**PROJECT TITLE: Critical Insights from Historical Lake Water Quality Data**

**I. PROJECT STATEMENT**

This project will derive historical water quality data from legacy Landsat satellite imagery to address three key questions: **1) how is water quality in our lakes changing; 2) what factors contribute to those changes; and 3) how do those changes effect lake use and economic conditions?** The project will use automated methods developed in our current LCCMR project to greatly expand the database on lake water quality by mining the **entire archive** of Landsat satellite imagery, make it readily accessible, and use that data to estimate the economic value of changes in water quality. When completed,these projects will produce a database containing almost **40 years of information** and maps of key water quality measures for **over 10,000 Minnesota Lakes**. We will use the database to 1) link differences in water quality and **ecosystem services** to in-lake and watershed factors via geospatial and temporal analyses, and 2) conduct an economic analysis to evaluate the economic value of water quality changes through lake-user surveys and property value analyses.

The current LCCMR-supported project (ML2018 Ch 214 Art4 Sec2 Subd 03b E8181LM) is developing an automated system to deliver near real-time water quality data from 2015 onward using current generation Sentinel 2 and Landsat 8 imagery. This project will modify the automated system to derive water quality products (e.g., water clarity and color) from the 30-year archive of **Legacy (1985-2015) Landsat** 5 and 7 imagery. The combined water quality database of almost 40 years will be ideally suited to identify lakes with changing water quality and to analyze in-lake factors, watershed stressors and climatic conditions that impact water quality.

The database will also enable economic analysis of lake water quality. Minnesotans derive economic value from lakes in various ways, including water-based recreation, scenic amenities from lakeshore property, and broader ecosystem services. As an initial but significant step, this project will estimate the value of changing water quality through data collected from surveys of lake visitors and lakeshore property value records, linked to remotely sensed water quality data. The results of this analysis will inform resource management, by identifying the settings where improved water quality yields the largest economic benefits to lake users, including the economic values of designated uses such as swimming, boating and fishing. The project creates a framework for future work, leading to a comprehensive assessment of the economic value of water quality to inform data-driven resource management.

This project is a compelling opportunity to take advantage of the **freely available** but largely **untapped** 30-year archive of Landsat 5 and 7 satellite imagery and the **high performance computing** resources at the University of Minnesota. The Water Resources Center (WRC) will coordinate the project and disseminate its products within a larger agenda that the WRC is advancing on "**Digital Water**," which is expanding water quality information and strengthening understanding of our changing water resources. This proposal was developed in cooperation with state (e.g., DNR, PCA) and local water management agencies and is designed to support their management needs.

The almost 40 years of spatial water quality data and maps for over 10,000 lakes from these projects will be available in an interactive web interface that is being developed in the current LCCMR project. We expect that the enhanced LakeBrowser, which will have more data and capabilities, will be even more popular than the current version ([lakes.rs.umn.edu](https://water.rs.umn.edu/lakebrowser) **~9,000 unique visitors monthly**), which is limited to late summer clarity every five years. This project will dramatically improve data-driven resource management decisions, benefit researchers, and inform the public about changing water quality conditions and the economic impact of those changes.

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| **II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1:** **Modify and apply automated methods for measuring water quality in** **> 10,000 Minnesota lakes using historical (1985–2015) remote sensing imagery** | **Budget: $185,000** |
| We will modify image processing code to process the historical Landsat 5 and 7 imagery and retrieve water quality data using high performance computing techniques. The generated database of water quality data will be validated with field data, and added to an interactive web interface where citizens, researchers and lake managers can easily access and visualize the data.  |

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| **Outcome** | **Completion Date** |
| 1. System to automatically retrieve, prepare and process historical Landsat images for water quality measurements (e.g., water clarity, color) in > 10,000 lakes | June 2021 |
| 2. Water quality database creation (1985–2015) | September 2021 |
| 3. Validation of results with **available** citizen and agency collected water quality data | Jan 2022 |
| 4. Add historical (1985–2015) water quality data to interactive Web Interface | July 2022 |
| **Activity 2: Geographic, Temporal and Economic Analysis of Lake Water Quality**  | **Budget: $295,000** |
| This activity involves three components. 1) The database developed in Activity 1 will be analyzed statistically for spatial distributions, seasonal and temporal trends, and relationships with in-lake conditions (depth, size, invasive species…) and watershed-landscape factors (e.g., land use, population and drainage density, BMPs) that potentially affect lake quality and ecosystem services. Using this analysis and consultation with agency lake managers, we will identify representative lakes in different regions throughout the state for economic analyses. 2) We will conduct lake-user surveys at statistically sampled pairs of lakes distributed in different regions (e.g., metro, southern, Ely and Brainerd areas) throughout the state to quantify recreational expenditures, and by doing so, estimate visitors’ value. Each pair of lakes will differ in water quality and/or water quality history, but be similar in other socio-economic factors, allowing the value estimates to be driven by water quality differences. We will conduct the surveys with undergraduate researchers and estimate the value of the changing water quality by sampling hundreds of people over multiple weeks. 3) We will analyze the monetary impact of changing water quality using publicly available property value information. Statistical analyses will yield estimates of the economic value of changes in measured lake water quality variables, as well as the socioeconomic and spatial factors associated with higher quality benefits.  |
| **Outcome** | **Completion Date** |
| 1. Geospatial and temporal analysis of the database with in-lake and watershed factors  | June 2022 |
| 2. Surveys of lake-users | October 2022 |
| 3. Analysis of property values in relation to changing water quality | June 2022 |
| 4. Statistical analysis of survey data and property values | June 2023 |

**III. PROJECT PARTNERS:**

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| **Name** | **Title** | **Affiliation** | **Role** |
|  **A. Partners receiving ENRTF funding** |
| Jeffrey Peterson | Director WRC | UMN WRC | PI |
| Leif Olmanson | Research Associate | UMN FR | Co-PI/Technical PI |
| Lucia Levers | Research Associate | UMN WRC | Co-PI |
| Benjamin Page | Research Fellow | UMN WRC | Co-I |
| David Porter | Research Associate ccCons | UMN MSI | Co-PI |
|  **B. Partners NOT receiving ENRTF funding**  |
| Marvin Bauer | Professor emeritus | UMN FR | Co-I |
| Patrick Brezonik | Professor emeritus | UMN CSE | Co-I |

**IV. LONG-TERM- IMPLEMENTATION AND FUNDING:** The Water Resources Center will maintain the system into the future, with capability to incorporate new data sources and data products driven by user demand.