Leesville Lake 2025 Water Quality Monitoring

Prepared for:
Leesville Lake Association

Prepared by:
Dr. Thomas Shahady University of Lynchburg

February 2026

This page left intentionally blank.

Table of Contents   Page

      1.1 General
      1.2 Methods
      1.3 Water Quality: Current Test Results
            1.3.1   Temporal Analysis by Station
                1.3.1.1 Dam (Lacustrine)
                1.3.1.2 Leesville Lake Marina
                1.3.1.3 Tri County Marina
                1.3.1.4 Mile Marker 6 (Transition)
                1.3.1.5 Mile Marker 9
                1.3.1.6 Toler Bridge (Riverine)
                1.3.1.7 Pigg River
                1.3.1.8 Smith Mountain Lake Tail waters

      2.1 Analysis of Trophic State
      2.2 An Analysis of Oxygen Loss and Green House Gas Release in the Reservoir.

References
Appendix A: Background of Water Quality Program
Appendix B: Water Parameter Testing Details
Appendix C: Quality Assurance (QA)/ Quality Control (QC)
Appendix D: Quality Assurance (QA)/ Quality Control (QC) Checklist
Appendix E: Measures Over Study Period (2020)
Appendix F: Letter to Technical Review Committee dated Dec 3, 2020 over concerns of low Dissolved Oxygen Content in tail water release from SML.

ID	Table Description	Page
1.2.1	Table of Leesville Lake Sampling Sites	12
1.1	Dam (Lacustrine) Conductivity (ms/cm) measures over study period	Appendix D
1.2	Dam (Lacustrine) Dissolved Oxygen (mg/L) measures over study period	Appendix D
1.3	Dam (Lacustrine) Temperature (°C) measures over study period	Appendix D
1.4	Dam (Lacustrine) Chlorophyll a (ppb) concentrations over study period	Appendix D
1.5	Dam (Lacustrine) pH measures over study period	Appendix D
1.6	Dam (Lacustrine) ORP (mV) measures over study period	Appendix D
1.7	Dam (lacustrine) Turbidity (NTU) measures over study period	Appendix D
1.3.2	Dam (Lacustrine) Other Parameters Over Study Period	27
1.3.3	Leesville Lake Marina other parameters measured over study period	28
1.3.4	Tri County Marina other parameters measured over study period	29
1.12	Mile Marker 6 (Transition) Conductivity (ms/cm) measures over study period	Appendix D
1.13	Mile Marker 6 (Transition) Dissolved Oxygen (mg/L) measures over study period	Appendix D
1.14	Mile Marker 6 (Transition) Temperature (°C) measures over study period	Appendix D
1.15	Mile Marker 6 (Transition) Chlorophyll a (ppb) concentrations over study period	Appendix D
1.16	Mile Marker 6 (Transition) pH measures over study period	Appendix D
1.17	Mile Marker 6 (Transition) ORP (mV) measures over study period	Appendix D
1.18	Mile Marker 6 (Transition) Turbidity (NTU) measures over study period	Appendix D
1.3.5	Mile Marker 6 (Transition) Other Parameters Over Study Period	37
1.3.6	Mile Marker 9 other parameters measured over study period	39
1.22	Toler Bridge (Riverine) Conductivity (ms/cm) measures over study period	Appendix D
1.23	Toler Bridge (Riverine) Dissolved Oxygen (mg/L) measures over study period	Appendix D
1.24	Toler Bridge (Riverine) Temperature (°C) measures over study period	Appendix D
1.25	Toler Bridge (Riverine) Chlorophyll a (ppb) concentrations over study period	Appendix D
1.26	Toler Bridge (Riverine) pH measures over study period	Appendix D
1.27	Toler Bridge (Riverine) ORP (mV) measures over study period	Appendix D
1.28	Toler Bridge (Riverine) ORP (mV) measures over study period	Appendix D

List of Acronyms and Abbreviations

AEP	American Electric Power
DCR	Virginia Department of Conservation & Recreation
DEQ	Virginia Department of Environmental Quality
DO	Dissolved Oxygen
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FPA	Federal Power Act
LLA	Leesville Lake Association
mV	Millivolts
MPN	Most Probable Number
NTU	Nephelometric Turbidity Unit
ORP	Oxygen Reduction Potential
TP	Total Phosphorus
SML	Smith Mountain Lake
SMP	Shoreline Management Plan
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
VDEQ	Virginia Department of Environmental Quality

Glossary of Terms

Jargon is used in this report to describe certain aspects of lake function and water concerns in the lake. Here we define key terms to facilitate comprehension of the document and the trends that the research reveals.

Lake or Reservoir – These terms, while not technically synonymous, are used interchangeably and in accordance with lay usage. The term reservoir is reserved for a river system with a dam to create a lake. In the southeastern United States, all of these bodies of water are reservoirs with a few notable exceptions. Lakes are the natural bodies of water typically formed through glacial processes (great lakes) or other geological phenomenon (Mountain Lake Virginia). Reservoirs are always deepest at the dam while lakes are deepest in the center.

Riverine and Lacustrine – These are terms we used to describe reservoirs. Riverine describes conditions that are dominated by river conditions and often occur in the upper portions of a reservoir. Lacustrine is a term used to describe conditions dominated by lake processes and often occur near the dam. The term **transition** is used often throughout the center of the reservoir to describe a blend between riverine and lacustrine.

Pelagic and Littoral – This is a term used to describe the deepest part of the reservoir. It is more often used to describe the open water of a lake. Littoral is the term used to describe the shallow portion of a lake and is often an area covered by floating or rooted plants. These terms are not as often associated with reservoirs because water movement prevents development of significant littoral zones.

Eutrophic – This is the condition of lakes and other bodies of water resulting from the input of excess nutrients. As this condition worsens it leads to algae blooms, formation of toxic algae growth, high pH, low dissolved oxygen and poor water quality. All of these conditions are harmful to beneficial aquatic life and enjoyment of the reservoir.

Trophic State – this is a convenient method to translate measured conditions of eutrophication into a scale. We consider lakes and reservoirs to be eutrophic (high levels of eutrophication), mesotrophic (moderate levels of eutrophication) or oligotrophic (low levels of eutrophication). Often these levels must be balanced as oligotrophic conditions are not good for fishery productivity and eutrophic conditions lead to severe water quality problems. One additional classification is **Dystrophic,** which is characterized by high levels of tannins in the water. Tannins are created when leaf litter degrades. Dystrophic water is often tea colored and found more often in coastal systems.

Polymictic – a term used to describe lakes that turn over multiple times in a year. Turn over reflects the condition where the lake is the same temperature from top to bottom, allowing the water to mix. Many lakes in temperate climates such as Leesville

8

Lake stratify during summer months characterized by warm water floating on top of colder water. During this period of "stratification," the warm water is isolated from the lower cooler water. When the lake is stratified it only mixes in the upper layer. When the lake warms or cools to the same temperature it mixes throughout. If this only occurs in the spring and the fall a lake is considered dimictic – or mixing only twice in a year. Leesville Lake is considered polymictic because in addition to the spring and fall stratification heavy rain input and water movement by Smith Mountain Lake will break up the stratification. After these events, stratification occurs. This causes the lake to mix many times in a year hence the term polymictic.

Hypolimnion and Epilimnion – These are terms used by limnologists (a person who studies lakes) to describe the layers that form during stratification. The epilimnion is the upper layer and the hypolimnion is the lower layer. The term **Metalimnion** is also used to describe the layer of changing conditions between the two other layers. Temperature is the most common measure used to define these layers, and the most often referenced criterion to define a new layer is a temperature in excess of 1 degree centigrade per one meter of depth. But, because these lakes are polymictic, this clear definition is often not applicable.

Heterogrades – These are terms to describe the shape of oxygen curves throughout the water column. Oxygen is influenced by many factors and the heterograde curves help describe these influences. When phytoplankton accumulate at the thermocline, they tend to photosynthesize creating a visible increase of oxygen in that area. This is called a **positive heterograde**. When oxygen decreases due to bacterial consumption of oxygen with depth without change this is a **clinograde**. Within a clinograde, an increase in oxygen below the thermocline due to the physical characteristics of the water is termed a **positive heterograde**. Oxygen that remains unchanged with depth is an **orthograde**.

Thermocline – Area in the lake defined from a depth profile where water temperature decreases at a rate greater than 1 degree centigrade per meter.

Phytoplankton and Chlorophyll *a* – These are terms to describe the algae or plant life that occupies the pelagic portion of the reservoir. Phytoplankton are single celled or filamentous microscopic plants that grow in the water and are stimulated by water movement, depth of light penetration and nutrients such as phosphorus and nitrogen. Chlorophyll *a* is the photosynthetic pigment found in all plants and a very convenient way to measure the amount of phytoplankton in the reservoir. These terms are often used interchangeably.

E. coli – This term is used to describe a group of bacteria that are associated with health risk in water. They are typically not pathogenic but are easy to quantify in the laboratory. Because their presence is associated with presence of pathogens, we measure their concentration and issue warnings when levels are high. Sediment that is brought into reservoir is often associated with high levels of *E. coli*.

Executive Summary

The Leesville Lake Association and University of Lynchburg, in partnership with American Electric Power Company, monitored water quality of Leesville Lake between April and October of 2025. University of Lynchburg monitored the lake seven times at mid-month while the Leesville Lake Water Quality Committee monitored end of month during June, July and August. The results of that monitoring are reported here with analysis of lake trends at each station and additional analysis on problems or concerns. The intent of this report is to provide a technical and scientific background for sound management of Smith Mountain Lake and Leesville Lake in order to protect and improve these lake resources for future generations.

Leesville Lake continues to meet prescribed water quality parameters measured in the main stem of the reservoir. Water quality is very stable with minimal fluctuations from a slightly eutrophic condition. Two predominate factors contribute to this condition – river input from the Pigg River emptying into the headwater region that drains primarily an agricultural watershed *and* tailwater release from Smith Mountain Lake along with American Electric Power pump-back operations. When comparing the water quality of Leesville Lake to worldwide lakes and reservoirs with agricultural watersheds the water by comparison is of very high quality.

This does not preclude concerns that need continued monitoring and management. Excessive debris pouring into the reservoir from the Pigg River during storm events continues to be a hazard. During 2025, excessive debris prevented passage beyond Toler Bridge during one of the sampling events. Pump back operations exacerbate this problem by moving debris back into the channel when water movement is reversed. If management of woody debris cannot occur in the Pigg River Watershed, a more aggressive approach needs to be considered during rain events. It is understood and then documented in this report the extent of debris entering the reservoir from heavy (> 1 inch) rain events.

Other operational considerations should include the relationship between precipitation and reservoir productivity including chlorophyll a production and dissolved oxygen concentrations. Both are dependent upon precipitation with a build-up of Chlorophyll a observed with increased oxygen during lower precipitation years and the reverse observable during higher precipitation years. Pump-storage operations integrate into this relationship, so coordination with water quality should be considered. Coordinating the movement of water with both energy production and water quality needs to be analyzed.

Year 2025 conclusions include:

1. Leesville Lake remains slightly eutrophic and this measure is very stable in the reservoir. It has maintained this status throughout the monitoring period of

study (2010-2025) and this result is currently stable and not expected to worsen or improve in the foreseeable future.

2. Leesville Lake behaves as a pump storage reservoir with headwaters impacted by tail release from the upper reservoir along with input from the Pigg River. Both are situated in the headwaters of the reservoir and both provide a unique input into the system. Each is integrated into the water quality and cannot be analyzed very well separately.

3. Analysis of all data suggests management needs to be closely aligned with precipitation as it drives productivity, the input of debris and oxygen loss in the reservoir. It additionally has a significant impact on the bacteriology of the reservoir that is analyzed in a separate study and subsequent publications.

The following management recommendations are suggested after conclusion of the 2025 sampling season:

1. Precipitation is a driver of water quality and aesthetics in the reservoir and must be part of future management of the reservoir.

2. Aggressive deployment of debris removal needs to continue. Correlations between pump-storage activity and water quality necessitate that dam operations be adjusted to preclude negative impacts on water quality when feasible. Knowing that retention of water in the reservoirs tends to increase productivity and oxygen, negative impacts of low oxygen can be countered by increasing water retention. Generally, increasing water retention in the lake will increase zooplankton populations and fish productivity.

3. Low dissolved oxygen needs to be managed at the tailwaters. All possible operational scenarios including syncing with precipitation need to be considered.

4. APCo's upcoming (April/May 2026) submission of a Dissolved Oxygen (DO) Improvement Plan to the Virginia Department of Environmental Quality for review and approval will address these issues. "APCo will develop a comprehensive plan, designed in consultation with VDEQ, the Department of Wildlife Resources (DWR) and other state or federal agencies to address depressed DO levels downstream from Smith Mountain Lake Dam. This plan is in accordance with APCo's final Permit VWP number 24 1547 signed on July 7, 2025. The plan is to protect instream beneficial uses, to ensure compliance with applicable water quality standards, to prevent impairment of state waters or fish and wildlife resources, and to provide no net loss of wetland acreage and function through compensatory mitigation and success monitoring and reporting."

11

Section 1: Current Conditions

1.1   General:

This is the 15th year of water quality monitoring of Leesville Lake by University of Lynchburg (formerly Lynchburg College in previous years of study) in partnership with Leesville Lake Association (LLA). Fifteen years of data continue to strengthen our understanding of Leesville Lake's water quality and support our effort to optimize management of this important natural resource. We will also incorporate broader findings in the watershed as these relate to water quality of the watershed of which Leesville Lake is a part.

Section 1 documents results from the current year's sampling. Data are reported in graphical form with interpretations. In **Appendix D**, all data are reported in tabular form to facilitate future analysis and use with other projects. This project continues to provide essential baseline data for the condition of the lake and interpretation of changing conditions. A full background of the study and its rationale is located in **Appendix A**.

1.2   Methods:

Data were collected by University of Lynchburg through a series of water samplings and testing monthly from April through October. These dates coincide with the most productive period of the reservoir, i.e., when lake productivity is greatest. Leesville Lake Association (LLA) supplements sampling over the three summer months of June, July and August to provide biweekly analysis. LLA collection is not as extensive as the university sampling but adds vital data to understanding trends in the lake (LLA and University of Lynchburg, have actively pursued additional investigations of water quality in the watershed). The following eight sites (Table 1.0) continue to be sampled, as stated in the Leesville Lake Water Quality Monitoring Plan:

Table 1.2.1. Leesville Lake Sampling Sites

LC Station	LLA Station	Site ID	DEQ Station ID	Latitude	Longitude
Leesville Lake Dam	11	2636	LVLAROA140.66	37.0916	-79.4039
Leesville Lake Marina	5	1275	LLAOQC000.58	37.05939	-79.39574
Tri County Marina	3	1273	LLATER000.33	37.05942	-79.44489
Mile Marker 6	8	1373	LLAROA146.87	37.06320	-79.47110

Mile Marker 9	2	1272	LLAROA149.94	37.03993	-79.48233
Toler Bridge	1	1271	LLLAROA153.47	37.01090	-79.47530
Pigg River	9	1374	LLAPGG000.47	37.00430	-79.48590
SML Tail Waters	12	2637	LVLAROA157.92	37.0382	-79.531306

Detailed methodologies used by University of Lynchburg and Leesville Lake Association are located in **Appendix B** for reference. Quality Control and Quality Assurance are located in **Appendix C** for reference.

Site Descriptions
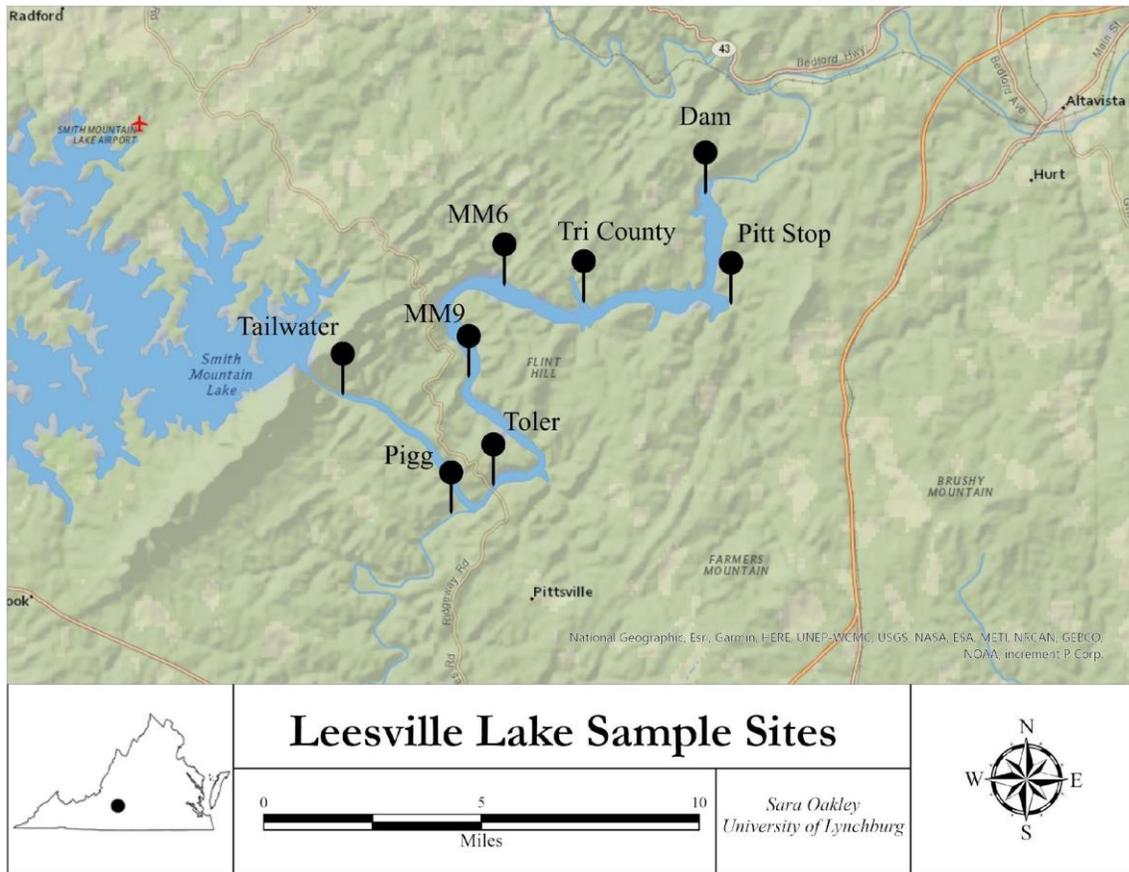
Figure 1.0 – Map of Leesville Lake showing locations of sampling stations along the reservoir.

Leesville Lake Dam

The Dam sampling site is located on the northwest (N 37° 5' 35.215", W 79° 24' 9.809") quadrant of the Old Womans Creek subwatershed (Figure

1). This part of the reservoir is considered as **lacustrine** and its characteristic resembles lake qualities. The water upstream progresses into this station as the season progresses and water characteristics are expected to be isolated from the influence from Smith Mountain Lake Operations.

Leesville Lake Marina (Originally Pitt Stop Marina)

The Leesville Lake Marina sampling site is located on the northwest quadrant (N 37°5' 35.21, W 79°24' 10.425) of the Old Womans Creek subwatershed (Figure 1). This portion of the reservoir is potentially impacted by Old Womens creek and identified by DEQ as an impacted watershed.

Tri County Marina

Tri County Marina sampling site is located further south of the northwest quadrant (N 37°3' 35.158, W 79°23' 219) of the Old Womans Creek subwatershed (Figure 1.0). This part of the reservoir is considered as a **transition zone** between **riverine** and **lacustrine**. Water in this zone is expected to not be as influenced from Smith Mountain Lake Operations, but more so by transition position. This tributary is expected to deposit nutrients and other pollutants, with periods of drawback potentially enhancing impact of effluents spent in the reservoir.

Mile Marker 6 (MM6)

MM6 sampling site is located further south of the mid- southeast quadrant (N 37° 3' 46.501, W 79° 26' 48.006") of the Old Womans Creek subwatershed (Figure 1). This part of the reservoir is also considered as a **transition zone**. Positioned further upstream the patterns observed here provide a point to compare and discern trends of that are comprised moving up or down the reservoir.

Mile Marker 9 (MM9)

MM9 sampling site is located further south of the southeast quadrant (N 37° 4' 5.7325", W 79° 28' 21.015") of the Old Womans Creek subwatershed (Figure 1). This part of the reservoir is considered as a **riverine zone**. Water transported upstream from the Toler Bridge sampling site subject this sampling site to further mixing from influxes of the tail waters of Smith Mountain Lake Dam and Pigg River are expected to be heavy influencers and expect to reflect degradation of water quality from water transported from Toler Bridge.

14

Toler Bridge

The Toler Bridge sampling site is located south of the southeast quadrant (N 37° 2' 23.3955", W 79° 28' 53.152") of the Old Womans Creek subwatershed (Figure 1). This part of the reservoir is also considered as a **riverine zone.** This sampling site is of interest to study as it is the confluence point of dichotic water qualities from expected poor water conditions quality from Pigg river and the expected good water quality conditions from Smith Mountain Lake. Since the resulting water quality is driven from mechanistic (SML Dam) and stochastic (Pigg River), the qualities here will be challenging to interpret.

Pigg River

The Rig River sampling site is located on the furthest southeast aspect (N 37° 0' 17.333", N 37° 0' 17.333) of the Old Womans Creek subwatershed (Figure 1). This area is considered a **riverine** zone. The water quality measures reflected clearly impact water quality in the reservoir. This sampling site here is to reflect the impacted water quality that merges into the reservoir compared to the relatively unimpaired water quality released by the Smith Mountain Lake Tail waters.

Smith Mountain Lake Tailwaters

The Smith Mountain Lake Tail waters sampling site is located further north the southeast aspect of the Clay Branch-Leesville Lake subwatershed (Figure 1). This area is considered as a **riverine** zone as the input patterns are similarly reflective of a river. The water inputs at this location are of very good water quality because of the inputs of nutrient concentration and the settling sediments from the water column. This site is of interest to sample due to the quality demonstrating which areas are of interest for sound management of Smith Mountain Lake and Leesville Lake.

1.3 Leesville Lake Water Quality: Current Test Results

1.3.1 Temporal Analysis by Station

Background

Leesville Lake is a reservoir by definition (a glossary of terms used in this report is provided on page 8 for helpful reference). It is a river course with a dam constructed and filled to form this reservoir. Leesville Lake is somewhat different than a typical reservoir because it serves as a water storage source (pump back operations) for the generation of electricity by the Smith Mountain Lake Hydroelectric Plant. The reservoir receives water input primarily from Smith Mountain Lake but secondarily from several other river systems with the Pigg River the most significant. This river drains a considerably large watershed with significant agriculture and some urban land disturbance throughout. These inputs and pumping operations at the Smith Mountain Lake Dam create a unique hydrology that impacts the water quality of the reservoir.
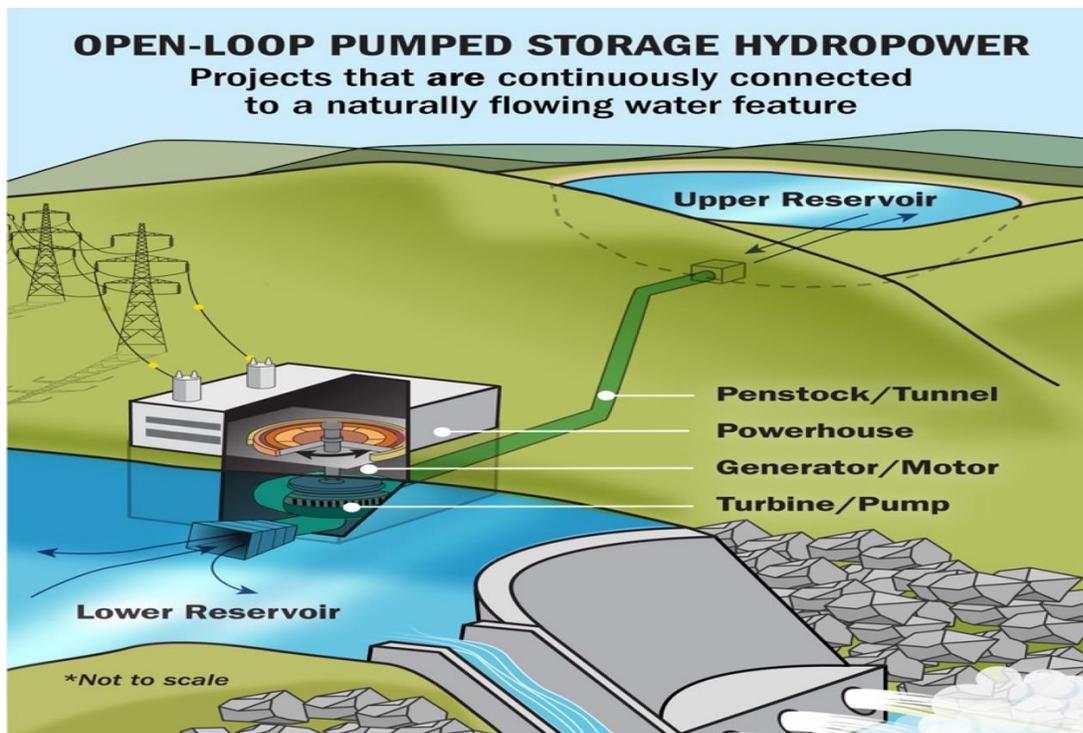

Figure 1.3.1. – Graphical representation of a pump-storage reservoir. Water from lower (storage reservoir) is pumped up to the upper reservoir to generate power by spinning turbines in the dam. (graphic from Dept. of Energy at energy.gov).

16

In any reservoir, water quality needs evaluation along a spatial and horizontal gradient. This gradient begins in the headwaters of the reservoir where river inputs generate patterns similar to a river. This section, characterized as riverine, is often the area with the highest productivity and nutrient input and the poorest water quality. As water travels further into the reservoir, these riverine conditions begin to lessen and more lake qualities (lacustrine), influence water quality. This middle portion of the reservoir is considered a transition zone as the riverine and lacustrine portions of the reservoir mix. This area may have the highest overall productivity in the reservoir as sediments associated with river flow settle from the water column yet nutrient concentrations are plentiful. The final sections of a reservoir are considered lacustrine and resemble lake qualities. This area often is lower in productivity due to settling of particulates and lower nutrient concentrations. If stratification is continuous, upper layers become very isolated from lower portions of the reservoir further isolating nutrients and other pollutants. The best water quality for the reservoir is located in this section.

Because Leesville Lake is a storage reservoir (Fig 1.3.1) it does not necessarily follow this typical pattern. First, the headwaters are fed by release of tail water from Smith Mountain Lake lacustrine zone. This release is of very good quality water because of the aforementioned typical water quality in a reservoir. Thus, one source of incoming water to Leesville Lake is excellent and often mesotrophic or even oligotrophic in quality. However, during later portions of the year the oxygen content of water released from Smith Mountain Lake may have very low oxygen content due to the reservoir properties of stratification that depletes oxygen in the hypolimnion of eutrophic reservoirs. A secondary source of water into Leesville Lake is the Pigg River. This is an impaired river delivering high concentrations of nutrients, sediment and bacteria into Leesville Lake particularly during storm events. While there are many pump-storage reservoir systems in the US, each one has unique properties due to the input of various river systems.

Additionally, the headwater region of Leesville Lake is subject to a bidirectional movement of water. This forces water flow from the Pigg River into the Smith Mountain Lake (SML) lacustrine zone. The fate of this mixing depends on hydroelectric operations, amount of water pumped back and time this water remains in the upper reservoir. The impacted area within Leesville Lake is 4 miles from the Pigg River mouth to the SML dam. Then during energy production, Pigg River water mixed with SML lacustrine discharge flows into Leesville Lake headwaters. This pattern is variable and at any time the water in this 4-mile stretch may consist of Pigg River water, SML release or a combination of both. This pattern significantly altered by stormwater.

The transition portion of the reservoir is not as heavily influenced by Smith Mountain Lake Operations. Water is drawn back and forth above this zone but the volume of water buffers the influence these operations exert on water quality. During periods of heavy rain, sediment-laden water does travel into the transition portions of the reservoir. Water in this zone is influenced by Smith Mountain Operations but more so by its position as the transition zone. The dam area of Leesville Lake is isolated from influence of Smith Mountain Operations and reflects the water quality of the lacustrine area. At multiple points along the reservoir, tributaries of various water quality empty

17

into the lake. These tributaries do not account for a bulk of the water flowing through Leesville Lake but do deposit nutrients and other pollutants. And during periods of drawback, these pollutants are pulled back through the reservoir potentially enhancing impact and time spent in the reservoir.

The analyses in this report examine the data to support or revise the above described limnology of Leesville Lake. Section 1 analyzes each station relative its position (Riverine, Transition or Lacustrine) and the potential impact of each tributary has on observed water quality. Section 2 examines lake-wide trending and consideration of problems that should be investigated further. Section 3 presents management recommendations.

1.3.1.1 Dam (Lacustrine)

Background

The area near the Leesville Lake Dam is considered a Lacustrine section. It exhibits characteristics similar to a natural lake, allowing analysis for similarities to lake conditions.

Conductivity
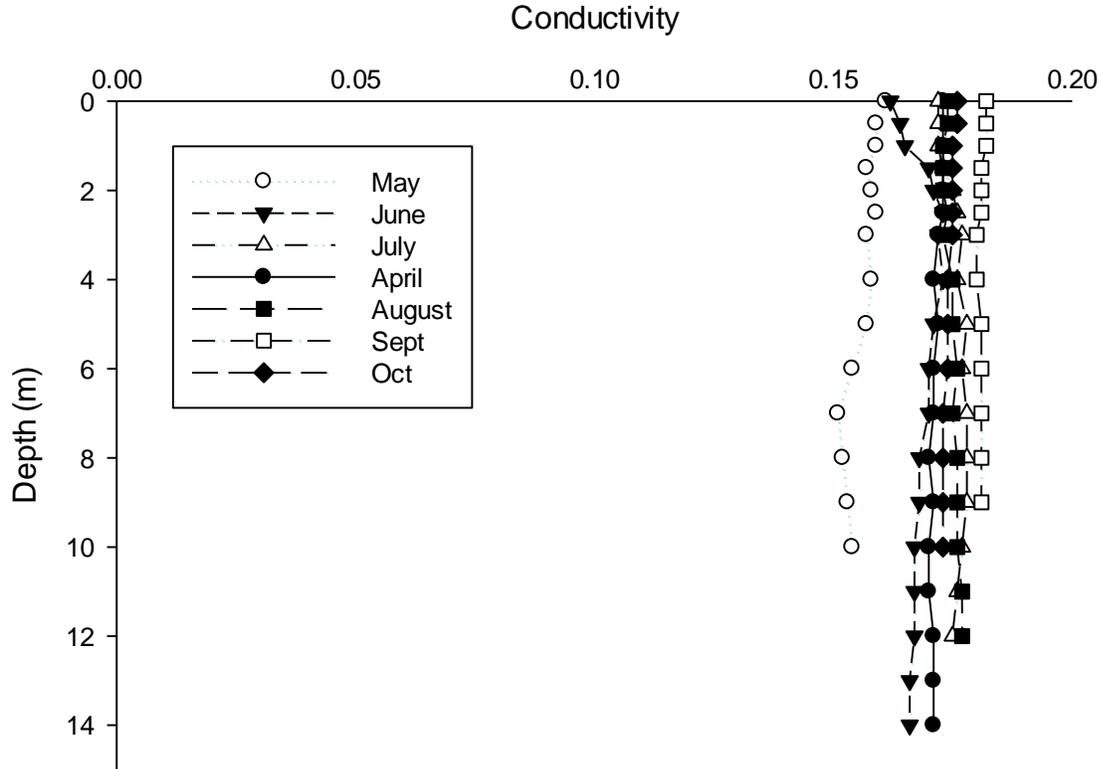
Conductivity

Figure 1.3.2. Dam (Lacustrine) Conductivity (ms/cm) measures over study period (2025)

Seasonal Analysis

Conductivity reflects the presence or absence of pollution or particulates that conduct an electrical current in the water. It is possible to correlate pollution or a water source with levels of conductivity as this measure reflects the concentration of dissolved material in the water. For this study, conductivity can be used to track water movement as Pigg River contains a lower conductivity than SML tail water release.

In 2025, conductivities were relatively similar throughout with May the lowest and September the greatest. This reflects greater input from Pigg River early in season with greater isolation from Pigg and connection to SML in the latter half of season as precipitation lessened relative to the first half of the season. This pattern is reflective in the other parameters.

19

Comparisons Across Years

All data collected in this study suggest conductivity is strongly driven by stormwater flow. Because Pigg River conductivity is considerably lower than water release from SML Dam, lower conductivity measures during any sampling date reflect increasing content of water from the Pigg River. Lower conductivity at the dam station suggests high flow from Pigg River and impact throughout the reservoir. This trend is evident in 2025.

Dissolved Oxygen
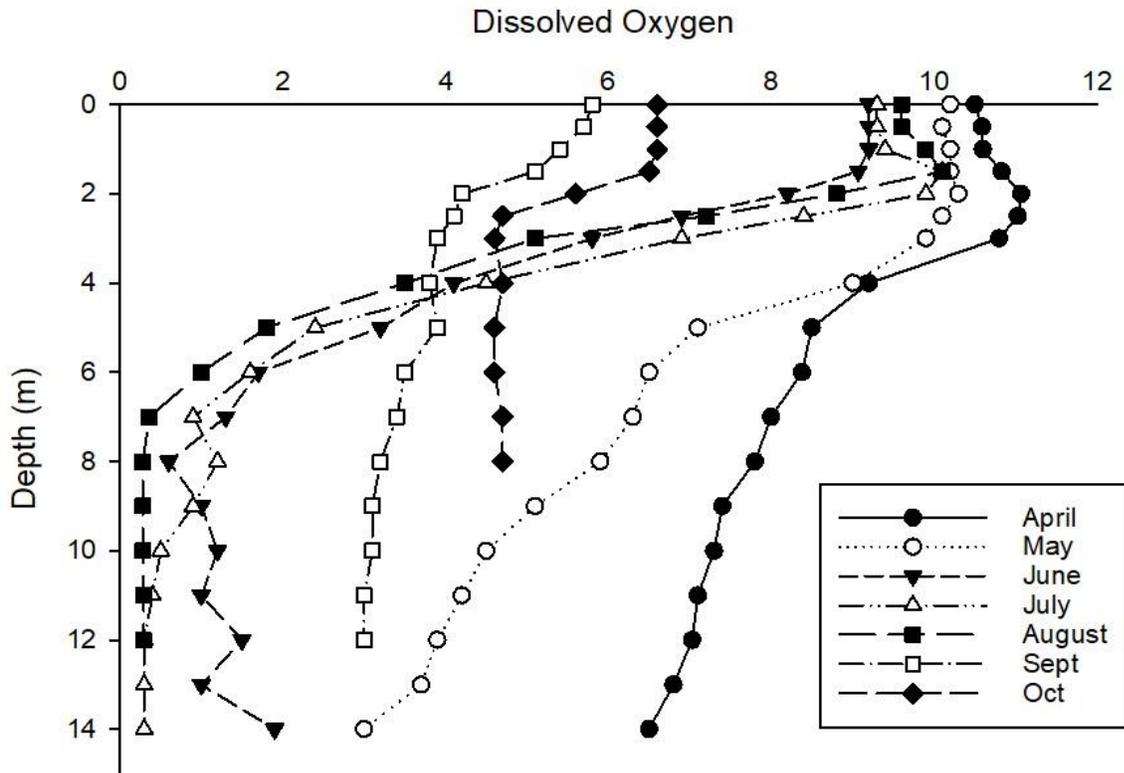
Figure 1.3.3. Dam (Lacustrine) Dissolved Oxygen (mg/L) measures over study period (2025)

Seasonal Analysis

Dissolved oxygen patterns in the reservoir demonstrate that the lake is eutrophic, that is stratifies throughout the sampling period and that oxygen loss occurs quickly beginning at approximately 2 meters depth. Between 2-4 meters depth the loss of oxygen is

variable and dependent upon environmental conditions (temperature and precipitation). Water depleted of oxygen tends to be evident higher into the water column as the season progresses. Oxygen loss is continual with concentrations at depth moving below 2 mg/L from June through August. With some variation, this is the typical pattern for the reservoir. Because September and October were not impacted by stormwater the lake remained stratified in the fall months.

Comparisons Across Years

Oxygen profiles are very consistent throughout the years of study. Oxygen peaks occur between 2-3 meters of depth during months outside of July and August. These two months (July and August contain the lowest oxygen measures at depth (often below 2 mg/L). Turnover of water occurs either in September or November when temperatures in the upper water column match those lower in the column and depends on the season and temperatures. Oxygen in the water during turnover is generally close to 6 mg/L but varies between 5-7 mg/L depending on the year.

Oxygen loss throughout the reservoir is dependent upon the strength of stratification. Thus, while the reservoir is polymictic (it can mix often due to precipitation events) it takes a very strong storm event for mixing to occur at the dam. This did occur this season in September. Alternatively, the reservoir may be considered monomictic only mixing in the fall. Also, the degree of oxygen loss (how low observed levels of oxygen are in the hypolimnion) is a function of strength of stratification. Water temperature and stormwater inflow have tremendous impact on this parameter, which may at times become problematic.

<u>Temperature</u>
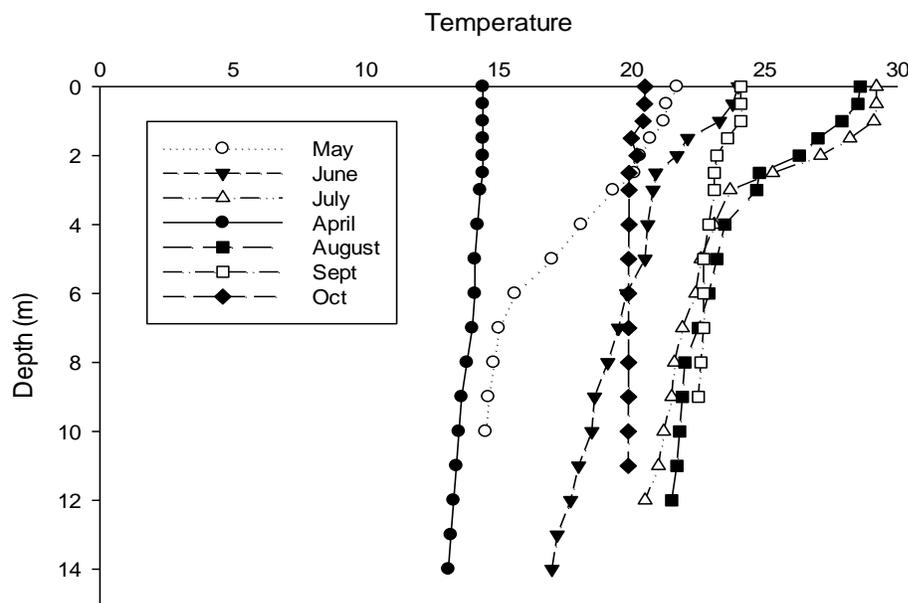
Figure 1.3.4. Dam (Lacustrine) Temperature (°C) measures over study period (2025)

Seasonal Analysis

Reservoir became stratified in May continuing through September. The reservoir was not stratified in April when sampling began and turned over as demonstrated in the October Sampling. Surface water was very warm during the July and August samplings approaching 30C (86F). Timing of stratification is the only variation we see in this pattern.

Comparisons Across Years

We do see variability in these profiles over time. Some years July is the warmest month while in other years August may be the warmest. It is not uncommon to see temperatures reach 30C in these profiles. While in 2025 precipitation did not flush the reservoir in the latter half of the year we did not see excessive warming and this may be a sole function of climate. Stratification is consistent across years usually starting in April or May. The epilimnion establishes above 2 meters depth. The depths of 2-4 meters are the transition zone or metalimnion. The hypolimnion is below 4 meters depth. Throughout the seasons this is a consistent pattern in the reservoir.

Chlorophyll *a*
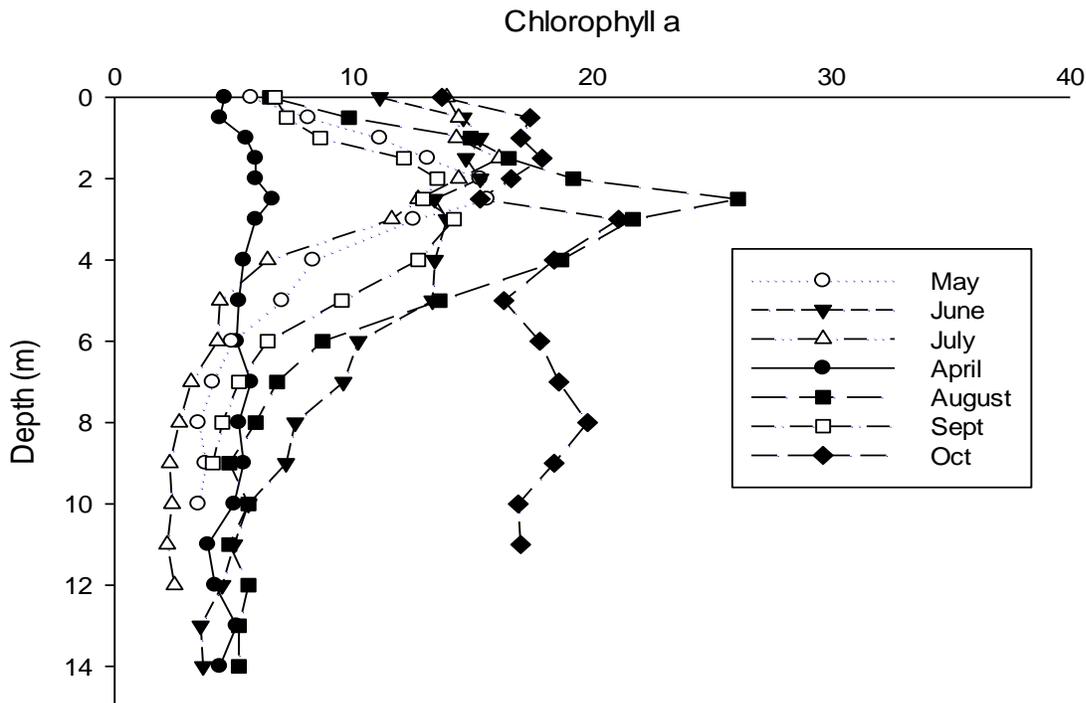
Chlorophyll a

Figure 1.3.5. Dam (Lacustrine) Chlorophyll *a* (ppb) concentrations over study period (2025)

Seasonal Analysis

The reservoir continues to demonstrate a pattern of greatest phytoplankton growth, as indicated by increased chlorophyll content, just above the thermocline (between 2-4 meters). In 2025, peak production at the dam occurred in August and higher up in the water column at 2 meters. This pattern continued into the fall supporting the idea that limited precipitation leads to increased productivity due to limited flushing of the reservoir.

Comparisons Across Years

The pattern of increased phytoplankton along the 2-4 meter thermocline (metalimnion) in the reservoir is a well-established phenomenon in eutrophic lakes. This season's peak was similar to seasons past – approaching 30 ug/L in August. This measure has variability and must be monitored closely to track eutrophication. Looking at this data over many years of monitoring and in the trends analysis, stormwater entering the reservoir and flushing of phytoplankton biomass is a strong driver of this variability.

<u>pH</u>
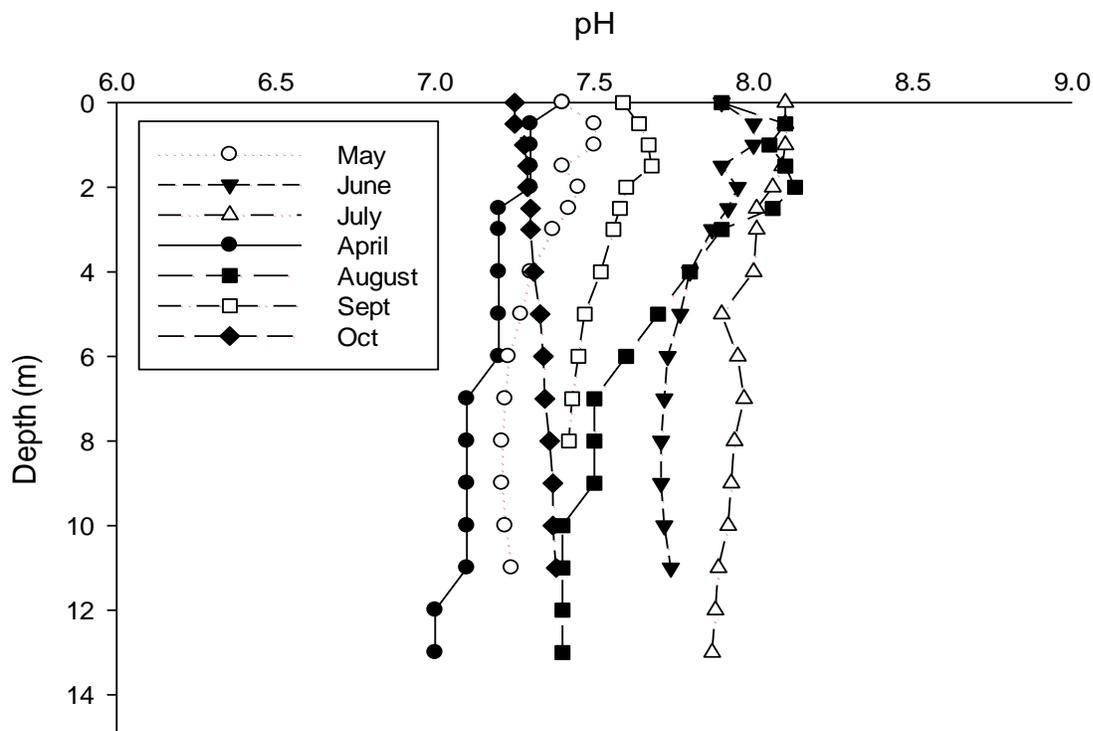
Figure 1.3.6. Dam (Lacustrine) pH measures over study period (2025) Seasonal Analysis

The pH of water in the reservoir follows a typical curve for eutrophic reservoirs with soft water. Chlorophyll productivity is a strong driver of pH and in 2025 greatest readings for pH did coincide with summer months.

Comparisons Across Years

The pattern of pH observed in the reservoir is relatively consistent across years. High pH (9 and above) can sometimes be expected in the summer months when phytoplankton growth is at its peak with this measure strongly correlated to phytoplankton biomass. But peak pH is variable. In many seasons, the pH does not exceed 8.5. This season similar to 2024 peaks were lower.

<u>ORP</u>
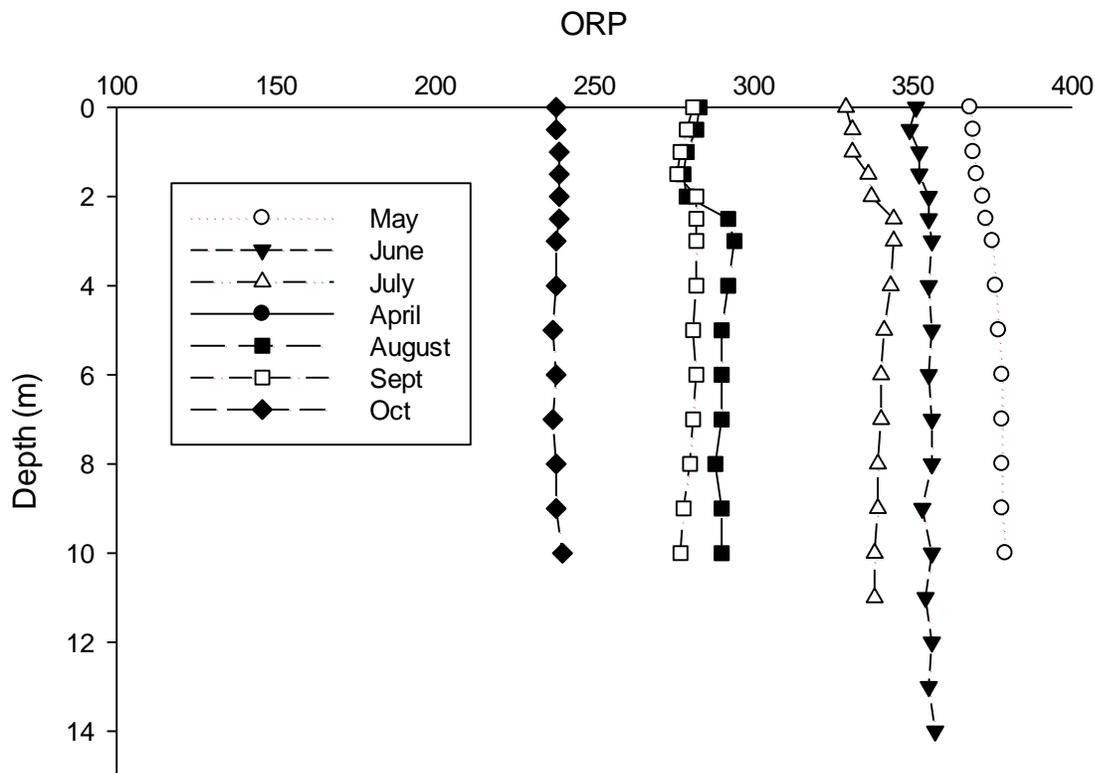
Figure 1.3.7. Dam (Lacustrine) ORP (mV) measures over study period (2025)

Seasonal Analysis

ORP remains in the very oxidized region through the sampling period. There is a pattern of slightly increased ORP with increasing water depth but this change is minimal through the water column.   ORP is very high in the spring with a decrease as the season progresses. This results from stratification depleting oxygen and the warming temperatures holding less oxygen in the water.

Comparisons Across Years

On an annual scale, ORP measures differ from year to year. In some years we have observed seasonal values up to 700 or as low as 100 mV. This shows the tremendous variability with this measure occurring month to month. Consistently, the cooler and well-mixed months in the reservoir tend to have the greatest ORP measures. While this parameter only measures the potential for a redox reaction occurring, the values in the higher range (greater than 400) suggest better water quality.

Nitrate
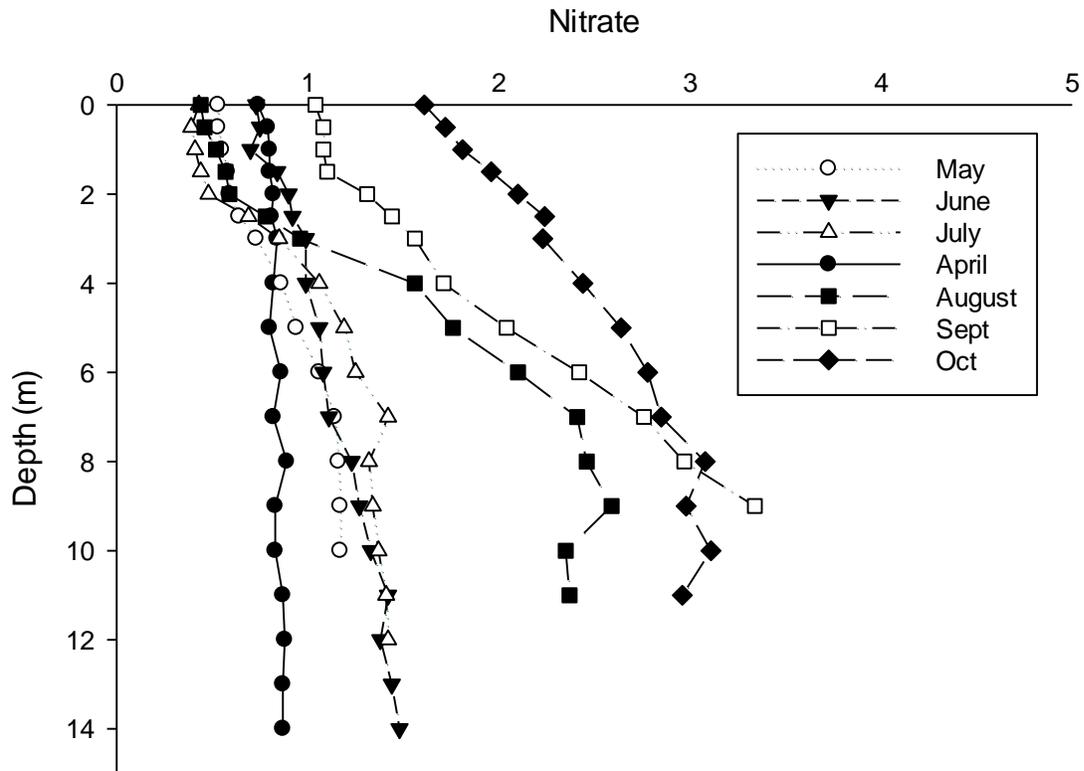
Figure 1.3.8. Dam (lacustrine) Nitrate (mg/L) measures over study period (2025).

Seasonal Analysis

Nitrate patterns suggest general availability of nutrients in the reservoir throughout the season. However, the fall (August – October) this season suggested increased availability as the season progressed. This may be a product of degradation of organic material along with limited flushing due to low precipitation. Regardless, this is concerning as increasing levels of nutrients lead to greater productivity along with deleterious effects of eutrophication.

Comparisons Across Years

Nitrate is a more recent addition to the data collected through monitoring. Results this season in 2025 were elevated and very elevated in the fall sampling season. Analysis would suggest that reservoir flushing is very important to maintain low nutrient levels in the reservoir. Similar problem (elevating nitrate in the fall) occurred in tailwaters from SML in 2025.
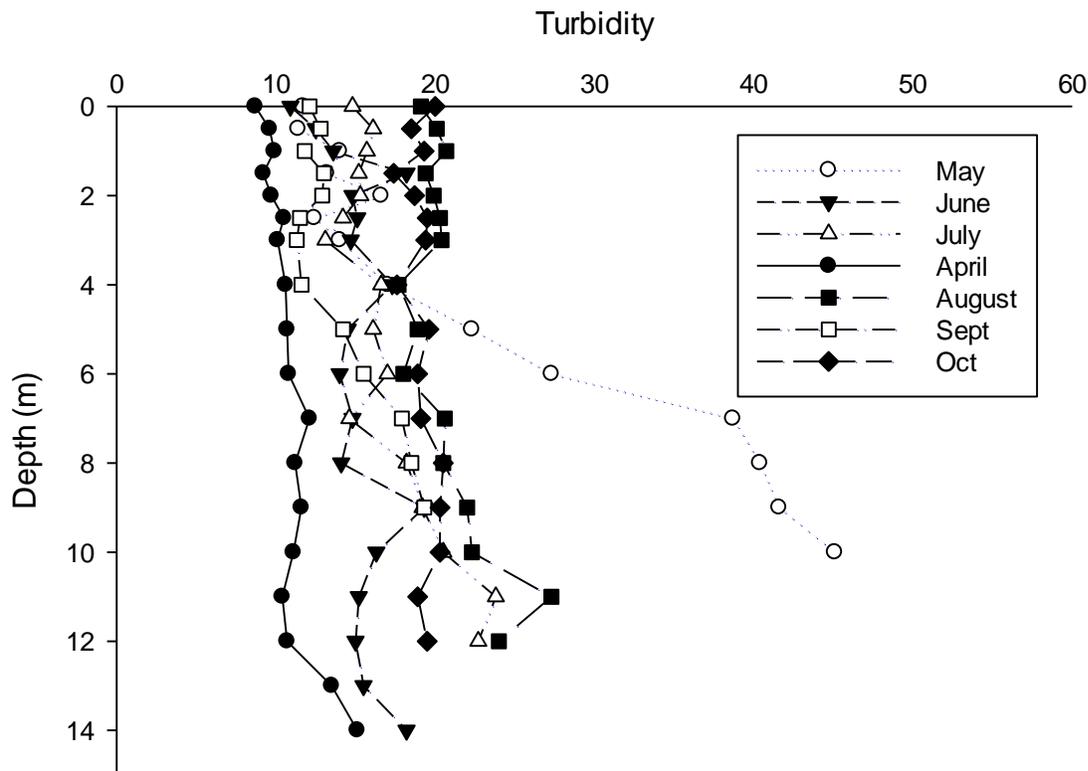
Figure 1.3.9. Dam (lacustrine) Turbidity (NTU) measures over study period (2025).

Seasonal Analysis

Turbidity patterns at the dam suggest most of the turbidity is from algal production. In general, turbidity is separated between algal and non-algal or sediment turbidity. The lower numbers < 20 NTU suggest algal turbidity is predominate at this station as much greater turbidities would be expected if sediment turbidity was predominant. May was the exception. Non-algal turbidity likely from Pigg River flow with confirmation of this from the conductivity data (Figure 1.2). Lower conductivity water is suggestive of Pigg River input.

Concerning turbidity along the vertical profile, stratification controls much of this pattern. In the upper and warmer layers, algae grow and give water its color and turbidity. Conversely and in the cooler lower layers, silt and sediment and particulates (non-algal) remain suspended and can resuspend due to density currents. Settling of particulates (non-algal) and growth of algal particles can generate similar turbidities throughout the water column while the measure of chlorophyll *a* shows a distinct pattern with much greater density in the upper water column because it is a direct measure of productivity rather than necessarily density. Yet at times (in May of this season) sediment turbidity flows from the upper reaches of the reservoir through the cooler and lower stratified layers following similar density gradients. This is what was observed this season.

Comparisons Across Years

Data in 2025 is consistent with patterns observed. Turbidity at this station follows Chlorophyll *a* production with the exception of high flow events.

Other Parameters Measured

Table 1.3.2. Other parameters measured over study period (2025). Dates represent sampling of both the volunteers and University of Lynchburg. First column represents each parameter with units of measure.

Time	16-Apr 10:27 AM	19-May 12:35 PM	17-Jun 8:55 AM	25-Jun 8:57 AM	18-Jul 10:45 AM	31-Jul 8:40 AM	18-Aug 9:45 AM	27-Aug 9:00 AM	22-Sep 10:50 AM	21-Oct 2:50 AM
Secchi (M)	2.20	1.40	2.2	2.3	1.8	2.00	1.9	1.80	2.20	1.45
TP Surface	0.101	0.028	0.032	0.055	0.016	0.021	0.02	0.024	0.012	0.015
Integrate Chl a	5.19	8.32	10.11		7.99		11.09		9.05	17.48
TSI S	49	55	49	48	52	50		52	49	55
TSI TP	67	50	52	59	43	47	46	48	40	43
TSI CHL	47	51	53		51		54		52	59
TSI AVG	54	52	51	53	49	48	50	50	47	52
Daphnia	2.02	0.91	2.43		0.00		9.71		0.00	2.43
Bosmina	19.82	10.21	0.00		0.00		6.87		0.40	1.62
Diaptomus	2.83	0.40	0.20		0.00		2.43		1.01	1.21
Cyclops	11.32	0.30	1.62		0.00		6.07		2.43	1.01
Naupaii	0.00	0.00	0.40		0.00		0.00		0.00	0.00
Cerodaphnia	0.00	0.00	0.00		0.00		0.00		0.00	0.00
Diaphanosoma	0.00	0.00	3.44		0.00		4.25		0.00	0.40
Leotodora	0.00	0.00	0.00		0.00		0.00		0.00	0.00
E. coli MPN	4.10	6.20	5.2	28.80	1	6.30	2	35.90	2.00	13.10

1.3.1.2 Leesville Lake Marina / Old Woman's Creek

Photograph of Leesville Lake Marina taken by Jade Woll.

Table 1.3.3. Leesville Lake Marina other parameters measured over study period (2025).

	16-Apr	19-May	17-Jun	25-Jun	18-Jul	31-Jul	18-Aug	27-Aug	22-Sep	21-Oct
Time	10:55 AM	12:48 PM	9:20 AM	9:12 AM	11:20 AM	8:15 AM	10:15 AM	9:20 AM	11:12	3:15 PM
Secchi (M)	1.60	1.40	1.7	2	1.5	1.80	1.3	1.60	1.40	1.60
(PPM)	0.021	0.131	0.023		0.015		0.027		0.008	0.037
TSI S	53	55	52	50	54	52	56	53	55	53
TSI TP	47	71	48		43		50		36	54
TSI AVG	50	63	50		48		53		46	53
E. coli	7.40	17.50	6.3	9.8	3.1	42.80	2	5.20	9.70	7.50

1.3.1.3 Tri County Marina

Photograph of Tri County Marina taken by Jade Woll.

Table 1.3.4. Tri County Marina other parameters measured over study period (2025).

	16-Apr	19-May	17-Jun	25-Jun	18-Jul	31-Jul	18-Aug	27-Aug	22-Sep	21-Oct
Time	11:06 AM	1:05 AM	9:30	9:26 AM	11:25	9:10 AM	10:20	9:35 AM	11:20	3:22 PM
Secchi (M)	1.40	1.10	1.8	1.3	1.4	1.60	1.5	1.50	1.80	1.40
TP Surface (PPM)	0.145	0.040	0.017		0.053		0.024		0.047	0.042
TSI S	55	59	52	56	55	53	54	54	52	55
TSI TP	72	55	44		58		48		57	55
TSI AVG	64	57	48		57		51		54	55
E. coli cfu/100ml	10.90	77.60	9.8	30.1	3.1	35.90	3	1.00	6.30	3.10

1.3.1.4 Mile Marker 6 (Transition)[1]

Background

In discussing water quality at the transition station (MM6), comparisons are made back to Lacustrine and Riverine portions of the lake. This section does not provide further discussions of the patterns observed at the Dam (Lacustrine) or Toler Bridge (Riverine), but to discern any trends the data provides on a spatial scale moving up or down the lake.

---

[1] *Photograph of Leesville Lake taken by Jade Woll*
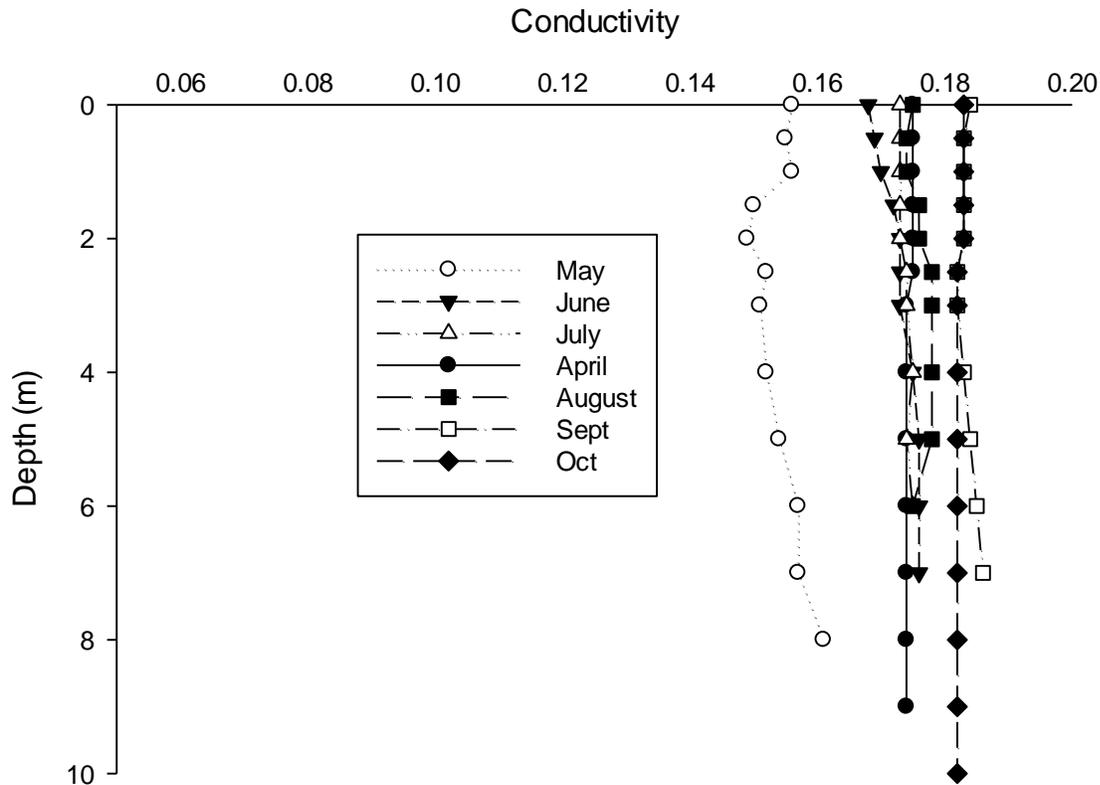
Conductivity

Figure 1.3.10. Mile Marker 6 (Transition) Conductivity (ms/cm) measures over study period (2025)

Seasonal Analysis

Conductivity patterns at the transition region are reflective of a mixed condition, i.e., a general absence of stratification as we see at the dam. This station is additionally more sensitive to input from Pigg River than is evident at the LVL dam, as travel distance is much shorter. This is evident in these data from 2025, where the conductivity in May was impacted by increased Pigg River flow at that time, while remaining sample dates reveal greater conductivities indicative of dominant tailwater influence.

Comparisons Across Years

Conductivity is a good predictor of water masses and movement in the reservoir. The complexity of this analysis occurs when water movement into the reservoir from the Pigg River and SML tail release mix and move below the entrainment evident in the upper portion of the reservoir.

31
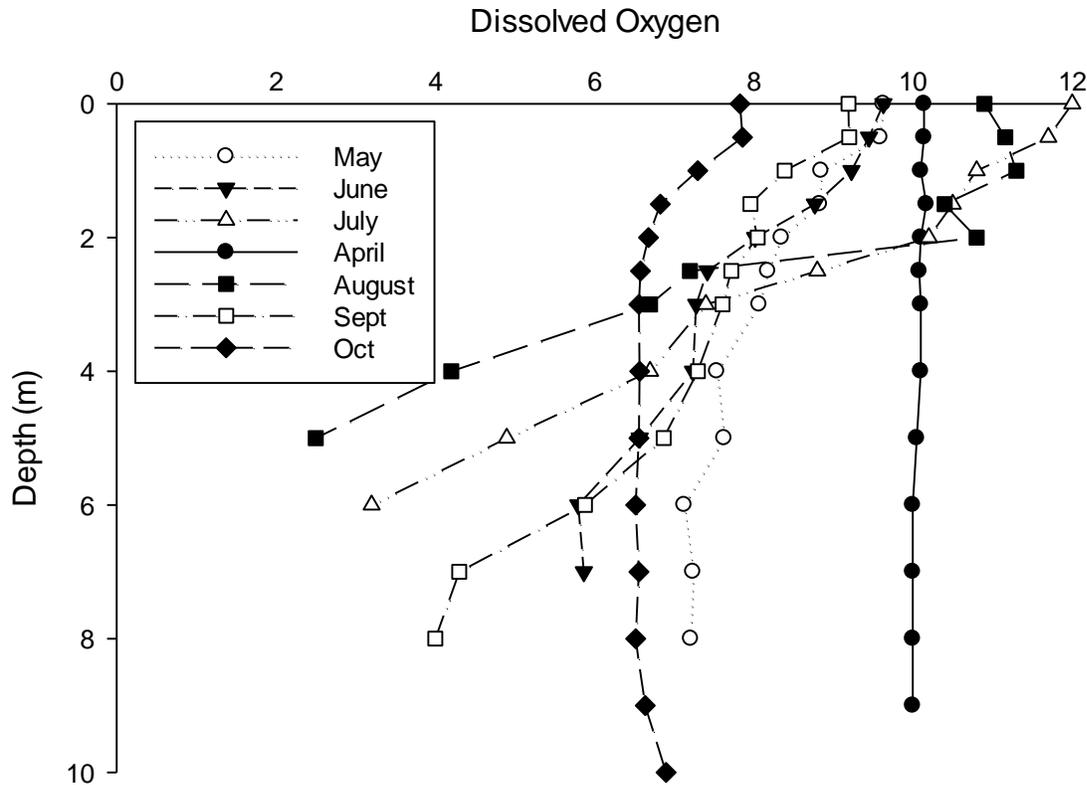
Dissolved Oxygen

Figure 1.3.11. Mile Marker 6 (Transition) Dissolved Oxygen (mg/L) measures over study period (2025)

Seasonal Analysis

This portion of the reservoir was stratified throughout the sampling season with the exception of April sampling. As in past seasons, we did not see an overall reduction in dissolved oxygen during the fall months. As this fall was extremely dry (total precipitation for September and October = 4.14 inches) a reduction of the volume of water from SML may have been a contributing factor. Loss of oxygen is rapid below 2 meters during the warmest summer months (June – August).

Comparisons Across Years

Oxygen observations are variable across seasons and within season with supersaturated conditions in the epilimnion and hypoxic and anoxic conditions apparent in the hypolimnion typical of eutrophic lakes. In some seasons, oxygen is very low throughout the water column during turnover while in other oxygen remains relatively high as in 2025.

32
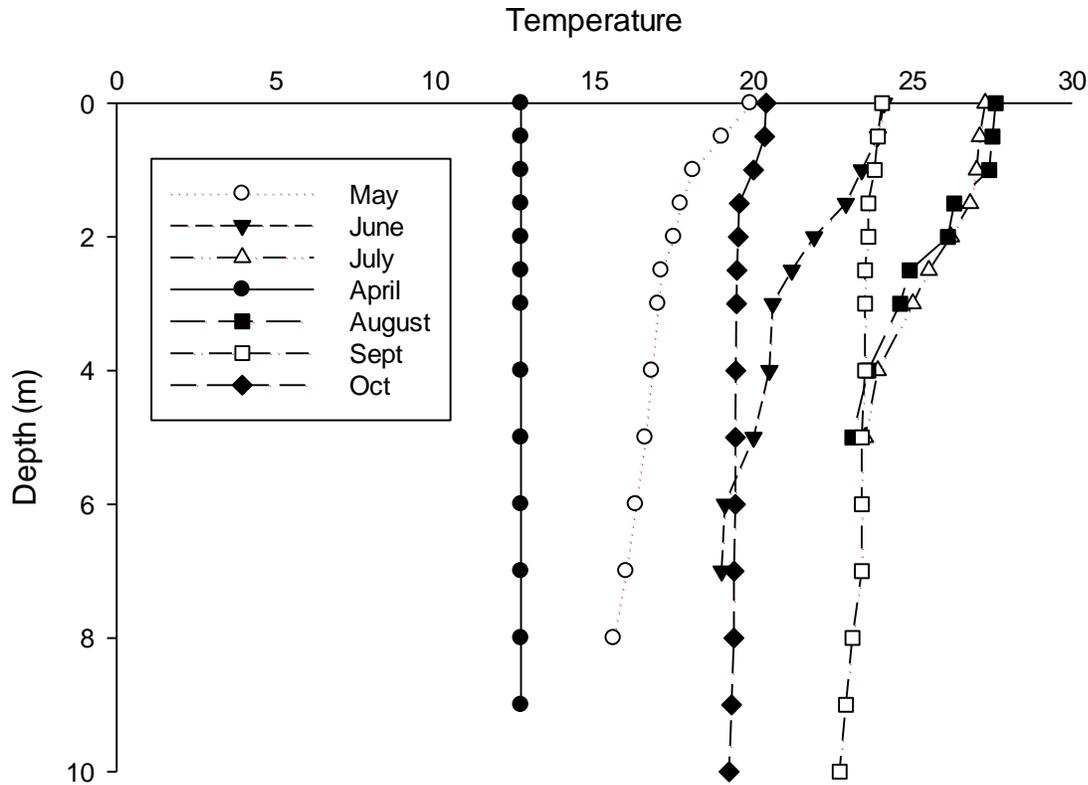
Temperature

Figure 1.3.12. Mile Marker 6 (Transition) Temperature (°C) measures over study period (2025)

Seasonal Analysis

Thermal stratification in this section of the reservoir is weak (subject to fluctuation and mixing due to weather and water movement). This is consistent with the previous observations of oxygen content. The benefit of this weak stratification is that it increases oxygen content, which has become a significant concern. Conceptually, this station is situated between the LVL dam (stronger stratification because of depth and restricted water movement) and Toler Bridge headwaters (limited stratification due to water movement from Pigg River and SML dam release).

Comparisons Across Years

The pattern of minimal stratification at this site is consistent across and within years. Thus, this station is a good example of a transition zone, influenced by both riverine and lacustrine forces.

Chlorophyll *a*
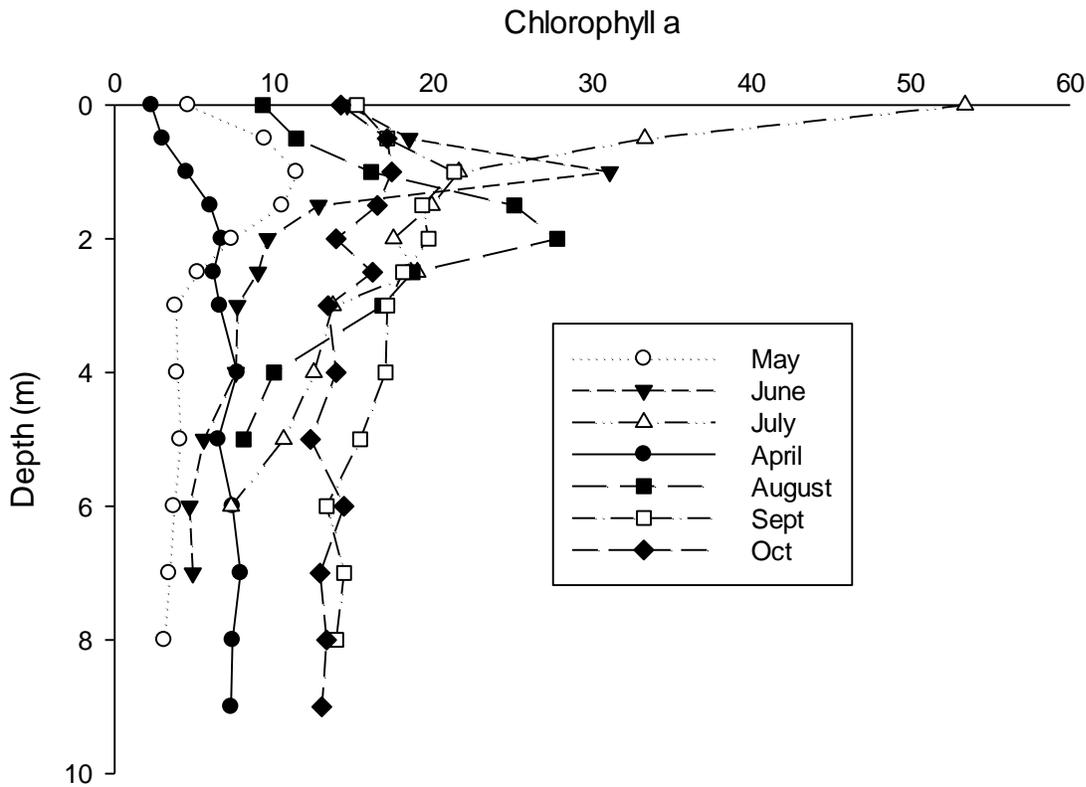
Figure 1.3.13. Mile Marker 6 (Transition) Chlorophyll *a* (ppb) concentrations over study period (2025)
Seasonal Analysis

The transition area is theoretically the portion of the reservoir where phytoplankton abundance measured by Chlorophyll *a* can be very high and may be the greatest in the entire reservoir. Nutrient input from the upper portions of the reservoir mixes with the warmer and slowly moving water mass to create ideal conditions for phytoplankton growth. This was observed this season as Chlorophyll a exceeded 50 ug/L in July. This amount of Chlorophyll a suggests hypereutrophy and is very concerning.

34

Comparisons Across Years

High peaks in phytoplankton biomass and pattern of growth above the thermocline are not consistently observed at this station across years. Typically, phytoplankton biomass is elevated throughout the water column from 2-5 meters depth and at concentrations of 20-30 ug/L. Chlorophyll *a* minimums may occur during flushing and turnover but respond and increase when conditions normalize (flushing stops and levels stabilize) and phosphorus is readily available.

pH
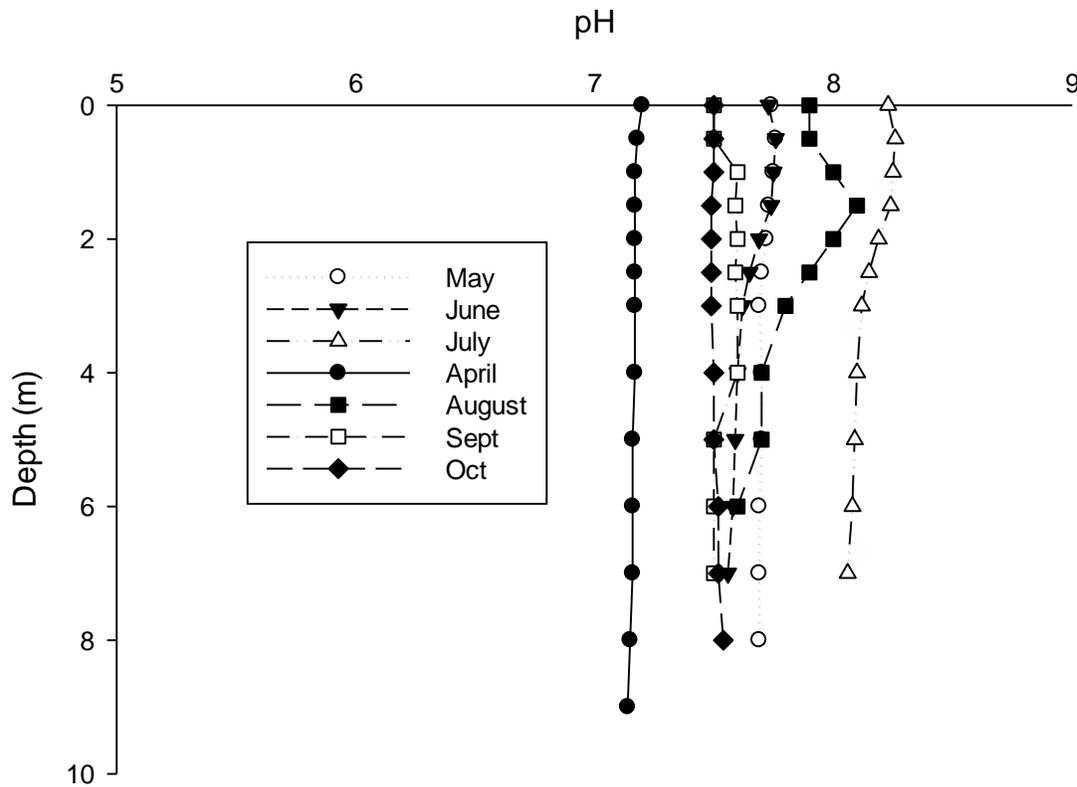
Figure 1.3.14. Mile Marker 6 (Transition) pH measures over study period (2025)

Seasonal Analysis

The seasonal pH pattern is very similar to that observed at the dam but the pattern of stratification in the reservoir is blunted at this station. Elevated pH does follow the pattern of Chlorophyll a with peak pH coinciding with high July chlorophyll.

35

Comparisons Across Years

This is a variable station and influenced by a multitude of factors. Readings generally reflect conditions that influence phytoplankton growth.

ORP
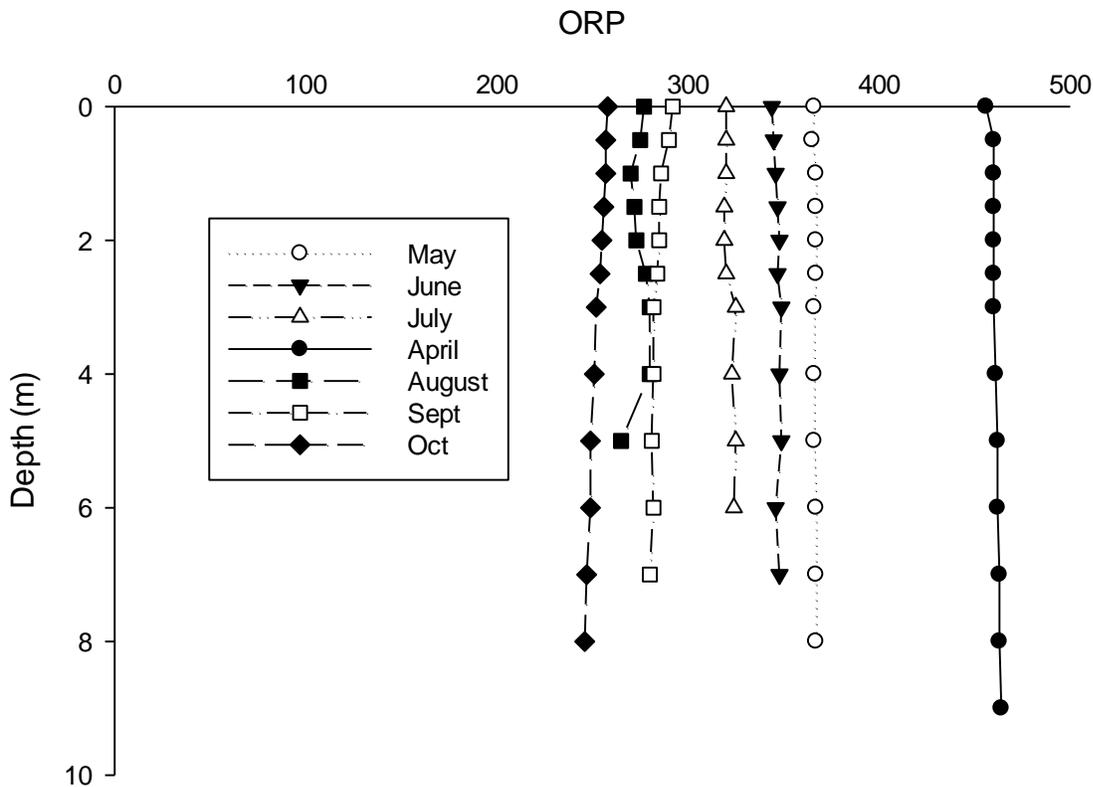
Figure 1.3.15. Mile Marker 6 (Transition) ORP (mV) measures over study period (2025)

Seasonal Analysis

Patterns of ORP at this station are similar to those observed at the dam. You might expect slightly more reducing conditions at the site (lower ORP) due to a greater influence from river inputs and this did occur in April. This measure is variable over the season reflecting tracking closely to temperature, as warmer water holds less oxygen.

36

Comparisons Across Years

ORP has been variable over multiple years at this station. Identifying specific factors that may have led to this trend is challenging; however, decreased ORP observed in recent years may indicate a decline in water quality. Still, observations in this year's sampling are in the expected range for this reservoir.

Nitrate
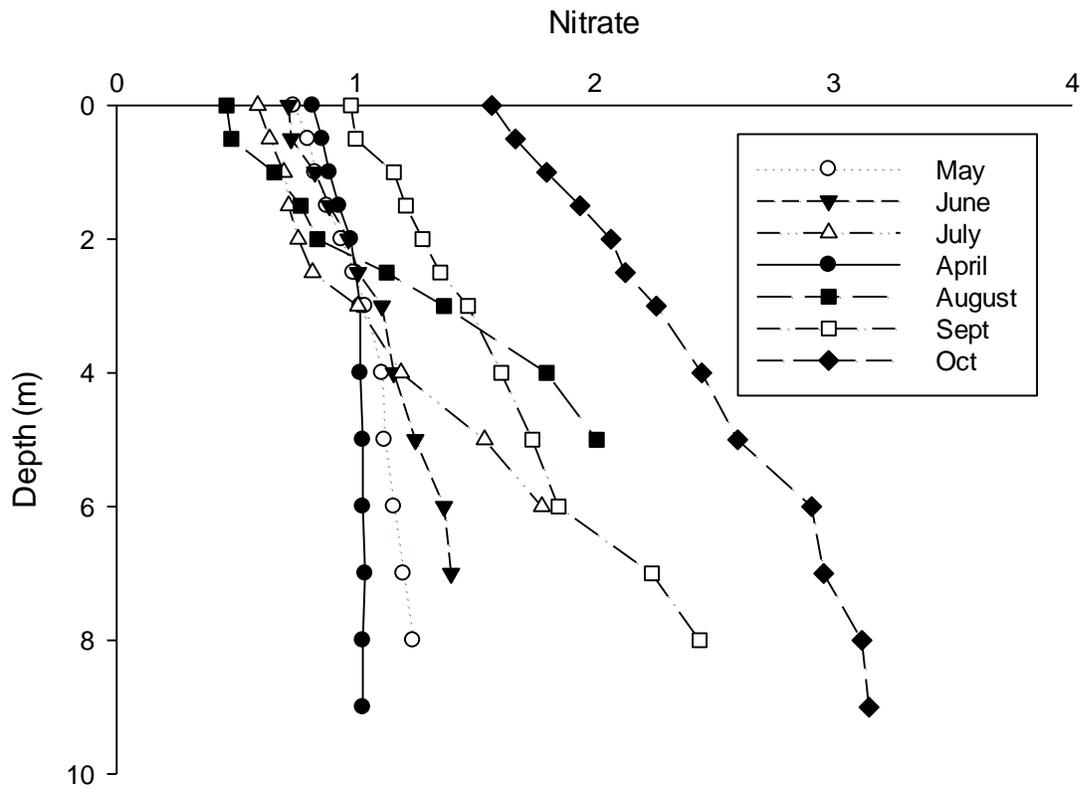
Figure 1.3.16. MM6 (Transition) Nitrate (mg/L) measures over study period (2025)

Seasonal Analysis

The pattern of nitrate concentrations at this site is very similar to that at the dam. As this station is closer to Pigg River and tailwater than the dam site, flushing may have a greater impact at this station even during dry periods. Because nitrate levels were lower than at the dam station this may be a plausible explanation. Regardless, nitrate levels were elevated at this station in the latter half of 2025.

Comparisons Across Years

Nitrate patterns consistent with those at the dam were observed here and throughout the reservoir.
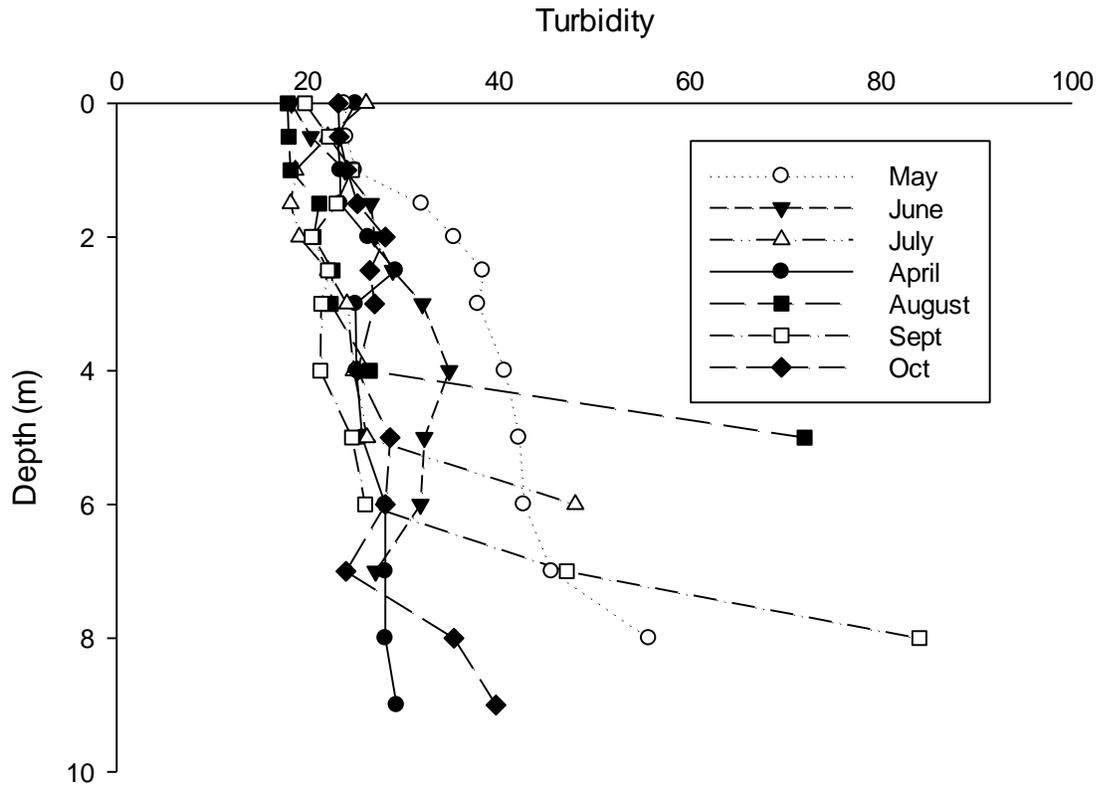
Figure 1.3.17. MM6 (transition) Turbidity (NTU) measures over study period (2025).

Other Parameters Measured

Table 1.3.5. Other parameters measured over study period (2025). Dates represent sampling of both the volunteers and university. First column lists each parameter measured along with units of measure. All TSI measures are unitless and zooplankton are in animal per liter.

	16-Apr	19-May	17-Jun	25-Jun	18-Jul	31-Jul	18-Aug	27-Aug	22-Sep	21-Oct
Time	11:15 AM	1:15 PM	9:42	9:35 AM	11:35 AM	9:20 AM	10:30 AM	9:45 AM	11:28 AM	3:30 PM
Secchi (M)	1.20	1.10	1.6	1.3	0.8	1.60	1.5	1.50	1.20	1.20
TP Surface (PPM)	0.033	0.049	0.031		0.096	0.081	0.038	0.012	0.053	0.079
Integrate Chl a (PPB)	6.12	5.87	11.46		20.88		15.92		16.82	14.50
TSI S	57	59	56	56	63	53	54	54	57	57
TSI TP	52	57	51		66	64	54	40	58	64
TSI CHL	48	48	55		60		58		58	57
TSI AVG	53	55	54	56	63	59	55	47	58	59
Daphnia	1.01	0.81	1.82		0.00		1.82		3.64	4.04
Bosmina	13.55	0.71	0.20		0.00		1.42		21.03	2.83
Diaptomus	8.09	0.40	0.40		0.00		2.83		0.61	9.30
Cyclops	4.45	0.20	1.01		0.00		0.40		2.43	2.02
Naupaii	0.00	0.00	0.61		0.00		0.00		2.22	0.00
Cerodaphnia	0.00	0.00	0.00		0.00		0.00		0.00	0.00
Diaphanosoma	0.00	0.00	5.66		0.00		5.66		3.03	1.62
Leotodora	0.00	0.00	0.00		0.00		0.00		0.00	0.00
E. coli MPN	118.70	163.20	3	35.00	4.1	12.10	6.1	4.10	5.20	1.00

1.3.1.5 Mile Marker 9 (Riverine)

Photograph of Leesville Lake taken by Jade Woll.

Table 1.3.6. Mile Marker 9 other parameters measured over study period (2025)

	16-Apr	19-May	17-Jun	25-Jun	18-Jul	31-Jul	18-Aug	27-Aug	22-Sep	21-Oct
Time	11:40 AM	1:40 PM	10:09	9:45 AM	12:03	9:35	10:50	10:02 AM	11:50	4:00 PM
Secchi (M)	1.60	0.70	1.2	1	0.4	1.20	1.1	1.20	1.40	1.25
TP Surface	0.042	0.131	0.1835		0.241		0.048		0.073	0.123
TSI S	53	65	57	60	73	57	59	57	55	57
TSI TP	55	71	75		79		57		63	70
TSI AVG	54	68	66		76		58		59	63
E. coli	118.70	312.00	4.1	77.6	231	35.00	5.2	8.50	7.50	5.20

1.3.1.6 Toler Bridge (Riverine)[2]

Background

Riverine conditions as well as influx of tail waters of Smith Mountain Lake and influx of Pigg River water heavily influence waters at the Toler Bridge station. We see a combination of the water qualities from Pigg River discharge and SML hypolimnion release. The resulting water quality is completely driven by hydrological dynamics of the SML Dam (a mechanistic event) with river flow from the Pigg River (a stochastic event) thus creating a very dynamic system that is challenging to interpret.

---

[2] *Photograph of Toler Bridge taken by Jade Woll.*

Conductivity
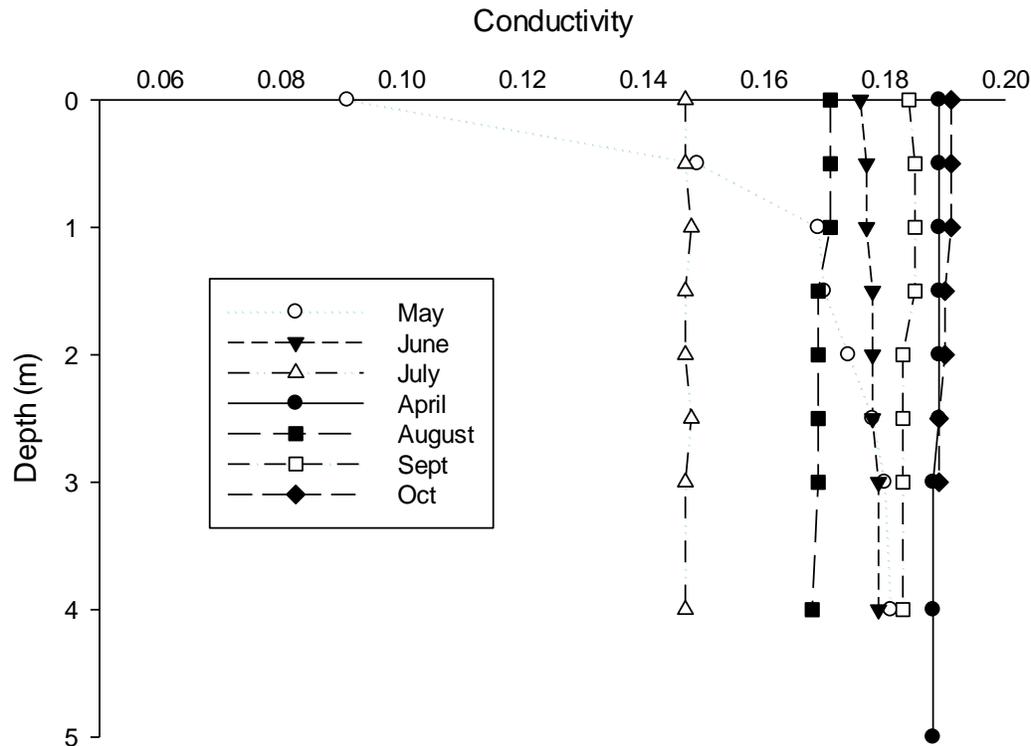
Conductivity

Figure 1.3.18. Toler Bridge (Riverine) Conductivity (ms/cm) measures over study period (2025).

Seasonal Analysis

Conductivity in this portion of the reservoir is usually consistent (minimal change) from top to bottom unless pumping conditions or heavy flow from the Pigg River occasionally produces stratification. However, such stratification was not observed in 2025. Water quality at this site during May and July was impacted heavily by water input from Pigg River. While the influence of Pigg River input on conductivity in May was detected throughout the reservoir, the decreased conductivity observed here in July was limited to the upper sections of the reservoir. Other conductivity measures were consistent with the remainder of the reservoir (between 0.17-0.19).

Comparisons Across Years

Observations of conductivity at this station over time demonstrate that SML release is the predominate controlling hydrology in the headwaters of LVL. Only during certain periods of time (most likely driven by stormwater flow) does the Pigg River contribute enough water to influence readings at this station. When Pigg River flow impacts water quality, these impacts may be isolated to this area or may be observed further down the reservoir depending on conditions.

Dissolved Oxygen
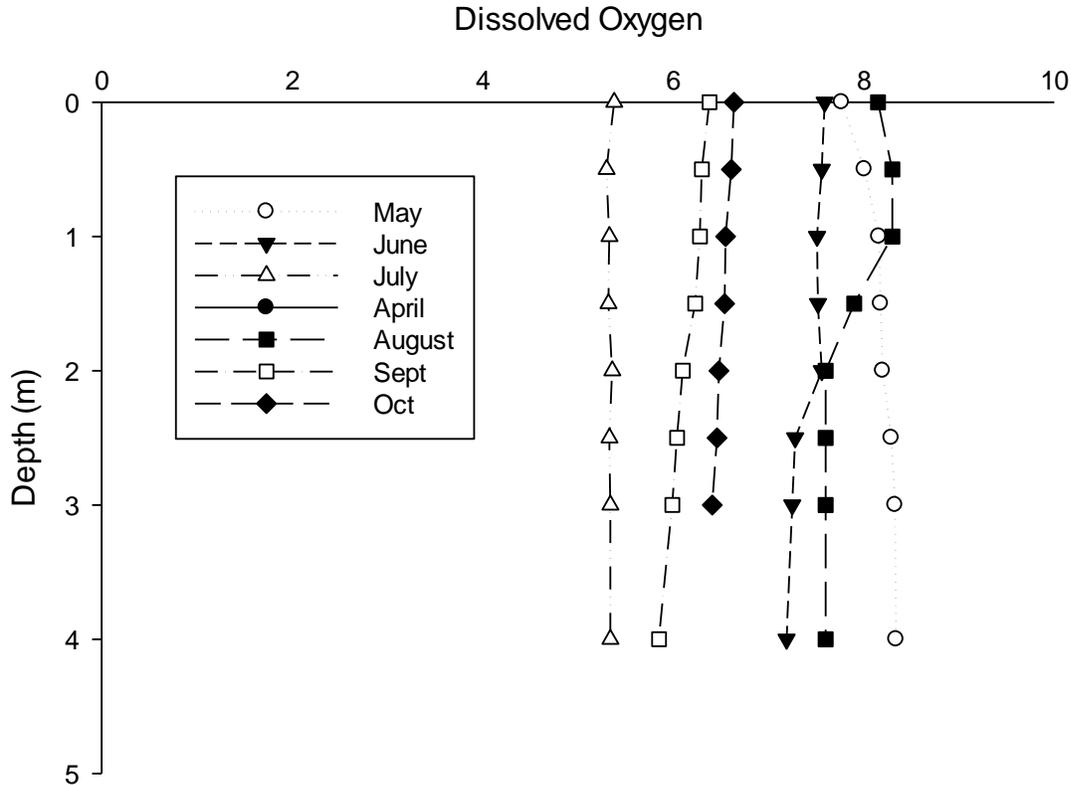
Figure 1.3.19. Toler Bridge (Riverine) Dissolved Oxygen (mg/L) measures over study period (2025)

Seasonal Analysis

Dissolved oxygen here is often a reflection of SML release but can be elevated due to Pigg River input if mixing occurs. Yet in some instances, Pigg River oxygen content is low as observed this season in July. It is unclear what is contributing to the low oxygen content from Pigg River as observed in July. Otherwise this station oxygen content maintained levels above 5 mg/L even in the late fall.

Comparisons Across Years

Dissolved oxygen at this station is a function of water release from SML and operations such as the lowering of water levels and input from Pigg River. When conductivity is elevated, dissolved oxygen is low however as observed in 2025 and a few instances in the past Pigg River water can be low in oxygen. This may be a function of water flow as tailwater when released under lower flow conditions will flow up into the Pigg River as far as Toshes Road (personal observations). In the later months of the season, dissolved

42

oxygen levels typically fall below 5 mg/L. Tailwater release (and at times Pigg River input) have a very strong impact on water quality at this station.

Temperature
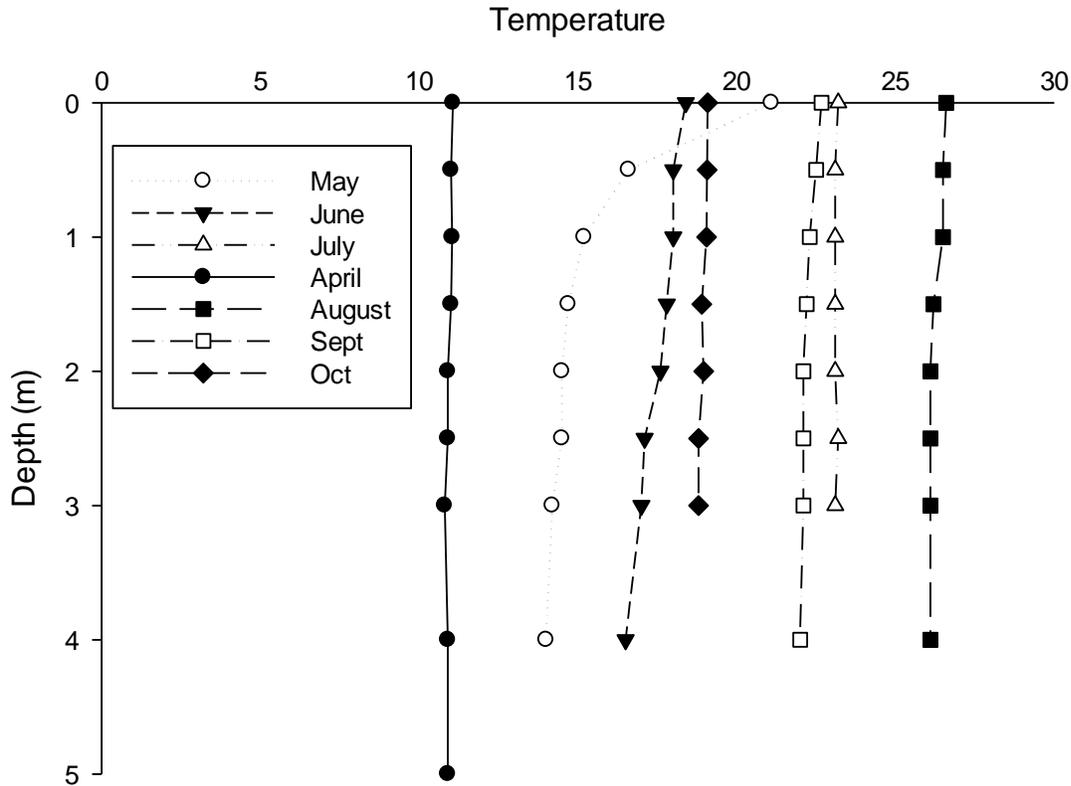
Temperature

Figure 1.3.20. Toler Bridge (Riverine) Temperature (°C) measures over study period (2025)

Seasonal Analysis

This station does not stratify (or minimally as observed in May) because of water release and pumpback. The water movement is frequently too strong to allow the water enough time to develop layers, although during periods of operation where electricity demand is low this may occur due to limited water movement. This station tends to be cooler than the main stem of the reservoir due to SML release from the hypolimnion.

Comparisons Across Years

Lack of stratification at Toler Bridge is consistently observed across the years. Water flow from SML causes constant movement of the water at this station, limiting the opportunity for stratification. We usually see this only during the spring months. During the summer, electricity demand and typically lower stormwater flow set up

43

conditions for extensive water movement from pump back and release in LVL headwaters.

Chlorophyll *a*
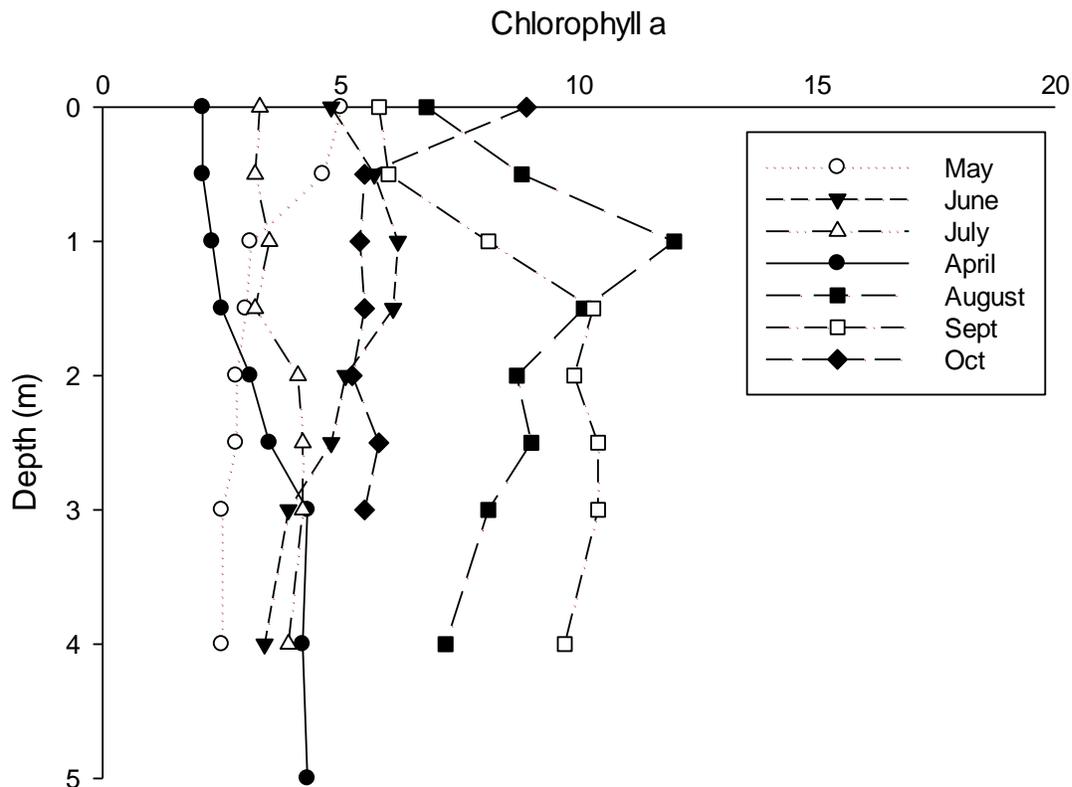
Figure 1.3.21. Toler Bridge (Riverine) Chlorophyll *a* (ppb) concentrations over study period (2025)

Seasonal Analysis

This station typically contains the lowest readings of phytoplankton biomass throughout the entire reservoir. And the pattern in this portion of the reservoir are driven by water movement. Chlorophyll *a* is relatively low and even during low precipitation periods as observed in 2025 August-October productivity at this station remained low - as opposed to conditions at stations lower in the reservoir.

Comparisons Across Years

Growth of phytoplankton in this area is completely dependent on flow and movement of water and is usually low. In some seasons we can detect a buildup and increase in

Chlorophyll *a* during the summer months, yet increased phytoplankton biomass is quickly reduced or mitigated due to the impact of hydrology.

pH
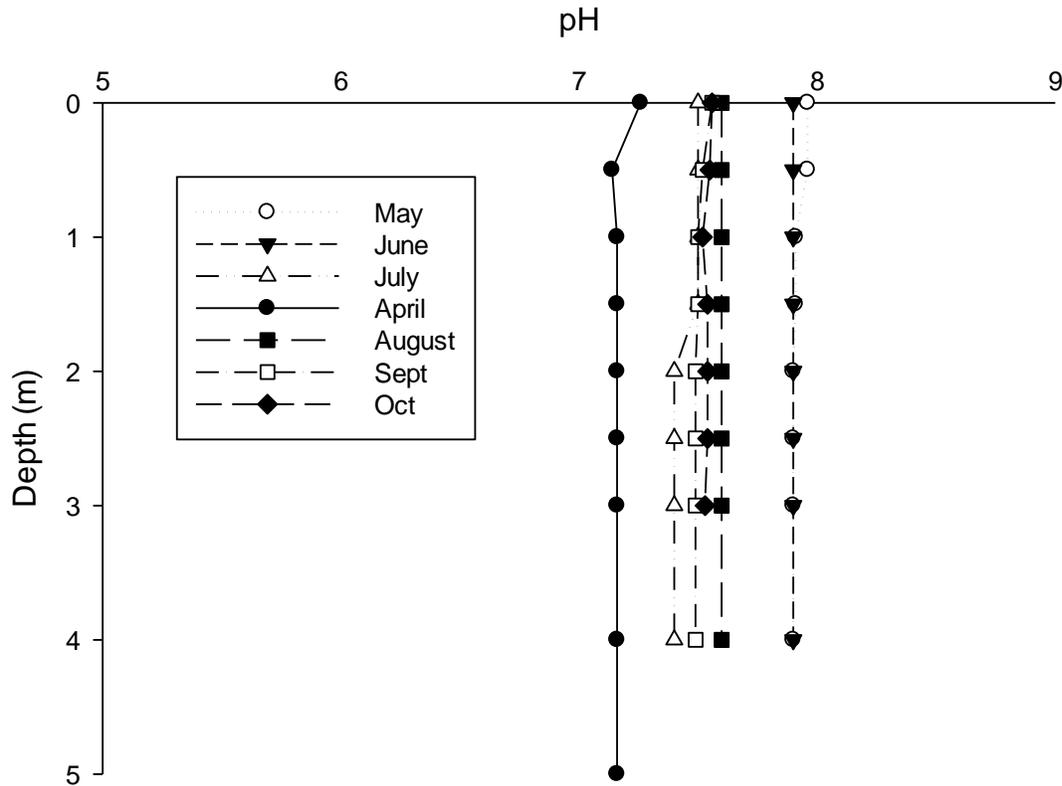
Figure 1.3.22. Toler Bridge (Riverine) pH measures over study period (2025)

Seasonal Analysis

The pH at this station is strongly influenced by water flow and reflects the chemical constituents in the water rather than phytoplankton productivity. Water movement may push water with higher pH readings into this area from LVL but more likely it is driven from the mix of Pigg River and SML tailwaters. While phytoplankton productivity may be lower, pH can remain elevated until acid – base chemistry equilibrates.

Comparisons Across Years

The pH at this station can exceed a pH of 8 as was observed in April but typically does not. It is hard to pinpoint the cause, as these higher readings do not correlate well with observed Chlorophyll *a* concentrations. Without knowledge of pH in SML or the exact movement of water between the two reservoirs it is difficult to predict this pattern.

45

Nevertheless, in all instances pH elevation is lower than observed downstream in the lake where readings may exceed 9.

ORP
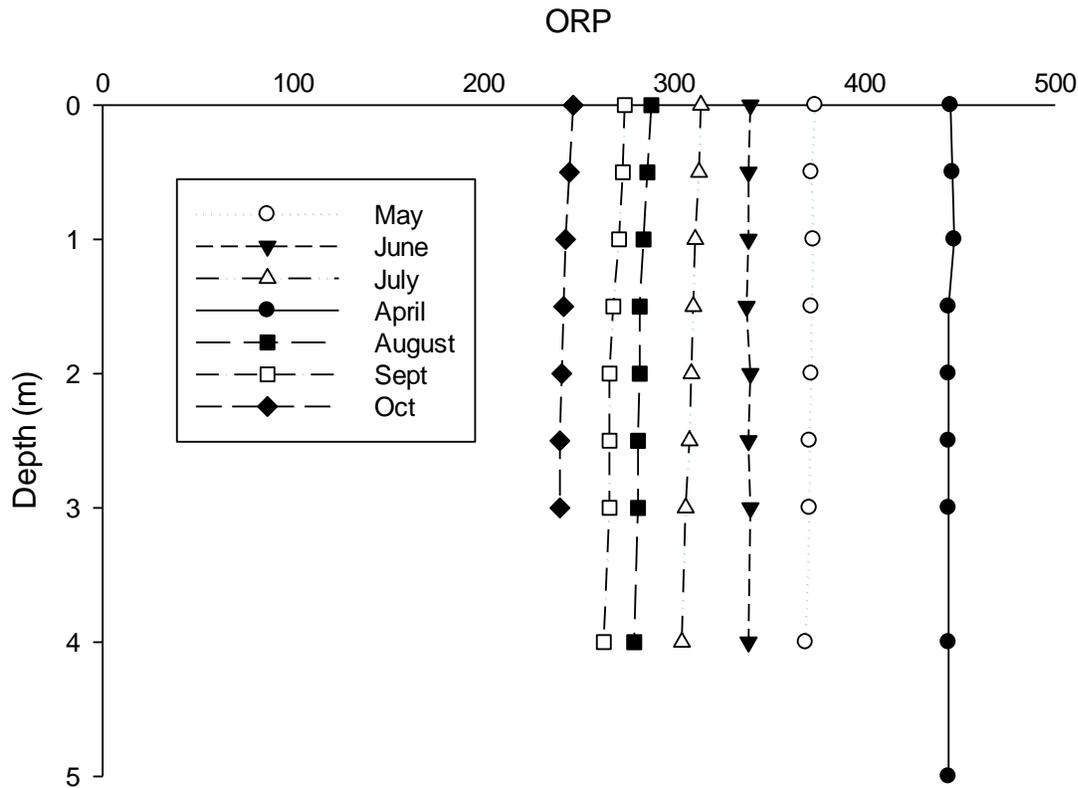
Figure 1.3.23. Toler Bridge (Riverine) ORP (mV) measures over study period (2025)

Seasonal Analysis

The ORP measures in this section of the reservoir do not provide any new interpretation between stations and the increased measures in June are discussed in MM6 section. Importantly, we do not observe reductions in ORP here creating concerns for reduced rather than oxidized conditions.

Comparisons Across Years

ORP is generally between 250 – 500 mV at this station. Some exceptions to this pattern have occurred but return to this range in the following season. ORP remains in a favorable range for the reservoir.
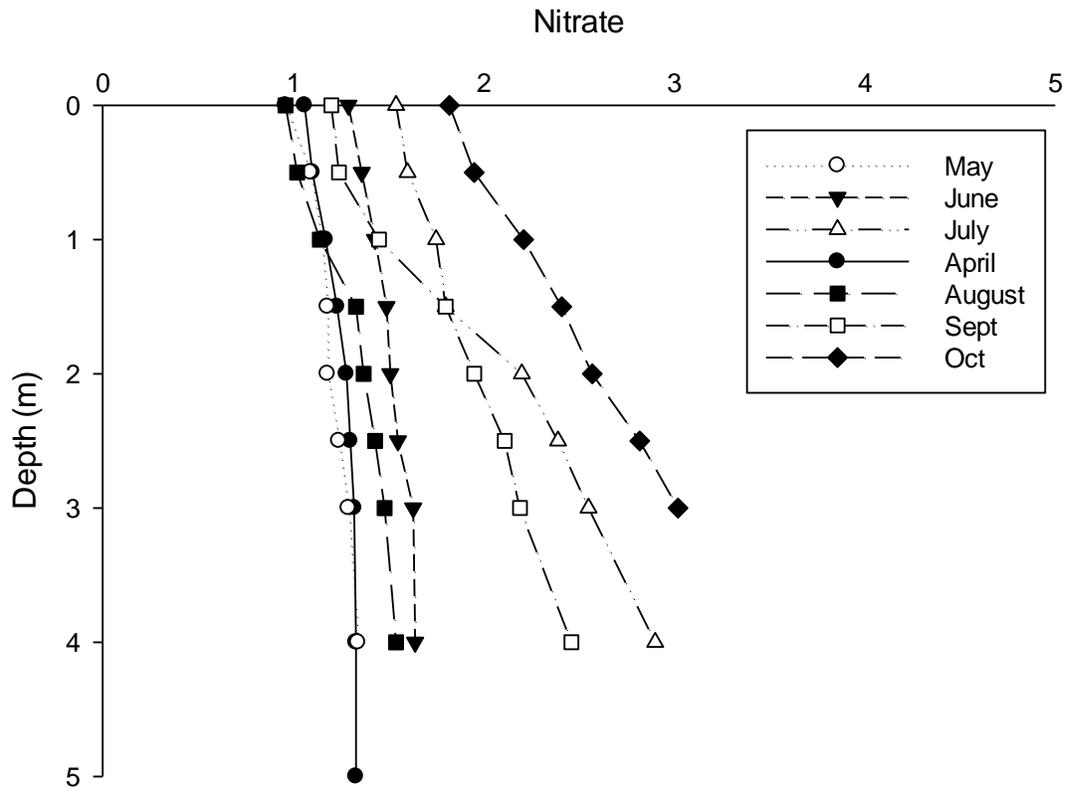
Nitrate

Figure 1.3.24. Toler Nitrate (mg/L) measures over study period (2025)

Seasonal Analysis

Nitrate patterns suggest greater availability during April and June. This is clearly driven by water movement rather than lake dynamics as suggested at the other portions of the reservoir. The concentrations observed were lower compared to other sections of the reservoir, likely due to reduced nitrogen release from the SML dam.

Comparisons Across Years

More data on Nitrate is needed for yearly comparisons.
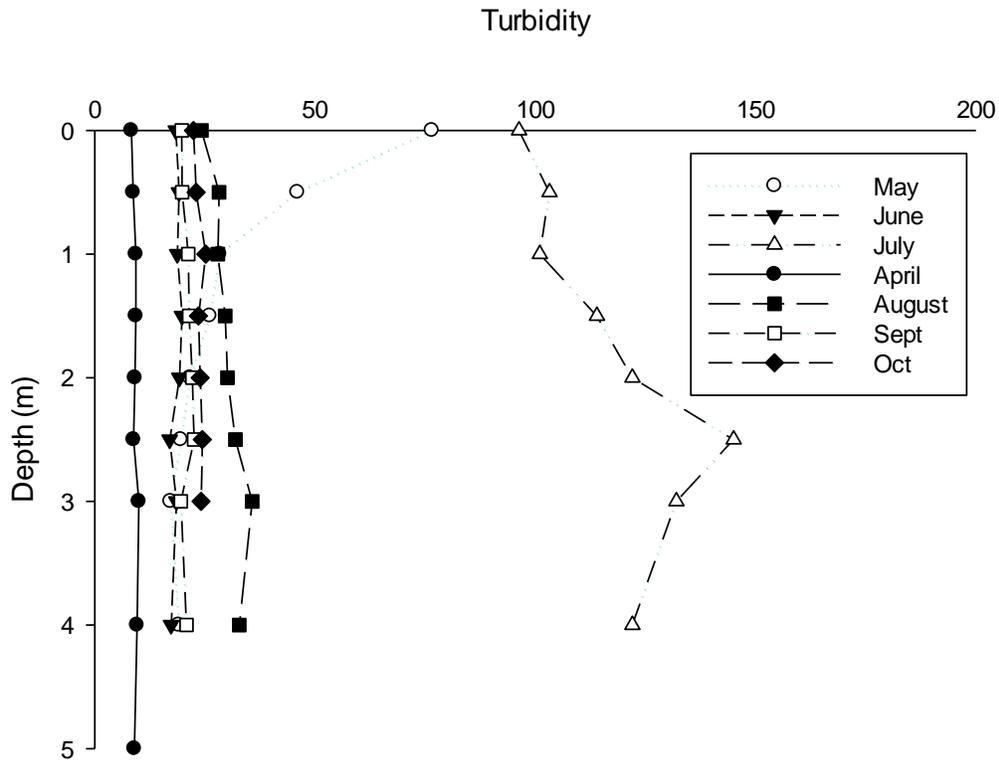
Turbidity

Figure 1.3.25. Toler Bridge (Riverine) Turbidity (NTU) measures over study period (2025). Other Parameters Measured

Table 1.3.7 Other parameters measured over study period (2025). Dates represent sampling of both the volunteers and university. First Column represents each parameter measured along with units of measure.

	16-Apr	19-May	17-Jun	25-Jun	18-Jul	31-Jul	18-Aug	27-Aug	22-Sep	21-Oct
Time	11:50 AM	1:50 PM	10:15 AM	9:58 AM	12:10 PM	9:55 AM	11:00 AM	10:20 AM	11:55 AM	4:05 PM
Secchi (M)	2.50	0.40	1.5	0.8	0.3	1.20	1.3	1.60	1.50	1.50
TP Surface (PPM)	0.023	0.138	0.004	0.026	0.135	0.026	0.044	0.031	0.021	0.035
Integrate Chl a (PPB)	3.16	3.29	5.00		3.70		8.84		8.83	5.98
TSI S	47	73	54	63	77	57		53	54	54
TSI TP	48	71	30	49	71	49	56	51	47	53
TSI CHL	42	42	46		43		52		52	48
TSI AVG	45	62	44	56	64	53	54	52	51	52
E. coli MPN	25.60	455.00	10.9	64.00	203	38.80	7.3	3.10	8.40	17.10

1.3.1.7 Pigg River

Photograph of Pigg River taken by Jade Woll.

Table 1.3.8. Pigg River other parameters measured over study period (2025). Measures are integrative throughout the entire water column. Profile data located in the appendix.

	16-Apr	19-May	17-Jun	25-Jun	18-Jul	31-Jul	18-Aug	27-Aug	22-Sep	21-Oct
Time	12:00 PM	2:05 AM	10:05 AM	10:06 AM	12:20 PM	10:05 AM	11:20 AM	10:30 AM	12:15	4:23 PM
Secchi (M)	0.60	0.30	0.2	0.5	0.1	0.70	0.6	0.80	0.80	0.80
TP Surface (PPM)	0.072	0.237	0.017	0.079	0.376	0.072	0.077	0.049	0.075	0.101
TSI S	67	77	83	70	93	65	67	63	63	63
TSI TP	62	79	44	64	86	62	63	57	63	67
TSI AVG	65	78	64	67	89	64	65	60	63	65
E. coli cfu/100ml	285.10	663.00	1850	1006	512	307.60	185	123.60	69.75	58.60
Temp C	14.27	21.2			23.3		26.9		23.5	16.57
DO mg/L	9.66	7.7			5.86		7.3		8.7	9.5
DO%	96.30	90.20			20.80		93.80		101.90	100.90
Turbidity (NTU)	34.7	117.9			373.6		70.3		39.5	44.2
Conductivity	0.102	0.068			0.129		0.094		0.095	0.107
pH	6.9	7.7			7.2		7.3		8.5	7.45
ORP	445	379			327		347		281	305
CHL (ug/L)	3.3	4.9			4		2.7		7.83	24.5
NO3 mg/L	4	2.7			2.63		1.37		0.96	2.49
Enterococci	520	850	5172	2723	1714	7270	1336	2720	3076	1576
E. coli/Entercocci	0.55	0.78	0.36	0.37	0.30	0.04	0.14	0.05	0.02	0.04

1.3.1.8 Smith Mountain Lake Tail Waters

Table 1.3.9. Smith Mountain Lake Tail Waters other parameters measured over study period (2025). Measures are at the surface.

	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
Time	12:07 PM	2:20 AM	10:05 AM	12:35 PM	11:30 AM	12:30 PM	4:35 PM
Secchi (M)	2.50	2.50	DNS	2.6	1.7	2.40	1.6
TP Surface (PPM)	0.010	0.028		0.016	0.02	0.008	0.011
TSI S	47	47		46	52	47	53
TSI TP	38	50		43	46	36	39
TSI AVG	42	48		45	49	42	46
E. coli cfu/100ml	26.20	10.90		20.1	10.9	10.90	10.9
Temp C	10.8	15.1		19.3	24.17	20.8	19.33
DO mg/L	10.76	8.5		5.7	6.87	4.42	6.29
DO%	97.7	86.9		63.1	83.5	50.6	70.2
Turbidity (NTU)	7.3	11.2		11.6	4.1	16.2	17
Conductivity (ms/cm)	0.187	0.185		0.188	0.174	0.193	0.196
pH	7.4	7.76		7.4	7.3	7.56	7.39
ORP	425	343		373	295	300	0
CHL (ug/L)	2.15	1.7		1.5	4.5	1.97	4.23
NO3 mg/L	1.3	1.25		1.27	1.85	0.74	2.46

51

Section 2: Lake-Wide Trends

The purpose of this section is to look at the functioning of the reservoir and establish trends. These trends are important to give a trajectory of lake health and allow us to manage the lake for optimum water quality. These trends are based on collected water quality parameters over the entirety of this study, and their compilation into trophic state indices (TSI) and other predictive indicators help track the health of the lake. The use of these indices allows ease of comparison among known parameters for lake and reservoir function and facilitates the translation of raw data into a usable management tool. As with any index, confounding parameters may, at times, reduce the value of a given index necessitating alternate interpretations and hypotheses. However, within the science of limnology (the study of lakes), use of indices is widespread and offers good explanations. There are 3 main categories under TSI; eutrophic, mesotrophic, and oligotrophic. Eutrophic lakes are highly productive and concentrated in nutrients; mesotrophic lakes experience moderate productivity and have lower nutrient levels; oligotrophic lakes have little productivity and low nutrient levels. When the TSI value is greater than 51, lakes are classified as eutrophic. Eutrophic lakes can be plagued by low water clarity, loss of oxygen in the hypolimnion, high sediment turbidity and high nutrient levels. This stimulates an abundance of algae growth and even noxious forms throughout the summer months. Excessive eutrophication is to be avoided. A TSI > 61 is considered excessive. Water has more clarity in oligotrophic and mesotrophic lakes, low concentrations of algae and typically an abundance of oxygen throughout the water. This is a desired state in management of a lake.

2.1 Analysis of Trophic State[3]

In this analysis, trends of all the measurable trophic state indices (TSI) are evaluated for all of the sampling data collected during this project. The usefulness of this is many-fold. First, we can examine several parameters that are used to predict TSI or lake

---

[3] *Photograph of Leesville Lake taken by Jade Woll*

health (Carlson 1977). The use of multiple parameters always strengthens any scientific investigation. Second, each parameter measured provides a predictor based on differing influences within the reservoir. Secchi depth is influenced by both sediment input and phytoplankton growth, whereas total phosphorus (TP) simply reflects the concentrations of this limiting nutrient but also dynamics within the reservoir. Additionally, Chlorophyll *a* concentration reflects use of TP for phytoplankton growth within the limitations of shading (sediment inputs) and grazing by zooplankton (*Daphnia* abundance). It is interesting and useful to note how each parameter (Secchi Depth, TP and Chlorophyll *a*) differs in predictive power. While the parameters evaluated may yield TSI that differ quantitatively, often the predictions are within similar ranges. We are also interested in trends over time. The trends observed lead to conclusions about how the reservoir is changing over time. These observations will guide our management decisions and conclusions as well as future work.

It is important to understand sediment input in this reservoir and how it may influence trophic state. Within reservoirs of the southeastern United States, sediment input constantly occurs. While sediment consists of many forms, clay is the predominate component in this region. Clay is problematic for many reasons. First, it stays in suspension for extended periods of time. Secondly, it binds with phosphorus helping to transfer this nutrient into reservoirs and depositing it into the sediments causing long term problems. It also competes for phosphorus and shades select species of phytoplankton. While lowering phytoplankton growth can be beneficial, clay often limits desirable forms of plankton and replacing them with undesirable species.

In this analysis we use the three main stations in the reservoir for ease of comparison: Dam, MM6 and Toler Bridge. Evaluation of water quality at these sites provides an overview of the spatial pattern from the headwaters to the dam. Reservoirs are typically most productive (eutrophic) in the headwaters with decreasing productivity near the dam. Mid stations in a reservoir (MM6 for Leesville Lake) reflect an area of mixing. This is the portion of the reservoir where the river flow (area higher in sediment and nutrients with greater input of water and water movement) meets the lake portions (area low in sediment and nutrients with very slow water movement). This area can be highly productive due to a multitude of factors.

Leesville Lake is unique due to headwater input from Smith Mountain Lake (a slightly eutrophic reservoir) and the Pigg River (a highly timbered and agricultural developed watershed). This unique combination has a very profound impact on water quality. This trophic state analysis (Section 2.1), precipitation and Pigg River inputs (Section 2.2), predictions of mid-summer chlorophyll peak (Section 2.3) and SML oxygen loss (Section 2.4) explore this unique relationship in the context of Leesville Lake water quality. We try to quantify these inputs and speculate on impacts. This leads to our management recommendations.

Secchi Depth TSI
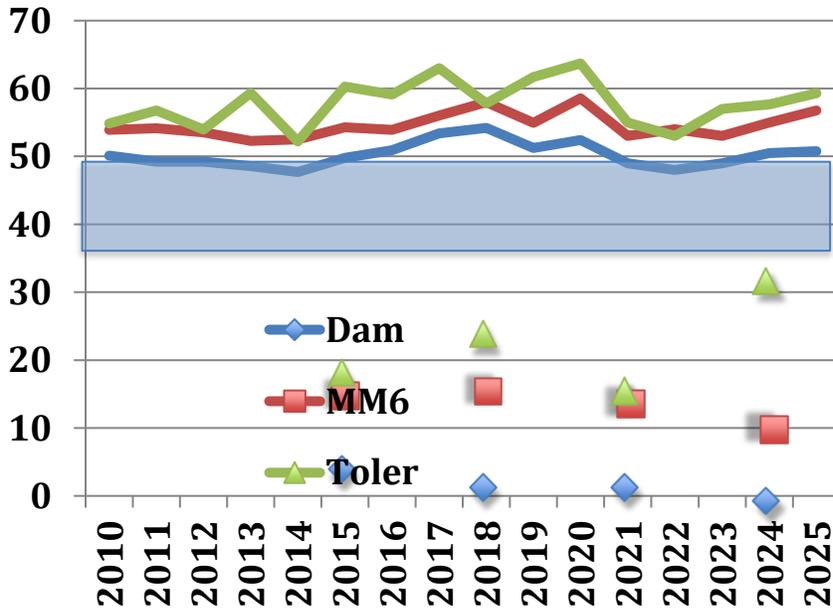
Figure 2.1. Trophic State Index (TSI) based upon Secchi disk (meters) measurements in Leesville Lake from 2010-2025. Y-axis reflects the calculated TSI for each of the three primary sampling stations throughout the reservoir. The shaded box represents the mesotrophic range for TSI where below this range is oligotrophic conditions and above represents eutrophic conditions.

Analysis

In 2025, predictions of trophic state using Secchi depth suggested LVL water clarity, while showing slight variations, is trending toward worsening (Figure 2.1). This trend has occurred previously with decreasing clarity from 2016 until 2021 when conditions improved (Table 2.1). The pattern where Secchi Depth improves (2010-2015) then worsens ((2016-2020) and then improves (2012-2025) may be repeating again.   By comparison to Chlorophyll *a* trophic state (Fig 2.3) and TP TSI (Fig 2.2), this is the only parameter that may be slightly increasing over the past 5 years in the lake.

Table 2.1 – Analysis of previous 15 years of Secchi TSI data showing mean measures and standard error for each 5-year block of time.

Dates	TSI Secchi	Standard Error
2010-2015	52.93	0.83
2016-2020	56.59	1.06
2021-2025	53.40	1.05

54

When comparing the Secchi depth TSI from the headwaters (Toler Bridge) to the Dam we see a very distinct pattern. Toler Bridge is expected to have the most eutrophic waters based on Secchi measurements, with increasing clarity and improved TSI moving down lake to the dam. But this trend is variable and driven by two competing factors. Water from SML tail water release can be extremely clear even to the point of oligotrophic. Pigg River on the other hand can be very turbid to the point of hypereutrophy. Often what we see here is the predominance of tail release over Pigg River inputs. With the addition of 2025 data, these trends appeared consistent as we have observed in the past. Toler Bridge and MM6 are very similar in clarity with increasing clarity at LVL dam.

Total Phosphorous TSI
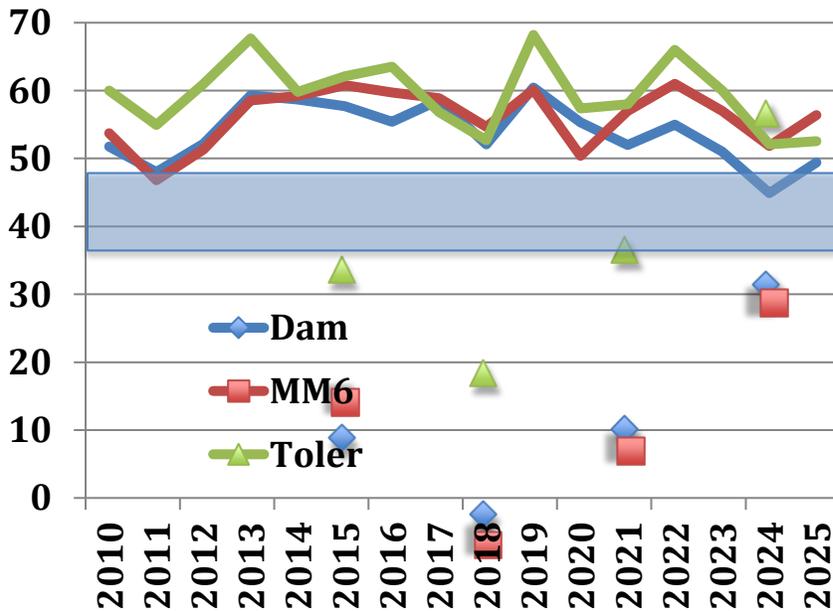
Figure 2.2. Same as Figure 2.1 but TSI based on Total Phosphorus (TP).

Analysis

By contrast to the Secchi-based TSI, trends in TP show decreasing TSI or improving conditions (Fig 2.2). Because water flow is very controlling this may be a reflection of water input and a predominance of SML Dam release which contains much less TP than the Pigg River. This index does show greater variability with MMG and Toler Bridge stations fluctuating. This suggests again the SML tailwater and Pigg River inputs are variable in impact depending upon conditions and most importantly precipitation and flow.

Chlorophyll *a* TSI
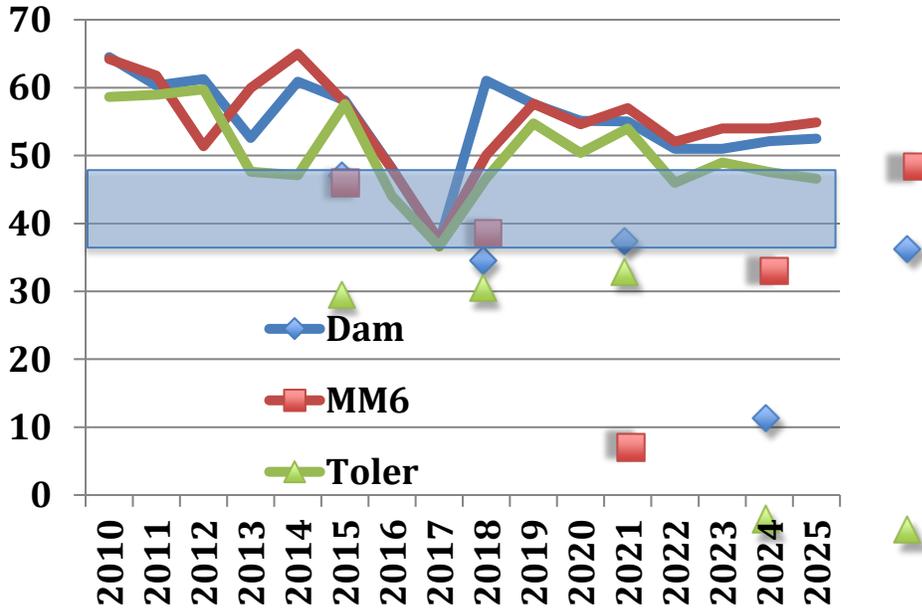
Figure 2.3. Same as Figure 2.1 but TSI is based on Chlorophyll *a*.

Analysis

Trophic state based upon Chlorophyll *a* has been relatively stable since 2018. TSI Chlorophyll *a* (Figure 2.3) continues to suggest the lake is slightly eutrophic with lowest readings occurring at Toler Bridge. The latter is is a reflection of SML tailwater and Pigg River inputs, both of which have relatively low algal content. MM6 contains the highest chlorophyll content, which is expected based on the nature of the transition station. Chlorophyll *a* in Leesville Lake is much more responsive to flushing and water movement than TP concentrations.

TSI Average
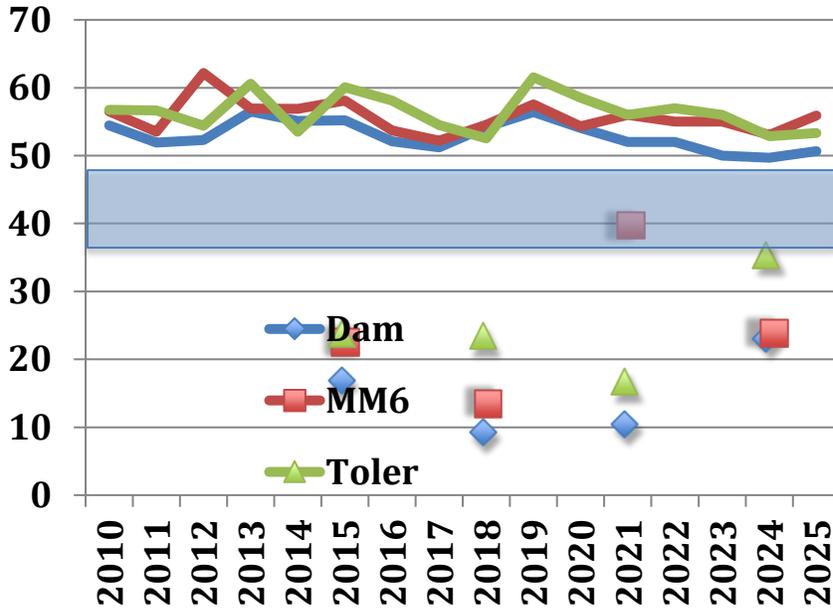
Figure 2.4. Same as Figure 2.1 but TSI presented is the average of TSI for all parameters evaluated (Secchi Depth, Total Phosphorous, Chlorophyll *a*).

Analysis

Averaging trophic state indices has value in determining if the lake is trending in a particular direction.   Based upon multiple parameters the reservoir continues to be amazingly steady. The lake remains mildly eutrophic with some fluctuation but meeting desired uses. While we are observing some worsening of water quality entering the reservoir from the Pigg River, these symptoms are not expressed in the overall TSI or at the Toler Bridge station. Often, time lags are associated with changes thus it is not surprising these changes are not yet reflected in the overall TSI. However, it is important to note that we are not observing time lags at this point and can be confident the water quality in the reservoir is stable.

Daphnia Productivity
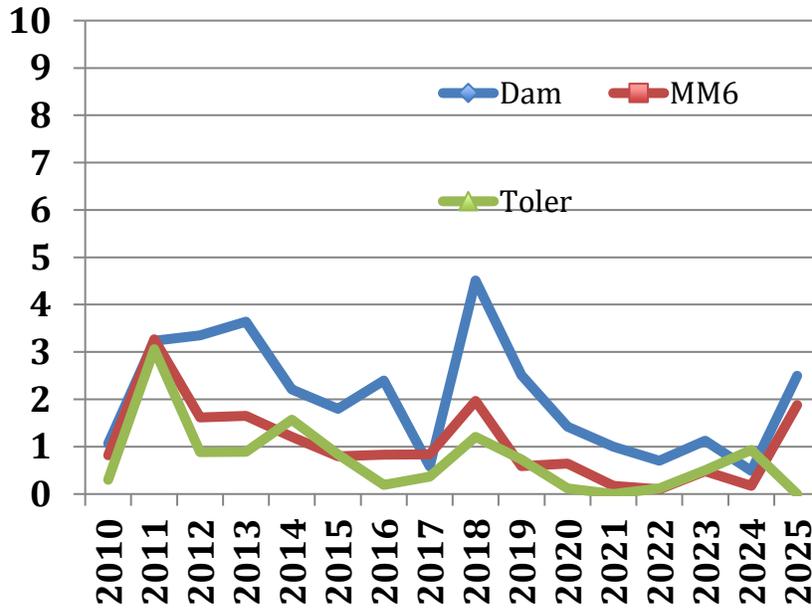
Figure 2.5. Average *Daphnia* concentrations in Leesville Lake from 2010-2025. Numbers on y-axis represent *Daphnia*/ liter.

Analysis

The abundance of *Daphnia* in 2025 increased after 5 years of very low abundances. This may be a reflection of increased phytoplankton productivity but more likely is a result of fish or other predators. It is difficult to determine the exact cause, but greater Daphnia productivity is beneficial the reservoir for both grazing of phytoplankton and providing the basis of the food chain for fish productivity.

Additional Trophic State Analysis

As in our 2024 report, an additional analysis was undertaken. Based on the literature (Sobolewski 2016), lakes in catchments with greater than 60% agricultural land use exhibit poorer water quality than those in less agricultural dominated watersheds. Greater than 60% agricultural land use in the watershed had lakes with 0-5 on the following scale. Lakes in catchments with agricultural land use less than 60% (60-35) tended to have much better water quality (8-10).

Table 2.2 – measures of water quality for lake from around the world. Leesville Lake water quality is quite good based on this scale.

Pollutant Measures	Low	Medium	High	LVL 2025	LVL 2022	LVL 2023	LVL 2024
Secchi Depth (m)	>2.10	1.15-2.10	<1.15	1.93 = 1 pts.	2.33 = 2 pts.	2.13 = 2 pts.	1.99 = 1 pts
Conductivity (uS/cm)	<289	289-402	>402	171 = 2 pts	168 = 2pts.	175 = 2 pts.	164 = 2 pts
Total Nitrogen (mg/m3)	<1.04	1.04-1.67	>1.67	0.78 = 2	0.12 = 2 pts.	0.31 = 2 pts.	0.46 = 2 pts
Total Phosphorus (mg/m3)	<0.043	0.043-0.08	>0.08	0.03 = 2 pts	0.06 = 1 pt.	0.03 = 2 pts.	0.03 = 2 pts
Chl a (ug/L)	<12.5	12.5-31.5	>31.5	9.89 = 2 pt	8.23 = 2 pts	8.12 = 2 pts.	9.28 = 2 pts
Points	2	1	0	9/10 points	9/10 points	10/10 points	9/10 points

The combination of lower than 60% agriculture in the watershed and influence of SML tailwater release keep Leesville Lake in the good zone of water quality (Table 2.1). Leeville Lake has scored 9/10 points in 3 of the past 4 years suggesting the reservoir exhibits excellent water quality even in an agriculturally dominated Pigg River Watershed. This strongly suggests that SML tailwater release mitigates the negative potential impacts from Pigg River input. This situation must be continually monitored to determine if conditions are continuing or are progressing toward greater expression of Pigg River Water quality.

2.2 Analysis of Data

In this section, long-term collection of data is analyzed to look at what is controlling productivity in the lake. Productivity is the greatest concern as eutrophication and land use surrounding the lake and watershed are of greatest concern. Excessive productivity (measured as Chlorophyll *a* and translated into TSI) causes problems such as Harmful Algal Blooms (HABs) as experienced in Smith Mountain Lake, greater loss of oxygen as this material decays and less appealing aesthetic quality of water. Management of the lake should have the goal of reducing productivity or keeping it at current levels. These levels are represented by the blue-shaded areas in Figures 2.1-2.4.

This analysis was conducted to examine what might be controlling productivity in the lake. Productivity measured as Chlorophyll *a* at station MM6 is the greatest in the reservoir as it is the point where riverine and lacustrine conditions combine. MM6 TSI measures were also used in this analysis as a response variable as this measure includes Secchi disk and Total Phosphorus measures. For this analysis, two primary drivers were examined. Water quality entering from the Pigg River represented as Dissolved Oxygen

(DO) and Total Phosphorus (TP) and the same measures from Smith Mountain Lake measured as Tail Waters. One additional variable included was precipitation. This data was collected monthly from Lynchburg Airport as a general representation throughout the area.

Data analyzed included monthly measures from April – October from 2012-2025 (Table 2.2.1). This provided a data set of 98 observations over a span of 13 years. In general, precipitation ranges from a low year of 15.97 inches in 2012 to high of 44.37 inches in 2020. This does have an impact on lake water quality as this variation represents a 2.77x difference in precipitation. Interestingly, monthly totals do not represent much variability. May and July were the wettest months but July was greatest due to very high reading in 2023 (over 10 inches). Concerning water quality, the variability in yearly totals is of much greater significance.

Table 2.3 – Monthly precipitation over a 13-year seasonal study period in Leesville Lake. Precipitation is displayed in inches for presentation here (converted to mm in the analysis) and totaled. Measures are from Lynchburg Va regional airport as representations for the watershed.

Year (Inches)	April	May	June	July	Aug	Sept	Oct	Total
2012	2.44	2.36	1.71	2.73	2.7	2.35	1.68	15.97
2013	3.38	6.12	6.32	3.41	3.55	0.48	2.34	25.6
2014	5.62	5.39	2.4	5.79	4.78	1.62	3.57	29.17
2015	4.06	1.66	5.59	3.79	1.98	7.13	4.07	28.28
2016	2.12	6.89	6.27	6	1.19	3.38	1.73	27.58
2017	4.18	7.88	2.09	3.3	2.24	1.91	2.57	24.17
2018	4.8	8.32	4.87	5.87	4.44	6.77	4.76	39.83
2019	4.02	2.09	3.79	3.24	3.24	0.17	6.73	23.28
2020	8.15	3.7	4.91	3.47	8.69	9.02	6.43	44.37
2021	3.52	1.7	5.14	2.59	2.44	2.62	2.76	20.77
2022	2.42	5.81	2.15	5.03	7.08	0.97	2.8	26.26
2023	5.15	1.91	4.29	10.83	2.32	3.53	0.9	28.93
2024	2.24	2.59	0.04	5.86	6.48	4.35	0.5	22.06
2025	2.13	7.87	1.94	8.97	1.5	2.72	1.42	26.55
Totals	54.23	64.29	51.51	70.88	52.63	47.02	42.26	382.82

Response parameters were analyzed individually but also summarized to see differences and compare inputs from Pigg River with Tail water (Table 2.2.2). The primary goal of this analysis is to determine function of the reservoir pertaining to water quality and to determine how these inputs maybe impacting water quality along with precipitation.

The greatest disparity between inputs is in phosphorus loading between the Pigg River and SML tail water. In some years the ratio (Pigg River/Tail Water) is near 1 (equal loading from both sources) but more typically it is up to 3x and even 10x as in 2025. Clearly, TP loading from Pigg River has much greater impact on the reservoir. Dissolved

60

oxygen patterns were much less clear. Slightly greater loading of oxygen from Pigg River than SML with the deficient occurring between August – October. This is a concerning problem but the impact on overall water quality appears minimal. Precipitation inputs are variable with highs over the study period up to 3x low input years.

Table 2.4. Response parameter summaries from analysis. Ratios display the division between Pigg measures and Tail Water measures for direct comparisons. Totals represent the sum of all 7 months. TSI average are average of the 7 month totals.

Year	Pigg/Tail DO Ratio	Pigg/Tail Tp Ratio	CHL Total	Rain Total	Pigg DO Total	Pigg TP Total	Tail DO Total	Tail TP Total	TSI Average
2012	1.22	0.96	177.24	15.97	58.97	0.521	48.2	0.545	52.1
2013	1.07	3.38	71.00	25.6	62.47	1.260	58.18	0.373	54.5
2014	1.01	2.33	242.05	29.17	59.23	1.073	58.44	0.46	60.5
2015	0.98	4.90	159.12	28.28	55.82	1.648	56.96	0.336	58.8
2016	1.12	1.17	54.13	27.58	51.22	0.792	45.85	0.676	54.6
2017	1.12	1.05	19.02	24.17	52.61	0.603	47.1	0.573	52.6
2018	1.25	9.45	55.84	39.83	56.88	1.049	45.39	0.111	54.5
2019	1.11	3.33	125.14	23.28	56.96	1.810	51.14	0.544	57.6
2020	1.14	3.84	94.79	44.37	52.44	1.703	45.81	0.444	55.6
2021	1.12	3.93	113.92	20.77	47.52	1.070	42.57	0.272	55.7
2022	1.17	3.44	68.18	26.26	54.4	1.000	46.51	0.291	53.8
2023	1.15	3.27	79.67	28.93	54.77	1.038	47.69	0.317	54.2
2024	1.29	4.03	84.52	22.06	48.29	0.508	37.35	0.126	54.3
2025	1.15	10.02	91.57	26.55	48.72	0.930	42.54	0.093	56.8

To determine the impact of these parameters on response variables several statistical analyses were performed. Principal Component Analysis allows us to correlate all observations (576 total) to determine possible patterns. From the graphical output, patterns are discerned looking along both axes for clusters or increase vs decrease in the output. From this analysis (Figure 2.2.1), Chlorophyll (response variable) showed a decrease with precipitation increase. The remaining variables were not strongly associated with changes in Chlorophyll.

This relationship was confirmed using Partial Least Squares Regression Variable in the Projection (PLS-VIP) analysis (Figure 2.2.2). Here, precipitation is very strongly correlated (values over 2) with changes in Chlorophyll *a* at MM6. The pattern is clear in the reservoir, less precipitation leads to increases in Chlorophyll *a* due to reduced flushing of the reservoir. Water quality decreases with lower precipitation.

This idea can be counter intuitive as increased precipitation brings in greater loading of nutrients that stimulate plant growth. Yet because Leesville Lake is a pump-storage reservoir, this relationship can be complicated by dam operations. To look at this idea, a PLS-VIP analysis was conducted on parameters to determine if dam operations were of greater influence than precipitation on Pigg River Total Phosphorus inputs.

Variables (axes F1 and F2: 48.38 %)
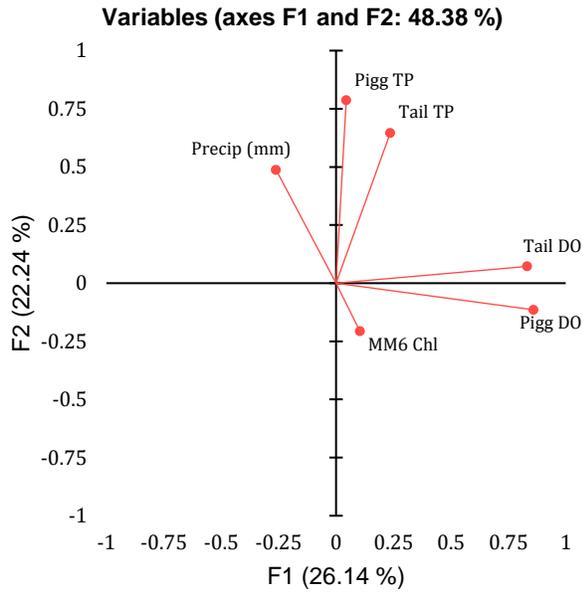
Figure 2.6. PCA analysis of all variables
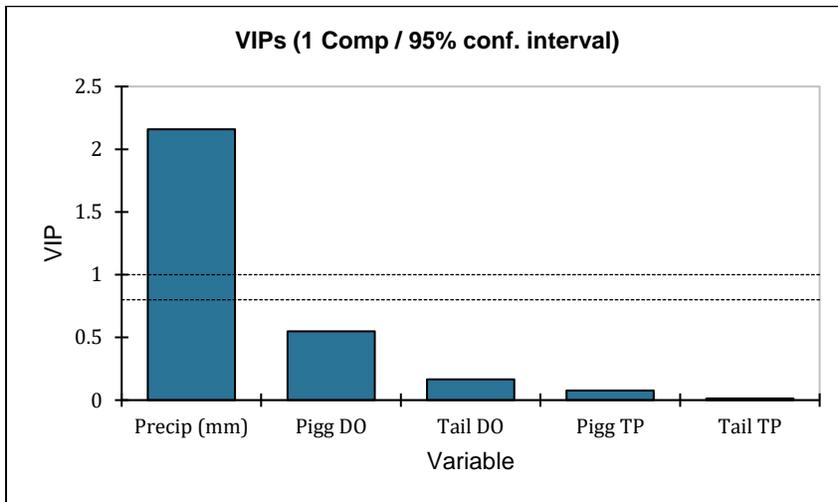
Figure 2.7. Influence of variables using partial least squares regression on MM6 Chlorophyll a. In this analysis, VIP (Variable in the Projection) is strongly associated with the test parameter (here Chlorophyll a at MM6) when the VIP correlation is greater than 1.

Section 3. Persistent Problems

3.1   Debris

Debris (primarily branches and trunks of trees) constantly plagues Leesville Lake. This debris presents a significant navigational hazard along with aesthetic and property management problems. AEP has a program to report and remove this debris, yet the continual influx of material appears to make this task difficult to manage.

The problem originates in the Pigg River. Stormwater transports not only sediment and bacteria but also debris (Figure 3.1.1). Large branches and logs can been seen flowing down river during storm events. This material may become log jammed during the journey to Leesville Lake but will eventually be transported during a significant storm or series of storms (Figure 3.1.2). The amount of debris can be significant and prevent safe navigation. Another problem occurs when pump back is in operation. Reverse water flow draws debris back into the main channel. If water flow was constant from headwater to tailwater. The main channel would clear as water flow entering and traveling down reservoir tends to short circuit remaining in the middle.   The unique hydrology of Leesville Lake compounds this problem.
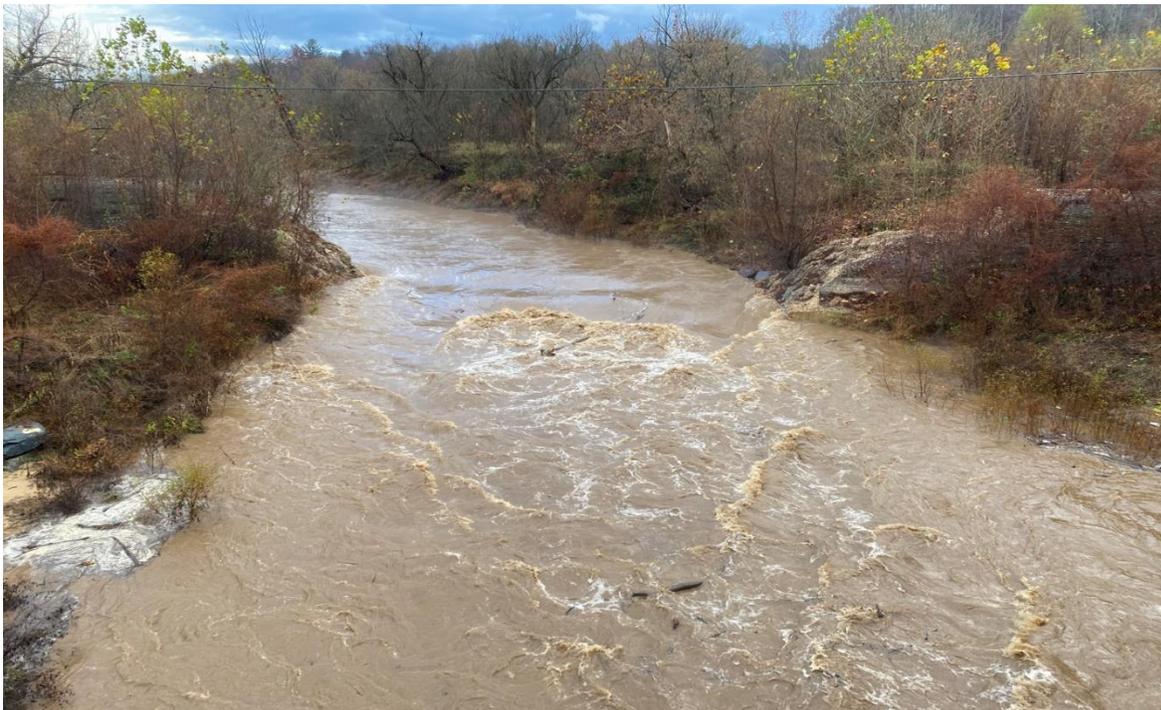
Figure 3.1. Stormwater flowing though old power dam location. Significantly sized debris (branches and logs) can be seen flowing with the stormwater that will eventually enter Leesville Lake.

Figure 3.2 – Debris at Toler Bridge June 17 2025 blocking the upper end of reservoir.

Table 3.1 – Precipitation data (inches) from Lynchburg Airport associated with sampling of Leesville Lake in 2025.

Date	3 day	7 day	Month
April 16	0.07	2.03	2.61
May 19	0.27	5.0	9.56
June 17	0.85	0.85	4.48
June 25	0.44	0.44	4.48
July 18	2.24	2.66	4.41
July 31	0	0	4.41
August 18	0	0.92	2.85
August 27	0	0	2.85
September 22	0	0.11	3.98
October 21	0.04	0	1.33

3.2 Dissolved Oxygen

Low dissolved oxygen (DO) concentrations are a persistent problem in the lake. Stratification of Smith Mountain Lake (SML) throughout the summer generates low oxygen concentrations in the hypolimnion where various discharges from the dam occur. SML stratification and low DO in summer and through the fall months has occurred since the lake was impounded.

Table 3.2 – Monthly surface oxygen concentrations at SML tailwater. All readings are in mg/L.

Year	Tail DO April	May	June	July	Aug	Sept	Oct	Average
2012	11.6	9.2	6.99	6	5.51	2.27	6.63	6.9
2013	10.7	9.9	9.5	7.4	7.34	6.42	6.92	8.3
2014	12.05	9.3	7.38	8.37	6.84	7	7.5	8.3
2015	12.66	9.7	8.8	6.38	7.22	5.26	6.94	8.1
2016	7.88	7.41	8.62	6.15	5.61	4.38	5.8	6.6
2017	8.81	7.88	7.1	6.2	4.72	5.77	6.626	6.7
2018	10.8	7.9	7.6	5.2	4.5	4.2	5.3	6.5
2019	10.07	8.11	6.99	6	6.7	6.57	6.7	7.3
2020	9.2	8.3	7.01	5.99	3.74	6.77	4.8	6.5
2021	10.25	8.54	9.62	5.84	3.82	4.5		7.1
2022	8.28	8.14	7.25	5.53	4.16	5.45	7.7	6.6
2023	9.87	8.27	8.1	6.25	5.1	4.86	5.24	6.8
2024	9.45		6.6	6.2	4.6	3.8	6.7	6.2
2025	10.76	8.5		5.7	6.87	4.42	6.29	7.1
Average	10.2	8.5	7.8	6.2	5.5	5.1	6.4	
Total	142.3	111.1	101.6	87.2	76.7	71.7	83.1	

This creates historically low dissolved oxygen (below 5 mg/L) beginning in August and often persisting through October. For reservoirs listed in 9VAC25-260-187 that undergo thermal stratification, the daily average DO criterion of 5.0 mg/L (and the instantaneous minimum of 4.0 mg/L) applies only to the epilimnion. Under non-stratified conditions, this criterion applies throughout the entire water column.

Dissolved oxygen discharge during August and September often fall below the criterion established in 9VAC25-260-187. The simplest explanation and one that correlates with the data is the relationship with precipitation. Precipitation is driving most of the functioning in the reservoir – input of debris, dilution of chlorophyll a and reduced dissolved oxygen concentration from SML in August and September (Figure 3.2.1). But as stated previously, pump storage operations add greater complexity to interpretation.

September Oxygen vs Precipitation

$R^2 = 0.4344$

Oxygen mg/L — Precipitation Inches

August Precipitation vs Oxygen

$R^2 = 0.3529$

Oxygen mg/L — Precipitation Inches
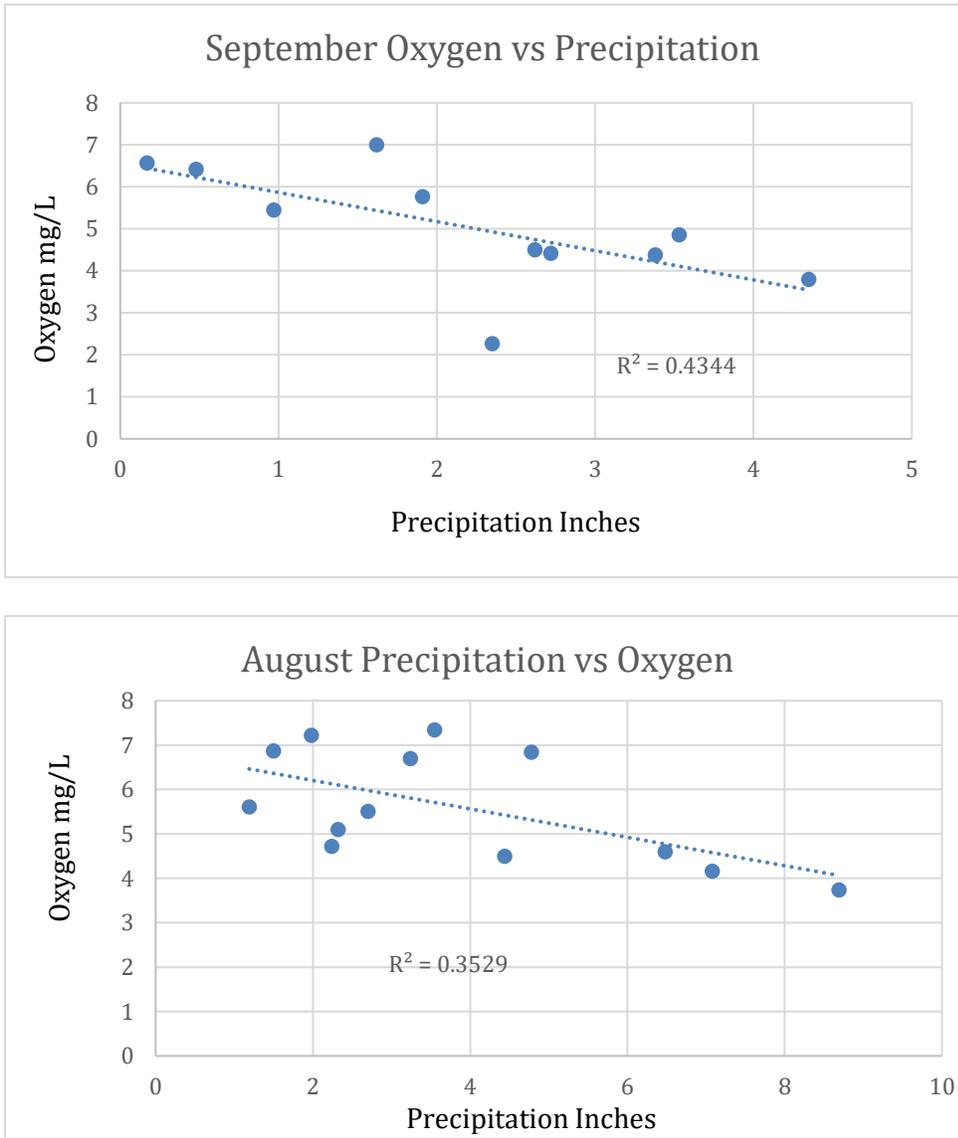
Figure 3.3. Dissolved oxygen and precipitation relationships in Leesville Reservoir during August and September from 2012-2025. Oxygen measures are from surface just beyond SML dam release. Precipitation are monthly totals from Lynchburg airport.

We know lower precipitation months generate greater Chlorophyll a productivity. Precipitation has a flushing impact and this appears to include oxygen as well. Thus, lower productivity and lower oxygen concentration correlate with increased precipitation. It is recommended that these relationships be considered in the movement of water throughout the project.

Section 4: Conclusions and Management Implications

4.1 Conclusions

As presented throughout this report, water quality in Leesville Lake is relatively stable and meeting goals prescribed for the reservoir. While the lake remains eutrophic and this condition can be improved, it is not worsening in trophic condition and this is a positive result.

The addition of more data improves relationships and allows continued analysis of data trends to help improve management. This season conclusions are as follows:

1. Leesville Lake remains slightly eutrophic and this measure is very stable in the reservoir. It has maintained this status throughout the monitoring period of study (2010-2025) and this result is currently stable and not expected to worsen or improve in the foreseeable future.

2. Leesville Lake behaves as a pump storage reservoir with headwaters impacted by tail release from the upper reservoir along with input from the Pigg River. Both are situated in the headwaters of the reservoir and both provide a unique input into the system. Each is integrated into the water quality and cannot be analyzed very well separately.

3. Analysis of all data suggests management needs to be closely aligned with precipitation as it drives productivity, the input of debris and oxygen loss in the reservoir. It additionally has a significant impact on the bacteriology of the reservoir that is analyzed in a separate study and subsequent publications.

4.2 Management Implications

The following management recommendations are suggested after conclusion of the 2025 sampling season:

1. Precipitation is a driver of water quality and aesthetics in the reservoir and must be part of future management of the reservoir.
2. Aggressive deployment of debris removal needs to continue. Correlations between pump-storage activity and water quality necessitate that dam operations be adjusted to preclude negative impacts on water quality when feasible. Knowing that retention of water in the reservoirs tends to increase productivity and oxygen, negative impacts of low oxygen can be countered by increasing water retention. Generally, increasing water retention in the lake will increase zooplankton populations and fish productivity.
3. Low dissolved oxygen needs to be managed at the tailwaters. All possible operational scenarios including syncing with precipitation need to be considered.
4. APCo's upcoming (April/May 2026) submission of a Dissolved Oxygen (DO) Improvement Plan to the Virginia Department of Environmental Quality for

review and approval will go a long way to addressing these issues. "APCo will develop a comprehensive plan, designed in consultation with VDEQ, the Department of Wildlife Resources (DWR) and other state or federal agencies to address depressed DO levels downstream from Smith Mountain Lake Dam. This plan is in accordance with APCo's final Permit VWP number 24 1547 signed on July 7, 2025. The plan is to protect instream beneficial uses, to ensure compliance with applicable water quality standards, to prevent impairment of state waters or fish and wildlife resources, and to provide no net loss of wetland acreage and function through compensatory mitigation and success monitoring and reporting."

References

Burns, N. 1995. Using hypolimnetic dissolved oxygen depletion rates for monitoring lakes. N. Z. J. Mar. Freshwat. Res. 29:1-11.

Carigan, R. and D. Lean. 1991. Regeneration of dissolved substances in a seasonally anoxic lake: The relative importance of processes occurring in the water column and in sediments. Limnology and Oceanography. 36:683-707.

Carlson, R. 1977. A trophic state index for lakes. Limnology and Oceanography. 22:361-369.

de Sherbinin A, Bowser A, Chuang T-R, Cooper C, Danielsen F, Edmunds R, Elias P, Faustman E, Hultquist C, Mondardini R, Popescu I, Shonowo A and Sivakumar K. 2021. The Critical Importance of Citizen Science Data. Front. Clim. 3:650760. doi: 10.3389/fclim.2021.650760

Dillon, P., and F. Rigler. 1974. The phosphorus-chlorophyll relationships in lakes. Limnology and Oceanography. 19:767-773.

Federal Energy Regulatory Commission. Office of Energy Projects. (2009, August). *Final Environmental Impact Statement for Hydropower License, Smith Mountain Pumped Storage Project, FERC Project Number 2210 Virginia*. Retrieved from http://www.smithmtn.com/Project%20Relicensing/FinalEISAugust2009.pdf

Federal Energy Regulatory Commission. (2009, December 15). United States of America 129 FERC ¶ 62,201, Federal Energy Regulatory Commission, Appalachian Power Company Project No. 2210-169, Order Issuing New License. Retrieved from http://www.smithmtn.com/
Gregory, K. 2019. Human influence on the morphological adjustment of river channels: The evolution of pertinent concepts in river science. River Res. Applic. 35:1097-1106.
Heck, D., D. Johnson, C. Love, B. Pohlad, M. Puccio and C. Thomas. 2019. Smith Mountain Lake Water Quality Monitoring Program. Ferrum College, Ferrum Virginia.

Kleinschmidt, 2020. Water quality monitoring program and dissolved oxygen enhancement evaluation. Smith Mountain Hydroelectric Project. FERC No. 2210.

Leesville Lake Association. *About the Lake*. Retrieved from
http://www.leesvillelake.org/AboutLake.htm

Leesville Lake Association. (2009, July 11). *Minutes, Leesville Lake Association, July 11, 2009, Annual General Membership Meeting*. Retrieved from
http://www.leesvillelake.org/Minutes.htm

Leesville Lake Association. (2008, April 10). *Minutes, Leesville Lake Association, April 10, 2008, Quarterly General Meeting*. Retrieved from
http://www.leesvillelake.org/Minutes.htm

Leesville Lake Association. (2003, September 25). *Minutes, Leesville Lake Association, September 25, 2003*. Retrieved from http://www.leesvillelake.org/Minutes.htm

Leesville Lake Association. *Articles of Incorporation of Leesville Lake Association, Inc*. Retrieved from http://www.leesvillelake.org/Documents/ArticlesOfInc.htm

Livingstone, D. and D. Imboden. 1996. The prediction of hypolimnetic oxygen profiles: A plea for a deductive approach. Can. J. Fish. Aquatic Sci. 53:924-932.
Lobue, Michael A. (2010, January). *Leesville Lake Water Quality Monitoring Program 2009 Report*. Leesville Lake Association.

Reynolds, J. 1967. Water quality in pumped storage reservoirs. Journal of the Power Division 93:15-35.

Sobolewski, W. 2016. Effect of Agricultural Land Use on the Water Quality of Polish Lakes: a Regional Approach. Pol. J. Environ. Stud. 25:2705-2710.

Steinsberger, T., R. Schwefel, A. Wuest and B. Muller. 2020. Hypolimnetic oxygen depletion rates in deep lakes; Effects of trophic state and organic matter accumulation. Limnology and Oceanography. 65:3128-3138.

The Louis Berger Group, Inc. (2009, February). *Smith Mountain Project Socioeconomics Study Phase II Report*. Retrieved from http://www.smithmtn.com/

The Louis Berger Group, Inc. (2003, August 29). *Smith Mountain Pumped Storage Project FERC No. 2210 Shoreline Management Plan*. Retrieved from
http://www.smithmtn.com/shorelinemanagement/Plan/pdf/Final/FinalSMP.pdf

Virginia Department of Environmental Quality (2007). *DEQ's 2007 Water Quality Monitoring Strategy*. Retrieved from http://www.deq.state.va.us/watermonitoring/monstrat.html
Virginia Department of Game and Inland Fisheries. (2002). *Leesville Reservoir 2002 Management Report*. Retrieved from
http://www.dgif.virginia.gov/fishing/waterbodies/reports/2002%20Leesville%20Reservoir.pdf

Virginia Department of Game and Inland Fisheries. (2008). *Leesville Reservoir 2008*. Retrieved from

http://www.dgif.virginia.gov/fishing/waterbodies/reports/2008%20Leesville%20Biologist%20Report.pdf

Virginia Tech. Department of Biological Systems Engineering. (2006, April). Bacteria Total Maximum Daily Load Development for Pigg River, Snow Creek, Story Creek, and Old Womans Creek. Retrieved from http://www.deq.virginia.gov/tmdl/apptmdls/roankrvr/piggec.pdf.

Yuan, L., and J. Jones. 2020. Rethinking phosphorus-chlorophyll relationships in lakes. Limnology and Oceanography. 65:1847-1857.

Appendix A
Background of Water Quality Program

For many years, the Virginia Department of Environmental Quality (DEQ) monitored Leesville Lake water quality either annually or biannually. Beginning in 2006, DEQ placed Leesville Lake on a six-year rotation for water monitoring. However, DEQ collected water quality data in 2009 and 2010.

In an effort to supplement DEQ water quality monitoring, the Leesville Lake Association (LLA) began a Citizen Water Quality Monitoring Program in April 2007. Citizen volunteers monitored bacteria, Secchi depth, temperature, dissolved oxygen (DO), pH, and conductivity. LLA outlined four goals for the program: (a) gain a greater understanding of the lake's water quality, (b) supplement the DEQ water quality monitoring, (c) increase the community's awareness of the importance of water quality, and (d) inform residents about harmful factors that damage water quality and age the lake (Lobue, 2010).

The Virginia DEQ provided LLA with a water quality monitoring probe to measure DO, temperature, and pH. With the DEQ Citizen Water Quality Monitoring Grant, LLA purchased Coliscan Easygel□ test kits for *E. coli* testing along with Secchi discs and other necessary equipment (Lobue, 2010). Over the next three years, LLA published annual reports of the water quality test results. As part of the water quality monitoring plan required by its new license, Appalachian Power Company committed $25,000 for a water quality monitoring program.

Under the Federal Power Act (FPA) and the U.S. Department of Energy Organization Act, the Federal Energy Regulatory Commission has the power to approve licenses for up to 50 years for the management of non-federal hydroelectric projects (FERC, 2009, p. ii). The Commission issued the first license for the Smith Mountain Pumped Storage Project to Appalachian Power on April 1, 1960 with a set expiration date of March 31, 2010 (FERC, 2009).

As part of its relicensing process, Appalachian Power was required by the Federal Energy Regulatory Commission to implement a Shoreline Management Plan (SMP). In July 2005, FERC approved a SMP proposed by Appalachian for the Smith Mountain Project. The purpose of this plan is *"to ensure the protection and enhancement of the project's recreational, environmental, cultural, and scenic resources and the project's primary function, the production of electricity."* (FERC, 2009, p. 22).   The SMP works to preserve green space, wetlands, and wildlife habitats along the shoreline. Property owners may not remove vegetation within the project boundary unless they have received permission from Appalachian Power. The project boundary for Leesville Lake lies at the 620-foot contour elevation (LLA, 2009).

To renew their license, Appalachian Power Company (Appalachian Power), a unit of American Electric Power (AEP), submitted an application for a new license in March 2008. In August 2009, the Federal Energy Regulatory Commission issued a Final

71

Environmental Impact Statement for the Smith Mountain Project relicensing. While reissuing, the Commission reviewed AEP's methods and proposals for "the protection, mitigation of damage to, and enhancement of fish and wildlife (including related spawning grounds and habitat), the protection of recreational opportunities, and the preservation of other aspects of environmental quality." (FERC, 2009, p. 1). In the final Environmental Impact Statement (EIS), FERC endorsed Appalachian Power's proposed $25,000 annually to the LLA to support the on-going water quality monitoring program (FERC, 2009, p. 25). The Commission approved the new license, effective April 1, 2010.

FERC recommended a few modifications to Appalachian Power's *Water Quality Monitoring Plan* including a proposal to develop a lake water quality monitoring plan. FERC determined that the primary water quality issues for Smith Mountain and Leesville lakes arise from nutrients and bacteria. Rather than coming from the dams' operations, the nutrients and bacteria come from shoreline development and overall watershed development. In conclusion, FERC recommended the (a) continuation of water-quality monitoring for Smith Mountain Lake, (b) establishment of a water quality monitoring program for Leesville Lake, and (c) ensuring the future health of the lakes by monitoring lake quality to verify that any changes in operational strategy at the Smith Mountain project do not harm water quality.

In summary, a timeline of significant events is outlined below:
- ☐ April 1960: First license for Smith Mountain Project issued
- ☐ April 2007: Development of Leesville Lake Citizen Water Quality Monitoring Plan
- ☐ 2007-2009: LLA annually reports on water quality
- ☐ 2008: AEP proposed $25,000 in 2010 to LLA for water quality monitoring plan
- ☐ August 2009: FERC issues a final EIS for Smith Mountain Project relicensing, recommending a water quality plan for Leesville Lake
- ☐ April 2010: AP's new license for Smith Mountain Project becomes effective
- ☐ June 2010: Lynchburg College begins water quality testing of Leesville Lake
- ● February 2011: Lynchburg College reports on 2010 water quality
- ● February 2012: Lynchburg College reports on 2011 water quality
- ● February 2013: Lynchburg College reports on 2012 water quality
- ● February 2014: Lynchburg College reports on 2013 water quality
- ● February 2015: Lynchburg College reports on 2014 water quality

Participants:
In August 2003, a group of Leesville Lake residents formed a non-profit 501(c)(3) corporation called the Leesville Lake Association. The association addresses the issues of debris, shoreline management, environmental and biological health, safety, future development, and fishing for Leesville Lake (LLA, 2003).

In 2007, the Department of Environmental Quality revised the Millennium 2000 Water Quality Monitoring Strategy. The Virginia DEQ maintains the "Water Quality

72

Monitoring and Assessment (WQMA) Program" with the ultimate goal to *"provide representative data that will permit the evaluation, restoration and protection of the quality of the Commonwealth's waters at a level consistent with such multiple uses as prescribed by Federal and State laws (VDEQ, 2007)."*

LLA partnered with University of Lynchburg to establish the Water Quality Monitoring Plan. University of Lynchburg agreed to conduct the samplings and testing, and report results. LLA water monitoring volunteers for 2020 were: Tony Capuco, David Waterman and Kathleen Giangi.

For a description of Leesville Lake and communities, refer to Section 2 of Lynchburg College's report titled *Leesville Lake 2010 Water Quality Monitoring* dated February 28, 2011.

Statement of Goals and Objectives
(Also stated in the 2010 and 2011 Leesville Lake Water Quality Monitoring Reports):

Goals and Objectives of the Leesville Lake Water Quality Monitoring Plan:
The Federal Energy Regulatory Commission recommended that a water quality plan for Leesville Lake be developed. In a collaborative approach, Leesville Lake Association and Lynchburg College developed a plan in February 2010 to continue and expand the testing and monitoring of water quality, to monitor nutrients and trophic status, and to supplement data collected by the Virginia Department of Environmental Quality in order to better understand the current state of Leesville Lake.

Leesville Lake Association
The objectives of the Leesville Lake Association, according to its Articles of Incorporation, are as follows (http://www.leesvillelake.org):

☐   Plan projects and studies that:
   a. Monitor and protect the water quality of Leesville Lake
   b. Contribute to the clean-up and preservation of the lake's shorelines
   c. Promote safe recreational use
   d. Improve the condition of the surrounding land as a high-quality recreational and residential area
   e. Maintain favorable water levels in Leesville Lake for the Smith Mountain Pumped Storage Hydro Project

☐   Educate to individuals, organizations, and the general public information concerning:
   a. Water quality monitoring results
   b. Management techniques and practices to preserve the environmental quality of Leesville Lake and its watersheds
   c. Safe recreational activities

73

d. Commercial and government activities that could harm geographic area of Leesville Lake

e. How to maintain optimum water levels in Leesville Lake

Appendix B
Water Parameter Testing Details
Oxygen

Dissolved oxygen (DO) in Leesville Lake shows a lot about the lake's metabolism. At a certain depth, the concentration of oxygen represents the temporary equilibrium between oxygen-producing processes (such as photosynthesis and aeration) and oxygen-consuming processes (such as decomposition and respiration).   The amount of dissolved oxygen that lake water can retain is dependent upon the water's temperature. As temperature increases, the solubility of DO decreases. Because the solubility of gas increases in a liquid as barometric pressure increases, the amount of DO is greater at deeper parts of the lake. Lake eutrophication increases the consumption of dissolved oxygen at the bottom layer of the lake (the hypolimnion), and lowers DO concentrations (Kaulff, 2002, p. 226-236). Dissolved oxygen levels are measured in milligrams per liter (mg/L) or "percent saturation." Percent saturation of dissolved oxygen (DO%) is calculated by taking the amount of oxygen in a liter of water over the total amount of oxygen that the liter can hold.

Large amounts of decaying vegetation lower DO levels in certain areas. In addition to decreasing DO levels, the decomposing material also lowers pH by producing acids. Highly colored acids such as tannic acids, humic acids, and fulvic acids build up and color the water.

DO and percent saturation of dissolved oxygen (DO%) were measured in the field using a Hydrolab probe. Prior to sampling at Leesville Lake, the Hydrolab probe was calibrated at University of Lynchburg.

DO and DO%, along with other Hydrolab parameters, were measured near the dam, at Mile Mark 6, downstream of Toler Bridge, and near the confluence of Pigg River and the lake. Measurements were taken in milligrams per liter. Starting at the surface, readings were typically taken every half meter for 3 meters. At 3 meters and deeper, readings were taken every meter.

Temperature

Measuring temperatures at various depths indicates if the lake is stratified. Freshwater lakes typically are stratified into three zones—the hypolimnion, the epilimnion, and the metalimnion (typically called the thermocline). The hypolimnion, the deep water zone, has little turbulence and contact with the atmosphere. Its respiratory processes use organic matter from the surface layer for fuel. The uppermost layer is the epilimnion, which is turbulent and provides the energy needs of the biota's animals and microbes. In the metalimnion layer, between the hypolimnion and epilimnion, is the temperature gradient called the thermocline. The temperature difference and resulting density difference of the thermocline disrupts nutrient and gas circulation, resulting in lake stratification (Kaulff, 2002, p. 154).

75

Temperature was measured at the same test sites as the other Hydrolab parameters by University of Lynchburg. The Hydrolab probe measured the temperature of the lake at specific depths in degrees Celsius. Before taking readings out in the field, the temperature probe was calibrated.

pH

pH indicates the alkalinity or acidity of water. For freshwater lakes, this parameter typically lies between 6 and 8. Measuring the pH shows the softness or hardness of water and the biological activities of the water zones. At pH values below 6 and above 8, species diversity and abundance decreases, although the few remaining species can be in high abundance.

A lake's pH can change throughout the day due to photosynthesis. When phytoplankton and other aquatic plants use sunlight to synthesize energy, they remove carbon dioxide from the water and raise pH. Thus, the highest pH levels are typically found in the late afternoon while the lowest levels are found before sunrise.

pH levels can also depend on the amount of decaying vegetation. In a lake's deeper waters, decomposing plants lower pH through the production of tannic acids, humic acids and fulvic acids. These acids are colored and are characteristic of marshes and heavily-vegetated areas.

pH readings were taken by using a Quanta Hydrolab in the field at the same test sites as the other hydrolab parameters. The process for calibrating the pH probe prior to field sampling is described in the Quality Control and Quality Assurance section.

Conductivity

Conductivity shows the capacity for water to carry electrical currents. Dissolved inorganic solids that carry positive and negative charges influence conductivity. Examples of anions (negatively charged ions) include chloride, nitrate, sulfate, and phosphate; examples of cations (positively charged ions) include sodium, magnesium, calcium, iron, and aluminum. Oil, phenol, alcohol, and sugar are organic solids that remain neutral in water, and thus do not affect conductivity.

Temperature and geology are other factors that influence conductivity. As temperature increases, so does conductivity. The bedrock of the land over which water flows can affect conductivity. In areas with clay soils, conductivity is higher because the dissolved soil ionizes. Areas composed of granite bedrock do not dissolve into ionic materials, and therefore do not affect conductivity as much as areas with clay. The discharge that flows into streams has the ability to raise or lower conductivity. Sewage overflow, which contains chloride, phosphate, and nitrate ions, increases conductivity, while oil leakages lower conductivity. The measurement for conductivity is micromhos per centimeter

(⌈mhos/cm) or microsiemens per centimeter (⌈s/cm) (http://water.epa.gov/type/rsl/monitoring/).

Once established, a body of water's range of conductivity does not typically fluctuate. Noticeable differences in readings can mean that a source of discharge or pollution has entered the water.

University of Lynchburg measured conductivity with Quanta Hydrolab Monitoring Probe at the same test locations as the other Hydrolab parameters. Before sampling, the Hydrolab was calibrated. In the field, readings were taken by applying a voltage between two of the probe's electrodes in the water. The resistance of water creates a drop in voltage that the probe then uses to calculate the conductivity.

Turbidity

Turbidity focuses on levels of sediment pollution in water. Turbidity levels affect the passage of light: soil particles, algae, plankton, and microbes can block light and alter the water color. In addition to reducing light penetration, suspended particles also increase water temperatures due to their absorption of heat.

High turbidity levels also affect aquatic life by reducing photosynthesis, decreasing DO, clogging fish gills, and decreasing fish resistance to disease and growth rates. Once materials settle on the bottom of the lake or river, fish eggs and benthic macro invertebrates can be coated in sediment. According to the Environmental Protection Agency (EPA), high turbidity levels can result from soil erosion, waste discharge, urban runoff, eroding stream banks, large numbers of bottom feeders, and excessive algal growth (http://water.epa.gov/type/rsl/monitoring/). It is important to note that turbidity is a measurement often used in coordination with Secchi depth and total dissolved solid (TDS). Secchi depth, which measures a lake's transparency and clarity, is another good indicator of sediment levels. TDS measures sediment in water through filtration.

A turbidity meter was used for this parameter. Consisting of a light and a photoelectric cell, the meter measured the amount of light that was deflected at a 90-degree angle by the particles in the water sample. The units used for turbidity were nephelometric turbidity units, or NTUs.

The Hydrolab probe's transparency tube measured turbidity at the same stops as the other six Hydrolab parameters. Prior to measuring the lake's turbidity, the transparency tube in the probe was calibrated.

Oxidation-Reduction Potential

The oxidation-reduction potential (ORP), also called redox potential, of a lake defines the overall balance between oxidizing and reducing processes (Kaulff, 2002, p. 239). ORP measures the potential electrical energy of a liquid by measuring the specific

77

electrical charges of either oxidizing or reducing agents. In water with a high pH value, there are more reducing agents (a negative ORP value), whereas in water with a low pH value, there are more oxidizing agents resulting in a positive ORP value (http://www.livingspringwaterionizer.com/water-essentials/water-ph-and-orp). Redox reactions are critical for aquatic systems: they lead to organic-matter oxidation, the recycling of nutrients, and the flow of energy from microbes to more complex organisms (Kaulff, 2002, p.246). University of Lynchburg and LLA called for the measurement of ORP in the final proposal to further understand chemical activity and developing eutrophication.

ORP is measured in millivolts (mV) by a sensor on the Hydrolab. Within the ORP sensor is a piece of platinum that built up charge without initiating any chemical reactions. This charge was then measured in comparison to the charge in the water. ORP was measured by the Hydrolab probe at three test sites by University of Lynchburg. For the lab calibration prior to field sampling, the same steps as the pH calibration were followed.

Total Phosphorus

Total phosphorus (TP) was measured to show nutrient levels in the water. TP levels were compared over time to determine if the lake had current or potential algae problems.
Phosphorus is a critical nutrient, often in short supply, for aquatic animals and plants. According to the U.S. Environmental Protection Agency, an increase in phosphorus may accelerate plant growth and algae blooms, lower dissolved oxygen, and contribute to the death of fish, invertebrates, and other aquatic animals. Phosphorus can originate from both natural and human sources such as soil and rocks, sewage, fertilizer, agricultural practices, animal manure, residential and commercial cleaning practices, and water treatment. In bodies of water, phosphorus is either organic or inorganic. Plant or animal tissue contains organic phosphate while inorganic phosphate is required by plants and used by animals (http://water.epa.gov/type/rsl/monitoring/).

Total phosphorus levels measure all forms of phosphorus, which are total orthophosphorus, total hydrolyzable phosphorus, and total organic phosphorus. Ortho phosphorus describes the plain phosphorus molecule, hydrolyzable refers to phosphorus that has undergone hydrolysis, and organic phosphorus is the phosphorus in animal or plant tissue (http://www.uga.edu/sisbl/epa-po4.html).

University of Lynchburg conducted total phosphorus testing at each test site. Leesville Lake samples were collected in labeled polyethylene bottles that had been cleaned and rinsed with tap water, soap, DI water, 10% HCl, and DI water. Samples were refrigerated until testing. At several test sites, water samples were taken at the surface and at a deeper depth.

The method for determining total phosphorus first involved digesting the sample to change all of the phosphate to orthophosphorus. Samples were then reacted with ascorbic acid to determine concentrations of both dissolved and un-dissolved ortho phosphorus. University of Lynchburg used a Systea EasyChem analyzer to test for TP in the samples. Samples were tested within 28 days of collection. Below is the Systea EasyChem method used for detecting total phosphorus.

Systea EasyChem Method
Summary:
Under this method for the determination of total phosphorus, the aqueous sample was mixed with sulfuric acid, ammonium molybdate and antimony potassium tartrate to form antimony-1, 2-phosphorous molybdenum acid. The resulting complex was then reduced by ascorbic acid to get a blue heteropoly acid (molybdenum blue). To determine the concentration of ortho-phosphate, the absorbance of the formed blue complex, was measured at 880nm.

Since only orthophosphorus formed a blue color in this test, polyphosphates (and some organic
phosphorus compounds) were converted to the ortho phosphorus form by manual sulfuric acid hydrolysis. Organic phosphorus compounds were converted to the orthophosphorus form by manual persulfate digestion. The developed color was then measured
automatically.

List of Chemicals:
- Ammonium Molybdate, $(NH_4)_6Mo_7O_{24}$ $4H_2O$
- Ammonium Persulfate, $(NH_4)_2S_2O_8$
- Antimony Potassium Tartrate, $K(SbO)C_4H_4O_6$ $3H_2O$
- Ascorbic Acid, $C_6H_8O_6$
- Isopropyl Alcohol, $(CH_3)_2CHOH$
- Phenolphthalein, $C_{20}H_{14}O_4$
- Potassium Dihydrogen Phosphate, KH_2PO_4
- Sulfuric Acid conc., H_2SO_4

Preparation of Reagents and Standards:
Stock Standards:
- 4.0g of ammonium molybdate were dissolved in 75mL DI water, and then the solution was diluted to 100mL with DI. The solution was transferred to a light-resistant polyethylene container and was stable for one month.
- 14.0mL of concentrated sulfuric acid were mixed with 70mL of DI water. The solution was diluted to 100mL with DI water and transferred to a glass container.
- 0.3g of antimony potassium tartrate were dissolved in 75mL DI water, diluted to 100mL with DI water, and transferred to a light-resistant container at 4oC. The solution was stable for approximately 4 weeks.

Reagents:
- For a range up to 20mg/L, a working reagent made up of 50mL sulfuric acid stock,

5mL antimony stock, 15mL molybdate stock, and 50mL of DI water was made and transferred to an EasyChem reagent bottle.
- For the second reagent, 0.9g of ascorbic acid was dissolved in 40mL of DI water. The solution was then diluted to 100mL with DI water and transferred to an EasyChem reagent bottle.

Standards used in the digestion process:
- 15.5mL of sulfuric acid were added to 30mL of DI water. The solution was cooled, diluted to 50mL with DI water, and transferred to a glass container.
- 2.0mL of 11N sulfuric acid solution were added to 50mL of DI water and diluted to 100mL.
- 0.5g phenolphthalein were dissolved in 50mL isopropyl alcohol and 50mL DI water.

Standards:
- A phosphate stock standard of 1000mg/L was prepared by dissolving 4.395g of potassium dihydrogen phosphate in 1000mL of DI water in a 1000mL volumetric flask.
- The 100ppm and 10ppm phosphate stock standard were prepared by subsequently diluting the 1000ppm.

<u>Dissolved Phosphorus</u>

Dissolved phosphorus is the amount of total phosphorus that is in soluble form. This parameter indicates the amount of phosphorus immediately available for aquatic life and, just like one for total phosphate, shows potential algae growth problems.

Dissolved phosphate plays an important role in the aquatic environment. Inorganic dissolved phosphorus is consumed by plants and changed to organic phosphate as it's incorporated into the plant tissue. The organic phosphate then moves to animal tissues when aquatic animals eat the plants. Dissolved phosphate thus ends up in a continual cycle of inorganic phosphorus, organic phosphorus in plant tissue, organic phosphorus in animal tissue, and back to inorganic phosphorus once the animals die and bacteria converts the phosphorus (http://www.uga.edu/sisbl/epa-po4.html). Too much dissolved phosphorus can cause the same problems as increases in total phosphorus.

Dissolved phosphorus testing was completed for all test sites by University of Lynchburg. Leesville Lake samples were collected in labeled polyethylene bottles that had been cleaned and rinsed with tap water, soap, DI water, 10% HCl, and DI water. Samples were refrigerated until testing. At several test locations, water samples were taken at the surface and at a deeper depth.

The method for determining dissolved phosphate first involved filtering the samples to remove any suspended particles. Samples were then tested for phosphorus using the

same method as total phosphorus. University of Lynchburg used a Systea EasyChem analyzer to test for dissolved phosphorus in the samples.

Nitrogen

In addition to phosphorus, nitrogen is also an important element that determines a lake's biota. Inputs of nitrogen include drainage basins and the atmosphere. The largest source of nitrogen comes from atmospheric deposits, which have doubled globally due to fossil fuel emission and other human activities (Kaulff, 2002, p. 270-271).

Excess nitrogen has detrimental effects on lake health. High nutrient levels accelerate eutrophication through algal growth. As the plants grow and decompose, the levels of dissolved oxygen (DO) in water decrease. Reduced DO levels can result in the die-off of fish, foul odors, and reduced recreational and atheistic value.

To determine nitrogen levels, University of Lynchburg tested water samples for nitrate (NO_3). Samples were collected in acid-washed, labeled polyethylene bottles, placed in a cooler with ice, and then transferred to a refrigerator upon the return to University of Lynchburg. Within 48 hours of collection, the samples were tested for NO_3 using the Systea EasyChem analyzer according to the following method.

Summary of Method:
In this method used to determine nitrate levels, nitrate was reduced to nitrite using Systea's Chemical RI. The resulting stream was treated with sulfanilamide and N-1-naptylethylenediamine dihydrochloride under acidic conditions to form a soluble dye, which was measured colormetrically at 546nm. The product was the sum of the original nitrite ion present plus the nitrite formed from nitrate. Systea has shown that, regardless of the sample matrix used, recovery of NO3 to NO2 is consistently between 95% and 105% recovery.
To determine the nitrate levels, the nitrite alone was subtracted from the total.

List of Chemicals:
Systea (1-Reagent) Nitrate Solution contained:
- Hydrochloric acid, (HCl)
- N-1-naptylethylenediamine dihydrochloride, (NEDD) $C_{12}H_{14}N_2$ 2HCl
- Sulfanilamide, $C_6H_8N_2O_2S$

Stock Standard contained:
- Potassium Nitrate, KNO_3

Preparation of Reagents and Standards:

Reagents:

- The Systea (1-Reagent) Nitrate Solution was transferred to an EasyChem reagent bottle and placed in the instrument.

Standards:
- A nitrate stock standard of 1000 mg/L was prepared by dissolving 7.218 grams of potassium nitrate in 1000 mL of DI water in a 1000mL volumetric flask.
- The 100 ppm and 10 ppm nitrate stock standard were prepared by subsequently diluting the 1000 ppm.

Summary of Run:
1. Standards and reagents were prepared by the above steps and then placed in the EasyChem instrument.
2. A standard curve for a range of 0.05-10mg/L (check) was created by the following steps:
- A 10ppm nitrate standard was placed in the instrument.
- The instrument made 5, 1, 0.5, 0.10, and 0.05ppm standards through dilutions.
- The instrument read the optical density of the calibrants. O.D. readings of a 0ppm standard and of two blanks (composed of DI water) were taken.
- A standard curve was set. The linear correlation coefficient (r^2) was always greater than 0.995.
3. The optical density of the samples was measured. By comparing the O.D. values to the standard curve set in Step 1, the concentration of nitrate in the lake samples was determined.
4. For every 10 samples, a check standard, spike, and a duplicate were included. Thus, for 40 cups of samples, there were 4 check standards of a known 10ppm nitrate solution, 4 spikes from different samples, and 4 different duplicates of lake samples. The check standards, serving as the Quality Control Samples (QCS), fell within 10% of the QCS true value.
5. The analysis ended with a blank to check the validity of the instrument's readings.

Fluorescence
Using a surface sample, University of Lynchburg measured fluorescence. Florescence measurements correlate with the concentration of Chlorophyll in water. University of Lynchburg field and lab verified and calibrated the barometer. A fluorescence probe connected to a monitoring screen was lowered into the water at half meter and whole meter intervals by University of Lynchburg.

Integrated Chlorophyll *a*
Water samples were measured for integrated Chlorophyll *a* to show the amount of productivity throughout the photic zone. Chlorophyll, a green pigment that synthesizes organic elements from sunlight in plants, is required for algal growth. Chlorophyll *a* is the most common type of pigment found in algae. High levels of Chlorophyll *a* demonstrate high algal levels (http://www.chesapeakebay.net/Chlorophylla.aspx?menuitem=14655).

University of Lynchburg took water samples at four test sites for Chlorophyll *a* testing. Water samples were collected in labeled polyethylene bottles that had been cleaned and rinsed with tap water, soap, DI water, 10% HCl, and DI water. Samples were placed in a cooler half-filled with ice at the site of the collection, and then stored in a refrigerator back at University of Lynchburg.

To determine Chlorophyll *a* levels, University of Lynchburg used the Chlorophyll *a* filtration method. Within 48 hours, the water samples were filtered through a vacuum pump. First, to prevent phytoplankton from licing to the filter, some magnesium carbonate was squirted onto a 0.45 micron 4.25 cm glass fiber filter. Then, about 150 mL or 200 mL of the lake sample was poured and drained through the filter using a vacuum pump. The filter was then folded, placed in aluminum foil, labeled, and refrigerated until it was tested.

Secchi Depth
Measured Secchi depth is one of the simplest ways to determine lake eutrophication and light transparence. The amount of nutrients in lake water determines a lake's cloudiness by accelerating the growth of phytoplankton (microscopic animals) and therefore the growth of zooplankton (microscopic animals). Inorganic solids from fertilizers, soil erosion, and sewage also increase a lake's cloudiness. Secchi disk transparency, Chlorophyll *a*, and total phosphorus together define a lake's trophic status (degree of eutrophication).

Typically Secchi depth is lowest during the spring and summer months, when water runoff and phytoplankton productivity is most vigorous. Water clarity often increases, sometimes doubling Secchi depths, during the fall and winter months. Weather is another factor: a drought will lead to increased water clarity while storms with heavy rain increase runoff and subsequently decrease Secchi depth.

A Secchi disk, consisting of a 20 cm black and white round disk attached to a line, is used to measure Secchi depth. The disk is lowered into the water until the lines separating the black and white sections on the disk are no longer distinguishable. Secchi depth is then recorded at that depth in the water column. University of Lynchburg measured Secchi depth at all of the eight stops. The rope attached to the disk was marked in meter increments. Measurements were recorded in meters and taken to the tenth decimal place. Volunteers from LLA also took Secchi depth readings on or around similar dates as University of Lynchburg.

Trophic State
Secchi depth, integrated Chlorophyll *a*, and total phosphorus (TP) are used to determine a lake's trophic status. Exposing a lake's health, a trophic state shows the lake's degree of eutrophication. There are 3 main categories under the Trophic State Index (TSI); eutrophic, mesotrophic, and oligotrophic. Eutrophic lakes are highly productive and concentrated in nutrients; mesotrophic lakes experience temperate productivity and have moderate nutrient levels; oligotrophic lakes have little productivity and low nutrient levels. When the TSI value is greater than 51, lakes are classified as eutrophic.

Water has more clarity in oligotrophic lakes rather than in eutrophic lakes due to the lower nutrient levels (http://www.rmbel.info/reports/Static/TSI.aspx).

E. coli

To determine levels of bacteria and look for health hazards, University of Lynchburg and LLA took *E. coli* readings at Leesville Lake. *Escherichia coli* (*E. coli*) is the accepted indicator organism for bacteria levels in Virginia. For the purposes of this report, *E. coli* levels are representative of coliform levels.

High levels of coliform bacteria found in lakes may point to the presence of human or animal excrement. Coliform bacteria are not harmful; however their presence shows that disease-causing bacteria or viruses may be present. Waterborne diseases such as dysentery, giardiasis, typhoid and other gastrointestinal infections can be contracted by swimming or drinking water from a lake containing human sewage. To assure the safety of water from such diseases, the water must meet the state standard for bacteria. In Virginia, the calendar-month geometric mean concentration of *E. coli* cannot exceed 126 cfu/100 mL, and no sample can exceed a concentration of 235 cfu/100mL (Virginia Tech,2006).

Conducting a fecal coliform test will show if sewage pollution is the problem. Additional tests can distinguish between human and animal sources if necessary. Nonpoint sources are the primary reason for high bacteria levels. Agriculture, land-applied animal waste, and livestock manure are the main nonpoint sources. Cattle and wildlife directly dumping feces into streams cause a large bacteria load. Nonpoint sources from residential areas include straight pipes, failing septic systems, and pet waste (Virginia Tech, 2006).

Prior to 2011, Leesville Lake Association citizen volunteers used Coliscan Easygel→ test kits for *E. coli* testing. Beginning in 2011 water samples collected by both LLA volunteers and University of Lynchburg were tested for *E. coli* with the Colilert™ test method. Samples were collected in sterile 125 ml polypropylene bottles and stored according to standard methods. A Colilert™ media packet was added to each water sample; the mixture was poured into a sterile Quanti-Tray, sealed and incubated. A color change from clear to yellow indicates a positive result for total coliform and fluorescence indicates a positive result for *E. coli*. The number of yellow and fluorescent wells are counted and the values are evaluated using a Most Probable Number (MPN) chart developed by the IDEXX Company, which developed the test method. MPN is used instead of colony forming units (cfus) and is generally considered an equivalent measure of the microbial and bacterial populations. The Colilert™ method has been rated as the "best" in agreement with a reference lab, has the lowest detection limit and the method is EPA approved for ambient water.

Zooplankton

To assess the health and structure of the lake's biological community, water samples were tested for zooplankton levels. Nutrient-rich (eutrophic) lakes, in comparison to

nutrient-poor lakes have more zooplankton. As the levels of phytoplankton increase, zooplankton also increase but at a slower rate (Kaulff, 2002).

Appendix C
Quality Assurance (QA) / Quality Control (QC)
Sample Collection, Preservation, and Storage:

Leesville Lake samples were collected in labeled polyethylene bottles that had been cleaned and rinsed with tap water, soap, DI water, a 2M HCl (we used 1M HCl) acid wash and finally more DI water. Each label denoted date, location, station, and depth if relevant.
Samples were refrigerated.
For detecting nitrate, nitrite, orthophosphate, and ammonia, samples were analyzed within 48 hours of collection. For total phosphorus (TP) and Total Kjedahl nitrogen (TKN), the samples were analyzed within 28 days.

Hydrolab Calibration and Sampling post Calibration:
☐☐☐ A Hydrolab Quanta Water Quality Instrument is used for all in situ water quality measurements. Each parameter is calibrated before use according to procedures established by the manufacturer.

☐☐ The sensors were cleaned and prepared for the following parameters:

☐☐ Specific Conductance - A calibration standard was poured to within a centimeter of the top of the cup. Any bubbles within the measurement cell of the specific conductance sensor were tapped out. The conductivity of the calibration standard was 1.412.

☐☐ Dissolved Oxygen %Saturation and mg/L:
1. Cleaning and Preparation: The o-ring securing the DO membrane was removed, the old electrolyte was shaken out and the DO membrane was rinsed with fresh DO electrolyte. Fresh DO electrolyte was poured into the sensor until a meniscus of electrolyte rose above the entire electrode surface of the sensor. After checking to make sure there were no bubbles in the electrolyte, a new membrane was placed on the top of the DO sensor and secured with the o-ring. There were no wrinkles in the membrane or bubbles in the electrolyte. Excess membrane was trimmed away.
2. Calibration for DO: The Saturated Air-Method was used for the DO calibration. The Calibration cup was filled with DI water until the water was level with the o-ring. No water droplets were on the membrane. The black calibration cup cover, turned upside down, was placed on the top of the Calibration Cup. The barometric pressure, which was 762mmHg, was determined for entry as the calibration standard.

 pH and ORP (Redox):
1. Cleaning and Preparation: The pH sensor was clean with a soft cloth wet with rubbing alcohol and then rinsed with DI water. The platinum band at the tip of the ORP sensor was checked for any discoloration or contamination. Then the reference sleeve was pulled away from the Transmitter and the old electrolyte from the reference sleeve was discarded. Then two KCl salt pellets (or KCl rings)

86

were dropped into the reference sleeve and the sleeve was refilled with reference electrolyte. With the Transmitter sensors pointed toward the floor, the full reference sleeve was pushed back onto its mount until the sleeve had just covered the first o-ring located on the mount. The Transmitter was then turned so that the sensors pointed towards the ceiling, and the sleeve was pushed the rest of the way onto its mount. The sensors were rinsed with DI water. Next, the Low-Ionic Strength Reference (LISRef) was cleaned and prepared. First the plastic LISRef soaking cap was removed and set aside. The sensor tip was then checked for any visible contamination. Following cleaning, the plastic LISRef soaking cap was filled with reference electrolyte, reinstalled over the LISRef tip, and soaked overnight. The plastic LISRef soaking cap was removed for calibration and field use.

2. Calibration for pH and ORP: A two-point calibration was used, with two pH standards. First, a pH standard of 7 was treated as the zero, and then a pH standard of 4 was treated as the slope.   Both pH standards, when calibrated separately, were poured to within a centimeter of the top of the cup.

   Turbidity:
1. Cleaning and Preparation: A non-abrasive, lint-free cloth was used to clean the quartz glass tube to remove any scratches that might reduce the sensors accuracy. The sensor was then rinsed with DI water.
2. Calibration for Turbidity: A Quick-Cal Cube was cleaned and dried with a non-abrasive, lint-free cloth. The cube was then placed in the turbidity sensors optical area. Turbidity analyzed and also checked at 0 with DI water.

☐☐☐   Depth: Zero was entered for the standard at the water's surface.
☐☐   After all of the parameters were calibrated, the calibration cup was filled with ¼ of tap water to protect the sensors from damage and drying out during transportation to the lake and storage in University of Lynchburg.

☐☐☐   The hydrolab was calibrated the morning of each day of lake sampling.

Post Calibration

Pre Sampling at Leesville Lake
☐☐   The bottled were washed according to above procedures, labeled, and placed in a milk crate. 18 bottles were taken: 3 for zooplankton, 12 for nutrients, and 3 for whole water.
☐☐☐   The Hydrolab was calibrated and the information was recorded.
☐☐   An ice chest was half-filled with ice.
☐☐☐   Batteries in the Hydrolab were checked.
☐☐   At the lake, the following parameters were recorded:
     o Smith Mountain Lake tailwaters: whole water for TP
     o Pigg River near its mouth: Secchi depth, TP, Hydrolab data

> o Toler Bridge (after confluence with Pigg River/riverine zone): Secchi depth, TP, no Hydrolab data was taken because the flow of water was too quick
> o Mile Mark 9 (mixing zone): Secchi depth, TP?
> o Mile Mark 6 (end of mixing zone/beginning of lacustrine): Secchi depth, TP, hydrolab data
> o Tri-County Marina: Secchi depth, TP
> o Leesville Lake Marina: Secchi depth, TP
> o Near dam (end point of lacustrine): Secchi depth, TP, Hydrolab data

No data for E. Coli was collected because of a lack of zithromax packs.

Nitrate Method

Summary of Method:
In this method used to determine nitrate levels, nitrate was reduced to nitrite using Systea's Chemical RI. The resulting stream was treated with sulfanilamide and N-1-naptylethylenediamine dihydrochloride under acidic conditions to form a soluble dye, which was measured colormetrically at 546nm. The product was the sum of the original nitrite ion present plus the nitrite formed from nitrate. Systea has shown that, regardless of the sample matrix used, recovery of NO3 to NO2 is consistently between 95% and 105% recovery.
To determine the nitrate levels, the nitrite alone was subtracted from the total.

Summary of Run:
1. The lake samples were chilled to about 4°C and analyzed within 48 hours
2. Standards and reagents were prepared by the above steps and then placed in the EasyChem instrument.
3. A standard curve for a range of 0.05-10mg/L (check) was created by the following steps:
☐☐ A 10ppm nitrate standard was placed in the instrument.

Standards were prepared through dilutions at 5, 1, 0.5, 0.10, and 0.05ppm

The instrument read the optical density of the calibrants. O.D. readings of a 0ppm standard and of two blanks (composed of DI water) were taken.
☐☐ A standard curve was set. The linear correlation coefficient (r^2) was always greater than 0.995.
4. The optical density of the samples was measured. By comparing the O.D. values to the standard curve set in Step 1, the concentration of nitrate in the lake samples was determined.
5. For every 10 samples, a check standard, spike, and a duplicate were included. Thus, for 40 cups of samples, there were 4 check standards of a known 10ppm nitrate solution, 4 spikes from different samples, and 4 different duplicates of lake samples. The check standards, serving as the Quality Control Samples (QCS), fell within 10% of the QCS true value.
6. The analysis ended with a blank to check the validity of the instruments readings.

Total Phosphate Method

Summary of Method:
Under this method for the determination of total phosphate, the aqueous sample was mixed with sulfuric acid, ammonium molybdate and antimony potassium tartrate to form antimony-1, 2-phosphorous molybdenum acid. The resulting complex was then reduced by ascorbic acid to get a blue heteropoly acid (molybdenum blue). To determine the concentration of ortho-phosphate, the absorbance of the formed blue complex, was measured at 880nm.
Since only orthophosphate formed a blue color in this test, polyphosphates (and some organic
phosphorus compounds) were converted to the orthophosphate form by manual sulfuric acid hydrolysis. Organic phosphorus compounds were converted to the orthophosphate form by manual persulfate digestion. The developed color was then measured
automatically.

Summary of Run:
1. The lake samples were chilled to about 4oC and analyzed within 48 hours
2. Standards and reagents were prepared by the above steps and then placed in the EasyChem instrument.
3. A standard curve for a range of 0-5mg/L (check) was created by the following steps:
□□   A 5ppm total phosphate standard was placed in the instrument.
□□
 Standards were prepared through dilutions at 5, 2, 1, 0.5, 0.1, and 0ppm

□□   The instrument read the optical density of the calibrants. O.D. readings of a 0ppm standard and of two blanks (composed of DI water) were taken.
□□   A standard curve was set. The linear correlation coefficient (r^2) was always greater than 0.995.
4. The optical density of the samples was measured. By comparing the O.D. values to the standard curve set in Step 1, the concentration of nitrate in the lake samples was determined.
5. For every 5 samples, a blank and a duplicate were included. Halfway through the run and at the end of the run there were 2 check standards. Thus, for 40 cups of samples, there were 2 check standards of a known 1ppm phosphate solution and 2 check standards of a known 0.5ppm phosphate solution, and 8 different duplicates of lake samples. The check standards, serving as the Quality Control Samples (QCS), fell within 10% of the QCS true value.
6. The analysis ended with a blank to check the validity of the instruments readings.

Quality Assurance/Quality Control

Initial demonstration of laboratory capability was established through the following methods:

Method Detection Limit (MDL): According to the Code of Federal Regulations, the MDL is the minimum concentration that can be determined with 99% confidence that the true concentration is greater than zero. This method guarantees the ability to detect nutrient concentrations at low levels. In order to proceed with testing, the MDL in reagent water for nutrients had to be less than or equal to the concentrations in the table below. These concentrations were taken from the Ambient Water Quality Monitoring Project Plan for the Department of Environmental Quality:

Nitrate	0.04 mg/L
Nitrite	0.01 mg/L
Orthophosphate	0.01 mg/L
Total Phosphate	0.01 mg/L
Ammonia	0.04 mg/L

Initial Precision and Recovery (IPR): This practice establishes the ability to generate acceptable precision and accuracy. 4 Laboratory Control Samples (LCS) were analyzed and the average percent of recovery (X) along with the standard deviation of the percent recovery (s) for nitrate was determined. Our tested recovery did not exceed the precision limit and X did not fall outside the 90-110% range for recovery. In instances were recover was not accomplished analysis was repeated to achieve the acceptable recover limits.

Matrix spikes (MS) and matrix spike duplicate (MSD) samples were analyzed to demonstrate method accuracy and precision and to monitor matrix interferences.

Out of each set of ten samples, one sample aliquot was analyzed. First, the background concentration (B) of analyte was determined. Then the sample was spiked with the amount of analyte stock solution to produce a concentration in the sample of 1mg/L, or a concentration 1 to 5 times the background concentration. Finally, two additional sample aliquots were spiked with the spiking solution, and the concentrations after spiking (A) were measured.

The percent recovery of analyte in each aliquot was determined using the follow equation:

$P = [100(A - B)]/T$

The spike recovery percentage had to lie within the QC acceptance criteria of 90 to 110%. The relative percent difference between the two spiked sample results also had to be less than 20%.

Laboratory reagent water blanks were analyzed with each analytical batch to demonstrate freedom from contamination and that detected nitrate is not at a concentration greater than the MDL.

To demonstrate that the analysis system was in control, the LCS procedure was performed on an ongoing basis, with results lying within +/-10% of the true value.

Records defining the quality of data generated, including LCS data and QC charts, were maintained. A statement of laboratory data quality for each analyte, with the average percent recovery (R) and the standard deviation of the percent recovery (s_r). The accuracy as a recovery interval was expressed as $R - 3s_r$ to $R + 3s_r$.

To demonstrate that the analytical system was in control, the laboratory periodically tested an external reference sample. We have not yet conducted this analysis but will strive to this standard in 2012.

Quality Assurance (QA) / Quality Control (QC) Checklist:
General Procedures:
- Checklist of all routine material and equipment:
  Checklist should include field data sheets showing sampling sites, QA sites if QC samples are collected, containers, preservatives, and labels including QC labels
- Also a topo map, GPS unit, safety gear, and cell phone
- Print field data sheets and labels from CEDS for the run
- Clean equipment, check its condition, and charge batteries

Sampling Requirements:
- For the collection of organic materials, se non-organic or inert materials such as Teflon or stainless steel
- Water matrices: 1. Rope on spool   2. Stainless steel bucket with fitting for bacteria sample bottle   3. Syringe, filter paper, filter holder etc.

Sampling Equipment Preparation and Cleaning:
- Water Sampling Equipment:
- Daily: Rinse buckets at the end of the day with analyte free water and allow to dry; if a pump/hose was used, pump 5 gallons of analyte free water through system and allow to drain; if using Kemmerer or Alpha Bottle sampling devices, follow manufacturer's instructions using analyte free water
- Weekly: Wash buckets with lab grade soap (Liquinox or Alconox) using a brush to remove particulate matter or surface film; rinse with tap water and then analyte free water, allow to dry
- Monthly: pump 5 gallons of a 5% solution (consists of 1 quart of vinegar mixed with 4 ¾ gallons of water) through hose and pump apparatus; pump 5 gallons of anaylte free water through hose and pump apparatus and completely drain
- Annually: replace hoses of pump and hose sampling devices
- Sample container handling and preservation:

- Refer to the DCLS laboratory catalog in CEDS for the appropriate preservation procedures. Samples not preserved properly may be rejected by DCLS.
- make sure the lids were on tight
- Sample containers should be stored with the tops fastened.
- Samples should be iced to 4°C in a cooler immediately after collection. In the cooler, samples shall be placed upright and if possible, covered with ice in such a manner that the container openings are above the level of ice. Chlorophyll a filter pad samples will be placed in appropriately sized Ziploc bags and placed on top of the layer of ice. Ziploc bags containing filters should be oriented so that the sealed opening of the Ziploc bag hangs outside the cooler lid when the lid is closed. Bacteria sample bottles should be stored in mesh bags, placed in coolers and surrounded with wet ice.
- Package glass sample containers in bubble wrap or other waterproof protective materials
- Make sure that every cooler used to ship samples to DCLS contains one temperature bottle to determine sample temp upon arrival at DCLS.
- Regional office should date boxed or packaged sample containers upon receipt and stock on shelves with the oldest dated box/packages used first.

Sample identification:
- Identify each sample by the station description, date, time, depth description, collector initials, parameter group code, sample type, container number, preservation used and volume filtered, if applicable.
- Print sample identification information on an adhesive Avery label and applied to the exterior of the container.
- Print labels for established sampling sites from CEDS

Field Sampling Procedures:
- Use protective gloves: latex or nitrile gloves may be used for common sampling conditions; disposable ones are needed for clean metal sampling
- Rinse sample equipment with sample water before taking actual sample. Dispose of rinse water away from sampling site.
- Take surface water samples facing upstream and in the center of main area of flow
- For bacteria samples, do not rinse bottle before collecting sample and always collect as a grab sample, do not composite

Sampling from a boat:
- Bacteria samples: grab from the water in direction of current, do not use a pump or hose
- Sample away from engine in direction of current (if possible)
- Clear the pump and hose using the air bubble method or calculate the clearing time

Secchi disk:
- Use disk 20 cm in diameter attached to a line/chain marked in 0.1 m increments, check these once a year

- Lower Secchi disk on shaded side of boat until black and white quadrants are no longer distinguishable
- Note the above depth, and then depth at which the quadrants are once again distinct
- Secchi depth is the average of the two depths to the closest 0.1 m

Vacuum Filtering Method (In-Line Filtering)
- Nitrogen, phosphorus, and Chlorophyll **a**
- conduct filtering as soon as possible after collection but no later than 2 hours after sample collection

Preparation:
- Muffle 25 mm diameter glass fiber filters utilized for PNC (Particulate Nitrogen and Particulate Carbon analysis),
- Acid wash the towers, graduated cylinders and plastic sample bottles
- Rinse the forceps with DI water
- Ensure proper delivery of uncontaminated, dry filter samples to DCLS.

Filtration of samples:
- Rinse acid washed and DI washed container with sample water, then fill container with enough sample water to filter more than one sample
- Rinse filtration towers and base with DI water, connect vacuum power pump to battery
- Place filters on bases, place clean NTNP bottles under PP bases, rinse graduated cylinders with sample, and transfer sample to towers
- Turn pump on
- Add $MgCO_3$ to last 25 ml of Chl a sample
- Close valves or turn off pump to remove filtration vacuum
- Bleed excess pressure off and then open vacuum valves of stacks slowly
- Rinse forceps with DI water
- Remove filters from base
- Record volume filtered
- Remove NTNP bottle from PP cylinder and cap tightly
- Label- station, date, time depth, unit code, collector's initials, group code, container #, volume of sample filtered
- Place samples on ice

Collection of samples for Chlorophyll a using syringe filtration p. 21
- Field filtration is done with positive pressure and a syringe
- Filter approx. 300 ml of site water through a 150cc polypropylene syringe

Field Quality Control Samples
- Equipment Blanks: need to be collected in field between stations, once for each 25 sites sampled, flush/rinse with analyte free water
- Field split samples: collect for each 25 sites sampled, obtain 1 bucket of water and fill 2 identical containers sequentially

<u>Field Testing Procedures (p. 69)</u>
pH/mV/Ion meter
- calibrate meter each day before use with minimum of 2 fresh standard buffer solutions that bracket expected pH
- check calibrations using standard buffer solutions at least once during or end of sampling and record in log sheet, if pH is off by more than 0.2 pH units, flag data collected
- check instrument at least once a month and record in log sheet

Dissolved oxygen and temperature meter
- Calibrate daily when in use, air calibration is the easiest
- Record the % saturated DO in the log sheet
- A DO% saturation confirmation needs to be performed in the middle of run
- Field probe maintenance: average life of membrane is 2-4 weeks, but may vary
- Some gases can contaminate the sensor, evidenced by discoloration of gold cathode
- Check probe performance every month when probe is in daily use
- For the DO meter, make calibration checks daily. Check calibration during sampling and at conclusion of day's sampling. Record onto log sheet; if check is off ±5%, flag data
- Monthly, place probe into a clean bucket full of analyte free or uncontaminated water, rinse BOD bottle 1 or 2 times with water, determine DO by Winkler method
- If the oxygen concentration of the air calibration disagrees with average results of Winkler value by more than 0.5 mg/l, have the electrode or meter serviced or replaced
- Check temperature probe against another multiprobe instrument's temp. probe semi-annually

<u>DO and conductivity meter calibration checks</u>
- Daily: check calibration during sampling and at conclusion of day's sampling, record and flag data if off by more than 5%
- Monthly: place probe in bucket of analyte free water, rinse BOD bottle with water from bucket, determine the DO by the Winkler method
- If oxygen concentration of air calibration disagrees with results of Winkler value by more than 0.5 mg/l, service or replace electrode

<u>Thermistor Verification</u>
- Check temperature probe against another multiprobe instrument's temperature probe semi-annually
- Check against 3 points such as an ice/water mixture, room water temperature, and warm water temperature
- Do not use thermistor if the difference is more than 0.5 degrees C

<u>Sample Identification and Corrective Action</u>

94

- Make entries in field data sheet for all field parameters
- Print label from pre-print label file in computer. Include station ID, date collected, time collected, depth, unit code, collector, group code, preservative, lab processing code, blank/dup designation, priority and container number
- Corrective Action: CAR form must be forwarded to QA officer for review and recommendations

Appendix D – Collected Data

Table 1.1. Dam (Lacustrine) Conductivity (µs/cm) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	0.173	0.161	0.162	0.172	0.174	0.182	0.176
0.5	0.173	0.159	0.164	0.172	0.174	0.182	0.176
1	0.173	0.159	0.165	0.172	0.173	0.182	0.175
1.5	0.173	0.157	0.17	0.173	0.173	0.181	0.175
2	0.173	0.158	0.171	0.175	0.173	0.181	0.175
2.5	0.173	0.159	0.173	0.176	0.174	0.181	0.175
3	0.172	0.157	0.172	0.177	0.173	0.18	0.175
4	0.171	0.158	0.173	0.176	0.175	0.18	0.174
5	0.172	0.157	0.171	0.178	0.175	0.181	0.174
6	0.171	0.154	0.17	0.177	0.176	0.181	0.174
7	0.171	0.151	0.17	0.178	0.175	0.181	0.173
8	0.17	0.152	0.168	0.178	0.176	0.181	0.173
9	0.171	0.153	0.168	0.178	0.176	0.181	0.173
10	0.17	0.154	0.167	0.177	0.176		0.173
11	0.17		0.167	0.176	0.177		
12	0.171		0.167	0.175	0.177		
13	0.171		0.166				
14	0.171		0.166				

Table 1.2. Dam (Lacustrine) Dissolved Oxygen (mg/L) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	10.3	10.4	9.68	10.1	11.04	9.48	7.17
0.5	10.3	10.2	9.72	10.19	10.8	9.48	7.06
1	10.3	10.1	9.65	10	11.8	9.41	7.03
1.5	10.3	9.8	8.79	8.78	12.4	7.9	6.5
2	10.2	9.3	8.66	7.59	12.2	7.49	6.42
2.5	10.2	9.15	8	5.86	9.72	7	6.19
3	10.2	8.4	7.92	3.68	7.5	6.52	6.19
4	10	7.33	7.62	3.6	3.6	5	6.43
5	9.4	6.58	7.5	2.2	2.2	3.64	6.1
6	9.86	6.32	6.58	2.4	2.1	2.54	6.05
7	9.78	6.89	6.29	1.52	1.43	2.08	6.04
8	9.72	7.09	5.88	1.19	1.14	1.51	5.93
9	9.54	7.08	5.46	1.07	1.04	1.57	5.92
10	9.5	7.17	5.34	0.77	0.87		5.93
11	9.5		5.07	0.53	0.07		5.97
12	9.3		4.96	0.54	0.05		
13	9		4.53				
14	8.8		4.22				

96

Table 1.3. Dam (Lacustrine) Temperature (°C) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	14.4	21.7	24	29.2	28.59	24.1	20.5
0.5	14.4	21.3	23.8	29.2	28.5	24.1	20.48
1	14.4	21.2	23.3	29.1	27.9	24.1	20.43
1.5	14.4	20.7	22.1	28.2	27	23.6	19.98
2	14.4	20.3	21.7	27.1	26.3	23.2	20.2
2.5	14.4	20.1	20.9	25.3	24.8	23.1	19.9
3	14.3	19.3	20.8	23.7	24.7	23.1	19.9
4	14.2	18.1	20.6	23.1	23.5	22.9	19.9
5	14.1	17	20.5	22.6	23.2	22.7	19.88
6	14.1	15.6	19.8	22.4	22.9	22.7	19.88
7	14	15	19.5	21.9	22.5	22.7	19.88
8	13.8	14.8	19.1	21.6	22	22.6	19.88
9	13.6	14.6	18.6	21.5	21.9	22.5	19.88
10	13.5	14.5	18.5	21.2	21.8		19.87
11	13.4		18	21	21.7		19.87
12	13.3		17.7	20.5	21.5		
13	13.2		17.2				
14	13.1		17				

Table 1.4. Dam (Lacustrine) Chlorophyll *a* (ppb) concentrations over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	4.6	5.7	11.1	13.9	6.5	6.7	13.7
0.5	4.4	8.1	14.6	14.4	9.8	7.2	17.4
1	5.5	11.1	15.3	14.3	14.9	8.6	17
1.5	5.9	13.1	14.7	16.1	16.5	12.1	17.9
2	5.9	15.3	15.3	14.4	19.2	13.5	16.6
2.5	6.6	15.6	13.4	12.7	26.1	12.9	15.3
3	5.9	12.5	13.9	11.6	21.7	14.2	21.1
4	5.4	8.3	13.4	6.4	18.7	12.7	18.4
5	5.2	7	13.3	4.4	13.6	9.5	16.3
6	5.1	4.9	10.2	4.3	8.7	6.4	17.8
7	5.7	4.1	9.57	3.2	6.8	5.2	18.6
8	5.2	3.5	7.56	2.7	5.9	4.5	19.8
9	5.4	3.8	7.17	2.3	4.8	4.1	18.4
10	5	3.5	5.6	2.4	5.6		16.9
11	3.9		5	2.2	4.8		17
12	4.2		4.5	2.5	5.6		
13	5.1		3.6		5.2		
14	4.4		3.7		5.2		

Table 1.5. Dam (Lacustrine) pH measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	7.4	7.4	7.9	8.1	7.9	7.59	7.25
0.5	7.3	7.5	8	8.1	8.1	7.64	7.25
1	7.3	7.5	8	8.1	8.05	7.67	7.28
1.5	7.3	7.4	7.9	8.09	8.1	7.68	7.29
2	7.3	7.45	7.95	8.06	8.13	7.6	7.29
2.5	7.2	7.42	7.92	8.01	8.06	7.58	7.3
3	7.2	7.37	7.87	8.01	7.9	7.56	7.3
4	7.2	7.3	7.8	8	7.8	7.52	7.31
5	7.2	7.27	7.77	7.9	7.7	7.47	7.33
6	7.2	7.23	7.73	7.95	7.6	7.45	7.34
7	7.1	7.22	7.72	7.97	7.5	7.43	7.345
8	7.1	7.21	7.71	7.94	7.5	7.42	7.36
9	7.1	7.21	7.71	7.93	7.5		7.37
10	7.1	7.22	7.72	7.92	7.4		7.37
11	7.1	7.24	7.74	7.89	7.4		7.38
12	7			7.88	7.4		
13	7			7.87	7.4		

Table 1.6. Dam (Lacustrine) ORP (mV) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	587	368	351	329	283	281	238
0.5	584	369	349	331	282	279	238
1	583	369	352	331	279	277	239
1.5	582	370	352	336	278	276	239
2	581	372	355	337	279	282	239
2.5	580	373	355	344	292	282	239
3	579	375	356	344	294	282	238
4	578	376	355	343	292	282	238
5	578	377	356	341	290	281	237
6	577	378	355	340	290	282	238
7	578	378	356	340	290	281	237
8	577	378	356	339	288	280	238
9	577	378	353	339	290	278	238
10	576	379	356	338	290	277	240
11	575		354	338			
12	575		356				
13	575		355				
14	575		357				

Table 1.7. Dam (lacustrine) Turbidity (NTU) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	8.7	11.7	10.9	14.8	19.1	12.1	20
0.5	9.6	11.4	12.5	16.1	20.1	12.8	18.5
1	9.9	14	13.6	15.7	20.7	11.8	19.3
1.5	9.2	13.2	18.2	15.2	19.4	13	17.4
2	9.7	16.6	14.8	15.3	19.9	12.9	18.7
2.5	10.5	12.4	15.1	14.2	20.3	11.5	19.5
3	10.1	14	14.7	13.1	20.4	11.3	19.4
4	10.6	17	17.3	16.6	17.7	11.6	17.6
5	10.7	22.3	14.5	16.1	18.9	14.2	19.6
6	10.8	27.3	14	17	18	15.5	18.9
7	12.1	38.7	14.8	14.6	20.6	17.9	19.1
8	11.2	40.4	14.1	18.2	20.5	18.5	20.5
9	11.6	41.6	19.3	19.2	22	19.3	20.3
10	11.1	45.1	16.3	20.5	22.3		20.3
11	10.4		15.2	23.8	27.3		18.9
12	10.7		15	22.7	24		19.5
13	13.5		15.5				
14	15.1		18.2				

Table 1.8. Dam (lacustrine) Nitrate (mg/L) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	0.74	0.53	0.73	0.43	0.44	1.04	1.61
0.5	0.79	0.53	0.75	0.39	0.46	1.08	1.72
1	0.8	0.55	0.70	0.41	0.52	1.08	1.81
1.5	0.8	0.58	0.84	0.44	0.57	1.1	1.96
2	0.82	0.59	0.9	0.48	0.59	1.31	2.1
2.5	0.81	0.64	0.92	0.69	0.78	1.44	2.24
3	0.84	0.73	0.99	0.85	0.96	1.56	2.23
4	0.82	0.86	0.99	1.06	1.56	1.71	2.44
5	0.80	0.94	1.06	1.19	1.76	2.04	2.64
6	0.86	1.06	1.08	1.25	2.1	2.42	2.78
7	0.82	1.14	1.11	1.42	2.41	2.76	2.85
8	0.89	1.16	1.23	1.32	2.46	2.97	3.08
9	0.83	1.17	1.27	1.34	2.59	3.34	2.98
10	0.83	1.17	1.33	1.37	2.35		3.11
11	0.87		1.42	1.41	2.37		2.96
12	0.88		1.38	1.42			
13	0.87		1.44				
14	0.87		1.48				

Mile Marker 6

Table 1.9. Mile Marker 6 (Transition) Conductivity (µs/cm) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	0.175	0.156	0.168	0.173	0.175	0.184	0.183
0.5	0.175	0.155	0.169	0.173	0.174	0.183	0.183
1	0.175	0.156	0.17	0.173	0.174	0.183	0.183
1.5	0.175	0.15	0.172	0.173	0.176	0.183	0.183
2	0.175	0.149	0.173	0.173	0.176	0.183	0.183
2.5	0.175	0.152	0.173	0.174	0.178	0.182	0.182
3	0.174	0.151	0.173	0.174	0.178	0.182	0.182
4	0.174	0.152	0.175	0.175	0.178	0.183	0.182
5	0.174	0.154	0.176	0.174	0.178	0.184	0.182
6	0.174	0.157	0.176	0.175	0.175	0.185	0.182
7	0.174	0.157	0.176			0.186	0.182
8	0.174	0.161					0.182
9	0.174						0.182
10							0.182

Table 1.10. Mile Marker 6 (Transition) Dissolved Oxygen (mg/L) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	10.14	9.63	9.63	12	10.9	9.19	7.83
0.5	10.14	9.59	9.45	11.7	11.16	9.2	7.86
1	10.1	8.85	9.23	10.8	11.3	8.39	7.3
1.5	10.17	8.83	8.77	10.5	10.4	7.96	6.83
2	10.1	8.35	8.02	10.2	10.8	8.05	6.68
2.5	10.08	8.18	7.42	8.8	7.2	7.72	6.58
3	10.1	8.07	7.28	7.4	6.7	7.61	6.56
4	10.1	7.54	7.24	6.7	4.2	7.3	6.57
5	10.05	7.63	6.57	4.9	2.5	6.87	6.56
6	10	7.13	5.8	3.2		5.88	6.52
7	10	7.24	5.87			4.3	6.56
8	10	7.21				4	6.52
9	10						6.64
10							6.9

100

Table 1.11. Mile Marker 6 (Transition) Temperature (°C) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	12.7	19.9	24.1	27.27	27.6	24.03	20.4
0.5	12.7	19	23.9	27.1	27.5	23.9	20.35
1	12.7	18.1	23.4	27	27.4	23.8	20
1.5	12.7	17.7	22.9	26.8	26.3	23.6	19.55
2	12.7	17.5	21.9	26.2	26.1	23.6	19.52
2.5	12.7	17.1	21.2	25.5	24.9	23.5	19.48
3	12.7	17	20.6	25	24.6	23.5	19.47
4	12.7	16.8	20.5	23.9	23.6	23.5	19.44
5	12.7	16.6	20	23.5	23.1	23.4	19.43
6	12.7	16.3	19.1			23.4	19.43
7	12.7	16	19			23.4	19.39
8	12.7	15.6				23.1	19.38
9	12.7					22.9	19.31
10						22.7	19.23

Table 1.12. Mile Marker 6 (Transition) Chlorophyll *a* (ppb) concentrations over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	2.3	4.6	14.6	53.4	9.3	15.2	14.2
0.5	3	9.4	18.5	33.3	11.4	17.1	17.1
1	4.5	11.4	31.1	21.6	16.1	21.3	17.4
1.5	6	10.5	12.8	19.9	25.1	19.3	16.5
2	6.7	7.33	9.6	17.5	27.8	19.7	13.9
2.5	6.2	5.2	9	19	18.7	18.1	16.2
3	6.6	3.8	7.7	13.7	16.8	17.1	13.4
4	7.7	3.9	7.6	12.5	10	17	13.9
5	6.5	4.1	5.6	10.6	8.1	15.4	12.3
6	7.4	3.7	4.7	7.3		13.3	14.4
7	7.9	3.4	4.9			14.4	12.9
8	7.4	3.1				13.9	13.3
9	7.3						13

101

Table 1.13. Mile Marker 6 (Transition) pH measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	7.2	7.74	7.73	8.23	7.9	7.5	7.5
0.5	7.18	7.76	7.76	8.26	7.9	7.5	7.5
1	7.17	7.75	7.75	8.25	8	7.6	7.5
1.5	7.17	7.73	7.74	8.24	8.1	7.59	7.49
2	7.17	7.72	7.69	8.19	8	7.6	7.49
2.5	7.17	7.7	7.65	8.15	7.9	7.59	7.49
3	7.17	7.69	7.62	8.12	7.8	7.6	7.49
4	7.17	7.7	7.6	8.1	7.7	7.6	7.5
5	7.16	7.7	7.59	8.09	7.7	7.5	7.5
6	7.16	7.69	7.58	8.08	7.6	7.5	7.52
7	7.16	7.69	7.56	8.06		7.5	7.52
8	7.15	7.69					7.54
9	7.14						

Table 1.14. Mile Marker 6 (Transition) ORP (mV) measures over study period (2025)

	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	456	366	344	320	277	292	258
0.5	460	365	345	320	275	290	257
1	460	367	346	320	270	286	257
1.5	460	367	347	319	272	285	256
2	460	367	348	319	273	285	255
2.5	460	367	347	320	278	284	254
3	460	366	349	325	280	282	252
4	461	366	348	323	280	282	251
5	462	366	349	325	265	281	249
6	462	367	346	324		282	249
7	463	367	348			280	247
8	463	367					246
9	464						

Table 1.15. Mile Marker 6 (Transition) Turbidity (NTU) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	25	23.8	18.3	26.1	17.9	19.7	23.2
0.5	23.1	24	20.3	22.1	18	22.2	23.3
1	23.4	24.9	23.9	18.7	18.2	24.6	24.1
1.5	23.4	31.9	26.6	18.2	21.2	23	25.2
2	26.3	35.3	27	19.1	20.6	20.4	28.1
2.5	29.2	38.3	28.9	22.1	22.6	22.1	26.5
3	25	37.8	32	24.1	22.4	21.4	27
4	25.1	40.6	34.8	24.8	26.5	21.3	25.2
5	25.7	42.1	32.2	26.2	72	24.6	28.6
6	28.1	42.6	31.8	48		26	28.1
7	28.1	45.5	27.1			47.1	24
8	28.1	55.7				84	35.3
9	29.3						39.7

Toler Bridge

Table 1.16. Toler Bridge (Riverine) Conductivity (µs/cm) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	0.189	0.091	0.176	0.147	0.171	0.184	0.191
0.5	0.189	0.149	0.177	0.147	0.171	0.185	0.191
1	0.189	0.169	0.177	0.148	0.171	0.185	0.191
1.5	0.189	0.17	0.178	0.147	0.169	0.185	0.19
2	0.189	0.174	0.178	0.147	0.169	0.183	0.19
2.5	0.189	0.178	0.178	0.148	0.169	0.183	0.189
3	0.188	0.18	0.179	0.147	0.169	0.183	0.189
4	0.188	0.181	0.179	0.147	0.168	0.183	
5	0.188						

Table 1.17. Toler Bridge (Riverine) Dissolved Oxygen (mg/L) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	10.58	7.77	7.59	5.38	8.15	6.38	6.64
0.5	10.53	8.01	7.56	5.3	8.3	6.3	6.61
1	10.53	8.16	7.51	5.33	8.3	6.28	6.55
1.5	10.55	8.18	7.52	5.32	7.9	6.23	6.54
2	10.5	8.2	7.56	5.36	7.6	6.1	6.48
2.5	10.5	8.29	7.28	5.33	7.6	6.04	6.46
3	10.5	8.33	7.25	5.34	7.6	5.99	6.41
4	10.5	8.34	7.19	5.34	7.6	5.85	
5	10.5						

Table 1.18. Toler Bridge (Riverine) Temperature (°C) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	11.06	21.1	18.4	23.2	26.6	22.67	19.09
0.5	11	16.6	18	23.1	26.5	22.5	19.07
1	11.04	15.2	18	23.1	26.5	22.3	19.05
1.5	11	14.7	17.8	23.1	26.2	22.2	18.9
2	10.9	14.5	17.6	23.1	26.1	22.1	18.96
2.5	10.9	14.5	17.1	23.2	26.1	22.1	18.8
3	10.8	14.2	17	23.1	26.1	22.1	18.8
4	10.9	14	16.5		26.1	22	
5	10.9						

Table 1.19. Toler Bridge (Riverine) Chlorophyll *a* (ppb) concentrations over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	2.1	5	4.8	3.3	6.8	5.8	8.9
0.5	2.1	4.62	5.7	3.2	8.8	6	5.5
1	2.3	3.1	6.2	3.5	12	8.1	5.4
1.5	2.5	3	6.1	3.2	10.1	10.3	5.5
2	3.1	2.8	5.1	4.1	8.7	9.9	5.24
2.5	3.5	2.8	4.8	4.2	9	10.4	5.8
3	4.3	2.5	3.9	4.2	8.1	10.4	5.5
4	4.2	2.5	3.4	3.9	7.2	9.7	

Table 1.20. Toler Bridge (Riverine) pH measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	7.26	7.96	7.9	7.5	7.6	7.56	7.56
0.5	7.14	7.96	7.9	7.5	7.6	7.52	7.55
1	7.16	7.91	7.9	7.5	7.6	7.5	7.52
1.5	7.16	7.91	7.9	7.5	7.6	7.5	7.54
2	7.16	7.9	7.9	7.4	7.6	7.49	7.54
2.5	7.16	7.9	7.9	7.4	7.6	7.49	7.54
3	7.16	7.9	7.9	7.4	7.6	7.49	7.53
4	7.16	7.9	7.9	7.4	7.6	7.49	

Table 1.21. Toler Bridge (Riverine) ORP (mV) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	445	374	340	314	288	274	247
0.5	446	372	339	313	286	273	245
1	447	373	339	311	284	271	243
1.5	444	372	338	310	282	268	242
2	444	372	340	309	282	266	241
2.5	444	371	339	308	281	266	240
3	444	371	340	306	281	266	240
4	444	369	339	304	279	263	

Table 1.22. Toler Bridge (Riverine) Turbidity (NTU) measures over study period (2025)

Depth:	16-Apr	19-May	17-Jun	18-Jul	18-Aug	22-Sep	21-Oct
0	8.3	76.5	18.4	96.3	24.2	19.7	22.4
0.5	8.7	46	19.1	103.2	28.2	19.8	23
1	9.3	28.3	18.7	101	27.9	21.2	25.2
1.5	9.3	26.1	19.8	114	29.6	21.4	23.5
2	9.1	21.6	19.2	122	30.1	22.1	23.9
2.5	8.8	19.5	17	145	31.9	22.5	24.4
3	10	17.2	18.5	132	35.7	19.5	24.1
4	9.6	19	17.3	122	32.8	20.8	