Environment and Natural Resources Trust Fund
2017 Request for Proposals (RFP)

Project Title: **ENRTF ID: 014-A**

Quantifying Color and Fluorescence in Minnesota Waters

Category: A. Foundational Natural Resource Data and Information

Total Project Budget: $ 370,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2017 - June 2020

Summary:

Color and fluorescence of natural waters provide highly specific tools for the analysis of lake and river waters. New analytical tools and correlated satellite data can assess Minnesota water quality.

Name: Scott Alexander

Sponsoring Organization: U of MN

Address: 310 Pillsbury Dr SE

Minneapolis MN 55455

Telephone Number: (612) 626-4164

Email alexa017@umn.edu

Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Figure shows example dye trace spectra and fluorescence excitation/emission matrix plots from Minnesota and scientific literature

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Quantifying Color and Fluorescence in Minnesota Waters

I. PROJECT STATEMENT

Color and clarity of our lakes and rivers are the most obvious factors of water quality to users. While obvious to even casual users, color and clarity are difficult to quantify. The color and clarity of our water is an important aesthetic component ranging from clear sky blues and tannin rich "teas" to pea soup greens and muddy storm waters. Even in crystal clear waters, natural organics produce fluorescence adding to the depth and brightness. The natural fluorescence of organics in ground waters form a background to be separated from fluorescent dyes used to map springsheds in karst areas. The distinctive background fluorescence in springs and rivers has been long noted in dye tracing studies of SE Minnesota. In the marine environment color and fluorescence have been used extensively to quantify water quality, identify potential stressors, and locate pollution sources. More recently satellite imagery has been used to create real time monitoring networks; especially in coastal waters.

Gains in modern instrumentation and numerical tools allow rapid quantification of color and fluorescence. Both dissolved and suspended components can be analyzed. Color is measured as adsorption of the light spectrum. Fluorescence is defined as the adsorption and re-emission to light at longer, lower energy wavelength. Fluorescent compounds have distinct excitation and emission properties allowing quantitative separation of distinct chlorophylls, humic and fulvic acids, and other natural pigments. Many potential pollutants are also distinctly fluorescent (i.e. gasoline and diesel fuels, laundry whiteners, and anti-freeze additives). Recent acquisition of a new fluorometric instrument in our lab has increased sensitivity, resolution, and sample throughput. New numerical routines, developed in the last ten years, allow separation of component peaks in Excitation-Emission Matrix (EEM).

Building on protocols of the MPCA Advanced Citizen Lake Monitoring Program (CLMP+) water samples can be collected by volunteers and preserved for analysis. Weekly or bi-monthly samples can be compared to water quality results from the CLMP+ testing and correlated with satellite data. By ground truthing satellite data with direct color and fluorescence samples associated water quality measurements can be leveraged to assess lakes across larger eco-regions. Rapid identification of algal and cyanobacteria blooms or man-made contaminants can be used to manage and inform public health advisories.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Develop consistent color and fluorescence analytical procedures **Budget: $30,000**

Work with Jerry Spetzman of Chisago County to collect preliminary samples. Jerry has been using a simple household paint color selector to consistently assess particulate color on filter paper. This simple color comparison will be improved to better assess color using Munsell color charts and adding fluorescence.

Outcome	Completion Date
1. Collect and analyze preliminary water samples from representative lakes	12/31/2017
2. Improved field analysis of color with apps and/or quantitative color charts	12/31/2017
3. Develop preliminary laboratory analytical procedures	12/31/2017

Activity 2: Develop a network of volunteer samplers **Budget: $30,000**

Find and train volunteer water samplers from each of Minnesota's eco-regions. Use existing CLMP+ volunteers, Soil and Water Conservation District, and Watershed District staff who are already collecting routine samples.

Outcome	Completion Date
1. Identify samplers from representative areas of Minnesota	01/31/2018
2. Write sampling protocol and produce "youtube" training video ala CLMP+	01/31/2018
3. Have samplers trained and ready to go	04/30/2018

Activity 3: Use LacCore facilities to identify specific colorants and fluorophores **Budget: $95,000**

LacCore staff has experience and the tools to identify specific aquatic species.

Outcome	Completion Date
1. Identify colorants and fluorescent compounds in natural biota	12/31/2019
2. Compare with observations in the scientific literature	12/31/2019
3. Peer reviewed journal article	06/30/2020

Activity 4: Use LacCore samples to gain historic perspective **Budget: $95,000**

LacCore has collected many sediment cores throughout Minnesota. These cores contain preserved biological materials and insoluble organics indicative of species present in the original water column. Current observations, recent sediments, and older sediments can be compared.

Outcome	Completion Date
1. Correlate recent sediments with color and fluorescence of present lake waters	12/31/2019
2. Compare with preserved sediments in core samples	12/31/2019
3. Peer reviewed journal article	06/30/2020

Activity 5: Combine satellite observations with water quality, color and clarity results **Budget: $120,000**

Identify appropriate, publicly available aerial and satellite observations to correlate with water quality, color and fluorescence results.

Outcome	Completion Date
1. Identify potential sources of observational data	12/31/2019
2. Compare and correlate observational and field data	12/31/2019
3. Peer reviewed journal article	06/30/2020

III. PROJECT STRATEGY

A. Project Team/Partners

P.I. Scott Alexander, Univ. of Minnesota, Dept. of Earth Sciences (½ time support from ENTRF) will oversee project, coordinating the different research partners. Hee will take the lead on analytical procedures and sampling (Activities 1 and 2) and will work with LacCore staff providing fluorescence tools (Activities 3 and 4).

Co-P.I. Amy Myrbo, Univ. of Minnesota, Dept. of Earth Sciences, LacCore, will work research staff and undergraduates to correlate color and fluorescence with particular organic compounds and algal/bacterial species in waters and sediments (Activities 3 and 4).

Co-P.I. Katsumi Matsumoto, Univ. of Minnesota, Dept. of Earth Sciences, will advise one graduate student working on combining satellite imagery with monitoring results (Activity 5).

B. Project Impact and Long-Term Strategy

This project builds on years of dye tracing in SE Minnesota. The natural background fluorescence of individual springs is often diagnostic but has not been systematically related to specific processes. Previous work was limited by long instrument scan times, small instrument range and sensitivity, and weak analytical tools. By correlating color and fluorescence with active biologic processes, and contributions of humics and fulvics from ground waters, we can gain insight into the water quality and separate ground water and surface water components. The relatively simple analytic tools used to measure color and fluorescence can be added to existing MPCA and DNR monitoring programs. Combining the results of this study with aerial and satellite observations we can identify water quality indicators for virtually every surface water in Minnesota.

C. Timeline Requirements

Activities 1 and 2 of this project would be completed in the first nine months allowing data from two full summers (2018 and 2019) to be collected. Activities 3, 4, 5 will analyze and build on these two full summers of data to produce final results by the end of June 2020.

2017 Detailed Project Budget

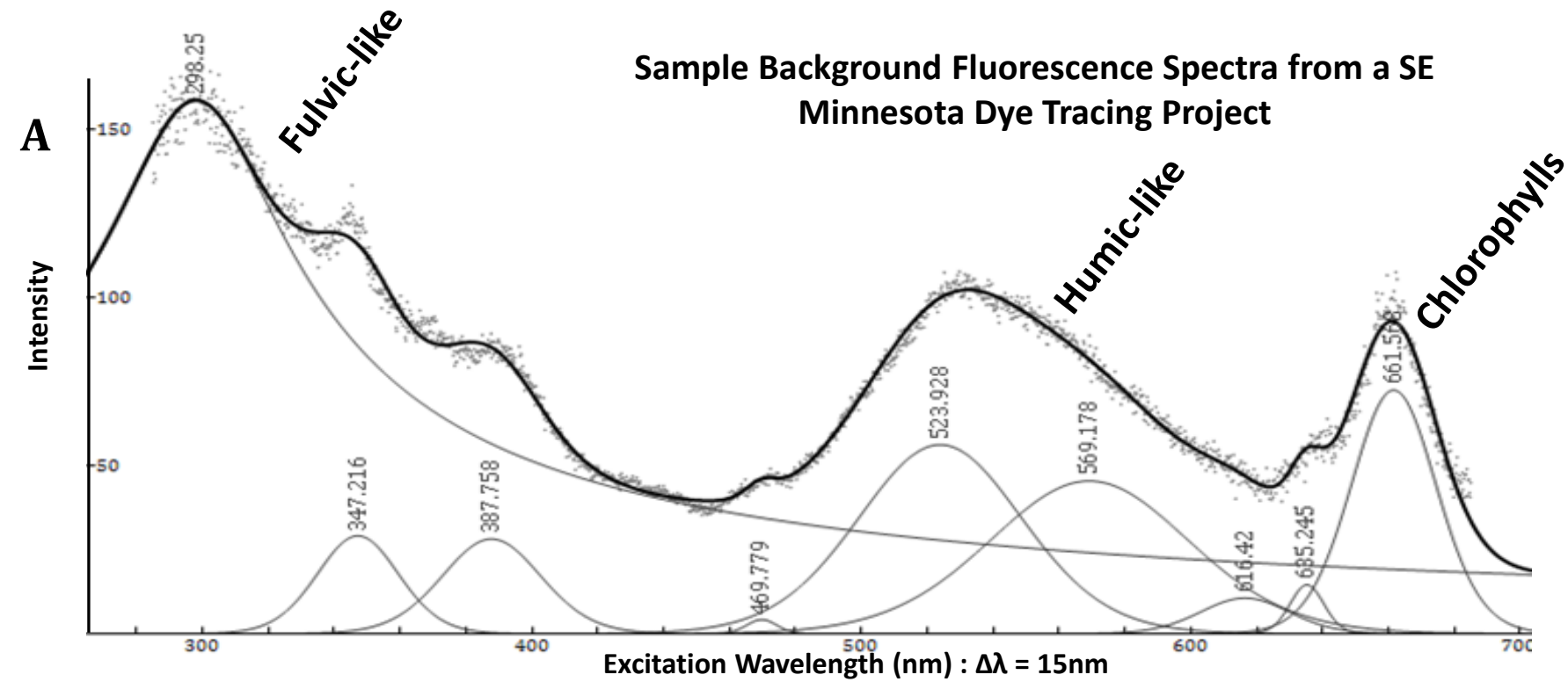
Project Title: Quantifying Color and Fluorescence in Minnesota Lakes and Rivers

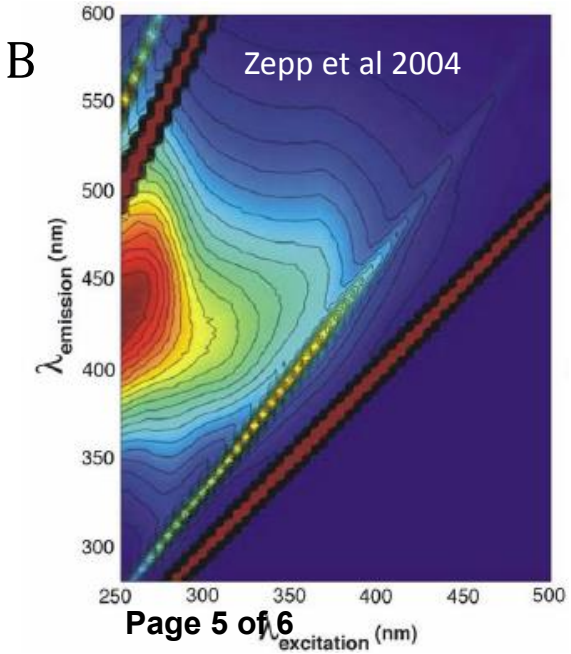
IV. TOTAL ENRTF REQUEST BUDGET *[Insert # of years for project]* **years**

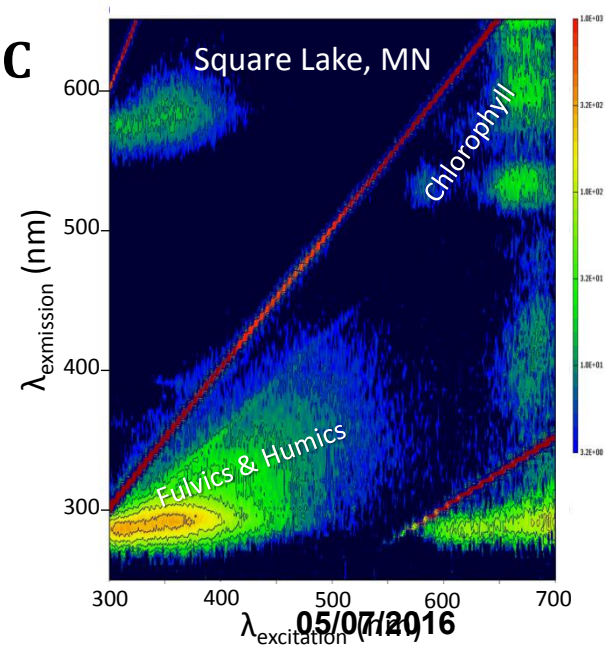
BUDGET ITEM *(See "Guidance on Allowable Expenses", p. 13)*	**AMOUNT**
Personnel: Scott Alexander, Research Scientist, 50% time 3 years (78.7% salary, 21.3% fringe)	$ 104,000
Personnel: LacCore Research Scientist, 25% time 3 years (78.7% salary, 21.3% fringe)	$ 52,000
Personnel: 6 Undergraduate Researchers, 25% time each for 2 years ($10/hr, no fringe)	$ 62,500
Personnel: 1 Graduate Student Full time for 2 years (56.3% salary, 43.7% fringe)	$ 87,000
Professional/Technical/Service Contracts: NA	NA
Tools: Temp/Diss. Oxygen meter with 30m cable for water column profiling (8 at $1,313)	$ 10,500
Supplies: Field sampling supplies (120 sample sites, 10 rounds/year for 2 years) vials, filter paper, field supplies, postage to UM	$ 12,500
Supplies: Laboratory supplies (cuvettes, laboratory expendibles)	$ 12,500
Supplies: Chemical and isotopic analysis to augment CLMP+ data 2 rounds/yr	$ 25,000
Acquisition (Fee Title or Permanent Easements): *NA*	NA
Travel: Overnight trips to each Minnesota ecoregion to meet with and train volunteers	$ 4,000
Additional Budget Items: *NA*	NA
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST	$ 370,000

V. OTHER FUNDS

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ To Be Applied To Project During Project Period: *Indicate any additional non-state cash dollars secured or applied for to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.*	NA	*Indicate: Secured or Pending*
Other State $ To Be Applied To Project During Project Period: *Indicate any additional state cash dollars (e.g., bonding, other grants) secured or applied for to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.*	NA	*Indicate: Secured or Pending*
In-kind Services To Be Applied To Project During Project Period: *Indicate any additional in-kind service(s) secured or applied for to be spent on the project during the funding period. For each type of service, list type of service(s), estimated value, and indicate whether it is secured or pending. In-kind services listed must be specific to the project.*	NA	*Indicate: Secured or Pending*
Funding History: *Trout Stream Springshed Mapping in SE Minnesota ENRTF (2011). Springshed Mapping for Trout Stream Management Part 1 & 2 ENRTF (2009). Innovative Sprinshed Mapping for Trout Stream Management ENTRF (2007).*	$ 780,000	
Remaining $ From Current ENRTF Appropriation: *Specify dollar amount and year of appropriation from any current ENRTF appropriation for any directly related project of the project manager or organization that remains unspent or not yet legally obligated at the time of proposal submission. Be as specific as possible. Indicate the status of the funds.*	NA	*Indicate: Unspent? Legally Obligated? Other?*







A - Example fluorescence spectra with naturally occurring fluorescent compounds in a Minnesota dye trace study. (Synchronous spectra with constant separation between excitation and emission wavelength.) Component peaks separated with numerical peak fitting analysis.

B – Excitation/Emission Matrix from a marine environment.

C – Excitation/Emission Matrix from a Minnesota lake. (Note that MN example covers a larger range of wavelengths to include chlorophyll.

Scott C. Alexander

Research Scientist V
Department of Earth Sciences, University of Minnesota
Minneapolis, MN 55455
alexa017@umn.edu

Scott has worked for more than 30 years at the Department of Earth Sciences at the University of Minnesota. His projects began with ground water flow in kart regions and contaminant migration in many rock types and evolved to studying the interaction of ground water and surface water across Minnesota. All of this work is grounded in physical, chemical, and isotopic measurements of real world systems as a starting point for computer based and laboratory scale simulations. Current work focuses on rain water reuse and geothermal heat pump systems. His work on dye tracing studies utilizing fluorescent tracers has continued throughout his career. He has applied natural fluorescence to cave drip waters and speleothem research.