Little Bitterroot Lake
Water Quality Monitoring Program
2018 Annual Report

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Glossary of Terms

Benthic – the bottom region of a lake including the sediment surface

Bloom – a significant increase in algae population triggered by favorable conditions for growth

Chlorophyll-*a* – a green pigment found in photosynthetic plants and algae

Depth profile – a chart showing a water chemistry parameter at various depths within a lake

Epilimnion – the uppermost portion of a stratified lake

Eutrophic – having high biological productivity (meso-eutrophic is moderately high), high productivity is commonly an indicator of high nutrients and poor water quality

Hypolimnion – the bottom layer of a stratified lake

Mesotrophic – having moderate biological productivity

Metalimnion – the middle (transitional) layer of a stratified lake

Oligotrophic – having low biological productivity (meso-oligotrophic is moderately low), low productivity is an indicator of low nutrient concentrations and good water quality

Trophic – relating to available nutrients (ex. trophic status)

Trophic status – a lake's ability to produce and sustain populations of algae in response to available nutrients, also referred to as lake productivity or biological productivity

List of Acronyms

AIS – aquatic invasive species
CFS – cubic feet per second
DEQ – Montana Department of Environmental Quality
DNRC – Montana Department of Natural Resources and Conservation
DO – dissolved oxygen
DOC – dissolved organic carbon
FLBS – Flathead Lake Biological Station
GPM – gallons per minute
LBLA – Little Bitterroot Lake Association
SAP – sampling and analysis plan
SC – specific conductance
TN – total nitrogen
TP – total phosphorus
TSI – trophic state index
TSS – total suspended sediment
USGS – United States Geological Survey
WET – Water & Environmental Technologies
WLI – Whitefish Lake Institute

Executive Summary

Little Bitterroot Lake was sampled twice in 2018, including a spring event on June 13, and a mid-summer event on July 31-August 1. These represent the 19th and 20th sampling events since 1999. The June sampling event was added in 2018 to provide information about nutrient loading to the lake during spring runoff. Lake sites were sampled for field parameters, nutrients, and chlorophyll-a, and stream sites were sampled for field parameters, nutrients, total suspended solids, and dissolved organic carbon. Four stream sites were sampled in June and August. Two lake sites were sampled in June, and 7 lake sites were sampled in August 2018. Depth profiles were recorded at the lake center on July 16, and attached algae was sampled from 2 shoreline locations in August 2018.

Little Bitterroot Lake continued to show excellent water quality in 2018. Total nitrogen in 2018 was slightly higher than 2017, and was near the average concentration for the entire monitoring period. The average total phosphorus concentration also increased slightly from 2017, although concentrations were still among the lowest average on record. Nitrogen concentrations ranged from 0.14 to 0.27 mg/L at the lake locations, while river sites ranged from 0.09 to 0.20 mg/L. Total phosphorus concentrations ranged from 0.003 mg/L (below detection) to 0.008 mg/L at lake sites, while stream sites ranged from 0.006 to 0.019 mg/L. Little Bitterroot Lake continues to be phosphorus limited, meaning that sufficient nitrogen is available for algae growth, and algae blooms are most likely to occur with inputs of phosphorus. There were no considerable differences in results between the spring (June) event and the mid-summer (August) sampling event.

Near surface lake temperatures in August were around 21.5°C (70.7°F). The lake was thermally stratified with an epilimnion from 0 to 25 feet, a metalimnion from 25 to 60 feet, and a hypolimnion below 60 feet, which is typical for mid-summer in Little Bitterroot Lake. Measurements of other field parameters in 2018 were consistent with previous years, including specific conductance, pH, and dissolved oxygen.

Algae in the water column (chlorophyll-a) was very low, with only 2 samples above the analytical detection limit. These samples were collected at depths of 30' and 60' below the lake surface. Dissolved oxygen also peaked near this depth, which is expected because algae produce oxygen during daylight hours. Algae concentrations in the water column did not reach nuisance levels, and were comparable to data from previous sample years. Two benthic algae samples were collected in 2018 from Locke Bay and a southeast location. Benthic algae concentrations at the Locke Bay site were very low and comparable to previous samples. However, the benthic algae sample collected from the southeast site displayed elevated concentrations of chlorophyll-a (26.0 mg/m2), and considerable quantities of sloughed filamentous algae was observed on the substrate and vegetation at this sample site. According to the neighboring landowner, they had observed prolific algae growth in 2018 compared to previous years. Additionally, an area of prolific algae growth was observed just south of the sample location, which appeared to be the source of sloughed algae in the sample area. This area may have been subjected to land-use changes that induced a slug of nutrients or sediment into the lake. As a result of conditions observed in 2018, this area will continue to be monitored during future years.

The trophic state index for Little Bitterroot Lake was oligotrophic based on concentrations of chlorophyll-a and phosphorus, meaning the lake has low primary productivity and good water quality. Total nitrogen concentrations indicate the lake has potential to be eutrophic, but the lake is phosphorus limited and the low concentrations of available phosphorus help prevent nuisance algae blooms. When compared to 10 regional large lakes, Little Bitterroot Lake ranks 5th lowest in nitrogen concentration, and 2nd lowest in phosphorus and chlorophyll-a.

Additional samples were collected from the Herrig Creek watershed in 2017 and 2018 to evaluate effects of logging and slash burning from recent timber sales. The upper Herrig Creek sites have shown slightly higher nutrient concentrations than the lake, which suggest that Herrig Creek may be a source of nutrient loading to Little Bitterroot Lake. All samples of total suspended sediment were below the analytical detection limit during 2017 and June 2018; however, all stream sites showed some detection of TSS in August 2018, ranging from 1.2 mg/L at the mouth of Herrig Creek to 35.0 mg/L at the middle Herrig Creek site. Dissolved organic carbon samples were also collected 2018. The highest concentrations of DOC were recorded at the upper Herrig Creek site, which is consistent with results from 2017. These sites will continue to be sampled in 2019 in order to provide baseline data on nutrient, carbon, and sediment loading from Herrig Creek.

In addition to the routine water quality sampling conducted on Little Bitterroot Lake, additional efforts were made in 2018 in regards to the threats from aquatic invasive species (AIS), especially invasive mussels and vegetation. Activities conducted in 2018 related to AIS included: AIS Day in June, sampling for mussel veligers, a complete vegetation shoreline survey, classroom instruction with the Marion Elementary School, development of educational materials and curriculum for Marion School, and the creation of a boat launch education and awareness program designed to educate boaters about threats and prevention of AIS. AIS Day in June involved speakers on lake ecology, water quality, aquatic invasive species, lake etiquette, and boat inspection procedures. This event was hosted at the Marion Fire Hall, and was attended by more than 70 members of the community. The mussel sampling included sample collection at 4 locations around Little Bitterroot Lake, which resulted in no positive detections of mussel veligers. The aquatic vegetation survey created an exhaustive species list of plants identified in 2018, and no invasive species were identified (including Eurasian Water-milfoil, Curlyleaf Pondweed, and Flowering rush). Additional water samples were also added to include parameters that indicate potential colonization by AIS, especially calcium and alkalinity. Calcium levels in Little Bitterroot Lake ranged from 13-14 mg/L, while alkalinity measured 49 mg/L. These results are near the low end of values considered suitable for AIS colonization, which suggests that AIS colonization in Little Bitterroot Lake may not be limited by water quality. Activities and sampling related to AIS were funded through a grant provided by the Department of Natural Resources and Conservation.

In order to improve or maintain water quality in Little Bitterroot Lake, efforts should be made to reduce sources of nutrients, such as limiting application of fertilizer to lawns, maintaining septic systems, keeping a vegetated buffer area, and reducing shoreline erosion. Little Bitterroot Lake is phosphorus limited, meaning that additional inputs of phosphorus are more likely to cause undesirable algae blooms. Fertilizers with little or no phosphorus are recommended to help maintain good water quality. This can be accomplished by selecting fertilizers with a zero as the middle value (i.e. 16-0-0).

1.0 Introduction

Little Bitterroot Lake is the headwaters for the Little Bitterroot River located southwest of Kalispell near the community of Marion at an elevation of approximately 3900 feet (**Attachment A**, **Figure 1**). The lake has a maximum depth of 260 feet, a surface area of approximately 4.6 square miles (2,950 acres) and a drainage area of 34.4 square miles (22,000 acres). The area exists within the Salish Mountains Ecoregion with a humid continental climate (Köppen classification Dfb) and an average annual precipitation of 21 inches. The geology of the watershed is primarily sedimentary rocks of the Belt series. The lake outlet is controlled by an earthen dam built in 1918, and is managed by the Flathead Irrigation Project for downstream irrigators. Herrig Creek is the only perennial stream flowing into the lake, although seven intermittent or ephemeral streams contribute seasonally. Groundwater contributes a substantial portion of water to the lake, especially from the Salish Mountains to the west and northeast. Local uses of the lake include water supply for domestic use, irrigation, fishing and recreation.

The Little Bitterroot Lake Association (LBLA) began in 1988 with the purpose of "preserving the high recreational value of Little Bitterroot Lake, maintaining its aesthetic integrity, and to educate the public and others as to the value of Little Bitterroot Lake as a recreational resource." Water quality monitoring has been conducted on the lake since 1999. The purpose of the monitoring program is to establish a water quality and nutrient baseline for the inflow, outflow, and lake water in conjunction with prior water quality projects. Information from this monitoring program may be used to make management decisions to help maintain the aesthetic and recreational conditions of the lake and surrounding drainages, and to help prioritize future monitoring efforts.

This report outlines the history of the monitoring program and presents water quality results from 2018 and past monitoring events. Long term trends in nutrient concentrations and trophic status are provided for locations that have been sampled consistently since 1999.

2.0 Monitoring Program History

Water & Environmental Technologies (WET) have conducted 20 sampling events on Little Bitterroot Lake since 1999 with assistance from the Little Bitterroot Lake Association. Data collected during sampling helps document existing water quality, track changes in nutrient concentrations over time, and to characterize the lake's productivity and trophic status. Additional data have been collected by the Flathead Lake Biological Station, Flathead Basin Commission, Flathead High School, Montana DEQ, University of Montana, and Whitefish Lake Institute.

Past monitoring events conducted by WET on Little Bitterroot Lake include:

November 30, 1999	May 24, 2000	September 27, 2004	September 1, 2005
September 25, 2006	October 8, 2007	October 13, 2008	October 5, 2009
June 3, 2010	August 23, 2010	September 20, 2011	September 10, 2012
May 20, 2013	August 29, 2013	August 11, 2014	August 11, 2015
August 3, 2016	August 2, 2017	June 13, 2018	July 31-August 1, 2018.

Depth profiles included with this report were measured in Little Bitterroot Lake on July 16, 2018, by the Whitefish Lake Institute, which oversees the Northwest Montana Lakes Volunteer Monitoring Network. The following sections describe the locations, dates, and methods for field sampling conducted in 2018 on Little Bitterroot Lake and the surrounding watershed.

3.0 Field and Analytical Methods

The water quality monitoring program on Little Bitterroot Lake includes annual field measurements and sample collection for laboratory analysis. Monitoring is conducted during mid-summer, typically the first week of August, although additional monitoring events have been conducted in spring and fall to evaluate seasonal changes in water quality. Monitoring is routinely conducted at 7 lake sites and 2 stream sites, although additional parameters or sites are added as warranted. Routine measurements of field parameters include water temperature, dissolved oxygen, specific conductance, and pH. Routine samples collected for laboratory analysis include basic nutrient parameters, including nitrate+nitrite, ammonia, total nitrogen, and total phosphorus. Lake samples are also collected for chlorophyll-a, which is a measure of algae growth. Two sites have been sampled for chlorophyll-a on near-shore rocks since 2014 as a means of monitoring algae growth on natural substrate. Depth profile monitoring is conducted annually by Whitefish Lake Institute at the lake center during late July or early August, and includes measurements of water temperature, specific conductance, dissolved oxygen, and pH.

In 2018 sampling events were conducted by WET on June 13 and August 3, and by Whitefish Lake Institute on July 16 with assistance from members of LBLA. Water quality sampling was conducted at 7 lake locations and 4 stream locations, including 3 sites on the inlet stream (Herrig Creek) and one site on the outlet stream (Little Bitterroot River) (**Figure 1**).

Several additions were made to the routine water quality sampling program in 2018 in order to collect additional baseline data and address emerging water quality issues around Little Bitterroot Lake. Additional parameters were added to the sampling program in 2018 in order to evaluate the potential colonization of aquatic invasive species, especially invasive mussels and non-native vegetation. The AIS-related water quality parameters added in 2018 included calcium, bicarbonate, and alkalinity, which were collected at all lake locations and the inlet and outlet streams. Results from these parameters may be compared against published guidelines for potential colonization of aquatic invasive species.

Additionally, early detection monitoring was conducted for aquatic invasive species in 2018 on Little Bitterroot Lake. Mussel veliger samples were collected from four open water locations on Little Bitterroot Lake, and a complete vegetation survey was conducted on the shoreline of Little Bitterroot Lake to document existing plant species and identify the presence of any aquatic invasive plants. Limited sampling had previously been conducted on Little Bitterroot Lake for invasive mussels or aquatic plants. The early detection monitoring was conducted on August 1-2, 2018, and was supported through an Aquatic Invasive Species Grant administered through the Montana Department of Natural Resources and Conservation (DNRC).

An additional spring sampling event was also added in 2018 in order to collected water quality data on the lake and neighboring streams. Limited sampling has been conducted during the spring season on Little Bitterroot Lake, yet this time period may represent significant loading of nutrients and sediment to the lake from spring runoff, especially during years with significant snowpack. Additional sampling was conducted for field parameters, nutrients, AIS-related parameters, total suspended solids, and dissolved organic carbon on two lake sites and the inlet and outlet streams. The spring sampling event coincided with AIS Day at Little Bitterroot Lake on June 13, 2018.

Two sites were also included in the upper watershed of Herrig Creek in 2018 to help evaluate potential effects from recent logging and slash burning. These sites were sampled for field parameters, nutrients, total suspended solids, and dissolved organic carbon. 2018 represents the second year of sampling at these locations.

Laboratory analyses in 2018 were provided by Energy Laboratories in Helena, MT, and funded by a grant from the Volunteer Monitoring Support Program administered by Montana Department of Environmental Quality (DEQ). Methods of each component of the monitoring program are summarized in the following sections. A complete description of field and analytical methods are provided in the project Sampling and Analysis Plan (SAP) (WET, 2018), which is provided to Montana DEQ to procure funding from the volunteer monitoring grant program.

3.1 Field Parameters

Field parameters are measured using a portable water quality meter (YSI Pro-Plus). Measurements are taken in the upper 3' of the water column at lake locations, or within the flowing portion of the stream at surface water locations. Field parameters include water temperature, dissolved oxygen, specific conductance and pH. The water quality meter is calibrated during the day of sampling. Water clarity is measured at the lake center using a Secchi disc. Stream flow is measured at surface water locations using a Marsh-McBirney electronic flow meter.

3.2 Water Chemistry Samples

Samples are collected for laboratory analysis of nutrients at each lake and stream location. Bottles are filled from moving water at the inlet and outlet streams, and from just below the surface at lake sites. At the lake center, samples are collected at various depths using a Van Dorn type sampler. All sample bottles are triple-rinsed with sample water prior to collection. Samples are filtered or preserved if necessary, and stored in a cooler on ice for delivery to the laboratory. Nutrient parameters analyzed at the laboratory include various forms of nitrogen (nitrate+nitrite, ammonia, total Kjeldahl, organic, total) and phosphorous (dissolved and total). Samples for total suspended solids (TSS) and dissolved organic carbon (DOC) were also collected in 2018 from the lake center, the inlet and outlet streams, and from two additional sites on Herrig Creek. All laboratory analyses were performed by Energy Laboratories in Helena, MT, using standard analytical methods, which are described in detail in the project SAP.

3.3 Algae Samples

Samples are collected from lake sites to analyze the concentration of chlorophyll-a, which provides a measurement of algae growth in the water column. Chlorophyll-a samples from open water are collected in amber glass bottles and are wrapped in aluminum foil to prevent exposure to sunlight, which can break down the chlorophyll and degrade sample integrity. Chlorophyll-a samples are collected from near the surface at 7 lake sites, and 2 samples are collected from various depths at the lake center using a Van-Dorn type sampler.

Samples were collected from two locations in 2018 to measure the algae growth on shoreline rocks, also called attached algae or benthic algae. For benthic algae collection, large rocks are selected from the wadeable portion of the lake that displays typical algae conditions for the area. A template is placed on the rock, and algae are removed from inside the template by scraping and brushing. The removed algae are filtered on a glass filter, placed in a centrifuge tube, wrapped in aluminum foil, and stored on dry ice for delivery to the Energy Laboratories in Helena, MT. Eleven template samples are collected at each location per the sampling protocol, which is described in the project SAP and based on standard collection methods approved by DEQ.

3.4 Depth Profile Sampling

Depth profile sampling is conducted at the lake center to evaluate changes in field parameters at depth, which indicates the degree of lake stratification at the time of sampling. Depth profile sampling was conducted by Whitefish Lake Institute on July 16, 2018, using a portable Hydrolab water quality meter which measures depth, chlorophyll-a concentration, water temperature, specific conductance, dissolved oxygen, and pH. The Hydrolab has a maximum sampling depth of 140 feet, which is sufficient to monitor for stratification in Little Bitterroot Lake.

3.5 Mussel Veliger Sampling

Mussel veliger sampling was conducted at four locations on Little Bitterroot Lake in 2018, including open water areas near the south boat ramp, the northeast boat ramp, the northwest boat ramp, and at the lake center (**Figure 1**). Sample collection was conducted using methods described in the field protocol document published by Flathead Lake Biological Station (FLBS, 2018), and field personnel were trained to conduct mussel veliger sampling by FLBS staff prior to sample collection.

Horizontal tow samples were collected by towing a plankton tow net (Wildco 12-inch diameter, 63-µm mesh) approximately 100 feet behind the boat for a total distance of approximately 300 feet (100 m). The speed of the boat was sufficient to pull the rope tight and allow the opening of the tow net to be submersed within the upper 5 feet of the water column. This horizontal tow method was used near the three main boat launches in the south, northeast, and northwest portions of the lake. A vertical tow sample was collected at the lake center by lowering the tow net twice to a depth of approximately 60 feet, which is the depth where peak algae concentrations are typically encountered during field sampling. A field blank was collected prior to lake sampling to ensure that the sampling net was properly decontaminated prior to sampling. The field blank was collected using de-ionized water to rinse the net into the collection bucket, and then preserved using the same methods as the lake samples.

Following sample collection, the organic material is washed into the net's collection bucket using a 95% solution of ethyl alcohol, which is also used to preserve the sample. The sample contents are collected in a 50 ml sample vial for transfer to the analytical laboratory. A small (5 ml) volume of baking soda solution is added to the sample to help maintain a high pH and prevent dissolution of shell material. The samples were stored in a dry, cool place, and transferred to the FWP laboratory in Helena, MT, for analysis within one week of collection.

3.6 Aquatic Vegetation Survey

An aquatic vegetation survey was conducted on the shoreline of Little Bitterroot Lake in order to document existing species and investigate the presence or absence of aquatic invasive plants. The vegetation survey was conducted using visual observations from a boat and the shoreline using methods described in the FWP guidance document "Aquatic Invasive Species Management Program Field Sampling and Laboratory Standard Operating Procedures" (FWP, 2018). A vegetation rake was used to pull plant samples to the surface for identification and collection. The survey was conducted in waters less than 25 feet where vegetation is more prolific, and extra focus was given in high-risk sites that are more susceptible to infestation from aquatic invasive species, such as boat ramps, docks, and shallow bays. Results from the aquatic vegetation survey were grouped into six regions based on habitat, including the Northwest Bay, Island Bay, Locke Bay, the Southwest shoreline, the East shoreline, and Herrig Creek Bay (**Figure 2**).

4.0 2018 Monitoring Results

Results from 2018 are provided in **Attachments A-B** and summarized in the following sections below.

4.1 2018 Field Parameter Results

Field parameter results from 2018 are provided in **Table 1** in **Appendix A**.

A June sampling event was conducted in 2018 in order to provide data during spring runoff following a winter with above average snowfall. The June event included all stream sites (3 on Herrig Creek and the Little Bitterroot River) and two lake sites. The lake sites were sampled from docks during June 2018, representing near-shore conditions. Weather during the June sampling event was calm with mostly cloudy skies and air temperatures around 67 °F. Lake temperatures ranged from 15.4 to 17.5 °C (59.7 to 63.5 °F), while Herrig Creek contributed cooler water around 10 °C (50 °F). pH in the lake varied from 8.10 to 8.19, while the stream sites ranged from 7.19 at upper Herrig Creek to 7.70 at the Little Bitterroot River. Specific conductance was around 125 µS/cm at the lake sites, and 43-48 µS/cm in the Herrig Creek sites. Dissolved oxygen ranged from 7.2 to 10.4 mg/L at all locations.

During the August sampling event, weather was warm (70-80°F) with clear skies and very little wind. There was also considerable smoke in the air from recent forest fires. In August 2018, the lake had a uniform surface temperature around 21.5°C (70.7°F). Herrig Creek was contributing cooler water around 17.3°C (63.1°F) at a flow of approximately 0.9 CFS (400 gallons per minute, GPM). The Little Bitterroot River at the outlet had a relatively cool temperature of 16.7°C (70.5°F) and also had flow of 0.9 CFS (400 gallons per minute, GPM). The pH at lake sites varied between 8.0 and 8.1, while the inlet and outlet streams measured 7.2 and 7.3, respectively. Biological activity by plants and algae raise pH during daytime hours when photosynthesis is occurring, which attributes to the higher pH measurements in the lake when compared to the inlet stream. Dissolved oxygen (DO) varied from 7.6 to 14.0 mg/L in the lake, while DO measured 8.1 mg/L in the inlet stream and 3.5 mg/L in the outlet stream. Specific conductance was quite low in the inlet stream (53 µS/cm) but uniformly around 113 µS/cm at the lake sites. Specific conductance at the outlet stream was higher than lake sites, measuring 162 µS/cm. These results are comparable to field parameters measured during previous sample years, and are indicative of good water quality and oligotrophic conditions.

Field parameters were also recorded at the additional sites on Herrig Creek during August 2018 (HC-1 and HC-2). Water temperature at Herrig Creek sites increased from 11.8°C (53.2°F) at the upper site to 15.8°C (60.4°F) at the middle site, and 17.3°C (63.1°F) at the mouth. Dissolved oxygen was highest at the upper Herrig Creek site (HC-1) with a concentration of 9.3 mg/L, although all sites had relatively high concentrations of dissolved oxygen sufficient to support aquatic life. Specific conductance measured 31 µS/cm at the upper site, and 49 and 53 µS/cm at the middle and lower sites, respectively. Readings of pH were lowest at the upper Herrig Creek site (7.15), and measured 7.58 and 7.19 at the middle and lower sites, respectively. Stream flow measured 0.3 CFS (135 GPM) at the upper Herrig Creek site, while the middle and lower Herrig Creek sites were flowing at approximately 0.6 CFS (170 GPM) and 0.9 CFS (400 GPM), respectively. These field parameter results are typical for a healthy mountain stream.

4.2 2018 Nutrient Results

Nutrient results from 2018 are provided in **Table 1**, and data for total nitrogen (TN) and total phosphorus (TP) are shown spatially in **Figure 3**, organized left to right from the lake inlet (Herrig Creek) to the lake outlet (Little Bitterroot River).

In 2018, total nitrogen concentrations were relatively low and comparable throughout the lake, varying from 0.09 to 0.24 mg/L. The highest values were recorded in August at the southeast location and at the lake center at a depth of 60' (0.24 mg/L). The lowest total nitrogen values were measured at the Little Bitterroot River (0.09 mg/L) and middle Herrig Creek (0.10 mg/L) in June, and at the upper Herrig Creek site (0.10 mg/L) on July 31. Total nitrogen results were comparable during both the June and August events, which suggest that significant nutrient loading was not occurring during the spring event relative to mid-summer conditions.

Total phosphorus measurements were also low and comparable throughout the lake in 2018, ranging from below detection (<0.003 mg/L) to 0.19 mg/L). The highest TP readings were recorded at the Herrig Creek sites on July 31, which ranged from 0.011 to 0.019 mg/L. Results from Herrig Creek were lower during June 2018 and likely affected by dilution during high water, ranging from 0.006 to 0.010 mg/L. This indicates that Herrig Creek may be a source of phosphorus loading to the lake during mid-summer months. Concentrations of TP measured at lakes sites ranged from <0.003 mg/L to 0.008 mg/L. Little Bitterroot Lake has historically shown low concentrations of total phosphorus and is described as "phosphorus-limited". Inputs of phosphorus from the inlet stream are likely consumed by algae and aquatic plants within the lake, resulting in lower measurements of total phosphorus in the lake samples.

4.3 2018 Chlorophyll-a Results

Samples for chlorophyll-a were collected in August 2018 from 6 open water locations and two benthic locations. In August 2018, algae growth in the water column was very low, with most samples being below the analytical detection limit. The only samples of chlorophyll-a above detection were collected from the lake center at depths of 30 feet (1.0 mg/L) and 60 feet (2.6 mg/L) below the lake surface. The highest concentration of dissolved oxygen occurred approximately 53' below the lake surface, which is expected because algae produce oxygen during daytime hours. Depth profile measurements collected by WLI using the Hydrolab measured a peak algae concentration of 6.7 mg/L at a depth of 85'.

Attached algae, also called benthic algae, were sampled at two shoreline locations in August 2018, including Locke Bay and the southeast corner. Results from Locke Bay reflected typical mid-summer algae conditions with very low chlorophyll-a (1.0 mg/m^2). The southeast location, however, displayed significant filamentous algae in the water column and collecting on shoreline rocks and vegetation. The algae appeared to be sloughed off and transported to the southeast corner from wind and wave action. The sample collected from the southeast corner yielded a chlorophyll-a concentration of 26.0 mg/L, which is significantly higher than typical concentrations shown from shoreline rocks. Conversations with the neighboring landowner indicated that the sloughed algae had been more significant in 2018 than previous years, and it may be related to land-use activities in the southeast portion of the lake, such as lot clearing or modifications to septic systems that may mobilize sediment or nutrients. A swath of prolific algae growth was identified during the vegetation survey that may be the source of sloughed algae sampled in August 2018. This portion of the lake will be revisited in future sampling events to evaluate if land-use changes are contributing to increased algae growth.

Prolific algae growth can be a problem because it consumes oxygen from the water column during the night, which can cause low oxygen levels for fish and other aquatic organisms. Algae can also be a physical nuisance to homeowners and recreationists due to prolific growth.

4.4 2018 Depth Profile Results

Depth profile sampling was conducted on July 16, 2018, to show changes in water chemistry at depth. Results from the depth profile sampling are shown in **Figure 4**, including charts for water temperature, dissolved oxygen, pH, and chlorophyll-a. Results from 2014 to 2018 are shown for comparison. Overall, depth profile measurements from July 2018 were comparable to previous years, showing similar trends at depth. Measurements from July 2018 were most comparable to those collected in August 2014, which displayed slightly higher measurements of chlorophyll-a, pH, and dissolved oxygen when compared to years 2015-2017.

In July 2018 the lake was thermally stratified with an epilimnion (upper layer) from 0 to 25 feet, a metalimnion (transitional layer) from 25 to 60 feet, and a hypolimnion (bottom layer) from approximately 60 feet to the lake bottom.

Dissolved oxygen was near 9.1 mg/L in the upper epilimnion in July 2018, with a peak occurring around 53' below the lake surface (13.4 mg/L). Dissolved oxygen typically peaks in the area with the highest algae growth because the algae produce oxygen during photosynthesis. Dissolved oxygen concentrations are well above the threshold for aquatic life (5 mg/L) throughout the water column, which is typical of an oligotrophic lake with good water quality and low biological productivity.

Depth profile measurements of pH in July 2018 were comparable to previous year. Measurements of pH typically range from 7.5 to 8.2 in the upper epilimnion, and increase to more than 8.6 within the photic zone of the metalimnion where phytoplankton are most prevalent. These results could be expected because photosynthetic activity from algae raises the pH during daytime hours.

The depth profile for chlorophyll-a in July 2018 was also comparable to previous years, with peak concentrations occurring between 60 and 90 feet. Chlorophyll-a serves as a measurement of algae production within the water column, and photosynthetic algae (phytoplankton) commonly peak at depth where availability of light, nutrients, and water density are optimal for algae growth.

4.5 Long Term Trends

Results from 2004 to 2018 are shown for all sample locations in **Figure 5,** and **Figure 6** shows minimum, maximum, and average results from 2004-2018. Nutrient concentrations have generally shown a decreasing trend since consistent yearly monitoring began in 2004. In August 2018, total nitrogen and total phosphorus concentrations in Little Bitterroot Lake were comparable to samples collected since 2012. Higher concentrations of nutrients were recorded during the high water year of 2011.

The downward trends in nutrient concentrations are encouraging from the standpoint of improving water quality, but should be interpreted with caution because of the limited temporal data available for Little Bitterroot Lake. Nutrient concentrations can vary between seasons or change rapidly due to episodic events such as runoff or lake turnover, so sample events may not coincide with periods of peak nutrient concentrations. Data and trends become more robust as future measurements are added to the dataset, and continuity and consistency are maintained within the monitoring program.

The ratio between nitrogen and phosphorus is also analyzed for long term trends. Within a lake system, algae growth is optimized when the ratio between nitrogen and phosphorus is around 16:1. A ratio higher than 16:1 indicates that the system has sufficient nitrogen for algae growth, but phosphorus is limited. Conversely, a ratio lower than 16:1 indicates that the system has limited nitrogen for algae growth, but has sufficient quantities of phosphorous. **Figure 8** displays the trend in N:P ratio from 2004 to 2018 on Little Bitterroot Lake. The 16:1 ratio is indicated by the green line on the graph, and the trend line is shown as the dashed line. In 2018, the N:P ratio was 31 (indicating that the lake is phosphorus limited), and the N:P ratio appears to be increasing from 2004 to 2018 despite the fact that concentrations of both nutrients are declining over this period. This result is occurring because concentrations of nitrogen are not declining as rapidly as phosphorus, and total nitrogen even shows an increasing trend from 2012 to present. Conversations with limnologists from FLBS reveal that this trend is prevalent across the western United States, and is primarily a result from increased human occupation around lake communities. Nitrogen is a nutrient that is commonly associated with human sources such as septic systems or fertilizers, and increasing trends in nitrogen concentrations are commonly seen around growing lake communities. Phosphorus is more commonly associated with natural sources such as surrounding geology or soils, and human sources can more easily be controlled with appropriate erosion or sediment control practices (although septic systems are also a primary source of phosphorus to lake systems). As a result, Little Bitterroot Lake has become increasingly phosphorus limited during this period of study, and land management around the lake should encourage practices that limited additional inputs of phosphorus by maintaining shoreline vegetation, limiting land clearing, and avoiding fertilizers that are high in phosphorus.

Data from 2004 to 2018 are analyzed spatially by combining all data for each sample location shown in **Figure 7**. These charts show the minimum, maximum, and average nutrient concentrations for each sample site for the period of record. Sample locations are organized from left to right in the general direction of flow through the lake, from the inlet (Herrig Creek) to the outlet (Little Bitterroot River). Average concentrations of total nitrogen are lowest at the lake center and highest at the lake outlet. Concentrations of total phosphorus are lowest at Herrig Creek Bay and the southeast location, while total phosphorus concentrations are highest at the outlet. Results for total nitrogen and total phosphorus are quite variable at each location and differences between sample locations may not be statistically significant.

4.6 Trophic Status

Trophic status refers to a lake's ability to produce and sustain populations of algae in response to available nutrients, also referred to as biological productivity. High biological productivity is an indicator of high nutrients and poor water quality, whereas low biological productivity is an indicator of low nutrient concentrations and good water quality. The trophic status of Little Bitterroot Lake was determined by calculating the Carlson's Trophic State Index (TSI) from measurements of total nitrogen, total phosphorus and chlorophyll-a (Carlson, 1977). The TSI for Little Bitterroot Lake is shown in **Figure 9** for data from 2004 to 2018.

TSI data suggest that Little Bitterroot Lake is classified as eutrophic based on concentrations of total nitrogen; however, measurements of total phosphorus and chlorophyll-a indicate that the lake is oligotrophic with low biological productivity. Total phosphorus concentrations in 2018 were very low, indicating oligotrophic conditions.

Despite having relatively high concentrations of total nitrogen, Little Bitterroot Lake typically does not experience large blooms of nuisance algae and has shown low concentrations of chlorophyll-a during sample events conducted from 2010 to 2018. The low biological productivity is likely because the lake's morphology is favorable to oligotrophic conditions and limited by low phosphorus concentrations. Little Bitterroot Lake has steep sides, limited littoral (shallow shoreline) habitat, and a low watershed/lake ratio of 4.8 (Ellis et al, 1998). The lake is also phosphorus-limited, meaning that it has an adequate amount of nitrogen compared to the amount of phosphorus needed to support algae growth. Lakes that are phosphorus-limited often show increased algae growth when phosphorus concentrations increase, but not necessarily when nitrogen concentrations increase. Total phosphorus is commonly associated with sediment, so high concentrations often occur in years following land disturbance (such as road building or logging) or increased precipitation and runoff.

4.7 Additional Sample Results from Herrig Creek

Additional samples were collected from two sites on Herrig Creek in June and August 2018 in response to recent logging and slash burning in the watershed. Baseline samples for nutrient parameters were collected, along with dissolved organic carbon and total suspended sediment, which can increase due to land disturbance such as logging, burning, or road building. Dissolved organic carbon (DOC) is an important food source for algae, and total suspended sediment (TSS) is a measure of the amount of sediment that is carried in the stream. For comparison, samples of DOC and TSS were also collected at the lake center and in the outlet stream. This is the second year of sampling the additional sites on Herrig Creek.

In 2018, concentrations of DOC ranged 2.0 to 6.9 mg/L, which were comparable to results in 2017 which ranged from 3.2 to 6.0 mg/L. These concentrations are considered typical for undisturbed watersheds, and serve as a baseline that can be evaluated against future results. Concentrations of TSS were below the analytical detection limit at all sites in 2018 with the exception of the middle Herrig Creek site, which measured 35.0 mg/L in August.

4.8 AIS Related Parameters

AIS-related water quality parameters were added to the sampling program in 2018, including calcium, bicarbonate, and alkalinity, which were collected at all lake locations and the inlet and outlet streams. These parameters may be used to evaluate the potential for colonization from aquatic invasive species, especially mussels who rely on calcium for shell growth.

Calcium concentrations were lowest in Herrig Creek (4-5 mg/L) and highest in Little Bitterroot River (16-20 mg/L). Concentrations of calcium in the lake were 13-14 mg/L. Calcium samples were previously collected from Little Bitterroot Lake in 1999 and 2000, and results from 2018 were very comparable in Herrig Creek (3.1 - 5.0 mg/L), Little Bitterroot River (21.5 mg/L), and the lake sites (12.1 – 14.6 mg/L). Measurements collected from 1974 and 1981 from Little Bitterroot Lake were also comparable, ranging from 13.6 mg/L in 1974 to 14.4 mg/L in 1981. These results indicate that calcium concentrations are relatively stable in Little Bitterroot Lake and the surrounding watershed.

Alkalinity concentrations in 2018 ranged from 19-26 mg/L in Herrig Creek, 48-49 mg/L in Little Bitterroot Lake, and 58-73 mg/L in Little Bitterroot River. These results are comparable to samples collected from Little Bitterroot Lake in 1999-2000, which ranged from 46.2 to 60.0 mg/L.

Risk categories have been published for determining the likelihood of dreissenid mussel establishment based on multiple field and laboratory studies (Wells et al., 2011). Risk categories based on calcium concentration are defined as very low (<12 mg/L), low (12-15 mg/L), medium (15-25 mg/L), and high (>25 mg/l). Calcium concentrations measured in Little Bitterroot Lake would put the lake at a low risk of dreissenid mussel establishment, however, established mussel populations have been found in lakes with significantly lower calcium concentrations (<10 mg/L) than Little Bitterroot Lake. Furthermore, alkalinity and bicarbonate concentrations are within the range of concentrations to support dreissenid mussel establishment.

4.9 Mussel Veliger Sampling Results

Plankton tow samples were collected at four locations on Little Bitterroot Lake in 2018 to be analyzed for the presence of mussel veligers. The sample locations included horizontal tows near the boat launches on the south, northeast, and northwest portion of the lake, and a vertical tow at the lake center (**Figure 1**). Mussel veligers were undetected at all locations in 2018. A copy of the results from FWP are provided in **Attachment B**. A dedicated plankton tow net has been obtained for Little Bitterroot Lake, and future sampling efforts will include horizontal and vertical tows for mussel veligers as long as analysis is supported by the FWP laboratory.

4.10 Aquatic Vegetation Survey Results

An aquatic vegetation survey was conducted in August 2018 around the entire shoreline of Little Bitterroot Lake in order to produce a species list for the lake and document the presence or absence of aquatic invasive species. Particular attention was given toward the most common aquatic invasive plants in the region, including Flowering-rush, Eurasian Water-milfoil, and Curly-leaf Pondweed. The lake was divided into six areas based on habitat, including the Northwest Bay, Island Bay, Locke Bay, the Southwest shoreline, the East shoreline, and Herrig Creek Bay (**Figure 2**). Plants were identified to species level where possible, and assigned a relative abundance score of 1-3, with 1 indicating a rare abundance, and 3 indicating common abundance. In total, 15 plant species were identified around the lake, and no aquatic invasive species were found during the survey. Results from each survey area are summarized below, and a complete list of species present in each area are provided in **Attachment B**.

Northwest Bay
The northwest bay of Little Bitterroot Lake is relatively shallow and contains the most prolific aquatic plant growth of any area around the lake. It also contains the most number of plant species on Little Bitterroot Lake. The area contains silty and rocky substrate, and is bordered on the south by a small island. The area is accessed by a public boat launch and receives a significant amount of boat traffic. Thirteen species were identified in the northwest bay, including one specimen of Beck Water-marigold, a rare aquatic herb listed as a species of concern. The area is dominated by Hardstem Bulrush, especially in the rocky habitat near the island. Largeleaf Pondweed and Horned Pondweed were also very common in the northwest bay.

Island Bay
The area identified as the island bay is located south of the island in the northwest portion of the lake extending to Locke Bay. This area is distinct from the northwest bay because it primarily contains rocky substrate and is much deeper than the northwest bay, which limits the diversity of aquatic plants. Seven species were identified for this area, which is dominated by Hardstem Bulrush. Largeleaf Pondweed and Water Smartweed are also common in the island bay.

Locke Bay
Locke Bay is located on the west portion of the lake, and contains a fair amount of shallow, silty substrate, although the majority of the bay is rocky. This area contains the second most diversity behind the northwest bay, with twelve species identified. The area is dominated by Hardstem Bulrush, Largeleaf Pondweed, and Water Smartweed. Additional pondweed species (Richardson's, White-stem, and Horned) were also common.

Southwest Shoreline
The southwest shoreline extends from Locke Bay to the boat ramp on the south end of the lake. This area is bordered by relatively dense housing, and is characterized by rocky substrate which limits the growth of aquatic plants. The area is dominated by clusters of Hardstem Bulrush, although Largeleaf Pondweed is also common. Algae mats adjacent to cabins and boat docks contained Chara, a plant-like green algae. Chara was found sporadically around Little Bitterroot Lake, but was most abundant in the southwest corner of the lake.

East Shoreline
The east shoreline extends from the south boat ramp north to Herrig Creek Bay. This area of the lake has steep banks with rocky substrate and limited littoral habitat, which limits the abundance and diversity of aquatic plants in this area. The shoreline in this area is also subjected to disturbance from wind, which typically blows from the west. There is also significant housing development in portions of this area, especially the southeast corner of the lake. Six species were identified in this area, but aquatic plant life was primarily limited to Hardstem Bulrush in isolated clusters. Vegetation is most abundant in the southeast corner near the boat ramp.

Herrig Creek Bay
Herrig Creek Bay is a relatively shallow bay in the northeast portion of the lake near the inlet of Herrig Creek. This area contains two boat launches, including a dirt boat launch in the northeast corner primarily used by small watercraft, and the boat launch at the Lion's Camp. Silty substrate is more common in this area, likely due to sediment inputs from Herrig Creek, although aquatic plant diversity is relatively limited. Six species were identified in Herrig Creek Bay, although Hardstem Bulrush was the only species with relatively high abundance. A large patch of Whitestem Pondweed exists near the culvert of Herrig Creek.

5.0 Outreach and Educational Activities

In addition to the routine water quality sampling, mussel veliger sampling, and aquatic vegetation survey, several outreach and education activities were implemented on Little Bitterroot Lake in 2018 with support from an Aquatic Invasive Species Grant administered through Montana Department of Natural Resources and Conservation (DNRC). Personnel from Little Bitterroot Lake Association (LBLA), Water & Environmental Technologies (WET), Montana Fish, Wildlife & Parks (FWP), Flathead Lake Biological Station (FLBS), Marion School, and the Marion Community all participated in the education and outreach portion of LBLA's Lake Education and Awareness Program (LEAP) in 2018. The major accomplishments of the education and outreach portion of this project in 2018 were:

- **AIS Day at Little Bitterroot Lake**
  AIS Day was conducted on June 13, 2018, at the Marion Fire Hall, and was attended by approximately 80 guests from Little Bitterroot Lake Association, Marion Elementary School, and the Marion Community. This event included presentations from LBLA board members, the principal of Marion School, scientists from Water & Environmental Technologies (WET) and Flathead Lake Biological Station (FLBS), and employees from MT Fish, Wildlife and Parks (FWP). Presentations included information on the threats of aquatic invasive species, lake ecology, boat inspection protocols, boat safety, lake etiquette, enforcement, and the recent collaboration between the AIS work group. Materials were provided to attendees including flyers on boat inspection protocol, effects of septic systems, lake etiquette, a map showing areas on Little Bitterroot Lake which are susceptible to AIS infestation, and an identification guide for common AIS species. The attendance at this event was considered to be a huge success for the lake association, especially considering AIS Day occurred on a Wednesday.

- **Education Program with Local Schools**
  During AIS Day, classroom instruction was provided to summer students at Marion Elementary School to educate them about lake ecology, the threats of AIS, measures to prevent AIS infestation, and common tools used to sample lakes. Books were donated to the Marion School on lake ecology, water education, and AIS, including a science fair project guide for future use by students. Following the conclusion of AIS Day, the presentations were uploaded to a YouTube channel created by members of LBLA for distribution to those who could not be in attendance. The presentations were later used by students from FVCC to create three sets of PowerPoint curriculum slides that could be distributed to schools for classroom instruction. Below is a link to the LBLA YouTube channel which hosts the presentations from AIS Day.

  https://www.youtube.com/channel/UC_7YOrrmjVzf0mYhyECLtxA

Information from AIS Day was also used to create educational canvas boards to be displayed at Marion School. Eight poster boards were developed to educate students about the threats of AIS and prevention methods. By engaging students at Marion School, LBLA and the AIS work group hope to educate future lake users about the serious threat of AIS and how to be pro-active about the spread of AIS.

- **Boat Launch Volunteer Program**
  During AIS Day, members of LBLA recruited and scheduled volunteers to staff two boat launches during peak summer periods to provide education and awareness about the threats of AIS, the availability of boat inspection/decontamination stations, and how to be pro-active about preventing AIS. This program was not funded through the DNRC grant program, but was offered as an in-kind service in 2018. Volunteers were staged during weekends and holidays during peak summer months at the county boat launch on the south end of Little Bitterroot Lake, and at the boat launch in the Northwest Bay, which typically see the most boat traffic. The volunteers recruited for this effort received training and education at AIS day, including a primer from FWP staff on how to conduct boat inspections. While the staff did not conduct inspections themselves, they inquired boaters about their experience with boat inspections, and if needed, referred them to available boat inspection and decontamination stations in the area. Volunteers also offered information on AIS threats and prevention, including the bathymetry map of LBL with the AIS identification guide, and handouts about FWP's Clean, Drain, and Dry campaign. This program was well received by LBLA members and the boating community, who were very appreciative of the efforts made toward preserving the quality of Little Bitterroot Lake for future users.

6.0 Discussion and Conclusions

Water quality in Little Bitterroot Lake was again very good in 2018, with low concentrations of nutrients and chlorophyll-a. Total nutrient concentrations (nitrogen and phosphorus) have generally been decreasing since the inception of the monitoring program in 1999. The highest concentrations of total nitrogen have typically occurred at Herrig Creek Bay and the lake outlet, while the highest concentrations of total phosphorus have occurred at the lake outlet. Elevated concentrations of both nutrients were exhibited in 2011, which was a high precipitation year during which excess nutrients may have been flushed into Little Bitterroot Lake from the surrounding watershed, although this result has not been exhibited in other high water years such as 2018. Past sampling events indicate that lake water quality is strongly influenced by ground water with less input from Herrig Creek and other intermittent streams.

The trophic state index for Little Bitterroot Lake suggests eutrophic conditions exist due to elevated concentrations of total nitrogen, but measurements of total phosphorus and chlorophyll-a indicate oligotrophic conditions with low biological productivity and very good water quality. Little Bitterroot Lake has typically been phosphorus-limited, meaning it has an inadequate amount of phosphorus compared to the amount of nitrogen needed to support algae growth. Based on this observation, Little Bitterroot Lake is more likely to experience algae blooms with the addition of phosphorus since concentrations of nitrogen are already relatively elevated. However, nutrient concentrations can vary significantly, and efforts to reduce inputs of both phosphorus and nitrogen should be encouraged to help maintain the water quality of Little Bitterroot Lake and limit algae growth.

Additional sampling was conducted for aquatic invasive species in 2018, including mussel veliger sampling, a complete vegetation survey, and the addition of water quality parameters that serve as indicators of potential colonization from aquatic invasive species. Mussel veligers were undetected in all samples in 2018. Additionally, aquatic invasive plant species were not identified during the vegetation survey. A complete species list was completed for Little Bitterroot Lake which may serve as a baseline for future sampling. The water quality parameters (calcium and alkalinity) indicate that Little Bitterroot Lake has low potential for colonization by invasive mussels based on water chemistry; however, invasive mussels have been detected in lakes with lower concentrations of calcium and alkalinity than those measured in Little Bitterroot Lake.

Furthermore, an education and outreach component was added in 2018, which included the creation of AIS Day in June, a classroom education component with Marion School, the development of classroom curriculum related to AIS for use at Marion School, the donation of education materials to Marion School (books, science project guides, and canvas poster boards), and the development of a boat launch education and awareness program staffed by volunteers during peak use times on Little Bitterroot Lake. Overall, the education and outreach projects were very successful at educating the community, lake users, and school children about lake ecology, and the threats and preventative measures of aquatic invasive species.

Overall, Little Bitterroot Lake has shown excellent water quality throughout its monitoring history. Nutrient and chlorophyll-a concentrations are low, algae blooms are rare, and field data indicate suitable ranges of temperature, dissolved oxygen and pH to support a viable fishery. Little Bitterroot Lake also displays excellent water quality when compared to other regional lakes. 41 lakes are presently monitored annually through the Northwest Montana Lakes Volunteer Monitoring Network (NWMTLVMN), including 10 lakes classified as large lakes with surface areas greater than 500 acres (WLI, 2018). Among the large lakes monitored through NWMTLVMN, Little Bitterroot Lakes is the 5th lowest in nitrogen concentration, and 2nd lowest in phosphorus and chlorophyll-a concentrations. These results are consistent with our monitoring program, which indicate that Little Bitterroot Lake is phosphorus limited and has a trophic status of oligotrophic.

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Attachment A – Tables and Figures

Table 1. 2018 Water Quality Data.

Sample Info			Field Water Quality				Nutrients				Chlorophyll-a		Additional Samples					
Site	Date	Site Description	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance (uS/cm)	pH	Nitrate + Nitrite Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Algae in Water (mg/L)	Benthic Algae (mg/m^2)	Calcium (mg/L)	Magnesium (mg/L)	Bicarbonate (mg/L)	Alkalinity (mg/L)	Total Suspended Solids (mg/L)	Dissolved Organic Carbon (mg/L)
							0.01	**0.05**	**0.04**	**0.003**	**0.1**	**0.1**	**1**	**1**	**1**	**1**	**4.0**	**0.5**
HC-1	6/13/18	Herrig Creek - upper site	9.20	9.7	48	7.19	ND	ND	**0.13**	**0.006**							ND	**6.9**
HC-2	6/13/18	Herrig Creek - middle site	9.70	10.4	43	7.47	ND	ND	**0.10**	**0.008**							ND	**4.7**
SP-7	6/13/18	Herrig Creek - at mouth	10.10	10.1	44	7.50	ND	ND	**0.11**	**0.010**			**4**	**1**	**22**	**19**	ND	**4.6**
SP-9	6/13/18	Ltl. Bitterroot River - at outlet	14.80	7.2	148	7.70	ND	ND	**0.09**	**0.008**			**16**	**3**	**70**	**58**	ND	**2.6**
SP-6	6/13/18	Southeast	17.50	8.9	126	8.10	ND	ND	**0.21**	**0.008**			**13**	**3**	**59**	**49**	ND	
SP-10	6/13/18	Northwest - Northwest Bay	15.40	9.1	125	8.19	ND	ND	**0.19**	**0.003**			**13**	**3**	**58**	**48**	ND	
SP-2	8/1/18	North - Herrig Cr. Bay	21.40	7.6	113	7.98	ND	ND	**0.27**	0.002	ND		**14**	**3**	**59**	**49**		
SP-10	8/1/18	Northwest - Northwest Bay	21.80	8.2	113	8.09	ND	ND	**0.14**	0.003			**14**	**3**	**60**	**49**		
SP-1	8/1/18	East - Slaughter House Bay	21.40	7.9	113	8.03	ND	ND	**0.15**	**0.004**			**13**	**3**	**59**	**49**		
SP-3	8/1/18	West - Lock Bay	21.10	8.0	113	8.08	ND	ND	**0.15**	**0.003**	ND	**0.9**	**13**	**3**	**60**	**49**		
SP-5	8/1/18	Lake Center - surface	21.40	7.9	113	8.02	ND	ND	**0.15**	0.002	ND		**13**	**3**	**60**	**49**	ND	**2.9**
SP-5-30	8/1/18	Lake Center - 30' depth	14.10	11.8	105	8.05	ND	ND	**0.16**	**0.004**	**1.0**		**13**	**3**	**60**	**49**		
SP-5-60	8/1/18	Lake Center - 60' depth	10.90	14.0	109	8.16	ND	**0.030**	**0.24**	**0.008**	**2.6**		**14**	**3**	**59**	**49**		
SP-4	8/1/18	Southwest	21.10	7.7	113	8.10	ND	ND	**0.15**	**0.004**			**13**	**3**	**60**	**49**		
SP-6	8/1/18	Southeast	20.90	7.9	113	8.06	ND	ND	**0.24**	**0.004**	ND	**26.0**	**13**	**3**	**60**	**49**		
HC-1	7/31/18	Herrig Creek - upper site	11.80	9.3	31	7.15	**0.010**	ND	**0.10**	**0.013**							2.4	**2.0**
HC-2	7/31/18	Herrig Creek - middle site	15.80	8.9	49	7.58	**0.010**	ND	**0.17**	**0.019**							**35.0**	**3.0**
SP-7	7/31/18	Herrig Creek - at mouth	17.30	8.1	53	7.19	ND	ND	**0.20**	**0.011**			**5**	**1**	**31**	**26**	1.2	**3.3**
SP-9	7/31/18	Ltl. Bitterroot River - at outlet	16.70	3.5	162	7.33	ND	0.040	**0.20**	**0.014**			**20**	**4**	**89**	**73**	1.2	**2.5**

The analytical detection limit for water quality parameters are provided below the constituent name.
Values in **BOLD** are above the analytical detection limit.
ND indicates "no detection", value is below the analytical detection limit.

Legend

- Mussels/Vegetation/WQ
- Vegetation/WQ
- Water Quality

N W E S

1 inch = 2,400 feet

Feet

0 600 1,200 2,400 3,600 4,800

WET Water & Environmental Technologies

Little Bitterroot Lake 2018 Sample Locations

Flathead County, Montana

Job#: LBHAM01

Date: 3/14/2018

FIGURE 1

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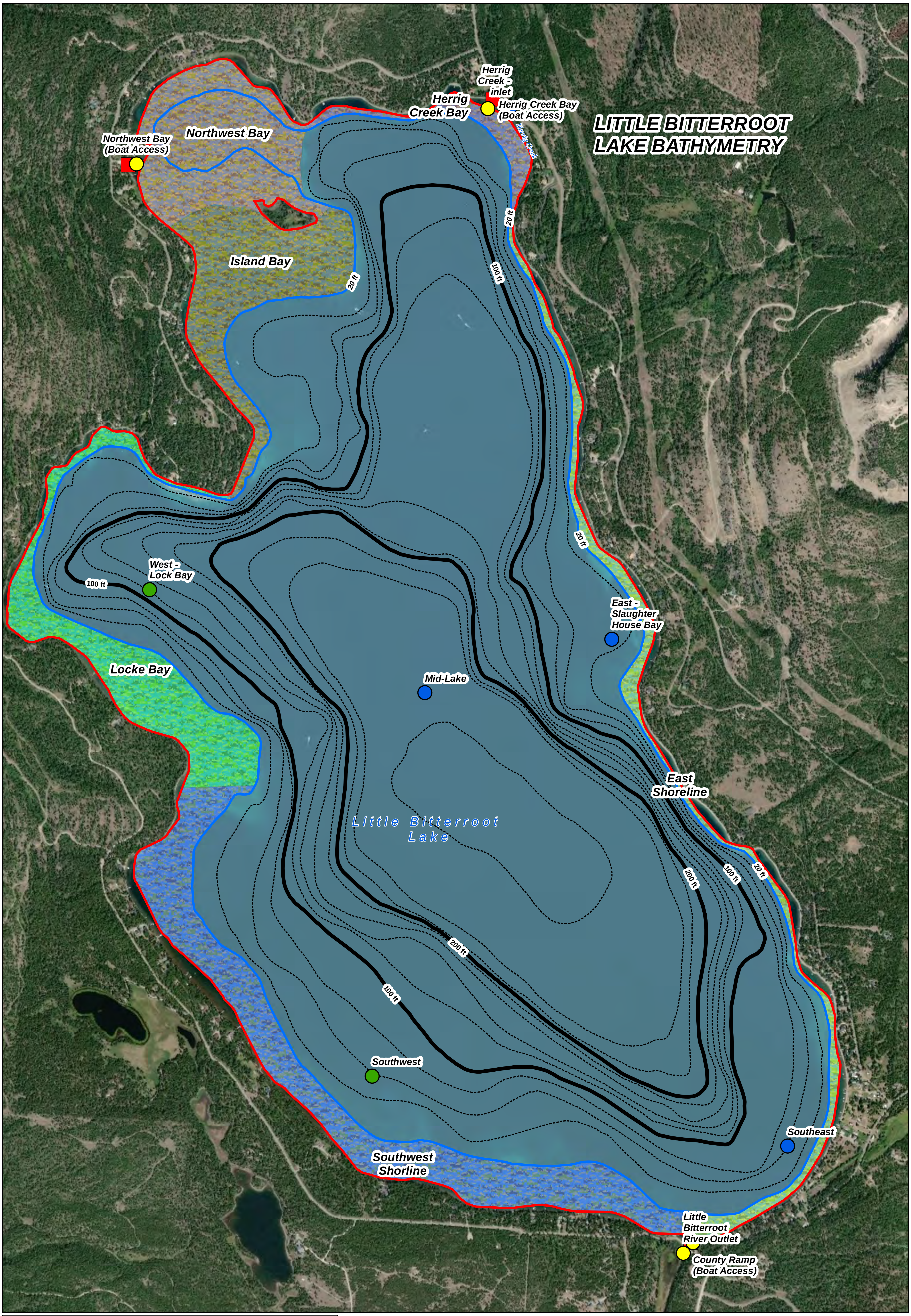

Legend

- Mussels/Vegetation/WQ
- Vegetation/WQ
- Water Quality
- Boat Launch
- Shoreline
- 20 ft Contour
- Major Bathymetric Contour (100 ft.)
- Minor Bathymetric Contour (20 ft.)
- Littoral Zone
- East Shoreline
- Herrig Creek Bay
- Island Bay
- Locke Bay
- Northwest Bay
- Southwest Shorline

N
W E
S

1 inch = 1,300 feet

Feet

0 600 1,200 2,400

Water & Environmental TECHNOLOGIES

Little Bitterroot Lake
Littoral Zone & Bathymetry

Flathead County, Montana

Job#: LBHAM01

Date: 5/31/2019

FIGURE 2

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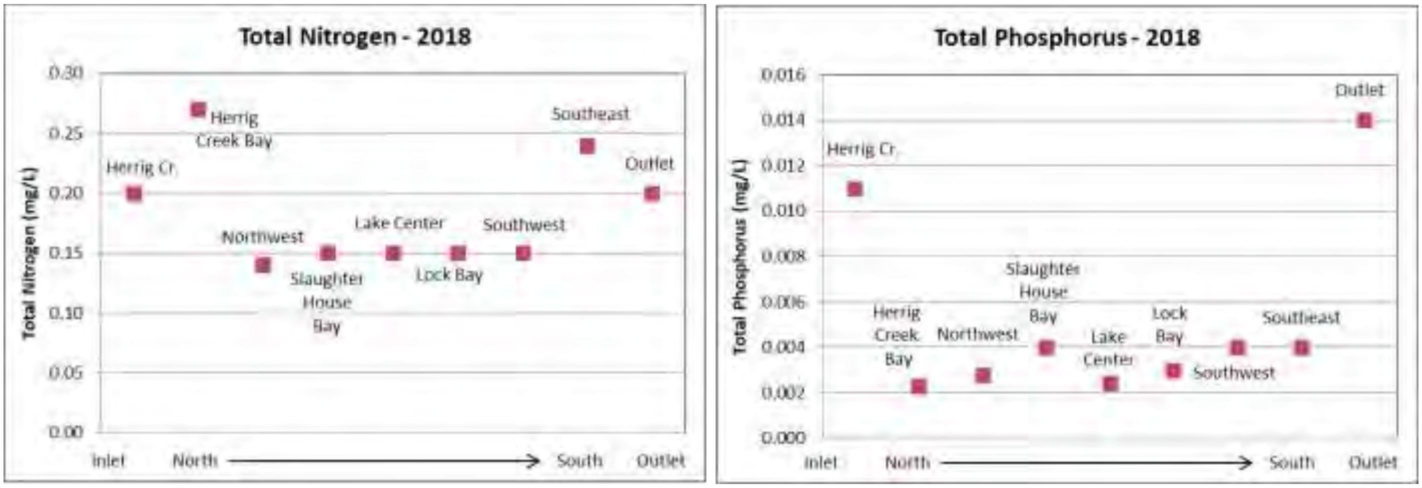

Figure 3. Total Nitrogen and Total Phosphorus Results for 2018.

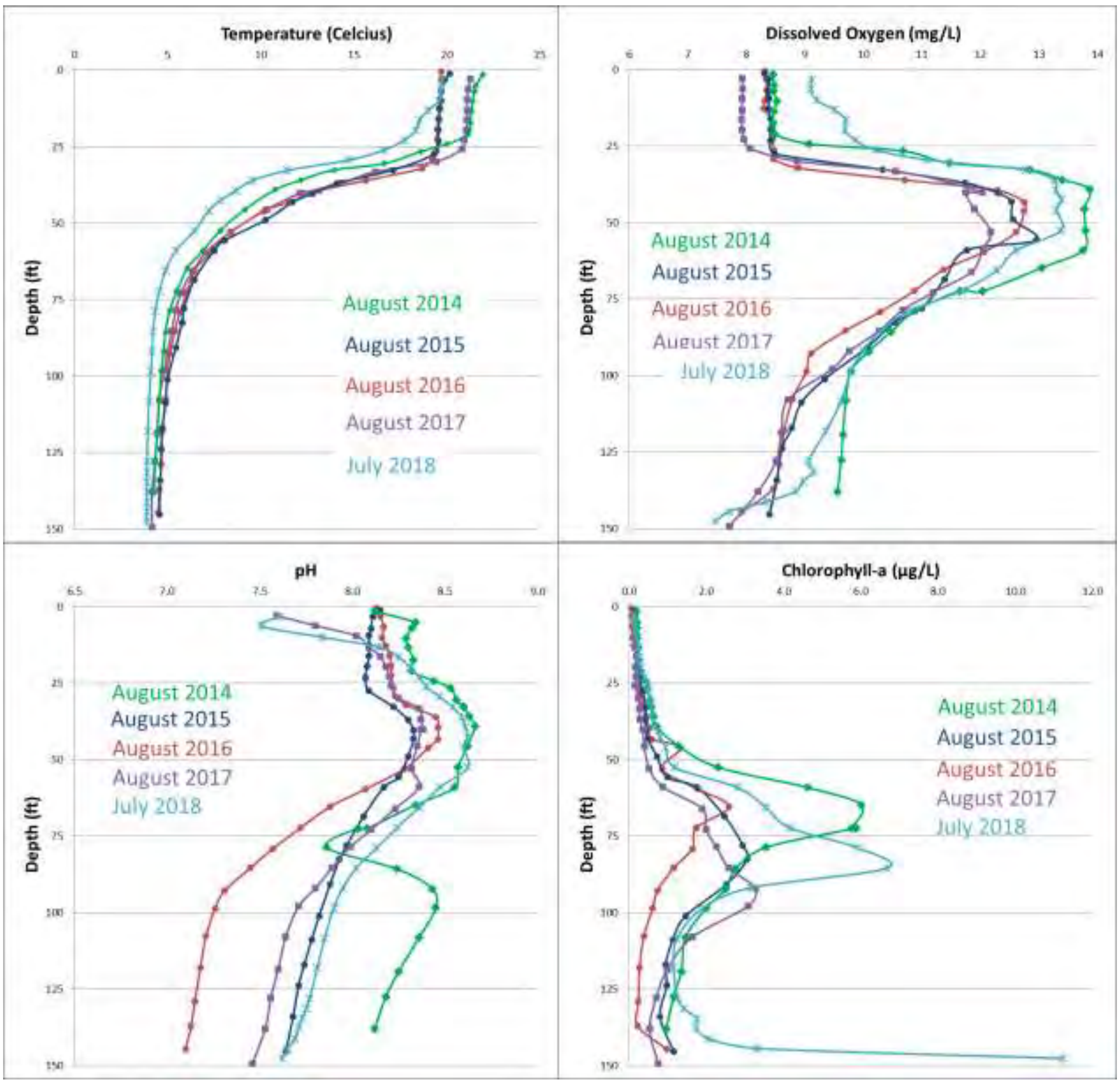

Figure 4. Depth Profile Results for 2018.

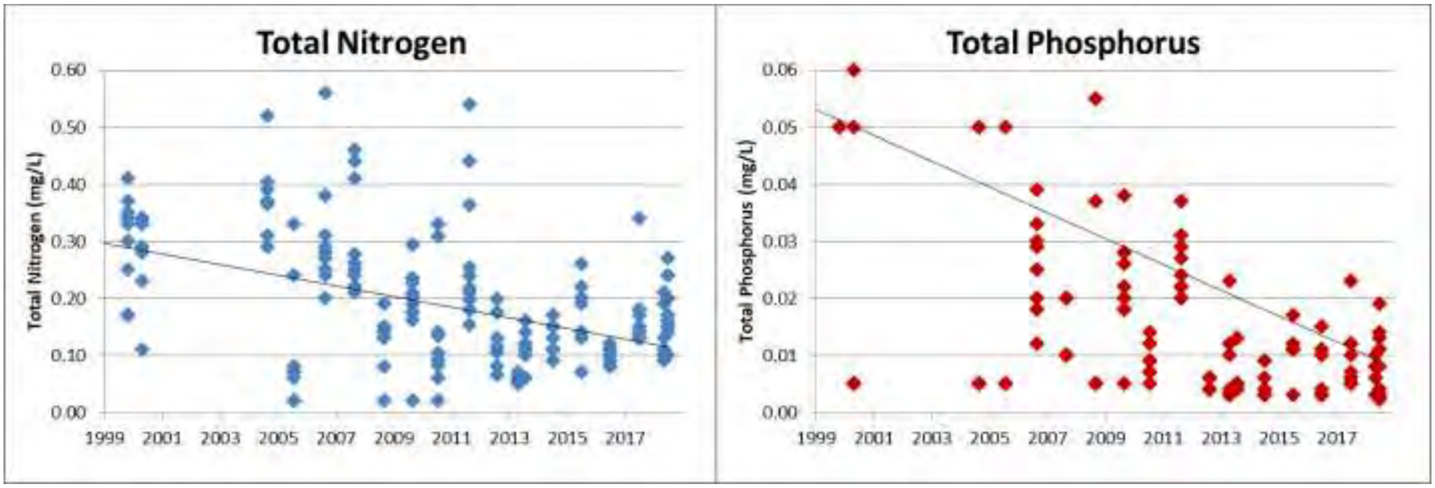

Figure 5. Total Nitrogen and Total Phosphorus Results for 2004-2018.

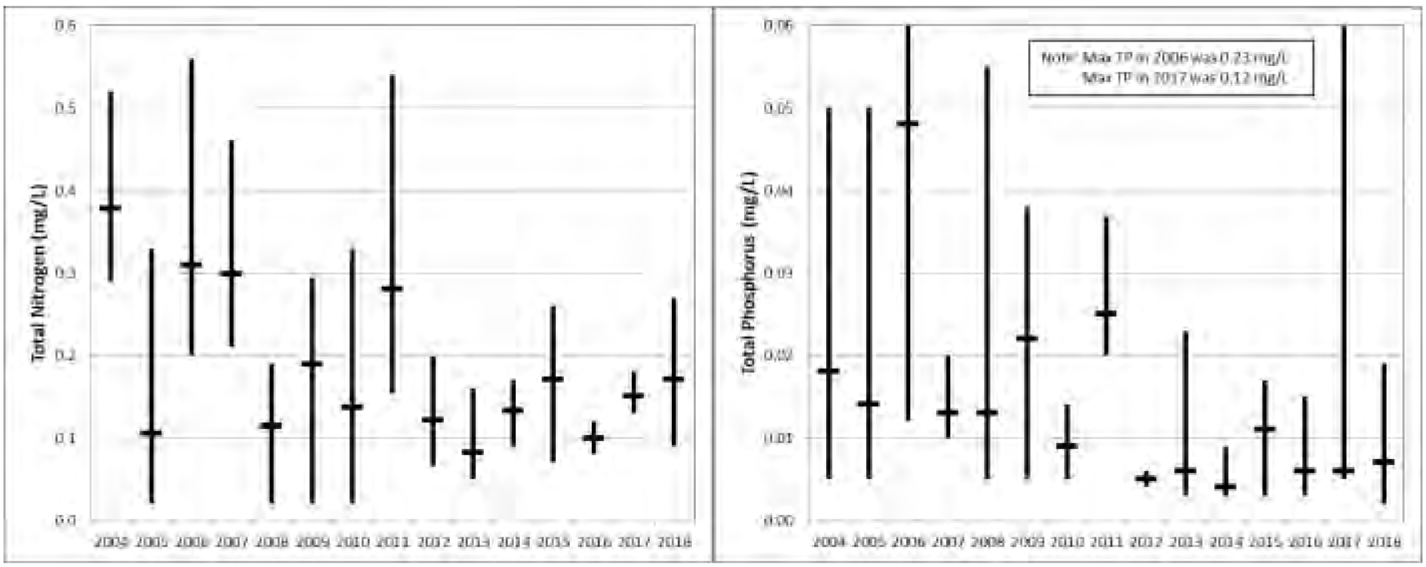

Figure 6. Yearly Nutrient Statistics (Minimum, Maximum, Average) from 2004-2018.

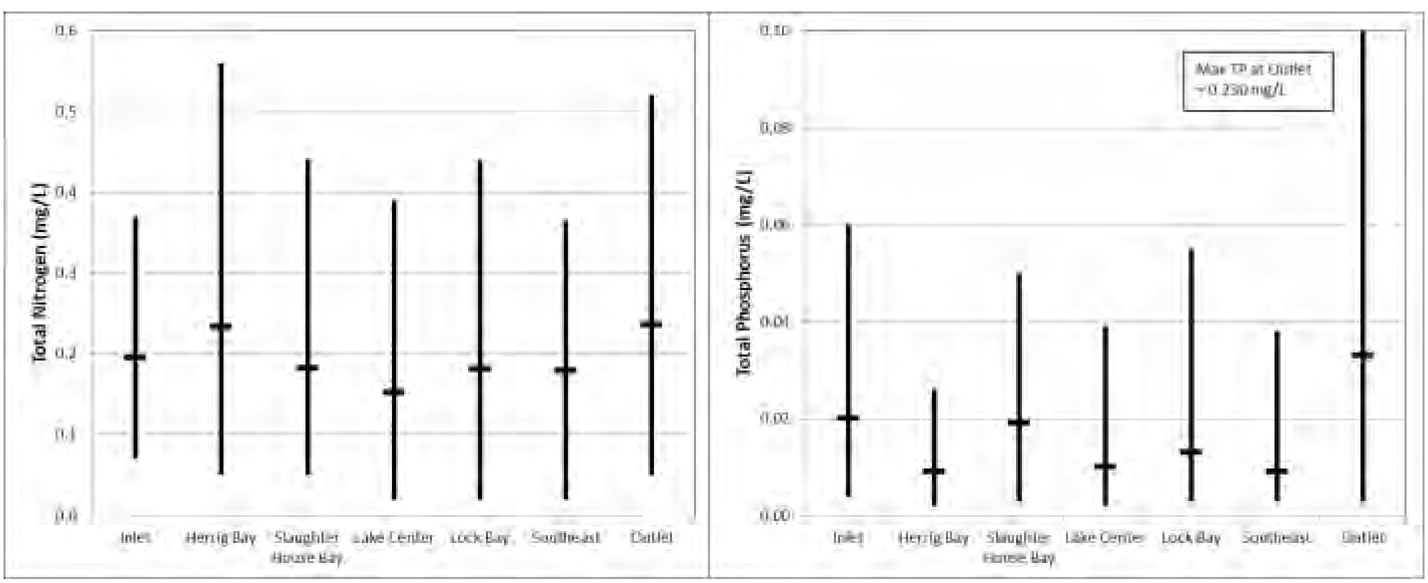

Figure 7. Spatial Nutrient Statistics (Minimum, Maximum, Average) from 2004-2018.

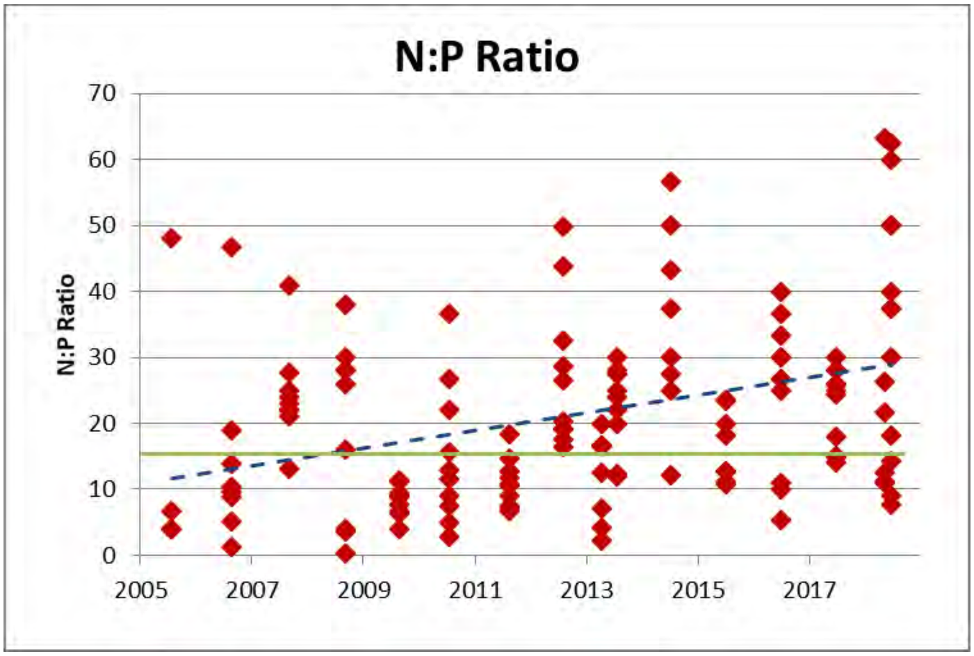

Figure 8. Nitrogen: Phosphorus Ratio from 2004-2018.

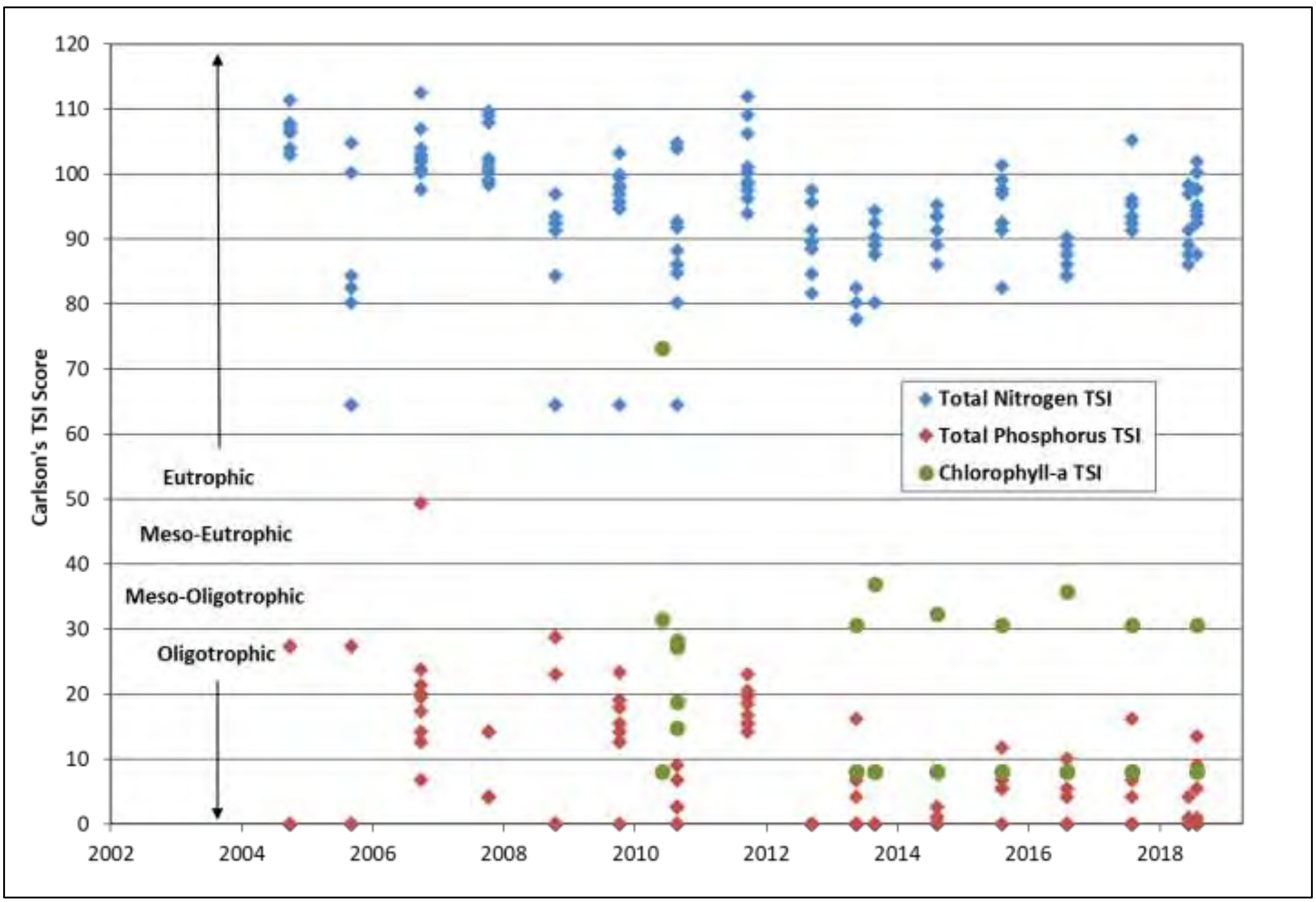

Figure 9. Trophic Status of Little Bitterroot Lake from 2004-2018.

Attachment B – AIS Sampling Results

John Babcock

From: Johnson, Gail <GJohnson@mt.gov>
Sent: Friday, September 14, 2018 3:27 PM
To: John Babcock
Cc: Schmidt, Stacy; Woolf, Thomas
Subject: Little Bitterroot Lake Samples

Hi John,

Veligers were undetected in the following 5 samples we received on 8/13/18.

5 Little Bitterroot Lake: South Ramp, Lion's Camp, West Ramp, Lake Center, DI Blank
Collected 8/2/18

Thank you!
Gail

Gail Johnson
AIS Lab Technician
Montana Fish, Wildlife & Parks

P.O. Box 200701
Helena, MT 59620-0701
Ph: (406) 444-5299

THE **OUTSIDE** IS IN US ALL.

Northwest Bay		Island Bay		Locke Bay	
Species	**R.A.**	**Species**	**R.A.**	**Species**	**R.A.**
Hardstem Bulrush	3	Hardstem Bulrush	3	Hardstem Bulrush	3
Largeleaf Pondweed	3	Largeleaf Pondweed	2	Largeleaf Pondweed	3
Horned Pondweed	3	Water Smartweed	2	Water Smartweed	3
White-stem Pondweed	2	Richardson's Pondweed	1	Richardson's Pondweed	2
Water Smartweed	2	Grassy Pondweed	1	White-stem Pondweed	2
Richardson's Pondweed	2	White-stem Pondweed	1	Horned Pondweed	2
Grassy Pondweed	1	Common Water-milfoil	1	Common Water-milfoil	1
Common Water-milfoil	1			Floating Pondweed	1
Floating Pondweed	1			Common Arrowhead	1
Common Arrowhead	1			White Water Buttercup	1
Chara	1			Chara	1
Broad Waterweed	1			Western Quillwort	1
Beck Water-marigold	1				

Soutwest Shoreline		East Shoreline		Herrig Creek Bay	
Species	**R.A.**	**Species**	**R.A.**	**Species**	**R.A.**
Hardstem Bulrush	3	Hardstem Bulrush	2	Hardstem Bulrush	3
Largeleaf Pondweed	2	Largeleaf Pondweed	1	White-stem Pondweed	2
Richardson's Pondweed	1	Richardson's Pondweed	1	Largeleaf Pondweed	1
Water Smartweed	1	Water Smartweed	1	Richardson's Pondweed	1
Floating Pondweed	1	Common Water-milfoil	1	Water Smartweed	1
Common Water-milfoil	1	White Water Buttercup	1	Broad Waterweed	1
Chara	1				
White-stem Pondweed	1				
Western Quillwort	1				

Complete Species List	
Name	Scientific Name
Richardson's Pondweed	*Potamogeton richardsonii*
Floating Pondweed	*Potamogeton natans*
Largeleaf Pondweed	*Potamogeton amplifolius*
White-stem Pondweed	*Potamogeton praelongus*
Grassy Pondweed	*Potamogeton gramineus*
Horned Pondweed	*Zannichellia palustris*
Water Smartweed	*Polygonum amphibium*
Hardstem Bulrush	*Schoenoplectus acutus*
White Water Buttercup	*Ranunculus aquatilis*
Common Arrowhead	*Sagittaria latifolia*
Broad Waterweed	*Elodea canadensis*
Common Water-milfoil	*Myriophyllum sibiricum*
Chara	*Chara sp.*
Western Quillwort	*Isoetes occidentalis*
Beck Water-marigold	*Bidens beckii*