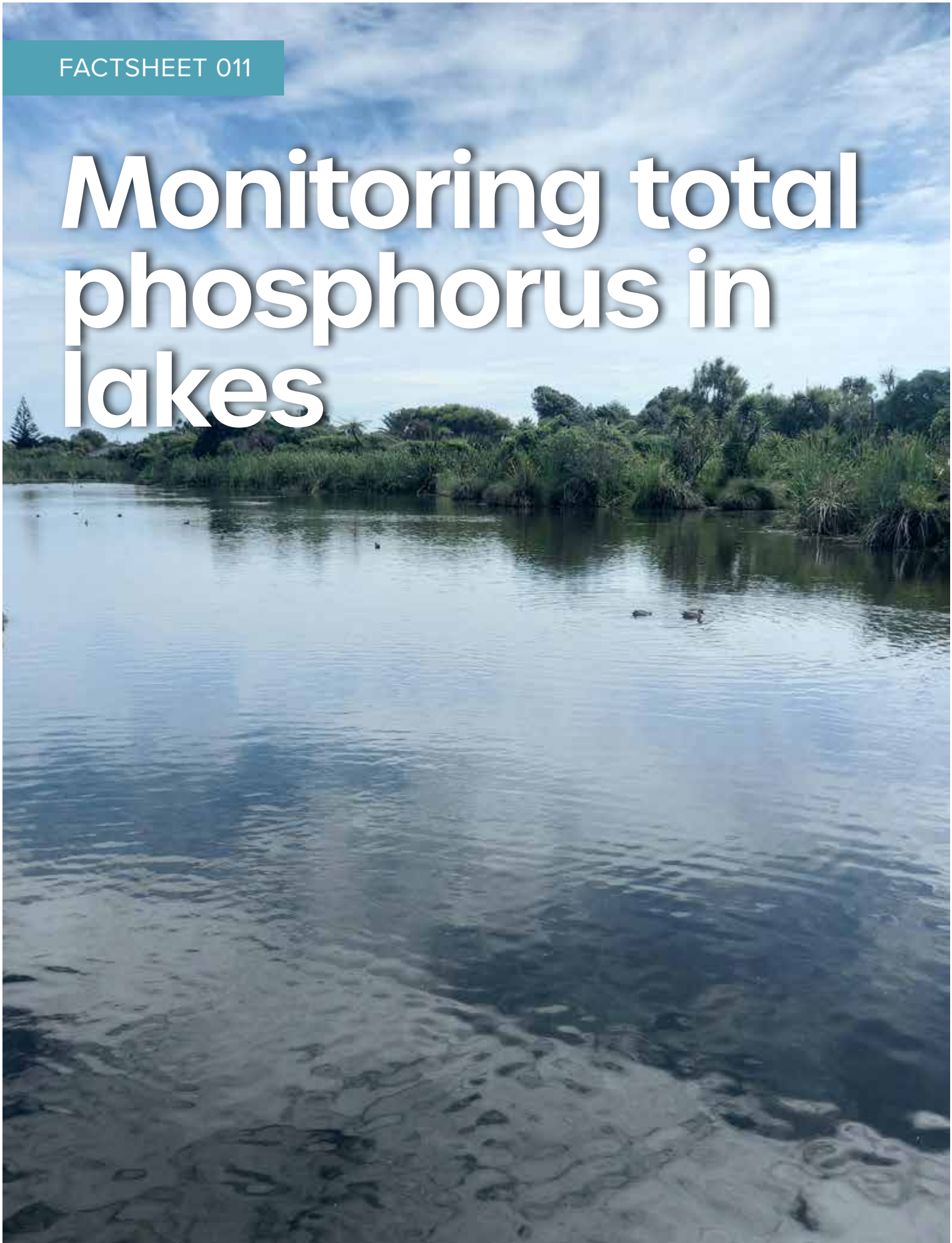
FACTSHEET 011

Monitoring total phosphorus in lakes



OUR LAND AND WATER

Toitū te Whenua, Toiora te Wai

National Science Challenges

Monitoring Freshwater Improvement

Phosphorus is an essential nutrient for the growth and development of plants and animals. However, elevated phosphorus concentrations in a lake can lead to eutrophication, a process that stimulates algal or aquatic plant growth to nuisance levels. Excessive algal or plant growth, especially when accompanied by cyanobacteria blooms, can impact a lake's ecological health, recreational and cultural values.

Phosphorus occurs naturally as phosphate bound to rocks and soil, and during weathering processes it is dissolved and released into water in a plant-available form. Total phosphorus in water includes all dissolved and particulate forms, both in organic and inorganic form. The most biologically available form of phosphorus is ortho-phosphate (PO_4^{3-}), which is commonly expressed analytically as dissolved reactive phosphorus (DRP). Under certain conditions, other forms of phosphorus can also become biologically available.

While phosphorus occurs naturally in rivers, lakes and groundwater, concentrations are generally very low in the absence of land use impacts and contaminant discharges (catchments with volcanic soils are one exception). Unlike nitrogen, most phosphorus attaches to soil particles, such that high phosphate concentrations in surface water are typically associated with high levels of soil erosion and overland runoff. Other sources of phosphorus include phosphate fertiliser and discharges of wastewater or animal effluent.

Phosphorus in lakes

Phosphorus enters lakes from inflows (rivers, streams and groundwater) and dust deposition. It can also come from the bottom of the lake when wind and wave action cause sediment resuspension, or when anoxia (absence of dissolved oxygen) of the bottom sediments or lower water column causes releases of dissolved phosphorus (e.g., PO_4^{3-}). Concentrations of total phosphorus can vary within a lake, particularly when there is seasonal stratification in deep lakes, leading to marked differences in concentrations and forms of phosphorus between the warm surface waters and cooler bottom waters. Near the surface, PO_4^{3-} can be depleted to levels below analytical detection limits, with most of the phosphorus contained within phytoplankton cells. In bottom waters, the PO_4^{3-} accumulates until seasonal mixing occurs, when surface and bottom waters become largely homogeneous.

Streams with high phosphorus can contribute to in-lake phosphorus concentrations.

Why is it important to monitor total phosphorus in lakes?

Monitoring total phosphorus 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. Total phosphorus is one of four attributes (along with total nitrogen, Secchi depth (visual clarity) and chlorophyll *a*) used to determine the 'Trophic Level Index' for New Zealand lakes[1].

Total phosphorus is both an indicator of potential for eutrophication, particularly when associated with elevated levels of PO_4^{3-}, and an outcome of eutrophication, as phosphorus is contained in phytoplankton cells. For this reason, strong positive linear correlations have been demonstrated between concentrations of chlorophyll *a* and total phosphorus, with the former used as a surrogate for phytoplankton biomass (see the factsheet *Monitoring chlorophyll a in lakes*).

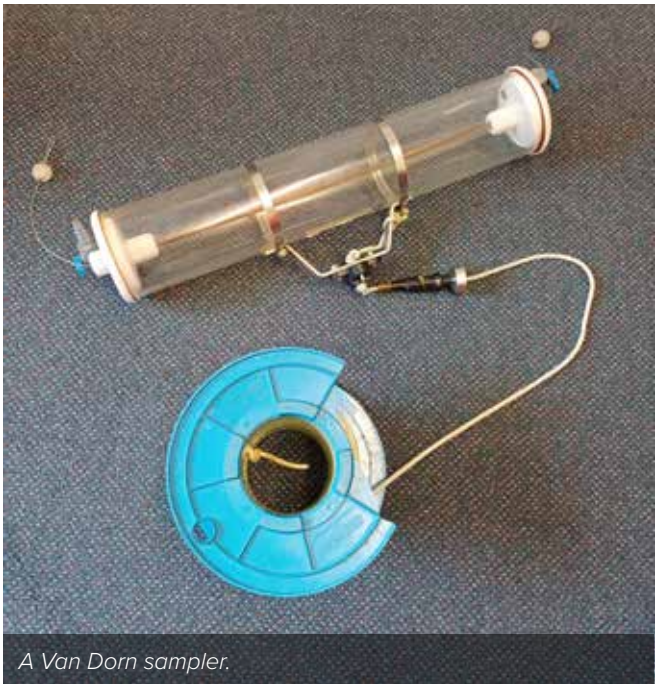
How do we monitor total phosphorus in lakes?

Monitoring total phosphorus concentrations in lakes involves taking water samples at known depths (usually monthly) and sending them to a laboratory for testing. The relevant National Environmental Monitoring Standard[2] provides information on how to collect, store and transport lake water samples. It is especially important to be aware of potential chemical interferences (e.g., silica) and ensure that the laboratory can reliably measure concentrations of total phosphorus to the low concentrations found in many lakes.

In the laboratory, the (unfiltered) sample must be digested with strong acid at high temperature and pressure, prior to analysis. This process imposes a major constraint on analysis of total phosphorus in the field using autonomous methods (e.g. a portable sensor). While autonomous ultra-violet and ion selective electrode sensors show some promise for measurements of phosphate, there is no such methodology for total phosphorus in the field.

In some small or shallow lakes, it may be possible to collect water samples by wading from the lake edge. However, in many cases, a boat, drone or helicopter will be required to sample from an appropriate site, often located at the deepest point of the lake. Special sampling equipment, such as a Van Dorn sampler (a type of sampler that enables samples to be taken from specific depths), may be required.

High phosphorus in a lake can indicate eutrophication (excess nutrients), which can stimulate phytoplankton growth leading to blooms. Photo: M. Heath



A Van Dorn sampler.

[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: 10.1080/0743814990935412.*

How much will it cost?

The cost of monitoring total phosphorus at a lake site will depend on how often samples are collected, the location and characteristics of the monitoring site (e.g., whether a boat and special sampling equipment is required) and laboratory charges for analysing the samples. Approximate operational costs for a single sampling occasion, based on a survey of regional councils and commercial laboratories in New Zealand in 2023, are shown in the table. Using these estimates, monthly monitoring of total phosphorus will cost about $8,000 per year. However, in addition there will be costs involved to purchase or hire sampling equipment (e.g., a Van Dorn sampler) and materials (e.g., chilly bins). For more information on the costs associated with running a lake water quality monitoring programme, see the Monitoring Costs information sheet on the Monitoring Freshwater Improvements website.

	Cost per sampling occasion
Laboratory analytical testing (TP)	$25*
Boat (running or hire cost)	$260
Mileage*	$35
Staff time – sampling, data entry	$330
Consumables (e.g., courier, ice)	$20
Total per sampling occasion	**$670**

**Laboratory cost is for one sample. However, depending on depth and stratification of the lake, several samples may be required at each site. Mileage is based on average distance to a lake monitoring site, derived from regional council survey results.*

Note many of these costs (e.g. boat costs, staff time) will stay the same regardless of how many other indicators are monitored.

Sampling from a boat using a Van Dorn sampler. Photo credit: Marlborough District Council

[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/*

Monitoring Freshwater Improvement

www.monitoringfreshwater.co.nz

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