

The Secchi Disk and Our Eyes -

Working Together To Measure Clarity of Our Lakes

To the citizen lake monitor and professional lake manager, the Secchi disk is an indispensable tool for assessing lake clarity. It has provided an index of water body clarity throughout the world for over 100 years. The Secchi depth measurement is valuable because it is simple, low cost, relates well to our general perception of a lake's clarity, and can be compared to a large historical database. Yet we tend to interpret this measurement in a variety of ways. Sometimes we consider it a rough measurement, giving a ballpark estimate of a lake's clarity. At other times we rely on the Secchi disk as a quantitative tool to help make costly lake management decisions. Most often we can select a tool designed just right for the specific task at hand. When I made up some "Chex Mix" last Christmas, I measured out the Worcestershire sauce with a teaspoon and the Chex cereal with a quart-size measuring container. I used 2 different tools because I needed to measure the Worcestershire sauce much more accurately than I needed to measure the Chex cereal. The citizen lake monitor usually has access to only one tool for measuring lake clarity – the Secchi disk. So should the Secchi disk measurement be considered a ballpark tool or a highly precise instrument? The answer is that it depends on the precautions taken while making the measurement. The Secchi depth measurement can be on par with and even exceed the utility of modern electronic instruments when following a well-defined protocol. To explain why following the protocol is so important, below is a discussion on the general science of the Secchi disk measurement and why variability can be large - or small.

How Does the Secchi Disk Work?

The Secchi depth measurement involves 4 basic elements common in optical measurements: a radiation source (sunlight), a medium that the radiation travels through, an object (the Secchi disk), and a sensor (our eye). The sun's radiation consists of various forms such as ultraviolet, visible, and infrared. Only the visible portion is important in the Secchi depth determination because our eye is the sensor. The medium includes outer space, the atmosphere, and the lake water. Visible light travels largely unobstructed from the sun to the atmosphere. The atmosphere absorbs and scatters (deflects) some of the light before it reaches the earth. This absorption and scattering is usually a consistent amount, except for variations caused by clouds and pollutants. When the sunlight reaches a lake surface, the light consists of both rays coming in a straight line from the sun and rays that strike the lake from various directions. At the lake surface some light bounces off (reflects), especially early and late in the day when more light strikes the water at low angles. While traveling through the water, the light intensity decreases (attenuates) much more per unit distance traveled than while in the atmosphere. This larger decrease partially results from the attenuating characteristics of pure water. But most of the decrease is usually due to absorption and scattering by algae, decaying particles, suspended soil particles, and colorants (yellow to brown) leached from plant material such as fallen leaves. The effect of these light attenuating materials in the water is what we sense when we make personal observations on a lake's clarity. This effect is also what the Secchi disk measures. After reflecting from the disk, the

What's a Secchi Disk?

Wisconsin uses an 8-inch diameter disk separated into 4 quadrants which alternate from white to black.

The disk is attached to a graduated rope and has a bottom weight to keep it horizontal as it is slowly lowered into the lake.



Wisconsin's Protocol

The general measurement protocol in Wisconsin is to take readings from the shady side of an anchored boat on a clear and calm day between 10 a.m. and 4 p.m. Slowly lowering the disk until it disappears gives one data point. Slowly raising the disk until it reappears gives a second data point. The midpoint between depth of disappearance and reappearance is the Secchi depth result.

light attenuates further as it travels back up through the water to the eye of the lake monitor. Now we are at the last stage of our Secchi disk reading, detection of the light by our eye. Our eye and brain work remarkably together to determine when they no longer can distinguish between the white and black quadrants of the disk surface.

What Are Sources of Variability?

As you can see from the above brief description, factors other than a lake's water clarity itself can affect the results obtained with this simple measurement. The more important of these external factors are:

1. Whiteness (and blackness) of the disk
2. Altitude of the sun
3. Surface ripples and waves
4. Shadow of the boat or observer
5. Surface reflections off the water
6. Clearness of the sky
7. Observer vision characteristics
(e.g., abnormalities, adaptation, sunglasses, etc.)
8. Number of repeated measurements

Because of external influence, investigators consider the Secchi depth an apparent optical property of the water. An inherent property would not have external influence. This does not make the Secchi depth measurement a poor measurement. But it does bring home the point that minimizing the external factors, or making them as constant as possible, is important to make the measurement precise. Following a well-defined measurement protocol is essential to maximizing the value of the Secchi depth measurement.

For example, taking the Secchi depth within the 10 a.m. to 4 p.m. period recommended in Wisconsin helps minimize the influence of the sun's altitude. Based on one study of the solar altitude effects, Secchi depth values would vary by about 6% due to altitude changes in mid summer Wisconsin over the 6-hour measurement period. Over the full May-September period, the variation increases to 15% because the sun's altitude is lower at the beginning and end of the summer season. Taking measurements outside the times recommended in the protocol will tend to introduce additional variability.

Another example is the effect of waves. Most monitors have experienced the difficulty of taking Secchi depths when the lake is rough and try to take readings when the lake is calm. Waves contributed an average 10% decrease in Secchi depth values when 5-inch waves were present in a recent study. This study and others have demonstrated that a view-scope (a tube between the eye and water to block out waves and glare) can decrease this effect of waves.

The above examples demonstrate the variations caused by individual factors can exceed a 10% range. The sum variation resulting from several factors can increase the variability far beyond that of just one factor. Although studies to date demonstrate potential protocol improvements, the studies are insufficient to be sure that changes would produce an overall benefit, especially in light of the large existing Secchi depth database using

Secchi Depths for 2005 in Wisconsin

Average – 10 ft.

Median – 9 ft.

Maximum – 44.75 ft., Maiden Lake, Oconto County, 5/16/05

Minimum – 0.25 ft., Yellowstone Lake, Lafayette County, 10/23/05

Goose Pond, Dane County, 9/3/05

Other Secchi Depth References

Crater Lake, OR – 144 ft., 1972

Weddell Sea, Antarctica – 262 ft., 1986

Spirit Lake, WA – 0.05 ft. after Mt. St. Helens eruption

the current protocol. Furthermore, a protocol change that increases complexity must be weighed against the possibility of reducing the number of times that monitors truly follow the protocol. The Wisconsin Citizen Lake Monitoring Network is conducting several studies this year to learn more about the importance of factors mentioned above. These studies will address a goal to reduce measurement variability, thereby improving ability to detect "real" clarity variations of a lake over time as well as differences among lakes.

In the meantime, careful attention to following the existing protocol will keep variation to a minimum. One step all monitors could add to improve precision, or reduce variability, is to take several consecutive readings on the day of sampling and report the average. This change would not jeopardize the current protocol. Averaging several readings is a well-documented and statistically sound method to reduce variability in measurements. In fact, following the protocol and averaging a few consecutive readings could reduce the uncertainty for a day's reported result to just a few percent.

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The full Secchi depth protocol for Wisconsin is at <http://dnr.wi.gov/org/water/fhp/lakes/selfhelp/forvolunteers.htm>.

For further reading on the Secchi disk, visit <http://dipin.kent.edu/secchi.htm>.

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