

Exxon Valdez Oil Spill
Restoration Project Annual Report

Sockeye Salmon Stocking Solf Lake

Restoration Project 99256B
Annual Report

This annual report has been prepared for peer review as part of the Exxon Valdez Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in the annual report.

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Study History: Subsistence resources and services were injured throughout Prince William Sound as a result of the *Exxon Valdez* Oil Spill. This project is the continuing investigation and enhancement of lost subsistence opportunities through the stocking of sockeye salmon (*Oncorhynchus nerka*) in Solf Lake, Herring Bay, in Prince William Sound (PWS). Solf Lake has been recognized as an opportunity for establishing a self-sustaining sockeye salmon population since the 1960's. The lake now provides an excellent opportunity to establish a replacement fishery to benefit subsistence users in Western Prince William Sound.

Habitat improvements were made in 1978, 1980 and 1981 to provide access to the lake for anadromous fish. The lake was never stocked and subsequent investigations suggest that it was fishless, but had adequate habitat to support a sockeye salmon population. There are two phases to this project: Phase 1, which began in FY96, verified the ability of Solf Lake to support a sustainable population of sockeye salmon. Phase 2 includes stocking the lake with 100,000 sockeye salmon fry, starting in 1998 and ensuring access to Solf Lake for returning adult sockeye salmon.

Abstract: During the 1999 field season Forest Service personnel completed a survey of the eastern outlet at Solf Lake then developed and approved a design for a fishway to be installed in 2000. Personnel from the Main Bay Hatchery successfully collected eggs from Eyak brood stock and reared them at their Main Bay facility. This resulted in the release of 105,829 fry into Solf Lake in the spring of 1999. The Alaska Department of Fish and Game reports that the 1999 stocking levels influenced the abundance or total biomass of the macrozooplankton population at Solf Lake but levels were still within parameters to continue stocking at the 100,000 fry level. Smolt outmigration data and a hydroacoustic survey of the Lake suggest that the majority of fry stocked in both 1998 and 1999 emigrated as age-0 smolt during late summer.

Key Words: *Exxon Valdez*, fishways, Limnology, Prince William Sound, sockeye salmon (*Oncorhynchus nerka*), Solf Lake, stocking.

Project Data: *Description of data* - There are three primary sets of digital data developed for this project: (1) The feasibility phase of the study included examination of zooplankton and algal biomass, temperature and light profiles, dissolved oxygen and water chemistry. (2) Modified Hankin and Reeves (1988) stream survey information that incorporates the geophysical and hydrological characteristics of the stream into distinct habitat units. (3) An inventory of fish and macro-invertebrate populations. *Format* - Data sets are in Excel spreadsheets and Word Perfect formats. *Custodian* - Contact Cliff Fox at the Glacier Ranger District Office, USDA Forest Service, POB. 129 Girdwood, Alaska 99587. PH. (907) 783-3242, Fax (907) 783-2094, E-mail: cfox02@fs.fed.us. *Availability* - copies of data sets are available upon written request.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY.....	1
INTRODUCTION.....	2
OBJECTIVES.....	4
METHODS.....	4
RESULTS.....	6
DISCUSSION and CONCLUSIONS.....	7
LITERATURE CITED.....	8
PERSONAL COMMUNICATIONS.....	9
APPENDIX.....	10

LIST OF FIGURES

Figure 1. Location Map.....	10
Figure 2. Site Plan.....	11
Figure 3. Zooplankton Composition.....	12
Figure 4. Zooplankton Biomass.....	12
Figure 5. Plan View Solf Fishway.....	13

EXECUTIVE SUMMARY

The *Exxon Valdez* Oil Spill injured subsistence resources and services throughout Prince William Sound. This project continues to improve subsistence opportunities through the stocking of sockeye salmon (*Oncorhynchus nerka*) and stream improvements to allow adult salmon passage into Solf Lake, Herring Bay, Prince William Sound (PWS). Solf Lake has been recognized as an opportunity for establishing a self-sustaining sockeye salmon population since the 1960's. The lake now provides an excellent opportunity to establish a replacement fishery to benefit subsistence users in Western Prince William Sound.

This project began in fiscal year 1996 when the Trustee Council funded project 96256. This project was a combined proposal to assess the feasibility of establishing a stocking program at both Columbia and Solf Lakes. Interim reports and a recommendation on the feasibility of these two lakes for stocking were provided to the Trustee Council in the fall of 1996. It was determined that Solf Lake could support stocking levels of as many as 400,000 fry based on the available zooplankton. In April of 1995, the proposal for this project was presented to the Prince William Sound Copper River Regional Fisheries Planning Team (RPT) for approval. The Forest Service discussed brood stock source, mixed stock issues and stocking levels with the RPT in 1997. At this time they approved the project recommending stocking at the lower level of 100,000 fry to achieve the goal of 10,000 adult fish returning to Solf Lake.

Solf Lake has two outlets; the eastern outlet has historically provided anadromous access, and the western outlet has an impassable waterfall. Currently both are impassable to anadromous salmon. For many years, Dolly Varden (*Salvelinus malma*) has been the only recorded species of fish in Solf Lake. In 1978, the Forest Service removed the barriers from the east channel and created a dam at the western outlet to provide adequate stream flows to the eastern channel, which would allow access for sockeye salmon. Additional improvements to the eastern outlet and dam were made in 1980 and 1981, but the system was never stocked with salmon. The old structures at the two outlets of the lake were evaluated in 1997. It was determined that the structures at both outlets required extensive reconstruction. Work on the western outlet was completed in 1998 and work at the eastern outlet will be completed in 2000.

In 1999 Forest Service engineers completed the survey of the eastern outlet and developed a preliminary design for the fishway to be installed in 2000. The final design for the fishway and Forest Service approvals occurred in early spring of 2000. Additionally the second stocking of 105,829 Coghill sockeye salmon fry was successfully completed in the spring of 1999. ADF&G and Forest Service biologists reviewed the macrozooplankton results for 1999, which were at approximately 50% of the pre-stocking densities, and determined that current stocking levels are still supported at Solf Lake. Smolt outmigration was monitored during May, June and July with unexpected results. Only a total of 248 sockeye smolt were captured in early June, mean size 134.7 mm. and 22.9 g. The lack of out-migrating sockeye prompted the need for further investigation. A hydroacoustic and tow net survey of the lake was conducted in late September resulting in no targets (fish) recorded by either survey. The large size of the sampled smolts during the spring emigration and the lack of targets during the hydroacoustic survey, suggest that the majority of fry stocked in both 1998 and 1999 emigrated as age-0 smolt during late summer. Future monitoring will be attempted to determine if smolt are out-migrating earlier than expected at Solf Lake.

INTRODUCTION

Subsistence use of resources in the oil spill area declined following the spill. Although restoration studies have shown that harvest levels have since returned to pre-spill levels in most oil spill communities, Chenega Bay and Tatitlek are exceptions (Seitz and Fall, 1995; Seitz and Miraglia, 1995). These communities showed reduced harvest levels in 1993/94 and an increased reliance on salmon harvests (Seitz and Fall, 1995; Seitz and Miraglia, 1995). Solf Lake provides an opportunity to establish a large replacement fishery that is easily accessible, approximately 40 miles from Chenega Bay.

Solf Lake is a clear water lake with a mean depth of 42.5 m and a surface area of approximately 0.61 km² (Barto and Nelson, 1982). Based on historical limnological data from the 1980's, stream survey collected in 1996, and analysis of current limnological data it is reasonable to expect that the lake is capable of supporting a sustainable sockeye population with an adult return of approximately 10,000 fish. Establishing this fishery would directly benefit subsistence users in Western Prince William Sound.

Solf Lake has long been recognized as an opportunity to reestablish a sockeye salmon run in Prince William Sound. According to Nickerson (1978), "This system had historic runs of sockeye salmon. An earthquake in the 1930's caused blockages of the natural outlet resulting in water flowing over an impassable fall." Starting in the early 1970's, various attempts have been made to reestablish sockeye salmon in Solf Lake. For two years in this same period, ADF&G personnel transported adult sockeye salmon from Eshamy River to Solf Lake (Jackson, personal communication). Unfortunately, necessary stream improvements had not been completed when the offspring from the transplanted fish returned. In 1978, 1980 and 1981, the USFS implemented improvements to the lake and outlet stream. The work consisted of improving the eastern outlet and partially damming the western outlet. The dam was designed to raise the level of the lake to provide adequate water flow for fish passage at the eastern outlet. The improved eastern outlet channel is less than 100 meters in length, with an average gradient of 23 percent, see Figure 2 in Appendix. Stocking of the lake never occurred after the habitat improvements because of other priority projects for both the USFS and ADF&G.

The ADF&G surveyed Solf Lake in 1985/1986 as part of a lake investigation study. The results of this survey, which included attempts to capture fish, suggest that the lake may be fishless (Pellissier and Somerville, 1987). However 1996 minnow trapping by USFS crews indicated a larger population of Dolly Varden than has been previously observed, but still not significant. These results are also supported by the composition and biomass of the zooplankton populations, which were sampled in 1986 (P. Shields, personal communication 1996). The Pellissier and Somerville (1987) survey also documented that water was flowing through the western outlet due to an incomplete seal by the dam structure. Three minor barriers to fish passage were identified in the eastern channel. The report also suggested that if all the water passing under the dam at the western outlet was stopped these barriers might disappear.

The eastern outlet to the lake also required reconstruction of the "irrigation type" control dam. That work was completed in 1997. The engineered survey of the western outlet and the suitable dam design completed in 1997 led to the installation of a new diversion dam at the western outlet in 1998. After construction, the new diversion dam was monitored for effectiveness. With a complete seal to the native bedrock, it appeared to completely divert all low flows to the eastern outlet.

The second stocking of Solf Lake was completed in 1999. It consisted of the release of 105,829 sockeye salmon into the lake. The eggs and fry for year 2000 stocking were also collected for rearing at the Main Bay Hatchery. The ADF&G recommends stocking based on their zooplankton studies and adds that the instability of the macrozooplankton community in barren lakes when faced with predation necessitates stocking programs based on a conservative approach. Close evaluation and experimentation with stocking strategies will ameliorate significant impacts to the macrozooplankton community. Major reasons for the disparity of response to stocking barren lakes include: 1) The inherent low productivity of these lakes; 2) macrozooplankton abundance, composition, and ability to adapt to predation; 3) stocking density; 4) morphometric factors and 5) variability in the indirect effects of predation in individual lakes. Consequently based on limnological information for the first three years, the stocking levels at Solf Lake could be 400,000 fry. Monitoring of the zooplankton once per month during June-October would be required. After three years of stocking at this level, if the zooplankton community did not show a significant impact, the level could be increased to perhaps 500,000 fry. This level of stocking could be done for another three years with continued evaluation of the zooplankton community. While Solf Lake is most likely capable of supporting stocking at this level, it has been decided to take a more conservative approach to stocking.

Based on the available spawning area, it is estimated that Solf Lake could sustain a run of approximately 10,000 sockeye salmon. An escapement goal of approximately 4,500 fish would be required to fully seed the system without depleting the zooplankton populations, leaving 5,500 sockeye available for harvest. Consequently, we are recommending stocking at the 100,000 fry level to meet the objective of the stated desired return and the assumption that there will be a high fry to adult survival.

Solf Lake is located off Herring Bay on Knight Island. By boat it is approximately 40 miles from Chenega Bay and 46 miles from Whittier. The lake is unnamed on USGS maps; however, Nickerson (1978), PWSRPT (1983 and 1986), Barto and Nelson (1982) all refer to the lake as Solf Lake (ADF&G Stream 690). The lake is described in the Anadromous Waters Catalog as number 226-10-16900-0010 (ADF&G, 1992; Figure 1, Appendix A).

OBJECTIVES

Phase 1. Determine the feasibility of stocking Solf Lake with sockeye salmon. The four components to this objective are:

1. Determine if Solf Lake can sustain a population of sockeye salmon (completed).
2. Determine appropriate stocking levels (completed).
3. Coordinate with PWSAC and Main Bay Hatchery to establish an appropriate brood stock and the necessary logistics to begin a stocking program (completed).
4. Evaluate the existing habitat improvement structures to ensure adequate conditions for adult migration (completed in FY98).

Phase 2. Implementation phase of the project, the three components to this objective are:

1. Design and construct necessary improvements to the outlet channel and dam to ensure adequate passage for adult salmon migration (75% completed).
2. Stock Solf Lake with sockeye salmon to produce a self-sustaining population that can provide an adequate subsistence harvest (ongoing).
3. Monitor zooplankton and smolt out-migration to ensure appropriate stocking levels (ongoing).

METHODS

Project 99256B involved developing an approved design for the fishway in the eastern outlet, the continuation of the sockeye salmon stocking program, limnological and water quality sampling and monitoring smolt outmigration. The following section is divided into three parts. Part 1 describes the methods needed to establish a self-sustaining sockeye salmon population. Part 2 describes the improvements needed to provide access for returning adult salmon. Part 3 describes the sampling methods used to collect biological, physical and morphological information.

Part 1. This section outlines the methods to implement a stocking program at Solf Lake.

Interagency Coordination (1997 to Present): Close coordination between the USFS, ADF&G, PWSAC and the PWS/CR RPT are mandatory for the success of this project. Prince William Sound is a complex ecosystem and the potential stocking of Solf Lake needs to be considered in perspective with the overall management of the Sound. Interagency coordination has occurred in 1996 through 1999 to identify appropriate brood stocks, determine appropriate stocking levels, meet hatchery-related requirements, and to address mixed-stock fisheries issues.

Stocking Program (1998 to 2002): Appropriate stocking levels and strategies will be determined in coordination with ADF&G and PWSAC using all available data. Sockeye fry will be short-term reared at the Main Bay Hatchery and transported to the lake for release. The Eyak and Coghill stocks are identified in the PWS/CR Phase 3 Comprehensive Salmon Plan (PWS/CR RPT, 1994) as potential stocks for Solf Lake. Stocking began in 1998 and is planned to continue until the year 2002.

The success of the stocking program is being monitored through sampling of the fish population during the smolt out-migration and during adult returns. Smolt will be collected by weir to estimate the total out migration, starting in 1999. Fish will be sampled to determine age, length, and weight to evaluate the health of the population. Fry stocked in 1999 were marked with half-length coded wire tags. Returning adults will be enumerated at a weir on the eastern outlet stream and, if possible, with aerial surveys. Scales and tags will be collected and the age structure of the returning fish will be analyzed.

Part 2. Describes the types of improvements needed to provide access for returning salmon.

ADF&G personnel visited Solf Lake as part of a PWS lake investigation project in 1985 (Pellissier and Somerville, 1987). Three minor barriers to fish migration were identified in the outlet channel. These barriers were velocity barriers that ranged in size from 1.5 to 2.5 meters. The barriers may potentially be removed through the creation of plunge pools or by installing steeppasses. The report also suggested that the barriers might not exist if more water were in the eastern outlet channel, which could be achieved by repairing the dam at the western outlet.

The eastern outlet to the lake required reconstruction of the "irrigation type" control dam; this work was completed in 1997. During the 1998 field season Forest Service personnel completed the installation of the diversion weir structure at the lakes western outlet, EVOS Project 98256b. The fishway in the eastern outlet will be completed in the summer of 2000 and is designed to provide sockeye salmon passage into Solf Lake. The design calls for two Alaska steep passes one 30 feet, another 40 feet in length to be installed at a 22% slope. Each steep pass will require a concrete head wall and footers. The upper pass will spill into an excavated section of bedrock lined with concrete to form a watertight trench. Additionally, five step pools will be created by the installation of five notched concrete weirs, to facilitate fish passage.

Part 3. Collection methods of biological, physical and morphological information at Solf Lake:

Limnological Sampling (1998): Data collection and analysis included: Algal biomass (chlorophyll *a*), zooplankton populations (biomass, body-sizes, species composition etc.), temperature and light profiles, dissolved oxygen, and water quality (nutrients) to estimate the potential productivity of the lake. Procedures for the collection of these samples are detailed in Koenings et. al. (1987). Samples were collected from a minimum of two permanent collection sites every three to four weeks May - September to assess seasonal variation.

Sustainable Sockeye Returns: These are based on the available spawning area times a redd density of 6.7 m² and a fecundity of 2,000 eggs / gravid female, and a 1:1 sex ratio. Survival rates assume a 10% egg to fry survival, a 15% fry to smolt survival and a 15% smolt to adult return.

Smolt out-migration: Surveys will be conducted by the Alaska Department of Fish and Game in early spring of 1999. ADF&G will be operating a total capture weir at the control structure in the eastern outlet to enumerate smolt numbers.

RESULTS

With the exception of 1986 prior to stocking activity, *Diaptomus* have accounted for more than 50% of the total biomass followed by *Cyclops*, which generally comprises about 30 % of the total. The remainder of the total macrozooplankton (TMZ) consisted primarily of the cladoceran form, *Bosmina* and very small numbers of *Daphnia*. Diet selectivity studies for rearing sockeye fry have shown that fry presented with a wide choice of food items tend to select for cladoceran and large calanoid forms. Although sockeye fry do graze on *Cyclops*, it is not actively selected. Thus, in Solf Lake, we would expect the large, red pigmented, and highly visible *Diaptomus*, to be an indicator species of excessive grazing pressure and a guide to gauge stocking levels.

The 1999 stocking level of 105,829, .41 g., sockeye fry did appear to have an influence on (TMZ) and the abundance of *Bosmina*, indicated by an 81% decline in density and an 84% decline in biomass from pre-stocking means. *Diaptomus* declined similarly by 43% in density and 45% in biomass however these levels fall within the range of pre-stocking observations. The decline in *Cyclops* 66% and 69% respectively also fall within annual fluctuations and is probably not due to grazing, it is doubtful we would see a decline in this species before the highly preferred types, see Figures 3 and 4 in Appendix.

On 2 May 1999 the smolt enumeration box was installed in the flow control structure (northeast outlet) to capture all migrating smolts at Solf Lake. Later a fine mesh net was placed across the northwest dam to block smolt passage, forcing all emigrating smolts through the counting live-box at the NE outlet. The live-box was monitored periodically to avoid crowding and smolt mortality. On 17 June the counting box was replaced with an inclined-plane trap (Todd 1994) and fished for the remaining duration of the project, until 26 July. No smolts were caught in May. The first smolts were caught on 5 June, and the peak count occurred on 6 June when 189 smolts were enumerated. The 1999 total count was 248 sockeye salmon smolt and 45 Dolly Varden. The mean size of sampled ($N=16$) sockeye salmon smolt was 134.7 mm and 22.9 g.

On the night of 27 September 1999 a hydroacoustic and tow-net survey were conducted on Solf Lake. There were essentially no targets (fish) recorded for the whole survey, 12 transects perpendicular to the longitudinal axis of the lake. Two tows were conducted at different depths using a 2 x 3 m tow-net and no fish were captured.

Personnel from the Main Bay Hatchery successfully collected 117,700 green eggs from Eyak brood stock and reared them at their Main Bay facility. Overall, survival of green eggs to released fry was 92.7%. This resulted in the release of 105,829, 0.41 g fry into Solf Lake in the spring of 1999. Of the total number of fry released, 2,687 were marked with half-length coded wire tags numbered 13-01-04-01-15. The expected return from the release of the BY98 Coghill stock sockeye to Solf Lake is expected to be 4,400. Approximately 60% of these should return as four-year-olds in 2002. The remaining 40% may return as five-year-olds in 2003.

An engineered survey of the eastern channel and hydraulic analysis revealed further improvements are necessary to ensure fish passage into Solf Lake. The approved design will provide sockeye salmon moderately difficult passage into Solf Lake during anticipated low flow periods of 10 cfs. at any tide stage. The design calls for two Alaska steep passes one 30 feet, another 40 feet long to be installed at a 22% slope. Each steep pass will require a concrete head

wall and footers. The upper pass will spill into an excavated section of bedrock lined with concrete to form a watertight trench. Additionally five step pools will be created by the installation of five notched concrete weirs, to facilitate fish passage during periods of low stream flow, see Figure #5 in Appendix.

DISCUSSION and CONCLUSIONS

Fishless lakes are susceptible to overgrazing by large numbers of obligate planktivores, i.e. sockeye fry, resulting in steep declines in macrozooplankton numbers and biomass. Diet selectivity studies for rearing sockeye fry have shown that fry presented with a wide choice of food items tend to select for cladoceran and large calanoid forms. Although sockeye fry do graze on Cyclops, it is not actively selected. Thus, in Solf Lake, we would expect the large, red pigmented, and highly visible Diaptomus to be an indicator species of excessive grazing pressure and a guide to gauge stocking levels.

In February ADF&G and Forest Service biologists and Project Investigators reviewed the macrozooplankton results from 1999 and determined that current stocking levels are still supported at Solf Lake and that the observed decline in macrozooplankton is within expected parameters.

The large sizes of sampled smolt and small number (248) counted during the spring emigration in 1999, and the lack of fish targets during the fall hydroacoustic survey suggest that the majority of fry stocked in both 1998 and 1999 emigrated as age-0 smolt in late summer. Cook Inlet Aquaculture Association (CIAA) has documented age-0 sockeye salmon smolts emigrating from their lake stocking programs; from 1990-1995, estimates of age-0 smolt emigrating Chelatna Lake (Susitna River basin) have ranged from less than 1% to 62% of the total outmigration (Fandrei 1995), and in Bear Lake (Seward) age-0 smolt estimates for 1990-1994 have ranged from less than 1%, up to 98% in one year (Hetrick and Prochazka 1998). At this time it is uncertain what the effects of this early emigration will have on ocean survival and consequently the number of returning adults to Solf Lake. This early outmigration is expected to discontinue as the available zooplankton is reduced and fry growth rates decrease and stabilize.

In 2000 the Regional Forest Service Engineer and the Trustee Council approved the final design for the fishway to be installed in the spring of the same year. However, the constructed fishway may vary slightly from this design due to unknown problems encountered during construction. The complete engineered plans are available at this office on request.

Both the diversion weir at the western outlet and the control structure at the eastern outlet have been successfully completed and are working properly. During the 1999 field season both structures were inspected for serviceability. After a full 2 years of exposure to the rigorous weather of Prince William Sound the structures remain operational showing little sign of wear.

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Figure 1. Location Map.

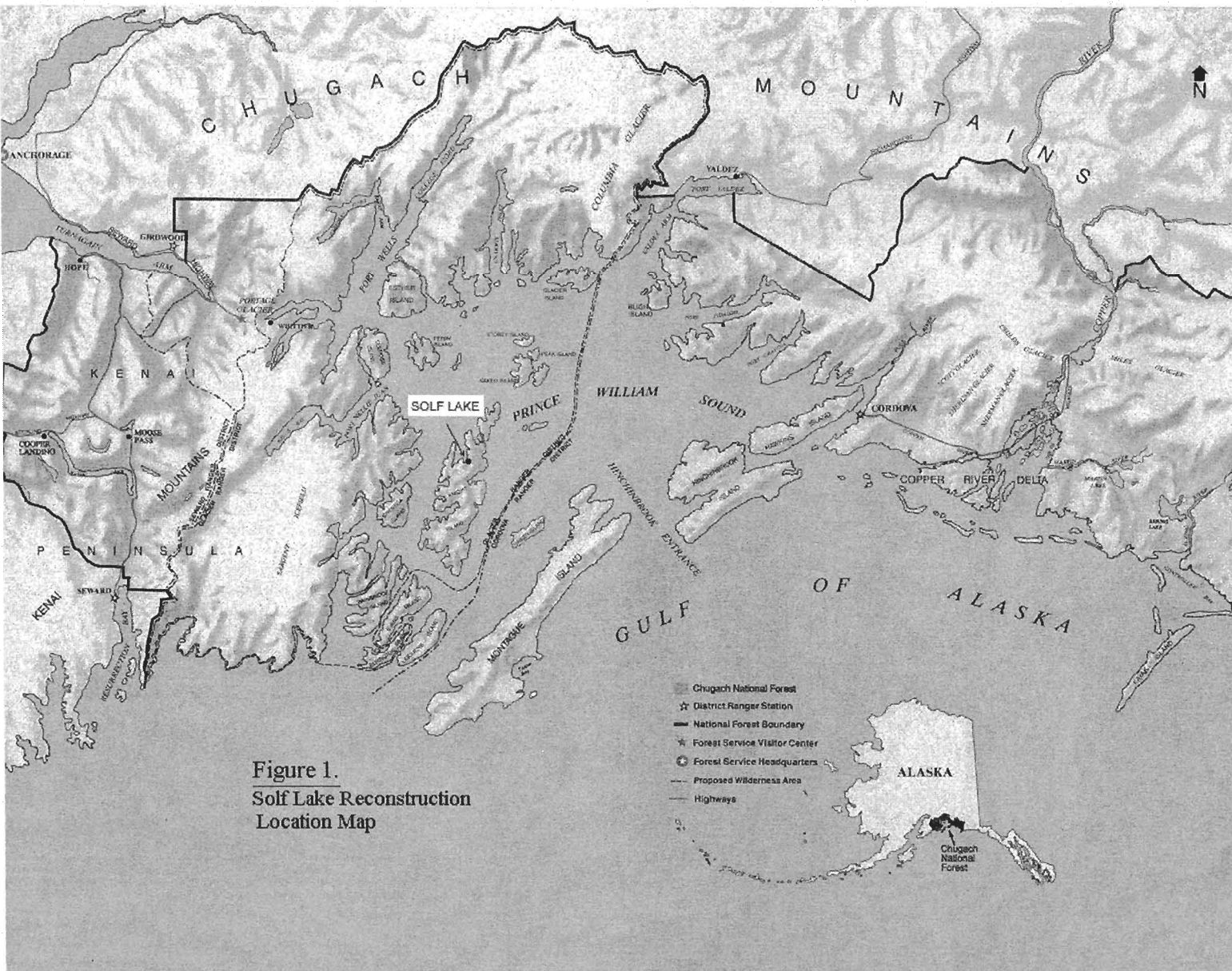


Figure 1.
Solf Lake Reconstruction
Location Map

Figure 2. Site Plan

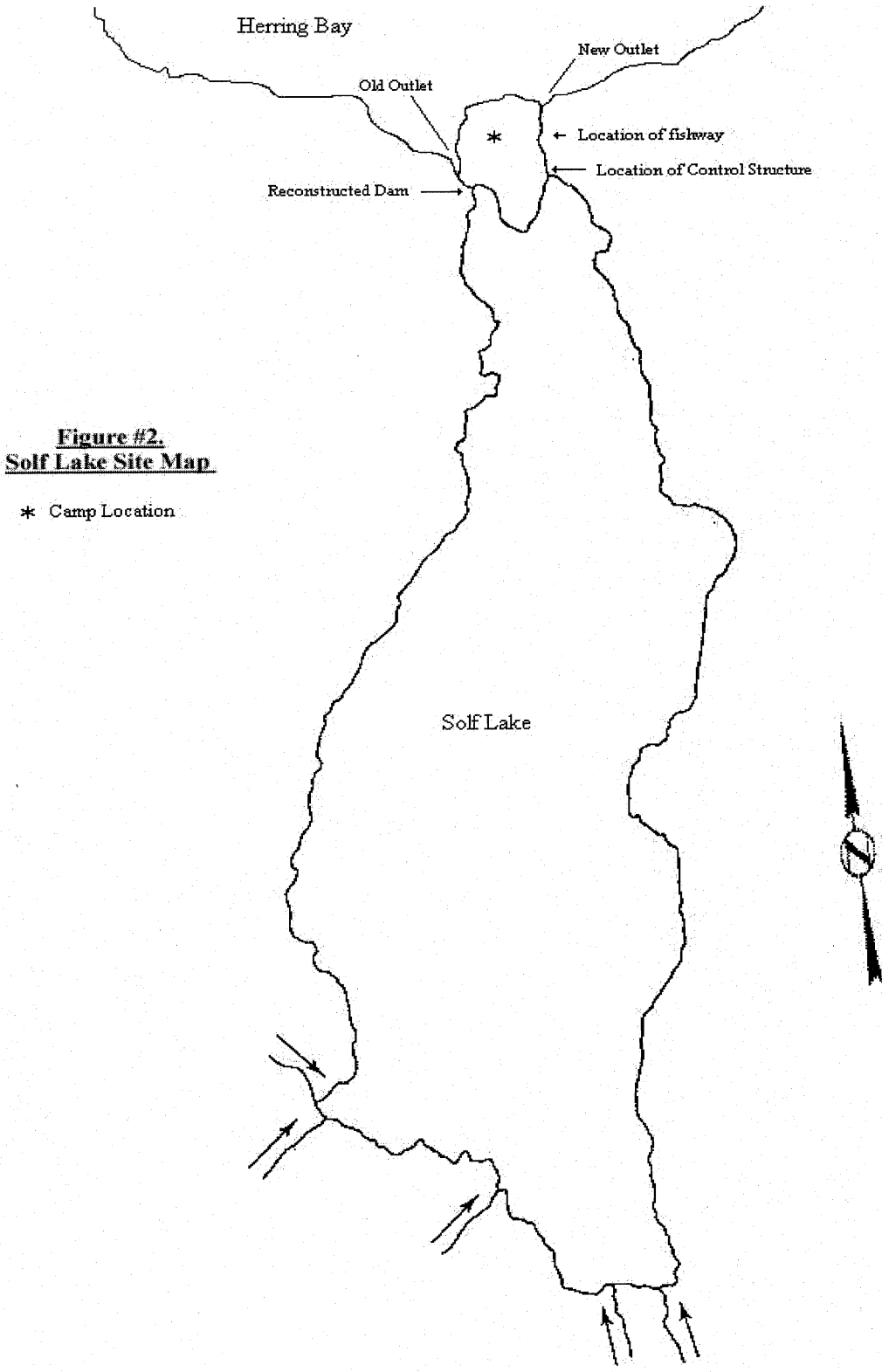


Figure #2.
Solf Lake Site Map

* Camp Location

Figure 3. Macrozooplankton Composition by Density.

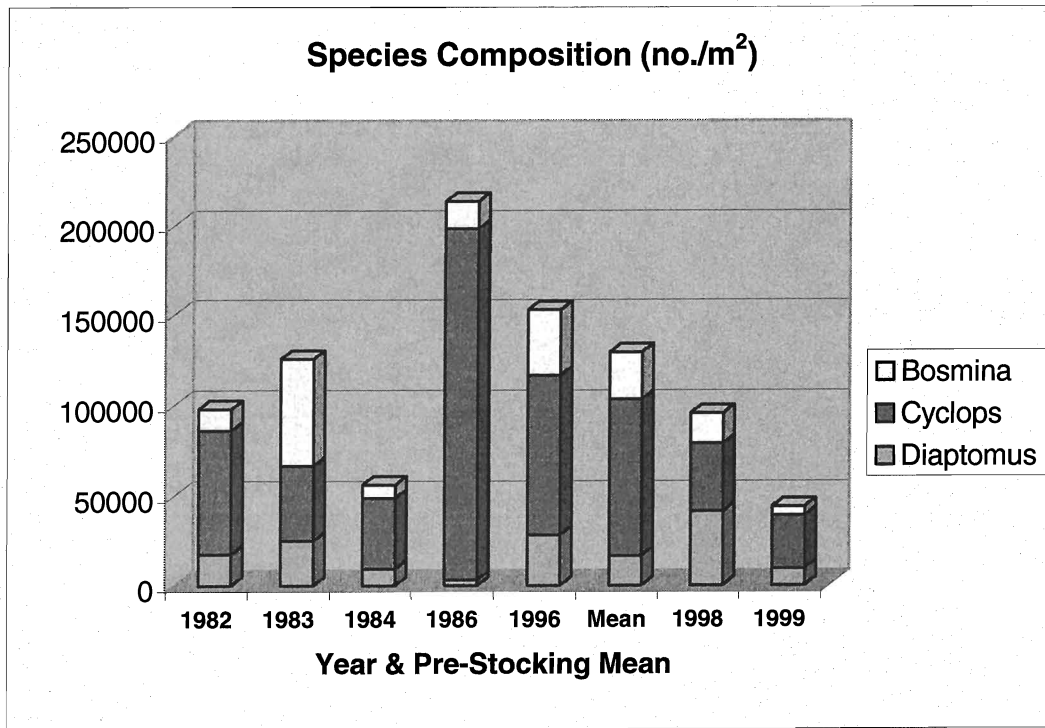
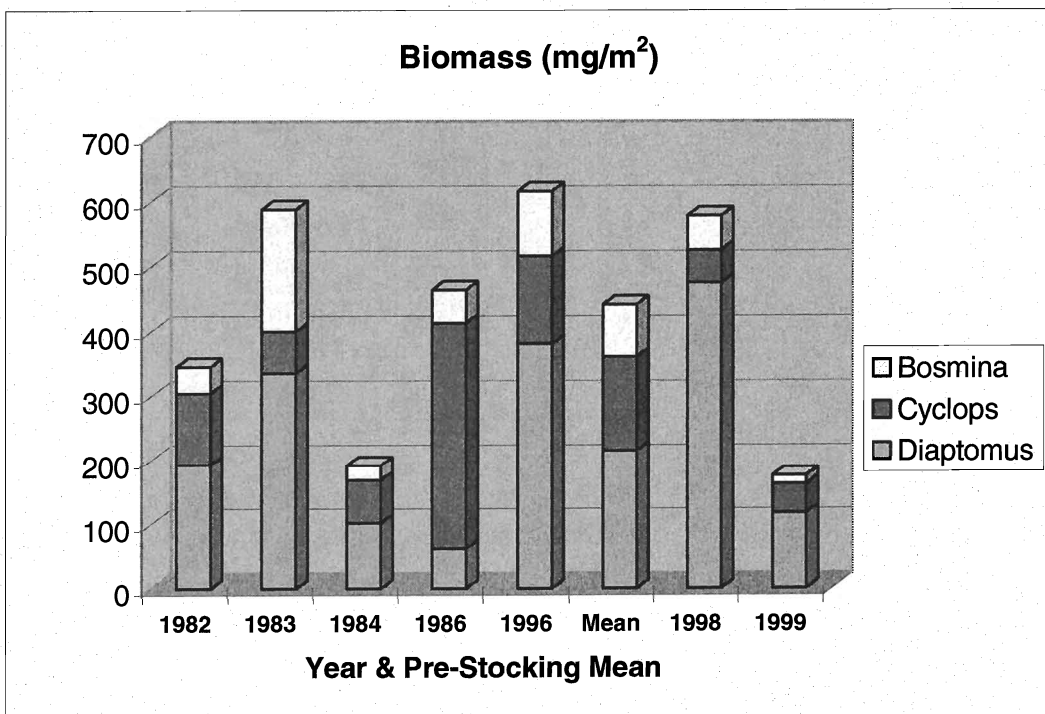


Figure 4. Macrozooplankton Biomass (mg/m²).



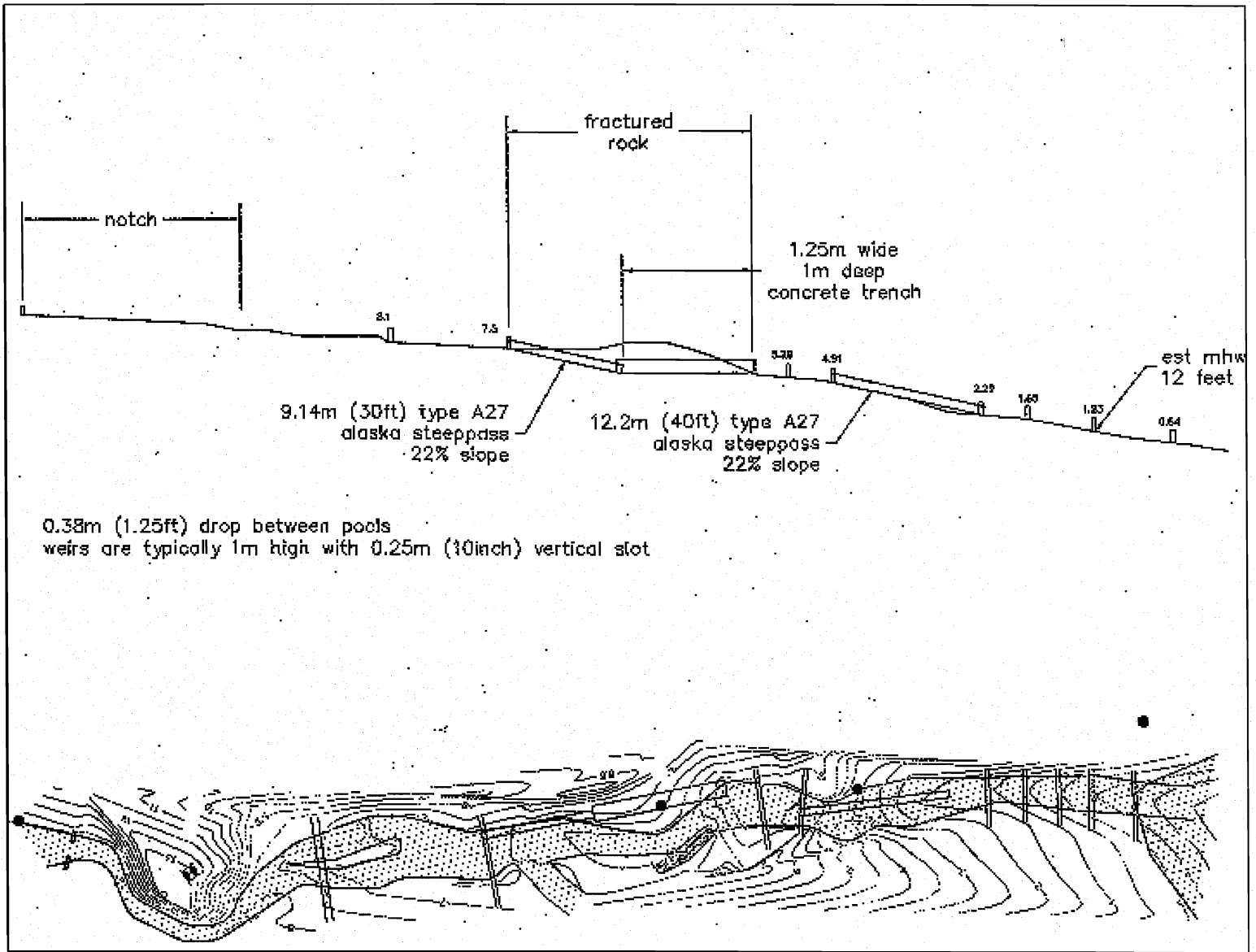


Figure 5. Plan View Solf Fishway.