LONG-TERM ECOLOGICAL MONITORING PROPOSAL

Biogeographic Association: Lakes and Rivers

Program Type: Individual

NATURAL RESOURCES INVENTORY AND MONITORING INITIATIVE

Katmai National Park and Preserve
Alaska

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Preface

Those unfamiliar with a large remote park will tend to think in millions of acres. Not so the visitors, or the guides, or the flight services. They know that the attractions and values are often preciously small and site specific. The entire valley may constitute the ecosystem which must be preserved ..., but the confluence of the salmon stream with the main river is where virtually all of the visitors will travel. Very shortly, incredibly swiftly sometimes it seems, the essence of a million acres is compromised by the impact of one hundred acres. The very first mistake is to view our northern and remote parks as vast - they are as site specific as a city park. ... Look at your remote areas through the eye of a needle. The management of 10 acres may determine the quality of 10 thousand. (Dennerlein 1988)

Chip Dennerlein
Former Director, Alaska State Division of Parks
Current National Parks and Conservation Association Alaska Regional Director

Introduction

Katmai National Park and Preserve lies near the north end of the Alaska Peninsula in southwestern Alaska. The landscape is varied from the rugged Pacific coastline to the Aleutian Mountain Range to the interior lake country and lowlands (Figure 1). Several large undisturbed watersheds, in their entirety, lie within the park. These watersheds are home to 28 species of fish, including the world renowned Bristol Bay sockeye salmon and the fishery it supports. The protected, relatively undisturbed, waters of this park, ranging from large lakes to geothermal springs to glacial-fed rivers, provide an important environmental setting upon which natural and anthropogenic change can be monitored.

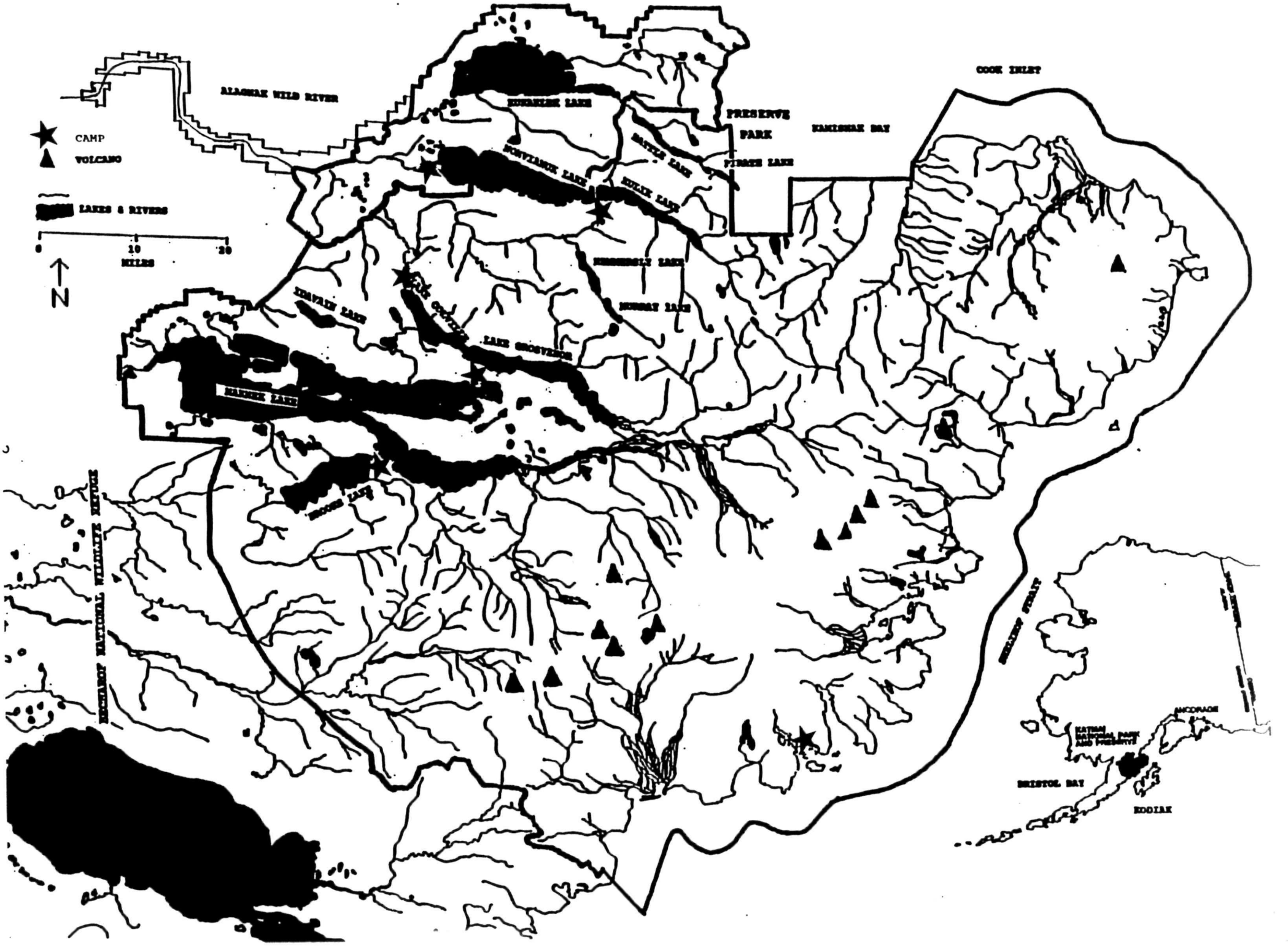
The goal of this proposed plan is to effectively, and in a timely manner, develop and implement a program of long-term ecological monitoring of the large lakes and large rivers in Katmai National Park and Preserve. The information gained by this monitoring will support park planning and management and, of equal importance, provide information on methodologies that can be applied to other national parks and natural areas with significant water resources. The objectives are:

- To develop standardized large lake/large river monitoring protocols for application in Katmai National Park and Preserve that can also be implemented in other national park units in the system; and

- Using these monitoring protocols and data generated through the monitoring program, determine baseline conditions, natural variability, and anthropogenic-induced changes in selected aquatic systems in Katmai National Park and Preserve.

The proposal calls for the monitoring program to be centered in the Naknek River drainage and the Alagnak Wild River watershed in the western part of Katmai. The 3-phased proposal includes: (1) Large Lakes [such as Naknek Lake (228 sq. mi.), Brooks Lake (29 sq. mi.), Colville Lake (13 sq. mi.), Grosvenor Lake (28 sq. mi.), Kukaklek Lake (67 sq. mi.), and Nonvianuk Lake (51 sq. mi.)]; (2) Large Rivers (Alagnak River - 70 miles administered by Katmai); and (3) the application of protocols developed in other park units to smaller coastal rivers in eastern Katmai. Phases 1 and 2 pertain to the I&M Program's *Lake and River* biogeographical association and its national objectives for aquatic monitoring.

Figure 1. Watershed Map, Katmai National Park and Preserve.



Recognized Management Need

The need for aquatic resource protection and management is formally recognized in the park's enabling legislation and repeatedly stated throughout the Katmai RMP. The Alaska National Interest Lands Conservation Act (ANILCA, 1980) represents the enabling legislation for the preservation of Katmai's resources. ANILCA specifically protects unimpaired water habitat, populations of fish and wildlife and their habitats, free flowing rivers, and maintenance of opportunities for scientific research on undisturbed ecosystems.

Katmai contains the most extensive and varied freshwater resources of any NPS unit. In addition to serving as the conduit for ocean nutrients that enter the park's ecosystem, Katmai's lakes and flowing waters contribute substantially to the Bristol Bay commercial salmon fishery, including the world's largest sockeye salmon industry. The rivers and lakes of Katmai are world renowned for sockeye salmon, chinook salmon, coho salmon, rainbow trout, Arctic grayling, Dolly Varden/Arctic char, lake trout, and other sportfishing opportunities.

The continued unimpaired functioning of this ecosystem is dependent upon the ability of park managers to preserve the pristine quality of water resources and habitat for aquatic and riparian species. Sixteen of 36 natural resource project statements contain statements of need for the inventory and monitoring of aquatic resources (Appendix I).

Status of Inventory

Following enactment of the Alaska National Interest Lands Conservation Act in 1980 where Alaska lands were expanded to constitute approximately 66% of the entire NPS land base, the Alaska Region developed a comprehensive science program to provide and allocate staffing for a greatly increased program of natural and cultural resources research, inventory and monitoring, and resource management. To implement the inventory and monitoring part of the program, position papers were prepared and several disciplinary and multidisciplinary workshops were held (e.g., Taylor and Meehan 1990; Peale, et al. 1993). An overall approach to inventory and monitoring for the huge NPS areas in Alaska was agreed upon by scientists and resource managers, setting the stage for selection of Katmai for lake and river protocol development.

The original Katmai National Monument is one of the oldest units of the National Park System, having been established in 1918. Extensive historic and current literature describes Katmai's aquatic resources. Buck, et al. (1978) published an annotated bibliography of 200 published references from studies of the Naknek River aquatic system, dating from 1920. A great deal of historical and current information exists regarding the 28 species of fish known to occur in Katmai. This is an extraordinarily large number of species for a specific inland region of Alaska. Salmon research has been conducted on the Brooks River and throughout the Naknek River system and other drainages since the late 1930's. The Brooks Lake Fisheries Research Station at the origin of the Brooks River is among the oldest in existence in Alaska, having operated under the direction of the U.S. Fish and Wildlife Service/Bureau of Commercial

Fisheries until the mid-1960's. Since that time, anadromous and resident fish inventory and monitoring work has continued in the region through the efforts of the Alaska Department of Fish and Game (Sport Fish and Commercial Fish Divisions), the USFWS Fisheries Assistance Office in King Salmon, and the NPS.

A three-year, comprehensive water quality baseline study, funded by the NPS, was undertaken in the Naknek and Alagnak River drainages from 1990 through 1992, with additional field work conducted in 1993. Preliminary findings are discussed in LaPerriere (1991). The final report is expected by December, 1993. Data for Battle, Brooks, Kulik, and Nonvianuk Lakes show water clarity is an outstanding feature of Katmai Lakes. Differences in alkalinity values correlated with elevation and LaPerriere postulates that small lakes and ponds will differ from the larger lakes. This is supported by Gunther (1987) who ascribed the differences to natural inter-drainage sulfate distributions. Jones (*In*: LaPerriere 1991) suspects that the large wetland at the headwaters of Colville Lake is responsible for the denitrification of inlet waters, explaining why Colville Lake is nitrogen limited.

Alaska Department of Environmental Conservation data are available for wastewater and drinking water systems of lodges situated on inholdings within the park. Ground and surface water contamination data related to leakages from underground fuel storage and distribution systems have been collected by an environmental consulting firm under contract to NPS. Their water monitoring protocols could be easily adapted for the LTEMS. Also, three monitoring wells have been established near the existing Lake Camp facility along the upper Naknek River, at the site of an old U.S Air Force recreational facility. An assessment of the effects of motorboat usage and angling on American Creek, a tributary of the Naknek system, was conducted in the late 1980's. Streambank vegetation impacts were determined and a follow-up study to quantify and describe the effects of boat traffic on sockeye salmon is being conducted by University of Alaska Fairbanks researchers. This work has resulted in the creation of a Limited Concession Permit system to regulate the number and size of motorboats that may be stored on the creek banks.

Much of the geological inventory has been completed with publication of *Quaternary Geologic Map of the Mount Katmai Quadrangle and Adjacent Parts of the Naknek and Afognak Quadrangles, Alaska*, which includes much of Katmai National Park (Riehle and Detterman 1993). Geophysical resource inventories have been conducted since 1915, when the Griggs expedition made their first visit to the area to observe and describe the effects of the historic 1912 eruption of the Novarupta Volcano, the third largest in recorded history. The bibliography of geological and volcanological literature for the Alaska peninsula area is more than 115 pages long and contains over 1,000 references. Current aquatic resource inventory work is being conducted by the U.S. Geological Survey and the Alaska Volcano Observatory to explore hydrothermal features of Katmai, including fumaroles and crater lakes (Keith 1991 and 1992).

Meteorological data have been collected in King Salmon and on Kodiak Island since World War II. Snowpack monitoring data are available for the Alaska Peninsula and several snowpack survey stations have recently been installed in the park in cooperation with the Soil Conservation Service (SCS). The park is currently working on a cost share agreement with SCS for installation and maintenance of automated snowpack and meteorological data recorders.

Species lists for park flora and fauna have recently been revised. The vertebrate list is essentially complete. Riparian vertebrates in Katmai National Park and Preserve include beaver, mink, muskrat, river otter, small mammals, harlequin ducks, osprey, bald eagle, and nesting neotropical migrant birds. Bald eagle and osprey nesting and productivity surveys have been conducted regularly throughout the

Naknek and Alagnak drainages over the last ten years, and continue. A draft monitoring protocol for harlequin duck productivity surveys on Katmai streams and rivers was developed in 1992. The park has developed several roadless and one road-side breeding bird survey (BBS) routes and has conducted BBSs since 1992. Additional roadless BBS routes are proposed for this effort to assess the condition of neotropical passerine populations that nest in riparian areas. The park coordinates and assists the USFWS in conducting nesting and productivity surveys for ducks, geese, and swans. Mew, glaucous-winged, and Bonaparte's gulls, Arctic terns, belted kingfishers, and common mergansers are predatory species that have been identified in energy flow models for the Naknek River system.

Aquatic invertebrates have been studied for many years in relation to fisheries investigations and a species list for aquatic invertebrates could be compiled from existing information, although it would likely be incomplete. Much work has been done on intertidal and marine flora and fauna following the Exxon Valdez oil spill in 1989. Collected specimens are being identified and catalogued as funding is obtained. The park-based NBS wildlife research biologist has initiated floristic mapping surveys and is coordinating the production of baseline thematic land cover maps, including riparian vegetation, for inclusion in the park GIS. Vascular and non-vascular vegetation is being inventoried in Aniakchak National Monument through National Natural Landmark project funding and will result in a significant enhancement to Katmai's floral species list, since many species are similar in the two park units. Aniakchak National Monument is administered by Katmai National Park and Preserve staff. Katmai has installed a ProCite computerized bibliographic program. Park staff are currently obtaining and entering relevant literature to supplement completed bibliographies from five other parks and bibliographies on fur bearers and paleoecology. The park plans to publish a natural and cultural resource bibliography by the end of FY 94.

Program Readiness

Katmai has gained significant momentum toward the development and implementation of an aquatic Long-Term Ecological Monitoring Site (LTEMS) through the recent work by LaPerriere and Reynolds of the NBS (formerly USFWS) Cooperative Fish and Wildlife Research Unit, Minard, Coggins, and Dunaway of the Alaska Department of Fish and Game (ADF&G) Sport Fish Division, Cross and Crawford of the ADF&G Commercial Fisheries Research unit, and Russell and Regnart of the ADF&G Commercial Fish Division. The park has been further assisted by the NPS Water Resources Division (WRD). Since 1989, eight WRD staff, including the past and current Division Directors, have visited Katmai and made on-site recommendations for the development of a water resources program. The NPS WRD is preparing a Water Resources Scoping Report based on their observations, with a target date for completion of the draft by April 1, 1994.

Interagency Agreements (IA), Cooperative Agreements (CA) and Memoranda of Understanding (MOU) currently in place indicating program readiness at Katmai include:

- IA with the NBS (formerly USFWS) Cooperative Fish and Wildlife Research Unit at the University of Alaska Fairbanks for the (Katmai) American Creek jetboat effects study;
- IA with the NBS (formerly USFWS) Cooperative Fish and Wildlife Research Unit at the University of Alaska Fairbanks for the Katmai Baseline Water Quality study;

- Two CAs with the Alaska Department of Fish and Game for brown bear monitoring and population studies;
- CA with the Alaska Department of Fish and Game for the Naknek River sockeye salmon smolt outmigration study;
- Regional IA with the U.S. Geological Survey for hydrologic studies;
- CA with the Bristol Bay Borough and the U.S. Fish and Wildlife Service for management of a Visitor Information Center in King Salmon, Anchorage, Fairbanks, and Tok, Alaska.
- Master MOU with ADF&G for fish and wildlife studies and the management of fish and wildlife in Alaska;
- Master MOU with the NBS for biological studies in Alaska.

Resource Management Plan programming tables and the Park's Resource Management and Research Division's Annual Work Plans address funding requirements for aquatic resource monitoring.

Draft monitoring designs are being developed for the park as part of the NBS water quality baseline study. Anadromous fish monitoring protocols are well developed. Breeding Bird Surveys, bald eagle, and osprey population monitoring is in place. A harlequin duck monitoring manual has been prepared by park staff. Standardized moose population monitoring protocols are available. Many elements of hydrologic and bathymetric monitoring are standardized, as are meteorological and climatological protocols.

Monitoring Program Design

The goal of long-term monitoring must be for effective management of environmental quality. Nowhere is this more imperative than in the national parks. Effective management requires knowledge of changes that occur in the environment, and of the factors that lead to, or cause, any changes that may be predicted or observed. Ideally, this includes the ability to distinguish variability associated with natural factors from changes or variability that may result from human intervention (Wolfe et. al 1987). These authors list five separate but overlapping scientific objectives of importance to resource managers in long-term monitoring: (1) field calibration of laboratory test results; (2) field validation of model predictions, (3) detection and analysis of long-term trends; (4) definition of long-term variability regimes; and (5) generation of testable hypotheses on observed patterns and relationships.

Research is currently being conducted in Denali National Park and Preserve to test a watershed monitoring approach for *Arctic/Subarctic* parks in Alaska. Conceptually, watersheds have definable boundaries and thus provide a means by which to subdivide large park areas into manageable units comprised of representative terrestrial habitats, aquatic systems, and climatic regimes. Glaciers are included in the monitoring design because they are present at the headwaters of many Alaskan rivers and streams, have an important role in shaping the physical environment, and serve as early indicators of global climate change.

Watershed research focuses on hydrological and biogeochemical cycling and the influence of key processes on observed patterns and trends of biological organization. Since glaciers, ponds, and lakes represent temporary storage of water enroute to the sea through surface and subsurface aquifers, the

watershed approach can be extended to the Katmai setting. The presence of the Aleutian Range in Katmai provides a natural separation of park watersheds into western (large lakes/large rivers) and eastern (coastal rivers) study areas. This division is important because, while the eastern coastal rivers contain important park resources, they are similar in size and geomorphology to those at Denali where monitoring protocols are being developed. Once these protocols have been peer reviewed and are ready for export and implementation, our plan will be to test their application to selected watersheds east of the Aleutian Range. Similarly, population monitoring protocols have been described for the *Pacific Coast* biogeographical association at Channel Islands National Park. These, too, will eventually be tested at coastal locations on Shelikof Strait.

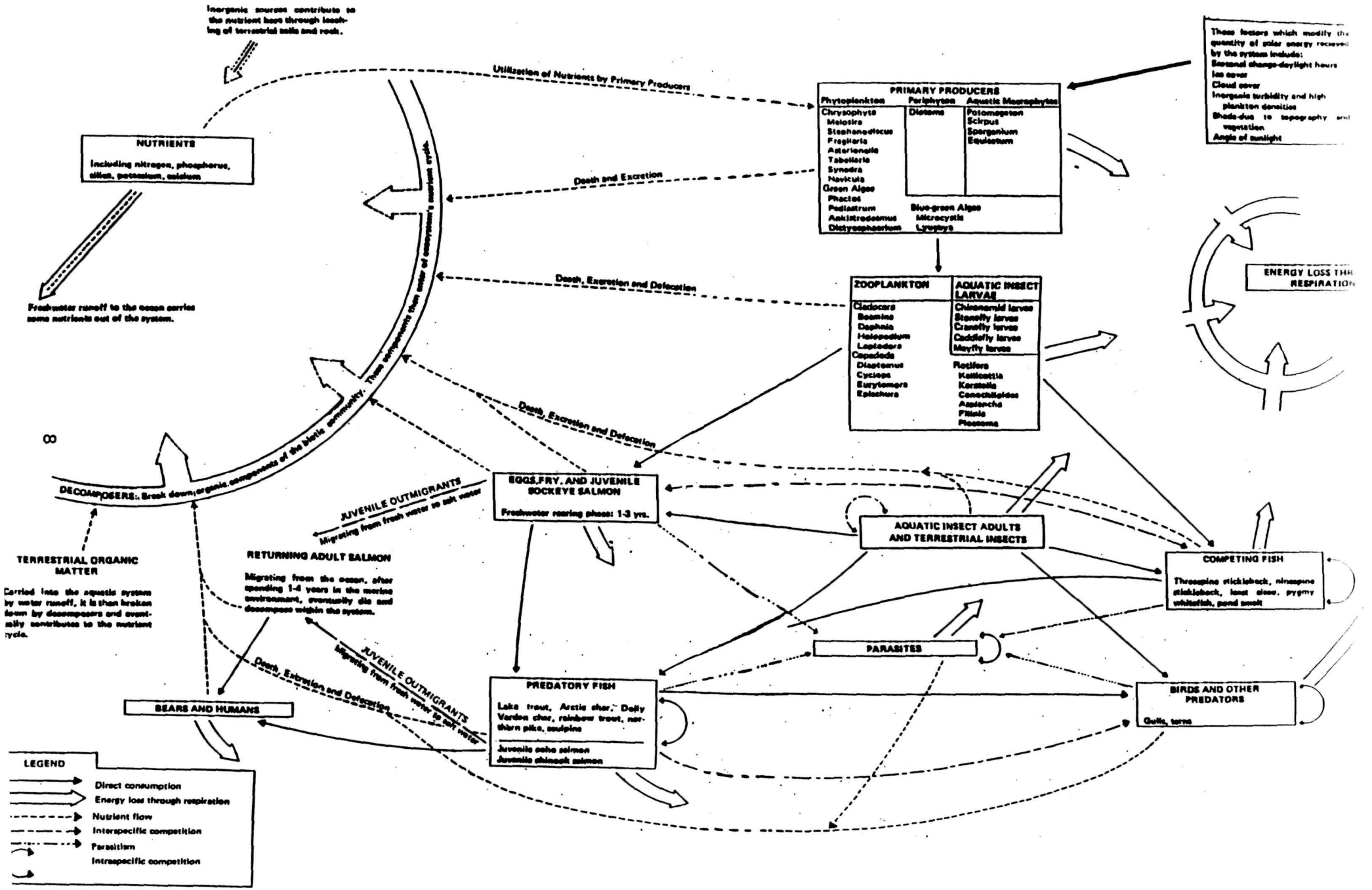
The large size of Katmai requires a phased approach to the planned research which will focus on representative large lake and river units in the western part of the park. Initial protocol development will occur in the Naknek River drainage (which includes Naknek, Brooks, Colville, and Grosvenor lakes) followed by additional research in the Alagnak River drainage to the north (which includes Nonvianuk and Kukaklek Lakes) (Figure 1). Specific site selections will be based on existing physical and biological information (including predictive models), environmental contrasts in the proposed systems (e.g., nitrogen vs. phosphorus limiting factors, volcanic ashfield incised streams), logistical considerations (e.g., camps and field sampling requirements), and applicability of the chosen systems to the national objectives of monitoring in the NPS. Wetland/riparian environments are included in the proposed systems approach because such areas are inextricably linked to adjacent waterways through the processing and storing of various detrital particles, nutrient cycles, bacterial and invertebrate community structure and function, and through other related food chain transfers. Consumptive use of small furbearers in preserve versus protected areas of the park offers an additional opportunity to monitor and contrast the dynamics of these animal populations.

NBS/NPS Phase 1 - Lake Monitoring (Years 1-5)

The large multilake Naknek River drainage (NRD) is the dominant drainage area on the Bristol Bay side of Katmai. The significance of Katmai lake environments to the overall salmon production in western Alaska, especially sockeye salmon, is unsurpassed in terms of numbers and worth. This drainage also contains the major salmon migration corridor in the park. Because the protection of the sockeye salmon resource and its habitats are specifically mentioned in the enabling legislation for Katmai, this species provides a key focus for initial planning. A conceptual model developed by Buck et al. (1978) (Figure 2) considers sockeye salmon production within a systems context (i.e., physical controls → water quality → decomposers → primary producers → secondary consumers → fish and other apex predators) with emphasis on energetic pathways and the life history of a valued species. The model provides a universally adaptable framework for interdisciplinary monitoring of lakes and other water bodies in the sense that appropriately obtained quantitative data at each successive trophic level can demonstrate interrelationships between major ecosystem components (Larson 1980).

Such a generic approach can emphasize trend detection and effects of environmental change at any level of the aquatic system. In fact, if detection of early signs of ecosystem degradation is a goal, a greater emphasis on taxonomy and species compositional changes, particularity in benthic and planktonic communities, must be pursued in the monitoring (Schindler 1987). Other early warning signs include a shortening of food webs and increased parasite loads in key species. Trend data on these attributes

Figure 2. **Conceptual Model of Aquatic Community Food and Energy Flows, Naknek River Drainage (From Buck, et. al., 1978).**



would be especially important in lakes already experiencing pollution stresses or eutrophication. The proposed monitoring would establish aquatic baselines on the near pristine conditions of Katmai water resources.

Buck et al. (1978) identify aquatic links to atmospheric and terrestrial environments through weather and climate variables, nutrient cycling (including biogenic inputs from adult salmon), plant life, and predation. Loopstra (1992) notes that salmon habitats are "products of the geology and soils, topography, vegetation, climate, and hydrology of a watershed" and that such characteristics of a watershed including aquatic productivity remain fairly constant over time. The proposed monitoring addresses these watershed processes and qualities so that observed changes in the biological and physical environments can be related to patterns of response in key indictor species.

Phase 1 activities are outlined below. It is recommended that they represent generalized visions of the monitoring design based on our information at this time. Prior to the undertaking of any field work, detailed study plans describing specific monitoring objectives, field and laboratory methods, analytical procedures, and reporting schedules would be required of all investigators. Priority research elements are listed below to indicate where new information is most critically needed in order to develop a scientifically defensible monitoring plan (not necessarily listed in order of importance). They include:

- Information review and synthesis.
- Field sampling to determine natural variability and spatial/temporal aspects of aquatic biota (e.g., plankton and fish) to optimize monitoring strategies.
- Develop recommended water quality monitoring techniques.
- Develop necessary taxonomic expertise.
- Develop sufficient understanding of biogeochemical cycling in atmospheric, aquatic, and terrestrial environments.
- Obtain appropriate climatic data.
- Validation of existing or developing predictive models.

With these in mind the following Phase 1 schedule is proposed. Note that Year 1 funding could be available as early as FY 1995.

Year 1

Information Management. The I&M Program will provide support to Katmai for completion of a park bibliography. Katmai has already committed park resources for this and will continue to archive other historical records. The I&M Program will also be supporting the conduct of a water resources inventory which will evaluate existing data and indicate where additional measurements are required. Additional effort will be expended on development of a Katmai relational database and GIS system in the park.

Field Work. Additional water quality and bathymetry surveys should be completed prior to the undertaking of a major field program (pers. comm. with Dr. J. LaPerriere). There is a need to complete synoptic water quality surveys in Naknek and Brooks lakes and for additional sampling in the major inlets and outlets of the NRD.

Years 1 and 2

Synthesis and Adaptive Environmental Assessment Workshop. The NPS and NBS will conduct reviews of existing environmental information and prepare synthesis products in anticipation of the long-term monitoring. One objective of the synthesis would be to orchestrate a technical evaluation and application of existing ecological models (food web-, euphotic zone- and zooplankton biomass-, and temperature-based) with respect to the biological productivity of Katmai lakes.

The synthesis report would serve as the basis for an interdisciplinary workshop of Katmai experts utilizing the Adaptive Environmental Assessment methodology (Holling 1978). Workshop objectives would be to promote interdisciplinary communication through the development of numerical simulation models and their validation requirements. This process would help identify research and monitoring requirements in the program development process. Submodels developed during the workshop will result in testable hypotheses for the NBS pilot research.

Disciplinary Objectives. Pilot research in Year 2 of funding would be initiated in the NRD with objectives to develop long-term monitoring protocols for the major ecosystem components identified in the Buck et al. (1978) model. Priority disciplinary objectives would include:

Climate. A remote weather station would be established near Brooks Camp and a reconnaissance performed to identify possible additional monitoring sites. Critical climate variables to be monitored include solar radiation, temperature, humidity, precipitation, and wind speed. A coherence analysis of data obtained at King Salmon, Alaska and Brooks Camp would be performed to determine the need for additional stations. Also, surveys to locate sites for monitoring snowfall and ice thickness measurements would be conducted. The need for seasonal information on lake and river temperatures would be assessed and thermographs installed as necessary.

Paleoecology. Lake sediment cores would be obtained to investigate paleo-vegetation and paleo-climate histories at Katmai (to determine organic matter accumulation and carbon settlement rates). Such an analysis is required to establish the disturbance history of the park and provide insights into natural pathways of successional change. Lake core sediments can be dated from known volcanic eruptions.

Water Quality/Quantity. A reconnaissance of the NRD system would be conducted to determine the level of hydrological data needed to support the monitoring. A hydrological gauging station will be installed at American Creek (at the head of Colville Lake) as this will likely be an area of intensive process oriented and habitat utilization research. The pilot research would include a water clarity objective that would address sampling requirements of the predictive model and the recommendations of the NBS.

Soils and Vegetation. Reconnaissance of wetland/riparian habitats and identification of permanent study sites would be conducted at American Creek and south of Nonvianuk Lake. The wetlands in each area are extensive and considered representative of this habitat-type in the park. The preserve site represents an important fur trapping area and long-term data collection there will facilitate important park comparisons.

Permanent vegetation plots adhering to size and replicate standards of the NSF at LTER sites in Alaska will be established near American Creek in the first year of study. Major plants will be identified to species, mapped in a coordinate system, and phenology noted. A microclimate station (including soils moisture and temperature probes provided by the USGS) will be installed in or near the plots. Soils samples will be collected and standard analyses for ionic elements, minerals, and major nutrients performed. The samples will also be examined for bacterial and meiofaunal components that may serve as major decomposers in the soil ecosystem. How well the plot sizes capture the biodiversity of plant life in Katmai wetlands will be evaluated as part of the NBS research.

If I&M Program funding for vegetation inventories in Alaska is obtained in 1995, satellite imagery, ground truthing, and GIS mapping may be initiated on a park-wide scale.

Aquatic Plants. The distribution and abundance of macrophytes in the aquatic habitats nearby the vegetation plots will be determined in first year surveys and used in the design of long-term monitoring sites. Protocol development will focus on (1) site selection, (2) the role of macrophytes in nutrient cycles, and (3) their contributions (dissolved oxygen and particulate organic matter) to the surrounding freshwater environments.

Biological Sampling. Ice breakup and spring plankton blooms play critical roles in the biological productivity of the NRD and the timing of salmon outmigrations. The availability, utility, and cost of remote sensing with CSEAWIF satellite technology will be examined and, if useful, pursued.

a. Lake Sampling. Pilot research will focus on statistical design and spatial/temporal requirements of the biological monitoring program. The primary issue is one of scale. As presently written, the proposed monitoring program would be developed on two systems of paired lakes (Naknek-Brooks and Colville-Grosvenor). If the areal dimensions of the initial program prove too great, the pilot research will be flexible enough for immediate modifications in the first few years. The NBS goal is to design a statistically reliable and realistic program for park implementation.

Exploratory fishing using hydroacoustic and tow net sampling gear will be conducted in the first two to three years of research. This amount of sampling will be needed to delineate temporal and spatial trends in the distribution and abundance of target species and to identify permanent index stations. Active fishing methods will be used as they are nondestructive and allow reliable estimates of population abundance and condition (length-weight relationships).

A small number of specimens (10 per species/index site/sampling period) will be retained in the catch for trophic analysis. Stomach contents will be identified and initially presented using the Index of Relative Importance (IRA). The IRA method graphically depicts frequency of occurrence, volume, and weight attributes of the dietary components, is widely used, and thus

allows time and areal (local and regional) comparisons. Computer software for IRA generations and computations of a variety of diversity indices (e.g., Main Food, Macintosh Index, and Simpson's Division of Numbers) are readily available. Zooplankton and other catch data will provide an easy indication of prey availability and fish habitat use.

Water samples (in triplicate), temperature profiles, aquatic drift, and zooplankton samples (triplicate surface hauls) will initially be obtained in concert with all fish sampling activities. Year 1 results should provide indications of how much sampling is required in future years. All plankton will be sorted to the lowest taxonomic level possible. A size frequency analysis will be conducted on dominant, or ecologically significant, components of the zooplankton in an attempt to develop defensible Production/Biomass ratios (P/B) as indices of the quality and quantity of salmonid foods.

A reconnaissance of the benthic infaunal component of the lake ecosystem will be conducted for information on the relative distribution and abundance of dominant species, identification of possible indicator species, and to locate permanent monitoring sites. The role of benthos in the nutrient dynamics of pelagic environments and secondary production will be investigated in the pilot research.

b. River Sampling. An aquatic sampling scheme will be developed for long-term monitoring at American Creek or comparable suitable site. One objective will focus on macroinvertebrates (drift and benthos) with monitoring design and sampling requirements adhering to precepts of the river continuum concept (i.e., nutrient spiraling and occurrence of guilds based on feeding morphology). Standard water quality and hydrological measurements will accompany this sampling.

Resident and anadromous fish utilization of selected habitats will be tested using minnow traps, inclined plane traps, fyke nets, and other nondestructive sampling devices. Appropriate seasonal considerations will be factored into the monitoring design and use of each gear.

The feasibility of a permanent counting station to develop escapement trend data on returning salmon to American Creek will be an initial focus of study. Initial work will involve comparative testing of estimates derived from aerial surveys and tower counts conducted simultaneously during selected time intervals of the summer.

Biogenic sources of nutrients can be important in the functioning of stream ecosystems (Kline et al., 1990). Pilot research to determine the importance of marine-derived nutrients (from adult salmon and their progeny) in local food webs will be initiated. Biogenic nutrients are hypothesized as an important link between terrestrial and aquatic ecosystems.

The NPS (in cooperation with the Alaska Department of Fish and Game) will continue to monitor juvenile salmon migration through the Naknek River. Sonar and fyke net technologies are employed in this monitoring to provide estimates of biomass; numbers; and age, weight, and length. The data are used to test hypotheses regarding the average number of smolts-per-returning adult, to study age relationships in the catch, and to determine survival and growth of juvenile salmon in Katmai's lakes.

c. Terrestrial Sampling. Mew, glaucous-winged, and Bonaparte's gulls, Arctic terns, belted kingfishers, and common mergansers are predatory species that have been identified in the NRD. Population monitoring will be conducted at several nesting colonies for gulls and terns on Naknek Lake and on selected streams and lakes for kingfishers and mergansers. Katmai staff will continue to participate in the national Breeding Bird Survey and to conduct off-road point counts in the western part of the park.

Katmai is planning to conduct an intensive moose population density and composition survey in the Naknek and Alagnak drainages during 1994. Survey protocols of Gassaway et al. (1986) will be followed. This intensive effort will be followed in succeeding years with trend surveys. Trapping harvest data for beaver, mink, and river otter is collected and is available from the Alaska Department of Fish and Game. Additional population density and distribution data will be collected through monitoring designs developed by the NBS. Monitoring protocols will focus on data acquisition in areas located nearby vegetation plots. Population structure and density will be compared and contrasted between protected populations of beaver, river otter, and mink, and those subjected to consumptive harvest in Katmai and the Alagnak Wild River Corridor.

The park will continue brown bear population density monitoring in the park and preserve, and will continue to seek funding from sources other than the I&M Program for wolf, coyote, and lynx population monitoring. This auxiliary information regarding predators will contribute to the long-term monitoring effort and enhance overall understanding of systematic processes.

Recreational Impacts. The long-term monitoring program will contain elements to assess and quantify the effects of human activities upon aquatic and riparian environments. Recreational impact surveys will be conducted to develop methods for evaluation of human use of river corridors, campsite assessments, angling harvest, motorboat, rafting parties, floatplane activities, and effects on water quality.

Years 2-5

The lake monitoring methods described above will be developed, tested, and protocols drafted and reviewed during the first five years of the program. Progress will be assessed annually by program managers utilizing an Annual Investigators Workshop format and requirements of annual technical reports. Once the protocols are described, the actual monitoring will be implemented by Katmai resource managers with NPS funding. The NBS will maintain technical oversight to assure the quality of data, monitoring results, and the adequacy of existing methods. NBS funds that were expended on completed Phase 1 activities will be redirected to other Phase 1 research or used to initiate Phase 2 efforts on the Alagnak River drainage.

NBS/NPS Phase 2 - Large River Monitoring (Years 3 - 10)

Phase 2 activities will be directed toward the description of a long-term monitoring program for large rivers. Fieldwork will be conducted in the Alagnak River drainage in northwestern Katmai (Figure 1). The location of this river and its association with Nonvianuk and Kulik lakes offers a unique experimental opportunity to: (1) research and monitor lacustrine effects on large river ecology, and (2) compare and

contrast the natural ecology of three paired lakes over time (i.e., Naknek-Brooks, Colville-Grosvenor, and Nonvianuk-Kulik). Existing water quality information from these lakes indicates environmental differences with respect to nutrient availability (N and P) and biological productivity. Historically, all of the lakes in Katmai have been exposed to volcanic ashfall. However, the inputs have varied with respect to eruption events with unknown but suspected differential effects on freshwater productivities.

Phase 2 research will proceed on two fronts. With respect to Nonvianuk and Kulik lakes, protocols developed for the NRD will be implemented, as appropriate, by NPS staff. The implementation of these protocols would require minimal assistance from the NBS. This early data acquisition would focus on climate, water quality, soils and vegetation, and human use activities elements of the monitoring program. Other monitoring protocols can be expected to still be in the research and development phase of the NBS.

The primary initial objective of the NBS in Phase 2 will be to conduct an extensive review of information on (1) large river ecology, (2) existing river monitoring programs, and (3) management issues and concerns (on a national level for the program design). Several main sources of information will be queried including but not limited to:

- **Susitna Hydroelectric Feasibility Studies.** More than 20 million dollars were expended between 1980 and 1986 to examine the potential impoundment effects on fish and wildlife resources and habitats on this river in southcentral Alaska. The environmental research focused on anadromous and resident fish species, juvenile salmon and their nursery habitats (e.g., instream flow requirements and description of habitat suitability curves), aquatic resources and water quality, and numerical modeling. Mammal research focused on habitat use in potentially impacted areas.

- **Bonneville Power Administration.** NBS has been charged with assuming a lead role in Columbia River salmon restoration research. This will allow immediate access to technical expertise and reference materials directly applicable to the Alagnak Drainage.

- **U.S. Army Corps of Engineers (Waterways Research Station).** This station has been involved in large river ecology research and modeling studies for years. Much of their efforts have focused on the Mississippi River Valley, Columbia River, and large rivers in the northeastern part of the United States.

- **U.S. Fish and Wildlife Service Programs.** The agency has legislated mandates to protect the welfare and habitats of anadromous and resident fish species nationwide.

- **Tennessee Valley Authority.** Similar to BPA (2 above), the TVA has funded numerous water research projects that will be appropriate to the NBS objective in Katmai.

- **Colorado River Multi-Agency Research.** Appropriate experts and references will be consulted in the NBS and other agencies. This effort will provide mid- and far west coverage in the review.

An NBS report will be produced summarizing the results of the review with emphasis on program development planning for monitoring of large river ecosystems. Priority monitoring recommendations and requirements presented in the report will be reviewed by the NPS to ensure park cooperation and

coordination in the pilot research. Pilot programs will begin in Years 2 and 3 and protocols developed within a five year framework.

NBS/NPS Phase 3 - Marine and Coastal River Monitoring. (Year 5 and Beyond)

The timing of Phase 3 activities is dependent on funding availability from NBS and NPS sources in the years ahead. Phase 3 activities involve the implementation of peer-reviewed protocols from *Pacific Coast* and *Arctic/Subarctic* prototype parks at Katmai coastal marine and river environments, respectively. Coastal protocols have been described and await further testing at other monitoring sites. Considering issues pertaining to oil and gas development in Cook Inlet, Alaska (i.e., tanker traffic and oil spill threats), coastal monitoring of park resources in Shelikof Strait should be viewed as a priority need. The NBS would only be consulted if modifications to the Channel Islands protocols or new research is needed.

A large (70 foot) research vessel will be required for coastal monitoring in Cook Inlet (Katmai has jurisdiction extending five miles from the coast along Shelikof Strait). It has been suggested that approximately 100 days of logistical support would be required. With crew, leasing costs on the order of $1,650/day are expected and should be considered for this preliminary analysis of cost. Other funding requirements for the coastal monitoring are known from Channel Islands and would be consulted in future planning.

Protocols (including costs) have not been described from pilot research on watershed ecosystems in Denali. Realistically, they will not be available for another three to five years. This is not especially critical to Katmai's immediate resource information needs about coastal drainages flowing into Cook Inlet. It should be noted, however, that the coastal rivers contain important fish and wildlife resources and are experiencing ever-increasing amounts of visitor use (e.g., sportfishing and wildlife viewing). For the interim, Katmai will direct resources to coastal issues as they arise and coordinate their efforts with those agencies and organizations conducting research on this part of the Alaskan coastline.

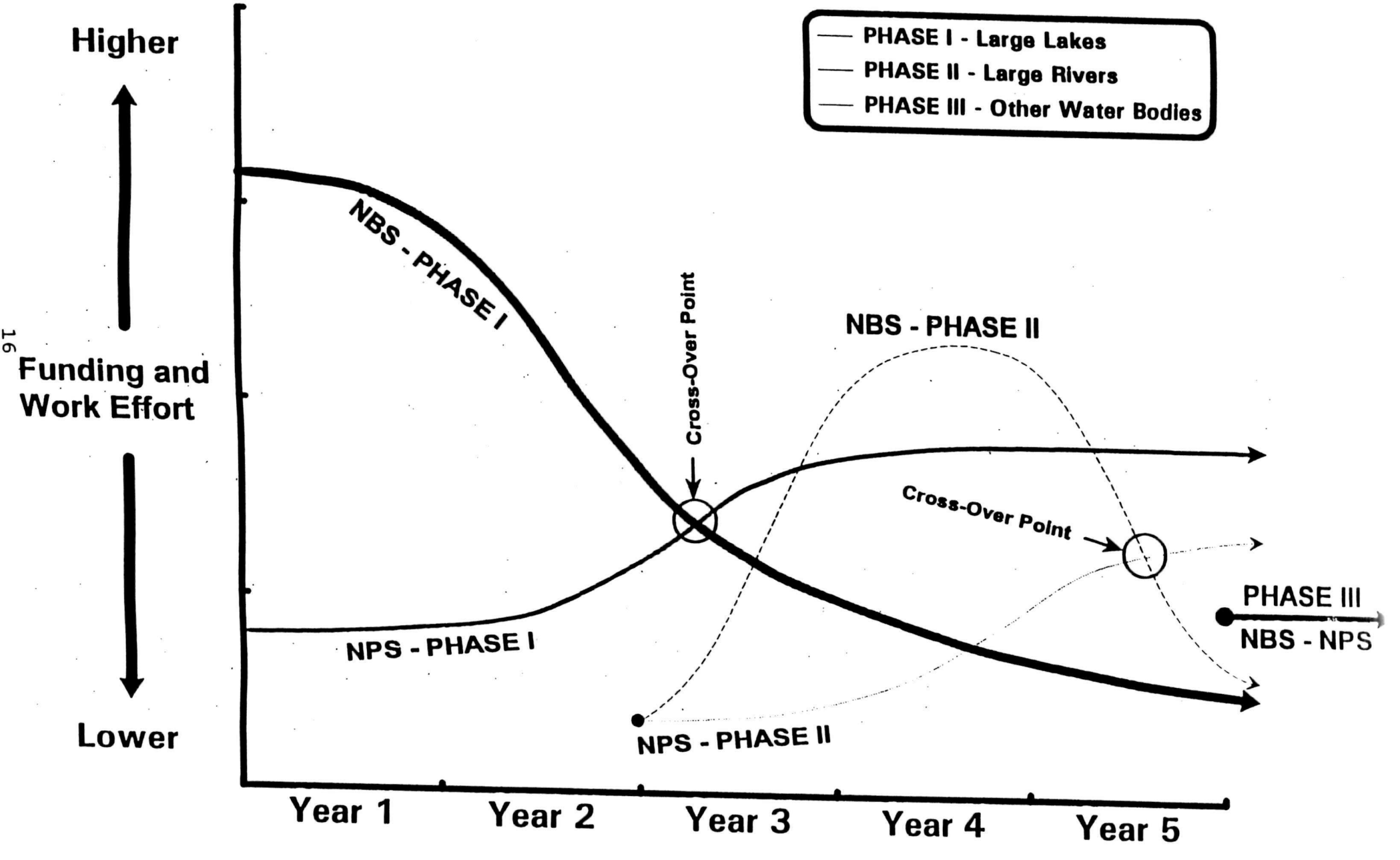
Interaction Between the National Park Service and the National Biological Survey

The National Park Service (NPS) and the National Biological Survey (NBS) are both necessary entities in designing and conducting a sound long-term monitoring program in Katmai. The NBS will be primarily responsible for research associated with protocol development and sampling design and the NPS will be primarily responsible for implementing the long-term monitoring program. Figure 3 depicts the relationship between NBS and NPS work activities as they relate to the research and monitoring phases of the proposed Katmai project.

Phase I: Large Lakes

The initial phase of the Katmai long-term monitoring program will focus on large lakes in the western part of the park. In the first 3-5 years, the NBS will be responsible for protocol development and sampling design. During this time the NPS will work in coordination with the NBS providing logistical, administrative, and field assistance and support. After Year 3, the emphasis will shift from protocol

Figure 3. Phasing of Work Effort and Funding by NBS and NPS



development to actual monitoring. From that point, the NPS will implement the monitoring, requiring an increase in the NPS workload and funding, while NBS will phase out their activities on large lakes, but still provide technical oversight to NPS.

Phase II: Large Rivers

Phase II will focus on large rivers, specifically the Alagnak Wild River and its main branch, the Nonvianuk River, which drains Kukaklek and Nonvianuk lakes in the western part of the preserve. As Phase I Large Lakes protocol development winds down in Year 3, the Phase II Large Rivers protocol development will be initiated by NBS. It is expected that the Large Rivers protocol development will take 2-3 years, during which time the NPS will provide logistical, administrative, and field assistance and support. At the end of Year 5, the work effort will shift from protocol development by NBS to implementation of monitoring by the NPS. NBS will continue to provide technical oversight to the NPS monitoring program.

Phase I and II Overlap

As the Phase I workload decreases for NBS, the Phase II workload will increase, thus separating the NBS workload into two periods. The NPS workload will increase as Phase I moves along, however, the NPS Phase II workload will remain relatively low until Year 5, at which time NPS will be responsible for monitoring both the Large Lakes and Large Rivers sites.

Phase III: Marine and Coastal Rivers

Phase III is the application of existing protocols developed in other parks, particularly Denali and Channel Islands, to coastal rivers in the eastern part of Katmai. The NBS and NPS will work cooperatively at a similar workload level in testing and applying the established protocols. Eventually the NPS will conduct the monitoring for Phase III coastal rivers, with technical oversight from NBS.

Research

Research scientists from NBS and the university community will be encouraged to design and conduct research in Katmai using the long-term monitoring study areas to better understand the ecosystem linkages among the monitoring parameters.

Scientific Credibility and Capability

The park Resource Management and Research Division Chief holds a Master of Science degree, is a graduate of the NPS Natural Resource Specialist trainee program (Class III), has 15 years of field experience in the collection and management of natural resource data, and seven years of I&M program management experience, including a significant role in coordinating the development and implementation of the successful Shenandoah National Park LTEMS. Two additional natural resource program managers on staff will assist with this project. Both hold Master of Science degrees and have extensive field monitoring experience. A wildlife research ecologist with the National Biological Survey is stationed at

Katmai and will assist with protocol development, data analysis, and publications. This person holds a doctorate in wildlife ecology and is in a research grade position.

Katmai has requested positions for a professional fishery biologist and a hydrologist. The fishery biologist position request was submitted to WASO by the Alaska Region for consideration under the Servicewide FY 1994 Professionalism Initiative. The Anchorage Regional Office (ARO) hydrologist (11 years Alaska experience) and ARO fishery biologist (20 years Alaska experience) are available for project work and consultation. The Inventory and Monitoring Coordinator (15 years Alaska experience), stationed with NBS, will continue in that capacity.

Scientific credibility will be further enhanced by the participation of two additional NBS research academicians, Dr. Jim Reynolds and Dr. Jackie LaPerriere, who hold posts as Leader and Assistant Leader of the NBS (formerly USFWS) Cooperative Fish and Wildlife Research Unit at the University of Alaska Fairbanks. Both have excellent personal working knowledge of Katmai's aquatic ecosystems and both have expressed a continuing interest in participating in this endeavor. In addition, University of Missouri professor Dr. Jack Jones, who has conducted nutrient research in Katmai, is interested in the Katmai I&M Program as is University of Alaska professors Dr. Mark Oswood and Dr. Alexander Milner.

Table 1 depicts a list of major identified lake and river I&M components of the Katmai LTEMS and institutions that have expertise in and/or have expressed interest in the Katmai I&M proposal.

Lakes and Rivers Monitoring Standards and Objectives

- To determine baseline and natural variability of selected aquatic systems;
- To predict, observe, quantify, and describe (in terms of scientific significance and management implications) anthropogenic-induced changes in the listed components.
- To develop standardized monitoring protocols for application in Katmai National Park and Preserve, and for easy export to a large number of NPS units having lake and river resource monitoring needs.

Budget and Cost Effectiveness

Long-term environmental monitoring in Katmai will be a watershed test of the relationships and long-term partnerships that form between the NPS and NBS. The shared benefits of the proposed research to the agencies are embedded in their common goals for ecosystem health and integrity through ecosystem management and research, respectively. Ecosystem monitoring is inherently complex whether objectives address biodiversity, nutrient cycles, ecological energetics, population dynamics, or a combination of these approaches. One major objective of the NPS prototype park program is to learn the true costs of monitoring in each of the biogeographical associations. The fiscal requirements listed in Table 2 reflect our best estimates of the science costs for research and development of aquatic monitoring protocols.

Table 1. Major Katmai Lake and River I&M Components and Potential Institutions Providing Expertise.

KATMAI LAKE AND RIVER I&M COMPONENTS	INSTITUTION
Water Chemistry	NBS, U. of Alaska Fairbanks, Coop. Fish and Wildlife Research Unit NPS, Alaska Regional Office
Nutrient Levels/Cycles	NBS, U. of Alaska Fairbanks, Coop. Fish and Wildlife Research Unit University of Missouri NPS, Alaska Regional Office
Hydrology, Hydrography, Bathymetry	NBS, U. of Alaska Fairbanks, Coop. Fish and Wildlife Research Unit University of Alaska Fairbanks, School of Engineering NPS, Alaska Regional Office Katmai National Park and Preserve
Geology	US Geological Survey and Alaska Volcano Observatory US Geological Survey, Geologic Division
Glaciology, Snowpack, Icefields	Soil Conservation Service
Hydrothermal, Volcanic Features	US Geological Survey and Alaska Volcano Observatory US Geological Survey, Geologic Division
Meteorology	National Weather Service
Resident and Anadromous Fishes	NBS, U. of Alaska Fairbanks, Coop. Fish and Wildlife Research Unit NBS, Alaska Research Center NPS, Alaska Regional Office ADF&G, Sport Fish Division ADF&G, Commercial Fish Division ADF&G, Alaska Pipeline Office
Aquatic and Riparian Vegetation	NBS, Katmai National Park Office
Riparian Vertebrates	NBS, Katmai National Park Office ADF&G, Wildlife Conservation Division
Aquatic Invertebrates	NBS, U. of Alaska Coop. Fish and Wildlife Research Unit NBS, Virginia Polytechnic Institute, Coop. Research Unit University of Alaska Fairbanks University of Alaska Anchorage
Contaminants	NPS, Water Resources Division National Marine Fisheries Service., Wash., D.C.
Geographic Information Systems	NPS, Alaska Regional Office NBS, Katmai National Park Office
Recreational Impacts	NBS, Virginia Polytechnic Institute., Coop. Research Unit

Table 2. Proposed Budget, in Thousands of Dollars (Combined NBS and NPS).

ELEMENT	YEAR 1	YEAR 2	YEAR 3	PHASE I Total Cost	YEAR 4	YEAR 5	YEAR 6 & Beyond	PHASE II Total Cost
Park Staffing	75	75	75	225	150	150	150	450
Transportation/Travel	10	90	90	190	75	75	75	225
Water Quality Monitoring	35	44	44	123	45	45	45	135
Hydrology/Bathymetry	35	35	35	105	65	65	65	195
Geology	0	12	12	24	15	0	0	15
Meteorology/Climate	23	23	10	56	26	11	11	48
Fish	40	90	85	215	85	85	85	225
GIS/Data Management	15	68	68	151	68	68	68	204
Vegetation	15	25	25	65	35	35	35	105
Mammals and Birds	10	60	60	130	75	75	75	225
Invertebrates	1	50	50	101	30	30	30	90
Plankton	1	57	57	115	45	45	45	135
Contaminants	0	5	5	10	10	10	5	25
Paleoecology	0	30	15	45	15	15	0	30
Recreational Effects	0	20	10	30	20	10	10	40
Information Synthesis	60	0	10	70	60	0	10	70
Contract Analysis	0	85	85	170	85	40	40	165
NBS Overhead	26	210	196	432	239	206	202	647
TOTALS	346	979	932	2257	1143	965	951	3059

The proposal instructions were ambiguous with respect to projected overhead charges of the NBS. For purposes here, we have assumed a standard 44% overhead on employee benefits. Scientists' salaries were computed based on expected field, laboratory, analysis, and reporting requirements in each disciplinary area. Senior scientist and technician support was estimated at $200.00/day and $100.00/day, respectively. Overhead on the salaries has been listed as a line item for negotiation. Importantly, an administrative charge of an additional 15% on overhead items may be another cost of doing business with the NBS. This overhead is not shown in Table 2; however, for now, it must be recognized as an area of potential increased costs.

A combined agency budget for the research and development phases of lake and river monitoring has been presented. Fiscal requirements of Phase 3 monitoring, the NPS implementation of marine and coastal river programs, were not developed. While they are germane to Katmai National Park and Preserve, they are not relevant, in the national sense, to the NPS's *Lake and River* biogeographic association. For now, the prototype monitoring must be viewed in a non-site specific context with widespread applicability. The budget presented is based on an idealized three-year protocol development schedule for lake and river units. Three to five year developmental periods are probably more realistic and thus we are recommending that the fiscal requirements of this effort be revisited at the end of Year 3 with revised cost proposals developed on the basis of technical performance and status of protocol development.

The Year 1 funding in Table 2 does not reflect the first year of intensive field research (Year 2). Instead, in order to ensure the timely procurement of equipment for Year 2, some start-up costs have been pushed ahead by one year. This is particularly important for the acquisition of hazardous materials that will be needed for sample preservation. Since some active fishing methods require a two-boat operation, and because investigator competition for research platforms may be great, funding for additional small craft support is requested. A 20-foot inboard jetboat, handheld radios, GPS, and other logistical support will be available to the NBS from the park.

An important feature of the prototype monitoring is to learn monitoring costs so that others can use them for planning purposes. Costs for nutrient, water quality, soils and vegetation, meteorology, invertebrate and plankton sorting, and paleoecology analyses are based on known actual costs from Denali and other sources. Spatial and temporal features of the pilot lake research assumed a seasonal sampling plan incorporating station sampling along fixed transacts. Similar time and areal budgetary constraints were imposed on the proposed sampling at American Creek and permanent plots nearby.

Field costs have been kept to a minimum by our selection of accessible lake and river study areas. Each proposed site is situated near an active field camp that will be maintained by the NPS with operational funds (See Figure 1). Additional measures of cost effectiveness will be assured by shared program management responsibilities of NPS and NBS officials (commitment not shown) and use, where possible, of existing contractual agreements to secure scientific support or other services (e.g., voucher archival at the University of Alaska Fairbanks). As an example, the park staff shown in Table 2 is for an I&M Coordinator at Katmai and for technician support (budgets shown are loaded, that is, overhead, etc., is included in the amount shown for NPS) and does not include the other resources personnel/facilities that will be utilized in support of the NBS and the monitoring. We have deliberately excluded GSA and other infrastructural costs that will be borne by the participating agencies.

The costs associated with synthesis and the Adaptive Environmental Assessment workshop are based on recent actual costs (Thorsteinson et al. 1989; Sonntag et al. 1980). With respect to the latter, the amounts

shown address travel, contracting costs associated with meeting facilitation and reporting, and a modest inflation factor. Flexibility is built into this proposal with the workshop approach such that hypotheses developed by experts provide additional perspectives on the specific requirements of the research. Some aspects of this proposal are designed to delineate biochemical linkages between aquatic and terrestrial ecosystem components, may require laboratory work, and may be outside the expertise of the NBS. These have been identified as "Contracted Services" in Table 2 and include meoifauna, biogenic nutrients, other nutrient cycling, and certain sediment analyses described in this proposal. Overhead charges have been rolled into the estimated budgets for Contracted Services and thus are separate from those of the NBS.

Field costs have been kept to a minimum by our selection of accessible lake and river study areas. Each site is situated near an active field camp that will be maintained by the NPS (See Figure 1). Additional measures of cost effectiveness will be assured by shared program management responsibilities of NPS and NBS officials and use, where possible, of existing contractual agreements to secure scientific support or other services (e.g., voucher archival at the University of Alaska Fairbanks).

Service-Wide Applicability

The selection of Katmai as the prototype Lakes and Rivers LTEMS park would provide exportable program applicability unmatched by any other NPS unit, due to the extensiveness and variety of freshwater and marine resources located there. Multiple entire watersheds lie within Katmai's boundary, including 11 major lakes; the largest freshwater lake in any NPS unit; the largest remaining lake in the entire United States that is free of any shoreline development; more than one thousand miles of permanent rivers and streams; tidal and tidally-influenced rivers, estuaries, and bays; volcanic ashfield incised streams; more than a quarter-million acres of glaciers; two large crater lakes; several lakes lacking outlet streams having landlocked salmon and other genetically isolated fish and invertebrate populations; more than a dozen major anadromous rivers with all five species of Pacific salmon present; geothermal pools and fumaroles; extensive wetland and riparian habitats; and literally thousands of ponds. The varied bathymetrical and chemical properties, along with a natural "pairing" of the major lakes, make them ideal candidates for long-term study of nutrient cycles, primary productivity, limiting nutrients, and other factors. Some lakes have been shown to be phosphorous limited, others nitrogen limited. Streams available for monitoring offer a wide variety of discharge, gradient, source of origin, order, geological underlayment, bottom substrate, riparian corridor, and biotic characteristics.

The water resources of Katmai National Park and Preserve are vast and relatively undisturbed. They provide an important baseline, relatively unaffected by anthropogenic factors, from which change can be detected. The importance of this type of baseline for Katmai and other national parks cannot be overstated, as we enter an era when anthropogenic impacts on natural resources are occurring, even in remote areas of the world. Due to the relatively unaltered conditions at Katmai, change may be detected earlier than other locations, and provide warnings not only for Katmai but to parks and areas nationwide.

Monitoring Katmai will provide basic information on how a relatively intact large lake/large river ecosystem functions. This information would be invaluable to parks and other natural areas where efforts are being made to restore damaged lakes and rivers and to reintroduce fish. Basic ecosystem functioning

information from the Katmai system would also be useful in light of the recent decline of Pacific Northwest salmon stocks and current concerns for the future of certain Alaska salmon stocks.

The location of Katmai would also provide water resource and fishery information and protocols for use by the NPS in current efforts to coordinate with the Russian Far East on the establishment of a protected area and the management of their natural resources, such as Lake Baikal. NPS could also utilize the Katmai monitoring program information in coordinating and planning aspects of the circumpolar Biosphere Reserves Program.

Monitoring protocol development on the Alagnak River, a unit of the Wild and Scenic River System, would be useful in establishing monitoring programs at other Wild and Scenic River units that the NPS manages throughout the country. The 70-mile long Alagnak Wild River receives heavy recreational use by floatplanes, motorboats, and rafters engaged in camping, fishing, and hunting activities and would serve very well as the prototype for monitoring similar recreational use river corridors throughout the system. Finally, establishing a monitoring program on the Alagnak River, and eventually implementing it at other Wild and Scenic units, would also demonstrate an NPS commitment to meeting the intent of the National Wild and Scenic River Act.

To insure Servicewide applicability, protocol developers will closely follow the guidelines for geophysical, chemical, and biological inventory and monitoring found in NPS-75, *Natural Resources Inventory and Monitoring Guideline*.

Park Infrastructure and Organizational Structure

The park office in King Salmon has sufficient office space for the existing natural resource staff and one resident NBS wildlife research ecologist. A 4-bunk cabin with full utilities at Brooks Camp would be available for this LTEMS effort. NPS field camps exist at the mouth of American Creek, the head of the Nonvianuk River, Bay of Islands (in Naknek Lake), at Brooks Camp, and on the Shelikof Strait coast in Geographic Harbor. There is a need for an additional administrative facility along the Shelikof coast in Kukak Bay. Temporary field camps would also be established in support of this program. The park currently does not have sufficient wet/dry laboratory facilities or cold storage that would be necessary to fully support this program. However, these facilities are included in the park's housing initiative plans.

Computer support is in place for all major programs, including network capabilities via cc:mail and CD ROM. Park aircraft are equipped with on-board Global Positioning System units and hand-held units are available for the park's 20-foot inboard resource management vessel, the Qulirak, designed for lake and river travel. Park aircraft and this boat are available to support the proposed project on a reimbursable basis for operation and maintenance. Additional Office of Aircraft Services certified air taxies, including charter aircraft on floats and wheels, are available for hire in King Salmon.

The park has a fully functional Division of Resource Management and Research. The Resource Management and Research (RM&R) Division Chief reports directly to the park Superintendent. The NBS Wildlife Research Biologist stationed at the park works in close cooperation with park staff. The RM&R

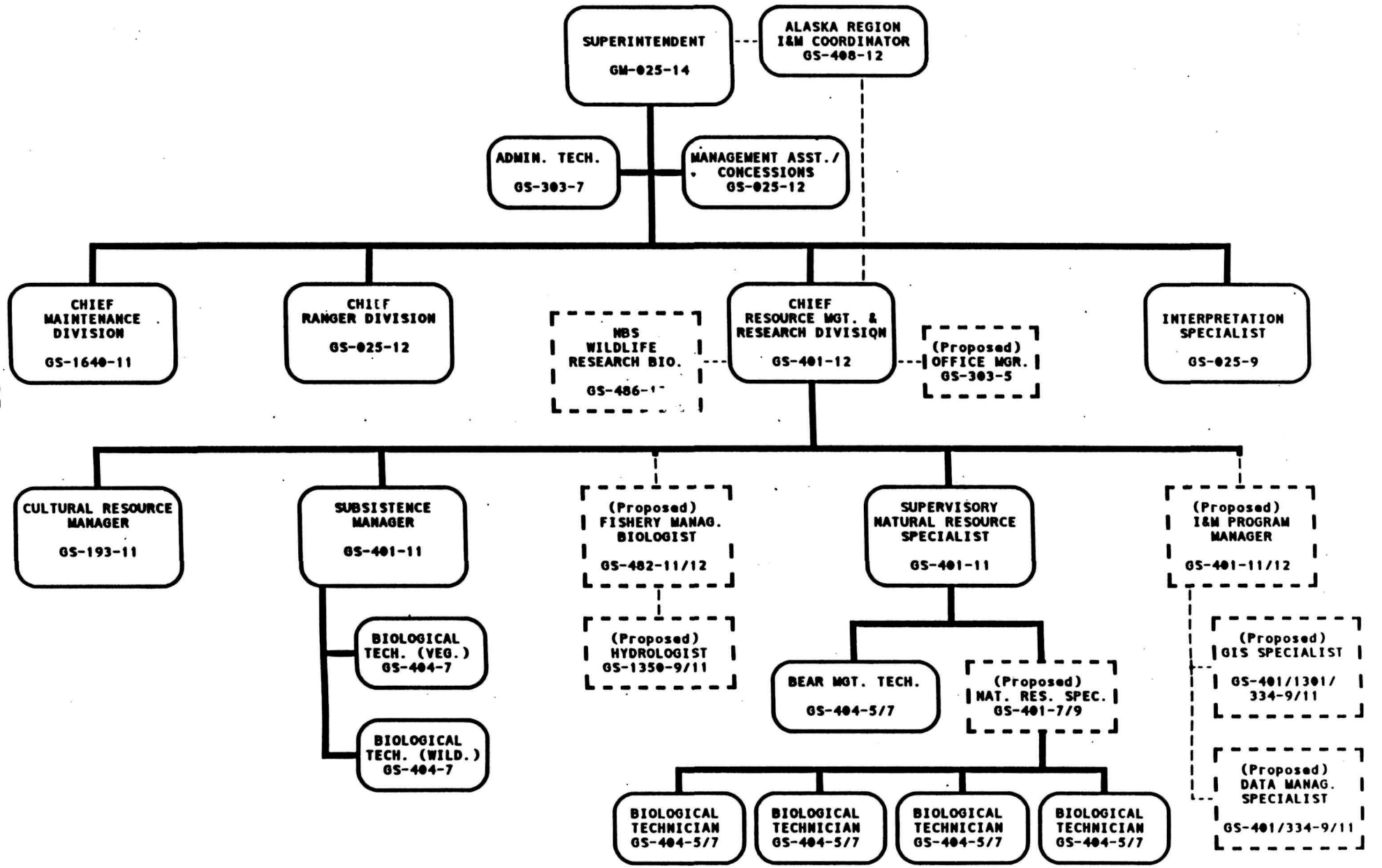
Division Chief brings the experience and continued interest of having successfully coordinated the development and implementation of the Shenandoah National Park LTEMS, which has received Servicewide recognition as a model program. The park also maintains a list of persons who have expressed an interest in performing volunteer services. The availability of volunteers will enhance the effectiveness of the Katmai LTEMS program. Figure 4 depicts a current organizational chart for the park, with emphasis on existing and proposed positions within the Resource Management and Research Division.

Data Management Plan

A customized computer database management program will be developed to support the Katmai Lakes and Rivers LTEMS. The program would be built upon the Servicewide standard database management software, dBase®, to facilitate transfer to other parks with minimal modifications. A database management system is an essential part of any large scale monitoring activity. Without it, the vast volume of data collected over time would become fragmented, altered, or irretrievable. The value of the information to research and management would be lost. Computer data entry screens will duplicate field data collection forms, facilitating complete and accurate data transfer. Automated data storage and transfer technology will be incorporated as it is developed and perfected. Data entry fields will be designed to assist the operator by defining parameter ranges and will incorporate other error detection features. QA/QC practices will be incorporated into all aspects of monitoring from protocol development, development of a field techniques manual, standardization of training for field monitoring crews, data sheet inspections prior to computer entry, and statistical testing to detect unexpected values. Also, specific parameter sampling techniques will include duplicate samples, blanks, blind known concentrations, and various other QA/QC checks that are recognized by subject matter experts as producing scientifically defensible data sets.

In addition to the creation and maintenance of the database management program described above, data security and continuity will be assured by the routine updating of back-up copies of all data sets, which will be stored in a theft and fire-proof vault in a separate physical location from the main work station. Also, all hard copy field data sheets will be archived in a climate controlled setting that meets NPS curation standards. A monitoring program manager and a data manager will be hired to assure program continuity and integrity.

Figure 4. Organizational Chart, Katmai National Park and Preserve



GIS Support and Integration

Katmai has recently procured a state-of-the-art GIS. This system is comprised of Unix-based SUN® microstation hardware with ARC/INFO® software. It will be the central focus for data input, management, retrieval, and manipulation.

All survey and monitoring data will be in formats compatible with the Katmai GIS using ARC/INFO® software. Formal guidelines for these data formats will be given to all project personnel. Survey data will be incorporated into NPS Resource Management Division files and appropriate thematic layers used by the GIS.

Data generated from inventory and monitoring in Katmai National Park will be carefully managed to maximize accessibility and utility. Computers will be used for data collection, input, storage, and retrieval. All monitoring project formats will be designed to implement current computer technology. For example, several vertebrate monitoring protocols will include an aerial survey component. Using GPS technology and flight-path tracking software, all survey flight paths will be stored in GIS-compatible file formats. Additionally, all survey data (e.g., numbers of moose, age, sex, etc.) will also be entered directly into the tracking program while in flight. At the office, these data will be transferred directly across to the GIS and incorporated into its relational database with a minimum of effort. Tabular data will be entered into desk-top computers so that programs such as dBase®, Lotus 1-2-3®, and Systat® can be used for information management, data manipulation, and statistical analyses.

Linkage and Leveraging

The Alaska Department of Fish and Game (ADF&G), Commercial Fish Division, conducts monitoring activities within Katmai National Park and Preserve including salmon population monitoring in the Naknek, Kvichak (Alagnak), King Salmon, and Kejulik River systems on the Bristol Bay side of the park, and Kamishak, Douglas, Big, Swikshak, Ninagiak, and Alagoshak Rivers, as well as smaller drainages on the Shelikof Strait (Pacific) side. The finer resolution monitoring of Katmai tributary streams proposed for this program will complement these larger watershed scale surveys.

The park and ADF&G are currently conducting a sockeye salmon smolt emigration/productivity study in the Naknek River system through a cooperative agreement. This study, jointly funded by ADF&G and the NPS Alaska Regional Office, Natural Resources Division, will help to quantify the biological results of the all-time record high escapement (i.e., the successful return of adult salmon to their spawning grounds) of 3.6 million sockeye salmon that occurred in the Naknek River in 1991 as a result of a commercial fisheries strike in Bristol Bay.

A study funded by NRPP is currently being conducted through an Interagency Agreement with the University of Alaska Cooperative Fish and Wildlife Research Unit (USFWS) on American Creek. It will determine the biological effects, if any, of shallow water operation of jetboats over salmon spawning grounds. The emphasis is upon determining salmon egg mortalities in stream gravels. Results of this

study, and the field techniques developed during the course of the study, will be directly linked and applicable to a comprehensive monitoring program.

The U.S Fish and Wildlife Service, Fishery Assistance Office in King Salmon has conducted inter-tributary movement and migration studies of rainbow trout in the upper King Salmon River drainage of Katmai. The monitoring techniques and information resulting from that work will be useful for this program.

The Becharof/Alaska Peninsula National Wildlife Refuge conducts waterfowl habitat and productivity monitoring on the Alaska peninsula. Park staff assist with this project on NPS lands. The waterfowl habitat classification and productivity protocols will directly link with this proposal and mutually benefit both efforts.

The Alaska Department of Fish and Game, Sport Fish Division, conducts periodic population status and creel surveys for game fish on popular streams in and around Katmai, primarily focussed on rainbow trout, chinook and coho salmon, Arctic grayling, Arctic char, and lake trout. The current proposal would complement these efforts by targeting a cross-section of the approximately 20 other species of resident (other than anadromous) freshwater fishes found in Katmai waters.

The U.S. Geological Survey currently monitors water chemistry parameters related to selected volcanic hydrothermal springs, lakes, and surface waters that have been affected by volcanic activity.

The U.S. Soil Conservation Service has expressed a desire to cost share an expanded snow pack monitoring system throughout this region. This information would be keenly valuable in understanding hydrologic patterns and is included as part of this proposal. NPS currently monitors precipitation in the King Salmon area in cooperation with the SCS.

The U.S. National Weather Service has expressed a desire to assist with the establishment of one or more meteorological stations in the park and has offered to make existing meteorological data available in support of research and monitoring.

Approximately 400,000 acres of Katmai's 4.3 million acres are open to sport and subsistence hunting and trapping. The Alaska Department of Fish and Game, Wildlife and Habitat Conservation Division, is interested in the extent and condition of riparian vegetation relative to populations of such wildlife species as moose, beaver, river otter, mink, and others. Riparian vegetation condition and wildlife population information would be combined with ADF&G hunting and trapping harvest data.

The U.S. Bureau of Land Management administers significant land holdings surrounding the NPS administered Alagnak National Wild River. This area is popular for sport and subsistence moose hunting and periodic moose population surveys are planned by NPS, BLM, and ADF&G.

Katmai will participate in the Conservation of Arctic Flora and Fauna (CAFF) group of 11 arctic countries with an established agenda for ecosystem protection and monitoring. Monitoring will include standard protocols used in the International Tundra Experiment (ITEX). It is through CAFF that Katmai will participate in the circumpolar Arctic Monitoring and Assessment Program (AMAP) and the Circumpolar database important for conservation of arctic ecosystems.

Reporting System

Annual administrative reports will be prepared for the Katmai I&M program. Results from individual projects will be summarized in report form and circulated for peer review. Revisions and final copy will be kept in park files. Ultimately, all project reports will be incorporated into a larger report dealing with the entire program.

Lead personnel for the major components will be responsible for the submission of annual work plans and progress reports. Workers will be encouraged to actively seek publication of their findings in appropriate peer reviewed journals and to present their findings at symposia such as The George Wright Society and others. At least one symposium will be held encompassing the complete Katmai Lake and Rivers LTEMS effort, with the proceedings published as an NPS technical paper. A complete set of field monitoring manuals will be produced by major monitoring component and printed for widespread circulation to all NPS units having need to monitor lakes, rivers, wetlands, and riparian flora and fauna.

LTEMS team members will be encouraged to participate in networking activities with other groups involved in related I&M activities, including the Circumpolar Biota Project, the Arctic Monitoring and Assessment Program (AMAP) Lakes and Rivers Project, and other NPS LTEMS parks. Other information transfer opportunities may be possible with joint publications prepared with NSF researchers involved in Long-Term Ecological Research investigations and other ecological/fisheries/limnological research in western Alaska. A series of non-technical publications will be produced in cooperation with regional and park interpretive specialists for distribution to park visitors and the interested public.

Park Threats

- Most of the vast, rugged, roadless area of Katmai is in nearly pristine condition. However, the transportation and use of some potentially contaminating substances, such as motor oil and fuels, occurs regularly. Gasoline and heating fuel is barged from the Lake Camp dock to Brooks Camp throughout the summer months. An underground distribution and storage system is used to manage these products at Brooks Camp. Fuels are flown in to the other lodges including Kulik, Grosvenor, Nonvianuk, Battle Lake, and Enchanted Lake, and either flown or brought in by boat or snow machine to seasonal hunting and trapping camps in the preserve. Hydrocarbon contamination from leaks and spills has been documented at Brooks Camp and near the mouth of Kulik River.

- Post-ANILCA (Alaska National Interest Lands Conservation Act) access throughout the park and preserve by aircraft, motorboats, and snow machines is largely unrestricted, increasing the probability that hydrocarbon pollution will occur through spills and leakages. Oil and fuel leaks from float planes and boat motors create sheens which are regularly observed in areas such as the Naknek Lake shore at Brooks Camp. Currently, planes may land on wheels, skis, or floats wherever physically possible.

- On March 24, 1989, the Tanker Vessel *Exxon Valdez* ran aground on Bligh Reef in Prince William Sound, rupturing cargo tanks and spilling more than 10 million gallons of crude oil into the sea, the largest oil spill in U.S. history. Winds and currents quickly dispersed the oil throughout the western Gulf of Alaska and deposited it over a wide area, including approximately 320 miles of Katmai's 398 miles of coastline.

- Fuel caches have been established along the coast to support legitimate management and research activities, and others were established by unknown persons for unknown reasons. A fuel spill resulted from the accidental dropping of a drum from a sling-load at Kukak Bay in 1990, ironically during clean-up operations of the *Exxon Valdez* oil spill.

- An overwhelming array of threats associated with petroleum hydrocarbon development jeopardizes national parks bordering Cook Inlet in Alaska. Currents and high tides carry the oil spills great distances from their source. These threats include:

  (1) Tanker traffic from the Valdez terminal. The Valdez terminal in Prince William Sound receives about **24.4 billion** gallons of oil per year via the TransAlaska Pipeline. The probability of a spill in Prince William Sound of between 300 and 3 million gallons is 1 every 1.3 years (Alaska Oil Spill Commission 1990). The 1989 Exxon Valdez oil spill deposited oil on 320 miles of Katmai's 398 miles of coastline.

  (2) Offshore drilling and production platforms in Cook Inlet. There are 15 production platforms currently operating in Cook Inlet. These platforms are responsible for episodic releases of hydrocarbons into the inlet (Hood and Zimmerman 1986).

  (3) The Drift River Marine Terminal is a privately owned offshore oil loading platform in 60 feet of water with an onshore storage facility constructed in 1967. The tanks can store about **83.6 million gallons of oil**. Volcanic explosions from Mt. Redoubt have twice resulted in debris flows that threatened the oil tank farm and terminal.

  (3) The Nikiski oil terminal and refinery on the eastern shore of Cook Inlet is the site of an oil refinery and three deep draft piers for the loading and unloading of crude oil and petroleum products from tankers. Heavy tanker traffic occurs there all year despite ice floes that are a severe problem between January and February.

  (4) Tanker traffic to and from the Nikiski terminal. The Cook Inlet oil loading facilities at the Drift River and Nikiski terminals transfer over **3.3 billion gallons** of oil per year. An average of 171 oil tankers per year call at terminals in Cook Inlet. The probability of a spill in Cook Inlet of between 300 and 1 million gallons is 1 every 2.2 years (Alaska Oil Spill Commission 1990). A tanker spill of up to 125,000 gallons of oil occurred in 1987 in Cook Inlet (Whitney 1992). Beach assessment surveys located stranded tarballs possibly from this spill on shore at Katmai National Park, over 200 miles from the spill site.

  (5) New discoveries of oil in Cook Inlet and the proposed leasing of southern Cook Inlet pose potential contamination problems into the future.

- There has been a trend of decreases in length of rainbow trout caught in the upper Naknek River in the fall. A decrease from about 600 mm in 1971 to about 475 mm during 1977 to 1982 was

followed by another decrease to a low of about 375 mm in 1988. Throughout this period, angler effort and catch have increased, although harvest has declined since a high in 1983 (Minard 1989; Dunaway 1990). In 1989 samples (n=25), 70% of the catch in the upper Naknek River were pre-spawning and young spawning fish aged 4 to 6 years (Dunaway 1990). This concentration of fish at these younger ages supported the hypothesis that size and age of rainbow trout in the upper Naknek River had been reduced further during the 1980's from their historical composition. Further, concerns about reproduction in the population resulted from the lower productivity associated with young spawners (Dunaway, pers. comm.).

In order to increase recruitment into the older age classes of spawning rainbow trout, ADF&G, Division of Sport Fish proposed regulations which were adopted that prohibited keeping rainbow trout $\geq$ 18 in. (457 mm) in length in the Naknek River, Naknek Lake, and Idavain Creek. This regulation has been in effect since 1990. There are currently proposals by private citizens to the Board of Fisheries to end the size restriction. The objective of increasing the proportion of older aged rainbow in the Naknek River drainage is common to both the goals of the ADF&G as expressed in the Southwest Alaska Rainbow Trout Management Plan (ADF&G 1989), "conservative wild stock management" towards "historic size and age composition," and of the NPS, "natural and healthy populations.".

- The sport fishery in the Bay of Islands area of Naknek Lake further impacts the upper Naknek River population, as well as the lower Brooks River and Idavain Creek populations, on their summer grounds (Gwartney 1985). That lake fishery uses heavier gear than is typical of the stream fisheries elsewhere in the park, to fish for rainbows in deep lake waters. Such a fishery may result in higher mortality among released fish. Little is known about the size of the fishery in the Bay of Islands other than it is increasing.

  Nearly all of the visitation to Katmai National Park and Preserve is water oriented, with facilities sited along lake and river shores, and travel by boat or float plane. Visitation in some of these areas has risen exponentially in the last decade, creating monitoring needs to support management actions. Visible impacts to soil and vegetation resulting from increasing visitor use of the park are evident in a number of developed or heavily used areas. Obvious backcountry human waste management issues exist in some areas, particularly along sections of the Alagnak Wild River and several popular camping areas in the Naknek Lake Bay of Islands. Associated with lodge developments on NPS lands and inholdings are grey water and sewage systems with possible outlets into park waters which may be evidenced by increased bacterial levels, changes in aquatic invertebrates and vegetation, and changes in water clarity. Developments along the Alagnak River, Brooks Camp, Kulik, Grosvenor, Battle Camp, and Cry of the Loon Lodge on Nonvianuk Lake should be monitored.

- Some exploratory work was conducted at a mining claim on Iron Springs Creek, a tributary of Battle Lake, however the mine was never fully developed. The claim was recently declared invalid. However, the potential for mine drainage still exists.

- Jetboats are used to transport visitors, primarily sport anglers, on streams that are too shallow for conventional motorboats. Because of the shallowness, the boats must maintain a high rate of speed. The turbulence as they pass may affect the stream substrate and their wake may wash bank materials into the water, increasing turbidity. Streams where heavy jet and propeller-driven boat activity presently occurs include the Alagnak River, Nonvianuk River, Kulik River, Kamishak

River, Grosvenor River, and American Creek. Increased sedimentation can be detrimental to the development of fish eggs and fry in the stream bed. Heavy levels of jetboat disturbance during salmon migration and fish spawning may cause mortality of fish eggs in stream gravels.

- The mouth of Brooks River at Brooks Camp changes rapidly, with consequent effects upon the adjacent developed area. These changes result from natural river processes influencing migration of the river course; changes in Naknek Lake levels; dynamics of prevailing winds, currents, and along shore sediment transport; and from development and improvements on the river such as the floating footbridge and importation of gravel. Loss of vegetation along the river's edge appears to be increasing erosion along foot paths.

- Katmai provides the sewage system and disposal of solid waste at Brooks Camp for both Brooks Lodge and park facilities. Sewage drains by gravity to a wet well and series of three underground septic tanks in the vicinity of the Fish Cleaning Building about 100 yards north of the mouth of Brooks River; then grey water is pumped to the leach field about 200 yards to the north-northwest. A practice of emptying the septic tanks of solid material in the fall by pumping it into the marsh west of the Fish Cleaning Building was stopped after 1988. Currently, maintenance of the septic tanks is scheduled for every two to three years. This involves pumping solid material from the tanks to a portable closed tank and transporting it to a gravel pit on the Valley road for burial. On occasion, when the sewage system has failed, sewage has been pumped similarly for burial. A septic system with a leach field also exists at the Brooks Lake development. Grosvenor Lodge on park land has a septic and leaching system for sewage disposal. Solid waste there is burned and flown out. Lodges exist on inholdings at Kulik River, Battle Lake, and Enchanted Lake. These lodges have similar requirements for disposal of solid waste and sewage.

- The Katmai ecosystem is heavily dependent upon the annual influx of nutrients flowing upstream from the ocean with the return of millions of adult salmon. Anadromous fish runs and harvests are strictly regulated by the State of Alaska, with escapement goals established to promote maximum sustained numerical and economic returns to the commercial fishery. The salmon harvest technology has advanced to the point that nearly every returning salmon could be intercepted by the commercial fleet before reaching their spawning grounds, if escapement goals were not strictly enforced. Runs of chum and pink salmon have recently decreased in a number of Shelikof Strait/Cook Inlet side streams and rivers within the park. Chinook and coho salmon are exploited by multiple user groups including commercial, sport, and subsistence, with an incomplete understanding of cumulative harvest effects to the populations.

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Appendix I

NATURAL RESOURCE PROJECT STATEMENTS

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