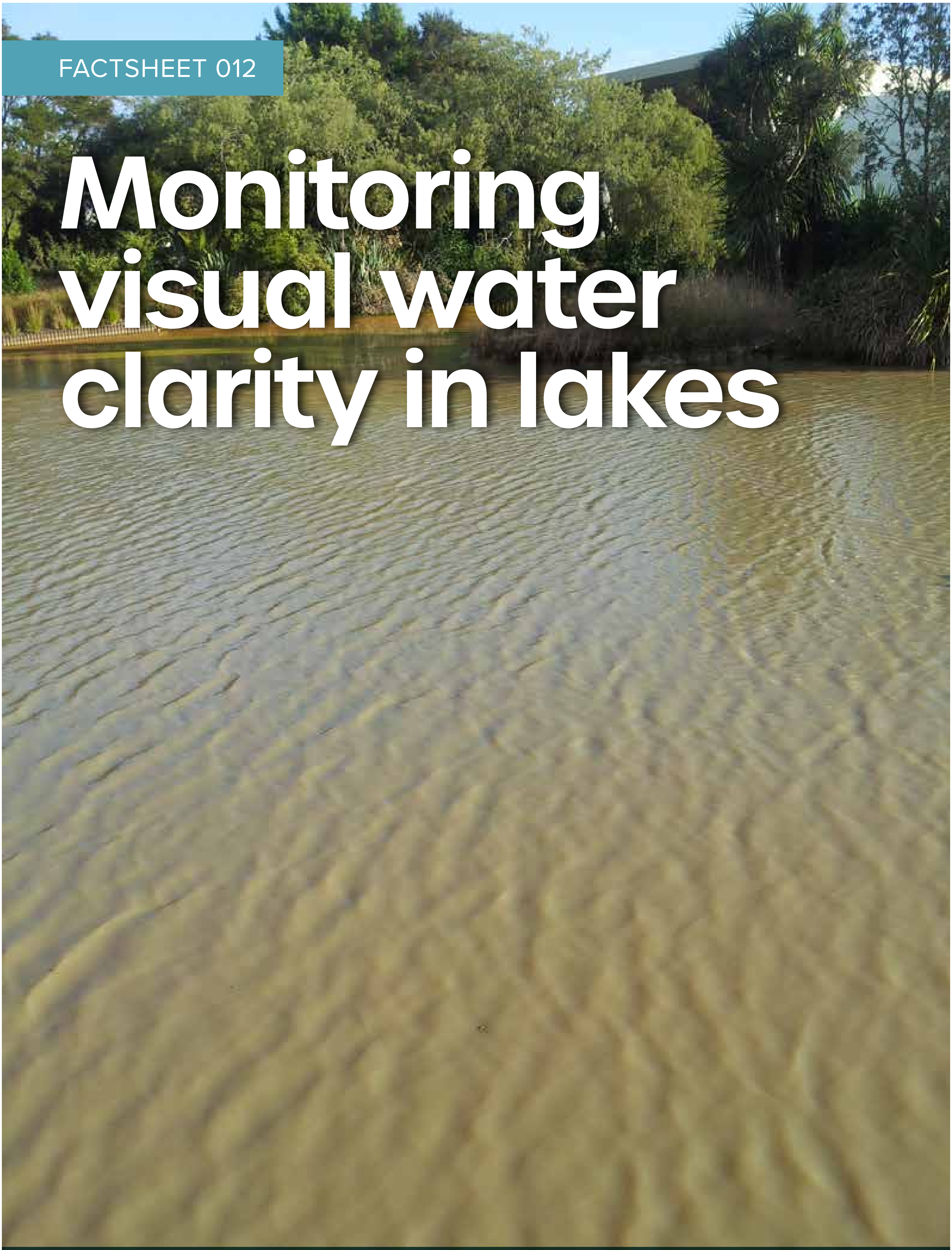
FACTSHEET 012

Monitoring visual water clarity in lakes



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Visual water clarity is a measure of the ability of light to travel through water. Visual clarity in lakes may be reduced due to suspended sediment or when there are phytoplankton or cyanobacteria blooms.

Visual water clarity is an important indicator of lake health. Reduced clarity can indicate high suspended sediment inputs to the lake from the surrounding catchment. Low visual clarity can also be a sign of algal (phytoplankton) or cyanobacteria blooms, which are an outcome of eutrophication (excess nutrients; see the factsheets *Monitoring total nitrogen in lakes* and *Monitoring total phosphorus in lakes*). Low visual clarity can impact the aesthetic and recreational values of a lake and adversely affect ecological health. For example, if light cannot reach the lake bottom the growth of aquatic plants will be affected.

Monitoring visual clarity is a key part of evaluating the trophic status of a lake, which is a common measure used to describe lake health in New Zealand. Trophic state provides an indicator of how much growth or productivity occurs in the lake, productivity being directly related to the availability of nutrients. Visual clarity is one of four variables (along with total nitrogen, total phosphorus and chlorophyll *a*) used to determine the 'Trophic Level Index' for New Zealand lakes[1].

How do we monitor visual clarity in lakes?

Visual clarity in lakes is generally measured using a Secchi disk, a 200 mm diameter disk painted with black and white quadrants. The disk is gently lowered into the lake to the point at which it is no longer visible through a viewer. A tape measure or graduated rope attached to the disk is used to measure both the depth at which the disk disappears from view and the depth at which it reappears. The average of these two measurements is recorded, and this measurement is commonly called 'Secchi depth'.

The Secchi disk method measures clarity vertically through the water column, usually from a boat. However, if the lake is shallow and clear, readings of Secchi depth may not be possible because the disk is visible to the bottom. In this case, the black disk method (as used in rivers) should be used to measure clarity horizontally. For details on both methods, see the relevant National Environmental Monitoring Standard (NEMS)[2].

Secchi depth is an apparent optical property because it is sensitive to the ambient light field. Calculations can be used to approximate a closely related inherent optical property, the beam attenuation coefficient (c). See the NEMS[2] for more details.


Using a Secchi disk. Photo: D Brown.

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[1] *Burns, N.M., Rutherford, J.C., Clayton, J.S. 1999. A monitoring and classification system for New Zealand lakes and reservoirs. Lake and Reservoir Management 15:4: 255-271, DOI: 10.1080/07438149909354112.*

[2] *National Environmental Monitoring Standard (NEMS): Water Quality, Part 3 of 4: Sampling, Measuring, Processing and Archiving of Discrete Lake Water Quality Data. Available from: https://nems.org.nz/documents/*

Light scattering is usually the dominant component of *c*. In water, light is attenuated by five main components: water itself, coloured dissolved organic matter, phytoplankton, detritus and inorganic suspended solids. Visual clarity is mostly affected by the major scattering constituents of phytoplankton, detritus and inorganic suspended solids. Therefore some lakes with high dissolved organic matter may have high light attenuation as they are highly coloured, yet they can also have high visual water clarity.


Phytoplankton blooms can reduce the visual clarity of a lake. Photo: M. Heath

Opportunities for autonomous monitoring

Beam transmissiometers measure the beam attenuation coefficient, and can therefore be used to estimate visual water clarity. This instrument emits a light source and has a detector to measure the light at a fixed distance from the source. Beam transmissiometers can be deployed in situ in an autonomous mode and are often included as part of a Conductivity Temperature Depth (CTD) instrument used in lake water column profiling. Another optical property of water that can be measured using in situ sensors is turbidity. Turbidity measures the amount of light scattered by suspended material particles in water. In lakes, changes in turbidity may be associated with several different light-scattering constituents, with large variations associated with algal blooms, sediment-laden inflows and resuspended sediments. Turbidity may therefore be a proxy for changes in other variables (e.g., chlorophyll *a* or suspended sediment concentrations). See the factsheet *Monitoring water clarity and turbidity in rivers* for further information on turbidity monitoring using sensors.

Above-water monitoring methods

A variety of above-water methods exist to approximate visual water clarity with a spatial and temporal coverage superior to current monitoring programmes[3]. Water reflectance captured by satellites (e.g., MODIS, Landsat 5, 7 and 8, and Sentinel 2 and 3) can be compared with Secchi disk readings to interpolate Secchi depth across individual lakes and compare values among lakes, potentially including unmonitored lakes. Satellite imagery has some caveats, including:

- a need for atmospheric correction
- inability to capture images on cloudy days
- potential for sun glint
- frequency dictated by the satellite overpass rate (usually a few days) and
- land or near-land pixel contamination as well as bottom reflectance – often in shallow areas from light reflecting off the lake bottom or submerged macrophytes.

More research is required to support widespread adoption of satellite data for visual water clarity assessments in New Zealand lakes, but the payback is the potential for obtaining comprehensive geospatially referenced visual water clarity datasets at reduced cost.

Similarly, spectroradiometers and some cheaper RGB cameras may be deployed above the water surface of a lake or on drones to provide a continuous daytime measurement of a few metres in area (fixed deployment) or a wider area (drone flight path) to estimate visual water clarity at high resolution.

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[3] *Lehmann, M.K., Nguyen, U., Muraoka, K., Allan, M.G. 2019. Regional trends in remotely sensed water clarity over 18 years in the Rotorua Lakes, New Zealand, New Zealand Journal of Marine and Freshwater Research 53:4: 513-535. DOI: 10.1080/00288330.2019.1609051.*

How much will it cost?

The cost of carrying out a visual clarity monitoring programme measuring Secchi depth will depend on how often measurements are taken and the location of the site. Some approximate operational costs are given in Table 1, based on a survey of regional councils in 2023. The table shows the average cost of a single monitoring occasion of one site on a lake, requiring a boat.

Secchi depth is quick to measure and requires low-cost equipment. Assuming other measurements and water samples are being collected (e.g., for laboratory measurement of nutrient and chlorophyll *a* concentrations), in practice the collection of Secchi depth measurements will add very little to the overall cost of a lake monitoring programme. For more details, see the Monitoring Costs document on the Monitoring Freshwater Improvements website.

Table 1: *Average operational costs of measuring Secchi depth in a lake using a boat.*

	Cost per sampling occasion
Boat operational costs	$260
Mileage	$35
Staff time – sampling and data processing	$330
Total per sampling occasion	**$625**

The cost of operating a high-frequency beam tranmissiometer on a lake buoy monitoring site will depend on many factors, such as:

- the type of sensor chosen and calibration frequency
- sensor and buoy set-up and maintenance requirements
- whether data are stored internally by the transmissiometer probe and periodically manually downloaded or transmitted (telemetered) via cell phone or satellite connection.

Table 2 shows the approximate costs of setting up and running a lake buoy with a transmissiometer. These costs exclude capital expenditure associated with vehicles, but include average mileage and boat operation costs, as indicated by a survey of regional councils in 2023. Note that equipment (transmissiometer, telemetry unit, data logger etc) may need to be replaced after ~6–10 years of use.

Table 2. *Estimated costs (CAPEX = capital expenditure and OPEX = operating expenditure) for setting up and running a lake buoy with a beam transmissiometer. Note that a formal calibration process is not included in the costs.*

	CAPEX	OPEX p.a.
Transmissiometer	$15,000	
Telemetry unit (with data)	$3,000	$200
Installation and ongoing cost (buoy, telemetry set-up, data logger, staff time, maintenance, average mileage, boat running costs)	$15,000	$8,000
Staff time for data processing		$960
Total	**$33,000**	**$9,160**

While high-frequency lake water quality monitoring can provide valuable information on lake processes, it is typically most useful as part of a broader programme of lake monitoring that includes, for example, monthly water quality sampling and measurements (including Secchi depth)[4].

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[4] *Based on information contained in: McBride, C.G. 2023. High-frequency monitoring of lakes: sensor options and approximate costs. Client report 2023-011. Limnotrack, Hamilton, New Zealand. 12 pp.*

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