2021 State of The Lake Report

OCT
2021

LAKE CHELAN, WA

LEARN ABOUT
& HELP MAINTAIN
THE PRISTINE
WATER QUALITY OF
LAKE CHELAN

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Executive Summary

The long-term sustainability of the clear, blue water that characterizes Lake Chelan is key to the economic viability of this region. Over recent decades, Lake Chelan has experienced significant changes including substantial development in the lower part of the Chelan Valley. Increasing population, tourism growth, changing land use, and invasive species threaten this sensitive aquatic ecosystem.

In open water, Lake Chelan exhibits remarkable long-term stability in water clarity, nutrient concentrations, and growth of algae. This stability reflects the large, mostly pristine nature of the lake's watershed. The nearshore environment of Lake Chelan is less stable, undergoing a transition in which algae along the shoreline have increased and Aquatic Invasive Species (AIS) have expanded over the last few decades.

Increases in algae and AIS along the shoreline are likely sentinels for long-term changes that could impact the entire lake. This situation underscores the importance of continuing systematic, long-term water quality monitoring to further our understanding of the year-to-year changes occurring within the lake.

Continued monitoring is vital to assess the impact of environmental events and allow early detection of water quality trends. Results will provide crucial information to management and conservation efforts, focusing local actions to control undesirable changes in Lake Chelan.

Lake Chelan Setting

Lake Chelan, located in Chelan County, was formed by glacial retreat at the end of the last ice age and is the largest natural lake in Washington State.

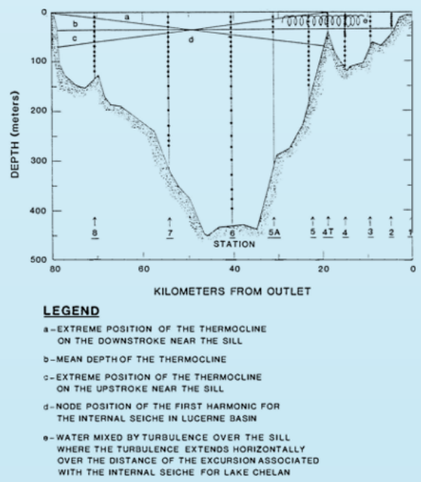
Lake Chelan consists of two distinct basins, separated by a relatively shallow “sill” at the narrowest part of the lake. The larger basin is the Lucerne Basin and the smaller is the Wapato Basin.

Wind-generated waves mix warmer surface waters to depths of roughly 100 feet, the “thermocline” depth. As air temperatures decrease in the fall and winter, surface waters cool and eventually mix throughout the depths of Lake Chelan.

The elongated shape of the lake, coupled with periodic strong winds, cause a significant water movement phenomenon known as an “internal seiche,” a slow but large internal rocking motion of the thermocline during the summer months. Although the surface elevation of the lake changes only slightly during this motion, the internal seiche raises and lowers the thermocline by roughly 100 feet at the two ends of the Lucerne Basin every few days (see graphic right, *Patmont et al. 1989; Selker et al 2021*). Lake Chelan’s internal seiche is among the largest documented in the world, and results in regular fluctuations of surface water temperatures readily apparent to swimmers.

Constructed in 1927, the Lake Chelan Hydroelectric Project raised the level of the lake by approximately 21 feet. Construction of the dam allowed the lake to be operated as a storage reservoir for power production. The lake level is maintained at full pool during the peak recreational season (June - September) but is typically lowered ~15 feet during the fall and winter months as power is generated. Nearly the entire Lake Chelan outflow is diverted through a penstock for power production, producing approximately 50 megawatts of electricity. Discharge from the powerhouse flows through a tailrace into the Chelan River and then into the Columbia River.

The population centers of Chelan and Manson, as well as most shoreline and nearshore residential properties on Lake Chelan, obtain their water supplies directly from Lake Chelan. The Lake Chelan Reclamation District draws both its irrigation and domestic (drinking) water supply from Lake Chelan. While community water systems treat drinking water supplies, the nearly pristine nature of the lake allows many individual residential properties to pump drinking water directly from the lake without treatment.

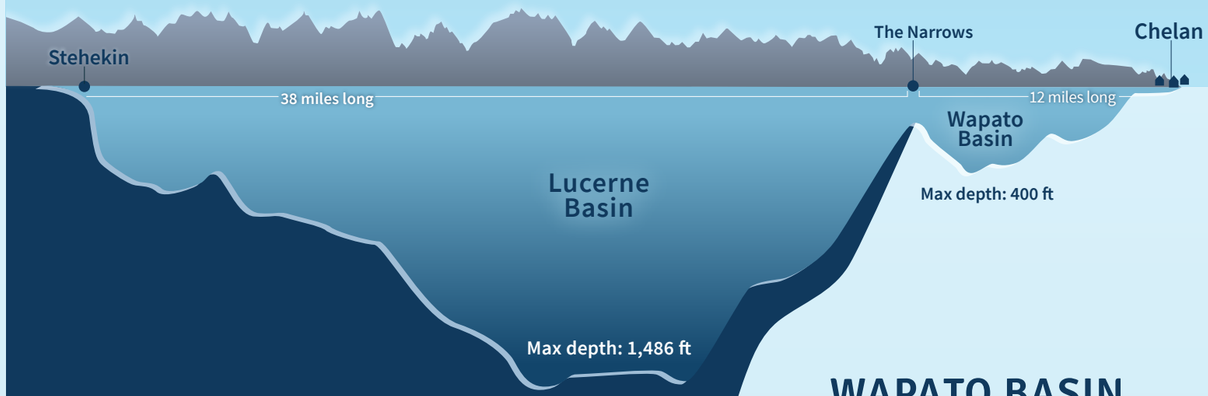


1st
Largest Natural Lake in Washington State

3rd
Third Deepest Lake in the United States

52
52 Square Miles of Total Surface Area

920
Entire Watershed Encompasses 920 Square Miles



LUCERNE BASIN

- Three times longer than the Wapato Basin and almost four times deeper
- Constitutes 92% of Lake Chelan’s total volume
- Water originates from forested and glacial fed tributaries
- Largely undisturbed by human activity
- Water resides in the Lucerne Basin for 10 years on average

WAPATO BASIN

- Surface temperatures are considerably warmer during the summer months than the Lucerne Basin
- Contains most of developed land within the watershed
- Contributes much of the total nutrient and bacterial loading
- Water quality characteristics here are a principal concern for lake use

Water Quality Monitoring Programs

Although periodic water quality monitoring of Lake Chelan began as early as the 1960s, the first detailed "baseline" water quality characterization of the lake wasn't completed until 1987. Subsequent water quality monitoring efforts largely focusing on nutrients occurred in 1995, 1996, 1999, 2007, 2018 and 2019. These data, discussed in more detail below, reveal that much of Lake Chelan continues to be nearly pristine, with exceptional water clarity and few identified water quality limitations. However, localized water quality degradation has been observed near irrigation return flow drainage outfalls and near the population centers of Chelan and Manson.

As humans develop the watershed, added nutrients can significantly alter water quality by reducing clarity through increasing microscopic algae in the lake. These nutrients can change the quality of beaches by promoting algae growth on rocks. Knowledge of the effect of these nutrient inputs from human development is critical to encourage responsible development.

The nutrient phosphorus controls the growth of algae in Lake Chelan. Approximately 10 to 25 percent of the phosphorus entering Lake Chelan is from human activities, with roughly half of this total coming from agricultural sources. Most sanitary wastes from businesses and residences along the lake shoreline are collected and treated by a regional sewer system that discharges into the Columbia River. Residences outside Chelan and Manson continue to use on-site waste treatment facilities.

Stormwater Runoff Can Contain:

- *Fertilizers*
- *Pesticides*
- *Herbicides*
- *Fecal Matter*
- *Various Pollutants*

Stormwater runoff can carry sediments and a variety of pollutants into Lake Chelan including: fertilizers, pesticides, and herbicides from agricultural and residential applications. The Lake Chelan Reclamation District and the Chelan County Conservation District have implemented irrigation water management programs. These programs are designed to minimize the amount of irrigation water used on orchards, maintaining orchard productivity while minimizing the amount of agricultural runoff.

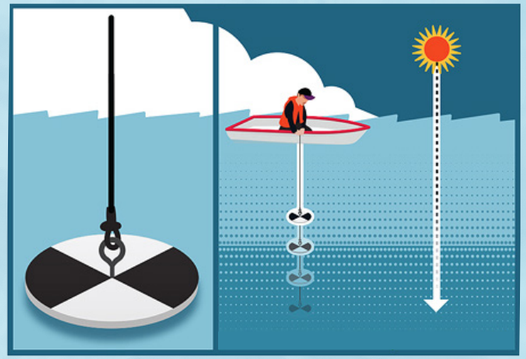
The following sections discuss the current state of water quality in the Wapato Basin and nearshore zones of Lake Chelan and trends over the last several decades.

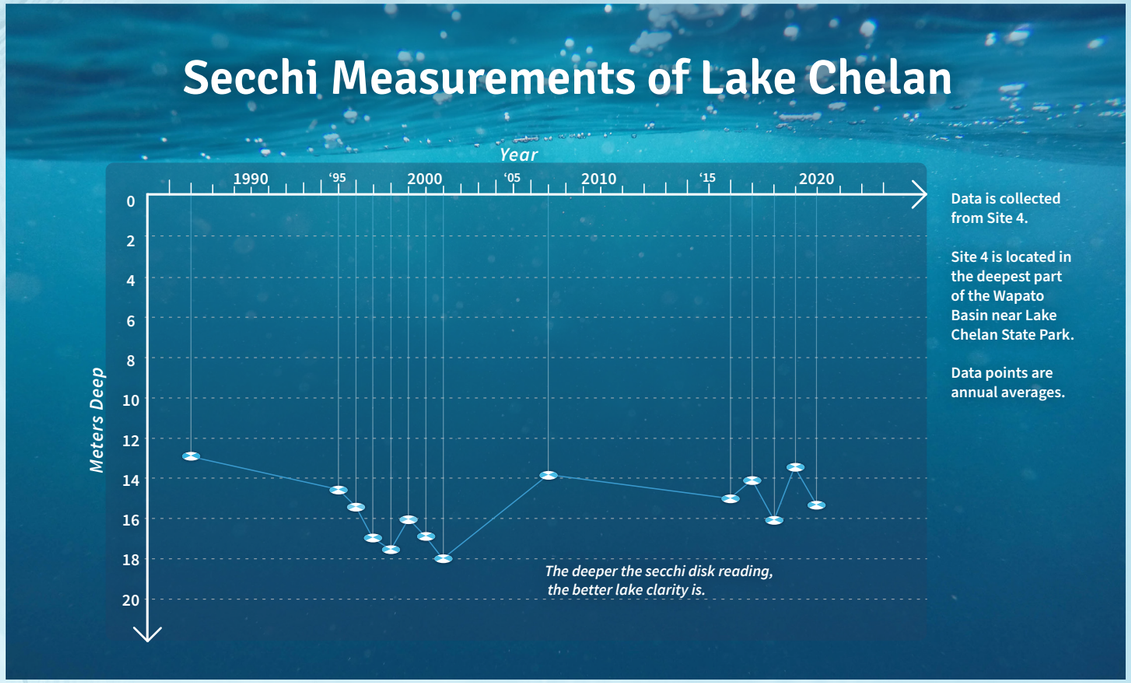
Wapato Basin Water Quality Status

Key water quality metrics for the Wapato Basin include water clarity, total phosphorus concentrations, chlorophyll concentrations, and dissolved oxygen depletion rates. Discussed below, these metrics have been remarkably stable for the past several decades.

1 Water Clarity

Water clarity is measured by using a "Secchi" disk that is mounted on a line and lowered slowly into the lake until it can no longer be seen from the surface. This disk, developed by Angelo Secchi in 1855, has become the world standard to measure water clarity. Below is a graphic showing water clarity measurements within the Wapato Basin (Site 4) over the last several decades. Fortunately, the greater Wapato Basin and other areas of Lake Chelan have maintained very high water clarity.





Wapato Basin Water Quality Status

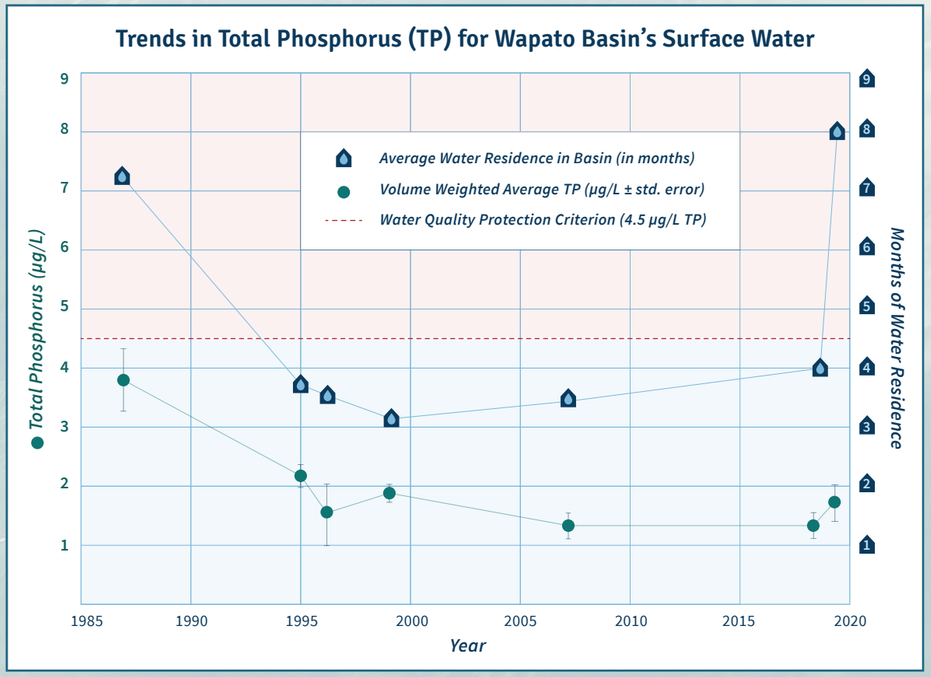
2 Total Phosphorus

Total phosphorus (TP) concentrations in lake surface waters provide a direct measure of nutrient fluxes to the Wapato Basin and control the growth of algae in Lake Chelan.

In 1991, the Washington State Department of Ecology and the U.S. Environmental Protection Agency established a TP concentration goal for the Wapato Basin of 4.5 micrograms per liter (µg/L) to protect its nearly pristine (ultra-low nutrient input and organic production) water quality.

Below is a graphic showing TP concentrations within the Wapato Basin (Sites 2 and 4; average values in surface water) over the last several decades, along with water residence time, which influences nutrient flux through the lake.

For the most part, TP concentrations in the Wapato Basin have declined over time and are successfully being maintained below the 4.5 µg/L water quality protection criterion. While these data are encouraging, human activity is increasing so we will need to take extra care to reduce our nutrient impact going forward.

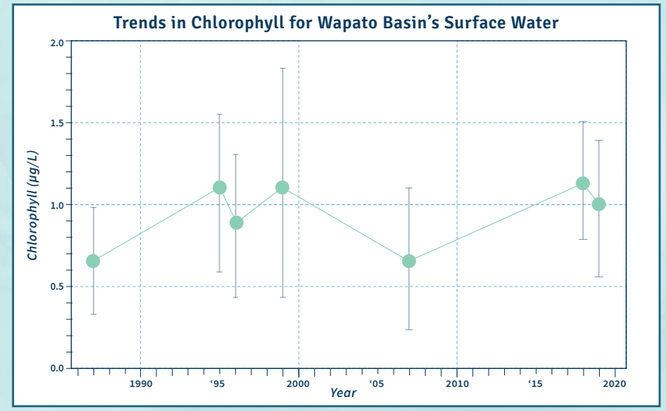


3 Chlorophyll

Measured concentrations of chlorophyll provide a direct estimate of the abundance of algae in surface waters of the Wapato Basin.

These results mirror the water clarity and TP concentration data summarized above (i.e., levels have remained low over the last several decades, see figure at right).

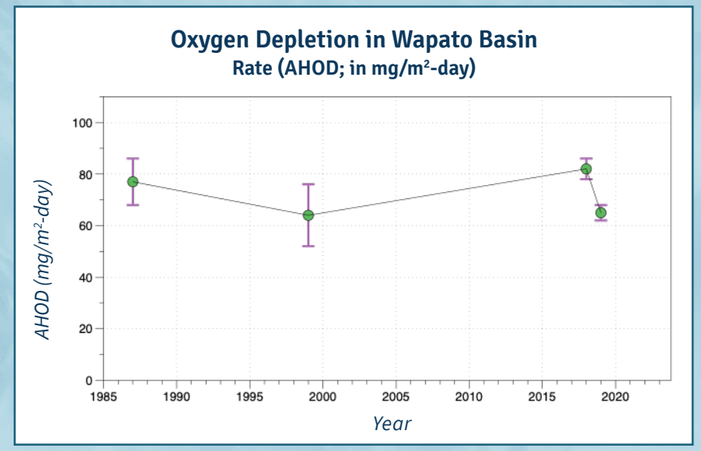
While we do not want nuisance amounts of algae, some amount is necessary because it is at the base of the food web that supports fish and other aquatic organisms.



4 Bottom Water Oxygen Depletion

As algae sink to the bottom of the lake, they decrease the oxygen concentration in bottom waters as they decay. The rate of dissolved oxygen depletion in the deep part of a lake from algae sedimentation and decay provides a sensitive measure of nutrient enrichment.

The rates of oxygen depletion within the deep (300 feet) Wapato Basin (Site 4) over the summer period are shown in the figure to the right. Again, oxygen depletion rates have remained low over the last several decades. The stability of oxygen depletion rates is additional excellent news for Wapato Basin water quality. Ongoing monitoring of oxygen depletion as well as other key water quality metrics is important to continue to ensure that Lake Chelan is protected into the future.

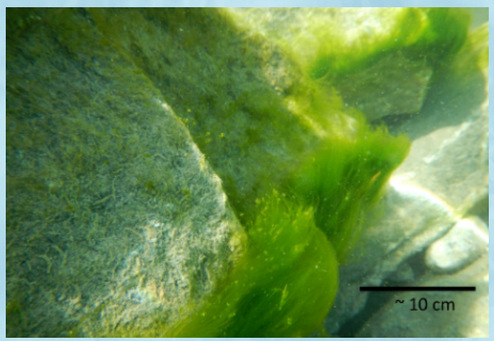


Nearshore Water Quality

Offshore Wapato Basin has mainly maintained its pristine status in water clarity. Unfortunately, this is not the case within nearshore ("littoral") areas of the lake. Accordingly, LCRI and CCNRD are focusing attentions on algae, pathogen indicators, and aquatic invasive species (AIS).

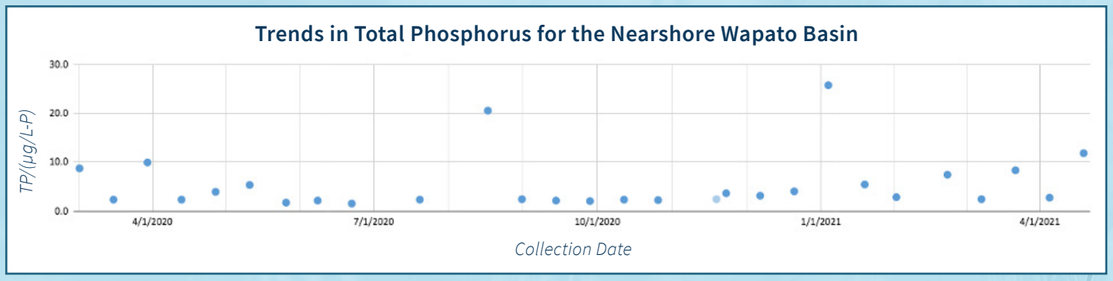
1 Nearshore Algae

Over the last several decades, researchers and waterfront homeowners have observed increasing amounts of attached algae ("periphyton") growing on nearshore rocks and structures along developed shorelines in the Lucerne and Wapato Basins. An example of profuse filamentous green algae growth in nearshore areas of Lake Chelan is shown in the photograph to the right (*Matthews and Strecker, 2021*).



Nutrient-rich drains and tributaries that enter the Wapato and lower Lucerne Basins cause 10 to 100-fold increases in periphyton growth, attributable to local TP inputs *(Jacoby et al. 1991)*. Both the composition and density of nearshore algae growth adjacent to drainage inputs exceed nuisance thresholds. In large lakes similar to Lake Chelan (e.g., Lake Tahoe, CA), nearshore periphyton growth is a sensitive, early indicator of nutrient increases that eventually affect the entire basin *(Naranjo et al. 2019).*

To further assess causes of increased nearshore algae, LCRI collected a detailed time series of nutrient concentrations at a representative nearshore location within the Wapato Basin. Nearshore TP and other measures of nutrient concentrations are variable, but overall are higher than mid-lake values. These data confirm that nutrient inputs are entering the nearshore environment from developed shorelines and drainage inputs. Nearshore water quality and periphyton monitoring are key metrics tracking the overall trajectory of the Lake Chelan environment.



2 Pathogen Indicators

Nearshore areas of the Wapato Basin and Lake Chelan outflow channel also have elevated concentrations of pathogen indicator bacteria. Nearshore bacterial levels exceed recommended levels for drinking water consumption but are within limits established for recreational uses. Many lake residents obtain their drinking water directly from the nearshore area, and local increases in bacterial levels above recommended drinking water levels have been reported for some shoreline locations. Waterfowl activities appear to be the most likely source of the observed bacterial inputs *(Anchor Environmental, 2000)*.

3 Aquatic Invasive Species (AIS)

Over the last several decades, the abundance of three AIS have been increasing in nearshore areas of the Wapato Basin *(AquaTechnex, 2015)*:

- **Eurasian watermilfoil** *(Myriophyllum spicatum)*
- **Curlyleaf pondweed** *(Potamogeton crispus)*
- **Freshwater clams** *(Corbicula fluminea)*
- **Chinese mystery snails** *(Cipangopaludina chinensis) (ESA, 2020)*

Lake Chelan is also at risk from:

- **Invasive zebra mussels** *(Dreissena polymorpha)*
- **Quagga mussels** *(D. rostriformis bugensis)*
- **Flowering rush** *(Butomus umbellatus)*

Always be on the lookout for zebra and quagga mussels

A detailed AIS survey is currently underway, funded by a combination of private donations and the Chelan County PUD. Results for this survey are anticipated to be available in 2022. More AIS surveys are needed to help manage the spread of invasive species and control potential economic and environmental consequences. Watercraft inspections and decontamination efforts are currently underway by the Lake Chelan Watershed Planning Unit and CCNRD.

Eurasian watermilfoil needs to be removed

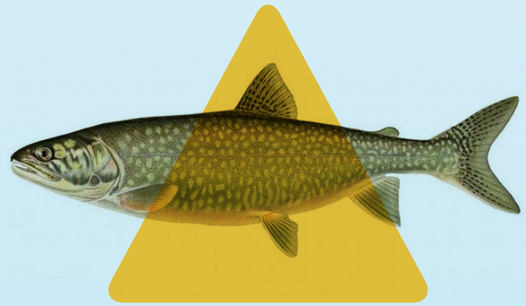
Contaminants in Lake Chelan

From approximately 1940 to 1972, DDT *(dichloro-diphenyl-trichloroethane)* was used in large areas of the Lake Chelan watershed as an agricultural and residential pesticide. DDT and its metabolites *(e.g., DDE; dichloro-diphenyl-dichloroethylene)* continue to migrate through drains and streams into Lake Chelan, where they remain persistent, accumulating in sediment and fish tissue, particularly slow-growing apex predators such as mackinaw (lake trout; *Salvelinus namaycush*; *Coots and Era-Miller, 2005*).

Mackinaw were introduced to Lake Chelan in 1980 and stocked heavily from 1990 to 2000 *(Schoen and Beauchamp, 2010)*. Recent sampling data by the Washington State Department of Ecology (Ecology) reveal that DDT/DDE concentrations in Lake Chelan mackinaw (lake trout) are among the highest levels reported throughout the U.S. and are not measurably declining over time *(Seiders et al. 2012)*.

The Washington State Department of Health has continued a fish advisory for DDT/DDE, limiting consumption of Lake Chelan mackinaw to one meal per week.

Other fish species in Lake Chelan (e.g., burbot, kokanee, and rainbow trout) have low enough contaminant concentrations that consumption of these species is not limited. Ecology is currently conducting a detailed survey of Lake Chelan mackinaw to inform resource managers about potential human health risks and evaluate remediation options. Results from this survey are anticipated to be available in 2023.



Use Caution Consuming Lake Trout (Mackinaw)

Final Summary

In open water, Lake Chelan exhibits remarkable long-term stability in water clarity, nutrient concentrations, and growth of algae. This stability reflects the large, mostly pristine nature of the lake's watershed. The nearshore environment of Lake Chelan is less stable, undergoing a transition in which algae along the shoreline have increased over the last few decades.

Unfortunately, such increases are likely sentinels for long-term changes that could impact the entire lake. This situation underscores the importance of continuing systematic, long-term monitoring of nutrient concentrations. Understanding the year-to-year changes is only possible with consistent monitoring. Continuing such monitoring will clarify the impact of environmental events and allow detection of trends. If trends are identified, we can focus local actions to control undesirable changes as needed.

Next Steps

Long-term monitoring and targeted surveys such as the AIS survey have been made possible by local government agencies support and private donations. Assuming those funding levels continue, we will continue the lake water monitoring program including water clarity, nutrient, chlorophyll, and dissolved oxygen concentrations, adaptively managing the program going forward.

Additional monitoring of open-water and nearshore water quality, monitoring of water quality of targeted creeks and drainages, as well as monitoring AIS spreading are critical next steps for the continued effort to monitor, manage, and conserve Lake Chelan's pristine water quality.

Funding for the continued support of the long-term water quality monitoring at Lake Chelan is provided through Chelan County, Lake Chelan Research Institute, City of Chelan, Lake Chelan Reclamation District, and Cascadia Conservation District. Through funding secured through the U.S. Bureau of Reclamation, Chelan County Natural Resource Department is working to develop a comprehensive AIS Program for Lake Chelan. Funding secured through the National Park Service will support the implementation of a mobile voluntary watercraft inspection program in 2022.

More funding is needed to conduct a field-scale test of AIS control measures (e.g., diver-assisted suction harvester and/or protracted lowering of lake level during freezing weather) and to conduct focused studies to quantify nearshore algae growth. Additional funding is needed to support the purchase of nearshore water quality monitoring devices to ramp up efforts and to leverage nearshore water sampling and support controls for threats to nearshore water quality.

Characterizing the Lake Chelan environment, including remotely operated vehicle (ROV) exploration of the deepest parts of Lake Chelan would enhance our efforts to understand internal lake dynamics and further inform management and conservation efforts.

Finally, additional funding is needed to support the development and implementation of mandatory watercraft inspections in Lake Chelan. On the subsequent page is a summary of currently funded activities for 2022 as well as highest priority activities that require funding for 2022 and beyond.

Workers using the Diver Assisted Suction Harvester to control Aquatic Invasive Species

Next Steps for Funding

Proposed 2023-2025 Activities Requiring Additional Funding

- Assess and recommend controls for threats to nearshore water quality, including nearshore algae and pathogens *($160k)*
- Assess the status of contaminants in Lake Chelan and recommend controls *($50k)*
- Characterize the Lake Chelan aquatic environment, including ROV exploration of the deepest parts of Lake Chelan *($30k)*

Priority 2022 Activities Requiring Additional Funding

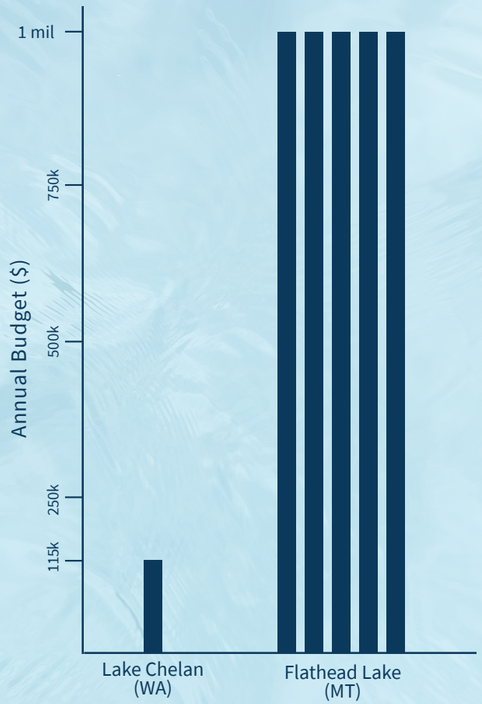
- **Field-scale test of AIS control measures (e.g., diver-assisted suction harvester and/or protracted lowering of lake level during freezing weather)** *($40k)*
- **Additional nearshore water quality monitoring to leverage open-water sampling** *($30k)*
- **Conduct focused studies to quantify nearshore algae growth** *($80k)*

Activities Already Funded for 2022

- Long-term monitoring of open-water and nearshore water quality *($40k)*
- Long-term monitoring of water quality of targeted creeks and drains *($10k)*
- Review of 2021 AIS survey results and recommend controls *($30k)*

We estimate that we spend only 10 to 20 percent of the water quality monitoring budgets of other highly valued lakes in North America. Compared to Flathead Lake (MT) we estimate that we spend less than three percent of their water monitoring and research budget *(see figure below).*

Given the local and national importance of Lake Chelan's water quality, there is broad opportunity for everyone from the managers of environmental agencies to private individuals to support Lake Chelan monitoring and research. By working with Keep It Blue—Lake Chelan, the Lake Chelan Research Institute and the Chelan County Natural Resources Department we can secure the future of Lake Chelan water quality.



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"Additional monitoring of nearshore water quality, targeted creeks and drainages, as well as AIS spreading are critical next steps for the continued effort to conserve Lake Chelan's pristine water quality."

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