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To: Bill Route, Great Lakes Network Coordinator, and Joan Elias, Great Lakes Network Aquatic Ecologist

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Re: Research Prospectus: Biomonitoring prospects for diatoms and paleolimnology in the Western Great Lakes National Parks

Overview:

With any environmental monitoring program it is important to have a basic understanding of natural fluctuations within the system. Reliable long-term data sets, on the order of 30 - 50 years, are generally not available for most regions of the country. Through the use of paleolimnological techniques and quantitative environmental reconstruction, we can estimate past conditions and natural variability, identify changes, and determine rates of change and recovery. This type of information allows managers and researchers to put present environmental stresses into perspective with the natural variability of the system. Paleolimnology can also be used to determine response to and recovery from short-term disturbances. It is particularly important in areas of low impact, such as wilderness areas, to have background information on natural variations. Such information makes it possible to identify early signs of unusual disturbance and allows for early action toward remediation or restoration.

In Great Lakes Network (GLKN) park units, climate change, environmental contaminants, exotics, and land and resource uses including shoreline and urban development, recreation, water level management, logging, and agriculture have raised concerns about the state of the parks' resources and how to best manage them in a future certain to bring change. In this prospectus, we outline a strategy to integrate the use of paleolimnological techniques and diatom analysis in an inventory and monitoring framework. Results will provide a management foundation by determining the natural variability or reference condition of national park lakes and by reconstructing a detailed history of lake response to ecological changes that have occurred in and around the lakes during the last 150 years. Because lake-sediment records integrate across both spatial and temporal scales, research results can be further used as a biomonitoring strategy by revisiting lakes on regular intervals (3-5 years) to quantify modern environmental conditions relative to historical conditions, to detect early ecological change and recent trends, and to evaluate success of management actions.

Background:

Paleolimnology is the analysis of lake sediments to reconstruct historical environmental and landscape changes. Paleolimnology offers unique opportunities for aquatic and terrestrial biomonitoring programs, primarily by providing historical data with which to contextualize modern monitoring in the absence of long-term monitoring data. Among the techniques for obtaining historical data, paleolimnology is often the only available or practical means for reconstructing ecosystem conditions. Many, if not most, modern lakes are significantly altered from their natural state; thus the use of reference lakes or computer models to simulate reference conditions may produce questionable results. We outline three analytical methods that are applicable to a biomonitoring and inventory program in GLKN parks.

1. Diatom analysis of sediment cores—Analysis of geochemical and biological remains in sediment cores has become a standard approach to determine timing and magnitude of ecological change, reference conditions, and trend assessment in aquatic systems (Dixit et al. 1992, Charles et al. 1994). The sediment record is an integrated signal of spatial and temporal variability and a single sediment core from the depositional basin is usually sufficient to reconstruct the environmental history of a lake with relatively simple basin morphometry. The analysis of diatom communities and the application of calibration models permits the researcher to reconstruct specific environmental variables of interest. Lead-210 dating and loss on ignition (LOI) analysis are used to determine whether a lake has continuous sedimentation, the timing of environmental change, and the sedimentation history of lake. Dating error bars do increase downcore but typically represent no more than one year in recent samples and +/- decadal resolution within the last 150 years. Analysis of biogenic silica provides an estimate of historical water column primary productivity. The same sediment cores can also be used for other research such as determining the historical accumulation of toxicants, algal pigments, or fossil remains of other biotic groups. Our proposed analysis of sediment cores can answer the following research questions:

- What is the natural condition and variability (biotic community, nutrients, pH, alkalinity, sedimentation rate, dissolved organic carbon) of an individual lake or set of regional lakes?
- When did observable changes begin and what are the current temporal trends?
- Have the lakes in question been historically impacted by different land use changes?
- What environmental stressors (logging, exotics, drought) have driven historical and recent changes in the lakes and how have the lakes responded?

2. Surface sediment analysis—Aquatic monitoring programs that require timely and periodic sampling (e.g. biweekly, monthly) tend to be costly, may miss short-term events, and are notoriously difficult to justify in the battle for continual funding. The upper few centimeters of sediment in a lake provide an integrated sample of what has happened in a lake and watershed over a short time period (months to years). Thus analysis of surface samples can be a powerful tool to detect recent environmental change, or to place modern conditions in a regional or historical context (Ramstack et al. 2003). Using diatom training sets, which represent a model of the relationship between modern diatom communities and environmental variables, mean annual averages of environmental variables of concern can be reconstructed from a single sediment sample. The most common environmental variables reconstructed using this technique are nutrients, salinity/conductivity, pH, alkalinity, and DOC (dissolved organic carbon). Second, diatom community data can also be integrated into biomonitoring; community or species-specific metrics that can be evaluated as a measure of ecological change. Surface sediments can also be used as a direct bioinventory tool. Because they integrate across various scales, surface sediments can be used to provide data on diatom species diversity, species richness, and presence of exotic species (Edlund et al. 2000). Last, surface sediment collection can be coordinated for other analyses such as screening for *Bythotrephes* caudal spines or screening for contaminants. Our proposed analysis of surface sediments will explicitly answer the following kinds of questions:

- What is the current ecosystem status of a particular lake in relation to other regional lakes?
- Are similar ecological trends occurring among regional lakes? (e.g., climate-related)
- What is the ecosystem status of this lake in relation to historical environmental change noted in regional sediment cores?
- Has this lake changed since the last time we sampled it? If so, how has it changed?
- When did this exotic species appear in our lake? Some diatoms are exotic species and can act as negative bellwether taxa; other exotics can also be monitored in this manner (e.g. *Bythotrephes*)
- Have efforts to reduce nutrient loading to the lake had a positive impact?
- Did this lake suffer following our decision to allow anthropogenic activity in the watershed?
- Everyone said this lake was different last year. What happened? Was it a natural occurrence?

3. Development of training sets specific to the region or individual park units—Surface sediment samples can be further used to develop calibration or training sets specific to ecoregions or individual park units. Appending additional surface sediment samples onto existing training sets is also possible and often advisable to improve their performance and regional applicability (e. g., Edlund and Kingston 2004). To develop or append a training set, environmental monitoring must be in place. Multiple chemical (nutrients, pH, DOC, ions) and physical (Secchi, morphometry) samples need to be taken over the course of one or two years to characterize mean lake conditions and provide a measure of interannual variability. Surface sediments are then collected (usually the upper 1-2 cm of sediment) that represent the sedimentary assemblage that corresponds to the environmental data. The relationship among diatom species distributions and environmental variables is explored using ordination techniques based on gradient analysis (ter Braak and Prentice 1988) such as canonical correspondence analyses. Environmental gradients that independently explain significant variation in the species data are available for constructing a transfer function using weighted average regression (Birks et al. 1990). Conductivity, pH, nutrients, alkalinity, and DOC are among the common environmental parameters that we can estimate using diatom transfer functions. The transfer function can then be applied to modern or downcore assemblages using weighted averaging of species abundances and environmental optima and tolerances to reconstruct environmental variables of interest (Birks et al. 1990). The environmental data collection is not included as a part of this prospectus and would have to be carried out coincident with this project or as a cooperative project with other park, federal, or state programs. However, if those data were available it would be relatively straightforward to construct new calibration sets or append surface samples into existing training sets.

A Proposed Sampling Strategy

The sampling strategy that we recommend is patterned in part after the project design of the federal NAWQA and EMAP monitoring programs (Hunsaker and Carpenter 1990, http://water.usgs.gov/nawqa/). Both of these programs have adopted a rotating sampling scheme where a set of lakes or rivers is sampled for several years, and sampling then moves to other sets of watersheds, until the rotation returns to the original set of lakes and rivers that were sampled. For the GLKN parks, we propose to collect and analyze sediment cores from three lakes and surface sediments from 15 lakes or reservoirs within the park units each year. The next year a new set of three lakes would be cored and surface sediments collected from a new set of 15 lakes. In the subsequent 3 years, more surface sediments and cores would be collected, and after a total of 5 years, we would return to the original set of 15 lakes to collect a new set of surface sediments for analysis. Thus after five years, we would have full environmental histories on at least 15 park unit lakes (in addition to the lakes cored and analyzed in the course of other projects). Furthermore, approximately 75 lakes will become part of a monitoring and inventory lake set that is resampled and reanalyzed every five years. A quick estimate of suitable lakes within the GLKN park units shows the following distribution of lakes: ISRO=40, VOYA=40, PIRO=6, SLBE=20, INDU=4 (lagoons and bog), APIS=4 (lagoons), SACN=3 (reservoirs, flowages), MISS=1 (Pig's Eye Lake?), GRPO=0. The 75 lakes that would become the monitoring subset would capture over half of the available lakes within the GLKN. Project managers, I&M coordinators, and park resource managers will be asked to collaborate to choose lakes for coring and surface sediment monitoring to meet the needs of other interested parties. In the St. Croix National Riverway funding is being sought to develop a slight modification of this strategy to assess the effects of nutrient controls and progress toward nutrients goals that were recommended for the basin. Surface sediments or short sediment cores would be collected on regular intervals and analyzed to determine planktonic:benthic ratios, prevalence of eutrophic indicator species, as well as to perform epilimnetic phosphorus reconstructions.

Available resources and cooperative projects

Diatom training sets are available and sediment cores have already been recovered or are planned to be taken from many lakes in the park units. These cores, if properly handled, are suitable for use in the proposed monitoring plan. Most existing cores have been 210-Pb dated during the course of other projects. An existing core that has been properly dated and stored would deduct approximately $3300 from an annual budget (core collection, dating, LOI). Details of possible available cores and their provenance are provided below:

Table 1. Dated sediment cores from Western Great Lakes park units.

Park	Lake	# Cores	Length (cm)	Collection Date	Investigator	Institution
APIS	West Twin	1	40	Jul-91	Deb Swackhamer	Univ. of MN
APIS	Outer Island	1	30	Jul-91	Deb Swackhamer	Univ. of MN
INDU	Cowles Bog	1	30	Nov-84	Ken Cole	USGS (CPSU)
ISRO	Lily Lake	1	84	Aug-93	Ken Cole	USGS (CPSU)
ISRO	Wallace Lake	1	75	Aug-93	Ken Cole	USGS (CPSU)
ISRO	Ojibway Lake	1	80	Aug-93	Ken Cole	USGS (CPSU)
ISRO	Siskiwit Lake	2	40	May-98	Jeff McDonald	Indiana Univ.
ISRO	Sargent Lake	1	72	Feb-99	Pat Gorsky	Univ. of WI
ISRO	Richie Lake	1	72	Feb-99	Pat Gorsky	Univ. of WI
PIRO	Legion Lake	2	52 & 63	Jul/87 & Jun/90	Ken Cole	USGS (CPSU)
SACN	Lake St. Croix	8	200+	Oct/99 & Oct/00	Mark Edlund	SCWRS
SLBE	Millington Bog	1	58	Sep-87	Ken Cole	USGS (CPSU)
VOYA	Little Trout	1	76	Jul-96	Dan Engstrom	SCWRS
VOYA	Locator	1	83	Jul-96	Dan Engstrom	SCWRS
VOYA	Loiten	1	80	Jul-96	Dan Engstrom	SCWRS
VOYA	Shoepack	1	80	Jul-96	Dan Engstrom	SCWRS
VOYA	Tooth	1	80	Jul-96	Dan Engstrom	SCWRS
VOYA	L. Kabetogama	1	70	May-01	Dan Engstrom	SCWRS
VOYA	Agnes Lake	1	70	May-01	Dan Engstrom	SCWRS
VOYA	Ryan Lake	1	70	May-01	Dan Engstrom	SCWRS
VOYA	KO Lake	1	70	Jul-93	Ken Cole	USGS (CPSU)

Additionally, the following three projects have funding in place for FY 2005-2007 and will be taking sediment cores suitable for biomonitoring from two park units.

1) "Determining the Historical Impact of Water-level Management on Lakes in Voyageurs National Park," USGS-NRPP funding.
Abstract: Damming of the Rainy-Namakan system in the early 20th century has resulted in nearly 100 years of water-level manipulation for logging and hydropower. In the 21st century, water-level management is the critical issue for managers at Voyageurs National Park (VOYA). Recent changes in water-level hydro management were instituted by the International Joint Commission (2000 rule curves) to produce a more natural hydrologic regime in the Rainy-Namakan Reservoir. Critical in this decision was a recommendation for monitoring impacts of the revised controls; however, with few historical or background data, determining the impacts will be challenging. We will conduct a paleolimnological study of four lakes (Kabetogoma, Rainy, Namakan, Lac La Croix) of contrasting management and size in VOYA to reconstruct the timing and magnitude of environmental impacts of damming, water-level manipulation, and land use changes using quantitative reconstruction of environmental variables from lake sediment geochemistry and microfossils. We will further determine pre-damming/pre-settlement trophic conditions and "natural" variability for each lake system.

2) "Using Wetland Environmental Histories to Develop Management Strategies for the St. Croix Riverway," National Park Service-WRD funding.
Abstract: Floodplains are a dominant feature in the Lower St. Croix National Scenic Riverway. Braided channels and wetlands along the St. Croix harbor high diversity of plants and wildlife, and are crucial nesting and nursery areas. Recreational uses include wildlife watching, fishing, and hunting. NPS management objectives for the St. Croix center on protection of natural ecological processes. Floodplains are a crucial component in preventing unnatural water quality degradation, maintaining natural patterns and amounts of flow, and maintaining native organisms and their habitats. However, historical data indicate that floodplain wetlands have undergone significant changes possibly from exotic species introductions, land use changes in the watershed, and river management. This project will recover sediment cores from three floodplain wetlands (Rice Lake-St. Croix Islands, Peasley Lake, Rice Lake-Osceola) in the Lower St. Croix River and analyze them to reconstruct the ecological history from geochemical and biological markers. These data will form a baseline for making management decisions regarding wetland protection and restoration.

3) "Oxygen depletion as a symptom of eutrophication in Lower St. Croix National Scenic Riverway: a historical investigation using sediment chironomid assemblages", National Park Service, NRPP Block Program funding, to begin FY2005.
Abstract: The St. Croix River basin has undergone significant land use change since European settlement and substantial human population growth in recent years. Related nutrient and sediment loading to the Riverway was identified as a primary resource management concern in the 1990s, and a series of nutrient-related studies was initiated. Several studies identified nutrient loading hot spots throughout the St. Croix Basin and modeled responses of Lake St. Croix to future changes in nutrient inputs. Paleolimnological studies demonstrated increased phosphorus loading and changes in diatom community composition, particularly since the 1950s. Collectively, these studies show the sensitivity of Lake St. Croix waters to nutrient inputs and indicate increasingly eutrophic conditions in the Riverway. The proposed research aims to extend these conclusions by investigating another symptom of eutrophication, deep-water oxygen loss, using chironomid remains in Lake St. Croix sediments. Evidence of oxygen depletion in Lake St. Croix would lend ecological significance to the eutrophication problem and inform the interagency St. Croix Basin Planning Team's ongoing nutrient management and goal-setting process.

Several diatom training sets are already available for use in Western Great Lakes Parks. Ramstack et al. (2003) is based on 55 Minnesota lakes and is useful for back-calculating phosphorus (10-70 ppb), alkalinity (as ANC; 300-3000 µeq/L), chloride (1-150 ppm), and DOC (as color; 3-110 Pt-Co units). This data set has been further modified to include 79 Minnesota lakes in a revised training set specifically developed for inferring historical total phosphorus (10-180 ppb TP; Edlund and Kingston 2004). Fritz et al. (1993) used a training set from Michigan lakes to reconstruct TP values ranging from 1 to 51 ppb. An unpublished training set for phosphorus reconstruction is used by the Wisconsin Department of Natural Resources (Paul Garrison). A regional training set for reconstructing DOC and pH was assembled by Kingston and Birks (1990; DOC approximately 50-1000 µmol/L, pH approximately 4.5-7.4 pH units) and may be available for use.

Methods:

(1) Surface sediment collection: A line-operated gravity corer will be used to collect the upper 0-1 cm of sediment for an integrated assessment of lake conditions during the past 1-3 years. Collection sites will be precisely located by GPS to allow resampling in the same location in subsequent years; sampling sites will target central depositional basins in each lake. This sampling can be done by park personnel during the open water season at locations chosen after consultation with the National Park Service IM Network

(2) Long core collection: A 1-2 m long sediment core will be collected from target lakes in the GLKN parks. Lakes and sampling sites will be chosen in consultation with the park and GLKN staff; coring locations will target central depositional basins in each lake. Cores may be collected during the winter through the ice using piston-coring methods that recover the very loose uncompacted sediment surface without disturbance (Wright 1991). Cores can also be easily collected during the open water field season if boats are available in the park units. As with surface samples, core locations will be recorded by GPS.

(3) Core extrusion and sectioning: The upper 20 cm of the sediment core will be extruded vertically from the coring tube at 1-cm increments and placed in polypropylene jars; the remainder of the core will be sectioned at 2-cm increments. Core sections will be transported to 4° C laboratory storage for further processing.

(4) Subsampling and freeze-drying: Sediment samples will be homogenized and subsampled for loss-on-ignition and diatom analyses. The remaining sediments will be freeze-dried within the sample jars for ^{210}Pb analysis.

(5) Loss-on-ignition: Dry-density (dry mass per volume of fresh sediment), water content, organic content, and carbonate content of sediments will be determined by standard loss-on-ignition techniques. All core increments will be analyzed.

(6) Lead-210: Sediment cores will be analyzed for ^{210}Pb activity to determine age and sediment accumulation rates for the past 150 years. Lead-210 will be measured at 16-20 depth intervals by ^{210}Po distillation and alpha spectrometry methods, and dates and sedimentation rates will determined using the c.r.s. (constant rate of supply) model. If dating indicates that a non-conformable sediment sequence has been recovered in a core, analysis of that core will cease.

(7) Cesium-137: The 1963-1964 peak in deposition of ^{137}Cs from atmospheric nuclear testing will be determined in each core. Eight to twelve freeze-dried samples will be measured for ^{137}Cs at 667 keV using a high-resolution germanium diode gamma detector and multichannel analyzer.

(8) Diatom analysis—long cores: A total of fifteen core increments from each core will be analyzed for diatom microfossils. Generally these samples are taken at decadal

intervals for the past 150 years to provide a chronology of environmental change following regional European settlement and a measure of reference or pre-settlement conditions. Sampling can also be adapted for specific research questions. For example, eight of the samples could be concentrated in the upper part of the core representing the last 40 years (5-year resolution), for example, if lake response to specific landscape change is being studied. The remaining samples could be taken at core intervals representing a 10-20 year resolution back to pre-settlement times. Diatoms and chrysophyte cysts will be prepared using standard oxidation and mounting techniques, identified to the lowest taxonomic level under 1250X magnification, and a minimum of 400 valves will be counted in each sample. Lake-water total phosphorus (TP), DOC (as color), pH, alkalinity, or chloride ion can be reconstructed from fossil diatom assemblages using diatom calibration models. For example, the diatom-TP model developed by Ramstack et al. (2003) from a suite of 55 Minnesota Lakes has recently been expanded to include 79 Minnesota lakes spanning a larger phosphorus gradient (Edlund and Kingston 2004) and it would be applicable to this project.

(9) Biogenic silica—long cores: The same fifteen samples from each long core that will be analyzed for diatoms will also be analyzed for biogenic silica. Biogenic silica is a measure of the quantity of biologically produced opaline silica in a sediment core. It is used as a proxy for historical biological productivity. For example, nutrient enrichment to most lakes results in an increased flux of biogenic silica to the sediments.

(10) Diatom analysis—surface sediments: Diatom samples will be prepared and counted as above for core samples. From each sample a lake-specific inventory of diatom species richness and relative abundance will be assembled. Transfer functions created from existing diatom calibration models will be applied to the relative abundance data to reconstruct environmental variables of interest. Additional numerical analyses are outlined below

(11) Numerical analysis: In addition to applying calibration set transfer functions using weighted averaging regression and calibration to reconstruct specific environmental variables, multivariate ordination techniques can also be used to explore community-level changes. For core or samples, the diatom assemblages from each core will be ordinated relative to surface sediment (calibration sets) using detrended canonical correspondence analysis (DCCA) to construct historical environmental lake trajectories (Engstrom et al. 2000). DCCA scores from all lakes will be projected on DCCA ordinations from the Ramstack et al. (2003), Edlund and Kingston (2004) or Kingston's (unpublished) modern sample training set to create lake trajectories that allow analysis of both direction and magnitude of community and environmental change (e.g. TP, alkalinity, color, recovery to natural conditions) among lakes or samples. Magnitude of change reflects specific environmental reconstructions. Direction of change can be interpreted in two ways. At a community level, analysis of a sample can be placed in context of other analyzed diatom communities. For example, if we look at the sequence of samples within a core, do the most recent samples begin to "return" to the pre-settlement condition (community) of a lake. Secondly, the community data can be passively plotted against an environmental-

diatom training set to identify along what environmental gradients the community is changing. Is the diatom community changing along a trophic gradient or a pH gradient? This can help identify what stressors are impacting a lake based on diatom community analysis. Trends in species composition can be further explored using nonmetric multidimensional scaling to quantify spatial variability and temporal trends (Philippi et al. 1998).

(12) Land-use history: A record of major land-use changes in each park unit over the last 150 years will be assembled by the GIS specialist or resource manager at each park. This land-use history will be compared with trophic reconstructions from the sediment cores to determine whether major changes in trophic conditions are temporally correlated with specific disturbances in the watershed.

References:

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Proposed Annual Budget:

NPS I&M Diatom Budget 2005-2009		Year 1	Year 2	Year 3	Year4	Year 5	5 yr Total
Research Task	**Unit Cost**	**Extension**					
Annual Core Collection/Travel	2000	2000	2060	2122	2185	2251	10618
Loss-on-Ignition/Subsampling/Freeze-drying	800	2400	2472	2546	2623	2701	12742
Dating Methods							
Lead-210, Cesium-137	2000	6000	6180	6365	6556	6753	31855
Biogeochemistry							
Biogenic silica (15 samples/core; 45 samples/yr)	13	585	603	621	639	658	3106
Diatom Analysis							
Microscopy (15 samples/core, 45 samples per year)	500	22500	23175	23870	24586	25324	119456
Microscopy (15 surf samples/year)	500	7500	7725	7957	8195	8441	39819
Numerical Analysis	7000	7000	7210	7426	7649	7879	37164
Data Synthesis/Annual Report	5000	5000	5150	5305	5464	5628	26546
Lab/Office supplies	3000	3000	3090	3183	3278	3377	15927
Subtotal		55985	57665	59394	61176	63012	297232
Indirects CESU rate (17.5%, for base see subtotal)		9797	10091	10394	10706	11027	52016
Total		65782	67756	69789	71882	74039	**349248**

Cooperators:

All work will be completed under the direction of Drs. Mark Edlund, Daniel Engstrom, and Brenda Moraska Lafrancois (NPS) at the St. Croix Watershed Research Station. Dr. Edlund is an internationally-recognized expert in diatom taxonomy and paleoecology at the SCWRS, Dr. Engstrom is Director of the SCWRS, and Brenda Moraska Lafrancois is the NPS regional aquatic ecologist and has her office at SCWRS. The SCWRS is a well-established laboratory and research station and provides approximately $250,000 in analytical equipment, field gear, computers, and microscope facilities at no-cost to this project.

Statement of Significant Involvement by the National Park Service

The Aquatic Ecologist at the Great Lakes Network (GLKN) coordinated peer review of the project proposal. As the project begins, the NPS will:

- Provide logistical support in getting to sampling sites
- Conduct appropriate environmental monitoring (chemical and physical sampling, multiple times over the course of a year or two) for the development of calibration sets
- Assist in the collection of cores
- Assist in the statistical analyses of diatom assemblages

The GLKN and MWR Aquatic Ecologists will review interim and final reports. The GLKN Aquatic Ecologist will coordinate a peer review of the year one draft final report.

Additional NPS contribution:

Individual park units would be involved in this project in several aspects. For lake coring park units would be asked to provide a boat and motor (summer coring) and preferably a boat operator if available (1-2 days use). If on-site housing is available within the park unit, no-cost access for the coring crew for up to two nights would be appreciated. If surface sediment analysis is to be a part of this project, collection would be made by park personnel (1 boat/motor, 1/2 day) or in conjunction with offshore sampling for water quality monitoring (would add 10 minutes to sampling time). Most important would be a contribution by either GIS staff or resource managers to provide a history of land use changes in the park units. Estimates on how much time this would entail would be best provided by the NPS; some park units may already have this information assembled. Last, park units would be expected to be involved in the decision making process on choosing lakes to be cored or sampled. Each park unit will have individual resource goals and concerns and by targeting specific lakes the management goals of the park will best be met.

Project Schedule:

This prospectus has outlined an annual project plan. An annual project timeline would involve core and surface sediment collection during the months of April and May, dating, geochemistry and diatom analysis completed by January of the following year, and numerical analysis and annual project synthesis completed by April. Deliverables as outlined in the above budget would be submitted and billed three times a year with an interim report submitted on July 31 (core collection, sample preparation), November 30 (dating, diatom analysis, geochemistry), and March 31 (numerical analysis, synthesis, annual project report).

<u>Schedule for diatom project - year 1</u>
September - December 2004 - compile information on existing cores
December 2004 - January 2005 - choose parks and lakes, determine sampling strategy for first year's core collections
January 2005 - May 2005 - conduct first year's sampling, core collection and surface sediment collection
March 2005 status report and Investigator's Annual Report
May 2005-July 2005 core processing, dating, and biogeochemistry
May 2005-Sept 2005 diatom and numerical analysis of first year's cores
Sept 2005 draft report on first year's core analyses

Invoices for payment (on government form SF270) will be submitted to Jerrilyn L. Thompson, NPS Research Coordinator, Great Lakes and Northern Forest CESU, University of Minnesota, 115 Green Hall, 1530 Cleveland Ave, N. St. Paul, MN 55108. Joan Elias will confirm adequate progress is being made on the project prior to approving payment.