EVOS ANNUAL PROJECT REPORT

Project Number: 040703A and 040703B

Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems

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Time Period Covered by Report: October 1, 2005 – September 30, 2006

Date of Report: September 15, 2006

1. **Summary of Work Performed**: This was the third and final year of the project. Prior to the sampling season, the PIs from the University of Alaska Fairbanks (UAF) and the Alaska Department of Fish and Game (ADF&G) met in Anchorage to discuss interim results and any adjustments needed for sampling during the 2006 field season. As in the two previous sampling seasons, the Alaska Department of Fish and Game conducted the smolt enumeration projects at Karluk and Spiridon Lakes. Also, an intensive limnology sampling plan was implemented. In 2006, ice-out on Karluk Lake and salmon runs in the study area were unusually late and the sampling schedule was adjusted in season. The last sampling date is scheduled for October 18 to ensure that measurements reflect post-spawning conditions. The organization of this report follows the six components of this project: (1) smolt studies, (2) basic limnology sampling, (3) lake productivity measurements, (4) periphyton and phytoplankton sampling, (5) terrestrial sampling, and (6) stable isotope sampling and analysis.

   Smolt Studies

   Smolt studies were conducted at Karluk and Spiridon Lakes (Figures 1 and 2). At Karluk Lake, smolt were collected and counted using a Canadian fan trap located approximately 2 km downstream from the lake. The site was chosen to coincide with the same project location used from 1999-2005 (ADF&G 2005). Project deployment in 2006 was later than in previous years due to late ice cover on the lake. The trap was deployed on May 16, 2006 (only three days after ice-out), and operated until sockeye salmon smolt counts declined at the end of June. The trap was pulled from the water on 27 June, 2006. A total of 68,227 smolt were enumerated from the trap. Four mark-recapture experiments were performed to estimate the capture probability of the trap (Sagalkin and Honnold 2003). Mean capture probability of the trap was 5.7%, ranging from a low of 3.6% to a high of 7.1%. The total outmigration estimate range was 965,308 to 1,381,196 sockeye salmon smolt (Figure 3). Smolt were sampled daily (40/day, 5 days per week) for age (scale samples), weight, and length (AWL). Length, weight and scale samples were taken from a total of 534 sockeye

smolt. The 2006 smolt age composition in the total outmigration was 33.5% age-2 and 65.9% age-3. The age 3-smolt component was unusually high; only once, in 1964, was a higher age 3-smolt percentage reported (ADF&G, unpublished data). The age 2-smolt had an average weight of 6.3g and an average length of 92.6 mm, and the age 3-smolt had an average weight of 7.9 g and an average length of 101.8 mm. The unusually high percentage of age 3-smolt in 2006 coincides with an unprecedented low zooplankton biomass in 2005. Smolt outmigration can be delayed when growth conditions in the lake are poor (Barnaby, 1944). All scale sample data have been edited and entered into the ADF&G database.

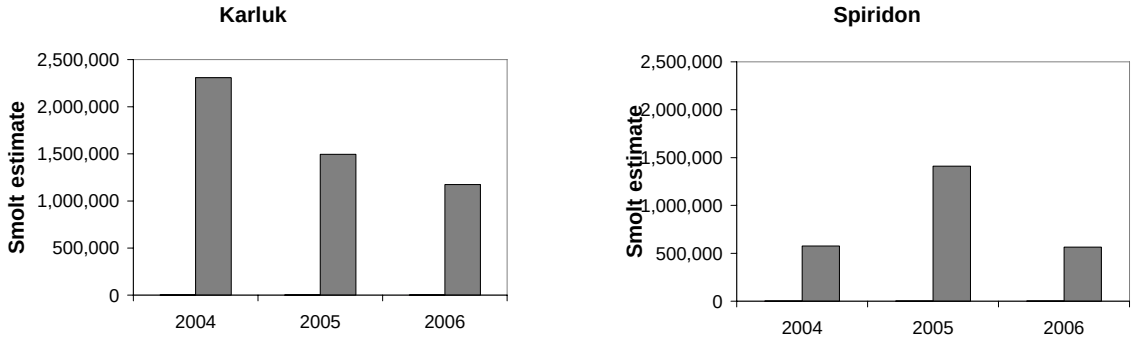

Figure 3.-Karluk and Spiridon Lake smolt outmigration estimates 2004-2006.

The smolt project at Spiridon Lake was funded by the Kodiak Regional Aquaculture Association (KRAA). Sockeye smolt were collected at Spiridon using a waterfall bypass system (ADF&G 2005). The bypass system consists of a smolt weir, two Canadian fan traps, two dewatering tanks, one tank for enumeration and sampling, and a pipeline. The system captures 100% of the emigrating smolt. The bypass system was operational on May 20, 2006 and was operated through July 3, 2006. A total of 564,959 smolt were enumerated through the pipeline (Figure 3). During periods of high emigration, numbers are estimated using timed-counts. Smolt were sampled daily (40/day, 5 days per week) for age (scale samples), weight, and length (AWL). Length, weight and scale samples were taken from a total of 990 sockeye smolt. The smolt outmigration was composed of 83.2% age 1-smolt and 16.8% age 2-smolt. The age 1-smolt had an average weight of 9.7g and an average length of 106.7 mm, and the age 2-smolt had an average weight of 32.6 g and an average length of 157.7 mm. These averages were similar to the previous years' averages (2003-2005). The large size and high age 1-smolt percentage in the outmigration indicate excellent rearing conditions in Spiridon Lake (Honnold, 1997). However, this is in disagreement with exceptionally low zooplankton biomass in 2006 Spiridon Lake samples. A preliminary investigation of smolt stomach contents indicated large amounts of insects in Spiridon Lake smolt.

Smolt were collected from Karluk and Spiridon Lakes and sent to the University of Alaska Fairbanks for isotope analysis.

Basic Limnology

Tentative sampling dates were chosen preseason to coincide with (1) pre-lake stratification; (2) lake stratification and pre-sockeye salmon spawning; and (3) the influx of carcass derived nutrients. Specific sample dates were modified in-season and were weather dependent, but the general schedule structure was maintained. Sampling was conducted at two river stations and two lake stations from each lake. However, in 2006 zooplankton sampling at river stations was abandoned because of the difficulty and cost associated with obtaining samples in the shallow river water, and limited information gained from samples obtained in 2005.

In 2006, we tried to get the first samples directly after ice-out. Because of the late spring, this was not until May 16 and even then, only one of the two Stations could be sampled because of remnant ice cover. The first productivity measurements were conducted on May 23 and the remaining stations were sampled then. Further sampling was conducted on June 5, June 27 and August 2. Due to high winds at Karluk Lake, the August 14 sampling was interrupted and the sampling schedule was then changed to August 21 and to two week intervals thereafter (September 5, September 19 and October 16). This schedule change was made because biological processes appeared to be approximately two weeks later than in average years.

Water samples were collected at 1, 5, 10, 15, 20, 25, 30, 35, and 50 m at both Spiridon stations and Karluk station 3. The maximum depth at Karluk station 2 is 37 m. At lake stations, light attenuation was measured using a secchi disk and a photometer. Surface water was collected at all river stations. Dissolved oxygen (DO) and light were not measured at river stations due to shallow depth. In May, June and July, a continuous water column profile of conductivity, temperature, depth and fluorescence was obtained at all lake stations using a SBE19 Seacat CTD. The CTD was also placed in the shallow water at the river stations for approximately 5 minutes.

We have completed analyzing DO, temperature, light attenuation, pH, and alkalinity through August 1. A more complete analysis with the remaining 2006 data will be provided in the final report. As in previous years, total Kjeldahl nitrogen (TKN) samples will be sent to the analytical laboratory at the University in South Dakota. Zooplankton samples from Spiridon Lake were analyzed through August and the remaining samples are being processed as time allows (density, biomass and size). Further nutrient sample processing is scheduled shortly after the last sampling using the University of Alaska Fairbanks auto-analyzer. Chlorophyll samples will be run at the end of the season in one batch at UAF following our standard procedures.

Temperatures

Spring lake temperatures in 2006 were lower than in 2004 and 2005; both lakes were still completely mixed in May (Figure 4). Likewise, both lakes began to stratify in June and showed further signs of thermocline development in July. Temperature was similar between stations and lakes. To examine the temporal changes in Karluk and

Spiridon Lakes' temperatures between May and October and evaluate interannual variation, historical temperature data were arranged and graphed by month.

Spiridon Lake is a dimictic system. In 2006 in May, the lake was well mixed, homoiothermic and between 3 and 4 ºC (Figure 4). On June 5, the surface water had warmed to 7.5 ºC and stratification was beginning. However, bottom temperatures were at 4 ºC compared to 5 ºC in 2004 and 2005. Stratification began in June and continued through August, when maximum surface temperatures were established. In comparison to the historical data (1993 -2003), Spiridon Lake temperatures in May and June were average in 2004 and 2005, but below average in 2006. In July and August, lake temperatures in 2004 were above average, in 2005 they were average and in 2006 they were below average. There are no apparent differences between Stations 1 and 2.

Karluk Lake is also a dimictic system. In May, the lake was well mixed, homoiotherm and between 3 and 5 ºC. If higher temperatures were observed, they were only at the very surface. Stratification began in June; samples taken in early June often had only slightly higher temperatures at the surface to 5m. Surface samples taken in mid or late June had temperatures between 8 and 10 ºC and the thermocline was between 10 and 20 meter. The onset of stratification varied by about two weeks; for example in 1999, the lake was still not beginning to warm at the surface on June 16. In all years, bottom temperatures were about 5 ºC from June until stratification dissolved in September and October. The surface layer warmed to 12 to16 ºC in July and August and cooled back down during September. At this time, mixing caused the surface layer to cool, while the bottom layer became warmer. In September of 2003 the thermocline was at 30 meter, but in all other years, stratification dissolved and the lake was mixed to about 40 meters with temperatures between 7 and 11 ºC in the top 30 meters and around 6 ºC near the bottom.

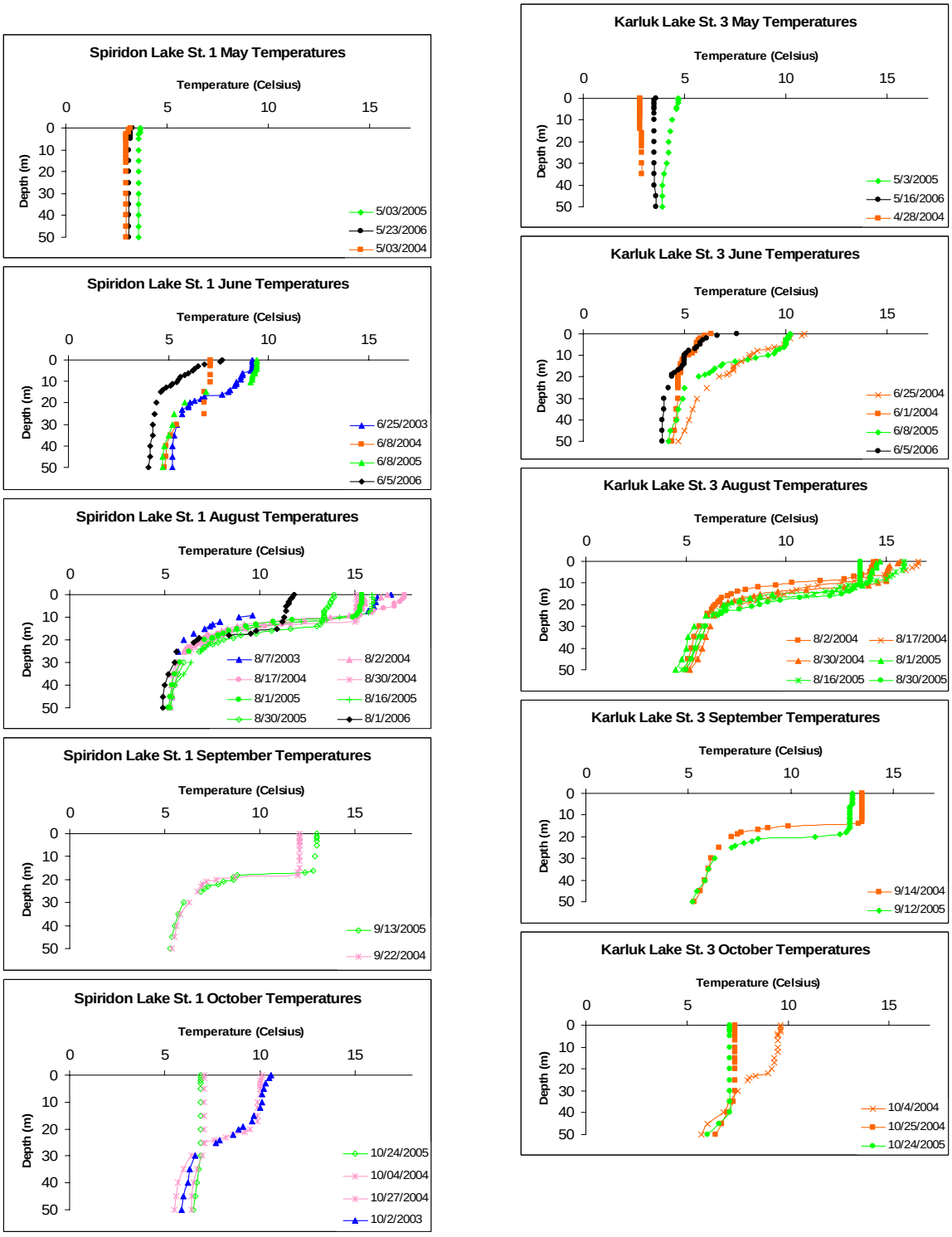

Figure 4. Temperatures at Spiridon Lake Station 1 and Karluk Lake Station 3 for May, June, August, September and October 2004-2006.

pH and Alkalinity

In 2006, pH ranged from a low of 7.1 to a high of 7.4 among all stations and all depths between both lakes. From May to August there was little variation in pH throughout the water column at all lake stations in both lakes. The pH at the river station 5 at Karluk was only slightly lower than at the lake stations.

Similarly, alkalinity had a very limited range (20.5 to 23 μg/L) among all lake stations and depths, between both lakes.

Total Phosphorus (TP)

Water samples from the surface and the deepest water depth were analyzed for TP content. So far, data are available for May, early June and late June. Laboratory analyses are ongoing as time permits.

In May, TP at Karluk Lake was between 7 and 9 ug/L. At Spiridon Lake, both surface and bottom TP were only about one-third to half of that concentration (2 to 4 ug/L).

Silicon

In 2006, Silicon analysis at the Near Island laboratory was discontinued, because the auto-analyzer, utilized for total filterable phosphate (TFP) and TKN analysis also measures Silicon concentration. Data will be available after analyses are complete in November 2006.

Zooplankton

All 2004 and 2005 zooplankton samples have been analyzed. 2006 samples are processed as time allows during the season. After 2005, the attempt to collect zooplankton samples at river stations was abandoned.

Analysis of 2006 Spiridon Lake zooplankton samples indicated unusually low biomass compared to previous years. It was also noted that the Cladoceran *Holopedium* had an unusually high density. Processing and analysis of these and all Karluk Lake zooplankton samples are ongoing.

Productivity Samples

Samples for productivity measurements were obtained during all the 2006 sampling trips, except for the first partial trip. Productivity samples are being determined from samples at three light depths (surface, 30%, 1%) from all the lake stations and at the surface from the river station. Chlorophyll and nutrient samples are collected at all productivity depths, in addition to the regular sampling intervals. Mass spectrometric analysis has been completed on the 2004 and 2005 samples, and revealed that our

sampling and incubation protocols are adequate for quality results. Karluk Lake productivity is higher during all sampling periods (by up to a factor of ~2 to 3). The data also suggest a different seasonal pattern, with Karluk having an additional peak in productivity in late August. Our preliminary productivity data is consistent with productivity inferred from the chlorophyll and TP data.

Periphyton and Phytoplankton Samples

Water samples have been collected from Karluk station 2 and Spiridon station 1 for phytoplankton analysis. For 2006, samples are being collected from our limnology sampling depths and preserved with Lugols. Phytoplankton data from the previous year's sampling demonstrated that algal biomass was consistently at least two to four times as great in Karluk Lake as in Spiridon Lake.

Algal composition at a coarse taxonomic level shows a high degree of similarity in the seasonal dynamics between Karluk and Spiridon lakes. Overall, the phytoplankton assemblages of both lakes are dominated by diatoms, chrysophytes and pyrrhophytes (i.e. dinoflagellates). The most dominant group, the diatoms, are generally considered to be a high quality food for cladocerans. At a species level, however, we see a strong distinction between Spiridon and Karluk lakes. *Cyclotella* cf. *bodanica*, which is common in oligotrophic to mesotrophic systems dominates (by biomass) the spring assemblage of Karluk Lake whereas *Asterionella formosa* (also an oligo- to mesotrophic indicator) dominates the spring assemblage at Spiridon Lake. The difference in dominant diatoms between these two lakes may be explained by resource competition theory, as Karluk Lake has a lower Si:P ratio than Spiridon. *Asterionella formosa* has been shown to be a good competitor for phosphorus and whereas a closely related species to *Cyclotella* cf. *bodanica* (i.e. *Cyclotella meneghiana*) has been shown to be a good competitor for silica. Expressing the phytoplankton data as cell densities, *Stephanodiscus parvus* is the numerically dominant diatom species in Karluk (instead of *Cyclotella* cf. *bodanica* which is biomass dominant), but like *Cyclotella, Stephanodiscus* is a good competitor for silica.

Additionally, bottom substrate was or is being collected from fixed quadrats for periphyton analysis at both river stations in both lakes during 2004 - 2006. Analysis of these samples is in progress to determine both periphyton biomass and isotopic composition, and their seasonal signatures. Preliminary observations indicate much higher biomass in Karluk Lake, and significant seasonal changes in both lakes, with significantly enriched $\delta^{13}C$ and $\delta^{15}N$. This years samples will be completed "in batch" for consistency of results following completion of collection of the 2006 samples.

Terrestrial Sampling

Pilot studies of terrestrial samples are underway. Due to time considerations and costs, routine sample collection is impossible during our sampling trips. We were

often able to collect samples of opportunity, such as brown bear fur and bird feathers. Brown bear samples have been obtained through collaboration with ADF&G biologist, Larry VanDaele, and analysis of claws is underway to determine seasonal changes in diet. Terrestrial plant and soil samples have been analyzed for stable isotopes, that were obtained from a previous year, and reveal that both soils and plants are enriched in the Karluk samples. However, we observe a sharp decline in $\delta^{15}N$ away from spawning streams, with background values found at ~100 m from the streams.

Stable Isotope Sampling and Analysis

Samples have been obtained from all sampling trips thus far for POM (particulate organic matter - phytoplankton) and zooplankton. POM samples were obtained from filtering water taken at all depths at each lake station, and at the river station. Zooplankton samples were obtained from vertical zooplankton hauls at all lake stations, and one Karluk River station during 2004. Sockeye smolt samples were obtained for most years from both lakes through the smolt projects. Any gaps are filled from analysis of archived scale samples. Adult sockeye will be sampled from scale collections obtained at the Karluk weir. Collection of terrestrial samples was described above. All samples are frozen until analysis, and are processed and run in a single batch at the end of the sampling season to ensure maximum consistency. Thus most of the data for 2004 and 2005 is complete.

Briefly, the 2004 and 2005 isotope data is summarized below. The data from the river stations reveal significant differences between lakes. The mean values in $\delta^{15}N$ in riverine POM for Spiridon are about 4 ‰ with little seasonal variability. However in Karluk, the $\delta^{15}N$ in riverine POM ranges from 6-10, and has peaks in both the early spring and in mid-summer. The mid-summer peak appears to correspond with the first run of spawning sockeye. The average lake values for Karluk Lake POM ($\delta^{15}N$ ~10 ‰) are higher than the mean for Spiridon Lake ($\delta^{15}N$ ~6 ‰). The $\delta^{15}N$ of pelagic POM in Karluk has large seasonal variability with peaks in the spring and late summer. The late summer peak could reflect a lag of transfer of salmon-derived nutrients that we observed earlier in the year in the riverine samples. Like POM, the average $\delta^{15}N$ values of zooplankton and sockeye smolt are higher in Karluk Lake than Spiridon Lake, by more than 4 ‰. For example, the mean $\delta^{15}N$ value of smolt from Karluk Lake is ~14-15 ‰, and ~10 ‰ in Spiridon Lake.

Literature Cited

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2. **Future Work**: Work planned for the upcoming year should not be substantially different from the proposal. Analyses of the water samples is more time consuming than anticipated and will require more time to complete. However, it appears that the budget may be sufficient for this fiscal year to perform all necessary tasks. We will complete sampling in October and process the majority of samples in November. Concurrent with the final sample processing, the PIs will be synthesizing data summaries and work on the final report. In addition, publications and presentations will be discussed and prepared.

3. **Coordination/Collaboration**: The field sampling for this project involves extensive coordination and collaboration. In April, the project PI's from the University of Alaska Fairbanks (Bruce Finney and Dean Stockwell) and the ADF&G in Kodiak (Steven Honnold and Switgard Duesterloh) and the Near Island Laboratory biologist Steve Thomsen held a one-day project workshop in Anchorage to discuss interim progress and coordinate the upcoming season.

   Smolt age data from the Spiridon smolt project have been collected and are in the process of being analyzed. Flights to Spiridon Lake were shared when possible to reduce costs. At the Karluk escapement weir total counts for the early and late sockeye salmon runs were collected and data were entered into the ADF&G database. Adult catch sampling has taken place and scales are currently being aged. Aged scales will be used in conjunction with age-marker analysis to reconstruct the Karluk Lake sockeye salmon run. Flights to re-supply the Karluk smolt research project were shared with the Frazer Lake fish pass project to reduce costs. We will integrate the

results of this project with the paleoecological work of the EVOS/GEM project "Reconstructing Sockeye Populations in the Gulf of Alaska over the last Several Thousand Years (D. Mann, B.Finney, PIs).

4. **Community Involvement/TEK & Resource Management Applications**: The ADF&G presented the project design to the Kodiak National Wildlife Refuge Staff, the Kodiak Regional Salmon Planning Team, and the U.S. Coast Guard for review and comment. The results of these consultations were considered prior to finalizing the operational plans and implementing the field project. Data collected will also be shared with these groups through copies of this annual report. The ADF&G gave preference to local residents, including qualified residents of the Villages of Karluk, when hiring sampling crews. The study sites were located in areas of high recreational use and frequent interaction with the public occurred. Employees were encouraged to provide accurate information to the public regarding the goals and objectives of the project. The results from this project have management implications regarding the effect to which fisheries may influence the overall productivity of watersheds. The results from this project will provide information critical in developing a monitoring program to detect annual changes in levels of marine nutrients in watersheds.

5. **Information Transfer**: This project is currently in the final year of gathering data. Preliminary data were presented at the 2005 Marine Science Symposium in Anchorage, where both, the University of Alaska Fairbanks and the ADF&G Kodiak presented posters. A seminar on project results was presented as part of the UAF Fisheries Seminar Series during the Spring semester 2006. Switgard Duesterloh will present a project summary at the annual AFS chapter meeting in Fairbanks, November 2006.

6. **Budget**: In 2006, flight costs were slightly higher than expected because of the late ice-out in the spring, which made it necessary to collect the first samples on two different days. Also, in August, a sudden change in weather interrupted a sampling trip. However, we saved some money by training Switgard Duesterloh (ADF&G Kodiak) to conduct the productivity experiments, thus saving the travel cost for a technician from Fairbanks to Kodiak. This money was used to fill in the shortage in the flight money for conducting the late season sampling trips.

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Project Web Site Address:
www.cf.adfg.state.ak.us/region4/finfish/salmon/kodiak/gem_res.php

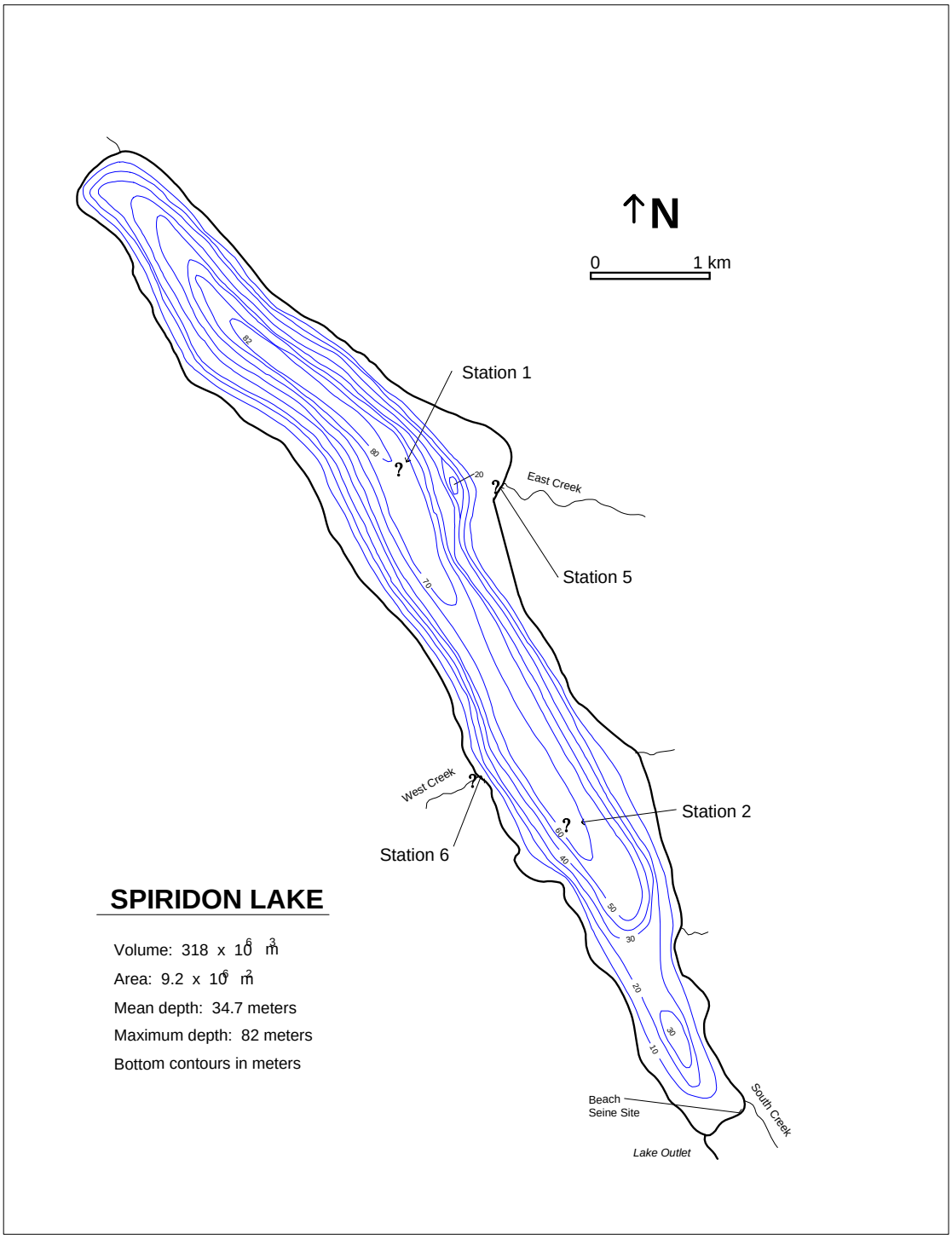

Figure 1. Bathymetric map of Spiridon Lake indicating sample stations.

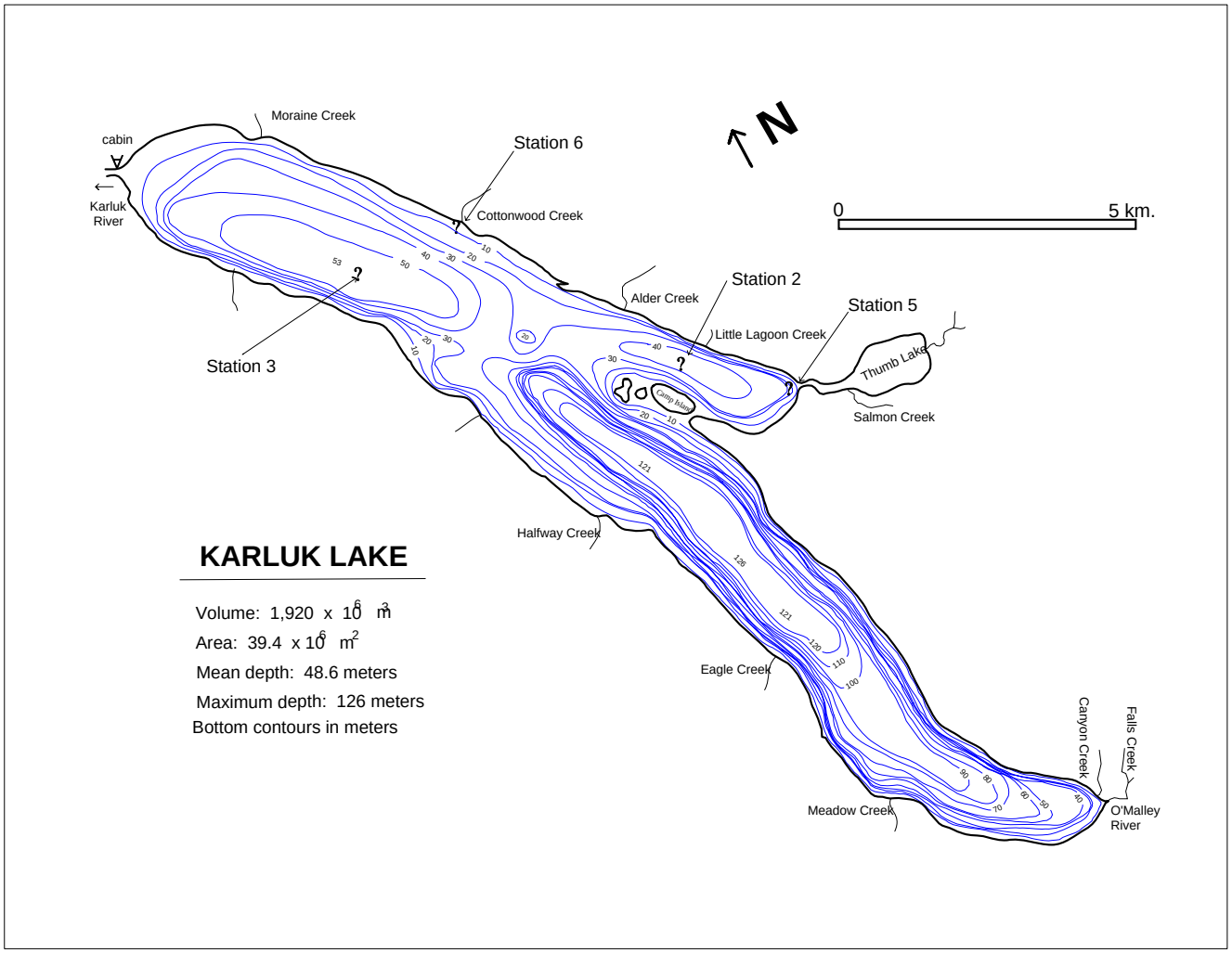

Figure 2. Bathymetric map of Karluk Lake indicating sample stations.