



# Lake Cyanobacteria Management Plan

## Blackmans Lake, Snohomish, Washington

Prepared for  
City of Snohomish

Prepared by  
Herrera Environmental Consultants, Inc.

Funded by  
Washington State Department of Ecology Freshwater Algae Program  
Grant Number WQALG 2024 Snohom-00036



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Prepared for  
City of Snohomish  
116 Union Avenue  
Snohomish, WA 98291  
Telephone: 360-568-3115

Prepared by  
Herrera Environmental Consultants, Inc.  
2200 Sixth Avenue, Suite 1100  
Seattle, Washington 98121  
Telephone: 206-441-9080

Funded by  
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## *Herrera Environmental Consultants, Inc.*

Rob Zisette assisted with lake and watershed monitoring. Timothy Clark, Katie Sweeney, and Rob Zisette wrote this document.

## *City of Snohomish*

Mayor Linda Redmon

Councilmembers:

Maygen Heatherington  
Judith Kuleta  
Felix Neals  
Tom Merrill  
David Flynn  
Lee Anne Burke  
Karen Guzak

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**Note:**

Some pages in this document have been purposely skipped or blank pages inserted so that this document will print correctly when duplexed.

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# Executive Summary

## About This Report

Blackmans Lake is a small and valuable lake in the City of Snohomish that suffers from harmful algal blooms (HABs). These HABs are comprised of a group of algae called cyanobacteria, which occasionally produces toxic substances capable of causing illness or death to humans and animals when consumed. Toxic cyanobacteria blooms not only impair beneficial uses of the lake by threatening human, pet, and wildlife health, but also restrict uses of the lake for user protection and form unsightly and odorous scums on the lake surface.

In 1992, the City of Snohomish (“the City”) initiated a Phase I monitoring and restoration study in response to concerns over declining lake conditions, including algae blooms, low dissolved oxygen, high fecal coliform bacteria, and impaired fisheries and habitat quality. This study recommended watershed controls and an alum treatment to reduce phosphorus, the primary nutrient fueling the algae blooms (KCM 1994). Some watershed controls have occurred, but alum treatments have not been performed to control internal sources of phosphorus from low dissolved oxygen. Lake monitoring over the past 30 years has shown increasing levels of phosphorus in the lake that may continue to increase unless actions are taken to reduce nutrient sources and change lake conditions.

In 2022, the City contracted Herrera Environmental Consultants (Herrera) to develop this Lake Cyanobacteria Management Plan (LCMP). Herrera first developed and implemented a watershed and lake monitoring plan to collect data, in order to evaluate what is causing the toxic algae blooms and how best to control them. After this monitoring program began, the City was awarded a grant from the Washington Department of Ecology (Ecology) through the Freshwater Algae Control Grant Program to partially fund the monitoring and preparation of the LCMP. Working with the public, the City, and the County, the LCMP identifies community concerns, develops priorities, outlines goals and objectives, and describes a lake management strategy to reduce the frequency and duration of toxic algae blooms and restore recreational use. The LCMP will be used as a guideline and tool for allocating resources to implement the recommended management activities, with a framework and decision steps for future management needs.

# What are Cyanobacteria and Why are They a Problem?

Cyanobacteria (also called “blue-green algae”) are a diverse group of bacteria found in freshwater, saltwater, moist soils, and even within plants and lichen. Cyanobacteria are a normal part of the algae community in lakes but, under certain conditions, they can also form unsightly scums. Some cyanobacteria also produce toxins (“cyanotoxins”), like anatoxin-a or microcystin, that are harmful to humans and animals when consumed or upon contact with skin. Cyanobacteria may have several competitive advantages over other algae, including the ability to fix nitrogen and store phosphorus (two crucial nutrients for growth). In addition, they can regulate their buoyancy, moving up and down in the water column; they have low energy demands; and they are generally unpalatable to grazers that eat algae.



Cyanobacteria bloom on Blackmans Lake, November 10, 2022.

# Why Does Blackmans Lake Have Toxic Algae Blooms?

Cyanobacteria bloom in Blackmans Lake because there is an abundance of nutrients to fuel their growth. For the LCMP, lake and watershed monitoring occurred between November 2022 and October 2023. We found the amount of algae growth is primarily controlled by the amount of phosphorus. Cyanobacteria were frequently the dominant algae group in summer. When cyanobacteria populations reach high densities, they often produce cyanotoxins at levels that are harmful to human health.

Cyanobacteria blooms are typically seen in August through October, and toxic levels over the state guidelines have been seen in October only. Toxic blooms in Blackmans Lake are predominantly made up of *Dolichospermum sp.*, which produce a liver toxin (microcystin) and neurotoxin (anatoxin). Since cyanotoxin monitoring began in 2009, microcystin concentrations have exceeded the state recreational guideline of 8 micrograms per liter (µg/L) in two samples, one in 2017 and one in 2021. A maximum concentration of 21.6 µg/L was observed in 2021. Anatoxin has not exceeded the recreational guideline of 1 µg/L. Snohomish County frequently posts Warning signs at the two public parks to not swim in the lake when they observe algae scums that look like cyanobacteria and without testing cyanotoxin levels.



## Where is the Excess Phosphorus Coming From?

There are three major pathways of phosphorus to Blackmans Lake: (1) internal release from lake sediments, (2) waterfowl feces, and (3) stormwater runoff. Figure ES-1 presents a diagram of a lake phosphorus cycle, with inputs, outputs, and transformations of phosphorus in a lake. The annual and summer phosphorus budgets of inputs and outputs to Blackmans Lake for water year 2023 are summarized in Table ES-1 and presented graphically in Figures ES-2 and ES-3.

Figure ES-1. Example Diagram of a Lake Phosphorus Cycle.

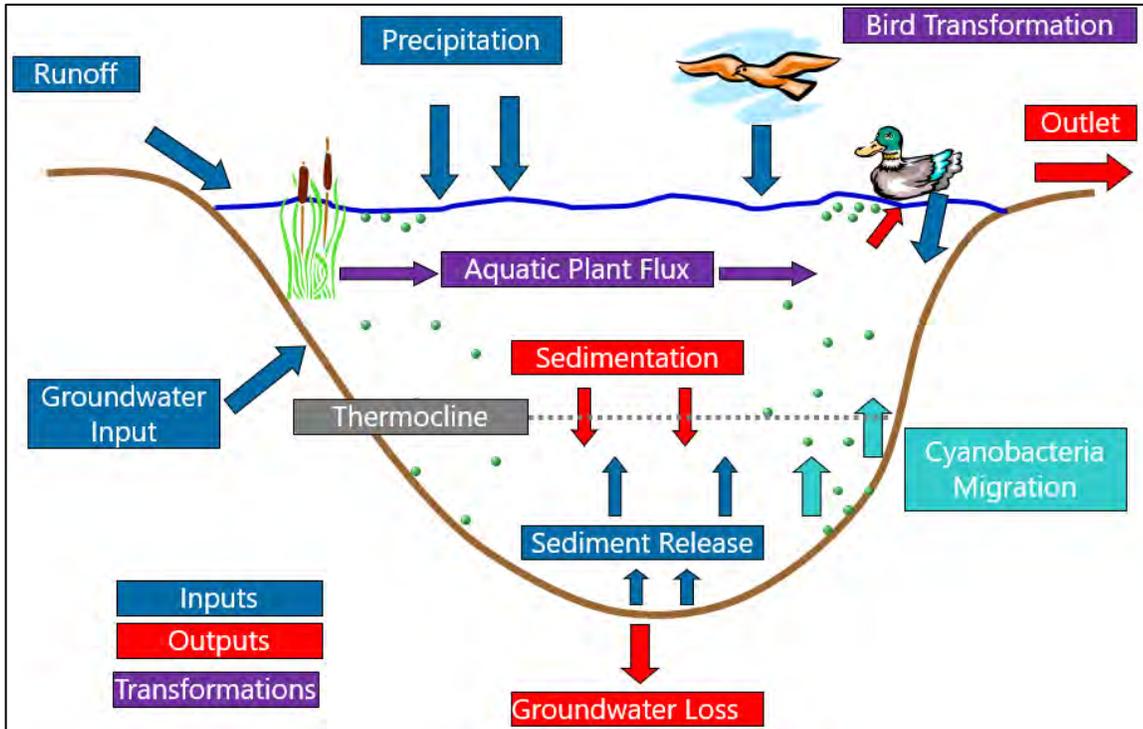


Table ES-1. Annual and Summer Total Phosphorus Loads to Blackmans Lake.

Pathway	Annual		Summer (May to October)	
	Mass (kg)	% of Total	Mass (kg)	% of Total
Watershed Base Flow	2.2	2.1%	1.1	1.5%
Watershed Storm Flow	17.0	15.8%	4.7	6.1%
Aerial Deposition	5.0	4.7%	1.4	1.8%
Groundwater Inflow	9.8	9.1%	0.4	0.5%
Waterfowl	24.7	22.9%	20.4	26.5%
Sediment Release	49.0	45.5%	49	63.7%

Sediment release estimates ranged from 26 to 79.6 kg per year, based on various estimation methods.

Most of the phosphorus loaded to the lake via waterfowl feces is not immediately available for algae growth and falls to the lake sediments, where it is later released from sediments via the internal load.

Most of the stormwater phosphorus is loaded to the lake during the winter months and falls to the lake sediments, where it is later released from sediments via the internal load during the summer algae bloom season.

Figure ES-2. Annual (November 2022 to October 2023) Phosphorus Loads (kg) to Blackmans Lake.

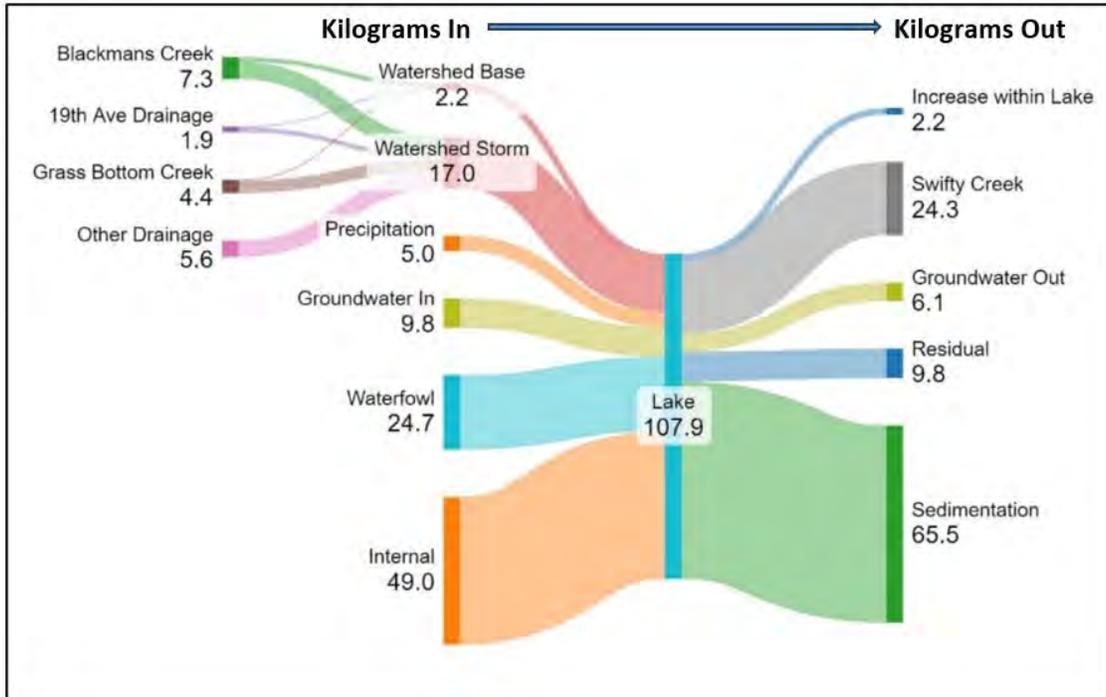
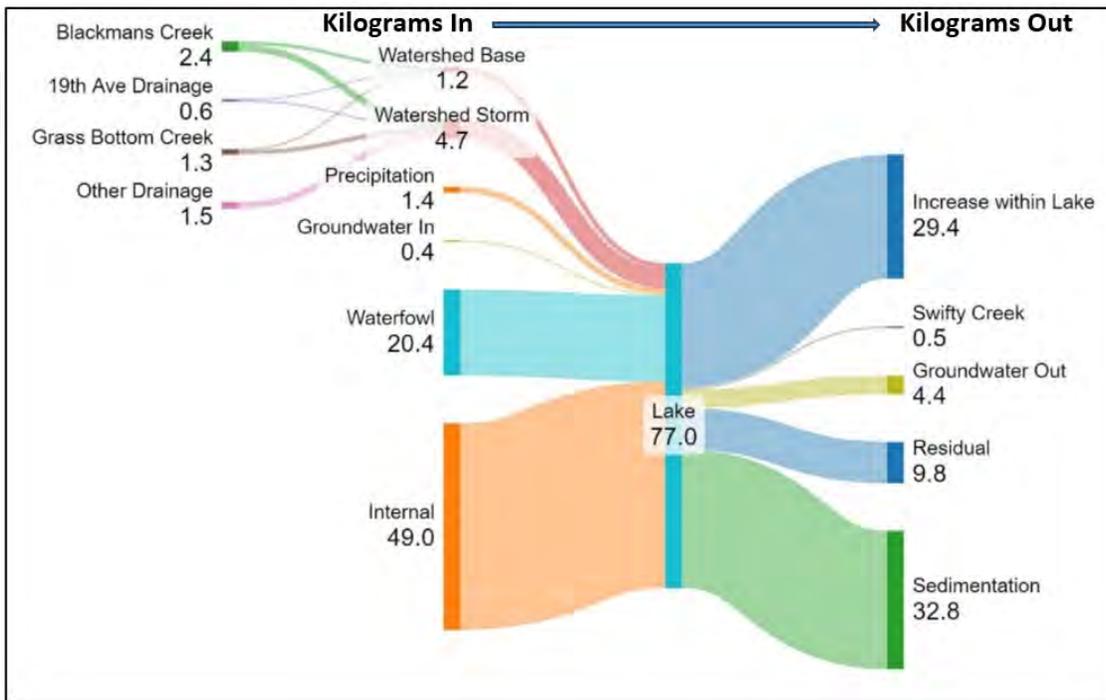


Figure ES-3. Summer (May to October 2023) Phosphorus Loads (kg) to Blackmans Lake.



The sediments of Blackmans Lake are rich in phosphorus bound to organic matter (e.g., decomposing algae, waterfowl feces, and leafy plant debris). During the summer, there are low levels of oxygen at depth, which changes the chemical structure of iron which then releases bound phosphorus. Furthermore, warmer temperatures increase microbial decay of sediment organic matter, which releases bound phosphorus up into the water column for algae uptake.

The primary sources of accumulated sediment phosphorus are waterfowl feces, watershed storm flows, and settled algae. Controlling external watershed loading of phosphorus, along with internal sediment release, will be important in the long term for mitigating algae blooms and curbing the replenishment of internal sediment loads.

## What are the Management Objectives for Blackmans Lake?

The goal for Blackmans Lake management is to improve and protect lake uses by decreasing cyanobacteria blooms and the conditions that support them. The recommended water quality objectives for Blackmans Lake are adapted from Washington Department of Ecology criteria for determining lake impairment due to harmful algae blooms. These objectives include the following:

- Within a 5-year period, there is no more than one year with two or more events with cyanotoxins exceeding state recommended guidelines.
- Within a 5-year period, there is no more than one year with a public health advisory lasting three weeks or longer.

To prevent harmful algae blooms, it is recommended to reduce the trophic state (amount of algae and nutrients) of Blackmans Lake from eutrophic (high algae and nutrients) to mesotrophic (moderate algae and nutrients) by not exceeding the following upper-mesotrophic thresholds, based on average summer (June through September) values in the epilimnion (1-meter depth) (Carlson 1977):

- Chlorophyll-a concentration not exceeding 7.2 µg/L
- Total phosphorus not exceeding 24 µg/L
- Secchi depth exceeding 2.0 meters.

## What Do We Do Next?

We recommend an adaptive management approach that provides long-term prevention through internal load reduction and watershed phosphorus control. We recommend oxygen saturation technology (OST) for internal phosphorus control and a combination of education and stormwater treatment for watershed phosphorus control. Ongoing monitoring should be used to monitor achievement of water quality objectives and to inform adjustments to management techniques.

## In-Lake Management

Sediment release is the primary source of phosphorus to cyanobacteria in the lake. While controlling watershed inputs is critical to preventing accumulation of additional phosphorus in the sediments, managing the existing reservoir of phosphorus in the lake is recommended to manage phosphorus and algae abundance in the lake. For long-term management, we recommend three alternatives:

1. Installation of a hypolimnetic oxygenation system, specifically an oxygen saturation technology (OST) system, to oxygenate the deep waters of the lake, reduce internal phosphorus loading, and improve fish habitat
2. Annual phosphorus water column stripping with a low dose of either alum or EutroSorb G (lanthanum)
3. Phosphorus sediment inactivation with high doses of either alum or EutroSorb G (lanthanum).

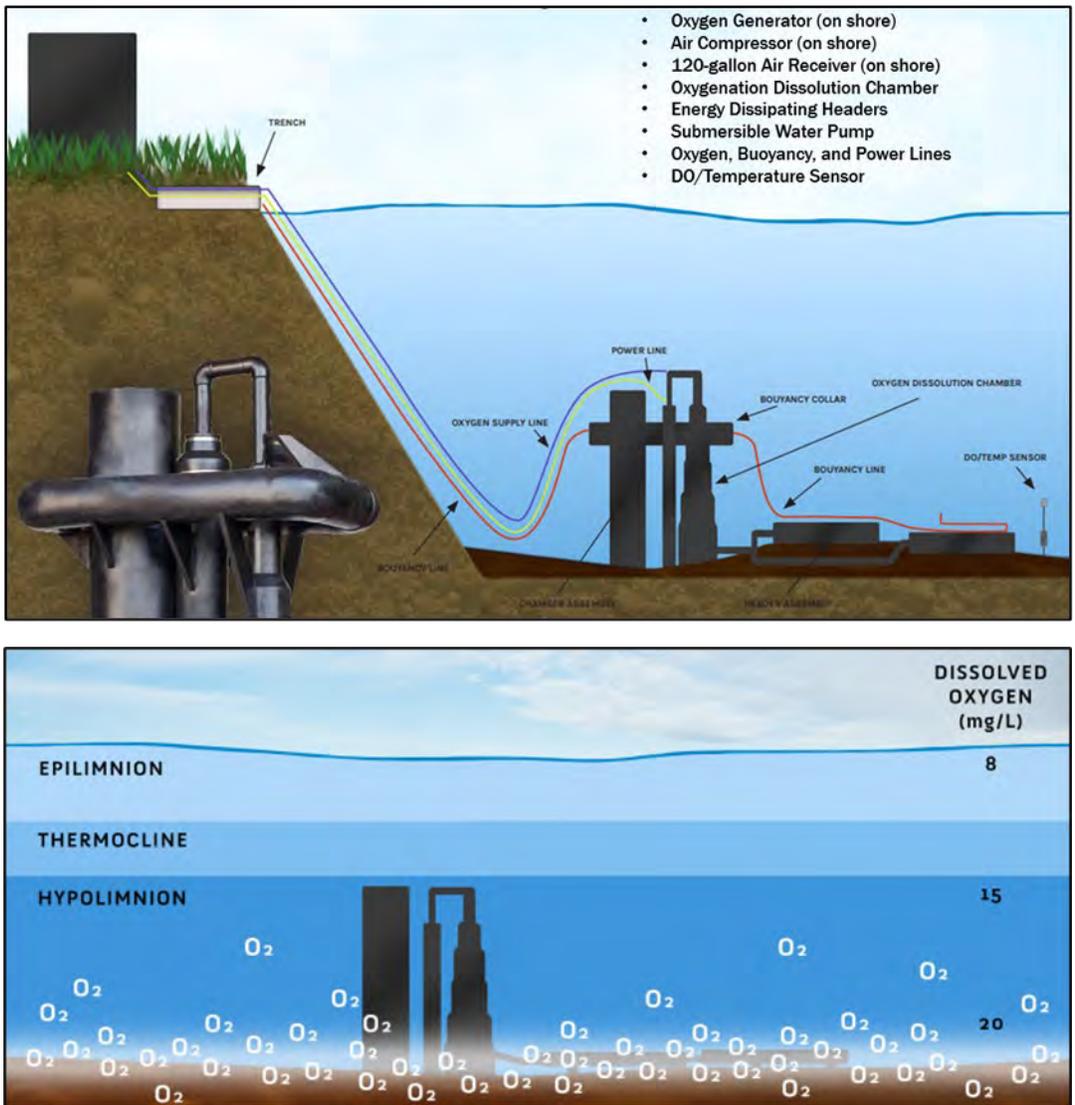
For long-term management, we recommend installation of a hypolimnetic oxygenation system, specifically an oxygen saturation technology (OST) system, to oxygenate the deep waters of the lake, reduce internal phosphorus loading, and improve fish habitat. The near- and long-term costs for sediment inactivation are dependent on the longevity of each treatment and the selected inactivation chemical. Overall, for a 23 period from 2025 to 2047, OST is the lowest cost option at \$0.9 million, followed by sediment inactivation at \$2.0 to \$3.5 million, and water column stripping at \$4.3 million. Due to the lower costs, greater sustainability, and potential ecological benefit of increasing the habitable zone, OST is the preferred option. In addition, OST is likely a better candidate than sediment inactivation for funding by another algae management grant, because of its innovation, sustainability, and habitat improvement.

Hypolimnetic (deep water) oxygenation or aeration techniques have been implemented in many lakes to combat low oxygen by maintaining or increasing oxygen levels in deep waters without causing whole-lake mixing. Hypolimnetic oxygenation systems have been successfully employed in many lakes, including Newman Lake in Spokane County, Washington, and is currently sought for Spanaway Lake in Pierce County, Washington. A hypolimnetic aeration system (injecting air rather than oxygen) was installed in 1994 and recently upgraded in 2022 in Lake Fenwick in Kent, Washington. Maintaining oxygenated conditions in the upper sediments suppresses the release of phosphorus (as well as nitrogen). Preventing lake destratification (mixing of epilimnion and hypolimnion, or top and bottom water layers) is important, to avoid introducing relatively nutrient-rich deep waters into the surface.

Oxygen Saturation Technology (OST) is a relatively new, patent-pending innovation used to administer precise concentrations of oxygen at strategic depths in a waterbody (Figure ES-4). The OST's design eliminates bubbles, which eliminates turbulence, sediment resuspension, and undesirable mixing. These systems can maintain dissolved oxygen (DO) levels as high as 20 mg/L directly over and into the sediments, where oxygen is needed most. They may also be helpful at preventing oxygen-related fish mortality. These high dissolved oxygen levels (exceeding those from simple saturation with the air) are important to overcome the high oxygen demand of organic-rich sediments in Blackmans Lake. Traditional hypolimnetic aeration systems can fail because they do not meet the sediment oxygen demand. OST has not been used in Washington State.

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Figure ES-4. Oxygen Saturation Technology.



An OST system functions by transporting approximately 95 percent pure oxygen from an onshore facility to an in-lake device where the water is supersaturated with oxygen. The water is then injected back into deep areas of the lake where it disperses over the sediment surface. The oxygenated water can coat and penetrate the sediments, preventing the release of phosphorus from iron-phosphate complexes and allowing the oxidized iron to bind to phosphate released by microbial decay of organic matter. The onshore facility consists of an oxygen generator and an air compressor and receiver tank. The compressor produces 67 decibels of noise, which is equivalent to a conversation by two people and can be reduced by an acoustic barrier. There is no storage of oxygen on premises.

It is anticipated that attaining permits and securing funding for the OST will take several years. We recommend that the City begin taking steps to attain both permits and funding as soon as possible. Environmental permits required by the State Environmental Policy Act (SEPA) and Shoreline Management Act (SMA) will be obtained through submittal of a Joint Aquatic Resources Permit Application.

An OST system is expected to cost \$0.3 to \$0.4 million for the system and installation. Ongoing operation and maintenance are estimated at approximately \$22,000 per year, with an estimated 3.5 percent escalation each year. Given this high upfront cost, we recommend pursuing funding in tandem with attaining permits. Viable funding sources are described in the *Funding the Plan* section.

## Watershed Source Control

A key long-term pathway to preventing cyanobacteria blooms is to decrease the loading of nutrients to the lake. This involves both source control and treatment. Source control is the removal or mitigation of a source, such as reducing phosphorus fertilizer use, installing livestock exclusion fencing along a stream, and fixing failing septic systems. Treatment is the reduction of a nutrient through built and natural infrastructure, such as infiltrating stormwater using LID techniques, filtering stormwater with phosphorus-adsorbing media, or installing vegetative buffers along waterways.

## Stormwater Management

Stormwater runoff can be an important pathway of nutrients to surface water and groundwater. Fertilized areas, domestic animals, and wildlife contribute phosphorus to stormwater runoff. The Blackmans Lake watershed is 81 percent residential development and 28 percent impervious surfaces from a combination of roadways, rooftops, and driveways. Estimates of stormwater runoff in the watershed indicate about 16 percent of the annual phosphorus load is from stormwater flow to the lake. Opportunities to install small phosphorus treatment systems in areas currently without stormwater treatment and to retrofit existing facilities with phosphorus treatment could be explored.

We recommend that a stormwater treatment and retrofit evaluation be completed in partnership with the City and Snohomish County Surface Water Management. The first step of such an effort would be to identify opportunity locations for stormwater treatment or retrofit based on existing infrastructure, land use/land cover, property ownership, and water quality data. This step includes identifying 15 to 20 opportunity locations and preparing high-level concepts and cost estimates. This first step is estimated to cost \$30,000 to \$40,000 but is variable with the number of opportunity locations and complexity of sites. Following this initial identification, the second step would be to conduct field

verification and develop detailed conceptual designs for a shortlist of the locations. Assuming 10 to 12 sites are on this shortlist, this second step is estimated to cost \$40,000 to \$50,000, again scaling with the number of sites and their complexity. Overall, \$100,000 should be budgeted for this initial planning effort over the next few years.

The cost of final design and installation for stormwater treatment and retrofit vary significantly based on the selected treatment approach and site conditions. Approximately \$2M should be budgeted over 20 years in anticipation for design and installation of 10 to 15 small phosphorus treatment systems comprised of bioretention systems or media filters with phosphorus retention media.

## Septic System Management

Septic systems are not believed to currently be a major contributor of phosphorus to Blackmans Lake based on the low levels of phosphorus found in drainage to the lake and the low number (70) of septic systems relative to the watershed size. However, we do recommend taking actions to identify existing septic systems that may be contributing disproportionate loads of phosphorus to Blackmans Lake. These include failing systems that are no longer functioning per their initial design and systems that do not appear to be failing but do not have adequate local conditions to remove phosphorus.

We recommend encouraging septic system owners throughout the watershed to complete routine inspections, as required by state law. Additionally, we recommend evaluating higher risk systems that are located around the lake or along streams to evaluate if adequate treatment is provided.

Replacing septic systems can be very expensive (up to \$20,000 to \$40,000), depending on the location and installation constraints. However, there are numerous grants and low-interest loans available that may ease the upfront investment. This includes Craft3 Clean Water Loans, a low-interest loan program. The LCMP does not include budget for septic system management.

## Shoreline and Waterfowl Management

Plants that grow in and along lake shorelines have an important role in protecting water quality and providing habitat aquatic organisms. Shoreline plants can absorb and slow runoff from upslope, removing nutrients. They are also important for fostering native insects that are food for fish and birds. Developing a healthy shoreline program to promote and fund replacement of bulkheads and lawns with native plants is a recommended management action to reduce nutrient inputs and cyanobacteria growth in Blackmans Lake. Snohomish County Surface Water Management runs an existing program, LakeWise, to encourage lake stewardship through lawn and yard care, septic system care, and healthy shorelines. The program provides online and in-person education and outreach materials. LakeWise offers free natural lawn care workshops and free native plants for shoreline landscaping.

Waterfowl droppings are a leading contributor to phosphorus loading to Blackmans Lake. They also have a negative aesthetic impact and present a potential health risk to lake users from fecal pathogens. These impacts are primarily driven by migratory geese populations in fall (seen in October 2023), where up to 4,000 geese were found on the lake. Because most phosphorus loading is associated with migratory geese rather than resident geese, there are legal and ethical considerations in taking actions to harass, relocate, or otherwise harm migrating geese. Additionally, actions taken to harass and displace migratory

geese may result in a shift in the migrating population to neighboring lakes, which may be negatively impacted by increased phosphorus loads. Relocation is generally not recommended because the birds are likely to create problems wherever they go. Snohomish Park municipal code prohibits the annoyance or feeding of any animal, bird, fowl, waterfowl, fish, farm animal, or wildlife (SMC 13.04.080).

It is important to prevent the migrating populations from becoming resident. Feeding waterfowl discourages natural winter migration; can lead to aggressive behavior; and encourages large resident bird flocks that degrade parks, lawns, and beaches with droppings. Proper signage with such messaging should be installed at the parks and boat launch. We also recommend property owner participation in the Snohomish County LakeWise program and for the Snohomish Park Department to evaluate waterfowl-d discouraging landscaping on its lands.

## Monitoring and Surveillance

No matter the management objectives or management strategy employed, ongoing monitoring is necessary to evaluate success and allow adaptive management. The adaptive management approach for Blackmans Lake includes short-term and long-term monitoring. Short-term monitoring is focused on key data gaps and will provide the information needed to confirm and refine the selected measures and develop more accurate cost estimates. Long-term monitoring will provide the information needed to evaluate progress toward achieving management goals and to adjust or augment the lake management measures.

As outlined in Table ES-2, we recommend developing a monitoring plan, which builds on current water quality and lake level monitoring programs to include the following:

- Additional routine lake monitoring
- Cyanobacteria bloom and fecal bacteria surveillance
- Stormwater treatment performance and inlet monitoring
- Sediment phosphorus monitoring

Costs are estimated for each monitoring element totaling a 20 percent contingency is included for a total annual cost of \$33,660.

## Adaptive Management

To further the long-term water quality and lake use goals for Blackmans Lake, this plan includes the following adaptive lake management framework to regularly reassess and amend LCMP strategies or goals as part of ongoing, adaptive lake management, pursuant to future lake needs, stakeholder values, and funding. This LCMP includes an adaptive management section describing: 1) the decision-making process and adaptation framework by which the LCMP shall be modified, 2) current knowledge gaps and the recommended monitoring plan for continued effectiveness evaluation, and 3) potential future LCMP adaptations to begin considering.

**Table ES-2. Recommended Monitoring Plan.**

Monitoring	Description	Parameters
Lake Monitoring	Monthly water quality sampling (1 m below surface and 1 m above lake bottom) May through October Twice monthly vertical profiling (1-m intervals) with water transparency measurements	Nutrients (nitrogen and phosphorus) Chlorophyll-a and some phytoplankton Secchi depth Temperature, dissolved oxygen, pH Lake level
Recreational Safety	Weekly monitoring (Memorial Day to Labor Day) at Hill Park and Ferguson Park for algae bloom observation and fecal bacteria testing.	Cyanotoxins <i>E. coli</i>
Surveillance for Cyanobacteria Blooms	Expand existing surveillance program for identifying and sampling cyanobacteria blooms to year-round to encompass reported wintertime algae blooms.	Algal scums Cyanotoxins
Sediment Monitoring	Collect two sediment cores every 5 years	Phosphorus fractions Iron
Stormwater/Inlet Monitoring	Monitor performance of stormwater treatment facilities (6 storm events at 1 site) and 2 lake inlets each year	Total phosphorus
Data QA and management	Input laboratory and field data into database, perform data QA/QC.	All
Annual Reporting and Project Management	Summary of Monitoring Data, Management Effectiveness (if applicable), and Adaptive Management Recommendations	All

We expect that the OST system will reduce internal phosphorus loading and meet the management objective for total phosphorus of less than 24 ug/L as a summer average at 1-meter depth. This total phosphorus objective is the boundary between mesotrophic (moderate productivity) and eutrophic (high productivity) classifications that is also expected to meet the other established objectives for water clarity (Secchi depth), algae biomass (chlorophyll-a) and toxic cyanobacteria blooms (cyanotoxins) (see Lake Management Objectives).

If the OST alone does not meet the total phosphorus or other lake management objectives, then modification of the management strategies is needed. Modifications may include the following, in order of priority:

1. Increase the oxygen input amount and/or extend the duration of oxygen input to the hypolimnion from the OST system.
2. Increase the amount of iron in the lake sediments to bind phosphate under oxygenated conditions by applying zero valent iron to either the entire lake or just the hypolimnion area.
3. Plan and initiate a phosphorus inactivation treatment of the lake using alum or lanthanum.

## Plan Cost and Funding

The recommended set of management strategies is estimated to cost approximately \$0.9 million in the first 3 years and about \$6.1 million over the next 20 years (Table ES-3). Additional funding sources will be necessary to implement the recommend elements of this plan. A combination of budget allocations, grants, and/or loans should be sought to fund and implement this management plan. We recommend considering the following sources:

- City of Snohomish Surface Water Management Fund.
- Snohomish County Surface Water Management Funds
- State Legislative Budget Allocations
- State Freshwater Algae Control Grants
- Clean Water State Revolving Fund Loans
- Centennial Clean Water Grants
- Section 319(h) Clean Water Grants
- Onsite Sewage Financial Assistance Loans (Craft3)

**Table ES-3. Recommended Cyanobacteria Plan Implementation Cost Summary.**

Plan Element	First Three Years		Next 20 Years	
	Description	Cost (2024\$)	Description	Cost (\$) <sup>a</sup>
Oxygen Saturation Technology (OST)	Permit, design, and install an OST.	\$620K	Ongoing maintenance and electricity costs (base cost: \$12.2K/year)	\$0.3M
Watershed Source Control Education/Outreach (Waterfowl, Septic, Shoreline, and Land Stewardship)	Leverage existing LakeWise program from Snohomish County to encourage and install best management practices.	\$0	Ongoing	\$0
Stormwater Retrofit Evaluation	Evaluate potential stormwater retrofit locations.	\$100K	Implement high-value, multi-benefit stormwater retrofits	\$2.0M
Monitoring and Reporting	Routine/supplemental lake monitoring, bloom and fecal surveillance, stormwater monitoring, sediment monitoring, and reporting (base cost: \$34K/year)	\$100K	Routine/supplemental lake monitoring, bloom and fecal surveillance, stormwater monitoring, sediment monitoring, and reporting (base cost: \$34K/year)	\$1.4M
Lake Management Administration	Finance and grant tracking. Adaptive management. Coordination with consultants and contractors. Implementation of management plan (base cost: \$60K/year)	\$120K	Finance and grant tracking. Adaptive management. Coordination with consultants and contractors. Implementation of management plan. (base cost: \$60K/year)	\$2.4M
<b>Total (first 3 years)</b>		<b>\$940K</b>	<b>Total (next 20 years)</b>	<b>\$6.1M</b>

<sup>a</sup> 20-year cost assumes cost escalation of 3.5 percent each year in consideration of wage, utility, and material cost increases.

# Introduction

Blackmans Lake, originally named Stillaguamish Lake (meaning “People of the River” in the Lushootseed language), is a lake located in the City of Snohomish, in Snohomish County, Washington, about 35 miles north of downtown Seattle (Figure 1). The lake was renamed for the Blackman family who had operated a logging camp along the shore from 1875 to 1884 (Heirman 1980). The lake features two public parks owned by the City of Snohomish (Hill Park and Ferguson Park), a public boat launch, and several private docks allowing abundant access for recreation. Blackmans Lake supports a range of wildlife such as ducks, migratory geese, and deer, and the lake is popular for fishing for stocked rainbow trout and a variety of other warmwater fish species.

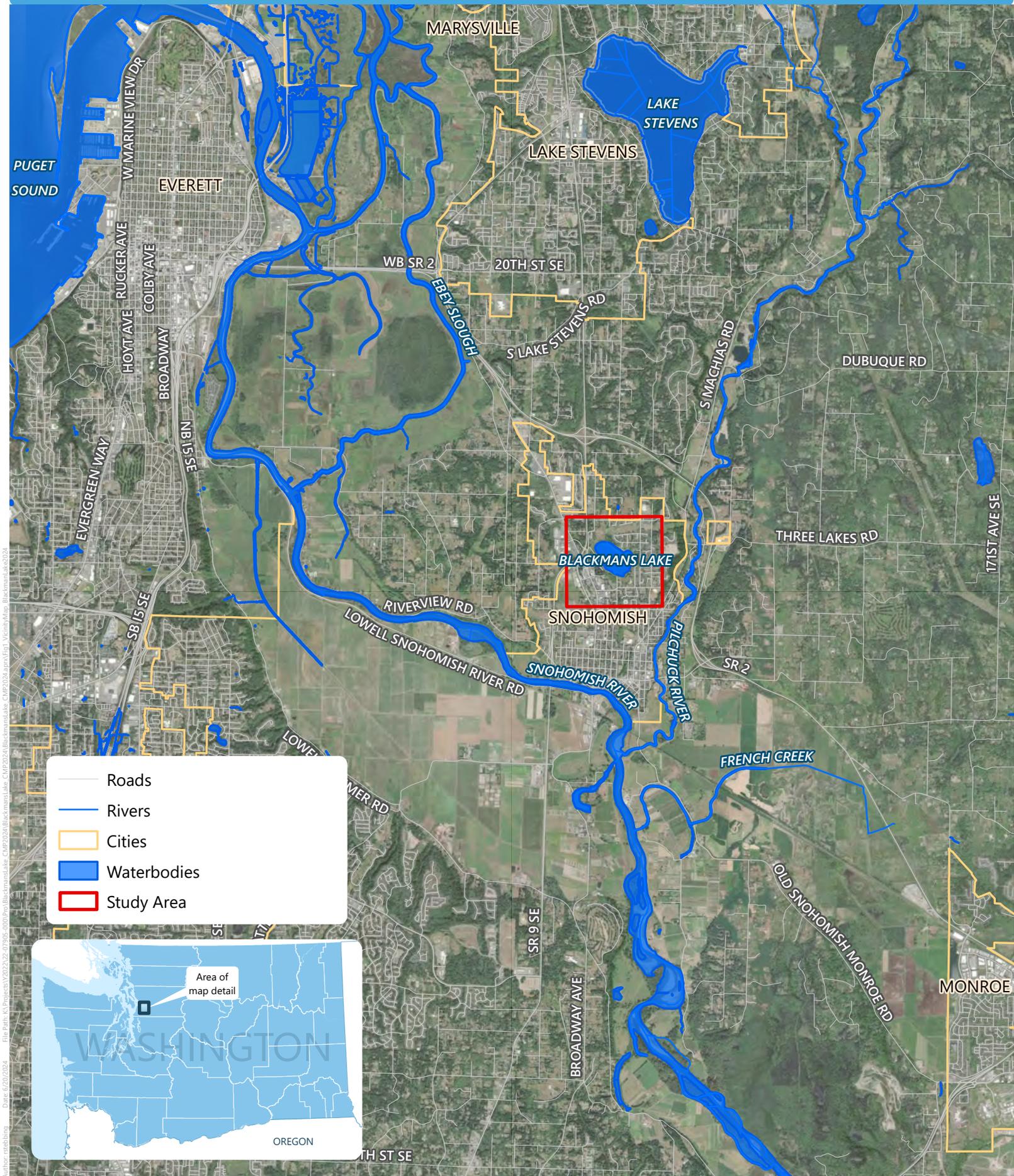
In 1992, the City of Snohomish (“the City”) initiated a Phase I monitoring and restoration study in response to concerns over declining lake conditions, including algae blooms, low dissolved oxygen, high fecal coliform bacteria, and impaired fisheries and habitat quality. This study collected hydrology and limnology, and water quality data, evaluated lake management alternatives, and recommended watershed controls and an alum treatment to reduce algae blooms (KCM 1994). Over the past 30 years, Snohomish County (the County) Surface Water Management is assisted by volunteers from the Friends of Blackmans Lake to conduct bimonthly water quality monitoring of the lake from May through October as part of the County’s Volunteer Lake Monitoring Program.

Blackmans Lake water quality assessments reveal lake conditions commonly associated with cyanobacteria blooms (KCM 1994; Snohomish County 2021, 2022a). Blooms of cyanobacteria are frequently seen on the lake, along with detectable levels of toxins produced by cyanobacteria (Ecology 2022). Toxins produced by these blooms can both inhibit recreational use of the lake and impact the supported wildlife. The blooms can also form scums along the lake surface which are often unsightly and odorous, further impairing community enjoyment and ecological uses. Based on observed increasing trends in nutrients and their relationship to cyanobacteria, toxic blooms in Blackmans Lake may continue to increase unless actions are taken to reduce nutrient sources and change lake conditions.

In 2022, the City contracted Herrera Environmental Consultants (Herrera) to develop this Lake Cyanobacteria Management Plan (LCMP). To inform the LCMP, Herrera developed a Quality Assurance Project Plan (QAPP) (Herrera 2022a) to collect a comprehensive set of scientific data from October 2022 through October 2023, including hydrological, chemical, biological information from the lake and watershed. In conjunction with the County’s long-term lake monitoring dataset, these scientific data were used to identify sources of phosphorus, understand causes of cyanobacteria blooms, and build on past management actions of Blackmans Lake to develop the recommendations in this LCMP. After this monitoring program began, the City was awarded a grant from the Washington Department of Ecology (Ecology) through the Freshwater Algae Control Grant Program to partially fund the monitoring and preparation of the LCMP.

Working with the public, the City, and the County, the LCMP identifies community concerns, develops priorities, outlines goals and objectives, and describes a lake management strategy recommended to reduce the frequency and duration of toxigenic algae blooms and restore recreational use. The LCMP will be used as a guideline and tool for allocating resources to implement the recommended management activities, with a framework and decision steps for future management needs. This LCMP is a technical document using lake terminology defined in the Lake Glossary (Appendix G).

Figure 1.  
Blackmans Lake Vicinity Map.



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# Study Area Background

## Lake and Watershed

Blackmans Lake is monomictic, meaning that it thermally stratifies once per year. Blackmans Lake is 61 acres (0.25 km<sup>2</sup>) in size with an average depth of 13.9 feet (4.2 m) and a maximum depth of 29 feet (8.8 m) at the central lake monitoring station (Figure 2) (Snohomish County 2021). Most of the shallow portion of the lake is on its north side. Table 1 presents the lake morphometric characteristics. Table 2 presents the lake area and volumes for each bathymetric contour shown in Figure 2.

**Table 1. Morphometric Characteristics of Blackmans Lake.**

Characteristic	English	Metric
Surface Area	60.9 acres	24.7 ha
Maximum Depth	28.9 ft	8.8 m
Mean Depth	13.9 ft	4.2 m
Volume	848.9 acre-ft	1,047,123 m <sup>3</sup>
Osgood ratio (mean depth [m]/ lake area [km <sup>2</sup> ] <sup>(1/2)</sup> )	--	8.5
Lake Altitude (NAVD88)	144 ft	44 m
Watershed Drainage Area	473 acres	1.9 km <sup>2</sup>

ha= hectares; ft = feet; m = meters; km = kilometers

**Table 2. Blackmans Lake Depth-Area-Volume.**

Depth		Area		Volume Below	
Meters	Feet	Hectares	Acres	Cubic Meters	Acre-feet
0	0	24.7	60.9	1,047,123	848.9
1.5	5	21.2	52.4	697,881	565.8
3.0	10	16.5	40.8	411,174	333.3
4.6	15	11.3	27.9	200,649	162.7
6.1	20	6.4	15.8	67,676	54.9
7.6	25	1.9	4.7	7,748	6.3
8.8	29	0	0	-	0.0

The Blackmans Lake watershed is small, draining approximately 500 acres of the Puget Sound glacial lowlands. Much of the watershed is within City limits, but a sizeable portion lies in unincorporated Snohomish County. The watershed map is presented in Figure 3 showing the basin boundaries of catchment areas draining to each watershed monitoring station established for this study. The shoreline of Blackmans Lake consists of private residential parcels with several in-water structures, two City parks, and open, privately-owned land including wetland and riparian areas. The watershed includes a wetland area to the north of the lake including a stormwater detention pond, which flows into Blackmans Creek, the lake’s sole inlet stream today and largest source of water. Another small perennial inlet stream (called Grass Bottom Creek in KCM 1994) feeds into the northeast corner of the lake via Champagne Lane,

draining the areas to the east and south of the lake. Surface water runoff drains to the lake via approximately four stormwater outfalls located along the north and east lake shorelines (Figure 4).

Water discharges from the lake to a southern outlet. The lake's outlet was historically a wetland and is today comprised of four 24-inch PVC culverts with fish screens. Water discharges from these culverts into Swifty Creek, which contains an earthen berm just downstream of the lake outlet to maintain lake levels and reduce winter flooding (Snohomish County 2021). Swifty Creek then flows south through the City of Snohomish to the Snohomish River and ultimately drains into the Puget Sound.

Underground springs to the west of the lake contribute water to the lake and its adjacent wetlands via shallow perched aquifers, contained in the ground by impermeable glacial till units (KCM 1994). The direction of water flow between the lake and wetlands changes seasonally but, generally, water flows from north to south through the lake to the outlet. Groundwater inflow and outflow was estimated to range from 0.5 to 5 cubic meters per day, according to a paired wellpoint analysis (KCM 1994).

The watershed is approximately 50 percent developed, zoned mostly for single-family residential use with some business parks and little medium/high density residential or commercial uses (Snohomish County 2022b; COS 2022). Sanitary wastewater in the watershed is in part delivered to and treated via City sewer connections, particularly from parcels along the northeast side of the lake. However, some parcels here and in unsewered areas north of the lake use on-site sewage/ septic systems (OSS).

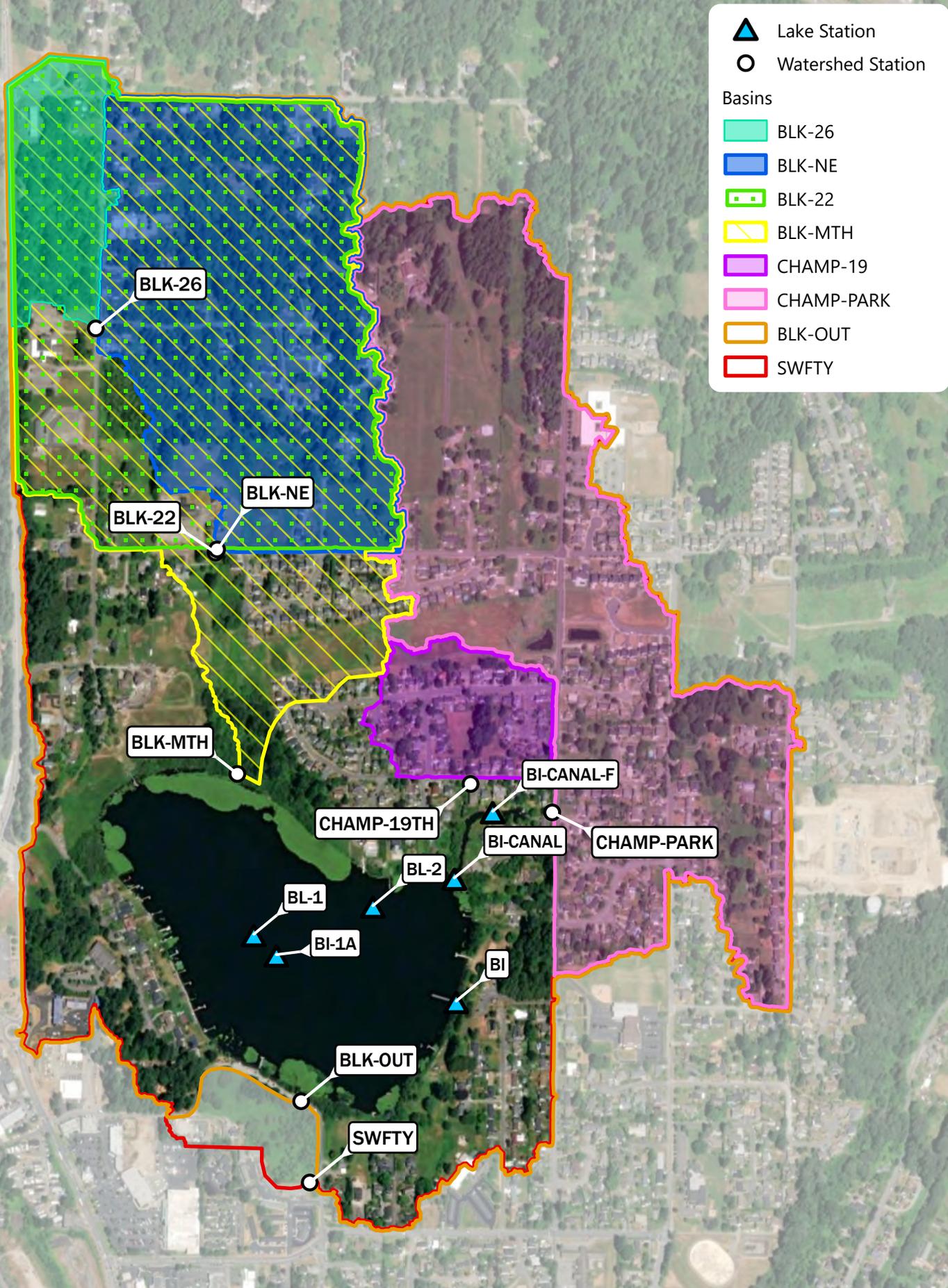
Since 1994 there have been two major changes to the hydrology of Blackmans Lake. Firstly, a retention pond was installed in the former flow path of Grass Bottom Creek in the powerline right-of-way, and a 12-inch stormwater pipe was replaced with a 24-inch pipe in the creek's flow path downstream of 19th Street and Park Ave, to prevent backwatering through the surface catch basin (COS 2013). Secondly, the lake outlet at Ferguson Park was modified to prevent lake level rise and flooding during storm events due to silt accumulation and vegetation growth in the outlet channel. Due to these major hydrologic changes, it was necessary to update the 1994 water budget for use in developing a phosphorus budget to inform this LCMP.

Figure 2. Blackmans Lake Bathymetry.

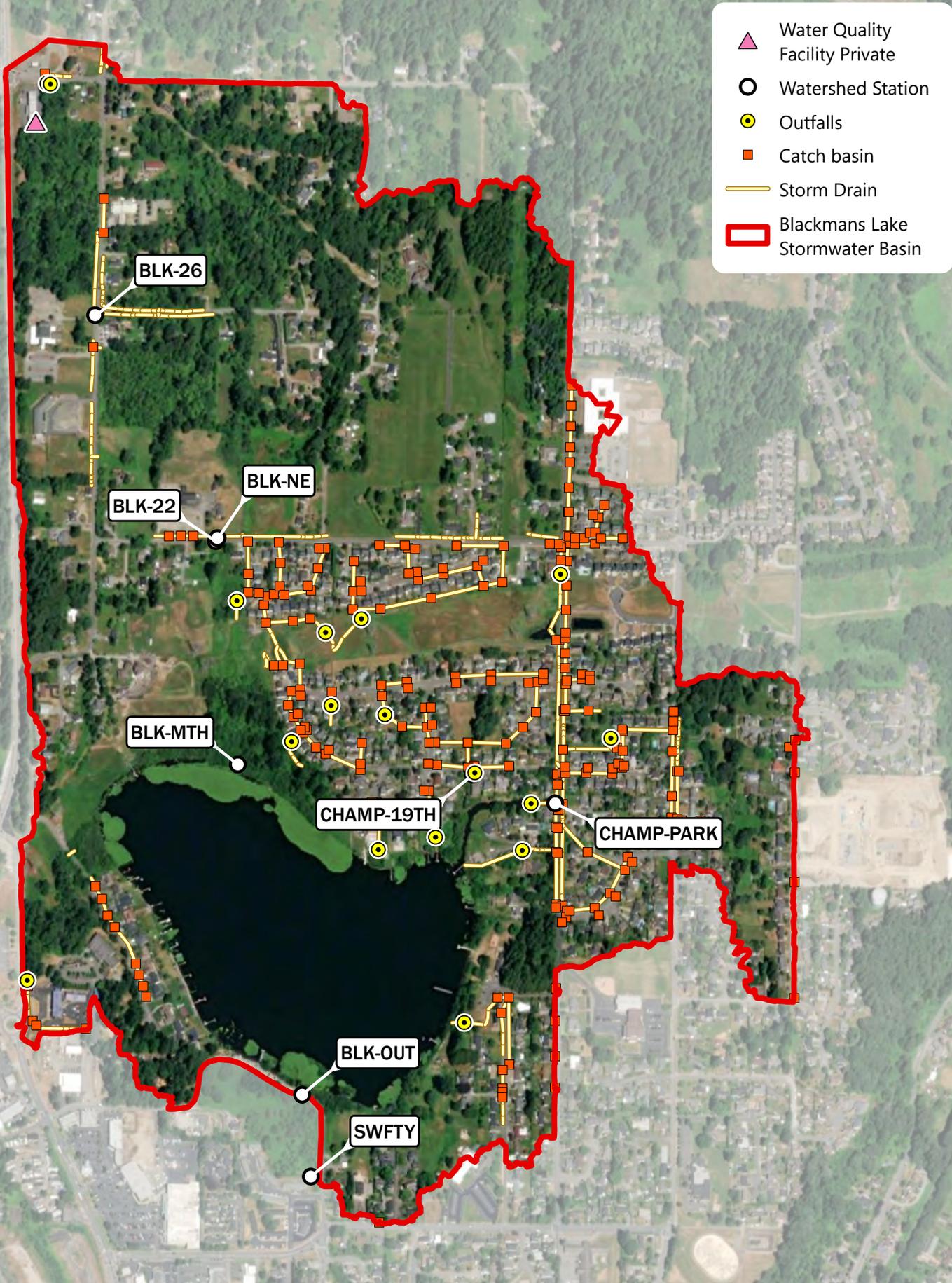


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Figure 3.  
Blackmans Lake Watershed and Monitoring Stations.



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## Beneficial Lake Uses

Blackmans Lake supports a variety of beneficial uses, including boating, fishing, and swimming, and provides a habitat for a range of wildlife such as ducks, migratory geese, fish, and deer. The lake is popular for fishing for stocked rainbow trout and a variety of other warmwater fish species. Public access to the lake is provided by two City parks:

- **Ferguson Park**, spanning 6.7 acres, stands out as a beloved destination in Snohomish, a sentiment echoed in the 2022 community survey. Located along the southwest shore of Blackmans Lake, the park is strategically positioned near residential areas to the northeast and the bustling Avenue D commercial corridor to the south and west. Notable amenities include a boat launch and fishing dock accessible from Avenue A, seamlessly integrated into the recreational space. Offering convenience with a parking lot, bike parking, restroom, shelter, picnic tables, benches, playground equipment, a basketball hoop, and a disc golf course, Ferguson Park provides a diverse array of recreational opportunities and stunning water views.
- **Hill Park**, spanning 5.6 acres, stands as one of the city's beloved parks. Nestled along the eastern shore of Blackmans Lake in a predominantly residential area, the park offers a serene lakeside experience. Shielded by towering evergreen trees, the park boasts a sandy beach, swimming docks, and fishing piers. With two picnic shelters, restrooms, picnic benches, playground equipment, and scenic water views, Hill Park provides a diverse range of recreational amenities for visitors.

Water from Blackmans Lake is designated for domestic, industrial, agricultural, and stock water supply uses. This does not include drinking water at present. Water Quality Standards for Surface Waters of the State of Washington provides use designations for freshwater bodies in Washington State (WAC 173-201A-600). Blackmans Lake has the following designated uses:

- Core summer salmonid habitat
- Primary contact recreation
- Water supply (domestic, industrial, agricultural)
- Stock watering
- Wildlife habitat
- Harvesting
- Commerce/navigation
- Boating
- Aesthetic value

## Current and Historical Land Uses

The land that is now the City of Snohomish was originally inhabited by the Tulalip and Snohomish Tribes (Native Land 2024). Blackmans Lake was originally named Stillaguamish Lake (meaning “People of the River” in the Lushootseed language). The first European settlers arrived in the 1830s and in 1855

Snohomish and Tulalip leaders signed the Treaty of Point Elliott (Cession 347), in which the tribes surrendered millions of acres of land in return for a small sum and permanent protection from the United States government, retaining responsibility and authority over fish and wildlife resources. Later, Blackmans Lake was renamed for the Blackman family who had operated a logging camp along the shore from 1875 to 1884 (Heirman 1980).

The land cover for the Blackmans Lake watershed is comprised of approximately 81 percent residential development, 11.5 percent open water, and 6 percent forest using data based on land cover. Land cover is from the 2021 National Land Cover Database (NLCD), which identifies land cover and percent imperviousness for 30-meter by 30-meter cells (Dewitz 2023) (Figure 5). A total of approximately 28 percent of the watershed is covered by impervious surfaces from a combination of roadways, rooftops, and driveways (NLCD 2023) (Figure 6). The watershed is zoned mostly for single-family residential use with some business parks and little medium/high density residential or commercial uses (Snohomish County 2022b; COS 2022).

The shoreline varies from a modified shoreline with bulkheads or fill, to a fully landscaped shoreline, and to a mix of native and weedy vegetation (COS 2017). There are approximately 40 homes occupied year-round along the shoreline and approximately 30 with docks or other in-water structures. The City maintains two parks along the shores of Blackmans Lake that allow public access as noted above: (1) Ferguson Park features a boat ramp, a fishing dock, a basketball court, trails, disc golf course, a playground, and picnic facilities; and (2) Hill Park features picnic facilities and two American with Disability Act (ADA) accessible fishing docks.

## Sanitary Wastewater Treatment

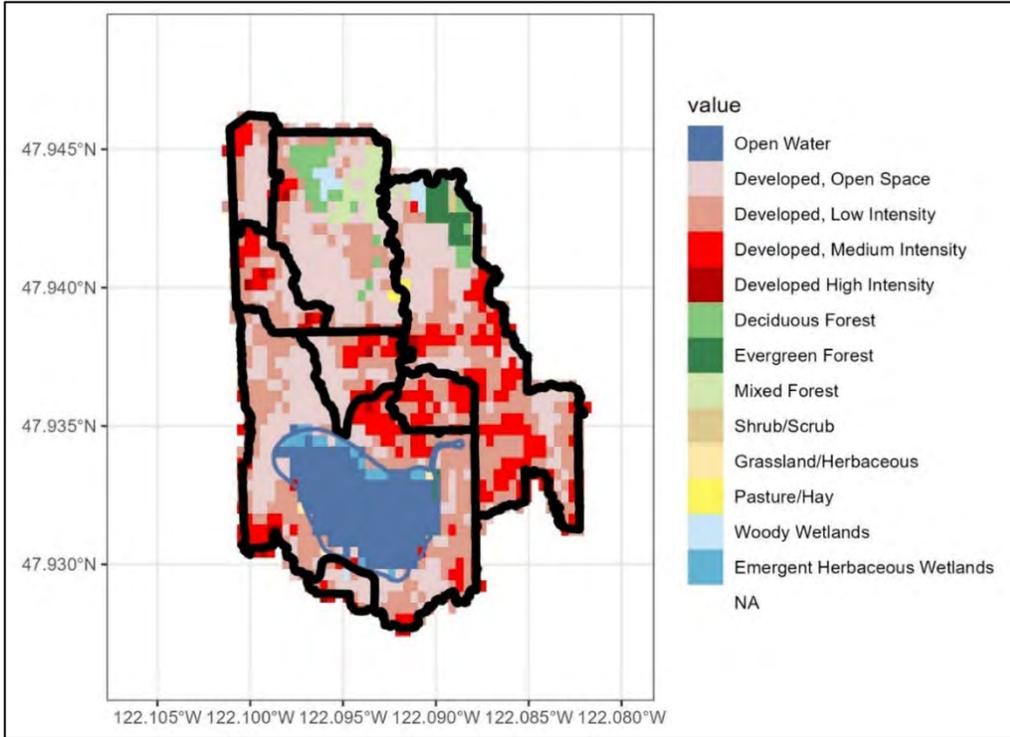
Sanitary wastewater in about half of the watershed is collected in sanitary sewers (Figure 7) and treated at the City's wastewater treatment plant located south of the lake on the Snohomish River. The sewered portion of the watershed consists of low- to medium-density residential development northeast of the lake.

On-site sewage systems (OSS or septic systems) are used to treat and infiltrate wastewater on 70 parcels in the north and northwest portion of the watershed. Three OSS are located approximately 500 feet north of the lake while the rest are all at least 1,000 feet from the lake (Figure 7).

## Water Withdrawals

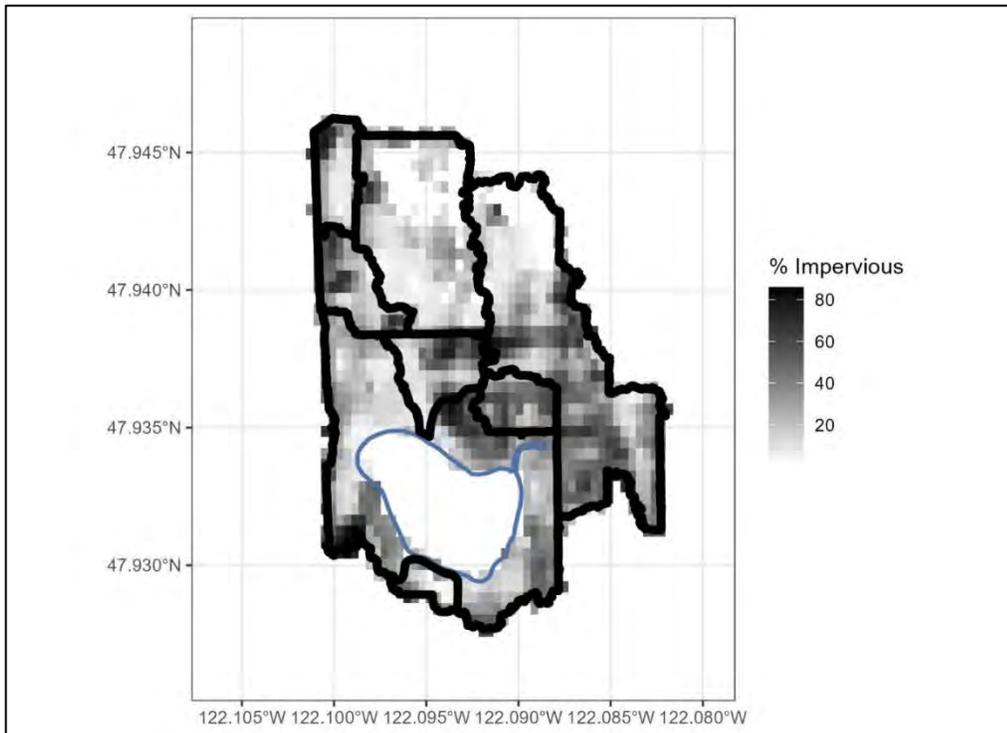
There are no known significant water withdrawals from Blackmans Lake for any water supply uses. According to Ecology's Water Rights Search application, there are 10 active water rights records in the Blackmans Lake watershed. Five of these records are for irrigation to properties on Lake Mount Drive along the west shoreline, with four for gravity flow of unspecified quantities and one for pump flow of 0.01 cubic feet per second (cfs) or 0.25 acre-feet of water from Blackmans Lake.

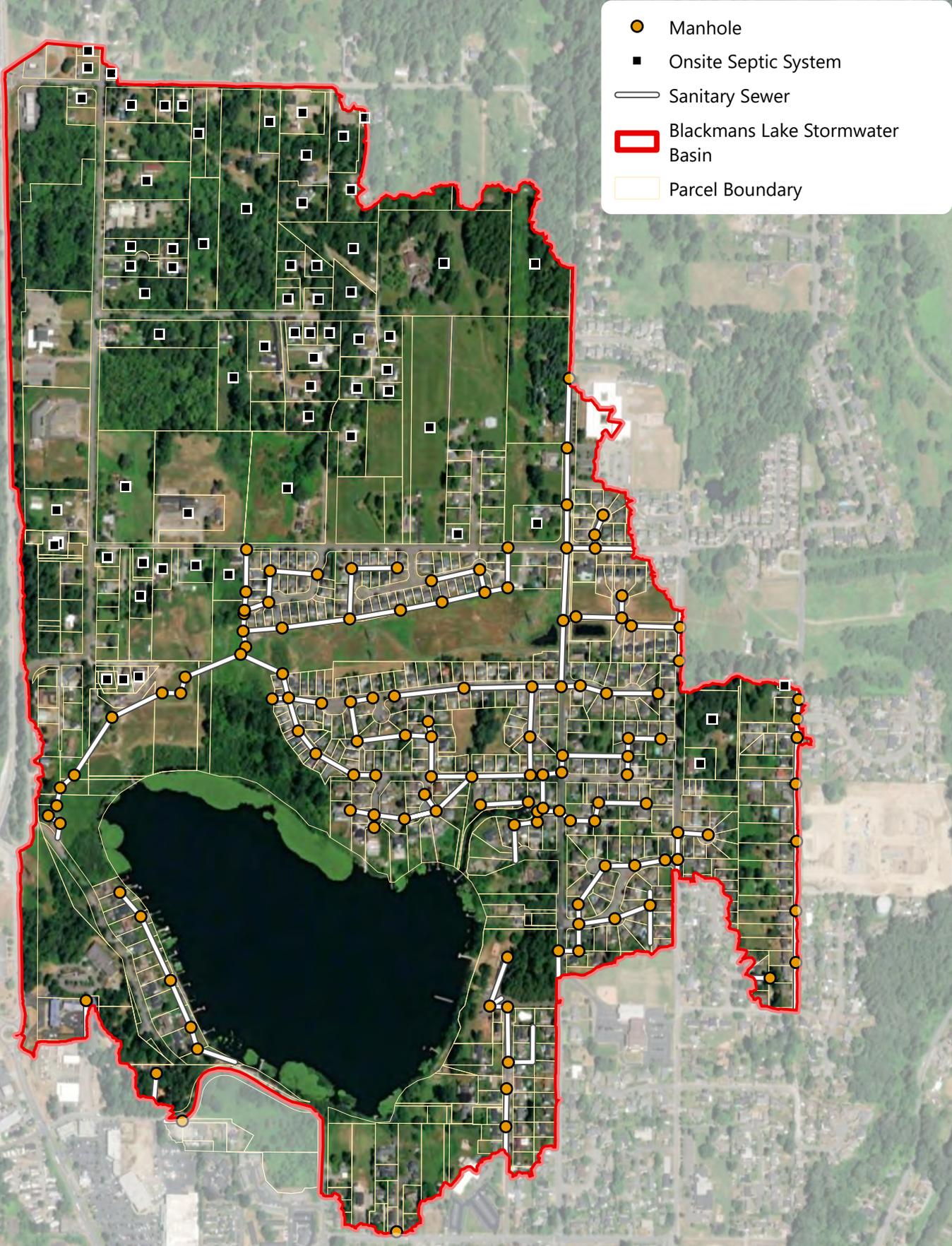
Figure 5. Land Use Density in the Blackmans Lake Watershed (NLCD 2021).



Basin outlines are shown in black, and lake surface is shown with the blue line. The water land cover for Champagne Lane is not captured.

Figure 6. Impervious Surface Density in the Blackmans Lake Watershed (NLCD 2021).





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Author: reebbing

# Fisheries

Blackmans Lake is popular for recreational fishing. According to Washington Department of Fish and Wildlife (WDFW 2024a), species present in Blackmans Lake include stocked trout, largemouth bass, black bullhead, black crappie, brown bullhead, common carp, pumpkinseed sunfish, and yellow perch. WDFW has stocked the lake with rainbow trout since at least 1995. Historical annual trout stocking data are presented in Table 3. No other estimates of fishery conditions or population sizes are available.

**Table 3. Blackmans Lake Annual Trout Stocking (WDFW 2024a).**

Year	Cutthroat		Rainbow		Steelhead	
	Number	Pounds	Number	Pounds	Number	Pounds
1995	15,225	288	3,316	892	–	–
1996	15,247	395	10,506	3,392	–	–
1997	–	–	9,211	2,777	–	–
1998	–	–	8,232	2,914	21,768	89
1999	4,020	201	7,250	1,946	–	–
2000	4,221	201	7,877	2,371	–	–
2001	–	–	9,039	2,863	–	–
2002	8,086	599	7,062	2,620	–	–
2003	7,500	405	6,761	2,080	–	–
2004	–	–	7,828	2,703	–	–
2005	8,100	450	6,836	2,643	–	–
2006	5,100	340	7,308	2,780	–	–
2007	8,300	553	7,641	2,955	–	–
2008	–	–	7,006	2,205	–	–
2009	16,051	796	7,021	2,160	–	–
2010	–	–	7,296	2,365	–	–
2011	17,606	1,286	8,594	2,195	–	–
2012	–	–	6,094	2,845	–	–
2013	18,996	1,196	4,759	2,192	–	–
2014	9,000	429	6,349	3,132	–	–
2015	9,000	464	7,282	3,388	–	–
2016	9,366	699	5,856	2,477	–	–
2017	7,564	382	7,001	2,870	–	–
2018	7,782	876	10,351	5,715	–	–
2019	7,791	891	7,003	3,045	–	–
2020	14,710	1,357	9,430	4,215	–	–
2021	8,500	708	7,020	3,435	–	–
2022	13,000	394	6,844	3,035	–	–
2023	9,200	484	10,928	7,217	–	–
<b>Mean</b>	<b>10,198</b>	<b>609</b>	<b>7,507</b>	<b>2,946</b>	<b>–</b>	<b>–</b>

In May 2023, 3,810 pounds of legal-size rainbow trout were stocked in Blackmans Lake, followed by 484 pounds of yearling coastal (resident) cutthroat trout in October and another 1,930 pounds of legal-size rainbow trout in November 2023 (WDFW 2024a). Trout stocking in 2023 totaled 20,128 cutthroat and rainbow trout weighing 7,701 total pounds, representing the largest fish plant by weight on record. The Snohomish Sportsmen’s Club also annually plants rainbow trout for their free kids’ fishing derby each May or June at Hill Park, which has been about 300–350 of catchable size (about 0.5 pounds each) in recent years.

## Aquatic Plants

Figure 8 presents results of an aquatic plant survey of Blackmans Lake in 2003 (Snohomish County 2003). Snohomish County qualitatively surveyed the aquatic plant community in Blackmans Lake annually from 2009 to 2022 through the Snohomish County lake monitoring program. The aquatic plant community in the lake is robust and diverse, including large patches of native yellow waterlily (*Nuphar*) and the invasive (Class C noxious weed) fragrant water lily (*Nymphaea odorata*). Additionally, there are moderately dense areas of the microalgae *Nitella* and *Chara*, as well as water nymph (*Najas flexilis*), common elodea (*Elodea canadensis*), and several species of native pondweed (*Potamogeton*).

In 2021 County staff identified the invasive plant (Class C noxious weed) curly leaf pondweed (*Potamogeton crispus*) near the boat launch. There were sparse plants in a small area. The City was notified and the pondweed was removed. The area was inspected for regrowth in 2023. The City hired a licensed applicator to treat fragrant water lilies near the lake outlet with a registered aquatic herbicide in 2022 (see the dark green area labeled N at the lake outlet in Figure 8).

## Endangered/Rare Species Present

According to WDFW’s Priority Habitats and Species (PHS) in Washington State tool (WDFW 2023, WDFW 2024b), there are no sensitive habitats within the Blackmans Lake watershed. Identified habitats include wetlands, lake, freshwater emergent wetlands, and freshwater forested/shrub wetland. Habitat notes by WDFW biologists indicate that Blackmans Lake, as a Puget Sound lowland lake, provides important overwintering food resources for diving ducks, cormorants, and wading birds (e.g., herons), in addition to loafing habitat for other waterfowl. Bald eagles may be observed hunting waterfowl on the lake. Additionally, biologists noted numerous wetlands around the lake and throughout the watershed which are important island refuge habitats or connective riparian corridors.

Endangered, sensitive, or rare species identified for the Blackmans Lake watershed may include but are not limited to Snohomish Coho salmon (*Oncorhynchus kisutch*), the little brown bat (*Myotis lucifugus*), and the Yuma myotis bat (*Myotis yumanensis*). WDFW cautions PHS users that these data are not an exhaustive list of all fish and wildlife presence and are for informational purposes only. WDFW strongly recommends users to schedule a field visit by a fish and wildlife biologist or habitat expert to make determinations about species presence, absence, or exact location before making any final decisions about a project.

Figure 8. Blackmans Lake Aquatic Plants in 2003.



Area	Density	Dominant Plants	Other Plants
A	Moderate	<i>Najas flexilis</i> (Water-nymph, Naiad) <i>Potamogeton amplifolius</i> (Large-leaf pondweed) <i>Nitella</i> sp. (Brittlewort) [in deeper water]	<i>Elodea canadensis</i> (Common elodea) <i>Potamogeton</i> sp. (Thin-leaf pondweed) <i>Ceratophyllum demersum</i> (Coontail)
B	Moderate	<i>Elodea canadensis</i> (Common elodea) <i>Potamogeton</i> sp. (Thin-leaf pondweed) <i>Najas flexilis</i> (Water-nymph, Naiad) <i>Nitella</i> sp. (Brittlewort) [in deeper water]	<i>Potamogeton amplifolius</i> (Large-leaf pondweed) <i>Ceratophyllum demersum</i> (Coontail) <i>Eleocharis</i> sp. (Spikerush)
N	Dense	<i>Nymphaea odorata</i> (Fragrant water-lily) <i>Nuphar polysepalum</i> (Yellow water-lily)	

Notes: There are sizeable wetlands (dominated by willow, spiraea) on the north and northwest shores of the lake. *Typha* sp. (Cattail), *Scirpus* sp. (Bulrush), *Potentilla palustris* (Marsh cinquefoil), *Juncus* sp. (Rush), and *Dulichium arundinaceum* (Three-way sedge) are found scattered in patches along the shoreline. One small patch of *Lythrum salicaria* (Purple loosestrife), a non-native, invasive plant, was found in the northwest wetland. *Iris pseudacorus* (Yellow Iris) is another non-native wetland plant found scattered along the shoreline. The Thin-leaf pondweed species has been identified as either *Potamogeton berchtoldii* or *Potamogeton pusillus*.

Source: Snohomish County 2003.

## Water Quality

Water quality in Blackmans Lake has been monitored through a variety of studies since 1976. The current bathymetric map of the lake was measured by the United States Geological Survey (USGS) in 1973.

Water quality data for Blackmans Lake has been collected by consultants, Snohomish County, City of Snohomish, Ecology, USGS, Washington State Department of Health (DOH), and volunteers. Previous studies of water quality in Blackmans Lake are summarized in Table 4. The most comprehensive of these water quality datasets, spanning most years since 1992, has been collected by citizen volunteers and County Surface Water Management staff as part of Snohomish County's ongoing Lake Management Program to conduct monthly summertime (May–October) monitoring.

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**Table 4. Summary of Previous Studies at Blackmans Lake.**

Title (Reference)	Description
Reconnaissance Data on Lakes in Washington Volume 2 (Ecology 1976)	A water quality characterization of >600 lakes in Washington State. This volume describes the physical, chemical, and general biological data collected from select lakes located in King and Snohomish counties, WA. Plus, a description of the physical setting, water quality, bathymetry, drainage area, and other morphometry is given.
Trophic Classification of Washington State Lakes Using Reconnaissance Data (Ecology 1985)	Trophic classification of Washington lakes using reconnaissance data, describing the physical, cultural, and water quality conditions for 134 Washington lakes. Each lake was indexed by trophic level using a relative, multivariate method and an absolute univariate method, each of which are based on Secchi-disc transparency and concentrations of total phosphorus, total organic nitrogen, and/or chlorophyll-a in the epilimnion.
Water Quality Survey of 25 “Citizen-Volunteer” Lakes from Washington State	A subset of 25 citizen-volunteer lakes was sampled for conventional water quality parameters to determine their current trophic status and provide a database for statewide assessment. Carlson’s trophic state index (TSI) was used to classify each lake.
1989 Lake Water Quality Assessment Project (Ecology 1991)	In 1989, Ecology added a statewide lake monitoring program to its ambient water quality monitoring network to identify lakes that are exhibiting water quality problems, assess trophic status of monitored lakes, and promote public awareness of lake ecology and protection. This program in 1989 consisted of (1) volunteer lake monitoring, (2) a conventional parameter water quality survey of a subset of the volunteer-monitored lakes, and (3) a toxic contaminant survey of fish tissues and sediments from nine lakes. This report presents results from the first two elements.
City of Snohomish Blackman Lake Phase I Restoration Study (KCM 1994)	Prepared by KCM for City of Snohomish, this is a restoration plan for Blackman’s Lake reduce or stop eutrophication by reducing phosphorus. The plan was informed by watershed and lake sampling, which were used to develop water and nutrient budgets. The final plan included programmatic recommendations – concerning erosion control, stormwater management, road maintenance, public education and technical assistance to landowners – as well as an alum treatment to reduce the release of phosphorus from lake sediments. The plan also recommended a variety of capital improvements to reduce erosion and the delivery of fine sediments and pollutants to the lake, such as converting roadside stormwater ditches to bioswales.
1993 Lake Water Quality Assessment Program (Ecology 1996)	A continuation of the 1989 statewide lake monitoring program, these 1993 Lake Water Quality Assessments featured the same objectives (see above). This report presents water quality sample and profile data collected from 86 Washington lakes in the summer of 1993.
1994 Water Quality Assessments of Selected Lakes Within Washington State (Ecology 1997)	As part of the statewide lake monitoring program, these 1994 Lake Water Quality Assessments featured the same objectives as in previous iterations (see above). This report presents water quality sample and profile data collected from 55 Washington lakes in the summer of 1994.
Regional Examination of Harmful Algal Blooms (REHAB) (King County 2009; Backer et al. 2015)	Biweekly toxin analysis and phytoplankton identification/enumeration from samples collected in June through October of 2009, 2010, and 2011 by volunteers and county staff throughout Washington, in partnership with the Washington State Department of Health (DOH) and King County Environmental Laboratory. REHAB was a project funded as part of the national Harmful Algae Bloom-related Illness and Surveillance System (HABISS) pilot project by the Centers for Disease Control and Prevention (CDC). Blackmans Lake was one of 30 monitored lakes in Washington state.
Snohomish County Stormwater Phosphorus Study (2011-2019) (Snohomish County 2021)	Due to observed increases in lake surface phosphorus concentrations, Snohomish County staff measured total phosphorus in storm drains emptying into the lake. Greater concentrations were observed during storm events which supports the hypothesis that a substantial portion of surface water phosphorus originates from the watershed.
City of Snohomish NPDES and TMDL Study (2014–2020) (Gray & Osborne 2021)	The City monitored fecal coliform bacteria at six drainage sites from 2014 through 2020 for their National Pollutant Discharge Elimination System (NPDES) permit and the fecal coliform bacteria Total Maximum Daily Load (TMDL) for tributaries to the lower Snohomish River. Annual geometric mean concentrations of fecal coliform bacteria exceeded Washington State Surface Water Quality Standards for each of 5 or 6 years at the monitoring stations nearest Blackmans Lake because of high populations of waterfowl at the lake. The City decided to choose these stations as their high priority sites for 2021 to do further source identification and elimination efforts including potential DNA testing to confirm the source of bacteria
Snohomish County Lake Monitoring Program (1992–present) (Snohomish County 2024)	Water quality in Blackmans Lake has been monitored by volunteers and County Surface Water Management staff regularly since 1992 as part of the Snohomish County Lake Monitoring Program to conduct monthly monitoring during the summers (May–October). Among general lake conditions and observations, water quality data collected and evaluated from this program include temperature, dissolved oxygen, Secchi depth, chlorophyll-a, cyanotoxins, trophic state index, total nitrogen, and total phosphorus.

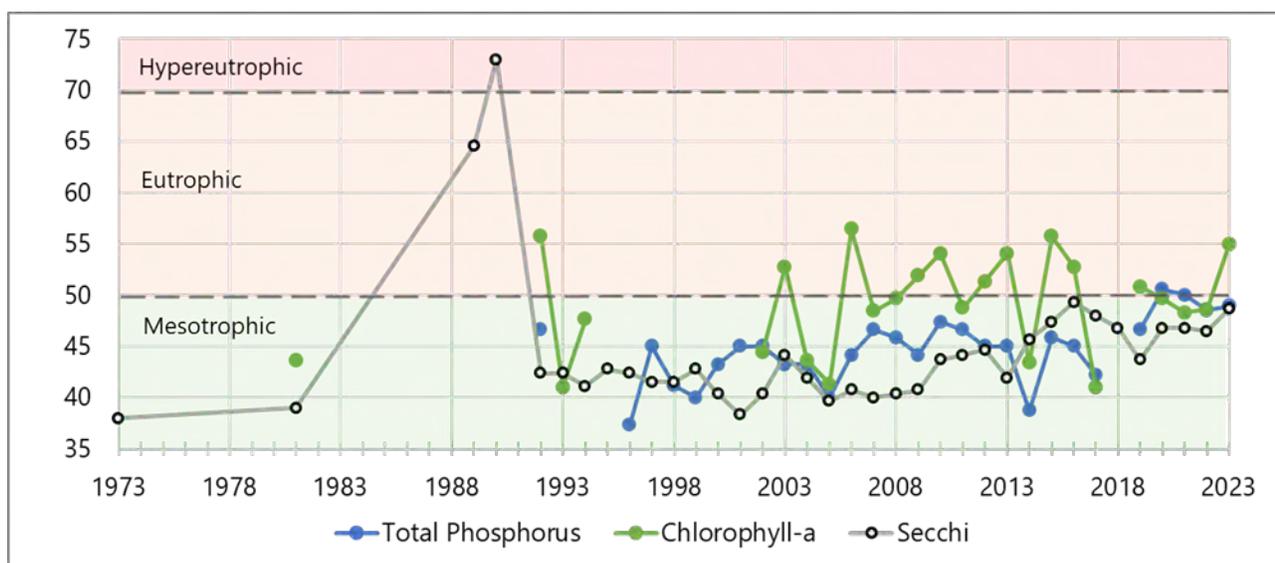
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## Past Conditions

Available water quality data sources for Blackmans Lake are summarized in Table 4 above and described in further detail in the QAPP (Herrera 2022a). Blackmans Lake forms a strong thermal stratification during the summer months, beginning around April and lasting until September. By October, the lake turns over and remains vertically well-mixed through the winter until spring. This stratification is typical for a lake of its size and depth, where surface temperatures warm and remain separate from denser, cooler water in the hypolimnion. Separated from well-oxygenated surface waters, the hypolimnion develops anoxic conditions in the summer due to decomposition of organic material in the sediment and lack of re-aeration.

Generally, Blackmans Lake shows a long history of moderate productivity as a mesotrophic to eutrophic lake, according to annual summer (June through September) mean values of Secchi depth, chlorophyll-a, and total phosphorus in surface water samples. Figure 9 presents the trophic state index (TSI) for each of these trophic state parameters (Snohomish County 2024). Mesotrophic to eutrophic lakes have moderate to high amounts of nutrients and are common in lowland western Washington, especially in areas with some development along the shoreline and in the watershed.

**Figure 9. Blackmans Lake Trophic State Index (1973–2023).**



Data source: Snohomish County (2024)

Nutrients (nitrogen, phosphorus, and iron) occur at greater concentrations in the hypolimnion than near the lake surface during the summer, likely due to the release of phosphorus from the iron minerals in the lake sediments during summertime anoxic conditions (KCM 1994). KCM's 1994 report calculated stormwater runoff as the greatest source of nutrients (at 55 percent on an annual basis), followed by nutrients from inlets (19 percent), internal loading during hypoxia (12 percent), wetland flow (7 percent), and precipitation (7 percent) (Table 5).

**Table 5. Blackmans Lake Phosphorus Budget (May 1992 to April 1993) (KCM 1994).**

Inflows	Mass (kg)	Percent of Total	Outflows	Mass (kg)	Percent of Total
Inlets (Grass Bottom and Blackmans creeks and unnamed intermittent western inlet)	14	19	Outlet (Swifty Creek)	15	20
Stormwater	41	55	-		
Precipitation	5	7	-		
Groundwater	0	0	Groundwater	0	0
Wetlands	5	7	Wetlands	3	17
Internal Load	9	12	Sedimentation	48	62
<b>Total</b>	<b>76</b>		<b>Total</b>	<b>76</b>	
Change in Lake Storage	0	negligible	Change in Wetland Storage	8	Net gain

Data indicate a potential increasing trend toward eutrophication in Blackmans Lake (see Figure 9). Despite some interannual variability, the 30-year trend in these water quality parameters indicates a statistically significant ( $p < 0.01$ ), increase in trophic state with reduced water clarity and increasing cyanobacteria blooms, toxins, and nutrients (KCM 1994; Snohomish County 2021, 2022a; Ecology 2022).

Due to contemporary increases in lake surface phosphorus concentrations, Snohomish County staff measured total phosphorus in storm drains emptying into the northeast corner of lake at Park Avenue, 19<sup>th</sup> Street, and at Hill Park (Table 6). Monitored during the wet season of water years 2011 through 2019, County staff found observed higher concentrations of total phosphorus during large storm events (Snohomish County 2021), supporting KCM’s results and the hypothesis that a substantial portion of surface water phosphorus originates from the watershed.

**Table 6. Average Total Phosphorus in Blackmans Lake Storm Drain Samples.**

Water Year	Park Avenue		19th Street		Hill Park	
	TP (µg/L)	n	TP (µg/L)	n	TP (µg/L)	n
2011	24	1	7	1	-	0
2012	78	3	52	3	24	2
2013	33	2	22	2	15	2
2014	38	3	15	3	-	0
2015	74	1	44	1	-	0
2017	47	1	28	1	-	0
2019	25	3	20	3	-	0
Sample Mean/Total	45	15	27	15	20	4

Source: J. Oden personal communication, 6/27/2024

TP = total phosphorus; n = number of samples

Additionally, Blackmans Lake today is listed as impaired (Category 5) due to fecal coliform bacteria pollution in Ecology’s 2018 Water Quality Assessment due to elevated levels documented by KCM (1994). The lake was originally listed as Category 5 based on the 1998 assessment. Although these data are more than 20 years old, there are no recent data to justify removing the listing.



## Improvement Efforts

The 1996 lake restoration plan recommended watershed management measures to reduce external phosphorus loading to the lake and an aluminum sulfate (alum) treatment of the lake to reduce internal phosphorus loading to the lake, recognizing that watershed management actions were not likely to reduce the occurrence of cyanobacteria blooms in the short term (KCM 1996). Watershed management recommendations included basin-wide controls and developed property controls that included education and implementation of best management practices (BMPs) to reduce soil erosion and phosphorus export from riparian, road, forest, agriculture, residential, and commercial areas. A dozen capital improvement projects were recommended to increase infiltration of Blackmans Creek through the wetland below 22nd Street, construct a stormwater pond immediately above 22nd Street, convert ditches to bioswales, fence livestock out of stream buffers, and reshape and vegetate ditch and stream segments to improve sediment retention. As summarized below, many of the recommended watershed management actions have been implemented by the City, but an alum treatment or other means to reduce internal phosphorus loading has not been performed on Blackmans Lake.

The City of Snohomish formed a stormwater utility in 2005. In response to the National Pollutant Discharge Elimination System (NPDES) Permit first issued to the City by Ecology in 2007, the City regularly updates a stormwater management program and prepares annual program reports (COS 2024). This program includes the following elements to protect water quality throughout the City:

- Stormwater Planning
- Public Education and Outreach
- Public Involvement and Participation
- MS4 Mapping and Documentation
- Illicit Discharge Detection and Elimination
- Controlling Run-Off from New Development, Redevelopment and Construction Sites
- Operations and Maintenance
- Source Control Program for Existing Development
- River Fecal Bacteria Total Maximum Daily Load (TMDL)

BMPs are implemented in accordance with the Stormwater Management Manual for Western Washington (Ecology 2019) that has been adopted by the City and includes updates focusing on using Low Impact Development (LID) stormwater techniques where possible for new and re-development. In general, LID effectively reduces phosphorus loading by infiltrating stormwater into the ground that is much more effective than traditional solids-settling devices such as vaults and even filtration devices which often clog and bypass untreated stormwater. Soils analysis and infiltration testing are required for development. On-site infiltration must be implemented if feasible. Stormwater facilities are owned and maintained by the owner(s) of the property(s) that conveys stormwater runoff to the facility. Any stormwater facility modifications must be in accordance with the Ecology Stormwater Manual and reviewed by the City.

## Current Conditions

Blackmans Lake suffers from annual algae blooms which often contain detectable cyanotoxins capable of causing frequent and enduring health advisories. These blooms are typically seen in late summer or fall, and often intermittently persist into the winter months (November–April). These toxic algae blooms threaten swimmers and pets, are aesthetic nuisances, and destabilize the lake's ecosystem. Cyanotoxin data collected since 2009 are presented and summarized in the QAPP (Herrera 2022a). The state guideline for microcystin has been exceeded in only one surface scum sample tested in 2017 and in 2020. However, Snohomish County has posted warning signs advising no swimming or pet use of the lake and for boaters to avoid scum areas on many occasions when algae scums are observed but not tested.

Based on historic data, nutrient availability (mainly phosphorus) is a primary driver of these algal blooms. Anoxic conditions at the lake bottom during summer months may also negatively impact aquatic life uses. Nutrient, algae, and other water quality data are presented and summarized in the QAPP (Herrera 2022a).

Water quality data collected in water year 2023 for this LCMP are presented and discussed in Appendix A.

## Contaminants of Concern

The contaminants of concern in Blackmans Lake are the cyanotoxins microcystin and anatoxin-a, total phosphorus, and fecal coliform bacteria. Blackmans Lake is listed as impaired (Category 5) due to elevated levels of fecal bacteria first measured in 1998, with no recent data from the lake to justify delisting. Excess waterfowl continue to be a problem in the lake and may have been the primary source of high bacterial concentrations observed in 1994. The City monitoring of fecal bacteria at six drainage sites from 2014 through 2020 found annual geometric mean concentrations of fecal coliform bacteria exceeding Washington State Surface Water Quality Standards (WAC 173-201A) criterion of 100 CFU/100 mL in each of the past 5 years at two of the six monitoring stations. However, these stations drain to the Snohomish River and not Blackmans Lake.

Ecology recently revised Water Quality Program Policy 1-11 to develop Narrative Water Quality Standards for the basis of impairment for Harmful Algae Blooms (Ecology 2023). Ecology will utilize a combination of public health advisory information, cyanotoxin data from the Northwest Toxics Algae Database, public health assessment information, and the DOH recreational guidance as the basis for evaluating the health of contact recreation in the Water Quality Assessment (WQA).

Fish in Blackmans Lake are impaired during the summer months by high water temperatures in surface waters and low dissolved oxygen levels in the bottom waters, as presented and described in the QAPP (Herrera 2022a).

## Community Involvement & Public Support

Public stakeholders include lakeshore homeowners and other Blackmans Lake community members who recreate on the lake and at either of the two City parks: Ferguson Park on the south shore and Hill Park on the east shore. This community is engaged in lake monitoring activities, which are orchestrated through the Friends of Blackmans Lake as the primary organization for homeowner and community engagement. The Snohomish Sportsmen's Club has stocked Blackmans Lake and organized fishing events.

Government stakeholders include:

- City of Snohomish operates the two City parks located on the lake's eastern and southern shores, directs and funds the development and implementation of this LCMP, and provides oversight, guidance, and monitoring support.
- City of Snohomish has entered into an interlocal agreement with Snohomish County to provide guidance, lake monitoring program leadership, and coordination.
- City of Snohomish maintains the public boat launch at Ferguson Park.
- Washington Department of Ecology provided a grant to prepare this LCMP and supports toxic cyanobacteria monitoring of the lake through the Washington State Toxic Algae Program.

For this LCMP, four community meetings were held on the following occasions:

- Stakeholder kickoff and QAPP meeting in December 2022
- Pre summer Volunteer monitoring meeting in March 2023
- Draft LCMP meeting and presentation to the public on May 20, 2024, and to the City Council on July 16, 2024

Public meeting notes and comments are presented in Appendix E.

# Project Description

## Project Goals and Objectives

The overall goal of the project is the development of a cyanobacteria management plan that identifies sources of phosphorous fueling the toxic algae blooms that occasionally occur during the summer in Blackmans Lake. Monitoring of Blackmans Lake water quality and other parameters were performed with the primary goal of evaluating the effects of environmental conditions and past lake management practices on algae growth and toxin production. Toxic algae blooms may have been stimulated by several factors, which may include but are not limited to the following:

- Stormwater runoff, washing nutrients into the lake
- Low oxygen in bottom waters or sediments from oxygen consumption by microbial respiration and decomposition, increasing the release of sediment phosphorus
- Warm weather, extending the period of low oxygen in bottom waters or sediments
- Wind mixing up nutrient-rich bottom waters
- Increased nutrients from the increased aquatic plant decay or waterfowl activity
- Trout stocking, reducing zooplankton grazing of algae
- Change in the dynamics of the northwest wetland to act as source, rather than a sink

The resulting cyanobacteria management plan builds on past management actions, provides recommendations for water quality improvements to enhance recreational and wildlife use of the lake, and primarily focuses on developing a management strategy to reduce the frequency and duration of toxic algae blooms. To meet this goal, the following objectives were defined for this project:

- Fill data gaps in water quality, watershed, and biological information for Blackmans Lake.
- Evaluate effects of environmental conditions and past lake management practices on algae growth and toxin production.
- Develop a phosphorous loading model and budget using data from the project and historical datasets.
- Identify the sources of phosphorous which stimulate cyanobacteria blooms.
- Determine predictors of chlorophyll-a concentration and algae production for modelling of treatment efficacies.
- Develop recommendations for watershed phosphorus loading reduction treatments and in-lake restoration techniques.
- Develop a cyanobacteria management plan which when implemented reduces the frequency and duration of cyanobacteria blooms.

- Inform and guide future aquatic plant and waterfowl management actions, and ongoing monitoring strategies with respect to cyanobacteria blooms.
- Provide high quality data for the City of Snohomish, Snohomish County, and other users.

## Lake Management Objectives

The goal for Blackmans Lake management is to improve and protect lake uses by decreasing cyanobacteria blooms and the conditions that support them. The recommended water quality objectives for Blackmans Lake are adapted from Ecology (2023) criteria for determining lake impairment due to harmful algae blooms. These objectives include the following:

- Within a 5-year period, there is no more than 1 year with two or more events with cyanotoxins exceeding state recommended guidelines.
- Within a 5-year period, there is no more than 1 year with a public health advisory lasting 3 weeks or longer.

To prevent harmful algae blooms, it is recommended to reduce the trophic state (amount of algae and nutrients) of Blackmans Lake from eutrophic (high algae and nutrients) to mesotrophic (moderate algae and nutrients) by not exceeding the following upper-mesotrophic thresholds, based on average summer (June through September) values in the epilimnion (1 meter depth) (Carlson 1977):

- Chlorophyll-a concentration not exceeding 7.2 µg/L
- Total phosphorus not exceeding 24 µg/L
- Secchi depth exceeding 2.0 meters.

## Schedule

Table 7 summarizes the schedule for the development of this plan.

## Data Used for Plan Development

This plan was developed using data collected as part of this LCMP project. A summary of the types of data gathered, methodology used, data quality assurance results, and sources of additional datasets are presented in Appendix A. Field data and laboratory data reports are compiled in Appendix B and Appendix C, respectively.

**Table 7. Project Schedule.**

Task	Item	Responsible Entity				Period / Completion Date
		HEC	COS	SCV	FOBL	
1	Project management	<b>X</b>	<b>X</b>			Ongoing
2	Draft QAPP	<b>X</b>	x			10/14/22
	Final QAPP	<b>X</b>	x	x	x	12/28/22
3	Stream/drainage monitoring	x	<b>X</b>			Nov 2022 to Oct 2023
	Lake water quality monitoring (Nov-April)	x		x	<b>X</b>	Nov 2022 to Apr 2023
	Lake water quality monitoring (May-Oct)	x		<b>X</b>	x	May to Oct 2023
	Lake sediment P monitoring	<b>X</b>				August 2023
4	Water/phosphorus budgets	<b>X</b>				February 2024
5	Pre-draft CMP	<b>X</b>	x			April 2024
	Draft CMP	<b>X</b>	x			July 2024
	Final CMP	<b>X</b>	x	x	x	August 2024
6	Stakeholder kickoff/QAPP meeting	<b>X</b>	x	x	x	12/12/2022
	Pre-summer monitoring meeting	<b>X</b>	x	x	x	3/26/2023
	Draft CMP stakeholder meeting	<b>X</b>	x	x	x	5/20/2024
	Draft CMP City Council meeting	<b>X</b>	x	x	x	7/16/2024

HEC=Herrera environmental Consultants, COS=City of Snohomish, SCV=Snohomish County Volunteers, FOBL= Friends of Blackmans Lake.

# Blackmans Lake Hydrologic Budget

## Development

A lake's hydrologic budget refers to the quantification and analysis of the various inflows, outflows, and storage changes that contribute to the overall water balance of the lake over a defined period, typically annually. This concept is vital for understanding the hydrological dynamics and sustainability of a lake ecosystem. A comprehensive description of a lake's water budget involves the following components:

- **Precipitation ( $P$ ):** Precipitation represents the input of water to the lake in the form of rain and snowfall.
- **Evaporation ( $E$ ):** Evaporation refers to the loss of water from the lake surface due to the conversion of liquid water to water vapor driven by solar radiation and atmospheric conditions. Evaporation rates vary based on factors such as air temperature, humidity, wind speed, and lake surface area.
- **Runoff ( $R$ ):** Runoff includes all surface water inflows to the lake from its watershed. Runoff can result from rainwater and snowmelt, and it carries nutrients, sediments, and pollutants into the lake. In Blackmans Lake, Runoff consists of inputs from Blackmans Creek ( $Q_{Blackmans}$ ), Grass Bottom Creek ( $Q_{Grass}$ ), a small unnamed inlet to Champagne Cove ( $Q_{Champ}$ ), and direct stormwater discharges from areas around the lake ( $Q_{Storm}$ ). Blackmans Creek, while surface at 22<sup>nd</sup> Street, does not have a discernible channel between the road and the lake. The area is quite marshy, and the flow in Blackmans Creek is expected to recharge groundwater at this location.
- **Groundwater Inflow ( $GW_{In}$ ):** Groundwater inflow represents the subsurface flow of water from aquifers into the lake. This contribution can significantly influence the lake's water budget, particularly in regions with permeable soils and high groundwater recharge.
- **Groundwater Outflow ( $GW_{Out}$ ):** Groundwater outflow represents the subsurface flow of water from lake into aquifers.
- **Outflow ( $O$ ):** Outflow consists of water leaving the lake via surface water. In Blackmans Lake, the outflow is Swifty Creek.
- **Change in Storage ( $\Delta S$ ):** This component accounts for the change in the lake's water volume stored over the defined time period. Positive values indicate an increase in storage (lake level rise), while negative values signify a decrease (lake level decline).

The water budget equation can be expressed as the difference between inflows and outflows:

$$\Delta S = P + Q_{Blackmans} + Q_{Grass} + Q_{Champ} + Q_{Storm} + GW_{IN} - (O + E + GW_{Out})$$

Because of the difficulty in measuring groundwater flows, the groundwater component is often expressed as the net ( $GW_{Net}$ ), calculated as the difference between inflows and outflows plus the change in storage:

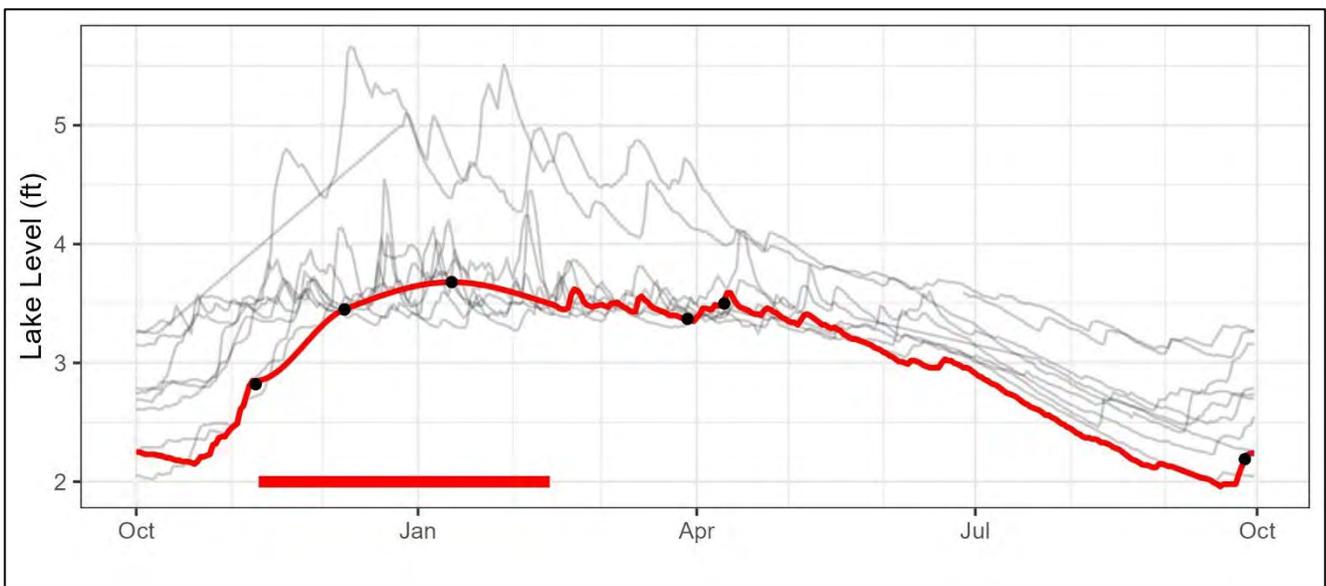
$$GW_{Net} = GW_{In} - GW_{Out} = (Outflows + \Delta S) - Inflow$$

## Change in Lake Storage

Continuous lake level measurements were recorded by Snohomish County using a level logger at the lake staff gauge on the fishing pier in Hill Park (BlackmansLake@HillPark). The volume of water in the lake for each day was estimated based on the lake level and lake bathymetry, and the daily changes in volume were calculated. Volumes were summed at a monthly basis.

There was a significant data gap in lake level data from November 10, 2022 to February 13, 2023 (Figure 10). During this period, two watershed sampling events occurred that included manual recording of the lake stage using the staff gauge: December 8, 2022 and January 12, 2023. The lake levels during the gap were estimated using Piecewise Cubic Hermite splining interpolation. Splining was used to provide a smooth approximation of the lake level. It is expected that the data gap and interpolation do not capture the extreme lake fluctuations seen in the winter. This is evident by comparing the interpolated period to the historic lake levels for previous years. By summarizing to a monthly, we can reasonably assume that the estimates approximate the change in lake storage well during the interpolated period.

**Figure 10. Blackmans Lake Level for Water Year 2023 Compared to Historic Levels.**

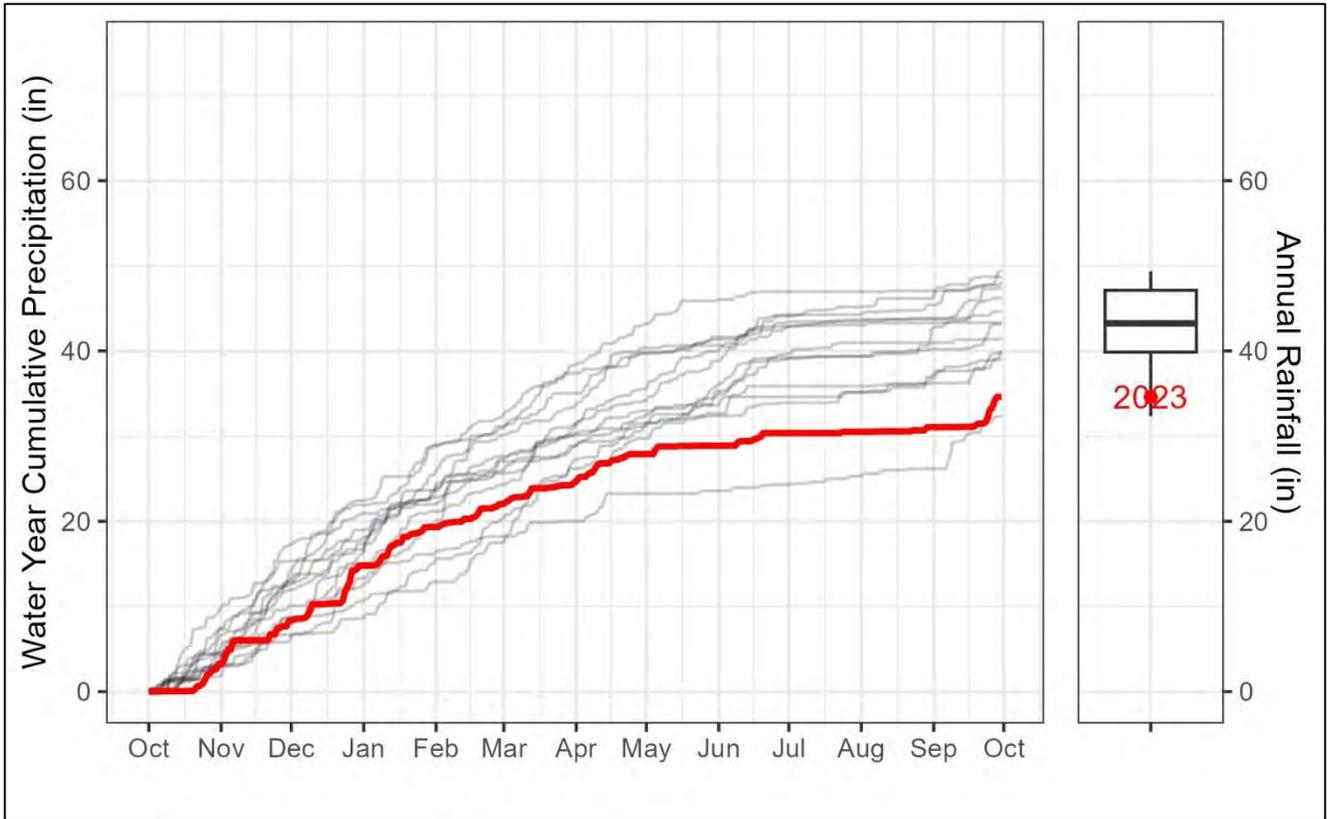


Water year 2023 highlighted as with the red line with black dots for staff gauge readings; past years shown in grey.

## Precipitation

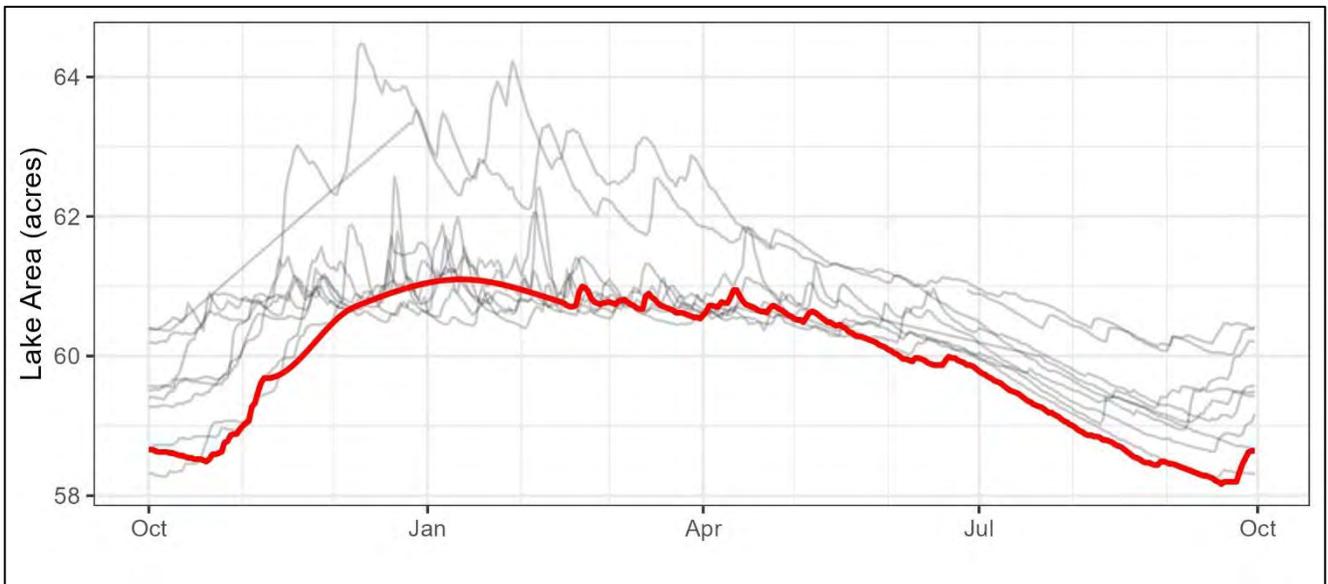
Daily rainfall data from the French Slough Pump Station operated by the City was used and were multiplied by the daily lake surface area to calculate the volume of direct precipitation. Calendar year 2023 was drier than typical, specifically October 2022 and a fairly dry spring (Figure 11). Water year 2023 had a total of 34.6 inches of rainfall, which is 20 percent less than the median rainfall between 2010 and 2023 was 43.2 inches. The low rainfall resulted in summer lake levels being the lowest on record beginning in June 2023 (Figure 12).

Figure 11. Daily Cumulative Rainfall (left) and Annual Water Year Rainfall (right) at French Slough Pump Station Rain Gauge.



Water year 2023 highlighted as with the red line, past years shown in grey.

Figure 12. Blackmans Lake Area for Water Year 2023 Compared to Historic Areas.



Water year 2023 highlighted as with the red line, past years shown in grey.

The lake level data gap and interpolated period may result in a slight underestimate of lake area but would not have a significant effect on the amount of direct precipitation input. The largest rainfall event was on December 27, 2022, at 1.32 inches. If the lake area was off by 2 acres on this day, this would net a difference of 271 cubic meters, which is insignificant compared to an annual total input of 1.5 million cubic meters of water to the lake (see below).

## Evaporation

Evaporation depth was calculated using daily average air temperature and dew point from the Everett Airport. The daily evaporation depth was multiplied by the daily surface area of the lake to calculate total monthly evaporation volume.

To estimate evaporation, we used the simplified Penman equation (Linacre 1977):

$$E = (700 * (T + 0.006 * h) / (100 - A) + 15 * (T - T_d)) / (80 - T)$$

Where:

- $E$  = evaporation (mm/day)
- $T$  = mean daily air temperature (deg C)
- $h$  = elevation (m)
- $A$  = Latitude (deg)
- $T_d$  = dew point

The interpolated lake level estimates would not significantly affect the evaporation estimates for Blackmans Lake because the lake level data gap occurred during the winter when evaporation is minor at about 2 millimeters per day. Assuming that evaporation rate, if the lake area estimate was off by 2 acres on a given day, this would net a difference of approximately 16 cubic meters compared to the annual water output of 1.5 million cubic meters.

## Surface Inflows

We estimated surface inflows separated by base flow and storm flow. We used monitored base flow discharge measurements collected by City staff for each of the stream stations. Based on an absence of base flow observed elsewhere during watershed reconnaissance, we assumed there was no surface base flow for the nonmonitored basins (designated as BLK-X drainage) and that all those loads would be captured in groundwater load.

For storm flow, we implemented the Simple method (Schueler, 1987). The technique requires a modest amount of information, including the watershed drainage area and impervious cover, and annual precipitation:

$$V_{S,i} = R_{v,i} * P * A_i$$

Where:

- V = runoff volume for watershed i
- R<sub>v</sub> = runoff coefficient for watershed i
- P = precipitation depth (m)
- A = total watershed area for watershed i (m<sup>2</sup>)

The runoff coefficient R<sub>v</sub> is calculated using the following equation:

$$R_{v,i} = 0.05 + 0.9 * I_{a,i}$$

Where: I<sub>a</sub> = impervious fraction for watershed i.

Drainage basin land cover and runoff coefficients are provided in Table 8. Due to the granularity of the NLCD at 30 m by 30 m cells (Figure 5), there may be some misclassifications. For example, about 11 acres of Blackmans Lake is characterized as developed or wetlands due to land cover cells at the border of the lake and in Champagne Lane.

**Table 8. Land Cover and Runoff Coefficient for Lake Drainage Areas.**

Watershed Station	NLCD Land Cover (2021)							NLCD Imperviousness (2021)			Rv
	Total Area	Agriculture	Forest	Wetlands	Grass/Shrub/Bare	Water	Developed	Total Area	Impervious	% Impervious	
BLK-26	18.5	0.0	0.0	0.0	0.0	0.0	18.5	18.7	5.2	28%	0.30
BLK-NE	84.5	0.9	16.5	2.0	0.0	0.0	65.2	86.2	12.0	14%	0.18
BLK-22	125.8	0.9	16.5	2.0	0.0	0.0	106.5	127.1	25.2	20%	0.23
BLK-MTH	151.0	0.9	16.5	2.2	0.0	0.0	131.4	152.0	33.8	22%	0.25
CHAMP-19	17.1	0.0	0.0	0.0	0.0	0.0	17.1	17.2	7.3	42%	0.43
CHAMP-PARK	127.0	0.4	11.1	1.6	0.7	0.0	113.2	126.7	38.5	30%	0.32
BLK-X	118.0	0.0	0.9	7.3	0.7	1.1	116.0	119.3	36.3	30%	0.32
LAKE	60.7	0.0	0.9	6.2	0.2	48.9	4.5	61.3	0.6	1%	NA
<b>TOTAL</b>	<b>474.0</b>	<b>1.3</b>	<b>28.5</b>	<b>11.1</b>	<b>1.3</b>	<b>50.0</b>	<b>381.9</b>	<b>476.4</b>	<b>116.5</b>	<b>28%</b>	-

Note that BLK-22, BLK-NE, and BLK-26 are part of the BLK-MTH watershed.

All values in acres except % impervious (%) and Rv (unitless).

National Land Cover Database (NLCD) 2021 used for land cover and imperviousness.

Importantly, during sampling and site reconnaissance, City and Herrera staff were unable to find a discrete mouth of Blackmans Creek where it would enter the lake. After flowing into the powerline right-of-way, multiple potential flow paths were observed, but it appears that the predominance of water percolated into the ground. We expect that all of the base flow and most if not all of the storm flow

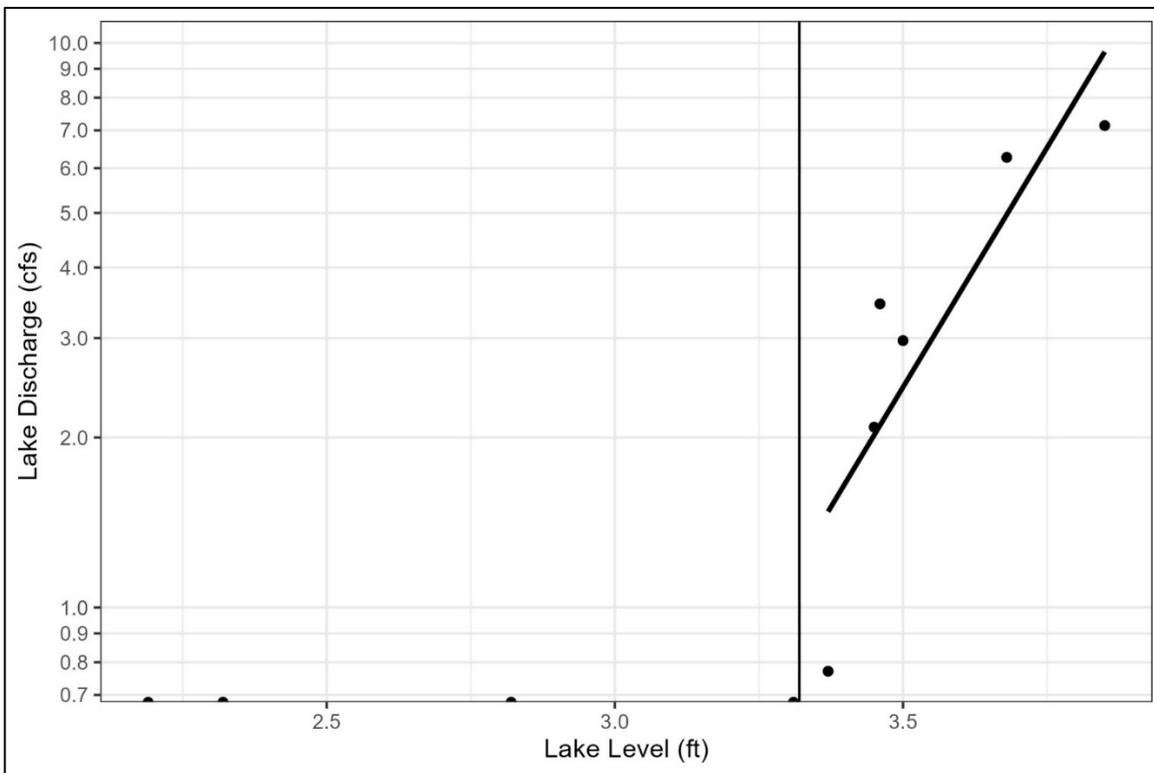
estimated in the water budget for Blackmans Creek actually enters the lake via groundwater rather than surface flow.

## Lake Outflow

Discharge at the lake outlet (BLK-OUT) was measured using the current meter to measure the velocity and depth of water in each the four 18-inch PVC pipes. If these pipes are not accessible, stream discharge was measured immediately downstream where the outflow passes over an earthen weir or further downstream in Swifty Creek (SWFTY) using open-channel cross-section method.

The instantaneous discharge measurements and the lake level were used to develop a rating curve (Figure 14). Seven sampling events were used to develop the rating curve. There were four additional sampling events where no outflow was observed. This rating curve was used to calculate daily discharge across the monitoring period, including the period with interpolated lake level values (Figure 15). Because the lake level never exceeded the maximum level used for rating curve development, no extrapolation was required.

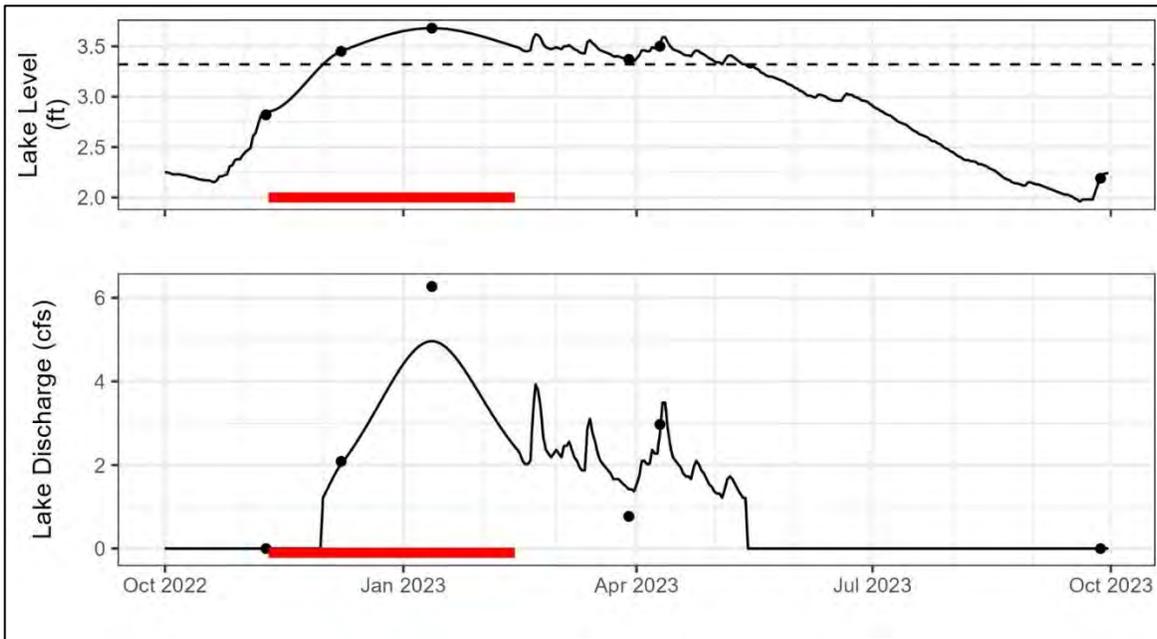
Figure 13. Blackmans Lake Outlet Discharge–Level Relationship.



Note y-axis is on log-scale. Vertical line is the elevation of the outlet pipe intakes (3.32 feet).

Best fit line equation:  $\text{Discharge} = \exp(-12.776) * \exp(\text{Level})^{3.91}$  ( $R^2 = 0.74$ ).

Figure 14. Blackmans Lake Outlet Estimated Discharge.



The lake level data gap and interpolated data likely resulted in significant underestimates of lake discharge. Further, we see that the rating curve underestimated the lake outflow compared to the measured value on January 12, 2023 (6.3 cfs observed vs. 5.1 cfs modeled). It is therefore possible that late-fall to early-winter surface outflow is underestimated, which would result in underestimates in the net groundwater inputs to the lake or overestimates of net groundwater outflow in the winter.

Once the lake level reached the outlet elevation in May 2023, no further surface outflow was estimated through the remainder of water year 2023.

## Groundwater

Groundwater flows into and out of the lake were calculated as the residual using the inflows and outflows described above as well as changes in lake storage volume. Blackmans Lake is located above recessional sand and gravel outwash and recessional outwash geologic soils. There is direct hydraulic connectivity between the wetlands on north and south shoreline of the lake (KCM 1994). Glacial till underlies the outwash and wetlands. The till unit is relatively impermeable and provides a perch for the lake and adjacent aquifers in the wetlands. Beneath the till, there is advance outwash and the regional aquifer. Due to the till, there is little hydraulic connectivity between the two layers of outwash, i.e., there is little connectivity between the lake and the regional aquifer. Groundwater flows through the lake via the shallow perched aquifers. Flows are typically from north to south, generally following the surface topography of the area, and surface soils in the watershed are well-draining (KCM 1994; Snohomish County 2006).

Because seepage through the till layer is expected to be minimal, estimating the groundwater component of the hydrologic budget via the residual is appropriate to provide approximate order of magnitude estimates.

## Results

### Tributary Inflows

Overall, the tributaries contributed most of their volume to Blackmans Lake during storm flow (438,000 m<sup>3</sup>) versus base flow (159,000 m<sup>3</sup>) (Table 9). Blackmans Creek (BLK-MTH) and Grass Bottom Creek (CHAMP-PARK) together contributed approximately two-thirds of the total tributary inflow to the lake. Grass Bottom Creek had lower base flow than Blackmans Creek, despite having higher estimated storm flows. This is likely driven by the higher amount of impervious area in the Grass Bottom drainage and that upstream retention ponds may infiltrate base flows that follow a different groundwater flow path to the lake.

### Blackmans Lake Hydrologic Budget

The water year 2023 monthly hydrologic budget for Blackmans Lake is displayed in Table 10. The budget had significant residuals during each month, which we have assumed to be Groundwater Inflow when positive and Groundwater Outflow when negative. Figure 16 presents the annual hydrologic budget graphically in and Figure 17 presents the summer hydrologic budget for May through October 2023 graphically, with lake inflows on the left and lake outflows on the right of each graph.

The annual net groundwater inflow was 725,000 cubic meters, which is approximately equal to the of the total surface inflow to the lake (precipitation + base flow + storm flow). The lake is a net groundwater importer. The glacial outwash soils around the lake are well-draining and likely allow substantial infiltration and groundwater exchange. In this budget, the discharge from Blackmans Creek is treated as surface flow but, as acknowledged previously, much of this flow may infiltrate in the powerline right-of-way and may instead enter the lake as subsurface flow, i.e., would be considered as “groundwater inflow.”

The residuals may also be due to over- or under-estimates in the surface inflows and outflows of the lake. Storm flow volume estimates are based on the Simple Method because continuous stream gauging data were not available, and base flow volume estimates were extrapolated from instantaneous discharge measurements. We believe the lake outflows may be underestimates for November 2022 through January 2023 as discussed above. If true, then the total groundwater inputs are expected to be even greater.

We believe the hydrologic budget provides adequate planning level estimates of the volume of water moving through Blackmans Lake. The water budget would benefit from further calibration of the Blackmans Lake gauge and the monitoring or modeling of groundwater levels, flow velocity, and direction.

Using the total annual lake inflow (1,531,800 m<sup>3</sup>) and a lake volume of 1,047,120 m<sup>3</sup>, we estimate that the lake residence time is 0.68 years. In other words, the whole lake volume flushes about 1.5 times per year. During the summer (May through October), the lake level decreased as outflows exceeded inflows. Evaporation was the dominant export of water from the lake, followed by groundwater export. Summer storms provided a moderate input of water.

**Table 9. Monthly Lake Surface Inflow Volumes.**

Base flow Volume (1,000 m <sup>3</sup> )									
Year	Month	BLK-26	BLK-NE	BLK-22	BLK-MTH	CHAMP-19	CHAMP-PARK	BLK-X	TOTAL
2022	11	4.8	7.6	8.1	8.1	2.5	2.5	0.0	13.1
2022	12	4.9	7.9	8.4	8.4	2.6	2.6	0.0	13.5
2023	1	4.9	7.9	8.4	8.4	2.6	2.6	0.0	13.5
2023	2	4.5	7.1	7.6	7.6	2.3	2.3	0.0	12.2
2023	3	4.9	7.9	8.4	8.4	2.6	2.6	0.0	13.5
2023	4	4.8	7.6	8.1	8.1	2.5	2.5	0.0	13.1
2023	5	4.9	7.9	8.4	8.4	2.6	2.6	0.0	13.5
2023	6	4.8	7.6	8.1	8.1	2.5	2.5	0.0	13.1
2023	7	4.9	7.9	8.4	8.4	2.6	2.6	0.0	13.5
2023	8	4.9	7.9	8.4	8.4	2.6	2.6	0.0	13.5
2023	9	4.8	7.6	8.1	8.1	2.5	2.5	0.0	13.1
2023	10	4.9	7.9	8.4	8.4	2.6	2.6	0.0	13.5
<b>Base Total</b>		<b>58.1</b>	<b>92.9</b>	<b>98.5</b>	<b>98.5</b>	<b>30.3</b>	<b>30.2</b>	<b>0.0</b>	<b>158.9</b>
Storm flow Volume (1,000 m <sup>3</sup> )									
Year	Month	BLK-26	BLK-NE	BLK-22	BLK-MTH	CHAMP-19	CHAMP-PARK	BLK-X	TOTAL
2022	11	2.9	7.9	15.2	19.9	3.9	21.4	20.5	65.8
2022	12	3.7	10.0	19.3	25.2	4.9	27.2	26.0	83.3
2023	1	2.6	7.0	13.5	17.7	3.5	19.1	18.3	58.5
2023	2	1.5	4.2	8.1	10.5	2.1	11.4	10.9	34.9
2023	3	1.4	3.9	7.5	9.8	1.9	10.6	10.2	32.6
2023	4	1.9	5.2	10.0	13.1	2.6	14.1	13.5	43.3
2023	5	0.6	1.5	3.0	3.9	0.8	4.2	4.0	12.8
2023	6	0.8	2.3	4.4	5.8	1.1	6.2	6.0	19.1
2023	7	0.1	0.2	0.4	0.6	0.1	0.6	0.6	1.9
2023	8	0.3	0.8	1.6	2.1	0.4	2.3	2.2	7.0
2023	9	2.0	5.5	10.6	13.9	2.7	14.9	14.3	45.9
2023	10	1.5	4.0	7.7	10.1	2.0	10.9	10.4	33.3
<b>Storm Total</b>		<b>19.4</b>	<b>52.5</b>	<b>101.4</b>	<b>132.5</b>	<b>26.0</b>	<b>142.9</b>	<b>136.9</b>	<b>438.3</b>
Total (Base + Storm flow) Volume (1,000 m <sup>3</sup> )									
<b>Base + Storm</b>		<b>77.6</b>	<b>145.3</b>	<b>199.9</b>	<b>231.0</b>	<b>56.3</b>	<b>173.0</b>	<b>136.9</b>	<b>597.3</b>

Note that BLK-26, BLK-NE, and BLK-22 drain sequentially to BLK-MTH in the Blackmans Creek watershed.

**Table 10. Blackmans Lake Water Budget (1,000 cubic meters).**

Year	Month	Precipitation	Base Flow	Storm Flow	Net Groundwater In	TOTAL INFLOW	Evaporation	Lake Outflow	Net Groundwater Out	TOTAL OUTFLOW	Change in Volume
2022	11	31.2	13.1	65.8	0.0	<b>110.1</b>	13.8	0.0	35.1	<b>48.9</b>	61.2
2022	12	40.4	13.5	83.3	107.2	<b>244.4</b>	8.6	211.4	0.0	<b>220.0</b>	24.4
2023	1	28.4	13.5	58.5	257.5	<b>358.0</b>	15.3	345.7	0.0	<b>361.0</b>	-3.1
2023	2	16.9	12.2	34.9	129.8	<b>193.7</b>	12.7	189.5	0.0	<b>202.2</b>	-8.4
2023	3	15.7	13.5	32.6	103.9	<b>165.7</b>	18.9	155.9	0.0	<b>174.8</b>	-9.1
2023	4	20.9	13.1	43.3	98.3	<b>175.6</b>	19.9	154.3	0.0	<b>174.2</b>	1.4
2023	5	6.2	13.5	12.8	27.9	<b>60.3</b>	33.5	45.0	0.0	<b>78.5</b>	-18.2
2023	6	9.1	13.1	19.1	0.0	<b>41.3</b>	33.6	0.0	20.3	<b>53.9</b>	-12.6
2023	7	0.9	13.5	1.9	0.0	<b>16.3</b>	43.0	0.0	6.2	<b>49.2</b>	-32.8
2023	8	3.2	13.5	7.0	0.0	<b>23.7</b>	45.0	0.0	0.4	<b>45.4</b>	-21.7
2023	9	21.3	13.1	45.9	0.0	<b>80.2</b>	33.0	0.0	41.0	<b>73.9</b>	6.3
2023	10	15.6	13.5	33.3	0.0	<b>62.4</b>	25.7	0.0	25.5	<b>51.2</b>	11.2
	<b>TOTALS</b>	<b>209.9</b>	<b>158.9</b>	<b>438.3</b>	<b>724.6</b>	<b>1531.8</b>	<b>302.9</b>	<b>1101.8</b>	<b>128.5</b>	<b>1533.2</b>	<b>-1.4</b>

Figure 15. Blackmans Lake Annual Water Budget (November 2022 to October 2023) (1,000 m<sup>3</sup>).

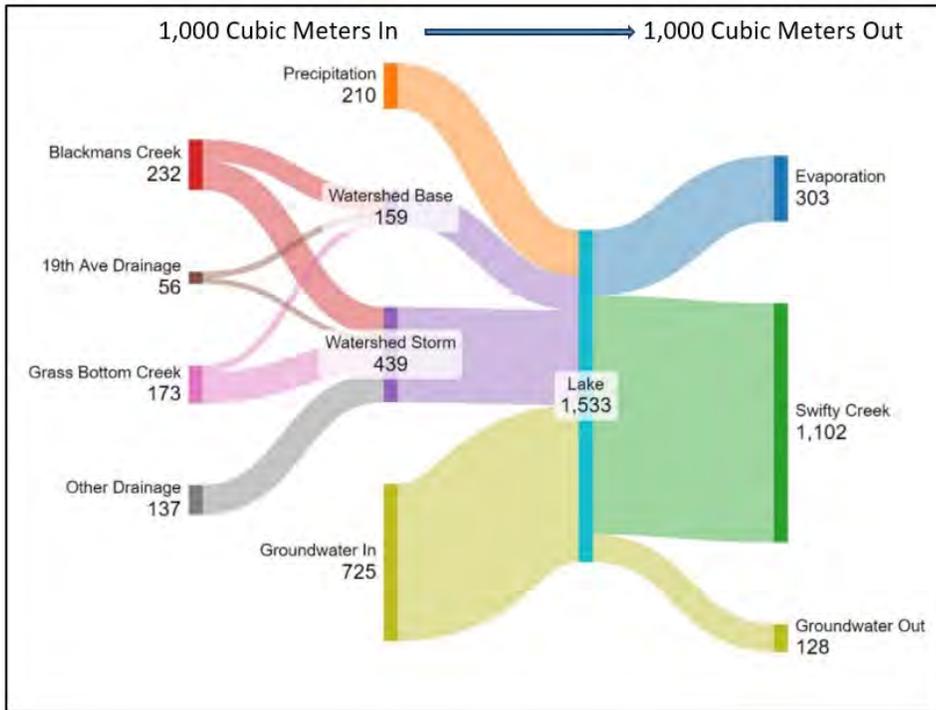
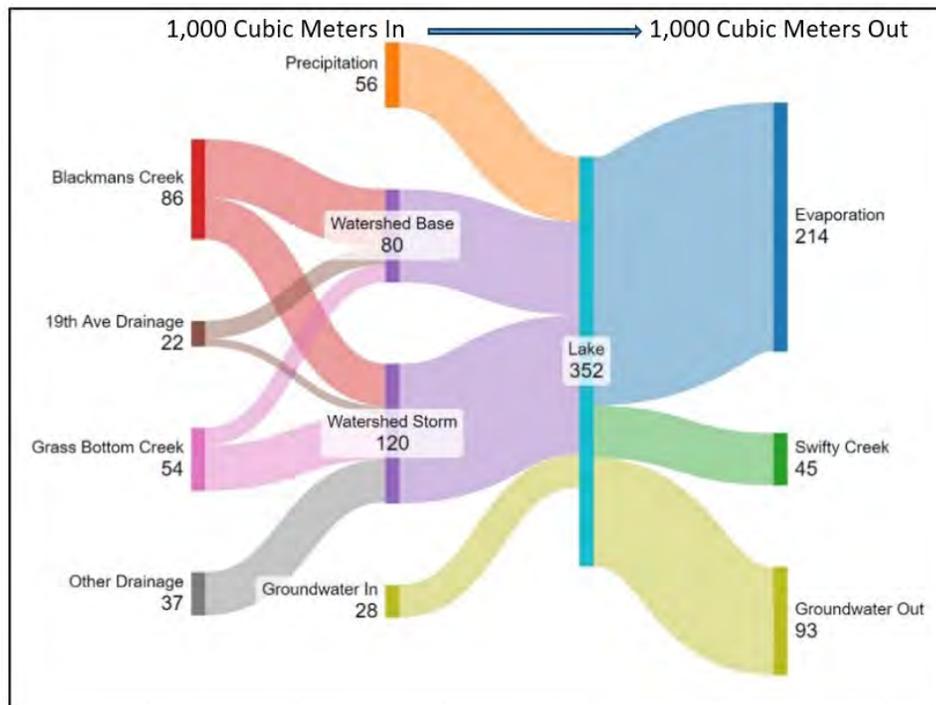


Figure 16. Blackmans Lake Summer Water Budget (May to October 2023) (1,000 m<sup>3</sup>).



# Blackmans Lake Phosphorus Budget

## Development

Using the water budget as a foundation, a phosphorus budget was created for Blackmans Lake that accounts for all movement of phosphorus into and out of the lake and within the lake itself. The difference between the total monthly external phosphorus inputs and outputs plus the change in phosphorus mass within the lake water from the previous month equals the amount of phosphorus retained in the lake for each month, where:

$$Retention (P_{ret}) = Inputs (P_{in}) - Outputs (P_{out}) + Lake Storage Change (\Delta P_{Lake})$$

The lake phosphorus retention amount is calculated as the difference between measured total phosphorus inputs and outputs and adding the change in the amount of phosphorus stored in the lake. The lake phosphorus retention incorporates measurement errors and unmeasured sources and losses, which primarily include internal phosphorus loading and sedimentation, respectively (Steinman and Spears 2020).

## Precipitation

The total phosphorus concentration in rainfall was estimated to be 0.024 mg/L. This value is based on the measured values ranging from 0.008 to 0.033 mg/L for five lakes in western Washington, and accounts for all atmospheric deposition (Ecology 2013). The total phosphorus concentration in rain was multiplied by the monthly precipitation volume to estimate phosphorus inputs from direct precipitation and other atmospheric deposition on Blackmans Lake.

## Surface Inflow

Surface inflow phosphorus loads were calculated by multiplying the base flow and storm flow volume by the average base flow and storm flow total phosphorus concentration (see Appendix A, Table 12), respectively, for each monitoring site.

## Outlet Flow

No lake outlet samples were collected for the study. Monthly average total phosphorus concentrations in the lake surface samples (1 m depth) were multiplied by the lake outlet flow volume to estimate phosphorus outputs from this source.

## Lake Storage

The monthly amount of total phosphorus in the lake was calculated by multiplying monthly volume-weighted average total phosphorus concentrations by monthly lake volume calculated as part of the hydrologic budget. Lake surface sample values were multiplied by the epilimnion volume and lake bottom sample values were multiplied by the hypolimnion volume. Monthly changes in the total mass of phosphorus in the lake were then calculated.

## Groundwater

Groundwater phosphorus loading to the lake was calculated by multiplying the monthly volume of groundwater input (if there was a net input) by the flow-weighted mean concentration of total phosphorus for the lake inflow samples during base flow conditions (13.5 µg/L), where each sample concentration is weighted proportional to the corresponding flow rate. This assumes that the base flow in the inlets is representative of groundwater because base flow is essentially surfacing groundwater.

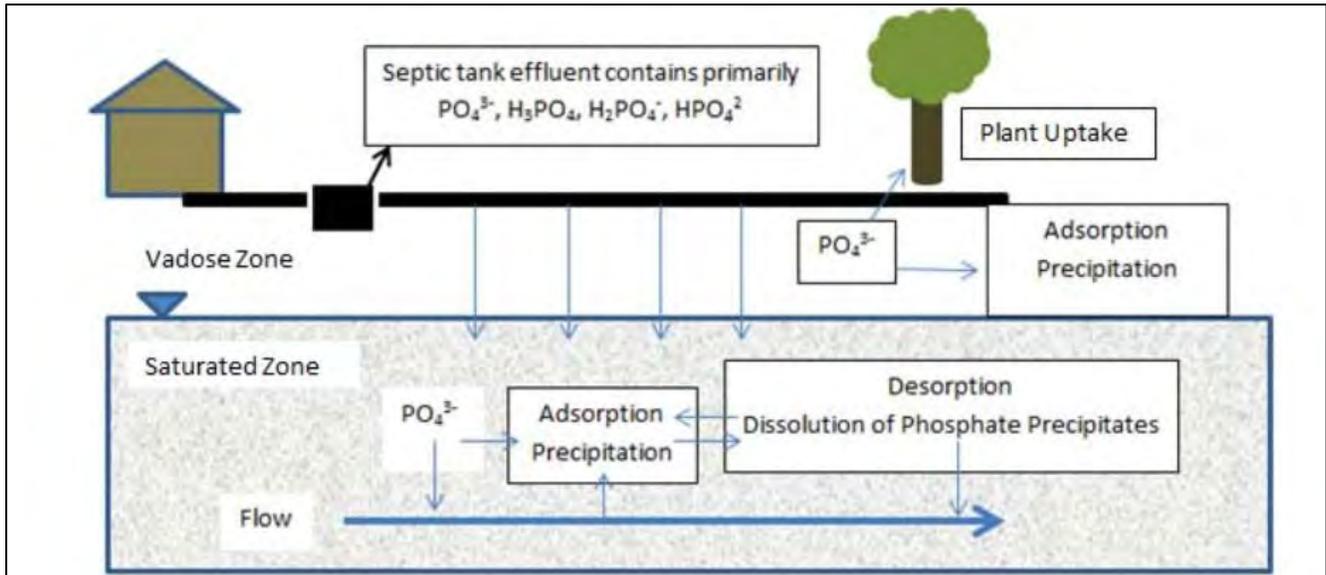
KCM (1994) estimated groundwater inflow concentrations at 150 µg/L based on a single sampling event of groundwater wells on May 13, 1993, at the three sets of paired nearshore and in-lake wells. The order of magnitude difference between the groundwater phosphorus estimates is important to consider. If they still exist, resampling groundwater wells around the perimeter of the lake may provide a better estimate of groundwater phosphorus concentrations around the lake. Groundwater sampling should be performed on a quarterly basis at a minimum at multiple locations and depths. Well sampling can overestimate groundwater phosphorus concentrations if the wells are not properly developed upon installation or purged and filtered before sampling. Stream base flow was deemed adequate and a better estimate of actual conditions for this study.

Groundwater phosphorus export from the lake was calculated by multiplying the monthly volume of groundwater output (if there was a net output) by the lake's monthly volume-weighted mean concentration of total phosphorus, where the lake surface and bottom water sample concentrations are weighted proportional to the lake epilimnion and hypolimnion volumes, respectively.

## Septic System Loading

Conventional septic systems offer little treatment or reduction of phosphorus, except the settling of solid-bound phosphorus to the bottom the septic tank. Total phosphorus concentrations in septic tank effluent range from 1 to 26 mg/L (1,000 to 26,000 µg/L) (McCray et al. 2005). Phosphorus is treated or removed in the drain field after leaving septic tank as effluent by precipitation, filtration, and adsorption to soils (Figure 18). Within a properly sized drain field, phosphorus will undergo mineralization, bind (adsorb) to soil particles, and be taken up by plants. A particular issue for lakes is septic systems located near the shoreline that may have critically undersized drain fields that offer limited opportunity for phosphorus removal. For this reason, septic systems are not allowed to be installed within 100 feet of a lake in Washington and up to 300 feet in other states.

Figure 17. Fate and Transport of Phosphate ( $\text{PO}_4^{3-}$ ) in a Septic System.



Most adsorption and precipitation reactions of phosphate are complete by the time the septic tank effluent reaches the water table. Thus, understanding how phosphate moves in the drain field is the key to determining the ultimate fate of phosphate from septic systems. Credit: Mary Lusk, UF/IFAS.

The effectiveness of soils and underlying aquifer materials in attenuating P movement to subsurface and surface water depends upon a number of factors including: the soil chemical and physical properties, the chemical properties and loading rate of the wastewater, site hydrology, proximity of the site to surface water, and the design and management of the onsite sewage disposal system (McCray et al. 2005). The soil type in Blackmans Lake’s immediate vicinity is largely gravelly loam (Tokul soil group). Generally, these soil groups have low capacity to attenuate phosphorus and are “very limited” for septic tank absorption fields due to high water table, filtering capacity, and/or slope (NRCS 2023).

We employed a simple model to estimate the potential loading of phosphorus from septic systems in Blackmans Lake. This model is adapted from Ecology (2013). For this preliminary, screening analysis, we focused on making estimates using the following equation:

$$P_{OSS} = n * Occ * P_{Person} * (1 - a)$$

Where:

- $P_{OSS}$  = annual phosphorus load in kg
- $n$  = number of residences served by septic systems
- $Occ$  = occupancy rate (number of people per residence)
- $P_{Person}$  = per capita phosphorus contribution (kg-P/person-year)
- $a$  = phosphorus attenuation rate (i.e., the loss to/removal by soil)

We assumed an occupancy rate of 2.2 people per residence, and 1 kg-P/person/year for  $P_{Person}$ . For the attenuation rate, 90 percent may be used for fully function systems and 50 percent for failing systems (including systems with inadequate drainfield sizing). We modified the attenuation rate to generate a range of loading estimates.

## Internal Loading – Sediment Release

Internal phosphorus loading by sediment phosphorus release into the lake was calculated by several methods described by Nurnberg (2009) and Steinman and Spears (2020), which include the lake mass accumulation method, phosphorus budget residual method, and various sediment phosphorus release rate equations.

### Mass Accumulation

The mass accumulation method calculates the monthly increase in the amount of phosphorus that accumulates in the lake for each summer month when dissolved oxygen concentrations near the sediment surface are low and external inputs are low.

This method is similar to the hypolimnion accumulation method, which calculates the monthly increase in total phosphorus mass in the hypolimnion for those months when the dissolved oxygen concentrations are less than 2 mg/L in the hypolimnion. Accumulation in the entire lake volume and higher bottom dissolved oxygen concentrations are often used for shallow lakes such as Blackmans Lake because it is recognized that sediment oxygen concentrations are much lower than those measured in the water in both the surface and bottom layers (epilimnion and hypolimnion). Another reason to include mass accumulation in the surface layer is that sediment release in the surface layer also occurs from high pH conditions caused by rapid algae growth and carbon dioxide consumption during summer algae blooms.

### Sediment Release Equations

In stratified and polymictic lakes, summer internal load may be estimated using the following equation:

$$L_{int} = RR * AF$$

Where:

RR = areal release rate of phosphorus in mg/m<sup>2</sup>/day

AF = anoxic factor in the sum of days per period with different oxycline depths

AF =  $\sum (t_i * a_i) / A_0$

Where:

$t_i$  = period of anoxia in days for each oxycline period

$a_i$  = corresponding sediment area in m<sup>2</sup> for each oxycline period

( $A_0$ ) = lake surface area in m<sup>2</sup>

Two sediment release equations were used based on the mobile phosphorus concentrations in the upper 10 cm of sediment in Blackmans Lake, including the Nurnberg (1988) and Pilgrim et al, (2007) equations. The Nurnberg (1988) equation ( $R^2 = 0.87$  for 14 lakes) is:

$$RR_{Nurnberg} = -1.38 + 0.285 * P_{Sed,Fe,WW}$$

Where:

$RR_{Nurnberg}$  = sediment release rate estimated using the Nurnberg (1988) equation in mg/m<sup>2</sup>/day  
 $P_{Sed,Fe,WW}$  = wet-weight iron-bound phosphorus sediment concentration in µg/g

From the Blackmans Lake sediment samples, the  $P_{Sed,Fe,WW}$  were 18.1 µg/g at the deep station as an average in the surface 10 cm and non-detect in the shallow station. Therefore, predicted release rate would be 3.8 mg/m<sup>2</sup>/day at the deep station and negligible in the shallows.

The Pilgrim et al. (2007) equation ( $R^2 = 0.90$  for 14 lakes) is:

$$RR_{Pilgrim} = 15.1 * P_{Sed,Mobile,WW} - 0.7$$

Where:

$RR_{Pilgrim}$  = sediment release rate estimated using the Pilgrim et al. (2007 equation) in mg/m<sup>2</sup>/day  
 $P_{Sed,Mobile,WW}$  = wet-weight mobile phosphorus sediment concentration in g/m<sup>2</sup>/cm

From the Blackmans Lake sediment samples, the  $P_{Sed,Mobile,WW}$  were 0.20 g/m<sup>2</sup>/cm at the deep station as an average in the surface 10 cm and non-detect in the shallow station. Therefore, predicted release rate would be 2.4 mg/m<sup>2</sup>/day at the deep station and negligible in the shallows.

AF is the expression of the period of anoxia and the fraction of the sediments experience anoxia:

$$AF = \sum_{i=1}^n t_i * a_i / A_0$$

Anoxia was observed below 5 m from May 21 to Sept 28, 2023. We would therefore calculate AF as 144 days \* 99,100 m<sup>2</sup> / 245,500 m<sup>2</sup> = 57.9 days. This estimate is higher than the 44.5 days predicted using the Nurnberg (1996) anoxic factor equation for polymictic lakes ( $R^2 = 0.67$  for 70 lakes) as follows:

$$AF_{pred} = -36.2 + (50.1 * \log_{10}(TP_{Summer})) + 0.762 * \frac{\bar{z}}{\sqrt{A}}$$

Where:

$TP_{Summer}$  = mean summer (May to October) volume-weighted total phosphorus concentration in µg/L (30.3 µg/L).  
 $\bar{z}$  = mean depth in m.  
A = lake surface area in km<sup>2</sup>.

## Biological Contributions

### Waterfowl

Waterfowl were counted by lake monitoring volunteers during each monthly-bimonthly event October 9, 2022 through October 23, 2023, and daily by volunteer shoreline residents at Blackmans Lake from December 19, 2022 through November 1, 2023. Counts were recorded at either the mid-lake station or from the southwest shoreline where a full view of the lake surface is accessible, and were performed at various times (e.g., early morning, midday, late afternoon, and late evening). Birds are typically less active midday; for instance, ducks are most active at dawn and dusk (Korner et al. 2016).

Approximately 73,380 birds were counted during this period, consisting of geese, both dabbling and diving ducks (e.g., mallards, mergansers, buffleheads, and grebes), cormorants, coots, gulls, herons, and swans. Additional birds observed at the lake included bald eagles and swallows. Most of the waterfowl observed were geese, accounting for approximately 82 to 87 percent of the total annual bird count at the lake, followed by ducks (10–13 percent). However, ducks were present most frequently, followed by geese. For a period of about two weeks in early October 2023, the gaggle was estimated to be comprised of 4,000 individuals. See Appendix A for more detail on bird counts.

Estimation of phosphorus loading from waterfowl was performed following the methods of Boros (2021) using published waterfowl excrement rates and residential time factors (Manny et al. 1994, Marion et al. 1994, and Boros 2021) (Table 11). Phosphorus loading rates from gulls vary substantially by species and region. An average rate was assumed for all gulls at Blackmans Lake from those reported by several sources listed in Table 11. Non-waterfowl bird species were not considered in this loading estimation.

**Table 11. Literature Values for Bird Excrement Loading Rates and Residential Time Factors.**

Bird Type	Residual Time Factor	Excrement Loading Rate (g P/day)	Source(s)
Geese	0.6	0.49	Boros 2021, Manny et al. 1994
Dabbling ducks	0.8	0.18	Manny et al. 1994
Diving ducks	1.0	0.20	Boros 2021, Manny et al. 1994
Cormorants	1.0	4.58	Marion et al. 1994, Boros 2021
Coots	1.0	0.2	Boros 2021
Gulls	0.6	0.4 <sup>a</sup>	Boros 2021, Gould and Fletcher 1978, Hahn et al. 2007, Winton and River 2017
Hérons	0.8	3.78	Marion et al. 1994, Boros 2021
Swans	0.8	0.11	Boros 2021

<sup>a</sup> Rate assumed from wide range in excrement phosphorus concentrations and loading rates for various gull species in literature (e.g., 0.07–1.5 g/day).

Rather than estimate loading using the daily mean abundances of each species per month, which would be multiplied by the days in each month (as in Boros [2021]), we calculated daily loading from the rich dataset of available daily bird observations collected by volunteers. To fill data gaps for those days when

bird observations were not recorded (n=130), we interpolated counts from the available data (n=259 out of 389 days). Interpolations were performed for each major bird type recorded (ducks, geese, coots, cormorants, and gulls). Other infrequently recorded waterfowl (e.g., swans, herons) were grouped as “other”. We then calculated daily load using the equation below, modified as noted from Boros (2021):

$$Load = A * E * RTF$$

Where:

*A* = daily abundance of a given species

*E* = daily net rate of excrement loading (e.g., mass phosphorus per individual per day)

*RTF* = residential time factor (proportion of a day that waterbird spends at lake)

Daily loads for each bird type were then summed together and across all days from November 2022 to October 2023 to arrive at the rate of annual phosphorus loading by waterfowl in Blackmans Lake. Using interpolated daily data rather than monthly means improved the accuracy of our loading estimations.

## Macrophytes

Phosphorus release from macrophytes was not explicitly estimated because macrophyte biomass data were not available. However, macrophyte contribution may be evaluated by examining the residual in the phosphorus budget in the late fall, when the macrophytes undergo senescence.

## Fish Stocking

In May 2023, 3,810 pounds of legal-size rainbow trout were stocked in Blackmans Lake, followed by 484 pounds of yearling coastal (resident) cutthroat trout in October and another 1,930 pounds of legal-size rainbow trout in November 2023 (WDFW 2024a). Total stocking in 2023 amounted to 20,128 fish at 7,701 total pounds (lbs) (3,493 kilograms [kg]), representing the largest fish plant by weight on record (since 1995). Approximately 150 pounds of rainbow trout were planted by the Snohomish Sportsmen’s Club in May or June 2023. According to WDFW, species present in Blackmans Lake include stocked trout, largemouth bass, black bullhead, black crappie, brown bullhead, common carp, pumpkinseed sunfish, and yellow perch.

Fish were not explicitly included in the nutrient budget. According to a study of rainbow trout diet and effluent, bioavailable phosphorus excreted from rainbow trout amounted to about 7 milligrams per kilogram (mg/kg) of fish per day when trout food at no more than the required nutrition to support juvenile growth (Flimlin et al. 2003). This rate would translate to about 2.1 grams of bioavailable phosphorus per trout per day assuming cutthroat trout excrete at the same rate as rainbow trout and assuming each fish weighed about 174 grams (0.383 lbs; i.e., the average weight of all trout stocked by WDFW in Blackmans Lake in 2023). Assuming all fish stocked in 2023 were present in the lake on average for 60 days until caught and removed, and assuming a reduced bioavailable phosphorus excretion rate of 4 mg/kg fish/day from reduced feeding on live food in the lake, annual loading from excretion by 3,493 kg of stocked trout would be about 0.8 kg (2 lbs) of bioavailable phosphorus in 2023. Despite the limitations of this method regarding the assumed duration of trout in lake and adjusted excretion rate for diet changes, this estimation suggests the contribution of stocked trout to the 2023 phosphorus load in

Blackmans Lake is negligible. compared, for example, to estimated total phosphorus loading by waterfowl (26 kg presented below). Furthermore, the total pounds of trout stocked in 2023 were more than double (136 percent higher than) the average annual pounds of trout stocked for all previous years combined (1995–2022).

While trout stocking may not directly increase phosphorus loading to the lake from fish excrement, trout stocking can have food web impacts by their consumption of zooplankton and the resulting reduced grazing of algae by zooplankton in the lake. See the Algae and Zooplankton results sections in Appendix A and/or the *Biomanipulation* section in Appendix D for potential impacts from food web (e.g., trophic cascade) interactions. Quantitative evaluation of future trout stocking on nutrient concentrations and frequency/timing of algae blooms could be performed by statistically comparing conditions before and after trout stocking, and/or conditions between the years when trout were stocked and those years when trout were not stocked.

## Results

### Tributary Inflows

The monthly and annual phosphorus loads from the inlets are presented in Table 12. Storm flow loads were greater than base flow loads for all basins except the BLK-NE. Basin BLK-NE is the northeast fork of Blackmans Creek that combines with the northwest fork before it crosses under 22nd Street at station BLK-22 (see Figure 3). On average, BLK-NE made up 95 percent of the flow into BLK-22 because the northwest fork basin is much smaller. The load in Blackmans Creek at BLK-22 combines with unmonitored drainage south of 22nd Street before it discharges as groundwater to the lake at station BLK-MTH.

The estimated base flow load at BLK-NE was slightly greater than the base flow load at BLK-22 because the mean TP concentration in base flow at BLK-NE (19.6 µg/L) was greater than that at BLK-22 (16.2 µg/L). Only three base flow samples were collected, and this difference in mean TP is well within the accuracy of the TP analysis (± 20 percent).

For storm flows, the non-monitored drainage basin, BLK-X, is estimated to have similar phosphorus loading to Blackmans Creek (BLK-MTH). This is reasonable because, despite being a smaller drainage area, the BLK-X drainage has more impervious surfaces. This is also seen with CHAMP-19 having a disproportionately higher load driven by elevated storm flow TP (mean of 62.2 µg/L).

### Septic System Loading

The results using the septic system loading equation discussed above are presented in Table 13. The annual loading estimates ranged from 0 kg per year when considering only the lake shoreline (sewered) residences, to 45 kg per year when considering all OSS in the watershed and assuming half are “failing.” If all OSSs in the watershed are fully functioning, the annual load is estimated at 15 kg per year. The combined annual groundwater phosphorus load and stream base flow load, which would be expected to include input from septic systems along with other sources, was 9.8 kg per year and less than the OSS fully functioning OSS load.

**Table 12. Monthly Lake Inlet Phosphorus Loading.**

Base flow Loading (kg)									
Year	Month	BLK-26	BLK-NE	BLK-22	BLK-MTH	CHAMP-19	CHAMP-PARK	BLK-X	TOTAL
2022	11	0.05	0.15	0.13	0.13	0.03	0.03	0.00	<b>0.18</b>
2022	12	0.05	0.15	0.14	0.14	0.03	0.03	0.00	<b>0.19</b>
2023	1	0.05	0.15	0.14	0.14	0.03	0.03	0.00	<b>0.19</b>
2023	2	0.05	0.14	0.12	0.12	0.03	0.02	0.00	<b>0.17</b>
2023	3	0.05	0.15	0.14	0.14	0.03	0.03	0.00	<b>0.19</b>
2023	4	0.05	0.15	0.13	0.13	0.03	0.03	0.00	<b>0.18</b>
2023	5	0.05	0.15	0.14	0.14	0.03	0.03	0.00	<b>0.19</b>
2023	6	0.05	0.15	0.13	0.13	0.03	0.03	0.00	<b>0.18</b>
2023	7	0.05	0.15	0.14	0.14	0.03	0.03	0.00	<b>0.19</b>
2023	8	0.05	0.15	0.14	0.14	0.03	0.03	0.00	<b>0.19</b>
2023	9	0.05	0.15	0.13	0.13	0.03	0.03	0.00	<b>0.18</b>
2023	10	0.05	0.15	0.14	0.14	0.03	0.03	0.00	<b>0.19</b>
	<b>Base Total</b>	<b>0.61</b>	<b>1.82</b>	<b>1.59</b>	<b>1.59</b>	<b>0.34</b>	<b>0.31</b>	<b>0.00</b>	<b>2.24</b>
Storm flow Loading (kg)									
Year	Month	BLK-26	BLK-NE	BLK-22	BLK-MTH	CHAMP-19	CHAMP-PARK	BLK-X	TOTAL
2022	11	0.12	0.16	0.66	0.86	0.24	0.62	0.83	<b>2.56</b>
2022	12	0.15	0.20	0.83	1.09	0.31	0.79	1.06	<b>3.24</b>
2023	1	0.10	0.14	0.58	0.76	0.22	0.55	0.74	<b>2.27</b>
2023	2	0.06	0.08	0.35	0.46	0.13	0.33	0.44	<b>1.36</b>
2023	3	0.06	0.08	0.33	0.42	0.12	0.31	0.41	<b>1.26</b>
2023	4	0.08	0.11	0.43	0.56	0.16	0.41	0.55	<b>1.68</b>
2023	5	0.02	0.03	0.13	0.17	0.05	0.12	0.16	<b>0.50</b>
2023	6	0.03	0.05	0.19	0.25	0.07	0.18	0.24	<b>0.74</b>
2023	7	0.00	0.00	0.02	0.03	0.01	0.02	0.02	<b>0.08</b>
2023	8	0.01	0.02	0.07	0.09	0.03	0.07	0.09	<b>0.27</b>
2023	9	0.08	0.11	0.46	0.60	0.17	0.43	0.58	<b>1.78</b>
2023	10	0.06	0.08	0.33	0.43	0.12	0.31	0.42	<b>1.30</b>
	<b>Storm Total</b>	<b>0.78</b>	<b>1.07</b>	<b>4.38</b>	<b>5.72</b>	<b>1.62</b>	<b>4.14</b>	<b>5.56</b>	<b>17.03</b>
Total (Base + Storm flow) Loading (kg)									
	<b>Base + Storm</b>	<b>1.39</b>	<b>2.89</b>	<b>5.97</b>	<b>7.31</b>	<b>1.96</b>	<b>4.44</b>	<b>5.56</b>	<b>19.27</b>

Note that BLK-22, BLK-NE, and BLK-26 are part of the BLK-MTH watershed.

**Table 13. Septic System Phosphorus Loading Estimates.**

Scenario	Phosphorus Load (kg/year)	Percent of Estimated Annual Base Flow + Groundwater Loads (9.8 kg)
<b>Shoreline OSS Only</b> (n=0) 100% Fully Functioning (a=0.9)	0	0%
<b>Shoreline OSS Only</b> (n=0) 50% Fully Functioning (a=0.9) 50% Failing (a=0.5)	0	0%
<b>Watershed OSS</b> (n=70) 100% Fully Functioning (a=0.9)	15	153%
<b>Watershed OSS</b> (n=70) 50% Fully Functioning (a=0.9) 50% Failing (a=0.5)	45	459%

We would not expect the total OSS load to exceed the total base flow and groundwater loads. This result suggests that there are no failing systems and there is greater attenuation ( $a > 0.9$ ) of septic system effluent than estimated due to better soil characteristics, further distance from surface drainages, and/or greater depth to the water table. The low TP concentrations in all base flow samples and lack of OSS near the lake further suggest that septic systems are not a significant source of phosphorus loading to Blackmans Lake.

## Internal Loading

### Mass Accumulation Method

The monthly sediment phosphorus release amount was calculated as the monthly increase in total phosphorus mass in the lake for May to October when dissolved oxygen concentrations were less than 2 mg/L near the sediment surface at the deep lake station and external phosphorus inputs were low at 28.0 kg. The phosphorus mass accumulation data are presented in Table 14. The total gain in summer 2023 was 107.6 kg with an external load of 28 kg; therefore, this method estimates an internal load of 79.6 kg.

### Sediment Release Equation Method

The load estimates based on predicted flux and anoxic factor (i.e., Nurnberg 1988 and Pilgrim et al. 2007), ranged from 26.0 to 54.1 kg, which is similar to the load estimates from the mass balance residual (59.0 kg) and lower than the mass accumulation estimate (79.6 kg). The mass accumulation difference appears to be largely driven by the high volume-weighted phosphorus concentration on August 28, 2023, where surface (1-m) TP was 34 µg/L, metalimnetic (6-m) TP was 188 µg/L, and hypolimnetic (7.5-m) TP was 423 µg/L. In-situ or laboratory sediment phosphorus flux monitoring would provide meaningful insight to confirm the sediment release rate.

**Table 14. Phosphorus Accumulation in for Internal Load Estimation in Blackmans Lake.**

Sample Date	Depth (m) at DO <2 mg/L	Bottom Measured DO (mg/L)	Volume-Weighted TP (µg/L)	Lake Volume (m <sup>3</sup> )	Lake TP Mass (kg)	TP Mass Gain (kg)
2023-05-21	6	0.34	16.9	1,020,580	17.3	--
2023-06-11	5	0.20	29.1	1,007,309	29.4	12.1
2023-06-25	5	0.10	30.6	1,005,214	30.7	1.4
2023-07-16	6	0.10	38.2	983,561	37.5	6.8
2023-08-01	NA	NM	50.1	967,496	48.4	10.9
2023-08-13	5	0.07	45.7	958,415	43.8	--
2023-08-28	5	0.10	92.5	944,446	87.4	43.6
2023-09-15	5	0.10	39.0	937,461	36.6	--
2023-09-28	6	0.20	72.9	952,129	69.4	32.8
2023-10-08	3	0.10	58.1	956,320	55.6	--
2023-10-23	6	0.14	56.2	960,511	54.0	--
2023-10-30	NA	NM	36.0	964,702	34.7	--
<b>June to October Total Gain (kg)</b>						<b>107.6</b>
<b>June to October External Load (kg)</b>						<b>28.0</b>
<b>Estimated Internal Load (kg) (Total Gain – External Load)</b>						<b>79.6</b>

NM= not measured; NA= not applicable

## Mass Balance Method

The phosphorus residual during winter months averaged -5.46 kg/month, which was assumed to be the average sedimentation rate for the lake for all months of the year. This rate was added to the summertime (May to October) residuals, and the positive values were summed to estimate the internal load via mass balance. As shown in Table 15, this totaled 59.0 kg for 2023.

**Table 15. Phosphorus Mass Balance (kg) for Internal Load Estimation in Blackmans Lake.**

Year	Month	Mass Balance Residual <sup>a</sup>	Sedimentation Rate Estimate	Summer Residual + Sedimentation
2022	11	-2.9	5.46	NA
2022	12	-16.9	5.46	NA
2023	1	-5.5	5.46	NA
2023	2	4.6	5.46	NA
2023	3	-12.5	5.46	NA
2023	4	0.4	5.46	NA
2023	5	-2.3	5.46	3.2
2023	6	11.6	5.46	17.1
2023	7	6.9	5.46	12.3
2023	8	21.0	5.46	26.5
2023	9	-8.1	5.46	-2.7
2023	10	-22.6	5.46	-17.1
<b>Sum of Positive Summer Residuals + Sedimentation for Internal Load Estimation</b>				<b>59.0</b>

<sup>a</sup> Residuals from total surface inputs minus outputs excluding internal loading (sediment release) and sedimentation.

Internal phosphorus loading estimates are presented in Table 16. For the purposes of the Blackmans Lake phosphorus budget, we used the average of the six estimates of internal loading at 49.0 kg and distributed that amount evenly from May through September.

**Table 16. Internal Phosphorus Loading Estimates.**

Internal Load Estimate Method	Flux Estimate (mg/m <sup>2</sup> /day) <sup>a</sup>	Anoxic Factor (days)	L <sub>int</sub> (mg/m <sup>2</sup> /year)	Load (kg/year)
Iron-bound Phosphorus Sediment (Nurnberg 1988)	3.8	44.5	169	41.6
		57.9	219	54.1
Mobile (Iron-bound + Labile) Phosphorus in Sediment (Pilgrim et al. 2007)	2.4	44.5	106	26.0
		57.9	137	33.8
Summer Phosphorus Mass Accumulation	6.3	51.2	323	79.6
Summer Mass Balance Residual (mean summer residual [sediment release – sedimentation] – mean winter residual [sedimentation])	4.7	51.2	240	59.0
<b>Average</b>	<b>3.9</b>	<b>51.2</b>	<b>199</b>	<b>49.0</b>

<sup>a</sup> Flux estimates for Summer Mass Accumulation and Mass Balance Residual methods are calculated using the average anoxic factor.

## Blackmans Lake Phosphorus Budget

Annually, the internal loading contributes 45.5 percent of all phosphorus loads to the lake (Figure 19; Table 17), and internal loading contributes 68.4 percent of all phosphorus loads during the summer (Figure 20; Table 17). There is a sizeable residual in both the annual and summer budgets indicating an unquantified input. This may be due to underestimates for the internal load (as we used the conservative sediment-based equations), underestimates for the external (surface and groundwater) loads, or overestimates in export via Swifty Creek, loss by sedimentation, or gain in lake storage. The sedimentation rate appears reasonable and is similar to estimates made by KCM (1994). As discussed earlier, the export via Swifty Creek may be an underestimate due to the lake level data gap between November 2022 and February 2023. Additionally, the large gain in summertime lake storage is primarily driven by a single sample in August 2023 with elevated TP in the metalimnion. It is possible that that sample was more representative of hypolimnetic waters, and the volume-weighted lake phosphorus concentration was overestimated for that month. If true and that metalimnetic sample is dropped, the summertime storage gain would decrease by 12 kg, reducing the summertime and annual residual to about 8 kg.

The watershed load is comprised of surface drainage during storm events (15.8 percent of the total load), surface drainage during dry weather base flow (2.1 percent), and subsurface groundwater inputs (9.1 percent). A negligible portion of loading comes from direct precipitation to the lake surface (4.7 percent). Waterfowl loading was substantial (22.9 percent of the total annual load), specifically in October 2023 when thousands of migrating geese rested at Blackmans Lake from October 5 to October 19. Much of the phosphorus waterfowl loading would be expected to immediately fall to the lake sediment as feces in particulate form. Some of the phosphorus from waterfowl feces would instead be released over-time from the lake sediments due to microbial decay and would be captured in future years' internal loading.

**Table 17. Monthly Phosphorus Budget for Blackmans Lake.**

Year	Month	Surface Input Mass (kg)			Waterfowl Loading (kg)	Internal Load (kg)	Groundwater Mass (kg)		Surface Output (kg)	Mass Balance (kg)		
		Precipitation	Watershed Base flow	Watershed Storm flow		Sediment Release	Inflow	Outflow	Lake Outflow	Change in Storage	Sedimentation <sup>a</sup>	Residual <sup>b</sup>
2022	11	0.7	0.2	2.6	1.0	0.0	0.0	1.6	0.0	0.0	5.46	2.6
2022	12	1.0	0.2	3.2	0.3	0.0	1.5	0.0	5.9	-16.7	5.46	-11.5
2023	1	0.7	0.2	2.3	0.4	0.0	3.5	0.0	7.6	-6.0	5.46	0.0
2023	2	0.4	0.2	1.4	0.5	0.0	1.8	0.0	4.9	3.9	5.46	10.1
2023	3	0.4	0.2	1.3	1.4	0.0	1.4	0.0	2.5	-10.4	5.46	-7.1
2023	4	0.5	0.2	1.7	0.7	0.0	1.3	0.0	2.8	2.0	5.46	5.9
2023	5	0.1	0.2	0.5	0.2	8.17	0.4	0.0	0.5	-1.4	5.46	-50
2023	6	0.2	0.2	0.7	0.6	8.17	0.0	0.6	0.0	12.8	5.46	8.9
2023	7	0.0	0.2	0.1	0.6	8.17	0.0	0.2	0.0	7.5	5.46	4.1
2023	8	0.1	0.2	0.3	0.8	8.17	0.0	0.0	0.0	22.3	5.46	18.3
2023	9	0.5	0.2	1.8	1.1	8.17	0.0	2.3	0.0	-6.9	5.46	-10.9
2023	10	0.4	0.2	1.3	17.1	0.0	0.0	1.3	0.0	-4.9	5.46	-25.3
<b>Annual Totals</b>												
<b>Mass (kg)</b>		<b>5.0</b>	<b>2.2</b>	<b>17.0</b>	<b>24.7</b>	<b>49.0</b>	<b>9.8</b>	<b>6.1</b>	<b>24.3</b>	<b>2.2</b>	<b>65.5</b>	<b>-9.8</b>
<b>Percent</b>		<b>4.7%</b>	<b>2.1%</b>	<b>15.8%</b>	<b>22.9%</b>	<b>45.5%</b>	<b>9.1%</b>	<b>6.3%</b>	<b>25.3%</b>	<b>--</b>	<b>68.4%</b>	<b>--</b>
<b>Summer (May to October) Totals</b>												
<b>Mass (kg)</b>		<b>1.4</b>	<b>1.1</b>	<b>4.7</b>	<b>20.4</b>	<b>49.0</b>	<b>0.4</b>	<b>4.4</b>	<b>0.5</b>	<b>29.4</b>	<b>28.4</b>	<b>-9.8</b>
<b>Percent</b>		<b>1.8%</b>	<b>1.5%</b>	<b>6.1%</b>	<b>26.5%</b>	<b>63.7%</b>	<b>0.5%</b>	<b>11.8%</b>	<b>1.4%</b>	<b>--</b>	<b>86.8%</b>	<b>--</b>

<sup>a</sup> Sedimentation rate is based on the average winter (November – April) residual. It is not believed to capture the sedimentation of waterfowl feces in October.

<sup>b</sup> Residual = (Lake Outflow + Sedimentation + Change in Storage + Groundwater Outflow) – (Surface Input + Waterfowl Loading+ Internal Loading + Groundwater Inflow).

Figure 18. Annual Phosphorus Budget (kg) for Blackmans Lake.

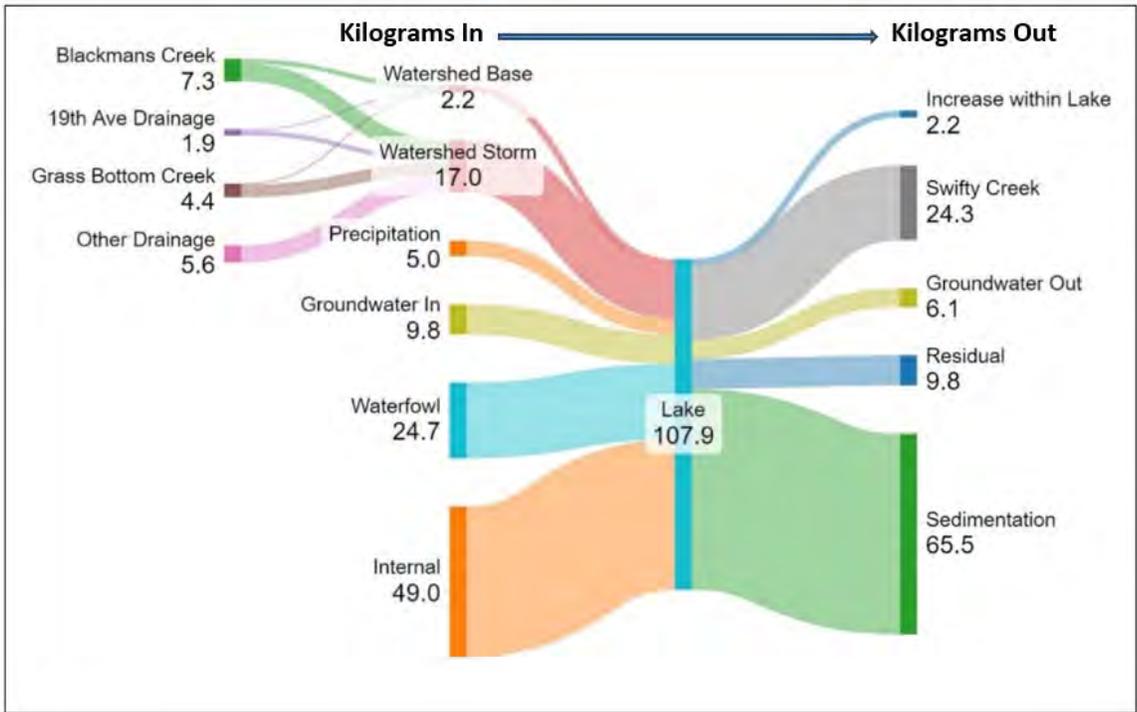
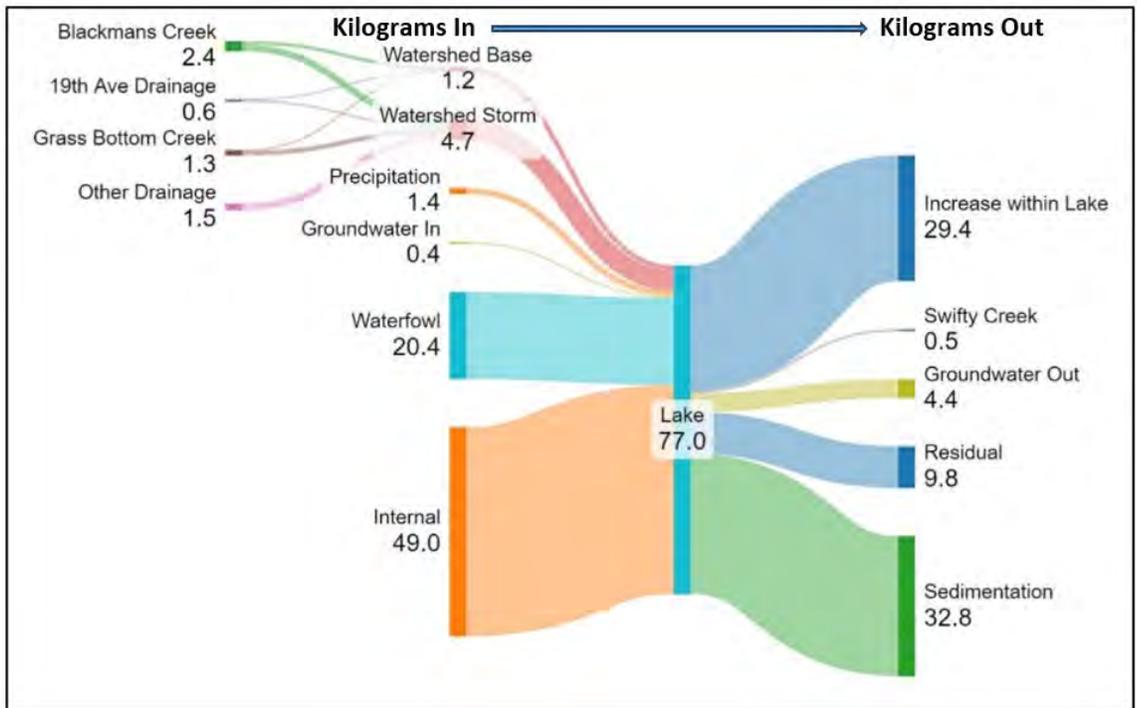


Figure 19. Summer (May to October) Phosphorus Budget (kg) for Blackmans Lake.



Most of the phosphorus entering the lake settles to the lake bottom (68.4 percent) (Figure 19; Table 17), while 25.3 percent leaves through Swifty Creek and 6.3 percent is exported via groundwater outflow. Some of the phosphorus settling to the lake bottom is active and may be released into the water column. The sediment samples indicated that about 44 percent of phosphorus in the biologically active zone (0 to 10 cm) was active, i.e., able to be released (see Appendix A).

The groundwater load estimates are based on the average concentration of stream base flow and the residual in the water budget, presented in the previous chapter. These estimates are very sensitive to the accuracy of the water budget estimates and the assumption that base flow and groundwater phosphorus concentrations are similar. Furthermore, a net negative groundwater residual (i.e., where there is more volume leaving as groundwater than entering) does not mean there is no groundwater inflow to the lake. In this way, these groundwater load estimates are likely underestimated.

We did not see strong signal in the mass balance residual caused by macrophyte decay in the fall. The only positive residual in the winter months was in February at 10.1 kg.

During the May to October period (Figure 20), most of the phosphorus load came from the internal loading (47.0 kg or 62.8 percent of total). Waterfowl loading accounted for 20.4 kg (27.2 percent), buoyed by the high counts of geese in October 2023. The next most important source during the summer period was storm flow (6.2 percent). There was a minor negative residual of (-9.8 kg), which is likely primarily driven by the high waterfowl load in October and that the sedimentation estimate does not capture the feces predominantly depositing on the lake bottom.

This summer phosphorus budget likely underestimates groundwater inflow loads because the net hydrologic groundwater was typically outflow in the summer, but there were likely still groundwater inputs during this period. Overall, the total phosphorus load during the May to October period was 77.0 kg, or 71.4 percent of the total annual load of 107.7 kg.

During the May to October period, incoming phosphorus either settled to the lake bottom or remained in the surface water. A small amount left via Swifty Creek and groundwater outflow. The decrease in surface outflow was primarily driven by limited lake discharge, in balance with decreased inflow to the lake.

# Comparison of 2023 and 1992–1993 Study Budgets

## Hydrologic Budget

Table 18 provides a comparison between the hydrologic budget from this study and that estimated by KCM (1994). We estimated substantially greater groundwater input to the lake than the KCM study, whereas KCM estimated higher creek base flow input. KCM (1994) noted that Grass Bottom Creek was the only perennial stream flowing into Blackmans Lake, and that no longer appears to be the case. This may be due in part to installation of two stormwater ponds in the powerline right-of-way crossing Park Avenue that are infiltrating stream drainage into groundwater, as well as development that may have diverted drainage away from the stream to the CHAMP-19 basin.

Further, we estimate lower groundwater outflow and higher evaporation than the KCM study. The KCM study relied on potential evapotranspiration rates for the Monroe, Washington, area estimated by the U.S. Soil Conservation Service in 1973. Because our model relied on local and contemporary meteorological data, we believe our estimates to be more accurate, which will provide better estimates of the net groundwater flow.

**Table 18. Comparison of Annual Hydrologic Budgets for 2023 Study to KCM (1994) Study for May 1992 to April 1993.**

	KCM 1994	2023 Study
<b>Rainfall (inches)</b>	39.2	34.6
<b>Inflows (1,000 m<sup>3</sup>)</b>		
Creek Base Flow	<b>594.2</b>	<b>158.9</b>
Storm Flow	451.1	438.3
Precipitation	219.3	209.9
Groundwater + Wetlands	<b>336.0</b>	<b>724.6</b>
<b>Outflows (1,000 m<sup>3</sup>)</b>		
Outlet	1,120.7	1,101.8
Groundwater + Wetlands	<b>337.7</b>	<b>128.5</b>
Evaporation	<b>125.3</b>	<b>302.9</b>

**Bold values** represent substantial differences between the two studies.

# Phosphorus Budget

Table 19 provides a comparison between the phosphorus budget from this study and that estimated by KCM (1994). KCM estimated the internal load based on a mass balance model where a positive residual was attributed to a net sediment phosphorus input. This would be considered the “net internal loads” whereas our estimate is of the “gross internal load.” Also, KCM (1994) did not explicitly estimate waterfowl loading, which would be captured in the mass residuals and defined as internal loading. An additional reason for higher internal loading estimates in this study is the accumulation of available phosphorus in the sediments since 1994.

A significant difference in the two phosphorus budgets is the watershed loads. This study attributed less to watershed loading and more to groundwater loading than KCM (1994). A primary driver for this difference is the measured inlet phosphorus concentration. KCM (1994) found TP concentrations in Blackmans Creek at 14 to 120 µg/L (n=11) and Grass Bottom Creek at 6 to 159 µg/L (n=18), and KCM (1994) measured TP three times in storm flow, with values ranging from 59 to 120 µg/L. This study found much lower TP base flow (6.4 to 21.1 µg/L) and storm flow (8.6 to 186 µg/L). Despite having similar watershed storm flow volume estimates, the loading estimates by KCM are nearly three-times higher, indicating the primary driver was concentration. Several stormwater infrastructure projects have been installed since that study, specifically in the CHAMP-PARK (Grass Bottom Creek) basin. If KCM overestimated the storm flow load, then they would have underestimated the internal load since they relied on the mass balance residuals.

We estimated a higher export via Swifty Creek than the KCM report, which was driven by higher lake surface total phosphorus concentrations (22 µg/L for the KCM study versus 32 µg/L for this study).

**Table 19. Comparison of Annual Phosphorus Budgets for 2023 Study to KCM (1994) Study for May 1992 to April 1993.**

Pathway	KCM 1994	2023 Study
Rainfall (inches)	<b>39.2</b>	<b>34.6</b>
<b>Inflows (kg)</b>		
Creek Base Flow	<b>14.4</b>	<b>2.2</b>
Storm Flow	<b>41.5</b>	<b>17.0</b>
Precipitation	5.0	5.0
Groundwater + Wetlands	<b>5.0</b>	<b>9.8</b>
Waterfowl	Not Estimated	24.7
Internal Load	<b>9.4</b>	<b>49.0</b>
<b>Outflows (kg)</b>		
Outlet	<b>15.2</b>	<b>24.3</b>
Groundwater + Wetlands	<b>13.0</b>	<b>6.1</b>
Sedimentation	<b>47.4</b>	<b>65.5</b>

**Bold values** represent substantial differences between the two studies.

# Summary of 2023 Study Findings

## What is Causing or Contributing to Cyanobacteria Blooms in Blackmans Lake?

Blackmans Lake is a meso-eutrophic lake with high algal productivity, but blooms are not always toxic and cyanotoxins have only rarely been shown to exceed state guidelines and risk the health of humans or wildlife. Cyanobacteria may have several competitive advantages over other algae, including the ability to fix nitrogen and store phosphorus (two crucial nutrients for growth). In addition, most can regulate their buoyancy, moving up and down in the water column; they have low energy demands; and they are generally unpalatable to grazers that eat algae.

Monitoring data from 2022–2023 indicate more nitrogen is available relative to phosphorus, meaning the amount of algae growth is primarily controlled by the amount of phosphorus (see Appendix A). Lake monitoring also found elevated chlorophyll-a concentrations in August and October when phosphorus was more abundant, resulting in reduced water clarity. When cyanobacteria populations reach high densities, they often produce cyanotoxins at levels that are harmful to human health. The greatest microcystin concentrations typically occur in October but cyanotoxins in Blackmans Lake have been sampled between June and December with blooms reportedly occurring well into the winter months (e.g., November through April).

## Where is the Excess Phosphorus Coming From?

There are three major pathways of phosphorus to Blackmans Lake: (1) internal release from lake sediments, (2) waterfowl feces, and (3) stormwater runoff. Most of the phosphorus loaded to the lake via waterfowl feces is not immediately available for algae growth and falls to the lake sediments, where it is later released via the internal load. Most of the stormwater phosphorus is loaded to the lake during the winter months and falls to the lake sediments, where it is later released via the internal load during the summer algae bloom season.

The sediments of Blackmans Lake are rich in phosphorus bound to organic matter (e.g., decomposing algae, waterfowl feces, and leafy plant debris). During the summer, there are low levels of oxygen at depth, which changes the chemical structure of iron which then releases bound phosphorus. Furthermore, warmer temperatures increase microbial decay of sediment organic matter, which releases bound phosphorus up into the water column for algae uptake.

The primary sources of accumulated sediment phosphorus are waterfowl feces, watershed storm flows, and settled algae. Controlling external watershed loading of phosphorus, along with internal sediment release, will be important in the long term for mitigating algae blooms and curbing the replenishment of internal sediment loads.

# Cyanobacteria Management Methods

This chapter provides a brief summary of watershed and in-lake management methods for cyanobacteria control, their advantages and disadvantages, and their suitability for implementation in Blackmans Lake. Actions assessed as suitable for implementation in Blackmans Lake are highlighted in green in Table 20 and further described in the sections below. These cyanobacteria management methods are described in Appendix D. Actions determined not feasible for implementation in Blackmans Lake and rationale are detailed in the *Methods Rejected* section of Appendix D.

**Table 20. Cyanobacteria Management Feasibility Screening for Blackmans Lake.**

Method	Effectiveness	Cost	Non-target Impact Risk	Feasibility	Suitability
<b>Watershed (External Nutrient Loading Control) Methods</b>					
<b>Septic System Management</b>	Low-Moderate	High	Low	Moderate	Yes
<b>Stormwater Management</b>	Low-Moderate	Moderate	Low	Moderate	Yes
Stream Phosphorus Inactivation	Low-Moderate	Moderate	Moderate	Low	No
<b>Waterfowl Management</b>	Low-Moderate	Moderate	Low	Moderate	Yes
<b>Shoreline Management</b>	Low-Moderate	Moderate	Low	Moderate	Yes
<b>In-Lake Physical Methods</b>					
Lake Mixing – Surface Mixing by SolarBees	Low-Moderate	Low-Moderate	Low	Moderate-High	No – uncertain effectiveness
Lake Mixing – Whole-lake Mixing by Aeration	Low-Moderate	Moderate	Low	Moderate	No – uncertain effectiveness
Sonication	Low-Moderate	Moderate	Low-Moderate	Low	No – uncertain effectiveness
Lake dilution	Moderate	High	Low	Low	No – high cost
<b>Hypolimnetic Oxygenation/ Aeration</b>	Moderate-High	Moderate-High	Low – fish benefits	Moderate	Yes
Ozone/ Microbubbles/ Nanobubbles	Low	Moderate	Low	Low	No – not effective, experimental
Hypolimnetic Withdrawal	Low	Moderate	High	Low	No – downstream impacts
Dredging	Low-Moderate	Very High	Moderate	Low	No – high cost/benefit

**Table 20 (continued). Cyanobacteria Management Feasibility Screening for Blackmans Lake.**

Method	Effectiveness	Cost	Impact Risk	Feasibility	Suitability
Shading (Dyes)	Moderate	Low-Moderate	High	Low	No – not feasible
Improve outlet conveyance capacity	Low	Low-Moderate	Low	Low	No – not effective
<b>Lake Chemical Methods</b>					
Algaecide treatment	Moderate	Low-Moderate	Low-Moderate	Moderate	No – costly, not a long-term solution
Sediment Phosphorus Inactivation with Alum or Lanthanum	High	Moderate	Low-Moderate	Moderate	Yes
Calcium treatment	Low	Low-Moderate	Low	Low	No – not effective with low hardness
Iron treatment	Low	Low	Low	Low-Moderate	No – not effective with anoxic hypolimnion
<b>Lake Biological Methods</b>					
Waterfowl Deterrence	Low	Low	Low-Moderate	Low-Moderate	Yes
Carp removal	Low	Moderate-High	Low-Moderate	Low	No – high cost/benefit
Bio-manipulation (Zooplankton planting; Piscivore stocking)	Low	Low-Moderate	Low-Moderate	Low	No – not feasible, low effectiveness
Macrophyte plantings	Low	Moderate	Low	Low	No – high cost/benefit
Barley Straw	Low	Low	Low-Moderate	Low	No – uncertain effectiveness

# Recommended Management Plan

This chapter describes the recommended management approach for controlling cyanobacteria in Blackmans Lake. We recommend an adaptive management approach that provides long-term prevention through internal load reduction and watershed phosphorus control. We recommend OST for internal phosphorus control and a combination of education and stormwater treatment for watershed phosphorus control. Ongoing monitoring should be used to monitor achievement of water quality objectives and to inform adjustments to management techniques.

LCMP recommendations are summarized in Table 21 and described in the following subsections. The total cost of LCMP implementation is \$940,000 for the first three years (in 2024 dollars) and \$6.1M for the following 20 years (including 3.5 percent/year inflation).

<b>Table 21. Recommended Cyanobacteria Management Plan For Blackmans Lake.</b>				
<b>Plan Element</b>	<b>First Three Years (2025 to 2027)</b>		<b>Next 20 Years (2028 to 2047)</b>	
	<b>Description</b>	<b>Cost (2024\$)</b>	<b>Description</b>	<b>Cost (\$) <sup>a</sup></b>
Oxygen Saturation Technology (OST)	Permit and install an OST in 2026.	\$620K	Ongoing maintenance and electricity costs (base cost: \$12K/year)	\$0.3M
Watershed Source Control Education/Outreach (Waterfowl, Septic, Shoreline, and Land Stewardship)	Leverage existing LakeWise program from Snohomish County to encourage and install best management practices. Revise stormwater code to require P treatment.	\$0	Ongoing	\$0
Stormwater Retrofit Evaluation	Evaluate potential stormwater retrofit locations.	\$100K	Implement high-value, multi-benefit stormwater retrofits	\$2.0M
Monitoring and Reporting	Routine/supplemental lake monitoring, bloom and fecal surveillance, stormwater monitoring, sediment monitoring, and reporting (base cost: \$34K/year)	\$100K	Routine/supplemental lake monitoring, bloom and fecal surveillance, stormwater monitoring, sediment monitoring, and reporting (base cost: \$34K/year)	\$1.4M
Lake Management Administration	Finance and grant tracking. Adaptive management. Coordination with consultants and contractors. Implementation of management plan (base cost: \$60K/year)	\$120K	Finance and grant tracking. Adaptive management. Coordination with consultants and contractors. Implementation of management plan. (base cost: \$60K/year)	\$2.4M
<b>Total (first 3 years)</b>		<b>\$940K</b>	<b>Total (next 20 years)</b>	<b>\$6.1M</b>

<sup>a</sup> 20-year cost assumes cost escalation of 3.5 percent each year in consideration of wage, utility, and material cost increases.

# In-Lake Phosphorus Management

Sediment release is the primary source of phosphorus to cyanobacteria in the lake. While controlling watershed inputs is critical to preventing accumulation of additional phosphorus in the sediments, managing the existing reservoir of phosphorus in the lake is recommended to manage phosphorus and algae abundance in the lake. For long-term management, we recommend three alternatives:

1. Installation of a hypolimnetic oxygenation system, specifically an oxygen saturation technology (OST) system, to oxygenate the deep waters of the lake, reduce internal phosphorus loading, and improve fish habitat
2. Annual phosphorus water column stripping with a low dose of either alum or EutroSorb G (lanthanum)
3. Phosphorus sediment inactivation with high doses of either alum or EutroSorb G (lanthanum).

These alternatives are compared in Table 22. If installing the OST system, we anticipate it will take two to three years to design the system and obtain the necessary permits. The near- and long-term costs for sediment inactivation are dependent on the longevity of each treatment and the selected inactivation chemical. Overall, for a 23 period from 2025 to 2047, OST is the lowest cost option at \$0.9 million, followed by sediment inactivation at \$2.0 to \$3.5 million, and water column stripping at \$4.3 million. Due to the lower costs and potential ecological benefit of increasing the habitable zone, OST is the preferred option.

**Table 22. Comparison of In-Lake Phosphorus Management Alternatives**

Alternative	First 3 Years		Next 20 Years	
	Description	Cost (2024\$)	Description	Cost (2024\$)
Oxygen Saturation Technology (OST) (Preferred Option)	Permit, design, and install an OST.	\$0.6M	Ongoing maintenance and electricity costs (base cost: \$12K/year)	\$0.3M
Annual Water Column Stripping	Annual water column inactivation dose of alum or lanthanum (based cost \$123K for alum, \$125K for EutroSORB G)	\$0.4M	Annual water column inactivation dose of alum or lanthanum	\$3.9M
Sediment Phosphorus Inactivation	Single large or several lower-dose treatments to inactivate phosphorus in the lake sediments. (Alum and lanthanum [EutroSorb G] costs are presented)	\$0.3M to \$0.4M	Additional inactivation dose every 5 or 10 years, informed by monitoring	\$1.7M to \$3.1M

It is expected that either of the three recommended alternatives would reduce summer phosphorus loading by approximately 50 percent, and that reduction would likely be sufficient to meet the lake management objectives for cyanotoxin concentrations (meeting guidelines less than twice in 4 of 5 years), public health advisory (no advisory over 3 weeks in 4 or 5 years), and trophic status (mesotrophic for all three trophic state parameters). OST and sediment phosphorus inactivation are expected to reduce summer sediment phosphorus release (49 kg for 2022) by at least 75 percent (37 kg

for 2022), which equates to a 48 percent reduction of the total summer phosphorus load (77 kg for 2022). Annual water column stripping is expected to reduce lake phosphorus mass (32 kg for 2022) by at least 75 percent (24 kg for 2022), which equates to a 31 percent reduction of the total summer phosphorus load (77 kg for 2022).

## Preferred Alternative: Oxygen Saturation Technology

Hypolimnetic (deep water) oxygenation or aeration techniques have been implemented in many lakes to combat low oxygen by maintaining or increasing oxygen levels in deep waters without causing whole-lake mixing. Hypolimnetic oxygenation systems have been successfully employed in many lakes, including Newman Lake in Spokane County, Washington, and is currently sought for Spanaway Lake in Pierce County, Washington.<sup>1</sup> A hypolimnetic aeration system (injecting air rather than oxygen) was installed in 1994 and recently upgraded in 2022 in Lake Fenwick in Kent, Washington. Maintaining oxygenated conditions in the upper sediments suppresses the release of phosphorus (as well as nitrogen). Preventing lake destratification (mixing of epilimnion and hypolimnion) is important, to avoid introducing relatively nutrient-rich deep waters into the surface.

Oxygen Saturation Technology (OST) is a relatively new, patent-pending innovation used to administer precise concentrations of oxygen at strategic depths in a waterbody (Figure 21). The OST's design eliminates bubbles, which eliminates turbulence, sediment resuspension, and undesirable mixing. These systems can maintain dissolved oxygen (DO) levels as high as 20 mg/L directly over and into the sediments, where oxygen is needed most. They may also be helpful at preventing oxygen-related fish mortality. These high dissolved oxygen levels (exceeding those from simple saturation with the air) are important to overcome the high oxygen demand of organic-rich sediments in Blackmans Lake. Traditional hypolimnetic aeration systems can fail because they do not meet the sediment oxygen demand. OST has not been used in Washington State.

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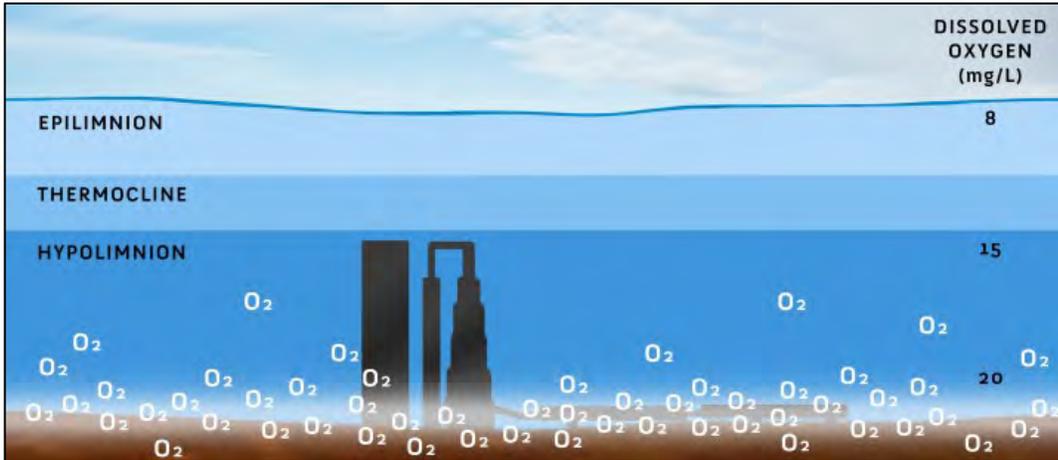
<sup>1</sup> For additional lakes with hypolimnetic oxygenation see:

Cooke GD, Welch EB, Peterson SA, Nichols SA (2005) In: Cooke GD (ed) Restoration and management of lakes and reservoirs, 3rd edn. Taylor and Francis, Boca Raton, Florida.

Bormans, Myriam & Marsálek, Blahoslav & Jancula, Daniel. (2016). Controlling internal phosphorus loading in lakes by physical methods to reduce cyanobacterial blooms: a review. *Aquatic Ecology*. 50. 10.1007/s10452-015-9564-x.

Preece, E.P., B.C. Moore, M.M. Skinner, A. Child, and S. Dent. 2019 A review of the biological and chemical effects of hypolimnetic oxygenation. *Lake and Reservoir Management* 35: 229-246.

Figure 20. Oxygen Saturation Technology.



An OST system functions by transporting approximately 95 percent pure oxygen from an onshore facility to an in-lake device where the water is supersaturated with oxygen. The water is then injected back into deep areas of the lake where it disperses over the sediment surface. The oxygenated water can coat and penetrate the sediments, preventing the release of phosphorus from iron-phosphate complexes and allowing the oxidized iron to bind to phosphate released by microbial decay of organic matter. The onshore facility consists of an oxygen generator and an air compressor and receiver tank. The compressor produces 67 decibels of noise, which is equivalent to a conversation by two people and can be reduced by an acoustic barrier. There is no storage of oxygen on premises.

It is anticipated that attaining permits and securing funding for the OST will take several years. We recommend that the City begin taking steps to attain both permits and funding as soon as possible. Environmental permits required by the State Environmental Policy Act (SEPA) and Shoreline Management Act (SMA) will be obtained through submittal of a Joint Aquatic Resources Permit Application for the following:

- Washington Department of Fish and Wildlife (WDFW) Hydraulic Project Approval (HPA)
- City of Snohomish Shoreline Substantial Development Permit
- City of Snohomish Building Permit for the oxygenation system on shore.

An OST system is expected to cost \$0.6 million for the system, permitting, design, and installation. Ongoing operation and maintenance are estimated at approximately \$12,200 per year, with an estimated 3.5 percent escalation each year. Given this high upfront cost, we recommend pursuing funding in tandem with attaining permits. Viable funding sources are described in the *Funding the Plan* section below.

Available sediment data indicates that the amount of iron in the sediment may not be sufficient to sequester the total amount of phosphorus in the sediments. The measured iron-to-phosphorus ratio in the deep portion of Blackmans Lake was 10:1, and a ratio of at least 15:1 is expected to provide complete control in oxygenated sediments (Jensen et al. 1992). The declining effectiveness of the hypolimnetic

oxygenation system at Lake Stevens, located north of Blackmans Lake, was partially attributed to decreased availability of iron in the sediments (TetraTech 2009). If hypolimnetic oxygenation alone does not result in achievement of water quality objectives, then iron salts or zero-valent iron (ZVI) may be applied in the lake. These materials are relatively low cost compared to alum, lanthanum, or other phosphorus inactivation chemicals. However, the hypolimnion must remain well-oxygenated because the iron-phosphorus complexes are sensitive to low-oxygen conditions. Appendix D describes the dosing and expected cost of such an iron treatment.

## Alternative: Phosphorus Inactivation

Alum, lanthanum, or proprietary chemicals may be applied in lakes to inactivate phosphorus in the water column and the sediments. Appendix D provides detailed description of inactivation approaches and the development of cost estimates. Table 23 describes three types of phosphorus inactivation chemicals that are suitable for use in Blackmans Lake.

**Table 23. Comparison of Phosphorus Inactivation Chemicals.**

<b>Water Column Inactivation Method</b>	<b>Alum</b>	<b>Lanthanum</b>	<b>Proprietary Blend</b>
<b>Commercial Products</b>	Available from general chemical suppliers	Phoslock EutroSORB G	MetaFloc EutroSORB WC
<b>Mode of Inactivation</b>	Forms stable complexes with dissolved phosphorus. Forms floccules that pull particulate phosphorus (i.e., algae and sediment) from the water column. Stable at pH 6 to 9.	Forms stable complexes with dissolved phosphorus. Binding efficiency is highest between pH 5 and 7. Dissolution may occur at elevated pH levels (>9). Does not remove particulate phosphorus.	Form complexes with dissolved phosphorus. Most blends include a floccule agent that, like alum, will pull particulate phosphorus (i.e., algae and sediment) from the water column.
<b>Application Approach</b>	Applied at water surface and settled to the sediment. Alum is expected to sink and incorporate into the lake sediments.	Applied as lanthanum modified bentonite or as lanthanum salt across the waters surface. Expected to incorporate into the lake's sediments.	Applied at water surface and settled to the sediment.
<b>Potential Negative Consequences</b>	Aluminum toxicity to aquatic life may occur if inadequate buffer is applied and the pH is outside permitted range of 6-8.5. This can be prevented through rigorous planning and monitoring as required by the permit.	Lanthanum concentration immediately following application may exceed estimated toxicity thresholds, particularly for zooplankton, and little study has been done for impacts on benthic organisms. Generally, because lanthanum is applied in phosphorus-rich waters, the amount of free lanthanum ions is low as they bind to phosphate. Jar tests prior to application can be used to ensure proper dosage.	The specific make-up of the blends is proprietary. If alum and lanthanum blend, then the same potential impacts and toxicity prevention approaches.

**Table 24 (continued). Comparison of Phosphorus Inactivation Chemicals.**

<b>Water Column Inactivation Method</b>	<b>Alum</b>	<b>Lanthanum</b>	<b>Proprietary Blend</b>
<b>Permitting</b>	Alum is an approved phosphorus inactivation chemical in the APAM permit. There are not water use restrictions during or after the application.	Lanthanum is an approved phosphorus inactivation chemical in the APAM permit. There are not water use restrictions during or after the application.	Ecology must be allowed to confirm that the chemicals in the product are already approved or an experimental application permit must be obtained.
<b>Water Stripping Estimated Cost for 2025 (including materials + sales tax, permitting, contractor fees, and monitoring; 2024\$)</b>	\$123,000 (unbuffered alum)	\$125,000 (EutroSORB G) \$147,000 (Phoslock)	\$128,000 (MetaFloc) \$143,000 (EutroSORB WC)
<b>Long-term 20-year Water Stripping Cost</b>	\$3.9 million	\$3.9 million (EutroSORB G) \$4.4 million (PhosLock)	\$4.0 million (MetaFloc) \$4.3 million (EutroSORB WC)
<b>Sediment Inactivation Estimated Cost for 2025 (including materials + sales tax, permitting, contractor fees, and monitoring; 2024\$)</b>	\$361,000 (buffered alum)	\$323,000 (EutroSORB G) \$1,000,000 (Phoslock)	\$409,000 (MetaFloc) \$879,000 (EutroSORB WC)
<b>Long-term 20-year Sediment Inactivation Cost</b>	\$1.0 to \$6.7 million	\$1.7 to \$5.9 million (EutroSORB G) \$5.3 to \$18.6 million (PhosLock)	\$2.2 to \$7.5 million (MetaFloc) \$4.6 to \$16.2 million (EutroSORB WC)
<b>Recent Past Applications</b>	Black Lake, Tumwater, Washington (2021) Waughop Lake, Lakewood, Washington (2020) Heart Lake, Anacortes, Washington (2018) Wapato Lake, Tacoma, Washington (2017) Green Lake, Seattle, Washington (2016)	Kitsap Lake, Bremerton, Washington (2020 – [annually]) Lake Lorene, Federal Way, Washington (2012)	No published case studies or management plans

Alternative inactivation approaches using iron (without oxygenation) or calcium were deemed to not be suitable for Blackmans Lake because of the lake’s low oxygen and hardness, respectively.

Phosphorus inactivation can be conducted annually to strip phosphorus from the water column and settle it to the sediments, or larger treatments may be conducted to both remove phosphorus from the

water column and inactivate sediment in the phosphorus (“sediment reset”). Figure 22 presents pictures of buffered alum treatments in Green Lake (Seattle) for sediment inactivation in 1991, 2004, and 2016.

**Figure 21. Buffered Alum Treatments in 1991, 2004, and 2016 (left to right) for Sediment Phosphorus Inactivation in Green Lake, Seattle.**



Water column stripping with alum often does not need a buffer because of the low dose and acidity. Sediment inactivation with alum needs to use sodium aluminate as a buffer to the acidic alum (aluminum sulfate) in the soft waters of Blackmans Lake, and unit product costs are higher than just alum for a stripping treatment because sodium aluminate is much more expensive than alum. Lanthanum products (EutroSORB G or Phoslock) are neutral and do not require a buffer for either water column stripping or higher doses for sediment inactivation. Either alum or lanthanum by water column stripping or sediment inactivation would be suitable phosphorus control approaches for Blackmans Lake.

Water stripping doses were developed assuming (1) that 32 kg of phosphorus in the water column would inactivate in the first year of treatment (2025) and (2) that subsequent phosphorus levels for treatment would be 25 percent lower (24 kg) (see Appendix D). An unbuffered dose of alum is appropriate due to the low alum dose required for only water column stripping. This resulted in an alum dose for annual water stripping is 0.6 mg/L Al (2.6 g Al/m<sup>2</sup>), which is greater than the annual dose of 0.15 mg/L Al applied to Lake Stevens and less than the annual dose of 3.0–6.1 mg/L applied to Lake Ketchum (see Appendix D).

Sediment inactivation doses were estimated based on an average sediment mobile phosphorus concentration of 466 mg/kg-DW and a treatment area of 247,000 m<sup>2</sup> (the entire lake area) to inactivate 1,037 kg of phosphorus in sediments to a depth of 10 centimeters. The sediment inactivation doses include water column stripping of 32 kg. The alum should be buffered due to the higher aluminum dose. (mg/L Al; g Al/m<sup>2</sup>). This resulted in an alum dose for sediment inactivation is 19.8 mg/L Al (84.1 g Al/m<sup>2</sup>), which is within the range of sediment inactivation doses in other Washington lakes( 6-40 mg/L Al and 11–84 g Al/m<sup>2</sup>) (see Appendix D).

Over the long-term, annual applications generally are expected to cost more than their respective sediment reset applications due to mobilization costs (Table 24). The longevity of sediment inactivation treatments is dependent on the control of external loading and stability of the bonds between the inactivation chemical and sediment phosphorus. Given the relatively low watershed phosphorus loading to Blackmans Lake, a long-term sediment inactivation treatment is likely to last approximately 10 years at a cost of approximately \$1.0 million for two treatments in 20 years. This cost compares favorably to the

23-year cost for OST at approximately \$0.9 million, but average annual costs should be lower for OST past 20 years and alum treatments do not have the fish habitat benefit of oxygenation.

**Table 25. Estimated Long-Term Cost of Phosphorus Inactivation through Water Stripping or Sediment Inactivation.**

Phosphorus Inactivation Chemical	Annual Water Stripping (20 years)	Long-Term 20-Year Cost ("Reset" every 10 years)	Long-Term 20-Year Cost ("Reset" every 5 years)	Long-Term 20-Year Cost ("Reset" every 2 to 3 years)
Buffered Alum	–	\$1,000,000	\$3,120,000	\$6,650,000
Unbuffered Alum	\$3,940,000	–	–	–
PhosLock	\$26,830,000	\$5,330,000	\$8,720,000	\$18,570,000
EutroSORB G	\$8,990,000	\$1,700,000	\$2,790,000	\$5,930,000
MetaFloc	\$11,240,000	\$2,160,000	\$3,540,000	\$7,530,000
EutroSORB WC	\$23,440,000	\$4,640,000	\$7,590,000	\$16,170,000

## Watershed Source Control

A key long-term pathway to preventing cyanobacteria blooms is to decrease the loading of nutrients to the lake. This involves both source control and treatment. Source control is the removal or mitigation of a source, such as reducing phosphorus fertilizer use, installing livestock exclusion fencing along a stream, and fixing failing septic systems. Treatment is the reduction of a nutrient through built and natural infrastructure, such as infiltrating stormwater using LID techniques, filtering stormwater with phosphorus-adsorbing media, or installing vegetative buffers along waterways.

## Stormwater Management

Stormwater runoff can be an important pathway of nutrients to surface water and groundwater. Fertilized areas, domestic animals, and wildlife contribute phosphorus to stormwater runoff. The Blackmans Lake watershed is 81 percent residential development and 28 percent impervious surfaces from a combination of roadways, rooftops, and driveways. Estimates of stormwater runoff in the watershed indicate about 16 percent of the annual phosphorus load is from stormwater flow to the lake. Opportunities to install small phosphorus treatment systems in areas currently without stormwater treatment and to retrofit existing facilities with phosphorus treatment could be explored.

We recommend that the City declare the Blackmans Lake watershed as phosphorus sensitive and revise stormwater code to require phosphorus treatment for all new and re-development projects within the watershed. This LCMP provides the documentation establishing the need for phosphorus treatment in accordance with NPDES regulations and Ecology’s stormwater management manual (Ecology 2019). This action will cost the City administrative time to change the code and educate the community, while the costs of phosphorus treatment are put upon land developers.

We recommend that a stormwater treatment and retrofit evaluation be completed in partnership with the City and Snohomish County Surface Water Management. The first step of such an effort would be to

identify opportunity locations for stormwater treatment or retrofit based on existing infrastructure, land use/land cover, property ownership, and water quality data. This step includes identifying 15 to 20 opportunity locations and preparing high-level concepts and cost estimates. This first step is estimated to cost \$30,000 to \$40,000 but is variable with the number of opportunity locations and complexity of sites. Following this initial identification, the second step would be to conduct field verification and develop detailed conceptual designs for a shortlist of the locations. Assuming 10 to 12 sites are on this shortlist, this second step is estimated to cost \$40,000 to \$50,000, again scaling with the number of sites and their complexity. Overall, \$100,000 should be budgeted for this initial planning effort over the next few years.

The cost of final design and installation for stormwater treatment and retrofit vary significantly based on the selected treatment approach and site conditions. Table 25 below provides high-level cost estimates for a variety of stormwater treatment systems based on work completed for King County’s Water Quality Benefits Evaluation (Herrera 2022b).

**Table 26. Example Stormwater Treatment and Retrofit Costs.**

Facility Type	Total Project Cost (not including land acquisition)	O&M	Area Treated (acres)	Median Phosphorus Concentration Removal
Drywell	\$16,000	\$1,800	0.01 to 0.02	NE (100% infiltration)
Cistern	\$26,000	\$2,100	0.03	0%
Rain Garden	\$24,000	\$2,800	0.02 to 0.06	NE (100% infiltration)
Media Filter Drain (MFD)	\$30,000	\$2,300	0.05	44.6%
Bioretention Planter	\$42,000	\$2,800	0.05	54.9%
Bioretention	\$85,000	\$2,800	0.2 to 0.3	54.9%
Bioswale	\$20,000	\$2,600	0.6	-37.2% (increase)
Deep Underground Injection Control Wells	\$46,000	\$2,000	NA	NE (100% infiltration)
Infiltration Vault	\$4,589,000	\$4,900	0.7	NE (100% infiltration)
Detention Vault	\$6,229,000	\$4,900	0.7	17.7%
Detention Pond	\$1,102,000	\$9,400	0.8	17.7%
High-rate Underground Filter System	\$106,000	\$2,900	0.8	41.5%
Infiltration Pond	\$705,000	\$5,500	0.8	NE (100% infiltration)
Stormwater Treatment Wetland	\$642,000	\$2,300	1.4	24.2%
Wet Pond	\$683,000	\$2,000	1.4	49.5%
Wet Vault	\$5,055,000	\$2,900	1.4	49.5%
Regional Vegetated Media Filtration Facility	\$6,038,000	\$12,000	396	41.5%

Source: Herrera 2022b. All costs in 2019 dollars. Project costs and treatment areas are based on costs for till soils.

NE= not evaluated and assumed to be 100 percent removal because all inflow infiltrates to groundwater

Approximately \$2M should be budgeted over 20 years in anticipation for design and installation of 10 to 15 small phosphorus treatment systems comprised of bioretention systems or media filters with phosphorus retention media. This level of treatment may reduce the annual phosphorus load by

20 percent, assuming 50 percent phosphorus removal from 40 percent of the stormwater inflow to the lake. Based on the estimated phosphorus loading for storm flow of 17 kg in 2022 (16 percent of the 108 kg total loading), the annual phosphorus loading would be reduced by only 3.4 kg (3 percent of the 108 kg total loading). This equates to a 20-year average annual cost for phosphorus removal of \$400,000/kg-yr compared to a 20-year average annual cost of phosphorus removal by OST of \$25,000/kg-yr (\$920,000/37 kg-yr). Thus, stormwater management is much less cost effective than OST.

## Septic System Management

Septic systems are not believed to currently be a major contributor of phosphorus to Blackmans Lake based on the low levels of phosphorus found in drainage to the lake and the low number of septic systems (70) relative to the watershed size (473 acres). However, we do recommend taking actions to identify existing septic systems that may be contributing disproportionate loads of phosphorus to Blackmans Lake. These include failing systems that are no longer functioning per their initial design and systems that do not have adequate local conditions to remove phosphorus. Systems that appear to be working can still be contributing phosphorus loading to the lake. Failing systems may be identified via operation and maintenance inspections by certified professionals. Important factors for improperly sited systems and drain fields are distance to a nearby lake or stream, depth to the water table, and soil chemistry.

We recommend encouraging septic system owners throughout the watershed to complete routine inspections, as required by state law. Additionally, we recommend evaluating higher risk systems that are located around the lake or along streams to evaluate if adequate treatment is provided. In locations where the systems are not adequate, advanced treatment systems (ATUs) may be necessary. For instance, membrane bioreactor systems treat wastewater before discharge to the drain field and therefore do not necessitate the full drain field treatment area. The installation of such technology must be permitted by Snohomish County Health Department, per WAC 246-272A. We recommend coordination with Snohomish County Health Department and the State Department of Health, to develop a pathway for upgrading septic systems that do not have adequate drain field areas or soil treatment.

Replacing septic systems can be very expensive (up to \$20,000 to \$40,000), depending on the location and installation constraints. However, there are numerous grants and low-interest loans available that may ease the upfront investment. This includes Craft3 Clean Water Loans, a low-interest loan program. The LCMP does not include budget for septic system management.

## Shoreline and Waterfowl Management

Plants that grow in and along lake shorelines have an important role in protecting water quality and providing habitat aquatic organisms. Rooted plants can prevent shoreline erosion through their root systems, and in-water plants can reduce soil erosion and sediment suspension by dampening energy from waves. Shoreline plants can absorb and slow runoff from upslope, removing nutrients. They are also important for fostering native insects that are food for fish and birds.

Developing a healthy shoreline program to promote and fund replacement of bulkheads and lawns with native plants is a recommended management action to reduce nutrient inputs and cyanobacteria growth

in Blackmans Lake. Snohomish County Surface Water Management runs an existing program, LakeWise, to encourage lake stewardship through lawn and yard care, septic system care, and healthy shorelines. The program provides online and in-person education and outreach materials. LakeWise offers free natural lawn care workshops and free native plants for shoreline landscaping.

Waterfowl droppings are a leading contributor to phosphorus loading to Blackmans Lake. They also have a negative aesthetic impact and present a potential health risk to lake users from fecal pathogens. These impacts are primarily driven by migratory geese populations in fall (seen in October 2023), where up to 4,000 geese were found on the lake. Because most phosphorus loading is associated with migratory geese rather than resident geese, there are legal and ethical considerations in taking actions to harass, relocate, or otherwise harm migrating geese. Additionally, actions taken to harass and displace migratory geese may result in a shift in the migrating population to neighboring lakes, which may be negatively impacted by increased phosphorus loads. Relocation is generally not recommended because the birds are likely to create problems wherever they go. Snohomish Park municipal code prohibits the annoyance or feeding of any animal, bird, fowl, waterfowl, fish, farm animal, or wildlife (SMC 13.04.080).

It is important to prevent the migrating populations from becoming resident. Feeding waterfowl discourages natural winter migration; can lead to aggressive behavior; and encourages large resident bird flocks that degrade parks, lawns, and beaches with droppings. Proper signage with such messaging should be installed at the parks and boat launch. We also recommend property owner participation in the Snohomish County LakeWise program and for the Snohomish Park Department to evaluate waterfowl-discouraging landscaping on its lands.

# Future Monitoring and Adaptive Management

To further the long-term water quality and lake use goals for Blackmans Lake, this plan includes the following adaptive lake management framework to regularly reassess and amend LCMP strategies or goals as part of ongoing, adaptive lake management, pursuant to future lake needs, stakeholder values, and funding. This section describes (1) the decision-making process and adaptation framework by which the LCMP shall be modified, (2) measurable management objectives, (3) current knowledge gaps and the recommended monitoring plan for continued effectiveness evaluation, and (4) potential future LCMP adaptations to begin considering.

## Adaptation Framework

The graphic insert depicts a generalized procedure that may be used for LCMP adaptive management and decision making. This LCMP assessed the problem and designed solutions. The next phase of the decision-making process is to implement components of the LCMP. Subsequent steps include:

- **Monitoring:** Monitoring is a key component of adaptive management. A basic monitoring program at Blackmans Lake should be conducted by trained staff and/or volunteers and should consist of elements described in the Recommended Monitoring section. Independent scientific review may be conducted at identified points of implementation, pursuant to study goals, and/or funding resources.
- **Effectiveness Evaluation:** Using monitoring data and observations, project performance and management effectiveness will be evaluated. An evaluation report should outline recommended actions, data gaps, and next steps for review. Relevant reports or petitions for rulemaking shall be shared with the public.
- **Adjustments:** Based on the recommendations established in the evaluation report and those provided by technical advisors, and the values of the community and general public, the City is responsible for all final decisions regarding LCMP adaptations/adjustments.



# Measurable Management Objectives

We acknowledge there is inherent uncertainty to the success of the recommended management actions. Therefore, it is critical to set measurable objectives, maintain monitoring of those objectives, and adjust the management plan if those objectives are not being met.

For each recommended management activity, we recommend the following measurable objectives and adaptive management actions for when objectives are not met (Table 26).

**Table 27. Measurable Management Objectives.**

Activity	Objective	Potential Adaptive Management Action
Water Column Phosphorus Inactivation	Reduce summertime phosphorus available for algae to average concentrations less than 24 µg/L in the water column.	Continue lake monitoring to track effectiveness of inactivation. Adjust dosage or chemical used.
Sediment Phosphorus Inactivation	Reduce summertime phosphorus available for algae to average concentrations less than 24 µg/L in the water column.	Continue lake monitoring to track effectiveness of inactivation. Adjust dosage or chemical used.
Hypolimnetic Oxygenation	Hypolimnetic oxygen levels are at least 4 mg/L through the summer. Internal loads via hypolimnetic phosphorus release are reduced by maintaining a summertime average total phosphorus concentration of less than 24 µg/L.	Work with manufacturer to adjust equipment to meet target oxygen levels. If ongoing internal loading is observed, evaluate alternative sediment phosphorus sequestration options, such as iron supplementation.
Beach Cyanotoxin Monitoring	Cyanotoxin samples are collected when a bloom is present and additional samples are collected following state protocol. Warning signs should be posted when there is an exceedance of state recreational and removed after two weeks without an exceedance. Beach closures should occur no more than twice in a five-year period, lasting no longer than three weeks.	If weekly samples are not collected or immediate public notification of exceedances is not completed, audit program to understand challenges. If beach closure objective is not achieved, re-evaluate cause(s) of cyanobacteria blooms in consideration of changes in internal and external loads resulting from management actions.
Waterfowl and Shoreline Management	Adoption of shoreline best management practices at all City parks. Appropriate signage at park locations discouraging waterfowl feeding. Adoption of shoreline and landscaping management practices by at least 50 percent of private residences along the lake perimeter.	Survey park managers and property owners to understand barriers to adopting management practices. Secure additional funding, if needed.
Stormwater Management	Maintain or reduce stormwater phosphorus loading to Blackmans Lake.	Evaluate effectiveness of retrofit projects. Secure additional funding for future retrofits if needed.

## Data Gaps

Data gaps identified for the characterization of water quality in Blackmans Lake (see Appendix A), which can be considered to inform cyanobacteria and adaptive lake management, include:

- Comprehensive and consistent lake water quality data (including chemistry, biology, and physical data). Specifically:
  - pH measurements throughout the water column
  - Orthophosphate, chlorophyll-a, ammonia nitrogen, and nitrate + nitrite nitrogen
  - Measurements of lake physical, biological, and nutrient conditions from November through April
  - Regular phytoplankton and zooplankton taxonomic composition and biovolume data
- Comprehensive and consistent stream and/or outfall water quality data (including chemistry and physical data). Specifically:
  - pH, conductivity, temperature, and DO
  - Orthophosphate, and nitrogen fractions
  - Year-round flow
- Long-term comparative analysis of cyanotoxin concentrations and cyanobacteria compositions from samples throughout the year, unrestricted to scum or bloom samples.
  - Occasional observation and sampling for benthic cyanobacteria species.
- Cyanobacteria DNA analyses for toxin-producing genes, in both current water column populations and historical populations from the lake sediment.
- Year-round groundwater flow and nutrient concentrations.
- Assessment of septic contributions to nutrient inputs.
- Long-term and/or year-round waterfowl, lake usage, and fish harvest data.

Additional discussion and water quality data details are presented in Appendix A.

## Recommended Monitoring

No matter the management objectives or management strategy employed, ongoing monitoring is necessary to evaluate success and allow adaptive management. The adaptive management approach for Blackmans Lake includes short-term and long-term monitoring. Short-term monitoring is focused on key data gaps and will provide the information needed to confirm and refine the selected measures and develop more accurate cost estimates. Long-term monitoring will provide the information needed to evaluate progress toward achieving management goals and to adjust or augment the lake management measures.

As outlined in Table 27, we recommend developing a monitoring plan which builds on current water quality and lake level monitoring programs to include:

- Additional routine lake monitoring
- Cyanobacteria bloom and fecal bacteria surveillance
- Stormwater treatment performance and inlet monitoring
- Sediment phosphorus monitoring

Estimated costs for each monitoring element are also presented in Table 27 and includes a 20 percent contingency for a total annual cost of \$33,660.

If conducting phosphorus inactivation treatment, additional monitoring will be required by the Aquatic Plant and Algae Management General Permit. Treatment monitoring costs are included in the treatment cost estimates. For certain applications, a jar test must be performed prior to treatment to identify appropriate dosing levels. These applications include iron and whole-lake alum treatments if a buffer other than sodium aluminate is used or if a ratio of liquid alum to liquid sodium aluminate differs from 2:1 by volume. Jar testing is not required for lanthanum-modified clay because Blackmans Lake is sufficiently alkaline ( $>20$  mg  $\text{CaCO}_3/\text{L}$ ). With alum, additional monitoring must be done before, during, and after treatment per S6.B of the permit (see the *Alum Treatment* subsection in Appendix D: Cyanobacteria Management Methods for a summary of monitoring requirements).

## Future Adaptations to Consider

We expect that the OST system will reduce internal phosphorus loading and meet the management objective for total phosphorus of less than 24  $\mu\text{g}/\text{L}$  as a summer average at 1-meter depth. This total phosphorus objective is the boundary between mesotrophic (moderate productivity) and eutrophic (high productivity) classifications that is also expected to meet the other established objectives for water clarity (Secchi depth), algae biomass (chlorophyll-a) and toxic cyanobacteria blooms (cyanotoxins) (see Lake Management Objectives).

If the OST alone does not meet the total phosphorus or other lake management objectives, then modification of the management strategies is needed. Modifications, in order of priority, may include:

1. Increase in the oxygen input amount and/or extend the duration of oxygen input to the hypolimnion from the OST system
2. Increase the amount of iron in the lake sediments to bind phosphate under oxygenated conditions by applying zero valent iron to either the entire lake or just the hypolimnion area
3. Plan and initiate a phosphorus inactivation treatment of the lake using alum or lanthanum

Once the hypolimnion is sufficiently oxygenated, iron may be used as a lower-cost phosphorus inactivation chemical, and can be applied either as zero-valent iron or an iron salt. The hypolimnion must be well-oxygenated because the iron-phosphorus complexes are sensitive to low-oxygen conditions.

**Table 28. Future Monitoring and Adaptive Management.**

Monitoring Component	Description	Reporting/Activity	Estimated Additional Cost
Lake water quality	Expand twice monthly summertime monitoring: <ul style="list-style-type: none"> <li>• Surface (1m) and deep (1m above bottom) water quality grab samples analyzed monthly for pH, chlorophyll-a, and total and dissolved phosphorus and nitrogen.</li> <li>• At least three samples per year analyzed for phytoplankton species biovolume.</li> </ul>	Continue annual reporting on monitoring activities, water quality, evaluating trends, emerging issues, and recommendations.	\$8,500 per year for routine Volunteer Lake Monitoring Program \$2,500 per year for additional lake management plan monitoring Assumes lake monitoring is performed by volunteers. Assumes three phytoplankton samples per year.
Lake level	Continue monitoring Snohomish County lake level gauge at Hill Park Fishing Pier.	Include lake level summary and trend evaluation in annual report.	\$0
Recreational Safety	Weekly monitoring (Memorial Day to Labor Day) at Hill Park and Ferguson Park for algae bloom observation and fecal bacteria testing (E. coli at 2/beach/week).	Compare results to state recreation criteria to issue beach closures. Include data summary and trend evaluation in annual report.	\$5,000 per year Assumes 56 E. coli samples at \$50 each by lab and 2 hours staff time per event at \$75/hour for 14 events.
Surveillance for Cyanobacteria Blooms	Expand existing surveillance program for identifying and sampling cyanobacteria blooms to year-round to encompass reported wintertime algae blooms.	If a bloom is detected, collect a sample to analyze through the Northwest Toxic Algae Program or King County Laboratory if outside program period. Compare results to state recreation criteria to issue beach closures. Include activities, advisory decisions, and results (including non-detects) in annual report.	\$2,000 per year Assumes 5 cyanotoxin sample analyses/year by King County at \$175/sample Assumes 16 hours staff time/year at \$75/hour.
Sediment Monitoring	Collect 2 sediment cores every 5 years for phosphorus fractionation, iron, and bulk density analysis in 5 sediment layers each. Collect additional cores pre-/post- phosphorus inactivation treatments as necessary.	Evaluate trends in concentrations and annual loads, assess for efficacy and/or dosage of phosphorus inactivation treatments, if applicable, and provide recommendations in reports.	\$2,100 per year (20-year average) Assumes lab cost = \$3,000 per event, every 5 years Assumes 50 hours consultant staff time per event at \$150/hour.
Stormwater/Inlet Monitoring	Monitor performance of stormwater treatment facilities for 6 storm events/year and TP analysis of inflow and outflow samples. Test 1 facility and 2 lake inlets each year	Evaluate phosphorus removal by each treatment facility and long-term trends at 2 lake inlets (BLK-22 and CHAMPARK).	\$3,300 per year (20-year average) Assumes 24 TP samples/year at \$25/sample lab cost Assumes 6 hours/event and 36 hours/year staff time at \$75/hour..
Data QA and management	Input laboratory and field data into database, perform data QA/QC.	Qualify data and modify procedures as necessary. Include QA results in annual report.	\$750 per year Assumes 10 hours staff time at \$75/year.
Annual Reporting	Summary of Monitoring Data, Management Effectiveness (if applicable), and Adaptive Management Recommendations	–	\$3,000 per year Assumes 40 extra hours staff time per year at \$75/year
Project Management	Coordination	–	\$900 per year Assumes 12 extra hours staff time per year at \$75/year.
<b>Subtotal Cost</b>			\$28,050
<b>Contingency at 20%</b>			\$5,610
<b>Average Annual Cost</b>			<b>\$33,660</b>

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# Funding Strategy

The recommended set of management strategies is estimated to cost approximately \$0.7 million in the first 3 years and about \$6.6 million over the next 20 years. Additional funding sources will be necessary to implement the recommend elements of this plan. A combination of budget allocations, grants, and/or loans should be sought to fund and implement this management plan. We recommend considering the sources provided in Table 28. Additional supplementary grants and programs which may provide limited or specialized benefit are summarized in Appendix F.

**Table 29. Funding Sources for Lake Management Actions.**

Funding Source	Description	Applicable Activities
City of Snohomish Public Works	The City of Snohomish Public Works Department maintains the public stormwater system in the incorporated areas draining to Blackmans Lake. Surface Water Management funds and grants are used to fund lake monitoring and improvements.	<ul style="list-style-type: none"> <li>● Water quality monitoring</li> <li>● Watershed management</li> <li>● On-site septic repair and replacement</li> <li>● In-lake management</li> <li>● Outreach and Education</li> </ul>
Snohomish County Surface Water Management (SWM) Funds	The mission of the Surface Water Management Division is to “work in partnership with the community to protect and enhance water quality and aquatic habitat, to minimize danger from flooding and erosion, and to preserve water resources for future generations”. SWM is funded in part through a per parcel utility service charge. SWM maintain the stormwater conveyance network in the unincorporated areas draining to Blackmans Lakes. Presently, SWM provides monitoring of Blackmans Lake through an interlocal agreement with the City, the volunteer-based program and supports lake residents to support and improve lake health .	<ul style="list-style-type: none"> <li>● Water quality monitoring</li> <li>● Watershed management</li> <li>● On-site septic repair and replacement</li> <li>● In-lake management</li> <li>● Outreach and Education</li> </ul>
State Legislature Budget Allocation	State funding of some lake management measures may be appropriate, providing sufficient political support can be generated in the State Legislature for selected lake management efforts. Legislative budget allocations may be particularly well suited to one-time capital expenditures as opposed to ongoing activities requiring stable, long-term funding sources.	<ul style="list-style-type: none"> <li>● Water quality monitoring</li> <li>● Watershed management</li> <li>● On-site septic repair and replacement</li> <li>● In-lake management</li> <li>● Outreach and Education</li> </ul>
Freshwater Algae Control Grants	The Washington State Freshwater Algae Program has an annual funding cycle for projects to manage toxic algae (cyanobacteria) blooms. The grant funds up to \$50,000 and requires a 25 percent in-kind match. In-lake treatments, such as OST, alum, or lanthanum, are eligible for this grant, provided the waterbody has an approved Lake Cyanobacteria Management Plan.	<ul style="list-style-type: none"> <li>● Water quality monitoring</li> <li>● Watershed management</li> <li>● On-site septic repair and replacement</li> <li>● In-lake management</li> <li>● Outreach and Education</li> </ul>
Clean Water State Revolving Fund Loans	The CWSRF program is funded via an annual U.S. Environmental Protection Agency (EPA) capitalization grant, state matching funds, and principal and interest repayments on past CWSRF loans. This program provides low-interest and forgivable principal loan funding for wastewater treatment construction projects, eligible nonpoint source pollution control projects, and eligible green projects. In-lake treatments, such as phosphorus inactivation and oxygenation, are eligible for these loans.	<ul style="list-style-type: none"> <li>● Water quality monitoring</li> <li>● Watershed management</li> <li>● On-site septic repair and replacement</li> <li>● In-lake treatments</li> <li>● Outreach and Education</li> </ul>

**Table 30 (continued). Funding Sources for Lake Management Actions.**

Funding Source	Description	Applicable Activities
Centennial Clean Water Grants	The Centennial Clean Water Fund is a Washington State-funded grant program administered by Ecology. Local governments, special purpose districts, conservation districts, and federally recognized Tribes are eligible for these funds applicable to water quality infrastructure (e.g., wastewater treatment facilities) and nonpoint source pollution projects to improve and protect water quality. In-lake treatments, including phosphorus inactivation and oxygenation <i>are not</i> eligible for these grants.	<ul style="list-style-type: none"> <li>● Water quality monitoring</li> <li>● Watershed management</li> <li>● On-site septic repair and replacement</li> <li>● Outreach and Education</li> </ul>
Section 319(h) Clean Water	EPA provides “Section 319(h)” grant funds to Washington State where the State is required to provide a 40 percent match in funding. The Section 319(h) program provides grants to eligible nonpoint source pollution control projects, similar to the state Centennial Clean Water Fund. Eligible projects include lake water quality planning, riparian and wetlands habitat restoration and enhancement, and other water quality improvement efforts. Non-profit organizations are also eligible for these funds. A 25 percent match is required, and grants may be limited to \$250,000 or \$500,000, depending on the match type. In-lake treatments, including phosphorus inactivation and oxygenation <i>are not</i> eligible for these grants.	<ul style="list-style-type: none"> <li>● Water quality monitoring</li> <li>● Watershed management</li> <li>● On-site septic repair and replacement</li> <li>● Outreach and Education</li> </ul>
Onsite Sewage Financial Assistance Loans (Craft3)	Ecology funding for a regional loan program to support the origination and servicing of loans to property owners for the repair and replacement of failing onsite sewage systems (OSS) throughout the marine (Puget Sound and coastal) counties. Ecology also contracted with local lender Craft3, a non-profit Community Development Financial Institution (CDFI), to originate and service loans for the Regional Onsite Sewage System Program. The program may provide lending measures to repair/replace failing OSS.	<ul style="list-style-type: none"> <li>● On-site septic repair and replacement</li> </ul>

# Roles and Responsibilities

Projects and partnerships succeed when participants share a common understanding of roles and responsibilities. It is important to establish clarity regarding those roles, responsibilities, and expectations for each participating entity at the outset, to ensure the best chance at achieving the project’s vision, mission, goals, and objectives. When roles and responsibilities are clearly defined, productivity, respect, communication, value for individual contributions, and shared ownership for success is enhanced throughout the team.

The relevant entities to fulfill the required roles and responsibilities of organizing, governing, and executing the decisions of the City, as the lake management structure and primary mechanism for decision-making, funding acquisition, and implementation of management activities for Blackmans Lake, have been defined below in Table 29.

Table 31. Role and Responsibilities.		
Agency/Group	Role	Responsibilities
<b>City of Snohomish Public Works</b>	Lead Entity	<ul style="list-style-type: none"> <li>• Administers the Cyanobacteria Lake Management Plan</li> <li>• Research and pursue grant and loan funding opportunities</li> <li>• Procure and manage contracts for lake improvement services</li> <li>• Lead permitting processes and NPDES permit administration</li> <li>• Revise stormwater code to require phosphorus treatment</li> <li>• Retrofit of existing stormwater infrastructure</li> <li>• Stormwater monitoring</li> <li>• Lead toxic algae monitoring program</li> <li>• Continue interlocal agreement with Snohomish County for lake monitoring services</li> </ul>
<b>Snohomish County Surface Water Management</b>	Administer Lake Water Monitoring and Data Management	<ul style="list-style-type: none"> <li>• Water quality and level monitoring of Blackmans Lake through Volunteer Lake Monitoring Program</li> <li>• Lead LakeWise public education program in Snohomish County</li> <li>• Provide supplemental funding through SWM utility fee</li> </ul>
<b>Snohomish County Health Department</b>	Management and Monitoring Support	<ul style="list-style-type: none"> <li>• Implementation of OSS O&amp;M Program</li> </ul>
<b>Friends of Blackmans Lake</b>	Monitoring Support	<ul style="list-style-type: none"> <li>• Assists City and Snohomish County in lake monitoring and surveillance for toxic algae bloom</li> </ul>

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# Appendix A

## Blackmans Lake Current Water Quality Conditions

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# Water Quality Report for the Lake Cyanobacteria Management Plan

**Blackmans Lake, Snohomish, Washington**

**Prepared for  
City of Snohomish**

**Prepared by  
Herrera Environmental Consultants, Inc.**

**Funded by  
Washington State Department of Ecology Freshwater Algae Program  
Grant Number WQALG 2024 Snohom-00036**



# **Water Quality Report for the Lake Cyanobacteria Management Plan**

## **Blackmans Lake, Snohomish, Washington**

Prepared for  
City of Snohomish  
P.O. Box 1589  
116 Union Avenue  
Snohomish, WA 98291  
Telephone: 360-568-3115

Prepared by  
Herrera Environmental Consultants, Inc.  
2200 Sixth Avenue, Suite 1100  
Seattle, Washington 98121  
Telephone: 206-441-9080

Funded by  
Washington State Department of Ecology Freshwater Algae Program  
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July 11, 2024

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# Introduction

Herrera Environmental Consultants (Herrera) contracted with the City of Snohomish to prepare a Lake Cyanobacteria Management Plan (LCMP) for Blackmans Lake, which is a eutrophic lake in the City that experiences frequent cyanobacteria blooms impairing recreational use of the lake. To inform the LCMP, Herrera developed a Quality Assurance Project Plan (QAPP) (Herrera 2022a) to collect a comprehensive set of scientific data from October 2022 through October 2023, including hydrological, chemical, biological information from the lake and watershed. This water quality report summarizes the methods and results of water quality monitoring conducted for the LCMP and is included as an appendix to the LCMP.

## Monitoring Methods

Water quality in Blackmans Lake has been monitored by volunteers and Snohomish County Surface Water Management staff regularly since 1992 as part of the Volunteer Lake Monitoring Program that conducts twice monthly monitoring during summer months from May through October. Understanding lake and watershed conditions is necessary to develop water and phosphorus budgets, understand the dynamics driving cyanobacteria blooms in the lake, and construct a successful and sustainable strategy for both short-term and long-term control of toxic cyanobacteria blooms.

To supplement historical datasets, high-quality monitoring data of the lake water quality, lake sediment, and watershed drainage were collected throughout water year 2023 (October 2022 through October 2023). Table 1 summarizes the types of data gathered, methodology used, and the locations at which those data were collected. Table 2 presents the lake monitoring schedule and Table 3 presents the watershed monitoring schedule. Figure 1 shows the station locations in Blackmans Lake and its watershed monitored for the LCMP.

Monitoring objectives and measurement quality objectives are specified in the QAPP. Monitoring procedures were according to procedures specified in the QAPP (Herrera 2022a) for field procedures, laboratory procedures, quality control procedures, and data management, analysis, and reporting. Deviations from the QAPP are described in the following section.

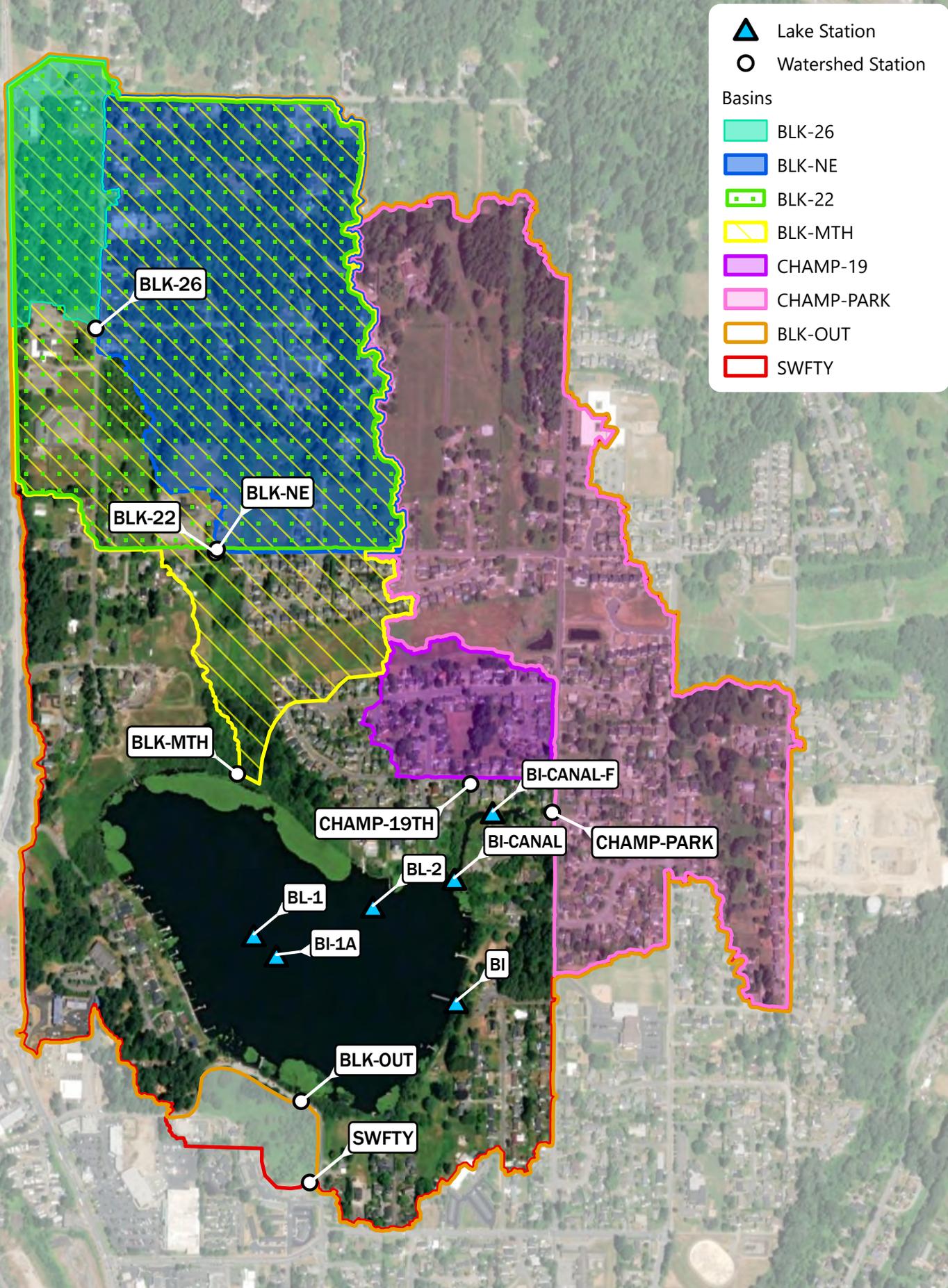
## Data Quality Assurance

An independent review of the laboratory quality control (QC) data from each sampling event was performed using the measurement quality objectives (MQOs) identified in the QAPP (Herrera 2022). The quality of these data was evaluated by Snohomish County Surface Water Management (SWM) staff and Herrera data managers for precision and completeness. The data quality for all parameters was generally considered acceptable, based on holding time, reporting limit, method blank, spike recoveries, control standard, and laboratory duplicate criteria specified in the QAPP. Acceptable data is either data that passes all QC criteria, or data that may not pass all QC criteria but has appropriate corrective actions taken. Deviations from the QAPP and results from the data QC review are described below.

**Table 1. Blackmans Lake Monitoring Program for LCMP.**

<b>Component</b>	<b>Element/Parameters</b>	<b>Summary</b>	<b>Station/Source</b>
Hydrological	Bathymetry	Hydro-acoustic mapping.	Ecology 1976
	Precipitation	Snohomish County's French Slough Rain Gauge	Fr
	Lake level	City's lake level gauge on the Fishing Pier in Hill Park	Bl
	Stream and lake outlet discharge	Discrete depth and velocity measurements using a Swoffer current meter during sampling.	SWFTY, BLK-22, BLK-26, BLK-NE, CHAMP-PARK, CHAMP-19, BLK-OUT
Stream Water Quality	Discrete sampling for total phosphorus	Grab samples at various stream and outfall locations.	BLK-22, BLK-26, BLK-NE, CHAMP-PARK, CHAMP-19
Lake Water Quality	Counts of waterfowl, boats, anglers, and swimmers	Additional observations about lake use and appearance during lake monitoring events, and daily bird counts.	Blackmans Lake field data
	Discrete sampling for total phosphorus, orthophosphate, total nitrogen, nitrate+nitrite, chlorophyll-a, phytoplankton, zooplankton	Grab samples with a Van Dorn sampler at 1 meter from surface, 1 meter from bottom, and at traditional bottom depth of 6 meters. Zooplankton samples by vertical tow through the water column.	BL-1, BL-CANAL
	Cyanotoxin Sampling for microcystin and anatoxin-a	Grab samples at scum location (on 9/7/23 only), analyzed through Ecology's Freshwater Algae Control program.	Boat launch
	Trout stocking data	Number or pounds of trout	WDFW 2024
Sediment Quality	Core sampling for phosphorus fractions (loosely bound, iron bound, aluminum bound, calcium bound, organic, biogenic, and total), total iron, percent solids, bulk density	One 2-foot core collected at each location using a universal percussion corer, processed into 5 discrete depth intervals.	BL-1, BL-2

Figure 1.  
Blackmans Lake Watershed and Monitoring Stations.



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**Table 2. Lake Monitoring Schedule for the Blackmans Lake Cyanobacteria Management Plan.**

Station/Parameter	Sample Depths (Meter) by Date																					
	10/9/22	10/30/22	11/13/22	12/14/22	1/22/23	2/14/23	3/16/23	4/16/23	5/7/23	5/21/23	6/11/23	6/25/23	7/16/23	7/30/23	8/1/23	8/13/23	8/28/23	9/15/23	9/28/23	10/8/23	10/23/23	10/30/23
<b>Station BL-1</b>																						
Secchi Depth	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
Temperature/DO									P	P	P	P	P	P		P	P	P	P	P	P	
pH									1			1		1						1		
Chlorophyll-a	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	
Total Phosphorus			1	1	1	1	1	1	1	1,6	1,6,7.5	1,6,7.5	1,6,7.5		1,6,8	1,6,7.5	1,6,7.5	1,6,7.5	1,6,7.5	1,6,7.5	1,6,7.5	1,7
Dissolved Ortho P											7.5		6			6,7.5		7.5			1,6,7.5	
Total Nitrogen											1,6		1			1		1		1	1	
Nitrate+Nitrite-N											1,6		1			1		1		1	1	
Phytoplankton									1			1		1			1			1		
Zooplankton												T					T			T		
<b>Station CANAL</b>																						
Chlorophyll-a														0					0		0	
Total Phosphorus														0					0		0	
<b>Station CANAL-F</b>																						
Chlorophyll-a																					1	

Station BL-1 = deep lake station located 70 meters southeast of historical location. Station CANAL located at mouth of canal. Station CANAL-F located near midpoint and deepest point of canal.

P=profile at 1-meter increments

T = vertical tow from 1 meter off lake bottom to surface

**Table 3. Watershed Monitoring Schedule for the Blackmans Lake Cyanobacteria Management Plan.**

Station	Base Flow			Storm Flow					
	11/9/22	3/29/23	11/29/23	12/8/22	1/12/23	4/10/23	9/27/23	10/11/23	12/5/23
BLK-22	D,P	D,P	D,P	D,P	D,P	D,P	D,P	D,P	D,P
BLK-NE	D,P	D,P	D,P	D,P	D,P	D,P	-	-	D,P
BLK-26	D,P	D,P	D,P	D,P	D,P	D,P	D,P	D,P	D,P
CHAMP-19	D,P	D,P	D,P	D,P	D,P	D,P	D,P	D,P	D,P
CHAMP-PARK	D,P	D,P	D,P	D,P	D,P	D,P	D,P	D,P	D,P
BL-OUT	D	D	D	D	D	D	D	D	D

D = Discharge measurement

P = Total phosphorus grab sample

- = no total phosphorus grab sample because no discharge

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Blackmans Lake monitoring was executed as planned, with lake monitoring events once per month October 2022 through April 2023 and twice per month from May through October 2023. Exceptions to the planned lake monitoring include:

- The mid-lake station BL-1 was moved 70 meters southeast of the historical monitoring location to what was determined to be the deepest point in the lake, typically 8.0 meters. This location is shown as station BL-1A in Figure 1 and referred to as station BL-1 in this report.
- The QAPP specified collecting the mid-lake bottom water sample from 0.5 meters from the lake bottom at station BL-1, which was typically collected at 7.5 meters. A second lake bottom sample was collected a depth of 6.0 meters for all but two events to match the historically-specified sample depth for the lake bottom sample.
- The QAPP specified monthly measurements of pH in May through October, but the September and October measurements were not taken.
- The BL-CANAL station was moved from the center of the canal specified in the QAPP to the mouth of the canal at the lake shore. For one event, a second canal sample was sampled from the center of the canal and identified as BL-CANAL-FOUNTAIN.

Watershed monitoring was executed as planned, with three base flow events and six storm flow events performed between November 2022 and December 2023 at each of five watershed stream stations and one lake outlet station.

Field and laboratory data were validated according to the QAPP. Quality control procedures and criteria defined in the QAPP were generally met, resulting in no data qualification or corrective action, with the following exceptions identified below.

The following results were qualified as estimated (J) due to laboratory analysis performed past the method specific hold time:

- Seven chlorophyll-a results for the lake surface on the following sample dates: 11/13/22, 12/14/22, 1/22/23, 2/14/23, 3/16/23, 4/16/23, and 6/11/23
- Six pheophytin-a results for the lake surface on the following sample dates: 11/13/22, 12/14/22, 1/22/23, 2/14/23, 3/16/23, and 6/11/23
- Eight orthophosphate phosphorus results from near the lake bottom on the following sample dates: 6/11/23, 7/16/23, 8/13/23, 10/8/23, 10/23/23

The chlorophyll-a, pheophytin-a, and total phosphorus results for the lake surface sample collected on 3/16/23 are additionally qualified as estimated (J) due to the sample exceeding method specific hold temperature upon receipt of the laboratory.

The following stream discharge results were qualified as estimated (J):

- All stream discharge results for BLK-NE because the flow was estimated visually in this northeast tributary and in the northwest tributary as relative percentages of their combined flow into the culvert draining downstream at BLK-22 and was calculated as the observed percentage times the measured flow at BLK-22.
- One result for the lake outlet (11/12/23) due to illegibility of a value on the field form.
- One result for BLK-22 (9/27/23) due to low water depth for accurately measuring velocity.
- Two results for BLK-26 (9/27/23 and 10/11/23) due to low water depth for accurately measuring velocity.

The results below are qualified as non-detects (U) due to concentrations not detected at or above the MDL:

- Nitrate+nitrite results for samples collected at the lake surface on 6/11/23, 7/16/23, 8/13/23, 9/15/23, and 10/8/23; and at 6.0 meters depth on 6/11/23.
- Orthophosphate result for the sample collected at the lake surface on 11/23/23.
- All results for loosely bound phosphorus in lake sediments at both BL-1 and BL-2.
- All results for iron bound phosphorus in lake sediments at BL-2.
- Stream discharge results for the lake outlet on 11/9/22, 9/27/23, and 10/11/23 due to no flow.
- Stream discharge result for Swifty Creek on 11/9/22 due to no flow.
- Stream discharge results for BLK-NE on 9/27/23 and 10/11/23 due to no flow.
- Stream discharge result for BLK-22 on 10/11/23 due to no flow.

Field data sheets for each lake and watershed monitoring event are presented in Appendix B of the LCMP. Laboratory data reports from each monitoring event are provided in Appendix C of the LCMP.

# Lake Monitoring Results

## Lake Observations

Lake observations were recorded on field sheets during each visit that include: weather, counts of recreators and waterfowl observed, and notes related to algae presence and appearance.

A total of five algae scums were reported during lake monitoring events, two of which were odorous and sampled and only one of which appeared to consist of filamentous algae. Lake water color was brown to yellow-brown from October 2022 through August 2023, greenish in September 2023, and yellow-brown in October 2023.

Most boaters were observed during the lake monitoring events in July (up to 14), while fishers appeared to be most active in early summer (up to 21 individuals on one occasion in late June). Swimmers were only observed mid-June through mid-August.

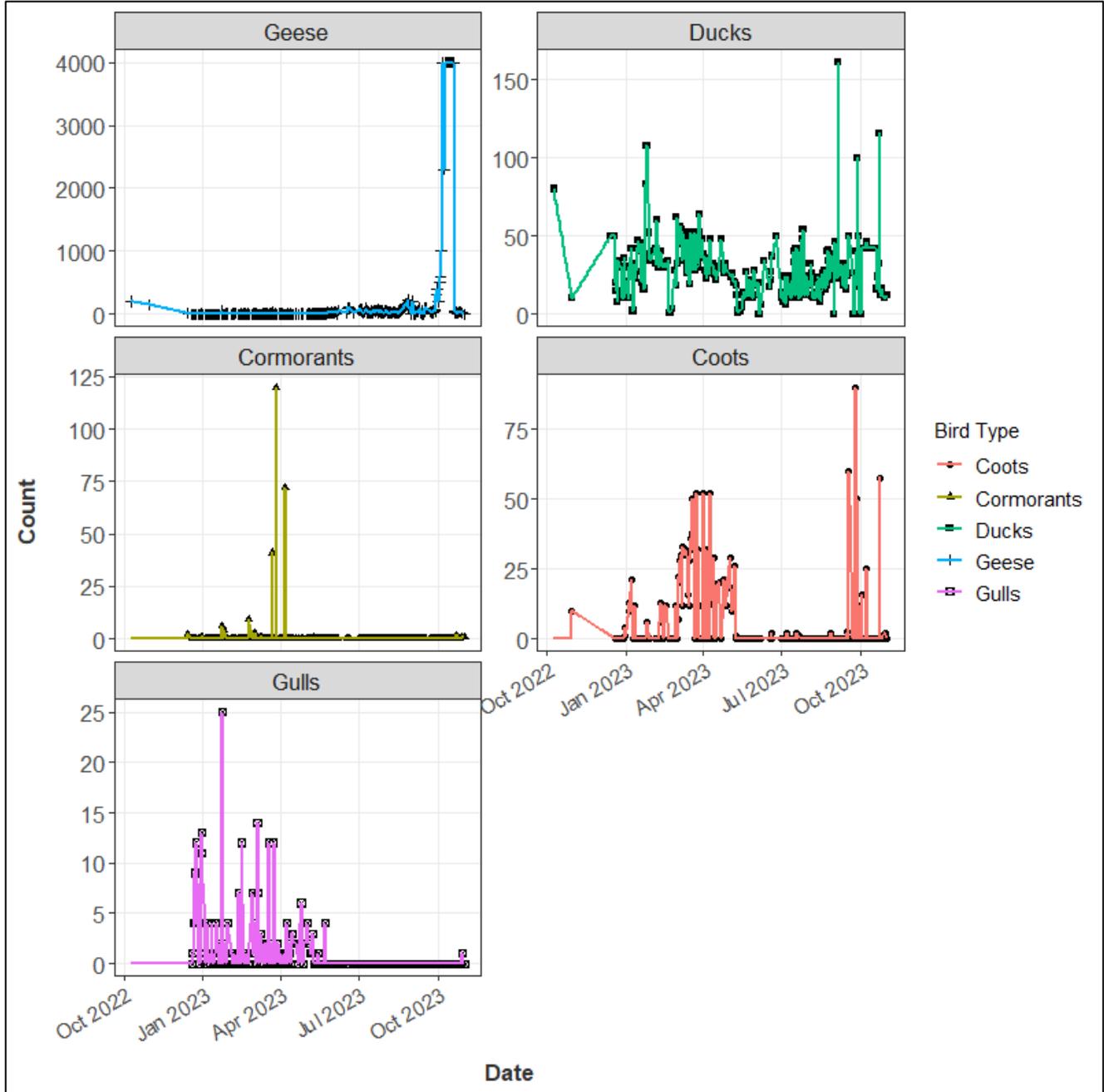
In addition to counts during regular summertime monitoring events, waterfowl data was supplemented for this project through additional daily counts by volunteer shoreline residents, primarily Kay Ditzenberger. Counts of waterfowl at Blackmans Lake were taken on 259 days between December 2022 and November 2023. Approximately 73,380 birds were counted at Blackmans Lake during this period. Waterfowl observed included geese, ducks (including mergansers, buffleheads, and grebes), cormorants, coots, gulls, herons, and swans. Additional birds observed at the lake included bald eagles and swallows.

Most of the waterfowl observed were geese, accounting for approximately 82–87 percent of the total annual bird count at the lake, followed by ducks (10–13 percent). However, ducks were counted for the greatest number of days, followed by geese (249 and 185 of 259 days, respectively). Most waterfowl were reported in August–October 2023, with geese and ducks often gathering in flocks of >100 individuals (Figure 2, Table 4). For a period of about two weeks in early October 2023, the gaggle was estimated to be comprised of 4,000 individuals!

**Table 4. Summary of Raw Bird Counts.**

Month	Days Counted	No. of Geese	No. of All Birds	Mean Geese/ Day	Mean All Birds/Day	Max Count/Day	Max Count Bird Type
December 2022	12	26	405	0.8	13.1	50	Ducks
January 2023	20	53	955	1.7	30.8	108	Ducks
February 2023	17	32	625	1.1	22.3	60	Ducks
March 2023	30	58	2,257	1.9	72.8	120	Cormorants
April 2023	20	27	1,066	0.9	35.6	72	Cormorants
May 2023	28	238	784	7.7	25.3	31	Geese
June 2023	13	539	803	18.0	26.8	110	Geese
July 2023	31	1,417	2,109	45.7	68.1	102	Geese
August 2023	31	1,982	2,642	64.0	85.2	220	Geese
September 2023	26	2,001	3,076	66.7	102	400	Geese
October 2023	30	57,423	58,645	1,852	1,892	4,000	Geese

Figure 2. Bird Observations at Blackmans Lake (December 2022–November 2023).



# Lake Water Quality

Lake water quality data collected for the Blackmans Lake LCMP are summarized on an annual basis (October 2022 through September 2023) in Table 5 and on a summer basis (May through October 2023) in Table 6. Results are presented graphically and described separately for each parameter.

**Table 5. Blackmans Lake 2023 Annual Water Quality Summary Statistics.**

Parameter	MDL and Unit	Depth	N	Percent non-detect	Annual Min.	Annual Median	Annual Mean	Annual Max.
<b>Station BL-1</b>								
Secchi depth	0.1 meter	S	18	–	1.2	2.38	2.35	3.37
Temperature	0.5°C	S	36	–	14.9	20.6	20.3	24.8
		M	24	–	11.0	18.2	18.2	22.9
		B	43	–	8.8	11.6	12.2	16.8
Dissolved oxygen	0.5 mg/L	S	36	–	6.03	8.56	8.70	11.9
		M	24	–	0.40	6.45	6.48	10.25
		B	43	–	0.07	0.20	1.07	8.45
pH	NA	S	4	–	7.15	7.26	7.28	7.46
Total phosphorus	2 µg/L	S	18	0	11	19	23	46
		B	22	0	16	91	193	547
Soluble reactive phosphorus	1 µg/L	S	1	100	<MDL	<MDL	<MDL	<MDL
		B	8	0	2	51	82	269
Total nitrogen	50 µg/L	S	6	0	373	487	501	659
		B	1	0	785	785	785	785
Nitrate+nitrite	10 µg/L	S	5	100	<MDL	<MDL	<MDL	<MDL
		B	1	100	<MDL	<MDL	<MDL	<MDL
Chlorophyll-a	0.1 µg/L	S	19	0	4.3	8.0	11.5	36.0
<b>Station BL-CANAL<sup>a</sup></b>								
Total phosphorus	2 µg/L	S	7	0	31	45	50.4	88
Chlorophyll-a	0.1 µg/L	S	4	0	2.9	11.8	50.6	176
<b>Boat Launch at Ferguson Park</b>								
Anatoxin-a	0.01 µg/L	S	1	0	0.01	0.01	0.01	0.01
Microcystin	0.15 µg/L	S	1	0	0.96	0.96	0.96	0.96

MDL = method detection limit; N= sample size; °C = degrees Celsius; mg/L = milligrams per liter; µg/L = micrograms per liter; S = Surface (epilimnion); M= Middle (metalimnion); B= Bottom (hypolimnion)

<sup>a</sup> All BL-CANAL samples were collected in the mouth of the canal at the lake shore except one was collected at the fountain near the mid-point of the canal in October 2023 which exhibited the maximum values.

**Table 6. Blackmans Lake 2023 Summer (May-October) Water Quality Summary Statistics.**

Parameter	MDL and Unit	Depth	N.	Percent non-detects	Summer Min.	Summer Median	Summer Mean	Summer Max.
<b>Station BL-1</b>								
Secchi depth	0.1 meter	S	12	–	1.2	2.44	2.34	3.37
Temperature	0.5°C	S	36	–	14.90	20.55	20.34	24.80
		M	24	–	11.00	18.15	18.21	22.90
		B	43	–	8.80	11.60	12.22	16.80
Dissolved oxygen	0.5 mg/L	S	36	–	6.03	8.56	8.70	11.90
		M	24	–	0.40	6.45	6.48	10.25
		B	43	–	0.07	0.20	1.07	8.45
pH	NA	S	4	–	7.15	7.26	7.28	7.46
Total phosphorus	2 µg/L	S	12	0	11	19	21.4	36
		B	22	0	16	91	193	547
Soluble reactive phosphorus	1 µg/L	S	1	100	1	1	1.0	1
		B	8	0	2	51	81.9	269
Total nitrogen	50 µg/L	S	6	0	373	486.5	501	659
		B	1	0	785	785	785	785
Nitrate+nitrite	10 µg/L	S	5	100	10	10	10.0	10
		B	1	100	10	10	10.0	10
Chlorophyll-a	0.1 µg/L	S	12	0	4.3	8.0	11.8	36
Phaeophytin-a	0.1 µg/L	S	12	0	0.5	3.0	3.4	7.4
<b>Station BL-CANAL<sup>a</sup></b>								
Chlorophyll-a	0.1 µg/L	S	4	0	2.9	11.8	50.6	176
Phaeophytin-a	0.1 µg/L	S	4	0	2.3	5.8	63	238
Total phosphorus	2 µg/L	S	5	0	31	45	51.6	88

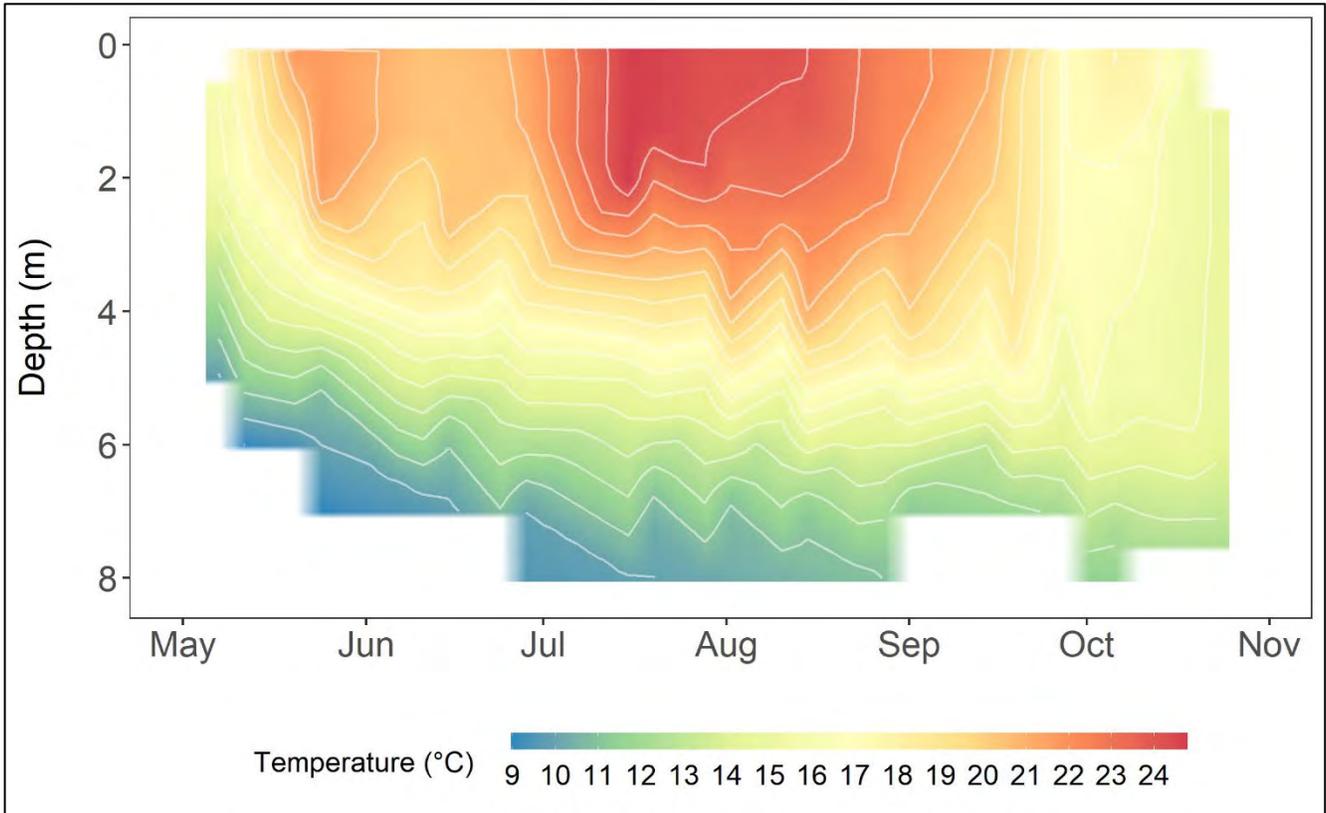
<sup>a</sup> All BL-CANAL samples were collected in the mouth of the canal at the lake shore except one was collected at the fountain near the mid-point of the canal in October 2023 which exhibited the maximum values.

## Water Temperature

Figure 3 shows lake water temperature profiles collected from the deepest part of Blackmans Lake from May through October 2023. Temperatures ranged from about 9 to 25 degrees Celsius (°C) (Table 5), with cooler temperatures near the lake bottom and warmer temperatures near the lake surface throughout the monitoring period. The warmest temperatures were observed at the lake surface in July and August. These profiles illustrate that Blackmans Lake was thermally stratified in May through September, which is typical for a lake of its size and depth. During the summer stratification period, temperatures in the epilimnion (upper warm, low-density layer generally less than 3 meters deep) remained well-mixed and warm. Uniform temperatures throughout the water column in late September and October is representative of fall turnover when the lake surface cools and the water column becomes fully mixed.

Surface temperatures exceeded the U.S. Environmental Protection Agency (EPA 2021) recommended maximum temperature for survival of juvenile trout (24 °C) in July and August, but never exceeded that for largemouth bass (34 °C).

Figure 3. Water Temperature Profile in Blackmans Lake (May–October 2023).



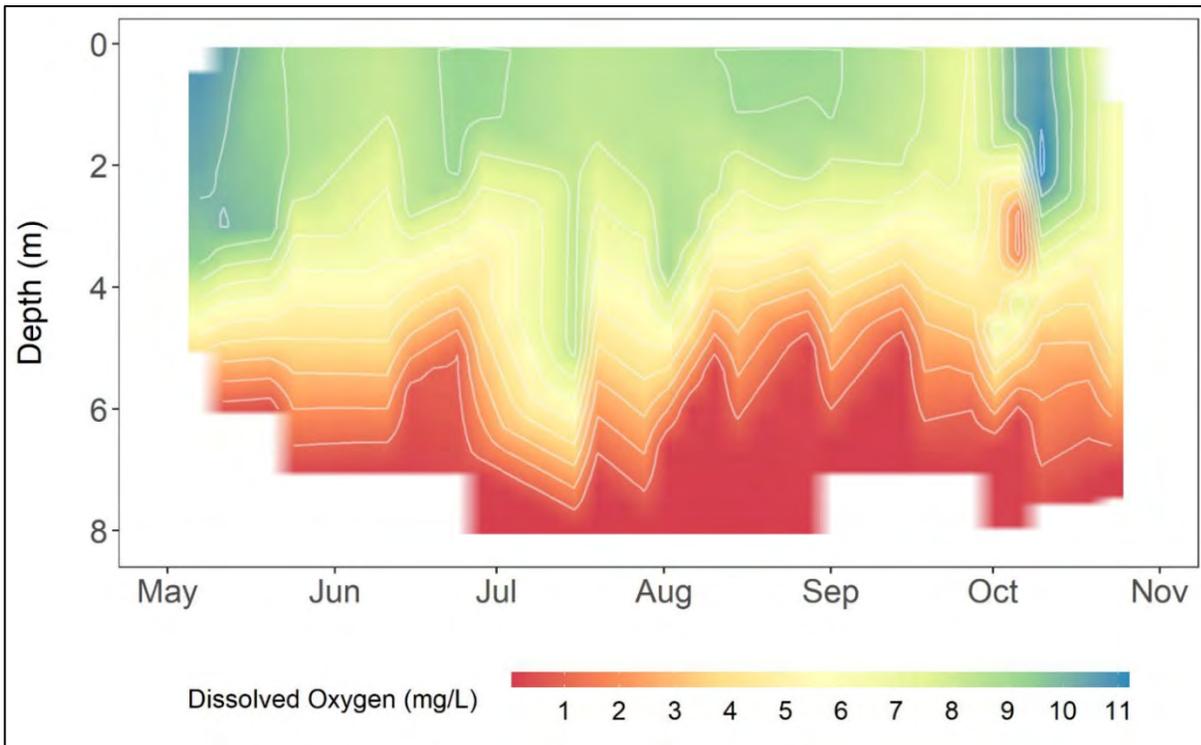
## Dissolved Oxygen

DO is an important water quality parameter for salmonids and other aquatic organisms. Low DO levels can be harmful to larval life stages and respiration of juvenile and adult fish. Therefore, it directly affects the survival of aquatic organisms. Depletion of oxygen in water bodies can also lead to a shift in the composition of the aquatic community. The EPA recommends a 1-day minimum DO concentration of 4.0 mg/L for adult trout and 3.0 mg/L for adult warm-water fish (EPA 2021).

Figure 4 shows dissolved oxygen (DO) profiles for Blackmans Lake during the summer stratification period from May through October 2023. During stratification, cooler, denser water in the hypolimnion is prevented from mixing with the warmer, well-oxygenated surface water by an abrupt temperature and water density transition (thermocline). At the lake surface, DO ranged from about 6 to 12 mg/L (Table 5) but was typically about 8.5 mg/L in June through October (Table 6). In mid-July, DO was unusually high at 5 meters depth that was likely caused by oxygen production from rapid phytoplankton growth near the nutrient-rich thermocline and forming what is known as metalimnetic oxygen maxima.

These profiles also show a clear persistence of anoxia (DO less than 1 mg/L) in the hypolimnion throughout the summer monitoring season (May–October) (see Figure 4). Anoxic conditions were observed at depths as shallow as 5 meters in August and September. DO concentrations within the hypolimnion were progressively depleted because of decomposition of organic material in the sediment and the lack of mixing.

**Figure 4. Dissolved Oxygen Profile in Blackmans Lake (May–October 2023).**



## pH

pH was not measured consistently throughout the monitoring period. Four individual surface measurements were taken, the results of which are presented in Table 7.

**Table 7. pH Results at BL-1, Blackmans Lake 2023.**

Date	pH
5/21/2023	7.22
6/25/2023	7.15
7/30/2023	7.30
10/8/2023	7.46

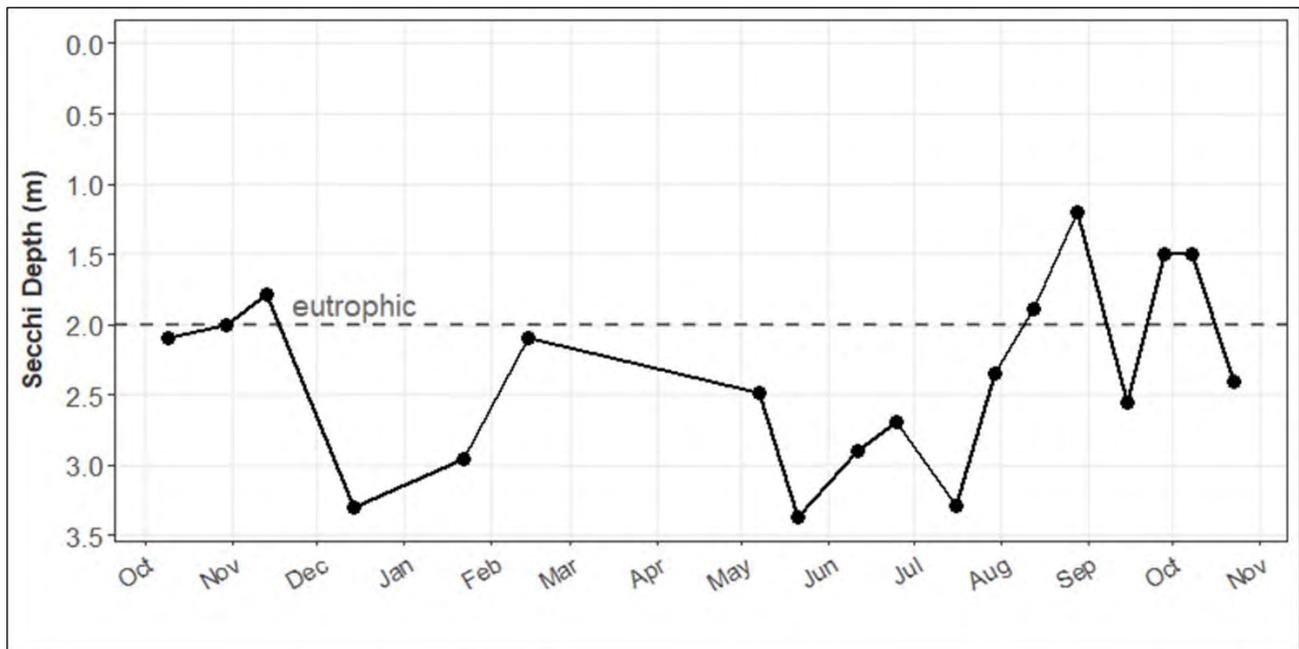
These near-neutral results are well within the state aquatic life criteria for pH (between 6.5 and 8.5) and did not cause sediment release of phosphorus. However, more comprehensive pH monitoring is needed throughout the summer to fully understand the variation and potential impacts of pH on aquatic life and sediment release of phosphorus.

## Secchi Depth

Secchi depth is a measure of water transparency, which is primarily affected by the amount and size of algae and other particles in the water. Secchi depth can also be affected by color in tannic waters, waves, and other factors. In temperate region lakes, Secchi depths often decrease (indicating reduced clarity) during spring algae (diatom) blooms, increase to a summer clear water maximum, and then decrease to a minimum in September or October as increased algae growth causes a more turbid state.

This seasonal pattern is somewhat less evident in Blackmans Lake. During the 2023 summer monitoring period, Secchi depth ranged from 1.2 to 3.4 meters, averaging about 2.3 meters (Table 6). The greatest surface water clarity occurred in May and mid-July (Figure 5) when chlorophyll-a at the surface was low (see below).

Figure 5. Secchi Depth in Blackmans Lake, October 2022–October 2023.



## Chlorophyll-a

Chlorophyll-a is the primary photosynthetic pigment used by phytoplankton (algae). As such, it is both a common measure of phytoplankton biomass and the most important factor used in determining a lake's trophic state (see *Trophic State Index* section below). However, chlorophyll-a is present in highly varied amounts among phytoplankton species and growth stages. As a result, it often does not relate well to other measures of phytoplankton biomass like cell biovolume. It typically negatively correlates well with Secchi depth (water clarity) unless there are large amounts of suspended inorganic particles causing turbidity in a lake.

Chlorophyll-a in Blackmans Lake has been measured at 1 meter below lake surface almost every summer since 2001. In 2023, chlorophyll-a at the deep lake station (BL-1) ranged from 4.3 to 36 micrograms per liter ( $\mu\text{g/L}$ ), with a mean summer surface value of 11.8  $\mu\text{g/L}$  (Table 6). These 2023 concentrations are similar to previous observations since 2002 when chlorophyll-a ranged from 1 to 34  $\mu\text{g/L}$  and exhibited summer mean values up to 14  $\mu\text{g/L}$  (Snohomish County 2024). In 2023, Blackmans Lake exhibited two chlorophyll-a peaks with concentrations  $>20 \mu\text{g/L}$ , in August and October (Figure 6) due to elevated algae growth. Both peaks resulted in reduced transparency and the October chlorophyll-a peak resulted in high DO and elevated nutrients near the lake surface, which are indicative of algae blooms.

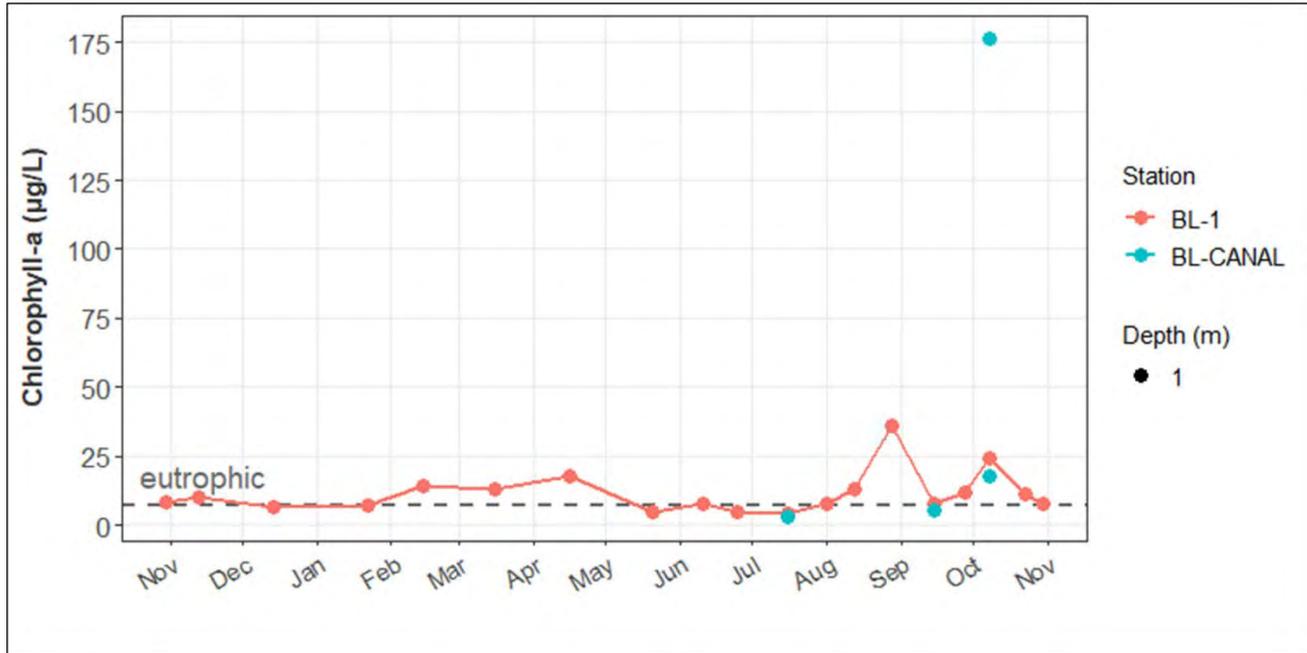
Additionally, chlorophyll-a was measured at BL-CANAL (the station at the mouth of the Champagne Lane canal inlet and adjacent to the lake shoreline in about 1 foot of water) on three occasions in 2023. Concentrations were 2.9, 5.6, and 176  $\mu\text{g/L}$  (Table 5) in July, September, and October, respectively. These conditions generally align with those observed in the main lake on those dates, except chlorophyll-a was much higher near shore at the canal mouth than in the lake center during the October bloom. Chlorophyll-a was measured once near the mid-point of the canal at the fountain at BL-CANAL-F and this sample was collected during the October bloom when the concentration was much lower than at the nearshore BL-CANAL station (176  $\mu\text{g/L}$ ) and similar to that observed at the main lake BL-1 station (24  $\mu\text{g/L}$ ). These observations indicate that the high chlorophyll-a concentration at BL-CANAL during the October bloom was from algae scum drifting to the north shore of the lake at the canal mouth rather than from algae growing in the canal.

Mesotrophic systems are defined by average surface chlorophyll-a concentrations in the epilimnion between 2.6 and 7.2  $\mu\text{g/L}$  while eutrophic systems exhibit chlorophyll-a concentrations between 7.2 and 56  $\mu\text{g/L}$  (see Trophic State below). Chlorophyll-a results from the surface of the deepest point in Blackmans Lake, both historical and from 2023, indicate the lake is at the lower, less productive end of a eutrophic state.

## Phosphorus

Key nutrients affecting algae growth in freshwater environments are phosphorus and nitrogen. Other nutrients like silica are also important for some groups such as diatoms, but do not typically limit algae growth in lakes. Phosphorus is typically the most limiting nutrient in Pacific Northwest lowland lakes. Total phosphorus (TP) is a combination of inorganic and organic forms of phosphorus, which can come from natural sources (e.g., wild animal waste, decaying vegetation, and resuspension or release from lake sediments) and anthropogenic sources (e.g., wastewater treatment plants, septic system failures, animal manure storage, and fertilizer runoff). Phosphorus is a concern in freshwaters because high levels can lead to accelerated plant growth and algal blooms, which, in turn, can result in low dissolved oxygen, decreases in aquatic diversity, and eutrophication.

Figure 6. Chlorophyll-a in Blackmans Lake, October 2022–October 2023.



Dashed line represents the lower threshold for classification as eutrophic for surface (1 m) waters (7.2 µg/L for summer average chlorophyll-a).

Generally, TP continued to increase with depth throughout the summer stratification period, reaching maximum concentrations in October (Figure 7). Maximum concentrations in the epilimnion and hypolimnion were 24 and 61 percent greater, respectively, in 2023 than any maxima recorded from 2002 through 2022. The higher hypolimnion TP in 2023 is likely due in part to sampling deeper in the lake. Historically, the bottom water samples were collected at a depth of 6 meters. In 2023, bottom water samples were collected at 6 meters for consistency with the historical data and at 7 to 8 meters depth, depending on the lake depth, for compliance with the QAPP specifying 0.5 meters above the sediment surface.

Additionally, we measured dissolved orthophosphate phosphorus (aka soluble reactive phosphorus [SRP]) at Blackmans Lake’s deep lake station on six occasions in 2023. SRP is the dissolved inorganic fraction of phosphorus that is produced by natural processes and from sources similar to those for total phosphorus such as septic system failure, animal waste, decaying vegetation and animals, resuspension from the bottom of a lake, and fertilizer runoff. It is a very unstable form of phosphate that is directly absorbed by aquatic vegetation and microbes such as algae. Neither Washington State nor EPA have established surface water quality criteria for soluble reactive phosphorus.

In 2023, SRP in Blackmans Lake was sampled only once at the lake surface when it was not detected (<1 µg/L) (Table 6). SRP in the hypolimnion ranged from 2 to 14 µg/L at 6 meters depth and 2 to 269 µg/L at 7.5 meters depth. Like TP throughout the water column, SRP in the hypolimnion as the summertime monitoring season progressed (Figure 8).

Figure 7. Total Phosphorus at Surface and Bottom Depths in Blackmans Lake, October 2022 – October 2023.

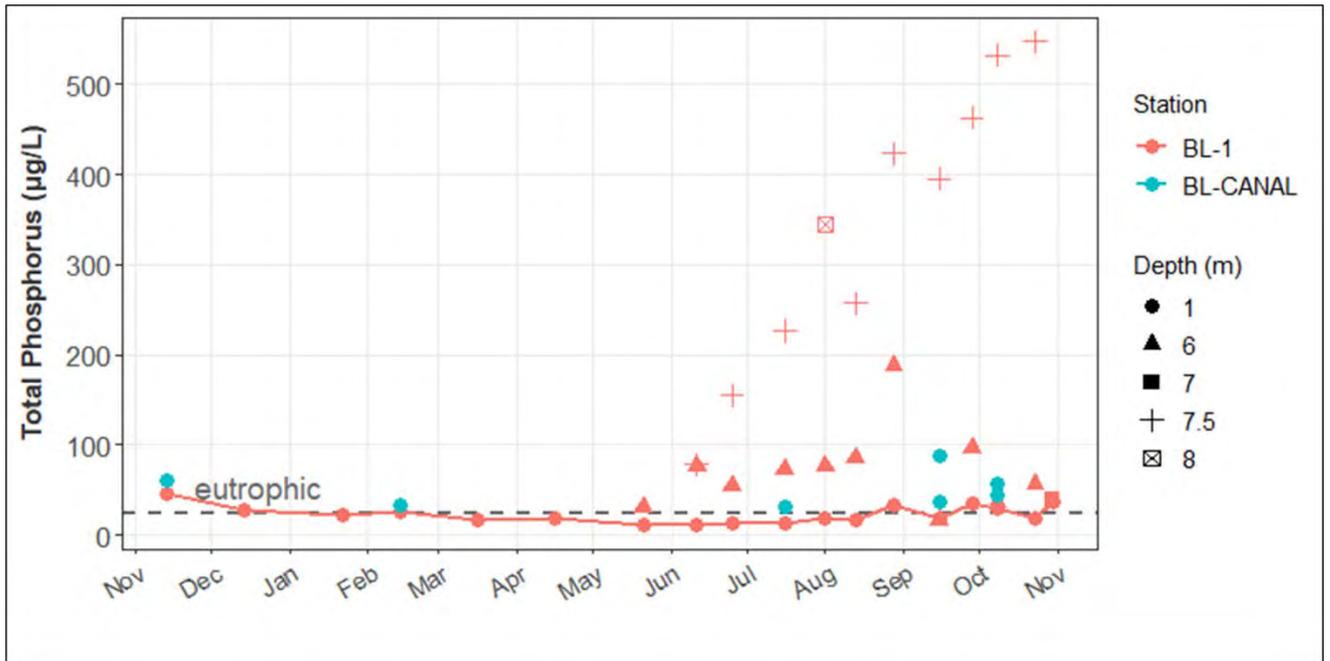
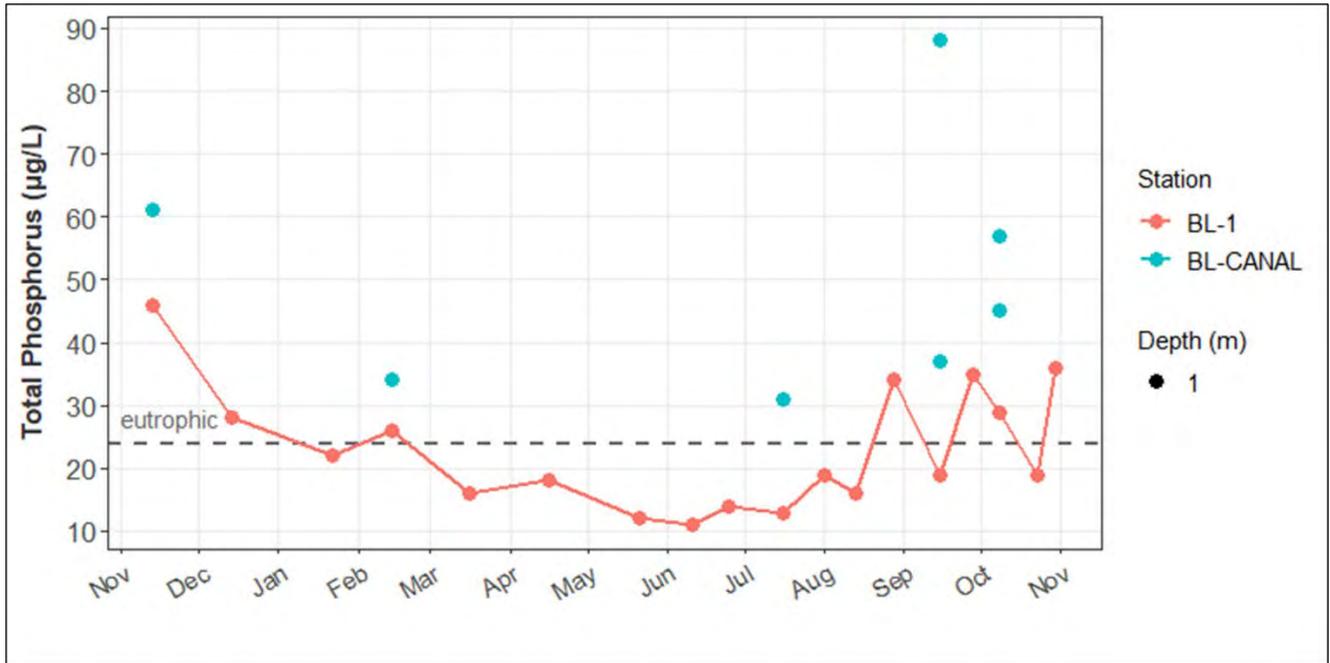
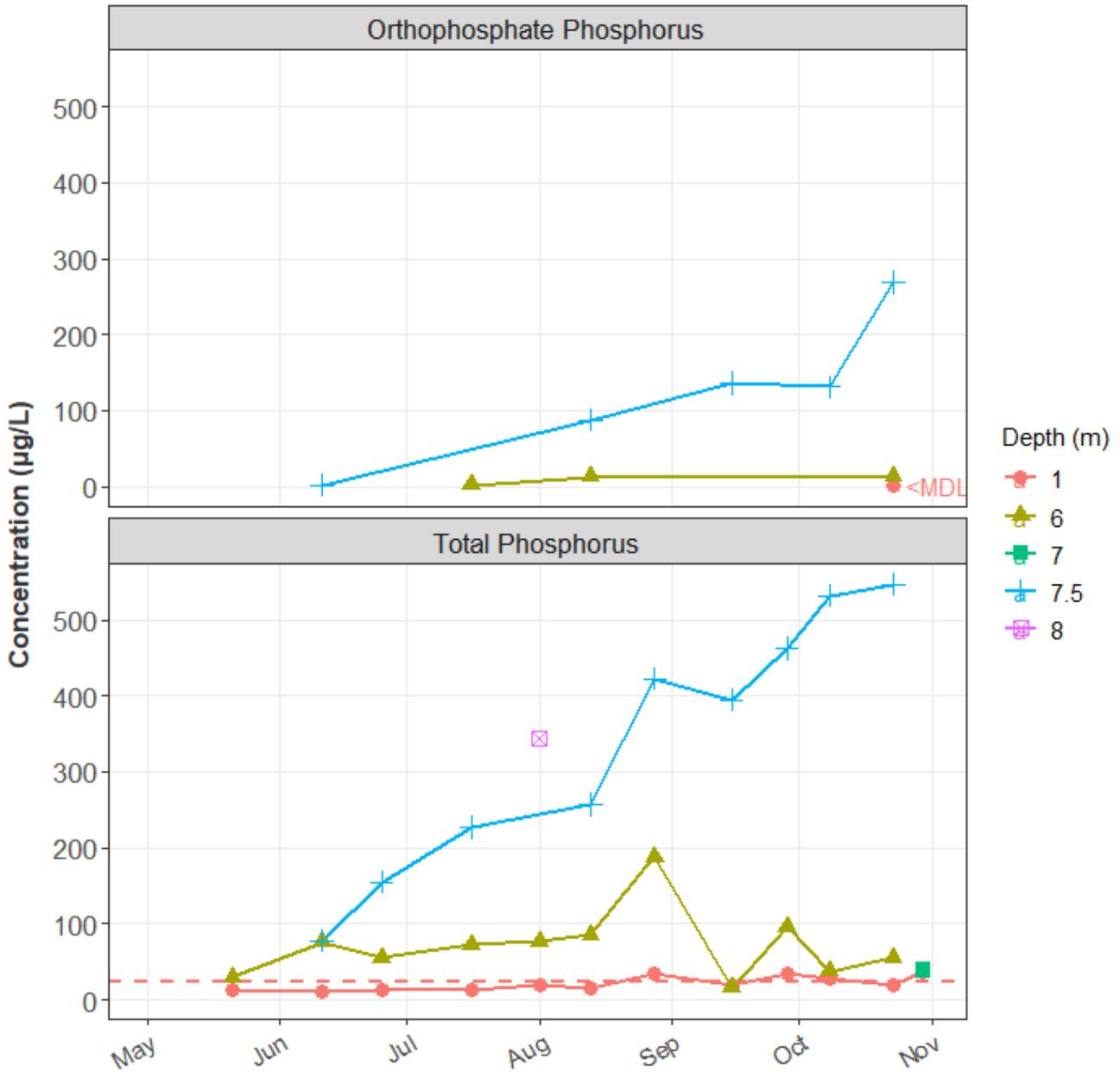


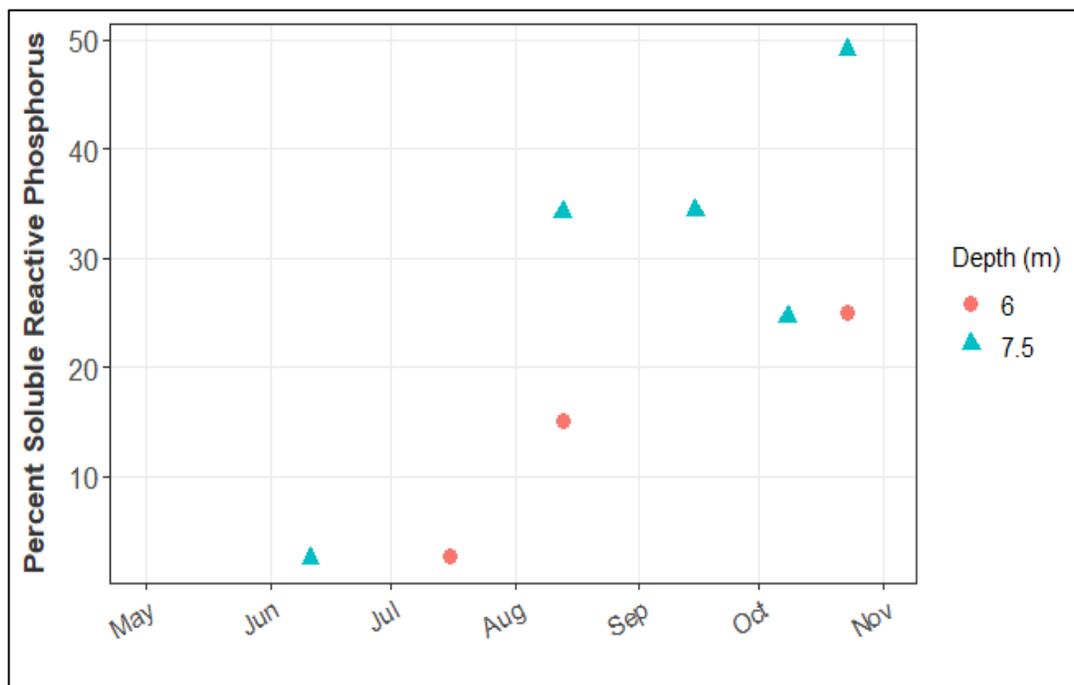
Figure 8. Orthophosphate and Total Phosphorus at BL-1 in Blackmans Lake, May–October 2023.



Dashed line represents the lower threshold for classification as eutrophic for surface (1 m) waters (24 µg/L for summer average total phosphorus). <MDL = less than the method detection limit (i.e., undetected).

Elevated phosphorus in the hypolimnion is primarily due to the release of phosphorus from iron in lake bottom sediment caused by anoxic conditions. The relative amount of SRP respective to TP (i.e., 2.6 to 49 percent) indicates how much phosphorus in the hypolimnion was available for additional algae growth while the remaining phosphorus was comprised by the standing crop of algae biomass (Figure 9). While most phosphorus was comprised within existing algae crop in June and July, a greater proportion of SRP became available for additional growth as the 2023 summer stratification period progressed into the fall.

Figure 9. Percent SRP of TP in the Hypolimnion at BL-1 in Blackmans Lake, May–October 2023.



Mesotrophic systems are defined by summer average surface TP concentrations between 12 and 24  $\mu\text{g/L}$  while eutrophic systems exhibit average TP concentrations between 24 and 96  $\mu\text{g/L}$  (see Trophic State below). Washington State Surface Water Quality Standards (WAC 173-201A) established an action level of 20  $\mu\text{g/L}$  for summer average surface TP in Puget Sound lowland lakes (Ecology 2000). Summer mean concentrations greater than 30  $\mu\text{g/L}$  generally result in undesirable algae growth that interferes with recreational uses of lakes in the Puget Sound region (Gilliom 1983). The summer mean total phosphorus concentration at the surface of Blackmans Lake was 21.4  $\mu\text{g/L}$  (see Table 6), barely exceeding state action level of 20  $\mu\text{g/L}$  and less than the lower threshold of 24  $\mu\text{g/L}$  for eutrophic state and guideline of 30  $\mu\text{g/L}$  for algae bloom problems.

## Nitrogen

Nitrogen is another important nutrient for algae. Total nitrogen (TN) includes organic nitrogen (bound to organic matter) and dissolved inorganic nitrogen (comprised of nitrate, nitrite, and ammonia). Nitrogen is typically in plentiful supply in lakes, in part because nitrogen gas readily dissolves in the water from the atmosphere and nitrogen-fixing bacteria and some cyanobacteria species use it.

TN and nitrate+nitrite nitrogen were both measured in five surface water samples and one bottom water sample from Blackmans Lake during the 2023 monitoring period. TN ranged from 373 to 659 µg/L at the lake surface (Table 5) and was measured at 785 µg/L in the one bottom water sample collected from 6 meters depth in June. Nitrate+nitrite nitrogen was not detected in any of the samples (less than a detection limit of 10 µg/L). Ammonia nitrogen was not tested and is typically not detected in surface waters because it is a preferred source of nitrogen for algae growth and is typically present in bottom waters because it is readily produced by bacteria under anoxic conditions. Thus, TN was primarily organic nitrogen in surface waters and may have also included ammonia in the bottom waters of Blackmans Lake.

Figure 10 shows TN increasing at the lake surface throughout the 2023 summer monitoring period, from a minimum in June to a maximum in early October. The October peak coincides with elevated TP, elevated DO, and chlorophyll-a, which all indicative of an algae bloom.

## Total Nitrogen: Total Phosphorus

Although phosphorus is generally the primary limiting nutrient in most lakes and nitrogen is generally the primary limiting nutrient in most marine waters, a review of nutrient limitation literature concluded that most lakes appear to be limited over the short term (months) by both phosphorus and nitrogen (co-limitation), and possibly by other resources such as iron (Sterner 2008). To elucidate this phenomenon, ratios of total nitrogen to total phosphorus (TN:TP) can be used to indicate which nutrient is most limiting to algae growth in the long term (Guildford and Hecky 2000). Based on nutrient relationships from 221 lakes, Guildford and Hecky (2000) found that ratios greater than 22 indicate phosphorus limitation, ratios less than 9 indicate nitrogen limitation, and ratios between 9 and 22 indicate co-limitation of algae growth by both phosphorus and nitrogen.

Figure 10. Total Nitrogen in Blackmans Lake, May–October 2023.

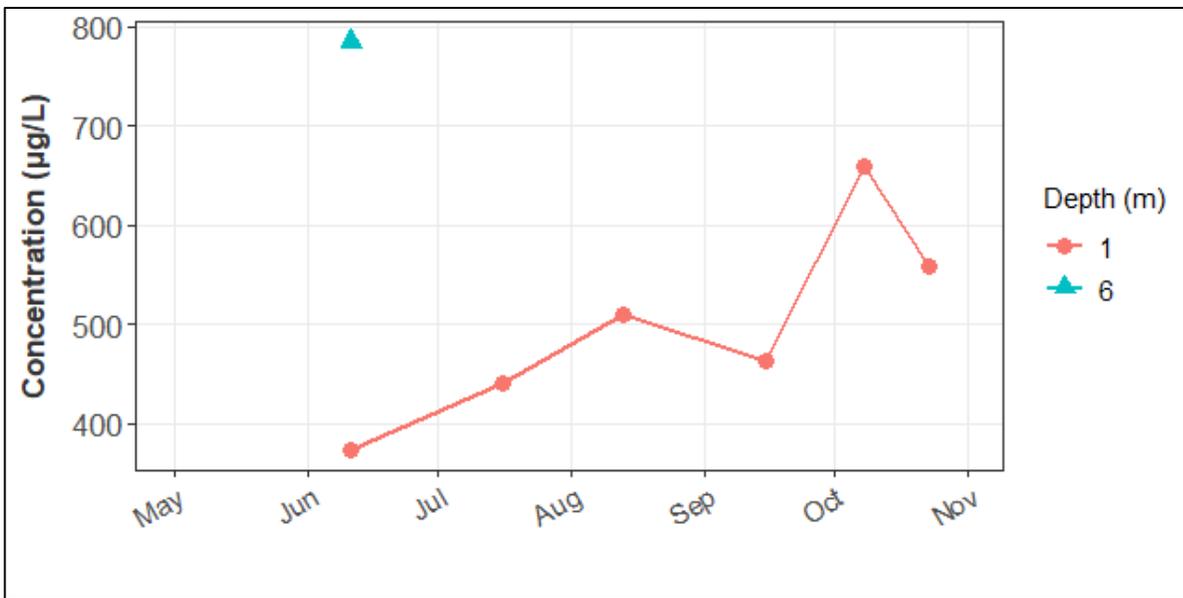
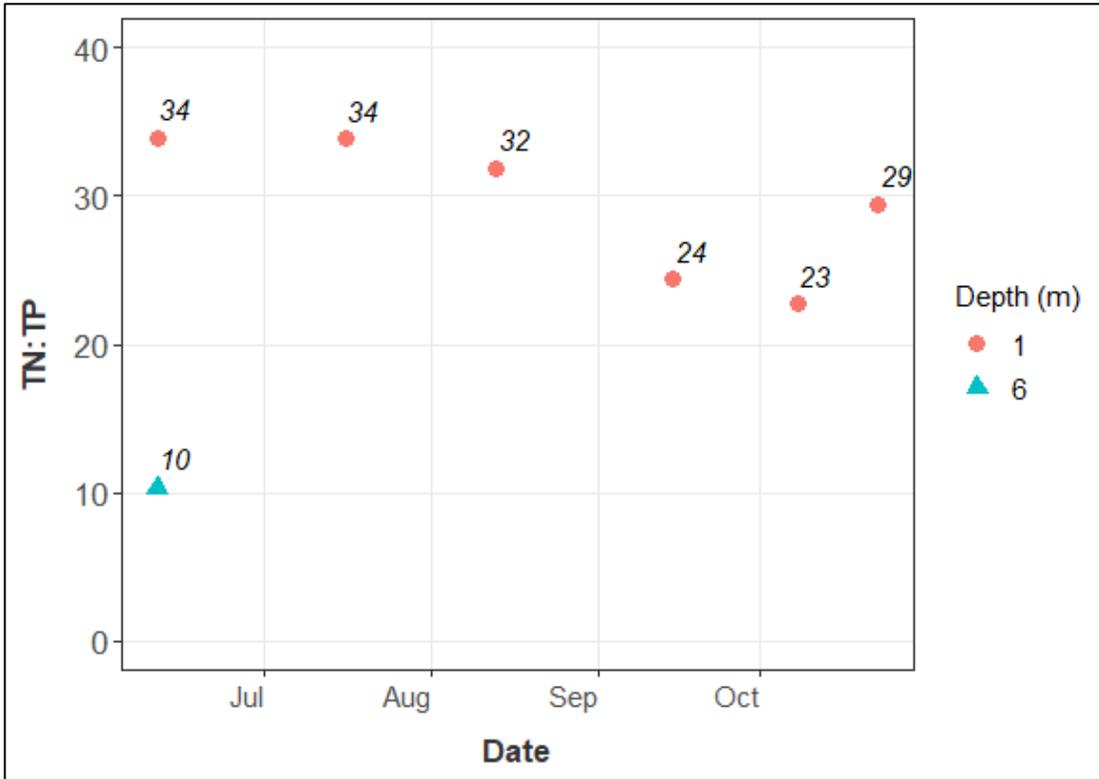


Figure 11 shows the TN to TP ratios for the six monthly monitoring dates in June through October when both TN and TP samples were collected. Italicized numbers adjacent to each point reflect the TN:TP values for each sample.

Figure 11. TN:TP Ratio at BL-1 in Blackmans Lake, May–October 2023.



TN:TP ratios ranged from 23 to 34 at the lake surface, indicating that algae growth in Blackmans Lake is limited by phosphorus. Undetectable concentrations of dissolved inorganic nutrients (nitrate+nitrite and orthophosphate) at the lake surface additionally suggests high nutrient uptake and limitation. The single TN:TP ratio calculated from the hypolimnion indicates potential co-limitation by both phosphorus and nitrogen. High available nutrient concentrations and lower TN:TP ratios in the hypolimnion suggest low nutrient uptake and limitation. Additional sampling would be beneficial to better understand the temporal and spatial variability in nutrient limitation since sampling for dissolved and hypolimnetic nutrients were infrequent in the present study.

In all, interpretation of TN:TP ratios indicates algae growth is primarily restricted by phosphorus in Blackmans Lake and limitation occurs at least June through October. Phosphorus limitation at the surface with some nitrogen limitation at depth is common for other Puget Sound lowland lakes. This suggests that phosphorus control, particularly during the summer months, is key to reducing algae and cyanobacteria blooms.

## Trophic State

The Trophic State Index (TSI) is a common index of a lake’s biological productivity, used to classify lakes into four trophic states based on their amount of nutrients and algae. Specifically, TSI is based on chemical and physical conditions measured in the lake surface layer and averaged over the summer months. Lake productivity is scaled between 0 and 100, as a continuum ranging from oligotrophic (e.g., low algae biomass and nutrients), to mesotrophic (e.g., moderate algae biomass and nutrients), to eutrophic (e.g., high algae biomass and nutrients), and to hypereutrophic (very high algae biomass and nutrients) (Table 8). Oligotrophic lakes (TSI <40) are very clear, with low nutrient concentrations and low algal growth. These lakes are often located in mountains or undisturbed forests. Eutrophic lakes (TSI 50–70) have cloudy water with high nutrient concentrations and high algal growth. These lakes can be naturally productive but are often highly altered and may have frequent algal blooms. Mesotrophic lakes (TSI 40–50) are in the middle, with fairly clear water and moderate nutrient concentrations and algal growth. Mesotrophic lakes are common in lowland western Washington, especially in areas with some development along the shoreline and in the watershed.

**Table 8. Lake Trophic State Classification System.**

Trophic Class	Trophic State Index	Total Phosphorus (µg/L)	Chlorophyll-a (µg/L)	Secchi Depth (m)
Oligotrophic	< 40	< 12	< 2.6	> 4
Mesotrophic	40 to 50	12 to 24	2.6 to 7.2	2 to 4
Eutrophic	50 to 70	24 to 96	7.2 to 56	0.5 to 2
Hypereutrophic	>70	>96	>56	<0.5

Arithmetic mean values for summer months (typically June through September) in the surface layer of the lake.

Lakes often transition between trophic states over time, depending on several factors such as human disturbance or geological origin. Eutrophication is the process of a waterbody becoming more productive due to associated increases in nutrients. This can lead to decreased water clarity, increased occurrence and/or magnitude of harmful algal blooms, and high variation in pH and/or DO, which can further impact public uses and fish and wildlife. Trophic state classifications are commonly used as a general evaluation of lake health.

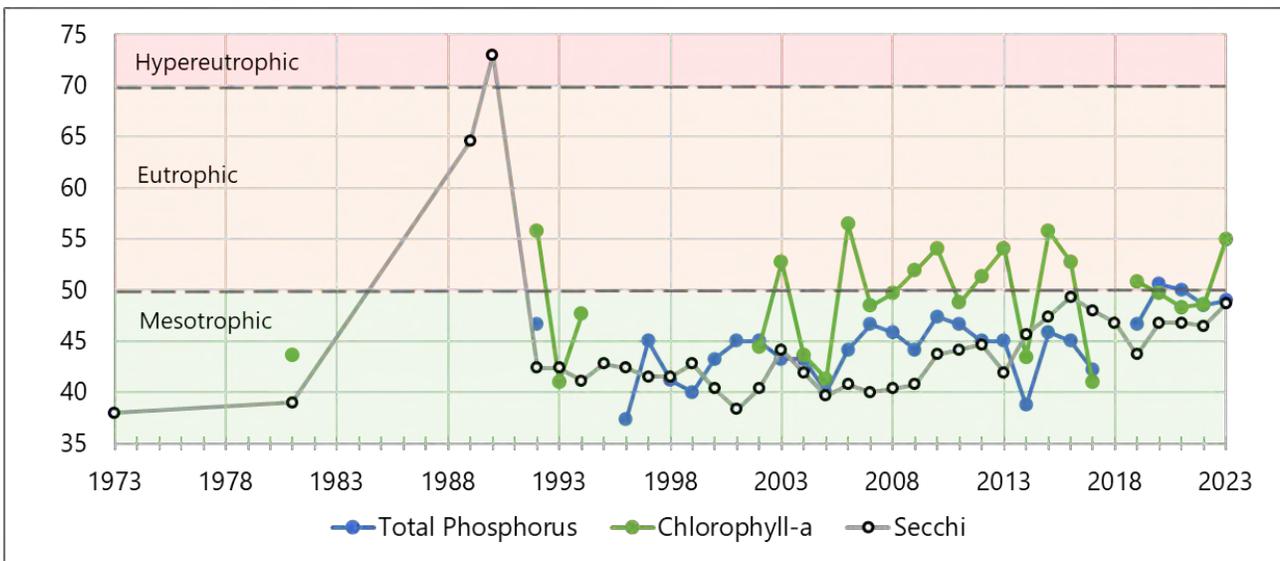
TSI values for Blackmans Lake based on Secchi depth, chlorophyll-a, and total phosphorus are presented in Table 9. Of these metrics, chlorophyll-a TSI is the most directly relevant to lake productivity, whereas Secchi depth and total phosphorus are good predictors of productivity. The summer 2023 TSI values for each Secchi depth and TP indicate Blackmans Lake is mesotrophic, while the TSI value for chlorophyll-a is indicative of eutrophication. Overall, Blackmans Lake is borderline meso-eutrophic according to these three indicators.

**Table 9. Trophic State Index Blackmans Lake.**

Parameter	2023	
	Mean	TSI
Secchi depth	2.3 m	48.0
Chlorophyll-a	11.8 µg/L	54.8
Total Phosphorus	21.4 µg/L	48.3
Classification	Meso-eutrophic	

Historical TSI values for Blackmans Lake are presented for total phosphorus, chlorophyll-a, and Secchi depth in Figure 12 for 1973 to 2023 (Snohomish County 2024). The TSI value for chlorophyll-a was higher in 2023 than recent years (the highest since 2015) but other TSI values for 2023 (see Table 9) were similar to recent historical values. Long-term trend analysis from by Snohomish County (2021) showed significantly decreasing Secchi depth (from 1992–2021), significantly increasing total phosphorus (from 1996–2021), and no significant change in chlorophyll-a (from 2002–2021).

**Figure 12. Blackmans Lake Trophic State Index (TSI).**



## Cyanotoxins

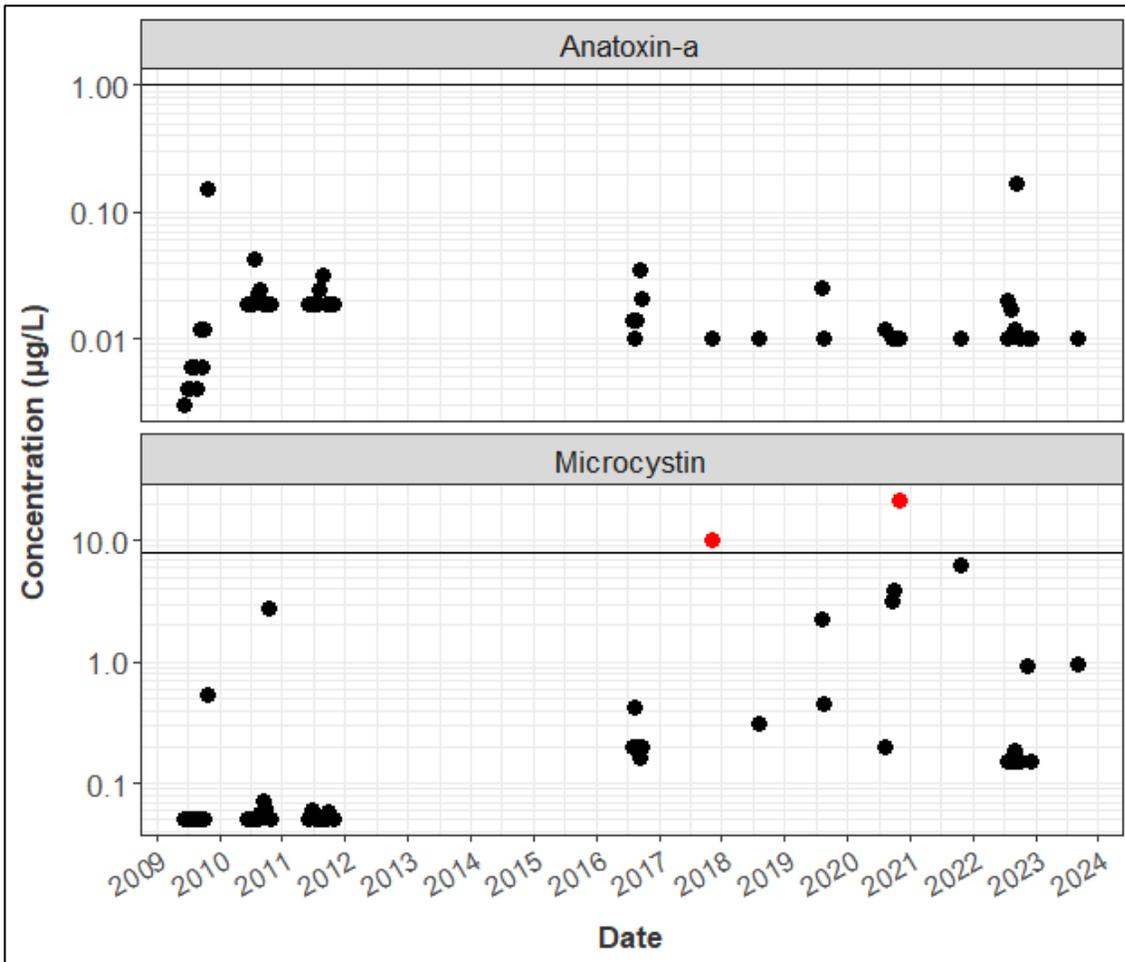
In recent years, algae scums have been observed at Hill Park and Ferguson Park in late summer, fall, and winter. Algae scums can persist intermittently through the winter (November–April), but sampling of these winter blooms has not been performed due to a lack of state funding and personnel resources (Snohomish County 2021).

Algae and cyanotoxin samples are collected from Blackmans Lake by Snohomish County staff when surface scums are present and sent for analysis as part of the statewide Northwest Toxic Algae program managed by Ecology. Between 1 and 10 samples have been analyzed for cyanobacteria toxins each year since 2009 (except 2012–2015), for a total of 11 years of toxin monitoring since the inception of the

program. Figure 13 presents concentrations of microcystin and anatoxin-a from 2009–2011 and 2016–2023, where red points represent samples exceeding state recreational guidelines. Anatoxin-a is frequently not detected and has never been detected above the state criterion (1 µg/L). Microcystin has only exceeded the state criterion (revised from 6 to 8 µg/L in 2019) twice since the inception of the program, once in 2017 and 2020 (Figure 13). Detectable microcystin toxins occur at both Ferguson Park boat launch and the Hill Park shoreline or dock. Too few samples have been collected from ‘Champagne Lane’ canal to evaluate trends, and locations for samples collected prior to 2020 were not specified.

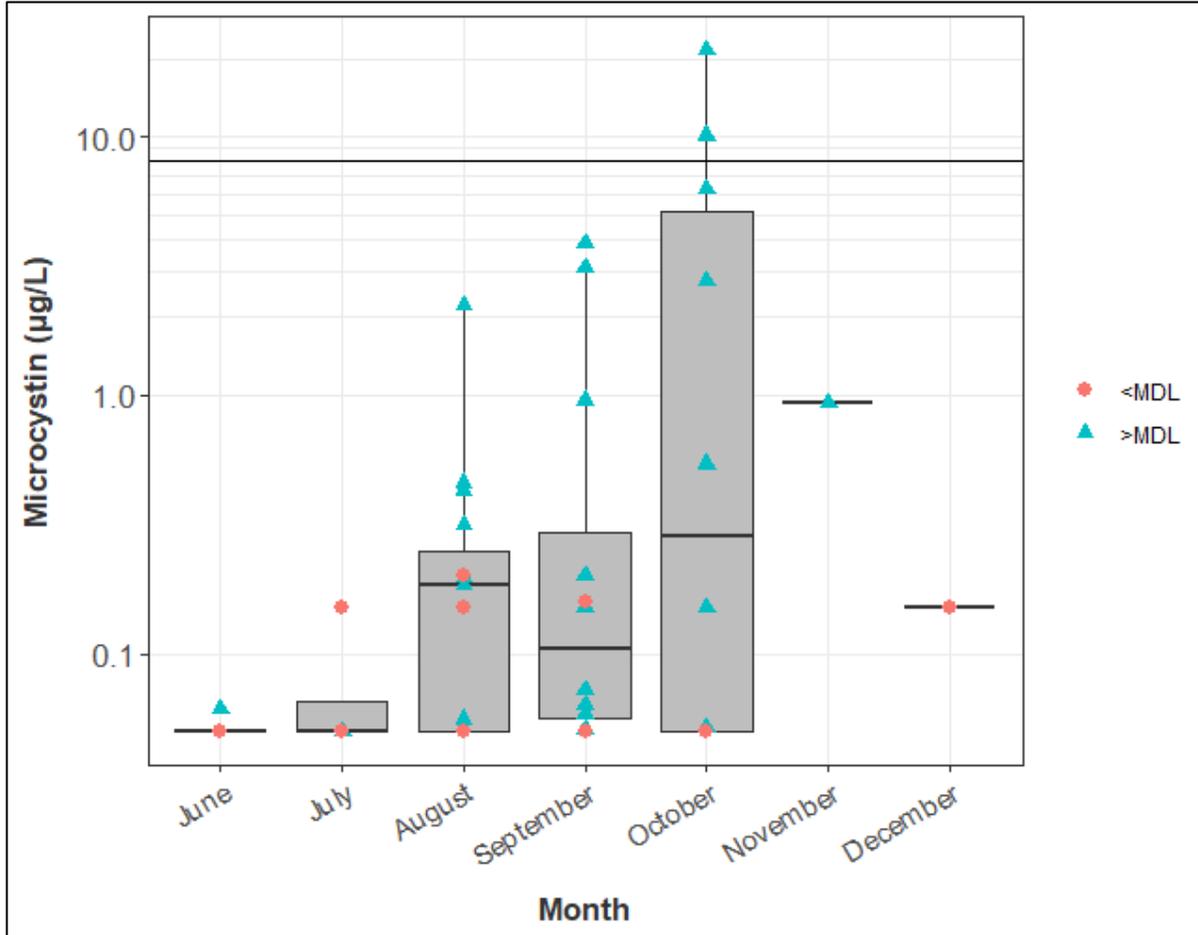
Figure 14 shows the concentration of microcystin in Blackmans Lake during all sampled months (June through December) between 2009 and 2023. The most frequently sampled months were August (n=15), September (n=12), and October (n=10). Concentrations in October were substantially higher than in other months, and included the only recorded exceedances of state criterion and the least number of non-detects.

Figure 13. Cyanotoxins in Blackmans Lake (2009–2023).



Data source: NW Toxic Algae (Ecology 2024). Note the log scale on the y-axes. Horizontal lines represent current state recreational guidelines (1 µg/L anatoxin-a, 8 µg/L microcystin). Guideline for microcystin prior to 2019 was 6 µg/L.

Figure 14. Microcystin in Blackmans Lake (2009–2023).

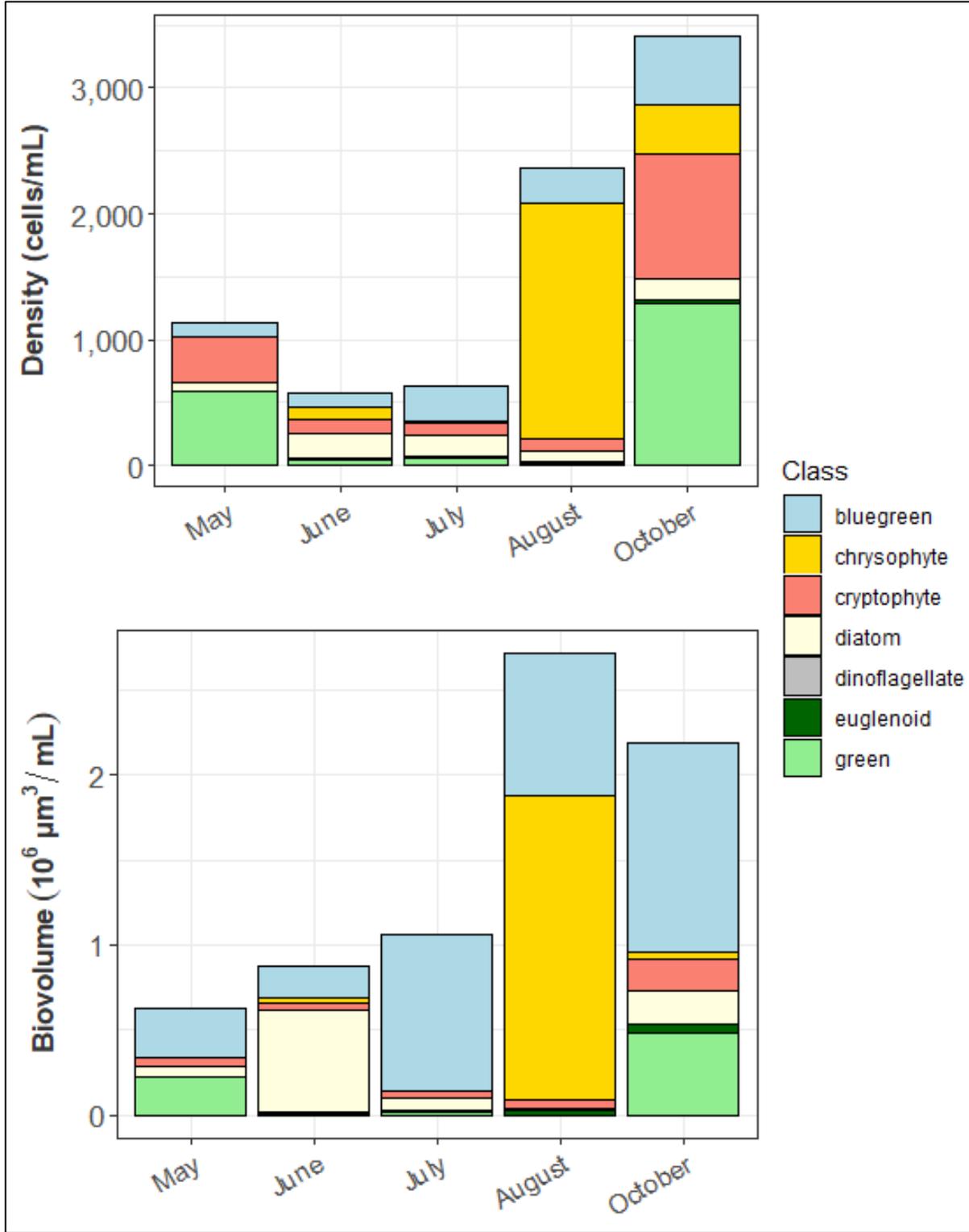


In 2023, only one algae scum sample was analyzed for cyanotoxins. The sample was collected on September 7, 2023 from the boat launch at Ferguson Park. Both toxins were detected well below the state criterion; anatoxin-a was measured at the method detection limit (0.01 µg/L) while microcystin was measured at 0.96 µg/L.

## Phytoplankton

As part of the LCMP project, phytoplankton (suspended algae) species were identified and enumerated in five monthly surface samples (May–August, and October 2023). Figure 15 shows the phytoplankton community composition on each of these sample dates, grouped by the following major algae classes: bluegreen algae/cyanobacteria, chrysophytes, cryptophytes, diatoms, dinoflagellates, euglenoids, and green algae. Composition is shown for both unit density and biovolume concentration. Note that unit density is based on natural units for counting that is a cell for unicellular species or multiple cells for colonial species with cells arranged in filaments or globular forms. Cyanobacteria are most commonly in filaments or globular colonies such that the actual cell density is higher than the reported natural unit density. In contrast, most diatoms are unicellular. Cell biovolume is a better unit for comparing phytoplankton species or class amounts, abundance, and dominance.

Figure 15. Phytoplankton in Surface Samples at BL-1, Blackmans Lake (2023).



In May, cyanobacteria were dominant by biovolume, but not natural unit density. In June, diatoms were dominant. In July, cyanobacteria became dominant again. In August, chrysophytes (golden algae) were

very abundant with the highest biovolume and percent composition (66 percent). In October, cyanobacteria again dominated by biovolume.

From the five samples collected, four species of cyanobacteria were identified: *Aphanizomenon flos-aquae*, *Anabaena flos-aquae*, *Anabaena planctonica*, and *Microcystis aeruginosa* (Figure 16). Of those cyanobacteria, *A. planctonica* was the most abundant on most sample dates. *M. aeruginosa* was the least frequently detected and least abundant cyanobacteria species (Table 10).

**Table 10. Cyanobacteria Species Presence and Percent Total Biovolume in Blackmans Lake, May–October 2023.**

Parameter	5/21/2023 BL-1 (1 m)	6/25/2023 BL-1 (1 m)	7/30/2023 BL-1 (1 m)	8/28/2023 BL-1 (1 m)	9/7/2023 <sup>a</sup> Boat Launch	10/8/2023 BL-1 (1 m)
<i>Aphanizomenon flos-aquae</i>		Present (6.2%)	Present (6.1%)	Present (4.5%)	Present	Present (8.7%)
<i>Dolichospermum (Anabaena) flos-aquae</i>	<b>Dominant (30.4%)</b>	Present (2.6%)		Present (4.2%)		Present (0.8%)
<i>Dolichospermum (Anabaena) planctonica</i>	<b>Sub-dominant (15.1%)</b>	<b>Sub-dominant (12.0%)</b>	<b>Dominant (80.4%)</b>	<b>Sub-dominant (22.3%)</b>		<b>Dominant (46.1%)</b>
<i>Microcystis aeruginosa</i>		Present (0.1%)	Present (0.1%)		Present	Present (0.4%)

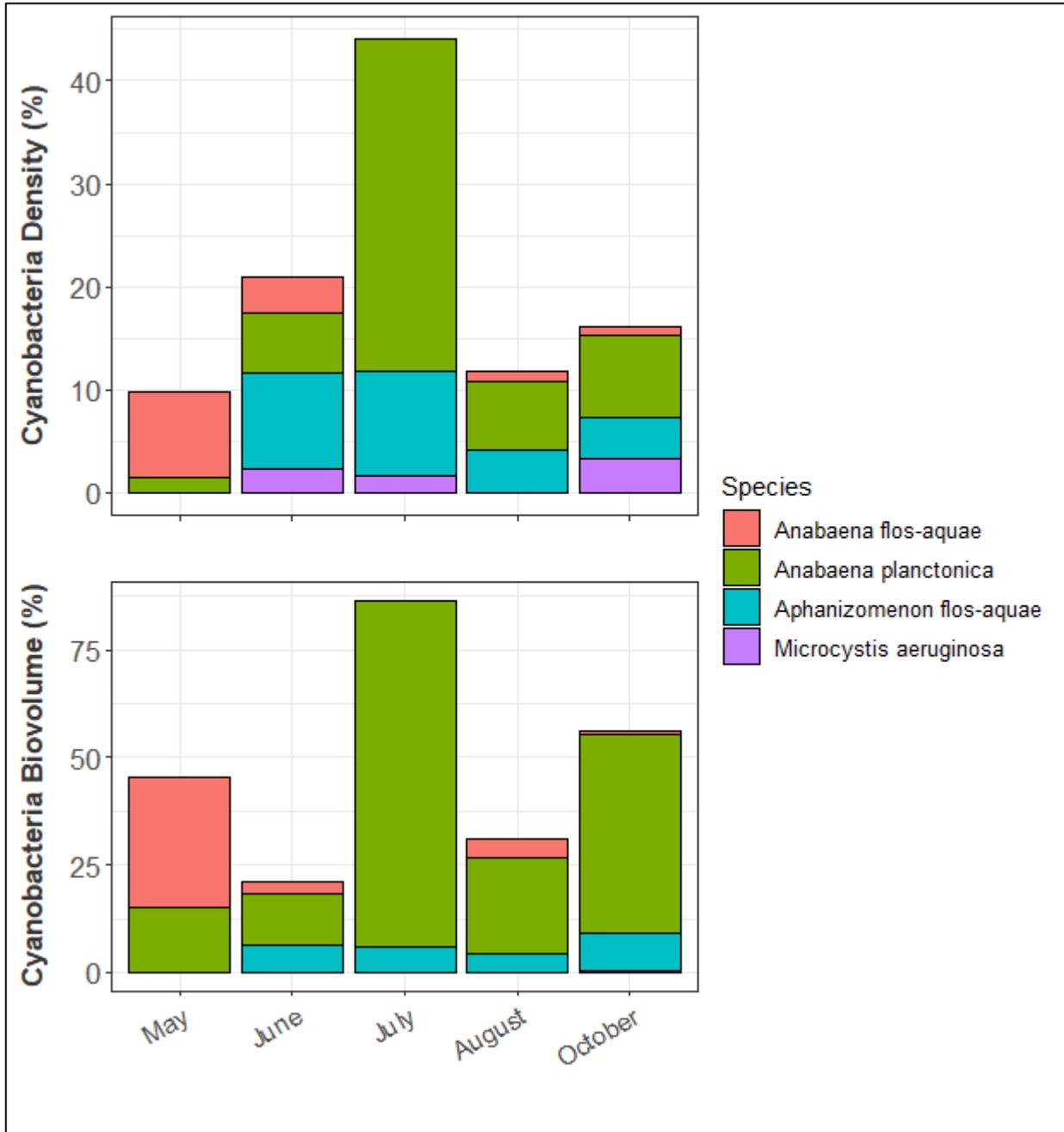
<sup>a</sup> Data source: NW Toxic Algae (Ecology 2024). Analyst note: "few algae seen on microscopic exam". Additional cyanobacteria observed in this sample include unspecified species of *Dolichospermum*, *Oscillatoria*, *Planktothrix*, *Woronichinia*, and an unidentified filament.

Additionally, the September 7, 2023 boat launch sample analyzed through the Northwest Toxic Algae program identified at least six cyanobacteria species, including four additional species not identified in the other 2023 samples (see Table 10). However, no single species appeared to be more dominant than another due to relatively few algae cells present in the sample during analysis.

In all, the toxin-producing cyanobacteria genera most frequently observed in Blackmans Lake in 2023 was two species of *Dolichospermum* (previously known as *Anabaena*), followed by *Aphanizomenon*, and *Microcystis*. *Dolichospermum* is a filamentous cyanobacteria shown to produce microcystin and/or anatoxin-a. *Aphanizomenon* is a filamentous cyanobacteria shown to produce anatoxin-a. *Microcystis* is a small-celled colonial cyanobacteria that produces only microcystin, which is the most widespread cyanotoxin (Ecology 2024). *Microcystis* is the most common bloom-forming genus and is almost always toxic. It may produce much higher amounts of microcystin in Blackmans Lake than its low biovolume (less than 1 percent) would suggest.

Other toxin producers, like *Oscillatoria* and *Planktothrix*, are also present in Blackmans Lake but did not appear to contribute to algae growth near the lake center. It is common to see both spatial and temporal differences in which cyanobacteria genera are identified.

Figure 16. Cyanobacteria Composition at BL-1 (1 meter depth), Blackmans Lake (May–October 2023).



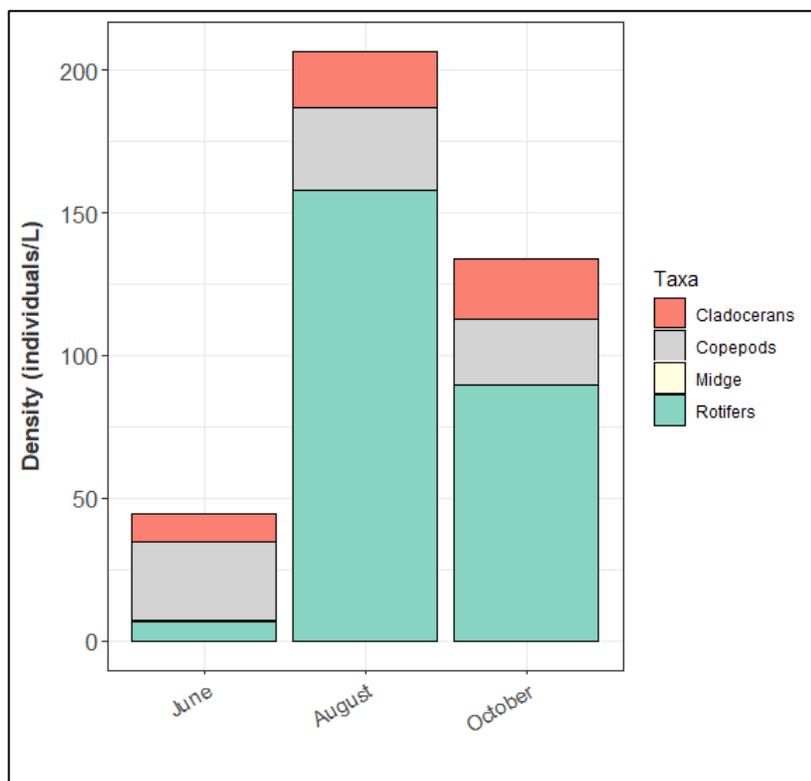
## Zooplankton

Zooplankton, microscopic animals between 20 microns and 2 mm in size, are the primary consumers of phytoplankton and are an important food source for many forms of aquatic life, such as juvenile salmonids and other small fish. The types of zooplankton present in a water body and their feeding habits can influence and provide insight to algae dynamics.

Zooplankton tows of the entire water column were performed from the deep lake site (BL-1) at Blackmans Lake three times during 2023. Figure 17 shows the 2023 zooplankton sampling results. Zooplankton at the lake surface featured a minimum in June of just 45 individuals/liter, a maximum of 207 individuals/liter in August, and a moderate amount of 135 individuals/liter in October.

In terms of composition by the average concentration of individuals in the water column, the zooplankton community in was dominated by copepods (61 percent) followed by cladocerans (22 percent) in July, and by rotifers in both August (77 percent) and October (67 percent) (see Table 11). Generally, crustacean zooplankton (copepods, and cladocerans like *Daphnia*) exhibited consistent abundance on each sampling date but were a low proportion of the community abundance on the second two sampling dates due to the abundance of the much smaller rotifers. This is not unexpected as crustaceans are predators significantly larger in size; ecosystems cannot support the same abundances of larger organisms as they can smaller organisms. However, crustaceans typically dominate freshwater systems by biomass and can exert substantial trophic impacts which may cascade through the food web.

Figure 17. Zooplankton Composition at BL-1 (vertical tow) in Blackmans Lake, June–October 2023.



**Table 11. Blackmans Lake Zooplankton Composition at BL-1, June–October 2023.**

Taxa/Species	Density (No./liter)		
	June	Aug	Oct
<i>Bosmina longirostris</i>	2.8	3.2	–
<i>Ceriodaphnia sp.</i>	–	13.3	12.2
<i>Chydorus sphaericus</i>	0.9	–	8.8
<i>Daphnia mendotae complex</i>	4.8	1.9	–
<i>Daphnia pulex</i>	1.4	1.3	–
<b>Cladocerans Total</b>	<b>9.9</b>	<b>19.6</b>	<b>21.0</b>
<i>Calanoida - copepodites</i>	1.7	–	4.1
<i>Calanoida - nauplii</i>	3.4	0.6	4.8
<i>Cyclopoida - copepodites</i>	16.2	12.7	6.8
<i>Cyclopoida - nauplii</i>	3.4	5.7	5.4
<i>Diacyclops thomasi</i>	0.3	–	0.7
<i>Mesocyclops edax</i>	1.7	7.0	1.4
<i>Skistodiptomus oregonensis</i>	0.6	3.2	–
<b>Copepods Total</b>	<b>27.3</b>	<b>29.1</b>	<b>23.1</b>
<i>Chaoborus punctipennis</i>	0.9	–	–
<b>Midge Total</b>	<b>0.9</b>	<b>–</b>	<b>–</b>
<i>Ascomorpha ecaudis</i>	2.3	–	0.7
<i>Asplanchna priodonta</i>	0.6	0.6	–
<i>Brachionus angularis</i>	–	–	0.7
<i>Collotheca sp.</i>	1.1	–	1.4
<i>Conochilus unicornis</i>	2.6	119.1	20.4
<i>Gastropus stylifer</i>	–	0.6	2.7
<i>Kellicottia bostoniensis</i>	–	24.1	63.1
<i>Kellicottia longispina</i>	–	–	0.7
<i>Keratella cochlearis</i>	–	5.7	–
<i>Keratella crassa</i>	–	7.6	–
<b>Rotifers Total</b>	<b>6.5</b>	<b>157.7</b>	<b>89.6</b>
<b>Grand Total</b>	<b>44.6</b>	<b>206.5</b>	<b>133.7</b>

Rotifers are not well-suited for grazing large filamentous or colonial cyanobacteria due to their relatively small body sizes and mouthparts and so instead typically prefer to consume small green algae and other smaller phytoplankton cells in addition to dead organic matter. Thus, the abundance of rotifers in Blackmans Lake in August and October when cyanobacteria were also abundant indicates they may be feeding on two competitive advantages, such that cyanobacteria growth may be facilitated by a lack of: 1) predators since they are often filamentous, toxic, and/or innutritious, and 2) competitors (e.g., green algae) since small zooplankton prefer to eat those more nutritious and easier-to-eat competitor algae.

## Fecal Bacteria

Fecal bacteria were not monitored in 2023 for this study; however, Blackmans Lake is listed as impaired (Category 5) due to fecal coliform bacteria pollution in Ecology's 2018 Water Quality Assessment (i.e., on the 303[d] list) due to elevated levels documented by KCM (1994). The lake was originally listed as Category 5 based on the 1998 assessment. Although these data are more than 10 years old, there are no recent data to justify removing the listing. Excess waterfowl continue to be a problem in the lake and may have been the primary source of high bacterial concentrations observed in 1994.

The City recently monitored fecal coliform bacteria at six drainage stations from 2014 through 2020 for their National Pollutant Discharge Elimination System (NPDES) permit and to inform the Total Maximum Daily Load (TMDL) for fecal coliform bacteria in tributaries of the lower Snohomish River (Gray & Osborne 2021). Only one monitoring station (SNOH5) was located in the Blackmans Lake watershed, just east and downstream of the drainage station BLK-26 for the LCMP study. At this station, annual geometric mean concentrations of fecal coliform bacteria exceeded the criterion of 50 CFU/100 mL established for drainage to lakes by the Washington State Surface Water Quality Standards (WAC 173-201A) in only one of the seven monitoring years. However, the upper 10th percentile criterion of 100 CFU/100 mL was exceeded in 6 of 7 years. Two stations on Swifty Creek downstream of Blackmans Lake (stations SNOH6 and SNOH7) exhibited much higher fecal coliform bacteria concentrations than the station upstream of Blackmans Lake.

## Lake Sediment Quality

To inform the LCMP, sediment cores were collected from the lake bottom at one deep (BL-1) and one shallow (BL-2) station in Blackmans Lake. Each core was processed into five depth intervals each and analyzed separately for phosphorus fractions, total iron, and percent solids (Table 12). This information was used to estimate internal phosphorus loading from sediment release into the deep waters under anoxic conditions and to estimate the amount of aluminum and lanthanum needed to inactivate the forms of phosphorus available for algae uptake.

The total solids content was low near the surface (~6 percent) and increased with depth in both cores. Iron concentrations ranged from 1,094 to 13,964 mg/kg. The iron to phosphorus (Fe:P) ratio ranged from 2.8 to 10.5 throughout the sediment cores, and were highest in the upper 10 cm of sediment where phosphorus is released. A total Fe:P ratio of 10 is believed to be the minimum for iron to regulate sediment phosphorus release (Caraco et al. 1993). If the sediment surface has oxygen and the Fe:P ratio is 15 or greater, then it is believed that internal loading may be altogether prevented (Jensen et al. 1992). A Fe:P ratio of 10 and high iron-bound phosphorus concentrations of 202–275 mg/kg were observed in the upper 10 cm of the core from the deep station BL-1, indicating that iron is regulating phosphorus release into the anoxic hypolimnion of the lake. The low Fe:P ratio of 3–8 and undetected iron-bound phosphorus (<2 mg/kg) in the upper 10 cm of the core from the shallow station BL-2 suggests that iron is not regulating phosphorus release from the oxygenated epilimnion of the lake.

**Table 12. Blackmans Lake Sediment Chemistry (8/21/2023).**

Core Sample Site	Depth Interval (cm)	Loosely Bound P (mg/kg-DW)	Iron Bound P (mg/kg-DW)	Aluminum Bound P (mg/kg-DW)	Calcium Bound P (mg/kg-DW)	Biogenic <sup>a</sup> P (mg/kg-DW)	Organic P (mg/kg-DW)	Total P (mg/kg-DW)	Total Fe (mg/kg-DW)	% Solids	Fe:TP Ratio
BL-1 (Deep)	0–2	<2	275	525	69.6	351	481	1,350	13,964	6.2	10.3
	4–6	<2	229	534	83.3	282	412	1,258	13,209	8.1	10.5
	8–10	<2	202	559	99.5	357	447	1,307	13,338	9.3	10.2
	16–18	<2	156	754	73.9	330	433	1,418	6,211	10.4	4.4
	24–26	<2	36.1	633	46.4	307	398	1,114	3,107	11.8	2.8
BL-2 (Shallow)	0–2	<2	<2	343	58.7	368	496	897	7,470	5.5	8.3
	4–6	<2	<2	243	46.0	442	515	804	5,036	8.8	6.3
	8–10	<2	<2	357	30.7	291	355	743	2,188	9.2	2.9
	16–18	<2	<2	232	19.1	194	252	503	2,225	9.5	4.4
	24–26	<2	<2	251	24.7	221	275	551	1,904	11.9	3.5

<sup>a</sup> Biogenic P is a fraction of the organic P not included in the calculation of total P.

P = phosphorus; Fe = iron

mg/kg-DW = milligrams per kilogram of dry weight; cm = centimeters

Other sediment phosphorus release mechanisms can include resuspension from wave action, bioturbation by benthic invertebrates and fish, decay of aquatic plants, decay of organic matter in sediments by bacteria, acceleration of organic phosphorus release by elevated temperatures, and acceleration of iron phosphorus release by high pH during algae blooms (Sondergaard et al. 2003). The complex mechanisms of internal phosphorus loading and how they vary with sediment and other lake characteristics is not well understood.

Phosphorus levels varied between the cores with the deep core (BL-1) exhibiting higher concentrations of total phosphorus, iron-bound phosphorus, aluminum-bound phosphorus, and calcium-bound phosphorus, and similar concentrations of organic phosphorus. Biologically unavailable aluminum-bound phosphorus typically made up about half of total phosphorus. Organic phosphorus was next most substantial component and was shown to be mostly biogenic (77 percent on average), which generally represents dead algae and other organic matter grown in the lake that decays more rapidly than the remaining organic phosphorus typically originating from the watershed. Loosely bound phosphorus (orthophosphate) was below detection in all samples, which is not uncommon in lake sediments because it readily diffuses into the water, but it also may have been due to binding of orthophosphate to iron when samples became oxidized during the holding time.

Concentrations of sediment phosphorus fractions available for release are summarized in Table 13. Results are summarized for the top 10 cm depth intervals because this is the zone where the most biologic activity and chemical diffusion into the water is occurring and is used as the appropriate target for phosphorus inactivation. Active phosphorus consists of chemically mobile phosphorus (sum of loosely- and iron-bound phosphorus) and biogenic phosphorus (readily degradable organic phosphorus). Active phosphorus represented approximately 43 to 45 percent of the total phosphorus in the biologically active sediment zone.

**Table 13. Depth Interval Summarized Sediment Phosphorus Fractions.**

Core	Depth Interval (cm)	Mobile P (mg/kg)		Biogenic P (mg/kg)		Active P (mg/kg)		Total P (mg/kg)		% Active P
		DW	WW	DW	WW	DW	WW	DW	WW	
BL-1 (DEEP)	0–10	235	18.1	330	25.9	565	44.1	1305	102.4	43%
	16–26	96	10.2	319	35.3	415	45.5	1266	139.5	33%
BL-2 (SHALLOW)	0–10	<2	<0.2	367	28.7	367	28.7	815	62.9	45%
	16–26	<2	<0.2	208	22.4	208	22.4	774	69.7	27%
<b>Average</b>	<b>0–10</b>	<b>118</b>	<b>9.1</b>	<b>349</b>	<b>27.3</b>	<b>466</b>	<b>36.4</b>	<b>1060</b>	<b>82.7</b>	<b>44%</b>

Mobile P = Labile P + Iron P

Active P = Mobile P + Biogenic P

DW = dry weight

WW = wet weight



The Phase 1 Restoration Study measured total phosphorus and total iron, but not phosphorus fractions, at 2-cm intervals in two sediment cores collected from the deep lake station in 1992 (KCM 1994). Table 14 compares the 2023 and 1992 sediment results. The average total phosphorus concentration in the surface 10 cm was substantially (30 percent) less at 1,305 mg/kg in 2023 compared to 1,720 and 2,011 mg/kg in the two 1992 cores. The average total phosphorus concentration decreased in the 16–26 cm subsurface interval to similar values of 1,266 mg/kg in 2023 and 1,390 mg/kg in 1992. Total iron concentrations and total Fe:P ratios were similar between years at both depth intervals and decreased with depth much more than total phosphorus (see Table 14). Thus, lake sediment quality at the deep station was similar in 2023 to that observed in 1992 except for a 30 percent decrease in total phosphorus concentrations in the surface sediments over the past 30 years.

**Table 14. Comparison of Sediment Phosphorus and Iron in 2023 and 1992 Deep Cores.**

Core	Depth Interval (cm)	Total P (mg/kg)	Total Fe (mg/kg)	Fe:TP Ratio
2023 DEEP (BL-1)	0–10	1,305	13,504	10.3
	16–26	1,266	4,659	3.6
1992 DEEP (1)	0–10	1,720	13,048	7.5
	15–27	1,390	4,878	3.5
1992 DEEP (2)	0–8	2,011	16,843	8.4

# Watershed Monitoring Results

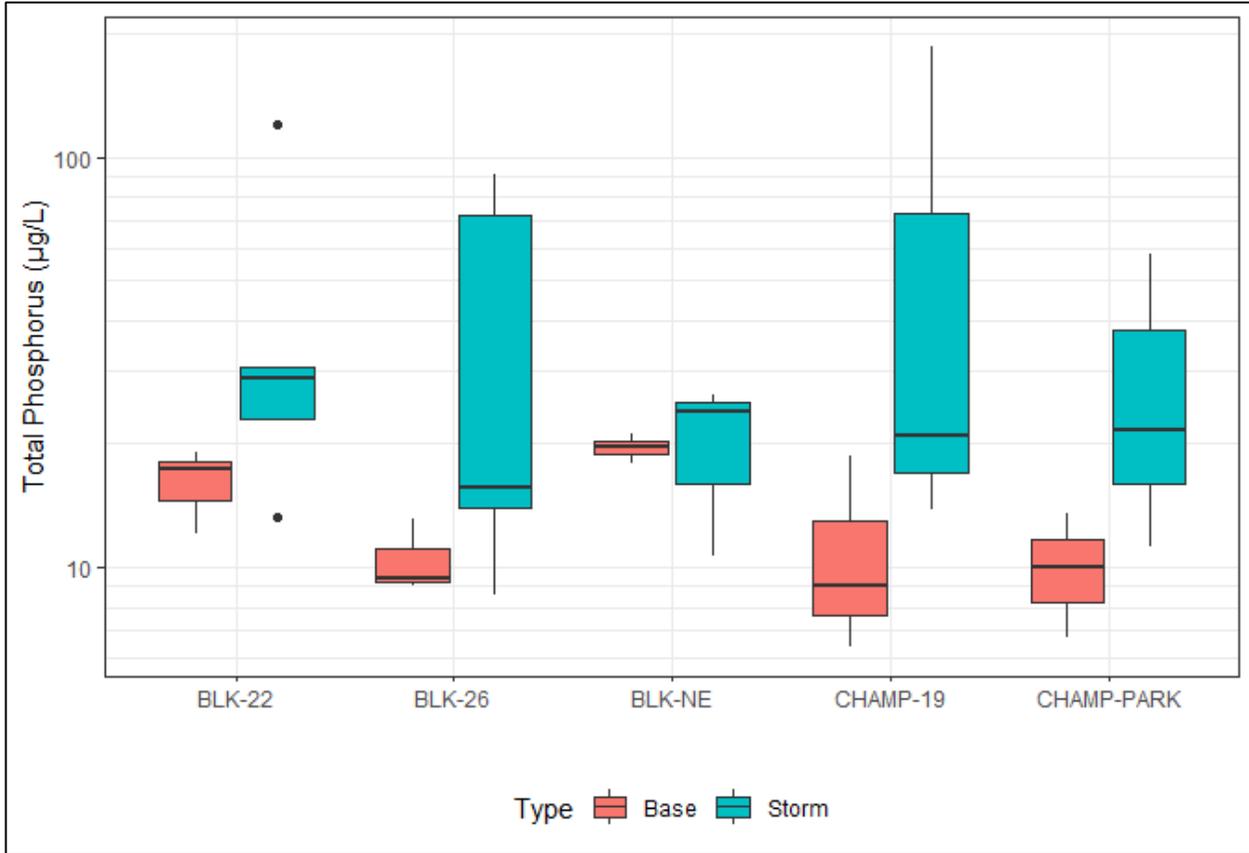
## Inflow Phosphorus

Grab samples of total phosphorus samples were collected by City staff from five drainages to Blackmans Lake between November 2022 and December 2023. Nine events were sampled, including three base flow events and six storm flow events. Total phosphorus results for watershed drainages are presented as statistics in Table 15 and as box and whisker plots in Figure 18. Box and whisker plots present base and storm event results separately and include medians as horizontal lines, interquartile range of 25th to 75th percent as boxes, range as vertical whiskers, and points for outliers.

**Table 15. Blackmans Lake Watershed 2023 Water Quality Summary Statistics.**

Parameter	MDL and Unit	Station	Event Type	N	Percent non-detects	Min.	Mean	Max.
Total Phosphorus	2 µg/L	BLK-22	Base	3	0	12.1	16.2	19.0
			Storm	6	0	13.2	49.8	120
		BLK-26	Base	3	0	9.0	10.5	13.1
			Storm	6	0	8.6	42.7	91.0
		BLK-NE	Base	3	0	18.0	19.6	21.1
			Storm	4	0	10.6	31.7	66.0
		CHAMP-19	Base	3	0	6.4	11.4	18.7
			Storm	6	0	13.8	68.3	186
		CHAMP-PARK	Base	3	0	6.8	10.1	13.6
			Storm	6	0	11.2	36.1	72.0

Figure 18. Total Phosphorus in Drainages to Blackmans Lake (November 2022–December 2023).



Total phosphorus concentrations in the sampled drainages ranged from 6.4 to 21 µg/L during base flow and from 8.6 to 186 µg/L during storm flow. Mean total phosphorus concentrations in these drainages ranged from 10 to 20 µg/L during base flow and from 32 to 68 µg/L during storm flow. Thus, base flow concentrations did not vary much between events or stations and were similar to or less than the range of 11 to 46 µg/L observed in the surface of Blackman’s Lake. Because base flow in the drainages is fed by shallow groundwater, these results indicate that shallow groundwater inputs to the lake are not a substantial source of total phosphorus to the lake and onsite septic systems are not a substantial source of total phosphorus in drainage to the lake.

Mean total phosphorus concentrations and overall variation were substantially greater during storm flow events than during base flow events at each station (Table 15; Figure 18). This pattern was observed for drainage from residential development in the Puget Sound region where median total phosphorus concentrations were 33 µg/L during base flow and 67 µg/L during storm flow, compared to drainage from forest/open space land use at 15 µg/L during base flow and 24 µg/L during storm flow (Herrera 2011). Thus, total phosphorus concentrations in drainage to Blackmans Lake are generally lower than those observed for residential development in the Puget Sound region and not much higher than those observed in forest and open space uses.

Comparing differences between stations, mean total phosphorus concentrations during base flow (see Table 15) increased in Blackmans Creek from 10.5 µg/L at the upstream station BLK-26 to 19.6 µg/L at the

northeast fork station BLK-NE, and decreased slightly to 16.2 µg/L at the downstream station BLK-22 due to input from the northwest fork, which represented less than about 20 percent of the combined base flow rate. Mean total phosphorus concentrations during base flow were also low in the Grass Bottom Creek basin (10.4 µg/L at CHAMP-PARK) and 19<sup>th</sup> Street basin (11.4 µg/L at CHAMP-19). These results indicate that groundwater inputs of phosphorus from watershed drainage were generally low overall but highest in the northeast basin of Blackmans Creek.

Mean total phosphorus concentrations during storm flow in Blackmans Creek decreased from 42.7 µg/L at the upstream station BLK-26 to 31.7 µg/L at the northeast fork station BLK-NE, and then increased to 49.8 µg/L at the downstream station BLK-22 due to higher concentrations in the northwest fork (see Table 15). Mean total phosphorus concentrations during storm flow were highest in the Grass Bottom Creek basin (68.3 µg/L at CHAMP-PARK) and moderate in the 19<sup>th</sup> Street basin (36.1 µg/L at CHAMP-19). These results indicate that stormwater inputs of phosphorus from watershed drainage were highest in the Grass Bottom Creek basin. However, stormwater phosphorus concentrations were not likely significantly different because the interquartile ranges (25th to 75th percentiles) overlapped (see Figure 18).

Currently, Washington State does not have surface water quality standards for total phosphorus in rivers and streams. The EPA recommended a nutrient criterion of 10 µg/L for total phosphorus in streams located in the Western Forested Mountains Ecoregion (EPA 2000), which these streams and outfalls frequently exceed.

## Inflow and Outflow Discharge

Figure 19 presents box and whisker plots of discharge measurements at each station for each storm flow and base flow monitoring events. As expected, the inflow tributary discharge was much higher during storm events than base flow events. Blackmans Creek (BLK-22 which is primarily comprised of flow from BLK-NE, which receives drainage upstream from BLK-26) and Grass Bottom Creek (CHAMP-PARK) together contributed the majority of tributary inflow to the lake. Grass Bottom Creek had lower base flow than Blackmans Creek but had similar rates of storm flow. This is likely driven by 1) the higher amount of impervious area in the Grass Bottom drainage and 2) upstream retention ponds which may infiltrate base flows and cause flows to follow a different groundwater flow path to the lake. In the Blackmans Creek basin, base and storm flow rates did not increase substantially downstream from the upstream station BLK-26 to the mouth of the northeast fork at station BLK-NE or the confluence of the northeast and northwest forks at station NE-22.

Figure 19. Inflow Discharge to Blackmans Lake (November 2022–December 2023).

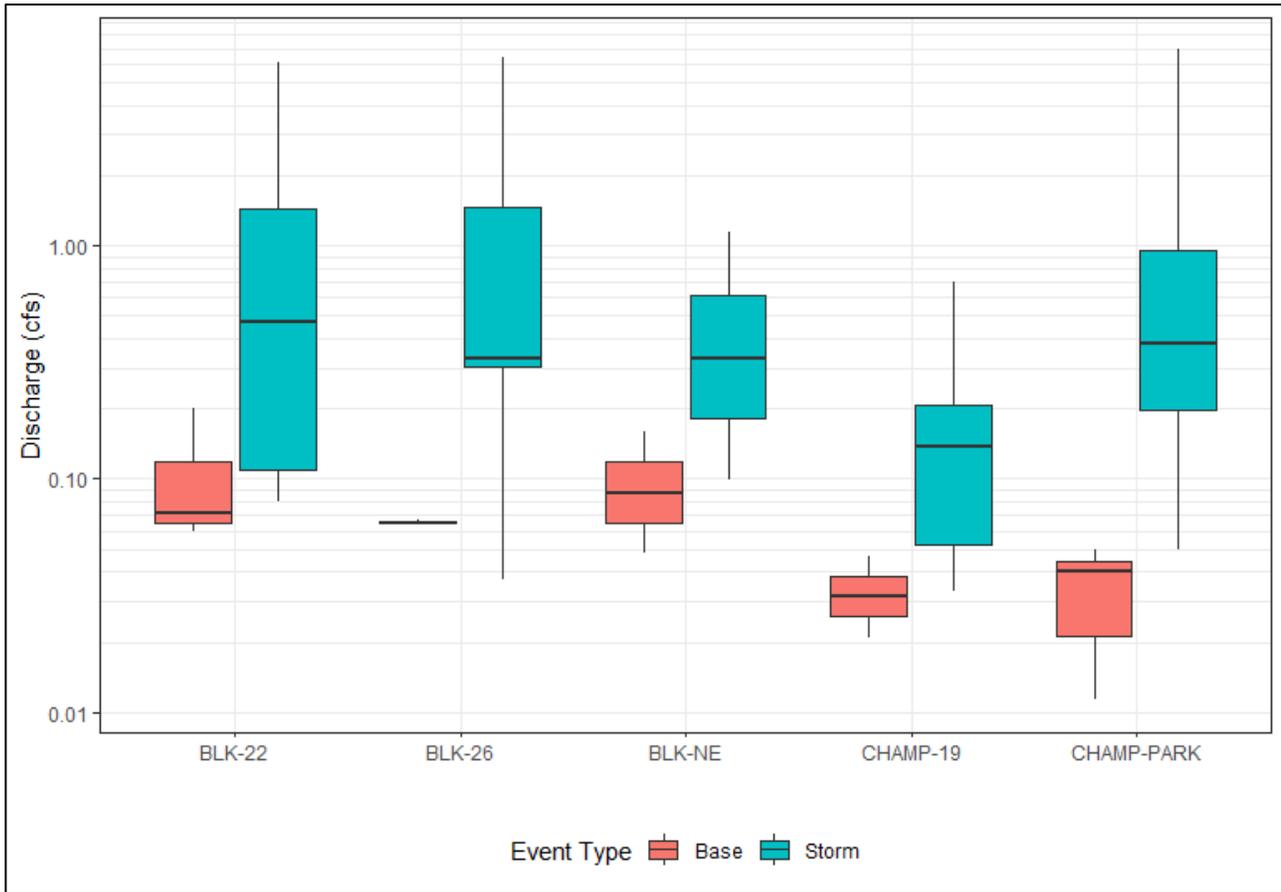
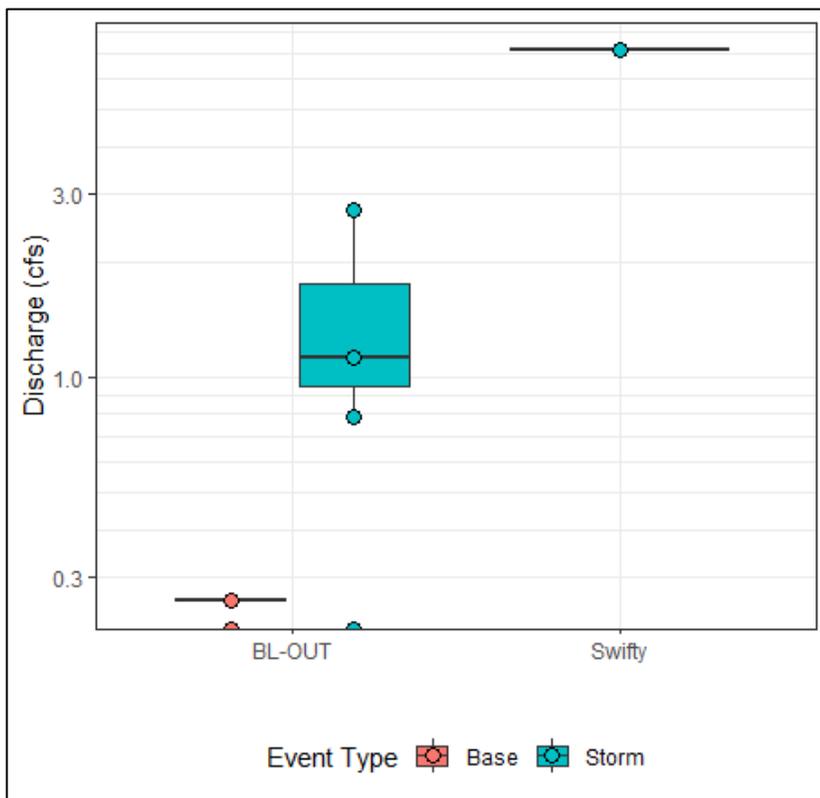


Figure 20 shows discharge measurements collected from the lake outlet (BLK-OUT) during all but one event where lake outflow was measured downstream in Swifty Creek. There was little to no lake outflow during the base flow sampling events. The median lake outflow rate of 1 cfs is similar to the sum of median lake inflows from Blackmans Creek (0.45 cfs at BL-22), Grass Bottom Creek (0.38 cfs at CHAMP-PARK), and drainage from the CHAMP-19 basin (0.13 cfs).

# Regulatory Criteria or Standards

Blackmans Lake’s designated uses include core summer salmonid habitat, primary contact recreation, water supply (domestic, industrial, agricultural), stock watering, wildlife habitat, harvesting, commerce and navigation, boating, and aesthetic values (WAC 173-201A). Toxic algae blooms can impair each of Blackmans Lake’s uses. Applicable Washington State surface water quality criteria to support these uses are listed in Table 16.

Figure 20. Outflow Discharge from Blackmans Lake (November 2022–December 2023).



**Table 16. Blackmans Lake Water Quality Criteria.**

Parameter	Water Quality Criteria
Temperature	Human actions considered cumulatively may not increase the 7-DADMax temperature more than 0.3°C (0.54°F) above natural conditions; remain below 16°C
Dissolved Oxygen	Human actions considered cumulatively may not decrease the dissolved oxygen concentration more than 0.2 mg/L below natural conditions; remain above 9.5 mg/L
pH	Within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units
Turbidity	5 NTU over background when the background is 50 NTU or less; or A 10 percent increase in turbidity when the background turbidity is more than 50 NTU
Fecal Bacteria ( <i>E. coli</i> )	<i>E. coli</i> organism levels must not exceed a geometric mean value of 100 CFU or MPN per 100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 320 CFU or MPN per 100 mL.

# Data Gaps

This section summarizes the data gaps identified in the characterization of water quality in Blackmans Lake. Collecting data to fill these gaps should be considered to inform continuing adaptive lake cyanobacteria management. Key data gaps include:

- Comprehensive and consistent lake water quality (including chemistry, biology, and physical conditions) data. Particularly:
  - pH measurements more frequently and throughout the water column
  - Orthophosphate, nitrate+nitrite, and ammonia more frequently in surface and bottom water samples
  - Chlorophyll-a in mid-depth and bottom water samples.
  - Measurements from November through April.
  - Regular (e.g., summer monthly) phytoplankton and zooplankton taxonomic composition and biomass data.
- Comprehensive and consistent stream water quality (including chemistry, biology, and physical conditions) data. Particularly:
  - pH, conductivity, temperature, and DO
  - Orthophosphate, nitrate+nitrite, and ammonia
  - Year-round flow rates
- Long-term comparative analysis of cyanotoxin concentrations and phytoplankton (cyanobacteria) compositions from samples collected throughout the year that are not limited to only scum or bloom samples, and include occasional observation and sampling for benthic cyanobacteria species.
- Quarterly estimates of groundwater flow and measurements of nutrient concentrations.
- Assessment of septic system contributions to nutrient inputs to the lake.
- Long-term and/or year-round waterfowl, lake usage, and fish harvest data.

Trophic cascade effects of stocked, native, and invasive fish on plankton communities are not well understood for Blackmans Lake or other Washington lakes. These impacts are difficult to monitor or to model. Conceptually, planktivorous fish that eat cyanobacteria-eating zooplankton may stimulate cyanobacteria blooms. Generally, cyanobacteria are not the preferred food source for most zooplankton. Population studies of fish and zooplankton in Blackmans Lake could help elucidate potential trophic cascade effects of stocked trout and other planktivorous fish in the lake.

# Summary and Interpretation

Blackmans Lake is a meso-eutrophic lake with high algal productivity. TSI values in 2023 agreed with contemporary TSI values, suggesting gradual, long-term eutrophication. Trend analysis by Snohomish County (2021) showed significantly decreasing water clarity, increasing total phosphorus, and chlorophyll-a). Meso-eutrophic conditions in Blackmans Lake are characterized by moderately high phosphorus concentrations, high algae growth, and moderate water clarity. Algae blooms in Blackmans Lake are not always toxic and rarely occur at levels which risk the health of humans or wildlife. Existing blooms are driven by an abundance of bioavailable nutrients and algae growth is typically limited by the amount of bioavailable phosphorus. Key evidence for these conditions, summarized from the monitoring data discussed above, include:

- Blackmans Lake undergoes summer thermal stratification from mid-May through late September, with particularly elevated surface temperatures in July and August, exceeding the EPA recommended maximum temperature for survival of juvenile trout (24°C).
- Anoxic conditions in the hypolimnion (>5 meters) were present throughout the monitoring period (May–October) and likely beyond.
- The greatest surface water clarity occurred in May and mid-July when chlorophyll-a at the surface was low.
- Summertime chlorophyll-a concentrations peaked in August and October, coinciding with reduced water clarity and elevated dissolved oxygen and nutrients, conditions indicative of algae blooms.
- Chlorophyll-a at the mouth of the Champagne Lane canal in nearshore waters of the lake generally aligned with concurrent conditions in the center of the lake but at higher concentrations during the fall bloom.
- Chlorophyll-a in 2023 was elevated in comparison to recent years, and cyanobacteria were typically the dominant taxa in terms of cell biovolume. However, scum reports and cyanotoxin concentrations (when measured) remained very low.
- Cyanobacteria accounted for 21–87 percent of phytoplankton biomass. All four cyanobacteria species identified are toxin-producers.
- Elevated summertime total phosphorus, orthophosphate, and total nitrogen concentrations in the hypolimnion were primarily caused by anoxic conditions.
- Undetected nitrate+nitrite in the lake suggests inorganic nitrogen is readily taken up by algae in the lake.
- The proportion of orthophosphate available for algae growth increased as summer stratification and anoxic conditions progressed through the summer season.
- Moderately high N:P ratios (>22) in the epilimnion indicate algae growth is limited by phosphorus at least in June through October. This suggests that phosphorus control, particularly during the summer months, is key to reducing algae and cyanobacteria blooms.

- Lake sediments are rich in phosphorus, more so in deep (> 5 meters) pelagic (central) region than in the shallow littoral (nearshore) region of the lake. The amount of iron relative to phosphorus is somewhat low in the deep sediments and very low in the shallow sediments. This indicates iron is likely sufficient to regulate phosphorus release from deep sediments but not from shallow sediments.
- The amount of free reactive (mobile) phosphorus is relatively high at about 45 percent of the total phosphorus in surface (0–10 cm) sediments, indicating abundant phosphorus available for sediment release and uptake by algae.
- Total phosphorus concentrations at watershed inflow monitoring locations were similar to concentrations at the lake surface. The low phosphorus concentrations in the sampled inflows suggest that watershed drainage is not a major source of phosphorus in the lake. Mean total phosphorus concentrations were greater during storm flow than during base flow conditions. These lines of evidence suggest stormwater runoff contributes to the lake's phosphorus load but may not be substantial compared to sources of internal of phosphorus loading to the lake.

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# Appendix B

## Field Sheets



Lake: Blackmans Date: 10/30/22 Time: 1500  
 Name(s): Rob Zisette

Staff Use Only  
 Entered   
 Verified

### WEATHER CONDITIONS

Air Temperature 12 °C 53°F  
 Water Temperature (~6 inches deep) 12 °C  
 Collected with: thermometer DO probe est.  
No DO/temp meter  
 Percent Cloud Cover  
 0%  10%  25%  50%  75%  90%  100%  
 Current Wind Conditions  
 calm  light  breezy  strong  
 (ripples) (small waves) (white caps)  
 Rain within last 2 days  
 none  slight  moderate  heavy

### WATER CLARITY

Secchi Disk  
 Repeat until readings are within 0.1 meter  
 1<sup>st</sup> Secchi Reading 1.9 meters  
 2<sup>nd</sup> Secchi Reading 2.0 meters  
 \*Did Secchi disk:  hit bottom?  enter weeds?  
 (leave blank if neither)

### ALGAE

Heavy Algae in Water?  Yes  No  
 (Use Secchi disk to assess 6-12 inches below surface)  
 Filamentous Algae Observed?  Yes  No  
 (Mats of stringy algae - does not dissipate if disturbed)  
 Algae Scum Observed?  Yes  No  
 (Looks like paint floating on surface - dissipates if disturbed)  
 Scum Type:  small clumps  light film  thick scum  
 Sample Taken:  Yes  No Location: \_\_\_\_\_

### LAKE LEVEL

Lake Level: \_\_\_\_\_ Unit: \_\_\_\_\_ (inches or feet)  
 (taken from established fixed point at shoreline or dock)  
 County Staff Plate: \_\_\_\_\_ feet

### WATER COLOR

Water Color  
 (Lower disk to half of today's Secchi depth to identify color)  
 Intensity:  light  moderate  dark  
 Tint:  green  brown  red  orange  
 yellow  green yellow  green brown  
 yellow brown  other \_\_\_\_\_

### WATER SAMPLES

Water Samples Collected:  Yes  No  
 Samples Collected & Labeled:  
 TP/TPN/Color - 1 meter  
 Chlorophyll a - 1 meter  
 TP - 7.9 meters  
 (1 meter from bottom)  
 Chain of Custody  
 Relinquished by \_\_\_\_\_  
 Sign: \_\_\_\_\_  
 Date: \_\_\_\_\_

Odor in Bottom Sample? (rotten egg)  Yes  No

### OTHER OBSERVATIONS

# of Waterfowl: 150 mostly at Park  
 ducks: 200 geese: 100 swans: 0 beach  
 # other Loons type(s): 810

Recreational Lake Usage:  
 # of boats: 0 # of people fishing: 0  
 # of swimmers/waders: 0

Recreational Suitability (disregard poor weather):

- 1 - beautiful could not be nicer
- 2 - minor aesthetic concerns
- 3 - swimming & boating slightly impaired
- 4 - swimming, boating & aesthetic enjoyment substantially impaired (would not swim, but boating ok)
- 5 - swimming, boating & aesthetic enjoyment are severely limited (would not swim or boat in lake)

### COMMENTS

(Provide additional comments for aquatic plants, odors, wildlife, pollution, equipment issues, etc - continued on back)  
Sampled 40 m SE of Anthony's position because it is deeper. Max depth = 8.0 m

Flagged Blackman's Creek inflow on E side of fence in lake

## BLACKMANS LAKE WATERSHED MONITORING FORM

PROJECT: Blackmans Lake Cyanobacteria Management Plan PROJECT NO.: 22-07905-000

CLIENT: City of Snohomish FIELD PERSONNEL: COZY MORTON, DAN HOTO

DATE AND EVENT TYPE/NUMBER: 12/8/2022 Storm 1 Base \_\_\_\_\_

WEATHER/RAIN AMOUNTS: \_\_\_\_\_

### SAMPLING DATA

SITE ID	PHOSPHORUS SAMPLE ID	SAMPLE TIME	DUPLICATE?	PHOTO(S) TAKEN?	WATER DESCRIPTION (TURBIDITY; UNUSUAL COLOR, ODOR, SHEEN)
BLK-26	BLK-26	12:26			
BLK-22	BLK-22	12:47			
BLK-NE	BLK-NE	2:25			
CHAMP-19	CHAMP-19	1:16			
CHAMP-PARK	CHAMP-PARK	1:27			

### DISCHARGE DATA

SITE ID	MEASURE LOCATION	WATER DEPTH (FT)*	VELOCITY (FT/SEC)*	CALC. FLOW (CFS)	OBSERVATIONS
BLK-26	24" pipe outfall to narrow channel	1: .46 2: .41 3: .33	1: .65 2: .57 3: .36		Total width (ft)= 2'
BLK-22	24" pipe outfall	.12	6.17		
BLK-NE	East ditch	.24	2.57		% of BLK-22 flow= 70% TW 3.1'
CHAMP-19	Narrow ditch	.17	.29		Total width (ft)= 1.35
CHAMP-PARK	24" E inlet pipe	.20	1.11		% of total from S pipe= 0
BL-GAUGE	Hill Park Dock	.345	NA	NA	
BL-OUT	4-24" pipes				

\*mean depth and velocity unless otherwise noted

BL-OUT DISCHARGE IN FOUR PIPES			SWIFTY CREEK DISCHARGE CHANNEL WIDTH = FEET							
Pipe	Depth (ft) from top of pipe	Velocity (f/s) at center	Point	Feet to bank	Depth* (ft)	Velocity (f/s)	Point	Feet to bank	Depth* (ft)	Velocity (f/s)
1 W	.73	.27	1				5			
2	.6	.21	2				6			
3	.46	.23	3				7			
4 E	.71	.20	4				8			
CALC FLOW (CFS)= _____			CALC FLOW (CFS)= _____							

NOTES:

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# BLACKMANS LAKE WATERSHED MONITORING FORM

PROJECT: Blackmans Lake Cyanobacteria Management Plan PROJECT NO.: 22-07905-000

CLIENT: City of Snohomish FIELD PERSONNEL: CORY MORTON, DAN HOTOVITSKY

DATE AND EVENT TYPE/NUMBER: 1/12/2023 Storm 2 Base

WEATHER/RAIN AMOUNTS: RAINING

## SAMPLING DATA

SITE ID	PHOSPHORUS SAMPLE ID	SAMPLE TIME	DUPLICATE?	PHOTO(S) TAKEN?	WATER DESCRIPTION (TURBIDITY; UNUSUAL COLOR, ODOR, SHEEN)
BLK-26	BLK-26	8:50			
BLK-22	BLK-22	8:55			
BLK-NE	BLK-NE	8:58			
CHAMP-19	CHAMP-19	9:06			
CHAMP-PARK	CHAMP-PARK	9:19			

## DISCHARGE DATA

SITE ID	MEASURE LOCATION	WATER DEPTH (FT)*	VELO-CITY (FT/SEC)*	CALC. FLOW (CFS)	OBSERVATIONS
BLK-26	24" pipe outfall to narrow channel	1: 0.30 2: .52 3: .65	1: 0.81 2: 1.15 3: 1.07		Total width (ft) = 30"
BLK-22	24" pipe outfall	0.24	6.70		
BLK-NE	East ditch				% of BLK-22 flow = 80
CHAMP-19	Narrow ditch	0.16	1.89		Total width (ft) = 1.4'
CHAMP-PARK	24" E inlet pipe	0.40	2.58		% of total from S pipe = 0. BACKWATER
BL-GAUGE	Hill Park Dock	3.68	NA	NA	
BL-OUT	4-24" pipes				

\*mean depth and velocity unless otherwise noted

BL-OUT DISCHARGE IN FOUR PIPES				SWIFTY CREEK DISCHARGE CHANNEL WIDTH = FEET							
Pipe	Depth (ft) from top of pipe	Velocity (f/s) at center	Point	Feet to bank	Depth* (ft)	Velocity (f/s)	Point	Feet to bank	Depth* (ft)	Velocity (f/s)	
1 W	0.76	0.81	1				5				
2	0.6	0.98	2				6				
3	0.7	1.12	3				7				
4 E	0.77	0.95	4				8				

CALC FLOW (CFS) = \_\_\_\_\_ CALC FLOW (CFS) = \_\_\_\_\_

NOTES: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

# BLACKMANS LAKE WATERSHED MONITORING FORM

PROJECT: Blackmans Lake Cyanobacteria Management Plan PROJECT No.: 22-07905-000

CLIENT: City of Snohomish FIELD PERSONNEL: Corey Morton/Dan Hotovitsky

DATE AND EVENT TYPE/NUMBER: 4/10/2023 Storm Base

WEATHER/RAIN AMOUNTS: Rain-After Heavy Nightly Rain

## SAMPLING DATA

SITE ID	PHOSPHORUS SAMPLE ID	SAMPLE TIME	DUPLI-CATE?	PHOTO(S) TAKEN?	WATER DESCRIPTION (TURBIDITY; UNUSUAL COLOR, ODOR, SHEEN)
BLK-26	BLK-26	8:40 am			
BLK-22	BLK-22	8:50 am			
BLK-NE	BLK-NE	8:50am			
CHAMP-19	CHAMP-19	9:00 am			
CHAMP-PARK	CHAMP-PARK	9:08 am			

## DISCHARGE DATA

SITE ID	MEASURE LOCATION	WATER DEPTH (FT)*	VELO-CITY (FT/SEC)*	CALC. FLOW (CFS)	OBSERVATIONS
BLK-26	24" pipe outfall to narrow channel	1: .38 2: .37 3: .33	1: .59 2: .56 3: .52		Total width (ft)= 24"
BLK-22	24" pipe outfall	.17	.75		
BLK-NE	East ditch				% of BLK-22 flow= 90% E-10% W
CHAMP-19	Narrow ditch	.16	.33		Total width (ft)= 1.6
CHAMP-PARK	24" E inlet pipe	.28	2.08		% of total from S pipe= 0
BL-GAUGE	Hill Park Dock	3.50	NA	NA	
BL-OUT	4-24" pipes				

\*mean depth and velocity unless otherwise noted

BL-OUT DISCHARGE IN FOUR PIPES				SWIFTY CREEK DISCHARGE CHANNEL WIDTH = _____ FEET							
Pipe	Depth (ft) from top of pipe	Velocity (f/s) at center	Point	Feet to bank	Depth* (ft)	Velocity (f/s)	Point	Feet to bank	Depth* (ft)	Velocity (f/s)	
1 W	.73	.31	1				5				
2	.60	.30	2				6				
3	.50	.35	3				7				
4 E	.71	.34	4				8				

CALC FLOW (CFS)= \_\_\_\_\_                      CALC FLOW (CFS)= \_\_\_\_\_

NOTES: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

# BLACKMANS LAKE WATERSHED MONITORING FORM

PROJECT: Blackmans Lake Cyanobacteria Management Plan PROJECT NO.: 22-07905-000

CLIENT: City of Snohomish FIELD PERSONNEL: CORY MORTON

DATE AND EVENT TYPE/NUMBER: 9-27-2023 Storm Base

WEATHER/RAIN AMOUNTS: RAIN, ~ 0.4 INCHES SINCE MIDNIGHT

## SAMPLING DATA

SITE ID	PHOSPHORUS SAMPLE ID	SAMPLE TIME	DUPLICATE?	PHOTO(S) TAKEN?	WATER DESCRIPTION (TURBIDITY; UNUSUAL COLOR, ODOR, SHEEN)
BLK-26	BLK-26	9:30			
BLK-22	BLK-22	1000			
BLK-NE	BLK-NE	-			
CHAMP-19	CHAMP-19	10:15			
CHAMP-PARK	CHAMP-PARK	10:25			

## DISCHARGE DATA

SITE ID	MEASURE LOCATION	WATER DEPTH (FT)*	VELO-CITY (FT/SEC)*	CALC. FLOW (CFS)	OBSERVATIONS
BLK-26	24" pipe outfall to narrow channel	1: .23 2: .22 3: .20	1: .49 2: .16 3: 0		Total width (ft)= 1'
BLK-22	24" pipe outfall	.05	~3		
BLK-NE	East ditch	0	0		% of BLK-22 flow= 0
CHAMP-19	Narrow ditch	.15	1.57		Total width (ft)= 1.6
CHAMP-PARK	24" E inlet pipe	.21	1.40		% of total from S pipe= 0
BL-GAUGE	Hill Park Dock	2.19	NA	NA	
BL-OUT	4-24" pipes	-	-		2' Below 10' etc

\*mean depth and velocity unless otherwise noted

BL-OUT DISCHARGE IN FOUR PIPES				SWIFTY CREEK DISCHARGE CHANNEL WIDTH = FEET							
Pipe	Depth (ft) from top of pipe	Velocity (f/s) at center	Point	Feet to bank	Depth* (ft)	Velocity (f/s)	Point	Feet to bank	Depth* (ft)	Velocity (f/s)	
1 W			1				5				
2			2				6				
3			3				7				
4 E			4				8				

CALC FLOW (CFS)= \_\_\_\_\_ CALC FLOW (CFS)= \_\_\_\_\_

NOTES: NO FLOW FROM BLK-NE. UNABLE TO MEASURE FLOW VELO IN BLK-22 DUE TO LOW WATER DEPTH.

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# BLACKMANS LAKE WATERSHED MONITORING FORM

PROJECT: Blackmans Lake Cyanobacteria Management Plan PROJECT NO.: 22-07905-000

CLIENT: City of Snohomish FIELD PERSONNEL: Cory Morton

DATE AND EVENT TYPE/NUMBER: 10-11-2023 Storm  Base

WEATHER/RAIN AMOUNTS: ~0.2 in of rainfall since midnight

## SAMPLING DATA

SITE ID	PHOSPHORUS SAMPLE ID	SAMPLE TIME	DUPLI-CATE?	PHOTO(S) TAKEN?	WATER DESCRIPTION (TURBIDITY; UNUSUAL COLOR, ODOR, SHEEN)
BLK-26	BLK-26	9:05		Y	
BLK-22	BLK-22	9:15			SAMPLE FROM POOL DUE TO NO FLOW
BLK-NE	BLK-NE	-			
CHAMP-19	CHAMP-19	9:25			
CHAMP-PARK	CHAMP-PARK	9:30			

## DISCHARGE DATA

SITE ID	MEASURE LOCATION	WATER DEPTH (FT)*	VELO-CITY (FT/SEC)*	CALC. FLOW (CFS)	OBSERVATIONS
BLK-26	24" pipe outfall to narrow channel	1: 2: 0.05 3:	1: 2: 0.50 3:		Total width (ft) = 1' LOW DEPTH & VELO. UNABLE TO MEASURE w/ SWOFFER
BLK-22	24" pipe outfall	-	-		NO FLOW
BLK-NE	East ditch	-	-		% of BLK-22 flow = NO FLOW
CHAMP-19	Narrow ditch	.16	.77		Total width (ft) = 1.6'
CHAMP-PARK	24" E inlet pipe	.11	.70		% of total from S pipe =
BL-GAUGE	Hill Park Dock	2.32	NA	NA	
BL-OUT	4-24" pipes	-	-		NO FLOW, 1.5' BELOW WEIR

\*mean depth and velocity unless otherwise noted

BL-OUT DISCHARGE IN FOUR PIPES			SWIFTY CREEK DISCHARGE CHANNEL WIDTH = FEET							
Pipe	Depth (ft) from top of pipe	Velocity (f/s) at center	Point	Feet to bank	Depth* (ft)	Velocity (f/s)	Point	Feet to bank	Depth* (ft)	Velocity (f/s)
1 W			1				5			
2			2				6			
3			3				7			
4 E			4				8			

CALC FLOW (CFS)= \_\_\_\_\_ CALC FLOW (CFS)= \_\_\_\_\_

NOTES: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_



# BLACKMANS LAKE WATERSHED MONITORING FORM

PROJECT: Blackmans Lake Cyanobacteria Management Plan PROJECT NO.: 22-07905-000

CLIENT: City of Snohomish FIELD PERSONNEL: CORY MORTON

DATE AND EVENT TYPE/NUMBER: 12/5/23 Storm X Base

WEATHER/RAIN AMOUNTS: ~1.4" RAIN IN LAST 24 HRS

### SAMPLING DATA

SITE ID	PHOSPHORUS SAMPLE ID	SAMPLE TIME	DUPLI-CATE?	PHOTO(S) TAKEN?	WATER DESCRIPTION (TURBIDITY; UNUSUAL COLOR, ODOR, SHEEN)
BLK-26	BLK-26	10:00			
BLK-22	BLK-22	10:10			
BLK-NE	BLK-NE	10:10			
CHAMP-19	CHAMP-19	10:25			
CHAMP-PARK	CHAMP-PARK	10:35			

### DISCHARGE DATA

SITE ID	MEASURE LOCATION	WATER DEPTH (FT)*	VELO-CITY (FT/SEC)*	CALC. FLOW (CFS)	OBSERVATIONS
BLK-26	24" pipe outfall to narrow channel	1: 1.11 2: 1.05 3: 0.92	1: 2.36 2: 3.37 3: 2.56		Total width (ft) = 3'
BLK-22	24" pipe outfall	0.73	5.73		
BLK-NE	East ditch				% of BLK-22 flow = 80% from NE
CHAMP-19	Narrow ditch	0.50	1.55		Total width (ft) = 1.8'
CHAMP-PARK	24" E inlet pipe	0.94	4.76		% of total from S pipe =
BL-GAUGE	Hill Park Dock	3.85	NA	NA	
BL-OUT	4-24" pipes	1.51 1.30	3.9 1.32	1.56 6.99	See below 15'

\*mean depth and velocity unless otherwise noted

BL-OUT DISCHARGE IN FOUR PIPES				SWIFTY CREEK DISCHARGE CHANNEL WIDTH = 15 FEET						
Pipe	Depth (ft) from top of pipe	Velocity (f/s) at center	Point	Feet to bank	Depth* (ft)	Velocity (f/s)	Point	Feet to bank	Depth* (ft)	Velocity (f/s)
1 W			1	3	0.51	1.30	5			
2			2	7.5	0.39	1.32	6			
3			3	13	0.56	0.99	7			
4 E			4				8			
CALC FLOW (CFS) = _____				CALC FLOW (CFS) = _____						

NOTES: Unable to reach Blackmans lake outlet pipes due to water level. Took flow readings over weir.



# BLACKMANS LAKE WATERSHED MONITORING FORM

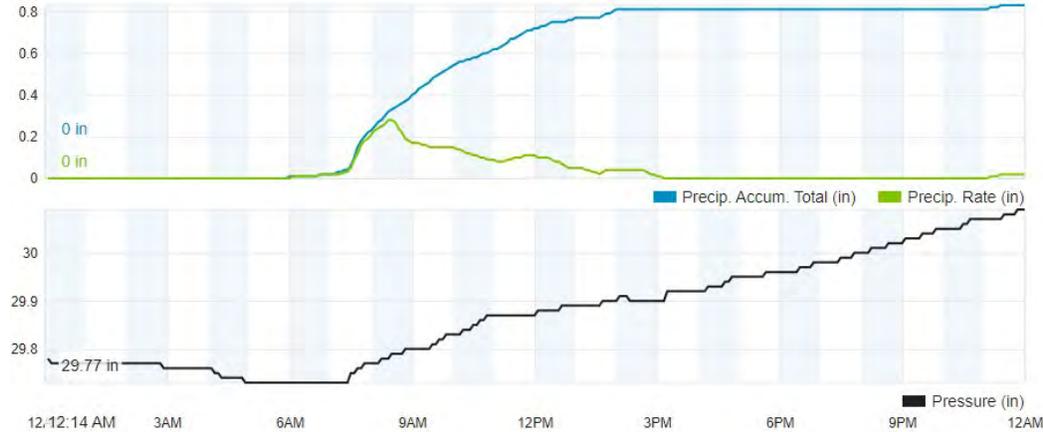
PROJECT: Blackmans Lake Cyanobacteria Management Plan PROJECT No.: 22-07905-000

CLIENT: City of Snohomish FIELD PERSONNEL: Rob Zisette

DATE AND EVENT TYPE/NUMBER: Storm 7 on 12-22-2023

WEATHER/RAIN AMOUNTS: Rain =0.81 inches from 0730-1400; lake gauge at 1504, outflow monitoring at 1525-1545

## RAIN DATA



**Weather underground station KWASNOHO436-Patty n Bill on 19<sup>th</sup> (Canal) for 12-22-2023**

<https://www.wunderground.com/dashboard/pws/KWASNOHO436/graph/2023-12-22/2023-12-22/daily>

## DISCHARGE DATA

SITE ID	MEASURE LOCATION	WATER DEPTH (FT)*	VELO-CITY (FT/SEC)*	CALC. FLOW (CFS)	OBSERVATIONS
BLK-26	24" pipe outfall to narrow channel	1: 2: 3:	1: 2: 3:		Total width (ft)=
BLK-22	24" pipe outfall				
BLK-NE	East ditch				% of BLK-22 flow=
CHAMP-19	Narrow ditch				Total width (ft)=
CHAMP-PARK	24" E inlet pipe				% of total from S pipe=
BL-GAUGE	Hill Park Dock	3.46	NA	NA	Ft gauge on dock at 1504 hours
BL-OUT	4-24" pipes				Pipes underwater and flowing but difficult to measure depth or velocity (see notes)

\*mean depth and velocity unless otherwise noted

BL-OUT DISCHARGE IN FOUR PIPES				SWIFTY CREEK DISCHARGE CHANNEL WIDTH = 14.7 FT FEET						
Pipe	Depth (ft) from top of pipe	Velocity (f/s) at center	Point	Feet to bank	Depth* (ft)	Velocity (f/s)	Point	Feet to bank	Depth* (ft)	Velocity (f/s)
1 W			1				5			
2			2				6			
3			3				7			
4 E			4				8			
CALC FLOW (CFS)= _____				CALC FLOW (CFS)= <u>3.5</u> OVER EARTHEN WEIR INTO CREEK						

*jb https://herrerainc.sharepoint.com/teams/22-07905-000-internaldocs/shared%20documents/internal%20docs/project-files/task3.0-monitoring/data-calcs/stormevent7-outlow-20231222/blackmanswatershed\_fieldform-12-22-2023.docx*

NOTES:

**Velocity at Depth Method**

Enter Prop. Assembly Number (0 = no correction):	0
Select Desired Output Units:	cfs

Clear		Discharge			3.446
Distance (ft)	Depth (ft)	Velocity (ft/s)	Corrected Velocity (ft/s)	Discharge (ft <sup>3</sup> /s)	
1.8	0.00	0.00	0.00	0.000	
2	0.15	0.00	0.00	0.000	
3	0.08	0.85	0.85	0.068	
4	0.32	1.55	1.55	0.496	
5	0.18	1.65	1.65	0.297	
6	0.15	1.32	1.32	0.198	
7	0.10	0.63	0.63	0.063	
8	0.05	0.20	0.20	0.010	
9	0.12	1.78	1.78	0.214	
10	0.15	1.99	1.99	0.299	
11	0.12	1.65	1.65	0.198	
12	0.08	1.00	1.00	0.060	
12.5	0.08	1.75	1.75	0.070	
13	0.07	1.42	1.42	0.075	
14	0.22	2.26	2.26	0.373	
14.5	0.22	3.30	3.30	0.363	
15	0.21	3.25	3.25	0.341	
15.5	0.12	2.50	2.50	0.150	
16	0.13	2.65	2.65	0.172	
16.5	0.00	0.00	0.00	0.000	
			0.00	0.000	

MEASURED FLOW USING HERRERA'S SWOFFER METER THAT WAS USED FOR ENTIRE PROJECT AND RECENTLY RETURNED BY CITY OF SNOHOMISH. PROPELLER #1 BLOW COUNT OF 327 (LOW); CALIBRATION VALUE = 186 (STANDARD). CROSS-SECTION STRUNG ACROSS WEIR FROM 1.8 TO 16.5 FEET WETTED WIDTH ON MEASURING TAPE (SEE PHOTO). OBSERVED DOWNSTREAM FLOW AT CULVERT TOO MANY BLACKBERRIES TO ACCESS

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# Appendix C

## Laboratory Data Reports

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# IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	1735884	<b>PAGE 1</b>
<b>REPORT DATE:</b>	12/02/22	
<b>DATE SAMPLED:</b>	10/30/22	<b>DATE RECEIVED:</b> 10/31/22
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Two water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL - 1S	0.036	8.0	6.0
BL - 1B	0.039		



# IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1735884</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>12/02/22</b>	
<b>DATE SAMPLED:</b>	<b>10/30/22</b>	<b>DATE RECEIVED:</b> <b>10/31/22</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
METHOD	SM18 4500PF	SM1810200H	SM1810200H
DATE ANALYZED	11/07/22	11/04/22	11/04/22
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BL - 1S	BL - 1S
ORIGINAL	0.005	8.0	6.0
DUPLICATE	0.005	8.3	5.2
RPD	1.62%	4.08%	14.29%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.005		
SPIKED SAMPLE	0.055		
SPIKE ADDED	0.050		
% RECOVERY	100.96%	NA	NA
QC CHECK			
FOUND	0.096		
TRUE	0.094		
% RECOVERY	102.13%	NA	NA
BLANK	<0.002	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.  
NA = NOT APPLICABLE OR NOT AVAILABLE.  
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



# IEH ANALYTICAL LABORATORIES

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3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1736090</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>12/02/22</b>	
<b>DATE SAMPLED:</b>	<b>11/09/22</b>	<b>DATE RECEIVED:</b> <b>11/09/22</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Five water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)
BLK-26	0.013
BLK-22	0.017
BLK-NE	0.020
CHAMP-19	0.019
CHAMP-PARK	0.014



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<b>CASE FILE NUMBER:</b>	<b>1736090</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>12/02/22</b>	
<b>DATE SAMPLED:</b>	<b>11/09/22</b>	<b>DATE RECEIVED: 11/09/22</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)
METHOD	SM18 4500PF
DATE ANALYZED	11/14/22
DETECTION LIMIT	0.002
DUPLICATE	
SAMPLE ID	BATCH
ORIGINAL	0.086
DUPLICATE	0.090
RPD	4.51%
SPIKE SAMPLE	
SAMPLE ID	BATCH
ORIGINAL	0.086
SPIKED SAMPLE	0.136
SPIKE ADDED	0.050
% RECOVERY	100.31%
QC CHECK	
FOUND	0.098
TRUE	0.094
% RECOVERY	104.26%
BLANK	<0.002

RPD = RELATIVE PERCENT DIFFERENCE.  
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NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	1736167	<b>PAGE 1</b>
<b>REPORT DATE:</b>	12/02/22	
<b>DATE SAMPLED:</b>	11/13/22	<b>DATE RECEIVED:</b> 11/14/22
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL-1-1		10	3.2
BL-1-1	0.046		
BLK-MTH	0.061		



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<b>CASE FILE NUMBER:</b>	1736167	<b>PAGE 1</b>
<b>REPORT DATE:</b>	12/02/22	
<b>DATE SAMPLED:</b>	11/13/22	<b>DATE RECEIVED:</b> 11/14/22
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL-1-1		10	3.2
BL-1-1	0.046		
BLK-MTH	0.061		



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<b>CASE FILE NUMBER:</b>	<b>1736167</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>12/02/22</b>	
<b>DATE SAMPLED:</b>	<b>11/13/22</b>	<b>DATE RECEIVED: 11/14/22</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
METHOD	SM18 4500PF	SM1810200H	SM1810200H
DATE ANALYZED	11/21/22	11/16/22	11/16/22
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.018	4.0	6.7
DUPLICATE	0.018	3.3	5.8
RPD	3.64%	18.18%	15.47%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.018		
SPIKED SAMPLE	0.071		
SPIKE ADDED	0.050		
% RECOVERY	107.37%	NA	NA
QC CHECK			
FOUND	0.098		
TRUE	0.094		
% RECOVERY	104.26%	NA	NA
BLANK	<0.002	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.  
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 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
 Laboratory Manager



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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	1736564	<b>PAGE 1</b>
<b>REPORT DATE:</b>	12/19/22	
<b>DATE SAMPLED:</b>	12/08/22	<b>DATE RECEIVED:</b> 12/08/22
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Five water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)
BLK-26	0.009
BLK-22	0.013
BLK-NE	0.011
CHAMP-19	0.014
CHAMP-PARK	0.011



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<b>CASE FILE NUMBER:</b>	1736564	<b>PAGE 2</b>
<b>REPORT DATE:</b>	12/19/22	
<b>DATE SAMPLED:</b>	12/08/22	<b>DATE RECEIVED:</b> 12/08/22
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM CITY OF SNOHOMISH</b>		

## QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)
METHOD	SM18 4500PF
DATE ANALYZED	12/12/22
DETECTION LIMIT	0.002
DUPLICATE	
SAMPLE ID	BATCH
ORIGINAL	0.063
DUPLICATE	0.064
RPD	1.53%
SPIKE SAMPLE	
SAMPLE ID	BATCH
ORIGINAL	0.063
SPIKED SAMPLE	0.114
SPIKE ADDED	0.050
% RECOVERY	102.29%
QC CHECK	
FOUND	0.095
TRUE	0.094
% RECOVERY	101.06%
BLANK	<0.002

RPD = RELATIVE PERCENT DIFFERENCE.  
NA = NOT APPLICABLE OR NOT AVAILABLE.  
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OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1736690</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>12/30/22</b>	
<b>DATE SAMPLED:</b>	<b>12/14/22</b>	<b>DATE RECEIVED:</b> <b>12/15/22</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL-1-1		6.3	2.3
BL-1-1	0.028		
BL-1-1 Dup	0.028		



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<b>CASE FILE NUMBER:</b>	<b>1736690</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>12/30/22</b>	
<b>DATE SAMPLED:</b>	<b>12/14/22</b>	<b>DATE RECEIVED:</b> <b>12/15/22</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
METHOD	SM18 4500PF	SM1810200H	SM1810200H
DATE ANALYZED	12/19/22	12/28/22	12/28/22
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BL-1-1	BL-1-1
ORIGINAL	0.010	6.3	2.3
DUPLICATE	0.009	6.3	2.8
RPD	5.11%	0.00%	18.42%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.010		
SPIKED SAMPLE	0.059		
SPIKE ADDED	0.050		
% RECOVERY	97.65%	NA	NA
QC CHECK			
FOUND	0.100		
TRUE	0.094		
% RECOVERY	106.38%	NA	NA
BLANK	<0.002	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.  
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NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



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<b>CASE FILE NUMBER:</b>	<b>1737082</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>01/25/23</b>	
<b>DATE SAMPLED:</b>	<b>01/12/23</b>	<b>DATE RECEIVED: 01/12/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Five water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)
BLK-26	0.016
BLK-22	0.031
BLK-NE	0.026
CHAMP-19	0.021
CHAMP-PARK	0.022



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<b>CASE FILE NUMBER:</b>	<b>1737082</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>01/25/23</b>	
<b>DATE SAMPLED:</b>	<b>01/12/23</b>	<b>DATE RECEIVED:</b> <b>01/12/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)
METHOD	SM18 4500PF
DATE ANALYZED	01/17/23
DETECTION LIMIT	0.002
DUPLICATE	
SAMPLE ID	CHAMP-PARK
ORIGINAL	0.022
DUPLICATE	0.021
RPD	2.38%
SPIKE SAMPLE	
SAMPLE ID	CHAMP-PARK
ORIGINAL	0.022
SPIKED SAMPLE	0.072
SPIKE ADDED	0.050
% RECOVERY	101.45%
QC CHECK	
FOUND	0.099
TRUE	0.094
% RECOVERY	105.32%
BLANK	<0.002

RPD = RELATIVE PERCENT DIFFERENCE.  
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OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	1737317	<b>PAGE 1</b>
<b>REPORT DATE:</b>	01/31/23	
<b>DATE SAMPLED:</b>	01/22/23	<b>DATE RECEIVED:</b> 01/23/23
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Two water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL 1-1		7.3	2.9
BL 1-1	0.022		



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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1737317</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>01/31/23</b>	
<b>DATE SAMPLED:</b>	<b>01/22/23</b>	<b>DATE RECEIVED:</b> <b>01/23/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
METHOD	SM18 4500PF	SM1810200H	SM1810200H
DATE ANALYZED	01/30/23	01/27/23	01/27/23
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.004	48	6.7
DUPLICATE	0.004	49	6.6
RPD	2.10%	3.31%	1.61%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.004		
SPIKED SAMPLE	0.053		
SPIKE ADDED	0.050		
% RECOVERY	98.77%	NA	NA
QC CHECK			
FOUND	0.097		
TRUE	0.094		
% RECOVERY	103.19%	NA	NA
BLANK	<0.002	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.  
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OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1737808</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>02/21/23</b>	
<b>DATE SAMPLED:</b>	<b>02/14/23</b>	<b>DATE RECEIVED: 02/15/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL-1-1		14	2.6
BL-1-1	0.026		
BLK-MTH	0.034		



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**CASE FILE NUMBER:** 1737808 **PAGE 2**  
**REPORT DATE:** 02/21/23  
**DATE SAMPLED:** 02/14/23 **DATE RECEIVED:** 02/15/23  
**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM CITY OF SNOHOMISH**

## QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
METHOD	SM18 4500PF	SM1810200H	SM1810200H
DATE ANALYZED	02/20/23	02/17/23	02/17/23
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.007	0.9	3.1
DUPLICATE	0.008	0.9	3.3
RPD	5.52%	0.00%	6.57%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.007		
SPIKED SAMPLE	0.062		
SPIKE ADDED	0.050		
% RECOVERY	109.97%	NA	NA
QC CHECK			
FOUND	0.098		
TRUE	0.094		
% RECOVERY	104.26%	NA	NA
BLANK	<0.002	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.  
NA = NOT APPLICABLE OR NOT AVAILABLE.  
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



# IEH ANALYTICAL LABORATORIES

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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	1738877	<b>PAGE 1</b>
<b>REPORT DATE:</b>	03/30/23	
<b>DATE SAMPLED:</b>	03/17/23	<b>DATE RECEIVED:</b> 03/17/23
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

One water sample was received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of this sample. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL-1-1	0.016	13	9.7



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<b>CASE FILE NUMBER:</b>	1738877	<b>PAGE 2</b>
<b>REPORT DATE:</b>	03/30/23	
<b>DATE SAMPLED:</b>	03/17/23	<b>DATE RECEIVED:</b> 03/17/23
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM CITY OF SNOHOMISH</b>		

## QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
METHOD	SM18 4500PF	SM1810200H	SM1810200H
DATE ANALYZED	03/27/23	03/24/23	03/24/23
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BL-1-1	BL-1-1
ORIGINAL	0.032	13	9.7
DUPLICATE	0.033	11	8.3
RPD	1.72%	11.11%	16.30%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.032		
SPIKED SAMPLE	0.079		
SPIKE ADDED	0.050		
% RECOVERY	92.86%	NA	NA
QC CHECK			
FOUND	0.092		
TRUE	0.094		
% RECOVERY	97.87%	NA	NA
BLANK	<0.002	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.  
NA = NOT APPLICABLE OR NOT AVAILABLE.  
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



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<b>CASE FILE NUMBER:</b>	<b>1739087</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>04/04/23</b>	
<b>DATE SAMPLED:</b>	<b>03/29/23</b>	<b>DATE RECEIVED: 03/29/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Five water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)
BLK-26	0.009
BLK-22	0.019
BLK-NE	0.018
CHAMP-19	0.009
CHAMP-PARK	0.010



# IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1739087</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>04/04/23</b>	
<b>DATE SAMPLED:</b>	<b>03/29/23</b>	<b>DATE RECEIVED:</b> 03/29/23
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)
METHOD	SM18 4500PF
DATE ANALYZED	04/03/23
DETECTION LIMIT	0.002
DUPLICATE	
SAMPLE ID	BATCH
ORIGINAL	0.096
DUPLICATE	0.098
RPD	1.70%
SPIKE SAMPLE	
SAMPLE ID	BATCH
ORIGINAL	0.096
SPIKED SAMPLE	0.147
SPIKE ADDED	0.050
% RECOVERY	100.65%
QC CHECK	
FOUND	0.098
TRUE	0.094
% RECOVERY	104.26%
BLANK	<0.002

RPD = RELATIVE PERCENT DIFFERENCE.  
NA = NOT APPLICABLE OR NOT AVAILABLE.  
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



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3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1739318</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>04/18/23</b>	
<b>DATE SAMPLED:</b>	<b>04/10/23</b>	<b>DATE RECEIVED: 04/10/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Five water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)
BLK-26	0.014
BLK-22	0.023
BLK-NE	0.024
CHAMP-19	0.017
CHAMP-PARK	0.016



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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	1739318	<b>PAGE 2</b>
<b>REPORT DATE:</b>	04/18/23	
<b>DATE SAMPLED:</b>	04/10/23	<b>DATE RECEIVED:</b> 04/10/23
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM CITY OF SNOHOMISH</b>		

## QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)
METHOD	SM18 4500PF
DATE ANALYZED	04/17/23
DETECTION LIMIT	0.002
DUPLICATE	
SAMPLE ID	CHAMP- PARK
ORIGINAL	0.016
DUPLICATE	0.016
RPD	1.59%
SPIKE SAMPLE	
SAMPLE ID	CHAMP- PARK
ORIGINAL	0.016
SPIKED SAMPLE	0.066
SPIKE ADDED	0.050
% RECOVERY	100.38%
QC CHECK	
FOUND	0.096
TRUE	0.094
% RECOVERY	102.13%
BLANK	<0.002

RPD = RELATIVE PERCENT DIFFERENCE.  
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OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	1739449	<b>PAGE 1</b>
<b>REPORT DATE:</b>	04/27/23	
<b>DATE SAMPLED:</b>	04/16/23	<b>DATE RECEIVED:</b> 04/17/23
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Two water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL-1-1		18	5.7
BL-1-1	0.018		



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<b>CASE FILE NUMBER:</b>	<b>1739449</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>04/27/23</b>	
<b>DATE SAMPLED:</b>	<b>04/16/23</b>	<b>DATE RECEIVED: 04/17/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

### QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
METHOD	SM18 4500PF	SM1810200H	SM1810200H
DATE ANALYZED	04/24/23	04/20/23	04/20/23
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.021	3.3	5.7
DUPLICATE	0.021	3.9	6.3
RPD	0.21%	16.67%	10.89%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.021		
SPIKED SAMPLE	0.071		
SPIKE ADDED	0.050		
% RECOVERY	100.47%	NA	NA
QC CHECK			
FOUND	0.096		
TRUE	0.094		
% RECOVERY	102.13%	NA	NA
BLANK	<0.002	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.  
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 NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1739911</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>05/22/23</b>	
<b>DATE SAMPLED:</b>	<b>05/07/23</b>	<b>DATE RECEIVED: 05/08/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## CASE NARRATIVE

Seven water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

## SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL - 1 - 1		14	3.0
BL - Dup		11	2.1
BL - Canal		7.3	2.0
BL - 1 - 1	0.016		
BL - Dup	0.019		
BL - 1 - B	0.031		
BL - Canal	0.015		



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<b>CASE FILE NUMBER:</b>	<b>1739911</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>05/22/23</b>	
<b>DATE SAMPLED:</b>	<b>05/07/23</b>	<b>DATE RECEIVED:</b> <b>05/08/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

## QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
METHOD	SM18 4500PF	SM1810200H	SM1810200H
DATE ANALYZED	05/17/23	05/12/23	05/12/23
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.022	2.3	3.7
DUPLICATE	0.023	2.0	4.5
RPD	3.60%	15.38%	19.35%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.022		
SPIKED SAMPLE	0.071		
SPIKE ADDED	0.050		
% RECOVERY	98.62%	NA	NA
QC CHECK			
FOUND	0.097		
TRUE	0.094		
% RECOVERY	103.19%	NA	NA
BLANK	<0.002	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.  
NA = NOT APPLICABLE OR NOT AVAILABLE.  
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski, PhD  
Laboratory Manager



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**LABORATORY & CONSULTING SERVICES**  
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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1740243</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>07/10/23</b>	
<b>DATE SAMPLED:</b>	<b>05/21/23</b>	<b>DATE RECEIVED: 05/22/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM SNOHOMISH COUNTY SWM</b>		

**CASE NARRATIVE**

Four samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)	ALKALINITY (mgCaCO3/L)
BL-1-1				25.2
BL-1-1	0.012			
BL-1-B	0.030			
BL-1-1		5.0	0.5	



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<b>CASE FILE NUMBER:</b>	<b>1740243</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>07/10/23</b>	
<b>DATE SAMPLED:</b>	<b>05/21/23</b>	<b>DATE RECEIVED: 05/22/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM SNOHOMISH COUNTY SWM</b>		

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/L)	CHLOR_a (ug/l)	PHAEO_a (ug/l)	ALKALINITY (mgCaCO3/L)
METHOD	SM18 4500PF	SM18 10200H	SM18 10200H	SM20 2320
DATE PREPARED	05/27/23	05/22/23	05/22/23	
DATE ANALYZED	05/30/23	05/31/23	05/31/23	05/25/23
DETECTION LIMIT	0.002	0.1	0.1	1.00
DUPLICATE				
SAMPLE ID	BATCH	BATCH	BATCH	BATCH
ORIGINAL	0.004	1.8	1.3	41.0
DUPLICATE	0.004	1.6	1.3	41.6
RPD	0.90%	10.53%	5.48%	1.45%
SPIKE SAMPLE				
SAMPLE ID	BATCH			
ORIGINAL	0.004			
SPIKED SAMPLE	0.050			
SPIKE ADDED	0.050			
% RECOVERY	92.98%	NA	NA	NA
QC CHECK				
FOUND	0.094			100
TRUE	0.094			100
% RECOVERY	100.00%	NA	NA	100.00%
BLANK	<0.002	NA	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.  
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 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

*Damien Gadomski*

Damien Gadomski  
 Project Manager



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3927 AURORA AVENUE NORTH, SEATTLE, WA 98103  
PHONE: (206) 632-2715 FAX: (206) 632-2417

**CASE FILE NUMBER:** 1740717 **PAGE 1**  
**REPORT DATE:** 07/10/23  
**DATE SAMPLED:** 06/11/23 **DATE RECEIVED:** 06/12/23  
**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM SNOHOMISH COUNTY SWM**

**CASE NARRATIVE**

Four samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)	TOTAL-N (mg/l)	N03+N02 (mg/L)
BL-CANAL	0.026		22	10		
BL-1-1	0.011		7.7	2.5	0.373	<0.010
BL-1-7.5	0.078	0.002				
BL-1-B	0.076				0.785	<0.010



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<b>CASE FILE NUMBER:</b>	<b>1740717</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>07/10/23</b>	
<b>DATE SAMPLED:</b>	<b>06/11/23</b>	<b>DATE RECEIVED: 06/12/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM SNOHOMISH COUNTY SWM</b>		

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)	SRP (mg/L)	CHLOR_a (ug/l)	PHAEO_a (ug/l)	TOTAL-N (mg/l)	N03+N02 (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM18 10200H	SM18 10200H	SM20 4500NC	SM184500N03F
DATE PREPARED	06/19/23		06/14/23	06/14/23	06/24/23	
DATE ANALYZED	06/24/23	06/13/23	06/15/23	06/15/23	06/27/23	6/14/2023
DETECTION LIMIT	0.002	0.001	0.1	0.1	0.050	0.010
DUPLICATE						
SAMPLE ID	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH
ORIGINAL	0.033	0.022	13	3.5	0.322	0.178
DUPLICATE	0.033	0.022	12	3.9	0.313	0.166
RPD	0.14%	0.41%	10.53%	10.91%	2.83%	7.13%
SPIKE SAMPLE						
SAMPLE ID	BATCH	BATCH			BATCH	BATCH
ORIGINAL	0.033	0.022			0.322	0.178
SPIKED SAMPLE	0.080	0.043			1.43	0.384
SPIKE ADDED	0.050	0.020			1.00	0.200
% RECOVERY	93.92%	102.29%	NA	NA	110.60%	102.98%
QC CHECK						
FOUND	0.095	0.041			0.479	0.420
TRUE	0.094	0.039			0.490	0.408
% RECOVERY	101.06%	105.13%	NA	NA	97.76%	102.96%
BLANK						
	<0.002	<0.001	NA	NA	<0.050	<0.010

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 NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski  
 Project Manager



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**LABORATORY & CONSULTING SERVICES**  
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<b>CASE FILE NUMBER:</b>	1741027	<b>PAGE 1</b>
<b>REPORT DATE:</b>	07/10/23	
<b>DATE SAMPLED:</b>	06/25/23	<b>DATE RECEIVED:</b> 06/26/23
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM SNOHOMISH COUNTY SWM</b>		

**CASE NARRATIVE**

Four samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL1-1	0.014		
BL1-6	0.055		
BL1-7.5	0.155		
BL1-1		4.8	1.5



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<b>CASE FILE NUMBER:</b>	<b>1741027</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>07/10/23</b>	
<b>DATE SAMPLED:</b>	<b>06/25/23</b>	<b>DATE RECEIVED:                    06/26/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM SNOHOMISH COUNTY SWM</b>		

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/L)	CHLOR_a (ug/l)	PHAEO_a (ug/l)
METHOD	SM18 4500PF	SM18 10200H	SM18 10200H
DATE PREPARED	06/30/23	06/26/23	06/26/23
DATE ANALYZED	07/01/23	07/06/23	07/06/23
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.009	23	6.0
DUPLICATE	0.008	25	6.8
RPD	0.47%	6.59%	11.93%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.009		
SPIKED SAMPLE	0.060		
SPIKE ADDED	0.050		
% RECOVERY	102.65%	NA	NA
QC CHECK			
FOUND	0.095		
TRUE	0.094		
% RECOVERY	101.06%	NA	NA
BLANK	<0.002	NA	NA

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 NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

**SUBMITTED BY:**

*Damien Gadomski*

Damien Gadomski  
 Project Manager

Herrera Blackmans Lake WA Zooplankton 2023

Data are not adjusted for subsampling



	Sample ID	BL-1-tow
	Collection Time	11:15
	Collection Date	06-25-2023
	Percent Analyzed	1.60%
EcoAnalysts Sample ID		8352.1-1
<b>Diptera</b>	Chaoborus punctipennis	3
<b>Crustacea</b>	Bosmina longirostris	10
	Calanoida - copepodites	6
	Calanoida - nauplii	12
	Chydorus sphaericus	3
	Cyclopoida - copepodites	57
	Cyclopoida - nauplii	12
	Daphnia mendotae complex	17
	Daphnia pulex	5
	Diacyclops thomasi	1
	Mesocyclops edax	6
	Skistodiaptomus oregonensis	2
<b>Rotifera</b>	Ascomorpha ecaudis	8
	Asplanchna priodonta	2
	Collotheca sp.	4
	Conochilus unicornis	9
	Gastropus stylifer	2
	Kellicottia bostoniensis	43
	Kellicottia longispina	56
	Keratella cochlearis	4
	Keratella crassa	8
	Polyarthra euryptera	3
	Polyarthra vulgaris	40
	<b>TOTAL</b>	<b>313</b>

## Phytoplankton Sample Analysis

**Sample:** Blackmans Lake  
**Sample Site:** BL-1-1  
**Sample Depth:**  
**Sample Date:** 25-Jun-23                      1100

**Total Density (#/mL):**                      582  
**Total Biovolume (um<sup>3</sup>/mL):**            878,536  
**Trophic State Index:**                      48.9

Species	Density #/mL	Density Percent	Biovolume um <sup>3</sup> /mL	Biovolume Percent
1 Cryptomonas erosa	95	16.3	49,298	5.6
2 Dinobryon sertularia	61	10.5	29,254	3.3
3 Aphanizomenon flos-aquae	54	9.3	54,608	6.2
4 Synedra radians	34	5.8	21,941	2.5
5 Anabaena planctonica	34	5.8	105,335	12.0
6 Oocystis pusilla	27	4.7	7,314	0.8
7 Rhodomonas minuta	27	4.7	542	0.1
8 Stephanodiscus hantzschii	20	3.5	2,438	0.3
9 Anabaena flos-aquae	20	3.5	23,139	2.6
10 Melosira italica	20	3.5	114,822	13.1
11 Fragilaria crotonensis	20	3.5	324,232	36.9
12 Asterionella formosa	14	2.3	8,939	1.0
13 Kephyrion littorale	14	2.3	1,287	0.1
14 Microcystis aeruginosa	14	2.3	1,083	0.1
15 Tabellaria fenestrata	14	2.3	81,261	9.2
16 Melosira ambigua	14	2.3	19,943	2.3
17 Oocystis lacustris	14	2.3	2,113	0.2
18 Synedra tenera	7	1.2	2,032	0.2
19 Navicula radiosa	7	1.2	2,201	0.3
20 Cyclotella stelligera	7	1.2	372	0.0
21 Fragilaria construens venter	7	1.2	650	0.1
22 Kephyrion sp.	7	1.2	427	0.0
23 Nitzschia frustulum	7	1.2	813	0.1
24 Achnanthes lanceolata	7	1.2	2,438	0.3
25 Glenodinium sp.	7	1.2	4,740	0.5
26 Ankistrodesmus falcatus	7	1.2	169	0.0
27 Fragilaria construens	7	1.2	758	0.1
28 Cyclotella comta	7	1.2	15,372	1.7
29 Gomphonema clevei	7	1.2	609	0.1
30 Chrysosphaerella sp.	7	1.2	406	0.0



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**CASE FILE NUMBER:** 1741431 **PAGE 1**  
**REPORT DATE:** 08/10/23  
**DATE SAMPLED:** 07/16/23 **DATE RECEIVED:** 07/17/23  
**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM SNOHOMISH COUNTY SWM**

**CASE NARRATIVE**

Two samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)	TOTAL-N (mg/l)	N03+N02 (mg/L)
BL-1-1	0.013		4.3	1.9	0.440	<0.010
BL-1-6	0.073	0.002				



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<b>CASE FILE NUMBER:</b>	<b>1741431</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>08/10/23</b>	
<b>DATE SAMPLED:</b>	<b>07/16/23</b>	<b>DATE RECEIVED: 07/17/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM SNOHOMISH COUNTY SWM</b>		

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)	SRP (mg/L)	CHLOR_a (ug/l)	PHAEO_a (ug/l)	TOTAL-N (mg/l)	N03+N02 (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM18 10200H	SM18 10200H	SM20 4500NC	SM184500N03F
DATE PREPARED	07/22/23		07/18/23	07/18/23	07/22/23	
DATE ANALYZED	07/24/23	07/18/23	07/21/23	07/21/23	07/25/23	7/19/2023
DETECTION LIMIT	0.002	0.001	0.1	0.1	0.050	0.010
DUPLICATE						
SAMPLE ID	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH
ORIGINAL	0.007	<0.001	1.1	1.5	0.329	0.198
DUPLICATE	0.007	<0.001	1.1	1.4	0.327	0.191
RPD	0.78%	NC	0.00%	12.84%	0.61%	3.39%
SPIKE SAMPLE						
SAMPLE ID	BATCH	BATCH			BATCH	BATCH
ORIGINAL	0.007	<0.001			0.329	0.198
SPIKED SAMPLE	0.055	0.020			1.45	0.430
SPIKE ADDED	0.050	0.020			1.00	0.200
% RECOVERY	97.24%	100.00%	NA	NA	111.90%	116.29%
QC CHECK						
FOUND	0.094	0.039			0.497	0.406
TRUE	0.094	0.039			0.490	0.408
% RECOVERY	100.00%	100.00%	NA	NA	101.43%	99.41%
BLANK						
	<0.002	<0.001	NA	NA	<0.050	<0.010

RPD = RELATIVE PERCENT DIFFERENCE.  
 NA = NOT APPLICABLE OR NOT AVAILABLE.  
 NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski  
 Project Manager



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**CASE FILE NUMBER:** 1741432 **PAGE 1**  
**REPORT DATE:** 08/10/23  
**DATE SAMPLED:** 07/16/23 **DATE RECEIVED:** 07/17/23  
**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM CITY OF SNOHOMISH**

**CASE NARRATIVE**

Three samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)	TOTAL-N (mg/l)	N03+N02 (mg/L)
BL-DUP	0.014	4.8	1.4	0.444	<0.010
BL-1-7.5	0.227				
BL-CANAL	0.031	2.9	2.3		



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<b>CASE FILE NUMBER:</b>	<b>1741432</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>08/10/23</b>	
<b>DATE SAMPLED:</b>	<b>07/16/23</b>	<b>DATE RECEIVED: 07/17/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)	CHLOR_a (ug/l)	PHAEO_a (ug/l)	TOTAL-N (mg/l)	N03+N02 (mg/L)
METHOD	SM18 4500PF	SM18 10200H	SM18 10200H	SM20 4500NC	SM184500N03F
DATE PREPARED	07/22/23	07/18/23	07/18/23	07/22/23	
DATE ANALYZED	07/24/23	07/21/23	07/21/23	07/25/23	7/19/2023
DETECTION LIMIT	0.002	0.1	0.1	0.050	0.010
DUPLICATE					
SAMPLE ID	BATCH	BATCH	BATCH	BATCH	BATCH
ORIGINAL	0.007	1.1	1.5	0.329	0.198
DUPLICATE	0.007	1.1	1.4	0.327	0.191
RPD	0.78%	0.00%	12.84%	0.61%	3.39%
SPIKE SAMPLE					
SAMPLE ID	BATCH			BATCH	BATCH
ORIGINAL	0.007			0.329	0.198
SPIKED SAMPLE	0.055			1.45	0.430
SPIKE ADDED	0.050			1.00	0.200
% RECOVERY	97.24%	NA	NA	111.90%	116.29%
QC CHECK					
FOUND	0.094			0.497	0.406
TRUE	0.094			0.490	0.408
% RECOVERY	100.00%	NA	NA	101.43%	99.41%
BLANK	<0.002	NA	NA	<0.050	<0.010

RPD = RELATIVE PERCENT DIFFERENCE.  
 NA = NOT APPLICABLE OR NOT AVAILABLE.  
 NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski  
 Project Manager



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<b>CASE FILE NUMBER:</b>	<b>1741784</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>08/28/23</b>	
<b>DATE SAMPLED:</b>	<b>08/01/23</b>	<b>DATE RECEIVED:</b> <b>08/01/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM SNOHOMISH COUNTY SWM</b>		

**CASE NARRATIVE**

Four samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL-1-1	0.019		
BL-1-6	0.077		
BL-1-8	0.344		
BL-1-1 (Large Brown Bottle)		7.7	2.0



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**CASE FILE NUMBER:** 1741784 **PAGE 2**  
**REPORT DATE:** 08/28/23  
**DATE SAMPLED:** 08/01/23 **DATE RECEIVED:** 08/01/23  
**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM SNOHOMISH COUNTY SWM**

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)	CHLOR_a (ug/l)	PHAEO_a (ug/l)
METHOD	SM18 4500PF	SM18 10200H	SM18 10200H
DATE PREPARED	08/05/23	08/01/23	08/01/23
DATE ANALYZED	08/07/23	08/08/23	08/08/23
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.014	18	2.2
DUPLICATE	0.014	18	2.5
RPD	2.53%	0.00%	12.77%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.014		
SPIKED SAMPLE	0.065		
SPIKE ADDED	0.050		
% RECOVERY	101.13%	NA	NA
QC CHECK			
FOUND	0.094		
TRUE	0.094		
% RECOVERY	100.00%	NA	NA
BLANK			
	<0.002	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.  
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 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski  
 Project Manager

## Phytoplankton Sample Analysis

**Sample:** Blackmans L  
**Sample Site:** BL-1-1  
**Sample Depth:**  
**Sample Date:** 30-Jul-23

**Total Density (#/mL):** 631  
**Total Biovolume (um<sup>3</sup>/mL):** 1,062,984  
**Trophic State Index:** 50.3

Species	Density #/mL	Density Percent	Biovolume um <sup>3</sup> /mL	Biovolume Percent
1 Anabaena planctonica	203	32.2	854,666	80.4
2 Asterionella formosa	85	13.6	48,905	4.6
3 Cryptomonas erosa	69	11.0	36,123	3.4
4 Aphanizomenon flos-aquae	64	10.2	64,636	6.1
5 Cyclotella stelligera	27	4.2	1,469	0.1
6 Synedra radians	27	4.2	9,618	0.9
7 Rhodomonas minuta	27	4.2	534	0.1
8 Sphaerocystis Schroeteri	16	2.5	3,759	0.4
9 Scenedesmus quadricauda	11	1.7	2,084	0.2
10 Cosmarium sp.	11	1.7	2,244	0.2
11 Stephanodiscus hantzschii	11	1.7	1,282	0.1
12 Microcystis aeruginosa	11	1.7	855	0.1
13 Tabellaria fenestrata	5	0.8	12,825	1.2
14 Achnanthes minutissima	5	0.8	267	0.0
15 Tetraedron regulare	5	0.8	615	0.1
16 Dinobryon sertularia	5	0.8	2,565	0.2
17 Pediastrum tetras	5	0.8	641	0.1
18 Gomphonema angustatum	5	0.8	962	0.1
19 Kephyrion sp.	5	0.8	337	0.0
20 Fragilaria construens	5	0.8	1,197	0.1
21 Glenodinium sp.	5	0.8	3,741	0.4
22 Crucigenia quadrata	5	0.8	1,817	0.2
23 Trachelomonas scabra	5	0.8	8,550	0.8
24 Staurastrum dejectum	5	0.8	2,137	0.2
25 Oocystis pusilla	5	0.8	1,154	0.1

Anabaena planctonica cells/mL = 4,670

Aphanizomenon flos-aquae cells/mL = 1,026

Microcystis aeruginosa cells/mL = 107



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<b>CASE FILE NUMBER:</b>	<b>1742057</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>08/28/23</b>	
<b>DATE SAMPLED:</b>	<b>08/13/23</b>	<b>DATE RECEIVED: 08/14/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM SNOHOMISH COUNTY SWM</b>		

**CASE NARRATIVE**

Two samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)	TOTAL-N (mg/l)	N03+N02 (mg/L)
BL-1-1	0.016		13	2.6	0.510	<0.010
BL-1-6	0.086	0.013				



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<b>CASE FILE NUMBER:</b>	<b>1742057</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	08/28/23	
<b>DATE SAMPLED:</b>	08/13/23	<b>DATE RECEIVED:</b> 08/14/23
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM SNOHOMISH COUNTY SWM</b>		

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)	SRP (mg/L)	CHLOR_a (ug/l)	PHAEO_a (ug/l)	TOTAL-N (mg/l)	N03+N02 (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM18 10200H	SM18 10200H	SM20 4500NC	SM184500N03F
DATE PREPARED	08/19/23		08/15/23	08/15/23	08/19/23	
DATE ANALYZED	08/25/23	08/15/23	08/18/23	08/18/23	08/22/23	8/15/2023
DETECTION LIMIT	0.002	0.001	0.1	0.1	0.050	0.010
DUPLICATE						
SAMPLE ID	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH
ORIGINAL	0.009	<0.001	1.2	1.1	0.508	0.216
DUPLICATE	0.009	<0.001	1.1	1.1	0.511	0.223
RPD	3.42%	NC	15.38%	6.56%	0.59%	2.92%
SPIKE SAMPLE						
SAMPLE ID	BATCH	BATCH			BATCH	BATCH
ORIGINAL	0.009	<0.001			0.508	0.216
SPIKED SAMPLE	0.061	0.022			1.49	0.430
SPIKE ADDED	0.050	0.020			1.00	0.200
% RECOVERY	103.89%	110.00%	NA	NA	97.90%	107.02%
QC CHECK						
FOUND	0.093	0.040			0.510	0.414
TRUE	0.094	0.039			0.490	0.408
% RECOVERY	98.94%	102.56%	NA	NA	104.08%	101.47%
BLANK						
	<0.002	<0.001	NA	NA	<0.050	<0.010

RPD = RELATIVE PERCENT DIFFERENCE.  
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 NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

*Damien Gadomski*

Damien Gadomski  
 Project Manager



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<b>CASE FILE NUMBER:</b>	<b>1742058</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>08/28/23</b>	
<b>DATE SAMPLED:</b>	<b>08/13/23</b>	<b>DATE RECEIVED: 08/14/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM SNOHOMISH COUNTY SWM</b>		

**CASE NARRATIVE**

Three samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL-DUP		<0.001		
BL-1-7.5	0.257	0.088		
BL-CANAL	0.051		5.0	5.5



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**CASE FILE NUMBER:** 1742058 **PAGE 2**  
**REPORT DATE:** 08/28/23  
**DATE SAMPLED:** 08/13/23 **DATE RECEIVED:** 08/14/23  
**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM SNOHOMISH COUNTY SWM**

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)	SRP (mg/L)	CHLOR_a (ug/l)	PHAEO_a (ug/l)
METHOD	SM18 4500PF	SM18 4500PF	SM18 10200H	SM18 10200H
DATE PREPARED	08/19/23		08/15/23	08/15/23
DATE ANALYZED	08/25/23	08/15/23	08/18/23	08/18/23
DETECTION LIMIT	0.002	0.001	0.1	0.1
DUPLICATE				
SAMPLE ID	BATCH	BATCH	BATCH	BATCH
ORIGINAL	0.009	<0.001	1.2	1.1
DUPLICATE	0.009	<0.001	1.1	1.1
RPD	3.42%	NC	15.38%	6.56%
SPIKE SAMPLE				
SAMPLE ID	BATCH	BATCH		
ORIGINAL	0.009	<0.001		
SPIKED SAMPLE	0.061	0.022		
SPIKE ADDED	0.050	0.020		
% RECOVERY	103.89%	110.00%	NA	NA
QC CHECK				
FOUND	0.093	0.040		
TRUE	0.094	0.039		
% RECOVERY	98.94%	102.56%	NA	NA
BLANK	<0.002	<0.001	NA	NA

RPD = RELATIVE PERCENT DIFFERENCE.  
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 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski  
 Project Manager



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<b>CASE FILE NUMBER:</b>	<b>1742335</b>	<b>PAGE</b>	<b>1</b>
<b>REPORT DATE:</b>	<b>10/17/23</b>		
<b>DATE SAMPLED:</b>	<b>08/21/23</b>	<b>DATE RECEIVED:</b>	<b>08/25/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SEDIMENT SAMPLES FROM HERRERA ENVIRONMENTAL</b>			

**CASE NARRATIVE**

Ten sediment samples were received by the laboratory in good condition and analyzed according to the chain of custody. Phosphorus fractions were determined according to the method of Rydin and Welch. Successive extractions with NH<sub>4</sub>Cl, Bicarbonate/Dithionate, NaOH, and HCL were performed and analyzed for phosphorus. One part of Organic P was determined by digesting the residue after the inorganic fractions were extracted. Organic P includes the P after the inorganic fractions plus Biogenic P. Total P is the sum of all fractions minus Biogenic P, which is part of the Organic P fraction. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows, while QA/QC data is contained on subsequent pages.

**SAMPLE DATA - SEDIMENTS (DRY WT. BASIS)**

SAMPLE ID	% SOLIDS	% WATER	IRON (mg/kg)	TOTAL-P (mg/kg)	LOOSELY BOUND P (NH <sub>4</sub> CL) (mg/kg)	FE BOUND P (DITHIONATE) (mg/kg)	AL BOUND P (NAOH) (mg/kg)	BIOGENIC P (mg/kg)	CA BOUND P (HCL) (mg/kg)	ORGANIC P (mg/kg)
BL-1-0-2	6.21%	93.8%	13964	1350	<2.00	275	525	351	69.6	481
BL-1-4-6	8.10%	91.9%	13209	1258	<2.00	229	534	282	83.3	412
BL-1-8-10	9.30%	90.7%	13338	1307	<2.00	202	559	357	99.5	447
BL-1-16-18	10.4%	89.6%	6211	1418	<2.00	156	754	330	73.9	433
BL-1-24-26	11.8%	88.2%	3107	1114	<2.00	36.1	633	307	46.4	398
BL-2-0-2	5.50%	94.5%	7470	897	<2.00	<2.00	343	368	58.7	496
BL-2-4-6	8.82%	91.2%	5036	804	<2.00	<2.00	243	442	46.0	515
BL-2-8-10	9.23%	90.8%	2188	743	<2.00	<2.00	357	291	30.7	355
BL-2-16-18	9.53%	90.5%	2225	503	<2.00	<2.00	232	194	19.1	252
BL-2-24-26	11.9%	88.1%	1904	551	<2.00	<2.00	251	221	24.7	275



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<b>CASE FILE NUMBER:</b>	<b>1742335</b>	<b>PAGE</b>	<b>2</b>
<b>REPORT DATE:</b>	<b>10/17/23</b>		
<b>DATE SAMPLED:</b>	<b>08/21/23</b>	<b>DATE RECEIVED:</b>	<b>08/25/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SEDIMENT SAMPLES FROM HERRERA ENVIRONMENTAL</b>			

**QA/QC DATA - SEDIMENTS**

QC PARAMETER	% SOLIDS	IRON	TOTAL-P	LOOSELY BOUND P (NH4CL)	FE BOUND P (DITHIONATE)	AL BOUND P (NAOH)	BIOGENIC P	CA BOUND P (HCL)	ORGANIC P
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
METHOD	SM18 2540B	EPA 6010	CALCULATED	SM18 4500PF	SM18 4500PF	SM18 4500PF	EPA 365.1	SM18 4500PF	EPA 365.1
DATE PREPARED	10/09/23	09/02/23	09/27/23	09/26/23	09/26/23	09/27/23	09/27/23	09/27/23	09/27/23
DATE ANALYZED	1.00%	2.00	5.00	2.00	2.00	2.00	2.00	2.00	2.00
DETECTION LIMIT									
DUPLICATE									
	BL-2-24-26	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH
SAMPLE ID	11.9%	264	1038	<2.00	144	309	55	426	159
ORIGINAL	11.9%	277	1022	<2.00	145	314	60	405	158
DUPLICATE	0.05%	4.81%	1.62%	NC	0.85%	1.85%	8.03%	5.28%	1.11%
RPD									
SPIKE SAMPLE									
SAMPLE ID									
ORIGINAL									
SPIKED SAMPLE									
SPIKE ADDED	NA	NA	NA	NA	NA	NA	NA	NA	NA
% RECOVERY									
QC CHECK (mg/l)									
FOUND		5.20		0.040	0.040	0.039	0.095	0.039	0.095
TRUE		5.00		0.039	0.039	0.039	0.094	0.039	0.094
% RECOVERY	NA	104.00%	NA	101.96%	101.96%	100.00%	101.06%	100.00%	101.06%
BLANK	NA	<2.00	NA	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00

RPD = RELATIVE PERCENT DIFFERENCE.  
 NA = NOT APPLICABLE OR NOT AVAILABLE.  
 NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

*Damien Gadomski*

Damien Gadomski  
 Project Manager



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PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1742347</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>09/18/23</b>	
<b>DATE SAMPLED:</b>	<b>08/28/23</b>	<b>DATE RECEIVED: 08/28/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

**CASE NARRATIVE**

Three samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL-1-1	0.034	36	3.5
BL-1-6	0.188		
BL-1-7.5	0.423		



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<b>CASE FILE NUMBER:</b>	<b>1742347</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>09/18/23</b>	
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<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)	CHLOR_a (ug/l)	PHAEO_a (ug/l)
METHOD	SM18 4500PF	SM18 10200H	SM18 10200H
DATE PREPARED	09/02/23	08/29/23	08/29/23
DATE ANALYZED	09/05/23	09/05/23	09/05/23
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.013	117	14
DUPLICATE	0.015	116	13
RPD	9.19%	0.86%	4.71%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.013		
SPIKED SAMPLE	0.065		
SPIKE ADDED	0.050		
% RECOVERY	102.37%	NA	NA
QC CHECK			
FOUND	0.097		
TRUE	0.094		
% RECOVERY	102.73%	NA	NA
BLANK			
	<0.002	NA	NA

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 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

*Damien Gadomski*

Damien Gadomski  
 Project Manager

## Phytoplankton Sample Analysis

**Sample:** Blackmans Lake  
**Sample Site:** BL-1-1  
**Sample Depth:**  
**Sample Date:** 26-Aug-23                      1410

**Total Density (#/mL):**                      2,364  
**Total Biovolume (um<sup>3</sup>/mL):**            2,715,420  
**Trophic State Index:**                      57.0

Species	Density #/mL	Density Percent	Biovolume um <sup>3</sup> /mL	Biovolume Percent
1 Dinobryon sertularia	1,855	78.5	1,780,723	65.6
2 Anabaena planctonica	158	6.7	605,686	22.3
3 Aphanizomenon flos-aquae	97	4.1	122,206	4.5
4 Cryptomonas erosa	97	4.1	50,434	1.9
5 Anabaena flos-aquae	24	1.0	113,720	4.2
6 Stephanodiscus hantzschii	12	0.5	1,455	0.1
7 Achnanthes minutissima	12	0.5	606	0.0
8 Tetraedron minimum	12	0.5	546	0.0
9 Quadrigula closterioides	12	0.5	2,328	0.1
10 Nitzschia amphibia	12	0.5	1,164	0.0
11 Cyclotella meneghiniana	12	0.5	4,607	0.2
12 Synedra radians	12	0.5	4,365	0.2
13 Kephyrion littorale	12	0.5	1,152	0.0
14 Trachelomonas volvocina	12	0.5	22,853	0.8
15 Nitzschia frustulum	12	0.5	1,455	0.1
16 Melosira distans alpigena	12	0.5	2,122	0.1

Aphanizomenon flos-aquae cells/mL = 1,940

Anabaena planctonica cells/mL = 3,310

Anabaena flos-aquae cells/mL = 1,697

**Herrera Blackmans Lake WA Zooplankton 2023**

Data are not adjusted for subsampling



	Sample ID	BL-1-tow
	Collection Time	14:45:00 AM
	Collection Date	08-28-2023
	Percent Analyzed	0.67%
	EcoAnalysts Sample ID	8352.2-1
<b>Crustacea</b>	Bosmina longirostris	5
	Calanoida - nauplii	1
	Ceriodaphnia sp.	21
	Cyclopoida - copepodites	20
	Cyclopoida - nauplii	9
	Daphnia mendotae complex	3
	Daphnia pulex	2
	Mesocyclops edax	11
	Skistodiptomus oregonensis	5
<b>Rotifera</b>	Asplanchna priodonta	1
	Conochilus unicornis	188
	Gastropus stylifer	1
	Kellicottia bostoniensis	38
	Keratella cochlearis	9
	Keratella crassa	12
	Polyarthra vulgaris	5
	<b>TOTAL</b>	<b>331</b>



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**CASE FILE NUMBER:** 1742802 **PAGE 1**  
**REPORT DATE:** 11/06/23  
**DATE SAMPLED:** 09/15/23 **DATE RECEIVED:** 09/15/23  
**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM CITY OF SNOHOMISH**

**CASE NARRATIVE**

Six samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)	TOTAL-N (mg/l)	N03+N02 (mg/L)
BL-1-1	0.019		8.0	3.7	0.463	<0.010
BL-Dup	0.019		8.3	3.1		
BL-1-6	0.016					
BL-1-7.5	0.395	0.136				
BL-CANAL	0.037		5.6	4.1		
BL-CANAL-Fountain	0.088					



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**CASE FILE NUMBER:** 1742802 **PAGE 2**  
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**DATE SAMPLED:** 09/15/23 **DATE RECEIVED:** 09/15/23  
**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM CITY OF SNOHOMISH**

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)	SRP (mg/L)	CHLOR_a (ug/l)	PHAEO_a (ug/l)	TOTAL-N (mg/l)	N03+N02 (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM18 10200H	SM18 10200H	SM20 4500NC	SM184500N03F
DATE PREPARED	09/23/23		09/16/23	09/16/23	09/30/23	
DATE ANALYZED	09/25/23	09/15/23	09/29/23	09/29/23	10/03/23	9/15/2023
DETECTION LIMIT	0.002	0.001	0.1	0.1	0.050	0.010
DUPLICATE						
SAMPLE ID	BATCH	BATCH	BL-1-1	BL-1-1	BATCH	BATCH
ORIGINAL	0.108	0.050	8.0	3.7	0.269	0.022
DUPLICATE	0.107	0.050	7.7	3.5	0.275	0.022
RPD	0.56%	0.42%	4.26%	3.70%	2.21%	0.72%
SPIKE SAMPLE						
SAMPLE ID	BATCH	BATCH			BATCH	BATCH
ORIGINAL	0.108	0.050			0.269	0.022
SPIKED SAMPLE	0.152	0.068			1.23	0.211
SPIKE ADDED	0.050	0.020			1.00	0.200
% RECOVERY	88.83%	92.04%	NA	NA	96.50%	94.60%
QC CHECK						
FOUND	0.095	0.041			0.505	0.402
TRUE	0.094	0.039			0.499	0.408
% RECOVERY	101.06%	105.13%	NA	NA	101.20%	98.53%
BLANK						
	<0.002	<0.001	NA	NA	<0.050	<0.010

RPD = RELATIVE PERCENT DIFFERENCE.  
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 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

*Damien Gadomski*

Damien Gadomski  
 Project Manager



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<b>CASE FILE NUMBER:</b>	<b>1743065</b>	<b>PAGE 1</b>
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<b>DATE SAMPLED:</b>	<b>09/28/23</b>	<b>DATE RECEIVED: 09/28/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

**CASE NARRATIVE**

Three samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)
BL-1-1	0.035	12	4.3
BL-1-6	0.096		
BL-1-7.5	0.436		



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<b>CASE FILE NUMBER:</b>	<b>1743065</b>	<b>PAGE 2</b>
<b>REPORT DATE:</b>	<b>10/28/23</b>	
<b>DATE SAMPLED:</b>	<b>09/28/23</b>	<b>DATE RECEIVED: 09/28/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

### QA/QC DATA

QC PARAMETER	TOTAL-P (mg/l)	CHLOR_a (ug/l)	PHAEO_a (ug/l)
METHOD	SM18 4500PF	SM18 10200H	SM18 10200H
DATE PREPARED	09/30/23	09/29/23	09/29/23
DATE ANALYZED	10/02/23	10/16/23	10/16/23
DETECTION LIMIT	0.002	0.1	0.1
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.026	32	4.4
DUPLICATE	0.023	34	3.6
RPD	9.41%	3.60%	19.12%
SPIKE SAMPLE			
SAMPLE ID	BATCH		
ORIGINAL	0.026		
SPIKED SAMPLE	0.075		
SPIKE ADDED	0.050		
% RECOVERY	99.20%	NA	NA
QC CHECK			
FOUND	0.099		
TRUE	0.094		
% RECOVERY	105.32%	NA	NA
BLANK			
	<0.002	NA	NA

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 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski  
Project Manager

**Herrera Blackmans Lake WA Zooplankton 2023**

Data are not adjusted for subsampling



	Sample ID	BL-1-tow
	Collection Time	17:35
	Collection Date	10-08-2023
	Percent Analyzed	0.67%
	EcoAnalysts Sample ID	8352.3-1
<b>Crustacea</b>	Calanoida - copepodites	6
	Calanoida - nauplii	7
	Ceriodaphnia sp.	18
	Chydorus sphaericus	13
	Cyclopoida - copepodites	10
	Cyclopoida - nauplii	8
	Diacyclops thomasi	1
	Mesocyclops edax	2
<b>Rotifera</b>	Ascomorpha ecaudis	1
	Brachionus angularis	1
	Collotheca sp.	2
	Conochilus unicornis	30
	Gastropus stylifer	4
	Kellicottia bostoniensis	93
	Kellicottia longispina	1
	Keratella cochlearis	7
	Keratella crassa	34
	Polyarthra euryptera	2
	Polyarthra vulgaris	1
	Synchaeta sp.	1
	Trichocerca similis	2
	Trichocerca sp.	4
	Trichotria pocillum	7
	<b>TOTAL</b>	<b>255</b>



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<b>CASE FILE NUMBER:</b>	<b>1743292</b>	<b>PAGE 1</b>
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<b>DATE SAMPLED:</b>	<b>10/08/23</b>	<b>DATE RECEIVED: 10/09/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

**CASE NARRATIVE**

Five samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)	TOTAL-N (mg/l)	N03+N02 (mg/L)
BL-1-1	0.029		24	7.4	0.659	<0.010
BL-1-6	0.037					
BL-1-7.5	0.532	0.131				
BL-Canal	0.045		176	238		
BL-Canal-Fountain	0.057		18	7.4		



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<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)	SRP (mg/L)	CHLOR_a (ug/l)	PHAEO_a (ug/l)	TOTAL-N (mg/l)	N03+N02 (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM18 10200H	SM18 10200H	SM20 4500NC	SM184500N03F
DATE PREPARED	10/14/23		10/09/23	10/09/23	10/14/23	
DATE ANALYZED	10/16/23	10/10/23	10/17/23	10/17/23	10/17/23	10/10/2023
DETECTION LIMIT	0.002	0.001	0.1	0.1	0.050	0.010
DUPLICATE						
SAMPLE ID	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH
ORIGINAL	0.080	<0.001	15	4.0	0.391	0.018
DUPLICATE	0.081	<0.001	16	4.5	0.387	0.019
RPD	0.98%	NC	8.70%	12.50%	1.03%	9.10%
SPIKE SAMPLE						
SAMPLE ID	BATCH	BATCH			BATCH	BATCH
ORIGINAL	0.080	<0.001			0.391	0.018
SPIKED SAMPLE	0.130	0.020			1.35	0.198
SPIKE ADDED	0.050	0.020			1.00	0.200
% RECOVERY	100.25%	100.00%	NA	NA	96.30%	90.32%
QC CHECK						
FOUND	0.094	0.040			0.441	0.403
TRUE	0.094	0.039			0.469	0.408
% RECOVERY	100.00%	102.56%	NA	NA	94.03%	98.77%
BLANK						
	<0.002	<0.001	NA	NA	<0.050	<0.010

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SUBMITTED BY:

Damien Gadomski  
 Project Manager

## Phytoplankton Sample Analysis

**Sample:** Blackman's Lake  
**Sample Site:** BL-1-1  
**Sample Depth:**  
**Sample Date:** 8-Oct-23

**Total Density (#/mL):** 3,410  
**Total Biovolume (um<sup>3</sup>/mL):** 2,184,435  
**Trophic State Index:** 55.5

Species	Density #/mL	Density Percent	Biovolume um <sup>3</sup> /mL	Biovolume Percent
1 Sphaerocystis schroeteri	908	26.6	412,913	18.9
2 Rhodomonas minuta	660	19.4	13,200	0.6
3 Cryptomonas erosa	330	9.7	171,600	7.9
4 Dinobryon sertularia	303	8.9	39,930	1.8
5 Anabaena planctonica	275	8.1	1,006,500	46.1
6 Aphanizomenon flos-aquae	138	4.0	190,575	8.7
7 Crucigenia quadrata	138	4.0	30,388	1.4
8 Microcystis aeruginosa	110	3.2	8,800	0.4
9 Oocystis pusilla	83	2.4	17,820	0.8
10 Asterionella formosa	83	2.4	90,750	4.2
11 Chryso-sphaerella sp.	55	1.6	3,300	0.2
12 Ankistrodesmus falcatus	55	1.6	2,063	0.1
13 Chlamydomonas sp.	28	0.8	8,938	0.4
14 Melosira ambigua	28	0.8	97,185	4.4
15 Pediastrum boryanum	28	0.8	5,500	0.3
16 Scenedesmus quadricauda	28	0.8	7,150	0.3
17 Fragilaria construens venter	28	0.8	1,320	0.1
18 Selenastrum minutum	28	0.8	550	0.0
19 Trachelomonas volvocina	28	0.8	51,838	2.4
20 Anabaena flos-aquae	28	0.8	18,425	0.8
21 Kephyrion littorale	28	0.8	2,613	0.1
22 Fragilaria construens	28	0.8	3,080	0.1

Microcystis aeruginosa cells/mL = 1,100

Anabaena planctonica cells/mL = 5,500

Aphanizomenon flos-aquae cells/mL = 3,025

Anabaena flos-aquae cells/mL = 275



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<b>CASE FILE NUMBER:</b>	<b>1743347</b>	<b>PAGE 1</b>
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<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

**CASE NARRATIVE**

Four samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)
BLK-26	0.072
BLK-22	0.029
CHAMP-19	0.186
CHAMP-PARK	0.038



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**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM CITY OF SNOHOMISH**

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)
METHOD	SM18 4500PF
DATE PREPARED	10/14/23
DATE ANALYZED	10/16/23
DETECTION LIMIT	0.002
DUPLICATE	
SAMPLE ID	BATCH
ORIGINAL	0.084
DUPLICATE	0.084
RPD	0.25%
SPIKE SAMPLE	
SAMPLE ID	BATCH
ORIGINAL	0.084
SPIKED SAMPLE	0.131
SPIKE ADDED	0.050
% RECOVERY	94.69%
QC CHECK	
FOUND	0.094
TRUE	0.094
% RECOVERY	100.00%
BLANK	<0.002

RPD = RELATIVE PERCENT DIFFERENCE.  
NA = NOT APPLICABLE OR NOT AVAILABLE.  
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski  
Project Manager



**IEH ANALYTICAL LABORATORIES**  
**LABORATORY & CONSULTING SERVICES**  
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103  
PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1743596</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>11/06/23</b>	
<b>DATE SAMPLED:</b>	<b>10/23/23</b>	<b>DATE RECEIVED:</b> <b>10/24/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM SNOHOMISH COUNTY SWM</b>		

**CASE NARRATIVE**

Six samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages.

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	CHLOR_a (ug/L)	PHAEO_a (ug/L)	TOTAL-N (mg/L)
BLACKMANS - 1M	0.019	0.000	11	4.7	0.559
BLACKMANS - 6M	0.056	0.014			
BLACKMANS - 7.5M	0.547	0.269			
LOMA - 1M	0.018		2.5	2.0	0.598
LOMA - 7M	0.162	0.127			
LOMA - 6.5M	0.110	0.085			



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**LABORATORY & CONSULTING SERVICES**  
 3927 AURORA AVENUE NORTH, SEATTLE, WA 98103  
 PHONE: (206) 632-2715 FAX: (206) 632-2417

**CASE FILE NUMBER:** 1743596 **PAGE 2**  
**REPORT DATE:** 11/06/23  
**DATE SAMPLED:** 10/23/23 **DATE RECEIVED:** 10/24/23  
**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM SNOHOMISH COUNTY SWM**

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	CHLOR_a (ug/l)	PHAEO_a (ug/l)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM18 10200H	SM18 10200H	SM20 4500NC
DATE PREPARED	10/28/23		10/24/23	10/24/23	10/28/23
DATE ANALYZED	10/30/23	10/25/23	10/26/23	10/26/23	11/01/23
DETECTION LIMIT	0.002	0.001	0.1	0.1	0.050
DUPLICATE					
SAMPLE ID	LOMA - 6.5M	BLACKMANS - 6M	BATCH	BATCH	BATCH
ORIGINAL	0.110	0.014	2.8	1.3	0.667
DUPLICATE	0.111	0.013	3.4	1.2	0.648
RPD	0.24%	2.08%	17.67%	7.30%	2.89%
SPIKE SAMPLE					
SAMPLE ID	LOMA - 6.5M	BLACKMANS - 6M			BATCH
ORIGINAL	0.110	0.014			0.667
SPIKED SAMPLE	0.160	0.035			1.57
SPIKE ADDED	0.050	0.020			1.00
% RECOVERY	99.04%	105.17%	NA	NA	89.90%
QC CHECK					
FOUND	0.094	0.039			0.464
TRUE	0.094	0.039			0.469
% RECOVERY	100.00%	100.00%	NA	NA	98.93%
BLANK	<0.002	<0.001	NA	NA	<0.050

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 OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski  
 Project Manager



IEH - Aquatic Research  
 3927 Aurora Ave N • Seattle • WA • 98103  
 P: 206-632-2715 F: 206-632-2417



Chain of Custody Form

1743596

REPORT TO:

Client: Snohomish County Surface Water Management  
 Address: 3000 Rockefeller Ave MS 303  
 Everett, WA 98201  
 Contact: Jennifer Oden  
 Email: jennifer.oden@snoco.org  
 Phone: 425-388-3464 Fax: 425-388-6455

INVOICE TO: (IF DIFFERENT FROM REPORT)

Client: \_\_\_\_\_  
 Address: \_\_\_\_\_  
 Contact: \_\_\_\_\_  
 Email: \_\_\_\_\_  
 Phone: \_\_\_\_\_ Fax: \_\_\_\_\_

PROJECT INFORMATION

Quote No.: \_\_\_\_\_  
 Client PO: \_\_\_\_\_  
 Client Project: Lakes

Reporting/Invoicing Format  
 Fax  Email  Mail  
 QC Data Reported  Yes  No  
 Sample Disposal  Yes  No  
 Specific Date: \_\_\_\_\_

Turn Around Time (TAT)\*  
 Next Day  2 Business Days  
 3 Business Days \* Standard  
 \*Advanced notice required for Rush Analysis

Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION
10-23-13	1015	SW	BLACKMANS-1M
			BLACKMANS-1M
			BLACKMANS-1M
			BLACKMANS-7.5M
			LOMA-1M
			LOMA-7M
			LOMAEAST-10.5M

Number of Containers	Analysis Requested						
	TP	TPN	Chlorophyll a	SRP	True Color	Alkalinity	Fe
2 X	X	X	X				
1 X			X				
2 X	X	X					
1 X			X				
1 X							
1 X							

Containers Received		LAB USE ONLY	
Temp	Lab ID	Case File Number	
		132959	
		132960	
		132961	
		132962	
		132963	
		132964	

\*\*Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil,  
 SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments: \_\_\_\_\_  
 Please reference Agreement Number CC08-19 on the invoice.

Sampled By: *Jennifer Oden* Date: 10/21/13 Time: 11:00  
 Received By: \_\_\_\_\_ Date: \_\_\_\_\_ Time: \_\_\_\_\_

Shipped By: *Sam Jones* Date: 10-29-13 Time: 11:00  
 Received at Aquatic By: *Le Sammas MS 15* Date: 9-9-02 Time: 10-29-13

Relinquished to Aquatic By (Signature): \_\_\_\_\_ Date: \_\_\_\_\_ Time: \_\_\_\_\_



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**LABORATORY & CONSULTING SERVICES**  
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103  
PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1744317</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>12/05/23</b>	
<b>DATE SAMPLED:</b>	<b>11/29/23</b>	<b>DATE RECEIVED:</b> <b>11/29/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

**CASE NARRATIVE**

Five samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)
BLK-26	0.009
BLK-22	0.012
BLK-ne	0.021
CHAMP-19	0.006
CHAMP-Park	0.007



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**LABORATORY & CONSULTING SERVICES**  
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103  
PHONE: (206) 632-2715 FAX: (206) 632-2417

**CASE FILE NUMBER:** 1744317 **PAGE 2**  
**REPORT DATE:** 12/05/23  
**DATE SAMPLED:** 11/29/23 **DATE RECEIVED:** 11/29/23  
**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM CITY OF SNOHOMISH**

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)
METHOD	SM18 4500PF
DATE PREPARED	12/02/23
DATE ANALYZED	12/04/23
DETECTION LIMIT	0.002
DUPLICATE	
SAMPLE ID	BATCH
ORIGINAL	<0.002
DUPLICATE	<0.002
RPD	NC
SPIKE SAMPLE	
SAMPLE ID	BATCH
ORIGINAL	<0.002
SPIKED SAMPLE	0.049
SPIKE ADDED	0.050
% RECOVERY	98.00%
QC CHECK	
FOUND	0.094
TRUE	0.094
% RECOVERY	100.00%
BLANK	<0.002

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NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.  
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski  
Project Manager



**IEH ANALYTICAL LABORATORIES**  
**LABORATORY & CONSULTING SERVICES**  
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103  
PHONE: (206) 632-2715 FAX: (206) 632-2417

<b>CASE FILE NUMBER:</b>	<b>1744424</b>	<b>PAGE 1</b>
<b>REPORT DATE:</b>	<b>12/18/23</b>	
<b>DATE SAMPLED:</b>	<b>12/05/23</b>	<b>DATE RECEIVED: 12/05/23</b>
<b>FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER</b>		
<b>SAMPLES FROM CITY OF SNOHOMISH</b>		

**CASE NARRATIVE**

Five samples were delivered to the laboratory in good condition. The samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages

**SAMPLE DATA**

SAMPLE ID	TOTAL-P (mg/L)
BLK-26	0.055
BLK-22	0.083
BLK-NE	0.066
CHAMP-19	0.099
CHAMP-PARK	0.072



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**LABORATORY & CONSULTING SERVICES**  
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103  
PHONE: (206) 632-2715 FAX: (206) 632-2417

**CASE FILE NUMBER:** 1744424 **PAGE 2**  
**REPORT DATE:** 12/18/23  
**DATE SAMPLED:** 12/05/23 **DATE RECEIVED:** 12/05/23  
**FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER**  
**SAMPLES FROM CITY OF SNOHOMISH**

**QA/QC DATA**

QC PARAMETER	TOTAL-P (mg/l)
METHOD	SM18 4500PF
DATE PREPARED	12/09/23
DATE ANALYZED	12/11/23
DETECTION LIMIT	0.002
DUPLICATE	
SAMPLE ID	BATCH
ORIGINAL	<0.002
DUPLICATE	<0.002
RPD	NC
SPIKE SAMPLE	
SAMPLE ID	BATCH
ORIGINAL	<0.002
SPIKED SAMPLE	0.053
SPIKE ADDED	0.050
% RECOVERY	105.07%
QC CHECK	
FOUND	0.095
TRUE	0.094
% RECOVERY	101.06%
BLANK	<0.002

RPD = RELATIVE PERCENT DIFFERENCE.  
NA = NOT APPLICABLE OR NOT AVAILABLE.  
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SUBMITTED BY:

Damien Gadomski  
Project Manager

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# Appendix D

## Cyanobacteria Management Methods

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# Appendix D: Cyanobacteria Management Methods

This appendix summarizes external and internal lake management methods for cyanobacteria control, their advantages and disadvantages, and their suitability for implementation at Blackmans Lake. Actions assessed as suitable for implementation at Blackmans Lake are highlighted in green in Table 1 and further described in the sections below. Actions determined not feasible for implementation in Blackmans Lake and rationale are detailed in the *Methods Rejected* section.

Table 1. Cyanobacteria Management Feasibility Screening for Blackmans Lake.					
Method	Effectiveness	Cost	Impact Risk	Feasibility	Suitability
<b>Watershed (External Nutrient Loading Control) Methods</b>					
<b>Septic System Management</b>	Low-Moderate	High	Low	Moderate	Yes
<b>Stormwater Management</b>	Low-Moderate	Moderate	Low	Moderate	Yes
Stream Phosphorus Inactivation	Low-Moderate	Moderate	Moderate	Low	No
<b>Waterfowl Management</b>	Low-Moderate	Moderate	Low	Moderate	Yes
<b>Shoreline Management</b>	Low-Moderate	Moderate	Low	Moderate	Yes
<b>Lake Physical Methods</b>					
Lake Mixing – Surface Mixing by SolarBees	Low-Moderate	Low-Moderate	Low	Moderate-High	No – uncertain effectiveness
Lake Mixing – Whole-lake Mixing by Aeration	Low-Moderate	Moderate	Low	Moderate	No – uncertain effectiveness
Sonication	Low-Moderate	Moderate	Low-Moderate	Low	No – uncertain effectiveness
Lake dilution	Moderate	High	Low	Low	No – high cost
<b>Hypolimnetic Oxygenation/ Aeration</b>	Moderate-High	Moderate-High	Low-fish benefits	Moderate	Yes
Ozone/ Microbubbles/ Nanobubbles	Low	Moderate	Low	Low	No – not effective, experimental
Hypolimnetic Withdrawal	Low	Moderate	High	Low	No – insufficient inflow, downstream impacts
Dredging	Low-Moderate	Very High	Moderate	Low	No – high cost/benefit
Shading (Dyes)	Moderate	Moderate	High	Low	No – not feasible

**Table 1 (continued). Cyanobacteria Management Feasibility Screening for Blackmans Lake.**

Method	Effectiveness	Cost	Impact Risk	Feasibility	Suitability
<b>Lake Chemical Methods</b>					
Algaecide treatment	Moderate	Low-Moderate	Low-Moderate	Moderate	No –not a long-term solution
Sediment Phosphorus Inactivation with Alum or Lanthanum)	High	Moderate	Low-Moderate	Moderate	Yes
Calcium treatment	Low	Low-Moderate	Low	Low	No – not effective with low hardness
Iron treatment	Low	Low	Low	Low-Moderate	No – not effective with anoxic hypolimnion
<b>Lake Biological Methods</b>					
Waterfowl Deterrence	Low	Low	Low-Moderate	Low	Yes
Carp removal	Low	Moderate-High	Low-Moderate	Low	No – high cost/benefit
Bio-manipulation (Zooplankton planting; Piscivore stocking)	Low	Low-Moderate	Low-Moderate	Low	No – not feasible, low effectiveness
Macrophyte plantings	Low	Moderate	Low	Low	No – high cost/benefit
Barley Straw	Low	Low	Low-Moderate	Low	No – uncertain benefit

## In-Lake Techniques

The following sections summarize the most feasible lake management techniques that may be used to improve the algae community and meet the water quality objectives. These techniques are considered feasible for reducing the magnitude and frequency of toxic cyanobacteria blooms. There are advantages and disadvantages to each management technique, some are more experimental with limited scientific studies of effectiveness, and there are wide differences in initial and long-term costs. Table 1 provides a comparative summary of these techniques.

It is important to recognize that any lake management technique aimed at controlling algae, if successful, is likely to impact aquatic macrophyte populations. The clearer water means more sunlight for plant growth. Since most plants obtain their nutrients from the sediments rather than the water, lake nutrient reduction techniques typically do not impact them. Although phosphorus inactivation methods reduce nutrient availability in sediments where most aquatic macrophytes obtain nutrients, macrophyte roots typically penetrate below the inactivation zone (upper 10 centimeters) and are not affected by inactivation treatments. Lake management should focus on achieving the appropriate ecological balance between algae and plants, since too much of either can be problematic.

## Algaecides

Algaecides provide short-term algae control by killing the algae and cyanobacteria in the water column. However, algaecides may affect other aquatic biota to varying degrees and accelerate recycling of nutrients. Algaecides are effective only while the active ingredient is in the water column and available for uptake by the algae (Cooke et al. 2005). Typically, two or more applications must occur within the same season to provide effective control of algae and cyanobacteria throughout the season. Algaecides do not reduce phosphorus or nitrogen concentrations and do not provide long-term control. In fact, they increase recycling of phosphorus and decrease dissolved oxygen from algae decay.

Currently, endothal (e.g., Hydrothol® 191) and sodium carbonate peroxyhydrate (e.g., PAK 27 or Phycomycin) are the only algaecides permitted for use in the State of Washington. The primary algaecide utilized in Washington State is sodium carbonate peroxyhydrate. When applied to the lake, this compound breaks down into hydrogen peroxide and sodium carbonate. The hydrogen peroxide oxidizes and thus kills the target algae. After contact, the hydrogen peroxide breaks down harmlessly into water and oxygen. When properly applied at a low rate, this algaecide is selective for cyanobacteria, which are lacking a cell wall, and does not harm many of the more beneficial green algae that are protected by a cell wall. When sodium carbonate peroxyhydrate is applied in accordance with directions on the label, no harm is expected to birds, other terrestrial animals, freshwater fish, or freshwater invertebrates (EPA 2011).

Sodium carbonate peroxyhydrate can also be used to kill *E. coli* and other fecal coliform bacteria that often cause beach closures due to waterfowl droppings and other fecal sources. Small peroxyhydrate treatments limited to the waters in the vicinity of a closed beach can be used to reduce *E. coli* counts to levels below the threshold for public safety closures.

## Advantages

- Rapid water quality improvement
- Inexpensive management option
- Sodium carbonate peroxyhydrate algaecides:
  - Have no use restrictions and are non-toxic to wildlife.
  - Oxidize intra-cellular cyanobacteria toxins and also kill fecal bacteria.
  - Can be applied at low rates to not impact most beneficial green algae.
  - Rapidly degrade into water and oxygen.
  - Do not accumulate in the environment.

## Disadvantages

- Effective short-term only, while the active ingredient is in the water.
- May affect other aquatic organisms if not applied according to the label.
- Do not reduce nutrients and can accelerate recycling of nutrients.

- Typically require more than one application within the same season for effective control.
- Hydrothol 191 requires a 24-hour swimming restriction and can have possible toxic effects to fish (which does not apply to sodium carbonate peroxyhydrate).
- Require a permit and licensed applicator.

## Suitability for Blackmans Lake

Algaecides are not a cost-effective tool for cyanobacteria management, because they only work for a short time. Since blooms are difficult to predict, there may be logistical challenges in mobilizing a contractor rapidly enough to provide treatment. An algaecide treatment may only lessen a bloom for as little as 2 days. In addition to the higher costs, relying on algaecides as a sole management strategy would have negative ecological consequences.

Under certain situations, sodium carbonate peroxyhydrate treatments may be suitable for short-term treatment of the entire lake or for impacted swim beaches and isolated areas of scum accumulation. Lake residents are accustomed to using herbicides for aquatic plant control, and they are not likely to object to the use of algaecides. Sodium carbonate peroxyhydrate has no use restrictions or aquatic toxicity. When applied at a low rate, it primarily oxidizes cyanobacteria and cyanotoxins rather than beneficial green algae.

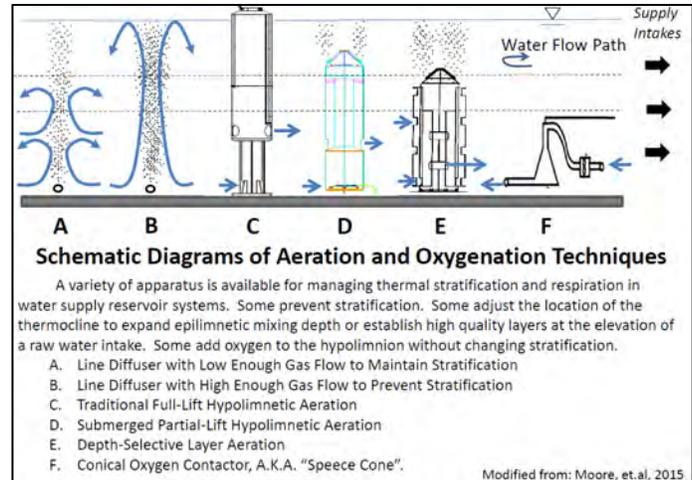
## Planning Level Costs

The cost for the material and application of sodium carbonate peroxyhydrate treatment is approximately \$250 per acre. A single whole-lake treatments would cost approximately \$15,000. However, multiple treatments may be required in a single year. Assuming two to four treatments per year, the cost of algaecide-only management would be \$30,000 to \$60,000 per year.

## Hypolimnetic Oxygenation and Aeration

Hypolimnetic oxygenation or aeration techniques are implemented to combat hypolimnetic anoxia by maintaining or increasing DO levels in the hypolimnion while preserving thermal stratification. Hypolimnetic oxygenation uses pure oxygen, whereas hypolimnetic aeration uses air to maintain oxygen levels. Maintaining oxygenated conditions in the hypolimnion transfers oxygen into the underlying surficial sediments to suppress the release of phosphorus and nitrogen from sediments, settled particulate matter, and groundwater inflow. Maintaining stratification reduces the mixing of nutrient-rich hypolimnion water to the epilimnion.

Hypolimnetic aeration/oxygenation systems typically involves the installation of diffuser tubes or plates on the lake bottom to inject air or oxygen into the bottom of the hypolimnion. A vertical structure is needed to carry the released bubbles and associated water up to the top of the hypolimnion (partial lift) or epilimnion (full lift). Once there, bubbles are released at the lake surface and the aerated water is discharged near the lake sediments. A summary of lakes where hypolimnetic oxygenation or aeration have been deployed is provided in Table 2.



**Table 2. Hypolimnetic Oxygenation and Aeration System Examples.**

Lake, Location	Install Year	Lake Characteristics	System	Effect on Phosphorus Release	Source
Newman Lake Spokane County, Washington	1992 (renovation planned as of 2022)	Mean depth = 5.8 m Max depth = 9.1 m Area = 490 ha	Hypolimnetic oxygenation with Speece Cone and alum emitter	Decrease in lake phosphorus concentrations	Moore et al. 2012
Stevens Lake Snohomish County, Washington	1994 (retired in 2012)	Mean depth = 20.5 m Max depth = 46 m Area = 421 ha	Hypolimnetic aeration	Reduced sediment phosphorus. Decrease in effectiveness in final years attributed to saturation of iron-binding sites for phosphorus	Snohomish County and TetraTech 2012
Lake Fenwick Kent, Washington	1994 (renovat ed in 2020)	Mean depth = 4.0 m Max depth = 9.4 m Area = 9 ha	Hypolimnetic aeration	Not evaluated.	Ecology 2002
Falling Creek Reservoir Vinton, Virginia	2013	Mean depth = 4.0 m Max depth = 9.3 m Area = 11.9 ha	Hypolimnetic oxygenation with Oxygen Saturation Technology	Increased DO and maintained thermal stratification. Decrease in hypolimnion TP and SRP during operation	Gerling et al. 2014
Sarah's Pond Orleans, Massachusetts	2021	Mean depth = 3 m Max depth = 5.3 m Area = 2.3 ha	Hypolimnetic oxygenation with Oxygen Saturation Technology	Reduction in sediment phosphorus release. Decreased effectiveness due to electrical service shutdown and expanded anoxic area due to hot weather.	Wagner 2022

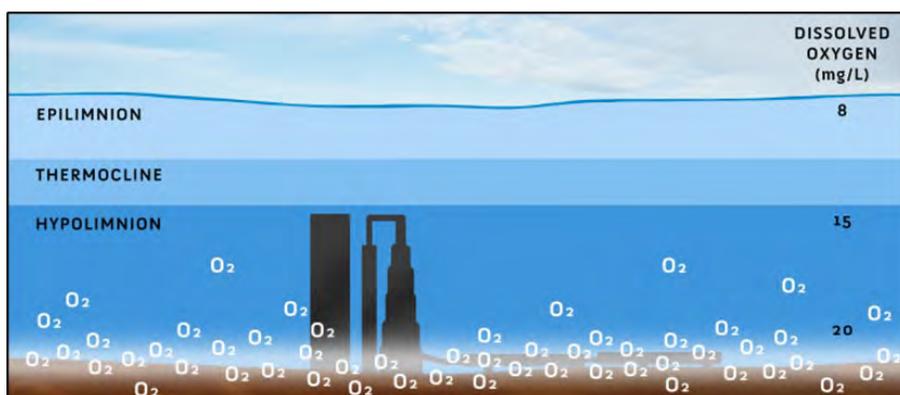
See Preece et al. 2019 for an expanded list of hypolimnetic oxygenation systems.

Generally, the cost of installing a hypolimnetic aeration system can range from hundreds of thousands to millions of dollars. Importantly, the cost of the system is not a one-time expense. It requires ongoing maintenance to ensure it operates efficiently. The maintenance cost can include electricity bills for running the system, periodic cleaning and replacement of diffuser membranes, and inspection of the system components. For example, the hypolimnetic aeration system installed in Lake Stevens in

Snohomish County in the 1990s ultimately failed. Now algae blooms in that lake are being controlled by alum treatments. Installation and operating costs for that system over a 10-year period was \$1,240/hectare/year (Cooke et al. 2005), or about \$5 million for 10 years in a 421-hectare lake. A hypolimnetic aeration system was installed in Lake Fenwick in King County in the 1990s, and recently this 10.4-hectare lake (about half the size of Blackmans Lake) was upgraded at a cost of \$900,000.

Oxygen Saturation Technology (OST) is a relatively new, patent-pending innovation used to administer precise concentrations of oxygen at strategic depths in a waterbody, also known as side-stream supersaturation (SSS). The OST's design eliminates bubbles, which eliminates turbulence, sediment resuspension, and undesirable mixing. These systems can maintain dissolved oxygen (DO) levels as high as 20 mg/L directly over and into the sediments, where oxygen is needed most. They may also help prevent oxygen-related fish mortality. These high dissolved oxygen levels (exceeding those from simple saturation with the air) are important to overcome the high oxygen demand of organic-rich sediments in eutrophic lakes. Traditional hypolimnetic aeration systems can fail because they do not meet the sediment oxygen demand. OST has not been used in Washington State

An OST system functions by transporting approximately 95 percent pure oxygen from an onshore facility to an in-lake device where the water is supersaturated with oxygen. The water is then injected back into deep areas of the lake where it disperses over the sediment surface. The oxygenated water can coat and penetrate the sediments, preventing the release of phosphorus from iron-phosphate complexes and allowing the oxidized iron to bind to phosphate released by microbial decay of organic matter. The onshore facility consists of a compressor and an oxygen generator. There is no storage of oxygen on premises.



## Advantages

An oxygenation system:

- Reduces phosphorus release from anoxic sediments and reduces cyanobacteria blooms.
- Increases deep water oxygen, improves fish habitat and aquatic life uses.
- Degrades organic matter and cyanotoxins faster by using aerobic microbes, which can improve water quality, reduce public health risk from cyanotoxins, and reduce the depth of sediment accumulation in deep portions of the lake..
- Is a non-chemical alternative.

In addition to these advantages, new oxygen saturation technology (OST) pumping oxygenated water to and from hypolimnion is very promising for small lakes because it is more effective and cheaper than traditional oxygenation systems.

## Disadvantages

An oxygenation system:

- May resuspend of sediment layer nutrients/ions in the water column if not properly installed, but this is a rare problem that is easily rectified and has not occurred with OST systems because their vertical position can be adjusted with the buoyancy line used to raise the system for maintenance.
- Requires installation and operational cost (electricity).
- Is ineffective in shallow lakes/ reservoirs with a large surface area (i.e., weak to no stratification).
- May require continuous operation.
- Can be ineffective when external nutrients are not controlled.

## Suitability for Blackmans Lake

Hypolimnetic oxygenation is a suitable management technique for Blackmans Lake. However, the existing capacity of the sediments to bind phosphorus via iron may be insufficient. In the sampled sediment cores, the ratio of Fe to P in the lake sediments was low; the total Fe:P ratios were near or below a threshold of 10 believed to be the minimum for iron to regulate sediment phosphorus release (Caraco et al. 1993). If the sediment surface has oxygen and the Fe:P ratio is 15 or greater, then it is believed that internal loading may be altogether prevented (Jensen et al. 1992). KCM (1994) concluded that there was suitable iron in Blackmans Lake to bind phosphorus if re-oxygenated. They based this on the observed high iron concentrations in the hypolimnion (0.583 mg/L) and low phosphorus concentrations after turnover (18 µg/L). Post-turnover concentrations were not measured in 2023 and no water samples analyzed for iron. Supplementation with iron, as iron salts or ZVI, may be necessary for the if hypolimnetic oxygenation is not immediately successful.

It is important to note that hypolimnetic oxygenation would support phosphorus retention in the deep-water sediments, but internal cycling in the shallow sediments due to microbial decay of organic material would persist.

## Planning Level Costs

KCM (1994) estimated the costs for a Blackmans Lake aeration system based on nearby costs for Phantom Lake (Bellevue, Washington) and Lake Stevens (Snohomish County). In 1994 dollars, the estimate ranged from \$50,000 to \$150,000 for construction and \$30,000 to \$60,000 for operation and maintenance. In 2024 dollars, this is \$106,000 to \$320,000 for construction, and \$64,000 to \$127,000 for annual operation and maintenance.

The OST system is a lower-cost alternative because it is much smaller and easier to install for an equivalent or higher oxygenation rate. The system is floated out to the install location and sunk to the desired depth. The cost breakdown of an OST system is provided below in Table 3. Overall, an OST system is estimated to initially cost \$305,000 (midpoint of manufacture estimate range of \$285,000 to \$325,000 including installation), and the building construction and electrical hookup is estimated to cost \$60,000 (assumed to be located in Hill Park and including sound insulation). Permitting and engineering oversight is estimated at (\$115,500 (30 percent of OST and building cost). We included 10.4 percent tax

and 20 percent contingency based on the OST and building cost, for a total installed cost of \$622,150. Ongoing maintenance and operation cost is estimated to average of \$12,170 per year, including tax and a 20 percent contingency.

**Table 3. Blackmans Lake Oxygen Saturation Technology Cost Estimate.**

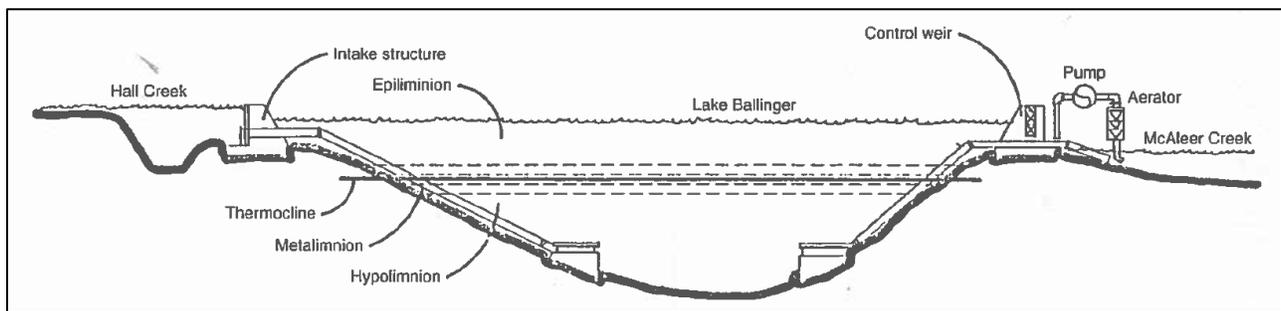
Initial Capital Costs	
<b>OST System</b> 1x Oxygen Generators 1x Air Compressors 1x 120-gallon Air Receivers Oxygenation Chamber Energy Dissipating Headers Submersible Pump Oxygen and Power Lines	\$305,000 (Midpoint of \$285,000 to \$325,000 range quoted by manufacturer)
<b>Building and Electrical Hookup</b> Includes Sound Insulation (assumed to be sited in Hill Park)	\$60,000
<b>Permitting and Engineering Oversight</b> (assumed at 30 percent of OST and building cost)	\$115,500
<b>Tax</b> (10.4% of OST and building)	\$37,960
<b>Contingency</b> (20% of OST and building)	\$95,990
<b>TOTAL</b>	<b>\$622,150</b>
Operation and Maintenance	
<b>Electricity</b> (assuming \$0.12/kWh, operating 75 hp compressors/ pump from June to October)	\$4,700
<b>Compressor Rebuild</b> (every 2 years at \$5,000 each)	\$2,500
<b>Replace Submersible Pump</b> (every 10 years at \$10,000 each)	\$1,000
<b>Zeolite Replacement</b> (every 5 years at \$5,000)	\$1,000
<b>Tax</b> (10.4%)	\$920
<b>Subtotal O&amp;M</b> (annualized)	\$10,120
<b>Contingency</b> (20%)	\$2,050
<b>Total</b>	<b>\$12,170</b>

## Hypolimnetic Withdrawal

Hypolimnetic withdrawal involves using a specialized pump system or deepwater dam intake to withdraw water from the hypolimnion and release it into the surrounding watershed. By removing nutrient-rich water from the hypolimnion, hypolimnetic withdrawal can reduce the amount of phosphorus available to support algal growth in the lake. To be effective and to avoid disrupting the natural balance of the lake ecosystem, hypolimnetic withdrawal must be carefully designed and managed. The process should be timed to coincide with the natural stratification and mixing patterns of the lake. The rate of withdrawal

should be adjusted to minimize the risk of causing sudden changes in temperature or water chemistry. As a control strategy, hypolimnetic withdrawal from stratified systems is most effective in systems where internal nutrient loads are the primary cause of the algal blooms and external nutrient loads are declining or low. A recognized disadvantage of hypolimnetic withdrawal is its impact on downstream waters, including eutrophication, temperature increase, oxygen depletion, and odor development (Nurnberg 2007).

A local example of a hypolimnetic withdrawal system is Lake Ballinger. In 1982, inflowing Hall Creek waters were injected into the hypolimnion. The hypolimnion was pumped from an intake structure on the lake bottom and discharged to the lake outlet on McAleer Creek (Cooke et al. 2005). The system substantially reduced hypolimnetic phosphorus concentrations (from 400-900 to 100-150  $\mu\text{g/L}$ ) and internal loading (70 percent reduction) during the first three years of operation. However, the lake was treated with alum in 1993 due to increasing external loading from development and intermittent system operation. Operations were curtailed because of odors from the discharge and high iron bacteria growth in McAleer Creek. Ecology ordered termination of system discharge in 2008 due to water quality impacts to McAleer Creek. They would require treatment of the discharge prior to future operation. Installation of the Lake Ballinger system cost \$420,000 in 2002 dollars (Cooke et al. 2005).



## Advantages

- No waste or by-products generated
- Readily available equipment
- Reported water quality and ecological benefits
- Minimal aesthetic impact to the lake

## Disadvantages

- Can be disruptive to the lake ecosystem, particularly if withdrawal rates are too high or the process is not carefully managed; can cause the lake to destratify and lead to changes in water chemistry, temperature, and oxygen levels that can harm fish and other aquatic life
- Infrastructure needs (electricity, piping), if no deep-water outlets are in the water body
- Potential downstream discharge issues, including water quality, smell, fueling downstream blooms, and delivery of algae blooms and cyanotoxins during flushing events

- Likely to require an NPDES permit and end-of-pipe treatment for discharge to downstream receiving waters
- Costly installation, maintenance, and monitoring of infrastructure or pumps; difficulty permitting

## Suitability for Blackmans Lake

A hypolimnetic withdrawal system is not feasible for Blackmans Lake. There are not adequate summertime surface water flows in the watershed to offset the loss of water by pumping out the hypolimnion. Other sources of water, like pumping groundwater or using drinking water, would be prohibitively expensive. Furthermore, a discharge treatment system would be needed to discharge hypolimnetic water to Swifty Creek.

## Planning Level Costs

KCM 1994 estimate the costs of hypolimnetic dilution and withdrawal system that uses drinking water as the water source. Their estimates include \$200,000 for the pipeline running water to the lake bottom, \$60,000 for the pipeline from the lake bottom to Swifty Creek, and \$46,000 to \$58,000 annually for the cost of water. Importantly, these estimates are over 30 years old. Adjusting for inflation to 2024 dollars, the cost of construction is \$552,000 and the annual cost of water is \$98,000 to \$123,000. These estimates do not include the costs for construction and operation of a treatment system.

## Lake Phosphorus Inactivation

### Alum Treatment

Applications of aluminum sulfate (alum), in a sufficient dose to inactivate all mobile sediment phosphorus, have been shown to be effective for at least 10 years in lakes with low watershed inputs (Cooke et al. 2005). When alum is added to water it forms a floc that grows in size and weight as it settles through the water column, sorbing inorganic phosphorus and incorporating particulate organic phosphorus through entrapment (Burrows 1977, Driscoll and Schecher 1990). The alum floc settles to the sediments, where it continues to control phosphorus by sorbing additional phosphorus that is present in the sediments. This forms a barrier to future phosphorus release from sediments into the water column. The resultant phosphorus that is bound to aluminum in the lake sediments is very stable and is thought to be permanently bound (Rydin and Welch 1998).

Alum treatments have been used successfully in many lakes in Washington (Table 2), and several strategies have been implemented in Washington and around the world to inactivate phosphorus in sediments and lakes, and from watershed inputs, including the following:

- Whole lake alum dose
- Multiple small alum doses
- Microfloc alum injection
- Inflow stream alum injection

**Table 4. Comparison of Alum Treatment Doses in Washington State.**

Lake (County)	Treatment Date	Volumetric Dose (mg Al/L)	Aerial Dose (g Al/m <sup>2</sup> )	Longevity (years) <sup>a</sup>	Reference
Heart Lake (Skagit)	April 2018	12.9	32.1	>5	Herrera 2019
Lake Campbell (Skagit)	October 1985	10.9	26	7	Huser et al. 2016
Lake Erie (Skagit)	September 1985	10.9	20	14	Huser et al. 2016
Lake Ketchum (Snohomish)	May 2014	19.5	71.3	NA	M. Burghdoff (per. com.)
	March 2015	20.4	74.6	NA	
	Annual 2016-2024	3.0-6.1/yr	11-22/yr	NA	
Lake Stevens (Snohomish)	Annual 2013-2020	0.15/yr	3.0/yr	NA	Tetra Tech 2022
Long Lake (Kitsap)	September 1980	5.5	10.7	>11	Rydin et al. 2000
	September 1991	5.5	10.7	>11	Rydin et al. 2000
	August 2006	2.5	4.6	NA	Tetra Tech 2010
	April 2007	17.5	36.2	10	Tetra Tech 2010
	April 2019	5.0	9.8	unknown	Tetra Tech 2019
Lake Ballinger (King)	June 1990	5.0	23	2	Huser et al. 2016
Green Lake (King)	October 1991	8.6	34	3	Herrera 2003
	April 2004	24	94	>10	Herrera 2004
	April 2016	8.2	32	>8	Herrera 2016
Phantom Lake (King)	September 1990	4.4	28	12	Huser et al. 2016
Hicklin Lake (King)	April 2005	22	60.4	3	King County 2006
Lake Fenwick (King)	May 2011	2.5	9	stripping	S. Brattebo (per. com.)
	October 2023	11.7	42.1	unknown	
Wapato Lake (Pierce)	July 1984	7.8	12	<1	Huser et al. 2016
	July 2008	67.7	108	5	Herrera 2017b
	April 2017	56.3	90	>6	Herrera 2018
Waughop Lake (Pierce)	March 2020	40	84	unknown	Tetra Tech 2023
	July 2020	40	84		
	July 2023	20	42		
Long Lake (Thurston)	N: September 1983	7.8	28	12	Huser et al. 2016
	S.: September 1983	7.4	28	5	Huser et al. 2016
	2008	15.2	54.9	unknown	Tetra Tech 2006
Pattison Lake (Thurston)	S: September 1983	7.8	30.8	12	Huser et al. 2016
	N: September 1983	7.2	31	<1	
Black Lake (Thurston)	April 2016	1.9	13	>5	Herrera 2017a
	May 2021	54.5	317	unknown	Herrera 2021
Liberty Lake (Spokane)	1974	1	5	0.5	Huser et al. 2016
	1980-1981	10	52	14	Huser et al. 2016
Medical Lake (Spokane)	Aug.-Sept. 1977	12.6	122	>10	Huser et al. 2016
Newman Lake (Spokane)	1989	2.8	15	1	Huser et al. 2016
	Annual 2021-2023	1.5/yr	12.7/yr	NA	D. Vilar (per. com.)

<sup>a</sup> Longevity reported by reference or observed through 2023.

mg Al/L = milligrams of aluminum per liter; g Al/m<sup>2</sup> = grams of aluminum per square meter

NA = not applicable

Multiple small alum doses typically cost more than a whole lake alum dose, due to higher mobilization costs. However, costs can be similar if an expensive buffer (sodium aluminate) is not needed to neutralized small alum doses but is needed for large alum doses. Multiple small alum doses are more appropriate for lakes with high external loading, which would reduce the longevity of a whole lake alum dose. Multiple small alum doses are sometimes preferred over a large long-term dose for financial reasons or to reduce potential impacts of aluminum toxicity to aquatic organisms. Multiple small alum doses can be used to strip phosphorus from the water column and to inactivate sediment phosphorus.

Because of the acute toxicity concerns of aluminum under acidic conditions, sodium aluminate (a base) and alum (an acid) are added as a buffer to soft water lakes. This prevents the pH from dropping below the lower end of the acceptable range (i.e., 6.0), which can result in widespread fish kills. The ratio typically used for alum and sodium aluminate is 2:1 by volume. This ratio is appropriate for Blackmans Lake because it is a soft water lake. Sodium aluminate is expensive and adds a lot to the cost of an alum treatment. Sodium aluminate is usually not needed, even in soft water lakes, for low dose (less than 5 mg Al/L) water column stripping applications that do not include sediment inactivation.

Under the Aquatic Plant and Algae Management General Permit, a jar test must be completed prior to whole lake treatments only if a buffer other than sodium aluminate is used or if a ratio of liquid alum to liquid sodium aluminate differs from 2:1 by volume. Furthermore, monitoring under S6.B of the permit is required. This includes:

- One surface water pH measurement in the morning, prior to any alum addition, and one surface water pH measurement 1 hour after alum addition has stopped for that day. These measurements may partially fulfill the permit conditions in S6.B.1.c.
- The Permittee must monitor pH for the duration of the treatment and for 24 hours following treatment completion. For continuous monitoring, measurements must be taken at intervals no longer than 15 minutes. The monitoring location must be representative of waterbody-wide conditions. If the pH decreases to less than 6.2, the Permittee must stop the treatment, analyze for alkalinity, and take immediate steps to increase the pH.
- For continuous injection treatments, the Permittee must measure pH at a minimum once every 2 weeks during the first month of continuous injection and thereafter once a month for the duration of the injection process. The Permittee must ensure that pH measurements represent waterbody-wide conditions, unless the injection system is in an isolated area in relation to the main waterbody (e.g., in a bay with a narrow channel to the main waterbody). For isolated areas of waterbodies, the Permittee must measure pH at the end of the bay and in the main waterbody.
- When performing any treatment using alum, the permittee must monitor for aluminum in the waterbody according to the following procedures:
- Before the alum treatment, permittees must take water samples to establish a baseline for the following metrics:
  - pH
  - Dissolved organic carbon (DOC)
  - Total hardness (as CaCO<sub>3</sub>)

- Water samples must be representative of the treatment area, with at least one shoreline sample and one open water sample.
- The latitude and longitude coordinates of water sample locations must be recorded in decimal degrees. Pre- and post-treatment water samples must be taken from the same locations.
- During the alum treatment, pH must be monitored continuously.
- Immediately after the alum treatment, the permittee must take water samples and test them for aluminum concentration. This measurement must include both total recoverable aluminum and dissolved aluminum.
- The permittee must take water samples to test for total recoverable aluminum, pH, DOC, and hardness 2 weeks after the treatment.
- The permittee must take water samples to test for total recoverable aluminum, pH, DOC, and hardness once per month for the 2 months following the alum treatment.
- The permittee must take water samples to test for total recoverable aluminum, pH, DOC, and hardness quarterly until one year after the alum treatment date.
- Reporting Aluminum Monitoring Data: The permittee will send all aluminum monitoring data to the Department of Ecology within 30 days of each sampling event. Permittees do not need to take any further action after measuring and reporting the results of these water samples.

Additionally, under the permit, an on-site storage facility is required for any treatment requiring 9,000 gallons of alum or more, or the project proponent must have a plan to store any unused alum or buffering products.

### *Advantages*

- Instantaneous water column phosphorus control
- Long-term, stable sediment phosphorus control
- Floc rapidly settled to bottom
- Promotion of water clarity
- Cost-effective and widely successful

### *Disadvantages*

- Potential impacts of aluminum toxicity to aquatic organisms (however, extensive use of a buffer and monitoring in our region has minimized this risk)
- Sediment phosphorus monitoring required for accurate dosage calculations
- Limited effectiveness when watershed load is dominant

## Suitability for Blackmans Lake

Alum treatment would be a suitable management method to inactivate available phosphorus in Blackmans Lake because of the high internal loading rate during the algae growing season. In comparison to other phosphorus inactivation products, alum is more effective than iron in lakes with an anoxic hypolimnion. Alum is comparable in cost to lanthanum-modified clay but typically has greater longevity because it is applied at rates with a higher phosphorus binding capacity than lanthanum-modified clay.

## Planning Level Costs

Planning level costs for water column stripping and sediment inactivation with alum are provided in the *Planning Level Comparison for Phosphorus Inactivation* subsection at the end of this section.

## Lanthanum Treatment

Lanthanum ( $\text{La}^{3+}$ ) has a strong affinity for phosphate ( $\text{PO}_4^{3-}$ ), such that it chemically inactivates phosphate through precipitation and forms a mineral of extremely low solubility. Therefore, similar to alum, it permanently binds the phosphorus. Lanthanum is available for application in lakes as lanthanum-modified bentonite (LMB), which is applied as a slurry using either Phoslock or EutroSORB. Bentonite is an adsorbent swelling clay commonly used as drilling mud. Unlike alum, however, LMB is not a coagulant and therefore does not trap and remove particles in the water column. Rather, LMB works mainly in the sediment to bind phosphate that would normally be released to the water through decomposition or changes in sediment chemistry. The lanthanum in LMB binds only to inorganic phosphate (soluble reactive phosphorus or orthophosphate) and does not address organic phosphorus until it degrades to phosphate. LMB can be applied in frequent small doses to 'strip' the water column of inorganic phosphorus. Although alum treatment effectiveness and duration has been much better studied (see Cooke et al. 2005), there are many Phoslock and a few EutroSORB studies published to date worldwide (see Copetti et al. 2016). Kitsap Lake, in Bremerton, Washington, has undergone annual lanthanum treatments with notable improvements in water quality and no closures during the high lake use periods of June through August.

Lanthanum concentrations immediately following application may exceed estimated toxicity thresholds, particularly for zooplankton, and little study has been done for impacts on benthic organisms (Copetti et al. 2016). Generally, because lanthanum is applied in phosphorus-rich waters, the amount of free lanthanum ions is low as they bind to phosphate. Jar tests prior to application can be used to ensure proper dosage.

Phoslock® is the tradename of the original commercially available LMB product that was developed in Australia in the 1990s. EutroSORB® is an LMB product developed over the past few years by SeaPRO®, a major manufacturer of lake management chemicals. Currently, there are three formulas of EutroSORB® used for sediment inactivation (EutroSORB® G), water column stripping (EutroSORB® G), and filtration of flowing waters (EutroSORB F). EutraSORB® WC has an undisclosed ingredient(s) to flocculate particulate phosphorus that is evaluated in the next section on *Proprietary Product Treatment*.

## Advantages

- Permanently inactivates phosphorus water column and/or sediment
- Remains effective and non-toxic under all pH and oxygen conditions

## Disadvantages

- Temporarily increases turbidity from clay
- Requires monitoring for accurate dosage calculations
- Has fewer case studies to evaluate effectiveness and duration of treatments compared to alum
- Has limited effectiveness when watershed load is dominant

## Suitability for Blackmans Lake

Lanthanum treatment would be a suitable management method to remove available phosphorus in Blackmans Lake. Phoslock and EutroSORB G are currently permitted for use in Washington and are best used for sediment inactivation lasting one to several years. However, either of these products could be applied to strip phosphate from the water column with some additional product to inactivate phosphate released from recent sediments over a 1-year period. EutroSORB WC is not currently permitted for use but could be approved by Ecology within a year or two, upon disclosure of the active ingredients (if those ingredients are limited to alum and lanthanum which are currently approved by Ecology), or it could be approved for use as an experimental phosphorus inactivation product.

In waterbodies with low alkalinity (< 20 mg/L), a jar test must be completed prior to treatment to identify proper dosing levels. Data from May 2023 indicate that Blackmans Lake is likely sufficiently alkaline with measured in-lake alkalinity at 1 m at 25.2 mg CaCO<sub>3</sub>/L, but additional sampling is recommended to confirm.

## Planning Level Costs

Planning level costs for Phoslock and EutroSORB G are provided in the *Planning Level Comparison for Phosphorus Inactivation* subsection at the end of this section.

## Proprietary Product Treatment

There are several proprietary formulations available on the market that provide binding sites for dissolved phosphorus in the water column and produce floccules that will pull particulates, including algae and sediment, from the water column. In this way, the products act similarly to alum.

Currently available products include EutroSORB WC, produced by SePRO, and MetaFloc, produced by Naturalake Biosciences. Both manufacturers claim that their products do not impact water chemistry (including pH) and have low toxicity to aquatic life and humans, but no case studies are as-of-yet available to support these claims.

## Advantages

- Permanently inactivates phosphorus in the water column and/or sediment

## Disadvantages

- Monitoring required for accurate dosage calculations
- Few case studies to evaluate effectiveness and duration of treatments
- Limited effectiveness when watershed load is dominant
- Uncertain stability and toxicity impacts, assumed to be similar to alum and lanthanum

## Suitability for Blackmans Lake

There is no available information to support the claims of the manufacturers, regarding the effectiveness and low ecological impacts. However, if the claims hold true, these products could be effective alternatives to alum (which has toxicity and pH concerns) and LMB (which does not remove particulate phosphorus).

The above-described proprietary products are not currently approved in the Washington State Department of Ecology's Aquatic Plant and Algae Management Permit. As such, an experimental application permit would need to be obtained for treatment in Blackmans Lake. This would likely entail thorough monitoring before, during, and after application.

## Planning Level Costs

Planning level costs for MetaFloc and EutroSORB WC are provided in the *Planning Level Comparison for Phosphorus Inactivation* subsection at the end of this section.

## Calcium Application

Calcium is applied to lakes in the form of lime ( $\text{CaO}$ ,  $\text{CaCO}_3$ ,  $\text{Ca}(\text{OH})_2$ ) or calcite ( $\text{CaCO}_3$ ). Lime addition mimics natural calcite ( $\text{CaCO}_3$ ) precipitation in hard water lakes that strips phosphorus from the water column.  $\text{CaO}$  and  $\text{Ca}(\text{OH})_2$  addition in water increases aqueous pH and facilitates the formation of  $\text{CaCO}_3$ . Direct addition of  $\text{CaCO}_3$  is deemed beneficial because it precipitates and then reacts with dissolved orthophosphate in the water column. Calcium applications are generally not effective in soft water lakes present in western Washington. There is so little background calcium that the applied amount is not sufficient to precipitate phosphorus as was demonstrated in Lake Steilacoom (Herrera 2009).

Under the Aquatic Plant and Algae Management General Permit, a jar test must be completed prior to treatment to identify proper dosing levels. This jar test needs to be conducted at least over a 24-hour period to ensure that the pH response is at equilibrium with water chemistry. Furthermore, monitoring under S6.B of the permit is required. This includes:

1. The Permittee must measure pH once on the day before treatment, once in the morning prior to treatment and once in the afternoon after treatment has stopped for the day, for the duration of

the treatment and for 24 hours following treatment. If the pH is above 9.0 due to the effects of the treatment (rather than through photosynthesis), the Permittee must stop treatment.

2. For continuous injection systems, the Permittee must measure pH at a minimum once every 2 weeks during the first month of continuous injection and thereafter once a month for the duration of the injection process. The Permittee must ensure that pH measurements represent waterbody-wide conditions, unless the injection system is in an isolated area in relation to the main waterbody (e.g., in a bay with a narrow channel to the main waterbody). For isolated areas of waterbodies, the Permittee must measure pH at the end of the bay and in the main waterbody.

### *Advantages*

- Short-term removal of available phosphorus from water column

### *Disadvantages*

- Possible limitation to provide only short-term improvements due to the redissolution of precipitating  $\text{CaCO}_3$  as it settles in deep waters
- Potential to cause high pH in the water column
- Limited effectiveness in soft water lakes
- Limited effectiveness when watershed load is dominant

### *Suitability for Blackmans Lake*

While calcium treatments would likely provide limited short-term improvements in Blackmans Lake, alternative phosphorus inactivation treatments are more effective due to the lake's soft water and low calcium content.

### *Iron Application*

Iron treatment is a relatively inexpensive control strategy (Matthijs et al., 2016) added to aquatic systems within the water column or sediment surface in the form of chloride and sulfate salts, such as  $\text{FeCl}_3$ ,  $\text{FeCl}_2$ , and  $\text{Fe}(\text{SO}_4)_3$ , or as zero valent iron (ZVI). Iron used to coagulate dissolved phosphorus is sensitive to potential redox changes, in that ferric iron ( $\text{Fe}^{3+}$ ) freely precipitates phosphorus in oxygenated conditions. In anoxic conditions, however, ferric iron is reduced to ferrous iron ( $\text{Fe}^{2+}$ ), and the binding capacity with orthophosphate declines. This results in release into the aqueous phase. As a result, iron applications are often done in combination with hypolimnetic oxygenation methods.

ZVI is a form of iron typically used in soil and groundwater remediation efforts to bind chemical contaminants by transferring an electron to a contaminant compound. Contaminants in groundwater that have been inactivated by ZVI include petroleum hydrocarbons, pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and nitrates.

ZVI has also been added experimentally to rural wastewater treatment systems where sewage strength was low. In these systems, ZVI additions helped enrich bacteria biofilms and prevent blooms of filamentous cyanobacteria, even under conditions without additional aeration treatments (Wang and Li 2022). However, primary sewage treatment requires at least basic oxygenation. This suggests that ZVI is

ineffective under anoxic conditions. ZVI could become effective, if applied in combination with hypolimnetic oxygenation methods, or if ZVI was applied as a modified clay composite like bentonite (Sarkar et al. 2019). Lake Lorene in Federal Way, Washington, is frequently treated with algaecide followed by ZVI applications to inactivate soluble phosphorus released by dead algae.

Under the Aquatic Plant and Algae Management General Permit, a jar test must be completed prior to treatment to identify proper dosing levels.

### **Advantages**

- Removes soluble reactive phosphorus from water column and from shallow sediments in the epilimnion (and deep sediments if hypolimnion remains oxygenated)
- Not expected to have environmental impacts at anticipated dosage

### **Disadvantages**

- Phosphorus bound to iron in lakes and reservoirs can be resuspended due to dissolution in anoxic conditions
- Limited effectiveness when watershed load is dominant

### **Suitability for Blackmans Lake**

Blackmans Lake's hypolimnion becomes anoxic during the summer. The application of iron to sequester water column phosphorus is therefore not expected to be effective, because much of the phosphorus bound to iron would settle to the hypolimnion and be released during the summertime anoxic period. Furthermore, iron-bound phosphorus can release from shallow sediments. This occurs due to high pH caused by algae blooms, or due to anoxic conditions developing immediately below the sediment surface. Such anoxic conditions develop by microbial decomposition of high organic matter content or under dense aquatic plant canopies. Additionally, there are relatively minor amounts of dissolved phosphorus in the water column, meaning that the applied iron would only remove a minor fraction of the phosphorus in the water column.

The Aquatic Pesticide and Algae Management Permit issued by the Washington State Department of Ecology specifically states, regarding iron:

*Do not apply where anoxic conditions (zero percent dissolved oxygen) may occur, including anoxic conditions created by applications of herbicide and algaecide.*

Potentially, if a hypolimnetic oxygenation strategy is also employed, iron application could be a useful tool to increase binding sites for phosphorus in the sediments and to strip bioavailable phosphorus from the water column. Such a treatment would not be suitable until a hypolimnetic oxygenation system is in operation, as noted above.

Assuming there is approximately 30.3 µg/L of soluble phosphorus to remove from the water column, a ZVI stripping dose would cost approximately \$114,000 (Table 4). The material cost (\$2,534) is notably lower than other phosphorus inactivation projects and may be a cost-effective tool for water column stripping and sediment inactivation following hypolimnetic oxygenation.

**Table 4. Zero-Valent Iron Application Dose and Cost Estimate for Water Column Stripping.**

Assumption	Value
<b>ZVI to P Adsorption Ratio</b> (125 µm ZVI) (mass-based)	44 ZVI : 1 P
<b>Available P Mass in Water Column (assume 30.3 ppb)</b>	32 kg
<b>ZVI Dose</b>	1,396 kg
<b>ZVI Cost</b> (\$1.21 per kg)	\$1,689
Shipping Fee	\$845
<b>Permitting, Monitoring, and Planning Cost</b>	\$50,000
<b>Applicator Fee</b>	\$50,000
<b>Total Cost</b>	<b>\$102,534</b>

## Planning Level Comparison for Phosphorus Inactivation with Alum, Lanthanum, and Proprietary Products

Approximate dose and cost estimates were prepared for the inactivation of phosphorus for water column stripping and sediment inactivation, using alum, lanthanum, and proprietary blends under current conditions with an anoxic hypolimnion for comparison to the cost for hypolimnetic oxygenation. These doses are based on available data for phosphorus in the water column and sediments. They are expected to last approximately 5 years based on continued moderate amounts of watershed and groundwater phosphorus loading. Table 5 provides the dosing and cost assumptions used for developing estimates.

**Table 5. Assumptions for Dose and Cost Estimates for Phosphorus Inactivation Chemicals.**

Approach	Ratio to Phosphorus	Cost per Unit
Alum (Buffered with Sodium Aluminate)	20 Al : 1 P (by mass)	Alum: \$2.00/gal; Buffer: \$5.10/gal
Alum (Unbuffered)	20 Al : 1 P (by mass)	\$2.00/gal
Lanthanum (EutraSorb G; 10% La)	50 product: 1 P or 5 La : 1 P (by mass)	\$3/kg
Lanthanum (Phoslock; 5% La)	100 product: 1 P or 5 La : 1 P (by mass)	\$6.6/kg
Proprietary Blend – MetaFloc	1.3 gallons : 1 kg	\$75/gal
Proprietary Blend – EutroSORB WC	1.28 gallons : 1 kg	\$200/gal

Water stripping doses were developed assuming (1) that 32 kg of phosphorus in the water column would inactivate in the first year of treatment (2025) and (2) that subsequent phosphorus levels for treatment would be 25 percent lower (24 kg). Table 6 provides cost estimates for water stripping using unbuffered alum, lanthanum modified bentonite (Phoslock and EutraSORB G), and proprietary products (MetaFloc and EutraSORB WC). An unbuffered dose of alum is appropriate due to the low alum dose required for only water column stripping (dose of 0.6 mg/L Al; 2.6 g Al/m<sup>2</sup>). The assumptions include a contractor fee

of \$50,000 for mobilization and application, and a consultant fee of \$50,000 for monitoring and oversight. A 15 percent contingency is included.

**Table 6. Water Phosphorus Stripping Cost Estimates.**

Phosphorous Inactivation Product	Application Dose	Materials Cost	Mob/ Application	Tax (9.25%)	Oversight, Monitoring	Contingency (+15%)	Total Year 1 Cost	Total Year 2 Cost
Unbuffered Alum	2,884 gal	\$6,057	\$50,000	\$5,381	\$50,000	\$15,360	<b>\$126,798</b>	<b>\$124,724</b>
PhosLock	3,173 kg	\$20,940.37	\$50,000	\$6,810	\$50,000	\$19,438	<b>\$147,188</b>	<b>\$140,016</b>
Eutrosorb G	1,586 kg	\$4,759.17	\$50,000	\$5,257	\$50,000	\$15,004	<b>\$125,020</b>	<b>\$123,390</b>
MetaFloc	91 gal	\$6,805.62	\$50,000	\$5,453	\$50,000	\$15,565	<b>\$127,824</b>	<b>\$125,493</b>
Eutrosorb WC	89 gal	\$17,869.11	\$50,000	\$6,515	\$50,000	\$18,596	<b>\$142,981</b>	<b>\$136,861</b>

Sediment inactivation doses were estimated based on an average sediment mobile phosphorus concentration of 466 mg/kg-DW and a treatment area of 247,000 m<sup>2</sup> (the entire lake area) to inactivate 1,037 kg of phosphorus in sediments to a depth of 10 centimeters. The sediment inactivation doses include water column stripping of 32 kg. The alum should be buffered due to the higher aluminum dose (19.8 mg/L Al; 84.1 g Al/m<sup>2</sup>). The estimated cost of sediment inactivation ranged from \$322,500 for EutroSORB G to \$1.0 million for Phoslock (Table 7).

**Table 7. Sediment Phosphorus Inactivation and Water Column Stripping Cost Estimates.**

Phosphorus Inactivation Product	Application Dose	Materials Cost	Mobilization + Application	Tax (9.25%)	Oversight, Monitoring	Contingency (+15%)	Total
Buffered Alum	41,528 gal alum 20,764 gal buffer	\$191,028	\$50,000	\$23,139	\$50,000	\$47,125	<b>\$361,292</b>
PhosLock	246,393 kg	\$705,102.05	\$50,000	\$72,490	\$50,000	\$131,639	<b>\$1,009,231</b>
EutroSORB G	123,197 kg	\$160,250.47	\$50,000	\$20,184	\$50,000	\$42,065	<b>\$322,500</b>
MetaFloc	7,047 gallons	\$229,158.17	\$50,000	\$26,799	\$50,000	\$53,394	<b>\$409,351</b>
EutroSORB WC	6,938 gallons	\$601,687.08	\$50,000	\$62,562	\$50,000	\$114,637	<b>\$878,886</b>

The longevity of sediment inactivation treatments is dependent on the control of external loading and stability of the bonds between the inactivation chemical and sediment phosphorus. We have developed ranges of costs for a 20-year period assuming a longevity of 2 to 3, 5, and 10 years, including a 5 percent escalation per year (Table 8). Sediment inactivation treatments are expected to last longer for alum than lanthanum because the phosphorus binding capacity is four times greater for alum (20 Al: 1 P) than lanthanum (5 La; 1P) (see Table 5). Note that these estimates include a dosage on the 20th year. We have also estimated the cost of annual water stripping.

Based on the low external loading rate to Blackmans Lake, it is reasonable to expect a 10-year longevity for sediment inactivation using buffered alum and a 2.5-year longevity for Lanthanum (Phoslock or EutroSORB G). Based on these assumptions, buffered alum treatments would cost the least at approximately \$1,910,000 over a 20-year period, which is equivalent to an average annual cost of \$95,500/year.

**Table 8. Estimated Long-Term Cost of Phosphorus Inactivation through Water Stripping or Sediment Inactivation at Varied Longevity Assumptions for Blackmans Lake in a 20-Year Period.**

<b>Phosphorus Inactivation Chemical</b>	<b>Annual Water Stripping for 20 Years</b>	<b>Sediment Inactivation with 10-Year Longevity (3 Treatments in 20 years)</b>	<b>Sediment Inactivation with 5-Year Longevity (5 Treatments in 20 years)</b>	<b>Sediment Inactivation with 2.5-Year Longevity (9 Treatments in 20 years)</b>
Buffered Alum	–	\$1,910,000	\$3,120,000	\$6,650,000
Unbuffered Alum	\$3,940,000	–	–	–
PhosLock	\$26,830,000	\$5,330,000	\$8,720,000	\$18,570,000
EutroSORB G	\$8,990,000	\$1,700,000	\$2,790,000	\$5,930,000
MetaFloc	\$11,240,000	–	–	–
EutroSORB WC	\$23,440,000	–	–	–

Table 9 provides a high-level summary and comparison of the evaluated water column inactivation chemicals suitable for Blackmans Lake. As noted in the *Iron Application* subsection, iron treatments may be a suitable phosphorus inactivation chemical alternative if the hypolimnion is oxygenated.

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**Table 9. Comparison of Water Column Phosphorus Inactivation Chemicals.**

<b>Water Column Inactivation Method</b>	<b>Alum</b>	<b>Lanthanum</b>	<b>Proprietary Blend</b>
<b>Commercial Products</b>	Available from general chemical suppliers	Phoslock EutroSORB G	MetaFloc EutroSORB WC
<b>Mode of Inactivation</b>	Forms stable complexes with dissolved phosphorus. Forms floccules that pull particulate phosphorus (i.e., algae and sediment from the water column). Stable at pH 6 to 9.	Forms stable complexes with dissolved phosphorus. Binding efficiency is highest between pH 5 and 7. Dissolution may occur at elevated pH levels (>9).	Form complexes with dissolved phosphorus. Most blends include a floccule agent that, like alum, will pull particulate phosphorus (i.e., algae and sediment from the water column).
<b>Application Approach</b>	Applied at water surface and settled to the sediment. Alum is expected to sink and incorporate into the lake sediments.	Applied as lanthanum modified bentonite or as lanthanum salt across the waters surface. Expected to incorporate into the lake’s sediments.	Applied at water surface and settled to the sediment.
<b>Potential Negative Consequences</b>	Aluminum toxicity to aquatic life may occur if inadequate buffer is applied and the pH is outside permitted range of 6-8.5. This can be prevented through rigorous planning and monitoring as required by the permit.	Lanthanum concentration immediately following application may exceed estimated toxicity thresholds, particularly for zooplankton, and little study has been done for impacts on benthic organisms. Generally, because lanthanum is applied in phosphorus-rich waters, the amount of free lanthanum ions is low as they bind to phosphate. Jar tests prior to application can be used to ensure proper dosage.	The specific make-up of the blends is proprietary. If alum and lanthanum blend, then the same potential impacts and toxicity prevention approaches.
<b>Permitting</b>	Alum is an approved phosphorus inactivation chemical in the APAM permit.	Lanthanum is an approved phosphorus inactivation chemical in the APAM permit.	Ecology must be allowed to confirm that the chemicals in the product are already approved or an experimental application permit must be obtained.
<b>Water Stripping Estimated Cost for 2025</b>	\$123,000 (unbuffered alum)	\$125,000 (EutroSORB G) \$147,000 (Phoslock)	\$128,000 (MetaFloc) \$143,000 (EutroSORB WC)
<b>Long-term 20-year Water Stripping Cost</b>	\$3.9 million	\$3.9 million (EutroSORB G) \$4.4 million (PhosLock)	\$4.0 million (MetaFloc) \$4.3 million (EutroSORB WC)
<b>Sediment Inactivation Estimated Cost for 2025</b>	\$361,000 (buffered alum)	\$323,000 (EutroSORB G) \$1,000,000 (Phoslock)	\$409,000 (MetaFloc) \$879,000 (EutroSORB WC)
<b>Long-term 20-year Sediment Inactivation Cost</b>	\$1.9 to \$6.7 million	\$1.7 to \$5.9 million (EutroSORB G) \$5.3 to \$18.6 million (PhosLock)	\$2.2 to \$7.5 million (MetaFloc) \$4.6 to \$16.2 million (EutroSORB WC)
<b>Recent Past Applications</b>	Heart Lake, Anacortes, WA (2018) Waughop Lake, Lakewood, WA (2020) Wapato Lake, Tacoma, WA (2017) Green Lake, Seattle, WA (2016)	Kitsap Lake, Bremerton, WA (2020 – [annually]) Lake Lorene, Federal Way, WA (2012)	No published case studies or management plans

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## Jar/Bucket Test Comparison of Phosphorus Inactivation Products

Jar (or bucket) tests may be conducted prior to selecting a phosphorus inactivation product, to evaluate its effectiveness at removing phosphorus and to evaluate negative consequences. Jar tests are essentially microcosm studies where a prescribed dose of a phosphorus inactivation product is added to a small volume (e.g., 5-gallon bucket) of lake water and the water chemistry is monitored over a short time period within 1 day. Samples for total phosphorus, orthophosphate, aluminum (alum only), alkalinity, and dissolved organic carbon analysis should be collected before dosing and 1 hour after dosing. Water pH should be analyzed at a higher frequency (e.g., before dosing, 2 minutes, 15 minutes, 30 minutes, and 1 hour after dosing). We recommend performing jar tests using both epilimnion water and hypolimnion waters collected during summer stratification and taking care to avoid aeration of the hypolimnion samples.

We recommend the doses in Table 10 for jar/bucket test (assuming 30.3 ppb or 0.57 mg in a 5-gallon-bucket). For this study, we selected EutroSORB G over Phoslock because of its lower material costs. Due to the low dose volumes for MetaFloc and EutroSORB G (9 µL), it may be challenging to precisely dose the proprietary products.

**Table 10. Phosphorus Inactivation Product Jar Test Dosing.**

Product	Dose Ratio to P	Dose to 5-Gallons	Concentration
Alum (unbuffered)	5 kg Al to 1 kg P	0.049 mL	0.15 mg/L Al
	10 kg Al to 1 kg P	0.099 mL	0.30 mg/L Al
	20 kg Al to 1 kg P	0.197 mL	0.61 mg/L Al
Lanthanum Modified Bentonite (EutroSORB G with 10% La)	10 kg product to 1 kg P	5.7 mg	0.3 mg/L EG
	20 kg product to 1 kg P	11.5 mg	0.6 mg/L EG
	50 kg product to 1 kg P	28.6 mg	1.5 mg/L EG
MetaFloc	2.86 gal product to 1 kg P	0.006 mL	0.3 µL/L
EutroSORB WC	2.816 gal to 1 kg P	0.006 mL	0.3 µL/L
Untreated	–	–	–

## External Loading Control Methods

The annual phosphorus budget for Blackmans Lake indicates that watershed sources of phosphorus primarily include waterfowl (23 percent) and storm flow (16 percent). Base flows and groundwater inflows were estimated to be a relatively small source of phosphorus to the lake. We therefore expect that there is a limited amount of OSS contamination at this time.

## Septic System Management

Conventional septic systems offer little treatment or reduction of phosphorus, except the settling of solid-bound phosphorus to the bottom the septic tank. Concentrations in effluent range from 1 to 26 mg/L (1,000 to 26,000 µg/L) (McCray et al. 2005). Phosphorus is treated or removed by soils in the drain field after leaving septic tank as effluent. Within a properly sized drain field, phosphorus will undergo mineralization, bind (adsorb) to soil particles, and be taken up by plants. A particular issue for lakes is the presence of septic systems, along the immediate perimeter, which may have critically undersized drain fields in shallow, pervious soils that do not offer the binding sites and residence time necessary for phosphorus removal. For this reason, septic systems are not allowed to be installed within 100 feet of a lake in Washington and within up to 300 feet in other states.

The effectiveness of soils and underlying aquifer materials in attenuating P movement to subsurface and surface water depends upon a number of factors including: the soil chemical and physical properties, the chemical properties and loading rate of the wastewater, site hydrology, proximity of the site to surface water, and the design and management of the onsite sewage disposal system (McCray et al. 2005).

Advanced septic system technology has shown promise for removing phosphorus in areas with limited drain field area or highly pervious soils. A pilot study at Newman Lake in Spokane County, Washington, installed membrane bioreactor treatment systems and measured the ability to reduce phosphorus, nitrogen, and other wastewater constituents. These systems can treat up to 97.9 percent nitrogen, 98.1 percent phosphorus, and 99.99 percent fecal coliform bacteria (Morrison Maierle 2022).

The cost of the membrane bioreactor systems is not trivial. In the Newman Lake pilot study, two models were installed (Morrison Maierle 2022). For a single residence, initial equipment costs ranged from \$27,500 to \$44,000, with an annual maintenance contract of \$500. Cost can vary substantially based on existing site conditions and electrical capacity. The lifespan of the installed systems is estimated at 25 to 35 years. The average cost to install a conventional septic system in Washington State is \$15,500, but this also varies widely and depending on many factors (<https://www.nexgenseptics.com/>).

Failing septic systems farther away from the lake and streams may also contribute substantial phosphorus to the lake via stream base flow and groundwater. Because proximity is the greatest factor, we recommend that inspections for failing or inadequate systems prioritize residences located adjacent to the lake and streams.

Techniques such as septic system function assessment, microbial source tracking, and nutrient source tracing should be used to assess cost-effective source-control actions, regardless of their immediate impact to lake phosphorus loading by septic systems in the watershed.

## Advantages

- Reduces phosphorus loading to the lake in the long term
- Maintains and upgrades critical individual wastewater infrastructure

## Disadvantages

- Costly
- Will not provide immediate relief

## Suitability for Blackmans Lake

We recommend taking actions to identify existing septic systems that may be contributing disproportionate loads of phosphorus to Blackmans Lake. These include failing systems that are no longer functioning per their initial design and systems that do not have adequate local conditions to remove phosphorus. Systems that appear to be working can still be contributing phosphorus loading to the lake. Failing systems may be identified via operation and maintenance inspections by certified professionals. Important factors for improperly sited systems and drain fields are distance to a nearby lake or stream, depth to the water table, and soil chemistry.

We recommend encouraging septic system owners throughout the watershed to complete routine inspections, as required by state law. Additionally, we recommend evaluating higher risk systems that are located around the lake or along streams to evaluate if adequate treatment is provided. In locations where the systems are not adequate, advanced treatment systems (ATUs) may be necessary. For instance, membrane bioreactor systems treat wastewater before discharge to the drain field and therefore do not necessitate the full drain field treatment area. The installation of such technology must be permitted by Snohomish County Health Department, per WAC 246-272A. We recommend coordination with Snohomish County Health Department and the State Department of Health, to develop a pathway for upgrading septic systems that do not have adequate drain field areas or soil treatment.

Replacing septic systems can be very expensive (up to \$20,000 to \$40,000), depending on the location and installation constraints. However, there are numerous grants and low-interest loans available that may ease the upfront investment. This includes Craft3 Clean Water Loans, a low-interest loan program.

## Planning Level Costs

Septic system inspections and enforcement should be performed by Snohomish County at an enhanced rate, as time and funding allow. Snohomish County Health Department should also identify how to allow and promote upgrading of septic systems that do not have adequate drain field areas or soil treatment. Funding of County Health Department activities and new septic systems are not included in this LCMP.

## Stormwater Management

Stormwater runoff can also be an important pathway of nutrients to surface water and groundwater. Fertilized areas, domestic animals, wildlife, and erosion of soils and organic matter contribute phosphorus to stormwater runoff.

Stormwater management seeks to treat or infiltrate runoff from impervious and pollutant-generating surfaces prior to discharge to lake. External phosphorus reductions may be achieved through source control and stormwater treatment. Source control can include reduction in phosphorus-containing fertilizer use, identification and removal of illicit sewage connections, pet waste management, and erosion control. Stormwater treatment can include detention facilities, rain gardens, and regional treatment facilities. Stormwater management that reduces peak flows entering streams will also reduce streambank erosion. Lake management plans can be used to declare a lake as sensitive to phosphorus inputs and require new developments to install stormwater treatment systems that are designed to remove phosphorus not just suspended solids.

### Advantages

- Reduces phosphorus loading to the lake in the long term
- Reduces other pollutants (e.g., metals)

### Disadvantages

- Expensive, low cost-effectiveness
- Does not address immediate bloom issues

### Suitability for Blackmans Lake

The Blackmans Lake watershed is 81 percent residential development and 28 percent impervious surfaces from a combination of roadways, rooftops, and driveways. Estimates of stormwater runoff in the watershed indicate about 16 percent of the annual phosphorus load is from storm flows. Opportunities to install small phosphorus treatment systems in areas currently without stormwater treatment and to retrofit existing facilities to provide treatment could be explored.

## Waterfowl Management

Feces from waterfowl, such as ducks, geese, and coots, can be significant source of nutrient and fecal bacteria to lakes. Populations of resident Canada geese have dramatically increased over the past 25 years, particularly in urban areas where there are few predators, prohibitions on hunting, and a dependable year-round supply of food and water (WDFW 2024). Canada geese are particularly attracted to mowed lawns around homes, golf courses, parks, and similar areas next to open water.

Waterfowl management approaches are summarized in Table 11. It is illegal to hunt, kill, sell, buy, or own migratory birds except in certain cases. The Migratory Bird Treaty Act of 1918 and State laws protect all native waterfowl in the United States, and that includes migratory and resident Canada geese.

## Advantages

- Reduces phosphorus loading to the lake in the long term
- Reduces fecal contamination

## Disadvantages

- Expensive, low cost-effectiveness on a large scale
- Does not address immediate algae bloom issues

## Suitability for Blackmans Lake

Waterfowl droppings are a leading contributor to phosphorus loading to Blackmans Lake. This is primarily driven by migratory geese populations in fall (seen in October 2023), where up to 4,000 geese were found on the lake. Because most loading is associated with migratory geese rather than resident geese, there are legal and ethical considerations in taking actions to harass, relocate, or otherwise harm migrating geese. Additionally, actions taken to harass and displace migratory geese may result in a shift in the migrating population to neighboring lakes, which may be negatively impacted by increased phosphorus loads. Relocation is generally not recommended because the birds are likely to create problems wherever they go.

It is important to prevent the migrating populations from becoming resident. Feeding waterfowl discourages natural winter migration; can lead to aggressive behavior; and encourages large resident bird flocks that degrade parks, lawns, and beaches with droppings. Proper signage with such messaging should be installed at the parks and boat launch. We also recommend property owner participation in the Snohomish County LakeWise program (described below) and for the City Park Department to evaluate waterfowl-d discouraging landscaping on its lands.

**Table 11. Waterfowl Management Approaches.**

<b>Management Approach</b>	<b>Description</b>	<b>Benefits</b>	<b>Challenges</b>
Feeding Discouragement	Signage and/or enforcement of public feeding of waterfowl.	Discourages resident waterfowl. Better for waterfowl health.	Not expected to be effective control for migrating populations.
Landscaping	Geese and ducks are grazers and prefer short, green grass for food. Let grass grow longer so it is unattractive to the birds. Along water edges, plant less appealing vegetation. Waterfowl prefer to land on water and walk onto nearby grassy areas to feed and rest. Use fences, hedgerows, and other physical barriers to make this difficult for them.	Non-lethal management approach to discourage resident waterfowl and dissuade resting by migrating waterfowl. Actions can also decrease residential stormwater pollution and shoreline erosion.	Requires social marketing and individual property owner expense to redesign existing landscaping. May not be effective at managing migrating waterfowl.
Harassment/Scare Tactics	Eyespot balloons, flags, streamers, scarecrows, noisemakers, lasers, dogs, chemical repellents, or similar devices/tools are deployed to discourage waterfowl use.	Non-lethal management approach to discourage resident waterfowl and dissuade resting by migrating waterfowl.	Effectiveness is highly variable and is dependent on extent of deployment. Lasers and noisemakers can have non-target species impacts (including people). Use of dogs can be expensive and is limited to public and willing landowners.
Lethal Control	A federal depredation permit authorizes capture or killing of birds to help reduce damage to agricultural crops/livestock, private property, human health & safety (including airports), and protected wildlife. A depredation permit is intended to provide short-term relief for bird damage until long-term nonlethal measures can be implemented to eliminate or significantly reduce the problem.	Permanent removal of individual waterfowl. Gunfire may encourage relocation of resident and present migrating waterfowl.	Requires Migratory Bird Depredation Permit. May not discourage future migratory resting. May not be used as a long-term solution.

## Shoreline Management

Over the years, people altered the lakeshore by removing trees and dead wood from the shorelines and by building bulkheads. Concrete or rock wall bulkheads negatively impact fish and wildlife habitat. They can accelerate erosion of shallow lake sediments by increasing wave energy, which can fuel cyanobacteria growth by suspending sediment nutrients and wash them deeper into the lake releasing more phosphorus in the anoxic hypolimnion.

Best management practices for lake shorelines include healthy shoreline alternatives that use native plants, beaches, and wood to protect houses while improving habitat for fish and wildlife, views, and recreational opportunities. Healthy shoreline alternatives are designed to create a more gradual sloping shoreline and overhanging vegetation to provide protected, shallow water habitat needed by fish and a food source for native birds and wildlife. Healthy shorelines are simply lake edges planted with shrubs, trees, or perennials instead of lawn to the water's edge (Snohomish County 2023; see example planting plan). These plants have lots of benefits over lawn because they:

- Have deeper roots that trap and filter up to nine times more phosphorus
- Stabilize the shoreline, preventing erosion
- Provide great habitat and food for birds, turtles, frogs and other beneficial aquatic life
- Can add beauty to your shoreline and potentially increase property values
- Need little maintenance once established.

Benefits of healthy shorelines for property owners include:

- Reduced lake sediment erosion
- Reduced wave-induced sediment nutrient recycling and cyanobacteria growth
- Reduced Canada geese activity and droppings on property
- Easier access to beach and water
- Shallow gradient shorelines are often favored over steeper designs, especially if you have small children
- More usable shoreline with beach and cove
- Reduced maintenance
- Potential for increased property values.
- Many shoreline management actions may also reduce attractiveness to waterfowl, described in the previous section.

## Advantages

- Reduces phosphorus loading to the lake in the long term
- Improves lake habitat quality

## Disadvantages

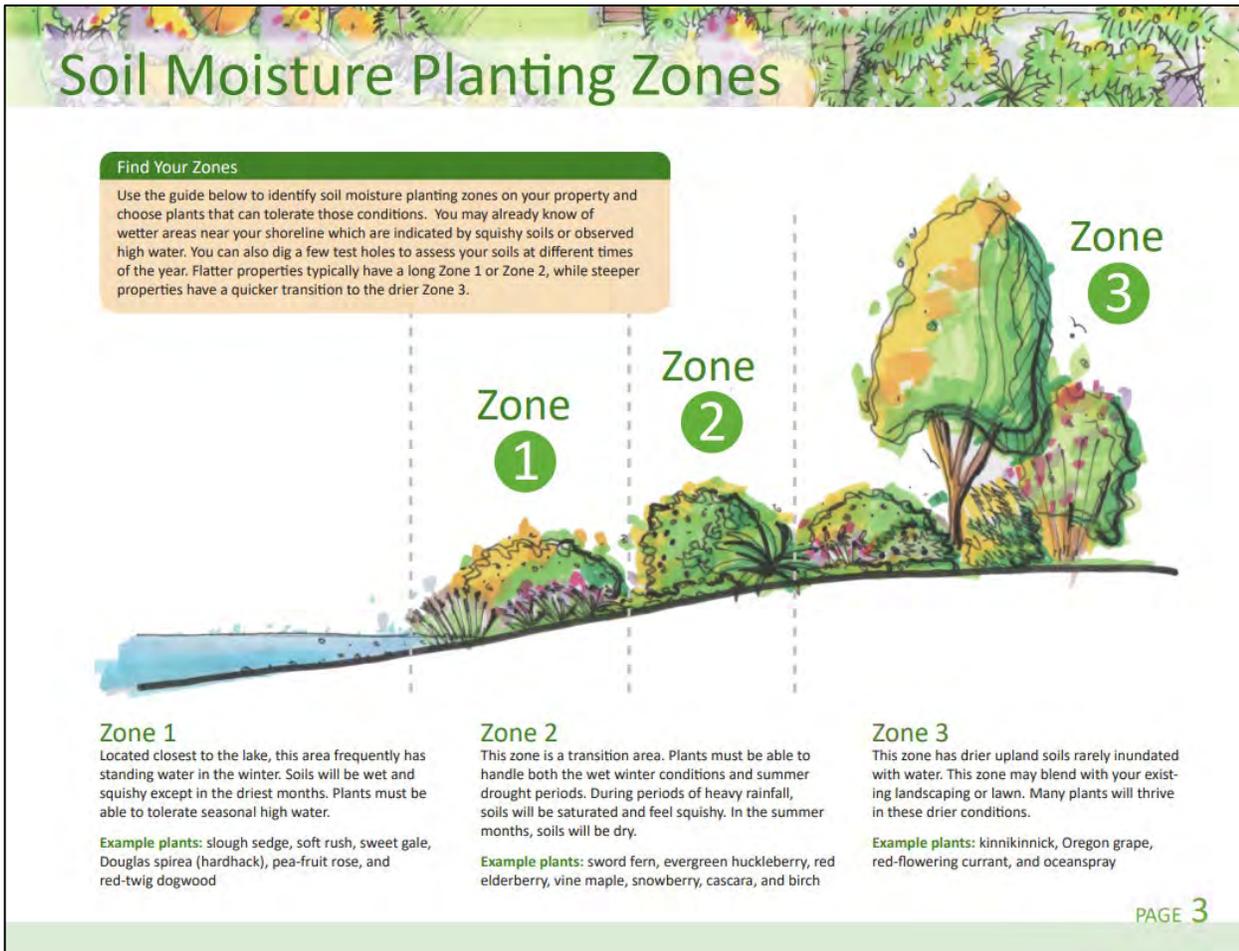
- Expensive, low cost-effectiveness on a large scale
- Does not address immediate algae bloom issues

## Suitability for Blackmans Lake

Developing a healthy shoreline program to promote and fund replacement of bulkheads and lawns with native plants is a suitable management action to reduce nutrient inputs and cyanobacteria growth in Blackmans Lake. Snohomish County Surface Water Management runs an existing program, LakeWise, to encourage lake stewardship through lawn and yard care, septic system care, and healthy shorelines. The program provides online and in-person education and outreach materials (see example in Figure 1). LakeWise offers free natural lawn care workshops and free native plants for shoreline landscaping.



Figure 1. LakeWise Shoreline Planting Guide Excerpt.



## Planning Level Costs

Snohomish County LakeWise program implements in-person and online workshops to promote healthy shorelines and provide educational materials. The City of Snohomish may add additional outreach to City residents to the existing contract with the County. The cost of individual shoreline restoration projects varies from property to property based on existing conditions, slope, and more. The estimated cost of establishing a 10-foot natural shoreland buffer ranges from \$50 to \$150 per linear foot of shore. The cost of changing existing lawn and landscaping management practices, such as eliminating fertilizer use, is expected to be minimal.

## Methods Rejected

We rejected several management and restoration methods for Blackmans Lake due to high cost and/or low certainty in success. Rejected methods and rationale for rejection are described in the sections below and summarized below in Table 12.

**Table 12. Rejected Management/Restoration Methods for Blackmans Lake.**

Management Method	Rationale for Rejection
Stream Phosphorus Inactivation	Expensive; risk of toxicity; relative watershed contribution is low
Sonification	Low confidence in success
Ozone/Microbubble/Nanobubbles	Low confidence in success
Dredging	Very expensive, difficult to permit
Lake Mixing	Expensive, low confidence in success
Biological Control (biomanipulation, barley straw, macrophyte plantings)	Potential for unintended ecological consequences. Low confidence in success.
Calcium Application	Less effective than other phosphorus inactivation methods.

### Stream Phosphorus Inactivation

Phosphorus inactivation products can be applied at the mouth of streams or stormwater outfalls entering a lake to inactivate phosphorus prior to it becoming available for lake algae. Systems that pump aluminum-based inactivating compounds into an inflow pipe, ditch, or stream have become more widespread (Pilgrim and Brezonik 2005, Wagner et al. 2017). In some cases, a retention pond is provided to capture aluminum floc before it enters the lake, whereas in others the floc is allowed to enter the lake and settle onto target sediments where further P inactivation can occur. Due to high installation and operating costs, alum injection is most effective for large volumes of water that a system either conveys from a large drainage area or stores in a large basin (EPA 2021).

An alum injection system could be designed for lake inlet(s) that injects low doses of alum through tubing from onshore storage tanks to an aeration or circulator system mounted in the stream bed for through mixing of the alum with stream waters. A flow-weighted dosing system would be used that adjusts the dose with stream flow and may be integrated with a water quality monitoring system to measure pH or other parameters to terminate treatment exceeded programmed thresholds. A buffer such as sodium hydroxide or aluminate can be added but is not likely needed for low doses, mixed systems, and pH feedback mechanisms.

Alternatively, lanthanum-modified clay or zero valent iron can be used to inactivate stream phosphorus in lake inlet(s). Porous bags can be filled with either product and placed in the bottom of the stream channel and may require installation of a hard substrate to prevent them from sinking in soft stream sediment. The bags are turned on one occasion before they are replaced when they are expected to become ineffective based on the phosphorus loading rate relative to the amount of inactivation product.

## Advantages

- Reduces phosphorus loading to the lake long-term

## Disadvantages

- Alum could impact aquatic biota from aluminum toxicity if the pH is outside 6.5-8.5.
- Ecology may not permit alum injection in a stream without containment and removal of the alum floc
- Requires routine O&M and has an annual operating cost

## Suitability for Blackmans Lake

Stream phosphorus inactivation with an alum injection system is not suitable for Blackmans Lake because placement and operation at any of the lake inlets would be difficult, presents a risk for aluminum toxicity to aquatic organisms under extreme pH conditions (less than 6 or greater than 8.5), may not be allowed by Ecology without a floc retention system, and the relative contribution of stream phosphorus input to the lake is low. Stream phosphorus inactivation with filter bags of lanthanum-modified clay or zero valent iron is not suitable for Blackmans Lake because the bag replacement would be labor intensive and difficult to predict, and the relative contribution of stream phosphorus input to the lake is low.

## Sonification

Sonication treatment implements high frequency (>20 Khz) ultrasound for the control of cyanobacterial blooms. The ultrasonic waves act as a barrier to upward movement of algal cells into the photic zone. The waves also reduce cyanobacterial growth by causing structural and functional cellular damage. The LG Sonic system continuously monitors cyanobacteria pigments and water quality parameters to systematically transmit ultrasonic waves when conditions warrant. There are few well-studied implementations of sonication systems and reports are largely anecdotal with highly variable results. In a recent review, Luring and Mucci (2020) concluded that low-frequency ultrasound should be avoided, as it is ineffective; high-frequency treatment is more effective, but it is costly due to energy demand, and its effective range is limited.

## Advantages

- Permanent control.
- Some devices provide real-time data on lake quality

## Disadvantages

- Few lake case studies to confirm effectiveness. Results have been variable
- May cause cell lysis, and increase extracellular cyanotoxin levels
- Benthic blooms may still occur

- Limited by the effective treatment radius
- Requires a permanent contract for monitoring

## Suitability for Blackmans Lake

Sonification treatment in Blackmans Lake is not recommended due to the low certainty of success.

## Ozone, Microbubbles, and Nanobubbles

Ozone is a strong oxidant that is majorly employed in water treatment for pre-oxidation to control natural organic matter to minimize the formation of disinfection by-products. Studies have shown its ability to damage cyanobacteria cells (Coral et al., 2013; Fan et al., 2013; Wert and Rosario-Ortiz 2013) while simultaneously oxidizing cyanotoxins and taste and odor compounds (Meriluoto et al., 2017; Wert et al., 2014). Ozone application for managing blooms at the source may be promising but is limited by structural and safety requirements that make for a complex application. Furthermore, the efficiency of aqueous ozone oxidation is restricted by rapid decay rates.

Microbubbles (diameter 10-50  $\mu\text{m}$ ) and nanobubbles (<200 nm) have attracted increasing scientific attention in recent years. Due to their small diameters, these tiny bubbles have low rising velocities in the aqueous phase, high internal pressures, and rapid mass transfer rates that can significantly improve gas solubility (Atkinson et al., 2019; Hu and Xia, 2018; Li et al., 2014).

Nanobubble aeration uses compressed gas (e.g., air, ozone, carbon dioxide) to produce nanobubbles (bubbles 2,000 times smaller than a grain of salt) to aerate the water column. The key advantage of using nanobubbles versus traditional aeration technologies is that the very small bubbles move both vertically and horizontally, spreading out evenly and remaining in the water column for long periods of time (versus floating to the surface and dispersing), and therefore this technology greatly increases oxygen transfer. Another advantage is that the bubbles are too small to cause water currents and disrupt a stable thermocline. Bubbles are typically injected near the sediment surface, thus reducing phosphorus release from the sediments without physically disturbing the sediments, which can occur from traditional aeration systems. The high oxygen transfer rate and resultant oxidation (through creation of ozone and other oxidative compounds) has been shown to breakdown algae cells and degrade toxins.

## Advantages

- Very small bubbles spread out evenly and remain in the water column for long periods of time (versus floating to the surface and mixing water column)
- Greatly increases oxygen transfer and benefits aquatic life uses
- Reduces phosphorus release from sediments
- Breaks down algae cells and degrades toxins
- Easily scalable modular units
- Low/no design costs

## Disadvantages

- Requires supply of compressed gas (e.g., air, ozone, carbon dioxide)
- Few case studies to evaluate effectiveness and duration of treatments with some recent reports of ineffective systems
- New technology with many companies, specifications and costs vary

## Suitability for Blackmans Lake

Ozone, microbubbles, or nanobubble are not recommended for Blackmans Lake due to the limited information on effectiveness and the initial investment cost.

## Dredging

Dredging is a technique that can be used to control phosphorus levels in lakes. The process involves removing sediment and organic material from the bottom of the lake, which can contain significant amounts of phosphorus that have accumulated over time. By removing this material, the amount of phosphorus in the lake can be reduced, which can help to prevent the growth of harmful algal blooms and promote better water quality.

Dredging can be a complex and costly process that requires specialized equipment and expertise. The process typically involves the use of a dredge, which is a machine that is designed to scoop up sediment and other material from the bottom of the lake. The material is then transported to a dewatering site to remove excess water and then to a disposal site, where it can be treated or stored for later use. Dredging is very expensive primarily due to costs associated with dewatering and disposal of the material. Alum may be used to settle suspended sediment and associated phosphorus suspended by dredging and to inactivate phosphorus in remaining sediments.

## Advantages

- Removal of sediment as a phosphorus source
- Increased lake depth, causing reduced aquatic weed entanglement risk and improving recreational uses

## Disadvantages

- Difficulty to permit
- Prohibitive expense (\$ millions)
- Impacts to aquatic life
- Temporary increased turbidity
- Temporary public use disturbance

## Suitability for Blackmans Lake

Dredging is not suitable for Blackmans Lake due to its high cost.

## Lake Mixing

The key objective of lake aeration or mixing technologies is that the circulating or mixing motion of the water is also circulating and mixing algae cells. Most bloom-forming cyanobacteria can regulate their buoyancy to optimize their position in the water column and float to the surface. Mixing promotes growth of preferred algae such as green algae and diatoms because under natural conditions their time in the sunlit photic zone is determined by their sinking rate, so mixing increases their time in the photic zone. Cyanobacteria have air vacuoles that provide buoyancy and allow them to remain within the photic zone for longer periods of time. Aeration or mixing reduces this advantage, although to do so requires that mixing velocities need to be high enough to overcome cyanobacteria buoyancy, which can vary and be difficult to predict.

While cyanobacteria concentrations may be reduced, total algal biomass and chlorophyll-a concentrations may increase and green the water from the decreased settling rates. Whole-lake mixing by aeration disrupts the thermocline and increases nutrient availability by mixing deep waters to the surface. These technologies also introduce oxygen either passively through increased mixing and turbulence of surface waters or more actively through pumping air through the water. These changes in algal community populations and oxygen levels result in other changes in the lake food web.

## Surface Mixing (SolarBees)

The SolarBee is a solar-energy–driven, mixing device that is used to mix either the epilimnion or the entire lake volume. Like other mixing devices it controls algae through mixing them throughout the water column (Hudnell et al. 2010). Although no air is pumped into the water, additional oxygen is added through turbulence and increased contact with air above the lake surface. Surface mixing is theorized to combat cyanobacteria dominance by (1) increasing contact with cyanobacteria pathogens, predators, and bacteria that lyse cyanobacteria; (2) promoting competitor algae; and (3) interfering with the advantages of buoyancy-regulating cyanobacteria (Hudnell et al. 2010).

There are no significant design costs or issues associated with these; they are modular units that are easily scalable depending upon lake surface area. While SolarBees appear to primarily be used in small lakes and ponds, there have been successful applications in larger lakes, reservoirs and drinking water supplies.

## Advantages

- SolarBees have no long-term energy costs because they are solar-powered
- Can sink algae to below the photic zone, decreasing productivity
- Mixing systems can mix either epilimnion or entire water column
- Can give advantage to diatoms and other beneficial algae that can't control their buoyancy

- Easily scalable modular units
- Low/no design costs

### *Disadvantages*

- Epilimnetic mixing does not address sediment-derived phosphorus
- Few case studies for epilimnion mixing
- Can increase algae biomass and decrease water clarity by reducing settling rate of non-buoyant algae
- Often insufficient oxidation of sediments to reduce sediment phosphorus release

### *Suitability for Blackmans Lake*

Surface mixing with a SolarBee unit is not expected to be an effective tool to manage cyanobacteria in Blackmans Lake.

### *Whole-Lake Mixing*

Artificial circulation and mechanical mixers have been successfully used in lakes and reservoirs as physical controls to increase oxygen concentrations in bottom waters and to destratify the water column to remove the optimal habitat for buoyant cyanobacteria.

The two most common types of destratification are air injection and mechanical mixing (Hudson and Kirschner 1997). Air injection is a “bottom-up” approach that quickly pumps air to the bottom of the lake so that it will rise and carry the water from the hypolimnetic layers to the top layer. Mechanical mixing uses a “top-down” approach wherein a rotating propeller in the surface layers pushes the water downward, displacing bottom waters to the surface, where they are reoxygenated by the atmosphere. Popular commercially available models are powered by solar panels. Although artificial circulation is beneficial for oxygen and nutrient redistribution, the ecological effects on plant and animal life of destratifying a lake are not always predictable and could potentially be harmful (Hudson and Kirschner 1997).

### *Advantages*

- Permanent control by both mixing and oxygenation
- Depending upon design may also target sediment derived phosphorus
- Many lake applications for case studies for whole-lake mixing

### *Disadvantages*

- Resuspension of sediment layer nutrients in the water column
- Sedimentation of organic matter
- Installation and operational cost

- Ineffective in shallow lakes/ reservoirs with a large surface area
- May require continuous operation
- Can be ineffective when external nutrients are not controlled
- These need to be carefully designed and engineered. Poorly sized or designed applications can worsen problems.
- Larger mixing systems require shore based electrical supply and long, air supply line.

### **Suitability for Blackmans Lake**

Whole-lake mixing is not recommended for Blackmans Lake because of its high cost and high uncertainty in its ability control the internal phosphorus load.

## **Biomanipulation**

This method involves increasing the pressure on phytoplankton communities by reducing or removing planktivorous fish (Shapiro, 1990; Shapiro and Wright, 1984) or by increasing grazers and zooplankton populations (Ger et al., 2014; Kâ et al., 2012). By increasing pressure on phytoplankton, the goal is to reduce their populations through increased consumption by other feeders. Biomanipulation can also involve removal of common carp or other benthivorous fish to reduce phosphorus loading from sediment disturbance and fish excretion. Removal of zooplanktivorous and benthivorous fish and the addition of piscivores are the most frequently applied biomanipulation methods.

Some species of cyanobacteria are more resistant to grazing pressures from zooplankton. Cell/colony/filament size, toxicity, and poor nutritional value are defense mechanisms against grazing (Moustaka-Gouni and Sommer 2020). Grazers may fail to feed if cyanobacterial species, especially filamentous species, can surpass the optimal size range for food based on grazer body size.

### **Advantages**

- Potential for long-term benefits
- No chemical residuals

### **Disadvantages**

- Uncertainty of success
- Does not address nutrient issues
- May remove desirable fish species (e.g., trout)

### **Suitability for Blackmans Lake**

Biomanipulation is not recommended for Blackmans Lake because of the uncertainty of success.

## Macrophyte Plantings

Submerged macrophytes can control cyanobacteria through three main processes: (1) macrophytes compete with phytoplankton for nutrients, taking up nutrients from the sediments, and can reduce resuspension of sediments during rainfall and wind events; (2) macrophyte coverage provides habitat for zooplankton grazers of cyanobacteria; and (3) some macrophytes secrete allelochemicals that are inhibitory to phytoplankton. Emergent macrophytes on the shoreline can reduce nutrient inputs into the lake by filtering nutrients from upland runoff and reducing soil erosion.

Native aquatic macrophytes can be planted along the shoreline and in lakes that have low macrophyte cover.

### Advantages

- Potential for long-term benefits
- No chemical residuals
- Increased fish habitat

### Disadvantages

- Uncertainty in ideal macrophyte coverage
- Relatively minor nutrient control
- Does not address external nutrient loads
- Macrophytes may not be desired by shoreline homeowners

### Suitability for Blackmans Lake

The aquatic plant community in the Blackmans Lake is robust and diverse, including large patches of native yellow waterlily (*Nuphar*) and the invasive (Class C noxious weed) fragrant water lily (*Nymphaea odorata*). Additionally, there are moderately dense areas of the microalgae *Nitella* and *Chara*, as well as water nymph (*Najas flexilis*), common elodea (*Elodea canadensis*), and several species of native pondweed (*Potamogeton*). Blackmans lake is considered not suitable for macrophyte planting based on the robust and diverse aquatic plant community presently in the lake.

## Barley Straw

Applying straws such as barley and rice straws in lake systems is considered an alternative cyanobacterial control strategy. The mode of action of barley straws for cyanobacteria control is not entirely understood and has been a subject of much debate. However, various researchers have indicated that the release of allelopathic compounds during the aerobic decay of straws is a potential mechanism for controlling algae. Barley straws do not provide immediate improvements in water quality. The decomposition of straws may create an oxygen demand in the water column. Therefore, successful application may require

oxygen-rich systems as low oxygen levels can slow or hinder the straws from releasing algal inhibitory substances.

## Advantages

- No chemical residuals
- Rotting straw may provide habitat for invertebrates
- Low cost

## Disadvantages

- Do not provide immediate relief
- Inhibitory action is not understood
- May reduce lake oxygen levels due to decomposition
- May be a visual or boating nuisance
- Does not address nutrient issues

## Suitability for Blackmans Lake

The use of straws is not recommended for Blackmans Lake due to the low certainty in success.

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# Appendix E

## Public Meetings and Comments

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## Community Meeting Summary

**Date:** 5/20/2024 6:00–7:30 pm      **Location:** Snohomish Carnegie Building (105 Cedar Avenue)

**Project Number:** 22-07905-000

### Hosted By:

Yoshihiro Monzaki (City of Snohomish)

Jennifer Oden (Snohomish County Surface Water Management)

Rob Zisette (Herrera Environmental Consultants)

T. Clark (Herrera Environmental Consultants)

Katie Sweeney (Herrera Environmental Consultants)

### Meeting Objective:

In 2022, the City Council authorized a contract with Herrera Environmental Consultants, Inc. (Herrera) to complete the Blackmans Lake Cyanobacteria Management Plan (Plan) to address blue green algae. In 2022 and 2023, Herrera coordinated Blackmans Lake and watershed sampling with volunteers, Snohomish County Lakes Division staff, and the City staff as part of the Plan. At this community meeting, Herrera will present to the public the study design, findings, and the draft recommendations for addressing blue-green algae blooms at Blackmans Lake that will be included in the Lake Cyanobacteria Management Plan.

### Post-Presentation Questions and Comments:

1. Please clarify if the map shown in the presentation represents the “natural” watershed or the altered drainage area due to municipal decisions for stormwater diversions. For future presentations of this map, clarify which portions are naturally draining to the lake and which portions are not. There are data available with which we can map the historical watershed. Previous reports (e.g., from 1996) show that in the past 30 years, stormwater drainage in the Blackman’s Lake watershed has expanded.

## Blackmans Lake Cyanobacteria Management Plan

Response: Yes, stormwater infrastructure in the watershed has expanded and has altered the natural drainage pathways from the watershed to the lake. It would be interesting to compare the drainage pathways with land cover and historical lake water quality. Stormwater drainage and treatment infrastructure is necessary to control pollutant loading to the lake from the increased area of impervious surface now in the watershed.

2. What is the approximate volume or area of anoxia in the lake?

Response: Oxygen basically runs out at 4 meters and is anoxic at all areas of the lake beneath that depth.

3. What do the colors in the land cover map represent and how do they relate to impervious surface?

Response: The red shades are representative of development and are generally representative of impervious surface. However, impervious surface does not correspond at a 1:1 ratio to where phosphorus is coming from. Roofs and roads make up most of the impervious surfaces in the watershed, and that area is what's used in calculating phosphorus loading in our budget models.

4. What is "Groundwater In" representing in the Water Budget figure?

Response: This represents shallow groundwater (subsurface water) flowing into the lake through the upper 10 feet of the soil horizon. We didn't calculate these values using a specific groundwater model but rather by difference, a residual from the budget that we assume is groundwater.

Resident comments that they can hear the trickling near their house like a faucet is flowing and questions if it's from the subsurface springs.

Response: Yes, that's why you have a lake. The amount of groundwater estimated here is a good amount of water, so when the subsurface water is exposed, it becomes surface water – a lake!

Resident: It looks like quite a bit of water still in ground.

Response: We assume the groundwater phosphorus concentration is equivalent to base flow concentrations we measured from stream sampling because we didn't collect groundwater or well samples. Fertilizers and septic tank overflows in the north part of basin are generally assumed to be potential sources of phosphorus to groundwater but we didn't see any high phosphorus concentrations indicative of those sources, in particular. Our findings suggest typical organic sources of phosphorus in the streams (e.g., wildlife waste, decaying detritus, natural background soil phosphorus).

5. You separated 19th Avenue and the Grass Bottom Creek drainages. Is Grass Bottom Creek the same as the Canal?

Yes. They are separate sources. Grass Bottom Creek is coming into the headwaters of the Canal.

## Blackmans Lake Cyanobacteria Management Plan

6. Jen Oden (Snohomish County) added a clarification about the new Washington State 303(d) listing requirements for harmful algae bloom (HAB) impairments, such that the listing is entirely dependent on the monitoring performed and which lake use decisions (advisories) are implemented (i.e., if there is no monitoring, there are no results to advise a waterbody to be listed for HABs even though it may be experiencing HABs). Ecology is not currently asking for data on health/lake use advisories. Right now, the new requirements are just a draft set of rules that have not yet been implemented for determining listings/impairments. When a resident reports a bloom and if Ecology is no longer accepting samples for the year, Jen will collect a sample and look at it under the microscope to decide on whether to post an advisory. If you see something, say something!

7. What is the expected duration of [effectiveness for] the oxygen saturation technology (OST) system?

Response: We are not sure, as conditions vary between lakes, and it is a relatively new technology so few long-term assessments currently exist. The manufacturer expects the system to last approximately 20 years.

8. How soon would chemical application occur?

Response: Application of the phosphorus inactivation chemicals could occur as early as this fall (2024), but the first treatment would ideally occur next spring 2025. The permit for application of this chemical is readily available, so we would not need to wait for that. Implementing the OST system is a bit different in that it would need to go through additional review and permitting, but that is dependent on jurisdictional processes. It will probably take at least a year and likely more to permit, design, and implement the OST. This gives the community and the City more time to decide on how to proceed.

9. What's the sensitivity of OST **to sedimentation, debris, or sinking?**

Response: If the OST system stops working (e.g., clogs) it will stop oxygenating the lake bottom and the lake will return to previous conditions (i.e., low oxygen at the lake bottom and phosphorus release). This means an inoperable OST wouldn't reduce algae, but conditions would not worsen compared to present conditions, which is not true for other algae control technologies that do disrupt the lake and may worsen algae conditions. Additionally, the OST's anchoring system accounts for sedimentation—it's designed specifically for use in small lakes which all have soggy bottoms! It is to ensure the system doesn't sink too deep into the sediments and prevents clogging.

10. Is it safe to say that oxygenation will speed up decomposition in the lake bottom? Will the lake become deeper over time?

A: Yes, aerobic bacteria will become more abundant, and the sediment will decompose faster so sediment at the lake bottom should settle faster. You probably won't notice it much in terms of

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additional depth, but in geologic time it would be noticeable. This process will mostly occur in the deep basin of Blackmans Lake.

11. Is there a way to look at the outcome from implementing this Plan? What's the projection look like?

A: In terms of geologic time, the lake is transitioning to a bog and we're trying to manage it to prevent that eutrophication.

12. If the input and drainage to the lake is managed, will the lake still be there in 50 years?

Response: Yes, the glaciers made the lake and it's going to be there for a while. Eutrophication is natural—humans have accelerated that natural process so we're just trying to slow it down to a more natural process. There is no threat of filling in the lake in the next 50 years.

13. How can we limit phosphorus pollution? (Tell us about LakeWise)

Response: LakeWise is a County program. The residents in unincorporated Snohomish County pay for it. It is not implemented within City limits, but the City does contract with the County to implement Blackmans Lake's annual monitoring program. Other cities implement their own version of LakeWise and we [Snohomish County] are happy to share those resources with landowners but cities do not qualify for the formal Snohomish County LakeWise program. If you have a septic tank—information and resources are available on website all the time. You can follow LakeWise on your own. If the community wanted to implement a program, you could put together something similar to LakeWise (e.g., [I Love Lake Stevens](#)). Don't have to wait for City to tell you how to participate.

14. How do I learn if there's going to be a bloom? Right now, I look at park to see if anyone is swimming there.

Response: We currently have a very reactive process to reports of blooms. Upon a report of a bloom, signs are posted at public access areas and on the County's Lakes [Toxic Algae Alerts](#) webpage. The City also posts on their webpage if there's a toxic algae alert. Also, look at the water! Use the stick test! If you can pick up long stringy strands, don't go in the water. Don't rely on other people using the lake to know whether there is a bloom or not. Check the signs at the park, check the websites, and tell others about it.

Resident comment: Yes, check the signs at the park. Last year, I got an eye infection. After I was treated, I went back to the park and saw the signs.

15. One of the pieces of data to be evaluated for determining if a lake is impaired by HABs and should be listed on the 303(d) list is cases of human or pet illnesses. How does that data get to the State and how should we help?

Response: The Washington State Department of Health tracks cases by working with local health departments and veterinarians, which funnel the data regarding toxic algae blooms (e.g., type of

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animal, toxin, etc.) up to the State. Please report any illnesses! Call the health department or contact Snohomish County Lakes ([lakes@snoco.org](mailto:lakes@snoco.org)) and we can direct you.

16. One time, there was a dog in the process of drowning in the lily pads in front of my house because it couldn't find a way out of the water. We helped it out and it survived. What are the consequences of spraying those lily pads? Would it contribute significantly to sediment loads of phosphorus?

Response: We estimated the amount of phosphorus from plant decay as part of that internal loading process. We expect that contribution to internal loading in the lake overall to be low given the total amount of plants in the lake. Since plants are mostly composed of water and they decay mostly in the fall—plants are not likely releasing phosphorus during the summer to fuel algae blooms. So no, we don't expect that controlling the lilies to significantly contribute to phosphorus loading.

17. In looking at the overall budget, if the City decides on pursuing lake management, would that [herbicide control of lilies] be part of that lake management strategy?

Response (City): Yes, that would be integrated into a Lake Management Plan addressing algae, lake levels, safety, flooding, etc. The City's priority right now is to focus on algae blooms.

Response (Herrera): However, in reducing algae blooms, the amount of plants in a lake may increase. They may not significantly increase, though, unless most of your aquatic plants are invasive. So, it's important to manage those invasive species. Blackmans Lake is tannic so the amount of light penetrating to the lake bottom is naturally limited, which means aquatic plant growth may not expand and control of invasive species may not be as important as it would be in other clearer lakes.

Response (County): We survey every year and we're working to create more interactive maps on the County website. Blackmans Lake is flush with native, beneficial plants. The City acted very fast to remove the small curly leaf pondweed infestation found by the boat launch. We also have new signage to provide to the City related to aquatic invasive species, as part of developing our tools for that type of management.

18. How do we know the funds allocated to lake management [e.g., as raised from the assessments in a special use district] are spent on lake management projects? For the lake outlet project, lots of residents got on board and Public Works got funding for a weir from the Council... but the weir was not implemented. If the same thing happens where we get support from property owners... what's not to say that Public Works will take the money for their own unrelated projects?

Response (County): Lake Management Districts (LMDs) are different [than a City or County as a lead funding/management entity]. Those [City/County] funds have to be used for a specific purpose (i.e., they're codified).

Follow-up question: What if City Council awards money and is not used for lake management?

## Blackmans Lake Cyanobacteria Management Plan

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Response (City): When we talk about the project to the Council, they approve specific funds to apply to that project. Here's the rough process: the City Council identifies a pool of funds to use towards all approved capital projects. Projects are already defined when presented to Council. If the projects are approved by the Council, a budget is applied to that project. It cannot be used for anything outside the definition of that project, as approved by City Council.

Response (Herrera): There are a variety of funding options available. One is for the City to fund all lake management activities, or they may be funded through establishing an LMD, and/or through grants, etc. The scope and decisions related to lake management are limited to the City's funds, unless an LMD is formed and may ear-mark other funds to be used for that purpose.

19. One other comment / question I couldn't hear about funds/grants?

# Appendix F

## Supplementary Funding Options

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**Table F-1. Blackmans Lake Cyanobacteria Management Plan – Potential Supplementary Funding Options**

Name	Funder or Administrative Agency	Award Range	Target Purpose	Required Applicants or Lead Entities	Match Requirement	Notes	Resource URL
National Estuary Program's Coastal Watersheds Grant Program	Restore America's Estuaries, US EPA Program	\$75K-\$250K	Protect/restore water quality or ecological integrity coastal or estuarine habitat	Public agencies (federal, state, tribal, intertribal, regional water pollution control, etc.), non-profits, local governments, academic institutions, for-profit organizations.	33% (25% total cost), but ability to request full or partial waiver	Projects within specific geographic areas (including Lower Columbia River and floodplains) following Congressionally set priorities (see list online; includes recurring HABs). Awarded annually to 3 to 10 awardees.	<a href="https://estuaries.org/coastal-watershed-grants/">https://estuaries.org/coastal-watershed-grants/</a>
Aquatic Invasive Plants Management Grants	WA Ecology	Depends on project: up to \$30K-\$75K	Aquatic invasive plants management activities (e.g., mapping/inventory, IAVMP development, public education, plant control activities, pilot projects, evaluation of implementation, and follow-up monitoring)	State agencies, counties, cities, special purpose districts, tribes	25%, or 12.5% if early infestation grant	Funds originate from boat trailer registration fees. Lower match % and higher grant total for early Infestation grants.	<a href="https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Aquatic-Invasive-Plants-Management-Grants">https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Aquatic-Invasive-Plants-Management-Grants</a>
Stormwater Capacity Grants Program	WA Ecology	Set biennially based on state budget	Stormwater projects	Phase I and Phase II NPDES municipal permittees	None	Noncompetitive; activities and equipment necessary for permit installation	<a href="https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Stormwater-capacity-grants">https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Stormwater-capacity-grants</a>
Stormwater Grants of Regional or Statewide Significance (GROSS)	WA Ecology	≤\$300K	Stormwater projects	Phase I and Phase II NPDES municipal permittees	None	Competitive; assist permittees in completing projects that will benefit multiple permittees	<a href="https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Grants-of-regional-or-statewide-significance">https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Grants-of-regional-or-statewide-significance</a>
Water Quality Combined Funding Program	WA Ecology	Varies	Single-application process for all funding sources at once- eligible projects benefit water quality	Varies	Varies	Funds from: CWA Section 319 grants, Centennial Clean Water Program grants, Clean Water Act State Revolving fund (CWSRF), stormwater financial assistance program (SFAP)	<a href="https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Water-Quality-grants-and-loans">https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Water-Quality-grants-and-loans</a>
Salmon Recovery Funding Program	WA State Conservation Commission, funded by state legislature	Unclear	Protect/restore riparian habitats and streams for salmon while maintaining agricultural viability	conservation districts (can be partnered with other entities, and/or landowners for cost-share)	NA	New in 2022, encourages incentive programs with landowners' involvement in riparian restoration projects; projects must be in riparian areas, instream projects must support riparian projects.	<a href="https://www.scc.wa.gov/salmon-recovery-program">https://www.scc.wa.gov/salmon-recovery-program</a>
Land and Water Conservation Fund-State Program	WA Recreation and Conservation Office	\$200K-\$2M	Develop outdoor recreation resources (parks, trails, wildlife lands)- available to all communities	local agencies, special purpose districts, tribes, state agencies	50%	Eligible projects: certain types of land acquisition, development/renovation of parks; applicants MUST have a comprehensive recreation or conservation plan.	<a href="https://rco.wa.gov/grant/land-and-water-conservation-fund/">https://rco.wa.gov/grant/land-and-water-conservation-fund/</a>
Land and Water Conservation Fund-Legacy Program	WA Recreation and Conservation Office	\$300K-\$9.85M	For urban communities to buy/develop land for parks/recreation; priority to disadvantaged areas	local agencies, special purpose districts, tribes, state agencies	50%	Eligible projects: certain types of land acquisition, development/renovation of parks; applicants MUST have a comprehensive recreation or conservation plan.	<a href="https://rco.wa.gov/grant/land-and-water-conservation-fund/">https://rco.wa.gov/grant/land-and-water-conservation-fund/</a>
Salmon Recovery & Puget Sound Acquisition and Restoration (PSAR) Grants	WA Recreation and Conservation Office	No maximum	Restore degraded salmon habitat and protect existing, high-quality habitat (including actual habitat used by salmon and land/water supporting salmon processes);	Local agencies, special purpose districts (port, park, conservation, school), tribes, state agencies, private landowners, nonprofits, regional fisheries enhancement groups	15%	The grant program for both salmon recovery and PSAR grants are run together and generally have the same requirements. PSAR program is to help implement habitat protection/restoration in the Puget Sound only, co-managed by the Partnership.	<a href="https://rco.wa.gov/grant/salmon-recovery/">https://rco.wa.gov/grant/salmon-recovery/</a>

**Table F-1 (continued). Blackmans Lake Cyanobacteria Management Plan – Potential Supplementary Funding Options**

Name	Funder or Administrative Agency	Award Range	Target Purpose	Required Applicants or Lead Entities	Match Requirement	Notes	Resource URL
Pacific Coastal Salmon Recovery Fund	NOAA	≤\$25M	Salmon recovery	Western US states, federally recognized tribes of the Columbia River and Pacific Coast	Yes (amount unclear)	Funds many other grants	<a href="https://www.fisheries.noaa.gov/grant/pacific-coastal-salmon-recovery-fund">https://www.fisheries.noaa.gov/grant/pacific-coastal-salmon-recovery-fund</a>
Aquatic Lands Enhancement Account	WA Recreation and Conservation Office	≤\$1M	Aquatic lands improvement	WA agencies or tribes may apply	50%	Usually awarded at \$500k for acquisition, improvement, or protection of aquatic lands for public purposes; or to provide or improve public access to the waterfront.	<a href="https://rco.wa.gov/grant/aquatic-lands-enhancement-account/">https://rco.wa.gov/grant/aquatic-lands-enhancement-account/</a>
WWRP- Farmland Preservation	WA Recreation and Conservation Office	No maximum (*but see note)	To buy development rights on farmlands to ensure they remain available for farming, and restore natural functions to improve land's viability for farming	Cities, counties, nonprofit nature conservancies, State Conservation Commission	50%	*Stewardship plans not to exceed \$10k; restoration elements may not exceed half of total land acquisition costs	<a href="https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-farmland-preservation/">https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-farmland-preservation/</a>
WWRP- Forestland Preservation	WA Recreation and Conservation Office	≤\$500K	Conserve land for timber, wildlife, public access. Used to lease or buy voluntary land preservation/conservation agreements to restore forests and/or ensure they remain available for timber production in the future.	Cities, counties, nonprofit nature conservancies, State Conservation Commission	50%	Commonly used with conservation easement/lease to restore stream corridors to support clean water/fish habitat. Eligible forests: industrial, private, community, tribal, publicly owned forests of contiguous 5+ acres devoted primarily to timber production and enrolled in a county's open space or forestland property tax program.	<a href="https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-forestland-preservation/">https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-forestland-preservation/</a>
WWRP- Habitat Conservation (includes 3 categories)	WA Recreation and Conservation Office	Varies by category (e.g., no cap, ≥\$25k request, and/or ≤\$1M)	Conserve natural areas/wildlife habitat, improve/acquire recreation areas	Cities, counties, towns, tribes, nonprofit nature conservancies, special purpose districts, port districts (and other political subdivisions), state agencies	50%	For a broad range of land conservation efforts, from conserving natural areas near big cities to protecting the most pristine and unique collections of plants in the state. Typically used to buy land to conserve wildlife habitat and to restore state lands	<a href="https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-habitat/">https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-habitat/</a>
WWRP- Recreation Projects	WA Recreation and Conservation Office	Varies by category (e.g., no cap, ≥\$25k request, and/or ≤\$1M)	Land protection and outdoor recreation (parks, trails, water access)	Cities, counties, towns, tribes, nonprofit nature conservancies, special purpose districts, port districts (and other political subdivisions), state agencies	Varies by applicant	For a broad range of land protection and outdoor recreation including for local and state parks, trails, water access, and the conservation and restoration of state land. Typically used to buy land for a park, building athletic facilities, building/renovating parks, developing regional trails, developing state lands. Applicants must have a comprehensive recreation or conservation plan.	<a href="https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-recreation/">https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-recreation/</a>

Note that this is a starting point and a non-exhaustive list that can and should be continuously updated as project needs and funding options change.

**Table F-2. Blackmans Lake Cyanobacteria Management Plan – Other Potentially Useful Programs**

<b>Name</b>	<b>Funder or Administrative Agency</b>	<b>Target Purpose</b>	<b>Required Applicants or Lead Entities</b>	<b>Notes</b>	<b>Resource URL</b>
Forest Legacy Program	US Forest Service	Encourage the protection of privately owned forest lands through conservation easements or land purchases.	States and tribes		<a href="https://www.fs.usda.gov/managing-land/private-land/forest-legacy">https://www.fs.usda.gov/managing-land/private-land/forest-legacy</a>
Family Forest Fish Passage Program	WA DNR	Assist private forestland owners in activities to improve fish passage to upstream habitat (e.g., removing culverts, stream crossing structures, and replacement of other eligible barriers with new structures).	Private or small forest landowner (timber harvest restrictions) with fish-bearing stream		<a href="https://www.dnr.wa.gov/fffpp">https://www.dnr.wa.gov/fffpp</a>
Healthy Forests Reserve Program	USDA NRCS	Protect and restore forest on private land with 10-year restoration agreements and 30-year or permanent easements for specific conservation actions.	Private owners, or owned by tribes	For acreage owned by an American Indian tribe, there is an additional enrollment option of a 30-year contract. Some landowners may avoid regulatory restrictions under the Endangered Species Act by restoring or improving habitat on their land for a specified period of time.	<a href="https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/forests/">https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/forests/</a>
Rivers and Habitat Open Space Program (WAC 222-23)	WA DNR	Easement to protect forestland with at-risk species (critical habitat), or CMZ river habitat	WA landowners of forestland, free of hazardous substances or other jeopardizing conditions to conservation	Program is funded by a grant and requires submission of an application	<a href="https://www.dnr.wa.gov/programs-and-services/forest-practices/small-forest-landowners/rivers-and-habitat-open-space">https://www.dnr.wa.gov/programs-and-services/forest-practices/small-forest-landowners/rivers-and-habitat-open-space</a>
Forestry Riparian Easement Program	WA DNR	Easement to protect fish habitat	Landowners with >20acres of contiguous forest, or >80acres forest in WA, with other timber harvest specs	Reimburses landowners for the value of the trees they are required to leave to protect fish habitat. The program provides compensation for a minimum of 50 percent of the timber value and applies to trees adjacent to streams, wetlands, seeps, or unstable slopes.	<a href="https://www.dnr.wa.gov/programs-and-services/forest-practices/small-forest-landowners/forestry-riparian-easement-program">https://www.dnr.wa.gov/programs-and-services/forest-practices/small-forest-landowners/forestry-riparian-easement-program</a>
Conservation Reserve Enhancement Program (CREP)	WA State Conservation Commission, Farm Service Agency, local conservation districts	Restore streams along farmland by planting native vegetation	Farmers/landowners	Farmers are paid directly by program for planting native vegetation as a buffer, project costs/maintenance for 5 years covered by program, landowners paid rent for acreage restored and receive enrollment bonus, renewable for 10–15-year contracts	<a href="https://www.scc.wa.gov/conservation-reserve-enhancement-program">https://www.scc.wa.gov/conservation-reserve-enhancement-program</a>

Note that this is a non-exhaustive list that can and should be continuously updated as project needs and program options change.

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# Appendix G

## Lake Glossary

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# Glossary of Lake Terms

Source: King County Lakes webpage:

<https://kingcounty.gov/en/legacy/services/environment/water-and-land/lakes/glossary>

**Aerobic:** Living in the presence of oxygen. Most organisms are aerobic and must have oxygen available in order to survive.

**Algae:** Single celled nonvascular plants occurring singly or in groups (colonies). They contain chlorophyll-*a*, used to produce their own food by means of photosynthesis. Algae form the base of the food chain in aquatic environments.

**Algal bloom:** Heavy growth of algae in and on a body of water, often a result of high nutrient concentrations.

**Alkalinity:** The acid neutralizing capacity of a solution, usually related to the amount of carbonates present; buffering capacity.

**Allochthonous.** Arising in another biotope, from outside of the lake basin.

**Anaerobic:** Living in the absence of oxygen. Some bacteria can survive and grow without oxygen present.

**Anoxic:** No oxygen present in the system; see anaerobic.

**Average:** The sum of a group of numbers divided by the total number of values in the group. (see "Mean")

**Bathymetric map:** A map showing the bottom contours and depth of a lake.

**Benthic:** Bottom area of the lake which hosts the community of organisms (benthos) that live in or on the sediment.

**Biochemical oxygen demand (BOD).** The decrease in oxygen content in milligrams per liter of a sample of water in the dark at a certain temperature over a certain period of time due to microbial respiration.

**Biogenic.** Arising as a result of life processes of organisms

**Biomass.** The total organic matter present.

**Biovolume:** Space occupied by organic matter.

**Bluegreen algae:** See cyanobacteria.

**Buffer.** A mixture of weak acids and their salts which (in solution) is able to greatly minimize changes in the hydrogen-ion concentration.

**Catchment basin:** See "Watershed."

**Chlorophyll-a:** A green pigment in plants which is used to capture light energy and convert it, along with water and carbon dioxide, into food or organic material.

**Chlorophyte algae:** Bright green algae that occur in lakes as plankton, as well as forming tangled masses of filaments coming up from the lake bottom or near shorelines. This group does especially well in warm water and bright light and is usually abundant in summer. The species are very diverse, including several that look more like grassy aquatic plants than algae. Another species, *Botryococcus*, turns bright orange under certain conditions, but is not toxic like the marine red tides.

**Chrysophyte algae:** Golden algae that are common members of the plankton in small lakes. They can be solitary or make colonies with large numbers of individuals. Some species make a protective silica sheath around the cells or have a covering of siliceous scales that preserve in lake sediments and have been used for reconstruction studies of past lake environments.

**Concentration:** The amount of one substance in a given amount of another substance, such as the weight of a chemical in a liter of water.

**Conductivity:** The measure of water's capacity to convey an electric current. Increasing the numbers of dissolved ions also increases the conductivity.

**Core.** Sample of soil or sediment taken in such a way as to keep the vertical characteristic of the sediment undisturbed.

**Cryptophyte algae:** Algae with a characteristic brown color, which are solitary and mobile, with two whip-like appendages ("flagella"). They are common residents of the plankton in lakes and are known as excellent food items for planktonic animals, thus supporting healthy food chains.

**Cyanobacteria:** Bacteria living in lakes and streams that make their own food instead of decomposing dead organisms and are very similar to freshwater algae in lake ecosystems. Many cyanobacteria grow especially well in lakes with high phosphorus content and are sometimes used as indicators of change due to human impacts through watershed development. Several species can make toxins dangerous to humans and other mammals if ingested. High concentrations of these cells in the water can result in closure of lakes to recreation or domestic use of water, although this has been relatively rare in occurrence historically.

**Decomposers.** Organisms, mostly bacteria or fungi, that break down complex organic material into its inorganic constituents.

**Detritus.** Settleable material suspended in the water: organic detritus, from the decomposition of the broken down remains of organisms; inorganic detritus, settleable mineral materials.

**Dimictic lake.** A lake which circulates twice a year.

**Drainage basin.** The area drained by, or contributing to, a stream, lake, or other water body.

**Ecosystems.** Any complex of living organisms together with all the other biotic and abiotic (non-living) factors which affect them.

**Diatoms:** Golden-brown algae that make intricate siliceous shells, which are found in lake plankton and attached to wood and rocks along shorelines. Many diatoms grow in cool water and low light, and are often abundant in winter and early spring in temperate lakes. Diatoms are nutritious food for planktonic animals and are important components of a healthy food chain in lakes. The shells preserve well in

sediments and can be used in studies of lake history.

**Dissolved oxygen:** The oxygen gas that is dissolved in water as O<sub>2</sub>

**Ecosystem:** Any complex of living organisms along with all other factors that affect them and are affected by them.

**Epilimnion:** The warmer, less dense, upper layer of a lake lying above cooler water (metalimnion and hypolimnion) in some seasons of the year.

**Euglenophyte algae:** Algae often found in ponds and smaller water bodies, particularly in the warm seasons of the year. They may be bright green, orange or brown. Euglenoid algae are mobile, using a whip-like appendage ("flagellum") to move through the water. Some make an organic shell that encloses the cell, with the flagellum inserted through a pore.

**Euphotic zone.** That part of a water body where light penetration is sufficient to maintain photosynthesis.

**Eutrophic:** Waters in which algae grow into large populations and biovolumes, generally related to nutrient supply. Trophic state indicators above 50 are classified as eutrophic.

**Eutrophication:** The physical, chemical, and biological changes associated with enrichment of a body of freshwater due to increases in nutrients and sedimentation.

**Fecal coliform bacteria.** A group of organisms common to the intestinal tract of vertebrates.

**Fall Turnover:** The mixing of thermally stratified waters that commonly occurs during early autumn. The sequence of events leading to a turnover includes: cooling of surface waters leading to a density change in surface water that produces convection currents from top to bottom, and circulation of the total water volume by wind action. Turnover generally results in uniformity of the physical and chemical properties of the water.

**Green algae:** See chlorophyte algae.

**Holomictic.** Lakes that are completely circulated to the bottom at the time of winter cooling.

**Humic substances:** Organic substances incompletely broken down by decomposers such as bacteria. Humic acids are large molecular organic acids that are present in water, often giving the water a yellow or brown color.

**Hydrogen sulfide gas.** A gas resulting from the reduction of sulfate containing organic matter under anaerobic conditions which is frequently found in the hypolimnion of eutrophic lakes.

**Hypolimnion:** The colder, dense, deep water layer in a thermally stratified lake, lying below the metalimnion and removed from surface influences.

**Isopleth.** A line for the same numerical value of a given quantity.

**Lake level.** Water level of a lake in centimeters relative to a given point established when the first King County lake level gauge was installed at the lake.

**Lentic.** slowly flowing.

**Limiting nutrient:** Essential nutrient for algae that is available in the smallest amount in the environment,

relative to the needs of the organisms.

**Limnology:** The study of lakes and inland waters as ecosystems.

**Littoral:** The shallow region in a body of water which can be inhabited by rooted aquatic plants. This is somewhat dependent on the ability of light to penetrate the water. Specific animal groups also inhabit this zone.

**Loading:** The total amount of material (sediment or nutrients) entering a water body via streams, overland flow, precipitation, direct discharge, or other means over time (usually considered annually). Recycling of nutrients among sediment, organisms and water is sometimes referred to as "internal loading."

**Mean:** (see "Average") The sum of a group of numbers divided by the total number of values in the group.

**Median:** The datum in a set of numbers that represents the exact center of the group: half of the numbers are smaller and the other half are larger.

**Mesotrophic:** Waters that promote algae growth at rates intermediate between eutrophy and oligotrophy. Trophic state indicators between 40 and 50 are classified as mesotrophic.

**Metalimnion:** The layer of water in a lake between the epilimnion and hypolimnion in which the temperature, and thus density, change rapidly over a short distance. (see Thermocline).

**Monomictic:** A water pattern of lakes in which thermal mixing and stable stratification alternate once per year.

**Morphology.** Study of configuration or form.

**Nannoplankton.** Those organisms suspended in open water which because of their small size cannot be collected by most nets. They can be recovered by sedimentation or centrifugation.

**NH<sub>3</sub>-N.** The ammonia nitrogen portion of total nitrogen in a sample. Increases in the absence of oxygen.

**NO<sub>2</sub>+3-N.** Nitrite and nitrate nitrogen portions of total nitrogen in a sample.

**Nitrogen:** One of the elements essential for the growth of organisms. Nitrogen is most abundant on the earth in the form of N<sub>2</sub>, comprising 80% of the atmosphere, but is usually taken up by plants in the forms NO<sub>3</sub>, NO<sub>2</sub> and NH<sub>3</sub>.

**Nonpoint source pollution:** Pollution from diverse sources difficult to pinpoint as separate entities and thus more complicated to control or manage. Examples of "nonpoint sources" include area-wide erosion (as opposed to landslides or mass wasting), widespread failure of septic systems, certain farming practices or forestry practices, and residential/urban land uses (such as fertilizing or landscaping).

**Noxious weeds:** A legal definition of by the State of Washington that lists specific non-native, invasive plants known to destroy habitat for other plants or animals, or documented as having caused serious agricultural problems. A list of names is published each year by the Department of Ecology which lists the level of threat posed by the plants and the legal responsibilities of owners who find them growing on

their properties. Individual counties may modify the list to fit specific distributions within the county.

**Nutrient:** Any chemical element, ion, or compound required by an organism for growth and reproduction.

**Oligotrophic:** Waters that are nutrient poor and which, as a result, have little algal production. Trophic state indicators below 40 are classified as oligotrophic.

**Orthophosphate (PO<sub>4</sub>):** The dissolved portion of phosphorus that is available for biological uptake. Also called soluble reactive phosphorus based on the analytical method.

**Oxidation.** A chemical process that can occur in the uptake of oxygen.

**Periphyton.** The biological community attached to substrate (such as rocks, sediments, aquatic plants) that is primarily composed of algae.

**pH:** The negative logarithm of the hydrogen ion concentration in a solution. This is a measure of acidity. pH decreases as acidity increases. Values below 7 are considered acidic.

**Precipitation.** Rain or snow. Volunteer lake monitors record daily rain in millimeters (or snow measured in millimeters of water equivalent).

**Pheophytin:** A pigment compound resulting from the degradation of chlorophyll a, usually found in algal remains, suspended organic matter, or bottom sediments.

**Phosphorus:** One of the elements essential for growth and reproduction. Phosphorus is often the limiting or least available nutrient for plant growth in temperate freshwater ecosystems. The primary original source of phosphorus is from the earth in the form of phosphate rocks.

**Photic Zone:** The upper water in a lake in which light penetrates enough to enable plants to carry out photosynthesis.

**Photosynthesis:** The production of organic matter (carbohydrates) from inorganic carbon and water, utilizing the energy of light.

**Phytoplankton:** Free floating microscopic organisms that photosynthesize (algae and cyanobacteria).

**Productivity:** The production and accumulation of organic matter, usually measured over a certain period of time.

**Pyrrophyte algae:** These algae, also called dinoflagellates, are solitary and mobile, with two appendages ("flagella") that move the cell through water using whiplike motions. In marine waters, certain species are known for making toxic "red tides" that can render shellfish poisonous for humans. Freshwater dinoflagellates are not known to produce toxins and, while they may color the water brown or red when abundant, have never been considered dangerous.

**Residence time:** The average length of time that water or a chemical within the water, such as phosphate, remains in a lake.

**Secchi disk:** A 20-cm (8-inch) diameter disk painted white and black in alternating quadrants. It is used to measure Secchi depth, which is the transparency of the water in lakes.

**Sediment:** Solid material deposited in the bottom of a lake over time.

**Stratification:** The separation of water into nearly discrete layers caused by differences in temperature and subsequent water density differences.

**Stagnation period.** The period of time in which through warming (or cooling) from above a density stratification is formed that prevents a mixing of the water mass.

**Stratification stability.** The work that must be done to destroy or equalize the density stratification existing in a lake.

**Standing crop.** The biomass present in a body of water at a particular time.

**Suspension.** Very finely divided particles of an insoluble solid material dispersed in a liquid.

**Thermocline:** The zone of rapid temperature decrease in a vertical section of lake water. Typically, the temperature decrease reaches 1°C or more for each meter of descent. (See metalimnion.)

**Transparency:** Water clarity of a lake as measured with a Secchi disk.

**Trophic State:** A term used to describe the productivity of a lake ecosystem classifying it as one of three increasing categories based on algal biomass: oligotrophic, mesotrophic, or eutrophic. Trophic state indicators are calculated on the basis of total phosphorus, chlorophyll-*a* and Secchi transparency measurements.

**Turbidity:** Cloudiness in water caused by the suspension of tiny particles (algae or detritus).

**Turnover:** The mixing of lake water from top to bottom after a period of stable stratification. This typically occurs in fall and is caused by wind and seasonal cooling of surface waters.

**UV254.** A measure of water color; measures water sample's absorbance of ultra violet rays at a wavelength of 254 nanometers.

**Van Dorn Sampler:** A water sampling device that allows collection of a water sample from a desired depth without contaminating the sample with water from other depths.

**Watershed.** The geographical area that contributes surface and groundwater flow to a stream, lake, or other body of water. This can also be referred to as the "catchment basin" or "drainage basin."

**Watershed Management:** The planning and carrying out of actions, legal requirements and protective measures taken by agencies and citizens to preserve and enhance the natural resources of a drainage basin for the production and protection of water supplies and water-based resources.

**Water Year (WY):** A division of the earth year based on the general pattern of annual wet and dry periods rather than by calendar months. The U.S. Geological Survey uses the water year of October 1 through September 30 for data analysis.

**Zooplankton:** Small animals found in the water of lakes that possess limited powers of locomotion, and which feed on bacteria, algae, smaller animals, and organic detritus present in the water.