Lake Toba: Insights and Options for Improving Water Quality

- Lake Toba is a unique natural asset of global significance located in the North Sumatra Province of Indonesia. The Lake has a rich cultural heritage and provides a wide range of environmental goods and services, making it one of Indonesia's priority tourism destinations for development.
- Tourism has the potential to attract more than 3.3 million visitors by 2041 (including 265,000 foreign visitors). This could provide long-term sustainable opportunities, including 5,000 additional jobs and an increase in annual tourism spending of IDR 2,200 billion (US$162 million).[1]
- Sustaining the long-term economic and environmental value of Lake Toba depends on addressing the deterioration of water quality. Acceleration in the deterioration of water quality since the mid-1990s has been driven by excessive nutrient loading resulting in algal blooms, massive fish kills, and health concerns. As one of the world's deepest volcano tectonic lakes, management of water quality in Lake Toba is further constrained by an 80-year residence time (i.e., time required to replace water) and non-homogenous mixing that results in compartmentalization of the lake's water (Figure 3).
- Sustainable solutions for addressing the deterioration of water quality are essential for realizing the long-term tourism opportunities and securing sustainable economic development pathways.
- A collaborative process involving local stakeholders, national agencies/ministries/organizations and international experts has proposed a set of investments to help improve water quality in Lake Toba. These investments are based on an assessment of the lake and its basin, and acknowledge the need for improved information, institutional coordination, and an Integrated Lake Basin Management Platform.

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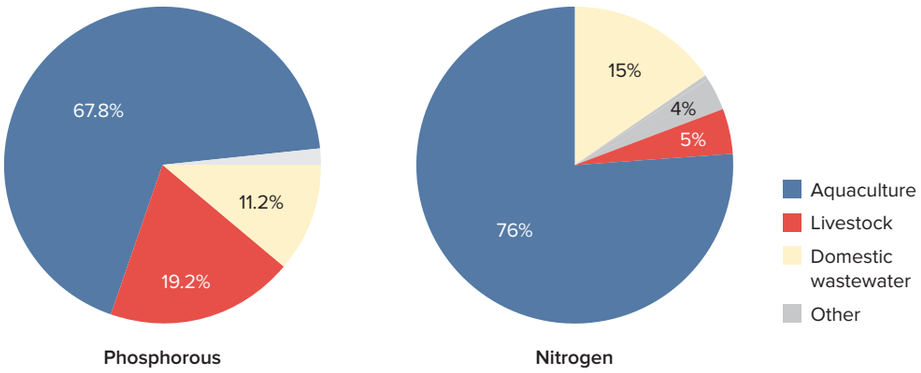
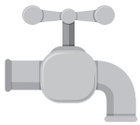
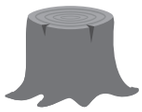
FIGURE 1. Relative contributions of total phosphorus (left) and total nitrogen (right) emission loads into Lake Toba (2015)



Source: World Bank (2018). *Improving the Water Quality of Lake Toba—Final Report.*

TABLE 1. Overview of primary sources of nutrient emissions into Lake Toba

	Aquaculture constitutes point-sources of pollution and accounts for **68 percent of total phosphorous** and **76 percent of total nitrogen** emissions into Lake Toba. Aquaculture development since the 1990s has culminated in a production capacity of more than 80,000 tons/fish/year in 2015. The main emissions of nitrogen and phosphorous come from fish feed, fish manure, and fish carcasses. Phosphorous emissions doubled to an estimated 2,124 tons between 2012 and 2016. This is equivalent to wastewater emissions from 2.3 million people.
	Livestock manure accounts for **19 percent of total phosphorous** and **5 percent of total nitrogen** emissions into Lake Toba. Emissions from livestock manure, either directly at shorelines or indirectly through waterways and groundwater in the catchment, constitute non-point sources of pollution. Livestock manure emissions correspond to population growth and livelihood options, with higher concentrations on Samosir Island and along the western shores of Lake Toba.
	Emissions from human wastewater and sewage of 0.5 million people living in the catchment account for **11 percent of total phosphorous** and **15 percent of total nitrogen** emissions into Lake Toba. Excessive emissions from wastewater enter the lake as non-point sources because of a predominant use of pit latrines and because the area's only wastewater treatment facility at Parapat is operating at 10 percent capacity. Few residents around Lake Toba are connected to off-site managed sewer networks, and on-site sanitation facilities in urban areas are mostly pit latrines, meaning that human waste is in direct contact with groundwater connected with the lake system, and with surface water during high rainfall events.
	Significant land-use changes and deforestation have occurred in the southwest areas of Lake Toba since 2000, in the Aek Manira/Silang watershed, which have exacerbated erosion and runoff into Lake Toba (e.g., approximately **1 percent reduction in vegetative cover between 2000 and 2010**). The projected 66 percent growth of urban areas in the catchment between 2018 and 2042, as well as accelerated development of land for industries and tourism, need to be managed to avoid exacerbating the emissions of nutrients and sediments released from erosion and deforestation.

Source: World Bank (2018). *Improving the Water Quality of Lake Toba—Final Report.*

Scale of the Problem

The quality of water in Lake Toba has deteriorated since the mid-1990s. Key indicators, such as dissolved oxygen, chlorophyll-a, and transparency, all reflect increasing levels of eutrophication. This is a process through which excessive amounts of dissolved nutrients stimulate the growth of aquatic plants. These can manifest in nuisance algal blooms and reduce oxygen levels, causing massive fish kills and other persistent environmental issues.

Government regulations require the nutrient inputs be managed within oligotrophic levels (i.e., to maintain its natural balance of oxygen and nutrients) and its classification as suitable for drinking, *Class-A: Raw water for drinking water.* However, current concentrations of nitrogen and phosphorous in the lake are indicative of mesotrophic or eutrophic conditions. There are a variety of potential point and non-point sources of nutrient inputs that can contribute to eutrophication. In Lake Toba, the assessment of water quality identifies the three primary sources of increased concentrations of nitrogen and phosphorous as aquaculture, livestock, and domestic wastewater (Figure 1, Table 1).

Recommendations

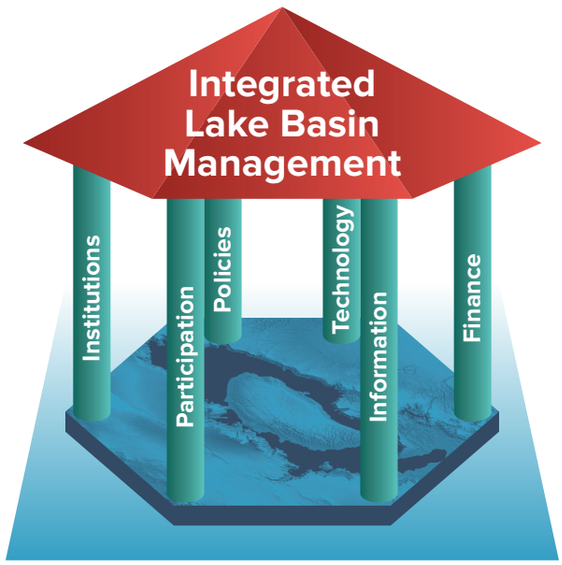
The Government of Indonesia is preparing an integrated, cross-ministerial and cross-sector approach for the future development of tourism at Lake Toba. This includes the development of comprehensive solutions for improved management and monitoring of the lake's water quality. To support the government, the

comprehensive assessment *Improving Water Quality in Lake Toba, Indonesia* (World Bank, 2018) has identified the following four recommendations:

The long-term sustainable development and implementation of an Integrated Lake Basin Management Platform. This requires adequate resources and enhanced coordination across the responsible agencies. Lakes and their catchments are a single interacting and interdependent management unit that need to be managed through an integrat ed framework to respond adequately to lake use management. This creates a variety of challenges, particularly because the boundaries of lake basins rarely coincide with established political and administrative systems. Addressing the challenges of lake basin management requires due consideration of the information requirements to inform timely decisions, the appropriate institutional and policy requirements, stakeholder participation, and targeted investments to ensure effective management responses (Figure 2).

Improvements in water quality can only be achieved through enforcement of policy measures relating to the carrying capacity of Lake Toba. Significant research has been conducted to determine the carrying capacity for aquaculture production. This has been established through government regulation at 10,000 tons of fish per year. Despite several assessments and regulations, the production capacity in 2015 exceeded 80,000 tons of fish per year. The enforcement of policy measures will require supporting measures to facilitate the transition in the structure of the local economy and livelihood restoration of those affected. Other investment options and catchment management measures, including the control of emissions from livestock manure and wastewater, can provide incremental gains but are not enough in isolation. Enforcing policy measures on established limits to the carrying capacity of aquaculture is critical to facilitate the transition of the lake to long-term oligotrophic conditions, and to protect the long-term water quality of Lake Toba that sustains ecosystems, drinking water supply, people's well-being and economic activity such as tourism.

FIGURE 2. **Conceptual model for integrated lake management and monitoring**



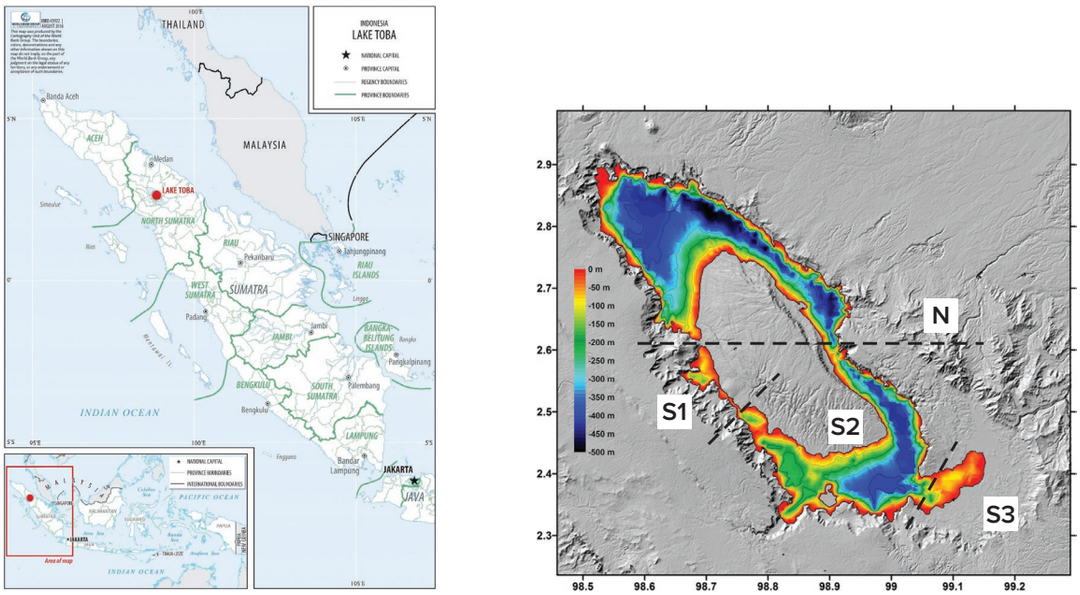
Source: International Lake Environment Committee Foundation, 2018.

A comprehensive and integrated water quality monitoring plan with a shared information management platform is required to assess the outcomes of any intervention and adapt to changing circumstances. Such a plan and platform should be capable of integrating data from several different sources to provide timely and

accurate data on lake dynamics and inform adaptive management of Lake Toba. New and innovative techniques, such as using various remote sensing techniques and ICT services, can be integrated to supplement traditional in situ measurements.

Cooperative institutional mechanisms are needed to provide an interagency platform and the enabling environment for the integrated management of Lake Toba. The success of any interventions to address the challenge of sustainable development in Lake Toba relies on the contributions of several different agencies across various sectors and levels of government. The scope of this analysis primarily covered the drivers of deteriorating water quality of Lake Toba and a range of interventions that will be necessary to address nutrient emissions into the lake. However, these scenarios highlight the importance of improving coordination and cooperation among relevant government agencies and other stakeholders. Realizing improvements in the water quality of Lake Toba ultimately requires fully functioning, financially viable cooperative institutional arrangements.

FIGURE 3. **Lake Toba compartment modelling (north, south 1, south 2 and south 3 compartments)**



Source: World Bank (2018). *Improving the Water Quality of Lake Toba—Final Report.*

1 Tourism spending in the Lake Toba area was IDR 931 bn (US$69 m) in 2015. Source: Howarth Hotel, Tourism and Leisure (HTL). 2017. *Lombok/Borobudur-Yogyakarta-Prambanan/Lake Toba: Baseline demand and supply, market demand forecasts, and investment needs.* Prepared for the World Bank. Available at: bpiw.pu.go.id/uploads/20170302_Lake_Toba_Market_and_Demand_Assessment.pdf; and World Bank. 2018. Indonesia—Integrated Infrastructure Development for National Tourism Strategic Areas (Tourism Development Project). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/839781527910281861/Indonesia-Integrated-Infrastructure-Development-for-National-Tourism-Strategic-Areas-Tourism-Development-Project