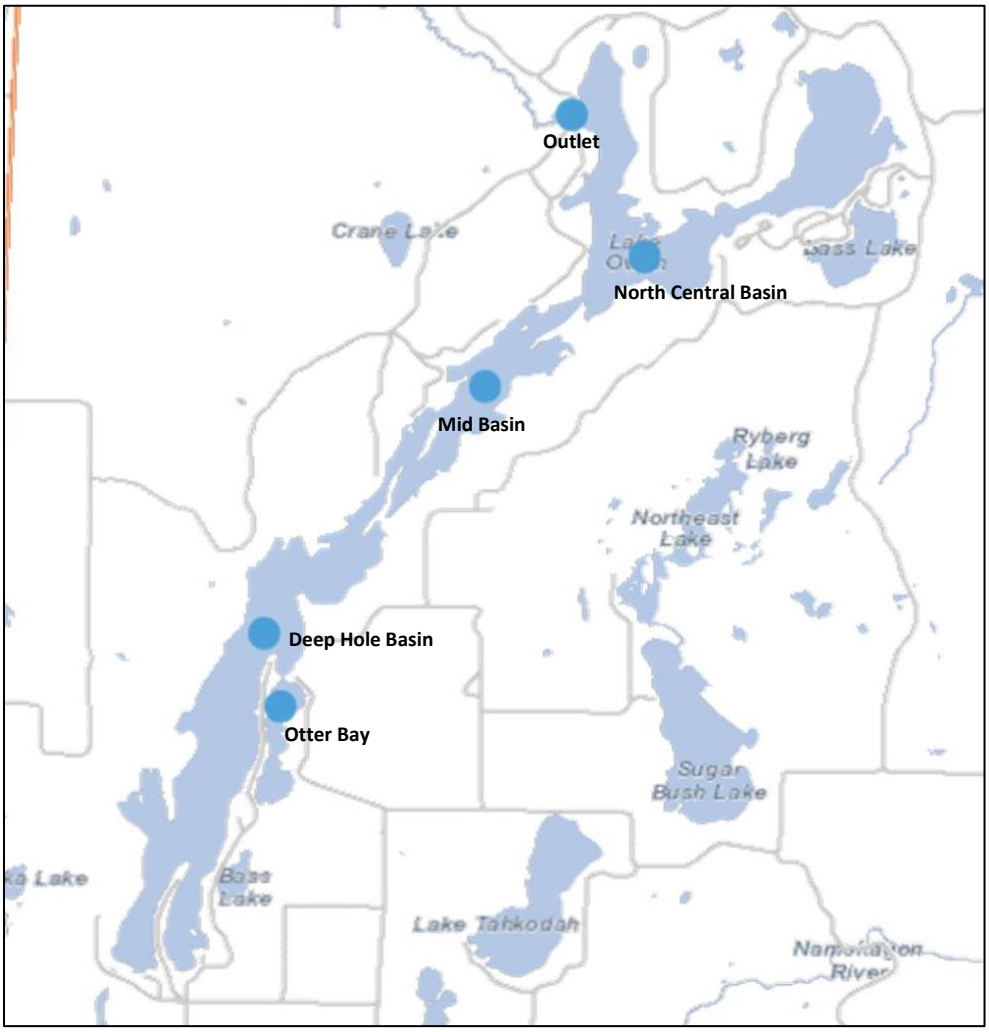
Lake Owen Water Quality Summary-2021 through 2022

Extensive water chemistry data were collected throughout 2021 and 2022. This summary will provide an overview of the data collected as well as the implications of this data. *Please refer to Appendix A on page 21 for an explanation of technical terms or concepts.*

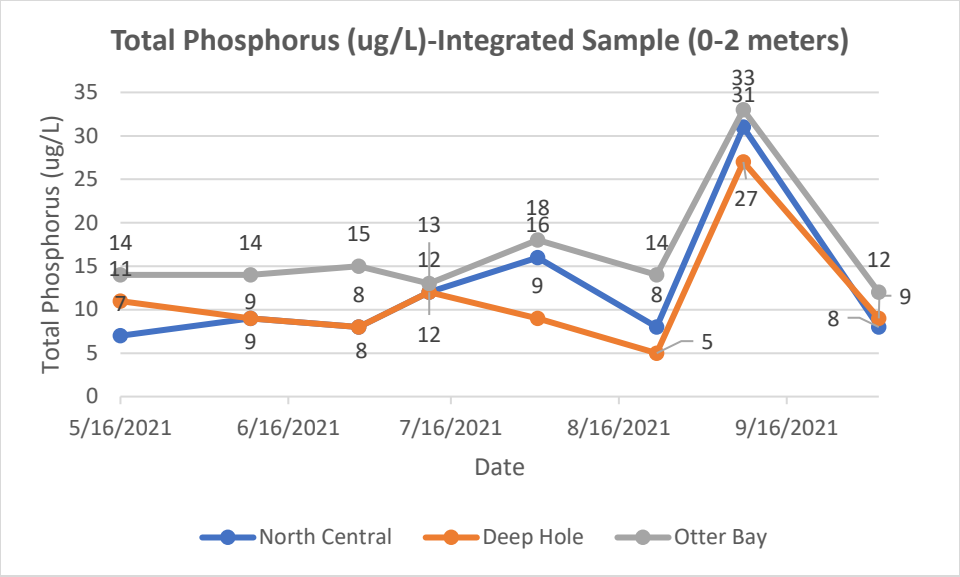
The map below shows the sample collection locations on Lake Owen.



2021 Data Summary:

<u>Epilimnion phosphorus</u>

Integrated (0-2 meters) water samples were collected monthly in three basins in Lake Owen in 2021. The graph displays the results of the total phosphorus concentration.



The total phosphorus data near the surface (integrated sample 0-2 meters) showed consistently low concentrations in all locations from May until late August. Otter Bay had higher total phosphorus concentrations than the other two basins, consistent with the previous year's data.

There was a spike in values, with all three basins showing a substantial increase in total phosphorus on Sept 8, which returned to values similar to the previous month's samples on Oct 3. There was no significant precipitation before the phosphorus spike, so the most likely source was the potential mixing of the epilimnion with the metalimnion. Interestingly, the spike occurred in Otter Bay, also isolated from the remainder of the lake.

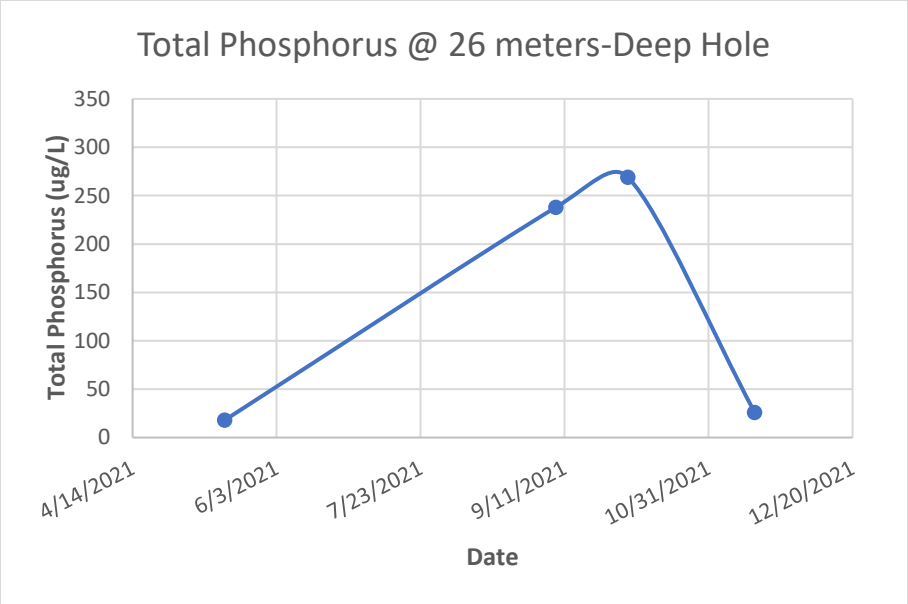
The average total phosphorus concentration in each basin is listed in the table below. The TSI value for each parameter is also listed. These data show that in 2021, Lake Owen was in the oligotrophic to mesotrophic state in the growing season based on total phosphorus concentration.

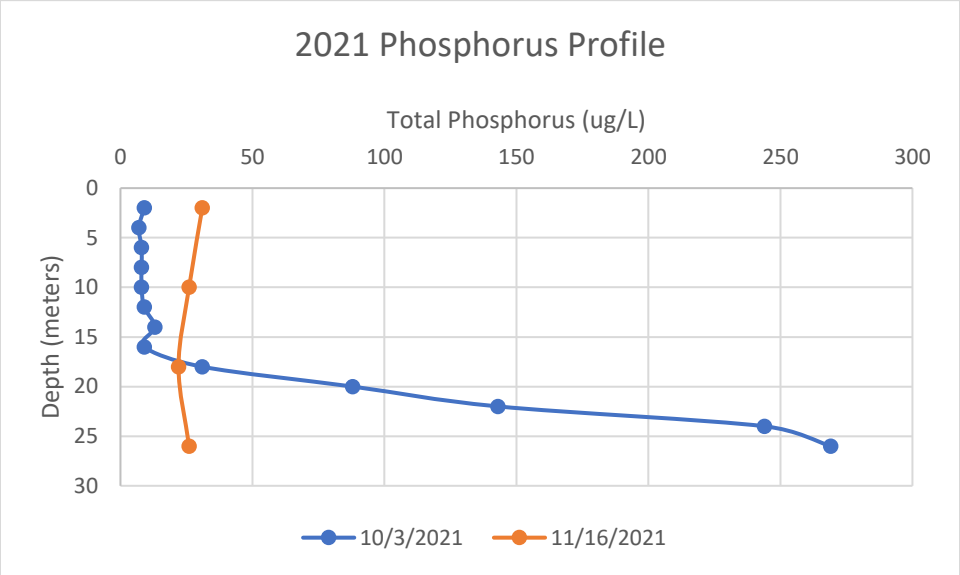
Basin	Mean TP concentration (May-Sept)	TSI value	Trophic State
North Central	13	41.1	mesotrophic
Deep Hole	11.6	39.5	oligotrophic
Otter Bay	17.3	45.3	mesotrophic

30-40=oligotrophic; 40-50=mesotrophic; >50=eutrophic

Hypolimnion/Internal load

The phosphorus profile in the deep hole sample site from 2021 shows that the lake accumulates phosphorus in the hypolimnion over time. The November total phosphorus concentration was much lower, showing turnover. The phosphorus concentration was the same from the surface to near the bottom, indicating the lake mixed thoroughly.





The graph above demonstrates the complete mixing that took place. The orange line shows the profile in November, following the turnover of Lake Owen. The blue line shows how the hypolimnion had accumulated phosphorus in October, before the turnover. Note the increase from October to November in the epilimnion (above 10 meters).

Using these profile data and lake volumes, it was calculated that the internal load that occurred during turnover was 582.6 kg. This load likely does not occur annually, as the previous year's profile data suggests Lake Owen doesn't thoroughly mix in all years in the fall. Additionally, since fall turnover, even if partial, occurs typically in November, the phosphorus that enters the epilimnion is so late in the fall that algae growth does not increase. By spring/early summer, this phosphorus settles back into the sediment as annual spring epilimnion total phosphorus concentrations are low and decrease further into

early summer. Therefore, the phosphorus released from the lake sediments over the summer has little to no impact on lake productivity, mainly due to the timing of the mixing.

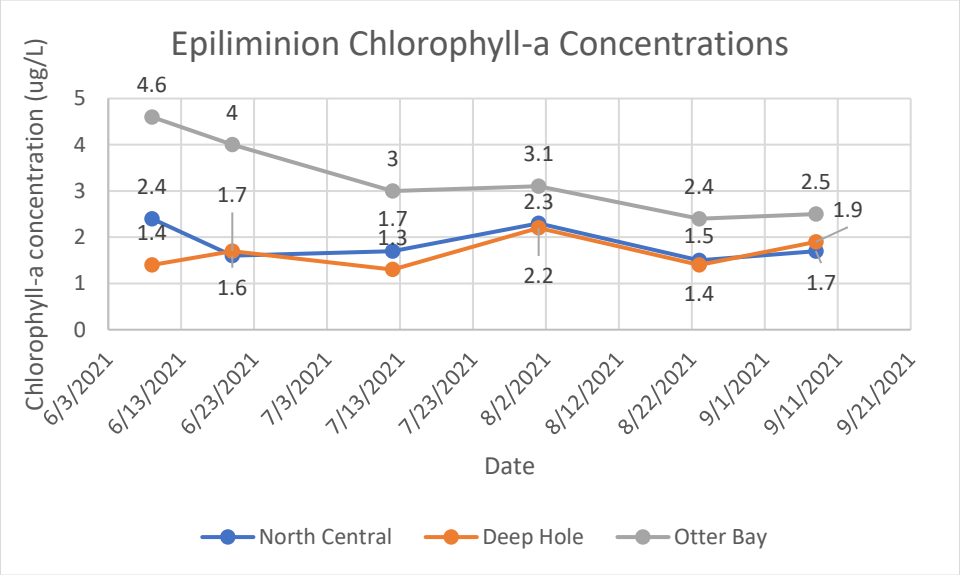
Total N: Total P ratio

The Comprehensive Lake Management Plan outlined the first evaluation of phosphorus, stating it was the limiting nutrient. However, there was no data presented to verify this assumption. To document this, total nitrogen was analyzed. It is typically recognized that if the total nitrogen to total phosphorus ratio is more significant than 10:1, then the lake is considered phosphorus limited.

The 2021 total nitrogen analysis yielded a mean June/July total nitrogen of 323 ug/L. This compares to the mean total phosphorus reading of 12.3 ug/L during the same period. Using this data, the TN: TP ratio is 26:1. This ratio verifies that Lake Owen is phosphorus limited.

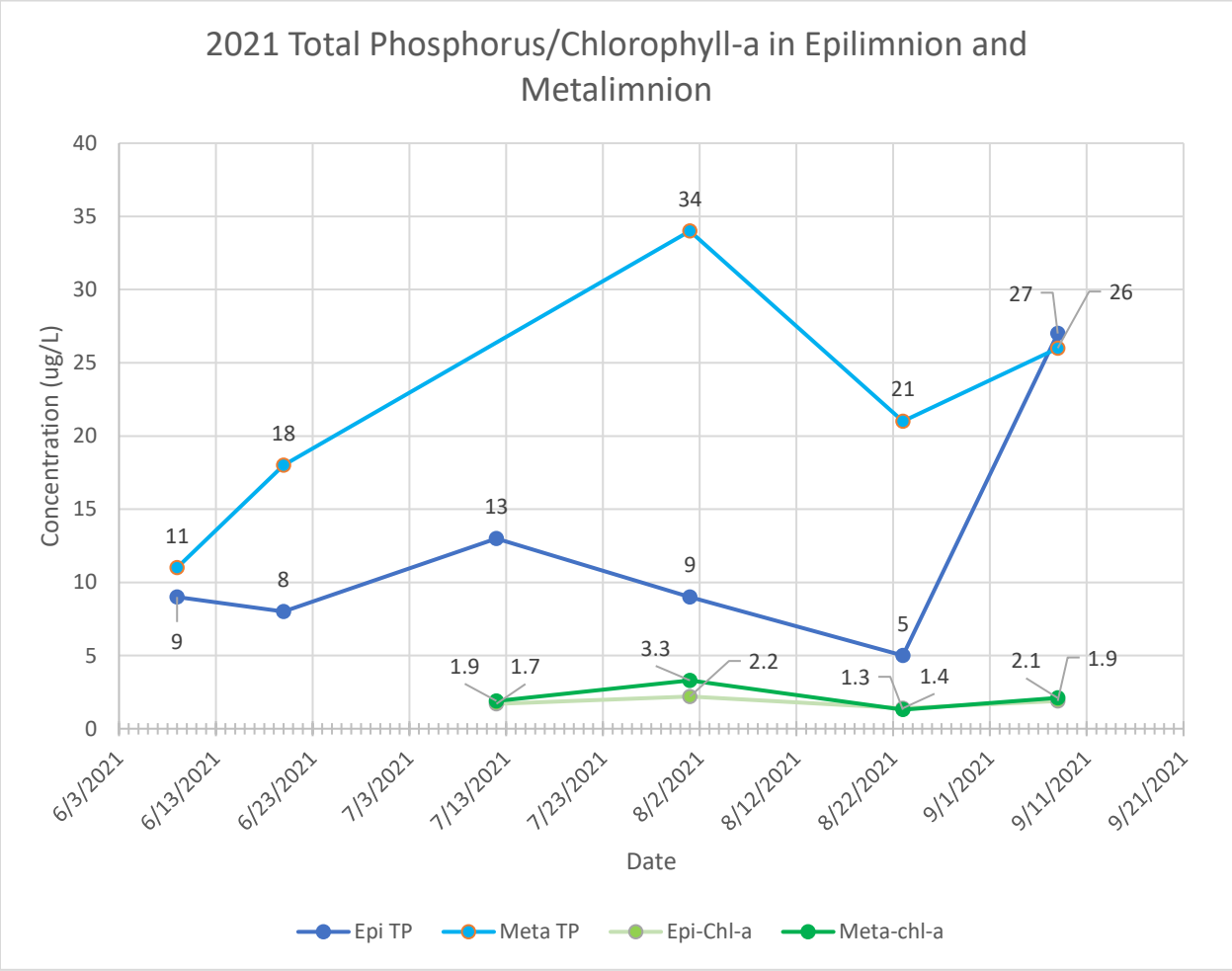
Epilimnion chlorophyll-a (indicates algae growth)

The data shows that the chlorophyll-a concentrations were similar in the North Central and Deep Hole basins. These values also show that algae growth was low in the epilimnion. In Otter Bay, the chlorophyll-a concentration was higher than in the main lake basins. This is consistent with the previous year's data.



Basin	Mean Chlorophyll-a Concentration (June-Sept)	TSI value for Chlorophyll-a	Trophic State
North Central	1.7	35.8	Oligotrophic
Deep Hole	1.9	36.9	Oligotrophic
Otter Bay	2.5	39.6	Oligotrophic

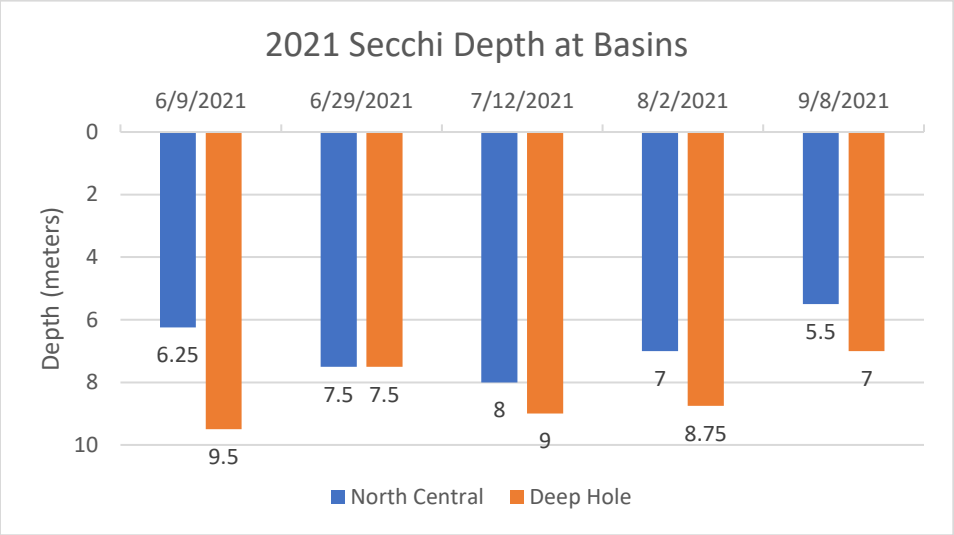
In 2019, the source of Lake Owen's substantial water clarity was evaluated. It was determined that most of the algae are growing in the metalimnion, where a combination of adequate light and available nutrients allows for this growth. Data was collected in the metalimnion and the epilimnion to further evaluate this dynamic. The graph below shows the epilimnion, metalimnion phosphorus, and chlorophyll-a data over the growing season.



The graph shows that the chlorophyll-a concentration was similar in the epilimnion and metalimnion. However, there was a significant difference between epilimnion total phosphorus and metalimnion total phosphorus during most of the growing season up through early September, yet the algae growth appears similar. This could be due to zooplankton foraging, which could reduce algae numbers and the phosphorus excretion from that same zooplankton. This is a possible explanation, but the actual reason is unknown. The September phosphorus readings in the two layers are similar, supporting the hypothesis that the upper two layers mixed some, leading to the September spike in the total phosphorus of epilimnion.

Secchi Depth

The graph below shows the Secchi Depth readings in 2021 in the North Central and the Deep Hole basins (no Otter Bay Secchi depth was collected due to the lack of depth).

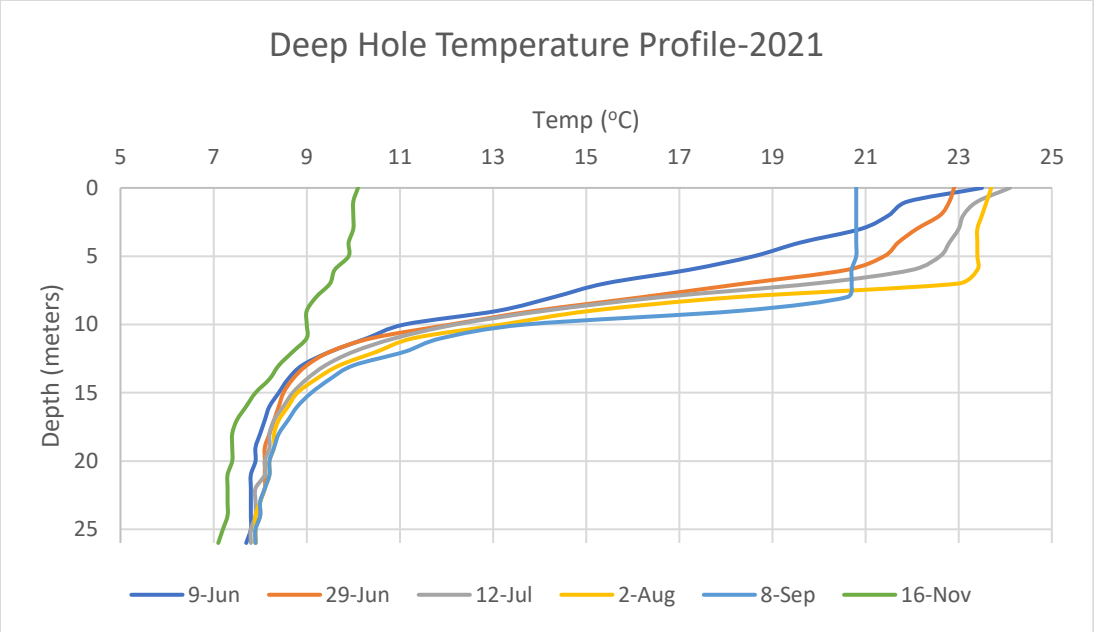


The graph shows that the Deep Hole Basin had higher water clarity than the North Central Basin. This is consistent with historical data. The Secchi depth in the Deep Hole ranged from 9.5 to 7 meters, which is high. The June Secchi depth in the North Central Basin was the lowest at 6.5 meters. This corresponds with higher chlorophyll-a concentration that was recorded on this same date. The value is still high clarity.

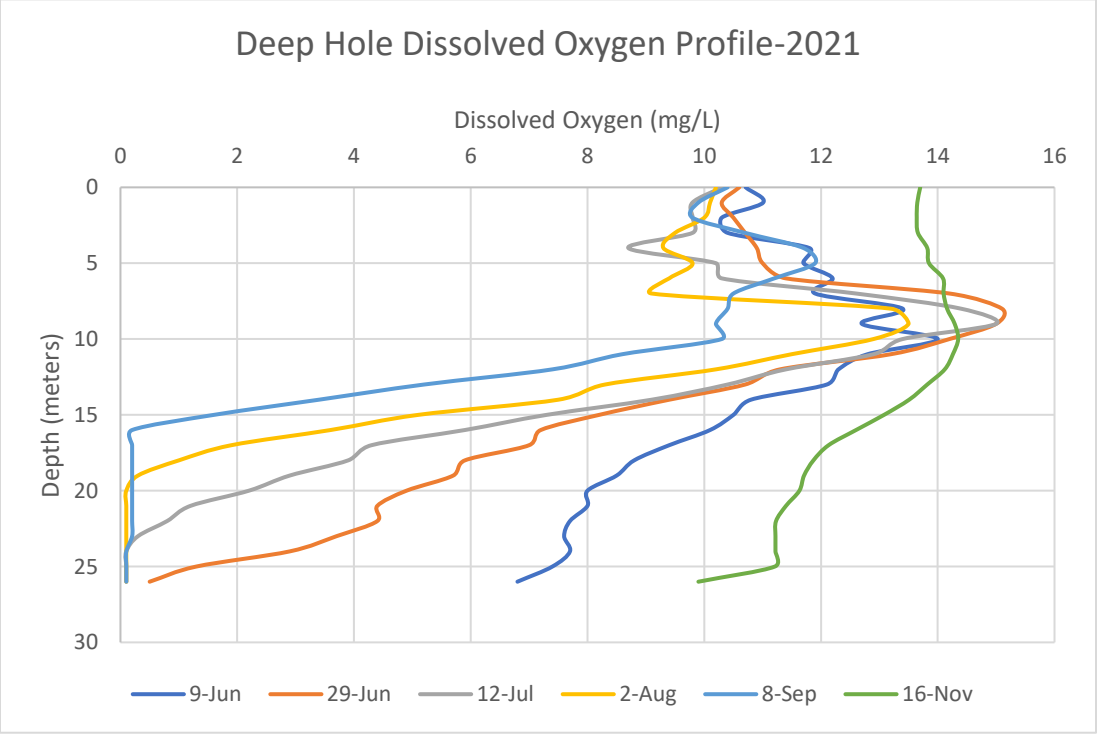
Basin	Mean Secchi Depth (June-Sept)(meters)	TSI Value (from Secchi depth)	Trophic state
North Central	6.85	32.3	Oligotrophic
Deep Hole	8.35	29.4	Oligotrophic

In 2021, the mean Secchi depth in both basins indicated an oligotrophic trophic state. In the Deep Hole, the TSI was below 30, which is phenomenal.

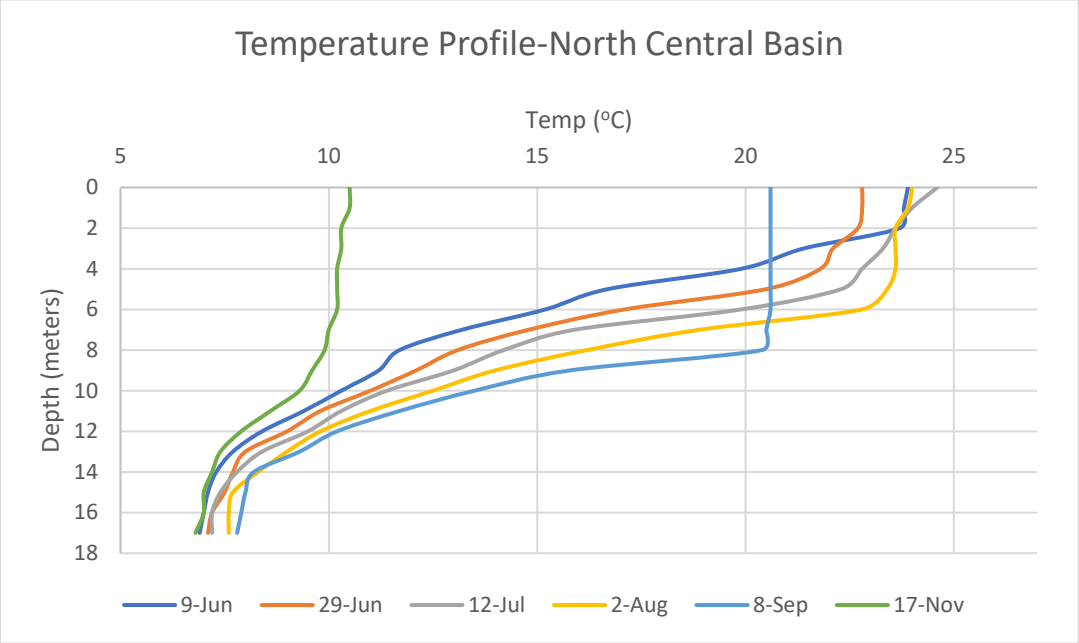
Temperature and Dissolved Oxygen Profiles



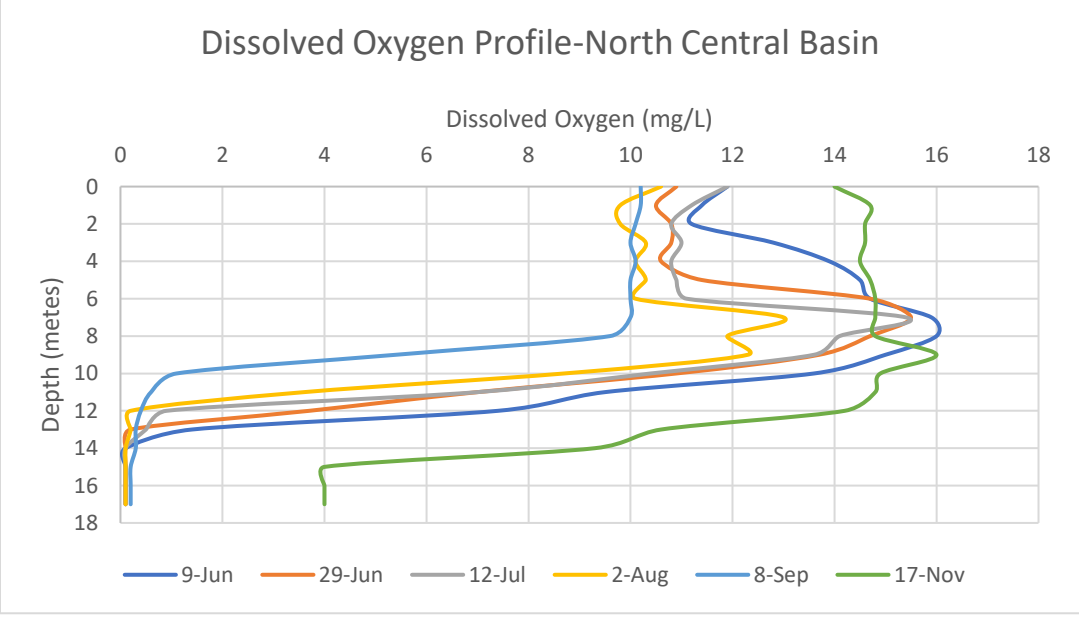
The temperature profile graph shows that Lake Owen was strongly stratified the whole summer, with a well-defined thermocline at about 7-10 meters. There is no evidence that the lake was mixed, but this data set is limited in scope.



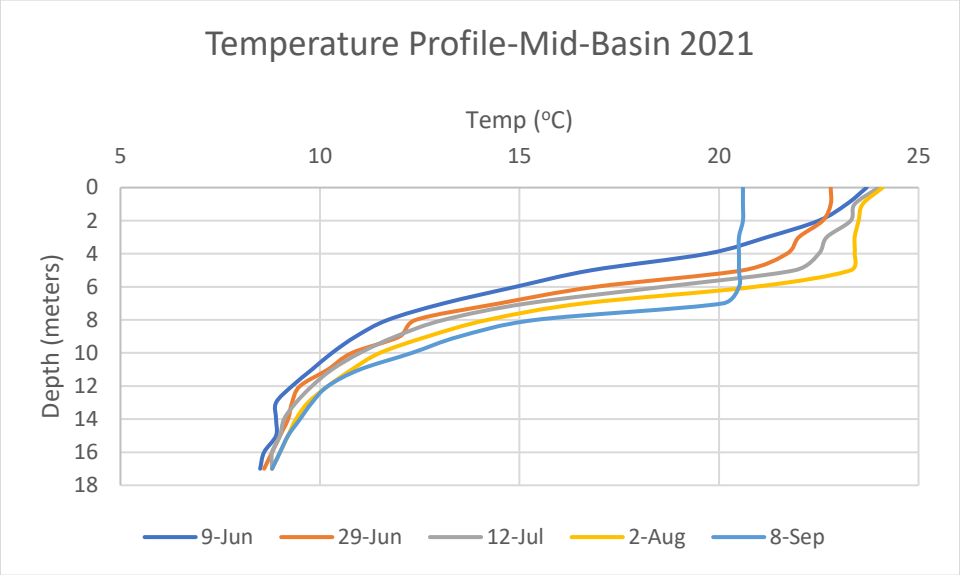
Note that the anoxic conditions don't begin near the bottom until the end of June. In July, the anoxic conditions start to occur in shallower depths until September 8, when the anoxic conditions occur up to 16 meters. The November 16 data supports that the lake was mixed at this time. Also, note the distinct increase in dissolved oxygen between 5 and 10 meters. This is likely due to a large population of algae occupying those depths, photosynthesizing.



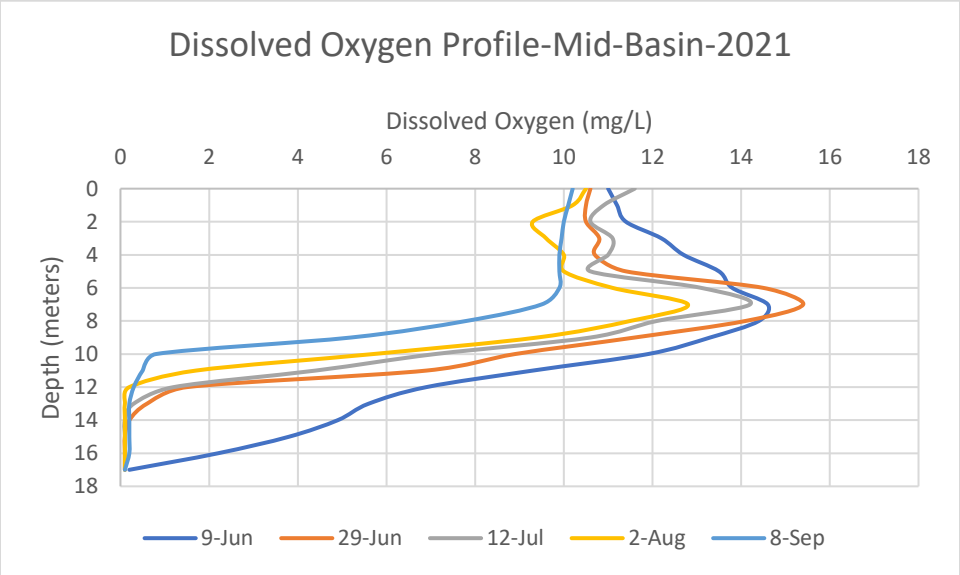
Note that the metalimnion ranges from 4-6 meters in June, but by September, it is 8-10 meters. The depth of the thermocline changes by about 5 meters (increase in depth). The lake is stratified in this basin from June until September (end of summer data). The November data shows it is mixed by this date.



Note that the anoxic conditions occur in early June and remain until November, when the lake is mixed. The anoxic conditions can lead to phosphorus release from lake sediment in Lake Owen.



The Mid-Basin profile shows stratification from June through September. The thermocline is more abrupt than in the North Central or Deep Hole Basin. The thermocline depth went from approximately 4 meters in June to around 8 meters in September. No water chemistry analysis was conducted at the Mid-Basin.

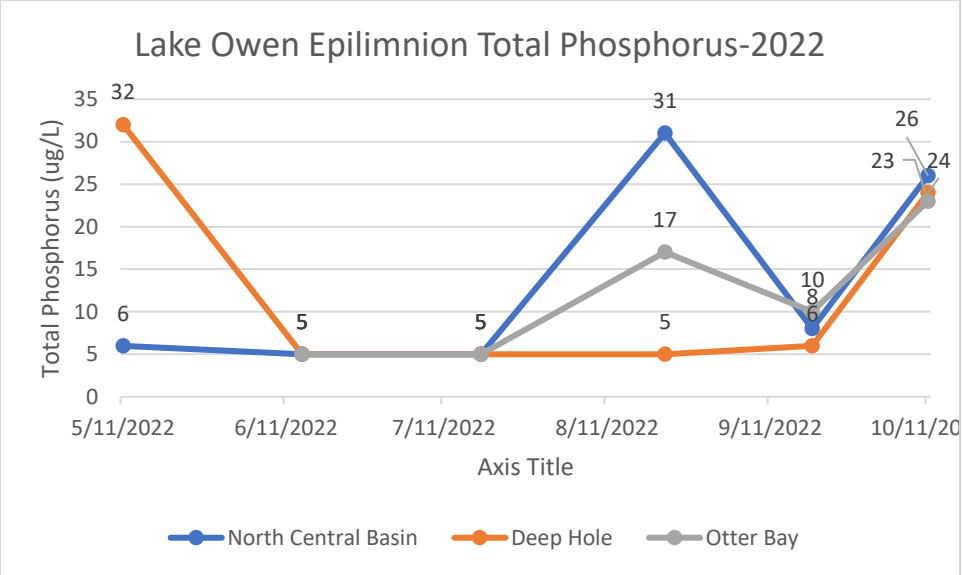


The Mid-Basin dissolved oxygen profile shows that anoxic conditions didn't start until the end of June. As with other basins, algae appeared to occupy the metalimnion with increased dissolved oxygen around 7 meters deep. The lake was anoxic in this basin, up to 10 meters deep in September.

2022 Data Summary:

Epilimnion Phosphorus Concentration

Water samples were collected monthly from May through October with an integrated sampler (0-2 meters). The results of the total phosphorus concentration in the three basins samples collected are shown in the graph below.



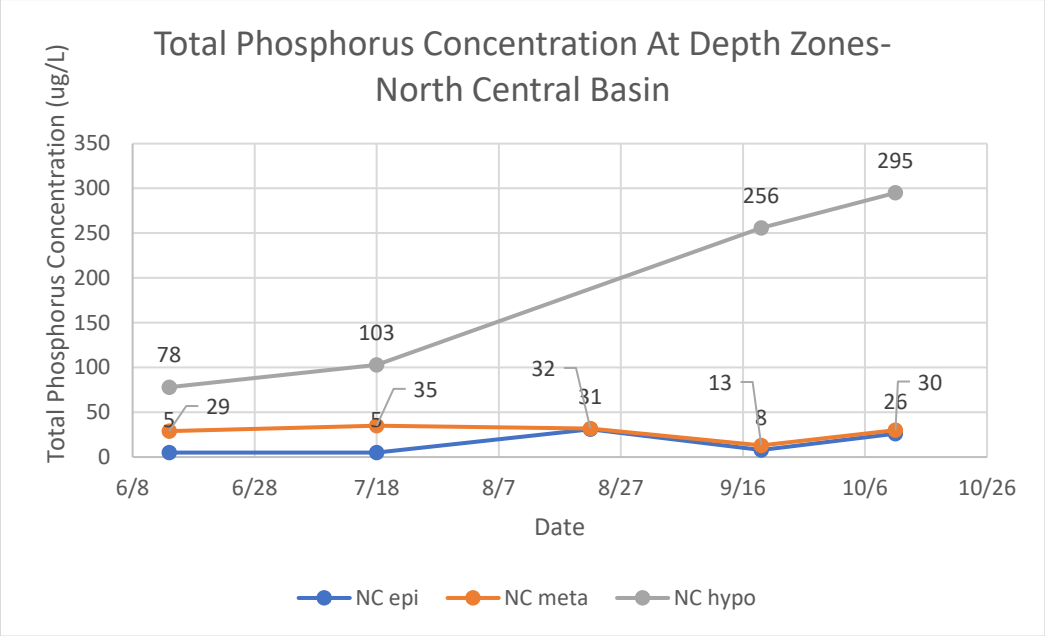
The epilimnion total phosphorus concentration was quite variable, and hard to decipher the cause for such variability. The phosphorus concentration started high in the deep hole basin in May but was very low in the North Central Basin and Otter Bay on that same date. There was a spike of high phosphorus concentration in the North Central Bay in August, but it was low on that same date in the Deep Hole basin. The profile data (end of this document) shows that the lake may have mixed in the North Central basin but did not mix in the Deep Hole basin). This mixing could cause entrainment of phosphorus up into the epilimnion, which would account for the August spike in phosphorus concentration. Otter Bay was also elevated in August, but all three basins were low in September. The lake mix started in October, reflected by elevated total phosphorus in all basins.

2022 was a drought year, with much lower-than-average precipitation.

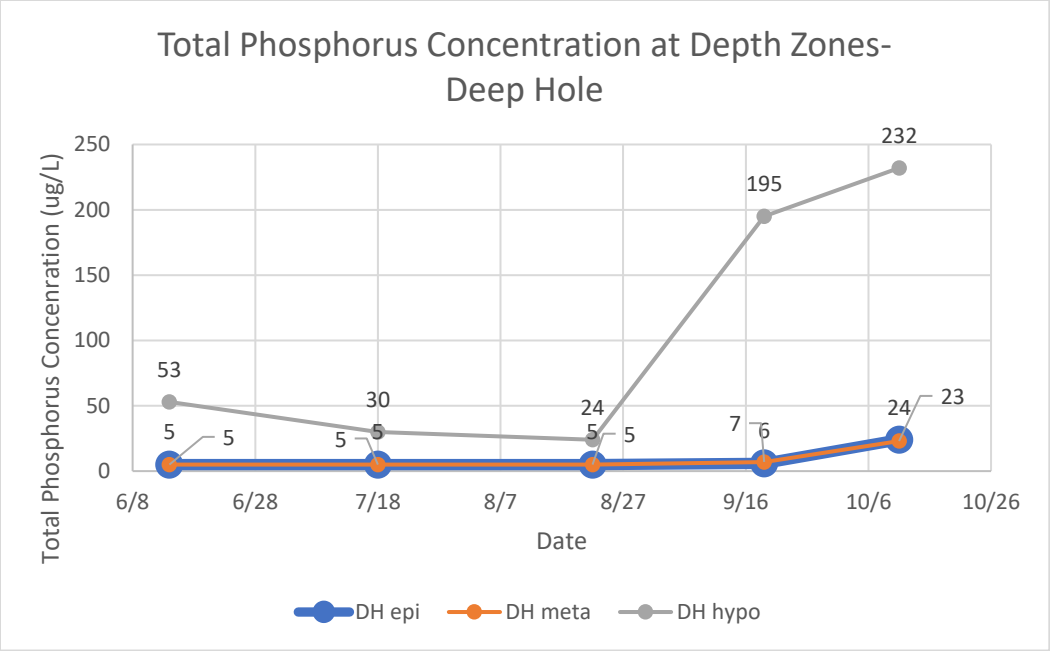
Basin	Mean Total Phosphorus Concentration (June-Sept)(ug/L)	TSI Value	Trophic State (based upon total phosphorus conc.)
North Central	12.3	40.3	Mesotrophic (just over the threshold of 40)
Deep Hole	5.3	28.2	Oligotrophic
Otter Bay	9.3	36.3	Oligotrophic

The total phosphorus average concentration resulted in TSI values that put the North Central Basin trophic state into mesotrophic. The Deep Hole Basin and the Otter Bay Basin were oligotrophic in 2022. Historically the Deep Hole basin total phosphorus has been oligotrophic, but Otter Bay has been solidly mesotrophic. The difference in 2022 likely reflects the lack of runoff in 2022, where precipitation totals were much lower than the 30-year average. It also supports the premise that storm runoff makes Otter Bay more susceptible to external phosphorus loading.

Metalimnion and Hypolimnion Phosphorus Concentrations

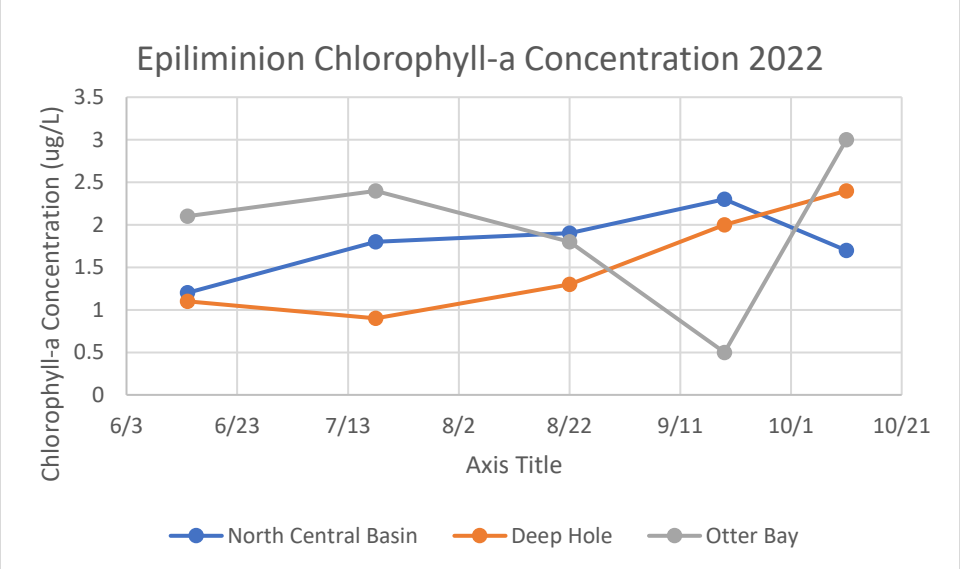


The total phosphorus concentrations in the metalimnion and hypolimnion were monitored to evaluate the available phosphorus for algae growth and phosphorus accumulation through sediment release in the hypolimnion. Two graphs reflect this data in the North Central and Deep Hole basins. In the North Central basin, the metalimnion phosphorus was slightly higher than the epilimnion most of the summer. In the Deep Hole Basin, this was different. We suspect the sample collections did not occur deep enough into the metalimnion. The temperature profile was used to determine the metalimnion layer, possibly leading to a thicker metalimnion layer with the upper portion sampled. Both basins showed a high total phosphorus concentration by October due to sediment release and hypolimnion water trapped due to solid stratification.



Epilimnion Chlorophyll-a

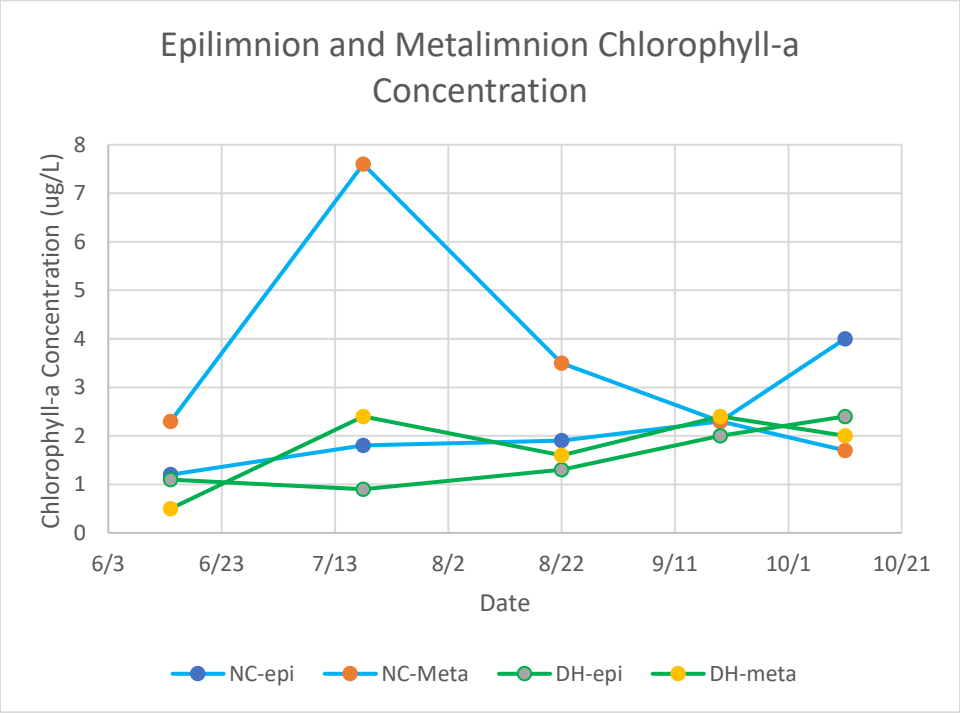
The chlorophyll-a concentrations were low throughout the summer. Otter Bay had higher concentrations each month except for September. The Deep Hole Basin had the lowest concentration all summer except for October. The concentrations sampled are consistent with the previous year's data, except Otter Bay was lower in 2022. The lack of runoff is likely reflected by these lower chlorophyll-a concentrations in Otter Bay in 2022 and is consistent with lower total phosphorus concentration.



The trophic state in each basin (from chlorophyll-a concentration) was oligotrophic in all three basins in 2022.

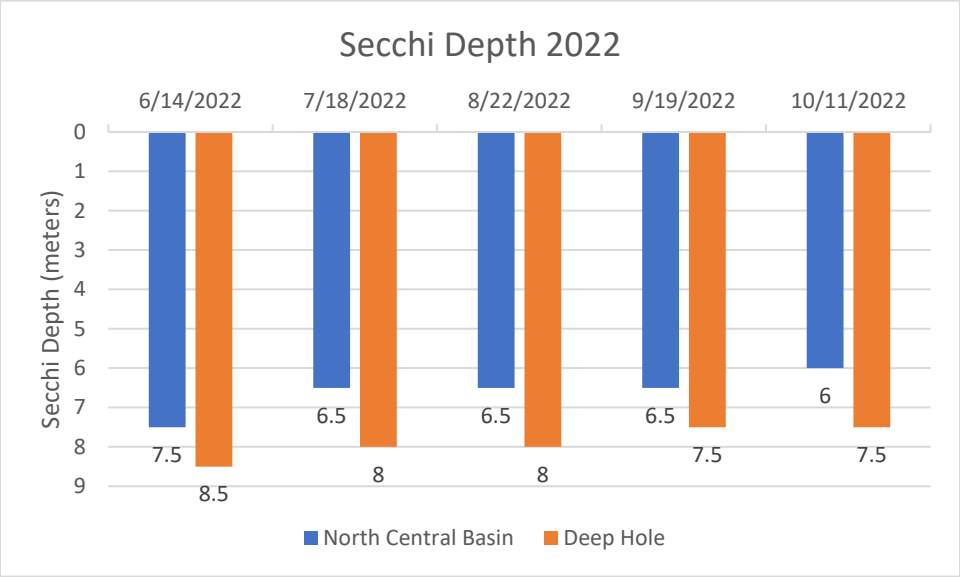
Basin	Mean Chlorophyll-a Concentration (June-Sept)	TSI Value based on chlorophyll-a concentration	Trophic State
North Central	1.8	36.4	Oligotrophic
Deep Hole	1.3	33.2	Oligotrophic
Otter Bay	1.7	35.8	Oligotrophic

Metalimnion chlorophyll concentrations were evaluated to determine if the historical data showed algae are growing mainly in the metalimnion. The graphs show that the algae growth in the North Central Basin was higher in the metalimnion compared to the epilimnion. This is due to the higher available phosphorus in this layer, with adequate light for photosynthesis. This difference was also present in the Deep Hole Basin but was more subtle. This could be related to the metalimnion samples being too shallow.



Secchi Depth

The graph below shows the Secchi depths in the North Central and Deep Hole basins. Otter Bay is too shallow as the Secchi disk hits bottom before the disk disappears.



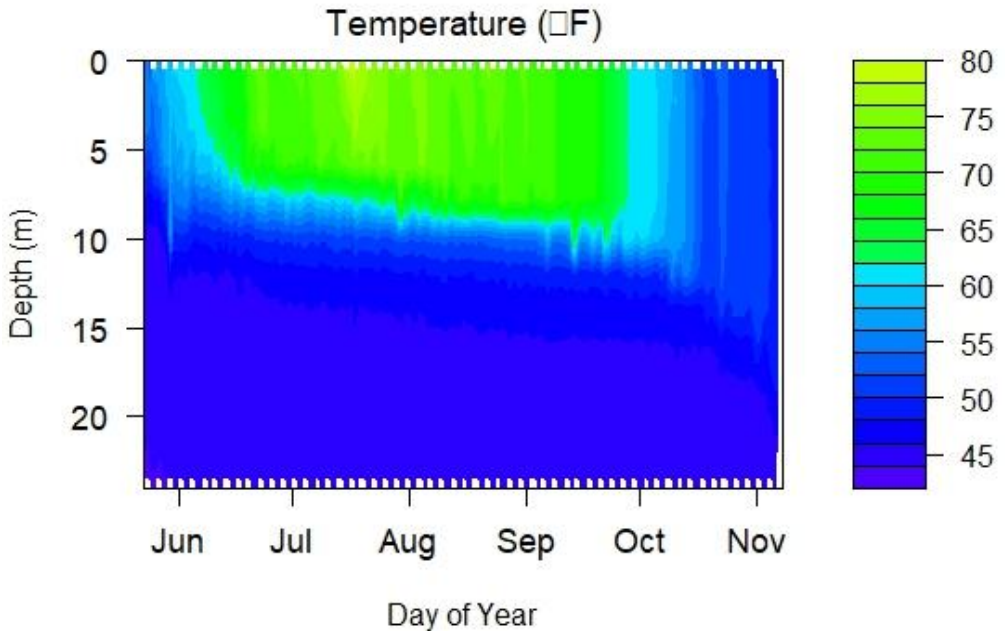
This data is consistent with historical data. The Deep Hole Basin has higher water clarity during the summer and falls than the North Central Basin. Also, the clarity is at its lowest in October, likely due to lake mixing.

Basin	Mean Secchi Depth (June-Sept)(meters)	TSI Value	Trophic State
North Central	6.75	32.5	Oligotrophic
Deep Hole	8.0	30.0	Oligotrophic

Both basins' Secchi Depth indicates an oligotrophic state from June through September 2022.

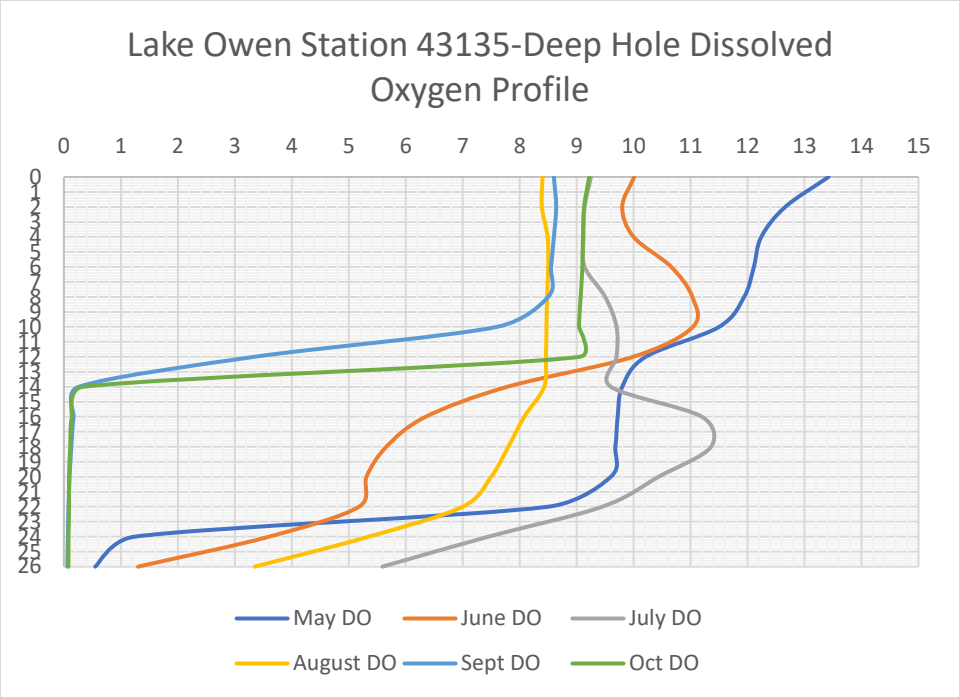
Dissolved oxygen and temperature profiles

Temperature and dissolved oxygen profiles were collected in three different basins (North Central, Deep Hole, and Mid-Basin). The graphs below are for these basins to demonstrate the significance of stratification in Lake Owen. The other two basins have similar data but aren't as deep. The temperature profile graph is from the thermistor string installed in 2022.

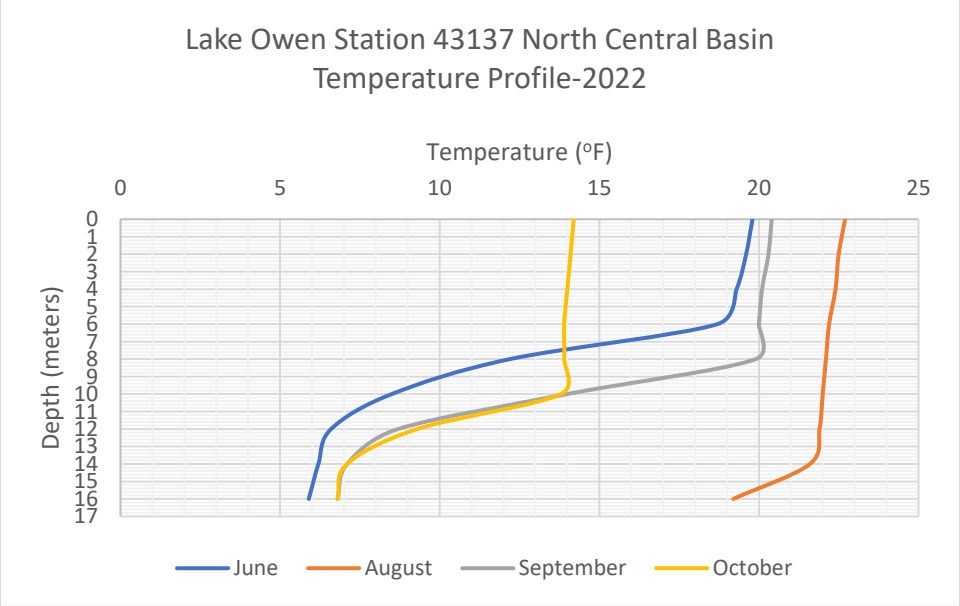


The temperature data shows that Lake Owen became strongly stratified from mid-June until October. The thermocline decreased in depth consistently until the lake mixed in late October. The difference in temperature between the upper epilimnion to the lower hypolimnion shows strong stratification that would lead to virtually no mixing between those two layers, which helps contribute to the high water clarity in Lake Owen.

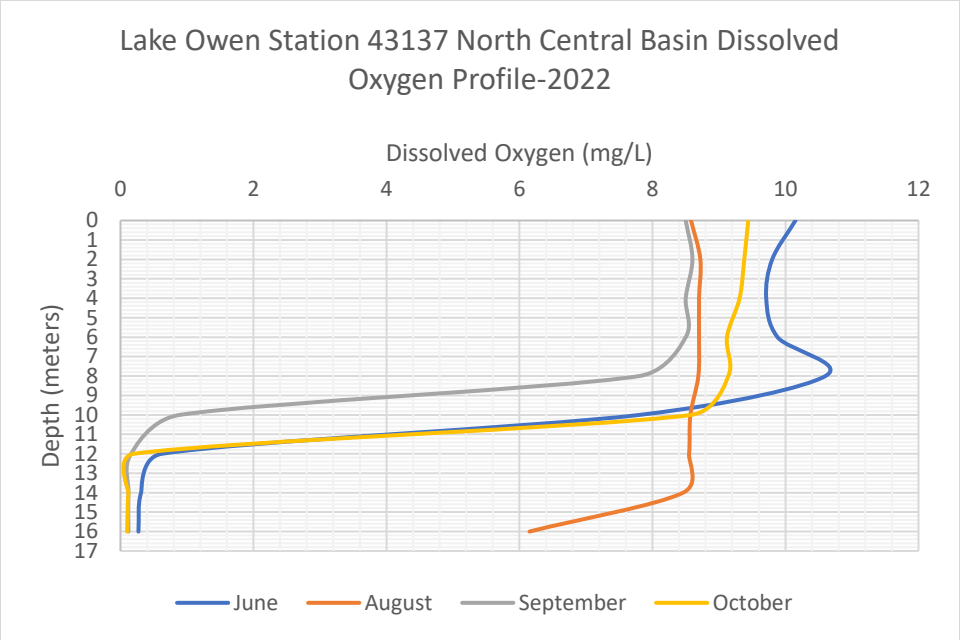
The dissolved oxygen profile is somewhat different from the previous year's data. The Lake was anoxic in May but wasn't anoxic again until September, when anoxic conditions occurred from 15 meters to the bottom. Previous years showed anoxic conditions maintained through much of the summer. There doesn't appear to be mixing present in the temperature data until maybe September (jagged green entering the dark blue).



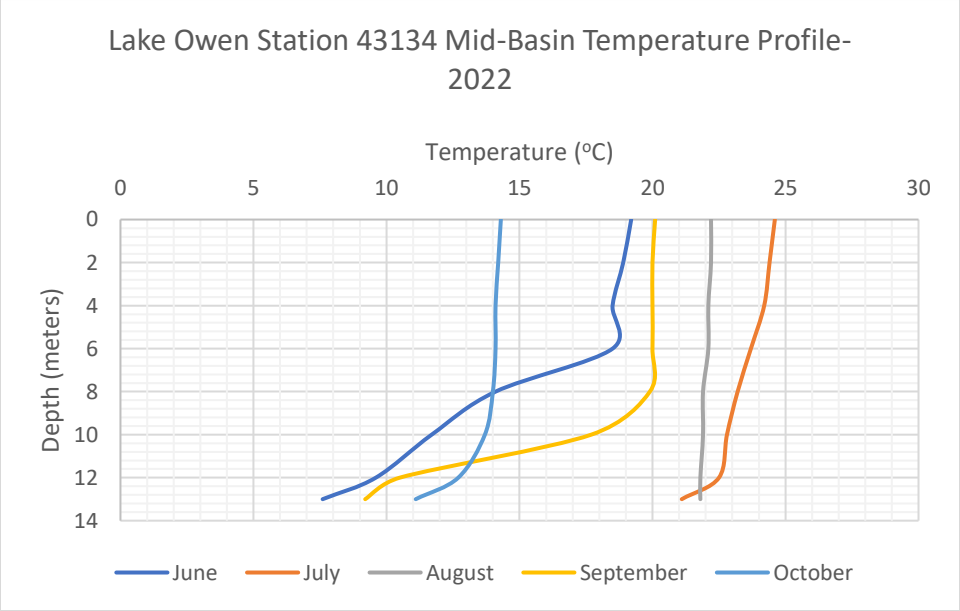
The profiles from the North Central Basin show that some lake mixing may have occurred in August. This may account for the spike in total phosphorus in the North Central Basin in August.

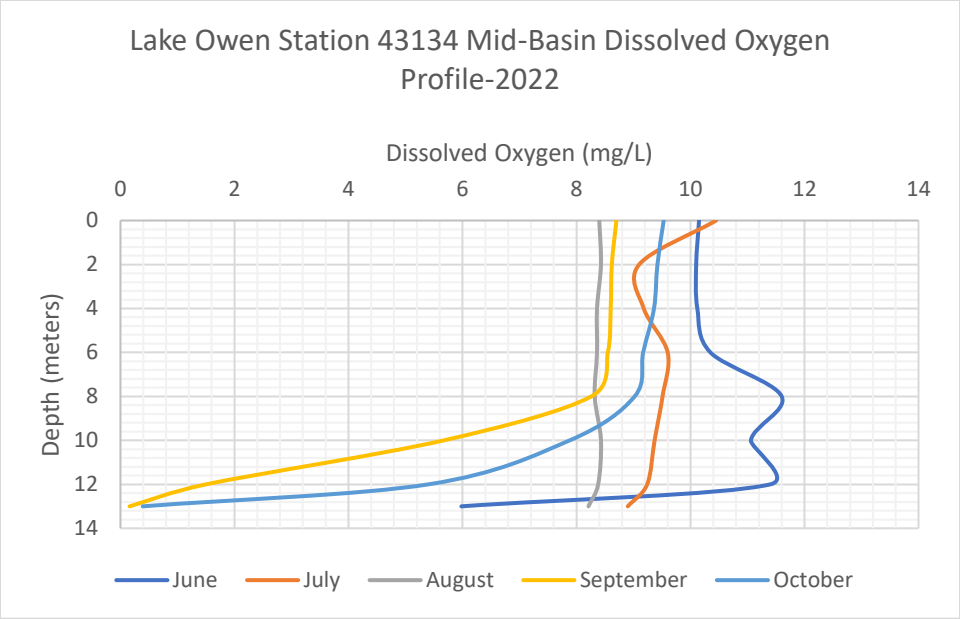


Note the orange line with consistent temperature from 0 to 14 meters, with a slight decrease at 16 meters. This indicates the lake mixed in this location.



Note the consistent dissolved oxygen values from 0 to 14 meters, and decline at 16 meters (but much higher than 1 mg/L, which designates anoxia). This shows that the dissolved oxygen went from anoxic to no anoxia from June to August, supporting the August mixing indicated by the temperature data (July data is missing in this graph due to meter technical issues in July).



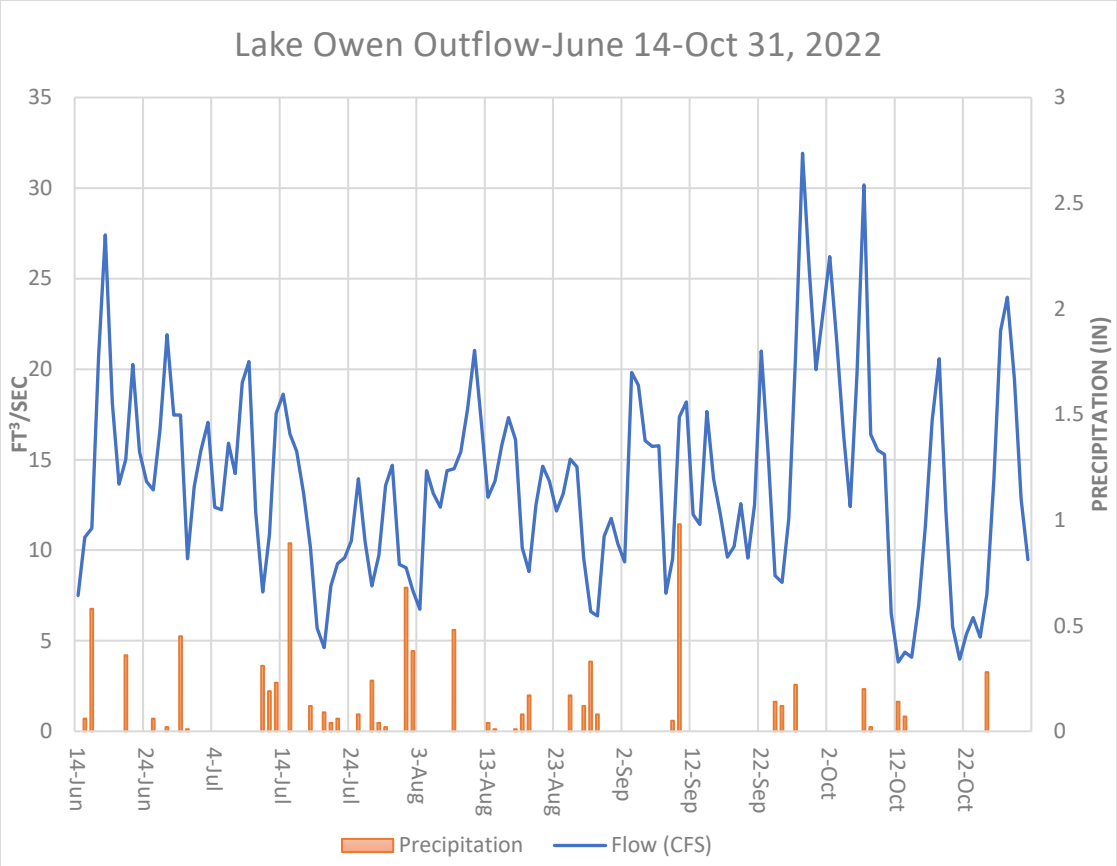


The Mid-Basin profiles supported a reduction in stratification in July and August 2022. This would allow the lake to mix more during these months. No chemical analysis occurred in this basin.

2022 Data Compared to Model

In 2020, a nutrient model for Lake Owen was built using the previous year's data and calibrated to an average year. That model predicts a GSM total phosphorus of 11 ug/L. With the reduced precipitation in 2022 (compared to a typical growing season), the model would predict a phosphorus concentration of 10-10.5 ug/L. The 2022 GSM total phosphorus concentration was 12.1 ug/L. This model would still be considered a fit to the lake data, but the difference in the predicted and the observed further supports that Lake Owen is a groundwater lake with limited runoff from the watershed. This leads to the direct drained watershed's reduced impact on the lake nutrients. Some causes of the slightly higher phosphorus readings (12.1 is still very low) may be higher lake residence time during a drought. This means the water spends more time in Lake Owen before it leaves the lake. The longer residence time could lead to slightly elevated phosphorus concentration.

Furthermore, there is some evidence of some mixing between the metalimnion and the epilimnion, which led to some entrainment of phosphorus into the epilimnion. This internal loading could account for slightly higher phosphorus concentration while little runoff occurred. Regardless, the model still does an excellent job of reflecting the nutrient sources in Lake Owen.



The mean outflow was 15 ft^3/s, about 10.9 ft^3/s less than in 2020. The precipitation amounts were substantially less in 2022 during the growing season (about 70% of normal). 2022 (outflow was not monitored in 2021) hydrograph above (with precipitation events in Cable, WI) shows that the flow got very low at times and responded with increases following more significant precipitation events but remained relatively low until October. This may be due to less evaporation from the lake's surface than in the summer months. This data supports that Lake Owen water sources mostly from groundwater, and the small watershed have some impact on water flow (and thus nutrient flow). Still, the watershed impact is reduced compared to lakes with larger watersheds and less groundwater influx.

Discussion

The 2021 and 2022 Lake Owen water analysis data shows that Lake Owen continues to have phosphorus, chlorophyll-a, and Secchi depth, which indicates the lake is oligotrophic. The data also shows that Lake Owen remained strongly stratified during the summer in the deepest hole, mixing in late fall (November). The mid-basin and north-central basins showed some evidence of reduced stratification in 2022 during the summer. The deep hole stratification data is consistent with historical data.

In 2019 and 2020, data were used to model Lake Owen's water and nutrient budget. There was less precipitation in 2021 and much less in 2022 than in 2019 and 2020. Yet the phosphorus concentrations and chlorophyll-a concentrations were similar. This supports the limited impact the small watershed that directly drains into Lake Owen has on the overall nutrient budget (from the model). Lake Owen's largest water source is groundwater, which helps to maintain its low nutrient state and exceptional water clarity.

Data in 2021 and 2022 suggest some entrainment of phosphorus from metalimnion/upper hypolimnion into the epilimnion. This potentially led to some phosphorus spikes that precipitation events could not account for. In addition, data collected from the hypolimnion shows that Lake Owen becomes anoxic near the sediment at some point in the summer and does release phosphorus into the hypolimnion. This phosphorus is trapped due to stratification. Mixing in November (fall turnover) 2022 resulted in an internal load calculation of over 580 kg. However, the phosphorus load does not lead to algae growth since overturn occurs so late in the fall.

The nutrient model created in 2020 is consistent with predicting the GSM phosphorus concentration compared to the observed values. Although the model predicts a lower concentration (due to drought conditions) in 2022 (the model predicted 10-10.5 ug/L vs. the 12.1 ug/L observed) than was observed in the lake, the phosphorus difference is slight. Lake Owen's total phosphorus concentration remains low. The increased residence time of the lake water (stays in the lake longer) may have contributed to similar phosphorus concentrations in Lake Owen in 2021-22 (during drought conditions) and 2021-20 when the precipitation amounts were higher. The lack of runoff didn't reduce phosphorus concentrations during the drought years.

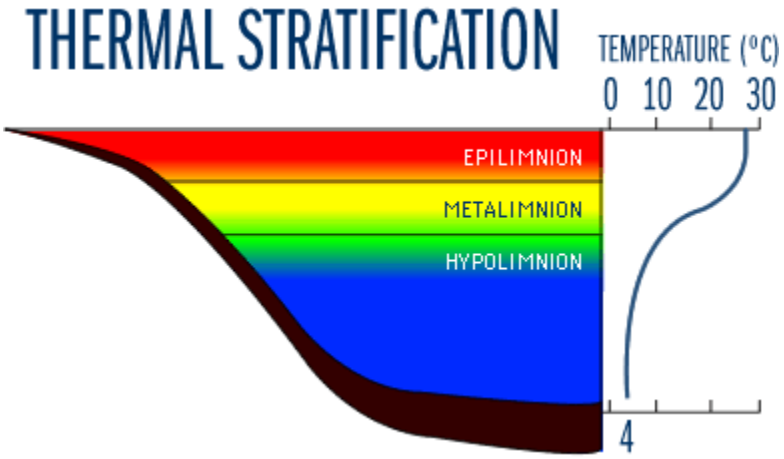
Otter Bay continues to have higher phosphorus and higher chlorophyll-a concentrations. This is likely due to higher overall development in the direct drained watershed, lower water volumes, and isolation from the main lake. Runoff reduction efforts (through management practices) could effectively reduce phosphorus and chlorophyll concentrations.

As stated in an earlier analysis, the runoff from the directly drained watershed and changes in the strength of stratification (reduced) during the growing season has the most significant potential for increasing nutrients into Lake Owen, resulting in more algae growth and lower water clarity. Currently, this is not an issue.

Appendix A: Explanation of lake terms and concepts

Lake Stratification and the implications

During the summer months, Lake Owen undergoes stratification. Stratification is when the lake forms distinct layers of water, based upon temperature, since water has a different density at different temperatures (colder, more dense than warmer). The resulting layers are referenced using epilimnion, metalimnion, and hypolimnion. The diagram below shows the layers, with the upper layer (warmer water near the surface) being the epilimnion, the middle layer metalimnion, where the temperature decreases abruptly, and the bottom hypolimnion is cold water trapped in the bottom.



Stratification is the layering of the lake based upon water density. There are three layers:

Epilimnion=top, less dense layer that more readily mixes.

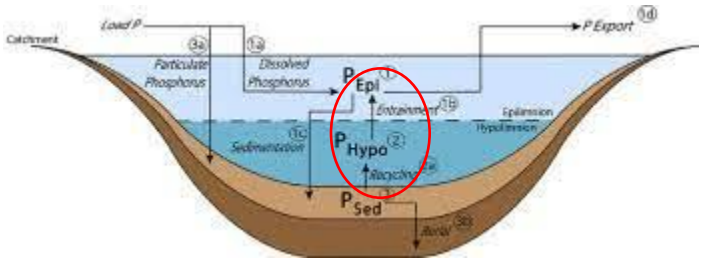
Metalimnion=middle layer where the temperature decreases and density increases dramatically.

Hypolimnion=deep layer of dense water which remains stable and doesn't reach upper depths until turnover occurs.

Stratification is crucial because once established, the mixing of the lake is highly reduced or even stopped. If the lake cannot mix, there is no way to get oxygen into the lower layer. In addition, bacteria in the sediment are consuming oxygen, with the resulting condition of anoxia. Anoxic conditions are typically referenced when the oxygen goes below 1 mg/L (1 ppm). The stronger the lake is stratified (resulting from more significant temperature differences), the less it will mix.

When anoxic conditions occur, the lake bottom sediment can release bound phosphorus. This phosphorus will generally remain in the hypolimnion since the lake cannot mix. However, if any mixing occurs or the metalimnion increases in depth, entrainment of phosphorus can occur. Entrainment

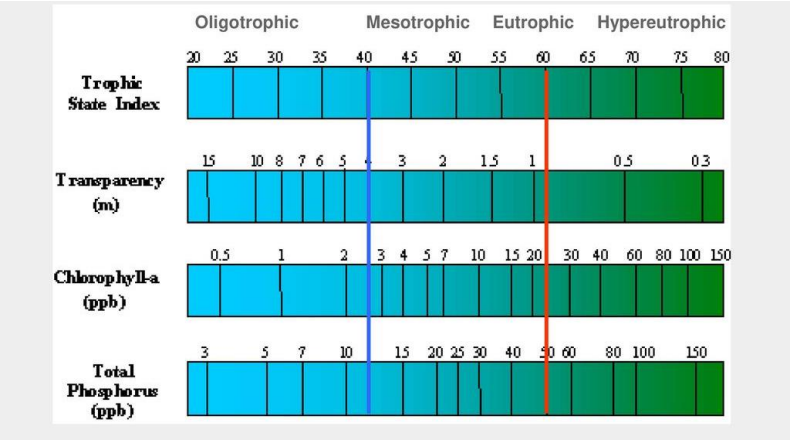
refers to the movement of the phosphorus up into the upper epilimnion layer. This addition of phosphorus to the epilimnion is referred to as internal loading.



Suppose phosphorus is released from the sediment. If trapped due to stratification, algae capture of phosphorus and growth will not occur since no light is available in the hypolimnion to allow photosynthesis. However, if entrainment of that phosphorus occurs (circled in red above), it can add phosphorus to the epilimnion, where algae can grow where there is adequate light intensity.

Trophic State Index (TSI)

The trophic state index (TSI) uses total phosphorus, chlorophyll-a, and Secchi depth to define a lake's trophic state (oligotrophic, mesotrophic, and eutrophic). The index is designed so that the same numerical trophic index will result based on correlations between phosphorus concentration, chlorophyll concentration, and Secchi depth.



TSI values:
<40 = oligotrophic
40-50 = mesotrophic
50-60 = mild eutrophic
60+ = eutrophic

Oligotrophic = minimal nutrients available, so the growth of tissue (algae and plants) is low (referred to as low productivity). These lakes have excellent water clarity and are more aesthetically appealing.

Mesotrophic = medium amount of nutrients leading to moderate algae and/or plant growth (productivity). A mesotrophic lake is still aesthetically appealing but may have minor water clarity issues or plant growth issues in portions of the lake.

Eutrophic = excessive nutrients leading to excessive algae and/or plant growth. A eutrophic lake typically has algae blooms in the summer and/or nuisance plant growth. These lakes are less aesthetically appealing due to less water clarity and possible nuisance plant growth.

Glossary of limnological terms

Anoxic-A state of having little oxygen (generally < 1 mg/L).

Bathymetry-The depth characteristics of a lake. Similar to a topographic land map.

Chlorophyll-The green pigment in plants and algae that absorb light for photosynthesis. One of the two forms (chlorophyll-a) represents the number of phytoplankton (algae) in the water column.

Epilimnion- The warm, oxygen-rich upper layer of a lake; less dense than lower layers.

Euphotic zone-The portion of the lake where photosynthesis can occur due to sufficient light. This zone ends just below the Secchi depth.

Eutrophic-A classification of a lake meaning that the lake is highly enriched (with nutrients).

Hypolimnion-A lower cold layer of a lake that lies below the metalimnion.

Limnetic zone-The open water zone of fresh waters (lake).

Littoral zone-The zone predominated by aquatic plants.

Macrophytes-Large aquatic plants.

Mesotrophic-Those lakes that are moderately enriched. Between oligotrophic and eutrophic.

Metalimnion-The intermediate layer in lakes between the epilimnion and the hypolimnion. The metalimnion is the zone of very rapid temperature changes (>1^{o}C/meter).

Morphometry-The method of measuring and analyzing the physical dimensions of a lake; a function of underwater contour lines, the shape of the lake, and its geologic origin when describing a lake.

Oligotrophic-A trophic classification of lakes having little nutrients.

Phytoplankton-The plant members of the plankton community, which are suspended or free-floating in the water column, include algae and are often referred to as “algae.”

Plankton-Collectively all those organisms (tiny) are suspended in the water with limited mobility in a current.

Production (productivity)-The amount or weight of organic matter synthesized by organisms from inorganic substances by autotrophs (plants or algae) per unit of time in a defined volume of water.

Secchi depth-A measure of the relative depth of light penetration. It uses a black and white disk lowered into the water with the depth it disappears from view being recorded.

Soluble reactive phosphorus (SRP)-The form of phosphorus dissolved in the water that is available for uptake by phytoplankton (bioavailable).

Thermocline-A depth defined significant temperature change within the metalimnion.

Total phosphorus-A value that represents all forms of phosphorus in the water.

Trophic state-Enrichment state of a lake; oligotrophic, mesotrophic, or eutrophic.

Trophic State Index (TSI)-A calculation using total phosphorus concentration, chlorophyll-a concentration, and Secchi depth to determine the trophic state.

Watershed-An area of land that intercepts and drains precipitation and collects water for a particular water body. A direct drained watershed is the area around the lake where the water will runoff directly into the lake (not another depression or pool).

Zooplankton-Collectively, all those animals suspended in the water of an aquatic habitat that is not independent of currents and water movements.

Appendix B: Data

2021 Data Set:

Lake	Station	Date	Depth (m)	TP(ug/L) LOD 6 ug/L LOQ 18 ug/L	Ortho P(ug/L) LOD 2 ug/L LOQ 6 ug/L	Chl-a (ug/L) LOD 0.6 ug/L LOQ 1.8 ug/L	Total Fe (mg/L)	NO2-NO3 ug/L) LOD 0.05 mg/L LOQ 0.15 mg/L	Total KjelN (ug/L)	TN (ug/L)	CHLORIDE (mg/L)
Owen	43137	5/16/2021	0-2	7	ND	1					
Owen	43137	5/16/2021	14	134	7		1.434				
Owen	43135	5/16/2021	0-2	11	ND	ND					
Owen	43135	5/16/2021	26	18			0.034				
Owen	10030464	5/16/2021	0-2	14	ND	1					
Owen	43137	6/9/2021	0-2	9	3	2.4		ND	25	248	
Owen	43137	6/9/2021	4	18							
Owen	43137	6/9/2021	6	11							
Owen	43135	6/9/2021	0-2	9	ND	1.4		ND	29	287	
Owen	10030464	6/9/2021	0-2	14	ND	4.6		ND	41	413	
Owen	43137	6/20/2021	0-2								
Owen	43137	6/20/2021	8	16							
Owen	43137	6/20/2021	10	18							
Owen	43137	6/20/2021	12	16							
Owen	43137	6/20/2021	14	141							
Owen	43137	6/29/2021	0-2	8	ND	1.6					
Owen	43135	6/29/2021	0-2`	8	ND	1.7					
Owen	43135	6/29/2021	10	14							
Owen	10030464	6/29/2021	0-2	15	ND	4					
Owen	43137	7/12/2021	0-2	12	3	1.7		ND	27	273	
Owen	43135	7/12/2021	0-2	13	2	1.3		ND	39	395	2.8
Owen	43135	7/12/2021	8			1.9					
Owen	10030464	7/12/2021	0-2	13	3	3.3					
Owen	43137	8/1/2021	0-2	16	4	2.3			12.33333333	323.2	
Owen	43135	8/1/2021	0-2	9	3	2.2					
Owen	43135	8/1/2021	10	34	3	3.3					
Owen	10030464	8/1/2021	0-2	18	4	3.1					
Owen	43137	8/23/2021	0-2	8	ND	1.5					
Owen	43135	8/23/2021	0-2	ND	2	1.4					
Owen	43135	8/23/2021	10	21		1.3					
Owen	10030464	8/23/2021	0-2	14	ND	2.4					
Owen	43137	9/8/2021	0-2	31	ND	1.7					

Lake	Station	Date	Depth (m)	TP(ug/L) LOD 6 ug/L LOQ 18 ug/L	Ortho P(ug/L) LOD 2 ug/L LOQ 6 ug/L	Chl-a (ug/L) LOD 0.6 ug/L LOQ 1.8 ug/L	Total Fe (mg/L)	NO2-NO3 ug/L) LOD 0.05 mg/L LOQ 0.15 mg/L	Total KjelN (ug/L)	TN (ug/L)	CHLORIDE (mg/L)
Owen	43135	9/8/2021	0-2	27	ND	1.9					
Owen	43135	9/8/2021	10	26	ND	2.1					
Owen	43135	9/8/2021	26	238			1.052				
Owen	10030464	9/8/2021	0-2	33	3	2.5					
Owen	43137	10/3/2021	0-2	8	3	1.9					
Owen	10030464	10/3/2021	0-2	12	3	6.1					
Owen	43135	10/3/2021	0-2	9	4	1.7					
Owen	43135	10/3/2021	4	7							
Owen	43135	10/3/2021	6	8							
Owen	43135	10/3/2021	8	8							
Owen	43135	10/3/2021	10	8							
Owen	43135	10/3/2021	12	9							
Owen	43135	10/3/2021	14	13							
Owen	43135	10/3/2021	16	9							
Owen	43135	10/3/2021	18	31							
Owen	43135	10/3/2021	20	88							
Owen	43135	10/3/2021	22	143							
Owen	43135	10/3/2021	24	244							
Owen	43135	10/3/2021	26	269							
Owen	43135	11/16/2021	2	31							
Owen	43135	11/16/2021	10	26							
Owen	43135	11/16/2021	18	22							
Owen	43135	11/16/2021	26	26							

Deep Hole	6/9/2021			6/29/2021			7/12/2021			8/2/2021			9/8/2021			11/16/2021		
Depth	Temp	DO	Cond	Temp	DO	Cond	Temp	DO	Cond	Temp	DO	Cond	Temp	DO	Cond	Temp	DO	Cond
0	23.5	10.71	141.7	22.9	10.6	143.2	24.1	10.3	143.8	23.7	10.2	141	20.8	10.4	141.7	10.1	13.7	145
1	21.9	11.01	141.4	22.8	10.3	143.6	23.4	9.8	144	23.6	10.1	141.3	20.8	9.9	141.8	10	13.65	145
2	21.5	10.3	141.6	22.6	10.5	143.6	23.1	9.8	143.8	23.5	10	141.1	20.8	9.8	141.7	10	13.64	145
3	20.9	10.4	141.6	22.1	10.7	144.2	23	9.8	143.9	23.4	9.5	141	20.8	10.7	141.6	10	13.66	145
4	19.6	11.8	141.6	21.7	10.9	144.1	22.8	8.7	143.7	23.4	9.3	141	20.8	11.7	141.6	9.9	13.82	145
5	18.6	11.7	141.4	21.4	11	143.9	22.6	10.2	143.9	23.4	9.8	141.1	20.8	11.9	141.4	9.9	13.85	145
6	17.2	12.2	141.4	20.6	11.4	144.6	22	10.3	143.9	23.4	9.4	141	20.7	11.2	141.4	9.6	14.09	145.1
7	15.4	11.9	141.5	18.4	14.2	144.8	19.9	12.6	145.8	23	9.1	142.3	20.7	10.5	141.3	9.5	14.1	145
8	14.3	13.4	143.4	16.2	15.1	144.6	16.6	14.4	145.2	18.2	13.2	146.3	20.6	10.4	141.5	9.2	14.16	144.8
9	13.1	12.7	148.5	13.9	15	144.9	14.1	15	145.5	15.1	13.5	147.3	18.3	10.2	146.9	9	14.29	144.7
10	11.1	14	146.4	12.1	14.2	145.7	12.2	13.4	146.8	13.2	12.9	146	13.7	10.3	147.6	9	14.35	144.6
11	10.3	12.8	147	10.4	13.2	146.4	10.9	12.9	147.3	11.3	11.5	146.8	11.9	8.6	147.7	9	14.26	144.9
12	9.5	12.3	146.8	9.5	11.3	147	10	11.4	147.2	10.5	10.2	146.9	11.1	7.4	147.5	8.7	14.12	144.8
13	8.9	12.1	147.1	9	10.7	147	9.4	10.4	147.3	9.7	8.3	146.7	10	5.2	147.8	8.4	13.82	144.9
14	8.6	10.8	147.1	8.7	9.4	147.1	9	9.1	147.3	9.2	7.5	146.5	9.5	3.4	147.7	8.2	13.51	145
15	8.4	10.5	148.1	8.5	8.2	147.4	8.7	7.3	147.6	8.8	5.1	147.7	9.1	1.6	148.2	7.9	13.08	145.2
16	8.2	10.1	148.7	8.4	7.2	148	8.5	5.9	147.8	8.6	3.6	147.9	8.8	0.2	149	7.7	12.6	145.2
17	8.1	9.4	149.5	8.3	7	147.8	8.3	4.3	148.3	8.4	1.9	148.3	8.6	0.2	149.6	7.5	12.13	145.3
18	8	8.8	150	8.2	5.9	148.2	8.2	3.9	148.3	8.3	1	148.8	8.4	0.2	150.6	7.4	11.87	145.3
19	7.9	8.5	150.6	8.1	5.7	148.6	8.2	2.9	149.1	8.3	0.3	149.3	8.3	0.2	152.9	7.4	11.71	145.4
20	7.9	8	152	8.1	4.9	149.3	8.1	2.2	149.8	8.2	0.1	149.6	8.2	0.2	154.8	7.4	11.63	145.4
21	7.8	8	152.9	8.1	4.4	149.7	8.1	1.2	150.9	8.2	0.1	150	8.2	0.2	155.3	7.3	11.4	145.5
22	7.8	7.7	154.2	8.1	4.4	149.7	7.9	0.8	151.4	8.1	0.1	150.7	8.1	0.2	156.7	7.3	11.23	145.5
23	7.8	7.6	155.6	8	3.7	149.9	7.9	0.3	152.1	8	0.1	151.9	8	0.2	158	7.3	11.22	145.5
24	7.8	7.7	157.5	8	2.9	150.8	7.9	0.1	152	7.9	0.1	154.5	8	0.1	160.3	7.3	11.22	145.5
25	7.8	7.4	158.8	7.9	1.3	152.3	7.8	0.1	152.4	7.9	0.1	155.5	7.9	0.1	163.1	7.2	11.21	145.7
26	7.7	6.8	160.2	7.9	0.5	153.4	7.8	0.1	153.3	7.9	0.1	156.6	7.9	0.1	164.5	7.1	9.9	145.9

North Central	6/9/2021			6/29/2021			7/12/2021			8/2/2021			9/8/2021			11/16/2021		
Depth	Temp	DO	Cond	Temp	DO	Cond	Temp	DO	Cond	Temp	DO	Cond	Temp	DO	Cond	Temp	DO	Cond
0	23.9	11.9		22.8	10.9	132.2	24.6	11.9	128.2	24	10.6	128.8	20.6	10.2	129.7	10.5	14	133.1
1	23.8	11.4		22.8	10.5	132.2	24	11.2	131.3	23.9	9.8	128.9	20.6	10.2	129.5	10.5	14.7	133.1
2	23.7	11.2		22.7	10.8	132.3	23.6	10.8	131.4	23.6	9.8	129.2	20.6	10.1	129.4	10.3	14.6	133.1
3	21.4	12.8		22.1	10.8	132.1	23.3	11	131.2	23.6	10.3	129.1	20.6	10	129.3	10.3	14.6	133.1
4	19.9	13.9		21.8	10.6	132.1	22.8	10.8	131	23.6	10.1	129	20.6	10.1	129.3	10.2	14.5	132.8
5	16.7	14.5		20.5	11.4	132.4	22.3	10.9	131.2	23.4	10.3	129.3	20.6	10	129.2	10.2	14.7	132.7
6	15.2	14.7		17.1	14.7	133	19.9	11.1	133.1	22.8	10.1	132.3	20.6	10	129.2	10.2	14.8	132
7	13.2	15.9		14.8	15.5	132.9	15.9	15.4	133.8	18.9	13	135.6	20.5	10	129.1	10	14.8	132
8	11.7	16		13.1	14.7	134.3	14.2	14.1	133.8	16.2	11.9	135.8	20.4	9.6	129.3	9.9	14.8	131.7
9	11.2	15		12.1	13.7	134.8	13	13.6	134.2	14	12.3	135.4	15.8	5.4	135.9	9.6	16	132
10	10.3	13.6		11	10.9	136.4	11.4	10.4	136.7	12.5	8.7	139.4	13.5	1.1	138.2	9.3	14.9	132.2
11	9.4	9.5		9.8	7	137	10.3	7	138.3	11	3.6	140.3	11.7	0.6	141	8.6	14.8	132.3
12	8.4	7.4		9	3.7	138.6	9.5	0.9	138.8	9.8	0.2	142	10.2	0.4	142.3	7.9	14.2	133.2
13	7.7	1.4		8	0.2	143	8.4	0.5	141.9	9	0.2	142.8	9.3	0.3	143.9	7.4	10.6	133.6
14	7.3	0.1		7.7	0.1	143.6	7.8	0.1	142.4	8.3	0.1	147.9	8.2	0.3	161.4	7.2	9.3	137.6
15	7.1	0.1		7.5	0.1	144.6	7.4	0.1	155	7.7	0.1	157.7	8	0.2	164	7	4	142
16	7	0.1		7.2	0.1	151.1	7.2	0.1	159.8	7.6	0.1	158.8	7.9	0.2	167.1	7	4	151
17	6.9	0.1		7.1	0.1	159.5	7.2	0.1	173.5	7.6	0.1	159.9	7.8	0.2	175.9	6.8	4	155

Mid-Basin	6/9/2021			6/29/2021			7/12/2021			8/2/2021			9/8/2021		
Depth	Temp	DO	Cond	Temp	DO	Cond	Temp	DO	Cond	Temp	DO	Cond	Temp	DO	Cond
0	23.7	11		22.8	10.6	143.2	24	11.6	143.5	24.1	10.5	135.3	20.6	10.2	140.3
1	23.2	11.2		22.8	10.5	143.2	23.4	10.9	143.5	23.6	10.2	139.4	20.6	10.1	140.6
2	22.5	11.4		22.6	10.5	143.2	23.3	10.6	142.7	23.5	9.3	139.2	20.6	10	140.7
3	21.2	12.2		22	10.8	143.1	22.7	11.1	142.1	23.4	9.6	139.3	20.5	9.95	140.6
4	19.7	12.7		21.7	10.7	143.5	22.5	11	142.2	23.4	10	139.4	20.5	9.9	140.6
5	16.8	13.5		20.6	11.4	143.9	21.9	10.6	142.7	23.3	10	139.3	20.5	9.9	140.5
6	14.9	13.8		16.9	14.5	145.8	18.6	13.1	146.8	20.9	11.1	147.3	20.5	9.9	140.6
7	13.1	14.6		14.5	15.4	146.2	15.2	14.2	148.2	16.6	12.8	149.8	20.1	9.5	142.1
8	11.7	14.4		12.4	14.1	148.1	13.1	12.1	148.5	14.2	11.5	150.6	15.4	7.8	152.4
9	10.9	13.3		12	11.6	147.9	11.9	10.6	149.6	12.7	9.4	150.1	13.5	5.2	153.7
10	10.3	11.9		10.8	8.9	148.9	11	7.1	150.6	11.5	5.7	151.9	12.3	0.8	155.2
11	9.8	9.3		10.2	6.9	150.4	10.3	4.4	151.8	10.8	1.7	154.5	11	0.5	158.3
12	9.3	6.9		9.5	1.5	156.3	9.8	1.2	155.7	10.2	0.2	155.8	10.2	0.3	161.3
13	8.9	5.6		9.3	0.6	156.3	9.4	0.3	157.9	9.7	0.1	159.1	9.8	0.2	162.5
14	8.9	4.9		9.2	0.2	156.7	9.1	0.1	159.3	9.4	0.1	160.9	9.5	0.2	166
15	8.9	3.8		9	0.1	157.3	9	0.1	162.1	9.2	0.1	165.3	9.2	0.2	177.5
16	8.6	2.2		8.8	0.1	161.3	8.8	0.1	170.5	9	0.1	170.4	9	0.2	185.5
17	8.5	0.2		8.6	0.1	173.6	8.8	0.1	176.7	8.8	0.1	200.6	8.8	0.1	197

2022 Data Set:

Lake	Site	Date	Depth (m)	TP (ug/L) LOD 6 ug/L LOQ 18 ug/L	Ortho (ug/L) LOD 2 ug/L LOQ 6 ug/L	Chl-a (ug/L) 0.6 ug/L 1.8 ug/L
Owen	43137	2/8/2022	0-2	13		
Owen	43137	2/8/2022	17	60		
Owen	43137	3/23/2022	0-2	6	2	
Owen	43135	5/11/2022	0-2	32		
Owen	43135	5/11/2022	4	28		
Owen	43135	5/11/2022	6	31		
Owen	43135	5/11/2022	8	31		
Owen	43135	5/11/2022	10	32		
Owen	43135	5/11/2022	12	31		
Owen	43135	5/11/2022	14	31		
Owen	43135	5/11/2022	16	32		
Owen	43135	5/11/2022	18	36		
Owen	43135	5/11/2022	20	32		
Owen	43135	5/11/2022	22	31		
Owen	43135	5/11/2022	24	28		
Owen	43135	5/11/2022	26	95		
Owen	43137	6/14/2022	0-2	ND	ND	1.2
Owen	43137	6/14/2022	8	29	3	2.3
Owen	43137	6/14/2022	17	78		
Owen	43135	6/14/2022	0-2	ND	4	1.1
Owen	43135	6/14/2022	9	ND	3	ND
Owen	43135	6/14/2022	26	53		
Owen	10030464	6/14/2022	0-2	ND	ND	2.1
Owen	43137	7/18/2022	0-2	ND	ND	1.8
Owen	43137	7/18/2022	9	35	ND	7.6
Owen	43137	7/18/2022	17	103		
Owen	43135	7/18/2022	0-2	ND	ND	0.9
Owen	43135	7/18/2022	10	ND	ND	2.4
Owen	43135	7/18/2022	26	30		
Owen	10030464	7/18/2022	0-2	ND	ND	4.1
Owen	43137	8/22/2022	0-2	31	3	1.9
Owen	43137	8/22/2022	10	32	ND	3.5
Owen	43137	8/22/2022	17	ND		
Owen	43135	8/22/2022	0-2	ND	ND	1.3
Owen	43135	8/22/2022	10	ND	ND	1.6
Owen	43135	8/22/2022	26	24		
Owen	10030464	8/22/2022	0-2	17	2	1.8
Owen	43137	9/19/2022	0-2	8	ND	2.3
Owen	43137	9/19/2022	10	13	6	2.3
Owen	43137	9/19/2022	17	256		
Owen	43135	9/19/2022	2	6	3	2
Owen	43135	9/19/2022	10	7	4	2.4
Owen	43135	9/19/2022	26	195		
Owen	10030464	9/19/2022	0-2	10	5	ND
Owen	43137	10/11/2022	0-2	26	ND	4
Owen	43137	10/11/2022	10	30	11	1.7
Owen	43137	10/11/2022	17	295		
Owen	43135	10/11/2022	0-2	24	6	2.4
Owen	43135	10/11/2022	10	23	3	2
Owen	43135	10/11/2022	26	232		
Owen	10030464	10/11/2022	0-2	23	6	3

ND = “not detectable” (below the LOD)

43135 (Deep Hole)												
May Temp	Depth	5/11/2023-DO	6/14/2023-Temp	6/14/2023-DO	7/18/2023-Temp	7/18/2023-DO	8/22/2023-Temp	8/22/2023-DO	9/19/2023-Temp	9/19/2023-DO	10/11/2023-Temp	10/11/2023-DO
6.4	0	13.42	18.6	10.01	25	9.25	22.1	8.4	20.3	8.6	14.4	9.22
6.4	2	12.66	18.4	9.8	24.9	9.14	22.1	8.39	20.1	8.64	14.3	9.13
6.3	4	12.24	18.4	10	24.7	9.12	21.9	8.49	20.1	8.6	14.3	9.11
6.3	6	12.11	16.8	10.66	24.6	9.14	21.9	8.5	20	8.55	14.2	9.1
6.2	8	11.94	15.2	11.03	23.6	9.5	21.9	8.48	20	8.5	14.2	9.07
6	10	11.5	10.9	11.04	23.2	9.7	21.9	8.47	19.2	7.6	14.2	9.04
5.6	12	10.21	8.5	9.99	22.8	9.7	21.8	8.46	10.5	3.34	14.2	9.05
5.5	14	9.8	7.5	7.78	21.9	9.6	21.8	8.43	8.6	0.26	9	0.33
5.5	16	9.72	7.1	6.35	18.5	11.2	21.6	8.08	7.9	0.17	8	0.14
5.5	18	9.68	6.9	5.66	13.8	11.36	18.4	7.8	7.5	0.13	7.6	0.11
5.5	20	9.6	6.9	5.31	11.2	10.44	13.5	7.5	7.4	0.1	7.4	0.09
5.5	22	8.5	6.8	5.18	10	9.45	11	7	7.3	0.08	7.3	0.09
4.6	24	1.24	6.8	3.6	8.8	7.45	9.8	5.35	7.2	0.07	7.2	0.08
4.5	26	0.55	6.7	1.3	8.3	5.59	9	3.35	7.1	0.06	7.2	0.08

43137 (North Central	6/14/2023-Temp	6/14/2023-DO	7/18/2023-Temp	7/18/2023-DO	8/22/2023-Temp	8/22/2023-DO	9/19/2023-Temp	9/19/2023-DO	10/11/2023-Temp	10/11/2023-DO
0	19.8	10.15			22.7	8.58	20.4	8.5	14.2	9.44
2	19.6	9.8	meter	didn't	22.5	8.72	20.3	8.6	14.1	9.38
4	19.3	9.71	work	properly	22.4	8.7	20.1	8.5	14	9.31
6	18.7	9.88			22.2	8.7	20	8.5	13.9	9.12
8	12.2	10.6			22.1	8.69	19.9	7.8	13.9	9.14
10	8.5	7.8			22	8.57	14	0.89	13.8	8.58
12	6.6	0.62			21.9	8.55	8.7	0.16	9.3	0.2
14	6.2	0.31			21.6	8.46	7.1	0.12	7.1	0.12
16	5.9	0.27			19.2	6.15	6.8	0.12	6.8	0.1

43134 (Mid Basin)										
Temp	Depth	6/14/2023-DO	7/18/2023-Temp	7/18/2023-DO	8/22/2023-Temp	8/22/2023-DO	9/19/2023-Temp	9/19/2023-DO	10/11/2023-Temp	10/11/2023-DO
19.2	0	10.15	24.6	10.45	22.2	8.4	20.1	8.7	14.3	9.53
18.9	2	10.1	24.4	9.1	22.2	8.43	20	8.62	14.2	9.42
18.5	4	10.12	24.2	9.18	22.1	8.36	20	8.6	14.1	9.36
18.5	6	10.35	23.7	9.6	22.1	8.36	20	8.55	14.1	9.17
14.1	8	11.6	23.2	9.51	21.9	8.32	19.9	8.26	14	9.02
11.7	10	11.06	22.8	9.37	21.9	8.43	17.7	5.67	13.7	7.88
9.6	12	11.4	22.5	9.24	21.8	8.38	10.5	1.5	12.7	5.4
7.6	13	5.98	21.1	8.9	21.8	8.21	9.2	0.16	11.1	0.39