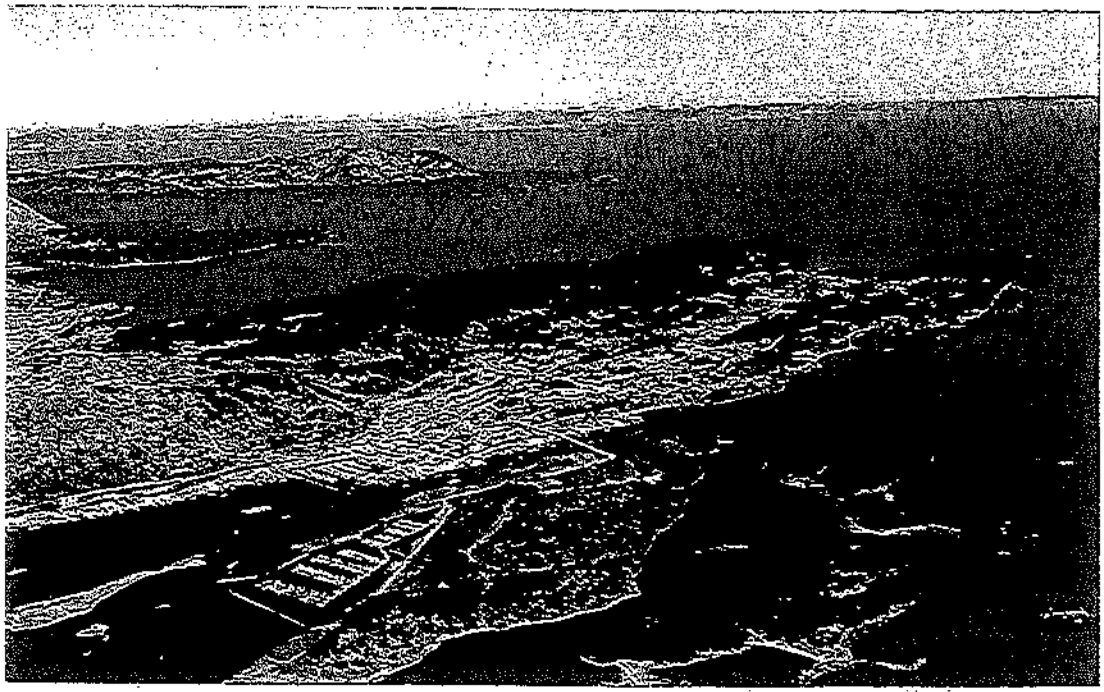
Technical Report,

Kodiak Urban Lakes Project



BY
CLEAN LAKES FOR KODIAK

A CITIZEN'S SUBCOMMITTEE OF

THE
KODIAK SOIL AND WATER CONSERVATION DISTRICT

JUNE 2, 1997

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Kodiak Urban Lakes Project

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by
the Clean Lakes for Kodiak Group

a subcommittee of
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EXECUTIVE SUMMARY

I. BACKGROUND

The Clean Lakes for Kodiak Group (CLK) was formed in 1991 as a subcommittee of the Kodiak Soil and Water Conservation District. The group came into being due to the interest of Kodiak Island residents who were concerned about maintaining healthy urban lakes.

Most of the population of Kodiak resides within the watersheds which feed the urban lakes. The lakes contribute fish for recreational use; opportunities for boating, swimming, ice skating, and snow mobiling; habitat for fish, otters, beavers, muskrats and birds; and scenic beauty.

Human activities have the potential to degrade the water quality of the lakes through siltation, contamination from salts, petroleum products, fertilizer, sewage, and other chemicals. Changes in land use from conservation and natural use to residential, business, commercial, and industrial uses have affected the appearance and water quality of the watersheds and lakes. CLK members wanted to: 1) document the current status of the lakes and watersheds; 2) identify problem areas; and 3) propose solutions to correct existing problems or to prevent future problems from occurring.

Clean Lakes for Kodiak members selected the following eight urban lakes for study:

1. Upper Horseshoe Lake
2. Lower Horseshoe Lake
3. Beaver Lake
4. Dark Lake
5. Island Lake
6. Lilly Lake
7. Potato Patch Lake
8. Mission Lake

Gertrude Lake in Fort Abercrombie State Park was selected as an undeveloped reference lake.

Potatopatch and Mission Lakes were given emphasis because the development in their watersheds is greater than the development in the watersheds of the other six lakes.

II. FUNDING AND ACTIVITIES

1. A proposal for funding to conduct an assessment and feasibility study was developed in 1991 and submitted by the Kodiak Soil and Water Conservation District to the Soil Conservation Service (now the Natural Resources Conservation Service) in January 1992.

2. Funding to conduct the assessment and feasibility study was made available during the summer of 1994.
3. A part-time environmental engineer was hired and a Plan of Work developed and approved during 1994.
4. Biological surveys and water testing began in January 1995 and continued into November 1995.
5. Additional focussed studies and data analysis continued during 1996.

Agencies involved in the assessment work included:

1. City of Kodiak's water testing laboratory,
2. Alaska Department of Fish and Game Commercial Fisheries Development Branch, and
3. Kodiak Island High School fisheries class.

III. ASSESSMENT WORK

Each of the eight urban lakes was tested during 1995 to assess the following parameters:

1. WATER QUALITY - 160 samples total - lab work donated by the City of Kodiak. Each sample was analyzed for the following:
   a. Fecal coliform bacteria (not a problem in itself, but an indicator of potential sewage contamination)
   b. pH (to determine acid/base balance)
   c. Total dissolved solids (salts) and total suspended solids (silt)
   d. Total iron concentration
   e. Turbidity and True Color
   f. Conductivity

2. INDEX OF FISH HEALTH AND ABUNDANCE - "minnow traps" were set in the lakes and streams in the spring and fall of 1995 with the assistance of students from Kodiak Island High School. The following data were collected on silver salmon, rainbow trout, dolly varden trout, and sticklebacks:
   a. Catch per trap
   b. Length
   c. Weight
   d. Age
   e. Condition Factor

3. TEMPERATURE AND OXYGEN PROFILES were collected during 1995 at approximate six week intervals for a total of six measurements for each lake using equipment belonging to the Alaska Department of Fish and Game.

4. LIMNOLOGICAL SAMPLING was done during 1995 on five occasions at the deepest point in each lake. These samples were analyzed at Alaska Department of Fish and Game's limnological laboratory in Soldotna. One additional sample was collected from each lake in late July 1996, and analyzed at the limno lab for the same parameters.

The limnological analyses generated information on

a. Nutrient levels for major and minor nutrients (N, P, Si)
b. Dissolved ion concentrations (Mg, Ca, Fe)
c. phyto- and zooplankton abundance and speciation
d. Chlorophyll, phaeophytin, and organic carbon concentrations
e. conductivity, pH, and alkalinity
f. turbidity, true color, total solids, dissolved solids

5. OTHER ACTIVITIES

a. Watershed maps were developed, land use percentages were estimated.
b. Aquatic weed species and abundance surveys were done.
c. Lake depth surveys were done, bathymetric maps were drawn.
d. Elevation surveys were performed at Mission and Potatopatch Lakes to determine when seawater can backflow into the lakes at high tide.
e. Salinity / Oxygen / Temperature measurements were performed through the ice at Mission Lake in March 1996 to evaluate the effects of seawater intrusion.
f. The Mission Lake outlet structure / tide gate was evaluated, and repair / replacement options and costs were evaluated.
g. Water samples from the Baranof Park storm sewer were collected in July 1996 and analyzed for toxic metals, nutrients, volatile organics, and semi-volatiles.
h. Intense water sampling for fecal coliform bacteria and turbidity analyses was conducted in September 1996 in the Island Lake watershed to localize previously detected "hot spots".
i. Recent and historic aerial photographs of the study area were collected to document changes in the watersheds and lakes.
j. Taped interviews of local pioneers were conducted to learn about the history of Kodiak's development and effects on the lakes, streams, and fish runs.

IV. ASSESSMENT CONCLUSIONS

By analyzing and surveying the water, aquatic plants, plankton, fish, topography, and land uses within the watersheds of our urban lakes, we have established a database which documents the status of the lakes in 1995 and 1996.

Due to our relatively high average rainfall (68 inches/yr) and the relatively small volume of our urban lakes, flushing is fairly rapid (hydraulic retention time of 4 to 75 days). Water quality is by and large quite good. Problems such as foul odors, fish kills due to low oxygen, and prolific growth of noxious blue-green algae which afflict many urban lakes in the States have not been observed here. During the 1960s and '70s, failed septic systems around several lakes resulted in very high fecal coliform counts and poor water quality. Installation of sanitary sewer systems corrected this situation, and current water quality is much improved.

Despite the relative "good health" of the lakes, we did identify some problem areas, and some areas of concern for the future. Elevated total phosphorus and turbidity was seen in several lakes, and seemed to correlate with the percentage of upstream watershed in residential or commercial use. High levels of dissolved iron from groundwater appeared to be responsible for elevated color and turbidity in other lakes. Some repeated but sporadic high fecal coliform counts were identified in creeks, but the sources of this contamination were not pinpointed. Seawater flow through the tidegate into Mission Lake was identified as a possible threat to the freshwater ecosystem there.

Conclusions and concerns are summarized below for each of the three watersheds containing the eight urban lakes in the study area.

1. ISLAND LAKE WATERSHED - starting from upstream, this system is composed of Horseshoe Lakes combined with the flow from Lower Reservoir, Beaver Lake, Dark Lake and Island Lake, which feeds into the ocean at Mill Bay.

   STATUS: Basically healthy. More than 70% of the watershed remains wooded and undeveloped.

   a. STOCKED SILVER SALMON: Present throughout the system. The average autumn size of age-0 fish was smaller than in Potatopatch and Mission Lake, probably due to lower primary productivity of the lakes. Spawning adult silver salmon continue to return, although upstream migration is impeded by a small waterfall downstream of Island Lake.
   b. SILTATION from the unpaved section of Selief Lane causes very high turbidity in Lower Horseshoe Lake and elevated turbidity in lakes downstream. This siltation results in elevated total phosphorus levels, may significantly reduce salmon production, and is visually unappealing.
   c. OXYGEN: Upper Horseshoe Lake has little inflow, and is very shallow. Oxygen is depleted under ice cover. The good news is that it warms rapidly in the spring, which triggers an early zooplankton bloom which may provide feed for silver salmon juveniles. Other lakes in the system maintain high oxygen levels through the year.
   d. pH: Remains steady at 6.5 to 7.5 year round.
   e. FECAL BACTERIA: High counts were found sporadically at several points in the Island Lake watershed, including the swimming beach in Island Lake and points upstream

of Beaver Lake. The counts could merely reflect the presence of animals, but further work should continue to isolate the source.

f. AESTHETIC CONSIDERATIONS: Upper Horseshoe Lake is extremely shallow, choked with weeds, and visually unappealing to the owner and surrounding neighbors.

g. OTHER: Fresh water mussels grow in Beaver Lake, Dark Lake, and Island Lake, and they may be partially responsible for the progressive downstream clearing of the turbid water.

2. POTATO PATCH LAKE WATERSHED including LILLY LAKE:

LILLY LAKE STATUS: Basically healthy, water clarity is good.

a. STOCKED RAINBOW TROUT: abundance and condition good, reportedly hard to catch on rod and reel.

b. SILTATION: Not an apparent problem.

c. OXYGEN LEVELS: Lilly Lake oxygen levels depleted under ice due to long retention time.

d. pH: Remains steady at 6.4 to 7.0 year round.

e. FECAL BACTERIA: Outlet never above 70 coliforms per 100 ml. Inlet creek counts low to moderate.

f. OTHER POLLUTANTS: Several reports of oil slicks and sheens entering the lake. ADEC identified heating oil spills as probable source.

g. AESTHETIC CONSIDERATIONS: Commercial trash, including empty drums, has accumulated on some lots next to Lilly Lake.

POTATOPATCH LAKE STATUS: Biologically healthy, but it receives more urban stormwater runoff than the Island Lake system. Potatopatch Lake has the highest nutrient levels of the urban lakes, and is very productive and very turbid.

a. STOCKED SILVER SALMON: 1995 abundance and condition good. Fall 1995 average length for age-0 fish was the highest of the urban lakes. Not stocked in 1996.

b. SILTATION: Shallow depth, mucky bottom, and inflow with high turbidity and iron concentration combine to produce high turbidity. This is more severe than in other lakes, including Mission Lake.

c. OXYGEN LEVELS: Potatopatch Lake remained near saturation year-round.

d. pH: Potatopatch Lake had greatly elevated pH levels June through August. Most probably the result of carbon limited plant growth and seawater influx.

e. FECAL BACTERIA: High counts on several occasions. Cause not yet isolated.

f. OTHER POLLUTANTS: Several reports of suds and oil slicks entering the lakes. Storm sewer water from the Baranof Park area draining into Potatopatch lake was very high in iron, fecals, color; low in dissolved and suspended solids. Diversion of the Baranof Park storm sewer water directly to the ocean might substantially improve lake water clarity.

g. AESTHETIC CONSIDERATIONS: City land adjacent to the SW tributary to Potatopatch Lake was a former dump site for snow. Is now unsightly bare, packed earth, and could be a candidate for landscaping and other improvements.

3. MISSION LAKE WATERSHED:

STATUS: Mission Lake has high nutrient levels and high productivity. Stocked silver salmon fingerlings grew rapidly in Mission Lake, although our catch rates were less than in Potatopatch Lake and the Island Lake system. Seawater enters the lake on frequent high tides through a worn-out tide gate. Aquatic plants have grown profusely during the summer in recent years, although densities reportedly decreased for unknown reasons during 1996.

a. SILVER SALMON:
   1) Relatively fewer silver salmon were caught in minnow traps in 1995 compared with other lakes for unknown reasons.
   2) Outmigrating salmon smolts are reportedly subject to heavy predation if they exit the tide gate at low tide and are discharged into a narrow creek high on the beach.

b. SILTATION: Bottom sediments are soft, but are average turbidity is slightly less than in Potatopatch Lake. Weeds may cut circulation and help silt settle.

c. OXYGEN LEVELS: Generally near saturation. Decomposition of aquatic macrophytes (mainly pondweeds) in the fall consumes oxygen.

d. pH: Greatly elevated pH levels June through August, more so than in Potatopatch Lake. Most probably the result of carbon-limited plant growth and seawater influx.

e. FECAL BACTERIA: High fecal bacteria counts when raw sewage entered the lake (See "pollutants" below).

f. OTHER POLLUTANTS:
   1) Occasional failure of a sewage lift station next to the lake has caused raw sewage to enter the lake in May 1997, May 1995, and Summer 1994. The volume of the 1994 spill was over 400,000 gallons.
   2) Saltwater incursions may occur during 5 to 15 high tides per month. Land surveys show that Mission Lake is 9.0 feet above mean lower low water, compared to an annual high tide of about 11 feet above MLLW. Tide gate

installed in the 1960's is worn, and is often prevented from sealing by floating debris. Ocean water sometimes flows into the lake in considerable quantities. Seawater, which is denser than freshwater, forms an unmixed layer on the lake bottom, particularly when the lake is iced over.

3) Runoff from an outdoor carwash introduced detergent (presumably containing high levels of phosphorus) into the lake. This flow was redirected to the sanitary sewer during remodelling in early 1997.

h: OTHER: Aquatic plant growth had been increasing over the past decade, and had reached objectionable levels in 1995. Macrophyte densities were less in 1996, but continued attention should be focussed on this in the future to determine if the decrease is persistent.

V. SUGGESTED REMEDIAL ACTIONS

(The following suggested actions are not in order of priority)

I. Island Lake System:

a. Support paving of Selief Lane to reduce siltation into the Island Lake System and to increase value of the habitat for salmon rearing.

b. Look for causes of sporadic high fecal counts at points in the Island Lake system.

c. Implement weekly fecal coliform or e. coli sampling at Island Lake swim beach during swimming season.

d. Support construction of pool&jump fishpass at Island Lake creek waterfall.

e. Investigate feasibility and funding for salmon spawning habitat enhancement at Selief Lane ditch.

f. Deepen Upper Horseshoe Lake by 6"-12" to improve aesthetics as part of the Selief Lane paving project.

3. Lilly Lake:

a. Clean up commercial trash around Lilly Lake with the assistance of property owners and the City of Kodiak.

b. Analyze tissue samples from line-caught rainbow trout to confirm that petroleum hydrocarbon levels are insignificant.

4: Potato Patch Lake:

a. Determine the importance of high iron concentration from Baranof Park area on chronic turbidity in the lake, assess feasibility of diverting this flow.

b. Determine source of occasional influxes of pollutants into Potato Patch Lake and develop plan to reduce pollutants.

c. Develop educational program about non-point source pollution reduction, and present to the public.

d. Develop landscape plan for City land on Potato Patch Lake.

5. Mission Lake
   a. Develop plan and budget for new tide gate.
   b. Attempt to annually monitor aquatic macrophyte abundance.
   c. Evaluate storm flow sewage elevation in sanitary sewers versus manhole rim elevations, and raise or seal manholes if the freeboard is insufficient. Provide an overflow line directly to the ocean which will prevent overflow to Mission Lake if the lift station fails.

Acknowledgements

The Clean Lakes for Kodiak group involved many community residents. The mainstay of the group was the Board of Directors, consisting of: Chris Blackburn (chair), Jim Ashford, Jim Blackburn, Bud Cassidy, Chris Clevenger, Dale Finley, and Norm Sutliff.

Al Burch attended most of the meetings, and his pragmatic point of view was greatly appreciated. Kathy Colwell contributed her energy toward organizing the lakes cleanup, and has brought watershed concerns to the Planning and Zoning Commission through the Kodiak Watersheds and Wetlands Association. Dave Colwell, Bill Donaldson, Marion Stirrup, Jon Hauser, and Deedee Pearson also contributed at numerous meetings and in the community.

The members of the Kodiak Soil and Water Conservation District provided funding, oversight, and the use of their computer and printer. This group included Jim Burton (district chair), Bill Burton, Cathy Burton, Charlie Dorman, Dewitt Fields, Wanda Fields, and Omar Stratman.

Bill Rieth of the Alaska Department of Environmental Conservation was present for most meetings, and he took some of our findings and diplomatically got problems solved in the watersheds. Fred Sorensen of the State of Alaska Cooperative Extension Service also contributed his thoughtful comments and points of view.

Bruce Short, independent biologist, performed most of the field work, regardless of the wind or weather. The City of Kodiak assisted us by providing *pro bono* water testing at the wastewater treatment plant lab. Hap Heiberg (manager) and Ken Wolkoff (lab technician) were extemely helpful and cooperative. Steve Honnold and Steve Schrauf of the Alaska Department of Fish & Game (ADF&G) helped us to establish our sampling methods and to understand the limitations of our methods. Special thanks go to Jim Blackburn of ADF&G for performing statistical analyses of our fish trapping data, and for writing most of the text in that section of the technical report.

The Kodiak Island Borough, under the leadership of Mayor Jerome Selby, administered the grant funding for this project and provided an office and meeting rooms for the Clean Lakes Group. Jim Woitel, the AutoCAD technician, produced beautiful maps under tight deadlines. Bud Cassidy, the Borough resource manager, contributed countless hours off the clock to Clean Lakes, and he was always positive and willing to help out.

Finally, we would like to thank Jim Schmidt, Duane Coffey, Terry Nelson, and particularly Mark Kinney of the Natural Resources Conservation Service for their support and patience in seeing this effort through to its completion.

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1.0 Introduction

CLK Mission Statement:

The mission of the Clean Lakes for Kodiak Group is to ensure that our urban lakes continue to provide safe recreation and scenic beauty for the people of Kodiak.

The Clean Lakes for Kodiak Group (CLK) originated in 1991 as a group of Kodiak residents concerned about apparent pollution problems in Potatopatch Lake. The Ismailov Road paving project constructed by the City of Kodiak during July of that year included the installation of a storm sewer which drained into the southeast corner of the lake. Possible negative effects of this concentrated source of stormwater disturbed a number of lake residents, and the state of the lake was discussed at a special City Council meeting on July 16, 1991. This meeting brought together members of the city and borough governments, state regulators from the Department of Fish & Game and the Department of Environmental Conservation, and a number of concerned citizens. It appeared to lakeshore residents that none of the government agencies had as great a stake in the health of Potatopatch Lake as they did.

Continued interest on the part of Kodiak residents resulted in the preparation of a grant proposal to the USDA Soil Conservation Service (SCS) for a lake water quality study. This was submitted in January 1992. After a number of revisions, a grant for $94,000 over 2-1/2 years was awarded on June 14, 1994. The scope of work was to include a watershed and waterbody evaluation study for all seven major lakes in urban Kodiak.

Funding has been provided by the SCS (now renamed the Natural Resources Conservation Services, or NRCS) to Clean Lakes for Kodiak through the Kodiak Soil and Water Conservation District, a local organization chartered to carry out soil, water, and related natural resources conservation. The Kodiak Island Borough has provided accounting and other administrative services. CLK is organized with a board of directors and a set of bylaws. Chris Blackburn has served as chairman of the board since its organization in 1994.

Mark Blakeslee was hired as technical advisor in August 1994, and is the primary author of this report. He developed the Plan of Work, and has directed the field work and mapping tasks. Bruce Short provided assistance in water quality sampling, limnology, and biological surveys throughout the 1995 field season, and for some of the work in 1996..

This document presents our findings to date. Interpretations of findings are preliminary in some cases, pending on-going field work, discussion, and review.

2.0 Project Objectives

The following section outlines the objectives of that portion of the Clean Lakes project supported by NRCS funding. The NRCS grant is limited to: establishing baseline data, diagnosing problems, planning, public outreach, and assessing and demonstrating feasibility of corrective actions. The members of Clean Lakes for Kodiak have moved forward with lake trash cleanups in 1994 and 1995, and they hope to do more beyond the scope of the grant in the future.

This technical report deals with work completed to date under the terms of the NRCS grant. The purpose of work under the grant is: 1) to define the current status of the lakes and watersheds with regard to public safety and health, fish and wildlife habitat value, recreational use, and aesthetic value; 2) to develop community consensus on the relative priority of identified concerns in order to guide future work; 3) to develop and evaluate design alternatives to improve the value of the lake systems. Future work to implement selected designs will be supported by a combination of local government funding, volunteer efforts, local private funding, and grant funding.

We prepared a document in the fall of 1994 called the Plan of Work (see Appendix A). The Plan of Work is an outline of all the project tasks and subtasks, the responsible person to supervise or accomplish each subtask, and an expected schedule. The Plan of Work has evolved as completed work has led us in new directions, but the original document has served as an excellent roadmap.

The Plan of Work has nine major tasks: 1) Mapping; 2) Pollutant Inventory; 3) Limnological and Fish Habitat Baseline Data; 4) Waterfowl Habitat Baseline Assessment; 5) Recreational and Scenic Value Assessment; 6) Public Involvement, Outreach, Education; 7) Intergovernmental Networking; 8) Feasibility Analysis; and 9) Reporting. Our work to date has focussed on the first three technical tasks.

We collected enough data to have a general idea of which lakes were most affected by human impacts in 1995. As 1995 was an abnormally wet year, we collected an additional limnology sample from each lake in July 1996 to expand our baseline data set. We also did some targeted chemical and bacteria sampling in 1996 to address specific unanswered questions. Additional discussions and continued studies may be needed to refine our understanding of certain problems.

The focus of the project has now changed to emphasize implementation and public involvement. Our dissemination and outreach efforts started by discussing our preliminary findings informally with staff of the City of Kodiak, the Kodiak Island Borough, Alaska Department of Fish & Game Regional Planning Team, Alaska Department of Environmental Conservation, and the Kodiak Regional Aquaculture Association. ADEC staff utilized our results in their local compliance work. The City of Kodiak has funded design of a raised outlet for Upper Horseshoe Lake and improved drainage and fish habitat for the Selief Lane ditch, with construction planned for Fall 1997.

We presented lectures on CLK activities and findings to a National Fish & Wildlife Service "Salmon Camp" for students in Kodiak during August of 1996. An expanded camp will include more presentations this year. The camp director is interested in conducting fish trapping and a possible creek clean-up in the Island Lake watershed, although the curriculum has not yet been finalized.

A new watersheds group called the "Kodiak Wetlands and Watersheds Association" has formed as an off-shoot of the Horseshoe Lake Homeowners Association. They have launched a public education campaign, and have used some of our maps in a newspaper ad. They also are interested in studying fish abundance and turbidity levels in the watershed, and we are helping them with that.

Other issues researched by CLK will be presented to the public in this report, in press releases, or in a public meeting. Public consensus will help prioritize the issues and decide how to allocate money and human energy to improve our environment.

3.0 Lake Synopses

3.1 Background

This section is intended for a reader who is **not** an environmental scientist or biologist. It is organized for the layman who wishes to get an overview of the particular one or two lakes which interest him or her most. As happens for any summary, many details are not reported in order to be brief. Those readers who wish to know more should see Section 4.0, "Task Reports". That section provides more detailed explanations of the methods used, explains more fully the significance of the results, and allows for easier comparisons between lakes and watersheds.

The overall study area is shown in Figure 3-1, the Kodiak Urban Lakes Watershed Map. This should be consulted to familiarize the reader with the relative size and locations of the lakes. Bathymetric maps containing lake outlines and depth contours are presented as Figures 3A - 3G. These may be examined for an idea of the shape of lake basins, and the routing of inlets and outlets.

Lake Synopses (summaries) are presented as Tables 1A through 1H. Each table has the same format, and presents the same parameters. The meaning and significance of the parameters presented in the synopses are explained briefly below. Further discussion is presented in Section 4.0 (Task Reports) and Section 5.0 (Conclusions and Recommendations). **The Glossary also provides definitions of some terms.**

3.2 Definition of Terms

The **Overview** presents the distinguishing characteristics of each lake, and highlights significant problems. **Surface Area, Average Depth,** and **Maximum Depth** are provided to give a general idea of the size of the lakes. Average depth also influences how much of the lake cross section receives bright sunlight for photosynthesis, how long it takes to flush the lake with water from rainfall, and whether wind wave action at the surface can suspend bottom sediments. **September Weed Cover** summarizes results of our aquatic weed survey. Weeds tend to grow wherever the water depth is shallow and the sediments are soft and organic. The percent cover figure includes both surface weeds such as lilies and submersed weeds like bladderwort.

Cumulative Watershed Area presents the area of land (and surface waters) upstream of (and including) the subject lake's outlet. The watershed area is also broken down into upsteam lakes; undeveloped land such as Wetlands, meadows, brush, or forests; residential and urban park land consisting of houses, lawns, yards, driveways, and side streets; and commercial and institutional land such as businesses, large structures, parking lots, and arterial streets. The land use is important because the runoff from city streets is more polluted than that off an undeveloped mountainside, and the quality of the runoff from the watershed is the biggest influence on the quality of water in the lake.

Trophic State Indicators refer to three parameters (total phosphorus, chlorophyll a, and Secchi disc clarity) which are commonly used to indicate how productive a lake is. Productivity in this context refers to production of plant biomass, either as microalgae or as aquatic weeds, which in turn forms the foundation of the food chain through zooplankton and insects to fish and higher predators. Trophic state is important to scientists who study the diversity and stability of animal and plant communities in lakes.

Phosphorus is a nutrient required for plant growth, and it is usually the scarcest nutrient relative to plant requirements. A lake with lots of phosphorus will not be phosphorus-limited for plant growth, and may therefore produce lots of plant tissue and have high levels of chlorophyll a (the major pigment used by plants in photosynthesis). A Secchi disk is a black and white sectored plate which is lowered into water until it is no longer visible. The depth at which it disappears is known as the Secchi depth, and this is a measure of water clarity. A lake with high phosphorus and high chlorophyll a will be murky, and the Secchi clarity will be low.

A lake with low nutrient levels has clear water, other things being equal, and is described as "oligotrophic". This is desirable for swimming, boating, and for aesthetic reasons. The Kodiak study lakes naturally have moderate levels of color due to staining from peat, and this cuts the water clarity somewhat. Silt off roads, from construction, from wind-borne dust, and from lake bottom sediments also enters the water column and decreases the clarity regardless of the productivity. Silt and color absorb sunlight which would otherwise be available to the microalgae, and so their presence decreases both Chlorophyll a and Secchi clarity regardless of phosphorus level.

Murky lakes which produce lots of microalgae are described as "eutrophic". Eutrophic lakes have a vigorous food chain, and can produce lots of fish. They are also attractive to waterfowl. If a lake is overly productive in the form of a microalgae bloom, however, the nutrients can be depleted and the bloom can "crash". The bacteria which digest the decaying microalgae can then consume all the oxygen in the lake, and if there is insufficient wind to mix and oxygenate the water, fish kills can result. Eutrophic lake conditions are thus beneficial for fish and wildlife, provided the productivity is not excessive.

Lakes which are intermediate in productivity between oligotrophic and eutrophic are known as mesotrophic. Mr. Jim Edmundson, a limnologist with the Alaska Department of Fish & Game provided general criteria for differentiating the three classes of lakes based on phosphorus, chlorophyll, and clarity levels. The numeric ranges for non-stained, non-silty lakes are as follows.

Trophic State	**Total Phosphorus**	**Chlorophyll a**	**Secchi clarity**
oligotrophic	<10 ug/l	<3 ug/l	>7 meters
mesotrophic	10 - 20 ug/l	3 - 7 ug/l	3 - 7 meters
eutrophic	>20 ug/l	>7 ug/l	< 3 meters

The trophic states according to this scheme are provided in the synopses. Mr. Edmundson cautioned us that the numeric ranges are approximate only. Mineral silt from erosion increases phosphorus and decreases Secchi clarity without increasing productivity. The trophic state indicator scheme was initially developed for deeper lakes than what we have studied. Shallow lakes in general tend to be indicated as productive regardless of the level of human impact.

Theoretical Water Retention Time is the number of days required for the average runoff from the watershed to replace the volume of the lake. This is based on the average annual rainfall for Kodiak of 67.58 inches, or an average of 0.185 inches per day. Lakes which stratify during the summer (Dark, Island, and Gertrude) tend to flush only the upper layer above the thermocline, so the retention time for the upper layer is less than the theoretical value for the entire lake volume. The retention time for water in back coves is greater than that for water near a line drawn from the major inlet to the outlet.

Zooplankton Biomass is derived from microscopic counts by Fish & Game on animal plankton strained from lake waters using a fine net. Zooplankton are food for many fishes (most notably sockeye salmon), but they are not the preferred feed for coho salmon. Zooplankton reproduce more slowly than phytoplankton (microalgae), so they may be "washed out" of lakes with extremely rapid flushing unless they employ mechanisms to resist the flow. High zooplankton biomass indicates that there is adequate phytoplankton feed, that predation on the zooplankton is not excessive, that the water contains no acute toxicity, and that the water retention time is long enough to let them reproduce before they are washed out of the lake. Low zooplankton biomass indicates that one or more of the above favorable conditions are absent.

Fish Catch Rate and Condition is based on minnow trapping of juvenile fish in October, 1995. The catch rate is the number of fish caught per trap. The condition factor is a relative measure of "plumpness". ADF&G has stocked area lakes with salmon and rainbow trout for many years. Hatchery reared silver salmon were stocked into Dark, Island, Potatopatch, and Mission lakes in early August, 1995. Hatchery reared rainbow trout were stocked into Lilly Lake and Gertrude Lake. Differences in catch rates, size, and condition factor reflect variations in stocking density, mortality, feed availability, and other habitat effects. Details of the methods and results are presented in the <u>Task Reports</u> section.

Water Quality is described here by results of analyses of fecal coliforms, turbidity, color, iron, pH, and conductivity. **Fecal Coliform Bacteria** are bacteria which grow by the trillions in the guts of warm-blooded animals. Alaska Department of Environmental Conservation (ADEC) water quality regulations require that water used for contact recreation (swimming, water skiing, etc.) not exceed 200 colony forming units (cfu's) per 100 milliliters of sample. In addition, the average of 5 weekly samples may not exceed 100 cfu/100ml.

Fecal coliforms are not disease-causing of themselves, but their presence in a water sample is an indication that some warm-blooded critter, be it man, beast, or bird, has defecated nearby. A sewage leak causes high coliform counts, but so does a dog kennel or a flock of feeding ducks. A sewage leak is obviously more dangerous to human health than a flock of birds because the sewage may contain human pathogens such as cholera. High fecal coliform levels should therefore always cause some concern until the source can be identified. Fecal coliforms normally survive for less than a week in natural waters. Chronically high coliform levels indicate a continuing influx of bacteria.

Turbidity is another name for cloudiness in the water. It is measured by illuminating a water sample and measuring how much light is scattered at a right angle from the illuminating beam. Turbidity can be caused by silt, plankton, or any other particles in the water. Murky water is less attractive to most people than clear water, so high levels of turbidity are aesthetically undesirable.

Turbidity is related to the Secchi depth, which may be more intuitive for most people, because it represents how far an observer can see into the water. For the 1995 limno samples, in order to see 3 feet, turbidity had to be less than about 8 NTU. Two foot clarity corresponded to about 12 NTU, 1.5 foot clarity corresponded to 15 NTU, and 1 foot clarity corresponded to about 25 NTU.

Color is caused by natural organic compounds and invisible colloidal particles originating from the breakdown of plant material or from iron compounds. It is determined by measuring how much a water sample absorbs yellow-brown light of 400 nanometer wavelength. Color cuts light penetration in water, and decreases potential chlorophyll a concentration and Secchi clarity.

Iron in water originates from iron compounds in bedrock (or possibly from buried metal debris). Groundwater contains high iron concentrations in some areas, whereas rainwater and surface runoff are very low in iron concentration. Dissolved iron will precipitate out from groundwater which is low in pH and oxygen when it is oxygenated and increased in pH. Precipitated iron can increase turbidity and color. High iron (above perhaps 1000 ug/liter) is an indicator of a relatively high percentage of groundwater relative to surface runoff. It seems to occur particularly in groundwater coming from areas where organic material or scrap metal has been covered with fill.

pH is a measure of the acidity of the water. Normal surface waters have a pH between 6.5 and 7.0 on Kodiak. When microalgae or aquatic plants are not limited by shortages of phosphorus or nitrogen, the next scarcest nutrient is often carbon. Uptake of carbon dioxide from water can elevate the pH. Fish may be stressed when the pH exceeds 8.5. The figures presented are averages of the five limnology samples from each lake, and the analyses were performed many months after sampling. Higher pH values were indicated for Potatopatch and Mission lakes by immediate testing performed by the City of Kodiak lab.

Conductivity (specific electrical conductance) is directly related to the salt content of the water, as salt ions carry electrical current in water. Full strength seawater has a conductivity of around 26,000 umhos/cm. Uncontaminated fresh water has a conductivity of 150 umhos/cm or less. Conductivities generally decreased through the summer. Salt probably enters lakes from three sources: 1) salt spray from wind storms; 2) road salt applied to melt ice by City of Kodiak and ADOT crews; and 3) backflow of salt water into tidewater lakes during high tides. All three of these are intensified during the winter season. Salt water is stressful to some organisms, and favors others.

The Lake Synopses are presented as Tables 1A through 1H following the Section 6 and the Glossary. A considerable number of other parameters were tested, and results and further discussion are presented in the Task Reports section.

4.0 Task Reports

4.1 Mapping

4.1.1 Introduction

Mapping was an important part of this project. The maps and aerial photos document the current and past levels of development in the watersheds. They allow us to conveniently depict how water flows from tributaries through the lakes to the ocean. They enable us to document where we collected water samples, and they present quantitative data on lake area, depth, and volume.

4.1.2 Methods

Watershed Maps: Mr. Jim Woitel, the Kodiak Island Borough (KIB) AutoCAD technician, assisted us in producing several series of maps which show the lakes and contributing watersheds. These maps consist of numerous overlapping layers, any or all of which can be viewed or printed in combination. Roads, lot lines, zoning classifications, streams, lakes, storm sewers, and numerous other features each have individual layers.

We purchased aerial photos of the study area dated June 1, 1994 from AeroMap in Anchorage. The Borough's base map of Kodiak town and nearby subdivisions was used as a starting point for our watershed maps. Lake and creek outlines were digitized from the 1994 aerial photos and from 1985 orthophotos (aerial photos with elevation contours inscribed). We borrowed as-built drawings of various storm sewer projects from the City of Kodiak Engineering Department, and added portions of the underground drainage network to the surface features digitized from aerial photographs.

We obtained a copy of a 1991 drainage study of urban Kodiak which was performed by VEI consultants for the City of Kodiak. This provided approximate watershed boundaries. Watershed boundaries in forested areas were located approximately by field surveys on foot.

Field Maps: The watershed maps were produced at different scales at 11"x17" size for use in the field. These maps generally omitted lot numbers and street addresses for clarity. Various features were accentuated depending on the purpose for use in bathymetry surveys, water quality sampling, macrophyte surveys, and fish trapping.

Lake and Stream Outline Maps: We used a lake and stream outline map to present water quality testing results. This was generated by plotting only the lake and stream outline layer from the AutoCAD watershed maps. Streams were shortened to produce not-to-scale schematic drawings of the lake systems for inclusion in this report. One 11"x`17" shows the Horseshoe Lakes, Beaver Lake, and connecting streams; one shows Dark Lake, Island Lake, and connecting streams; and the third shows Lilly Lake, Potatopatch Lake, Mission Lake, and connecting streams and storm sewers.

Historic Aerial Photos: The US Coast Guard mapping department has provided a photomosaic of urban Kodiak from 1957 which is now displayed at the KIB Community Development Department office. The KIB map room also has aerial photos from 1962-64, 1973, 1977, 1980, 1984, and 1985. The 1985 photos are orthophotos on 24"x36" mylar, and provide lot lines and elevation contours. These images have given us information on historical land use, lake shorelines, and macrophyte cover.

Land Use: We differentiated land use into five categories: lake surface, undeveloped land, residential land, urban park land, commercial land, and institutional land. Watershed and land use boundaries were traced onto mylar over a large scale aerial photo (30"x48"), and resultant areas were measured using a manual planimeter. A scaling factor was applied to get total acreage of each land use category in each watershed.

Bathymetry: Lake depth profiles were surveyed following protocols established by the ADF&G Commercial Fisheries Development Branch. These published procedures were explained to us by Steve Honnold and Steve Schrauf of the Kodiak Fish & Game office. In brief, numerous crisscrossing bottom profiles were logged on the surface of each lake using a paper strip depth sounder installed in an outboard powered inflatable boat. At the commencement of work at each lake, and periodically thereafter, the sounder zero offset was adjusted to read true to the depth measured with an inscribed depth staff.

Depth over distance from checkpoints on shore were logged onto our AutoCAD base maps. Spot depths were then digitized into a digital terrain mapping program, and bottom contours were drawn by computer. In some cases these contours were adjusted based on field knowledge. The terrain mapping software then calculated lake areas, volumes, and mean depths.

The depth sounder did not work reliably at depths less than about 3 feet. Upper and Lower Horseshoe Lakes were too shallow throughout, and no bathymetric maps were produced for those lakes. Contours for Mission Lake were corrected to reflect 35 depth measurements made with a measuring staff through holes in the ice cover in March 1996. The Potatopatch Lake map was produced from the sounder profiles despite the shallow depth.

Watershed and Lake Hydrological Characteristics: Watershed areas were taken from the land use mapping results. Lake surface areas and volumes were calculated by Jim Woitel from the bathymetry contours. Maximum lake depths were taken from the bathymetry maps. Average lake depths were calculated by dividing the lake volumes by the lake surface areas.

The retention time for each lake was calculated based on procedures presented in ADF&G's Limnology Field and Laboratory Manual by Koenings, Kyle, J.A. Edmundson, and J.M Edmundson. Kodiak's average annual rainfall of 67.58 inches was multiplied by the watershed area and a number of correction factors to account for evaporation and transpiration. Lake volume was then divided by the calculated annual runoff to determine the retention time.

4.1.3 Results and Discussion

Watershed Maps: Watershed maps were produced in 24"x36" format, and are not included in this report. Copies of the maps are available on the KIB computer system as AutoCAD 12 format files named H:\ACADR12\KOD\MARK10, MARK20, and MARK30.

Additional accuracy in defining lake shores, creek margins, and watershed boundaries could be achieved using diapositive stereo pairs on a new stereo-plotter available locally. This would be particularly useful to define watershed boundaries which are away from roads.

Historic Aerial Photos: The photomosaic of urban Kodiak from 1957 is particularly interesting because it shows most of present day Kodiak City as untouched forest, bog, and ponds. There was essentially no development between Mission Road and Mill Bay Road north of the present day high school. Mill Bay Road was a single lane dirt trail with virtually no buildings past present day Selig Rd.

The present day Horseshoe Lakes were not yet split by Selief Lane, and a beaver dam across the lake outlet impounded one to two feet more water than at present. Several acres of the present wetland behind Elderberry Heights subdivision on Selief Lane was flooded by the beaver dam.

The outlet of Lilly Lake (known then as Big Lake according to Deedee Pearson) flowed through a bog at present day East Addition park, and into Potatopatch Lake through the current gully. Present day Baranof Park was a pond in a bog which drained to the gully feeding Potatopatch Lake. Several small ponds which existed near the Safeway area have since disappeared.

Land Use: The results of this work are presented in Tables 4-1A (Individual watershed acreage and land use) and 4-1B (Cumulative watershed acreage and land use). Figure 4-1 shows the relative percent of land uses upstream of each of the nine study lakes. The white bars represent undeveloped land or lake surface. The grey bars represent residential land or urban (grassy) parks. The black bars represent commercial or institutional land characterized by a large proportion of roof area, gravel pads, and paved surfaces.

The land use in the watershed feeding each lake has an overriding effect on the water quality in the lake and tributary streams. Undeveloped land is usually covered with vegetation, and it tends to absorb contaminants and purify water passing over it. The water leaving this type of land runs off gradually, and is low in silt and chemical contaminants.

Runoff from residential land comes from a combination of hard surfaces (roofs, driveways, roads), and permeable surfaces (lawns, yards, gardens). Water from residential areas may contain detergents, fertilizers, oil (from vehicles or from heating oil spills). Commercial or institutional areas have yet more impermeable surfaces, and contribute more contaminants.

We have seen occasional pollution events at Lilly Lake, Potatopatch Lake, and Mission Lake. Fuel oil spills are fairly common, as are soap suds from car washing or pressure washing. The runoff from the outdoor commercial car wash at Buggy Banya drained to Mission Lake until January 1997, when it was plumbed to the sanitary sewer during a remodel.

In addition to point sources of pollution in developed areas, there are non-point sources, such as roadway runoff, which carry small amounts of oil, lawn fertilizer, silt, and other contaminants to the lakes. Thanks to our abundant rainfall, small amounts of non-point source pollutants from developed areas are diluted by large amounts of precipitation. The only way to reduce non-point urban pollution is to educate the public about the effects of over-fertilization and oil pollution on our lakes. This should be a part of the continuing work of Clean Lakes for Kodiak.

Lower Horseshoe Lake vies with Potatopatch Lake for the highest percentage of developed watershed area, and these lakes have the highest levels of turbidity, iron, phosphorus, etc. Dark Lake has the highest percentage of undeveloped watershed at 86%, but Beaver Lake and Island Lake both also exceed 75% undeveloped land in the upstream watershed. The large flow of clean water off of Pillar Mountain through lower reservoir has a tremendous positive influence on the water quality of Beaver, Dark, and Island Lakes. In general, water purity is greatest in watersheds with the greatest proportion of undeveloped land.

<u>Bathymetry:</u> The bathymetry maps were presented earlier as Figures 3-2A through 3-2G. The Horseshoe Lakes, Potatopatch Lake, and Mission Lake are particularly shallow, with maximum depths less than 5 feet and average depths less than 3 feet. Beaver Lake and Lilly Lake both have a maximum depth of 7.5 feet, and average depths less than 5 feet. Dark Lake has a maximum depth of 15.2 feet, and an average depth of 8.9 feet. Island Lake and Gertrude Lake (Abercrombie Park) both have maximum depths near 30 feet and average depths of 13 feet.

None of the study lakes is deep in relation to most of the "deep" lakes studied by ADF&G for sockeye salmon enhancement purposes. However, the distinction between "deep" and "shallow" lakes is based to an extent on whether the lakes thermally stratify during the summer. As the maximum measured temperature difference from top to bottom was 6 degC (11 degF) or more for Dark Lake, Island Lake, and Gertrude Lake, we may call these lakes deep for the purposes of comparison. The other lakes had maximum temperature differences of 3 degC (5.4 degF) or less.

Shallow lakes are more dynamic than deep lakes. Wave action from surface winds can stir up the bottom in shallow lakes, and that makes the nutrients in sediments available for photosynthesis. If the retention time is short, bottom sediments or other particles will not have time to settle out again before they are discharged from the lake.

Wind action can fully mix shallow lakes when there is no ice cover, so there is very limited temperature or oxygen stratification. Shallow lakes also tend to have short retention times, other things being equal, so there is little buffering against rapid thermal or chemical changes.

The entire water column is illuminated by sunlight in shallow lakes. Rooted aquatic plants can generally reach the surface where the water depth is 5 feet or less. Upper Horseshoe Lake, Mission Lake, and Potatopatch Lake, in particular, are heavily colonized by aquatic weeds. Juvenile silver salmon normally rear near river banks or near the shore in lakes, but it may be that they are able to utilize the entire bottom area of both these lakes because of the shallow depth and abundant cover.

Watershed and Lake Hydrological Characteristics: Lake and watershed characteristics are presented in 4-2. Lower Horseshoe, Potatopatch, and Beaver Lakes have average retention times of 12 days or less. Lilly Lake has a surprisingly long retention time in comparison with the other urban lakes.

The length of time that water resides in a particular lake affects water quality. Water enters lakes by three routes: surface runoff, groundwater flow, and precipitation to the lake surface. Each of these sources contributes water with different chemical characteristics. A lake with long retention time has a relatively large volume in comparison with the watershed area. With less watershed area, surface runoff is relatively less important than groundwater recharge, and the lake water quality is more like groundwater.

The retention time also affects how much of the sediment load entering the lake can settle to the bottom. Sediment increases turbidity, total iron, total phosphorus, and the concentration of other solid phase compounds, so water quality tends to be better in lakes with longer retention times.

If contaminants enter a lake on an occasional or seasonal basis, a lake with short retention time will rapidly flush them. A lake with long retention time will see a smaller rise in contaminant concentration because of its larger volume, but it will take longer for the contaminant level to decline to background concentration.

4.2 Water Quality Testing

4.2.1 Introduction

This water testing task complements the limnological water testing described below in section 4.3. Whereas the limnological samples were drawn from a sampling station at the deepest point of each lake, the water quality samples described here were drawn from streams at inlets and outlets of the lakes, as well as from some intermediate points on the streams. The parameters analyzed were oriented at gross characterization of the water with regard to public health, sedimentation, and appearance. This contrasts with the orientation of the limnological analyses toward the ability of the lakes to support biological communities.

At the request of the CLK Chairman and the City Manager, the City of Kodiak wastewater plant laboratory agreed to test our water samples free of charge. Around 160 samples were tested between January 25th and October 31, 1995. The samples were analyzed for total fecal coliform bacteria, total dissolved solids, total suspended solids, turbidity, true color, iron, and pH. A relatively small number of samples were also analyzed for chloride concentration.

4.2.2 Test Parameters, Significance, and Methods:

The significance of the test parameters is as follows.

- Total Fecal Coliforms: Indicates contamination from the feces of warm blooded animals. This test does not differentiate between animal wastes and human wastes. Fecal coliform bacteria are not directly disease-causing in people, but if they originate from human sewage, then the other microbes found in sewage may be present. Some of the other microbes in sewage do cause disease, but they are difficult to test for. ADEC regulates maximum fecal coliform levels for various water uses (i.e. drinking, contact recreation, boating recreation, rearing aquatic life, etc.). Fecal coliform counts are extremely variable over time and from place to place.

- Total Dissolved Solids: Indicates the presence of minerals and salts in the water. High levels of TDS indicate road salt, sea salt, or mineralized groundwater. Rainwater is low in dissolved solids.

- o Total Suspended Solids: Indicates filterable solids like silt, grit, and plankton. This is an approximate indicator of upstream erosion or high biological productivity.

- o Turbidity: This is a measure of "cloudiness" measured by optical sidescatter. Silt, plankton, or dissolved color will cause high turbidity.

- o True Color: This is a measure of "brownness" measured by optical transmittance of a filtered sample. Tannins from decaying vegetation or dissolved iron can cause high levels of true color. Silt is filtered from the sample before testing.

- o Iron: Indicates a high contribution of groundwater from high iron bedrock or from areas of buried ferrous debris.

- o pH: Indicates the acidity of water. The pH of rainwater is usually between 6 and 7. Seawater has a pH of about 8.3, raw sewage has a pH of about 7.2. The pH of lakewater can be raised by photosynthesis of weeds or phytoplankton when growth is limited only by dissolved carbon availability. Extremes in pH (perhaps below 5.5 or above 8.5) in pH level can be stressful to fish and other members of the food chain.

- o Chloride: Indicates the presence of salt from either seawater, salt spray from storms, or road salt.

Samples from each station were collected in two 500 ml sterilized polycarbonate bottles provided by the City lab. At the request of the labmanager, we generally limited ourselves to eight samples per sample day and two sample days per week. Analyses were performed at the City lab according to their Quality Assurance / Quality Control Plan. Analytical methods followed the procedures from <u>Standard Methods for the Analysis of Water and Wastewater</u>, 4th Edition.

We gathered water samples during 1995 from late January until late October. Sampling dates were chosen at four to six week intervals, and were arranged in advance with the laboratory. Samples were collected regardless of the weather, so quasi-random sampling (unconfounded by rainfall) was obtained.

4.2.3 Results and Discussion

The results of the testing are tabulated in Appendix B, and are presented graphically on schematic watershed maps in Figures 4-2 A-C (Coliforms), Figures 4-3 A-C (TDS, Iron), Figures 4-4 A-C (Turbidity, TSS), and Figures 4-5 A-C (pH).

Limitations of Water Quality Testing: Measures of water quality can change dramatically in streams and lakes in response to rain storms, air temperature excursions through freezing, daily cycles, and seasonal cycles. This is particularly severe in creeks and small, shallow lakes. Measurements are also more variable for some parameters (e.g. fecal coliform bacteria, turbidity) than for others (e.g. pH, TDS). Consequently, for some parameters a large number of samples must be analyzed over a the course of a year in order to adequately determine average levels, seasonal trends, and variability. Average fecal coliform counts should be interpreted with caution, because a single very high value averaged with low values can produce a misleading high average.

Most of our area-wide sampling took place in 1995, which was the second wettest year on record with the National Weather Service, with a total precipitation amount of 95.29 inches. 1996 was unusually dry, in contrast, with a total precipitation amount of only 56.41 inches. Average annual precipitation for Kodiak is 67.58 inches. Conclusions or speculations based on measurements of conditions in 1995 may not apply to dry years like 1996, or even to normal years.

Coliform Bacteria: We found several locations in the lakes and watersheds where fecal coliform levels were occasionally high. As stated before, fecal coliforms are not disease-causing of themselves, but their presence in a water sample is an indication that some warm-blooded animal, be it man, beast, or bird, has defecated nearby. Fecal coliforms normally survive for less than a week in natural waters. Chronically high fecal coliform levels indicate a continuing influx of bacteria.

We found occasionally high levels of fecal coliform bacteria at Lower Horseshoe Lake, in the Selief Lane ditch, at Island Lake Park, at Potatopatch Lake, and at the inlet to Mission Lake. The most important of these is probably Island Lake Park, because children often swim near there.

The Selief Lane ditch samples showed unexplained high levels on March 13, 1995, at the inlet and outlet of Beaver Lake, but not upstream. This was during a period of sub-freezing weather and no precipitation, so runoff carrying pet waste into the water was probably not a factor. The June 21 samples also showed rapidly increasing fecal coliform counts from the inlet to Lower Horseshoe Lake to Beaver Lake. These samples may indicate that either the sewer main, the sewage lift station near the inlet of Beaver Lake, or some of the sewer services which pass under the ditch may be leaking.

The highest fecal coliform counts were found in samples collected during or immediately following an intense rain storm. National Weather Service climatological data summaries for each month of 1995 and 1996 are presented in Appendix C. Sheet flow of runoff over land occurs during intense storms, and this would tend to wash accumulated animal wastes into the drainage ways and creeks. Major spikes which occurred in data from September 5, 1995, match a major storm which dumped over 2 inches of rain in the 24 hours prior to sampling.

On the other hand, our municipal sanitary sewage system suffers from locally high levels of inflow and infiltration (surface water and groundwater which enters the pipes), and this is worst during and following intense storms. Leakage of sewage into the groundwater and overflow of manholes is thus also most likely during and following storms. The correlation of high fecal coliform counts with intense rainfall does not therefore indicate whether the bacteria originate from domestic animal wastes or from sewage.

There is some discussion in Standard Methods for the Analysis of Water and Wastewater concerning the use of the fecal strep count in combination with the fecal coliform or E. coli counts to differentiate between human and non-human sources of bacterial contamination in surface waters. Further investigation of these techniques might be warranted if additional focussed testing or periodic monitoring is conducted in the future.

Total Dissolved Solids: The most likely sources of dissolved solids (salts) are road salt applied during winter, salt spray from storms, and seawater entering tidewater lakes at high tides. The samples representing the flow off undeveloped land on Pillar Mountain showed TDS levels of 50 ppm or less with the exception of one reading near 80 ppm in late March. Other locations in the Island Lake watershed started the year in the 120-160 ppm range, and dropped to 40-80 ppm by June. This is presumably due to winter road salt being washed away by rainfall through the spring. The "I2" flow which drains Smokey's, Safeway, and Brechan's yard, and enters Island Lake at the "swimming beach" remained elevated at 110-160 ppm throughout the summer and fall.

TDS levels in Potatopatch and Mission watersheds behaved similarly, although the decline was perhaps slightly delayed. TDS levels at the outlets of both Potatopatch and Mission Lake were substantially higher than elsewhere, reaching maxima of 291 and 890 ppm, respectively. This is due to seawater inflow into the lakes at high tides. More detailed information on this is presented below in sections 4.9, 4.10, and 4.11.

Turbidity and Total Suspended Solids: Water clarity is important aesthetically as well as ecologically. People prefer clear water to murky water. Where water clarity is decreased by microalgae and zooplankton, it indicates high biological production, and this is beneficial for fish rearing. Silt, on the other hand, clouds the water without providing organic matter to the food chain. Silt may actually interfere with biological production by shading microalgae and interfering with vision-based feeding strategies of zooplankton and fish.

Water clarity is usually expressed in terms of turbidity. This is a measure of how much a water sample scatters light. As a point of reference, Alaska drinking water regulations allow a maximum turbidity of 1 NTU. Light is scattered by particles, and the total suspended solids (TSS) measurement directly indicates the dry weight of particles in the water, in parts per million.

Another measure of water clarity is the Secchi depth. The Secchi depth is more intuitive for most people, because it represents how far an observer can see into the water. The Secchi disk is a black and white sectored disk which is lowered into a lake on a line. The average of the depth where the disk disappears when lowered and where it reappears when raised is the Secchi depth.

Figure 4-6 shows the correlation between turbidity and Secchi depth for the 1995 limno samples. In order to see 3 feet, turbidity had to be less than about 8 NTU. Two foot clarity corresponded to about 12 NTU, 1.5 foot clarity corresponded to 15 NTU, and 1 foot clarity corresponded to about 25 NTU.

Based upon average values from the limno samples taken from each lake, Lower Horseshoe Lake is by far the most turbid of the lakes (48.4 NTU), with Potatopatch (15.3 NTU), Mission (8.2 NTU), and Upper Horseshoe (7.3 NTU) following.

Siltation is a serious problem in Lower Horseshoe Lake, and it also affects the downstream lakes. A number of the microscopic phytoplankton counts for Lower Horseshoe and downstream lakes included remarks on the presence of silt or glacial flour in the samples. Aerial photographs also show a gray cast to the water in Lower Horseshoe Lake, and gradual clearing in the downstream lakes. This silt decreases the Secchi clarity, and biases the Trophic State Indication toward the eutrophic, despite low levels of total phosphorus and Chlorophyll a.

The water quality sampling from the streams, inlets, and outlets indicates that runoff from the unpaved section of Selief Lane is a more significant source of turbidity for Lower Horseshoe Lake than is the flow from Upper Horseshoe Lake. Selief Lane is constantly being ground down by traffic, and the resulting dust is washed into Lower Horseshoe Lake and the Selief Ditch whenever the rain comes.

The water coming off Pillar Mountain averaged about 3.2 NTU (excluding the 3/28 sample), but runoff from Selief Lane and the adjacent residential areas elevated the turbidity to an average of 10.1 NTU (excluding 3/28) by the time it entered Beaver Lake. An intense rain on 3/28 elevated the Pillar Mountain flow turbidity to 5.5 NTU, but runoff from the road and residential areas raised the turbidity of the combined flow to 440 NTU at the inlet to Beaver Lake. The highest turbidities seen in our study occurred as a result of runoff from the unpaved section of Selief Lane.

Elevated turbidity in Potatopatch Lake and Mission Lake may be caused by: 1) turbidity from silt, tannins, or iron precipitates in the water entering the lake; 2) chemical reactions which cause dissolved ions (most likely ferrous iron) in the influent water to precipitate and form particles; 3) resuspension of silty bottom sediments by wind; or 4) microalgae blooms.

Inspection of the turbidity data in figures 4-4A, B, and C shows that turbidity was generally less at lake outlets than in tributary streams. This is consistent with settling of silt or precipitate particles from the water column. On two occasions in both Potatopatch Lake and Mission Lake, however, outlet turbidity was higher than in the tributary stream. The first example, on May 11 and 15, 1995, may be due to microalgae blooms in the lakes. The second example, on October 31, 1995, occurred immediately after a major SE storm, and may reflect wind induced mixing of bottom sediments into the water column.

Iron: Iron concentrations generally increase with increasing turbidity. Dissolved iron can precipitate as an iron hydroxide floc under conditions of oxygen saturation and neutral or high pH. Rust colored deposits on pipes and debris at the outlet of the storm sewer into Potatopatch Lake suggests that iron precipitates are important there. This could be one of several contributing causes of elevated turbidity in area lakes.

The total iron test method uses an acid extraction to mobilize all forms of iron in an unfiltered water sample, so solid phase mineral iron from the silt particles, rather than dissolved ferrous iron, can also cause high iron reading which track with turbidity. Further studies are needed to sort out which source of turbidity is dominant in different lakes. We have contacted Dr. Randy Stahl of the University of Alaska, Juneau, School of Environmental Sciences. He is a specialist in iron chemistry in natural waters, and he is available to help design a research program to clarify the role of dissolved iron in turbidity of area lakes.

Iron testing was suspended at the end of June 1995 at the urging of one of the Clean Lakes Directors, so the data set is less complete than for some other parameters. The highest iron concentrations were seen in most cases in the March samples, more or less coincident with thawing of the soil after winter. We hypothesize that during winter, the ground is frozen and little precipitation can seep into the groundwater, so groundwater flux from seeps and springs is decreased. Water in contact with bedrock or other iron-rich material has more time to leach iron, and the decrease in availability of oxygenated surface water makes leaching more rapid, so the groundwater iron concentration is increased. Early spring rains displace this high-iron groundwater into streams and lakes, and produce high iron concentrations in surface waters.

In the Island Lake watershed, the Horseshoe Lakes and the Island Lake Park stream had elevated iron levels throughout the sampling period. Samples from Lilly Lake, the Baranof Park storm sewer, and Potatopatch Lake indicated that most of the iron (and turbidity) entering Potatopatch Lake originated from Baranof Park.

pH: pH is a measure of the concentration of hydrogen ions (H+) in solution. Neutral pH of pure water is 7.0. The pH of rainwater is usually between 6 and 7. Seawater has a pH of about 8.3, raw sewage has a pH of about 7.2. The pH of lakewater can be raised by photosynthsis of weeds or phytoplankton when growth is limited only by dissolved carbon availability. Extremes in pH (perhaps below 5.5 or above 8.5) can be stressful to fish and other members of the food chain.

pH levels were fairly constant in the Island Lake watershed. Only at the Island Lake Park creek did pH consistently exceed 6.8. The reason for the elevated pH at Island Creek Park is unknown, but it is accompanied by elevated turbidity, iron, TDS, and fecal coliforms.

pH levels in Potatopatch and Mission Lakes were elevated above 9.3 for most of the summer in 1995, and were again above 9.3 in the single 1996 limno samples collected July 30. This is probably due to the high nutrient levels in both lakes which facilitates microalgae and macrophyte growth. Plant growth requires carbon dioxide, and as the plants withdraw carbon dioxide from the water, the conversion of bicarbonate (HCO_3-) to carbon dioxide (CO_2) liberates hydroxyl ions (OH-) which raises the pH. The documented backflow of seawater into both these tidewater lakes has raised the carbonate alkalinity, and contributes to the pH increase.

4.3 Limnology and Fish Habitat Data

4.3.1 Introduction

The objective of the limnological water testing was to determine how well the lake systems function to produce the zooplankton (microscopic animals) and insects which feed fish. Fish eat zooplankton; zooplankton eat phytoplankton (microscopic plants); and phytoplankton "eat" nutrients and sunlight. The foundation of the food chain is therefore the nutrients required by phytoplankton. Excessive levels of nutrients can cause overproduction of phytoplankton, however, and if the phytoplankton population crashes and decays, this can lead to oxygen depletion and fish kills.

4.3.2 Methods

Lake Water Sampling: We entered into an agreement with the Alaska Department of Fish and Game (ADF&G) to guide us in assessing the biological health of our lakes, particularly as it relates to salmonid fish production. They provided us with copies of their standard operation procedures for establishing a sampling station in each lake, measuring oxygen concentration and temperature, collecting water samples, and filtering the samples in preparation for analysis. ADF&G also advised us on protocols for mapping the lake depth profiles (bathymetry) and conducting our fish trapping program.

We sampled each of the nine lakes five times between May 3rd and October 17th, 1995; once in the early spring, three times through the summer, and once in the fall. The sampling station was located as close as possible to the deepest spot in each lake, and the same location was sampled each time, subject to difficulties experienced holding position. At the deeper lakes we collected samples at 1 meter, 2 meters, and at an additional deeper depth at Dark, Island, and Gertrude Lakes. We filtered and preserved our samples at the Kodiak Fish & Game lab within several days of collection, and then sent them to their limnology lab in Soldotna for analysis.

The same sampling protocols were followed for a single round of sampling in 1996. Samples were collected from all nine lakes on July 29 and 30, 1996.

Temperature, Oxygen, and Secchi Clarity: We measured the temperature and oxygen concentration at 0.5 meter or 1 meter intervals through the water column at the sampling station at the time we gathered water samples for the other analyses. We also performed an additional temperature/oxygen profile at each lake through the ice in March 1995.

We measured Secchi clarity also when gathering each water sample. As described above, a Secchi disc is a black and white sectored disc about 6" in diameter tethered at the center to a line. The Secchi clarity is the average of the depths at which the Secchi disc appears when lowered and reappears when raised from the bottom through the water column. The Secchi depth is a commonly used measure of water quality for studies in fresh and marine waters.

Physical Parameters, Ions, and Nutrients: The ADF&G Soldotna Limnology Lab analyzed each of our filtered water samples for twenty different parameters. Of the twenty , six parameters (conductivity, pH, turbidity, color, iron, and total dissolved solids) were also tested in the water quality samples analyzed by the City of Kodiak laboratory. The latter samples were collected at the inlet streams and outlet streams of the lakes, whereas the limnology samples were taken from various depths at the deep point in each lake.

The limnology lab tested for physical parameters (conductivity, pH, alkalinity, turbidity, color, total solids, and total dissolved solids), metal ions (calcium, magnesium, iron), nutrients (total phosphorus, total filterable phosphorus, filterable reactive phosphorus, total Kjeldahl nitrogen, ammonia, nitrate + nitrite, reactive silicon), and organic indicators (particulate organic carbon, chlorophyll a, and phaeophytin a). Test methods and significance of parameters are presented in

ADF&G publication #71, Limnology Field and Laboratory Manual: Methods for Assessing Aquatic Production by Koenings, Kyle, J.A Edmundson, and J.M. Edmundson, published February 1987.

Elemental Metals: The limnology lab sent one sub-sample from each lake to Elemental Research Inc., of North Vancouver, B.C. for analysis of elemental concentrations in lake water. The late July samples were used. The mass spectrographic technique used is very precise, and results were reported in micrograms per liter, equivalent to parts per billion.

Phytoplankton: The limnology lab sent phytoplankton sub-samples from each lake sample to Eco-Logic Limited of North Vancouver, B.C. for microscopic counts of algal cell species, abundance, cell volumes, and cell weights. Eco-Logicalso produced a table of food values of the predominant microalgae, as well as alphabetized master species lists for the overall project and for each lake.

Zooplankton: Limnology lab staff performed microscopic zooplankton counts inhouse on each lake sample. They followed the procedures for zooplankton evaluation set forth in the Limnology Field and Laboratory Manual.

4.3.3 Results

Temperature, Oxygen, and Secchi Clarity: Surface water temperature, oxygen concentration, and Secchi clarity are presented in Table 4-3. Complete temperature and oxygen profiles for each lake are presented in Tables 4-4 A-G.

Physical Parameters, Ions, and Nutrients: A spreadsheet of all results from the limnology lab are presented in Appendix D. This includes five different sample dates from each of nine lakes, with twenty parameters tested for each sample. There were wide variations in results from different seasons in the same lakes. The **average** values from each lake for selected parameters are presented in Tables 4-5 A and B.

Elemental Metals: The results of these analyses are presented in condensed form in Table 4-6 A and B. The complete results are presented in Appendix E.

Phytoplankton: Eco-Logic's microscopic counts of algal cell species, abundance, cell volumes, and cell weights are presented in Appendix F. Eco-Logic also produced a table of food values of the predominant microalgae, as well as alphabetized master species lists for the overall project and for each lake. Complete results of these analyses are also presented in Appendix F.

Zooplankton: The limnology lab found around a dozen different zooplankton species in the urban lakes, and the number and size of each were recorded for each sample. An average abundance (weight per unit area of lake surface) and weighted abundance were calculated by the limno lab for each lake. The weighted zooplankton biomass is presented in Table 4-5B, Limnological Water Quality Summary. Complete results to the species level for each sample are presented in Appendix G.

4.3.4 Discussion

Jim Edmundson, a limnologist with ADF&G in Soldotna, reviewed the results of our 1995 limnology testing. He submitted a three page memorandum which discusses trophic level classifications, macrophytes, nutrients, and the likelihood of algal blooms or oxygen depletion. His memo is attached in Appendix H.

Temperature, Oxygen, and Secchi Clarity: There is little difference in surface temperatures between the lakes, although the ice normally goes out of Mission Lake and Potatopatch Lake about 2 weeks before it leaves the other urban lakes.

Oxygen may be problematic in Upper Horseshoe Lake during the winter because the ice prevents oxygen transfer, and the retention time is very long due to the small size of the watershed. Upper Horseshoe Lake is covered by a dense growth of macrophytes (mainly yellow lilies) during the summer, and these die back and decompose, consuming oxygen, during the winter.

Oxygen levels were somewhat depressed in Mission Lake during mid-October 1995. This may be similarly due to the decomposition of aquatic macrophytes, primarily pondweeds, which grew abundantly in that lake in 1995. Oxygen was also depressed under the ice in March 1995, but testing in March 1996 showed high oxygen levels.

Oxygen levels can and often do fluctuate daily, particularly in shallow productive lakes. Summer nighttime or winter under-ice oxygen depletion could cause a fish kill without leaving any long-lasting evidence.

The average Secchi Depth column in Table 4-3 summarizes the status of water clarity in the lakes. If we consider a Secchi depth of less than 1 meter to be aesthetically undesirable, then the Horseshoe Lakes, Potatopatch Lake, and Mission Lake could stand improvement.

Physical Parameters, Ions, and Nutrients: Specific conductance, pH, alkalinity, calcium, and magnesium levels were all elevated in Potatopatch and Mission Lakes. This is consistent with the documented backflow of seawater into the lakes at high tides. Backflow is more frequent at Mission Lake. 1996 limnology samples show a late July conductance at 1 meter depth of 4430 umhos/cm, compared with an August 1, 1995 value of 537 umhos/cm. The salt water intrusion into Mission Lake may have increased during the winter.

Turbidity, iron, and total suspended solids (total solids - total dissolved solids) generally track together. The ratio of total iron to turbidity is plotted versus turbidity for all of the 1995 limnology samples in Figures 4-7 A and B. Upper Horseshoe Lake has the highest ratio, as well as the highest total iron. Curiously, Potatopatch Lake and Mission Lake have the among the lowest ratios. This implies that the mechanism which causes turbidity in these lakes requires relatively little iron to produce a unit increase in turbidity. This could be because iron is unimportant in comparison with silt or phytoplankton, or it could be that iron colloids are particularly effective at scattering light for a given weight of suspended solids. Additional study and expert advice is needed to resolve this question.

Nutrients are important because they normally control the production of phytoplankton in a lake, and this forms the foundation of the food chain. Phytoplankton reproduce rapidly, and they usually proliferate until their growth is limited either by grazing, by the scarcity of some necessary nutrient, or by sunlight limitation. In natural fresh waters, phosphorus is usually the first nutrient to become limiting to growth. Where phosphorus levels are enriched, nitrogen is the next nutrient to become limiting. If both phosphorus and nitrogen are present in excess, carbon may become limiting. The absorbtion of carbon dioxide from lake water results in an increase in pH, particularly if the carbonate alkalinity is high.

High nutrient levels allow high phytoplankton production, which makes for murky water but good fish production. Lower Horseshoe Lake had the highest total phosphorus concentration with 55 ug/liter, followed by Potatopatch Lake with 43 ug/liter and Mission Lake with 33 ug/liter. These lakes are not phosphorus limited. Chlorophyll a, fish growth, and other measures of production are high in Potatopatch and Mission Lakes. High turbidity from silt in Upper Horseshoe Lake may be the cause of low production in that lake.

The other lakes in the Island Lake system, as well as Lilly Lake and Gertrude Lake all have around 10 ug/liter phosphorus, and may be phosphorus limited. Turbidity in these lakes is less, but fish growth rate is probably also less.

Elemental Metals: ADEC has promulgated water quality standards in 18 AAC 70. These standards provide maximum contaminant level criteria for various water uses. The most stringent criteria are specified for the use of water for "growth and propagation of fish, shellfish, other aquatic life, and wildlife," in fresh water. The toxics criteria are adapted from EPA's "Toxics

Rule". Some criteria are expressed by a formula dependant on water hardness. The criteria are presented with the results of the elemental analysis in Tables 4-6 A and B, with total hardness assumed to be 50 mg/liter. Blank entries in the table for contaminant criteria are presently unregulated. Blank entries for element concentrations were found below detection limits.

Lead was found slightly above the freshwater aquatic life criterion in Lower Horseshoe Lake, and near the limit in Lilly and Potatopatch Lakes. Iron was above the criterion in the Horseshoe Lakes and Beaver Lake, and near the criterion in Potatopatch Lake. In Lower Horseshoe, Island, and Lilly Lakes, selenium was above the criterion for selenite, but far below the criterion for selenate. The toxicity of the selenium in the water of the lakes depends on its oxidation state, which is presently unknown.

Aluminum was above the secondary drinking water criterion in Lower Horseshoe and Potatopatch Lakes. Manganese was above the secondary drinking water criterion in all lakes. Secondary drinking water criteria "mainly affect the aesthetic quality of drinking water", and do not imply toxicity at that concentration.

Aquatic life criteria are quite conservative, and are generally much stricter than drinking water criteria due to the possibility of bioaccumulation and bioconcentration. The results of the elemental analysis suggest that there is little or no toxic effect on aquatic life in the urban lakes due to analyzed metals.

<u>Phytoplankton:</u> Detailed interpretation of the phytoplankton results is beyond our capabilities. Results from Eco-Logics are presented in Appendix F as part of our baseline data set, and may be scrutinized by specialists in the future.

A cursory review of the results shows good species diversity, which is characteristic of healthy ecosystems. Blue-green algae are relatively scarce. Blue-green algae can fix atmospheric nitrogen, so they often form floating mats in hyper-eutrophic systems where phosphorus is abundant and nitrogen is limiting. Their relative scarcity in Kodiak's urban lakes confirms that phosphorus enrichment has not reached the level where anoxia, fish kills, decaying algal mats, and foul odors can be expected.

<u>Zooplankton:</u> Detailed interpretation of the zooplankton results is also beyond our capabilities. Results from the Soldotna Limnology Lab are presented in Appendix G as part of our baseline data set.

In the 1995 samples, Potatopatch, Mission, and Lower Horseshoe Lakes had seasonal average weighted zooplankton biomass levels below 10 mg/m2. Lilly Lake and Beaver lake had biomass levels near 15 mg/m2. Upper Horseshoe, Dark, Island, and Abercrombie Lakes had biomass levels of 216, 190, 427, and 884 mg/m2, respectively. Almost three fourths of the biomass in Upper Horseshoe Lake occurred as one species (Bosmina) in one of the five samples (June 22). The 1996 samples were gathered July 29 and 30, and zooplankton biomass was very low in Upper Horseshoe at that time. Excluding Upper Horseshoe results, the ranking of lakes by order of weighted zooplankton biomass is very similar for July'96 and average'95 results.

There appears to be a positive correlation of seasonal mean zooplankton biomass with retention time, but other factors such as primary productivity, turbidity, and grazing by fish and aquatic insects complicate the relationship. Zooplankton biomass may not have much value as an indicator of lake "health" or the capacity to support rearing silver salmon.

4.4 Fish Trapping

4.4.1 Introduction

We conducted minnow trapping surveys in all the lakes in the spring and the fall of 1995. Minnow trapping gave us samples of the small fish inhabiting the lakes. Steve Honnold and Steve Schrof of ADF&G provided us with guidance on trapping intervals, bait selection, and data analysis and interpretation. Mr. Jim Blackburn, a CLK board member and ADF&G data specialist, performed statistical analysis of our data and wrote portions of this section. The high school fisheries class, under the supervision of the instructor, Jane Eisemann, assisted during April and May in retrieving traps; counting, measuring, and weighing the fish; and recording the data.

The objective of the minnow trapping surveys was to assess the relative fitness (age, size, and condition factor) of salmonids in each of the nine lakes. We caught silver salmon, rainbow trout, Dolly Varden trout, and sticklebacks, as well as two sculpins. The Alaska Department of Fish and Game (ADF&G), Sport Fish Division has been stocking coho and king salmon, and rainbow trout juveniles for put and take sport fisheries since 1988. However, king salmon stockings were discontinued in 1994. The number of juveniles and species stocked each year (1990-1996) are summarized in Table 4-7.

The purpose of this review is to summarize the results of the minnow trapping for salmonids in the lakes evaluated under the Clean Lakes for Kodiak project. The relative fitness of salmonids in the studied lakes is important for two reasons. First, it is a guage of the health of the fish populations, which are important as sportfishing resources. Second, the fitness of the fish serves as an indicator of the "health" of the lake ecosystems, in that salmonids are sensitive to poor water quality.

4.4.2 Methods

Minnow trapping was conducted in April, May, October, and November of 1995. Minnow traps were 8 inch diameter by 24 inches in length, galvanized wire mesh cylinders with conical shaped ends. The tip of the conical ends are open, pointing inward to allow small fish to enter the trap, while making escape difficult. The openings of the trap are about 3/4 inch in diameter which limits the size of the fish that may enter.

We found that silver salmon or Dolly Varden trout longer than about 130 mm had difficulty entering the traps, and some were found stuck in the trap opening. Some 2+ year old silver salmon may be too large to trap with the current trap opening size. If we conduct more fish trapping studies in the future, we may enlarge the trap openings to minimize size selection by the traps.

The minnow traps set in April were baited with canned creamed corn. Catch rate with this bait was poor, and all further trapping used preserved king salmon roe for bait. Traps were set near lake tributaries, near outlets, and within 20 feet of shore near logs, bushes, and aquatic plants for 18-24 hours. Captured fish were sorted by species and enumerated. The number of sticklebacks was counted, but they were not measured due to their small size and great abundance in many lakes.

Coho salmon and rainbow trout were anaesthetized in MS-222 so we could measure, weigh, and collect scale samples for later microscopic age determinations. After being measured, fish were revived in fresh water and returned to the lake of origin. Lengths (in millimeters), weights (in grams), and condition factors (K) were averaged for each lake. The condition factor, defined by: $K = 100{,}000 \times \text{Weight} / (\text{Length})^3$ is the "measure of a fishes well-being relative to its length-weight proportions" (Rounsefell and Everhart, 1953, in Fishery Science: Its Methods and Applications). A larger condition factor indicates a plumper fish.

4.4.3 Results

Minnow traps were set in 11 different locations for 31 sets of samples (Table 4-8). The number of traps fished per location ranged from one to ten. The catch from 198 traps was 3,559 stickleback, 919 juvenile coho, 121 Dolly Varden, 83 Rainbow, and 2 sculpins. Table 4-9 shows the catch rates, average length and weight, and condition factor for coho, rainbow, and Dolly Varden from the urban lakes. The maximum catch rate for juvenile coho was 29 for one trap in Selief Ditch in

October, for Dolly Varden it was 5.4 and for Rainbow it was 5.3. Catch rates of coho were generally lowest in late April (probably due to poor effectiveness of the bait), increased in May, and were highest in October-November (Tables 4-8 and 4-9).

Condition factors for coho were higher (no significance tests were conducted) in autumn than spring (Table 4-9). Rainbows had higher condition factor only in Lake Gertrude in the fall (Table 4-9). Dolly Varden condition factor differed little by season with a tendency for higher values in fall (Table 4-9).

Scales were collected from juvenile coho. Age, length, and weight of these fish are presented in Table 4-10. In the spring, age-0 fish ranged from 59 to 116 mm, and age-1 ranged from 115 to 158 mm. In the autumn, age-0 fish were 73 to 123mm, and age-1 were 104 to 137mm. Thus, there was little overlap in size of the age classes in spring with some overlap in the autumn.

Size distributions of coho (Figure 4-8) describe the catch and show that Potatopatch Lake and Mission Lake fish were larger than fish from the other areas. The mean length of autumn coho of age-1 (Figure 4-9) provides a little more detail for area comparisons. Potatopatch Lake fish were significantly larger than even Mission Lake fish. Dark lake and Island lake fish were smaller than those in many of the other lakes (Figure 4-9). It is not known how factors such as choice of sampling location may affect the size distribution.

The size of Dolly Varden captured by season is presented in Figure 4-10. Most of the fish were in two modal groups, about 68-88 mm and 113-138mm. (These sizes are the mid points of 5 mm wide classes.)

4.4.4 Discussion

Fry stocking into Kodiak lakes by ADF&G Sport Fish division has been done every year recently. Coho fry have been stocked at different times, which greatly affects the size at stocking; 0.50 grams in June 1994 and 2.1 grams in August 1995 (Table 4-7). We do not know whether coho fry which are released earlier grow as well as hatchery reared fish, nor how survival compares. Additional fall fish trapping studies could help answer these questions.

These fish typically go to sea during the spring or early summer after having spent either one or two winters in the lakes or creeks. The timing of the spring outmigration is unknown, and may vary from lake to lake. The fall 1995 fish trapping data seem to show no age-1 fish in Mission Lake, with some in Potatopatch Lake and many in the lakes of the Island Lake watershed. We have documented seawater intrusion into Mission Lake (and to a lesser extent into Potatopatch Lake), and this may have an effect on the smolting process in Mission Lake. Using identical procedures as were used in the other lakes, our catch rate in the spring fish trapping in Mission Lake was very low (3 coho caught vs. 63 in Potatopatch). The reason for this is unknown.

The Fall round of fish trapping occurred 2-1/2 to 3 months after the lakes were stocked with raceway-reared age-0 silver salmon juveniles from the Pillar Creek hatchery on the Kodiak road system. According to Len Schwartz of ADF&G Sportfish, the average weight of the fish was 2.1 grams when stocked on August 3, 1995. The mean length was unavailable.

The fish which we trapped in the fall varied in average length from lake to lake. As shown in Figure 4-9, the age-0 coho juveniles which we captured in the Island Lake system had an average length of 75 mm while silvers which we captured in Potatopatch Lake and Mission Lake had average lengths of 98 mm and 91 mm, respectively.

We did not perform pre-stocking fish trapping, so we do not know the abundance or size of age-0 coho already in the lakes due to natural production. We did observe spawning pairs of adult silver salmon in the outlets of Beaver, Dark, and Island Lakes in Fall, 1995. A homeowner on Potatopatch Lake produced a photo of an adult silver salmon carcass near an inlet creek there, so even Potatopatch Lake may have had some natural production. The influence of naturally produced silver salmon on our fish trapping results is unknown. Pre-stocking fish trapping could help determine the significance of natural silver salmon reproduction in the urban lakes.

Individual fish grow well when they have abundant feed, and Potatopatch and Mission Lakes apparently produce larger juvenile silver salmon than the lakes of the Island Lake watershed. This is probably related to the high nutrient concentrations and resulting greater primary productivity in Potatopatch and Mission, but it might instead be related to initial stocking densities, the presence of natural reproduction in the watersheds, ecological effects caused by seawater intrusion, proliferation of aquatic weeds, or the relatively large areas of shallow water habitat.

Our fish trapping effort was quite limited in scope. The results have brought up far more questions than they have answered. We are concerned by the environmental changes which could result from continued or increased seawater intrusion into Mission Lake, and more study of rearing conditions there is needed. The members of the Kodiak Wetlands and Watersheds Association are concerned about juvenile coho in the Island Lake system, and they may wish to enhance rearing and spawning habitat there. Among the questions that have been raised are:

- Where do coho juveniles live (especially in shallow lakes)?
- Where do they feed (especially where there is a seawater lens)?
- What do they eat (deep lakes w/zooplankton vs. shallow lakes with none)?
- What fraction survive from stocking to smolting? and
- When do they go to sea?

Most of these questions are probably too expensive for us to answer. Steve Honnold of the ADF&G Commercial Fisheries Development Branch suggested that stomach content analyses of silver salmon in Mission Lake and control lakes might help indicate where and upon what they feed. An intensive mark/recapture fish trapping effort (using a dye marker) might economically give us a handle on abundance and mortality, and pre-stocking fish trapping might provide information on natural production.

Additional data on salmonid fish in the urban lakes would be a valuable addition to our environmental baseline data. It might also have bearing on how we should proceed with specific watershed rehabilitation or enhancement actions. Volunteers are available from the U.S. Fish and Wildlife Service "Salmon Camp" program and from the Kodiak Wetlands and Watershed Association. The scope of future fish work will depend on the interest of watershed groups, the continued support of ADF&G, and the support of local and federal agencies.

4.4.5 Sutliff and ADF&G Sportfish Fish Trapping through the Ice

Norm Sutliff, a lakeside resident and Clean Lakes for Kodiak board member, enlisted the assistance of ADF&G Sportfish biologists to perform fish trapping in Mission Lake in March 1996. They cut holes through the ice and placed minnow traps in four locations. There was no parallel fish trapping in other lakes. Len Schwarz wrote a memo describing their findings. This is included in Appendix I.

In brief, they caught a total of 25 coho salmon juveniles from four traps, each set twice. The average length of all fish was 106 mm. Scale aging indicated that all fish were from the August 7, 1995 stocking event. Len Schwarz wrote that the growth was excellent, and that these fish would all go to sea in the spring.

4.5 Macrophyte (Freshwater Aquatic Weed) Survey

4.5.1 Introduction

Freshwater macrophytes provide substrate for aquatic insects and cover for fish, but an overabundance can be ecologically damaging as well as aesthetically unappealing. Mission Lake had reportedly seen an increase in pondweeds in the early 1990s. The growth had become so thick by 1995 that recreational uses were interfered with, and macrophyte control in Mission Lake became a priority for the CLK Board.

For an unknown reason, weed growth was sparse in Mission Lake in 1996. This could be related to increased seawater intrusion through the tide gate, or to the absence of a sewage spill into the lake in 1996. A short duration sewage spill took place in May 1997, so macrophyte monitoring in 1997 may help determine whether the scarcity of the macrophytes was due to nutrient limitation or inhibition by seawater.

4.5.2 Methods

We conducted a macrophyte survey of the lakes in late August / early September 1995. We followed recommendations presented in EPA's publication 440/4-90-007 (August 1990) Monitoring Lake and Reservoir Restoration. Bruce Short identified the macrophytes found in each of the lakes using Hulten's taxonomic key. He plotted their location and abundance on bathymetric maps in Figures 4-11 A through H. A master species list is presented in Table 4-11. Bruce collected a voucher sample of most species, and this collection of pressed and dried plants is available for inspection at the Clean Lakes office.

4.5.3 Results and Discussion According to ADF&G Limnologist Jim Edmundson, "it is important to know that high aquatic weed biomass is common in shallow lakes with relatively clear water and organic rich sediments. In general, high nutrient loading does not cause excessive macrophyte growth, good light conditions within the littoral zone do". In other words, the high abundance of weeds in Mission Lake was caused more by the shallow depth and the thick sediment (and nutrients in the sediment) than by nutrient enrichment in the water column. The higher levels of turbidity found in Potatopatch Lake may inhibit the aquatic weeds somewhat (by shading) in that lake, despite higher water column nutrient levels.

Aquatic macrophytes may provide good habitat for rearing silver salmon. There are a number of macrophyte control options available, but each has different pros and cons depending on the species of weed to be controlled. In brief, the five options are: 1) periodical mechanical harvest; 2) biological control (grass carp); 3) periodical herbicide application; 4) lake deepening and sediment removal by dredging; and 5) lake drawdown and winter freeze killing of macrophyte propagules in sediments. A possible sixth option which may be occurring in Mission Lake is allowing a seawater lens in the lake to inhibit or kill rooted macrophytes. The least disruptive control measure (but probably also the least long-lasting) is mechanical harvest.

We have been in contact with an aquatic weed expert from Portland (Oregon) State University named Dr. Mark Sytsma, and he has assisted us with identifying the weeds and discussing control options. This macrophyte survey provides us with abundance and species information we would need to move ahead with a feasibility analysis of various control techniques. The scarcity of weeds in Mission Lake during 1996 has made this a low priority for the time being.

Norm Sutliff, a CLK Board member, contracted an environmental consultant based in Arizona to provide recommendations and cost estimates for macrophyte control. The study was paid for with private funds, and is not included with this report. The report concluded that the most feasible approach was mechanical harvest, with an annualized cost of $3743. The initial purchase of a $32,000 floating harvester is included in the annualized cost.

4.6 Freshwater Mussels

We found freshwater mussels in Beaver Lake, Dark Lake, and Island Lake. Dr. Bob Otto of the National Marine Fisheries Service in Kodiak put us in touch with Nora R. Foster, president of the Western Society of Malacologists, and a curator at the University of Alaska Museum in Fairbanks. She identified these molluscs as Anodonta beringiana. She posted our questions about propagation and filtration rates on the Internet, and there were many responses, some from as far away as Germany. The larval molluscs apparently spread by attaching to the gills of fish or the feet of birds.

The mussels feed by filtering particles from water, so they can be important in removing suspended silt as well as plankton. We have observed improved water clarity in the lower lakes of the Island Lake system compared with the upstream lakes, and this may be partially a result of the efforts of these mussels. Future studies could investigate how effective these animals are at filtering water, and whether these animals might be transplanted into Potatopatch Lake and Mission Lake to assist in clarifying the water in those lakes.

4.7 Island Lake Watershed Intensive Water Quality Testing

4.7.1 Introduction

Results of watershed sampling in 1995 indicated that the Island Lake watershed had some areas with very high turbidity, and other areas with occasional high fecal coliform counts. The highest turbidity and fecal counts often occurred during or following a heavy rain. We therefore decided to undertake more intensive sampling in the Island Lake watershed during a storm. The purpose of this work was to get a high resolution "snapshot" of the watershed in order to localize sources of turbidity and fecal contamination.

4.7.2 Methods

We collected 22 samples from the Island Lake watershed on September 13, 1996. 1.05 inches of rainfall had fallen in the 24 hours prior to sampling. Two people worked together to collect samples rapidly from upstream to downstream. All sampling was completed within about one hour. Samples were immediately delivered to the City's wastewater treatment plant laboratory, where they were analyzed by City staff. Fecal coliform samples were diluted by a factor of 10 before being analyzed by membrane filtration. Fecal coliform results are expressed in units of colony forming units per 100 milliliters (cfu/100ml). Turbidity samples were analyzed in a Hach turbidity meter. Turbidity results are expressed in units of Nephelometric Turbidity Units (NTUs).

4.7.3 Results and Discussion

Sampling locations and results are shown in Figure 4-12. Results for fecal coliforms and turbidity are also tabulated in Table 4-12.

In the watershed above Beaver Lake, fecal coliform levels were highest in flows from ditches next to unpaved roads. The creek from Pillar Mountain and Lower Reservoir had a count of 180 cfu/100ml. Flows draining upper Selief Lane, Lynden Way, and Mozart Circle had fecal coliform counts of 2490, 2100, and 1200 cfu/100ml, respectively. The Selief roadside ditch next to Elderberry Heights subdivision went from 800 cfu/100ml at Lot 13 to 550 cfu/100ml at Lot 11 (downstream of the Lynden Way input) to 490 cfu/100ml at Lot 6.

Following the addition of the 1200 cfu/100ml Mozart Circle flow, the combined flow had a count of 1460 cfu/100 ml at the inlet to Beaver Lake. This 1460 cfu count exceeds both of the immediate upstream counts, and if taken at face value, suggests that there is an additional source of fecal contamination downstream of the Mozart Circle flow. The unexplained decline in mainstem counts from Lot 13 to Lot 11 to Lot 6, however, calls into question just how variable fecal coliform counts may be in mainstem flows.

The relatively high fecal coliform count of 840 cfu/100ml at the inlet to Dark Lake may indicate that there is an additional source of fecal contamination near the outlet of Beaver Lake. Past testing at times of low flow has shown high fecal counts at this location. A sewage lift station is located near the intersection of Beaver Lake Loop and Beaver Lake Drive next to the lake, and there could possibly have been intermittent problems there.

Additional intensive sampling should be conducted to replicate this testing, with particular focus on the Selief ditch and the area downstream of the Mozart Circle input. Duplicate or triplicate samples from the same locations over a short span of time would help address the degree of variability between samples.

Turbidity levels were also very high in flows from ditches next to unpaved roads. Flows from Upper Horseshoe Lake (and associated ditches), upper Selief Lane, and Lynden Way had turbidities of 98, 107, and 143 NTU, respectively. The turbidity from the Mozart Circle flow was not available from the lab. These turbid side flows raised the turbidity of the mainstem flow progressively downstream: 5 NTU (Pillar Mountain creek); 12 NTU (Lot 13); 23 NTU (Lot 11); 28 NTU (Lot 6); 36 NTU (inlet to Beaver Lake). Silt runoff from the unpaved road decreased the equivalent water Secchi clarity from about 1.5 meters (five feet) to less than 0.3 meters (1 foot).

The subwatershed which drains into Island Lake at the Island Lake park was also tested intensively for fecal coliforms and turbidity. The reach of the creek which originates at the Smokey Stover Recreation Area had low coliform counts, but high turbidity due to ongoing construction activities.

The arm of the creek which originates behind Safeway had a jump in fecal coliform counts from 60 to 210 cfu/100ml before entering a 24" diameter culvert beneath the Brechan Enterprises yard. Turbidity jumped from 9 NTU to 56 NTU while passing through Brechan Enterprises property.

Both the turbidity (174 NTU) and the fecal coliform count (1310 cfu/100ml) were high in a ditch flow from Arctic Tern and Ptarmagin Pass Streets. This raised the turbidity (59 NTU) and fecal count (200 cfu/100ml) in the main flow to 116 NTU and 330 cfu/100ml, respectively, where the creek enters the lake.

The results of this intensive sampling confirm that runoff from unpaved roads in the Island Lake watershed can produce very high turbidities. Additional replicated sampling is required to determine whether there is an unidentified source of sewage entering surface waters near Mozart Circle or near the inlet of Dark Lake.

The very high coliform counts seen in the Island Lake Park creek on May 17 and June 21, 1995 (1800 and 1640 cfu/100ml, respectively) were not observed in the creek during this sampling event. Periodic sampling of the Island Lake Park creek should be conducted to monitor for safe fecal coliform levels for contact recreation. If extreme counts are encountered, additional intensive monitoring should be conducted throughout this subwatershed to isolate the source of contamination.

4.8 Baranof Park Storm Sewer Water Quality Testing

4.8.1 Introduction

Watershed and limnological samples from 1995 indicated high levels of turbidity, iron, and nutrients in Potatopatch Lake. The southwest corner of the lake, where the major tributary enters, is slow to freeze in the winter, and often provides the only open fresh water available to ducks. As groundwater is warmer than surface water in the winter, we have assumed that a significant source of groundwater flows into Potatopatch Lake. Watershed sampling which isolated the storm sewer flow originating in Baranof Park from Lilly Lake flow indicated that the Baranof Park flow was around four times higher in turbidity, iron, and other contaminants.

Our historical research has shown that the present Baranof Park area contained a 2-1/2 acre lake and surrounding wetlands in 1957. The area of the lake was filled with debris from the 1964 earthquake and tsunamis, as well as with construction debris and other trash. Clean fill was brought in to establish present grades as part of the 1974 construction project to build Baranof Park. A 1987 project revealed that some of the 24" diameter storm sewer in the park was severely corroded, and part was replaced. A considerable volume of flow runs in the storm sewer draining the area even during periods of dry weather. This flow is presumably groundwater which leaks into the storm sewer through perforations of the pipe or defects in joints or manholes.

We wondered whether this flow contained toxic levels of heavy metals, volatile organics, or semi-volatile organics. We were able to sample the flow on July 31, 1996. Sample bottles were sent to CT&E Environmental Services in Anchorage for analysis.

4.8.2 Methods

Sample bottles (including appropriate preservatives) for each analysis were provided by the analytical lab. Chuck Tripp of the City Engineering Department entered the manhole downstream (NE) of the intersection of Ole Johnson Avenue and Simeanoff Street, and filled the bottles. Samples were shipped to CT&E's lab the same day in chilled coolers. Chain of custody protocols were followed. Analysis followed CT&E's standard quality assurance procedures. The specific methods used for each analysis are listed with the test results in Appendix J.

4.8.3 Results

In order to interpret the chemical analysis results, it is helpful to first understand the water quality standards and contaminant criteria that have been developed by regulators and environmental scientists.

What are the Standards? Which water uses apply? ADEC has promulgated water quality standards for a variety of water uses in both fresh and marine waters. These uses include drinking, propagation of aquatic life and wildlife, contact recreation (swimming, etc.), secondary recreation (boating, etc.), aquaculture, industrial uses, and others. In addition to toxic chemical contaminants, there are limits on turbidity, sediment, dissolved oxygen, fecal coliform bacteria, pH, and several other parameters.

In practice, the ambient water quality standards are applied to the receiving water (in a lake, for example) rather than to a discharge in a pipe (the stormwater/groundwater flow, for example). The water in a lake is generally lower in turbidity, fecal coliform bacteria, and some other parameters than is the water in tributary streams or storm sewers due to settling of particulate in the lake.

The motivation behind the water quality standards is that if all contaminant concentrations are less than regulated levels for a particular use, then the water will be "safe" for that use. Safety is defined in various ways. For carcinogens, for example, the Alaska drinking water quality criteria are designed to ensure that any increase of cancer risk will be less than 10^{-5} (1 in 100,000).

Potatopatch Lake is used by people for canoeing, and therefore secondary recreation water quality standards would be applicable. It has been stocked with silver salmon fingerlings by Fish & Game Sportfish Division annually most years since 1988, and for the purpose of rearing salmon, the propagation of aquatic life standards would apply. Where more than one use takes place, ADEC uses the more stringent water quality standards, which in this case would be the aquatic life standards. In keeping with EPA direction, for aquatic life uses ADEC applies the more stringent of the drinking water criteria or the aquatic life criteria for toxic organic and inorganic contaminants .

What were results for toxic contaminants? The results for the toxic organics and heavy metals analyses are attached as Appendix J. Test results and water quality criteria are compared in Table 4-13. The water use criteria are presented in the sequence of most restrictive criteria (aquatic life) to least restrictive (secondary recreation such as boating).

To summarize the results for the sample taken from the Baranof Park storm sewer, no semi-volatile organics were detected and very few volatiles were detected, with none present above 1 percent of Alaska drinking water maximum contaminant levels (MCLs). For the aquatic life use, drinking water MCLs are more restrictive than EPA "Toxics Rule" aquatic life criteria for those volatile organic compounds which were detected.

Among the heavy metals, only cadmium, lead, and barium were above detection limits. Cadmium occurred at 0.744 ug/l, which is 113 percent of the freshwater aquatic life criterion, equivalent to 15 percent of the drinking water MCL. Lead occurred at 14 ug/l, which is 10.8 times the freshwater aquatic life criterion, equivalent to 93 percent of the EPA drinking water action level. Barium occurred at 3 percent of the aquatic life criterion, equivalent to 2 percent of the drinking water MCL.

The only contaminant which exceeded drinking water criteria was iron. Iron is listed among the secondary contaminants for drinking water because it poses more of an aesthetic or operational problem than a toxic threat. Iron occurred in the July 31 Baranof Park sample at a level 53 times higher than the Alaska drinking water secondary MCL. The freshwater aquatic life criterion of 1 mg/l was also exceeded by a factor of 16.

All other toxic contaminants except ammonia were below limits or not regulated by the water quality standards. Ammonia-N was present in the storm sewer sample at 2.59 mg/l, which is 117 percent of the freshwater aquatic life criterion. Ammonia is the most reduced form of inorganic nitrogen. It is readily taken up as a nutrient by aquatic plants and microalgae. The ammonia level in the limnological sample from Potatopatch lake from July 30 was less than 0.0017 mg/l, which is less than 0.1 percent of the freshwater aquatic life criterion.

These measurements, it should be noted, were on the undiluted water from the storm sewer draining Baranof Park. A considerably larger flow from Lilly Lake mixes with this flow before the combination enters Potatopatch Lake. The volatile organics, cadmium, lead, any other contaminants which may be present in the Baranof Park storm sewer flow are all diluted by a factor of four or more before they enter the lake.

4.8.4 Discussion

Toxic organics and heavy metals: With regard to toxic organic and inorganic chemicals, the limited testing conducted to date indicates that summertime dry weather (groundwater) flow from the Baranof Park area meets ADEC drinking water standards for toxic chemical contaminants, with the single exception that it is very high in dissolved iron. Cadmium and lead were present in the storm sewer at 1.13 and 10.8 times the freshwater aquatic life criteria, respectively. Cadmium is likely diluted below the aquatic life criterion by the substantial flow from Lilly Lake. Lead may remain above its aquatic life criterion, but it is likely far below the EPA action level for lead in drinking water. It appears that the concentration of regulated contaminants in the dry-weather storm sewer sample do not substantially exceed ADEC or EPA maximum levels.

Turbidity, Iron, & Phosphorus: Aerial photos, personal observations, residents' complaints, and Secchi disk (water clarity) measurements have confirmed that Potatopatch Lake often has unattractive murky brown water. The Secchi disk clarity is measured by lowering a black and white sectored disk into the water, and observing the depth at which it disappears. The average Secchi clarity in the middle of Potatopatch Lake was about 0.5 meters (19 inches). Turbidity, another measure of the "cloudiness" of water, averaged 11.9 NTU at the outlet of Potatopatch Lake and 15.3 NTU in the limnological samples taken from the middle of the lake. The relationship between turbidity and the clarity of lake water is shown in Figure 4-6. The distance one can see through the water column decreases rapidly from 2 meters as the turbidity increases above 5 NTU.

There is reason to suspect that the high iron concentration in Potatopatch Lake is partially caused by the stormwater / groundwater flow from Baranof Park. Limited water quality testing on May 11, 1995, at the confluence of the Baranof Park flow and the Lilly Lake / East Addition Park flow indicated that the Baranof Park flow had an iron concentration about 4-1/2 times greater than the Lilly Lake flow. There is also reason to suspect that the precipitation of iron may contribute to the murky brown color of the lake. Limnological testing in 1995 and 1996 indicated that Potatopatch Lake had the highest total iron concentration, the highest total phosphorus concentration, and the highest turbidity among the urban lakes, excepting Horseshoe.

The July 31, 1996, dry weather storm sewer water sample from near Baranof Park showed a total iron concentration of 15.9 mg/l (15900 ug/l), which is about 14 times the level found in the middle of the lake at the same time. When those samples were collected, the water was initially observed to be only slightly colored. After sitting in a cooler for an hour, a large amount of rust colored precipitate had formed inside the bottles. This precipitation probably forms in Potatopatch Lake as well.

Total phosphorus, although not regulated by EPA or ADEC, was present in the storm sewer sample at a relatively high level of 62 ug/l. This is double the level that was found at Potatopatch Lake in the limno sample from July 30. Phosphorus is normally the limiting nutrient to algae growth, and is present in excess in this flow.

According to Jim Edmundson, a limnologist with ADF&G in Soldotna, total phosphorus levels above 20 ug/l are associated with eutrophic (murky, highly productive) lakes. Total phosphorus in Lilly Lake was 9.8 ug/l. Water from Lilly Lake combined with the Baranof Park flow to produce a total phosphorus of 31.4 ug/l in Potatopatch Lake. It appears that the Baranof Park storm sewer flow is "fertilizing" Potatopatch Lake substantially. This results in blooms of microalgae and decreased water clarity.

Unfortunately, the Clean Lakes for Kodiak testing program was not designed to isolate the iron from Baranof Park as a cause of turbidity in Potatopatch Lake, so the results do not quantify what fraction of the total iron flux originates from Baranof Park, what fraction of the turbidity is caused by iron precipitates, or how turbidity is affected by wind-induced mixing. Additional testing, including flow measurements, should be performed to confirm whether the Baranof Park flow is primarily responsible for elevated turbidity in Potatopatch Lake.

Siphon solution: It may be possible to intercept the flow from the Baranof Park storm sewer and divert it directly to the ocean using a siphon. The cost of this approach would be held to a minimum because the siphon line could be run inside of existing storm sewers for all but 250 feet of its 1800 foot length. No road crossings would be required, and the siphon would not require external pumping except for priming.

A report regarding the Baranof Park storm sewer system was presented to the City Engineer in May 1997. Further feasibility analysis work is required to evaluate the benefit and cost of proceeding.

4.9 Tidewater Lakes Elevation Surveys

We used land surveying equipment to establish the elevation of Potatopatch and Mission Lakes with respect to the ocean. Our vertical references were survey monuments at the Spruce Haven entrance (+17.21 MLLW) and at power pole M33 on Mission Road (+19.48 MLLW). The elevations of these were provided by Roy Ecklund of Ecklund Surveying.

We found the bottom of the lower 30" outlet in Potatopatch to be +9.7' above mean lower low water (MLLW). The lake water level was +10.4' MLLW. The lip of the outlet weir in Mission Lake was +8.9 MLLW, and the lake water level was +9.0 MLLW.

Inspection of the 1995 Kodiak area tide table shows that high tide exceeds the level of Potatopatch Lake (+10.4' MLLW) only twenty times, but it exceeds the level of Mission Lake (+9.0' MLLW) 160 times. Field observations at both lakes have repeatedly documented the presence of drift Laminaria kelp and Neoptilota red marine macroalgae inside the outlet culverts.

We visited the tide gate at Mission Lake on December 22, 1995, at 1:31 PM to witness the highest tide of 1995 (+11.3' MLLW). The actual peak ocean level which we measured was +11.8' MLLW. There was a moderate NE wind blowing as well as an approximate 6" surge with a 20 second period, and these factors might have been responsible for the excess measured height of tide compared with the tide table value. The performance of the Mission Lake tide gate is discussed below in Section 4.12.

4.10 Tidewater Lakes Salinity Testing

4.10.1 Introduction

Having confirmed that seawater enters both Mission and Potatopatch lakes on certain high tides, we implemented a testing program to see whether there is a sudden high salt concentration in the lake water around the time of spring turnover.

In most ice covered lakes, the water stratifies under the ice because of temperature/density effects and because of the absence of mixing from wind and waves. Under these conditions, salt water which enters a tidewater lake will lie on the bottom, and it will not mix with the freshwater on the surface. When the ice melts, wind will mix the water column, and some or all of the salt water on the bottom will raise the salinity of the surface waters. We were concerned that a sudden spike in salinity, if it occurred, could stress or kill fish or other organisms in the lakes.

4.10.2 Methods

We began collecting water samples from Potatopatch and Mission Lakes on March 21 when the lakes were still 70% or more ice covered. Lilly Lake was sampled on three occasions to determine if residual road salt was a major factor. We ended sampling on April 16, when all the lakes were ice-free. All water samples were collected at the outlet structures in each lake, and represent surface water salinity. The City of Kodiak lab analyzed our samples for chlorides, with the results expressed as mg/liter sodium chloride, which is roughly equivalent to sea salt. The units of mg/liter are equivalent to parts per million (ppm). Salinity is often expressed in parts per thousand (ppt), which is a thousand times more than a ppm.

4.10.3 Results

The laboratory data sheets are presented in Appendix K. Mission Lake went from 650 mg/l on 3/23 to a peak of 1420 mg/l on 4/12. The average from 3/25 to 4/16 was around 1200 mg/l. Potatopatch Lake went from 375 mg/l on 3/23 to a peak of 800 mg/l on 4/3, and then declined to 163 mg/l on 4/16. The three Lilly Lake samples collected from 4/3 to 4/12 had salinities ranging from 100 to 110 mg/l. As a point of reference, seawater at Mission Beach had a total dissolved solids level of about 27,500 mg/l (27.5 ppt).

4.10.4 Discussion

We did note varying salinities in the saltwater influenced lakes, but there was no sharp salinity "spike". On the other hand, salinities in the outlet flow were noticeably higher than in the inland lakes. Pre-earthquake aerial photos show both Potatopatch and Mission Lake with abundant lily pads. The present seawater influence is apparently enough to keep the lilies from prospering. Near the outlets of both tidewater lakes, Ruppia spiralis (formerly Ruppia maritima) is abundant.

This ditchgrass is known to be tolerant of brackish water. The point here is that seawater influence probably altered the balance of the plant community in the lake.

4.11 Mission Lake Winter Salinity, Oxygen, and Temperature

4.11.1 Introduction

From time to time during the 1995 field season, we saw floating debris prevent the tide gate from sealing, and large quantities of seawater then entered the lake. We also saw evidence of raw sewage entering the lake, and indications that oxygen levels may be depressed by decomposing weeds in the Fall. We therefore decided to measure temperature, salinity, and oxygen concentration profiles as well as water depth and sediment thickness beneath the ice during March 1996.

4.11.2 Methods

We laid out a 200 foot grid on the ice covering the lake, along and perpendicular to a baseline running the length of Mission Lake. We chainsawed holes through the ice at 35 locations, and measured each of the parameters mentioned above at 1 foot increments of depth. Oxygen and temperature were measured using a YSI oxygen meter borrowed from ADF&G. Salinity was measured using a salinity meter borrowed from the National Marine Fisheries Service. We also measured ice thickness using a tape measure. We pushed a 1/2" diameter stainless steel probe with a rounded tip to hard bottom to determine the depth to the bottom of sediment. Depth to top of sediment was determined using the probe with a 6" diameter disk fastened to the end.

4.11.3 Results and Discussion

A map of the sampling locations as well as a table of results is presented in Appendix L. We found saltwater influence below 3' depth everywhere in the lake. Seawater salinity at Mission Beach was measured at 25.8 ppt (parts per thousand). Surface water in the lake was around 2 ppt. Water at 3' depth was around 5 ppt. In the few places that were deeper than 3', we found around 9 ppt at 3'6" depth, and up to 22 ppt at 4' depth near the outlet tide gate.

Oxygen concentrations were almost all above 10 mg/l at the surface, which is close to saturation. Salmonid fish (salmon, trout, etc.) do well when the oxygen concentration remains above 6 mg/l or so. Oxygen concentrations near the bottom were depressed, but plenty of oxygenated water column was available. We observed some areas that were supersaturated with oxygen. This may have been due to photosynthesis by weeds under the ice, although oxygen meter instability is also a possibility. High oxygen readings occurred in areas which had shown lush weed growth in previous aerial photos, and this is consistent with the photosynthesis hypothesis.

We found the sediment layer in most of the lake to range from 5" to 2' in thickness. We were surprised to find an area in the north arm of the lake where a couple feet of firm sediment (probably Katmai ash) was underlain by a deep (deeper than our 10' probe length) layer of black anoxic ooze.

4.12 Mission Lake Tide Gate

4.12.1 Introduction

We have documented seawater intrusion into both Mission Lake and Potatopatch Lake. Prior to the great earthquake of 1964, both lakes had meandering outlet creeks. During the great quake and following tsunamis, the land elevation around Kodiak fell by about 5 feet and the outlets of both lakes were washed away. Outlet bars were subsequently reconstructed with fill, and a tide gate was installed at Mission Lake in 1965.

As noted above, the lip of the lake outlet weir is at +8.9 feet elevation above mean lower low water (MLLW), and the lake surface is normally at about +9.0 feet MLLW. Annual extreme high tide for the Port of Kodiak is more than +11 feet MLLW, and high tide exceeded +9.0 feet 160 times in 1995. The tide gate does not seal reliably, and it also requires a great deal of maintenance to remove debris in the flapper valve and outfall line. Seawater has been passing through the tide gate into the lake, and we have observed elevated salinity in the surface water and a seawater lens on the bottom of the lake.

4.12.2 Condition and Function of Tide Gate

The Mission Lake outlet structure and tide gate consists of four parts: 1) the eight foot diameter (horizontal) circular lake outlet weir and bar screen; 2) a thirty inch diameter corrugated metal pipe (CMP) leading from the sump of the inlet weir to 3) a manhole containing a hinged cast iron flapper valve; and 4) another section of thirty inch diameter CMP discharging from the manhole to Mission Beach. The outfall pipe has a non-sealing flapper over the end to exclude debris, but it does not work very well.

The main physical defects in the existing tide gate are wear in the flapper valve and corrosion of the outfall CMP. Operational and maintenance difficulties arise mainly because debris, both from the lake and the ocean, reaches the manhole and prevents the flapper valve from sealing. Seawater flow into the lake then brings drift seaweed into the outfall CMP. The outfall pipe has reportedly sometimes been entirely clogged by kelp, and clearing it has been very time consuming for the Borough maintenance worker assigned the task.

When we visited the tide gate to witness the highest tide of 1995 (+11.3' MLLW), there was virtually no seawater leakage past the flapper valve. However, there was a considerable amount of kelp and red marine algae around the outlet weir inside the lake, and we had witnessed seawater gushing into the lake three inches higher than the outlet weir a few days before that extreme tide.

Numerous other observations suggest that the flapper valve seals well when there is a considerable head difference between the ocean and the lake, and when there is no debris to prevent the flapper from seating. When the high tide is less extreme, there is less pressure acting to seal the flapper valve, and it is more likely to leak. If the flapper valve bushings were refurbished and the mating surface between the flapper and the seat were repaired, the existing flapper would seal well even for small head differences.

The problem with clogging in the outfall pipe is caused by two factors. First, leakage past the flapper valve carries the seaweed and debris into the pipe. If the flapper sealed perfectly, there would be no net flow into the outfall pipe, and therefore little net transport of debris. The other factor is the location of the outfall pipe in the intertidal zone. The outfall pipe terminates at or below beach elevation, so drift seaweed and other debris are brought right to the pipe opening when the tide is at that level. If the outfall pipe terminated above the beach, then less seaweed would be sucked into the line.

To summarize, the two major problems with the tide gate at Mission Lake are: 1) it doesn't keep sea water out of the lake if the head difference is slight or if debris interferes with a good seal at the flapper valve, and 2) seawater leakage at the flapper and the design and condition of the outfall draw seaweed and debris into the outfall line, which makes maintenance difficult and expensive, and compounds problem #1.

4.12.3 Effects of Seawater Intrusion

We know that Mission Lake is receiving seawater through the tide gate. It is not entirely clear whether this is desirable or undesirable. The following paragraph lists some of the effects of seawater intrusion. Other unknown effects may exist.

- Seawater has a much higher carbonate alkalinity than Kodiak's fresh water, and this raises the equilibrium pH in the lake and provides a reservoir of carbon dioxide to support intense photosynthesis. Intense photosynthesis raises the pH.

- Higher pH, in the presence of calcium or magnesium ions, favors the settling of colloidal iron and other charged particles. This improves water clarity.

- Seawater has a high salt content, or ionic strength. Higher ionic strength favors the settling of colloidal iron and other charged particles. This improves water clarity.

- Seawater is more dense than fresh water, and has formed a distinct, poorly mixed layer on the bottom of the lake. Oxygen is exhausted from this layer, so it is unavailable as habitat for fish, aquatic insects, or zooplankton. Anoxia in sediments tends to mobilize phosphorus, which stimulates plant growth.

- Seawater is toxic to some aquatic macrophytes, stressful to others, and preferred by still others. The same is probably true for aquatic insects, zooplankton, and other organisms. The elevated salinity of Mission Lake changes the ecological balance in unknown ways.

- Seawater in the intertidal zone contains a great deal of zooplankton. This could be an important supplemental feed source for fish in the lake.

- Seawater is corrosive to airplane floats. Mission Lake has been used as a floatplane base from time to time over the years, and that use is still important to several residents. The elevated salinity of Mission Lake may accelerate the corrosion of aircraft which use that lake.

On February 18, 1997, I noticed a starry flounder pinned against the lake side of the bar screen at the outlet weir. There had been no high tide above +9.0 for several days, but the fish was still alive, and it immediately swam off when I released it into the outlet sump. According to Pat Holmes of ADF&G, starry flounders can tolerate brackish water, and are known to swim far up into estuaries. One additional side effect of seawater intrusion through the tide gate might be the introduction of marine predators which could eat stocked coho juveniles.

We really know very little about how seawater intrusion may affect the well-being of stocked silver salmon in Mission Lake. Unrestricted flow of seawater into Mission Lake would probably be undesirable, but the present level of seawater intrusion may be tolerable or even desirable. Further discussion and perhaps additional testing are necessary to resolve these questions.

4.12.4 Rolland A. Jones Outlet Study

CLK retained Rolland A. Jones, Consulting Engineer, to provide a study of the existing outlet structure and tide gate as well as two alternative locations for replacement outlets. This work included a topographic survey and preliminary cost estimates for repair or replacement. The report and accompanying drawing are attached in Appendix M.

Mr. Jones' study focussed on the inlet and outlet locations and elevations, and did not deal with tide gate issues. He estimated that replacing the outfall line of the existing structure would cost $18,950, while installing a new outlet structure would cost $43,000 to $48,000, depending on location. The latter two estimated costs do not include a tide gate or access manhole. This might add $8,000 to $15,000, depending on the design selected.

4.12.5 Design Issues

Before further tide gate design work is done, interested parties (including property owners, Borough staff responsible for maintenance, and ADF&G) should reach consensus on whether the *status quo* should be changed. Seawater intrusion may limit nuisance macrophyte growth and increase water clarity, as well as contribute to increased primary production and fish growth. A periodic monitoring program may be needed to evaluate how much seawater intrusion has occurred.

Any future repairs, modifications, or replacement of the Mission Lake outlet structure / tide gate should include consideration of the following issues.

- **Fish passage into the lake:** ADF&G Habitat Division has commented equivocally that adult salmon should be able to enter the lake for spawning. Although spawning habitat is very limited, lake residents report having observed dozens of spawners in past years. If possible, the migration of predatory marine fish (like starry flounders) should be prevented.

- **Fish passage into the ocean:** The outfall presently discharges silver salmon smolts onto Mission Beach at about elevation +5 MLLW. When the tide is low, out-migrating fish must travel over 100 feet in a narrow channel across the beach before they reach the ocean. Bald eagles and gulls reportedly sometimes line up along this channel and enjoy a fine meal. A new outfall at a lower point on the beach would cut mortality of smolts.

- **Maintenance:** Modifications or new designs should minimize maintenance costs. Routine maintenance is now required at four points: 1) Removing aquatic macrophytes at the bar screen to prevent the lake level from rising; 2) Removing debris such as scrap lumber and litter from the bar screen to prevent clogging the flapper valve; 3) Removing debris from the flapper valve to allow sealing; and 4) Removing drift seaweed and other debris from the outfall pipe.

- **Construction cost:** Construction cost should be held down, although recurring costs such as maintenance may be more important to minimizing the present value of the life cycle cost. Much of the existing outlet structure / tide gate is in relatively good condition, so repair of the flapper valve and reconstruction/extension of the outfall line may be the most economical approach.

4.13 Lake and Watershed Histories

4.13.1 Introduction

Kodiak City has grown tremendously since the Army arrived in the early 1940s, and quite a few of the movers and shakers of that era are still in Kodiak. There was virtually no development north of present day Powell Avenue as recently as 1957, and many folks in their 40s and 50s have clear recollections of our urban lakes in an undeveloped, pristine state.

The story of how Kodiak was transformed from a sleepy fishing village into today's bustling economic hub is of both historical and scientific interest. The historical aerial photos we have collected provide a bird's eye view of how development progressed. By conducting and recording interviews, we have also documenting how individuals, families, and events (wars, politics, natural disasters, and development) affected the lakes, streams, and runs of fish near Kodiak City. This documentation effort is now being continued by the Kodiak Wetlands and Watershed Association (KWWA).

4.13.2 Methods

We enlisted the assistance of Helga Descloux, a high school journalism student, to conduct taped interviews of some of Kodiak's old timers. Miss Descloux received training in the use of a professional grade tape recorder from Heidi Zemach, the news director of KMXT, our public radio station. She interviewed seven of the people from a list containing twelve names. The tapes have not yet been transcribed to written format.

late 1950s. We have learned the names of some of the people who first built cabins on the lakes and roads to the cabins. There are still a dozen or so names on our list of people to talk to. Historical interview work is being continued by Doneen Tweeten of the KWWA, and we have forwarded our list of old timers to her.

5.0 Summary

The technical portion of this project had three main objectives:

- Collect sufficient environmental data to establish a baseline for future comparisons;
- Diagnose problems and identify opportunities for improvements; and
- Evaluate the feasibility of potential remedial actions and enhancements.

The remainder of this section summarizes our accomplishments in these areas.

5.1 Baseline data collection

We gathered a tremendous amount of information about the Kodiak urban lakes and their watersheds during 1995. We collected over 160 watershed water samples, each of which was analyzed at the City water lab for five to eight parameters. Around 1000 analyses were performed on these samples. We gathered 60 limnology samples, each of which was analyzed by ADF&G's Soldotna Limnology lab for 20 parameters. Around 1200 analyses were performed on these samples. ADF&G also analyzed 45 other samples from the lakes for phytoplankton and zooplankton. Nine lake water samples were analyzed for elemental composition.

We performed aquatic macrophyte surveys and fish trapping surveys. We measured the length and weight of more than 1100 juvenile salmonids. We also surveyed lake elevations, recorded depth transects, prepared bathymetric maps, calculated lake areas and volumes, and cataloged watershed areas and land use. AutoCAD maps were prepared to present some of this information, and aerial photos of the study area from 1994 were purchased to assist in mapping and for future reference.

We conducted considerable additional work during 1996 on seawater intrusion in the tidewater lakes and on turbidity and fecal coliform contamination in the Island Lake watershed. We also gathered 12 limnology samples from all the lakes in late July, each of which was analyzed for 18 parameters. Nine phytoplankton and zooplankton samples were also analyzed.

1995 was an unusually rainy year and 1996 was unusually dry, but the comparison of July limnology results from the two years shows the same trends and ranking of water quality between the lakes. Although we had no choice but to select 1995 as our baseline year, it seems that results from that year will be useful for comparison with future years. We have successfully established a database of environmental baseline data for future reference.

5.2 Diagnose problems and identify opportunities

Our baseline environmental monitoring helped us spot lakes or locations in the watersheds where water quality was degraded. The causes of some problems were obvious, and our testing simply quantified the situation. Where necessary, focussed investigations and additional testing helped us diagnose the cause of the problem. In a few cases, we are still uncertain what is going on, and further testing and expert assistance may be called for.

The problems which we encountered fall into a limited number of categories:

- **Poor water clarity:** Objectionable partially on aesthetic grounds, poor clarity (high turbidity) can also interfere with photosynthesis by phytoplankton, which powers the food chain. Poor clarity is caused either by silty runoff, by precipitation of dissolved iron, or by excessive growth of phytoplankton caused by phosphorus enrichment. This was found in Lower Horseshoe Lake and Potatopatch Lake to the greatest degree.

- **High fecal coliform counts:** Indicates either a sewage leak or runoff containing animal wastes. Sporadic high levels were detected in the Selief Ditch, at the outlet of Beaver Lake, in the creek entering Island Lake at the park, and at Mission Lake. We localized the sources somewhat by intensive testing, but we have found "the smoking gun" only at Mission Lake, where sewage lift station malfunction has spilled raw sewage into the lake in 1994, 1995, and 1997.

- **Excessive macrophyte growth:** The definition of "excessive" is debatable, because aquatic macrophytes are good fish habitat. This is partially an aesthetic issue. Macrophyte abundance was high in Mission Lake in 1995 and prior years, but declined greatly during 1996 for unknown reasons. The Horseshoe Lakes are also choked with macrophytes.

- **Seawater intrusion:** Seawater enters both Mission Lake and Potatopatch Lake at extreme high tides. Potatopatch is high enough in elevation that the effect is slight. Mission Lake is lower, and was formerly protected by a tide gate which is now in poor repair. A seawater lens has formed in the lake, and salinity levels are elevated in the surface water. The net effect on macrophytes, water clarity, and silver salmon production is unknown.

- **Urban Non-Point Source (NPS) Pollution:** An unknown fraction of the increase in turbidity, fecal coliforms, and nutrients results from so-called NPS pollution. These parameters correlate well with the fraction of the watershed which has been developed.

Among the opportunities for betterment of the lakes and watersheds, we identified:

- **Enhancement of fish rearing and spawning habitat:** Self-propagating natural runs of silver salmon could be re-established in the Island Lake watershed by constructing a fish pass at a waterfall, and by providing new spawning habitat in the Selief ditch. Additional studies could help refine stocking rates for maximum return and determine the effect of seawater intrusion on rearing silver salmon juveniles.

- **Stewardship education opportunities:** There are opportunities for cooperative work with several other organizations to educate the community about watershed issues. The Kodiak Wetlandsand Watersheds Association, the Kodiak Wildlife Refuge's Salmon Camp, the high school environmental science class, 4-H, and others are interested in lakes, creeks, and watersheds.

5.3 Evaluate the feasibility of remedial actions and enhancements

Our list of possible actions and estimated costs is presented below in section 6.2. These proposed actions have been subject to little public scrutiny or debate. Order of magnitude cost estimates are provided based on engineering judgement and limited calculations.

If we want problems in the watersheds to be fixed, the proposed remedial actions must be both technically feasible and politically feasible. A political process must occur to advance a documented environmental circumstance to the level of a "problem" worthy of discussion and resolution. This document presents environmental data, our interpretation of what the problems are, and some ideas on how to solve them. Virtually none of the proposed actions will be feasible unless advocates from the community push them forward. On the other hand, none appear to involve complex technology or other risk factors that would threaten their technical feasibility.

6.0 Recommendations

Our recommendations for future technical work include some items which require further work at the community group level, and some items which are ready for implementation by City, Borough, or Federal agencies. In comparison with tasks recommended for implementation, those tasks recommended for further study are either: 1) less well understood; 2) more controversial; or 3) more social, educational, or aesthetic. Among those tasks which are ready for implementation, some include design studies to confirm feasibility, establish design parameters, and refine cost estimates.

6.1 Recommendations for Further Work by Community Watersheds Group

- **Island Lake watershed monitoring for fecal coliforms and turbidity:** Volunteer samplers can continue intensive water quality sampling, especially following intense rains, to localize sources of elevated fecal coliform bacteria or turbidity. A field turbidity meter ($500) could facilitate analysis of NPS pollution. The cost of analysis would depend on the price set by the City lab.

- **Monitor sewage lift stations:** Volunteers could meet with City Engineering and Public Works staff to learn the location of sewage lift station overflow routes. Citizen monitoring during heavy rains or at set intervals could expedite City response if sewage flow exceeds lift station capacity, or if malfunctions occur.

Mission Lake, Potatopatch Lake, and deeper lakes. This will help define the relative importance of aquatic weed habitat for rearing silvers. Analysis costs would be around $2500.

5. Integrate 1995 and 1996 limnology results with fish trapping results through discussions with scientists from ADF&G and other agencies.
6. Conduct adult spawning salmon counts in all lakes and tributaries. This could provide baseline data if spawning habitat enhancement or access improvements are implemented.
7. Catch rainbow trout from Lilly Lake and analyze their flesh for hydrocarbon and lead contamination.

- **Macrophyte quantitative surveys:** Any future efforts to control macrophyte abundance in the lakes will require permits from ADF&G because macrophytes provide good fish habitat. Annual quantitative surveys could provide data to decide whether macrophyte abundance is stable or increasing, and how current abundance relates to past conditions such as sewage spills or seawater intrusion. An aerial survey would probably be appropriate to survey floating macrophytes. Random biomass sampling would probably be required for submerged macrophytes.

- **Potatopatch Park conceptual design:** The City-owned lot adjacent to the major tributary to Potatopatch Lake has potential as a park. A conceptual design project was initiated to develop alternative development plans. A preferred option must be refined before it can be submitted to the City for consideration. Other potential improvements at Potatopatch Lake include erosion control plantings on steep banks, and the creation of nesting refuge islands for ducks.

- **Lake and watershed histories:** We have conducted interviews of some of the old timers who knew Kodiak watersheds in a pristine state. This is important in order to document pre-disturbance conditions. There are many more folks that we have yet to interview, and some of the taped interviews already completed have not been transcribed. The Kodiak Wetlands and Watersheds Association (KWWA) is continuing this important work.

- **Public outreach through press releases and presentations to groups:** Education is the most direct approach to changing personal habits which contribute to NPS urban pollution. A community watersheds group is best qualified to reach out to the community regarding watershed issues. This can be done through press releases, by engaging service groups and school children, and by utilizing the talents of the Cooperative Extension Service. Examples of newspaper articles originating from the Clean Lakes Group and KWWA are attached in Appendix N.

6.2 Recommendations for Implementation Actions

A list of actions which could be tackled over the next five years was compiled by Mark Blakeslee, P.E., the project technical advisor. It is believed to be complete, although some of the Board members might add or delete some items. Many of these potential actions are beyond the capability of a citizen's group, and could be properly undertaken only by City, Borough, State, or Federal government agencies.

On the other hand, citizen volunteers could assist with planning and preliminary studies for some of the big projects, and results could be provided to agencies for further consideration. If the Clean Lakes board and the public sentiment place a high enough priority on a project, the political process will eventually enable it to be constructed.

Some of the listed actions may be found, after further study, to be counterproductive, uneconomical, or overly controversial. Projects may be deleted from the list or added to it in the future. The following list is presented as a starting point for further discussion.

6.2.1 Actions completed or in progress

The "Buggy Banya" car wash near Safeway has an outdoor pressure washing station which formerly drained to the nearby roadside ditch, and ultimately to Mission Lake. The business changed hands in late 1996, and a reconstruction project was begun. The project technical advisor talked to Board member Norm Sutliff about the nutrient enrichment problems that can be caused by runoff containing phosphate detergents, and suggested that he might contact the new owner. Norm talked to the business owner, and the outdoor washing station was subsequently constructed with a catch basin draining to the sanitary sewer system. This eliminated a possibly large source of phosphorus pollution which previously entered Mission Lake.

The City of Kodiak has funded a design project to improve the drainage along Selief Lane. Construction is scheduled to be completed by November, 1997. This project focuses on two areas: the Selief ditch, and the culvert beneath Selief Lane connecting Upper Horseshoe Lake and Lower Horseshoe Lake. The Selief ditch will be improved by replacing undersized 30" driveway culverts with 71"x47" pipe arch culverts. The bottom of the pipes will be buried 1 foot below the stream bed, and will provide a continuous natural bottom for rearing juvenile (and possibly spawning adult) silver salmon. This will be a substantial improvement in habitat value compared to present conditions.

The culvert connecting Upper and Lower Horseshoe Lakes will be replaced with two new culverts. A small diameter culvert will be installed at approximately 2% slope to raise the outlet elevation of Upper Horseshoe Lake. This will deepen the lake, and improve both its appearance and its value as silver salmon habitat. The second, large diameter culvert will be placed with less than 1% slope, but the upstream end will terminate in a drop box which keep it dry unless the small culvert is clogged and lake level rises substantially. The small culvert will provide low velocity flow to facilitate upstream fish passage, while the large culvert will provide for overflow or flood discharges in either direction.

6.2.2 Recommended Future Actions

- **Selief paving and utilities reconstruction:** Paving Selief Lane will immediately improve water clarity and decrease phosphorus loading in Lower Horseshoe Lake and points downstream. Replacement of the existing sewer main and services will eliminate any possible sewage leaks, and may decrease fecal coliform levels in the Selief Ditch. This is an expensive public works project ($5 million plus), but it will have substantial environmental benefits.

- **Selief erosion control plantings:** Steep fill slopes below Mylark Drive, and unvegetated ditches next to Selief, Mozart, Bonaparte, and Lynden all suffer erosion and contribute silt and sediment to lakes and streams in the Island Lake watershed. Erosion control technologies have been advancing recently. The City should consider funding a pilot project in these areas to evaluate the effectiveness of various erosion control products and techniques. A pilot project could probably be designed and constructed for around $20,000. A community watershed group could assist with turbidity monitoring for product evaluation.

- **Selief ditch spawning habitat restoration:** The Island Lake watershed has limited salmon spawning habitat. Discussions with Homer ADF&G staff indicate that the Selief ditch could be modified to provide good spawning habitat by replacing soft sediments with washed gravel and grading ditch side slopes to minimize erosion. This would restore and enhance natural salmon propagation in the Island Lake watershed, and provide environmental education opportunities to the community. Estimated cost is $33,000. Both EPA and NRCS have programs which could fund most of this project.

- **Island Lake creek fish passage restoration:** A sharp turn in Island Lake creek at a 3' waterfall impedes the upstream migration of spawning salmon from the ocean to Island Lake. A pool and jump fishpass could be created here and at other points in the creek. Local ADF&G staff support this project, and they estimate the work could be accomplished for under $10,000. The Island Lake creek is on Borough-owned land, and a trail project was recently completed there.

- **Island Lake park weekly fecal coliform testing:** Our water quality testing at the creek and in the lake detected some samples with fecal coliform levels above ADEC contact recreation limits (200 cfu/100ml maximum, 100 cfu/100ml average of five weekly samples). As children often swim in the lake during summer, the City and Borough may wish to consider implementing a weekly fecal coliform testing program during the swimming season. The cost would depend on labor costs for a City or Borough employee to collect weekly samples and deliver them to the treatment plant lab for analysis. Time and materials would probably amount to about $75 per week.

- **Seal manholes / install overflow to ocean at Mission Lake:** Raw sewage spills into Mission Lake have been documented in 1994, 1995, and 1997 as a result of problems at the sewage lift station next to the lake. The City should consider the feasibility of raising or sealing manholes next to the lake. An overflow line which discharges to the ocean instead of the lake would provide for much faster dissipation of unavoidable sewage spills. Uncertainties in project feasibility, scope, and permitting make a cost estimate premature.

- **Improve Potatopatch Lake clarity by diverting Baranof Park stormwater to the ocean:** Flow in the storm sewer from Baranof Park is very high in iron and nutrients, which degrades the clarity of Potatopatch Lake. A siphon could intercept that flow and discharge it to the ocean at Pearson Cove. Estimated construction cost is $35,000. Additional study of iron water chemistry reactions is required.

- **Mission Lake tide gate, repair or replace:** Wear in the flapper valve and high maintenance requirements has allowed substantial seawater intrusion into Mission Lake. Fish and macrophyte data are insufficient to determine whether this is a threat to the lake. Improvements to decrease maintenance needs are probably justified. Repair of the existing flapper and extension of the outfall line away from drift seaweed would probably cost less than $15,000. Replacement and relocation could cost up to $65,000. The Borough has been maintaining the tide gate, but ownership is unclear.

7.0 Conclusion

We have completed a comprehensive examination of the health of Kodiak's urban lakes and watersheds. The technical issues are now on the table. Debate and further study may change our interpretation of the data, but we have established a point of departure.

It will be relatively easy to improve environmental conditions where we have identified a specific problem, and where we can fix that problem with a bushel of dollars and a pipe wrench, a track hoe, or a paver. It will be more difficult to solve problems related to land use, zoning, and non-point source urban pollution, because those problems arise from community members' cherished habits and values.

The emphasis of this project should now change from technical to social, educational, and political. The ultimate success of this effort will depend on harnessing the energy and enthusiasm of people in the community.

The recent and future efforts of the Clean Lakes for Kodiak board members, the Kodiak Wetlands and Watersheds Association, and the Kodiak Wildlife Refuge's "Salmon Camp" are all valuable and essential parts of the community effort to maintain the health, beauty, and safety of the lakes in our little corner of paradise. We sincerely hope that this Technical Report will inform interested citizens, and inspire them to act.

Figure 3-1. Kodiak Urban Lakes watershed map