Conclusion

The model demonstrates that in a closed system fishery, where fisherman access is not limiting, modest levels of fishing pressure can drastically reduce grayling population. In reality, the disappearance of the fish will probably result in a decrease in fishing pressure before the population totally disappears. The residual fishery, after such an event, would probably reflect recruitment by immigration of stock from other areas.

Although the data collected pertains to the streams that will be inundated by the impoundment, the similarity in age structure among the streams (ADF&G, 1983, Table 5-3-8) suggests that this data base may be applicable to grayling fisheries in other tributaries of the upper Susitna basin. The modeling of the available data resembles age/class

Appendix Table I-3. Results of analysis of effects of decreasing spawner populations caused by fishing pressure on twenty year catch rates.

		Relative Fishing Pressure (f) = 6.00			
		Total Number of Spawners (Age V+)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III+)	Spawners as a Percent of Total Population
Natural Instantnaeous Mortality (M)	.90				
Natural Survival (S)	.41				
Fishing Mortality (F)	.27				
Mark/Recapture (M^1/R) Ratio	.04				
Total Instantaneous Mortality (Z)	1.17				
Total Actual Mortality (A_{F+N})	.69				
Total Survival (S_{F+N})	.31				
Year: 1982		4289	646	3083	36
1983		1410	139	1427	21
1984		713	46	1014	13
1985		512	24	924	10
1986		494	18	917	9
1987		492	17	916	9
1988		492	17	916	9
1989		492	17	916	9
1990		492	17	916	9
1991		492	17	916	9
1992		492	17	916	9
1993		492	17	916	9
1994		492	17	916	9
1995		492	17	916	9
1996		492	17	916	9
1997		492	17	916	9
1998		492	17	916	9
1999		492	17	916	9
2000		492	17	916	9
2001		492	17	916	9
2002		492	17	916	9

Appendix Table I-3 (Continued).

		Relative Fishing Pressure (f) = 6.50			
		Total Number of Spawners (Age V+)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III+)	Spawners as a Percent of Total Population
Natural Instantnaeous Mortality (M)	.90				
Natural Survival (S)	.41				
Fishing Mortality (F)	.29				
Mark/Recapture (M^1/R) Ratio	.04				
Total Instantaneous Mortality (Z)	1.20				
Total Actual Mortality (A_{F+N})	.70				
Total Survival (S_{F+N})	.30				
Year:	1982	4289	668	3244	36
	1983	1291	127	1424	20
	1984	622	[illegible]	999	12
	1985	438	19	912	9
	1986	423	14	906	8
	1987	421	13	906	8
	1988	421	13	906	8
	1989	421	13	901	8
	1990	421	13	894	8
	1991	415	13	890	8
	1992	414	13	889	8
	1993	414	13	889	8
	1994	414	13	885	8
	1995	414	13	879	8
	1996	408	13	875	8
	1997	406	13	874	8
	1998	406	13	873	8
	1999	406	13	869	8
	2000	406	13	863	8
	2001	401	13	859	8
	2002	399	13	858	8

Appendix Table I-3 (Continued).

		Relative Fishing Pressure (f) = 7.00			
		Total Number of Spawners (Age V+)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III+)	Spawners as a Percent of Total Population
Natural Instantnaeous Mortality (M)	.90				
Natural Survival (S)	.41				
Fishing Mortality (F)	.31				
Mark/Recapture (M^1/R) Ratio	.04				
Total Instantaneous Mortality (Z)	1 22				
Total Actual Mortality (A_{F+N})	.70				
Total Survival (S_{F+N})	.30				
Year:	1982	4289	686	3395	36
	1983	1182	115	1415	19
	1984	543	32	983	11
	1985	374	15	898	8
	1986	362	11	894	7
	1987	361	10	893	7
	1988	361	10	847	8
	1989	361	10	794	9
	1990	319	10	760	8
	1991	306	9	753	8
	1992	304	9	753	7
	1993	304	9	716	8
	1994	304	9	672	9
	1995	271	9	643	8
	1996	259	8	635	8
	1997	257	7	634	7
	1998	256	7	605	8
	1999	256	7	569	9
	2000	230	7	543	8
	2001	219	6	536	8
	2002	216	6	534	7

Appendix Table I-3 (Continued).

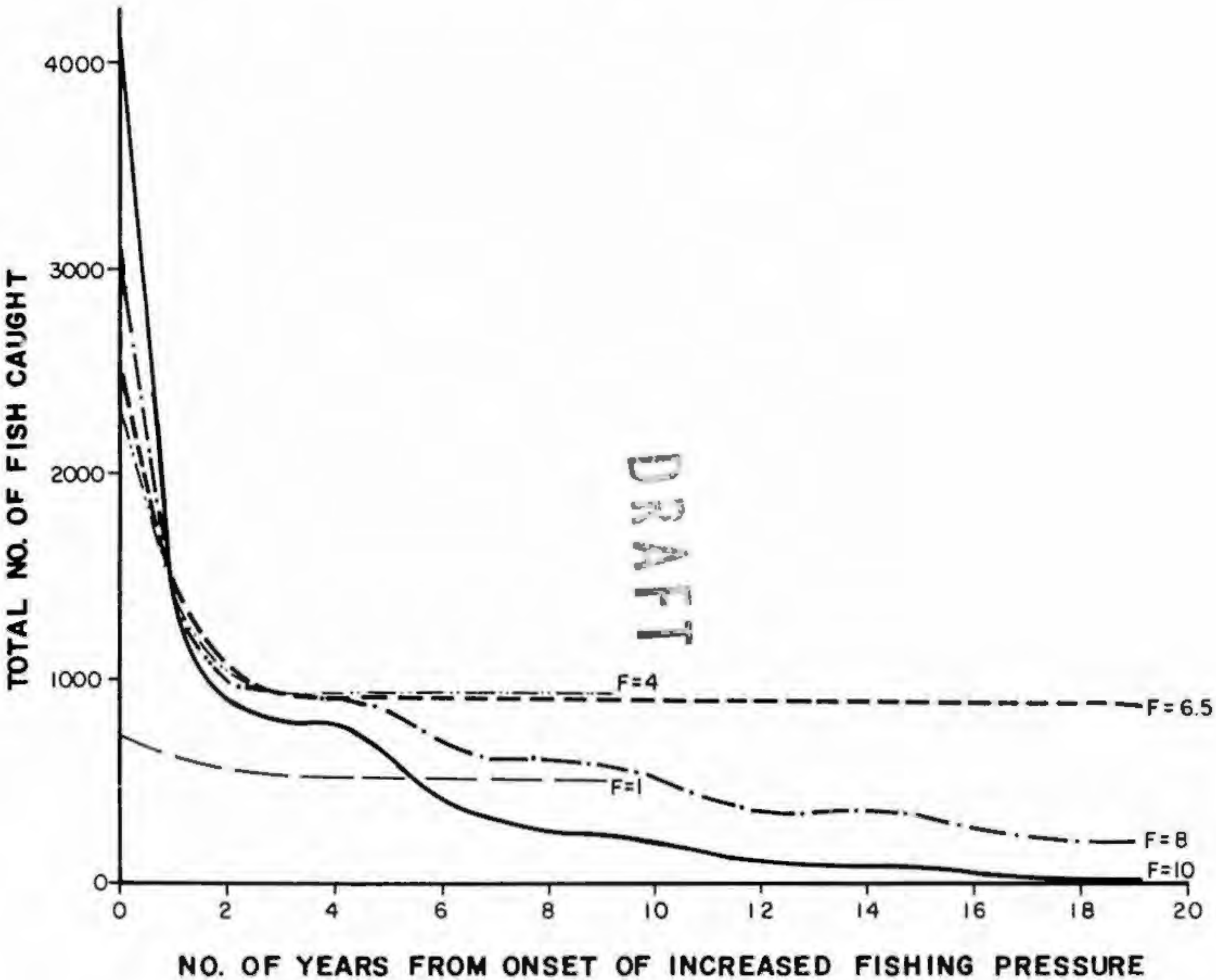
		Relative Fishing Pressure (f) = 8.00			
		Total Number of Spawners (Age V+)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III+)	Spawners as a Percent of Total Population
Natural Instantnaeous Mortality (M)	.90				
Natural Survival (S)	.41				
Fishing Mortality (F)	.36				
Mark/Recapture (M^1/R) Ratio	.04				
Total Instantaneous Mortality (Z)	1.26				
Total Actual Mortality (A_{F+N})	.72				
Total Survival (S_{F+N})	.28				
Year: 1982		4289	717	3672	36
1983		994	93	1386	18
1984		416	22	945	9
1985		275	9	869	6
1986		267	6	866	6
1987		267	6	853	6
1988		267	6	715	8
1989		259	6	599	9
1990		176	6	544	6
1991		167	4	539	6
1992		166	4	531	6
1993		166	4	450	8
1994		161	4	377	9
1995		112	4	341	6
1996		104	3	336	6
1997		103	2	331	6
1998		103	2	283	8
1999		101	2	237	9
2000		72	2	213	7
2001		65	2	209	6
2002		64	1	206	6

Appendix Table I-3 (Continued).

		Relative Fishing Pressure (f) = 9.00			
		Total Number of Spawners (Age V+)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III+)	Spawners as a Percent of Total Population
Natural Instantnaeous Mortality (M)	.90				
Natural Survival (S)	.41				
Fishing Mortality (F)	.40				
Mark/Recapture (M^1/R) Ratio	.04				
Total Instantaneous Mortality (Z)	1.31				
Total Actual Mortality (A_{F+N})	.73				
Total Survival (S_{F+N})	.27				
Year:	1982	4289	741	3918	36
	1983	837	75	1344	16
	1984	320	14	906	9
	1985	203	6	838	5
	1986	198	4	836	5
	1987	198	4	730	6
	1988	198	4	541	9
	1989	150	4	425	8
	1990	96	3	389	5
	1991	92	2	386	5
	1992	91	2	339	6
	1993	91	2	254	9
	1994	70	2	199	8
	1995	46	1	180	5
	1996	43	1	178	5
	1997	42	1	144	7
	1998	42	1	98	11
	1999	26	1	71	8
	2000	16	0	62	5
	2001	15	0	61	5
	2002	15	0	50	7

Appendix Table I-3 (Continued).

		Relative Fishing Pressure (f) = 10.00			
		Total Number of Spawners (Age V+)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III+)	Spawners as a Percent of Total Population
Natural Instantnaeous Mortality (M)	.90				
Natural Survival (S)	.41				
Fishing Mortality (F)	.45				
Mark/Recapture (M^1/R) Ratio	.04				
Total Instantaneous Mortality (Z)	1.35				
Total Actual Mortality (A_{F+N})	.74				
Total Survival (S_{F+N})	.26				
Year: 1982		4289	760	4137	36
1983		707	60	1296	15
1984		247	10	866	6
1985		151	3	807	4
1986		148	2	806	4
1987		147	2	623	6
1988		147	2	407	9
1989		87	2	302	6
1990		53	1	278	4
1991		51	1	277	4
1992		51	1	216	6
1993		51	1	143	9
1994		31	1	105	7
1995		19	0	96	4
1996		18	0	95	4
1997		17	0	75	6
1998		17	0	50	9
1999		11	0	37	7
2000		7	0	33	4
2001		6	0	33	4
2002		6	0	29	5



Appendix Figure I-2. Effort of heavy fishing pressure on Arctic grayling catch rates assuming effort of harvest on recruitment. The f value represents multiples of 6.05 hrs per mile of hook and line sport fishing per year.

population structures as presently found in exploited grayling systems in other parts of interior Alaska (Armstrong, 1982).

The spreadsheet program used in the analysis allows very rapid changes in assumptions and output of usable information with insignificant programming effort. Projections can be made given any reasonable set of assumptions concerning harvest, recruitment, management strategies, and other aspects of the population dynamics of grayling, with minor adjustments to the model presented.

How does f = 6.0 [illegible] compare to [illegible] in other Alaska streams - what is typical of exploited, non-exploited system [illegible]?

[illegible]

[illegible]

Literature Cited

ADF&G, 1981. Resident fish investigations on the upper Susitna River. Phase I. Final Draft. ADF&G Su Hydro Aquatic Studies Program, Anchorage, Alaska.

______. 1983. Basic Data Report, ADF&G Su Hydro Studies, Volume 5.

Armstrong, Robert H. 1982. Arctic Grayling Studies in Alaska. A special compilation of the Alaska Cooperative Fisheries Research Unit and the Alaska Department of Fish and Game, Division of Sport Fish. August, 1982.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. 191:382 p.

APPENOIX J

Aye-Length Relationships for Arctic Grayling and Rainbow Trout

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1. Introduction

Age-length curves and regressions were examined for Arctic grayling (*Thymallus arcticus*) to determine if the growth of the population in the proposed impoundment area above Devil Canyon was significantly different from that of the population below Devil Canyon. Preliminary analysis of 1981 data had indicated that there might be such a difference which, if true, would have relevance to proposed mitigation strategies for Arctic grayling in the impoundment area.

The same kind of data was analyzed for rainbow trout (*Salmo gairdneri*). This species is near the northern limit of its range in the Susitna River basin. Comparing the growth of the population in the Susitna River with that of other populations provides an indication of the capability of the Susitna population to absorb impacts associated with the proposed hydroelectric project.

2. Methods

Scales taken from rainbow trout and Arctic grayling captured and measured during 1981 and 1982 were aged. Log ($Y = a + b \ln(x)$) and linear ($Y = a + bx$) regressions of age versus length were then run for both species. Arctic grayling were divided into three groups by sampling reach: Cook Inlet to Chulitna River confluence, Chulitna River confluence to Devil Canyon, and Devil Canyon to Oshetna River confluence. Since there are no rainbow trout in the impoundment area except for a transplanted population in the High Lakes, rainbow trout were divided into two groups, above and below the Chulitna River confluence. Data from 1981 and 1982 were analyzed. Each year's data was analyzed by reach separately for comparative purposes and as a check on sampling and aging procedures. Selected slopes of different regressions were tested for equality (Dixon and Massey 1969).

Large catches of rainbow trout and Arctic grayling were most often made in May, June, or September and to compare rainbow trout captured in May with other rainbow trout captured in September only by year class would give biased results since most growth occurs during a short period in the summer. Therefore, data were entered by month for each age class of fish. For example, an age 1+ grayling was entered as 1.0 years of age if caught in May and 1.2, 1.4, 1.6, and 1.8 years of age if caught in June, July, August, and September respectively.

3. Results and Discussion

Arctic grayling

Log regressions of Arctic grayling age versus length generally fit the data as well or better than linear regressions (Appendix Table J-1). Although slopes and intercepts varied somewhat, by reach and year, all the log regressions are very similar and differences are probably due to chance. Growth rates of Arctic grayling in the impoundment and below Devil Canyon are nearly identical. Comparison of slopes (growth) of the log regressions of Arctic grayling captured in 1982 in the impoundment with those captured between the Chulitna River and Devil Canyon revealed

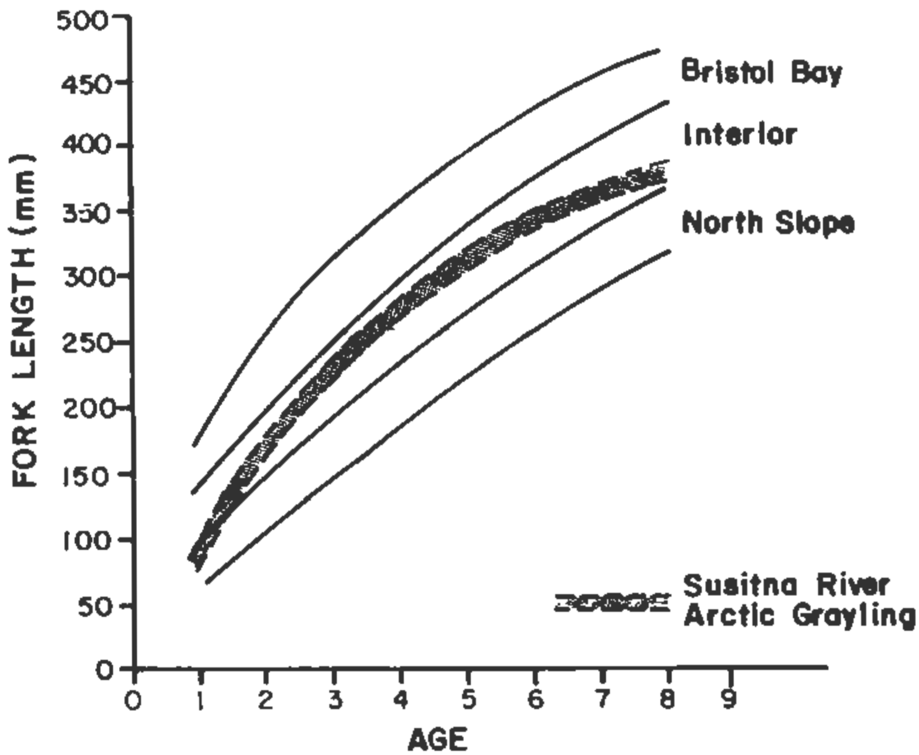
Appendix Table J-1. Results of regression analyses between length and age for Arctic grayling and rainbow trout captured on the Susitna River, 1981 and 1982.

	Area	Slope	Y Intercept	n	r^2	Std Error
Arctic Grayling						
Log	Impoundment, 1982	141.0	84.0	282	.90	14.9
	Above Chulitna, 1982	160.8	23.9	398	.83	27.4
	Below Chulitna, 1982	139.8	74.9	62	.88	24.8
	Impoundment, 1981	155.2	42.6	382	.82	18.4
	Above Chulitna, 1981	117.0	47.6	65	.93	19.0
	Below Chulitna, 1981	152.9	62.6	209	.87	23.5
Linear	Impoundment, 1982	29.6	144.5	282	.85	18.3
	Above Chulitna, 1982	46.6	54.6	398	.86	24.8
	Below Chulitna, 1982	47.7	68.3	62	.88	25.2
	Impoundment, 1981	33.2	119.5	382	.81	18.9
	Above Chulitna, 1981	44.8	71.1	65	.91	21.2
	Below Chulitna, 1981	38.2	101.5	209	.87	23.6
Rainbow Trout						
Log	Above Chulitna, 1982	271.3	-104.5	132	.84	34.5
	Below Chulitna, 1982	167.5	50.7	35	.76	--
Linear	Above Chulitna, 1982	57.0	36.4	132	.86	32.2
	Below Chulitna, 1982	42.0	103.0	35	.82	39.8
	Above Chulitna, 1981	50.5	73.6	92	.66	39.4
	Below Chulitna, 1981	62.4	43.5	92	.81	37.6

a statistically significant difference ($t=3.71$, $df=676$, $p<.01$), but this difference is probably not biologically important as 1981 data suggest the opposite trend. The growth rates of Arctic grayling in the Susitna River basin are very similar to those of other interior Alaskan populations (Appendix Figure J-1).

Rainbow Trout

Available rainbow trout length-age data from the Susitna River basin fit linear regressions as well or better than log regressions (Appendix Table J-1). Growth rates (slope of age/length regression) of rainbow trout captured above the Chulitna River confluence were not significantly different in 1981 than in 1982 ($t = 1.10$, $df = 220$). These data were pooled and a regression line computed for comparison with other rainbow trout populations (Appendix Figure J-2). The Susitna River rainbow trout were the smallest for any given age class of the other populations examined.



Appendix Figure J-1. Comparisons of age-length relationship of Arctic grayling in the Susitna River with growth rates of Arctic grayling in other regions of Ala.ka. Figure is adapted from Armstrong (1982).

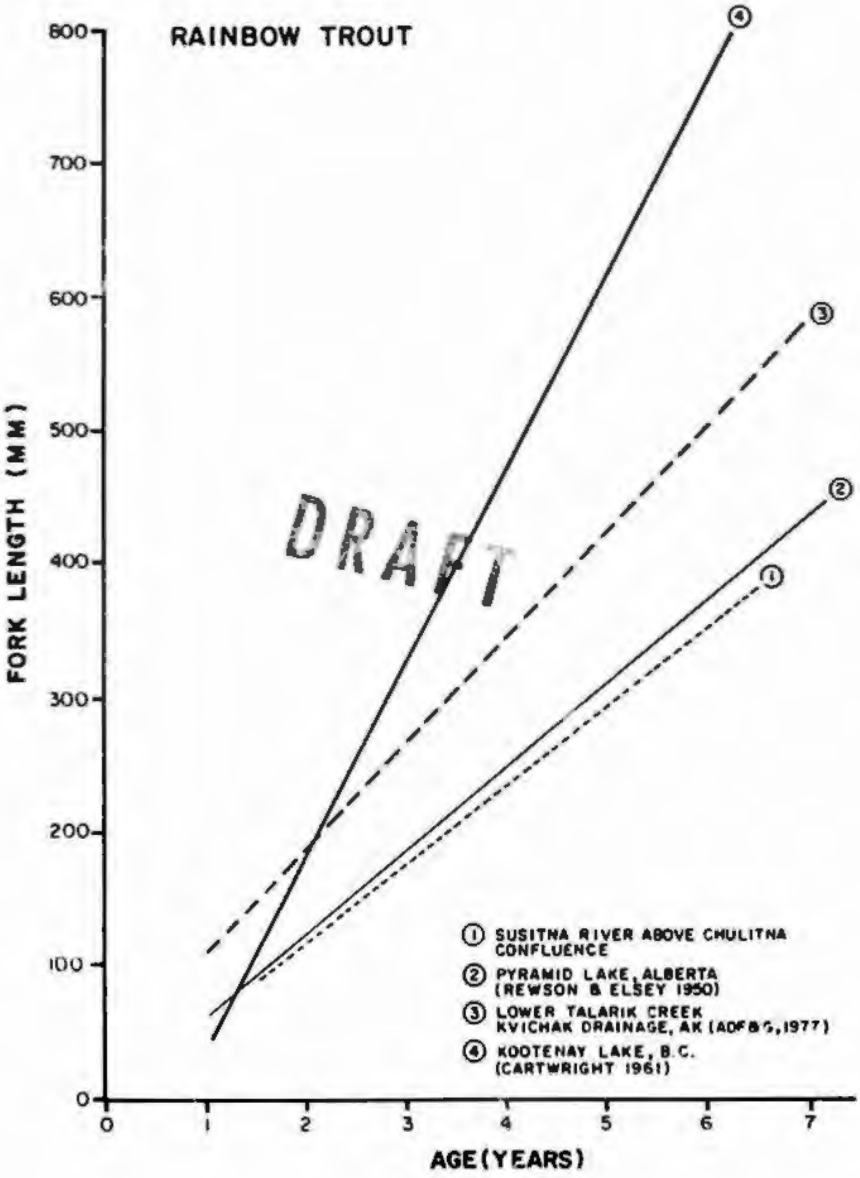


Figure J-2. Comparisons of age-length relationship of rainbow trout in the Susitna River above the Chulitna confluence with other systems.

Literature Cited

ADF&G, 1977. Rainbow trout life history studies in the lower Talarik Creek - Kvichak Drainage. Federal Aid in Fish Restoration, Vol. 18, Study No. G-II.

Armstrong, R.H. 1982. Arctic grayling studies in Alaska (Draft) Alaska Cooperative Fishery Research Unit and ADF&G Sportfish.

T.E.S. (Terrestrial Environmental Specialists, Inc.). 1981. Life history and ecology of selected fishes that occur in the Susitna River. Phoenix, New York. 59 pp.

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APPENDIX K

Evaluation of Arctic Grayling Spawning and Rearing Habitat and Notes on Salmon Spawning in the Impoundment Study Area of the Susitna River.

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ARCTIC GRAYLING

1. INTRODUCTION

The purpose of this study was to determine the locations of Arctic grayling, *Thymallus arcticus*, spawning and rearing habitats above and below the proposed impoundment elevation (PIE) within the eleven major tributaries of the impoundment study area (Figure K-1). Inundation of the lower reach of each of these streams below the PIE will result in the loss of existing lotic grayling spawning and rearing habitats. Therefore, the degree of continued spawning and rearing of Arctic grayling presently occurring in these streams will depend upon the quantity, quality and availability of habitat above the PIE.

2. METHODS

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General habitat investigations were conducted above and below the PIE on eight of the eleven major tributaries within the impoundment study area during 1982. Three small, steep gradient tributaries, Cheechako Creek (RM 152.5), Chinook Creek (RM 156.8), and Devil Creek (RM 161.4), because of time constraints and study priorities, were not adequately surveyed during the 1982 field season*. Therefore, these streams have been deleted from further discussion in this appendix.

* A foot survey, conducted at the mouth of Cheechako Creek and along the lower mile of Devil Creek indicated that very few grayling were present in these locations. Habitat was assessed to be poor in the extreme lower reach of Cheechako Creek, while good to excellent habitat was identified in Devil Creek. During aerial surveys above and below the PIE, several fish passage barriers were observed in

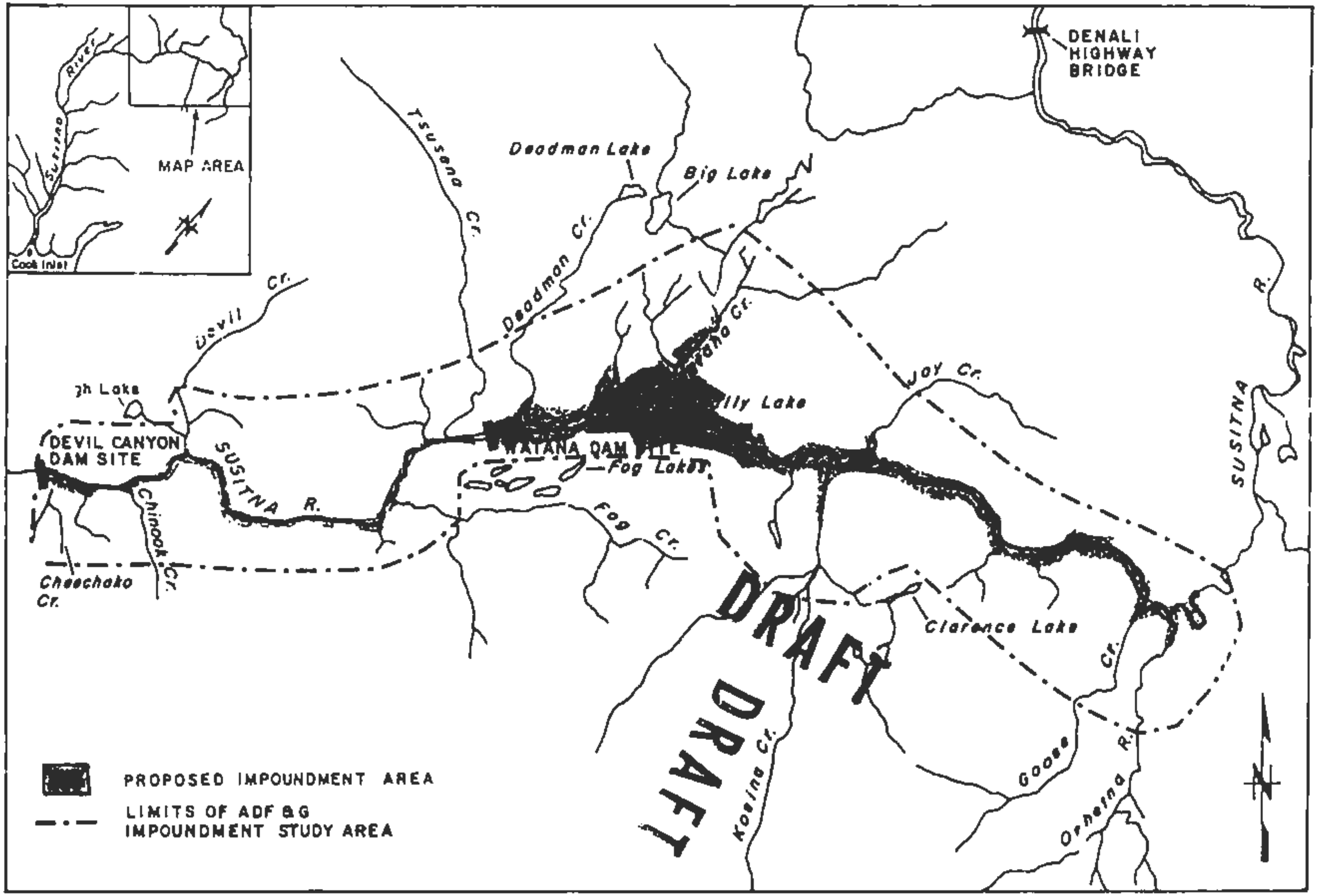

Figure K-1. Proposed Susitna Hydroelectric impoundment study area, 1982.

Investigations of the eight tributaries studied [Fog (RM 176.7), Tsusena (RM 181.3), Deadman (186.7), Watana (RM 194.1), Kosina (RM 206.8) and Jay (208.5) Creeks and the Oshetna River (RM 233.4)] were limited to the reach between the tributary mouth and a point five miles above the PIE on each stream. Evaluation of spawning and rearing habitats were based on stream gradient, substrate type, stream velocities and observations of grayling in each stream. Specifically, presence of preferred spawning habitat characteristics (gravel substrate and stream velocities of 0.8 to 3.3 feet per second (fps) (Tack 1973)) and/or observed use of habitat by spawning grayling were the criteria used to identify spawning habitat. ~~ft/sec (Tack 1973)) and/or observed use of habitat by spawning~~ ~~were the criteria used to identify spawning habitat.~~ Based on previous observations, slow flowing and backwater areas and/or observed young-of-the-year grayling (fry) were the criteria used to identify the presence of fry rearing habitat. Juvenile and adult grayling observations indicated the presence of adequate rearing habitat for these life stages.

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Data collection methods and detailed individual stream descriptions for the tributaries investigated are presented in the ADF&G Procedures Manual (ADF&G 1982) and the ADF&G Su Hydro Draft Basic Data Report, 1983 (ADF&G 1983a).

Cheechako and Chinook creeks. One barrier, a large waterfall 0.5 miles above the PIE, was identified in Devil Creek. The inundation of barriers below the PIE on each stream by the proposed Devil Canyon Reservoir will not affect the present inaccessibility to the upper reaches of these streams by Susitna River fish. Spawning and rearing habitats above and below the PIE were not assessed within Cheechako, Chinook and Devil creeks.

3. RESULTS

Adults, juveniles and grayling fry were found scattered throughout the study reach of all tributaries investigated. Because grayling fry spend their first summer near their hatch site (Tack 1980), the observations of fry indicated that spawning had taken place above and below the PIE in all tributaries. In addition, all streams contained the gravel substrates and medium to slow stream velocities necessary for suitable spawning habitat throughout their surveyed length. Actual grayling spawning was not observed because of spring turbid water conditions.

The observation of fry, juvenile and adult grayling along with the identification of spawning and rearing habitats within the study reach on each tributary indicated that grayling of all life stages were supported throughout these reaches.

Large waterfalls located within the study reaches of Tsusena and Deadman Creeks presently prevent fish passage from the Susitna River to the upper reaches of these streams. The waterfall located in Deadman Creek would be inundated by the proposed Watana Reservoir, eliminating this fish passage barrier. However, the proposed Devil Canyon Reservoir, which would flood the lower portion of Tsusena Creek, will not inundate the waterfall located on this stream but will decrease the amount of available habitat above the PIE and below the waterfall. Likewise, the proposed inundation of Fog, Watana and Jay Creeks below possible hydraulic fish passage barriers may also decrease the amount of available habitat in each stream below these barriers. A more complete discussion on fish passage barriers in the study area is presented in the ADF&G Draft Basic Data Report, 1983 (ADF&G 1983a).

4. CONCLUSIONS

All reaches of tributaries studied contained suitable spawning and rearing habitats above and below the PIE. However, the quality, quantity and accessibility of these habitats varies considerably among streams and within streams above and below the PIE. Most notable changes within streams above and below the PIE occur on Deadman and Kosina Creeks where an abrupt change in stream gradient and a change in stream gradient pattern, respectively, changes the quality of the available habitat (ADF&G 1983a). Habitat differences among streams are basically a function of stream gradient, discharge, substrate and morphology.

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Adult Arctic grayling are suspected to spawn* in the same section of river where they were hatched (Tack 1980) and have been shown to return to the same summer feeding station yearly (Schallock and Roguski 1967, ADF&G 1983a). Spawning and rearing habitats above and below the PIE on all tributaries surveyed are seasonally used by Arctic grayling which probably home to these specific areas yearly. However, after reservoir

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* Spring 1983 field studies located active grayling spawning areas. These data will be reported and compared to the information of this appendix in the FY84 ADF&G report.

development, grayling which had homed to the reach of tributary below the PIE will be displaced. The suspected invasion and use of spawning and rearing habitats above the PIE by these displaced grayling will likely affect the grayling population above the PIE. These effects cannot be predicted since estimating the grayling carrying capacity of these habitats is beyond the scope of this study. Therefore, the lotic habitats above the PIE cannot be considered as replacement habitat for habitat lost below the PIE.

<u>SALMON</u>

Cheechako and Chinook Creeks, located within lower Devil Canyon at RM 152.5 and 156.8, respectively, are the only tributaries of the Susitna River within the proposed impoundment areas presently known to be used by spawning salmon. Although unconfirmed sightings of salmon have been reported near the mouth of Jay Creek, RM 208.5 (USFWS 1954), studies conducted by ADF&G during 1981 and 1982 (ADF&G 1981, 1983b) have tentatively placed the upstream limit of the salmon migration in the Susitna River near the mouth of Chinook Creek, RM 157.0. The constricted river channel of Devil Canyon above Chinook Creek creates a fish passage velocity barrier which inhibits further upstream migration of fish.

ADF&G Su Hydro staff initially documented chinook salmon spawning within the Devil Canyon reach of the Susitna River in the glacial clearwater mixing zones of Cheechako and Chinook Creeks on August 4 and 5, 1982, respectively (ADF&G 1983b). On August 6, 1982, ADF&G Su Hydro Aquatic Habitat personnel measured streamflow velocities and depths associated with holding chinook salmon within the clear-water plume and mixing zone of Cheechako Creek (Figure K-2). Although actual spawning was not observed at this time, a semi-dewatered chinook salmon redd was observed along the water's edge approximately 150 feet downstream from the mouth of Cheechako Creek, indicating that spawning had taken place during a higher discharge period.

Subsequent surveys on Cheechako and Chinook Creeks during August, 1982 indicated that salmon used only a small portion of the habitat above the mouth on each stream. Several fish passage barriers within Cheechako and Chinook Creeks prevented salmon access to the upper reaches of these streams. Most of the lower reach on each stream was characterized by turbulent, high velocity whitewater areas and spawning habitat appeared to be limited.

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Additional investigations are planned FY 84 in the Devil Canyon area of the Susitna River to further document the extent of salmon movement above the Devil Canyon dam site, RM 152.0.

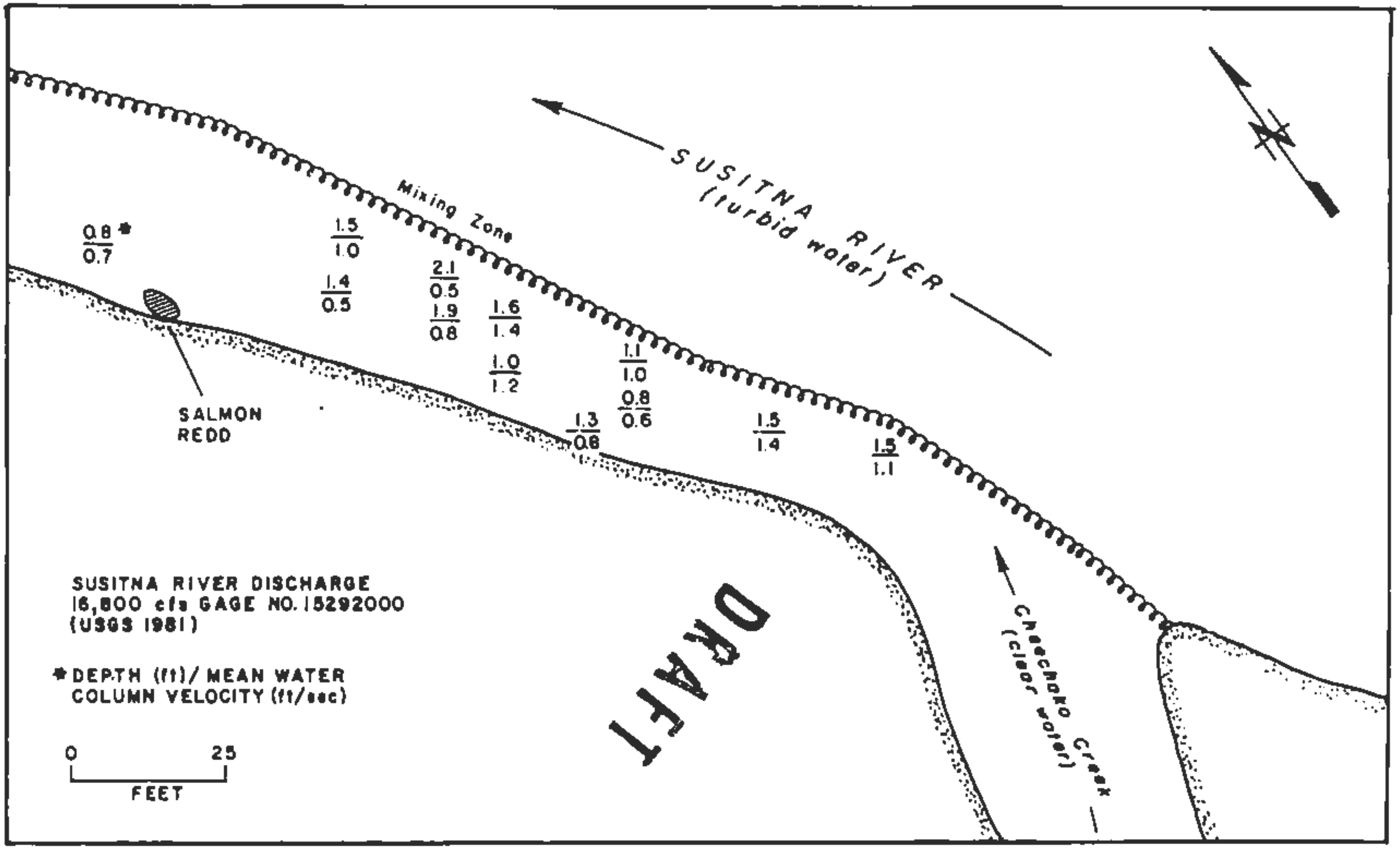

Figure K-2. Chinook salmon holding area near the mouth of Cheechako Creek in the Susitna River at RM 152.4 (GC S32N01E33CCB) August 6, 1982.

LITERATURE CITED

Alaska Department of Fish and Game (ADF&G). 1981. Adult anadromous phase 1 final species/subject report. ADF&G Su Hydro Aquatic studies Program. Anchorage, Alaska.

_____. 1982. Procedures manual. ADF&G Su Hydro Aquatic Studies Program. Anchorage, Alaska.

_____. 1983a. Su Hydro draft basic data report, Volume 5. ADF&G Su Hydro Aquatic Studies Program. Anchorage, Alaska.

_____. 1983b. Su Hydro draft basic data report, Volume 2. ADF&G Su Hydro Aquatic Studies Program. Anchorage, Alaska.

Schallock, E.W. and E.A. Roguski. 1967. Investigations of the Tanana River and Tangle Lakes fisheries: Migratory and population study. Alaska Dept. of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress 1966-1967, Project F-S-R-8, 8(16-B).

Tack, S.L. 1973. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Dept. of Fish and Game, Federal Aid in Fish Restoration, Annual Report of progress, 1972-1973, Project F-9-5, 14 (R-I).

____. 1980. Distribution, abundance and natural history of the Arctic grayling in the Tanana River drainage, Alaska. Dept. of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1979-1980, Project F-9-12, 21 (R-1).

U.S. Fish and Wildlife Service. 1954. A progress report on the fishery resources of the Susitna River Basin. Juneau, Alaska.

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