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The Maryland and Virginia suburbs of Washington, DC experienced rapid growth between 1984 (left) and 2011 (right). The most dramatic growth is near Dulles International Airport, image left. Bright white patches are clouds.

Opposite: Landsat provides the longest space-based record of Earth's landscapes in existence, making it possible to track change since 1972.

Effective Tools for Cleaning Our Waterways

Jeannette Allen

Pam Anderson and her colleagues at the Minnesota Pollution Control Agency's Lakes and Streams Monitoring Unit have an unusually big job. Popularly known as the Land of 10,000 Lakes and home to more than 12,000 of them, Minnesota has vast water resources, and Anderson and her colleagues are responsible for monitoring, managing, and protecting all of them. It would be an impossible task if not for satellite data, including a Landsat-based map of land use.

The Clean Water Act requires states to adopt standards for how much biological, chemical and physical pollutants (bacteria, nutrients, biosolids, oil, etc.) can be in the water and still be safely used for drinking, fishing, and swimming. States are responsible for implementing and enforcing these federal laws. Every two years, states must assess the health of their waters, determine which ones are not meeting water quality standards, and report on them to the Environmental Protection Agency. Bodies of water that fail to meet the standards automatically go on the EPA's list of impaired waters and are tagged for further study, monitoring, and restoration. Once water quality standards are restored in a body of water, it is removed from the impaired list.

States do their best, "but the impaired list keeps growing," says Jim Wickham, Senior Research Biologist with the Environmental Protection Agency. "It's easier to measure and report on water quality than to bring impaired waters back to health. Something on the order of 50,000 water bodies are currently impaired, roughly 1,000 per state."

In Minnesota, nearly 40 percent of the state's waters are listed as impaired, a rate comparable to what other states are finding. Anderson and others at the Minnesota Pollution Control Agency are hard at work to assess its waters, to preserve the health of those that are clean, and to restore those that are impaired.

"Where water sampling tells us the waters are impaired and not meeting the national and state standards, we have to determine why," says Anderson. "What is impairing the waters, stressing the fish? Is it land use change such as loss of forest to development? Is it low oxygen levels?"

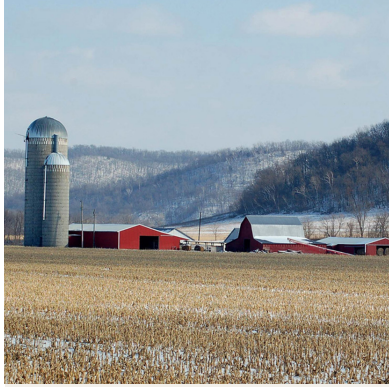


Photo information
Opposite: The Minnesota Pollution Control Agency monitors waterways such as Wolf Creek in Banning State Park so that drinking water remains clean for people downstream (below). Credit: (above) stta, (below), kuppa. Above: Land use, including farming, impacts water quality. Credit: dobak on flickr.com.

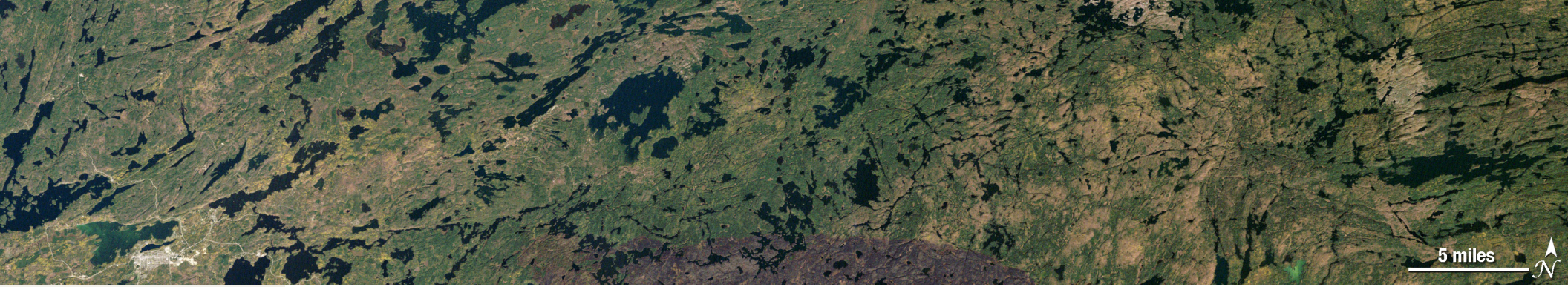


Image information
Landsat 5 acquired this image of northeastern Minnesota on October 10, 2011. Clear water is black, since sediment reflects light, making the water appear green. Land cover affects water quality. Forest is dark green, cities are gray, and bare earth is tan. The brown area is land recently burned in a wildfire. Credit: NASA's Earth Observatory

The National Land Cover Data Base

She and others have found that a profound influence on the life of waterways and their health is what happens on the lands surrounding them. Urbanization, farming, timbering, wild fires, or wetland removal impact water quality by adding chemical pollutants or physically altering the flow of water. For example, urbanization can increase municipal sludge production and facilitate movement of pollutants into waterways. Farmers apply fertilizers and pesticides to croplands, and rains and drainage systems can transport these to local water supplies. Livestock manure contains nitrogen and phosphorus that may also contaminate water supplies.

"We have to look at land use and determine whether or not it is a factor in impairment of the waters. In a big state with a lot of waters, that's a demanding job," says Anderson. In fact, the job would be nearly impossible without the view from Landsat satellites. Since 1972 the series of Earth-observing Landsat satellites have observed and measured changes in the world's land cover and land use consistently, reliably, and accurately. These observations have been compiled into a large database, called the National Land Cover Database, used by states to help them to characterize and quantify changes on the land and so comply with the Clean Water Act.

"Land cover and impervious cover are very critical to implementing the Clean Water Act, and the National Land Cover Database is the backbone of this process," explains Anderson, "Because we have the National Land Cover Database, we can look region by region, watershed by watershed, at our state, and how land use is impacting our waters."

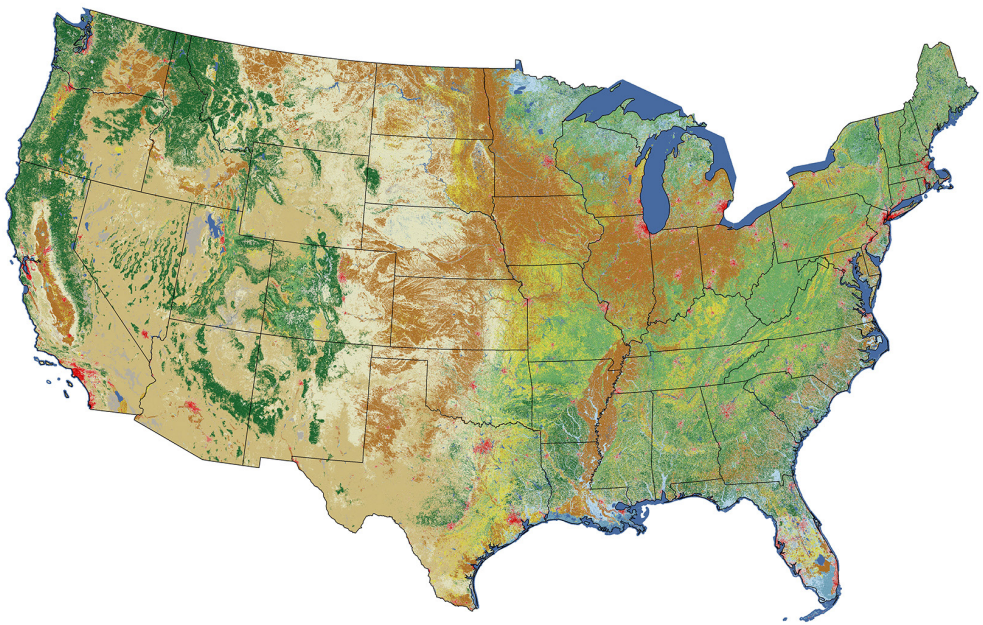
Tom Pearson, Research Analyst in the Watershed Division, explains further how watershed assessment for water quality in Minnesota works. "We study watersheds that average 1,000 square miles. They're big. We need the National Land Cover Database to give us the big picture of land use. Using Geographic Information Systems (GIS), we combine the land cover data with four other datasets for each watershed: riparian zone conditions; number of feedlots and feedlot animal density; surface water discharges; and the degree of channelization in streams. Out of that we generate a Human Disturbance Score for each of the 45-50 subwatersheds in the larger watershed. This helps us to focus our resources and to get the most water quality improvement out of the work we do."

"We need to be able to address both point and non-point sources of pollution," continues Pearson. "Non-point sources can be elusive and challenging to identify. The National Land Cover Database gives us the land use data we need to help identify non-point pollution sources that are often a very important part of the overall water quality picture."

Restoring Waterways

On the national level, Wickham fully expects use of the National Land Cover Database for state level water quality assessments to spread partly because of recent developments at the EPA. The Clean Water Act did not provide guidance on how states might strategically approach making improvements to their waterways' health. "In the beginning states tended to try cleaning up the most impaired waters, using the 'worst first' approach," he explains. "That's often a failure because some waters cannot be cleaned up!" The EPA developed a step-by-step how-to process for states to analyze their waterways and to determine the most likely ones to be brought back to health.

The guidelines contain multiple indicators that states can use to assess potential recovery, including the structure of the ▸



The National Land Cover Database is a16-class land cover classification scheme using a spatial resolution of 30 meters. What covers the surface of the land (such as forest, farmland, or urban areas) and how people manage their lands has profound influences on water quality and so affects human health. The Minnesota Pollution Control Agency uses the National Land Cover Database in multiple critically important ways to strategically implement federal and state water quality laws.

waterway, stability of shore lands, water flow and channel dynamics, integrity of the biological communities, ecological history, and several more traits of the waterway. Many of those indicators are developed from the National Land Cover Database.

Back in Minnesota, the National Land Cover Database has already helped to keep the list of impaired waters from lengthening. North Tamarack Lake is a large 3,520 acre shallow lake located in the northwestern part of the state. Anderson notes, "North Tamarack Lake tripped our threshold for impairment. But it's set in a natural background surrounding by Tamarac National Wildlife Refuge, and land use is very well intact." This meant that human activities had not harmed the lake. "Our understanding of the land use around it kept that lake off the impaired list."

Preventing Pollution with Land Use Decisions

Beyond helping authorities to understand the impacts that landscapes have on the life of specific waterways, the National Land Cover Database is an important component of models used to predict water quality. "We are a regulatory agency and we need to understand the effects of point source pollution for permitting purposes," says Charles Regan, hydrologist and lead modeler for the Technical Assistance Unit in the Watershed Division of Minnesota's Pollution Control Agency. "The National Land Cover Database is a critical data source in the models I use to make hourly estimates on dissolved oxygen, phosphorus, and nitrate amounts to measure against our water quality standards. We sample the water itself only 20 to 40 days per year, and the National Land Cover Database helps us to fill in the gaps."

"The National Land Cover Database is an integral part of our toolbox. Minnesota does not have any other way to get this kind of current data," remarks Anderson.

Photo Information
Above: The Mississippi River flows through brightly-lit Minneapolis. Urban landscapes must be carefully managed so that municipal sludge and pollutants are kept from waterways, allowing the water moving through them to remain healthy for people and ecosystems. Following full page photo: U.S. Geological Survey scientists collect a sample from the Knife River in Minnesota. Water quality field samples are tested for bacteria, turbidity, nutrients such as nitrogen and phosphorus, and specific pollutants such as mercury. Credit: U.S. Geological Survey.

"The National Land Cover Database gives us the land use data we need to help identify non-point pollution sources that are often a very important part of the overall water quality picture." —Tom Pearson

Learn More:

Land Use Impacts on Water
http://www.epa.gov/greenkit/toolwq.htm

Multi-resolution Land Characteristics Consortium
http://www.mrlc.gov/finddata.php

National Land Cover Database 2006
http://www.mrlc.gov/nlcd06_data.php

Recovery Potential Screening, EPA
http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/recovery/index.cfm

Testing the Waters: Using Satellites to Monitor Lake Water Quality
http://earthobservatory.nasa.gov/Features/WaterQuality/water_quality.php ■

Meet Thomas Pearson, Research Analyst with the Minnesota Pollution Control Agency

Thomas Pearson
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I learned to love the natural world when I was a boy, swimming and sailing in the Atlantic Ocean off the Rhode Island coast, and then hiking, canoeing, and swimming in the lakes and rivers of New Hampshire and Maine. I loved working as a camp counselor too, helping kids explore the outdoors, learn new skills, and develop confidence in their abilities.

In eighth grade I did a laboratory experiment in freshwater population ecology with snails and aquatic plants. The experiment clearly showed the results of overpopulation of animals in finite ecosystems, and the problematic effects this can have on water quality. The results of that eighth grade experience stay with me as a reminder of the importance of balance in natural systems.

I studied at the University of Wisconsin-Madison. Internships and early jobs with the Bureau of Land Management, the U.S. Geological Survey, the Environmental Protection Agency, and the National Oceanic and Atmospheric Administration helped me to build my skills and connections in the geospatial and environmental fields, which seemed to have strong potential for growth.

Working in water quality, remote sensing, and Geographic Information Systems for the Minnesota Pollution Control Agency allows me to combine interests in people/environment studies, environmental science, computer science, and graphic design. I like that diversity. I also feel that we have a very important mission because water is such a critical resource for life on the planet.

I encourage young people to find what they feel interest and passion for, and to balance that with finding a way to pursue those interests while making a living in the world. Finding a way to be useful, to make a contribution to something important, and to put one's strengths and skills to good use is a great foundation for a happy and fulfilling life.

Satellite Data Requirements:

16-day revisit (8-day revisit desired)

30 m resolution

Vis, NIR, SWIR, TIR

Global coverage

archive continuity & consistency

rapid delivery of free, unrestricted data

geolocation ≥ 15 m

Calibration ≥ 5%

≥ 11-bit bit data digitization

See inside back cover for more information