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# Myron Lake (Yakima County) Verification Monitoring

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# Myron Lake (Yakima County)
# Verification Monitoring

by

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Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area:

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# Abstract

In 1988 and 1989, the Department of Ecology conducted a joint investigation with the Washington Department of Wildlife into fish kills at Myron Lake in Yakima County.  The study found strong evidence of hypolimnetic anoxia in the lake.  The fish kills were attributed to rapid consumption of available oxygen during autumnal lake turnover.  A hypolimnetic withdrawal was installed in Myron Lake to reduce oxygen demand by both removing anoxic water and encouraging migration of oxygenated water from the epilimnion into the hypolimnion.  No fish kills have been observed since 1988.

Myron Lake is classified as impaired for ammonia on the 303(d) list, based on samples collected during the 1988 sampling effort.  This 2012 study primarily focuses on determining if the conditions that led to Myron Lake's inclusion on the 303(d) list are still present.  Additional nutrients, chemical characteristics, and physical parameters of the lake were measured to give a more complete picture of lake quality and to support future studies and modeling efforts.

Data collected for this study indicate that while ammonia concentrations in Myron Lake remain higher in the hypolimnion than in the rest of the lake, all of the collected samples met Washington surface water quality standards for ammonia.  The data also suggest that the hypolimnetic drain is at least partially responsible for lower ammonia concentrations as well as improvements in other water quality parameters.

# Acknowledgements

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- Amy Cook
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# Introduction

In the summer and autumn of 2012, the Washington State Department of Ecology (Ecology) staff conducted a verification study at Myron Lake in the city of Yakima, Washington at the behest of Ecology's Water Quality Program. The purpose of the study was to investigate whether or not conditions observed in previous work were still present in the lake, with the intent of providing the Water Quality Program sufficient information to determine if Myron Lake should remain listed as an impaired water body.

## Background

### Location and Characteristics

Myron Lake (also referred to as Lake Myron) is located on the north side of the city of Yakima, Washington along U.S. Route 12 and the Yakima Greenway Trail (Figure 1). The lake formed in an abandoned gravel pit in 1970 and has since been used primarily as a recreational resource. Myron Lake is stocked with rainbow trout by the Washington Department of Fish and Wildlife (WDFW). In March and April of 2012, 1,205 rainbow trout ranging from approximately half a pound to one and a half pounds were released in the lake.

Water input to Myron Lake is primarily from springs and seeps with minor contributions from direct precipitation and surface runoff. The lake drains to the Union Canal, which in turn drains to the Naches River near its confluence with the Yakima River. The surface area of the lake is 49,000 square-meters ($m^2$), and it holds a volume of 447,000 cubic-meters ($m^3$) of water. Myron Lake has a maximum depth of 13.9 meters (m) and an average depth of 9.1 m (Figure 2). Because of its depth, the lake is thermally stratified during the summer.

### Lake Stratification

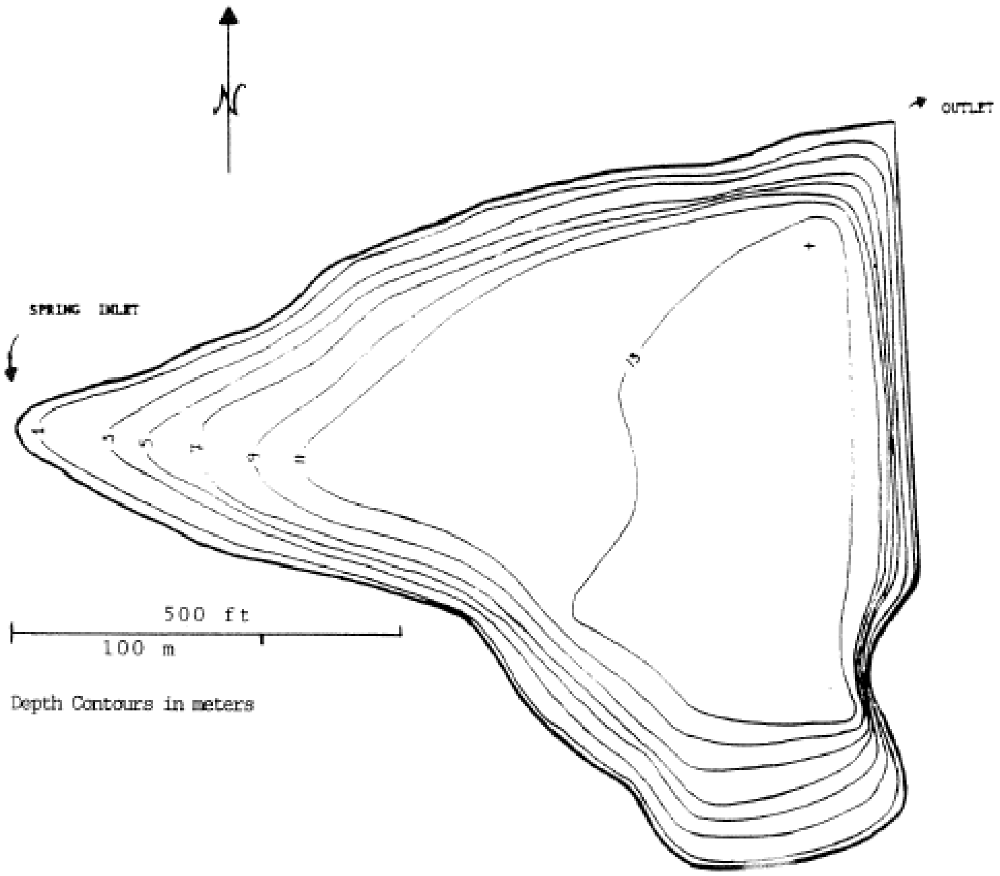
Thermally stratified lakes can be divided into three vertical layers:

- The epilimnion is the top layer of the lake. It is the warmest layer, and can directly exchange gases with the atmosphere. Most plant and phytoplankton growth occurs in the epilimnion.
- The metalimnion is a zone of relatively rapid temperature change that acts as a boundary between the epilimnion and the hypolimnion. The depth of the metalimnion can vary diurnally. Little or no exchange of the water above and below the metalimnion normally occurs.
- The hypolimnion is the bottom layer of the lake. Because it is cut off from direct contact with the atmosphere, the hypolimnion tends to become less oxygenated over time. Decomposition of organic matter that sinks down into the hypolimnion can add to oxygen consumption, resulting in the hypolimnion becoming essentially anoxic.

The relative thicknesses of the three layers can vary both diurnally and throughout the seasons.

Figure 1. Myron Lake and surrounding area.

Thermal stratification typically breaks down when decreasing air temperature cools the epilimnion to the point that it has a higher density than the hypolimnion. This causes the metalimnion to break down and the waters of the epilimnion and the hypolimnion to freely mix. This phenomenon is known as lake turnover and most frequently occurs in the fall. In lakes that are cold enough for winter stratification to occur, turnover can also happen in the spring. In some cases, mechanical mixing from wind or other events can also temporarily break down thermal layering.



WHOLE LAKE CHARACTERISTICS

| | |
|---|---|
| Volume ($m^3$) | 447,000. |
| Surface Area ($m^2$) | 49,000. |
| Mean Depth (m) | 9.1 |
| Maximum Depth (m) | 13.9 |
| Flushing Rate (volumes per year) | 0.9 |
| Hydraulic Residence Time (years) | 1.1 |
| Areal Hydraulic Overflow (m/year) | 8.0 |

HYPOLIMNION CHARACTERISTICS (7.5 m to Bottom)

| | |
|---|---|
| Volume ($m^3$) | 146,000. |
| Surface Area ($m^2$) | 33,300. |
| Mean Depth (m) | 4.4 |

Figure 2. Myron Lake bathymetric map and statistics.
*From Pelletier et al., 1990.*

## Historical Studies

A fish kill at Myron Lake in November of 1987 was investigated by the Department of Ecology and the Department of Wildlife (Pelletier et al., 1990). Another similar event occurred in the fall of 1988. The fish kills resulted from low dissolved oxygen (DO) concentrations in the lake caused by the mixing of anoxic hypolimnetic waters into the epilimnion during the autumnal lake turnover. To address the problem, a hypolimnetic drain was installed in 1990 and pulled water from the bottom of the lake and discharged it into the Union Canal. Drawing water from the lake bottom reduces the amount of anoxic water and high biochemical oxygen demand (BOD) material stored in the lake. It also disrupts stratification and encourages the migration of oxygenated water into the lower depths of the lake. However, the drain can result in the discharge of poor quality water from the lake into the receiving water below the outfall. A report from the Yakima CBS television affiliate KIMA in October 2011 about odor complaints at Myron Lake suggests that there may have been quality issues with the drain water (Spears, 2011).

The study conducted by Pelletier *et al*. in 1990 also resulted in Myron Lake being placed on the 303(d) list for ammonia. The 303(d) list is a list of impaired waters maintained by the states under the requirements of the federal Clean Water Act (CWA). Six samples collected between July and October during the 1988 sampling effort had ammonia concentrations that did not meet state water quality standards. Only the November 1988 sampling event had no samples in which ammonia concentrations were higher than allowable limits. All of the samples that exceeded water quality standards for ammonia were collected from near the lake bottom. Subsequent sampling in the winter of 1988-89 and spring/summer of 1999 did not test for ammonia concentration.

## Ammonia

Ammonia is classified as a toxic pollutant by the United States Environmental Protection Agency (EPA). It can originate from various wastes, from fertilizers, and can also occur naturally in the environment. Elevated levels of ammonia are known to cause fish kills as well as cause chronic problems in fish such as reductions in growth and gill condition (U.S. EPA, 2010). Ammonia can be found in both un-ionized ($NH_3$) and ionized ($NH_4$+) forms. In Washington, un-ionized ammonia is measured to determine whether a water body is meeting water quality standards. Temperature and pH both affect the toxicity of ammonia and must be measured concurrently with ammonia sample collection, as they are used in determining ammonia standards.

In an anoxic environment like that found at the bottom of Myron Lake, ammonia levels may be elevated because the oxidation of ammonia into nitrite and nitrate is limited by the lack of oxygen. Ammonia can, in fact, be formed from organic nitrate and nitrite in strongly reducing environments. Strongly negative oxidation-reduction potential (ORP) measurements suggest that this was likely the case in Myron Lake during the 1988 sampling. The BOD exerted by the ammonia found at the bottom of the lake likely contributed to the consumption of dissolved oxygen (DO) that resulted in the fish kills that occurred in 1987 and 1988.

# Methods

## Field Methods

Field measurements followed approved Environmental Assessment Program SOPs (Ecology, 2012):

- EAP011 Instantaneous Measurements of Temperature in Water
- EAP013 Determining Coordinates Via Hand-held GPS Receivers
- EAP015 Manually Obtaining Surface Water Samples
- EAP023 Collection and Analysis of Dissolved Oxygen (Winkler Method)
- EAP031 Collection and Analysis of pH Samples
- EAP032 Collection and Analysis of Conductivity Samples
- EAP033 Hydrolab® DataSonde and MiniSonde Multiprobes.
- EAP034 Collection, Processing, and Analysis of Stream Samples
- EAP070 Minimize the Spread of Invasive Species

Before sampling began, a site in the deepest part of the lake was chosen as the location for all subsequent lake profile sampling.

At each sampling event, the sampling site was located using a handheld GPS and landmarks on the lake shore. Field staff traveled to the sample site in a raft and dropped two anchors to stabilize the craft. They collected Secchi depth measurements and surface temperature at the beginning and end of each sample event to document variability in conditions over the course of the sample collection.

Conductivity, temperature, pH, and dissolved oxygen were profiled using a Hydrolab® MS-5 multi-parameter meter. The profile consisted of discrete measurements taken at depths of 0.5-meter, 1-meter, and then at 1-meter intervals to the bottom of the lake. Data from the depth profile were used to identify the upper and lower bounds of the metalimnion. Temperature was primarily used in identifying these boundaries, but other parameters were also considered, especially in cases where the precise boundaries weren't clear from temperature data alone.

Samples were collected at four depths in the lake and at the outfall of the hypolimnetic drain. These depths varied, based on the total depth of the lake and on the location of the metalimnion in the water column. On each visit, samples were collected from the surface (0.5 m depth), one meter above the metalimnion, one meter below the metalimnion, and at the bottom (0.5 m above the lake bottom).

To maximize the value of the sampling effort, the crew collected nitrite-nitrate, total persulfate nitrogen, orthophosphate, and total phosphorus samples as well as ammonia at each depth sampled. Additionally, water from each layer was composited and analyzed for total organic carbon (TOC), dissolved organic carbon (DOC), alkalinity, and total non-volatile suspended solids. Chlorophyll samples were collected 0.5 meters below the surface to aid in determining the trophic state of the lake.

Nutrient samples were collected using a Kemmerer sampler with a graduated rope to ensure that samples were taken from the correct depth. Sample bottles were filled directly from the sampler. The Kemmerer sampler was triple-cleaned with deionized water between each depth sampled. The process of lowering the open sampler also provided a local-water rinse prior to sample collection.

Composite samples were collected using a Kemmerer in a manner identical to the collection of nutrient samples. There were two sets of composite samples collected, one set in the epilimnion and one set in the hypolimnion. At each sampled depth, water from the Kemmerer was emptied into a compositing container. An equal volume of water was used from each depth. Sample bottles were filled from the composite container. The composite container was triple-rinsed with deionized water between each composite sample.

In addition to data collected in the lake, a Hydrolab® measurement and nutrient samples were also collected at the outfall of the hypolimnetic drain. Flow measurements were taken at the epilimnetic drain and above a culvert located approximately 10 meters downstream of the hypolimnetic drain. A Marsh-McBirney Flow meter was used for the flow measurements.

All samples were tagged and placed on ice immediately after collection. After staff completed their fieldwork, they packed samples in a cooler with cold packs and sent to the Manchester Environmental Laboratory (MEL) overnight via air freight. Sample temperature and pH were checked on arrival at MEL to ensure proper sample preservation.

# Quality Assurance

## Field Measurements

Parameters measured in the field were subject to quality assurance checks both in the field and in the data analysis phase. The Hydrolab® used for the collection of field data was calibrated daily and checked against appropriate standards before data were collected. The Hydrolab® was also checked for drift, using the same standards at the end of the sampling event. In addition, a replicate depth profile was conducted during the October 18, 2012 sampling event to ensure that Measurement Quality Objectives (MQOs) were being met. MQOs for the various parameters measured in the field can be found in Table 1.

In addition to the replicate depth profile, DO grab samples were collected at the lake surface and at the outfall drain and compared to DO results measured using the Hydrolab®. Initially, grab samples were to be taken throughout the water column along with the sample replicates, but the difficulty of collecting DO samples with the Kemmerer made it impractical to do so.

Table 1. Measurement Quality Objectives (MQOs) for data collected in this study

| Analysis | Method | Bias (deviation from true value) | Precision (replicate median RSD) | Method Lower Reporting Limit and/or Resolution | Expected Range |
|---|---|---|---|---|---|
| **Field Measurements** | | | | | |
| Water Temperature | Hydrolab® | n/a | +/- 0.2° C | 0.01° C | 0 – 30° C |
| Specific Conductance | Hydrolab® | n/a | 5% RSD | 0.1 µS/cm | 20 – 200 uS/cm |
| pH[1] | Hydrolab® | n/a | 0.20 s.u. | 0.01 s.u. | 1 to 14 s.u. |
| Dissolved Oxygen | Hydrolab® | n/a | 5% RSD | 0.1 mg/L | 0.1 - 15 mg/L |
| Dissolved Oxygen | Winkler Titration | n/a | +/- 0.2 mg/L | 0.1 mg/L | 0.1 - 15 mg/L |
| **Laboratory Analyses** | | | | | |
| Total Alkalinity | SM 2320 | 10% | 10% RSD | 5 mg/L | 5 – 100 mg/L |
| Chlorophyll a –water | SM 10200H(3) | 5% | 20% RSD | 0.05 µg/L | 0.1 – 100 ug/L |
| Dissolved Organic Carbon | EPA 415.1 | 10% | 10% RSD | 1 mg/L | 1 – 20 mg/L |
| Total Organic Carbon | EPA 415.1 | 5% | 10% RSD | 1 mg/L | 1 – 20 mg/L |
| Total Persulfate Nitrogen | SM 4500-NO3-B | 15% | 10% RSD | 0.025 mg/L | 0.025 – 20 mg/L |
| Ammonia | SM 4500-NH3-H | 10% | 10% RSD | 0.01 mg/L | 0.01 – 20 mg/L |
| Nitrate/Nitrite | 4500-NO3- I | 15% | 10% RSD | 0.01 mg/L | 0.01 – 10 mg/L |
| Orthophosphate | SM 4500-P G | 20% | 10% RSD | 0.003 mg/L | 0.003 – 1 mg/L |
| Total Phosphorus | EPA 200.8 | 10% | 10% RSD | 0.001 mg/L | 0.005 – 10 mg/L |
| Total Non-Volatile Suspended Solids | SM 2540 B & E | 10% | 10% RSD | 0.01 mg/L | 0.1 – 100 mg/L |

SM: Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA, 2005).

## Sample Collection

Total variability for samples sent to Manchester Laboratory for analysis was checked by collecting replicate samples (Table 2). This represents 19% duplication for nutrient samples and 38% duplication for composite samples. A chlorophyll replicate was collected with the replicate sample taken at surface depth. MEL routinely duplicates sample analyses in the laboratory (lab duplicate) to determine laboratory precision (MEL, 2008; MEL, 2012).

Table 2. Quality assurance samples collected at Myron Lake in 2012

| Date | Station | QA Sample Type |
|---|---|---|
| 8/15/2012 | Myron Lake bl Metalimnion | Replicate |
| 9/12/2012 | Myron Lake @ Surface (0.5 m) | Replicate |
| 10/18/2012 | Myron Lake ab Metalimnion | Replicate |
| 11/14/2012 | N/A | Blank |

A field blank was collected during the November 14, 2012 sampling event, using the same sampling equipment and procedures used to take regular samples−with the exception that the Kemmerer sampler was not lowered into the water. The sampler was triple-rinsed and then filled with de-ionized (DI) water, which was poured into the sample bottles. Orthophosphate blanks were run through a clean filter before bottling. Blanks for the composite samples used a similar procedure, with the addition that DI water was poured from the Kemmerer into the compositing container sampler before processing.

Sample results were checked against replicate results to determine whether MQOs for that parameter were met (Table 1).

# Results

## Overview

At each of the four site visits conducted for this study, data was collected for seven field parameters and ten laboratory parameters. Data collected during this sampling effort are available for review and download from Ecology's EIM database by searching under Study ID MIKA0002.

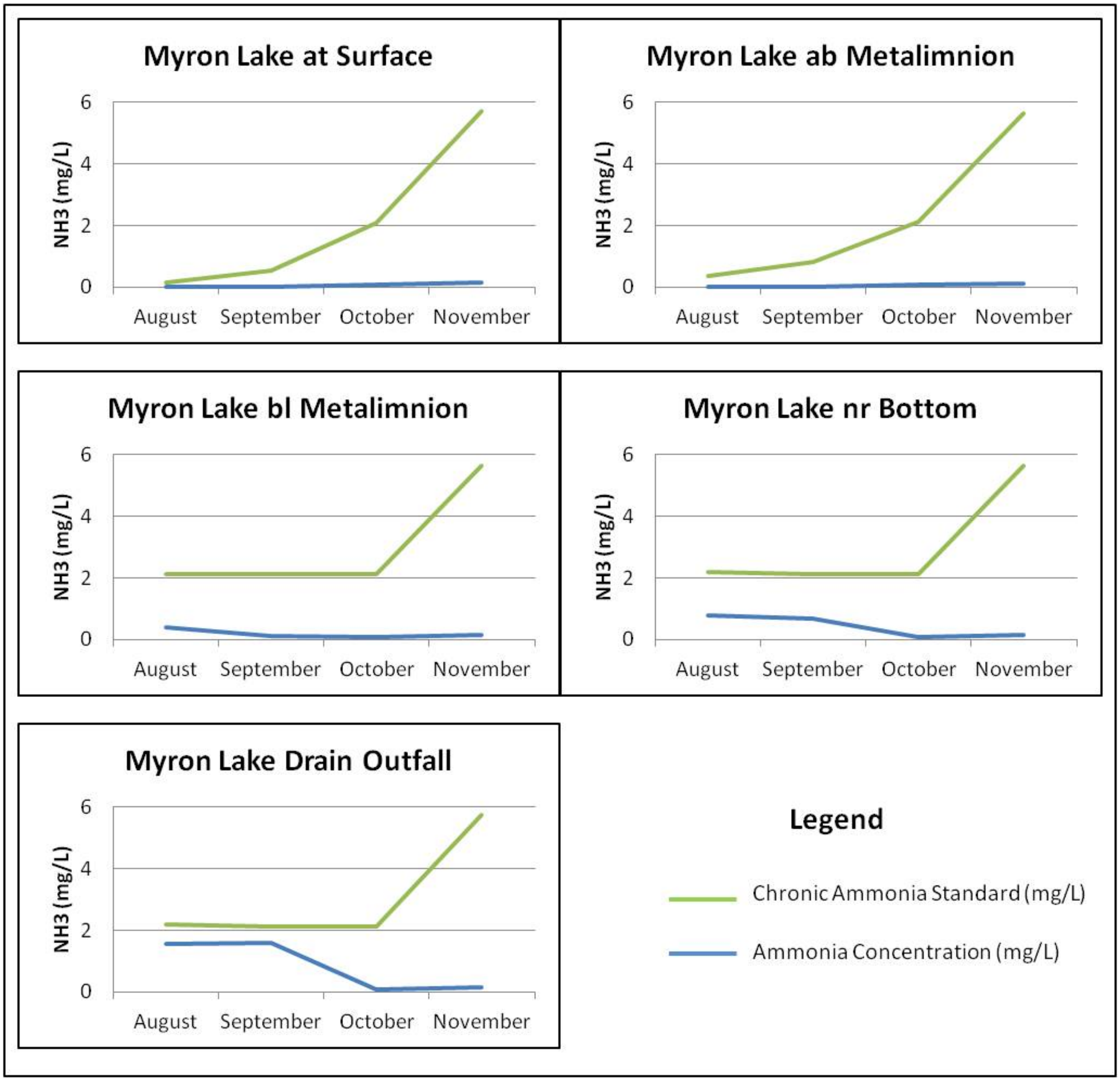
Analysis was done on a fairly broad range of parameters in an effort to maximize the value of the field effort and provide background lake data for future studies. The results for the parameters most pertinent to the questions addressed by this study are discussed below.

## Parameters of Interest

### Ammonia

Twenty ammonia samples (not counting replicates) were collected during the course of this study. These were evenly divided between the four stations in the lake profile as well as the hypolimnetic outfall below the lake.

Ammonia levels in the epilimnion were near the lower detection limit during the critical period in August and September, and levels increased slightly after the breakdown of thermal stratification that occurred in late September to early October (Figure 3). As expected, concentrations were substantially higher in the hypolimnion during the stratified period. The highest concentrations of ammonia were found in the water coming from the hypolimnetic drain, though it generally followed the same pattern as the samples from the hypolimnion. All of the collected samples met both the chronic and acute criteria for ammonia (Table 3).


Myron Lake at Surface

Myron Lake ab Metalimnion

Myron Lake bl Metalimnion

Myron Lake nr Bottom

Myron Lake Drain Outfall

Figure 3. Ammonia concentrations at Myron Lake in 2012 vs. Chronic Ammonia Standard.

Table 3. Sample results for Ammonia and Acute and Chronic Ammonia Standards.

| Date | Station | NH3 (as N mg/L) | NH3 Std (Acute) (mg/L) | NH3 Std (Chronic) (mg/L) |
|---|---|---|---|---|
| 8/15/2012 | Surface | 0.01 | 1.346 | 0.155 |
| 8/15/2012 | Above Metalimnion | 0.01 | 2.802 | 0.352 |
| 8/15/2012 | Below Metalimnion | 0.408 | 19.281 | 2.126 |
| 8/15/2012 | Near Bottom | 0.794 | 22.383 | 2.179 |
| 8/15/2012 | Outfall | 1.550 | 20.172 | 2.181 |
| 9/12/2012 | Surface | 0.011 | 3.539 | 0.535 |
| 9/12/2012 | Above Metalimnion | 0.017 | 5.010 | 0.824 |
| 9/12/2012 | Below Metalimnion | 0.120 | 17.286 | 2.117 |
| 9/12/2012 | Near Bottom | 0.681 | 18.835 | 2.137 |
| 9/12/2012 | Outfall | 1.580 | 19.950 | 2.127 |
| 10/18/2012 | Surface | 0.081 | 13.085 | 2.096 |
| 10/18/2012 | Above Metalimnion | 0.083 | 13.283 | 2.121 |
| 10/18/2012 | Below Metalimnion | 0.084 | 13.684 | 2.122 |
| 10/18/2012 | Near Bottom | 0.086 | 14.710 | 2.120 |
| 10/18/2012 | Outfall | 0.095 | 11.930 | 2.125 |
| 11/14/2012 | Surface | 0.137 | 21.410 | 5.71 |
| 11/14/2012 | Above Metalimnion | 0.133 | 20.790 | 5.630 |
| 11/14/2012 | Below Metalimnion | 0.137 | 20.790 | 5.630 |
| 11/14/2012 | Near Bottom | 0.135 | 20.790 | 5.630 |
| 11/14/2012 | Outfall | 0.141 | 19.590 | 5.740 |

## Temperature

Temperature data for this study was critical for two reasons. First, the thermal stratification of the lake is essential to understanding the processes that drive Myron Lake's chemical composition. Second, temperature is used in establishing the freshwater criteria for ammonia.

Thermal stratification was observed in the lake in both August and September (Figure 4). In both cases, the transition point between the epilimnion and metalimnion was fairly clear, but the transition to the hypolimnion was more muted. The changes in the temperature profile from August to September show that the epilimnion was advancing deeper into the water column. As the season advanced, the epilimnion cooled down while the hypolimnion slightly warmed.

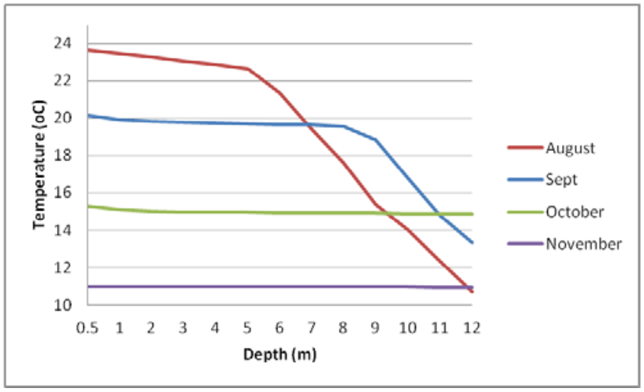


Figure 4. Temperature profiles of Myron Lake in 2012.

Breakdown of thermal stratification and the associated lake turnover occurred in early to mid-October. This was earlier than had been anticipated, based on the data collected in 1988 and 1989, which saw stratification continue into November. Temperatures throughout the water column hovered around the 15°C after turnover during the October 18 sampling event. By November 14, 2012, temperatures had dropped to around 11°C at all depths.

## pH

Like temperature, pH is important not only for its own impact on water quality and aquatic habitats, but because it influences the ammonia standard.

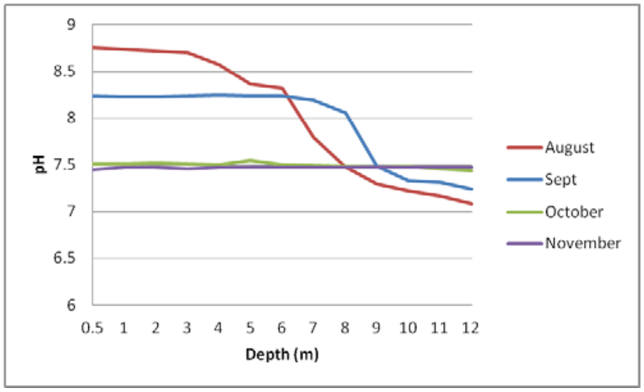


Figure 5. Profiles of pH values at Myron Lake in 2012.

Measured levels of pH at Myron Lake exceeded water quality criteria (8.5 s.u.) in the upper portion of the epilimnion during the August sampling (Figure 5). Epilimnion pH readings were generally basic during the stratified period. In the metalimnion, pH dropped sharply and continued to decrease through the hypolimnion. After the breakdown of the thermal stratification, pH settled to about 7.5. At the lake outfall, pH levels were similar to those found in the hypolimnion.

The pH profile is quite similar to the temperature profile, and temperature does influence pH. The shift in pH from August 2012 through September 2012 is further evidence of the encroachment of epilimnetic water deeper into the lake as the metalimnion and hypolimnion shrank.

## Dissolved Oxygen

Dissolved oxygen (DO) concentrations in Myron Lake were shown to range nearly as wide as the entire range found in nature (Figure 6). The epilimnion was supersaturated in both August and September. DO concentrations fell sharply through the metalimnion, and the hypolimnion was essentially anoxic. There was a noticeable spike in DO in the August depth profile at six meters depth. The spike was likely the result of having a slightly cooler temperature than the shallower water, while remaining in the fully oxygenated zone. The DO profiles from Myron Lake were fairly typical for a thermally stratified lake. DO levels at the outfall were also very low during the stratified period (mean=1.16 mg/L).

After stratification broke down, DO concentration settled down to around 8 mg/L. A slight downward trend was still evident as depth increases. This decrease may be the result of imperfect mixing or oxygen leaching from consumptive materials left at the bottom of the lake after a weak turnover.

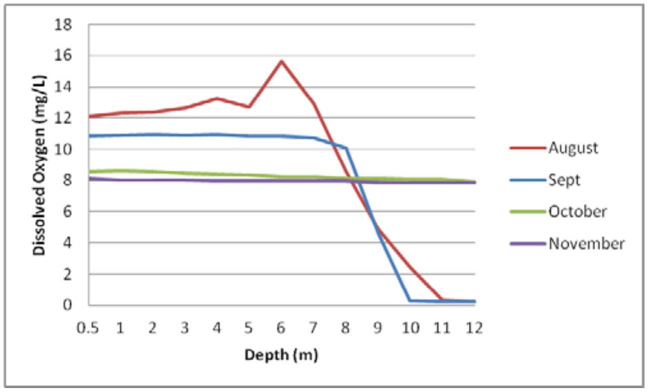


Figure 6. Dissolved oxygen profiles at Myron Lake in 2012.

## Trophic State

In the state of Washington, an analysis of a water body's trophic state is used to determine the "action value" above which total phosphorous concentrations would indicate the need for either listing a lake as impaired or for conducting a lake-specific study to demonstrate that the phosphorus levels were the result of natural processes (Ecology, 2004).

The trophic state of a lake is determined by calculating a Trophic State Index (TSI) value for three parameters: chlorophyll-a concentration, total phosphorus concentration, and Secchi depth (Carlson, 1977). The TSI value for each parameter is considered separately. It should be noted, however, that not all three parameters are of equal value in determining trophic state. Chlorophyll concentration is generally considered the best measure (Carlson, 1977). Determining trophic state requires data be collected during all portions of the critical period (typically June-September). Because data collected in the early part of the critical period were not included in this study, no definitive determination of trophic state is possible. The available data give a general indication of the trophic state of the lake (Table 2).

Table 4. Myron Lake Trophic State Index.

| Date | TSI Value | Trophic Class |
|---|---|---|
| Chlorophyll-a (ug/L) | 52 | Eutrophic |
| Total Phosphorus (ug/L) | 45 | Mesotrophic |
| Secchi Depth (m) | 46 | Mesotrophic |

The trophic state of Myron Lake is close to the boundary between mesotrophic and eutrophic. Note that one of the chlorophyll samples used to calculate the TSI value was flagged as an estimate (see *Data Quality* section of the report for details). Based on the available data, a tentative classification of Upper Mesotrophic is appropriate.

# Data Quality

Data quality was checked as described above in the *Methods* section of this report. Quality Assurance/Quality Control (QA/QC) data are shown in Appendix A. Overall, data quality was good, and the vast majority of samples and measurements met MQOs. There were a few instances where that was not the case, however, and these are discussed below.

## Dissolved Oxygen

While the Hydrolab® performed well when comparing replicate depth profiles, there were some discrepancies between the Hydrolab® and DO grab samples analyzed using Winkler titration. In three of the nine comparisons of Hydrolab® data to grab sample data, the difference between the two was greater than the 0.2 mg/L specified in the Quality Assurance (QA) Project Plan (Anderson, 2012).

One sample flagged in the QA check was collected at the wrong depth, using the Kemmerer instead of a grab sample from the surface. As mentioned in the *Methods* section, this technique was abandoned due to consistent problems like this one. Given that there was agreement between the Hydrolab® and the grab sample collected later on the same day (and at similar pH), this result can be ignored as sample collection error.

The remaining two samples in question were both collected at the outfall during the stratified period in August and September. In both cases, the Winkler DO was lower than the Hydrolab DO by roughly the same amount (0.76 mg/L in August, 0.77 mg/L in September). The consistent nature of the error suggests that instrument error is likely the cause of the variation. The lower DO from the Winkler samples bolsters the argument that the Hydrolab® may be over-measuring at low DO concentrations because an error in sample handling or titration would most likely result in a higher DO result.

The possibility of applying a correction to the Hydrolab® DO results to account for this variation was considered. However, running a simple correlation across the entire range of DO results showed that there was a 99.5% agreement between the Winkler samples and the Hydrolab® results. Applying a correction that small would still not result in agreement between the Winkler and Hydrolab® results. Additionally, the evidence suggests that it is only at low oxygen concentrations that this variation occurs, but there is insufficient data to come up with a defensible correction that only applies to the low end of the range. As a result, the data were not adjusted, but all data with DO concentrations below 4 mg/L were quality coded as estimates.

## Specific Conductivity

In September, the conductivity probe on the Hydrolab® failed to meet calibration requirements, and showed unusually high drift. The probe was found to be malfunctioning and the data collected in September using it were rejected. A replacement Hydrolab® was not available for the October sample collection. An Orion conductivity meter was used in October to measure specific conductivity (SpC) from grab samples at 2-meter intervals, but no calibration or QA data were recorded. Those data were also rejected.

## Chlorophyll

Only one replicate chlorophyll sample was collected during the course of this study, and it failed to meet the MQO set in the QA Project Plan. While the total difference between the two samples was not very large (2.4 ug/L), that amounted to a 26.9% relative standard difference (RSD). The cause of the variation between the sample and replicate is not clear. It may have been due to high natural variability, sampler error, lab error, or some combination of those factors. The sample result was flagged as an estimate.

## Other Parameters

Two other samples were flagged for not meeting the MQOs established in the study’s QA Project Plan.

The TNVSS composite sample collected below the metalimnion had a 47% RSD. However, the high percentage of variability was largely due to the very low reported results. The sample was quality coded as an estimate.

A Total Phosphorus sample collected from below the metalimnion in August was also flagged for not meeting MQOs. The cause of this variability is unknown. The result was quality coded as an estimate.

# Discussion

The primary purpose of this study was to determine if ammonia concentrations at Myron Lake remained at toxic levels. The answer to that question is fairly straightforward: there is no evidence that ammonia concentrations in Myron Lake did not meet the freshwater criteria in 2012.

The more nuanced question being addressed by this study is whether the installation of a hypolimnetic drain was effective at reducing ammonia concentrations, along with improving overall water quality and reducing the likelihood of new fish kills. Many factors, discussed below, suggest that the hypolimnetic drain that was installed in Myron Lake is, in fact, having a substantial positive impact on the water quality in Myron Lake.

## Parameters

### Ammonia

Ammonia concentrations in Myron Lake during the 2012 sampling showed a similar distribution to those measured in 1988 and 1989 (Pelletier et al., 1990). Ammonia concentrations were low in the epilimnion and metalimnion and much higher in the hypolimnion while thermal stratification was present. Ammonia was evenly distributed throughout the lake column after turnover. The key difference was that the concentrations in the hypolimnion were lower across the board in 2012 than at corresponding times in 1988. In the critical period in August and September, they were lower by an order of magnitude, and even after turnover, the 2012 ammonia levels were roughly 20% of those found in 1988.

The theory that this reduction in ammonia concentration was at least in part due to the installation of the hypolimnetic drain is supported by the fact that the highest concentrations of ammonia were collected at the drain outfall. The relatively high ammonia content of the outfall water confirms that physical removal of ammonia from the lake was occurring, and suggests that the water being removed was from the lowest part of the hypolimnion where water quality was the worst. Additionally, an overall weaker hypolimnion (both smaller and existing for a shorter duration) in 2012 was also conducive to a reduced ammonia buildup. The weakening of the hypolimnion, compared to 1988-89, was at least partially due to the influence of the hypolimnetic drain.

### Temperature

Temperature profiles measured in 2012, compared to those measured in 1988, show some clear differences (Figure 9).

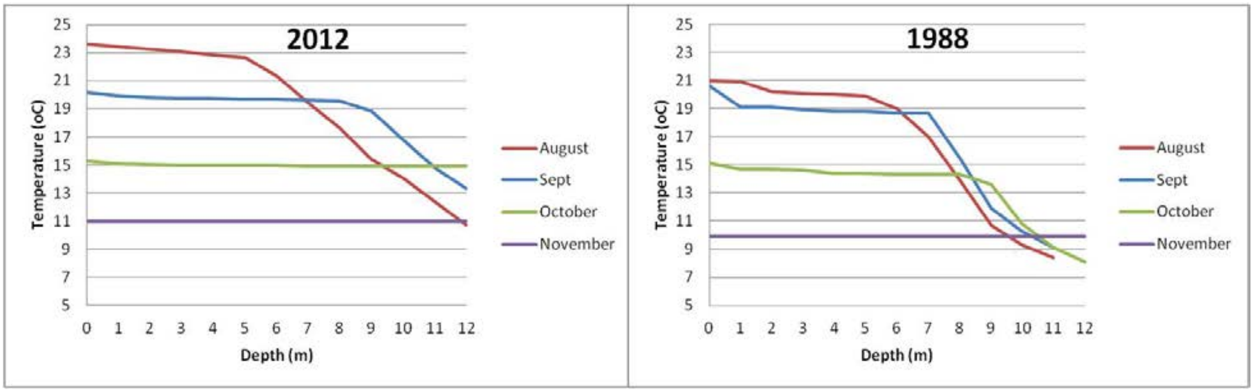


Figure 7. Comparison of temperature profiles at Myron Lake in 2012 and 1988.
*1988 data from Pelletier et al., 1990*

The profiles from August and September look fairly similar, though there are a few differences. In August 2012, the water was slightly warmer than in 1988, and this is evident throughout the profile. The thermal layers are noticeably more distinct in the 1988 profiles, particularly at the hypolimnetic boundary. In September 2012, the hypolimnion had nearly disappeared and was barely distinguishable from the metalimnion. By contrast, the hypolimnion in 1988 was distinct and had not deteriorated substantially since August. Hypolimnetic temperatures were also cooler in 1988 than in 2012, even accounting for the higher overall temperature in 2012.

The temperature profiles for October 2012 were very different from those of October 1988. By mid-October 2012, thermal stratification had already broken down, while in 1988 thermal layering was weakening but still clearly present. This, alone, is not terribly informative, since the timing of autumnal lake turnover has some annual variability depending on climate conditions. What is more interesting is that the temperature of the lake in 2012 was nearly the same as the epilimnetic temperature in 1988. In 1988, turnover did not occur until the epilimnion reached 10-12$^{o}$C. Data from 1989 shows a similar pattern, with breakdown occurring in November at temperatures between 8-11$^{o}$C (Pelletier et al., 1990). The October 1988 temperature profile is actually very similar to the September 2012 profile, in that it shows a thinning metalimnion and a much less distinct hypolimnion than in previous months.

Lake temperatures in November 2012 and November 1988 are quite similar to one another. Stratification is not present, and differences in temperature are likely due to annual variation.

## Dissolved Oxygen

Depth profiles of DO concentration in 1988 and 2012 show some marked differences. During the summer months, the DO concentrations in the epilimnetic and metalimnetic zones look fairly similar, though the 1988 profile notably lacks the spike seen on the August 2012 data. The major difference between these two years is the thickness and persistence of the anoxic zone in the lower depths of the lake. In both August and September 1988, DO concentrations bottom out at around eight meters (this extends well into the metalimnion) and maintain a thickness of three meters. In 2012, low oxygen concentrations were found deeper in the lake and were only one to two meters thick.

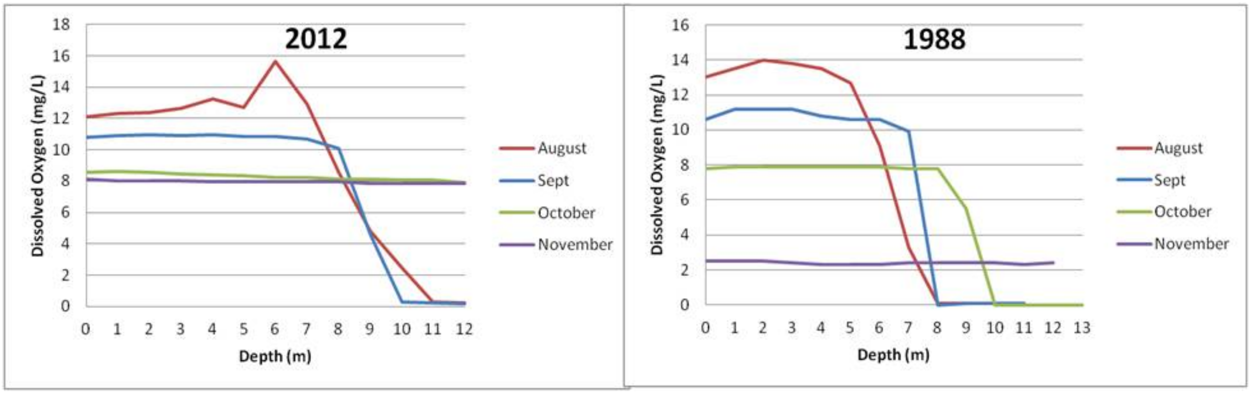


Figure 8. Comparison of dissolved oxygen profiles at Myron Lake in 2012 and 1988.
*1988 data from Pelletier et al., 1990*

October DO profiles in 1988 and 2012 were quite different, again due to the earlier breakdown of thermal layering in 2012. The 1988 chart is somewhat misleading; it appears to show a downward shift in the anoxic zone. In reality, the profile that month was two meters deeper than in August and September. Measuring from the bottom up, the anoxic zone is identical to the two previous months.

Unlike the temperature profiles, DO concentrations after the autumnal turnover were drastically different in 2012 from in 1988. In 2012, oxygen levels settled out to around 8 mg/L throughout the water column shortly after the turnover occurred. 1988 oxygen levels were at around 2.5 mg/L after turnover, and did not recover to the 7-8 mg/L range until January of 1989 (Pelletier et al., 1990). The relatively rapid equilibration of DO levels throughout the lake column to values similar to those found in the epilimnion prior to lake turnover suggests that the oxygen deficits observed in the 1988-89 study were present to a far lesser degree in 2012.

## Hypolimnetic Drain Effectiveness

The relatively short time-period over which this study was conducted does not allow any iron-clad conclusions on the efficacy of the hypolimnetic drain. A multi-year study would be required to definitively show that the water quality improvements found in this study were due to the drain and not to annual variation. However, all of the evidence available does seem to suggest that the installation of the drain has had an overall positive effect on the water quality in Myron Lake. The evidence for the hypolimnetic drain's effectiveness includes:

- No fish kill events have occurred since the drain was installed. Prior to that, there were back-to-back fish kills in 1987 and 1988.
- Oxygen and temperature data show that thermal layering was weaker and less persistent in 2012 than it was in 1988-89.
- Ammonia concentrations, which are related to the presence of the hypolimnion, were much lower in 2012 than in 1988.

- There is evidence that the drain is transporting hypolimnetic water out of the lake, providing a mechanical driver for the weakening of thermal stratification.

While this evidence does not conclusively show that differences in the water quality at Myron Lake between 1988-89 and 2012 were due to the hypolimnetic drain, it does make a compelling argument that the drain is at least partially responsible. The overall picture suggests that the drain is improving the water quality in the lake by both physically transporting ammonia and other materials out of the lake, and it is also providing mechanical mixing which results in an earlier and weaker turnover.

The water coming out of the drain has some potential water quality issues to consider. The most notable issue is that at times the water from the drain has a strong hydrogen sulfide odor and is colonized by sulfide-loving bacteria that form tissue-like colonies. As a result, users of the Yakima Greenway trails are exposed to some unpleasant odors and have reported sewage leaks in Union Canal, as mentioned in the introduction of this report. At the time of the 2012 study, oxygen levels in the water coming from the drain were very low, and other parameters were found at elevated levels nearly identical to those found in the hypolimnion. The canal drains into a series of shallow ponds below the lake and eventually into the Naches River near its confluence with the Yakima River. The assumption is that this relatively small volume of water is so diluted that it has little or no impact on these larger systems, but there are no available data to confirm that is the case. However, the odor from the hypolimnetic discharge is arguably already a violation of aesthetic standards, and the poor quality of water leaving the lake should prompt consideration of further examination of this issue.

# Conclusions and Recommendations

## Conclusions

The results of this 2012 study support the following conclusions.

- Ammonia concentrations were under the criteria set by the state of Washington at all lake depths during the critical period of late summer and after autumnal turnover had occurred.
- The installation of the hypolimnetic drain appears to be at least partially responsible for improved water quality in Myron Lake.

## Recommendations

The results of this 2012 study support the following recommendations:

- Myron Lake should have its 303(d) listing for ammonia reviewed for possible re-categorization.
- Ecology should evaluate the impact of the hypolimnetic withdrawal discharge on Union Canal and determine compliance with state water quality standards.
- While not a high priority, further study of the effectiveness of the hypolimnetic drain should be conducted to determine if this technique might be effective in lakes similar to Myron Lake.

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# Appendices

# Appendix A. Measurement Quality Objectives (MQOs)

## Depth Profile Replicate QC Comparisons

Table A-1. QA/QC statistics for temperature profiles collected on October 18, 2012 at Myron Lake.

| Depth Profile (°C) | Replicate (°C) | Diff. | StD | Mean | CV | RSD | RPD | Flag? |
|---|---|---|---|---|---|---|---|---|
| 15.28 | 15.42 | -0.14 | 0.098995 | 15.35 | 0.006449 | 0.6% | 0.9% | N |
| 15.11 | 15.29 | -0.18 | 0.127279 | 15.2 | 0.008374 | 0.8% | 1.2% | N |
| 15 | 15.1 | -0.1 | 0.070711 | 15.05 | 0.004698 | 0.5% | 0.7% | N |
| 14.98 | 15 | -0.02 | 0.014142 | 14.99 | 0.000943 | 0.1% | 0.1% | N |
| 14.97 | 14.97 | 0 | 0 | 14.97 | 0 | 0.0% | 0.0% | N |
| 14.95 | 14.95 | 0 | 0 | 14.95 | 0 | 0.0% | 0.0% | N |
| 14.94 | 14.93 | 0.01 | 0.007071 | 14.935 | 0.000473 | 0.0% | 0.1% | N |
| 14.93 | 14.92 | 0.01 | 0.007071 | 14.925 | 0.000474 | 0.0% | 0.1% | N |
| 14.92 | 14.91 | 0.01 | 0.007071 | 14.915 | 0.000474 | 0.0% | 0.1% | N |
| 14.92 | 14.9 | 0.02 | 0.014142 | 14.91 | 0.000949 | 0.1% | 0.1% | N |
| 14.9 | 14.91 | -0.01 | 0.007071 | 14.905 | 0.000474 | 0.0% | 0.1% | N |
| 14.89 | 14.91 | -0.02 | 0.014142 | 14.9 | 0.000949 | 0.1% | 0.1% | N |
| 14.89 | 14.89 | 0 | 0 | 14.89 | 0 | 0.0% | 0.0% | N |
| 14.88 | 14.88 | 0 | 0 | 14.88 | 0 | 0.0% | 0.0% | N |

Table A-2. QA/QC statistics for pH profiles collected on October 18, 2012 at Myron Lake.

| Depth Profile | Replicate | Diff. | StD | Mean | CV | RSD | RPD | Flag? |
|---|---|---|---|---|---|---|---|---|
| 7.51 | 7.6 | -0.09 | 0.06364 | 7.555 | 0.008424 | 0.8% | 1.2% | N |
| 7.51 | 7.58 | -0.07 | 0.049497 | 7.545 | 0.00656 | 0.7% | 0.9% | N |
| 7.52 | 7.57 | -0.05 | 0.035355 | 7.545 | 0.004686 | 0.5% | 0.7% | N |
| 7.51 | 7.55 | -0.04 | 0.028284 | 7.53 | 0.003756 | 0.4% | 0.5% | N |
| 7.5 | 7.53 | -0.03 | 0.021213 | 7.515 | 0.002823 | 0.3% | 0.4% | N |
| 7.55 | 7.51 | 0.04 | 0.028284 | 7.53 | 0.003756 | 0.4% | 0.5% | N |
| 7.5 | 7.5 | 0 | 0 | 7.5 | 0 | 0.0% | 0.0% | N |
| 7.49 | 7.48 | 0.01 | 0.007071 | 7.485 | 0.000945 | 0.1% | 0.1% | N |
| 7.48 | 7.52 | -0.04 | 0.028284 | 7.5 | 0.003771 | 0.4% | 0.5% | N |
| 7.47 | 7.48 | -0.01 | 0.007071 | 7.475 | 0.000946 | 0.1% | 0.1% | N |
| 7.48 | 7.47 | 0.01 | 0.007071 | 7.475 | 0.000946 | 0.1% | 0.1% | N |
| 7.46 | 7.47 | -0.01 | 0.007071 | 7.465 | 0.000947 | 0.1% | 0.1% | N |
| 7.44 | 7.44 | 0 | 0 | 7.44 | 0 | 0.0% | 0.0% | N |
| 7.43 | 7.43 | 0 | 0 | 7.43 | 0 | 0.0% | 0.0% | N |

Table A-3. QA/QC statistics for dissolved oxygen profiles collected on October 18, 2012 at Myron Lake.

| Depth Profile (mg/L) | Replicate (mg/L) | Difference | StD | Mean | CV | RSD | RPD | Flag? |
|---|---|---|---|---|---|---|---|---|
| 8.55 | 8.88 | -0.33 | 0.233345 | 8.715 | 0.026775 | 2.7% | 3.8% | N |
| 8.62 | 8.94 | -0.32 | 0.226274 | 8.78 | 0.025772 | 2.6% | 3.6% | N |
| 8.54 | 8.92 | -0.38 | 0.268701 | 8.73 | 0.030779 | 3.1% | 4.4% | N |
| 8.47 | 8.69 | -0.22 | 0.155563 | 8.58 | 0.018131 | 1.8% | 2.6% | N |
| 8.4 | 8.56 | -0.16 | 0.113137 | 8.48 | 0.013342 | 1.3% | 1.9% | N |
| 8.35 | 8.37 | -0.02 | 0.014142 | 8.36 | 0.001692 | 0.2% | 0.2% | N |
| 8.24 | 8.25 | -0.01 | 0.007071 | 8.245 | 0.000858 | 0.1% | 0.1% | N |
| 8.21 | 8.15 | 0.06 | 0.042426 | 8.18 | 0.005187 | 0.5% | 0.7% | N |
| 8.13 | 8.11 | 0.02 | 0.014142 | 8.12 | 0.001742 | 0.2% | 0.2% | N |
| 8.11 | 8.12 | -0.01 | 0.007071 | 8.115 | 0.000871 | 0.1% | 0.1% | N |
| 8.05 | 8.14 | -0.09 | 0.06364 | 8.095 | 0.007862 | 0.8% | 1.1% | N |
| 8.08 | 8.14 | -0.06 | 0.042426 | 8.11 | 0.005231 | 0.5% | 0.7% | N |
| 7.9 | 8.04 | -0.14 | 0.098995 | 7.97 | 0.012421 | 1.2% | 1.8% | N |
| 7.89 | 7.9 | -0.01 | 0.007071 | 7.895 | 0.000896 | 0.1% | 0.1% | N |

Table A-4. Comparison of Winkler grab samples to Hydrolab® LDO probe data.

| Date | Station | Depth (m) | DO (mg/L) | DO (Winkler, mg/L) | Diff. | StD | Mean | CV | RSD | RPD | Flag |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/15/2012 | Surface | 0.5 | 12.11 | 12.1 | 0.01 | 0.007071 | 12.11 | 0.000584 | 0.1% | 0.1% | N |
| 8/15/2012 | Drain | 0 | 1.06 | 0.3 | 0.76 | 0.537401 | 1.06 | 0.506982 | 50.7% | 71.7% | Y |
| 8/15/2012 | QC Check | 0.5 | 12.25 | 12.3 | -0.05 | 0.035355 | 12.25 | 0.002886 | 0.3% | 0.4% | N |
| 9/12/2012 | Surface | 0.5 | 10.82 | 10.39 | 0.43 | 0.304056 | 10.82 | 0.028101 | 2.8% | 4.0% | Y |
| 9/12/2012 | Drain | 0 | 1.26 | 0.49 | 0.77 | 0.544472 | 1.26 | 0.432121 | 43.2% | 61.1% | N |
| 10/18/2012 | Surface | 0.5 | 8.55 | 8.4 | 0.15 | 0.106066 | 8.55 | 0.012405 | 1.2% | 1.8% | N |
| 10/18/2012 | Drain | 0 | 7.82 | 7.8 | 0.02 | 0.014142 | 7.82 | 0.001808 | 0.2% | 0.3% | N |
| 11/14/2012 | Ab Meta-limnion | 4 | 7.97 | 8.5 | -0.53 | 0.374767 | 7.97 | 0.047022 | 4.7% | 6.6% | Y |
| 11/14/2012 | Drain | 0 | 8.05 | 7.9 | 0.15 | 0.106066 | 8.05 | 0.013176 | 1.3% | 1.9% | N |

## Sample Replicate QC Comparisons

Table A-5. QA/QC statistics for sample replicates.

| Date | Sample Location | Parameter | Sample Result | Replicate Result | Diff. | Std. Dev. | Mean | CV | RSD | RPD | Flag |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/15/2012 | Myron Lake Hypolimnion | Alkalinity, Total (mg/L) | 119 | 119 | 0 | 0.000 | 119.0 | 0.000 | 0.0% | 0.0% | N |
| 9/12/2012 | Myron Lake Epilimnion | Alkalinity, Total (mg/L) | 113 | 113 | 0 | 0.000 | 113.0 | 0.000 | 0.0% | 0.0% | N |
| 10/18/2012 | Myron Lake Hypolimnion | Alkalinity, Total (mg/L) | 114 | 113 | 1 | 0.707 | 113.5 | 0.006 | 0.6% | 0.9% | N |
| | | | | | | | | | | | |
| 8/15/2012 | Myron Lake bl Metalimnion | Ammonia (mg/L) | 0.408 | 0.413 | -0.005 | 0.004 | 0.411 | 0.009 | 0.9% | 1.2% | N |
| 9/12/2012 | Myron Lake Surface | Ammonia (mg/L) | 0.011 | 0.01 | 0.001 | 0.001 | 0.011 | 0.067 | 6.7% | 9.5% | N |
| 10/18/2012 | Myron Lake ab Metalimnion | Ammonia (mg/L) | 0.083 | 0.084 | -0.001 | 0.001 | 0.084 | 0.008 | 0.8% | 1.2% | N |
| | | | | | | | | | | | |
| 9/12/2012 | Myron Lake Surface | Chlorophyll (ug/L) | 7.5 | 5.1 | 2.4 | 1.697 | 6.300 | 0.269 | 26.9% | 38.1% | Y |
| | | | | | | | | | | | |
| 8/15/2012 | Myron Lake Hypolimnion | Dissolved Organic Carbon (mg/L) | 3.3 | 3.2 | 0.1 | 0.071 | 3.250 | 0.022 | 2.2% | 3.1% | N |
| 9/12/2012 | Myron Lake Epilimnion | Dissolved Organic Carbon (mg/L) | 3.3 | 3 | 0.3 | 0.212 | 3.150 | 0.067 | 6.7% | 9.5% | N |
| 10/18/2012 | Myron Lake Hypolimnion | Dissolved Organic Carbon (mg/L) | 2.9 | 2.9 | 0 | 0.000 | 2.900 | 0.000 | 0.0% | 0.0% | N |
| | | | | | | | | | | | |
| 8/15/2012 | Myron Lake bl Metalimnion | Nitrate-Nitrite as N (mg/L) | 0.033 | 0.03 | 0.003 | 0.002 | 0.032 | 0.067 | 6.7% | 9.5% | N |
| 9/12/2012 | Myron Lake Surface | Nitrate-Nitrite as N (mg/L) | 0.076 | 0.075 | 0.001 | 0.001 | 0.076 | 0.009 | 0.9% | 1.3% | N |
| 10/18/2012 | Myron Lake ab Metalimnion | Nitrate-Nitrite as N (mg/L) | 0.172 | 0.182 | -0.01 | 0.007 | 0.177 | 0.040 | 4.0% | 5.6% | N |
| | | | | | | | | | | | |
| 8/15/2012 | Myron Lake bl Metalimnion | Ortho-Phosphate (mg/L) | 0.003 | 0.003 | 0 | 0.000 | 0.003 | 0.000 | 0.0% | 0.0% | N |

| Date | Sample Location | Parameter | Sample Result | Replicate Result | Diff. | Std. Dev. | Mean | CV | RSD | RPD | Flag |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/12/2012 | Myron Lake Surface | Ortho-Phosphate (mg/L) | 0.0047 | 0.0048 | -1E-04 | 0.000 | 0.005 | 0.015 | 1.5% | 2.1% | N |
| 10/18/2012 | Myron Lake ab Metalimnion | Ortho-Phosphate (mg/L) | 0.0052 | 0.0052 | 0 | 0.000 | 0.005 | 0.000 | 0.0% | 0.0% | N |
| | | | | | | | | | | | |
| 8/15/2012 | Myron Lake Hypolimnion | Silica (SiO2) vitreous (mg/L) | 11.9 | 12.9 | -1 | 0.707 | 12.4 | 0.057 | 5.7% | 8.1% | N |
| 9/12/2012 | Myron Lake Epilimnion | Silica (SiO2) vitreous (mg/L) | 25.4 | 25.4 | 0 | 0.000 | 25.4 | 0.000 | 0.0% | 0.0% | N |
| 10/18/2012 | Myron Lake Hypolimnion | Silica (SiO2) vitreous (mg/L) | 26.5 | 26.6 | -0.1 | 0.071 | 26.6 | 0.003 | 0.3% | 0.4% | N |
| | | | | | | | | | | | |
| 8/15/2012 | Myron Lake Hypolimnion | TNVSS[1] (mg/L) | 2 | 1 | 1 | 0.707 | 1.500 | 0.471 | 47.1% | 66.7% | Y |
| 9/12/2012 | Myron Lake Epilimnion | TNVSS[1] (mg/L) | 2 | 2 | 0 | 0.000 | 2.000 | 0.000 | 0.0% | 0.0% | N |
| 10/18/2012 | Myron Lake Hypolimnion | TNVSS[1] (mg/L) | 2 | 2 | 0 | 0.000 | 2.000 | 0.000 | 0.0% | 0.0% | N |
| | | | | | | | | | | | |
| 8/15/2012 | Myron Lake Hypolimnion | Total Organic Carbon (mg/L) | 4.4 | 4.2 | 0.2 | 0.141 | 4.300 | 0.033 | 3.3% | 4.7% | N |
| 9/12/2012 | Myron Lake Epilimnion | Total Organic Carbon (mg/L) | 3.6 | 4.1 | -0.5 | 0.354 | 3.850 | 0.092 | 9.2% | 13.0% | N |
| 10/18/2012 | Myron Lake Hypolimnion | Total Organic Carbon (mg/L) | 3.4 | 3.7 | -0.3 | 0.212 | 3.550 | 0.060 | 6.0% | 8.5% | N |
| | | | | | | | | | | | |
| 8/15/2012 | Myron Lake bl Metalimnion | Total Persulfate Nitrogen (mg/L) | 0.782 | 0.713 | 0.069 | 0.049 | 0.748 | 0.065 | 6.5% | 9.2% | N |
| 9/12/2012 | Myron Lake Surface | Total Persulfate Nitrogen (mg/L) | 0.25 | 0.279 | -0.029 | 0.021 | 0.265 | 0.078 | 7.8% | 11.0% | N |
| 10/18/2012 | Myron Lake ab Metalimnion | Total Persulfate Nitrogen (mg/L) | 0.475 | 0.448 | 0.027 | 0.019 | 0.462 | 0.041 | 4.1% | 5.9% | N |

| Date | Sample Location | Parameter | Sample Result | Repli-cate Result | Diff. | Std. Dev. | Mean | CV | RSD | RPD | Flag |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  |  |  |
| 8/15/2012 | Myron Lake bl Metalimnion | Total Phosphorus (mg/L) | 0.0195 | 0.0148 | 0.0047 | 0.003 | 0.017 | 0.194 | 19.4% | 27.4% | Y |
| 9/12/2012 | Myron Lake Surface | Total Phosphorus (mg/L) | 0.0096 | 0.0093 | 0.0003 | 0.000 | 0.009 | 0.022 | 2.2% | 3.2% | N |
| 10/18/2012 | Myron Lake ab Metalimnion | Total Phosphorus (mg/L) | 0.0204 | 0.0198 | 0.0006 | 0.000 | 0.020 | 0.021 | 2.1% | 3.0% | N |

[1] Total Non-Volatile Suspended Solids

# Appendix B. Glossary, Acronyms, and Abbreviations

**Clean Water Act:** A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

**Conductivity:** A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

**Dissolved oxygen (DO):** A measure of the amount of oxygen dissolved in water.

**Epilimnion**: The top layer of water in a thermally-stratified lake. It is the warmest layer, can directly exchange gases with the atmosphere, and is usually mechanically mixed by wind-surface processes.

**Eutrophic:** Having a high concentration of dissolved nutrients and aquatic productivity, often resulting from human activities such as fertilizer runoff and leaky septic systems.

**Hypolimnion:** The bottom layer of water in a thermally-stratified lake. Physical and chemical processes within the hypolimnion can result in anoxic and/or toxic conditions in the hypolimnion.

**Mesotrophic:** Having a moderate amount of dissolved nutrients and associated aquatic productivity.

**Metalimnion:** A thin layer in a thermally stratified lake in which temperature decreases more rapidly with depth than in adjacent layers. The metalimnion acts as a barrier between the hypolimnion and the epilimnion. It is also commonly referred to as the thermocline.

**Nonpoint source:** Pollution that enters any waters of the state from any dispersed land-based or water-based activities. This includes, but is not limited to, atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

**Nutrient:** Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

**Parameter:** A physical chemical or biological property whose values determine environmental characteristics or behavior.

**pH:** A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

**Point source:** Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

**Pollution:** Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

**Salmonid:** Fish that belong to the family *Salmonidae*. Any species of salmon, trout, or char.

**Surface waters of the state:** Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

**Total Maximum Daily Load (TMDL):** A distribution of a substance in a water body designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

**Trophic state:** The weight of the biomass in a water body. Determined using an index which uses the more easily measured parameters phosphorus, Secchi depth, and/or chlorophyll-a. Trophic state is commonly used as a general indicator of lake health.

**Watershed:** A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

**303(d) list:** Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

## Acronyms and Abbreviations

| | |
|---|---|
| ab | Above |
| bl | Below |
| BMP | Best management practices |
| e.g. | For example |
| Ecology | Washington State Department of Ecology |
| EIM | Environmental Information Management database |
| EPA | U.S. Environmental Protection Agency |
| EAP | Environmental Assessment Program |
| et al. | And others |
| GIS | Geographic Information System software |
| GPS | Global Positioning System |
| i.e. | In other words |
| MEL | Manchester Environmental Laboratory |
| MQO | Measurement quality objective |
| NTR | National Toxics Rule |
| QA | Quality assurance |
| RPD | Relative percent difference |
| RSD | Relative standard deviation |
| SOP | Standard operating procedures |
| SRM | Standard reference materials |
| TMDL | (See Glossary above) |
| USGS | U.S. Geological Survey |
| WAC | Washington Administrative Code |
| WDFW | Washington Department of Fish and Wildlife |
| WRIA | Water Resource Inventory Area |

### *Units of Measurement*

| | |
|---|---|
| °C | degrees centigrade |
| cfs | cubic feet per second |
| ft | feet |
| g | gram, a unit of mass |
| kg | kilograms, a unit of mass equal to 1,000 grams |
| km | kilometer, a unit of length equal to 1,000 meters |
| m | meter |
| mg | milligram |
| mg/L | milligrams per liter (parts per million) |
| mL | milliliters |
| mm | millimeter |
| NTU | nephelometric turbidity units |
| psu | practical salinity units |
| s.u. | standard units |
| ug/L | micrograms per liter (parts per billion) |
| uS/cm | microsiemens per centimeter, a unit of conductivity |