FERNAN LAKE MANAGEMENT PLAN

Final Draft

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PRESENTED TO

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City Clerk
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Cover Photo: Aerial photo of Fernan Lake with a lake-wide harmful algae bloom

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Executive Summary

Fernan Lake, ID has experienced poor water quality for decades and frequent lake-wide algae blooms comprised of toxic cyanobacteria. Fernan Lake is currently 303(d) listed with waters impaired by total phosphorus, which drives growth of harmful algal blooms (HABs). The City of Fernan Lake Village and stakeholders can accelerate water quality restoration by gaining consensus on a lake management plan, develop projects, and go after available funding to implement targeted improvements. We revaluated previous studies, gathered additional sediment data and provided an updated lake assessment. The key findings related to emphasizing the difference in hydrology and nutrient loading annually vs the dry season on drivers of phosphorus concentration in the lake. Wetland and lake sediments contain a high amount of biologically available phosphorus, data suggests that most internal loading is releasing from the lacustrine wetland and deep lake sediments. In-lake management will be needed to complement watershed management to improve water quality in an acceptable timeframe for the community. From the details of the assessment, we recommend viable short-term solutions and where to continue long-term efforts. We recommend to focus on short-term efforts to 1) manage wetland aquatic vegetation (~$15-20K), 2) In-lake P sequestration of the wetland and deep lake sediments (~$1.28M), 3) Routine monitoring and data resources ($2-4K), and 4) rescoping the Fernan Restoration Alternatives of the Fernan Creek delta and floodplain for wetland enhancement while maintaining cultural uses. Long-term efforts should be focused on continued watershed management to reduce P loading and assess if additional in-lake management is needed to maintain reduced phosphorus concentrations in the dry season. The City of Fernan Village can lead efforts to gain consensus with this lake management plan and pursue funding for these short-term efforts. Coordination with other stakeholders will be vital to gaining consensus, accessing funding pathways, and implementing projects through partnerships.

Background

Fernan Lake is a 409-acre lake located outside of Coeur d'Alene, Idaho. This lake has experienced poor water quality for decades and frequent lake-wide algae blooms comprised of toxic cyanobacteria. Fernan Lake is currently 303(d) listed with waters impaired by total phosphorus, which increases trophic state and drives growth of harmful algal blooms (HABs). These blooms further degrade water quality, produce toxins that put humans and wildlife at risk, and have negative impacts on recreation, property values, and the local economy. Fernan Lake is a hotspot for activities such as fishing and boating with some of the highest numbers of recreation users per waterbody acre in the state. Fernan Lake and its watershed have been studied over the past decades to gain an understanding of nutrient sources and potential improvements needed. Although most of the phosphorus enters the lake from Fernan Creek, a data gap exists to the extent that phosphorus internally cycles in the lakes and drive conditions conducive to HABs. The City of Fernan Lake Village and stakeholders can accelerate water quality restoration by gaining consensus on this lake management plan, develop projects, and go after available funding to implement targeted improvements. It is expected that implementing both in-lake and watershed management approaches will be needed to meet stakeholder goals and state water quality criteria for Fernan Lake.

Goals and Objectives

The previous 2003 Fernan Lake Watershed Management Plan had a mission statement "to preserve the scenic and natural resource values of the Fernan Lake watershed, enhance its beneficial uses, both public and private, utilizing sound conservation practices". After two decades, additional system knowledge has been generated and progress has been made on watershed management presenting an opportunity to reassess management plans. This lake management plan document was developed to utilize this new information to address the reduction of phosphorus and other mitigation techniques needed to maintain and restore Fernan Lake to secure its beneficial use as outlined in the IDAPA 58 and Idaho Statue Title 39 Chapter 36. Objectives of this plan are to provide the following:

1. Determine short-term solutions aimed at what can be done within the next 3-5 years that specifically address HABs

2. Describe long-term solutions aimed at addressing phosphorus loading into Fernan Lake.

3. Identify funding options/sources available for short and long-term solutions

4. Outline potential roles and responsibilities of stakeholders for plan implementation

5. Identify additional efforts or research to pursue by stakeholders and partners

With stakeholder consensus on this plan, funding can be pursued, projects implemented, and water quality restoration can be accelerated for Fernan Lake. Results from implementation will need to be tracked to inform and revise future management strategies i.e. "adaptive management". This plan will complement other water quality improvement efforts in the region such as the Coeur d'Alene Lake Subbasin Assessment and Total Maximum Daily Loads (TMDL) (IDEQ, 2013).

Previous Studies

Several previous studies have been performed to assess Fernan Lake and its watershed to better quantify impairments or recommend implementation strategies. These studies have built a body of information on how the watershed and Fernan Lake ecologically function and were utilized as background information for our assessment. A list of these studies and their contributions are listed below. These studies should be referred to for additional information.

Fernan Lake Watershed Technical Advisory Committee (2003) - This draft plan details a comprehensive Watershed Management Plan for Fernan Lake, focusing on addressing concerns about declining water quality attributed to phosphorus and sediment inputs. Covering forested areas and diverse land uses, the plan involves a Technical Advisory Group to gather data, set goals, and propose management strategies. With implications for both lake and aquifer health, the plan aims to safeguard water quality for over 400,000 residents, emphasizing the significance of sustainable water resource management in the region.

Idaho Department of Environmental Quality (2013) - The paper focuses on developing a Total Maximum Daily Load (TMDL) for Fernan Lake to improve water quality by limiting pollutant loads, specifically targeting total phosphorus (TP) concentrations to 20 µg/L. It outlines the allocation of pollutant loads among various sources, including point and nonpoint sources, while considering natural background contributions. The TMDL aims to support beneficial uses of the lake, particularly recreational activities, and includes a margin of safety to account for uncertainties in load quantification. Monitoring and implementation strategies are also discussed to ensure effective management of nonpoint source pollution.

Balbiani & Wilhelm (2014) – The study focuses on the phosphorus release dynamics from sediment cores collected in the Fernan Lake wetland, revealing that the wetland can act as a nutrient source under anoxic conditions. It was found that the highest phosphorus release rate was 220 mg P m-2 by day 21 of the incubation experiment. The sediment composition analysis indicated significant variations in water and organic content across different sites. The research highlights the importance of understanding internal loading mechanisms, particularly in relation to flooding conditions caused by water level, which can lead to anoxic states in the wetland. Overall, the findings underscore the role of wetlands in nutrient cycling and their potential contribution to eutrophication in adjacent water bodies.

LaCroix & Wilhelm (2015) – The study investigates the impact of anthropogenic activities on nutrient delivery, particularly phosphorus, leading to harmful algal blooms in Fernan Lake, Idaho, since the 1990s. A detailed mass balance was conducted to quantify the retention of phosphorus and sediment, revealing that Fernan Lake retained 81% of the phosphorus and 68% of the sediment entering it during a calendar year. The majority of nutrient loads occurred during the runoff period from January to May, highlighting the seasonal dynamics of nutrient input. Internal loading sources were identified, but further research is needed to pinpoint the exact contributions. The conclusion emphasizes the importance of a dual approach to remediation, addressing both external nutrient loads and internal loading simultaneously to effectively combat cyanobacteria blooms.

Parker (2016) – The research paper investigates baseline erosion rates in the Fernan Watershed using cosmogenic ^{10}Be concentrations, comparing these rates to modern sediment yields over different time scales. The study concludes that modern sediment yields in the Fernan watershed exceed baseline rates, primarily due to increased soil erosion linked to land use changes. Overall, the findings indicate a significant alteration in sediment dynamics over time, that can be impacting water quality in Fernan Lake.

Piscitelli & Wilhelm (2017) - The research investigates the dissolved oxygen (DO) levels in the Fernan Lake littoral wetland during 2016 to assess conditions for internal phosphorus (P) loading, which can contribute to cyanobacteria blooms. Findings indicate that low DO levels persisted, suggesting the wetland is a significant P source, particularly across the summer.

Wilhelm (2018) – The research focused on using presenting results from wind currents and consumer-grade drones for dye tracing surveys to estimate water and nutrient exchange between the eastern littoral wetland and Fernan Lake. Daily wind patterns drive lake currents that mix water with the wetland interface and can redistribute phosphorus release from the littoral wetland area.

Hanna (2022) – The study involves quantifying the nutrient load from multiple culverts over a year, aiming to address the lack of data on nutrient delivery to the lake and its impact on water quality. It was determined that culverts contribute 4 kg of phosphorus annually and completed the external loading nutrient budget for the lake. Annual phosphorus load from road culverts was 400% higher than a previous estimate but remains insignificant compared to other inputs.

Ducks Unlimited (2022) – The paper discusses restoration concepts aimed at improving water quality in Fernan Lake to reduce harmful algal blooms (HABs) and benefit local ecosystems and communities. It emphasizes enhancing wetland and riparian vegetation to filter sediments and nutrients, potentially replacing invasive species with more beneficial ones. The proposed three-pronged approach suggested includes 1) Restoration of emergent vegetation at the east end of the lake, replacing dominant lily pads and submerged macrophytes. 2) Enhancement of floodplain function in lower Fernan Creek by reconnecting creek channels and floodplain wetlands. 3) Enhancement of sediment deposition and lake buffering functions of the Fernan Creek delta through creating features like islands, peninsulas, pools, and shallow bars

Watkins (2023) – The newsletter discusses the historical and ongoing water quality issues of Fernan Lake, including the impact of multiple stages of road construction projects and restoration efforts on the lake's ecosystem. It highlights history of the Fernan Lake Dam, ordinances, septic surveys, conservation efforts, and comments on the Ducks Unlimited report and proposed grant project.

Fernan Lake Assessment

Watershed

The Fernan Lake watershed has an area of 18.77 sq. mi. (~12,012 acres) of nearby forested mountains characterized by steeply sloped terrain (av. 34%) and dominated by evergreen forest cover (80%) (Stroud Water Research Center, 2024). The major tributary in the watershed is Fernan Creek. The headwaters primarily consist of US Forest Service lands and lower watershed consists of privately owned lands (IDEQ, 2013). There are hay and grazing pastures in the valley bottom and floodplain areas. Fernan Creek is the major tributary in the watershed that drains and flows through the valley bottom and a large wetland to the east end of the lake. Landcover of open space and low, medium, and high intensity development is limited to about 3.9% of watershed area in total. The majority of this development is at the west end of the lake comprised of homes within the City of Fernan Lake Village (Figure 1).

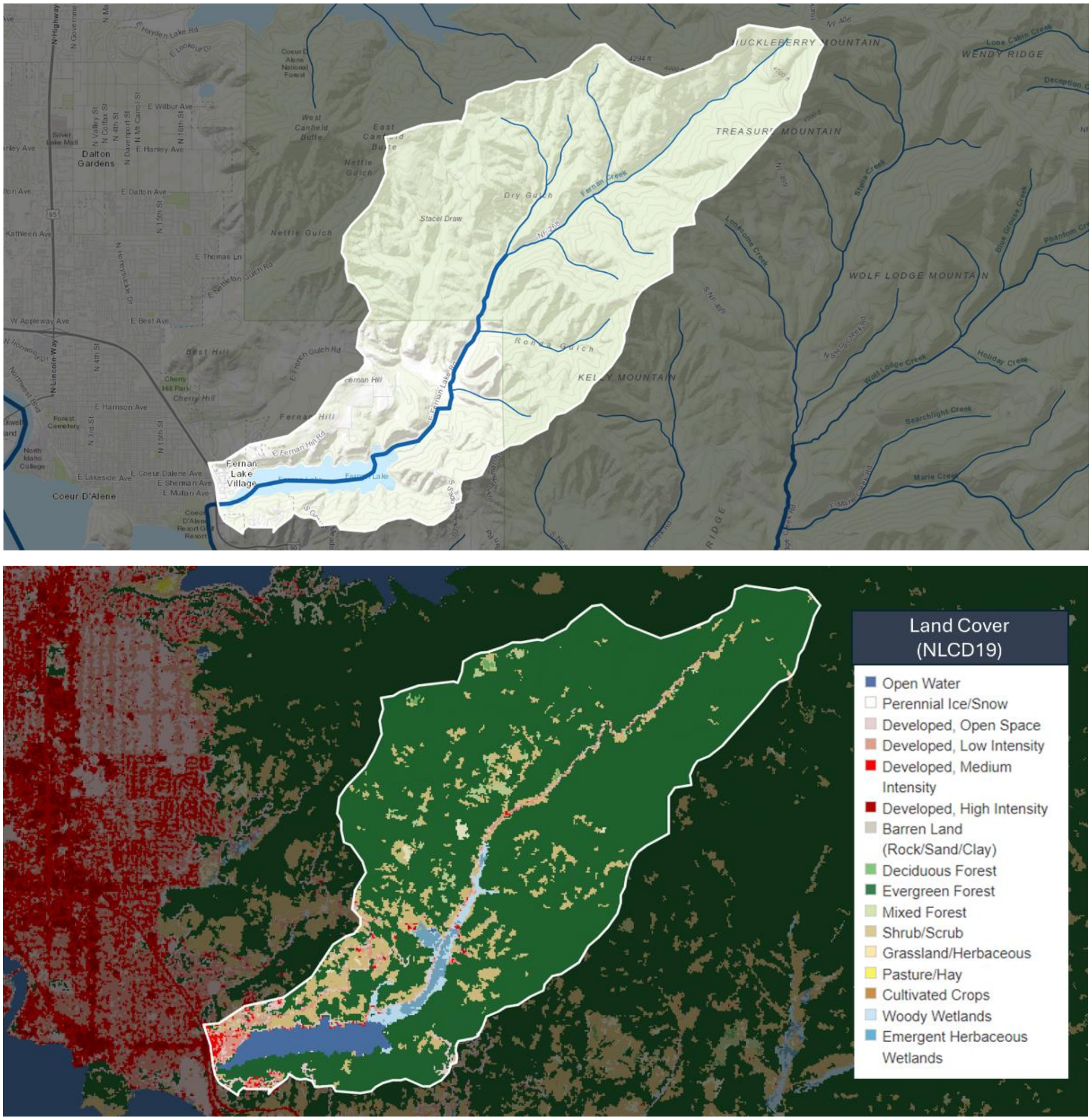


Figure 1: Fernan Lake watershed maps of tributaries (top) and NLCD 2019 landcover (bottom) (Stroud Water Research Center, 2024)

Lake Characteristics

Fernan Lake is a shallow freshwater lake 409 acres (Lake Map Database, 2011) in surface area and estimated volume of 6385 acre-feet (Figure 2). Only 24% of the lake area is less than 12ft, the majority of this region is located at west and the east ends of the lake. 57% of the lake area is 12-21ft in depth and around 19% of the lake area (75.6 acres) is greater than 21ft to a maximum depth of 27 ft. Due to lake morphology most of the water volume of the lake is from the surface down to 21ft depth, the region greater than 21ft holds only a small water volume of ~ 114 ac-ft (1.7%).

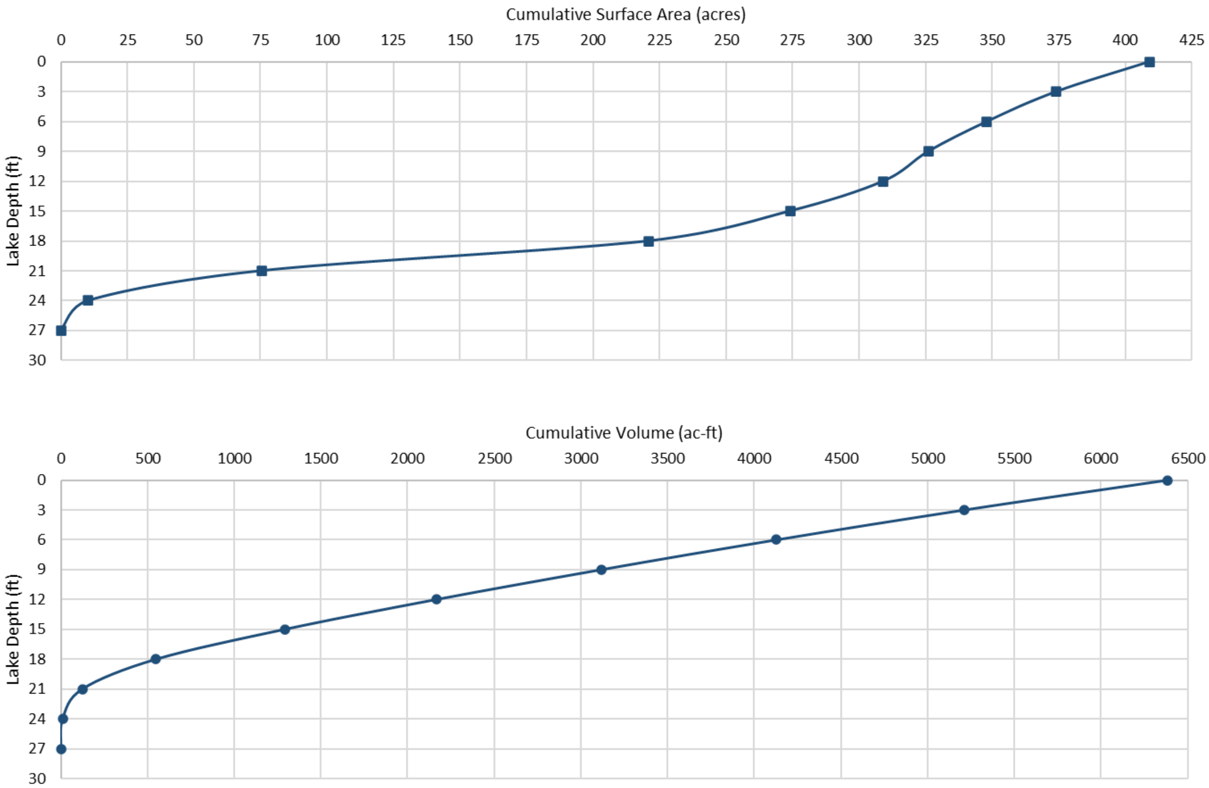


Figure 2: Hypsographic curves for cumulative area (top) and cumulative volume (bottom) from the maximum depth of the lake to the surface.

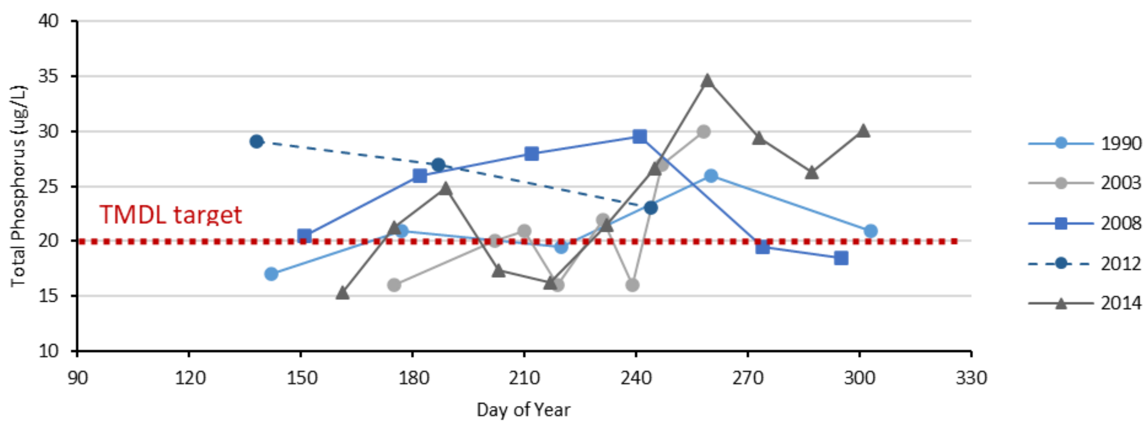
The hydrology of Fernan Lake is dominated by precipitation within the watershed and snowmelt in the wet season (January to May). The majority of the watershed drains into Fernan Creek which flows into Fernan Lake. The annual water budget developed by LaCroix is converted to imperial units and summarized in Table 1 (LaCroix & Wilhelm, 2015). Assuming a lake volume of 6,385 ac-ft, the hydraulic residence time (HRT) for the 2014-2015 water year would be ~0.6 years. Other estimates of HRT from previous studies have ranged from 0.16 and 0.32 years (Idaho Department of Environmental Quality, 2013) demonstrating a high flushing rate with annual variability of the water budget. Due to the timing of watershed inflows seasonally, the volume of water in the lake is replaced almost 2-6 times every wet season, then little to no flushing during the dry season (June-Dec). This seasonal hydrology is important to determining the drivers of water quality impairment.

Table 1: Annual water budget for Fernan Lake during the 2014-2015 water year

Inputs	**Ac-ft/yr**	**Annual Percent**
Fernan Creek	6,729	64%
Precipitation	1,054	10%
Culverts	15	0%
Gain from groundwater	2,756	26%
Outputs		
Fernan Dam	7,134	70%
Evaporation	1,378	14%
Loss to aquifer	1,621	16%

Water Quality

Historical water quality data for Fernan Lake has been collected over multiple study periods since 1990. Data reported by Idaho Department of Environmental Quality (2013) list data collected in 1990, 2003, 2007-2009, and 2011-2012 and additional lake data from 2014-2015 in LaCroix & Wilhelm (2015). The TMDL for Fernan Lake focuses on total phosphorus (TP), as it is a key nutrient that determines the trophic state or productivity of a lake. Generally recognized ranges are 0-12 µg-P/L indicates oligotrophic, 12-24 µg-P/L indicates mesotrophic, 24-96 µg-P/L indicates eutrophic lake conditions (North American Lake Management Society, 2024). The TMDL set a water quality goal of total phosphorus at 20 µg-P/L to meet beneficial use designations. Previous studies show Fernan Lake has exceeded this threshold often across study periods (Figure 3, top). At the end of the wet season (May) 4 of the 5 study periods were at or under 20 µg-P/L, but often exceed that TMDL threshold during the dry season (June-Dec.) Investigating these data specifically for the dry season there is a significant increase in TP in Fernan Lake with day of year (R^2=0.138, *p*=0.04) (Figure 3, bottom). Chlorophyll measurements (proxy for algae biomass) were taken during 2003, 2008, 2012 and showed values of 10 µg/L or less through most of the year except high values >30 µg/L that would occur from August - September. Due to the hydrology of the lake being minimally influenced by inflows during the dry season, internal nutrient cycling and primary production are likely causes for these trends. In the available studies there was one study period from LaCroix & Wilhelm (2015) with total nitrogen data for Fernan Lake. Total nitrogen values ranged from 223-498 µg/L, average of 334 µg/L which is characteristic of low nutrient oligotrophic lakes. The mass ratio of TN:TP ranged from 8.7-20 which indicates nitrogen limited, or co-limiting conditions for nitrogen and phosphorus. TN:TP ratios >25 generally indicate P limiting conditions. Reducing phosphorus can shift TN:TP ratios towards P limiting conditions.



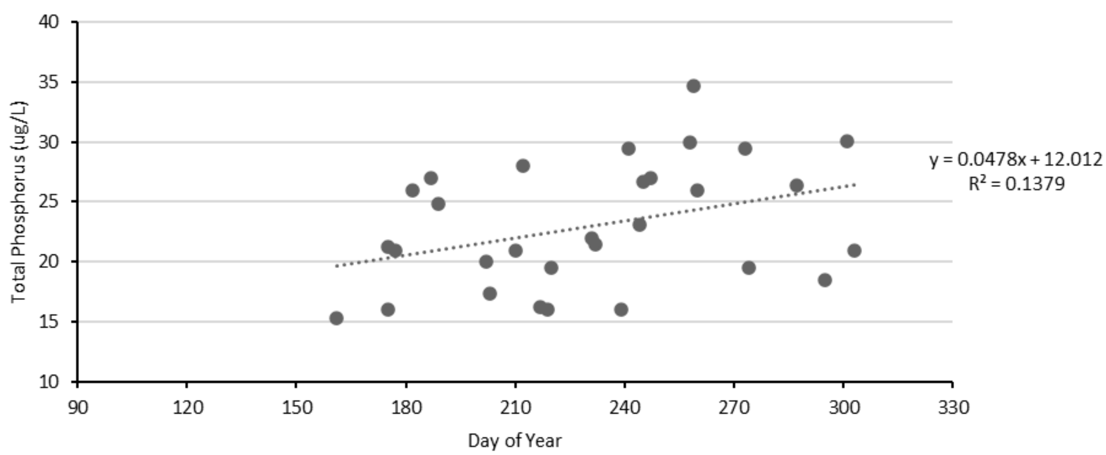


Figure 3: Total phosphorus of Fernan Lake (surface, average, or depth integrated samples) per study period (top) and dry season (June – October) phosphorus trend by day of calendar year (bottom).

Fernan Lake is a polymictic shallow lake that is generally well mixed due to E-W orientation and wind patterns of the local mountain geography. Wilhelm (2018) performed wind drogue and dye tracer studies to quantify magnitudes of surface currents and circulation patterns on the lake. Although there are abundant mixing conditions, Fernan Lake does experience some periods of stratification when a temperature gradient isolates bottom waters from the surface. Additionally, there are brief periods (days-weeks) where dissolved oxygen levels in the water column are depleted to hypoxic conditions (DO < 2 mg/L) near the lake bottom. Hypoxia was measured 3 times at 6m depth and 7 times at 7m depth over 34 sample events in July – September, 9% and 21% respectively (Idaho Department of Environmental Quality, 2013; LaCroix & Wilhelm, 2015). These brief periods can rapidly release phosphorus from the sediment and mix up into the water column during the following mixing event (frequency daily - week). The lacustrine wetland was also evaluated for oxygen by Piscitelli & Wilhelm (2017) and they found that DO levels were under 1mg/L across most of the dry season (from July – November in 2016). High sediment oxygen demand during the summer and minimal mixing within dense emergent waterlilies stands are likely driving those conditions.

Sediments

A major knowledge gap for determining management approaches on Fernan Lake was to improve the understanding of the quantity of phosphorus cycling between the wetland, lake bottom sediments, and water column. To fill that gap, 9 surficial sediment samples of the top 4-10cm of the lake bottom were collected on 11/16/2023 and sent to SePRO Research & Technology Campus Lab for analysis (Figure 4). All sediment samples were analyzed Level 2 Sediment P fractionation package that includes physical characteristics (% Solids and Wet Bulk Density), phosphorus fractionation (modified from Psenner et al., 1988). The forms of P separated during the fractionation procedure include soluble and loosely sorbed PO4-P (Labile-P), redox-sensitive iron and manganese bound P (Reductant-Soluble P or Redox Sensitive P), P bound to hydrated oxides of aluminum and nonreducible iron (Metal-Oxide P), organic forms of P derived from biological organisms (Organic P), as well as highly stable calcium bound P (Apatite P or Stable Mineral P) and residual P contained within non-biodegradable organic matter (Residual P). Determining the chemical characteristics of sediment allows for an estimate of the portion of sediment P that, under certain environmental conditions, can become available for primary production in a water body. The sequential extraction procedure provides useful information on the proportions and forms of P that will not participate in the nutrient cycle but are buried with deposited material. A subset of 4 sediment samples were analyzed with the Level 3 Sediment P fractionation package that has additional analytes for diffusion related parameters, redox P release parameters, iron stability and stripping potential, organic P release & burial parameters, pH release parameters, and stable mineral formation parameters. These parameters are used to calculate release indices for each P fraction to aid in interpretation (SePRO Corp. patent pending). The full lab results are available in the Appendix.

Fernan Lake has similar total phosphorus concentrations to other lakes in the Pacific Northwest, but has a high proportion of Reductant-Soluble and Organic P fractions combined with high diffusion characteristics (% solids <10%, wet bulk density <1.1 kg/L) that contribute to P release from the sediment. Phosphorus fractionation from all 9 sites demonstrated changes in P fractions and properties correlated to the spatial gradient from the Fernan Creek wetland out to the deepest areas of Fernan Lake (Figure 5). Reductant-Soluble P, Total P, and % solids are lowest in the wetland area and significantly increases towards the deepest areas of the lake (linear regression R^2 of 0.63, 0.54, 0.64 respectively; P values <0.05). Conversely, Organic P fraction is highest at the wetland area and significantly decreases to the deepest areas of the lake (linear regression R^2=0.64, $P < 0.02$). Reductant Soluble P was positively correlated with Total P across all sediments (linear regression R^2=0.71, $P < 0.005$). These gradients of P fractions demonstrate that the wetland plants generate abundant organic P and may slowly redistribute to the rest of the lake. Reductant Soluble P and TP are highest in the deepest part of the lake indicating phosphorus and iron are being concentrated in this section in the lake, and are actively released from wetland sediments.

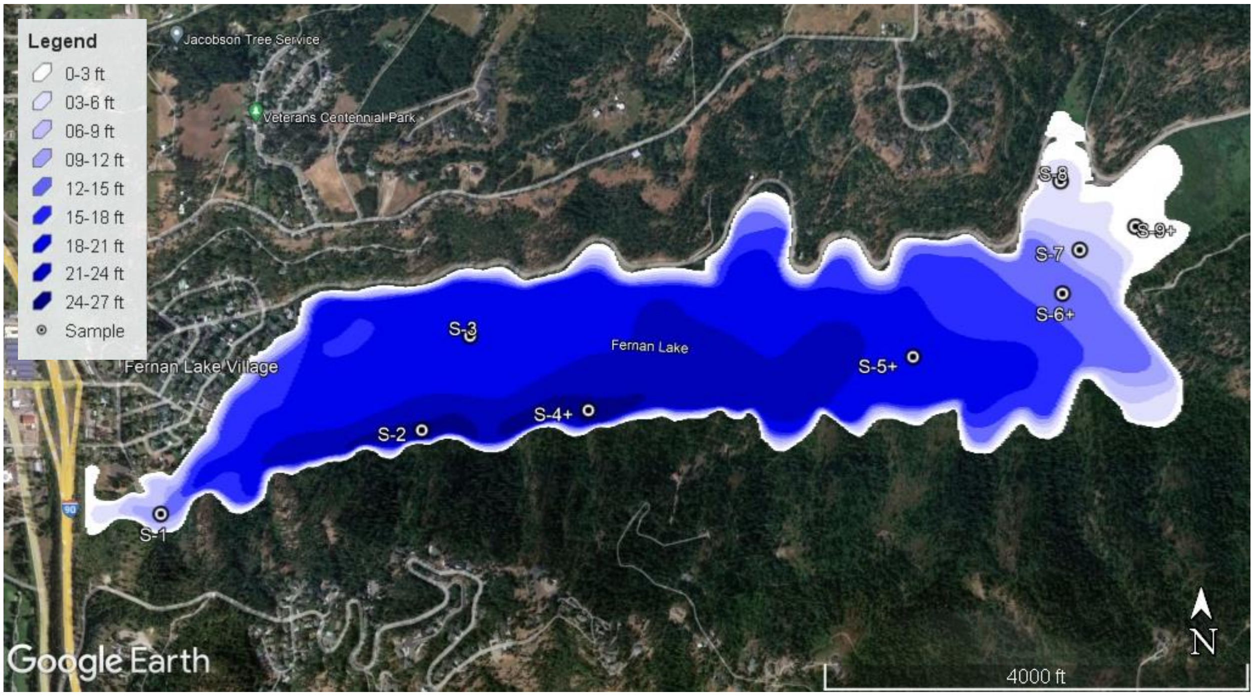


Figure 4: Sediment sample locations across Fernan Lake and wetland. Samples with + symbols indicate Level 3 sediment P fractionation package.

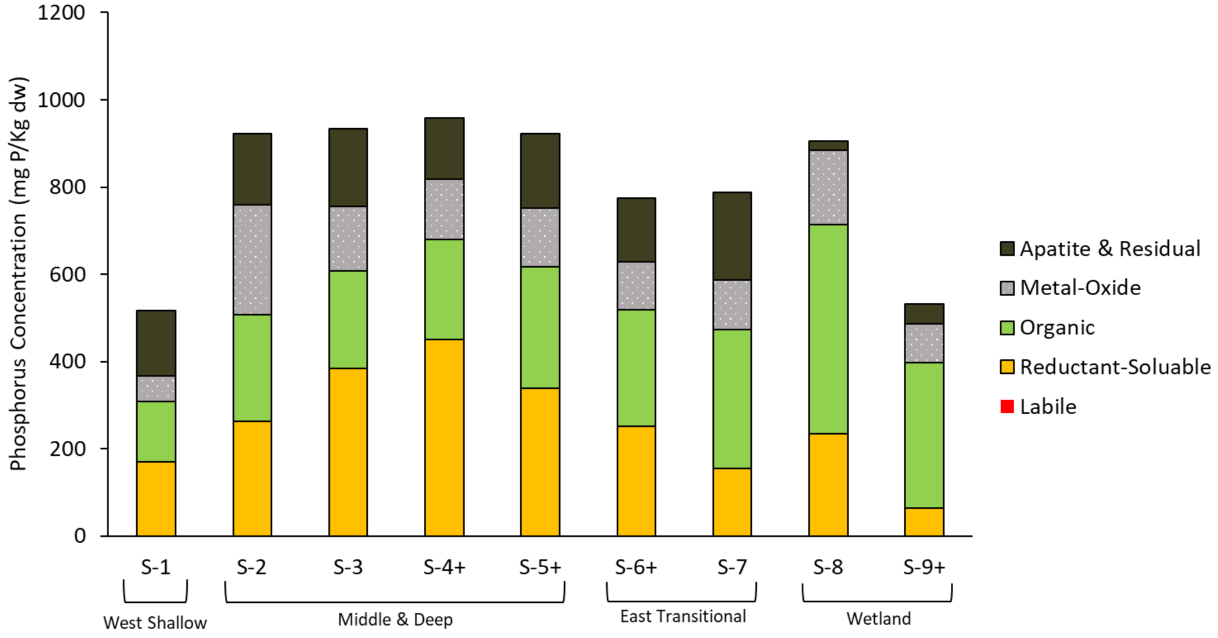


Figure 5: Phosphorus fraction concentrations for Fernan Lake sediment samples grouped by representative locations within the lake. Labile, Reductant-Soluble, and Organic P fractions have high bioavailability and potential to release to the water column.

The 4 samples with Level 3 analysis provided additional insight on release and burial dynamics. Samples in Fernan Lake have iron-rich sediment, which under adequate oxygen conditions allows the lake to capture and store phosphorus in the lake sediment. Yet, iron rich sediments are also sensitive to anoxia (no dissolved oxygen conditions) that will rapidly break iron-phosphate bonds and release both in soluble forms to the water column. Across all samples, high soluble manganese levels were detected indicating that most of Fernan Lake sediments experienced anoxic conditions within the sediment profile (4-10cm) prior to collection. The wetland sample had lower available iron indicating wetland sediments are likely releasing a significant mass of both iron and phosphorus from this sediment type. This wetland sample with high organic P fraction also has 81% of the organic matter in a bioavailable form, which supports bacterial degradation with a high sediment oxygen demand driving anoxia of the overlying water column. Field studies by (Piscitelli & Wilhelm, 2017) indicate there are multiple months of anoxic conditions within the lacustrine wetland. Sediments within the majority of the lake further degrade the remaining bioavailable organic matter and accumulate Reductant-Soluble P but experience some intermittent Reductant-Soluble P anoxic release. Dissolved oxygen and temperature profiles taken in the lake across multiple years indicate there are brief periods of low oxygen or anoxic conditions (days – weeks in duration) across the deeper sediment of the lake. Burial parameters from sediment samples indicate that sediments in the lake and wetland generally have a low potential to bury phosphorus in organic matter or in stable mineral forms, only 8-15% of TP was in stable mineral form. In summary, phosphorus in Fernan Lake tends to stay in actively cycling forms of organic and reductant soluble P, with a low potential for permanent binding and burial.

Phosphorus fractionation results were utilized further to calculate a mass of biologically available phosphorus (BAP) within Fernan Lake sediments that are influencing water quality. To do this the concentration of BAP is calculated from the P fractions and release indices, then BAP concentrations are converted to a mass of BAP per unit area of lake bottom. Sediment samples were grouped to depth regions of the lake and BAP averaged for 1) Wetland and east shallows <12ft, 2) West shallows, 3) Mid depths 13-20ft, 3) Deep depths 21-27ft. This BAP method determined a total BAP of 13,529 lbs. for Fernan Lake, with the highest areal BAP in the deep zone of the lake at 41 lbs. BAP/acre (Table 2). Although there is BAP across Fernan Lake, release rates vary based on environmental conditions (water temp, anoxia, pH). BAP estimates are used to calculate dosing of P sequestration materials to convert BAP into permanently bound forms of phosphorus and reduce rates of P release/cycling.

Table 2: Estimated biologically available phosphorus (BAP) in Fernan Lake sediments

Lake Region	Representative Sample Sites	Representative Area (acres)	Av. BAP (mg/kg)	Av. BAP (lbs./acre)	BAP (lbs.)
Wetland and East shallows	S-7, S-8, S-9+	49.5	542	27.2	1,346
West shallows	S-1	10.0	226	28.3	283
Mid depths (13-20ft)	S-3, S-5+, S-6	229.5	489	33.0	7,574
Deep depths (21-27ft)	S-2, S-4	75.6	533	40.7	3,077
Other shallows	na	45.4	na	*27.5 estimated*	1,249
				Total	**13,529**

We also made some rough estimates to consider the potential impact of external loading to deposit and regenerate new BAP over time. External total residue (sediment and particulate matter) estimates from LaCroix estimated that ~2000 metric tonne/yr over their study period was retained (~67% of the total residue input) within Fernan Lake. We determined based on available information that a BAP layer of 10cm that is 10% solids and 1.04g/cm3 would be rebuilt with new sediment slowly over ~85 years. Conversely the current sediment BAP layer likely represents phosphorus dynamics that occurred from the past decades of sediment and phosphorus loading. This estimate is a lakewide average, when in reality sedimentation is spatially heterogeneous with the highest rates likely occurring in the Fernan Creek wetland and lowest sedimentation at the west end of the lake. If sediment and P loading is reduced, a new sediment equilibrium would potentially form longer than 85 years under improved conditions.

Phosphorus Cycling & P Budget

Phosphorus is an immutable element that can only be physically moved, released in dissolved form, bound up, or buried. Phosphorus is transported through a landscape downgradient from the terrestrial/upland of the watershed down to the floodplain/wetland, and eventually Fenan Lake. Each of these areas can act as a P sink, source, and transformer (Reddy et al., 2023). External sources of phosphorus from the watershed and internal recycling processes for phosphorus (sediment release, wind induced mixing, fish) need to be considered for lakes. Multiple studies have quantified external loading and internal loading estimates. Idaho Department of Environmental Quality (2013) estimated existing external loads of 3571kg/yr and internal cycling at 570kg/yr. LaCroix & Wilhelm (2015) performed a more detailed mass balance study of phosphorus sources of Fernan Lake during the 2014 study period. External loading of Fernan Creek was extensively monitored along with lake samples across the year. From this study they developed an annual phosphorus budget for the lake which was dominated by external phosphorus loading. Fernan Lake has a high degree of seasonality, making a seasonal or monthly phosphorus budget more useful in investigating drivers of HABs. Through review and analyses of the previous studies (Hanna, 2022; LaCroix & Wilhelm, 2015), we provide an updated annual and bloom period phosphorus budget that explicitly includes internal loading estimates (Table 3). By improving the resolution of the phosphorus budget there are major comparisons between the annual budget and bloom period. Fernan Creek is 68% of the annual load, but only 11% of the bloom period load. Internal loading was 18% of the annual load, but 72% of the phosphorus load during the bloom period. This combined with the understanding of hydrology of Fernan Lake demonstrates that external loading in the wet season strongly determines phosphorus concentrations to start each summer (annual reset), but internal loading is important to phosphorus concentrations present during the bloom period. Internal loading is likely highly variable year to year in this system from a combination of anoxic wetlands and lake sediment P release, wind-induced sediment P diffusion, and fish excrement.

Table 3: Annual and Bloom Period Total Phosphorus budget for Fernan Lake in 2014

	Annual			Bloom period (June-Oct)		
Inputs	**mass (kg)**	**% of Total**	**Source**	**mass (kg)**	**% of Total**	**Source**
Fernan Creek	1125	68%	LaCroix 2015	44	11%	LaCroix 2015
Wet Deposition	145	9%	LaCroix 2015	30	7%	LaCroix 2015[4]
Dry deposition	99	6%	LaCroix 2015	41.2	10%	LaCroix 2015[4]
Road Culverts	4	0%	LaCroix 2015	0	0%	Hanna 2022
Internal Loading (wetlands, wind, sediment, biotic)	293	18%	LaCroix 2015[1]	293	72%	LaCroix 2015
Outputs						
Fernan Dam	264	16%	LaCroix 2015	0.2	0%	LaCroix 2015
Lake P storage	0	0%	LaCroix 2015[2]	109	27%	LaCroix 2015[2]
Sediment P storage	1432	84%	LaCroix 2015[3]	299	73%	LaCroix 2015[3]

Note

1: Estimate of internal loading from 2014 of 189.3mg/m2/yr at min pool area of 1.6km2, other internal load estimates ranged from 49kg to 570kg annually

2: Assumed no change in phosphorus concentration year to year, Bloom period increase of 14.7 µg/L TP in water column

3: Remainder from sum of inputs and other outputs

4: Estimated 150mm of rainfall June-Oct 2014 from figure 2.5, 775mm total. 1kg of P for each 5mm of rainfall

5: Estimated evenly 5 months out from the annual estimate

Summary of Findings

Our lake assessment of previous studies, water quality data, and additional sediment assessment has provided additional insights to determine a management plan. The key findings are summarized below.

1. The hydrology of Fernan Lake functions like an annual reset of water quality. The water within the lake is replaced multiple times over during the wet season and sets a new baseline to start each summer. Many years this has been below the 20µgP/L TMDL goal.
2. Phosphorus concentrations of Fernan Lake during the summer dry season are impacted by internal loading of phosphorus that are driven by wetland and lake sediment P release, wind-induced sediment P release, and fish excrement. The lacustrine wetland sediment is a major P release source and deepest lake bottom sediments are an intermittent P release source based on oxygen conditions. Organic matter across all the lake bottom may slowly release P to the water column as it degrades in the summer.
3. Sediment chemistry in the lake indicates that the surficial sediments are rich in reductant soluble and organic P forms which are biologically available phosphorus (BAP) forms. Conversely sediments are poor at permanently binding phosphorus so P is not cycled and eventually buried. Additional P binding elements would need to be introduced to the system to reduce BAP and improve P burial. Fernan Lake is very sensitive to low oxygen conditions that rapidly release reductant soluble P to the water column.
4. Fernan Lake Wetland is a P sink of the watershed, P transformer, and P source to Fernan Lake. Wetland plants uptake nutrients from the water and local sediment to incorporate them into biomass and organic P forms. As plants die, organic matter deposits move into the lake and slowly degrades releasing organic P. Anoxic conditions within high organic matter sediment can release its reductant-soluble P. Plant production of wetlands cannot be easily reduced, but reducing anoxic conditions and altering biogeochemistry could be achieved. Dissolved forms of phosphorus loading need to be managed as they are the most biologically available.
5. Estimates of physical sedimentation in Fernan Lake indicate the BAP layer of sediment would take around 85 years to replace. Therefore, if only external loading reductions took place, springtime P concentrations would be lower, but internal loading processes would still dominate and increase phosphorus concentrations in the dry season above the 20 µg-P/L threshold. There would also be a recovery lag that could last for many decades after external loading reductions occurred.
6. To improve the speed of water quality improvement, in-lake management approaches can be paired with watershed management approaches to meet goals. Prioritizing P sources with high proportions of BAP will have the largest impact on improving lake water quality.

Recommended Management Plan

Adaptive Management Process

The findings of our assessment recommend that watershed and in-lake management approaches should be pursued to meet water quality goals and beneficial uses. There will always be gaps in our understanding of Fernan Lake, but there is more than sufficient base knowledge to start working on improvement projects. There will be additional understanding of Fernan Lake by monitoring results of improvement projects and adjusting the lake management plan going forward. We promote addressing water quality improvement programs with this adaptive management process (Figure 6) of implementing a few projects, measuring results, review results and adjust management plan every 5-10 years. We divided our recommendations down into long-term efforts and short-term efforts to move the needle forward on water quality improvement. We recommend initially focus efforts on 1) wetland aquatic plant management ~$15-20K, 2) In-lake P sequestration of the wetland and deep sediments (~$1.28M), 3) Routine monitoring and data resources ($2-4K), and 4) rescoping the Fernan Restoration Alternatives of the Fernan Creek delta and floodplain for wetland enhancement while maintaining cultural uses. Long-term efforts should be focused on continued watershed management to reduce P loading, and assessing if additional in-lake management is needed to maintain reduced phosphorus concentrations in the dry season.

Figure 6: A process diagram of adaptive management. Copyright SePRO Corporation.

Short-term: Wetland Aquatic Plant Management

In-lake management approaches need to be implemented to address the magnitude of internal nutrient cycling in Fernan Lake. We propose management of the eastern lacustrine wetland (wetland in the lake) to reduce the abundance of waterlilies (Nuphar and Nymphae sp.) which prevent oxygen exchange and primary productivity, then sequestering wetland sediment BAP. Currently there is persistent anoxia within the water lilies that drives P release and reduces the availability of this habitat for most aquatic life during the summer. Managing water lilies will allow for the establishment of submerged aquatic plants which will increase oxygen levels with primary productivity and allow for additional oxygen exchange and mixing. Improved oxygen conditions within the wetland will reduce P release and provide a better buffer to natural lake circulation currents (Figure 7).

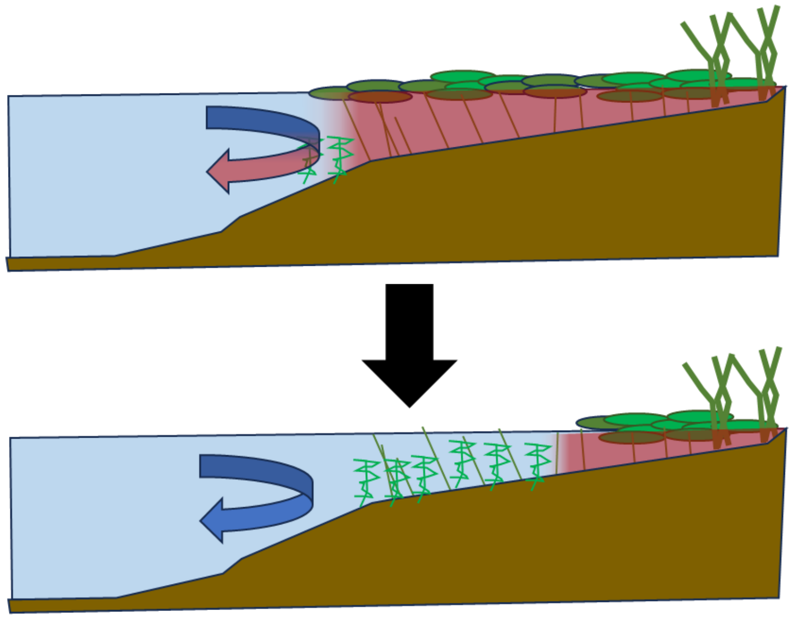


Figure 7: Lacustrine wetland of Fernan Lake is dominated by water lilies which causes persistent anoxic conditions and high P release in which P can be circulated into Fernan Lake (top). Managing water lily extent of the wetland should improve oxygen conditions, reduce P release, and provide an additional buffer of lake circulation currents (bottom). Red colored water indicates high phosphorus concentration

Waterlilies can be selectively controlled by aquatic registered herbicide Clearcast® (a.i. imazamox) with applications made during the early fall. Clearcast has a very favorable environmental profile and classified as practically nontoxic to birds, fish, algae and aquatic invertebrates (SePRO Corporation, 2024). We identified an initial waterlily management zone of 13 acres. Up to three years of management on decreasing abundance of lilies may be needed to remove them from the management area. We estimate that this will cost ~$15,000-20,000 for 3 years of application.

Short-term: In-lake Phosphorus Sequestration

Sediment BAP can be converted from available forms to permanently bound forms of phosphorus to reduce P release in Fernan Lake. Aluminum, Iron, Calcium based materials would not be effective here due to chemistry of the lake (low alkalinity/hardness and anoxic conditions), and sediment characteristics (shallow, pH<6, very low Ca-P and inefficient Al:P binding). Aluminum needs to be carefully applied (often with buffering agent) in low alkalinity water to prevent pH swings and fish kills. Lanthanum based materials would provide effective binding of P, not impact other water quality parameters, and provide sufficient margins of safety for aquatic taxa in Fernan Lake. Two available products that could be utilized is EutroSORB® G which is a 10% lanthanum modified bentonite and EutroSORB® SI which is a liquid lanthanum-based sediment P binder. These formulations are highly specific to binding dissolved forms of phosphorus and not impacting other water quality parameters. They also have favorable safety assessments with aquatic organisms, birds, and mammals to support their use in aquatic environments. EutroSORB G is dosed at 50 lbs. of material to 1 lb. of phosphorus, and the bentonite clay can help reduce sediment resuspension. EutroSORB SI is dosed at ~2.5 gallons to 1 lb. of phosphorus and allows for optimized applications and is ideal for use in wetland sites.

There is strong evidence that the lacustrine wetland area is a significant P source to Fernan Lake and the BAP should be mitigated with EutroSORB. We identified a 38.5-acre area that could be reached by application boat/airboat (Figure 8). This area has a BAP estimate of 27.2 lbs. BAP/acre, 1047lbs. of BAP total that would require dosing with 52,350 lbs. of EutroSORB G or 2,617 gallons of EutroSORB SI. Costs for implementation would be $255,000-280,000. Implementation of this work could be split across multiple years based on budget limitations or project funding opportunities.

Fernan Lake sediments contains a large mass of BAP in the upper sediment layer that can release P under the right environmental conditions. Increasing permanent P binding and burial can decrease BAP and P release from the lake sediment. We recommend initially targeting P sequestration to the lake sediments at the deepest area of the lake where intermittent hypoxia has been detected. The 21ft and greater lake area is roughly 75.6 acres (Figure 8) and highest the highest concentration of BAP at 40.7 lbs. BAP/acre, or 3,077 lbs. BAP total. This would need to be dosed with 153,850 lbs. EutroSORB G or 7,693 gallons of EutroSORB SI. P mitigation of the deeper sediments would cost an estimated $770K to implement. Implementation of this work could be split over multiple years based on budget limitations or project funding opportunities.

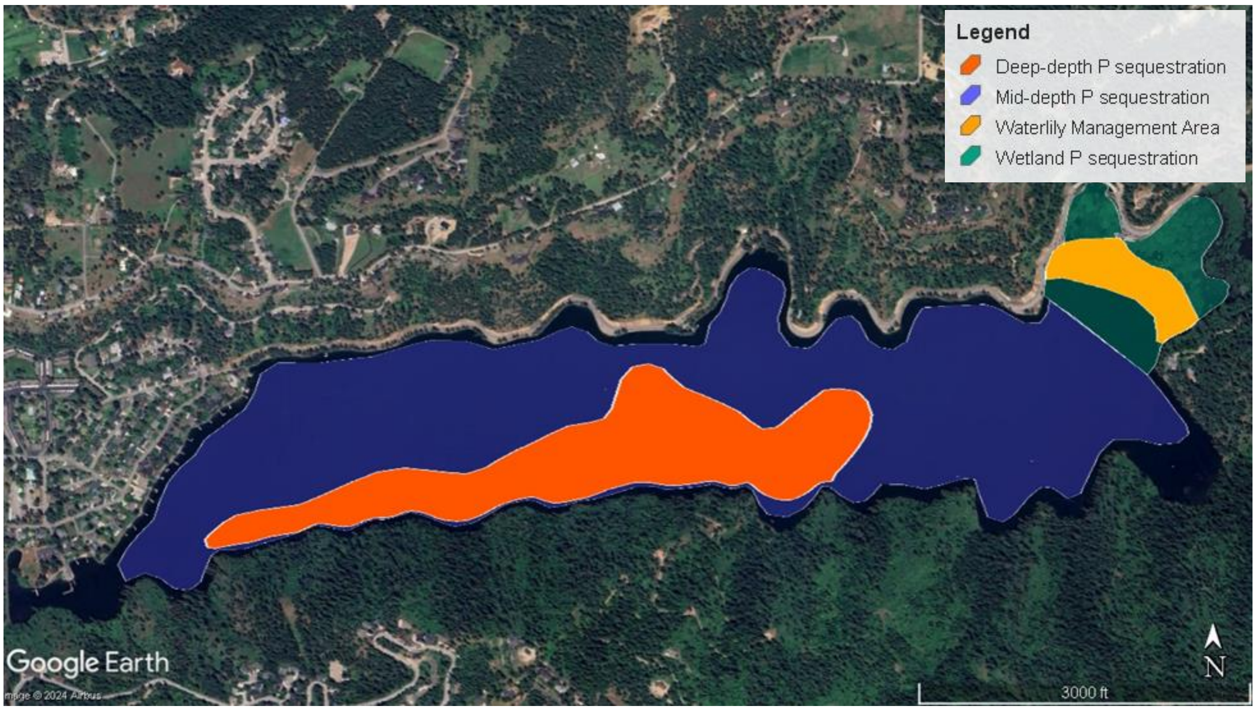


Figure 8: Map of in-lake management areas on Fernan Lake for P sequestration and management of waterlilies.

Long-term: In-lake Phosphorus Sequestration

After P mitigation of wetland and deeper lake sediments is completed the resulting water quality should be assessed to determine how well internal cycling is reduced to maintain lake phosphorus concentrations below 20 µg-P/L. Monitoring may indicate after several years to decades that p release is returning, and some BAP regenerated. Maintenance dosing with additional applications may be needed to maintain reductions of internal loading, most notably in the wetland sediments.

If monitoring indicates that P release is suppressed from those targeted areas, but internal cycling is still high, additional lake sediments could be targeted for mitigation. We would recommend targeting the mid-depth sediments 229.5 acres (Figure 8), 7,574 lbs. BAP, with an estimated cost up to $1.9 million, that could also be broken down over multiple applications or longer time scales of 5-15 years.

Long-term: Watershed Management

Watershed management is needed to reduce phosphorus loading into Fernan Lake across the wet season to decrease the phosphorus concentration in the lake at the start of the summer. The 2013 TMDL recommends a 35% reduction in all phosphorus sources as a target, and re-evaluating the response of Fernan Lake in phosphorus concentrations and meeting beneficial uses. Reducing loading from sources with a higher proportion of soluble phosphorus, plant material, and organic sediments should be more effective than focused on TP alone. Therefore, reducing erosion in the lower watershed and floodplain and increasing sediment retention may be the best place to focus efforts. Agricultural BMPs and wetland enhancement should be pursued. Wetland restoration (putting the wetland back to the original condition or hydrology) may not be viable for meeting this goal and maintaining cultural uses of Fernan Lake. Wetland enhancement should be pursued to modify its functioning to decrease soluble phosphorus release, increase phosphorus/sediment retention, and enhance wildlife habitat. The Ducks Unlimited (2022) restoration plan could be revisited and redesigned before implementing enhancements in the delta and/or floodplain made. This original plan was estimated to cost ~$1million. BMP adoption with private landowners can be pursued with local NRCS staff, and continuing adoption and implementation of BMPs on USFS land can be coordinated with that agency. Watershed based projects often take years to decades to implement so long-term effort and coordination is needed to be successful.

Routine Monitoring & Data Resources

Fernan Lake has more data available, and studies performed than most lakes. Due to the annual variability in hydrology and nutrient loading sources it can be difficult to assess whether water quality is improving or decreasing over time if there is only data collected once every 5 or 10 years. For adaptive management to drive water quality improvement there needs to be a measurement of results. We recommend restarting a routine monitoring program to at least track in-lake water quality April – October. If the program could support additional Fernan Creek monitoring that would provide additional value. We recommend water quality samples could be taken monthly (6 events/ in the dry season (May-Oct) or reduced to 4 events/year (April, June, Aug, Oct). For routine monitoring we recommend one lake station over the deepest area of the lake (47.672677°, -116.730896°) samples collected at 0.5 m from the surface and 0.5m from the lake bottom. Samples should be analyzed for parameters of total nitrogen, total phosphorus, ortho-phosphorus, and chlorophyll. Secchi disk measurements of water clarity and vertical profiles of dissolved oxygen and temperature should also be taken. Water samples can be sent to SePRO SRTC Lab with overnight shipping or to a local analytical lab with low-range phosphorus analyses detection limits. This program could be implemented by a citizen volunteer monitoring group like in the past, and limit costs to equipment, sample analyses, and sample shipping. Initial equipment needed would be an optical dissolved oxygen sensor and 10m cord ($1300-2100), water sampler ($120-500), and secchi disk ($40-80). We expect a monthly water monitoring program to cost $2,500-$4,500 per year for lake sampling by volunteers pending the total number of samples taken.

Existing water quality data becomes useful the more accessible it is, not buried within multiple reports. To make better use of collected limnological data, we recommend working to create a data repository of previous lake data and catalogue with newly collected data going further. There are many free and easy to use resources (Google Suites, Excel Workbook) to achieve this goal. This data should be publicly available through a spreadsheet file download or a data dashboard for visualization. An online webpage should list and host/provide url links for all the previous studies pertaining to the lake. This effort will help maintain this information going into the future and helping stakeholder groups and partners make informed decisions.

Roles, Responsibilities, Funding Strategy

There are many ways water quality improvement projects proceed based on investment of use, land or water rights, legal or financial ability. The City of Fernan Lake Village has elected to take leadership in coordination and approval of projects aimed at maintaining and improve water quality of Fernan Lake. There are additional potential stakeholders that are involved with management of the land and water of Fernan Lake or to drive specific projects as outlined by Idaho Department of Environmental Quality (2013):

- Tribal Government – Coeur d'Alene Tribe
- Federal Government – Natural Resources Conservation Service, US Forest Service, Bureau of Land Management, Bureau of Indian Affairs, US EPA
- State Government – Department of Environmental Quality, Lands, Transportation, Fish and Game, Agriculture, and Idaho Soil and Water Conservation Commission
- County Government – Kootenai County
- City Government – City of Coeur d'Alene
- Quasi-government – Kootenai-Shoshone Soil and Water Conservation District
- Non-Profit – Fernan Lake Recreation and Conservation Association
- Private individuals, residents, and volunteers.

The City of Fernan Lake Village could operate a committee with stakeholders as voting members of decisions (similar to the Moses Lake Watershed Council https://www.moseslakewatershed.org/), or utilize a hub and spoke approach that engage closely with stakeholders for specific projects which is often done with lake management districts or lake associations.

Water quality restoration projects take time & effort, a plan, and funding. Once stakeholders around a problem have consensus on a plan, going after funding becomes easier and effective. We anticipate that most projects will need state or federal funding to proceed. There are numerous grant opportunities to implement watershed management projects through the Clean Water Act and NRCS from federal funds that would require local or state matches from the listed stakeholders. There currently are no Idaho state or federal programs clearly designated towards in-lake management to improve water quality since that portion was removed from the Clean Water Act in the 1980s. There likely would need to be efforts to achieve a state or federal appropriation pursued by The City of Fernan Lake Village with wide stakeholder support. A table of possible funding opportunities are listed in a table below. The water quality issues of Fernan Lake have a strong story, impact to the community that could be successful pursuing an appropriation. Alternatively municipal loans could be pursued. Smaller cost items and projects like implementing wetland aquatic plant management or routine monitoring and data resources could be handled by City of Fernan Village, Fernan Lake Recreation and Conservation Association, or donations.

Table 4: Funding Sources for Lake & Watershed Management Activities.

Funding Source	Description	Limitations
State and Federal Appropriations	Appropriation request for funding specific projects to Fernan Lake to state legislature and/or US House of Representatives.	- Subject to inclusion in legislation - Projects must follow National Environment Protection Act guidelines
IDEQ - Federal section 319 grants	DEQ administers federal funds for Clean Water Act § 319 grants. Request must focus on reducing pollutants and improving the water quality of lakes, streams, rivers, and aquifers. Funds may be used to address a variety of NPS management and prevention activities.	- Up to $250,000 - Require 40% match - Cannot be used to fund in-lake P sequestration
IDEQ – State Agricultural Best Management Practices Grant	These state funds are to be used to implement agricultural best management practices to help meet water quality standards in impaired water bodies in Idaho.	- Annual budget limited to $279,000 total for SFY2025
IDEQ - Surface Water Protection Grants	DEQ's source water protection grants fund projects to protect public drinking water sources. Eligible activities include those that reduce the risk of contamination of a drinking water source. Projects must contribute to improved protection of one or more public water supply sources.	- Up to $25,000 - Must protect and have nexus to public drinking water supply
IDEQ - CWSRF Rural Community Assistance Corporation Grant	Provides low interest loans and grants to refurbish or replace individual septic systems	- Income limitations of applicants - Up to $15,000
Non-Profit/NGO Grants	Outside organizations with a mission to restore water resources and wetlands such as conservation groups	- Usually require matching funds if primary funding source
Private Donations	Private donations to non-profit entity to fund routine monitoring, projects, and matching	
Local Match	Matching funds from local governmental entities to state or federal funds	- Approvals needed
Taxes	Utilize existing government entities or setup new entity with taxing authority for required lake improvements.	- Approval from voters

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Appendix:

SePRO Lab Results

COC 18087 SRX 19498

SRTC

SePRO Research & Technology Campus

SePRO

Algae & Water Quality Analytical Services

SeSCRIPT® Chain of Custody

Water Body Name: Fernan Lake City Fernan Lake Village State ID

Water Body Size: (acres) 423 acres Average Depth: (feet) 16 ft Date/Time Sample Collected: 11/16/23 11:00am **One form for each water body**

Bundle Analysis:

- [x] Water Quality Baseline Bundle (pH, alkalinity, conductivity, hardness, dissolved oxygen, turbidity, total phosphorus, free reactive phosphorus)
- [ ] Water Quality Baseline Plus Bundle (Baseline Bundle plus chlorophyll *a*, nitrates, nitrites and total nitrogen)
- [ ] Algae and WQ Baseline Plus Bundle (WQ Baseline Plus Bundle and algae I.D./enumeration)
- [ ] Comprehensive Algae Bioassay (A multi-phase bioassay screening process to evaluate site specific algaecide performance. Also includes the Algae & WQ Baseline Plus analyses. Contact SePRO prior to collection and shipment.)

Individual Analysis:

- [ ] Algae ID††
- [ ] Alkalinity
- [ ] Chloride††
- [ ] Chlorophyll *a*
- [ ] Conductivity
- [ ] Dissolved Oxygen†
- [ ] Hardness
- [ ] Microbial Bacteria†† (total coliform & E. coli)
- [ ] Nitrates & Nitrites
- [ ] Nitrogen, Total (Kjeldahl)
- [ ] pH
- [ ] Phosphorus, Total (water)
- [ ] Phosphorus, Free Reactive (water)
- [ ] Phosphorus, Total & Free Reactive (water)
- [ ] Phosphorus, Total (sediments)
- [ ] Salinity††
- [ ] Total Dissolved Solids
- [ ] Total Suspended Solids
- [ ] Turbidity

Phosphorus, Fractioning†† (sediments)

- [ ] Level 1 Total & Available P
- [ ] Level 2 SRTC Comprehensive

Algae Infestation:

- [ ] Low
- [ ] Moderate
- [ ] High

Additional description:

Water Uses:

- [ ] Swimming
- [ ] Fishing
- [ ] Potable
- [ ] Irrigation
- [ ] All listed

Describe algae management history (*if any*):

† In order for the lab to generate more accurate D.O. data, it is recommended to preserve the sample immediately after collecting using appropriate reagents. †† This laboratory is not accredited for these tests: Salinity, Chloride, Phosphorus fractioning, Algae ID and Microbial Bacteria.

Client Sample Site I.D. (Required field)	Date Sample Collected (Required field)	Depth Sample Collected (feet)	Sample Location – Identify sites on map (GPS coordinates preferred)	Lab Use Only - Notes
1. S-4+T (top) (.5m below surface)	11/16/23	1.5ft		49647
2. S-4+B (bottom) (.5m from bottom)	11/16/23	~22ft		49648
3. S-5+	11/16/23	~1.5ft		49649
4. S-9+	11/16/23	~1.5ft		49650
5.				
6.				

Shipped by: Bradley Roth **Date/Time:** 11/16/23 3:00pm

To be filled out by laboratory

Received by: CWB **Date/Time:** 11/17/23 1100 am

Sample condition upon receipt: [x] Good condition [ ] No (explain)

Sample temperature upon receipt: ______ **Thermometer ID:** ______

 Revision Date: 11/10/2015 Effective Date: 11/11/2015 QAQC_F044_SeSCRIPT COC_11112015

SRTC

SePRO Research & Technology Campus

SePRO

Algae & Water Quality Analytical Services

SeSCRIPT® Chain of Custody

Company Name:* Aquatechnex, LLC

Contact Person:* Bradley Roth

Billing Address:* Internal EutroPHIX – Fernan Lake

Telephone:* 509-939-0631

Email Address:* bradley@aquatechnex.com

Site Location/State:* Fernan Lake, ID

*Required fields

Project/Reference Name: Fernan Lake Sediment Sampling 2023

SePRO Aquatic Specialist Name: Ryan Van Goethem

Sampler: Bradley Roth

Number of samples to be analyzed: 4

Billing: Internal EutroPHIX – Fernan Lake

Check Payment Method: ☐ PO Number______ ☐ VISA ☐ MasterCard Card No.______ CCV Code:______ Expiration Date:______

☐ Check here if you would like us to keep this credit card information on file for future lab analysis orders. Quote No.: ______

(To establish a secure credit card file for future billing, please contact the SePRO Accounting Department at 317-580-8291).

Sample Location and Identification

Draw a map of water body, to include sample locations by sample identification number as listed on the other side of this form or enclose a copy of a prepared map with this information.

Field Notes:

Direct all inquiries about your sampling and SeSCRIPT results to your SePRO Technical Sales Specialist.

Ship samples to:
SePRO SRTC
16013 Watson Seed Farm Road
Whitakers, NC 27891-9114
Email: srtclab@sepro.com
Tel: (252) 437-3282

COC 18088

SRTC

SePRO Research & Technology Campus

SePRO

Algae & Water Quality Analytical Services

SeSCRIPT® Chain of Custody

Water Body Name: Fernan Lake City Fernan Lake Village State ID

Water Body Size: (acres) 423 acres Average Depth: (feet) 16 ft Date/Time Sample Collected: 11/16/23 11:00am **One form for each water body**

Bundle Analysis:

- ☐ **Water Quality Baseline Bundle** (pH, alkalinity, conductivity, hardness, dissolved oxygen, turbidity, total phosphorus, free reactive phosphorus)
- ☐ **Water Quality Baseline Plus Bundle** (Baseline Bundle plus chlorophyll *a*, nitrates, nitrites and total nitrogen)
- ☐ **Algae and WQ Baseline Plus Bundle** (WQ Baseline Plus Bundle and algae I.D./enumeration)
- ☐ **Comprehensive Algae Bioassay** (A multi-phase bioassay screening process to evaluate site specific algaecide performance. Also includes the Algae & WQ Baseline Plus analyses. Contact SePRO prior to collection and shipment.)

Individual Analysis:

- ☐ Algae ID††
- ☐ Alkalinity
- ☐ Chloride††
- ☐ Chlorophyll *a*
- ☐ Conductivity
- ☐ Dissolved Oxygen†
- ☐ Hardness
- ☐ Microbial Bacteria†† (total coliform & E. coli)
- ☐ Nitrates & Nitrites
- ☐ Nitrogen, Total (Kjeldahl)
- ☐ pH
- ☐ Phosphorus, Total (water)
- ☐ Phosphorus, Free Reactive (water)
- ☐ Phosphorus, Total & Free Reactive (water)
- ☐ Phosphorus, Total (sediments)
- ☐ Salinity††
- ☐ Total Dissolved Solids
- ☐ Total Suspended Solids
- ☐ Turbidity

Phosphorus, Fractioning†† (sediments)

- ☐ Level 1 Total & Available P
- ☒ Level 2 SRTC Comprehensive

Algae Infestation:

☐ Low ☐ Moderate ☐ High

Additional description: ______

Water Uses:

☐ Swimming ☐ Fishing ☐ Potable ☐ Irrigation ☐ All listed

Describe algae management history (*if any*): ______

† In order for the lab to generate more accurate D.O. data, it is recommended to preserve the sample immediately after collecting using appropriate reagents. †† This laboratory is not accredited for these tests: Salinity, Chloride, Phosphorus fractioning, Algae ID and Microbial Bacteria.

Client Sample Site I.D. (Required field)	Date Sample Collected (Required field)	Depth Sample Collected (feet)	Sample Location – Identify sites on map (GPS coordinates preferred)	Lab Use Only - Notes
1. S-1	11/16/23	12 ft		49651
2. S-2	11/16/23	25 ft		49652
3. S-3	11/16/23	20 ft		49653
4. S-7	11/16/23	7 ft		49654
5. S-8	11/16/23	4 ft		49655
6.				

Shipped by: Bradley Roth **Date/Time:** 11/16/2023 3:00 pm

To be filled out by laboratory

Received by: CWS **Date/Time:** 11/17/23 1100 am

Sample condition upon receipt: ☑ Good condition ☐ No (explain)______

Sample temperature upon receipt: ______ **Thermometer ID:** ______

SRTC

SePRO Research & Technology Campus

SePRO

Algae & Water Quality Analytical Services

SeSCRIPT® Chain of Custody

Company Name:* Aquatechnex, LLC

Contact Person:* Bradley Roth

Billing Address:* Internal EutroPHIX - Fernan Lake

Telephone:* 509-939-0631

Email Address:* bradley@aquatechnex.com

Site Location/State:* Fernan Lake, [illegible] ID

*Required fields

Project/Reference Name: Fernan Lake Sediment Sampling 2023

SePRO Aquatic Specialist Name: Ryan Van Goethem

Sampler: Bradley Roth

Number of samples to be analyzed: 5

Billing: Internal EutroPHIX - Fernan Lake

Check Payment Method: ☐ PO Number ______ ☐ VISA ☐ MasterCard Card No. ______ CCV Code: ______ Expiration Date: ______

☐ **Check here if you would like us to keep this credit card information on file for future lab analysis orders.** Quote No.: ______

(To establish a secure credit card file for future billing, please contact the SePRO Accounting Department at 317-580-8291).

Sample Location and Identification

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Field Notes:

Direct all inquiries about your sampling and SeSCRIPT results to your SePRO Technical Sales Specialist.

Ship samples to:
SePRO SRTC
16013 Watson Seed Farm Road
Whitakers, NC 27891-9114
Email: srtclab@sepro.com
Tel: (252) 437-3282

COC 18089

SRTC SePRO Research & Technology Campus

SePRO

Algae & Water Quality Analytical Services

SeSCRIPT® Chain of Custody

Water Body Name: Fernan Lake City Fernan Lake Village State ID

Water Body Size: (acres) 423 acres Average Depth: (feet) 16 ft Date/Time Sample Collected: 11/16/23 11:00 am **One form for each water body**

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Individual Analysis:

- ☐ Algae ID††
- ☐ Alkalinity
- ☐ Chloride††
- ☐ Chlorophyll *a*
- ☐ Conductivity
- ☐ Dissolved Oxygen†
- ☐ Hardness
- ☐ Microbial Bacteria†† (total coliform & E. coli)
- ☐ Nitrates & Nitrites
- ☐ Nitrogen, Total (Kjeldahl)
- ☐ pH
- ☐ Phosphorus, Total (water)
- ☐ Phosphorus, Free Reactive (water)
- ☐ Phosphorus, Total & Free Reactive (water)
- ☐ Phosphorus, Total (sediments)
- ☐ Salinity††
- ☐ Total Dissolved Solids
- ☐ Total Suspended Solids
- ☐ Turbidity

Phosphorus, Fractioning†† (sediments)

- ☐ Level 1 Total & Available P
- ☐ Level 2 SRTC Comprehensive
- ☒ level 3 P Fractioning

Algae Infestation:

☐ Low ☐ Moderate ☐ High

Additional description:

Water Uses:

☐ Swimming ☐ Fishing ☐ Potable ☐ Irrigation ☐ All listed

Describe algae management history (*if any*):

† In order for the lab to generate more accurate D.O. data, it is recommended to preserve the sample immediately after collecting using appropriate reagents. †† This laboratory is not accredited for these tests: Salinity, Chloride, Phosphorus fractioning, Algae ID and Microbial Bacteria.

	Client Sample Site I.D. (Required field)	Date Sample Collected (Required field)	Depth Sample Collected (feet)	Sample Location – Identify sites on map (GPS coordinates preferred)	Lab Use Only - Notes
1.	5-4+	11/16/23	24 ft		49656
2.	5-5+	11/16/23	20 ft		49657
3.	5-6+	11/16/23	13 ft		49658
4.	5-9+	11/16/23	4 ft		49659
5.					
6.					

Shipped by: Bradley Roth Date/Time: 11/16/23 3:06 pm

To be filled out by laboratory

Received by: CWB Date/Time: 11/17/23 1100 am

Sample condition upon receipt: ☑ Good condition ☐ No (explain)

Sample temperature upon receipt: Thermometer ID:

SePRO Research & Technology Campus

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Algae & Water Quality Analytical Services

SeSCRIPT® Chain of Custody

Company Name:* Aquatechnex, LLC

Contact Person:* Bradley Roth

Billing Address:* Internal EutroPhix – Fernan Lake

Telephone:* 509-939-0631

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*Required fields

Project/Reference Name: Fernan Lake Sediment Sampling 2023

SePRO Aquatic Specialist Name: Ryan Van Goethem

Sampler: Bradley Roth

Number of samples to be analyzed: 4

Billing: Internal EutroPHIX – Fernan Lake

Check Payment Method: ☐ PO Number______ ☐ VISA ☐ MasterCard Card No.______ CCV Code:______ Expiration Date: ______

☐ Check here if you would like us to keep this credit card information on file for future lab analysis orders.

Quote No.: ______

(To establish a secure credit card file for future billing, please contact the SePRO Accounting Department at 317-580-8291).

Sample Location and Identification

Draw a map of water body, to include sample locations by sample identification number as listed on the other side of this form or enclose a copy of a prepared map with this information.

Field Notes:

Direct all inquiries about your sampling and SeSCRIPT results to your SePRO Technical Sales Specialist.

Ship samples to:
SePRO SRTC
16013 Watson Seed Farm Road
Whitakers, NC 27891-9114
Email: srtclab@sepro.com
Tel: (252) 437-3282

SePRO Research & Technology Campus SeSCRIPT*

16013 Watson Seed Farm Road, Whitakers, NC 27891

Chain of Custody: COC18087 LABORATORY REPORT

Customer Company **Customer Contact**

Company Name: Aquatechnex LLC-Main	Contact Person: Bradley Roth
Address: 2124 Grant St. Bellingham, WA 98225	E-mail Address: bradley@aquatechnex.com
	Phone: 208-559-8737

Waterbody Information

Waterbody:	Fernan Lake - ID
Waterbody size:	423
Depth Average:	16

Sample ID	Sample Location	Test	Method	Results	Sampling Date / Time
CTM49647-1	S-4 + T	Turbidity (NTU)	EPA 180.1	2.8	11/16/2023
		Conductivity (uS/cm)	EPA 120.1	52.0	
		Free Reactive Phosphorus (ug/L)	EPA 365.3	<5	
		Total Phosphorus (ug/L)	EPA 365.3	49.6	
		Alkalinity (mg/L as CaCO3)	EPA 310.2	23	
		Total Hardness (mg/L as CaCO3)	EPA 130.2	<10	
		pH	EPA 150.1	6.9	
CTM49648-1	S-4 + B	Turbidity (NTU)	EPA 180.1	2.8	11/16/2023
		Conductivity (uS/cm)	EPA 120.1	48.4	
		Free Reactive Phosphorus (ug/L)	EPA 365.3	<5	
		Total Phosphorus (ug/L)	EPA 365.3	49.4	
		Alkalinity (mg/L as CaCO3)	EPA 310.2	19.2	
		Total Hardness (mg/L as CaCO3)	EPA 130.2	<10	
		pH	EPA 150.1	7	
CTM49649-1	S-5 +	Turbidity (NTU)	EPA 180.1	3	11/16/2023
		Conductivity (uS/cm)	EPA 120.1	47.7	
		Free Reactive Phosphorus (ug/L)	EPA 365.3	<5	
		Total Phosphorus (ug/L)	EPA 365.3	30.2	
		Alkalinity (mg/L as CaCO3)	EPA 310.2	18.6	
		Total Hardness (mg/L as CaCO3)	EPA 130.2	<10	
		pH	EPA 150.1	7	
CTM49650-1	S-9 +	Turbidity (NTU)	EPA 180.1	5.2	11/16/2023
		Conductivity (uS/cm)	EPA 120.1	44.2	
		Free Reactive Phosphorus (ug/L)	EPA 365.3	5.8	
		Total Phosphorus (ug/L)	EPA 365.3	64.2	
		Alkalinity (mg/L as CaCO3)	EPA 310.2	13.3	

Total Hardness (mg/L as CaCO3)	EPA 130.2	<10
pH	EPA 150.1	6.8

ANALYSIS STATEMENTS:
SAMPLE RECEIPT /HOLDING TIMES: All samples arrived in an acceptable condition and were analyzed within prescribed holding times in accordance with the SRTC Laboratory Sample Receipt Policy unless otherwise noted in the report.
PRESERVATION: Samples requiring preservation were verified prior to sample analysis and any qualifiers will be noted
in the report.
QA/QC CRITERIA: All analyses met method criteria, except as noted in the report with data qualifiers.
COMMENTS: No significant observations were made unless noted in the report.
MEASUREMENT UNCERTAINTY: Uncertainty of measurement has been determined and is available upon request.

Laboratory Information
Date / Time Received: 11/17/23 11:00 AM
Date Results Sent: Monday, November 27, 2023

Disclaimer: The results listed within this Laboratory Report relate only to the samples tested in the laboratory. The analyses contained in this report were performed in accordance with the applicable certifications as noted. All soil samples are reported on a dry weight basis unless otherwise noted in the report. This Laboratory Report is confidential and is intended for the exclusive use of SRTC Laboratory and its client. This report shall not be reproduced, except in full, without written permission from SRTC Laboratory. The Chain of Custody is included and is an essential component of this report.

This entire report was reviewed and approved for release.

Reviewed By: Laboratory Supervisor

SRTC

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Water Quality Analysis Explanation

These water quality parameters are essential to document the condition of a water body and design custom treatment prescriptions to achieve desired management objective

pH: Measure of how acidic or basic the water is (pH 7 is considered neutral).

<6 notably acidic ***6 - 9 standard for typical freshwaters*** ***>9 notably basic***

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Hardness: Measure of the concentration of divalent cations, primarily consisting of calcium and magnesium in typical freshwaters. *0-60 mg/L as CaCO3 soft; 61-120 moderately hard; 121-180 hard; > 181 very hard*

Alkalinity- Measure of the buffering capacity of water, primarily consisting of carbonate, bicarbonate and hydroxide in typical freshwaters. Waters with lower levels are more susceptible to pH shifts.
<= 50 mg/L as CaCO3 low buffered; 51-100 moderately buffered; 101-200 buffered; > 200 high buffered

Conductivity- Measure of the waters ability to transfer an electrical current, increases with more dissolved ions.
< 50 uS/cm relatively low concentration may not provide sufficient dissolved ions for ecosystem health; 50-1500 typical freshwaters; > 1500 may be stressful to some freshwater organisms, though not uncommon in many areas

Phosphorus: Essential nutrient often correlating to growth of algae in freshwaters.

Total Phosphorus (TP) is the measure of all phosphorus in a sample as measured by persulfate strong digestion and includes: inorganic, oxidizable organic and polyphosphates. This includes what is readily available, potential to become available and stable forms. *<12 µg/L oligotrophic; 12-24 µg/L mesotrophic; 25-96 µg/L eutrophic; > 96 µg/L hypereutrophic*
Free Reactive Phosphorus (FRP) is the measure of inorganic dissolved reactive phosphorus (PO4-3, HPO4-2, etc). This
form is readily available in the water column for algae growth.

Nitrogen: Essential nutrient that can enhance growth of algae.

Total N is all nitrogen in the sample (organic N+ and Ammonia) determined by the sum of the measurements for Total Kjeldahl Nitrogen (TKN) and ionic forms.
Nitrites and Nitrates are the sum of total oxidized nitrogen, often readily free for algae uptake.
< 1 mg/L typical freshwater; 1-10 potentially harmful; >10 possible toxicity, above many regulated guidelines

Chlorophyll a: primary light-harvesting pigment found in algae and a measure of the algal productivity and water quality in a system.
0-2.6µg/L oligotrophic; 2.7-20 µg/L mesotrophic; 21-56 µg/L eutrophic; > 56 µg/L hypereutrophic

Turbidity- Measurement of water clarity. Suspended particulates (algae, clay, silt, dead organic matter) are the common constituents impacting turbidity.
< 10 NTU drinking water standards and typical trout waters; 10-50 NTU moderate; > 50 NTU potential impact to aquatic life.

SRTC SePRO Research & Technology Campus SePRO

Company Name:	Aquatechnex	**Size (ac.):**	423
Billing Address:	Internal EutroPHIX	**Average Water Depth (ft):**	16
City, State, Zip:	Fernan Lake, ID	**Sample Collection Date:**	11/16/2023
Project Name:	Fernan Lake Sediment Sampling 2023	**Contact Person:**	Ryan Van Goethem
Waterbody Name:	Fernan Lake	**Email Address:**	bradley@aquatechnex.com
Chain of Custody:	18089	**Telephone:**	509-939-0631
Report Date:	12/8/2023		

Comprehensive Level 2 Fractionation Results Summary

Sample Name	% Solids (% Dry Wt.)	Wet Bulk Density (kg/L)	Labile (mg-P/kg)	Reductant-Soluble (mg-P/kg)	Metal-Oxide (mg-P/kg)	Organic (mg-P/kg)	Apatite & Residual (mg-P/kg)	Total P (mg-P/kg)
S-1	18%	1.2	*	171	58	138	149	516
S-2	11%	1.1	*	262	251	246	164	923
S-3	9%	1.1	*	384	147	224	179	935
S-7	8%	1	*	155	113	319	201	788
S-8	4%	1	*	235	170	479	21	905

*** Concentration was less than reportable limits with 99% confidence**

All concentrations are reported based on dry weight

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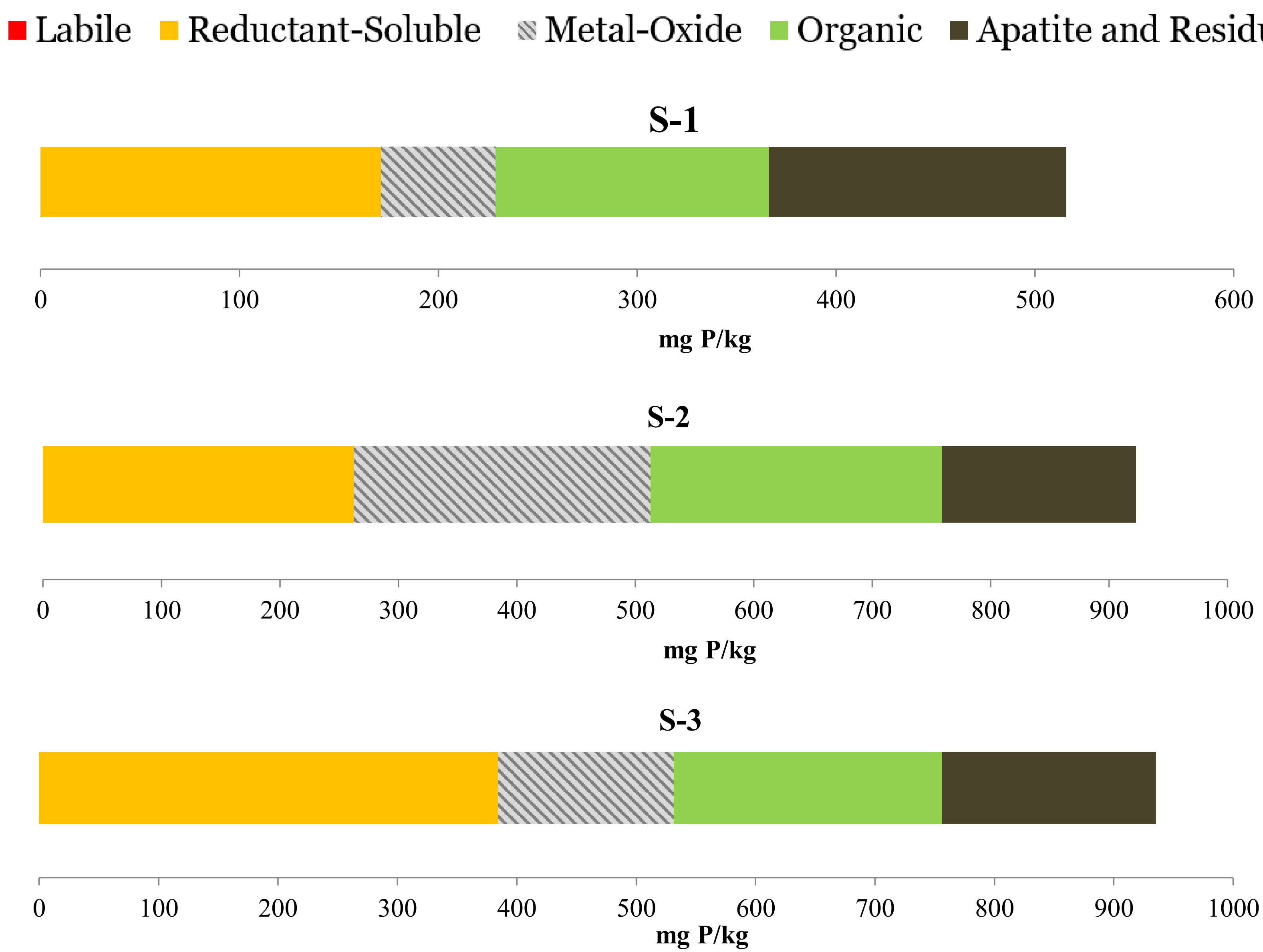
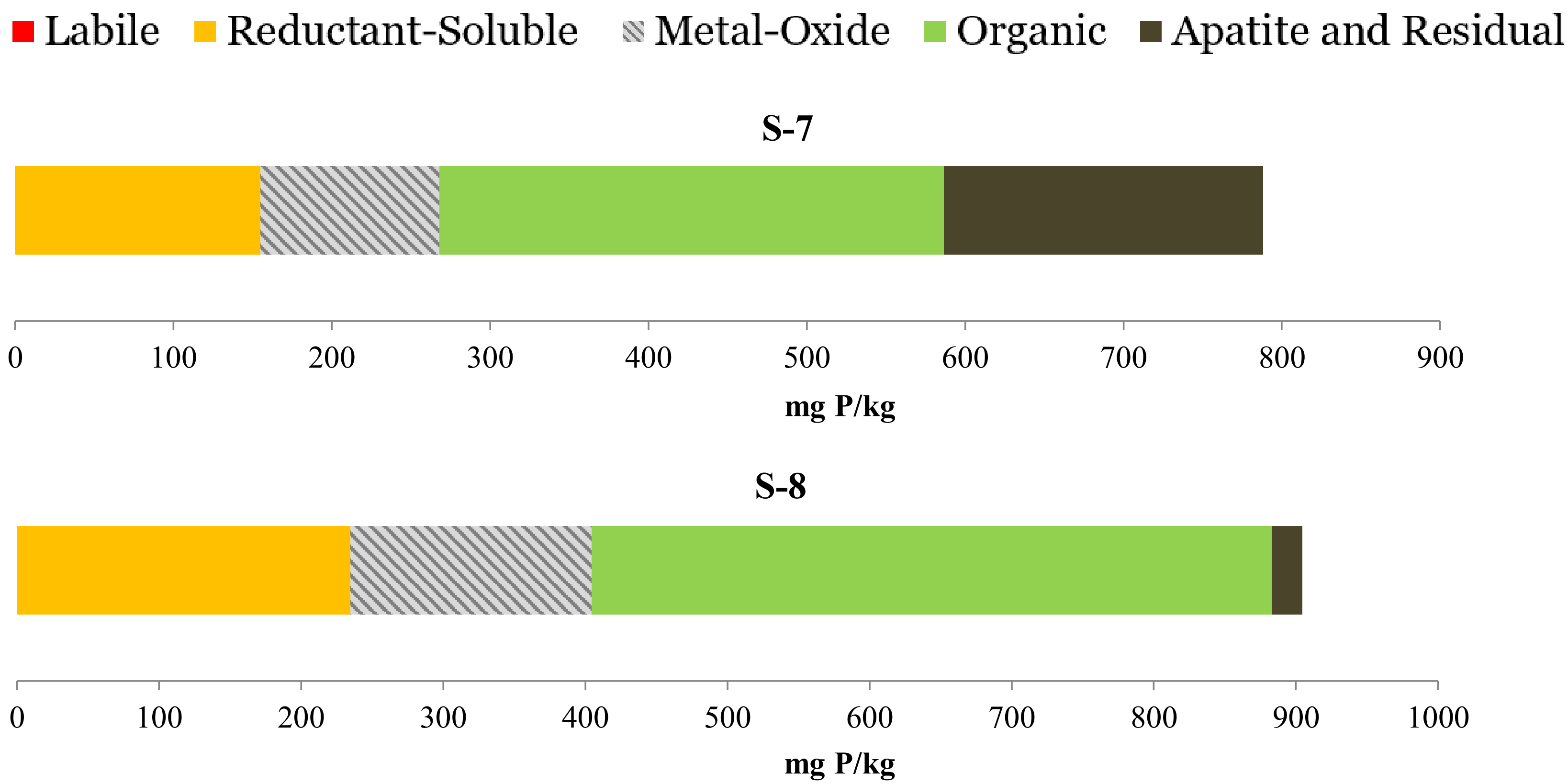
SeSCRIPT* Analysis


Labile
Reductant-Soluble
Metal-Oxide
Organic
Apatite and Residual
S-1
0
100
200
300
400
500
600
mg P/kg
S-2
0
100
200
300
400
500
600
700
800
900
1000
mg P/kg
S-3
0
100
200
300
400
500
600
700
800
900
1000
mg P/kg


Labile
Reductant-Soluble
Metal-Oxide
Organic
Apatite and Residual
S-7
0
100
200
300
400
500
600
700
800
900
mg P/kg
S-8
0
100
200
300
400
500
600
700
800
900
1000
mg P/kg

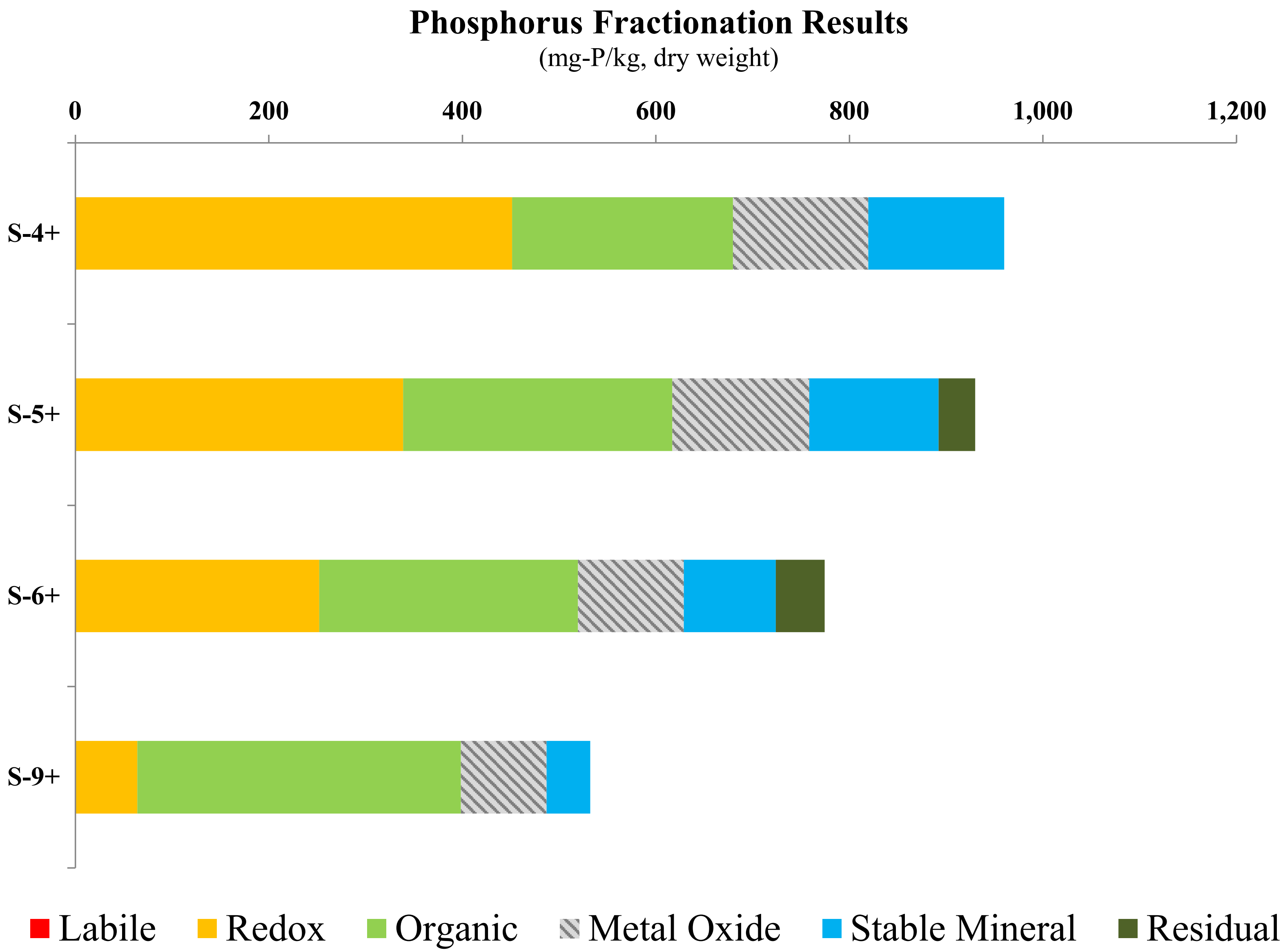
Company Name: Aquatechnex
Billing Address: Internal EutroPHIX
City, State, Zip: Fernan Lake, ID
Contact Person: Ryan Van Goethem
Email Address: bradley@aquatechnex.com
Telephone: 509-939-0631
Chain of Custody: 18089

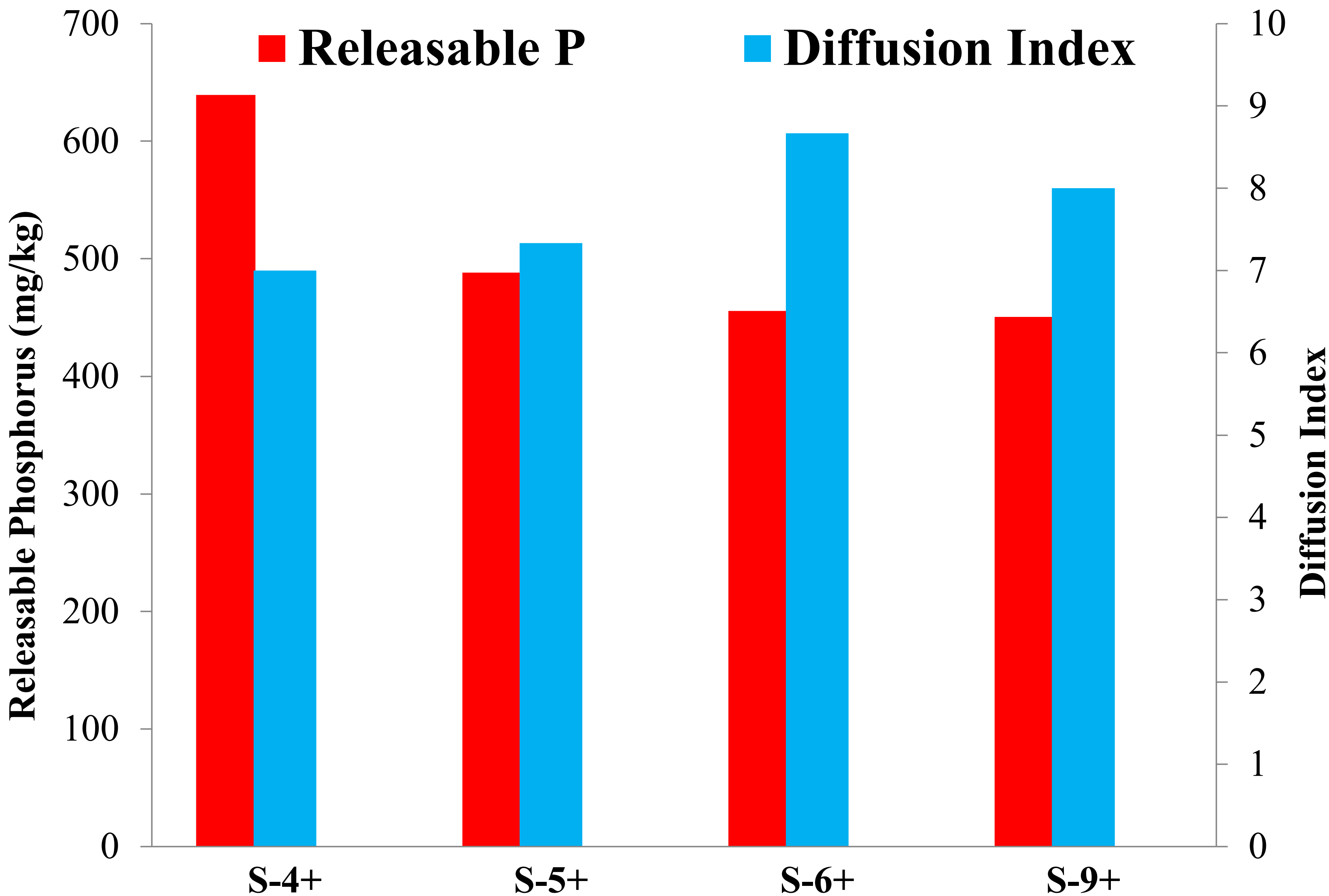
Report Date: 12/13/2023
Sample Collection Date: 11/16/2023
Waterbody Name: Fernan Lake
Project Name: Fernan Lake Sediment Sampling 2023
Size (ac.): 423
Average Water Depth (ft): 16
Calculated Osgood Index: 3.7

Sample Name	Site Depth (ft)	% Solids	Labile P (mg-P/kg)	Redox Sensitive P (mg-P/kg)	Organic P (mg-P/kg)	Metal Oxide P (mg-P/kg)	Stable Mineral P (mg-P/kg)	Residual P (mg-P/kg)	Total P (mg-P/kg)
S-4+	24	10%	*	451	228	140	140	*	960
S-5+	20	10%	*	339	278	141	134	38	930
S-6+	13	9%	*	252	267	109	95	51	774
S-9+	4	8%	*	64	334	89	45	*	532

^All concentrations reported in dry weight (mg/kg)
*** Concentration was less than reportable limits with 99% confidence**

Sample Name	Wet Bulk Density (kg/L)	Site Specific Osgood Index	Diffusion Index	Redox Release Index	Organic P Release Index	pH Release Index	Overall Phosphorus Burial Potential	Releasable P (mg/kg)	% Releasable P
S-4+	1.00	5.6	7.0	9.5	8.0	2.0	Low	639	67%
S-5+	1.00	4.7	7.3	7.0	7.7	2.7	Moderate	488	52%
S-6+	1.00	3.0	8.7	8.0	8.0	3.7	Moderate	456	59%
S-9+	1.00	0.9	8.0	8.0	10.0	7.3	Low	451	85%


Phosphorus Fractionation Results
(mg-P/kg, dry weight)
0
200
400
600
800
1,000
1,200
S-4+
S-5+
S-6+
S-9+
Labile
Redox
Organic
Metal Oxide
Stable Mineral
Residual


Releasable P
Diffusion Index
Releasable Phosphorus (mg/kg)
Diffusion Index
0
100
200
300
400
500
600
700
0
1
2
3
4
5
6
7
8
9
10
S-4+
S-5+
S-6+
S-9+

Diffusion Related Parameters									
Sample Name	% Solids	Total Organic Matter Content	Wet Bulk Density (g/cm^3)	Dry Bulk Density (g/cm^3)	Particle Density (g/cm^3)	Porosity	Sediment Expansion Coefficient	Site Specific Osgood Index	Diffusion Index
S-4+	10%	12%	1.00	0.67	1.48	55%	85%	5.6	7.0
S-5+	10%	12%	1.00	0.60	1.34	56%	84%	4.7	7.3
S-6+	9%	12%	1.00	0.39	1.58	75%	76%	3.0	8.7
S-9+	8%	20%	1.00	0.36	0.90	60%	78%	0.9	8.0

Iron Related Insight									
Sample Name	Redox P Release Parameters				Iron Stability and Stripping Potential				
	% Soluble Manganese	Bioavailable Organic Matter Content	Redox Sensitive Fe to P Molar Ratio	Redox Release Index	% Dissolved Iron	% Redox Sensitive Iron	% Metal Oxide Iron	Total Relevant Fe to P Molar Ratio	Iron-Stripping Potential
S-4+	58%	6%	17	9.5	2%	94%	5%	24	Moderate
S-5+	75%	5%	17	7	10%	83%	7%	26	High
S-6+	97%	6%	11	8	21%	69%	10%	16	Moderate
S-9+	40%	16%	14	8	27%	46%	28%	8	Low

Sample Name	Site Depth (ft)	Organic P Relase Parameters				pH Release Parameters			
		% Bioavailable Organic Matter	% Bioavailable Organic Phosphorus	Carbon to Phosphorus Ratio	Organic P Release Index	Sediment pH	Metal Oxide to P Molar Ratio	% Metal Oxide Aluminum	pH release index
S-4+	24	49%	100%	114	8.0	5.8	28	90%	2.0
S-5+	20	47%	88%	83	7.7	5.6	33	89%	2.7
S-6+	13	50%	84%	86	8.0	6.1	39	90%	3.7
S-9+	4	81%	100%	134	10.0	5.6	82	93%	7.3

Phosphorus Burial Insight									
Sample Name	Organic P Burial Parameters				Stable Mineral Formation				Overall Phosphorus Burial Potential
	% Refractory Organic Matter	% Refractory Organic Phosphorus	Carbon to Phosphorus Ratio	Organic Matter Burial Potential	% Stable Mineral P out of Total P	Acid Soluble Calcium Content (g/kg)	Lanthanum Content (mg/kg)	Stable P Mineral Formation Potential	
S-4+	51%	0%	114	Low	15%	0.6	0	Low	Low
S-5+	53%	12%	83	Low	14%	0.5	0	Low	Moderate
S-6+	50%	16%	86	Low	12%	0.4	0	Low	Moderate
S-9+	19%	0%	134	Low	8%	0.4	0	Low	Low

General Index Interpretation Guidance

Index or Parameter	Low (Less than 4)	Moderate (Between 4 to 6)	High (Greater than 6)
Diffusion Index	Generally better sediment quality and lower depth of diffusion from underlying sediment.	Average sediment quality and anticipated depth of diffusion.	Poor sediment quality leading to greater depth of diffusion from underlying sediment.
Redox P Release Index	Less likely to experience anoxia and P-release from redox sensitve iron-oxides.	Moderate likelihood for anoxia and redox related P-release.	More likely to experience anoxia and P-release from redox sensitve iron-oxides.
Iron Stripping Potential	Low likelihood of excess iron-oxides preventing sediment P-release.	Excess iron may prevent some sediment P-release.	High likelihood of excess iron-oxides preventing sediment P-release.
Organic P Release Index	Most organic P will be buried as refractory P after bacterial decomposition.	Some organic P will be buried and some will be released.	Most organic P will be released into the water colum after bacterial decomposition.
pH Release Index	Environmental conditions are unlikley to lead to the release of metal oxide P.	Some potential for the release of metal oxide P.	Environmental conditions are very likley to lead to the release of metal oxide P.
Organic Matter Burial Potential	Most organic P will be released into the water colum after bacterial decomposition.	Some organic P will be buried and some will be released.	Most organic P will be buried as refractory P after bacterial decomposition.
Stable P Mineral Formation Potential	Environmental conditions are not favorable for apatite formation.	Some apatite formation or La treatment success.	Conditions are favorable for apatite formation or La treatment is effective.
Overall Phosphorus Burial Potential	Most sediment phosphorus will eventually be released into the water column.	Similar amounts of P will be buried and released.	Most sediment P will be buried or bound before diffusing into the water column…………….

^All indices range from 0 (lowest) to 10 (highest) based on parameters on pages 4 and 5

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