Lake Water Clarity Monitoring Using Satellite Imagery

About once a week during the summer months, Harold Dziuk boats to the same spot of a lake near his Minnesota home. Each time, he lowers a white disk into the water, takes a few notes, raises the disk back up and takes a few more notes. Afterwards, he packs up, motors around the lake to take in the natural surroundings and heads home.

Like thousands of other volunteers in the Upper Great Lakes region, Harold is collecting Secchi disk readings - measurements that indicate lake water clarity. Because collecting this type of data is so easy, citizens volunteers in Minnesota, Wisconsin and Michigan are working with their local and state agencies to help them determine the clarity of all lakes in their state. Unfortunately, budgets are tight and agencies cannot get Secchi disk readings for every lake in each state, even with volunteers. In fact, only a small percentage of lakes are monitored, which means that only a small percentage of lakes are managed to protect their clarity.

Meanwhile, at the University of Minnesota, University of Wisconsin-Madison and Michigan State University, remote sensing specialists are using satellite imagery to determine lake water clarity in their respective states. With Secchi disk readings, satellite images, image processing software and trained analysts, this research collaboration is working to determine lake water clarity for all lakes in the region. This fact sheet is an overview of how satellite imagery is being used to generate maps of lake water clarity in Minnesota.

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Between Minnesota, Wisconsin and Michigan, the Upper Great Lakes (UGL) region boasts nearly 30,000 inland lakes. Given this, and considering all the ways residents value their lakes, each state has established lake water monitoring programs to preserve and protect their plentiful natural resource.

One of the most pervasive problems that programs strive to thwart is eutrophication; a natural process which decreases lake water clarity - an indicator of lake water quality. Eutrophication is a result of aging but is significantly enhanced by human activities. It develops as storm water runoff carries large amounts of chemical nutrients, like nitrogen and phosphorus, into lakes. In turn, these nutrients, which are commonly carried from agricultural settings and construction sites, encourage excessive growth of aquatic plants and algae. As a result, lake water clarity decreases, eventually creating what is known as a hypereutrophic lake (Figure 1).

Lake monitoring is one of the most important activities to manage eutrophication and restore good lake water clarity. The purpose of this fact sheet is introduce a new way of monitoring lake water clarity, which combines traditional monitoring methods with space technology.

**The Traditional Approach**

Secchi disk readings are the most common way to measure lake water clarity. They give water resource managers an indication of how clear lakes are by observing how deep an 8-inch, white disk can be lowered into a lake before it is not visible. When the disk disappears from sight, the depth is recorded as indicated on a rope with markings.

**Figure 1. The lake on the left is a clear lake, known as an oligotrophic lake. On the right is a hypereutrophic lake.**
Then, the disk is raised back up and another measurement is recorded when the disk reappears. The final measurement is an average of the two readings.

Recognizing the importance of preserving and improving lake water clarity, citizen volunteers have joined forces with monitoring programs to help sample as many lakes as possible within their state. Typically, citizens donate their time during the summer months and collect Secchi disk readings at designated locations on a weekly basis.

Although water quality protection is priority for water agencies, budgets restrict the number of lakes monitored. As a result, thousands of lakes are unmonitored, preventing agencies from identifying and managing problem lakes.

**THE NEW APPROACH**

At the University of Minnesota’s Remote Sensing and Geospatial Analysis Laboratory and Water Resources Center, analysts are exploring a new approach to monitoring lake water clarity. With images captured from earth observing satellites, they are estimating lake water clarity based on the spectral reflectance of lakes.

This satellite-based approach is part of a broader research collaboration with the University of Wisconsin-Madison and Michigan State University. To date, this group has used moderate-resolution Landsat TM imagery to evaluate state and regional lake water clarity and high-resolution IKONOS imagery to monitor lake water clarity at city scales.

The most valuable products of this satellite-based approach are maps of lake water clarity displaying the variability within and between lakes, as well as changes over time. These tools can direct managers to lakes that need specific attention, which then allows them to focus their monitoring efforts. Ultimately, this approach can help managers optimize management efforts with limited resources.

Although results demonstrate that satellite imagery has the potential to overcome budget and time constraints needed to monitor more lakes, the approach still requires ground-based Secchi disk readings. Without these readings, analysts cannot calibrate the satellite imagery - a key component to generating maps of lake water clarity.

**AN INTEGRATED APPROACH**

There are well over 10,000 inland lakes in Minnesota, and with current monitoring methods and the help of citizen volunteers, approximately 850 lakes are monitored each year. By integrating ground-based readings with satellite imagery, analysts have determined lake water clarity for over 10,500 lakes in Minnesota that are over 20 acres in size. Following are three steps that analysts used to create useful lake water clarity maps.

**STEP 1:** For a statewide assessment, Landsat TM images from the early 1990s and 2000 were acquired from the U.S. Geological Survey. Twenty-one images were needed to cover the state of Minnesota.

**STEP 2:** Next, the images were registered to maps, and land and vegetation were masked out, narrowing the analysis to lakes.

**STEP 3:** Lastly, a multiple regression of the relationship of in situ Secchi disk transparency (SDT) measurements and the Landsat spectral-radiometric responses was developed. With a very strong relationship between SDT measurements and the Landsat responses in the blue and red (chlorophyll) spectral bands, the model was applied to all lakes in the image greater than 20 acres in size (See Figure 3).

![Figure 3. Relationship between measures of lake water clarity with Secchi disk transparency and Landsat TM estimates of transparency.](image-url)
These maps have provided water resource managers a more affordable view of statewide lake water clarity. Bruce Wilson from the Minnesota PCA says, “Out of the sky - literally - has come this opportunity to help provide the information we are asked for thousands of times a year by citizens, business owners, and local units of government. This is a truly significant evolutionary step for using water-quality monitoring.”
The University of Minnesota’s Remote Sensing and Geospatial Analysis Laboratory (RSL), a unit of the Department of Forest Resources and College of Natural Resources, was established in 1972 and focuses on geospatial research and development for forestry and natural resources. Current efforts emphasize quantitative approaches to natural resource assessment, carried out in cooperation with resource agencies. Core activities at the RSL include research, education and outreach, and the facilities feature an array of hardware and software for image processing, mapping, modeling, statistical analysis and visualization.