APPENDIX E

Final reports on winter-run steelhead spawning surveys - Sultan River, Washington.

E-1. 1987 Report

E-2. 1989 Report

APPENDIX E-1

Final report on the 1987 winter-run steelhead surveys–
Sultan River, Washington.

FINAL REPORT ON

1987 WINTER-RUN STEELHEAD TROUT SPAWNING SURVEY

Prepared by

Parametrix, Inc
Tom Schadt
Jeff Neuner
13020 Northup Way
Bellevue, WA 98005

Prepared For

Public Utility District No. 1 of Snohomish County
Roy Metzgar, Project Leader
P.O. Box 1107
Everett, WA 98206

July 1987

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Cont.)

LIST OF TABLES

INTRODUCTION

The Jackson Hydroelectric Project on the Sultan River in northwestern Washington State (Figure 1) was completed in 1984. The Sultan River and its tributaries are utilized for spawning and rearing by chum, pink, coho and chinook salmon, steelhead and sea-run cutthroat trout, and Dolly Varden. These anadromous salmonids utilize the area between the mouth of the Sultan River and the Everett Diversion Dam River Mile (RM) 9.7. No spawning or rearing occurs above RM 9.7 because the Everett Diversion Dam is a block to upstream migration.

Recognizing that certain flow regimes may create passage problems for adult fish migrating upstream past the powerhouse, the fish management agencies required mitigative steps by the owner/operator Public Utility District No.1 of Snohomish County (District). The key element for this mitigation is a low-head dam, referred to as the fish passage berm, installed at the upstream end of the powerhouse (Figure 2).

The primary species of concern that utilize the five mile reach between the powerhouse (RM 4.5) and Everett Diversion Dam (RM 9.7) are chinook and summer and winter-run steelhead. A study of these species was initiated in the Fall, 1984 to determine if the passageway successfully facilitated migration past the powerhouse, to monitor adult upstream migrations past the powerhouse, and to investigate project effects through comparison of pre-project and post-project spawning distribution. The complete results of that study and more explanatory background information are presented in Adult Fish Passage (Powerhouse Berm) Study (1987) prepared for the District by Parametrix, Inc.

WINTER-RUN STEELHEAD TROUT RESULTS - 1985

With the winter-run steelhead trout, a radio tagging study was conducted to monitor their passage in the powerhouse vicinity. Spawning surveys were used to evaluate spawner distribution within the Sultan River. The radio tagging results, while limited (two tagged fish migrated past the powerhouse), indicated that winter-run steelhead could migrate past the powerhouse during potentially confusing flow situations without any delay or entry into the powerhouse discharge canals. The 1985 areal distribution of wither-run steelhead spawning was similar to pre-project distributions observed in 1979 and 1980 suggesting that winter-run steelhead were able to successfully migrate past the powerhouse during a variety of flow scenarios which occurred during the 1985 winter-run steelhead migration.

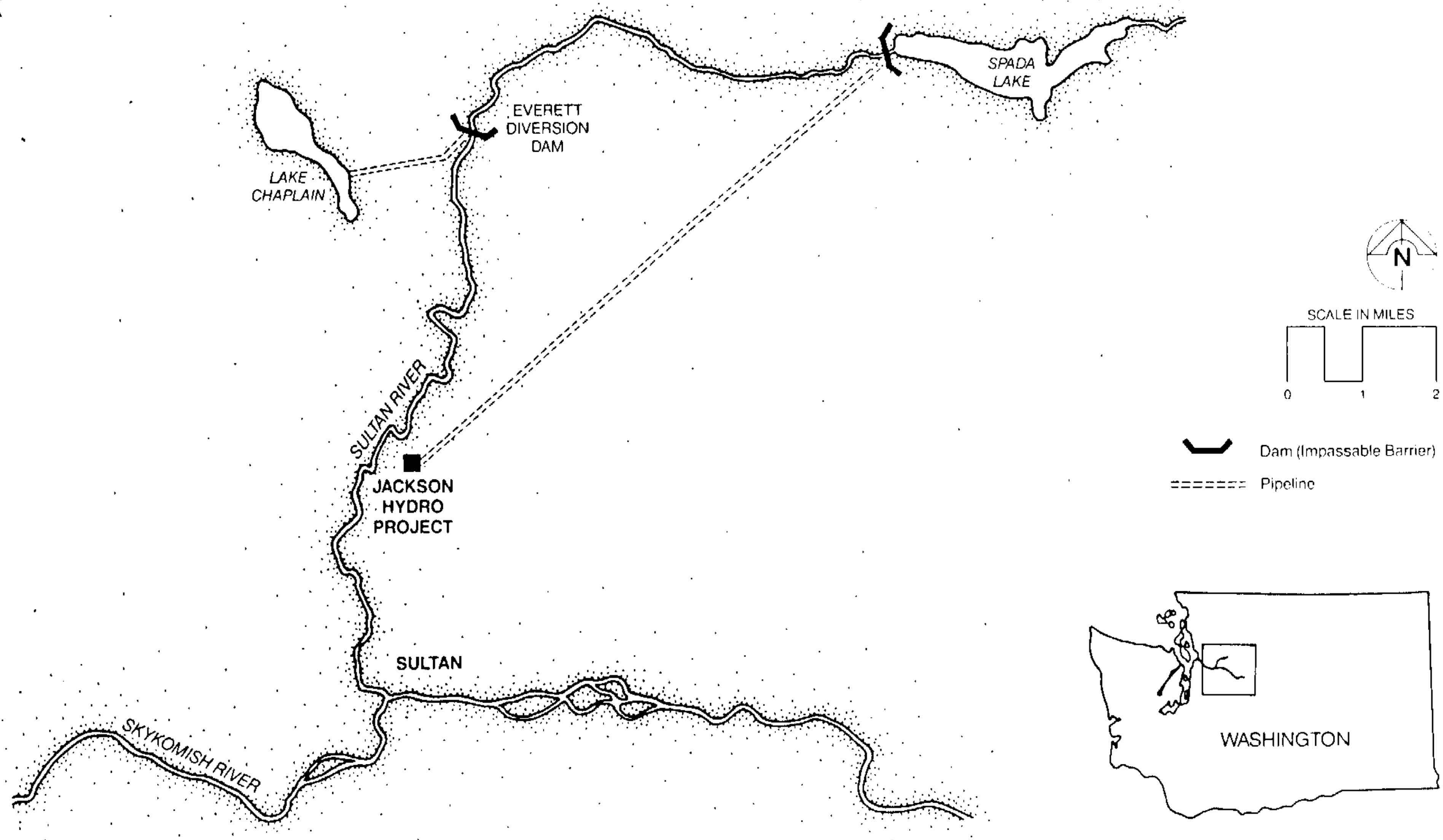


Figure 1. Jackson Project vicinity map.

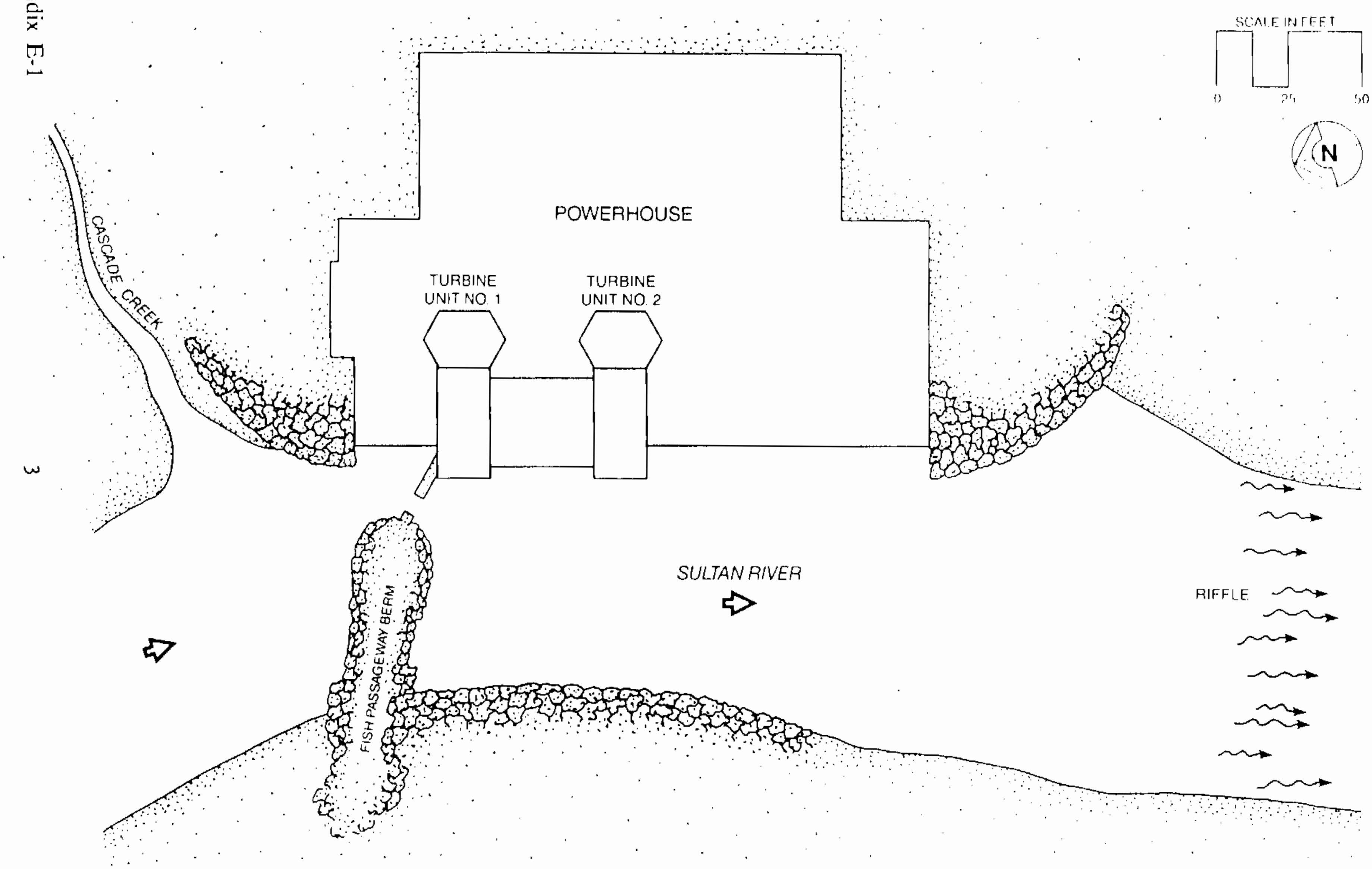


Figure 2. Powerhouse and fish passageway berm.

Although the results of the steelhead spawning ground surveys conducted in 1985 as part of the original study indicated that redd distribution was similar to pre-project years, additional surveys were requested by the Washington Department of Game because powerhouse discharge during the 1985 migration was only moderate. Winter-run steelhead migration and distribution might be affected during periods of higher project discharge which might create a more confusing situation for fish passage than periods of lower powerhouse discharge. To address this concern, the District agreed to conduct three more steelhead spawning ground surveys through 1990, if necessary. If a high powerhouse discharge scenario should occur prior to then, further surveys might not be needed, depending upon satisfactory results. At the time of the agreement to conduct more surveys, the District was uncertain whether the next steelhead spawning survey in the series could be started in 1987. Since it was, the survey series now concludes in 1989 or earlier. This report presents the results of the 1987 steelhead spawning ground survey.

METHODS

Six surveys were conducted during the 1987 spawning season. Survey dates were March 16 and 31; April 20; May 6 and 20; and June 3. Originally eight surveys were proposed, with three to occur in March, two in April, two in May, and one in June. However, high flows during early March and much of April precluded two of the surveys during those months. Surveys consisted of observations from a helicopter over a length of the Sultan River from the confluence with the Skykomish River (RM 0) to the Diversion Dam (RM 9.7). Observers noted all redds observed during each flight and plotted the number and location on maps of the Sultan River channel.

In addition to the redd count maps and location notes made during each survey, redd life data were also collected. The purpose of collecting redd life data was to eliminate double counts of the same redds seen on consecutive surveys, and ultimately adjust the redd count data to total counts of individual redds observed during the 1987 season. Redd life was determined by periodically marking artificial redds, or newly created natural redds, with colored rocks and observing their detectability during subsequent surveys.

After establishing artificial redds and collecting the redd life data, it became apparent that some natural redds were still visible on subsequent surveys, even after redd life data suggested that they should no longer be visible. This was perhaps due to the size of the redd, its location, the possibility of repeated use of the same area, or some combination of these or other factors. In any case, the results raised a concern regarding the applicability of the redd life data to a situation like the Sultan River where relatively few redds are observed. Since the location of redds observed during each survey was plotted on maps, the possibility of using these maps to distinguish duplicative counts was investigated. It was determined that through combined use of the maps, field notes, and applying generalized redd life data, the best estimates of total redds counted could be made. Maps were relied on most heavily for distinguishing new redds from old redds. In areas where new redds appeared in the same location as previously observed redds, but several weeks after the old redd, redd life data were used to differentiate between new and old.

In general the combination of maps and redd life data was an effective way to distinguish new from old redds and develop an accurate total estimate. In some locations where spawning was extremely heavy, the use of base maps was somewhat limited due to the difficulties of plotting precise redd locations. These types of areas, however, are limited on the Sultan River. Given the limited amount of this type of "confusing" habitat, the map and redd life approach provides a more reliable estimate for the Sultan River than absolute application of redd life data to each survey's total counts.

RESULTS

The redd counts and adjusted or "new" redd counts made during each survey are summarized in Table 1. A total of 68 redds were observed during the 1987 surveys. Redd distribution relative to the powerhouse was 34 upstream (50 %) and 34 downstream (50 %).

Table 1. Summary of 1987 steelhead redd observations in the Sultan River.

	Entire Survey Length		Downstream from Powerhouse		Upstream from Powerhouse	
Date	Total Count	New Redds	Total Count	New Redds	Total Count	New Redds
March 16	2	2	2	2	0	0
March 31	13	11	6	4	7	7
April 20	32	22	11	8	21	14
May 6	41	20	17	10	24	10
May 20	37	5	14	3	23	2
June 3	33	8	12	7	11	1
TOTALS	158	68	62	34	86	34

The results of the 1987 surveys indicate a slightly higher distribution of redds in the area upstream from the powerhouse than in previous years. For the two years of pre-project survey data (1979 and 1980) the percentage of total redds that were observed upstream from the project was 29 and 30 percent, respectively (Washington Department of Game and Snohomish County PUD 1982). In 1985, the only other post-project year that redd count data were collected, about 30 percent of the total redds were also located upstream. Increased spawning usage of the area upstream from the powerhouse by adult steelhead in 1987 indicates that the project operation during the migration period in conjunction with the berm did not create a passage problem.

STREAMFLOW AND POWER GENERATION

During the majority of the survey period (December - May) the powerhouse was responsible for more than 50 percent of the total river flow. The daily mean flow from the powerhouse and total daily mean river flow for the referenced spawning period are shown in Figures 3-8. Occasionally, the powerhouse contributed less than 50 percent of the total flow, but it was typically during periods of low flow (less than 500 cfs total). During periods of high total flow, when steelhead are likely to be migrating, the powerhouse contribution was always very high and ranged between 60 and 80 percent of the total flow. Overall, 1987 was a good test of how well steelhead would migrate past the project during confusing flow scenarios in the powerhouse vicinity. The Pelton turbines, which discharge directly to the river, were only shut down a few weeks during the entire migration period, and consistently contributed a substantial portion of the total flow in the river.

Due to the location of the discharge tunnels relative to the passage slot, the turbine unit generating the discharge may also play a role in passage efficiency. Turbine 1 discharges next to the slot, while Turbine 2 discharges downstream from the slot. Both units discharge flow in a direction that is perpendicular to the direction of flow passing through the berm slot. A summary of Unit 1 versus Unit 2 daily-mean discharge for the December-May migration period is presented in Figures 9-14.

Project power generation records (expected and actual) provide further perspective on adult migration past the powerhouse. Expected generation (megawatt hours - MWh) at average water, compared with actual generation, is shown in Table 2 and Figure 15. Over the last 2.5 years, actual generation has been lower than that expected with average water, (with the exception Q2/85 and Q1/86). This is the result of lower than average water conditions in the Sultan basin. Generation during the first and second quarters of 1987 was 83 and 65 percent, respectively, of that expected. In the context of power generation and survey

Table 2. Actual versus expected power generation for the Jackson Project at average water conditions

Quarter	Actual Jackson MWh Generation	Expected MWh Generation at Average Water	Actual as a Percentage of Average Water
01/85	42,347	123,000	34.43%
02/85	155,054	128,000	121.14%
03/85	28,772	66,000	43.659%
04/85	100,748	148,000	68.07%
TOTAL 1985	326,921	465,000	70.30%
01/86	129,518	123,000	105.30%
02/86	84,399	128,000	65.94%
03/86	33,733	66,000	51.11%
04/86	126,850	148,000	85.70%
TOTAL 1986	374,500	465,000	80.53%
01/87	102,442	123,000	83.329%
02/87	83.492	128,000	65.23

purposes that result is disappointing. However, as described above the power generation schedule or pattern with the Pelton turbines provided useful flow scenarios in the tailrace for evaluating adult upstream migration past the powerhouse and passage effectiveness of the berm.

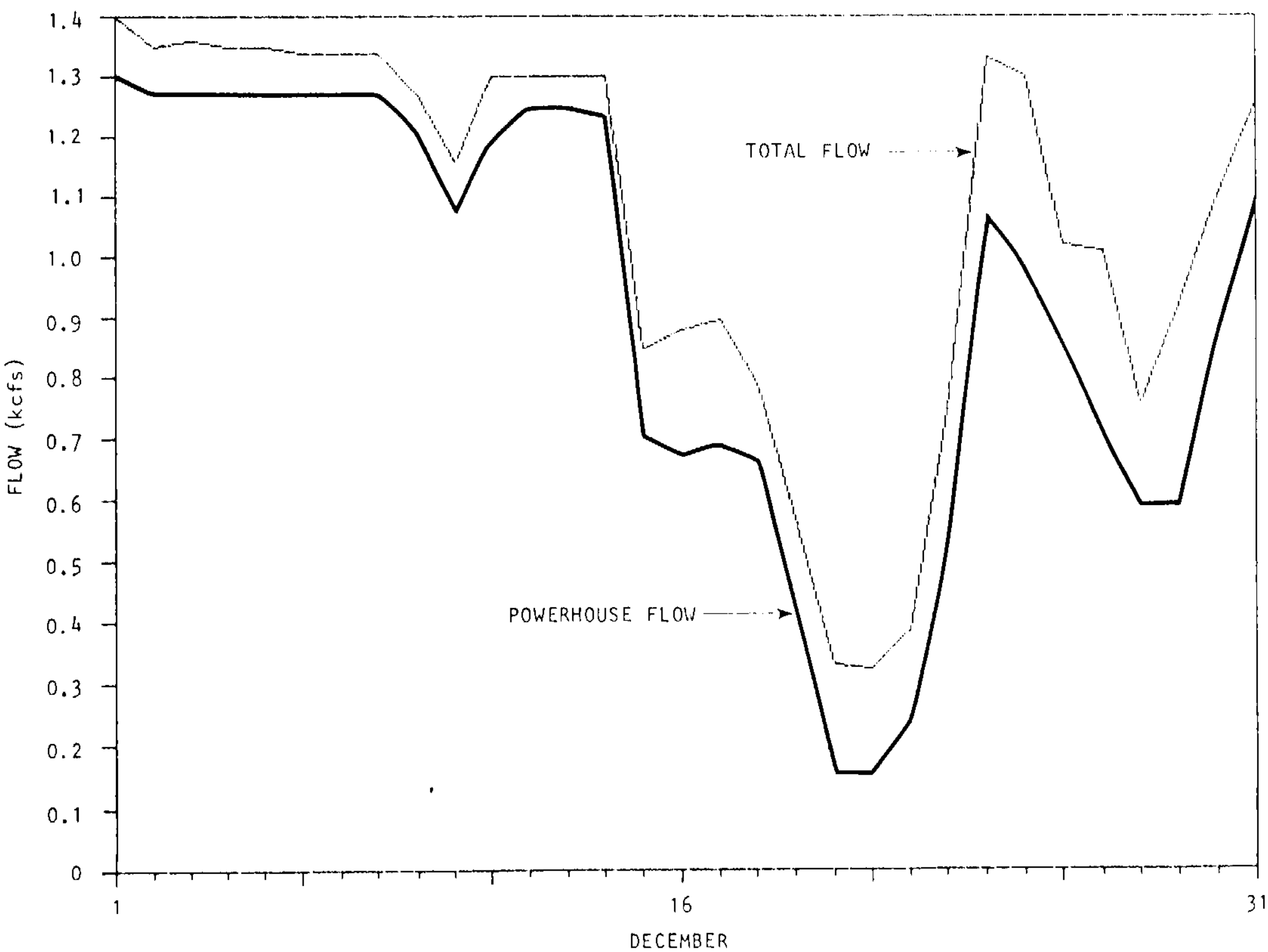


Figure 3. Sultan River daily mean streamflow data, December, 1986.

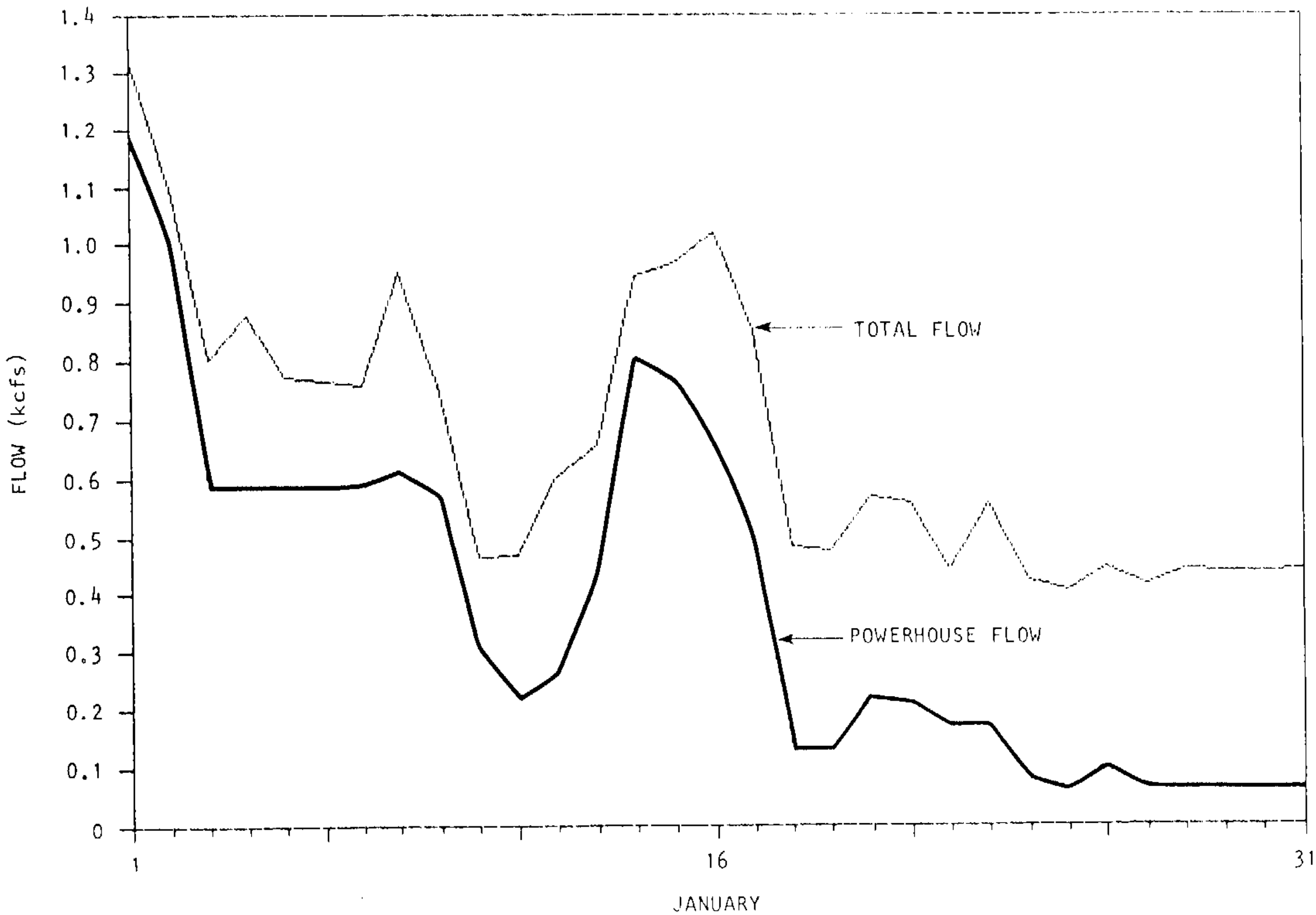


Figure 4. Sultan River daily mean streamflow data, January, 1987.

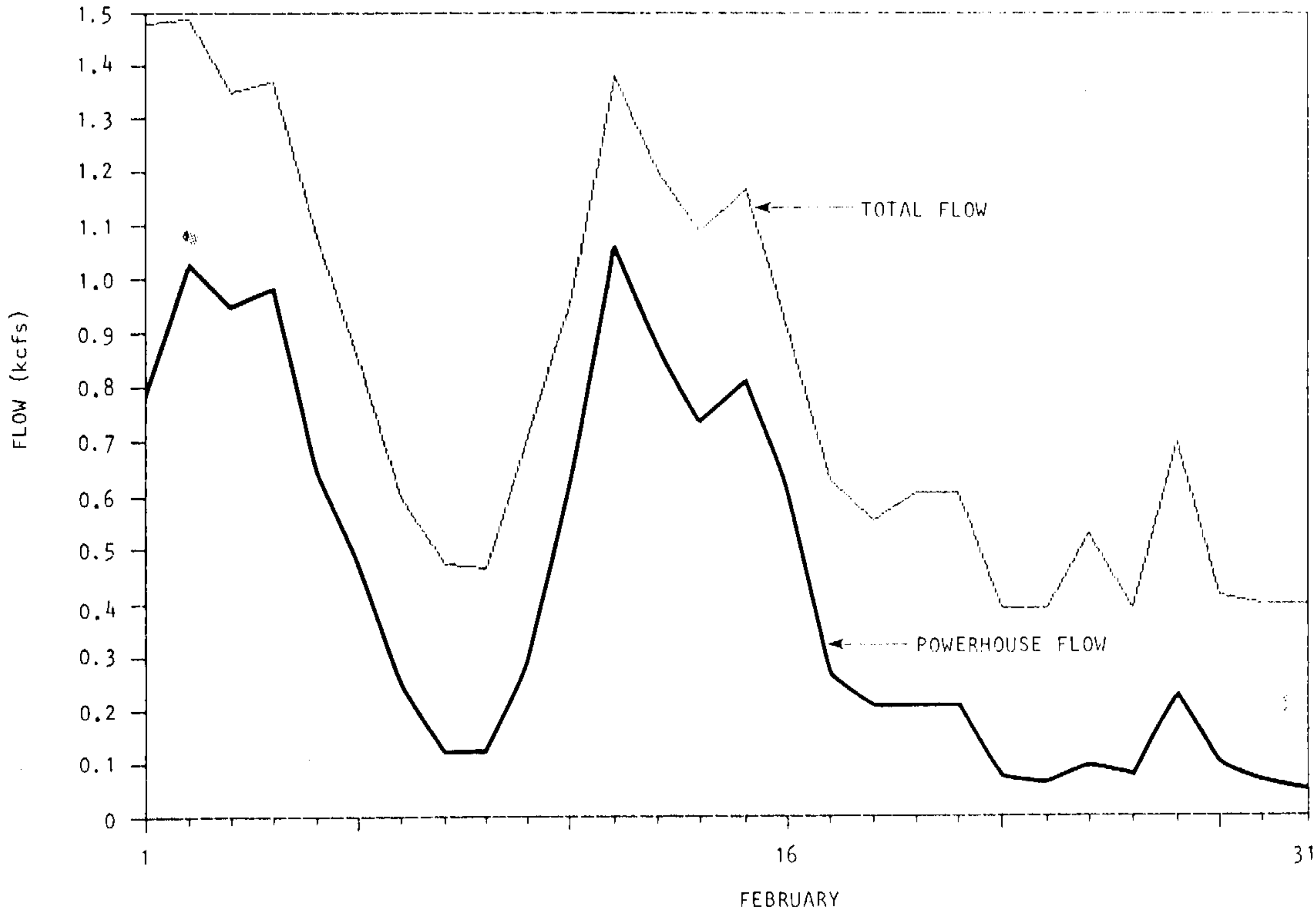


Figure 5. Sultan River daily mean streamflow data, February, 1987.

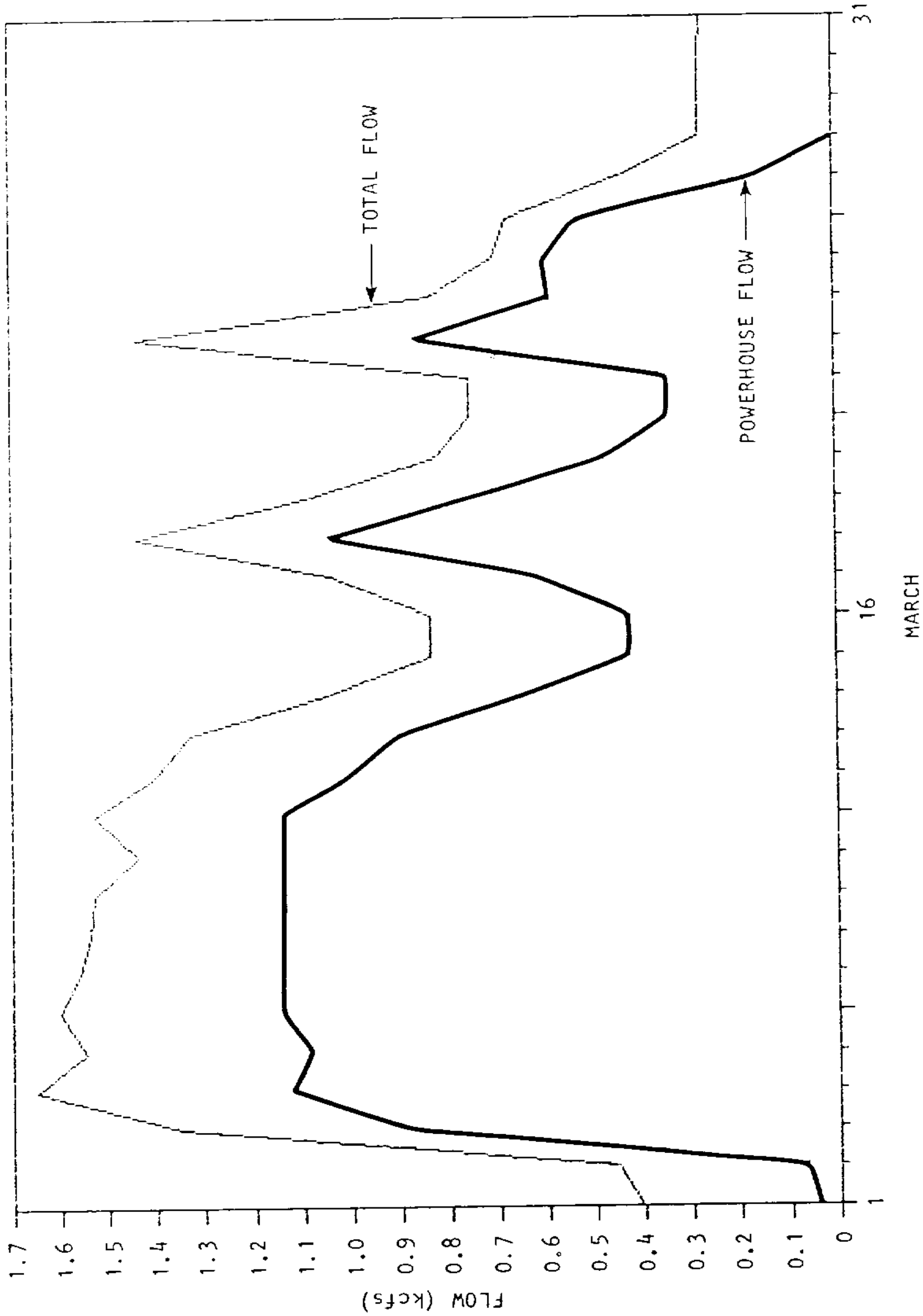


Figure 6. Sultan River daily mean streamflow data, March, 1987.

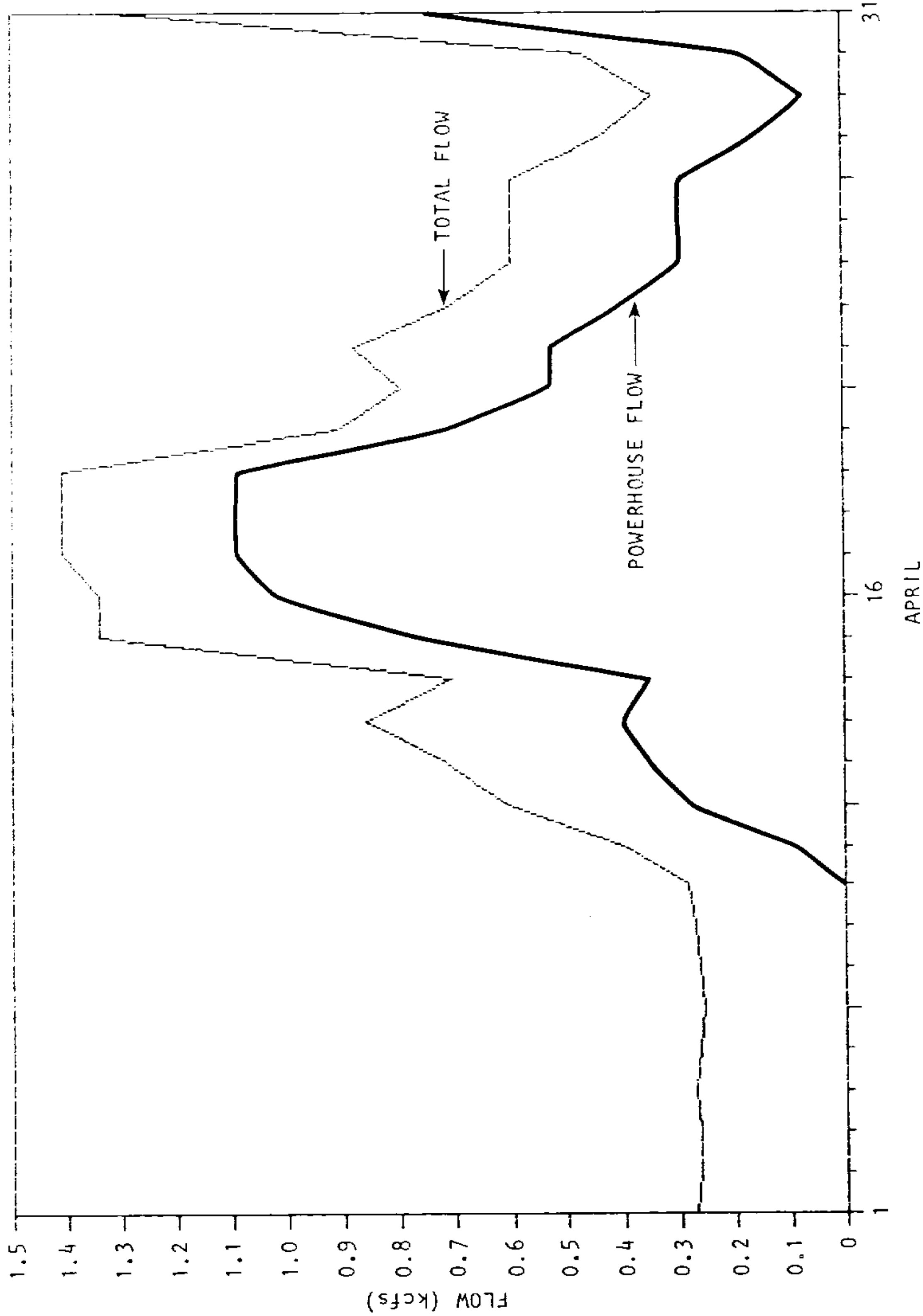


Figure 7. Sultan River daily mean streamflow data, April, 1987.

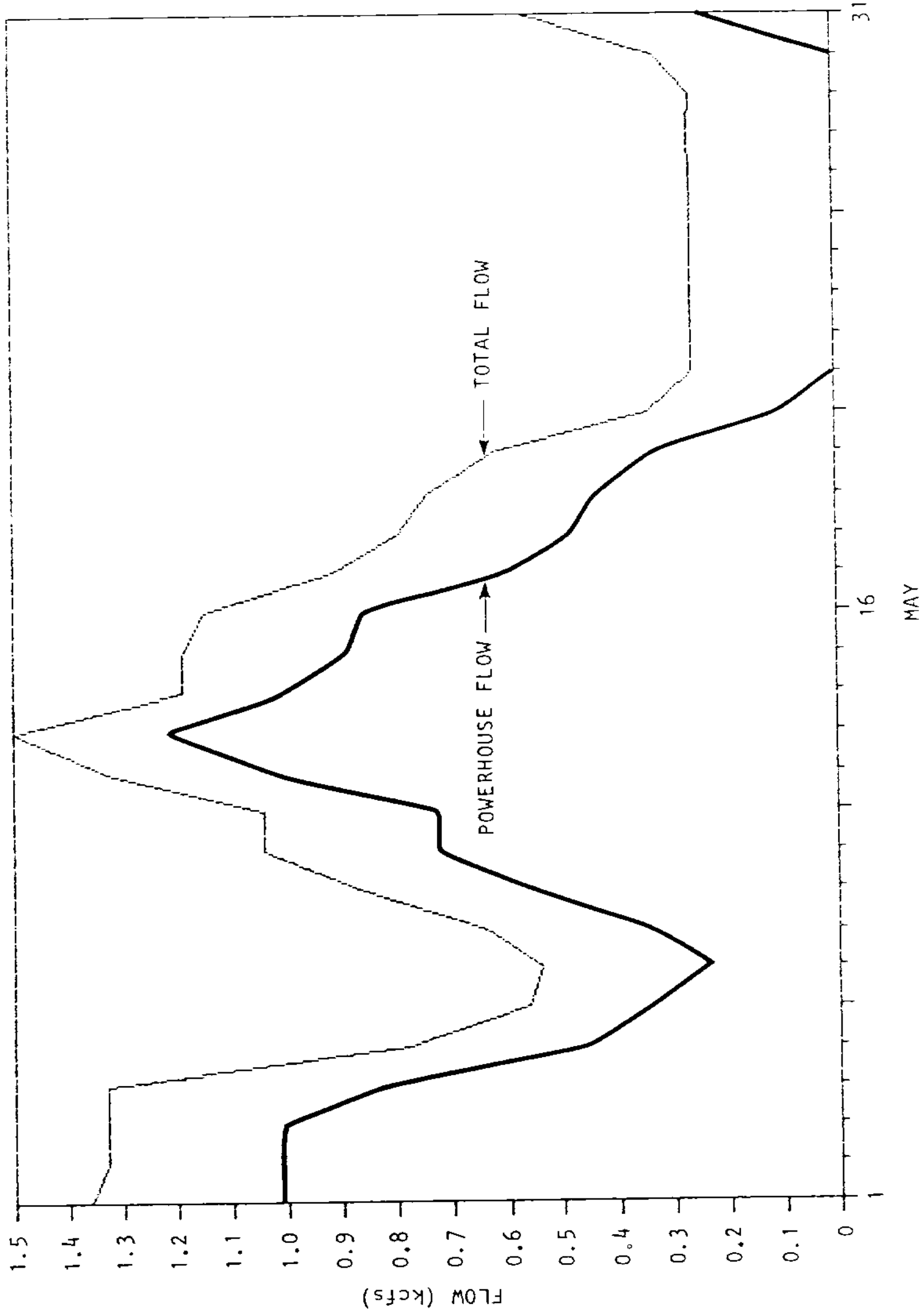


Figure 8. Sultan River daily mean streamflow data,
May, 1987.

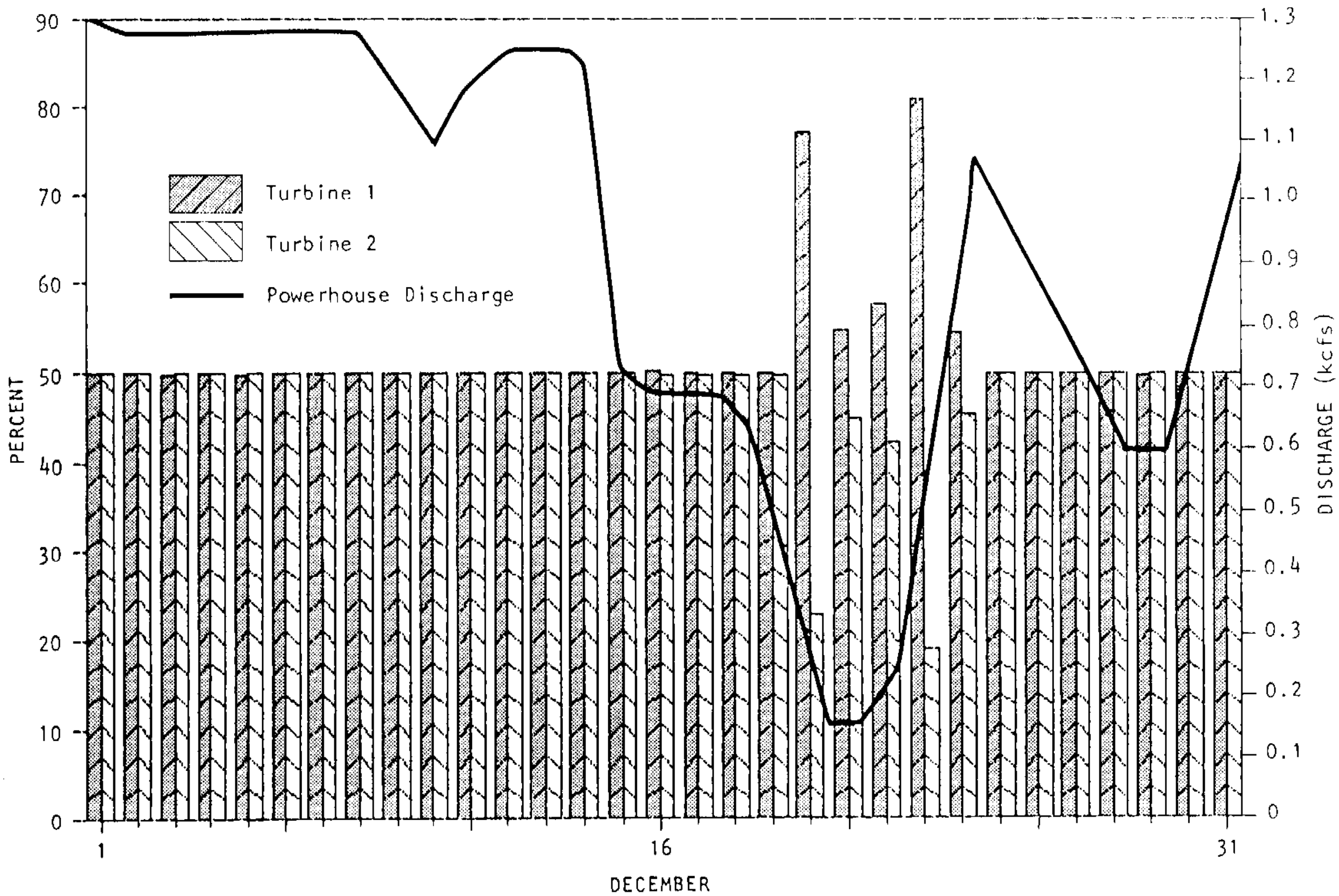


Figure 9. Daily mean discharge contributions of Unit 1 and Unit 2 (percent), and total powerhouse discharge (kcfs) for the Jackson Project, December, 1986.

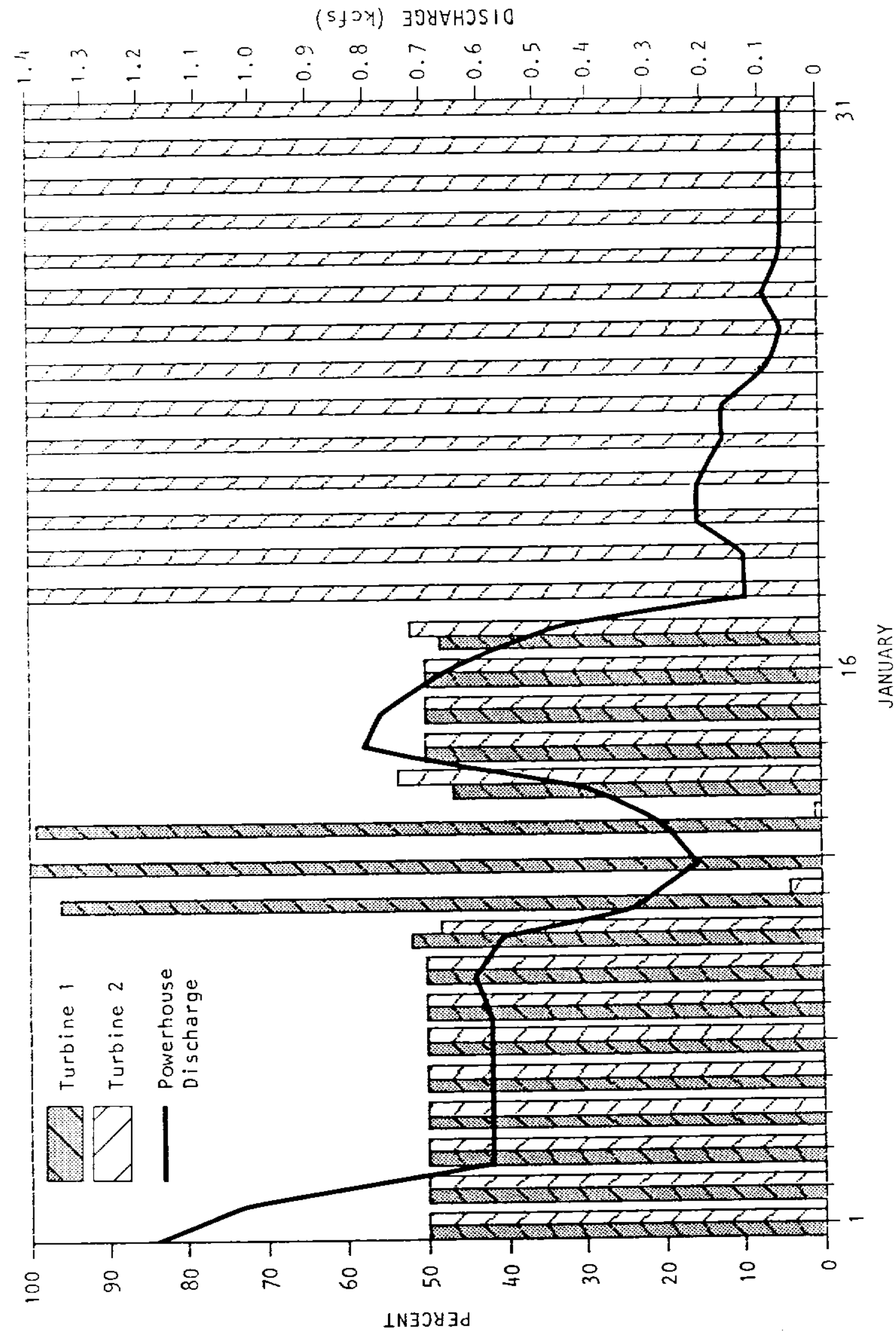


Figure 10. Daily mean discharge contributions of Unit 1 and Unit 2 (percent), and total powerhouse discharge (kcfs) for the Jackson Project, January, 1987.

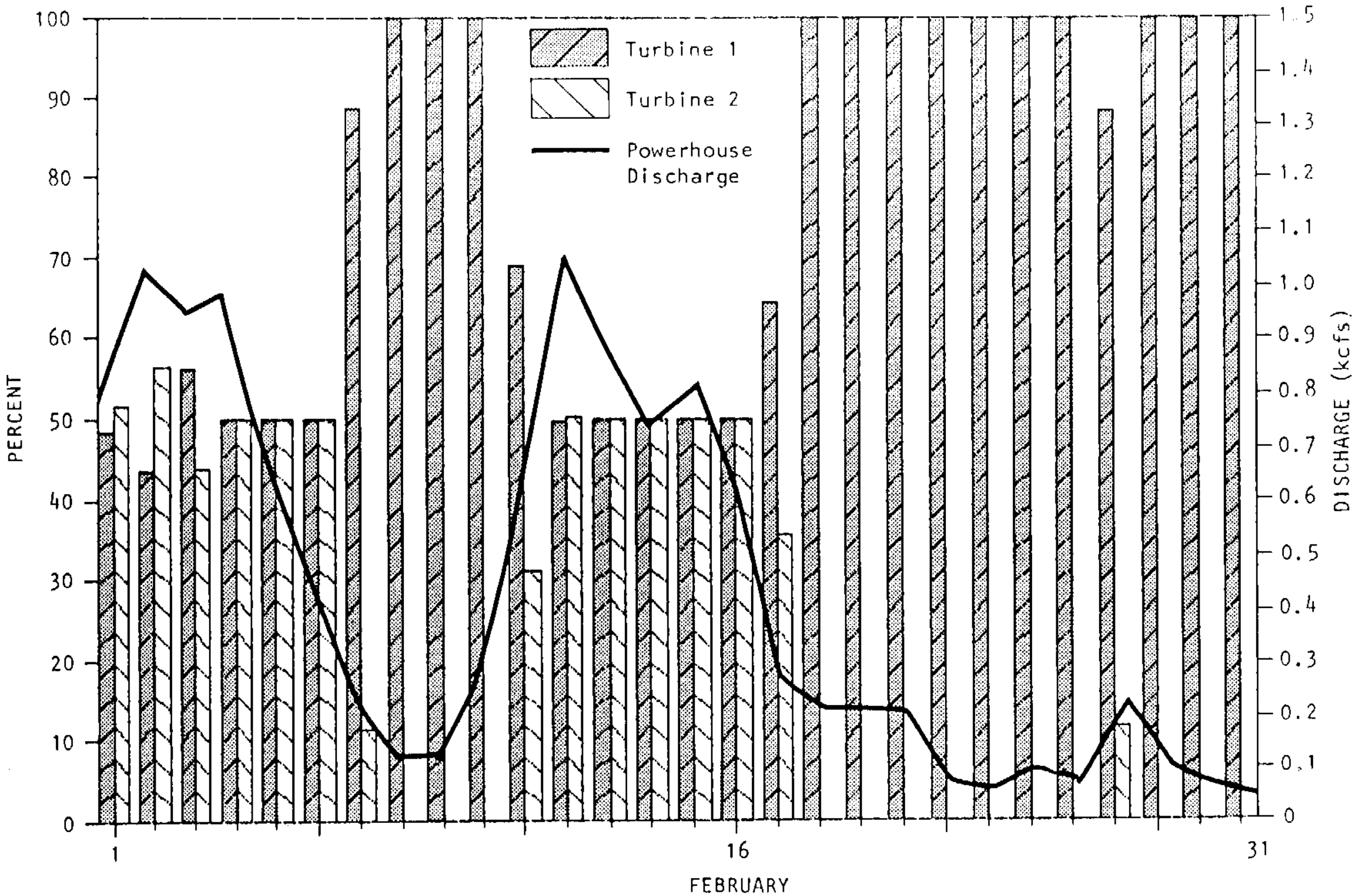


Figure 11. Daily mean discharge contributions of Unit 1 and Unit 2 (percent), and total powerhouse discharge (kcfs) for the Jackson Project, February, 1987.

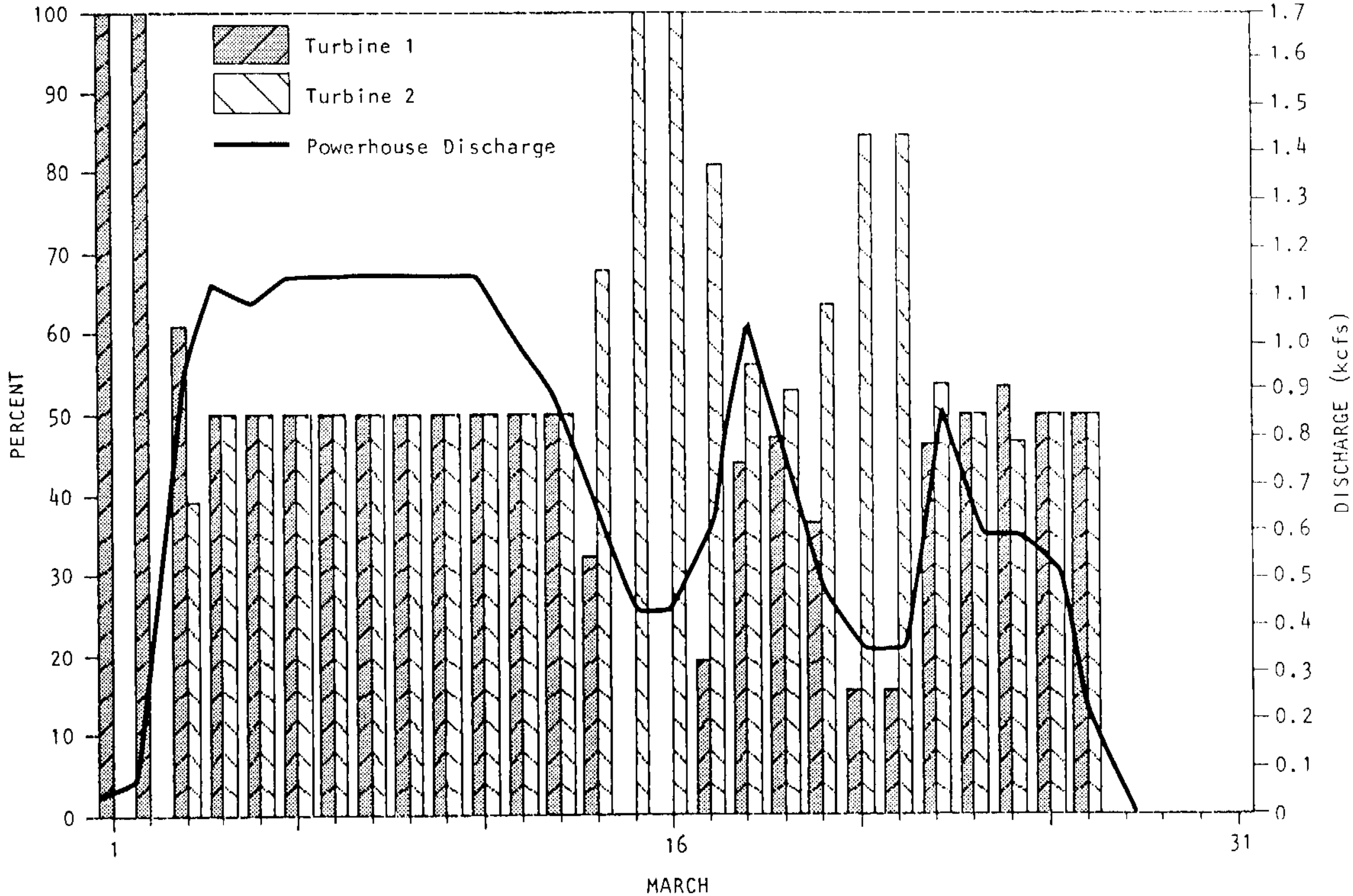


Figure 12. Daily mean discharge contributions of Unit 1 and Unit 2 (percent), and total powerhouse discharge (kcfs) for the Jackson Project, March, 1987.

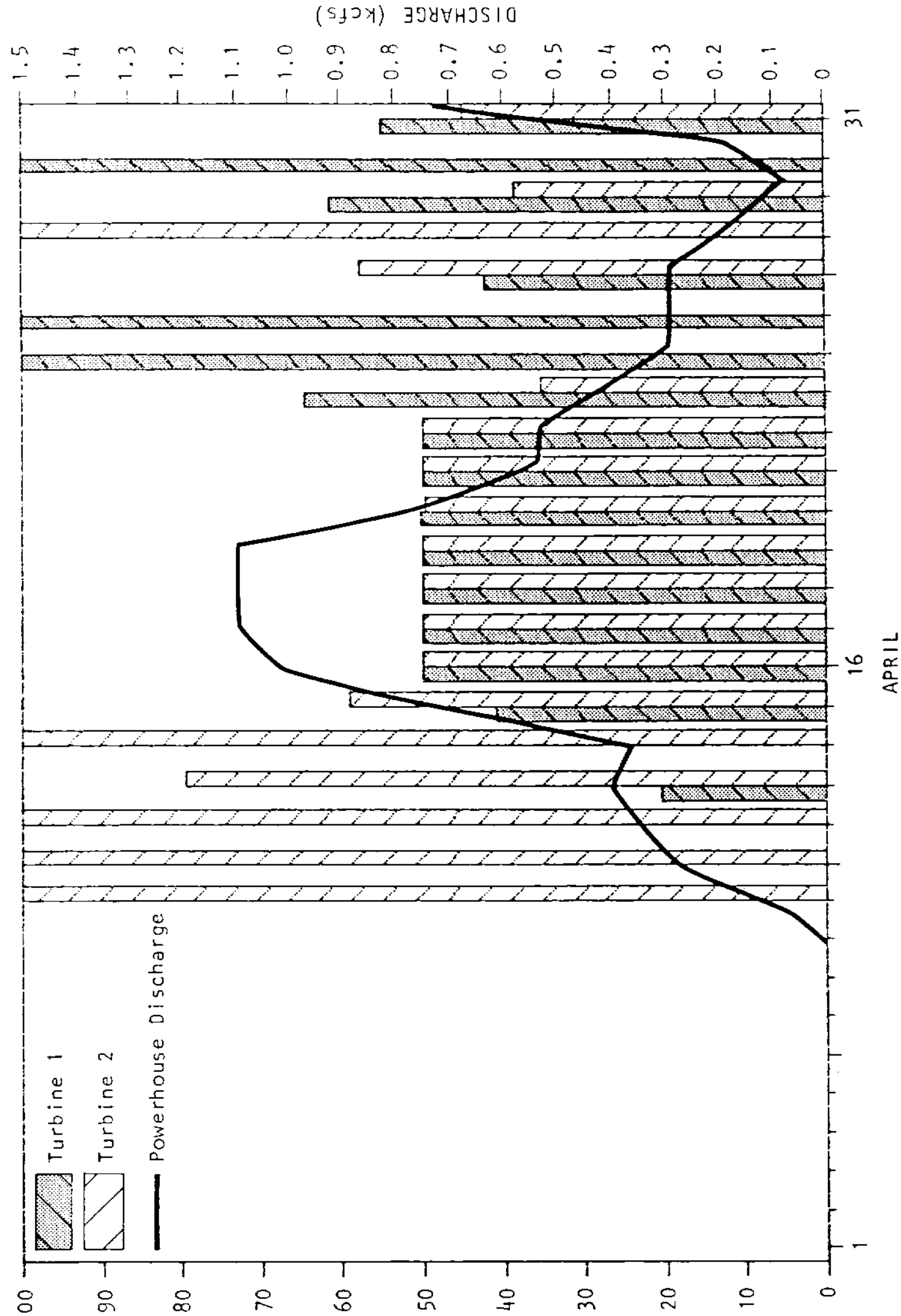


Figure 13. Daily mean discharge contributions of Unit 1 and Unit 2 (percent), and total powerhouse discharge (kcfs) for the Jackson Project, April, 1987

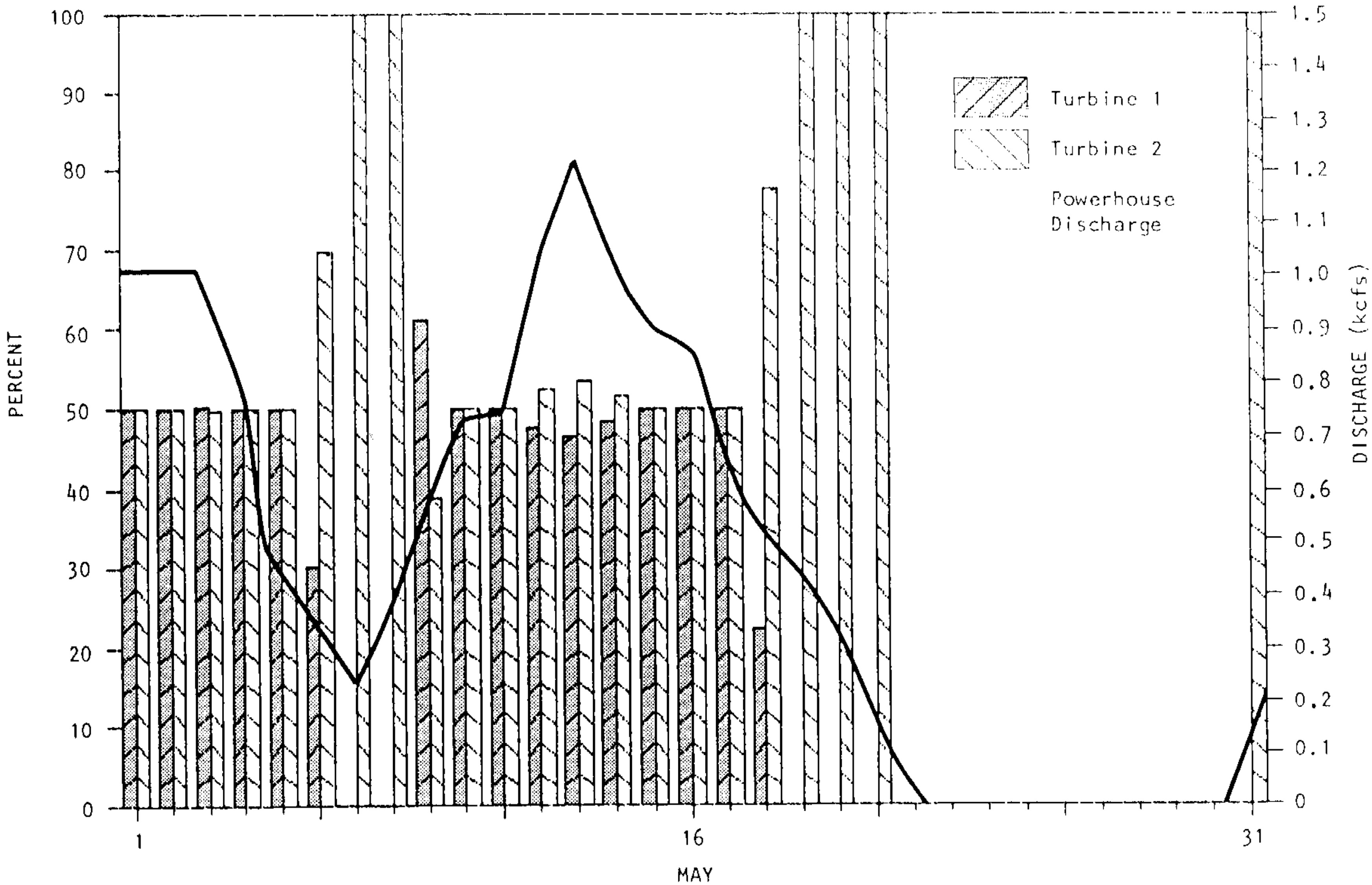


Figure 14. Daily mean discharge contributions of Unit 1 and Unit 2 (percent), and total powerhouse discharge (kcfs) for the Jackson Project, May, 1987.

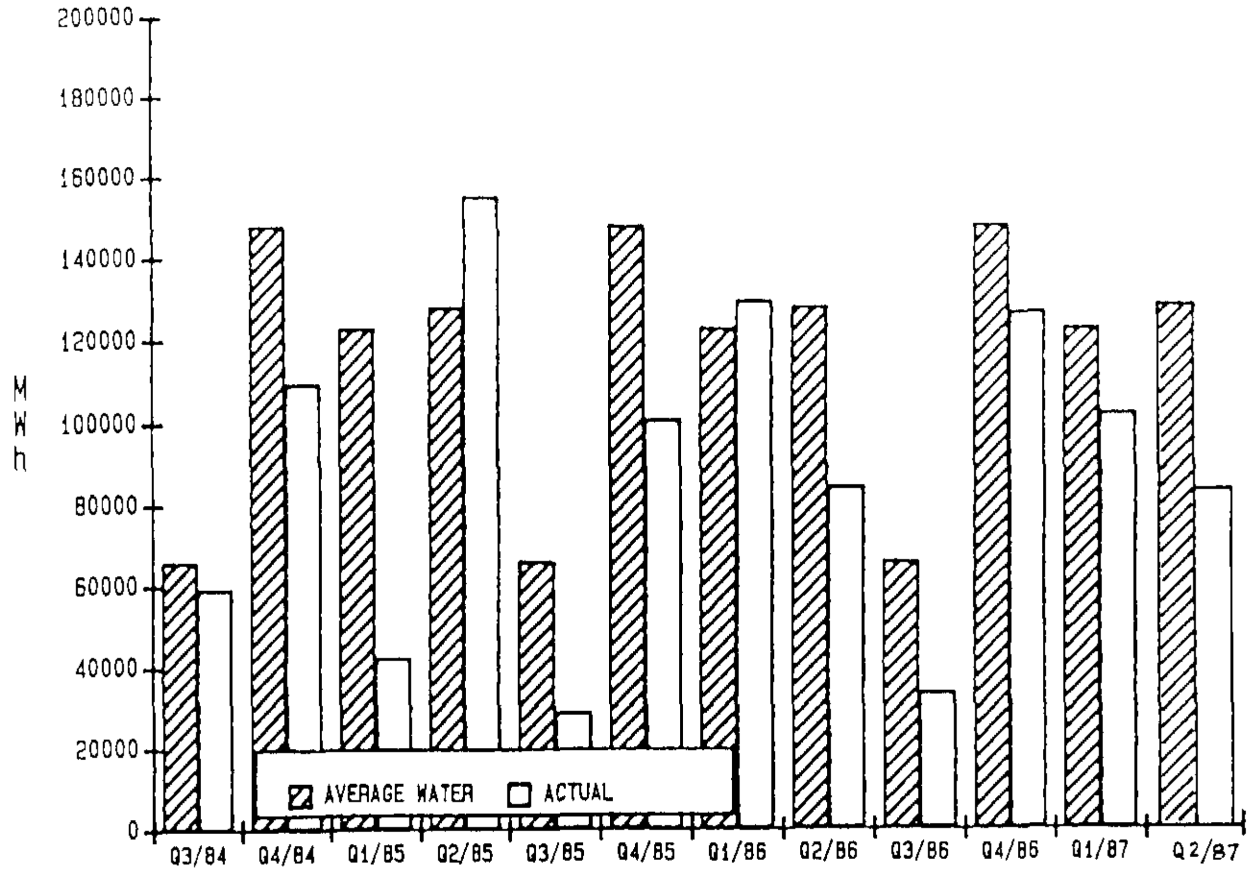


Figure 15. Actual Jackson Project power generation compared to expected generation at average water conditions.

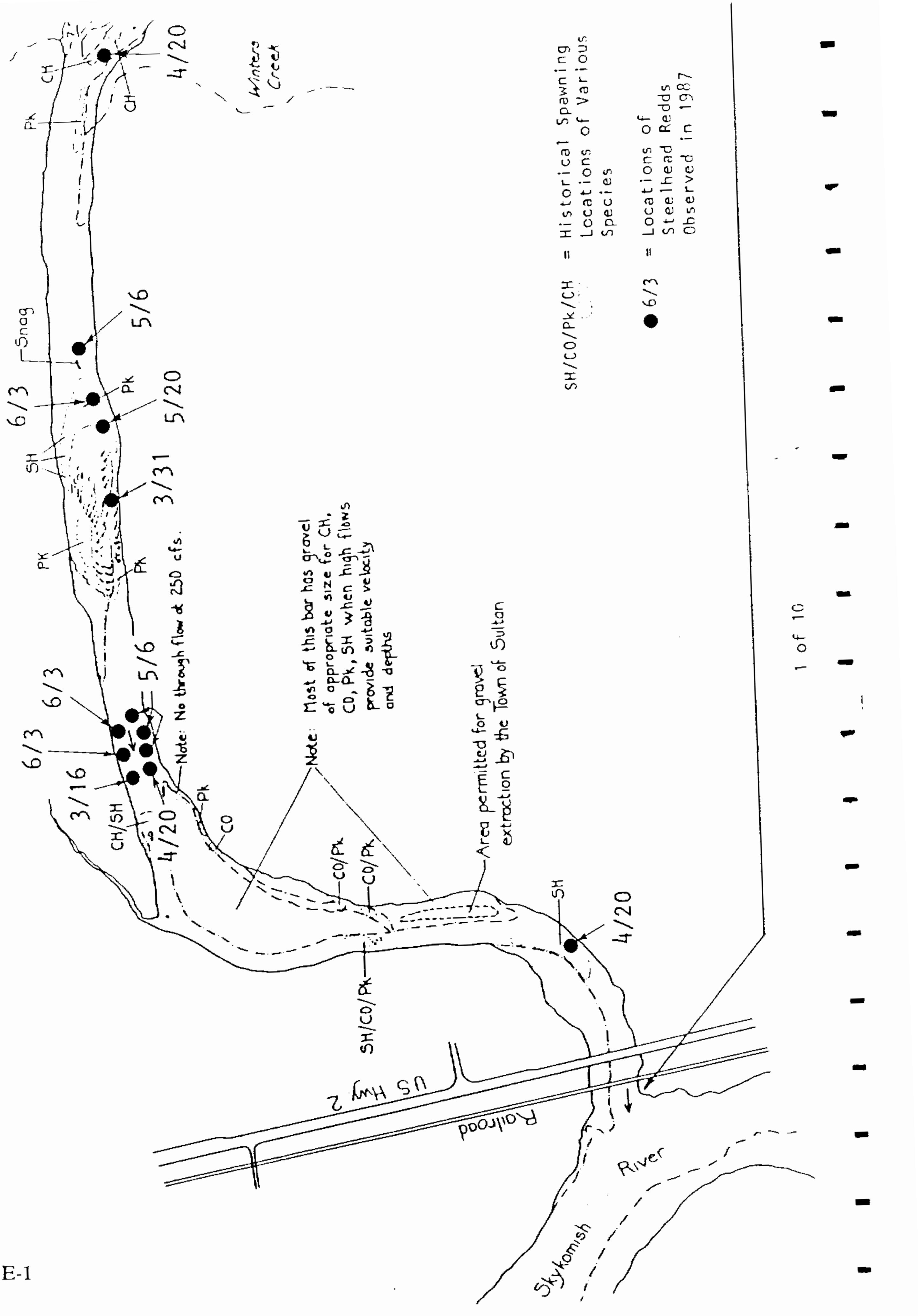
REFERENCES

Parametrix. 1987. Adult Fish Passage (Powerhouse Berm) Study. Final Project Report to Snohomish County PUD, submitted by Parametrix, Inc. Bellevue, WA.

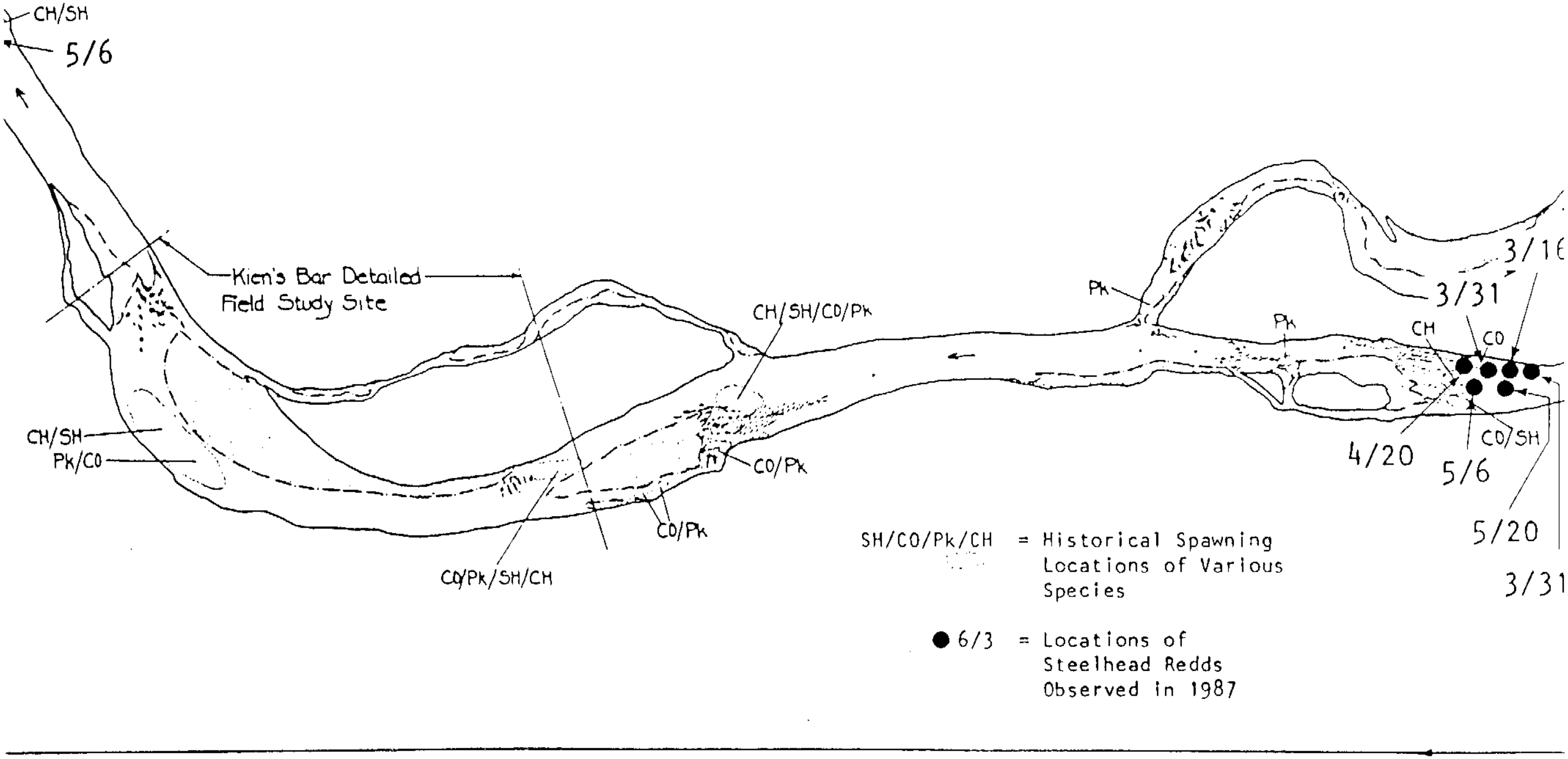
Washington Department of Game and Snohomish County PUD. 1982. Fish and Wildlife Resource Studies Sultan River Project Stage II Final Report. Washington Department of Game and Eicher Associates, Inc.

APPENDIX A

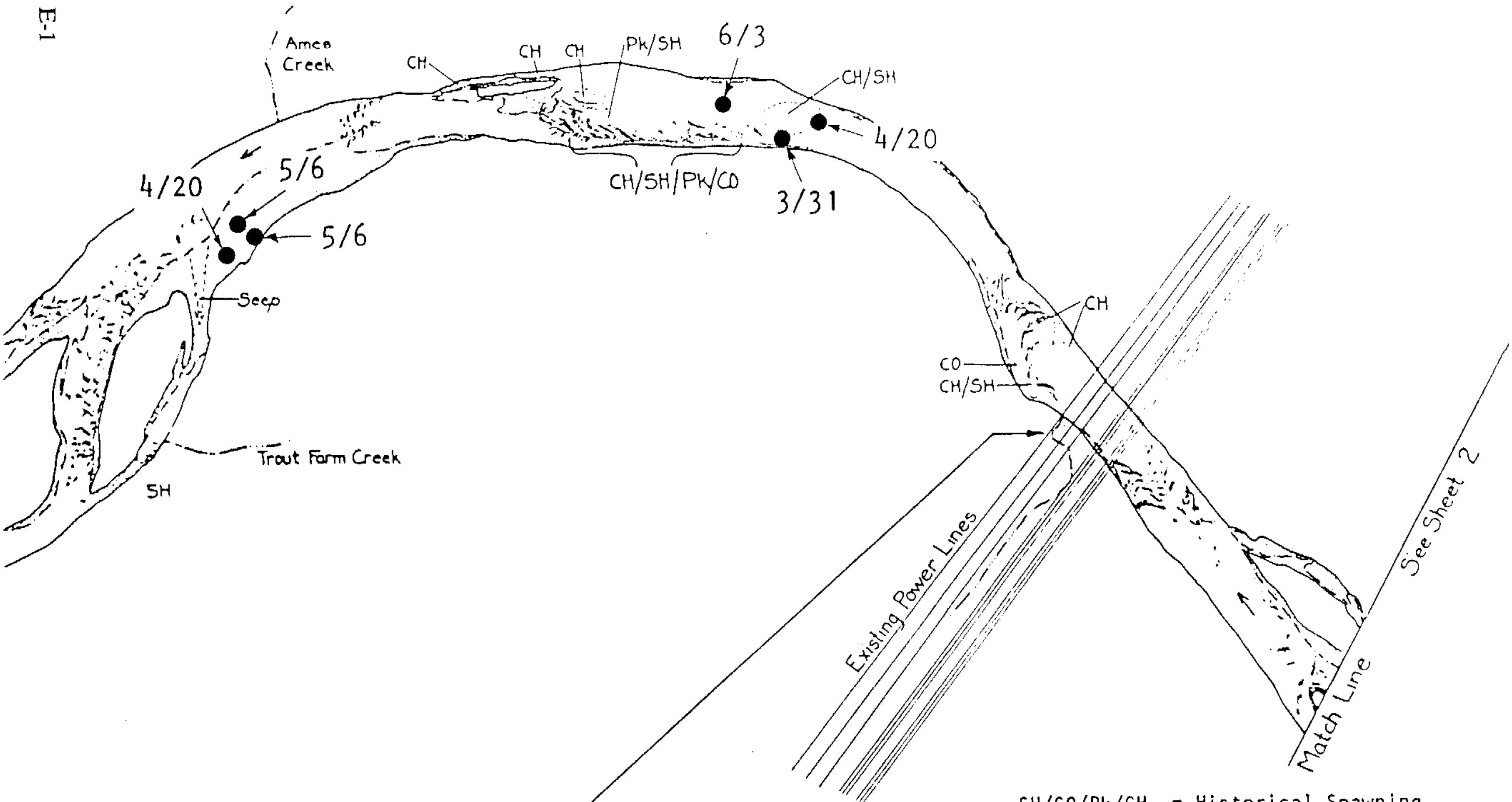
SUMMARY BASE MAP DEPICTING REDD LOCATIONS AND DATES OBSERVED



Winters Creek
4/20
CH
CH
Pk
Snag
5/6
6/3
Pk
5/20
SH
3/31
Pk
Pk
Note: No through flow at 250 cfs.
Most of this bar has gravel of appropriate size for CH, CO, Pk, SH when high flows provide suitable velocity and depths
5/6
6/3
6/3
3/16
CH/SH
4/20
Note:
Pk
CO
CO/Pk
CO/Pk
Area permitted for gravel extraction by the Town of Sultan
SH
4/20
SH/CO/Pk
US Hwy 2
Railroad
Skykomish
River
SH/CO/Pk/CH = Historical Spawning Locations of Various Species
6/3 = Locations of Steelhead Redds Observed in 1987
1 of 10



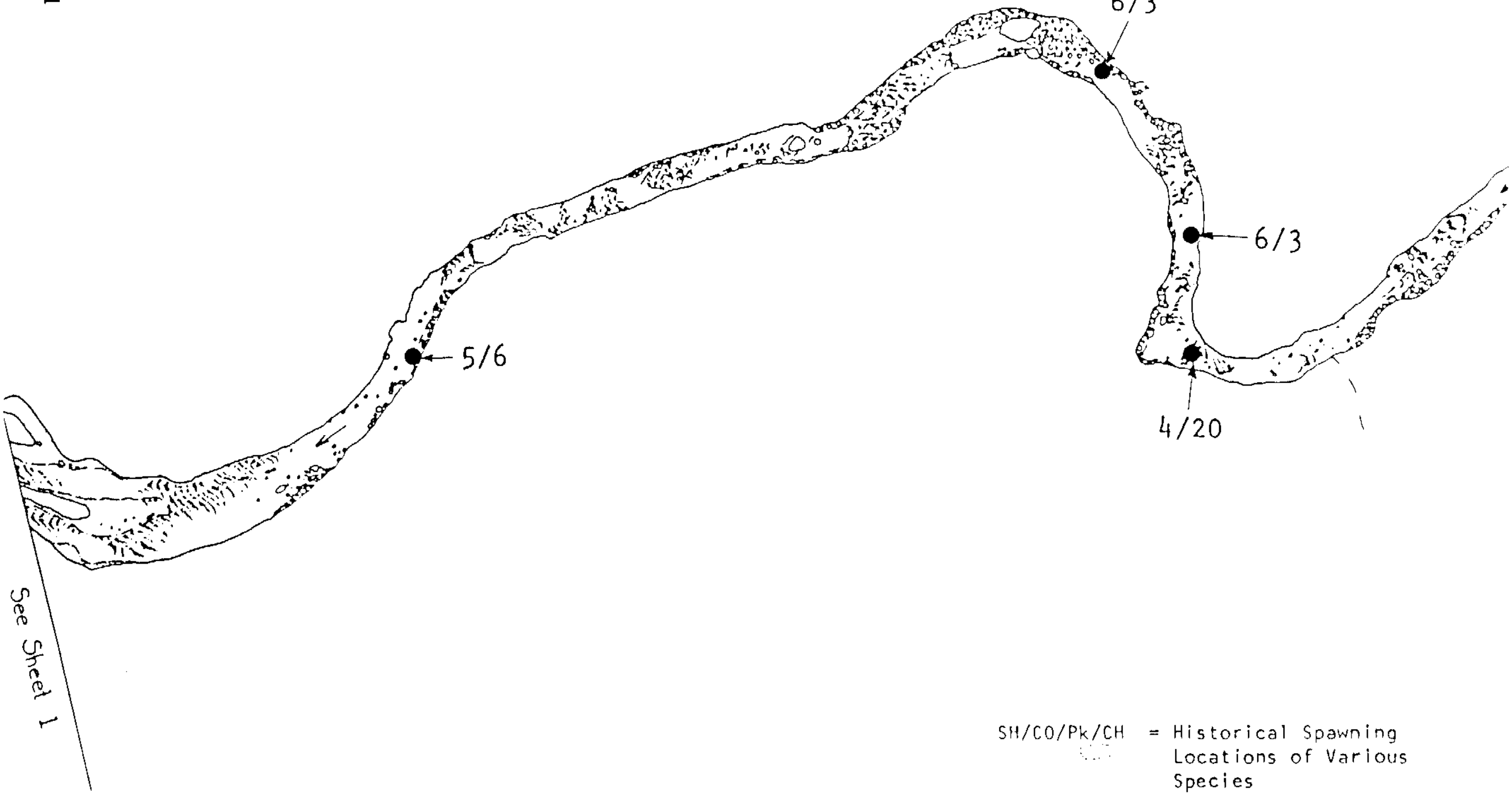
CH/SH
5/6
Kien's Bar Detailed
Field Study Site
CH/SH/CO/Pk
Pk
Pk
CH
CO
3/16
3/31
CH/SH
Pk/CO
CO/Pk
CO/Pk
CO/Pk/SH/CH
4/20
5/6
CO/SH
5/20
3/31
SH/CO/Pk/CH = Historical Spawning Locations of Various Species
6/3 = Locations of Steelhead Redds Observed in 1987



SH/CO/Pk/CH = Historical Spawning Locations of Various Species

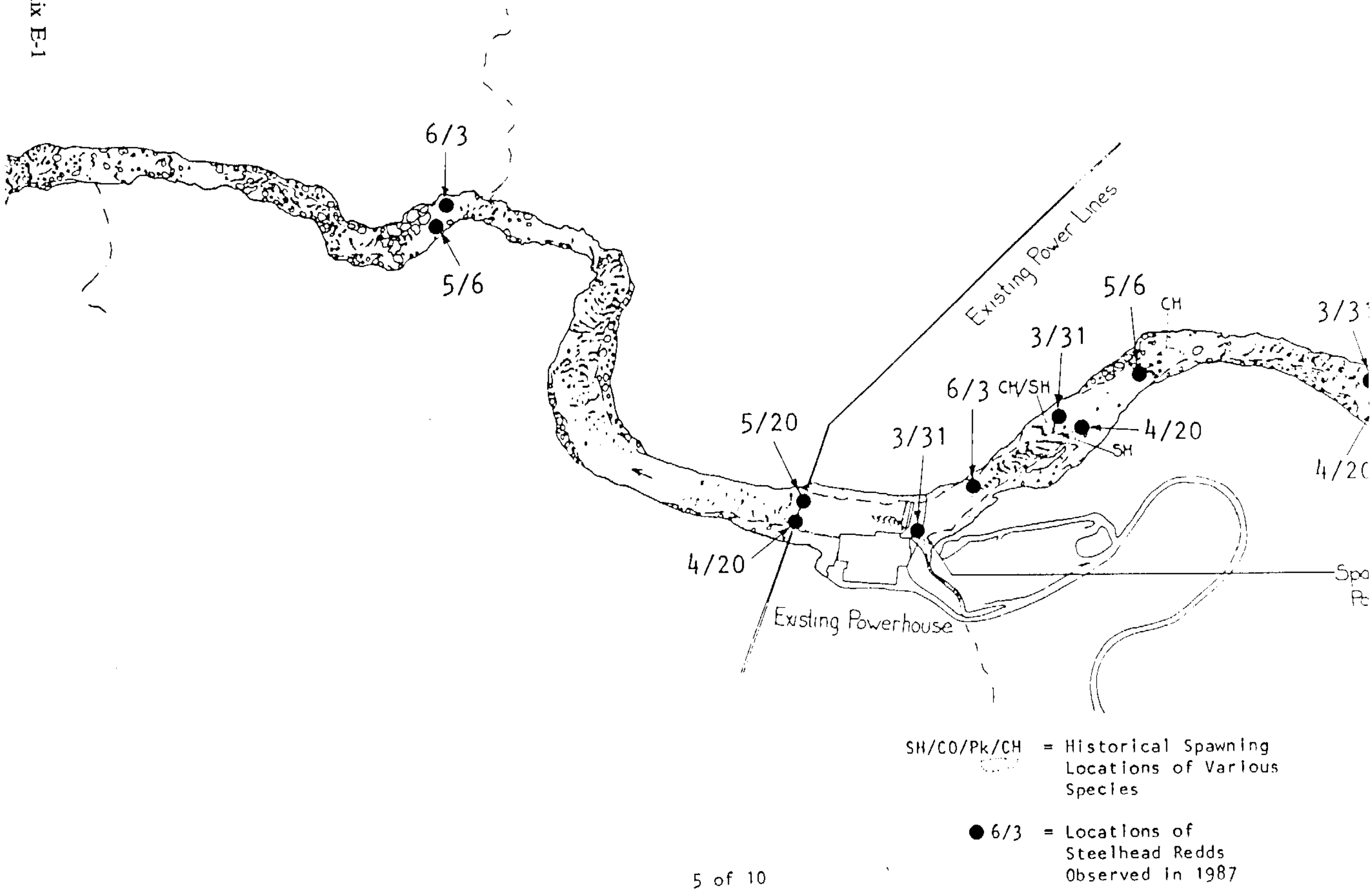
● 6/3 = Locations of Steelhead Redds Observed in 1987

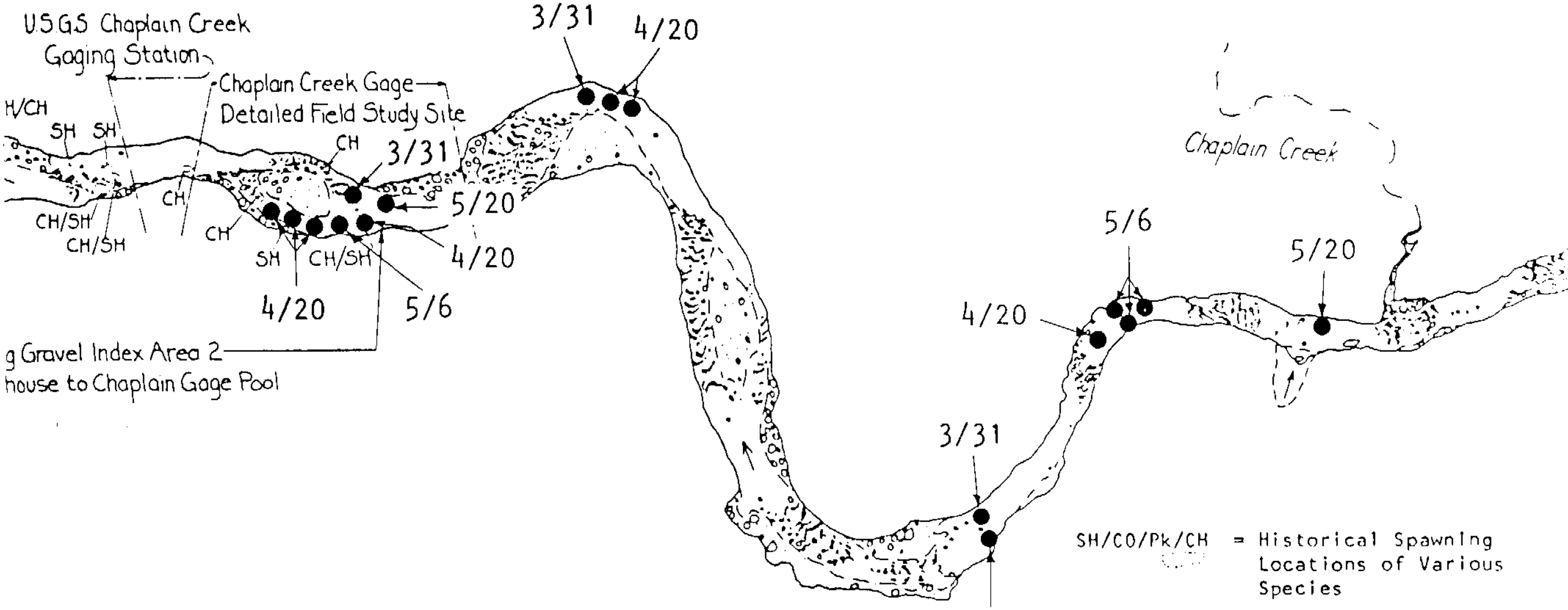
– Spawning Gravel Index Area 1
River Mouth to BPA Powerlines



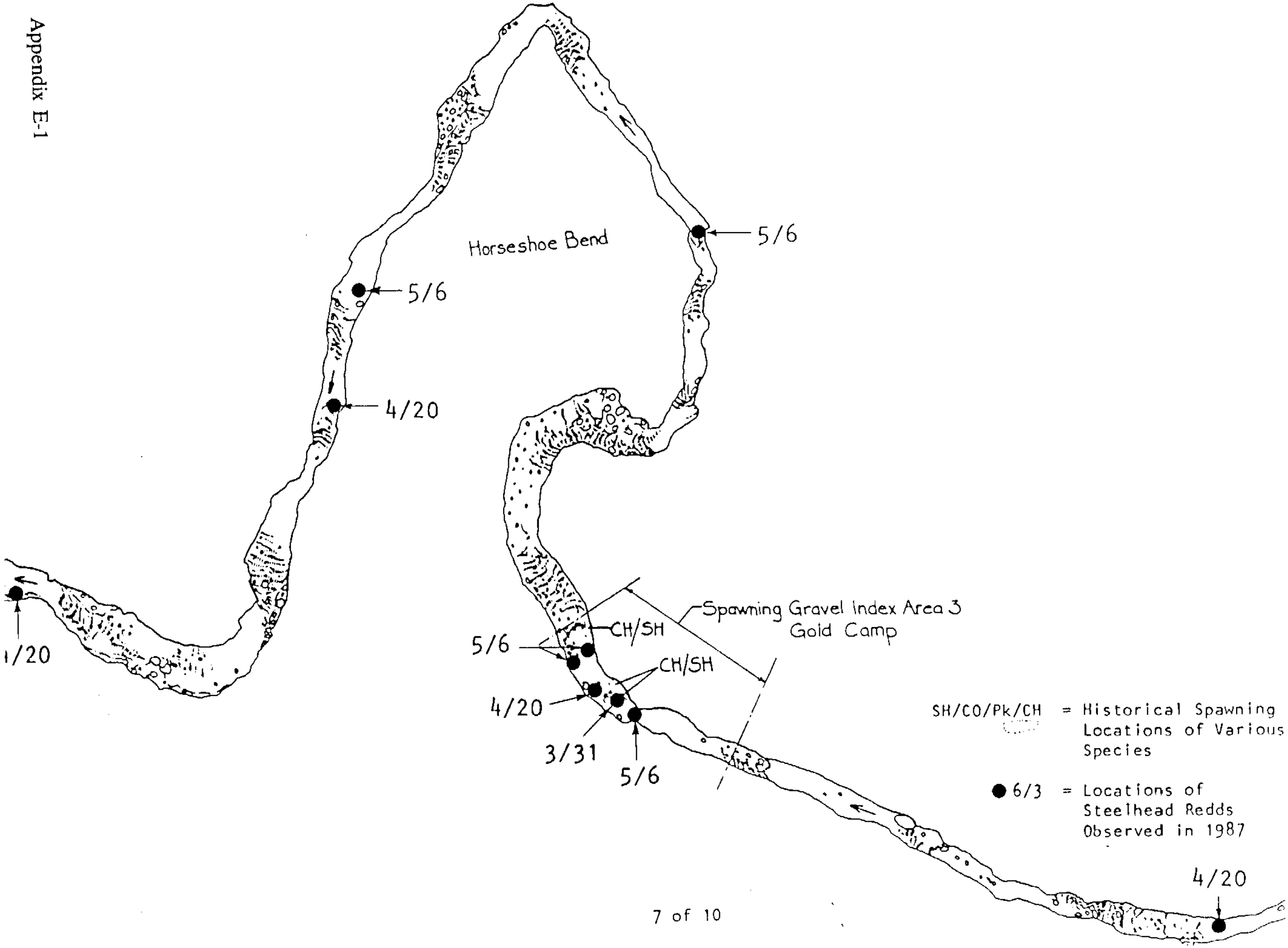
SH/CO/Pk/CH = Historical Spawning Locations of Various Species

● 6/3 = Locations of Steelhead Redds Observed in 1987


6/3
5/6
Existing Power Lines
5/6
CH
3/31
3/31
6/3
CH/SH
4/20
SH
4/20
5/20
3/31
4/20
Existing Powerhouse
SH/CO/Pk/CH = Historical Spawning Locations of Various Species
6/3 = Locations of Steelhead Redds Observed in 1987


U.S.G.S Chaplain Creek
Gaging Station
Chaplain Creek Gage
Detailed Field Study Site
H/CH
SH
SH
CH
CH/SH
CH/SH
CH
CH
3/31
5/20
SH
CH/SH
4/20
4/20
5/6
g Gravel Index Area 2
house to Chaplain Gage Pool
3/31
4/20
Chaplain Creek
5/6
5/20
4/20
3/31
4/20
SH/CO/Pk/CH = Historical Spawning Locations of Various Species
6/3 = Locations of Steelhead Redds Observed in 1987

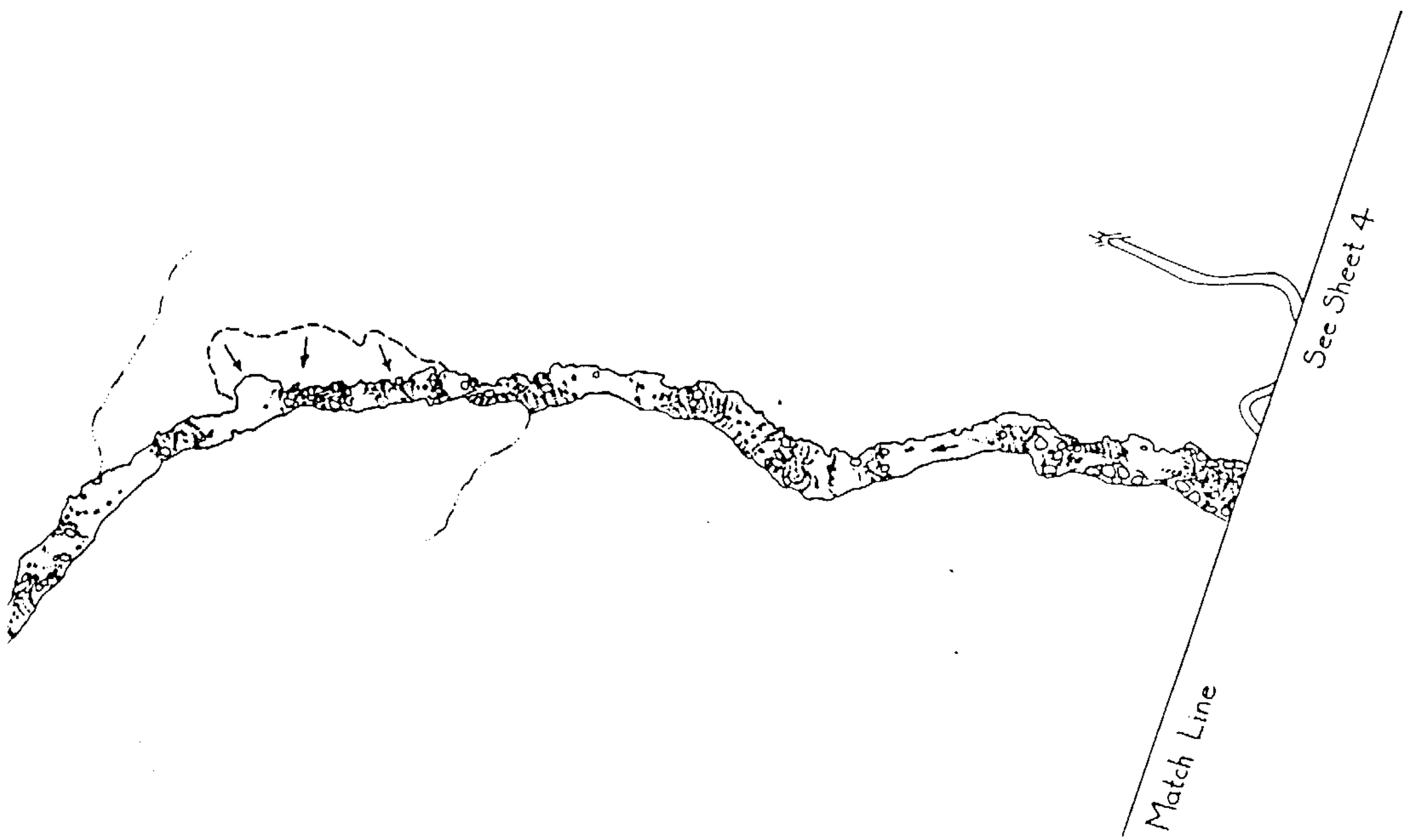
Appendix E-1



Horseshoe Bend
5/6
5/6
4/20
1/20
Spawning Gravel Index Area 3
Gold Camp
CH/SH
CH/SH
5/6
4/20
3/31
5/6
4/20
SH/CO/Pk/CH = Historical Spawning Locations of Various Species
6/3 = Locations of Steelhead Redds Observed in 1987

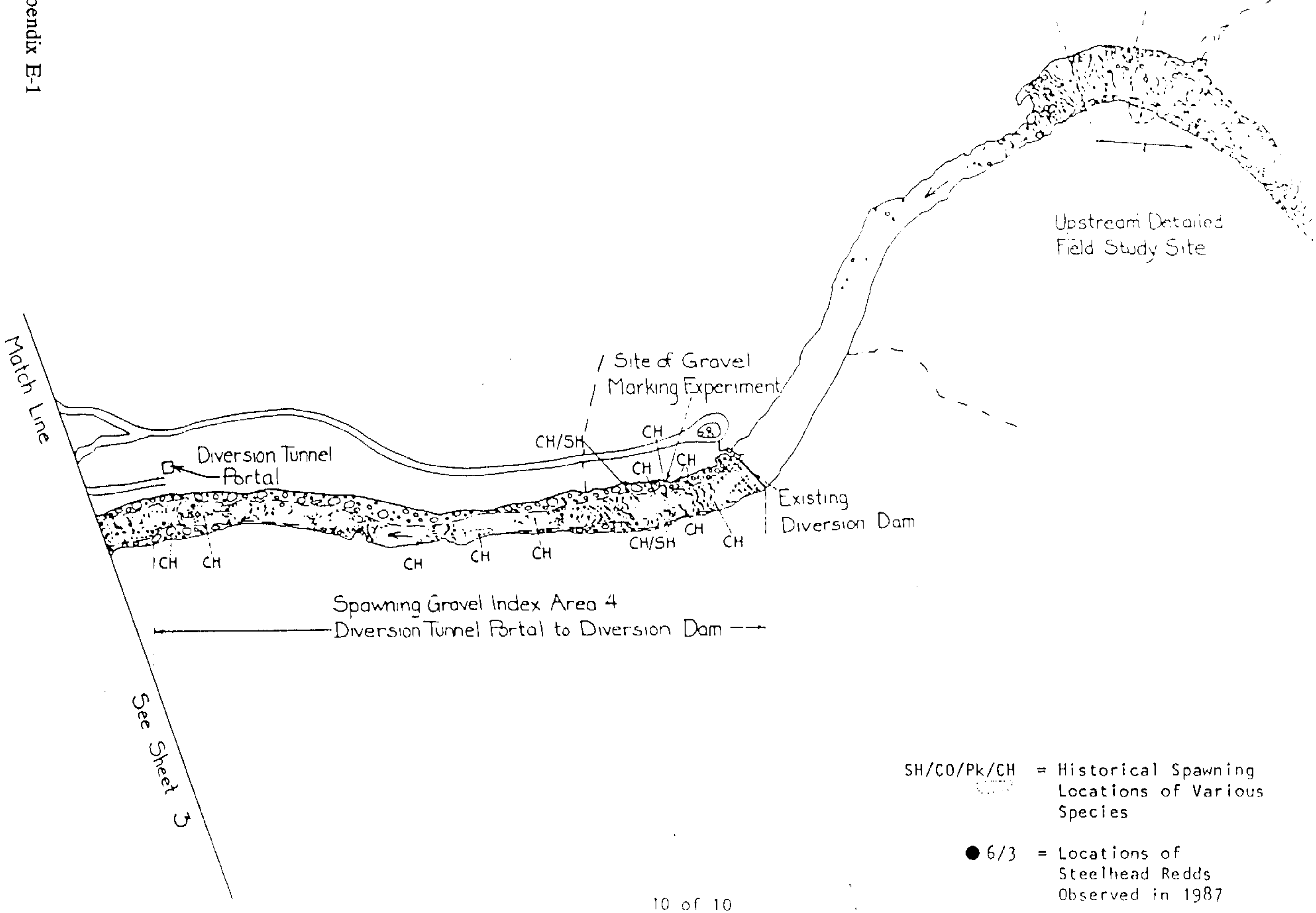
8 of 10

Appendix E-1



SH/CO/Pk/CH = Historical Spawning Locations of Various Species

● 6/3 = Locations of Steelhead Redds Observed in 1987


Upstream Detailed
Field Study Site
Site of Gravel
Marking Experiment
Existing
Diversion Dam
Diversion Tunnel
Portal
CH/SH
CH
CH
CH
CH
CH/SH
CH
CH
CH
CH
CH
CH
CH
Match Line
See Sheet 3
Spawning Gravel Index Area 4
Diversion Tunnel Portal to Diversion Dam
SH/CO/Pk/CH = Historical Spawning Locations of Various Species
6/3 = Locations of Steelhead Redds Observed in 1987

APPENDIX E-2

Final report on the 1989 winter-run steelhead surveys–
Sultan River, Washington.

FINAL REPORT ON

1989 WINTER-RUN STEELHEAD SPAWNING SURVEY

Prepared by

Parametrix, Inc
Bob Sullivan
Tom Schadt

13020 Northup Way
Bellevue, WA 98005

Prepared For

Public Utility District No. 1 of Snohomish County
Roy Metzgar, Project Leader
P.O. Box 1107
Everett, WA 98206

August 9, 1989

Appendix E-2

Table of Contents

List of Tables

List of Figures

INTRODUCTION

BACKGROUND

Completion of the Henry M. Jackson Hydroelectric Project on the Sultan River in north-western Washington State (Figure 1) occurred in 1984. The facility is owned and operated by the Public Utility District No. 1 of Snohomish County (District). The project consists of a tunnel and pipeline linking Culmback Dam at river mile (RM) 16.5 to the powerhouse (RM 4.5). Water passing through two of the four turbines is diverted up to Lake Chaplain while water through the other two turbines flows directly into the river. Water sent to Lake Chaplain can be transported back to the Sultan River via another tunnel/pipeline system to provide required in-stream flows, when needed to supplement natural flows, for fish spawning and rearing. This water enters the river upstream, at the Everett Diversion Dam, located at river mile (RM) 9.7. The Diversion dam is the upstream limit to fish migration and spawning.

At the upstream end of the powerhouse is a low-head dam (berm) which creates attraction flows for fish migrating upstream past the powerhouse (Figure 2). The fish passage berm was part of the mitigative measures required by the fish management agencies. The agencies recognized that certain flow regimes may create passage problems for adult fish. The berm is intended to alleviate potential problems. To evaluate the success of this mitigation measure the District was required to conduct studies, including spawning ground surveys. The Sultan River and its tributaries are used for spawning and rearing by chum, pink, coho, chinook, and steelhead salmon, and sea-run cutthroat trout, and Dolly Vardon. However, the area above the powerhouse is used primarily by chinook and steelhead making them the species of concern.

A study to determine if the passageway successfully facilitated migration past the powerhouse began in 1984. This initial study evaluated the effects on fish passage by comparing the pre-project and post-project spawning distributions. Earlier 1979 and 1980 surveys provide the pre-project data used for these comparisons. The complete results of that study and more explanatory background information are presented in Adult Fish Passage (Powerhouse Berm) Study (1987) prepared for the District by Parametrix, Inc.

The results of the steelhead spawning ground surveys conducted in 1985 as part of the initial study indicated that redd distribution was similar to pre-project years. However, the Washington Department of Game (now Wildlife) requested additional surveys because powerhouse discharge during the 1985 migration was only moderate. The agency believed that higher powerhouse discharge might be more difficult for fish passage than lower flows. To address this concern, the District agreed to conduct three more years of steelhead spawning ground surveys through 1990, if necessary.

The first of these additional surveys was conducted in 1987. The 1987 survey results indicated a slightly higher distribution of redds (50%) in the area upstream from the powerhouse than in pre-project years. For the two years of available pre-project survey data (1979 and 1980) the percentage of total redds observed above the powerhouse was 29 and 30 percent, respectively (Washington Department on Game and Snohomish County PUD 1982). The initial post-project study found 30% of the total redds upstream from the powerhouse (Parametrix 1987).

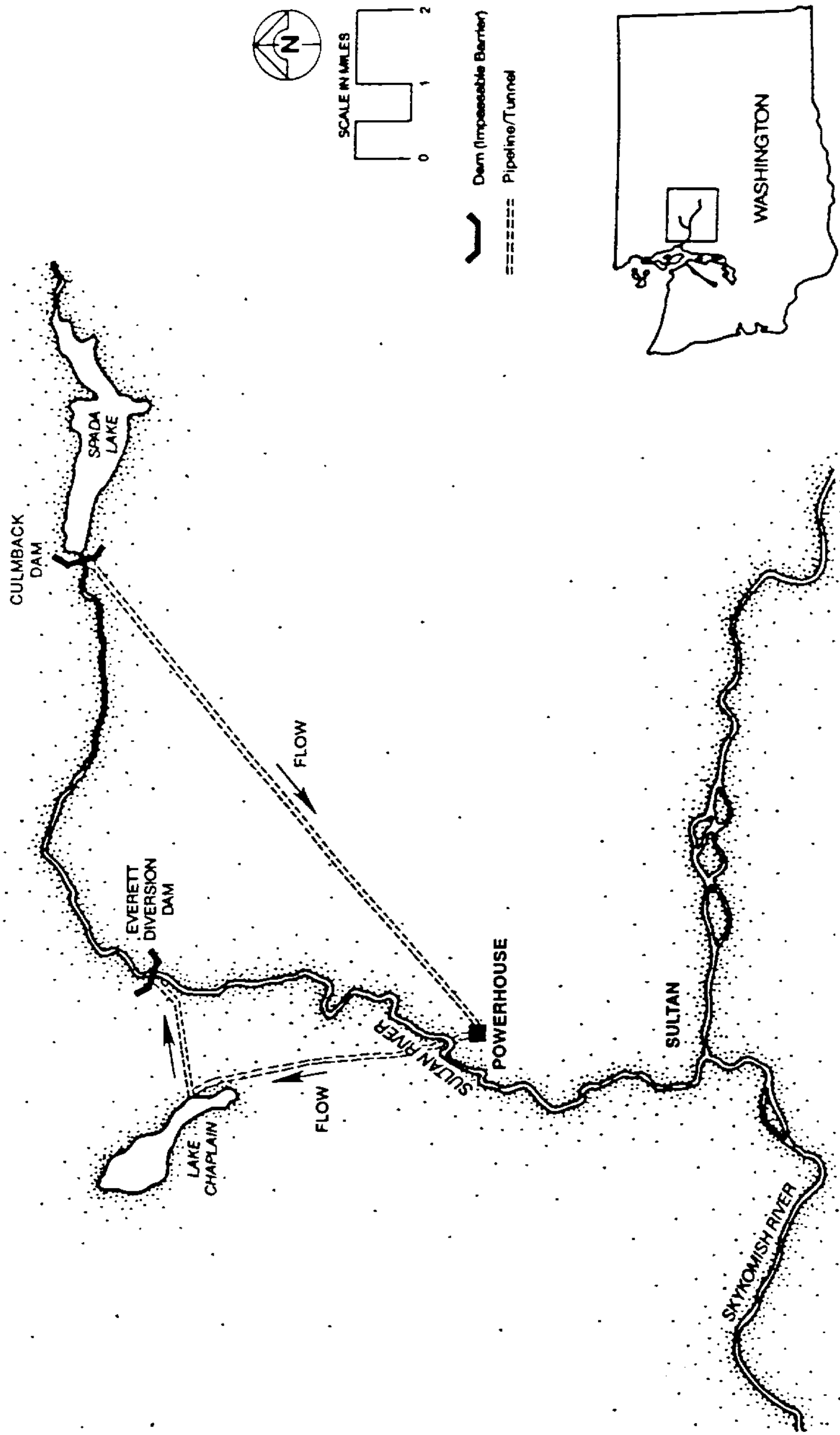


Figure 1.
Jackson Project vicinity map

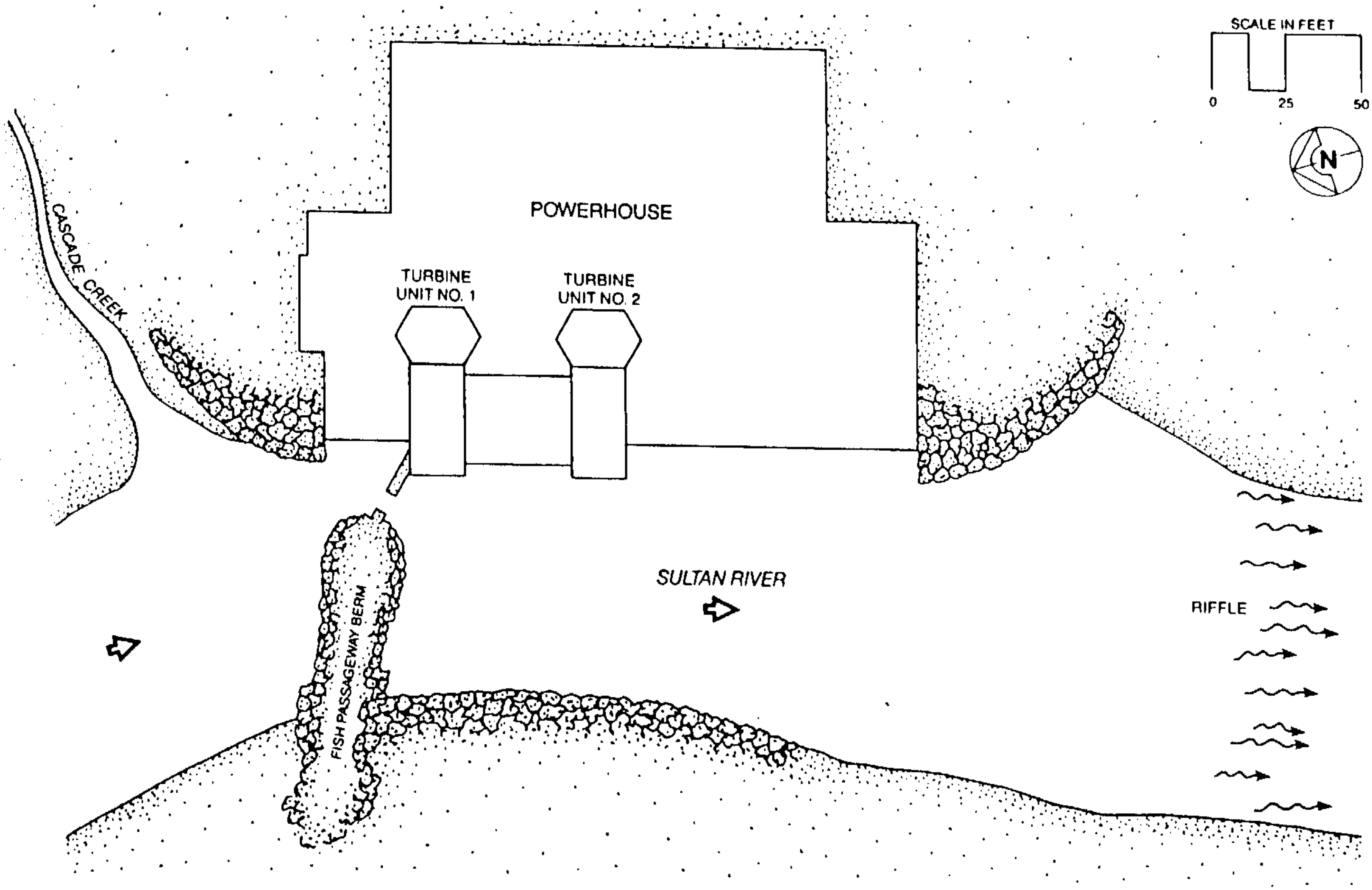


Figure 2. Powerhouse and fish passageway berm.

The second year in the series of additional spawner surveys was to have been 1988. However, low river flows during the migration period were projected because of drought conditions. Since the purpose of the additional surveys is to evaluate spawning distributions during a high flow year, the District and the agencies agreed to postpone the second year of surveys. Therefore, the 1989 survey became the second year in the series of three and is the subject of this report.

METHODS

Seven surveys were conducted during the 1989 spawning season. Survey dates were March 8 and 23; April 11 and 26; May 11; June 2 and 23. Originally eight surveys were proposed, with three to occur in March, two in April and May, and one in June. However, high flows in early March delayed the first survey by a week and poor visibility in May precluded a survey. The surveys consisted of observations from a helicopter over a length of the Sultan River from the confluence with the Skykomish River (RM 0) to the Diversion Dam (RM 9.7). Observers noted all redds visible during each flight and plotted the number and location on maps of the river channel (Appendix A).

In addition to the redd count maps and location notes made during each flight, redd life information was also collected (i.e., the number of days that a redd remained distinctly visible). Redd life was determined by periodically marking artificial redds, or newly created natural redds (fish actively digging), with colored rocks and observing their detectability during subsequent surveys.

The purpose of collecting redd life data is to eliminate double counts of the same redds seen on consecutive surveys. It also provides an indication of the overall accuracy of the seasonal counts. In other words, if an artificial redd was not visible from one survey to the next it may be reasonable to expect that some new, natural redds (dug after the previous survey) might also be non-detectable.

Artificial redd detectability was categorized as 100, 75, 50, 25 and 0% visible. When a redd was determined to be less than 50% visible due to scour or algae and silt build up, a new one was constructed and marked. In order to eliminate the bias created by the different flow and light conditions above and below the powerhouse, redds were marked in each reach. The redds were checked during each subsequent flight, as well as from the ground prior to the survey. The ground check provided a relative measurement, to access the viewing conditions for the flight. These redds were also checked between surveys, to insure that a redd of known life would be visible on the following flight.

RESULTS

The results of the 1989 steelhead surveys are summarized in Table 1. The table provides the number of redds observed above and below the powerhouse and combined for the entire survey. The total redd count columns represent the number of visible redds observed regardless of whether they had been counted on previous surveys. The "new" redd columns indicate the number of redds observed for the first time during the survey and is indicative of the run timing in the Sultan River.

Table 1. Summary of 1989 steelhead redd observation in the Sultan River.

Date	Entire Survey Length		Downstream of Powerhouse		Upstream of Powerhouse	
	Total Count	New Redds	Total Count	New Redds	Total Count	New Redds
March 8	0	0	0	0	0	0
March 23	7	7	0	0	7	7
April 11[1]	8	5	---	---	8	5
April 26	8	3	2	2	6	1
May 11	22	16	13	11	9	5
June 2	28	9	18	8	10	1
June 23	34	6	24	6	10	0
Totals	107	46	57	27	50	19

1/ Survey not conducted in the lower reach due to poor water conditions (low visibility).

A total of 46 redds were observed during the 1989 spawning season. This total is lower than the other two post-project years: 100 (1985) and 68 (1987). Redd distribution relative to the powerhouse was 27 (59%) downstream and 19 (41%) upstream. This distribution is mid-range of the previous Sultan River surveys (29 - 50% upstream of the powerhouse). The percentages of redds above and below the powerhouse for the five years that surveys were conducted are summarized in Table 2.

Table 2. Summary of percentages of steelhead redds observed upstream and downstream from the powerhouse.

Year	% Upstream	% Downstream
1979[a]	29	71
1980[a]	30	70
1985	30	70
1987	50	50
1989	41	59

a/ Pre-project year.

The peak in spawning activity (for the entire survey reach) occurred between April 26 and May 11, when 35% of the total number of redds were dug. However, the run timing to the upper reach appears to have been earlier than the lower reach. The mid-point of the run (when 50% of the redds had been dug) was about a month later in the lower reach. This difference may be somewhat exaggerated because the visibility in the lower section was not very good through the first four surveys. In addition the lower reach was not surveyed on April 11 due to extremely poor water conditions. Therefore, some lower river redds may have been dug earlier than when they were first observed.

Artificial redd data is summarized in Table 3. A total of six artificial redds were built during the season (three in each reach). The average redd life (duration of visibility) was 30 days above the powerhouse and 45 days below. The average life of the first three redds built (1 below and 2 above) was 22.7 days while the last three redds were visible for more than 52 days. The exact average can not be calculated for the last three redds since they were still visible on the last survey.

Table 3. Redd life data for the 1989 winter steelhead run based on the visibility of artificial test redds dug in the reaches above and below the powerhouse.

Test Redd	Date Dug	Date Last Seen	# of Days Visible	Location Above/Below Powerhouse
1[a]	3/08	----	----	Below
1	3/23	4/26	34	Below
2	3/23	4/11	19	Above
3	4/11	4/26	15	Above
4	4/26	6/23	>57[b]	Above
5	4/26	6/23	>57[b]	Below
6	5/11	6/23	>43[b]	Below

a/ Redd was enlarged on 3/23.
b/ Still visible on last survey.

Natural redds were also tracked from survey to survey by comparing notes and map locations. Table 4 shows the average life of natural redds observed above and below the powerhouse in each of the surveys. The averages are biased on the low side, for redds detected late in the season because the final survey date is used as the zero visibility point. Since larger numbers of fish spawned in the lower reach during the latter part of the season, those numbers are potentially the most biased.

On the Sultan River, where we can map specific redd locations, we have found the natural redd life data is more accurate in the process of correcting total survey redd counts. The relatively low number of redds and accurate river channel base maps makes this possible. On other river systems where spawning densities are higher, artificial redd life is the only means of correcting total counts. Therefore, natural redd life data were used instead of the artificial redd information to correct the Sultan River survey counts. The artificial redd data was used in a more general fashion to determine the overall quality of the seasonal counts.

Table 4. Estimated redd life (duration of visibility) of natural redds observed above and below the powerhouse.

Date Observed	# of New Redds Below Powerhouse	Mean # of Days Visible	# of New Redds Above Powerhouse	Mean # of Days Visible
3/23	0	--	7	45.3
4/11	---	--	5	56.6
4/26	2	36.5	1	15.0
5/11	11	41.1	5	43.0
6/02	8	21.0	1	21.0
Average		33.0		44.8

The average daily river flow was moderate to low during the 1989 steelhead spawning season (Appendix B). However, the contribution to these flows from the powerhouse was generally greater than 50% for April, May and June (Figure 3). The powerhouse contribution was below 50% primarily during the first two weeks in March. Total river flows below the powerhouse averaged less than 1.5 kcfs for all but 5 days (all in April) of the season and below 1 kcfs for most of March (except 2 days) and all of May and June. However, in April the flows were above one kcfs for 21 of the 30 days.

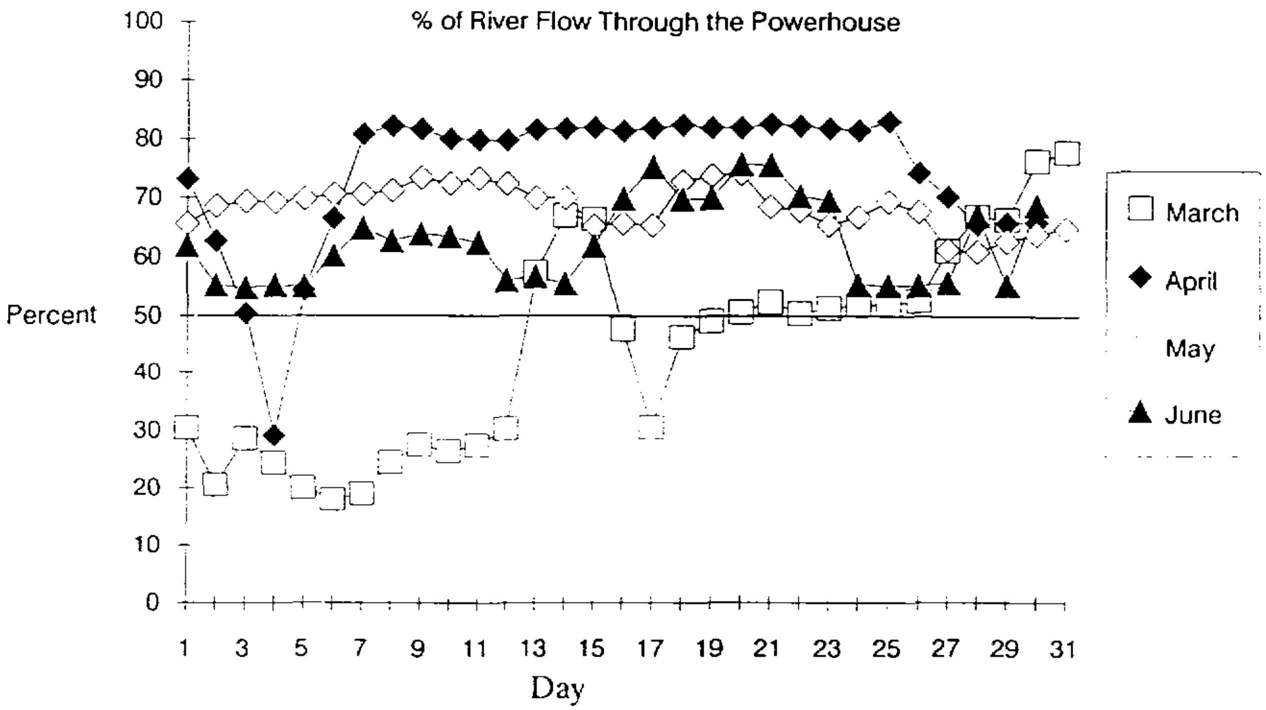


Figure 3. Proportion of the total Sultan River flows contributed by the powerhouse during the steelhead spawning season.

DISCUSSION

The post-project years have shown the same or higher proportions of redds above the powerhouse, as the pre-project distributions. The pre-project distribution is based on the 1979 and 1980 surveys which showed ≈30% of the redds above the powerhouse. Post-project spawning usage in the upper reach indicates that the project operation in conjunction with the berm has not created a passage problem for winter-run steelhead.

The early season redds had shorter periods of visibility (redd life) than those built later in the season because of higher flows in March and April (Figure 4). The higher flows and shorter redd life, particularly in April, may have resulted in the scouring of some natural redds before they were observed. Since the upper reach is steeper and narrower with a potentially higher scouring rate, it tends to have the shortest redd life. Therefore the possibility of missing redds due to scouring is greater above the powerhouse.

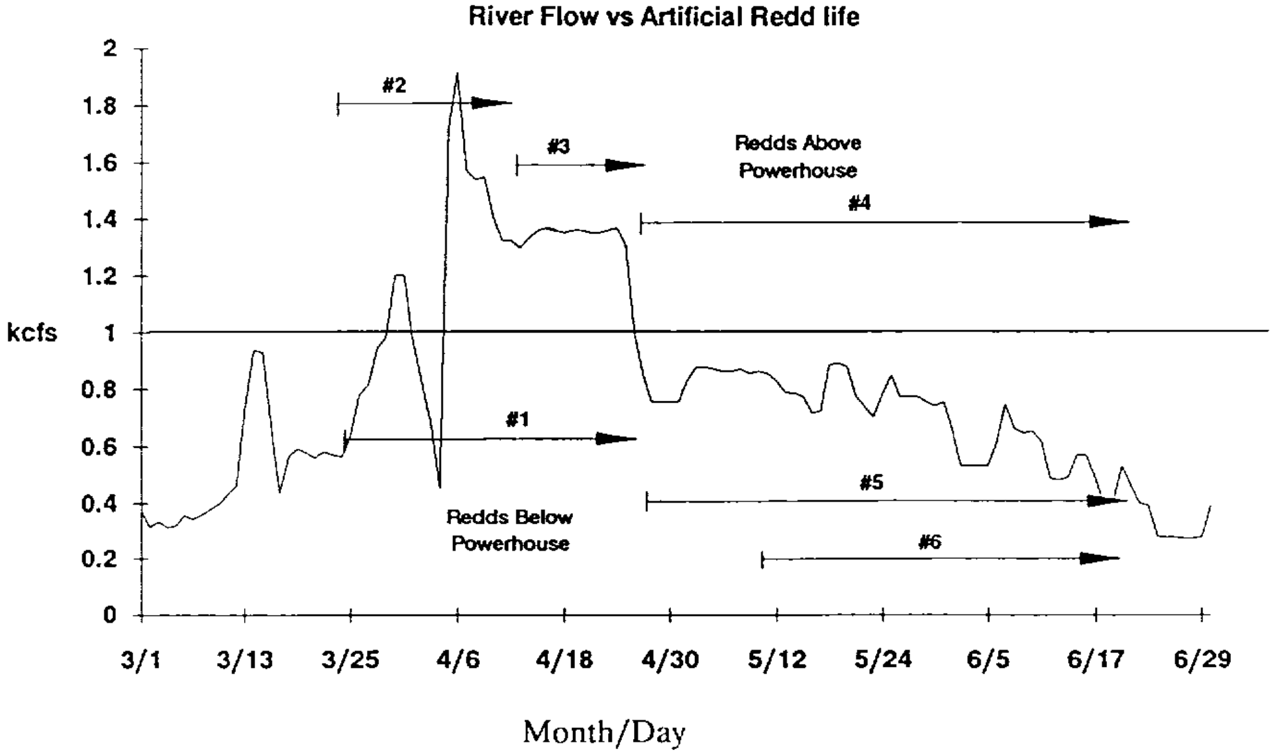


Figure 4. Average daily flows in the Sultan River as measured at the powerhouse and the duration of visibility of artificial test redds

The lower reach experienced greater turbidity than the upper reach during the 1989 steelhead season. This turbidity was the result of a number of landslides around Spada Lake early in the spring. Although there were also some slides in the river above the powerhouse, the river cleared up faster than the lake. Therefore, the introduction of turbid lake water into the river at the powerhouse resulted in poor visibility for the first four surveys below the powerhouse. This poor visibility may have resulted in the delayed detection of redds or the loss of detectability due to siltation.

Although both reaches had situations that could have resulted in missing redds, we believe that the error, if any, is only minor. This determination is based on the facts that the total river flows were relatively low through most of the season, and the artificial redd data indicated relatively long redd life. In addition, tracking the detectability of natural redds from survey to survey, indicated relatively long redd life throughout the season.

The natural redd information showed longer redd life above the powerhouse while the artificial redd data indicated the opposite. This apparent disparity is caused by the higher number of natural redds dug below the powerhouse late in the season. Since the last survey date is used as the zero visibility date, redds dug late in the season have abbreviated periods of visibility.

Power generation during the migrating season was slightly above average (152,888 MWh vs 138,000 MWh), based on the project's operating simulation model (Table 5). April was a "wet month" with generation more than twice the average while the other months were below average. April also had the highest flows during the survey period as well as the highest proportion of powerhouse flows (see Figures 3 and 4)

Table 5. Jackson project power generation (average and actual) during March - June.

Month	Average Generation (megawatt hours)	Actual Generation (megawatt hours)
March	31,000	24,854
April	26,000	57,960
May	44,000	43,360
June	37,000	26,714
Totals	138,000	152,888

Despite only moderate total flows in 1989, the contribution to the total flow by the powerhouse was equal to or greater than 50% for most days after the middle of March. This situation of higher flows from the powerhouse than the upper river was the reason for constructing the fish passage berm. The idea was to provide attraction flows by channeling the upper river water through a narrow slot thereby increasing the velocity. These higher velocities attract fish to the berm passageway, facilitating upstream migration. Therefore, the high powerhouse flows observed in 1989, especially in April, provided a good test for the effectiveness of the fish berm at attracting fish and aiding their upstream migration.

REFERENCES

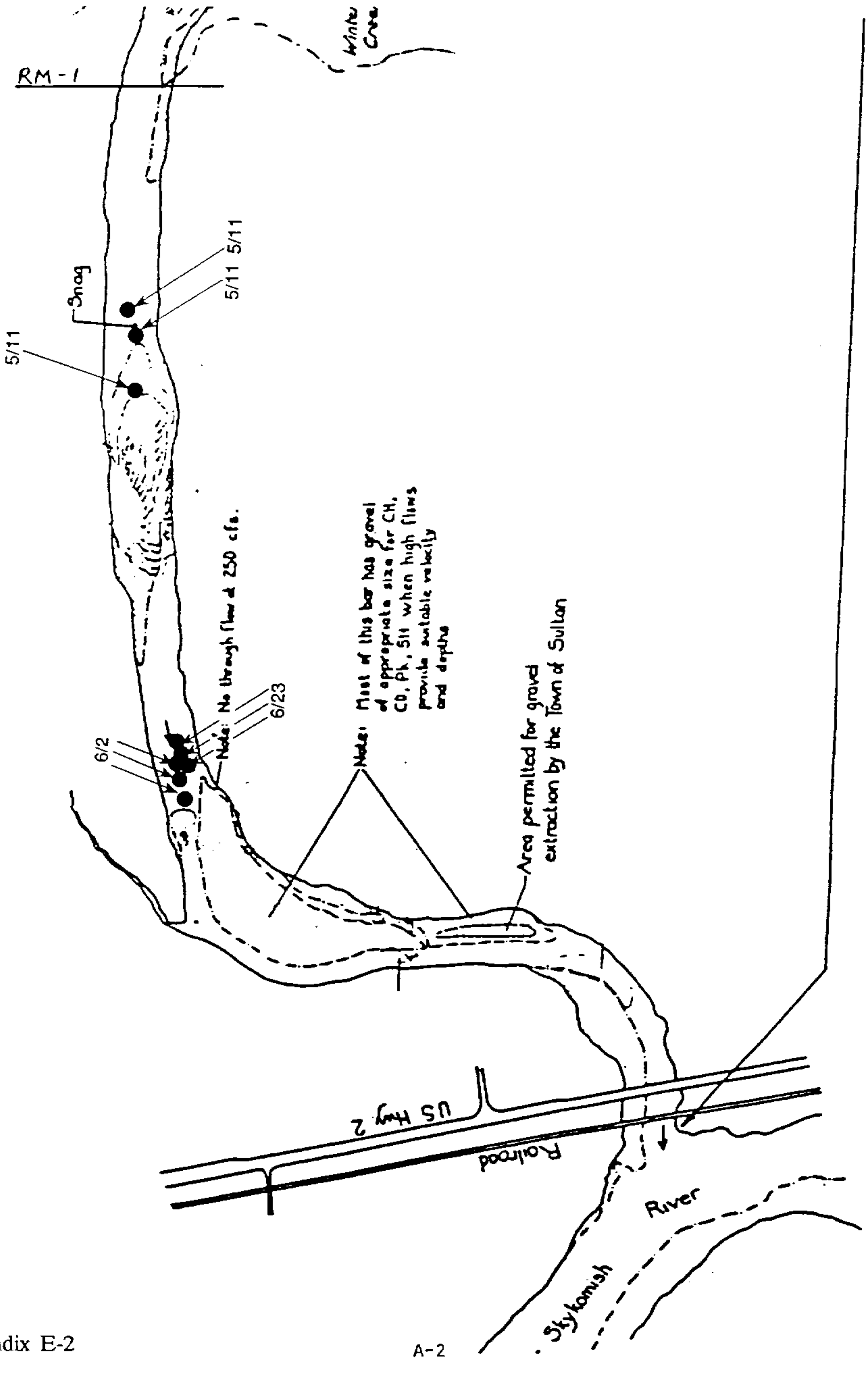
GeoEngineers. 1984. Phase I Report, River Gravel Quantity Study, Henry M. Jackson Hydroelectric Project (Sultan River Project). Report to Snohomish County PUD, submitted by GeoEngineers, Inc., Bellevue, WA.

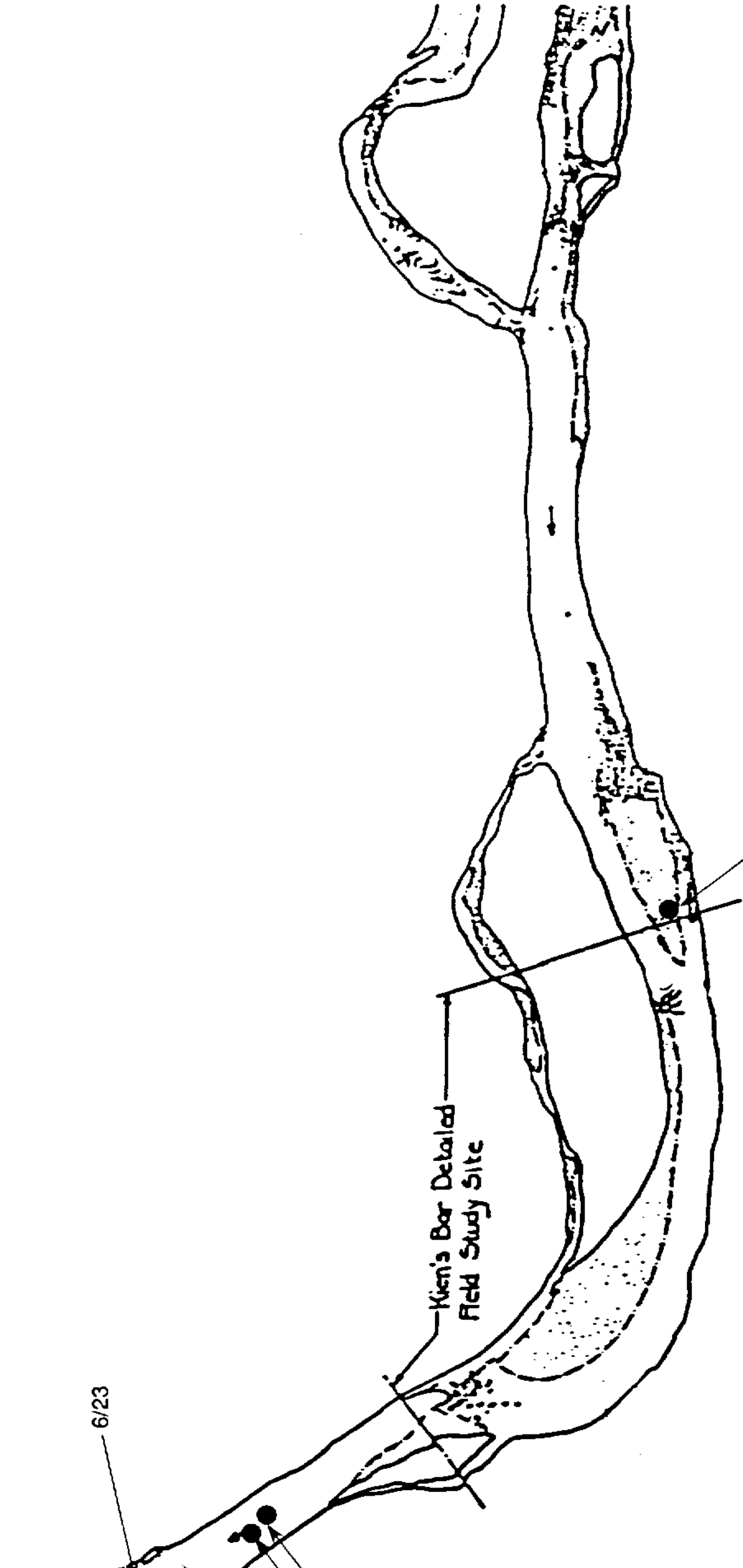
Parametrix. 1987. Adult Fish Passage (Powerhouse Berm) Study. Final Project Report to Snohomish County PUD, submitted by Parametrix, Inc., Bellevue, WA.

Parametrix. 1987. 1987 Winter Run Steelhead Trout Spawning Survey, Sultan River, Snohomish County, Washington. Final Project Report to Snohomish County PUD, submitted by Parametrix, Inc., Bellevue, WA.

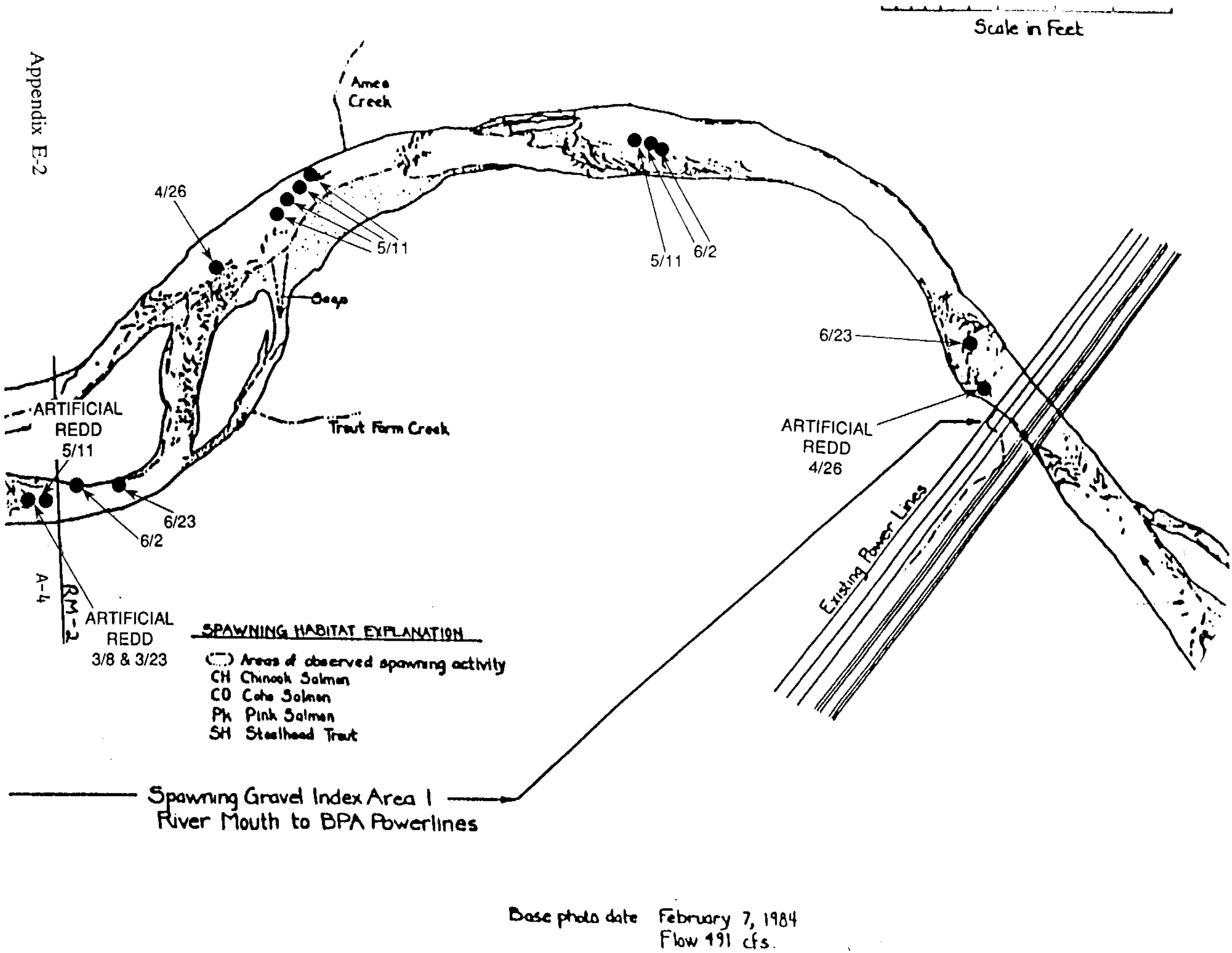
Washington Department of Game and Snohomish County PUD. 1982. Fish and Wildlife Resource Studies, Sultan River Project Stage II Final Report. Washington Department of Game and Eicher Associates, Inc.

Base map of the Sultan River channel used during spawning ground surveys, with the location and first observation date of all redds seen during the 1989 season. (Map source: GeoEngineers, 1984)

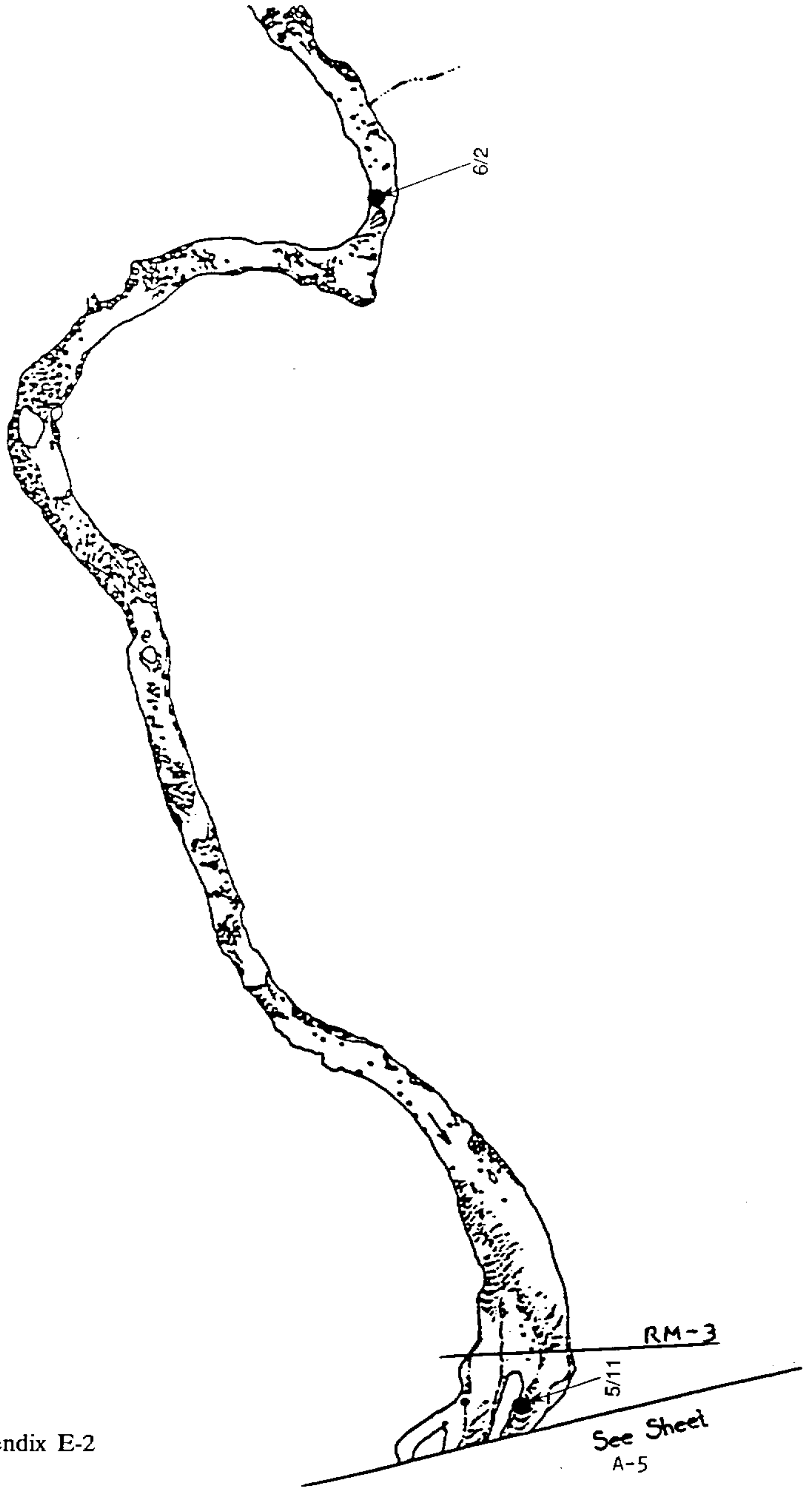

RM-1
Snag
5/11
5/11
5/11
6/2
6/23
Note: No through flow at 250 cfs.
Note: Most of this bar has gravel of appropriate size for CH, CO, PK, SH when high flows provide suitable velocity and depths
Area permitted for gravel extraction by the Town of Sultan
US Hwy 2
Railroad
Skykomish River



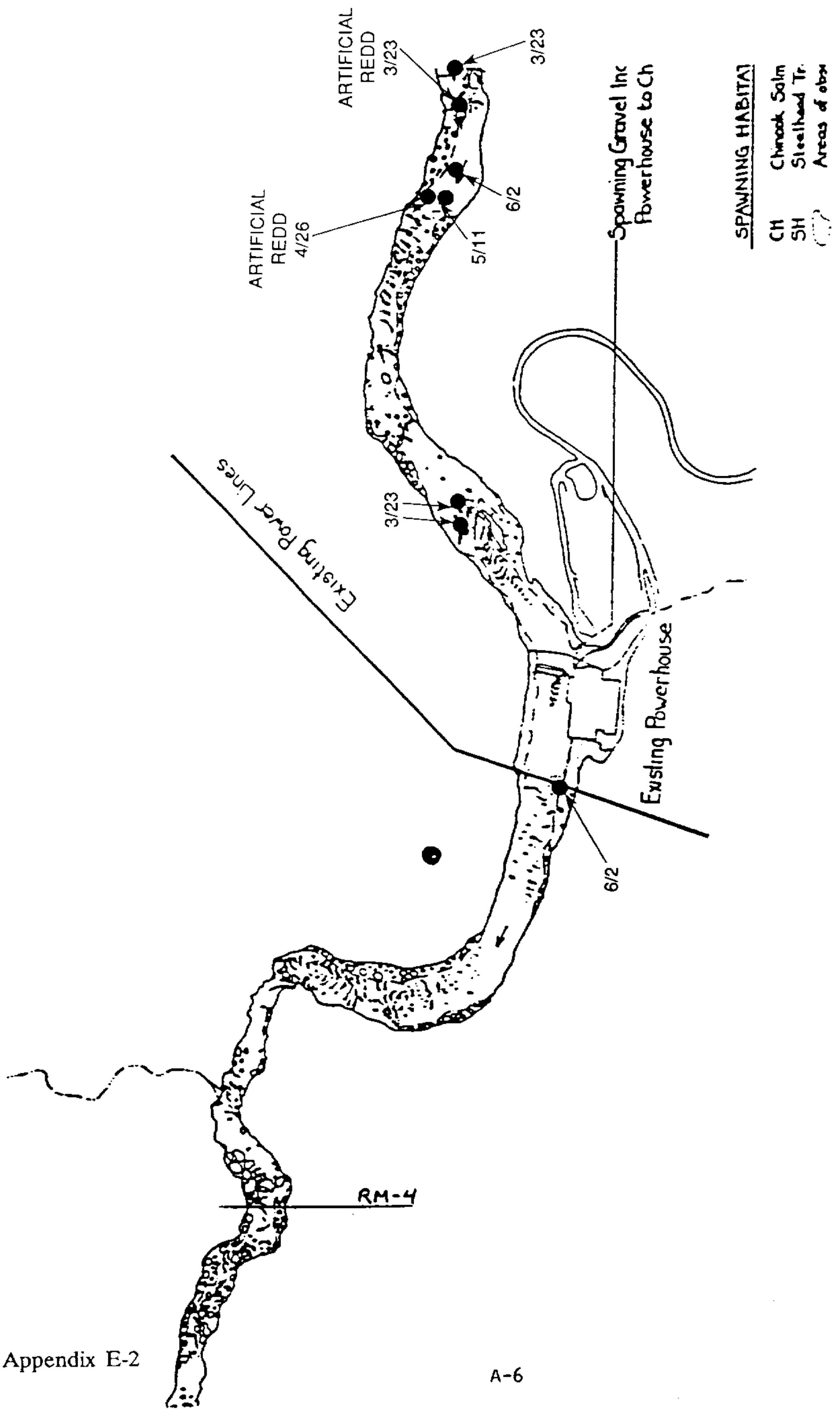
Appendix E-2

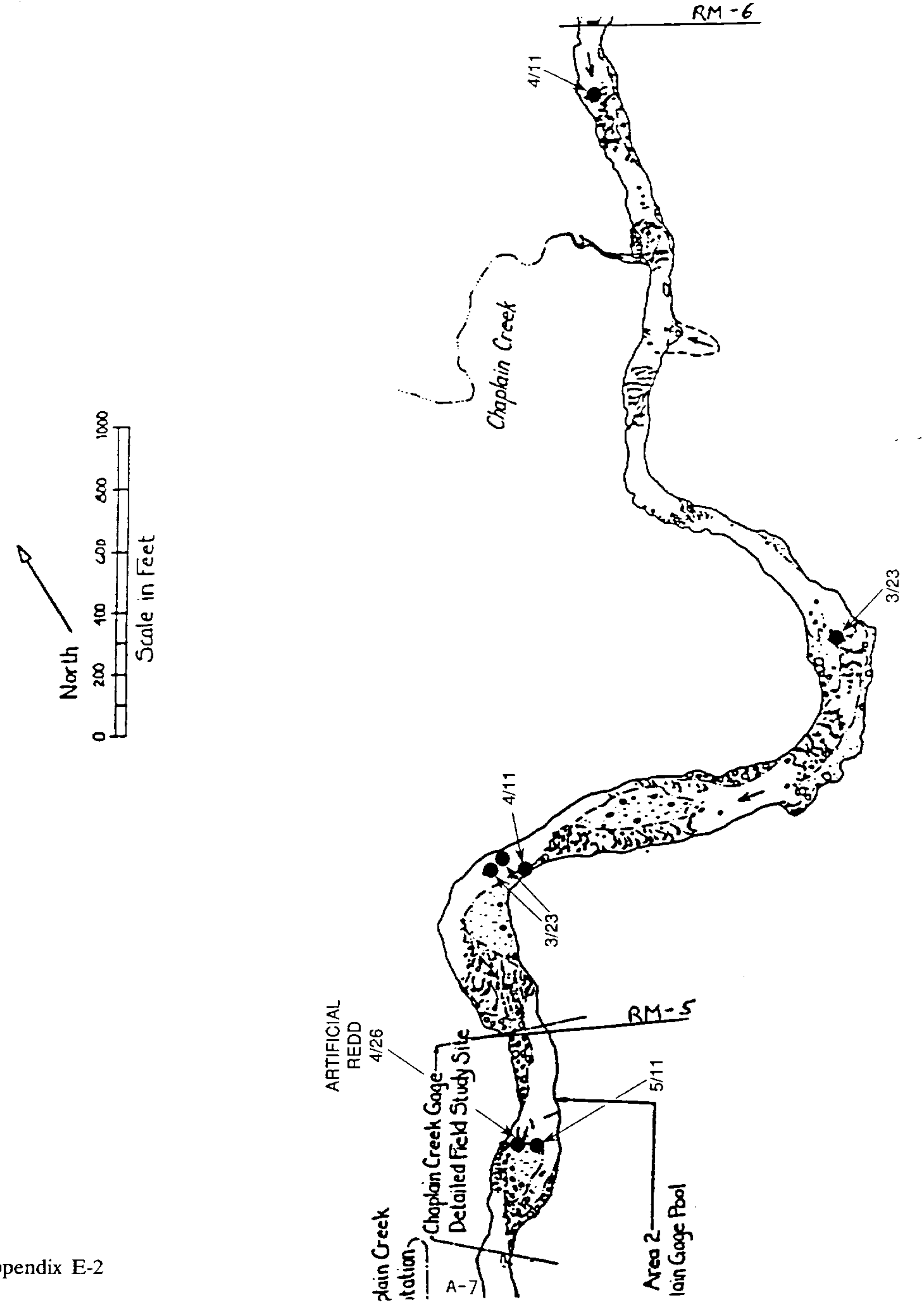


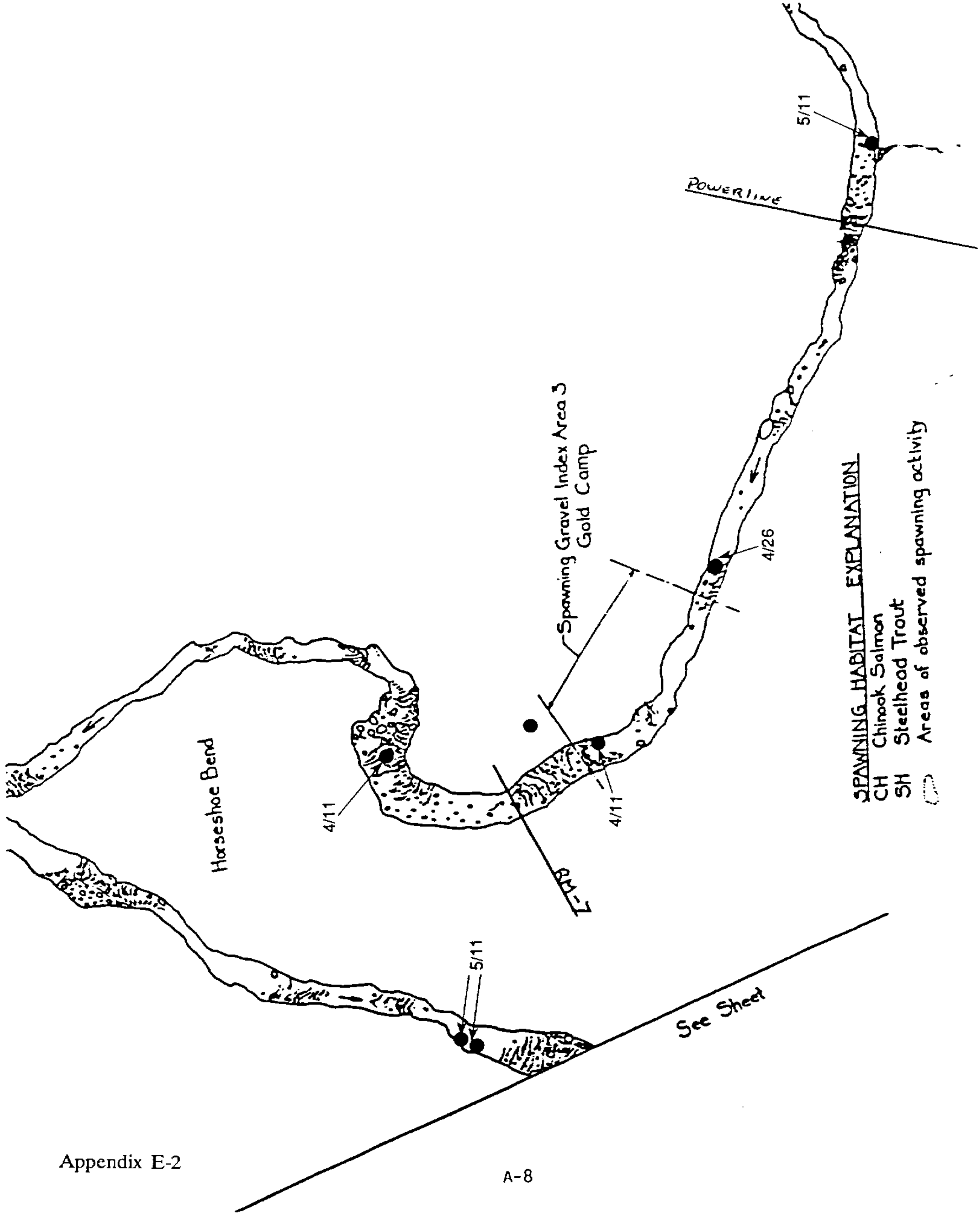
Scale in Feet
Ames Creek
4/26
5/11
Seep
5/11
6/2
6/23
ARTIFICIAL REDD 4/26
ARTIFICIAL REDD 5/11
Trout Farm Creek
6/23
6/2
A-4
RM-2
ARTIFICIAL REDD 3/8 & 3/23
Existing Power Lines
SPAWNING HABITAT EXPLANATION
Areas of observed spawning activity
CH Chinook Salmon
CO Coho Salmon
Pk Pink Salmon
SH Steelhead Trout
Spawning Gravel Index Area 1
River Mouth to BPA Powerlines
Base photo date February 7, 1984
Flow 491 cfs.

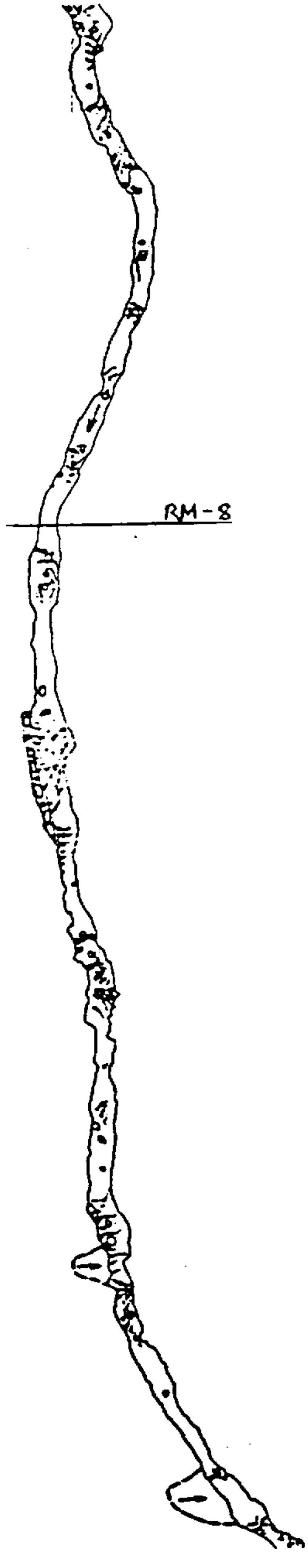


Appendix E-2

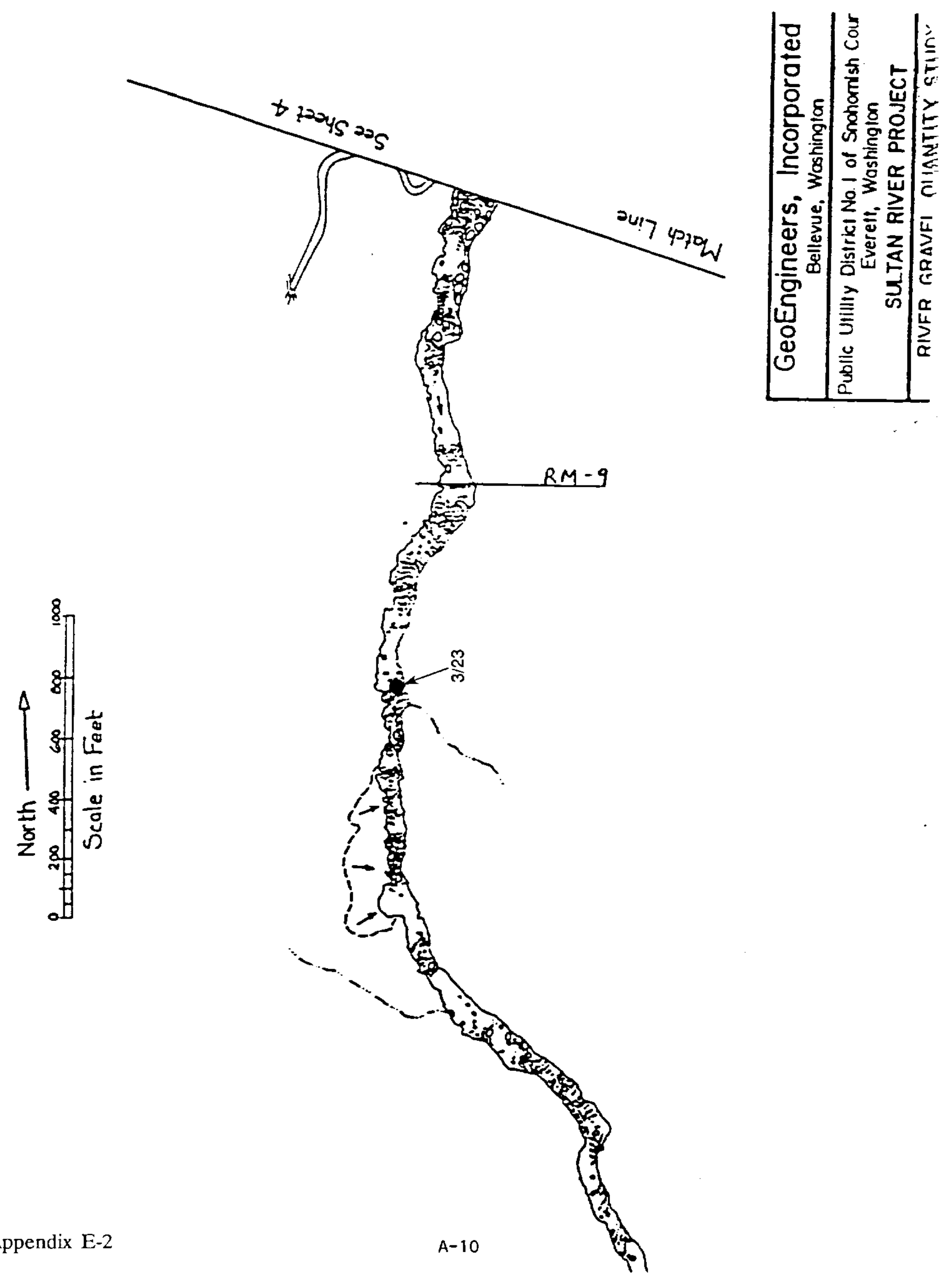

ARTIFICIAL
REDD
3/23
3/23
ARTIFICIAL
REDD
4/26
5/11
6/2
Spawning Gravel Inc
Powerhouse to Ch
SPAWNING HABITA
CH Chinook Salm
SH Steelhead Tr
Areas of obs
Existing Power Lines
3/23
Existing Powerhouse
6/2
RM-4

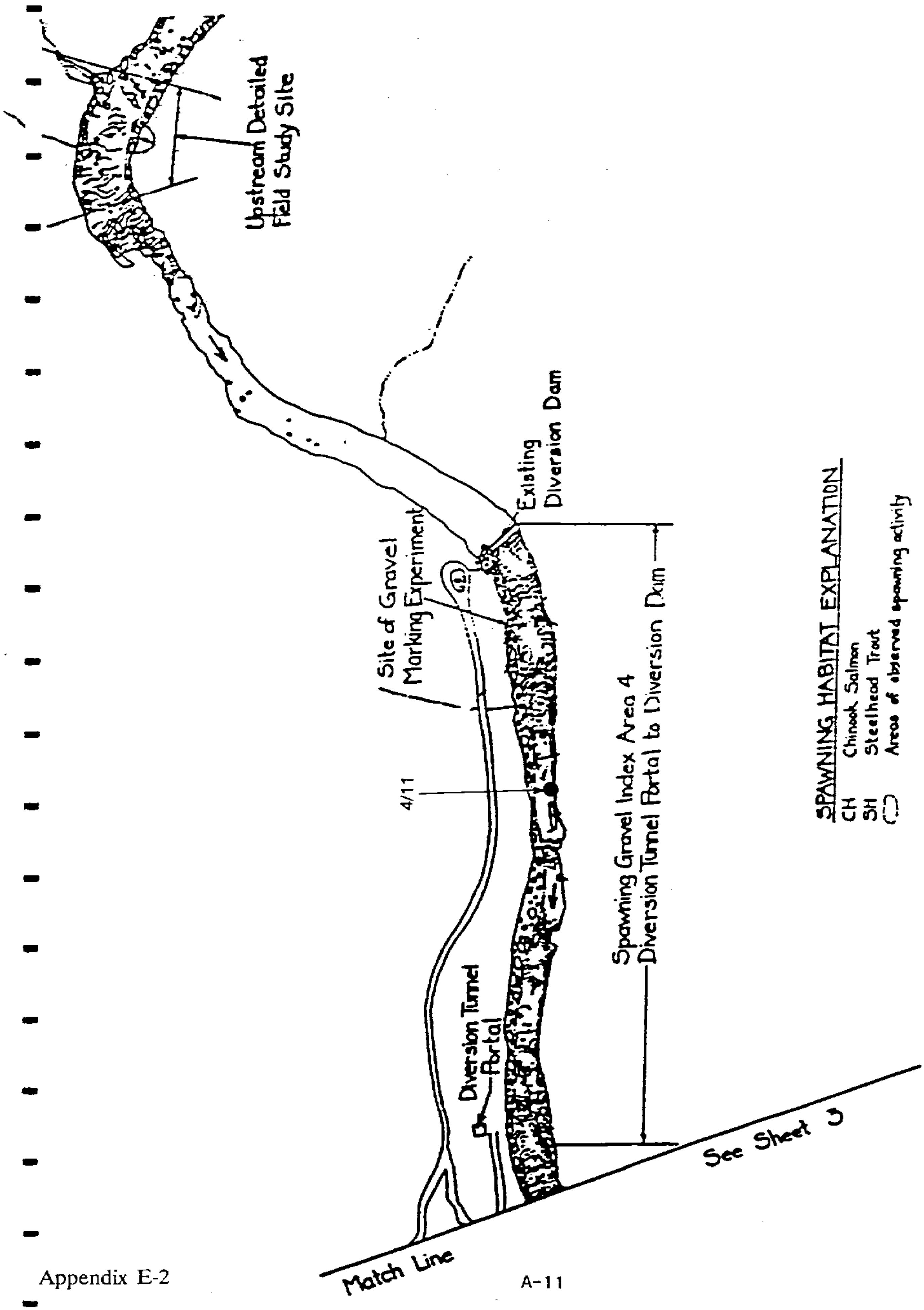

RM-6
4/11
Chaplain Creek
North
0
200
400
600
800
1000
Scale in Feet
3/23
4/11
3/23
RM-5
ARTIFICIAL
REDD
4/26
Chaplain Creek Gage
Detailed Field Study Site
5/11
Area 2
lain Gage Pool
A-7


5/11
POWERLINE
Spawning Gravel Index Area 3
Gold Camp
4/26
SPAWNING HABITAT EXPLANATION
CH Chinook Salmon
SH Steelhead Trout
Areas of observed spawning activity
Horseshoe Bend
4/11
4/11
5/11
See Sheet



Appendix E-2

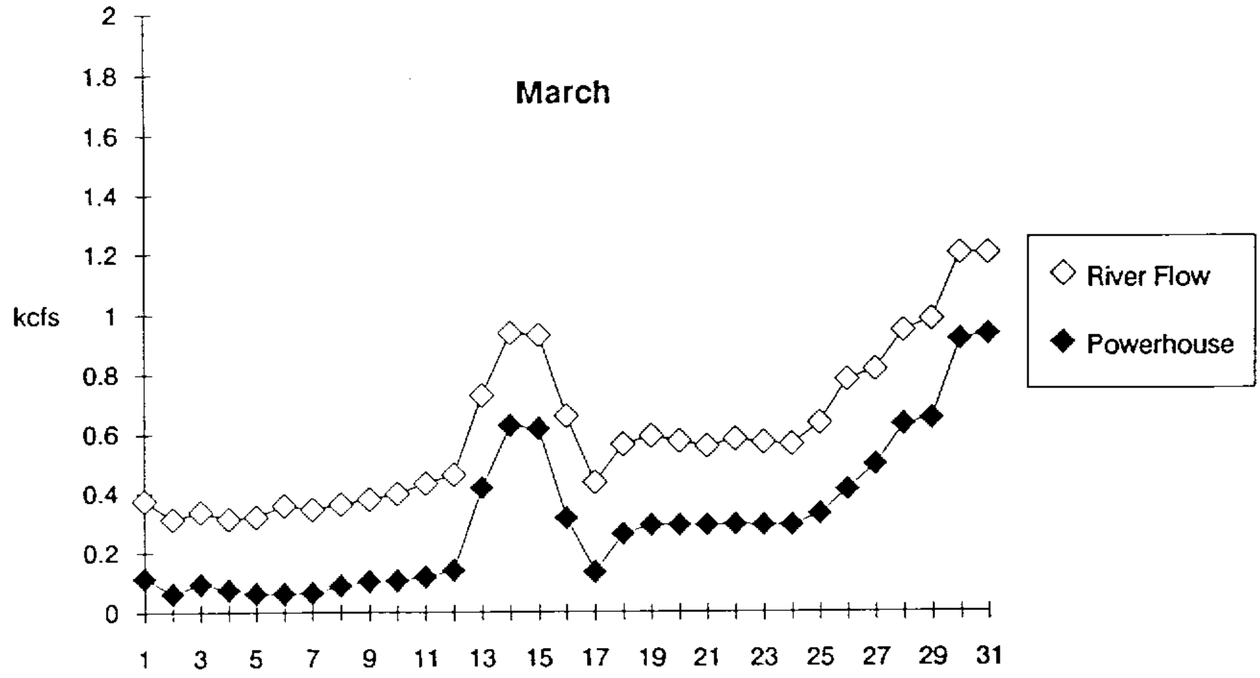

GeoEngineers, Incorporated
Bellevue, Washington
Public Utility District No. 1 of Snohomish Cou
Everett, Washington
SULTAN RIVER PROJECT
RIVER GRAVEL QUANTITY STUDY
See Sheet 4
Match Line
RM-9
3/23
North
0 200 400 600 800 1000
Scale in Feet

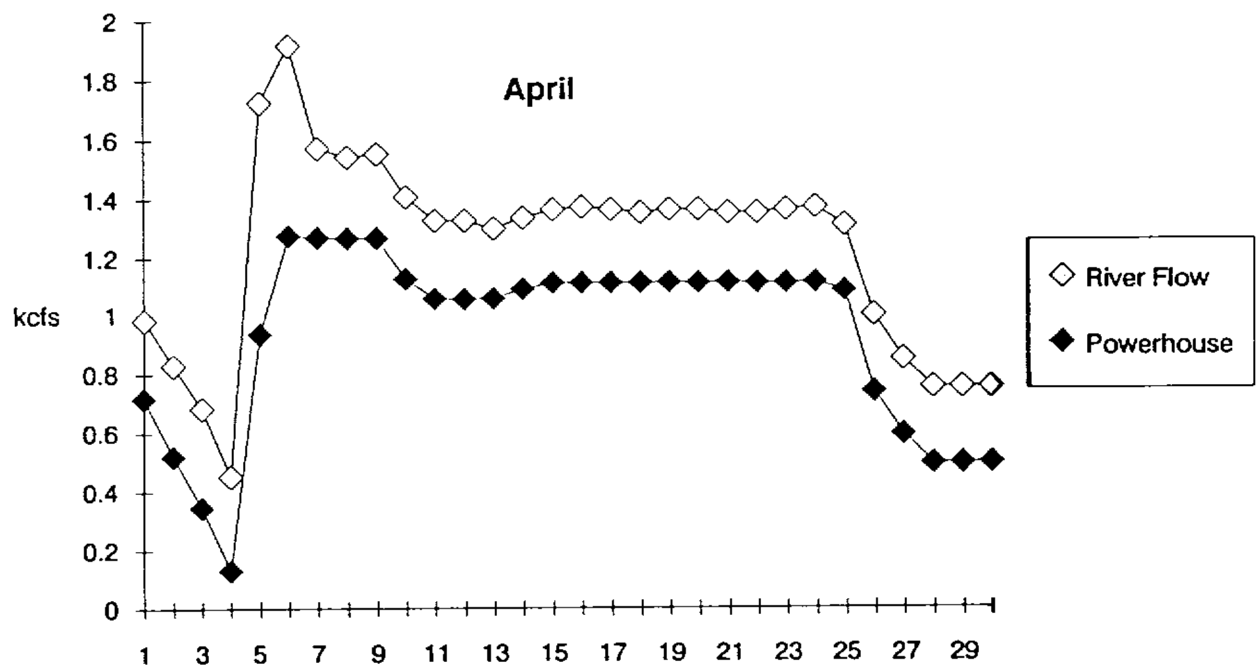


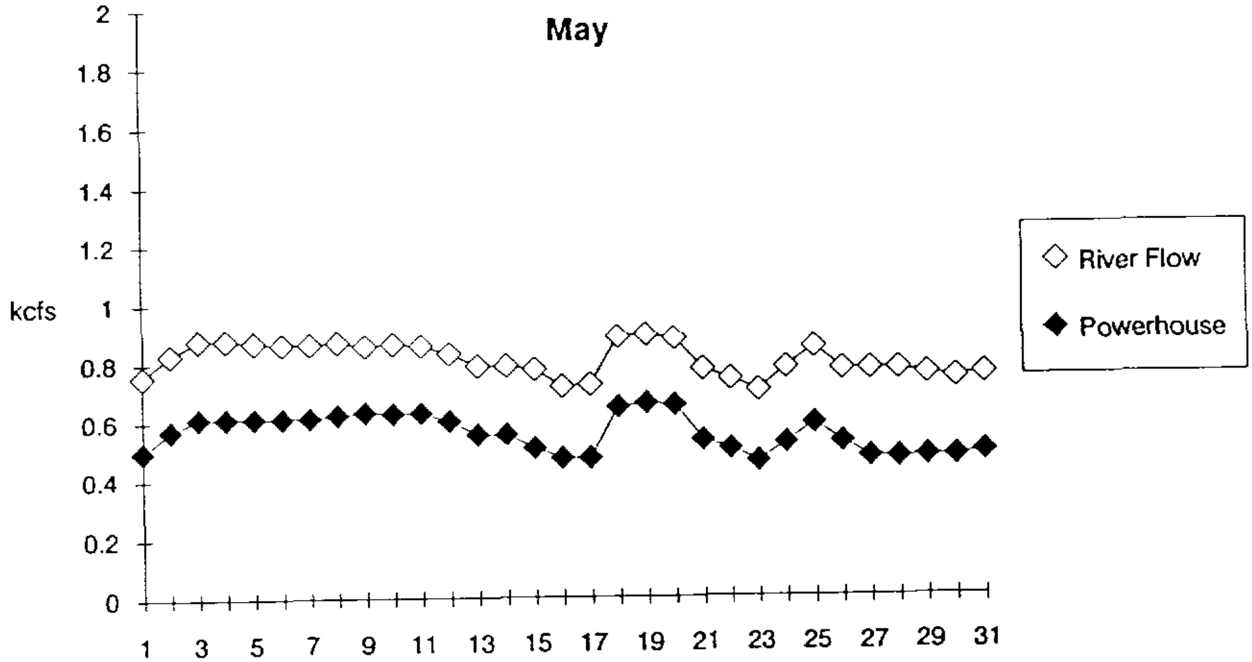
Upstream Detailed
Field Study Site
Existing
Diversion Dam
Site of Gravel
Marking Experiment
4/11
Spawning Gravel Index Area 4
Diversion Tunnel Portal to Diversion Dam
Diversion Tunnel
Portal
SPAWNING HABITAT EXPLANATION
CH Chinook Salmon
SH Steelhead Trout
Areas of observed spawning activity
See Sheet 3
Match Line

Appendix B

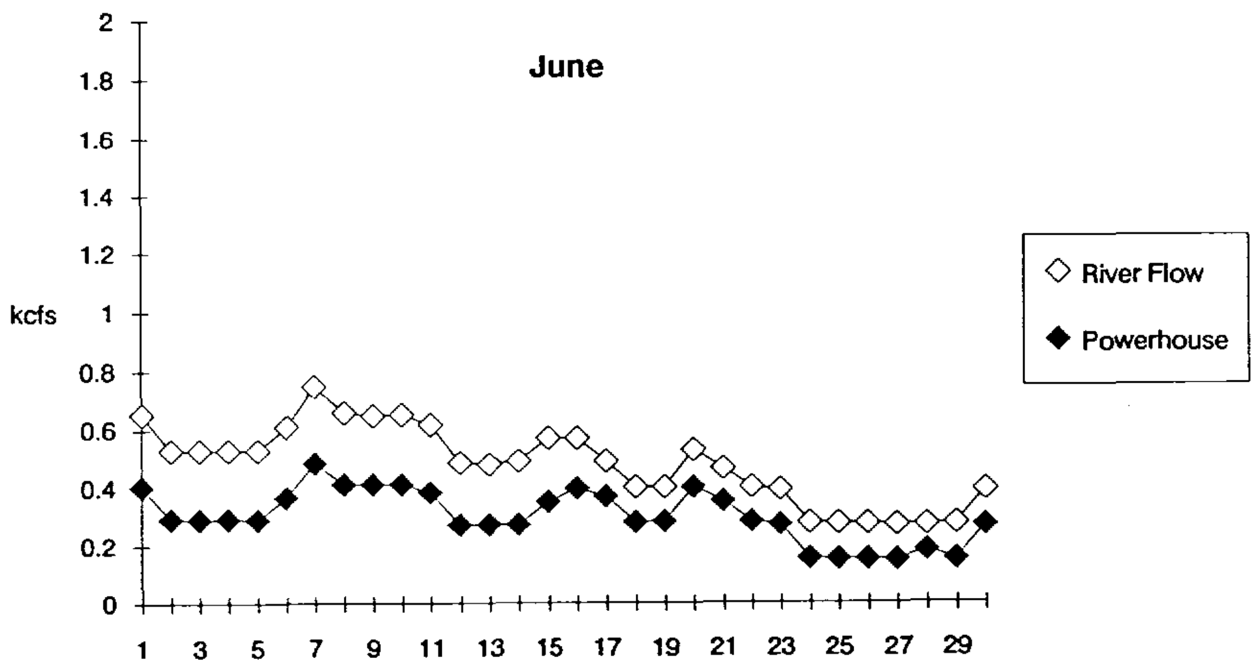
Total river and powerhouse flow rates (measured at the Henry M. Jackson powerhouse) during the 1989 steelhead spawning season (Mar - June).


March
kcfs
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
River Flow
Powerhouse


April
kcfs
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
River Flow
Powerhouse



May
kcfs
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
River Flow
Powerhouse



June
kcfs
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
River Flow
Powerhouse