Trust Fund 2009 Work Program

Date of Report: 29 May 2009
Date of Next Progress Report: 15 April 2010
Date of Work Program Approval:
Project Completion Date: 30 June 2012

I. PROJECT TITLE: Assessing the consequences of ecological drivers of change on water quality and habitat dynamics of deep-water lakes with coldwater fish populations.

Project Manager: Dr. Donald L. Pereira
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Location: Statewide. See Attachment B for a map

Total Trust Fund Project Budget:	**Trust Fund Appropriation**	**$ 825,000**
	Minus Amount Spent:	**$ 0**
	Equal Balance:	**$ 825,000**

Legal Citation: M.L. 2009, Chp. 143, Sec. 2, Subd. 5c

Appropriation Language:
$825,000 is from the trust fund to the commissioner of natural resources to assess the consequences of large ecological drivers of change on water quality and habitat dynamics of deep water lakes with coldwater fish populations. This appropriation is available until June 30, 2012, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

II. PROJECT SUMMARY AND RESULTS:

Water quality, habitat, and fish in Minnesota lakes are or will be facing substantial levels of stress primarily due to two very large drivers of change: land use changes (both urban and agricultural) and climate change. Herein, we outline a 3-yr cooperative study in several sentinel lake watersheds throughout the state that will help us understand, predict, and monitor the consequences of climate change and land cover alterations. Multiple national, state, and local government and academic partners are currently enrolled in this large-scale effort called Sustaining Lakes in a Changing Environment (SLICE) that includes a focus on monitoring basic

watershed, water quality, habitat, and fish indicators in 24 sentinel lakes across a gradient of ecoregions, depths, and nutrient levels. Work outlined in this work program is a component of the larger SLICE program but focuses on detailed assessments in 7 sentinel lakes that harbor cold-water fish populations (namely cisco). This work will assess cause-effect mechanisms affecting the past, present, and future status of cold-water habitat and identify the appropriate indicators to monitor to track the status of these habitats. Detailed assessment and modeling of past, present, and future conditions in these cold-water sentinel lakes will inform revisions to lake monitoring programs, provide an empirical foundation for proposed watershed "best management practices," and inform climate change adaptation policies related to lake management.

III. PROGRESS SUMMARY AS OF

IV. OUTLINE OF PROJECT RESULTS*:*

Result 1:
Establish 24 sentinel lakes and their associated watershed as focal points of collaborative long-term monitoring, research, and environmental education

Description:
In the original submitted proposal, we identified only 7 lakes with cold-water habitat that would be considered in this project. Although, the focus remains on understanding dynamics of lakes with cold-water habitat, we must consider a wider range of lake habitat conditions in order to simulate possible changes to lake habitats and biotic communities as they become warmer and more productive. The wide geographical spread and gradient of productivity and other disturbances among our cool and warm-water sentinel lakes affords us a better ability to make comparisons.

Result 1 mostly involves project initiation activities and sets the stage for the deliverables listed in Results 2, 3, and 4. Result 1 also lays the ground work for long-term partnerships and monitoring after this work program is completed in 2012. Specifically Result 1 focuses on building interdisciplinary partnerships to conduct intensive monitoring of several physical, chemical, and biological parameters in 24 sentinel lakes, distributed across the 4 major ecoregions of the state. Efforts will be made to compare and model differences between cold-water and cool-warm water lake habitats and indicators that are particularly sensitive to these differences. In addition, we will establish meteorological and water quality sensors and flow gaging stations (See Attachment C) built and managed by the USGS in 3 "super" sentinel lakes that span a range a watershed conditions but still harbor cold-water fish populations. Data from these lakes will be housed in the National Water Inventory System (NWIS) database and be used to facilitate predictive watershed and lake nutrient modeling discussed in Result 3.

Summary Budget Information for Result 1: **Trust Fund Budget: $269,968**
Amount Spent: $ 0
Balance: $ 269,968

Deliverable	Completion Date	Budget
1. Network of 24 sentinel monitoring and research sites	July 2009	$0
2. Flow, climate, and water quality monitoring systems in Carlos L., Douglas Co.; Elk L., Clearwater Co.; and Trout L., Cook Co.	June 2012	$269,968

Result Completion Date: 29 June 2012

Result Status as of 15 April 2010:

Result Status as of 30 October 2010**:**

Result Status as of 15 April 2011**:**

Result Status as of 30 October 2011**:**

Final Report Summary 29 June 2012**:**

Result 2: Reconstruct post-European to present water chemistry, sedimentation and erosion

Description:
To complement modern sampling and inform modeling of future lake responses, we will partner with the Science Museum of Minnesota (Lead: Dr. Mark Edlund) to comprehensively evaluate post-European colonization changes in lake conditions and evaluate major environmental events that coincided with these changes using analysis of biogeochemical signals preserved in sediment cores the seven cold-water sentinel lakes. The sediment record of a lake faithfully preserves chemical and biological clues or proxies that can be used to reconstruct the environmental history of a lake and its watershed. With any environmental assessment programs such as the SLICE, 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, let alone most lakes in Minnesota. Using paleolimnological techniques and quantitative environmental reconstructions, we can estimate past environmental conditions and natural lake variability. In Minnesota, paleolimnological techniques, especially diatom-based analyses, have been used throughout the state to quantitatively reconstruct historical environmental conditions, including nutrient concentrations (Ramstack et al. 2003; Edlund and Kingston 2004), inform TMDLs and nutrient reduction targets (Edlund et al. 2009), and to develop nutrient criteria specific to

ecoregion and lake-type (Heiskary and Wilson 2008). These successes have been based on paleolimnological analysis of only about 200 of Minnesota's 13,000 lakes. Although lake environmental histories vary across the wide range of ecoregions and land uses in Minnesota, major periods of change are generally associated with initial Euroamerican settlement and land clearance, post-WWII changes in agricultural practices, (sub)urbanization, and climate change, although other site-specific land uses (e.g., lakeshore development, damming) have also been identified as drivers of change.

Summary Budget Information for Result 2: **Trust Fund Budget: $90,000**
Amount Spent: $ 0
Balance: $ 90,000

Deliverable	Completion Date	Budget
1. Reconstruct historical water quality and habitat conditions in the seven coldwater sentinel lakes.	Oct. 2011	$70,000
2. Report explaining how past landuse and major environmental cycles (wet/dry, warm/cool) of the recent past shaped current water quality and habitat conditions in each sentinel lake	June 2012	$20,000

Result Completion Date: 30 June 2012

Result Status as of 15 April 2010:

Result Status as of 30 October 2010**:**

Result Status as of 15 April 2011**:**

Result Status as of 30 October 2011**:**

Final Report Summary:

Result 3: Utilize watershed and lake mixing models to forecast future water quality conditions in deep lakes with cold-water fish populations given different climate change and land-use scenarios.

Description:
The ability to project the potential outcomes of a range of large scale drivers of change such as watershed land use alterations or climate change is needed to proactively manage Minnesota lakes. A number of regional and state-wide lake modeling studies have illustrated the potential linkages between climate change, lake morphology, and fish habitat in the form of temperature and dissolved oxygen distributions for Minnesota and the north-central United States (e.g., see summaries

in Stefan et al. 1995; De Stasio et al. 1996; Fang et al. 1999). These models have documented the relative importance of lake-basin geometry, ice-free season, thermal stratification, dissolved oxygen stratification and wind-driven mixing to the development of sustainable fish habitat in deep-water lakes of the region. However, the potential trophic-dynamic response to simultaneous changes in climate and land-use is less well understood, as is the response of specific lakes to these historical and hypothetical changes. Questions also remain as to how the complex food webs that support fish guilds within these modeled systems will respond to the predicted physical changes in fish habitat (De Stasio et al. 1996).

The USGS (Dr. Richard Kiesling) will develop predictive tools to evaluate the trophic response of three sentinel lakes ("super" sentinel lakes) to current climate and watershed land-use conditions. We will accomplish this by developing watershed-loading models coupled with in-lake water quality models. Calibrated lake models will be used to forecast changes to water quality and deep-water thermal habitat conditions under changing climate and land-use scenarios. Where data are sufficient, models will be used with historic land use and climate data to provide historical benchmarks for comparison with output from scenario models.

By the conclusion of the study, we will outline the steps needed to take this result from a highly technical exploration to something in a more usable format for land use planners and policy makers. Interactive web-tools may be a promising mechanism by which local planners, policy makers, and even educators and students could "plug-n-play" different land use and climate change scenarios and evaluate the potential consequences of policy decisions on water quality and fish habitat.

Forecasting various scenarios and where to concentrate mitigation measures is not unique to this project and many groups at various scales are currently engaged in developing lake or watershed assessment tools. These groups include the Midwest Glacial Lakes Partnership (a regional subsidiary of the National Fish Habitat Initiative), North Central Lakes Collaborative, NRRI, University of Minnesota Remote Sensing Lab (http://lakesandland.umn.edu/; http://water.umn.edu/cgi-bin/mapserv-3?mode=browse&map=/data/web/water.umn.edu/map/mnlakes2005.map&layer=lakes&year=2005&mapext=184475.144386+4816443.707056+756218.568285+5470451.562617) and DNR Ecological Resources-U of MN (http://www.dnr.state.mn.us/watershed_tool/index.html). The likelihood of more efforts given new clean water legacy amendment funding is high. The need for coordination of these activities for maximum mutual gain with minimum redundancy is obvious. By completion of the LCCMR project, we (lead Ray Valley) will draft a proposal outlining other similar efforts and tools in development and how these efforts can be coordinated or adapted for web tools that focus on watershed-lake links. Modeling efforts coupled with long-term monitoring and recalibration of watershed and lake models could be used to form a strong empirical basis for these tools.

Summary Budget Information for Result 3: **Trust Fund Budget: $41,290**
Amount Spent: $ 0
Balance: $ 41,290

Deliverable	Completion Date	Budget
1. Predictive models to form an empirical foundation for the development of watershed best management practices and climate change adaptation policies that will protect the resiliency of coldwater lakes.	June 2012	$41,290
2. Strategies for building future interactive web-applications of these models for state policy makers, educators, and local land use planners.	June 2012	see proj. coord. budget below

Result Completion Date: 29 June 2012

Result Status as of 15 April 2010:

Result Status as of 30 October 2010**:**

Result Status as of 15 April 2011**:**

Result Status as of 30 October 2011**:**

Final Report Summary:

Result 4: Identification of a set of habitat and fish indicators sensitive to human-caused disturbances to serve as an early warning sign of lake ecosystem stress.

Description:
Result 4 is a weave of several in-kind efforts funded by DNR Fisheries operating budgets (the Game and Fish Fund and reimbursement by Federal Sportfish Restoration Dollars) and PCA Environmental Analysis an Outcomes Division operating budgets. Clean Water Legacy funding will contribute a small in-kind contribution from PCA and DNR Ecological Resource budgets during the project period for standard nutrient and biotic assessments in the sentinel lakes. Trust funds will supplement this work. To more clearly describe how Trust funds will be spent, deliverables 1 and 2 are revised from our original submitted proposal.

Deliverable 1 will be mostly funded by DNR Fisheries operating budgets with trust fund supplemental dollars for interns, travel and fleet expenses, water quality assessments in all 24 lakes, and survey equipment and repairs. Again, work will be weighted more heavily in the lakes with cold-water habitat, and basic assessment data will be collected in the other 17 sentinel lakes. Six fisheries research staff are

currently focused on collaborating on Deliverable 1. Refer to Valley et al. (2008) for details on this work. It is important to note that the budget in Deliverable 1 will directly benefit the other Results and Deliverables listed in this work program.

Deliverable 2 focuses on the promising potential of zooplankton as being rapid assessment indicators of water quality and habitat conditions. Despite their promise as indicators of changing environmental conditions and their importance to food webs in north-temperate lakes (Rusack et al. 2002, Beisner et al. 2003, and Olden et al. 2006), no studies have examined the linkages of zooplankton populations to environmental conditions in Minnesota inland lakes. We will investigate the sensitivity and robustness of common zooplankton indicators to changes in lake productivity along the gradient of the 24 sentinel lakes. The overall objective of this analysis is to identify which characteristics of pelagic zooplankton communities in Minnesota lakes change in consistent, predictable patterns in response to human disturbance or increased nutrient loading. Trust fund dollars for this deliverable will fund Jodie Hirsch's classified salary at the 10% FTE level. Ms. Hirsch's time will be backfilled by a temporary student worker. Trust fund dollars will also be used to contract with DNR's Management Information System Bureau to write a zooplankton counting program that is necessary to efficiently process the volume of zooplankton data that will be coming in. Jeff Reed and Dr. David Staples in DNR Fisheries will lead the final statistical analysis and report writing. No trust fund budget is requested for their time on Deliverable 3.

Deliverables 3 and 4 focus on better understanding the biology and status Cisco *Coregonus artedi*, a sensitive cold-water indicator species. This work will be led by University of Minnesota-Duluth Associate Professor of Biology, Dr. Tom Hrabik and a TBA M.S. graduate student. Cisco are an important component of the fish community in many Minnesota lakes. They provide a significant forage base for walleyes, northern pike, muskellunge, and lake trout (Ryder and Kerr 1978; Colby et al. 1987). Walleyes grow significantly faster when foraging on energetically rich cisco (Henderson et al. 2004), and more large northern pike are produced when cisco are present (Jacobson 1993). As a dominant planktivore in many lakes, cisco can play an important role in structuring zooplankton communities (Rudstam et al. 1993). Cisco also provide a growing winter sport fishery and are the target of a traditional gill net fishery in Minnesota.

Climate warming has the potential to reduce coldwater fish thermal resources through direct warming in increased hypolimnetic oxygen depletion in stratified lakes from extended periods of stratification (Magnuson et al. 1997; Fang et al. 2004). Cisco are the most common and widespread coldwater cold water fish in Minnesota lakes. Gillnetting assessments found cisco in 648 lakes throughout central and northern portions of the state and cross several ecoregions (Minnesota DNR files). The wide distribution suggests that cisco are somewhat more adaptable than other native coldwater fish such as lake whitefish *Coregonus clupeaformis* (sampled in 155 lakes), lake trout *Salvelinus namaycush* (124 lakes) and burbot *Lota lota* (233 lakes). The combination of their wide distribution and cold water preference make cisco an excellent sentinel species and indicator of climate change.

Despite the importance of cisco to Minnesota fisheries and the sensitivity of this species to climate change and eutrophication, relatively little is known about their habitat use and consumptive demand in Minnesota lakes. Furthermore, these pelagic species are difficult to sample with traditional survey gears (horizontal bottom gillnets), thus population status has been difficult to track. Hydroacoustics is an advanced assessment tool that has been proven effective for assessing population status of cisco in the Great Lakes and inland lakes in Wisconsin (Hrabik et al. 2006). Some Minnesota lakes harboring cisco do present some challenges to hydroacoustics (abundant populations of acoustically reflective *Chaoborus* zooplankton) that warrant exploration by a professional well versed in fisheries hydroacoustics. The seven cold-water sentinel lakes represent a wide range of conditions and will be good testing grounds for this technology. Accordingly, we will lead evaluate hydroacoustics as an assessment tool for cisco in Minnesota lakes while simultaneously exploring basic questions about their habitat use and diet.

Summary Budget Information for Result 4: **Trust Fund Budget: $408,922**
Amount Spent: $ 0
Balance: $ 408,922

Deliverable	**Completion Date**	**Budget**
1. Report(s) evaluating a lake monitoring framework for early detection of changes in habitat and fish community status	June 2012	$266,822
2. Assessment of zooplankton indicators.	June 2012	$42,100
3. Evaluation of hydroacoustics to assess the status of cisco populations in inland lakes.	June 2012	$50,000
4. Evaluation of cisco habitat use and behavior	June 2012	$50,000

Result Completion Date: 29 June 2012

Result Status as of 15 April 2010:

Result Status as of 30 October 2010**:**

Result Status as of 15 April 2011**:**

Result Status as of 30 October 2011**:**

Final Report Summary:

Additional Budget for Project Coordinator	**Trust Fund Budget:**	**$14,820**
	Amount Spent:	**$ 0**
	Balance:	**$ 14,820**

Major coordination activities as of: 15 April 2010

Major coordination activities as of: 30 October 2010

Major coordination activities as of: 15 April 2011

Major coordination activities as of: 15 October 2011

V. TOTAL TRUST FUND PROJECT BUDGET:

Personnel: $ 76,780*
Contracts: $ 713,682
Equipment/Tools/Supplies: $ 20,738
Acquisition, including easements: $ 0
Travel: $13,800
Other: $

*We are requesting $14,820 from the Trust Fund to temporarily supplement (Rule 10 work assignment) the current Classified 10L DNR salary (MAPE bargaining unit) of the project coordinator (Ray Valley) to a 14L MAPE salary (N.R. Program Coordinator) that is commensurate to the work duties involved with this project. This is equivalent to a 7% FTE. Mr. Valley's salary will return to the level of 10L after the project is completed.

We are also requesting $25,000 from the Trust Fund to pay 10% of Jodie Hirsch's Classified DNR salary. The salary savings will be used to backfill Ms. Hirsch's position with a student worker.

Intern positions are unclassified.

TOTAL TRUST FUND PROJECT BUDGET: $825,000

Explanation of Capital Expenditures Greater Than $3,500:

- Data platforms will be constructed from multiple components costing less than $3,500. Existing USGS platforms will be used whenever possible and equipped with new sensors costing less than $3,500 as needed. Most sensors have an average useful life of approximately three years under continuous operation**.** Platforms purchased and assembled with trust fund monies will continue to be used for the same water quality monitoring program through its useful life. Collection of physical water quality data for the project will require purchase of one multi-parameter water quality sonde with optical probes for dissolved oxygen (DO) and chlorophyll *a*. The YSI

6600 model V2 is available from the USGS HIF facility for $6,435.00 and matched units are already in service at the USGS MN Water Science Center, allowing sharing of spare parts and components. The instrument purchased with trust funds will be used as a field meter and as a back-up for the other sondes deployed in each lake. The sonde purchased with trust fund monies will be under ownership of the State, but will be used for continued cooperative work with the USGS through its useful life.

VI. PROJECT STRATEGY:

A. Project Partners:

1. DNR Divisions of Parks, Waters, and Ecological Resources
2. MN PCA – Env. Anal. Outcomes Div., Water Monitoring Section (Shannon Lotthammer program manager)
3. US Forest Service – Superior National Forest (Jason Butcher acting Fisheries program manager)
4. US Geological Survey – Water Science Center (Dr. Richard Kiesling, Limnologist)
5. Natural Resource Research Institute (Dr. Lucinda Johnson)
6. Science Museum of Minnesota (Dr. Mark Edlund)
7. University of Minnesota – Departments of Fisheries, Wildlife and Conservation Biology (Dr. Raymond Newman) and Forest Resources (Dr. Joe Magner)
8. University of Minnesota-Duluth Department of Biology (Dr. Tom Hrabik)

B. Project Impact and Long-term Strategy:

Work outlined in this proposal will lay the necessary ground work for ongoing monitoring and assessment. Work proposed here represents a significant adaptation of DNR Fisheries lake survey program to better assess lake habitat conditions and factors affecting habitat. We expect that equipment utilized, data collected, and models built for the proposed project will continue to be utilized and built upon long after this project expires. Understanding the myriad of factors driving changes to lake habitats will require a long-term adaptive approach. Support from the Environmental Trust Fund will kick-start this effort and help prioritize future monitoring efforts with operating budgets.

C. Other Funds Proposed to be Spent during the Project Period:

Trust fund dollars will supplement at least $508,000 spent during the project period originating from the Game and Fish Fund, USGS cooperative funds, US Forest Service Operating budgets, PCA operating budgets and Clean Water Legacy.

D. Spending HIstory: $120,000 (FY 2009)

VII. DISSEMINATION:

1. PCA has a website providing basic "fact-sheets" on all 24 sentinel lakes. http://www.pca.state.mn.us/water/sentinel-lakes.html
2. Another DNR website on the overall SLICE program is under construction
3. Twenty-four retrospective lake assessment reports
4. Several manuscripts submitted to peer-reviewed journals by project partners
5. Several technical presentations given at state, regional, national, and potentially international symposia. Local outlets include MN chapter of the American Fisheries Society and MN Waters
6. Most water quality data will be housed in EPA's national water quality database STORET (http://www.epa.gov/storet/dbtop.html). GIS data is available at http://deli.dnr.state.mn.us/. Fisheries and aquatic plant data will be housed in a central database and available upon request.
7. A "file transfer protocol" (ftp) site will be maintained by the project coordinator which will house all GIS layers, reports, analyses, and raw data relevant to the project. This information will be available to any interested parties.

VIII. REPORTING REQUIREMENTS:

Periodic work program progress reports will be submitted not later than 15 April 2010 and every October and April thereafter. A final work program report and associated products will be submitted by June 30 2012.

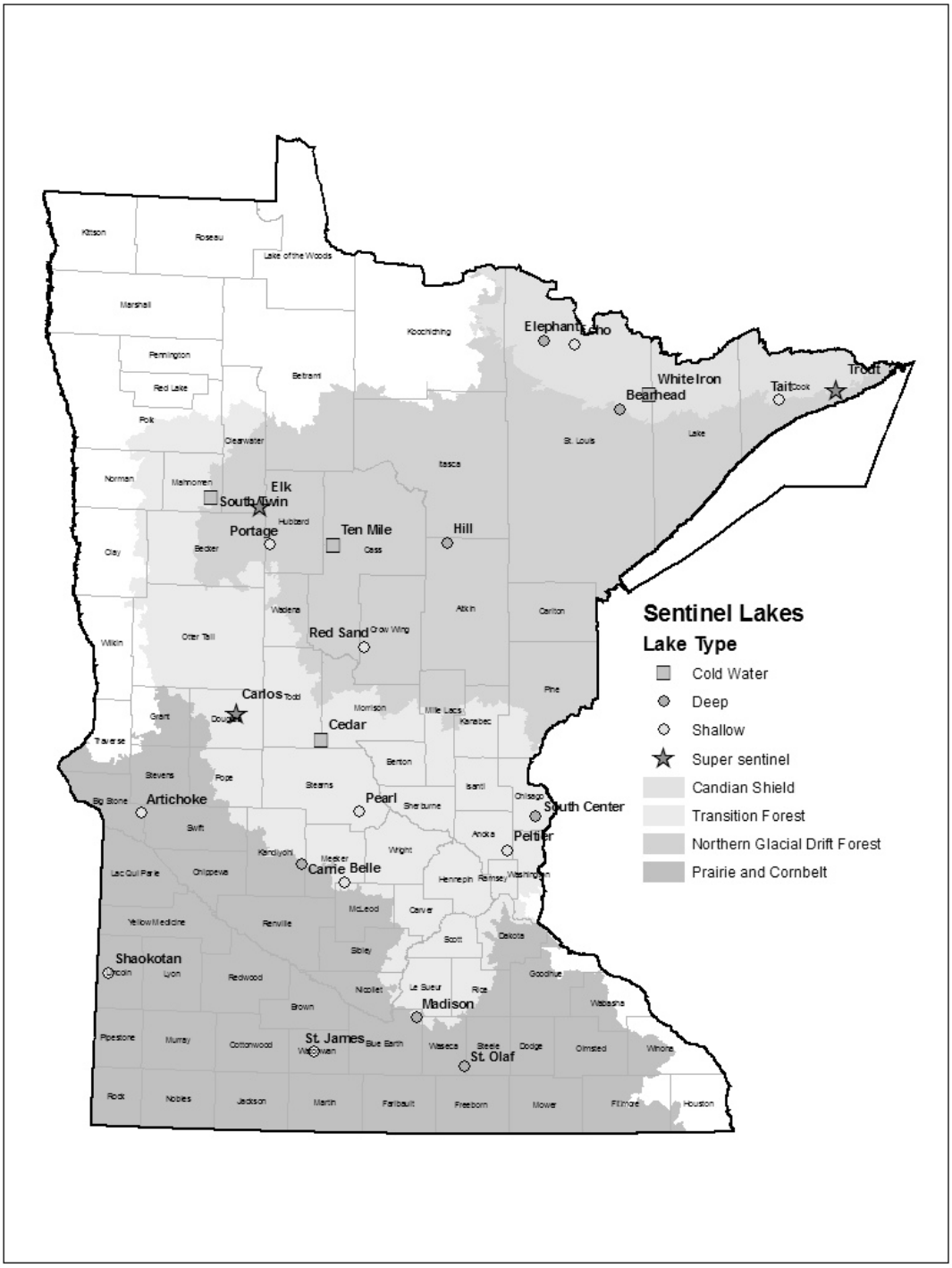
IX. RESEARCH PROJECTS:

See research addendum document

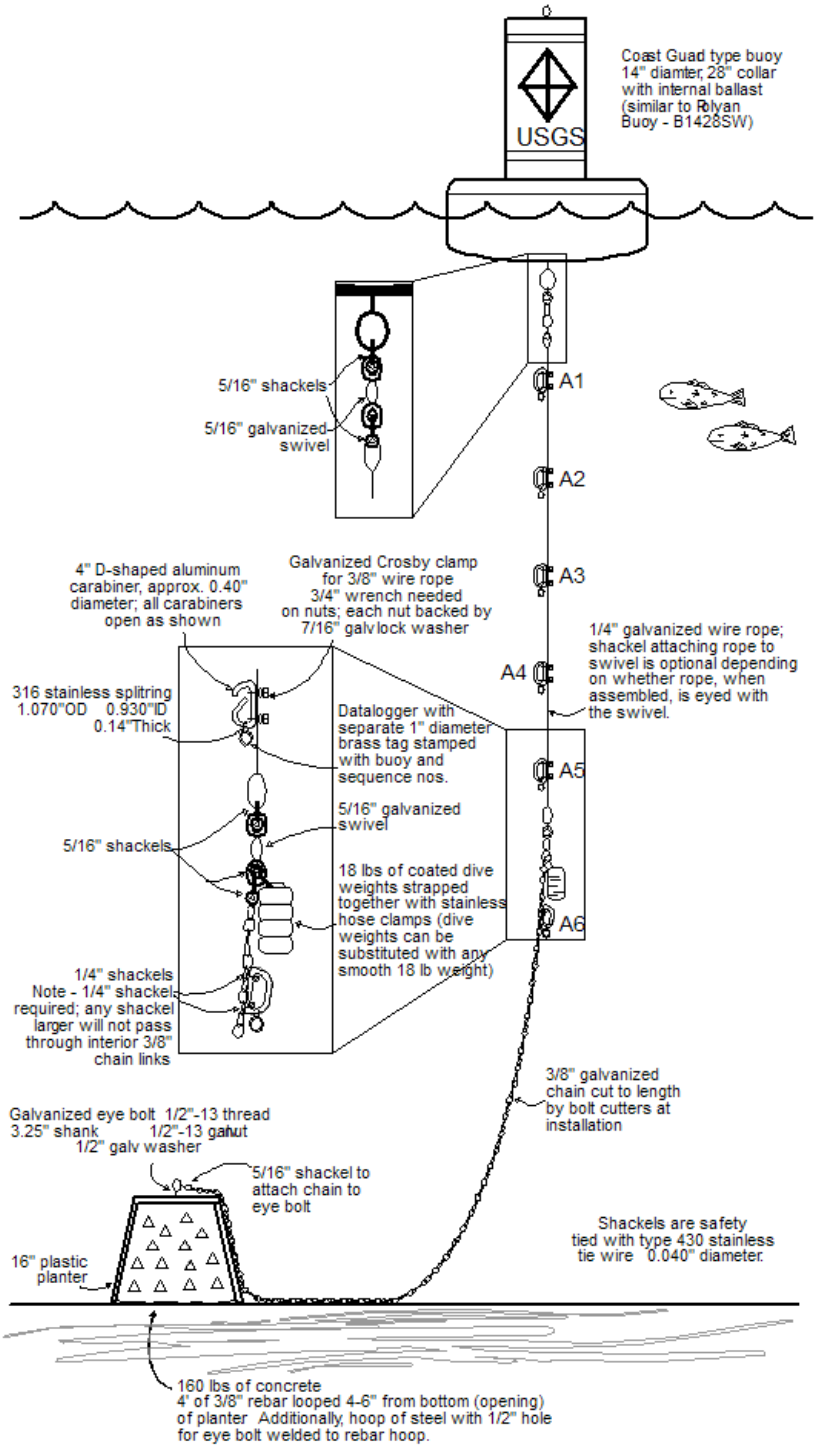
X. ATTACHMENTS

A. Itemized Trust Fund Budget
B. Map of the sentinel lakes
C. Schematic of thermistor chain and photograph of data collection platform
D. Literature Cited

Attachment B



Attachment C



An example of a moored data platform that will be stationed during the open water season on the super-sentinel lakes to collect continuous information on meteorological and water quality conditions. The platform monitors and records net radiation, solar radiation, photoactive radiation (PAR) from the sky, down-welling PAR in the water column, wind speed, wind direction, air temperature, vapor pressure of water in air, very near surface water temperature with two separate probes, shelter temperature, and battery voltage.

Attachment D

Literature Cited

Beisner, B.E., C.L. Dent, and S.R. Carpenter. 2003. Variability of lakes on the landscape: roles of phosphorus, food webs, and dissolved organic carbon. Ecology 84:1563-1575.

Colby, P. J., P. A. Ryan, D. H. Schupp, and S. L. Serns. 1987. Interactions in north-temperate fish communities. Canadian Journal of Fisheries and Aquatic Sciences 44(Supplement 2):198-215.

DeStasio, B.T. Jr., D.K. Hill, J.M. Kleinhans, N.P. Nibbelink, and J.J. Magnuson. 1996. Potential effects of global climate change on small north-temperate lakes: physics, fish, and plankton. Limnology and Oceanography 41:1136-1149.

Edlund, M.B & J. C. Kingston. 2004. Expanding sediment diatom reconstruction model to eutrophic southern Minnesota lakes. Final report to Minnesota Pollution Control Agency, CFMS Contract No. A45276. 32 pp + appendix.

Edlund, M. B., Triplett, L. D., Tomasek, M. and Bartilson, K. 2009. From paleo to policy: partitioning of historical point and nonpoint phosphorus loads to the St. Croix River, Minnesota-Wisconsin, USA. Journal of Paleolimnology DOI: 10.1007/s10933-008-9288-1

Fang, X, H. G. Stefan, and S. R. Alam. 1999. Simulation and validation of fish thermal DO habitat in north-central US lakes under different climate scenarios. Ecological Modelling 118: 167–191.

Fang, X., H. G. Stefan, J. G. Eaton, J. H. McCormick, and S. R. Alam. 2004. Simulation of thermal/dissolved oxygen habitat for fishes in lakes under different climate scenarios Part 2. Cold-water fish communities in the contiguous US. Ecological Modelling 172:39-54.

Heiskary, S.A. and C.B. Wilson. 2008. Minnesota's approach to lake nutrient criteria development. Lake and Reservoir Management 24: 282-297.

Henderson, B. A., G. E. Morgan, and A. Vaillancourt. 2004. Growth, ingestion rates and metabolic activity of walleye in lakes with and without lake herring. Journal of Fish Biology 65:1270-1282.

Hrabik, T., D. Schreiner, M. Balge and S. Geving. 2006. Development of a hydroacoustic sampling design to quantify prey fish abundance in the Minnesota waters of Lake Superior. Minnesota Department of Natural Resources Investigational Report 530.

Jacobson, P. C. 1993. Analysis of factors affecting growth of northern pike in Minnesota. Minnesota Department of Natural Resources, Division of Fish and Wildlife Investigational Report 424, St. Paul.

Magnuson, J.J., and B. T. De Stasio. 1997. Thermal niche of fishes and global warming. In: Global warming: implications for freshwater and marine fish. Edited by C. M. Wood and D. G. McDonald. Cambridge University Press. Cambridge, U.K.

Olden, J. D., O. P. Jensen, and M. J. Vander Zanden. 2006. Long-term dynamics of fish and zooplankton communities for among lake comparisons. Canadian Journal of Fisheries and Aquatic Sciences 63: 1812-1821

Ramstack J M, S. C. Fritz, D. R. Engstrom, and S. A. Heiskary 2003. The application of a diatom-based transfer function to evaluate regional water-quality trends in Minnesota since 1970. Journal of Paleolimnology 29: 79-94.

Rudstam, L. G., R. C. Lathrop, and S. R. Carpenter. 1993. The rise and fall of a dominant planktivore: direct and indirect effects on zooplankton. Ecology 74:303-319.

Rusack, J.A., N.D. Yan, K.M. Somers, K.L. Cottingham, F. Micheli, S.R. Carpenter, T.M.Frost, M.J. Paterson, and D.J.McQueen. 2002. Temporal, spatial, and taxonomic patterns of crustacean zooplankton variability in unmanipulated north-temperate lakes. Limnology and Oceanography 47: 613-625.

Ryder, R. A., and S. R. Kerr. 1978. The adult walleye in the percid community- a niche definition based on feeding behavior and food specificity. Pages 39-51 in R. L. Kendall, editor. Selected coolwater fishes of North America. American Fisheries Society Special Publication 11, Bethesda, Maryland.

Stefan, H.G., Hondzo, M., Eaton, J.G., McCormick, J.H. 1995. Validation of a fish habitat model for lakes. Ecological Modelling 82: 211–224.

Valley, R., T. Cross, P. Jacobson, A. Carlson, J. Reed, J. Hirsch, C. Tomcko, D. Dustin, M. McInerny, J. Hoxmeier, N. Proulx, D. Staples 2008. Designing a long-term monitoring program to track the status of fish communities and their habitats in Minnesota lakes, identify efficient indicators, and evaluate mechanisms. Minnesota Department of Natural Resources, Division of Fish and Wildlife. Federal-Aid Study 605.

Attachment A: Budget Detail for 2008 Projects - Summary and a Budget page for each partner (if applicable)

Project Title: Assessing the consequences of ecological drivers of change on water quality and habitat dynamics of deep-water lakes with coldwater fish populations.

Project Manager Name: Dr. Don Pereira

Trust Fund Appropriation: $825,000 - *3yrs*

Trust Fund Budget (three yr cost 2009-2011)	**Result 1 Budget:**	**Amount Spent** *(date)*	**Balance** *(7/1/09)*	**Result 2 Budget:**	**Amount Spent** *(date)*	**Balance** *(7/1/09)*	**Result 3 Budget:**	**Amount Spent** *(date)*	**Balance** *(7/1/09)*	**Result 4 Budget:**	**Amount Spent** *(date)*	**Balance** *(7/1/09)*	**TOTAL BUDGET**	**TOTAL BALANCE** ***(7/1/09)***
	Establish 24 sentinel lakes and their associated watershed as focal points of collaborative long-term monitoring, research, and environmental education			Reconstruct post-European to present water chemistry, sedimentation and erosion.			Utilize watershed and lake mixing models to forecast future water quality conditions in deep lakes with cold-water fish populations given different climate change and land-use scenarios			Identification of a set of habitat and fish indicators sensitive to human-caused disturbances to serve as an early warning sign of lake ecosystem stress.				
BUDGET ITEM														
PERSONNEL: wages and benefits														
Ray Valley (coordinator 7% FTE - $14,820) DNR Fisheries Research (Classified)													$ 14,820.00	$ 14,820.00
Jodie Hirsch (invertebrate biologist 10% FTE - $25,000) DNR Ecological Resources (Classified)										$ 25,000.00		$ 25,000.00	$ 25,000.00	$ 25,000.00
2 DNR Fisheries Interns (Unclassified Salary)										$ 36,960.00		$ 36,960.00	$ 36,960.00	$ 36,960.00
Contracts														
USGS														
USGS Hydrologist - Dr. Richard Kiesling (PI)	$ -		$ -				$ 41,290.00		$ 41,290.00				$ 41,290.00	$ 41,290.00
USGS Hydrology Technicians	$ 59,968.00		$ 59,968.00				$ -		$ -				$ 59,968.00	$ 59,968.00
3 Data collection platforms	$ 166,565.00		$ 166,565.00				$ -		$ -				$ 166,565.00	$ 166,565.00
YSI 6600 model V2 water quality sonde*	$ 6,435.00		$ 6,435.00				$ -		$ -				$ 6,435.00	$ 6,435.00
12 Tributary gages and water level loggers	$ 23,200.00		$ 23,200.00				$ -		$ -				$ 23,200.00	$ 23,200.00
Travel and fleet	$ 13,800.00		$ 13,800.00				$ -		$ -				$ 13,800.00	$ 13,800.00
Contract Total													**$ 311,258.00**	
MN Pollution Control Agency														
Interns 2 positions (Unclassified Salary)										$ 36,960.00		$ 36,960.00	$ 36,960.00	$ 36,960.00
Travel expenses										$ 17,540.00		$ 17,540.00	$ 17,540.00	$ 17,540.00
Vehicle Lease										$ 15,000.00		$ 15,000.00	$ 15,000.00	$ 15,000.00
Contract Total													**$ 69,500.00**	
UMD														
Dr. Thomas Hrabik (8% FTE)										$ 21,504.00		$ 21,504.00	$ 21,504.00	$ 21,504.00
Graduate Research Assistant (M.S. - TBD)										$ 67,165.00		$ 67,165.00	$ 67,165.00	$ 67,165.00
Travel Expenses										$ 11,331.00		$ 11,331.00	$ 11,331.00	$ 11,331.00
Contract Total													**$ 100,000.00**	
Science Museum of MN - Dr. Mark Edlund (PI)				$ 90,000.00		$ 90,000.00							$ 90,000.00	$ 90,000.00
MN Department of Health - Myra Kunas	$ -			$ -			$ -			$ 121,824.00		$ 121,824.00	$ 121,824.00	$ 121,824.00
Internal **MN DNR** - or TBD external contract - zooplankton counting software app.	$ -			$ -			$ -			$ 16,100.00		$ 16,100.00	$ 16,100.00	$ 16,100.00
													$ -	$ -
Equipment / Tools													$ -	$ -
Preservative reagent alcohol - zoops	$ -			$ -			$ -			$ 1,000.00		$ 1,000.00	$ 1,000.00	$ 1,000.00
Hach Optical Dissolved O2 meters**	$ -			$ -			$ -			$ 11,869.00		$ 11,869.00	$ 11,869.00	$ 11,869.00
Misc. survey equipment and repairs***	$ -			$ -			$ -			$ 12,869.00		$ 12,869.00	$ 12,869.00	$ 12,869.00
Travel expenses in Minnesota										$ 13,800.00		$ 13,800.00	$ 13,800.00	$ 13,800.00
COLUMN TOTAL	**$ 269,968.00**	**$ -**	**$ 269,968.00**	**$ 90,000.00**	**$ -**	**$ 90,000.00**	**$ 41,290.00**	**$ -**	**$ 41,290.00**	**$ 408,922.00**	**$ -**	**$ 408,922.00**	**$ 825,000.00**	**$ 825,000.00**

*Capital Expenditure

**Quantity = 7 meters @ ~ $1,695 ea.

***Nets, misc. equip. or repairs not expected to be greater than $3,500