LINWOOD LAKE TRIBUTARIES

Water Quality Analysis

ANOKA CONSERVATION DISTRICT

DECEMEBER, 2024

Background

In 2024, the Anoka Conservation District monitored three stream sites that drain to Linwood Lake. The purpose was to identify subwatersheds with the greatest phosphorous concentrations, thereby determining if a subwatershed analysis study should be conducted to identify and rank water quality improvement projects. Samples for total phosphorous and total dissolved phosphorous were collected and sent in for laboratory analysis. In addition, standard grab sample measurements were done for pH, dissolved oxygen, turbidity, specific conductivity, and stream stage.

Three sites were monitored within the Linwood Lake watershed.

1) Rice Lake Subwatershed: Rice Lake Inlet
2) Linwood Lake Subwatershed: Linwood Lake Inlet @ AMA
3) Boot Lake Subwatershed: Boot Lake Inlet

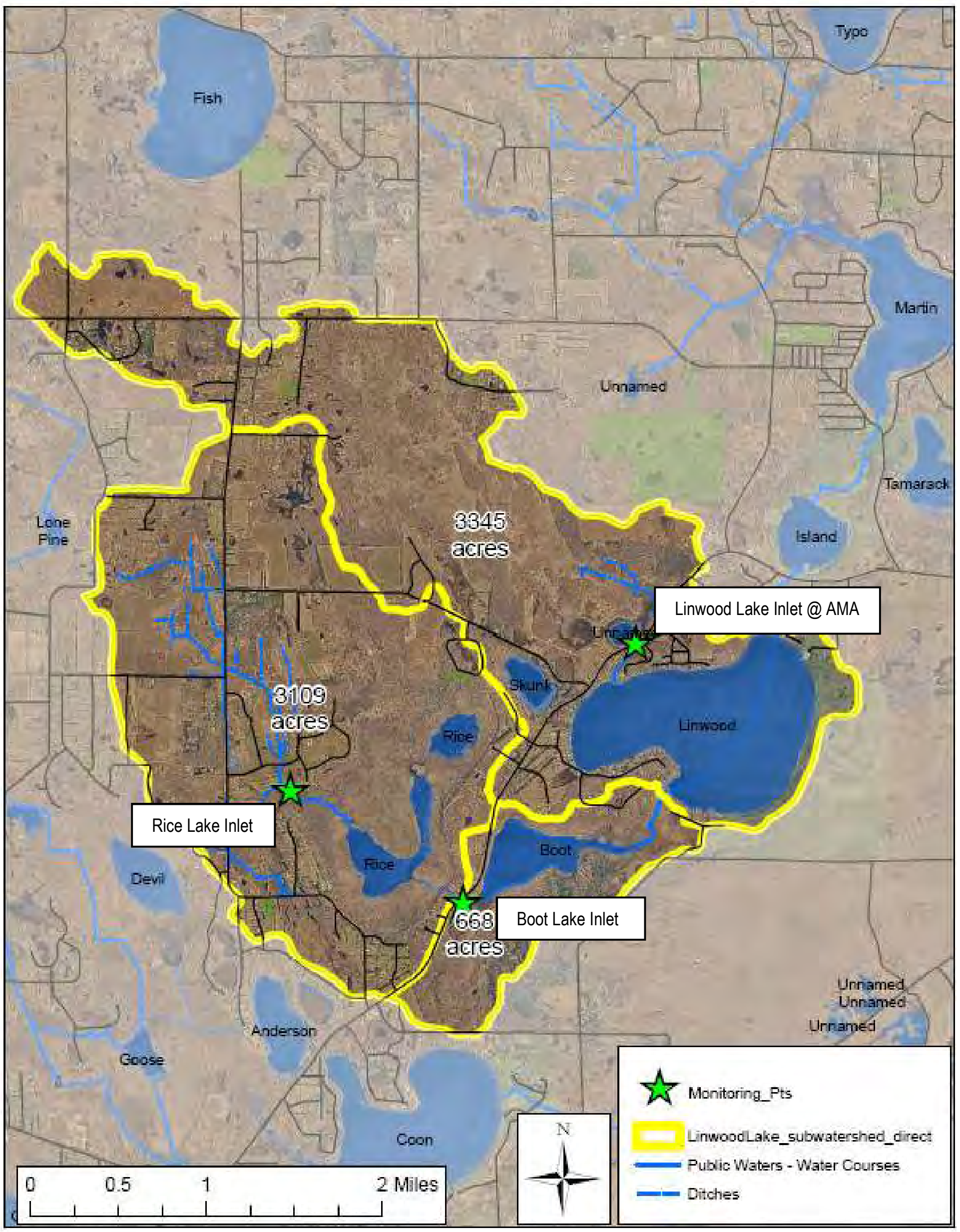


Figure 1: 2024 Monitoring Sites for Linwood Lake Watershed

<u>Rice Lake Inlet</u> is located approximately 2,400 feet upstream from Rice Lake, and approximately 300 feet downstream from tributary ditches. Landowner permission was granted to collect samples from private property. This site is characterized by its slow flow, deep water, and a mucky bottom.

Figure 2: Rice Lake Inlet (downstream)

<u>Linwood Lake Inlet @ AMA</u> is located approximately 1,400 feet upstream from Linwood Lake, and immediately downstream from the a DNR aquatic managed area (AMA) which contains a pond. Samples were collected at the culvert on the downstream side of Viking Blvd. This site is characterized by its slow flow, mucky bottom, frequently stagnant surface water, and abundant emergent aquatic vegetation.

Figure 3: Linwood Lake Inlet @ AMA (upstream)

<u>Boot Lake Inlet</u> is approximately 750 feet upstream from Boot Lake and 600 feet downstream of Rice Lake. Samples were collected at the culvert on the upstream side of Viking Blvd. This site is characterized by its relatively normal flow compared to the other two sites.

Figure 4: Boot Lake Inlet (upstream)

Results Summary

The purpose of water quality monitoring in this report was to determine which Linwood Lake tributaries may be contributing the most phosphorous to the lake, thereby contributing to its impairment for excess nutrients. This report includes data from 2024 and an overview of historical data when available, followed by management recommendations. The results are intended to guide future investigation or implementation of water quality projects.

Overall, the primary concerns are the low dissolved oxygen levels at all sites and the extraordinary high phosphorous levels at *Linwood Lake Inlet @ AMA*. Further investigation within the DNR's aquatic management area may provide further insight into the reasons for high phosphorous and potential practices to reduce it. The tributary draining to Linwood Lake through Rice and Boot Lakes is of lesser concern and not a current focus for management.

Results for each water quality parameter:
Dissolved constituents were measured by specific conductivity, which were all within a healthy range at all monitoring sites.

pH was within a healthy range (6.5 to 8.5) at all monitoring sites. In general, the pH levels at *Linwood Lake Inlet @ AMA* were lower than the other two sites, with a couple of its measurements hovering above the minimum state standard of 6.5.

Dissolved oxygen was below the minimum state standard of 5 mg/L at all sites except for only two occasions. While the low dissolved oxygen levels are concerning, they are likely the result of elevated nutrients in the system from decomposition in the surrounding peaty wetlands combined with a flat, slow-moving stream network.

Phosphorous levels were frequently above the state standard of 100 µg/L at all sites, however total phosphorus levels were significantly higher at *Linwood Lake Inlet @ AMA* than at any other site. Both total phosphorous and total dissolved phosphorous samples were collected and analyzed, and results show that total dissolved phosphorous only made up a small portion of the total phosphorous at these sites except for a couple occasions, suggesting that particulate phosphorous at these locations is the primary component for algal blooms and eutrophication. Total phosphorous levels at *Rice Lake Inlet* is moderate, while it is relative low at *Boot Lake Inlet, suggesting phosphorus removal occurs in Rice Lake.* Total phosphorus at *Linwood Lake Inlet @ AMA* is high, often 2x to 5x greater than the other sites or State standards.

Suspended solids were not collected in 2024 due to prioritizing phosphorous testing under a limited budget. Historical data at Boot Lake Inlet show that total suspended solids were below the state standard of 30 mg/L and were not a concern.

Turbidity remained at acceptable levels at all sites. This suggests that the high particulate phosphorus may be attached to small particles that would not be detected in a turbidity reading. Future testing of total suspended solids is recommended.

Linwood Lake water monitoring was also collected in 2024. Phosphorous levels and chlorophyll-a levels were moderately high and were generally consistent with previous years. The lake is listed as impaired for excess nutrients, but is not grossly exceeding those standards.

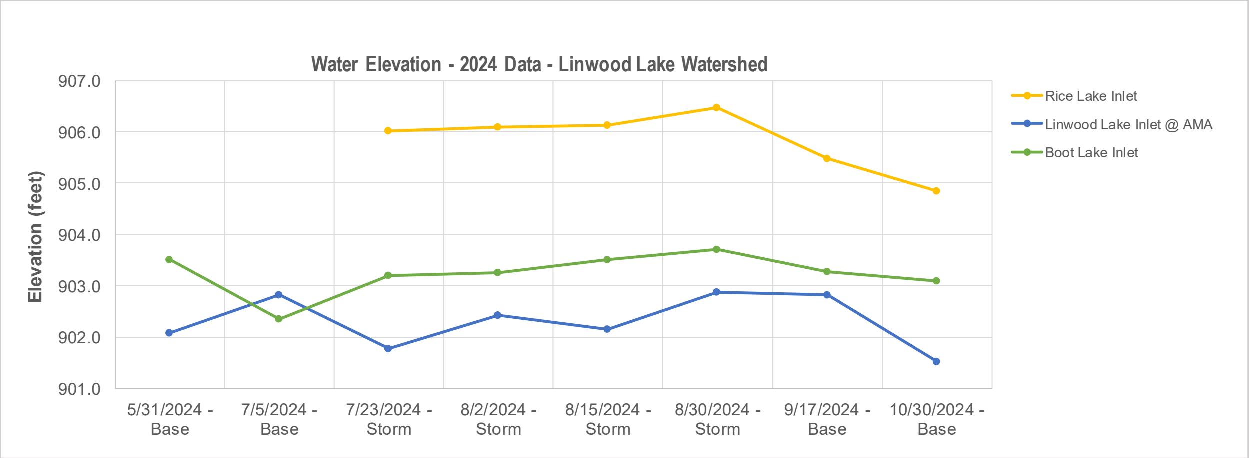
Flow

Flow measurements were taken on the last sample occasion of the year and are shown in the table below. Throughout much of the year, all sites were noted to have "slow flow", "no visible surface flow", or "stagnant" water. The values below confirm that while water may appear stagnant on the surface, there is a small amount of discharge at each site. To ensure accurate readings, all grab samples were generally taken at elbow's depth below the water surface.

	Total Discharge (ft^3/s)	Total Area (ft^2)	Mean Depth (ft)
Rice Lake Inlet	0.334	6.81	0.946
Linwood Lake Inlet @ AMA	0.462	10.5	2.1
Boot Lake Inlet	1.09	4.36	0.605

Water Elevation

Water elevation data was collected during the majority of sampling occasions. As shown below, water elevation at all sites is fairly consistent throughout most of the year.



Phosphorous

The nutrient phosphorus is one of the most common pollutants to local waterways, and can be associated with stormwater runoff, wastewater, fertilizers, soil loss, and many other sources. Since it is an essential nutrient in the natural ecosystem, even a slight increase of phosphorus levels in a waterway can result in harmful algae blooms, accelerated plant growth, low dissolved oxygen levels, and other negative effects to fish, macroinvertebrates, and other aquatic animals. For this study, total phosphorous (TP) and total dissolved phosphorous (TDP) were analyzed. TP measures all phosphorous in a sample, regardless if that phosphorous is dissolved or particulate. TDP only measures the amount of dissolved phosphorous in a sample.

The State deems a stream or river "impaired" in the central region of Minnesota when TP measurements exceed 100 µg/L and a second condition is met. The second condition is chlorophyll-a >18 µg/L, diel dissolved oxygen flux of 3.5 mg/L, or periphyton chlorophyll-a >150 mg/m^2.

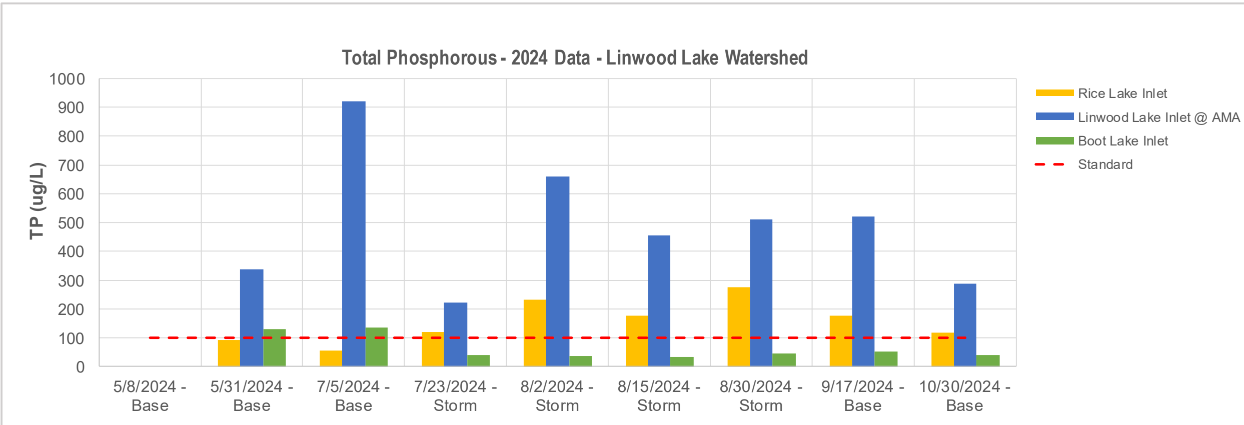
In 2024, TP levels were generally above state standards at *Rice Lake Inlet* and *Linwood Lake Inlet @ AMA*, but not a *Boot Lake inlet*. Average values for each site during baseflow and post-storm conditions can be found in the table below.

TP - 2024 Baseflow Data

	AVG	MED	TOTAL	> 100 µg/L
Rice Lake Inlet	110	105	4	2
Linwood Lake Inlet @ AMA	516	428	4	4
Boot Lake Inlet	90	92	4	2

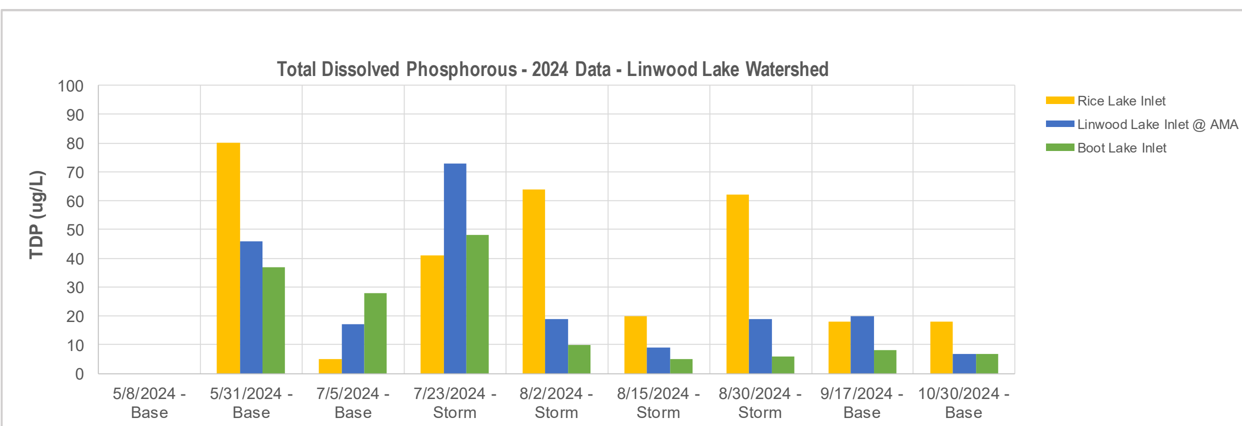
TP - 2024 Stormflow Data

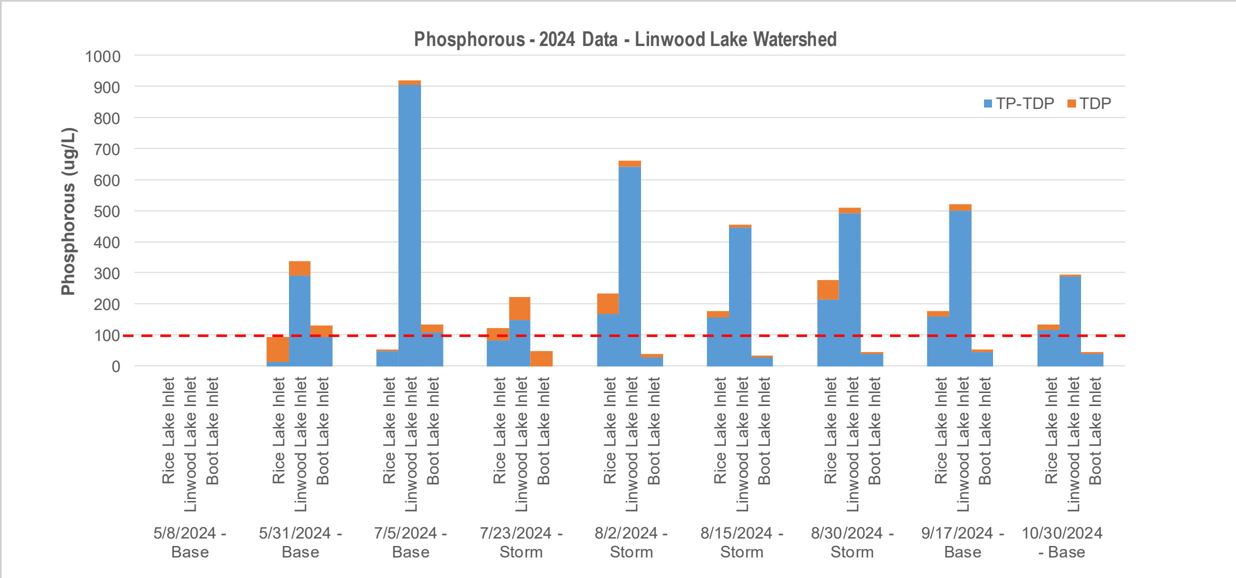
	AVG	MED	TOTAL	> 100 µg/L
Rice Lake Inlet	202	205	4	4
Linwood Lake Inlet @ AMA	462	482	4	4
Boot Lake Inlet	39	40	4	0



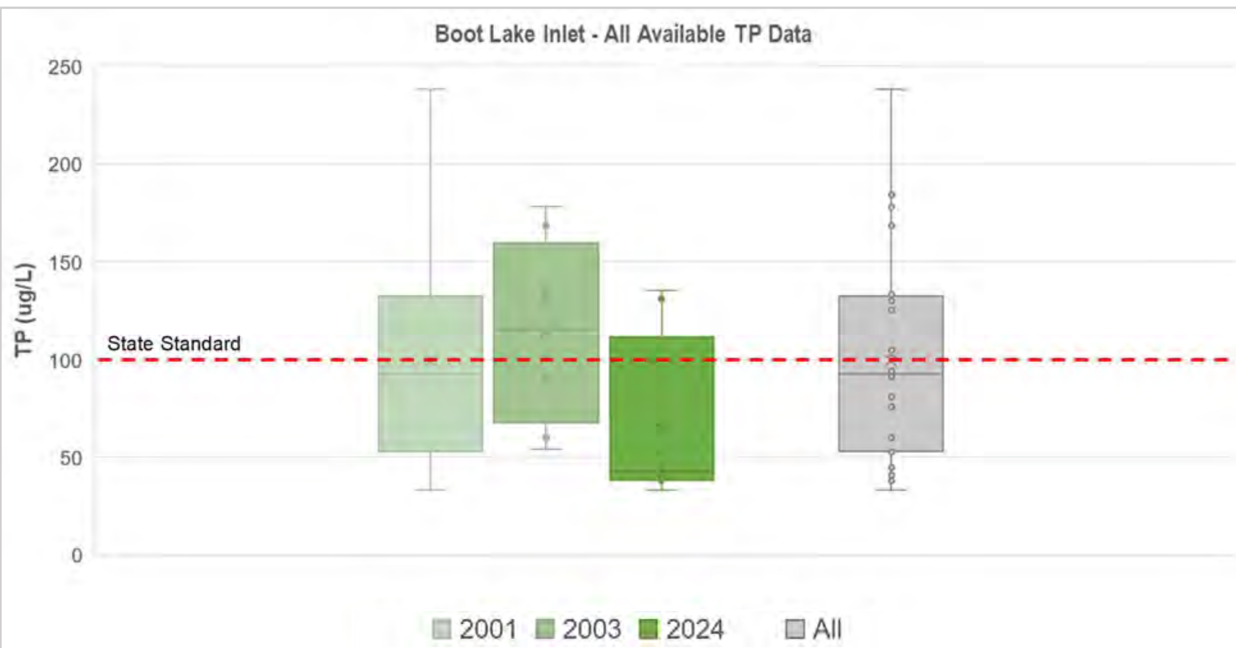
TP levels were much higher at the *Linwood Lake Inlet @ AMA* site than at any other site. This site is immediately downstream of the DNR's aquatic management area pond with a slow discharge. Upstream of that pond is 2,000+ acres which is mostly a broad area of wetland. *Boot Lake Inlet* had the smallest concentrations of TP and was consistent throughout most of the year. Interestingly, TP levels at *Rice Lake Inlet* are moderately higher than *Boot Lake Inlet*, suggesting that a good amount of available phosphorous is captured within Rice Lake.

As shown below, total dissolved phosphorous only makes up a small portion of total phosphorous at these sites except for a couple occasions. Processes such as sediment resuspension can significantly increase the amount of available particulate phosphorous. Algae itself can also contribute to particulate phosphorus.





Except for *Boot Lake Inlet*, there is no available historical data for total phosphorous. 2001 and 2003 data are available for *Boot Lake Inlet*. The results are shown in the box-and-whisker graph below. In general, total phosphorus hovers around the state standard of 100 µg/L, but is frequently sampled below this value. Overall, the 2024 data and this historic data are similar and suggest that high phosphorous is not problematic in the Boot Lake subwatershed.



Dissolved Oxygen

Dissolved oxygen (DO) is necessary for aquatic life to survive and thrive. Organic pollution causes oxygen to be consumed during decomposition. If oxygen levels in water fall below 5 mg/L, aquatic life begins to suffer. A stream is considered impaired if 10% of observations are below 5 mg/L in the last 10-years. Dissolved oxygen levels are typically lowest in the early morning because of decomposition consuming oxygen at night without the offsetting of oxygen production by photosynthesis.

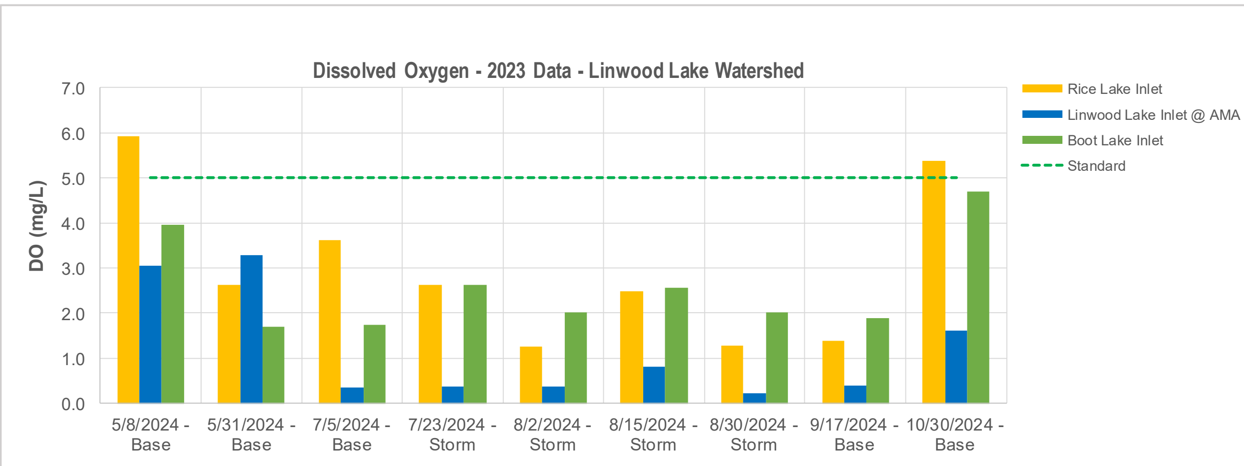
In 2024, DO levels at all three sites during all conditions averaged 2.34 mg/L with a median of 1.89 mg/L. Average values for specific sites during baseflow and post-storm conditions can be found in the table below.

DO - 2024 Baseflow Data

	AVG	MED	TOTAL	<5 mg/L
Rice Lake Inlet	3.79	3.62	5	3
Linwood Lake Inlet @ AMA	2.80	1.62	5	5
Boot Lake Inlet	2.80	1.90	5	5

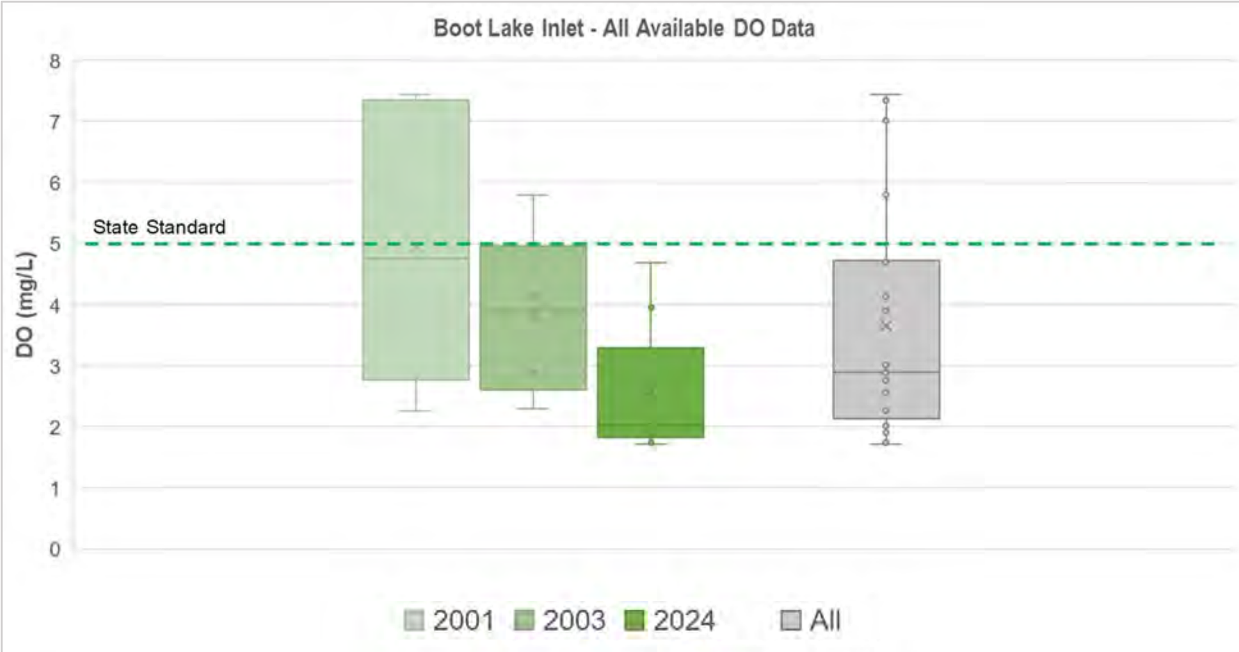
DO - 2024 Stormflow Data

	AVG	MED	TOTAL	<5 mg/L
Rice Lake Inlet	1.91	1.88	4	4
Linwood Lake Inlet @ AMA	0.45	0.37	4	4
Boot Lake Inlet	2.31	2.29	4	4



In general, DO levels were almost entirely (25 out of 27 total occasions) below the state standard of 5 mg/L. The low dissolved oxygen levels are likely the result of decomposition in adjacent wetlands. The water has a lot of contact with decaying organic matter which can strip the water of oxygen. As a result, identifying projects for the purpose of increasing low oxygen impairment is difficult, and the scope of any such projects would need to be large.

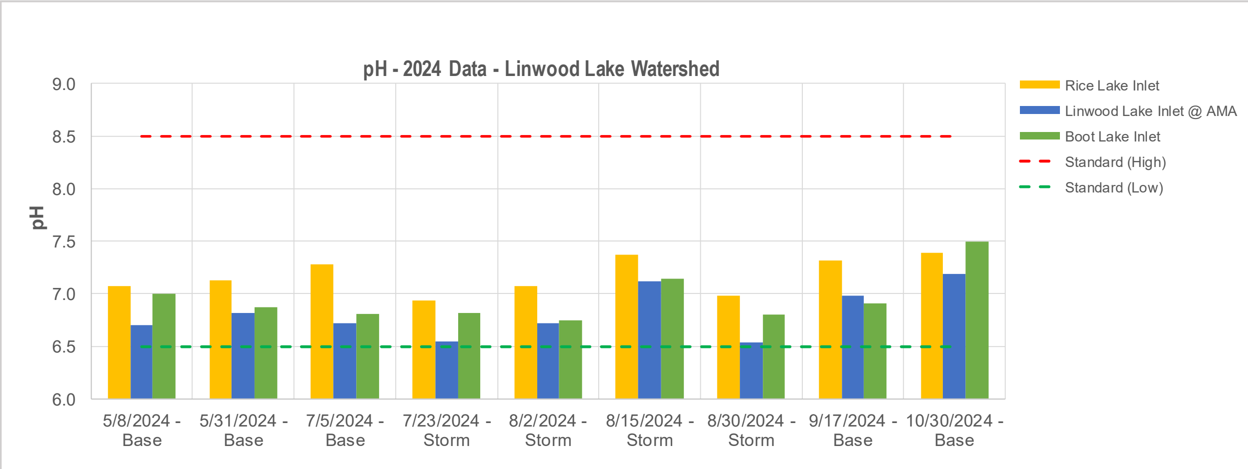
Except for *Boot Lake Inlet*, there is no available historical data for dissolved oxygen. 2001 and 2003 data are available for *Boot Lake Inlet*. The results are shown in the box-and-whisker graph below. In general, average DO levels are below the state standard of 5 mg/L.

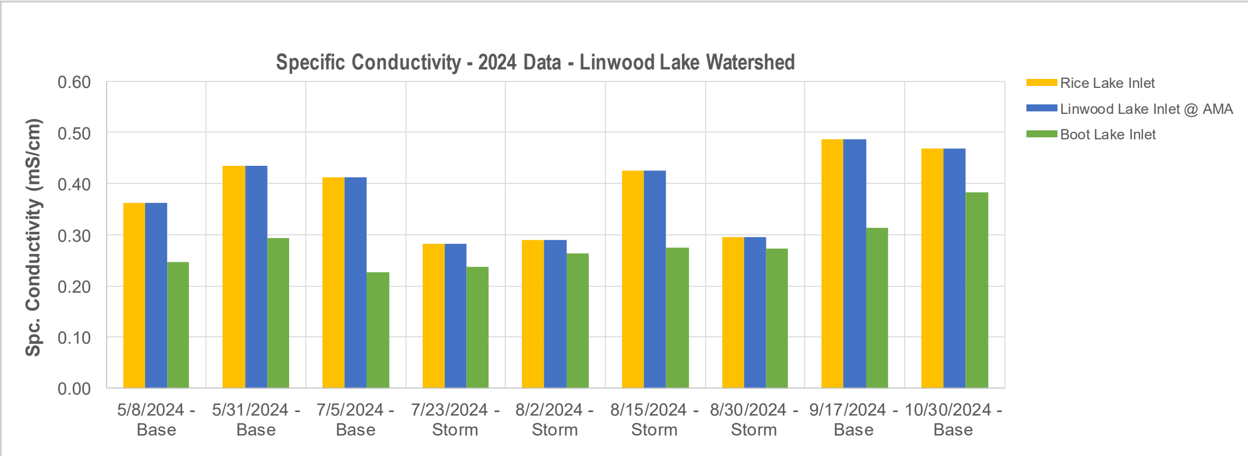


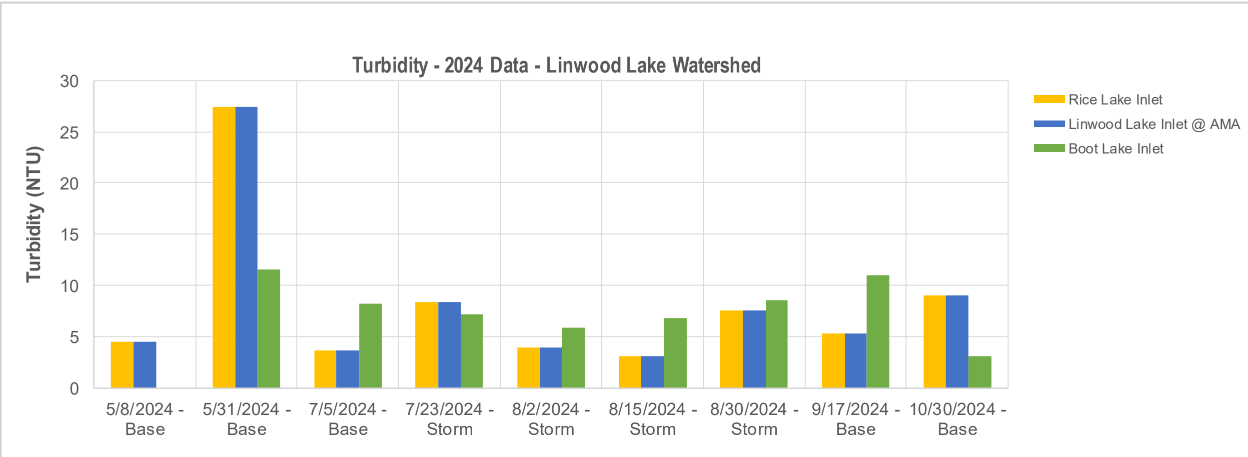
Boot Lake Inlet - All Available DO Data
DO (mg/L)
8
7
6
5
4
3
2
1
0
State Standard
2001
2003
2024
All

pH, Conductivity, and Turbidity

Miscellaneous data, such as pH, turbidity, and specific conductivity, are available below. Overall, there is nothing concerning about this data that warrants further investigation.

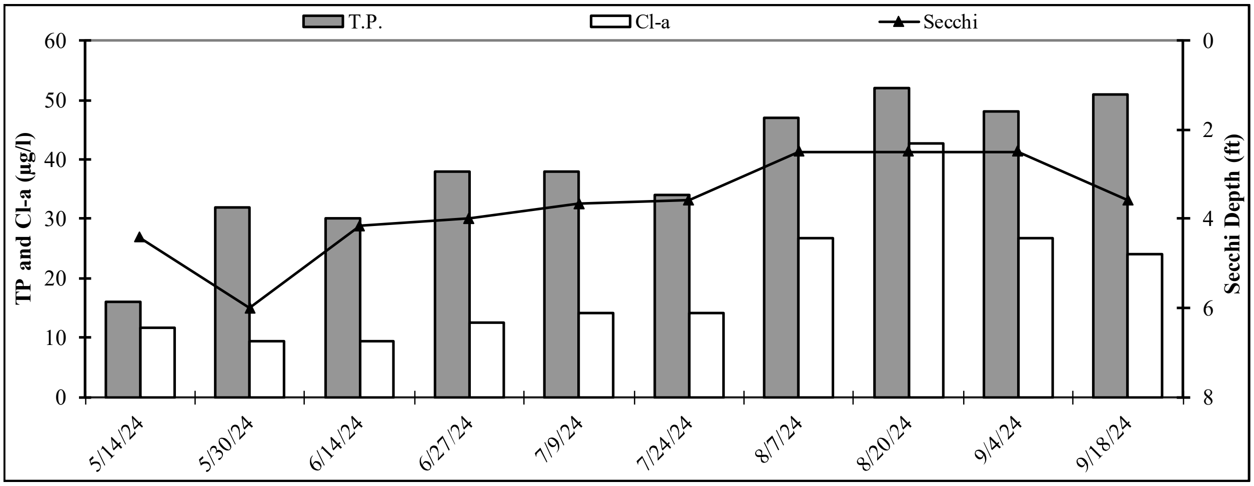






Linwood Lake Water Quality

Linwood Lake itself was monitored in 2024 and prior years. That data is summarized below.



Linwood Lake
02-0026-00-204
2024 Water Quality Data

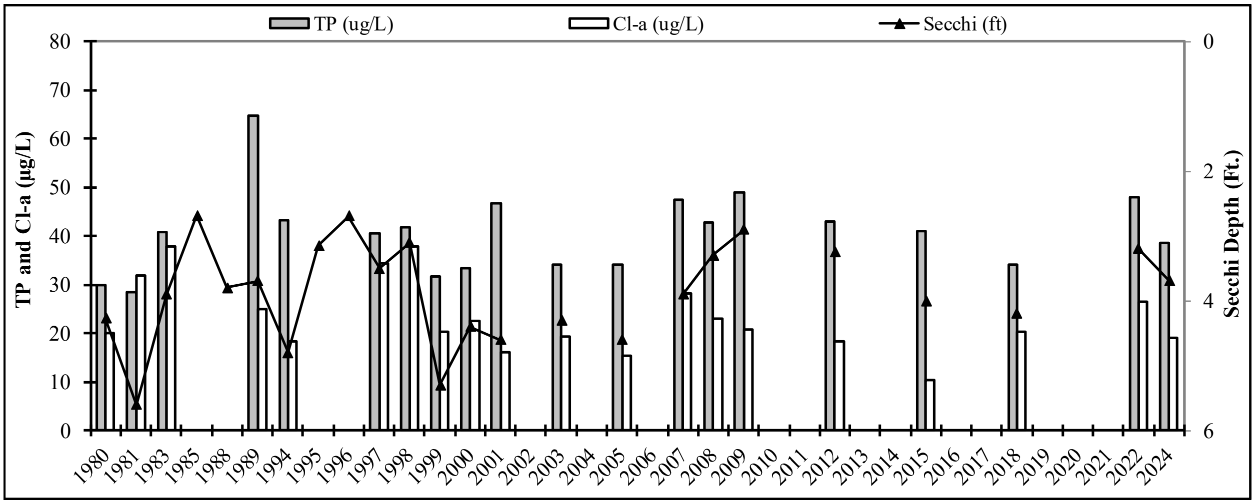
	Units	R.L.*	5/14/2024	5/30/2024	6/14/2024	6/27/2024	7/9/2024	7/24/2024	8/7/2024	8/20/2024	9/4/2024	9/18/2024	Average	Min	Max
Time			14:00	12:36	13:05	12:35	12:36	14:00	12:50	13:00	13:20	13:10			
pH		0.1	8.38	8.24	8.32	8.35	8.89	8.59	8.44	8.93	8.05	8.72	8.49	8.05	8.93
Specific Conductivity	mS/cm	0.01	0.308	0.311	0.302	0.291	0.284	0.280	0.276	0.289	0.284	0.279	0.290	0.276	0.311
Turbidity	FNRU	1	1.9	2.24	2.78	5.14	6.91	10.80	12.02	13.08	11.35	8.51	7	2	13
D.O.	mg/L	0.01	10.57	9.49	9.37	9.93	12.25	8.39	8.36	12.54	7.87	9.43	9.82	7.87	12.54
D.O.	%	1	113.5	106.1	107.9	117.9	146.8	98.7	100	152	91	112	114.6	90.7	152.1
Temp.	°C	0.1	18.7	20.8	22.3	23.8	24.5	24.4	24.5	25.0	22.3	23.8	23.0	18.7	25.0
Temp.	°F	0.1	65.7	69.4	72.1	74.8	76.1	75.9	76.1	77.0	72.1	74.8	73.4	65.7	77.0
Salinity	%	0.01	0.15	0.15	0.14	0.14	0.13	0.13	0.13	0.14	0.13	0.13	0.14	0.13	0.15
Cl-a	mg/m³	1	11.74	9.34	9.34	12.46	14.14	14.24	26.70	42.72	26.70	24.03	19.1	9.3	42.7
T.P.	mg/L	0.005	0.016	0.032	0.030	0.038	0.038	0.034	0.047	0.052	0.048	0.051	0.039	0.016	0.052
T.P.	µg/L	5	16	32	30	38	38	34	47	52	48	51	39	16	52
Secchi	ft	0.1	4.4	6.0	4.2	4.0	3.7	3.6	2.5	2.5	2.5	3.6	3.7	2.5	6.0
Secchi	m	0.10	1.35	1.83	1.27	1.22	1.12	1.09	0.76	0.76	0.76	1.09	1.1	0.8	1.8
Physical			2	1.0	2.0	2.0	3.0	2.0	2.0	3.0	2.0	3.0	2.2	1.0	3.0
Recreational			1	1.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0	3.0	2.0	1.0	3.0

*reporting limit

2024 Median Results

pH		8.41
Specific Conductivity	mS/cm	0.29
Turbidity	NTU	7.71
D.O.	mg/l	9.46
D.O.	%	109.95
Temp.	°F	74.84
Salinity	%	0.14
Cl-a	µg/L	14.19
T.P.	µg/l	38.00
Secchi	ft	3.63

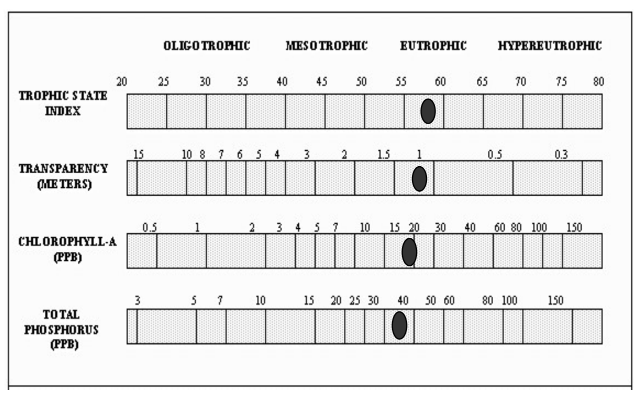
Linwood Lake
Historical Results



Year	TP	Cl-a	Secchi	Overall
1975			F	
1980	B	B	C	**B**
1981	B	B	C	**B**
1983	C	C	C	**C**
1985			D	
1988			D	
1989	C	C	D	**C**
1994	C	B	C	**C**
1995			D	
1996			D	
1997	C	C	D	**C**
1998	C	C	D	**C**
1999	C	C	D	**C**
2000	C	C	C	**C**
2001	C	B	C	**C**
2003	C	B	C	**C**
2005	C	B	C	**C**
2007	C	C	D	**C**
2008	C	C	D	**C**
2009	C	C+	D	**C**
2012	C	B	D	**C**
2015	C	B	C	**C**
2018	C	C	C	**C**
2022	C	C	D	**C**
2024	C	B	D	**C**
State Standards	40 ug/L	14 ug/L	>4.6 ft	

Grade	Percentile	TP (µg/L)	Cl-a (µg/L)	Secchi Disk (m)
A	< 10	<23	<10	>3.0
B	10 - 30	23 – 32	10 - 20	2.2 - 3.0
C	30 – 70	32 – 68	20 – 48	1.2 – 2.2
D	70 – 90	68 – 152	48 – 77	0.7 – 1.2
F	> 90	> 152	> 77	< 0.7

Carlson's Trophic State Index



Recommendations

The subwatershed draining to Linwood Lake through the MN DNR aquatic management area (AMA) along Viking Blvd has high phosphorus concentrations. Due to this, management recommendations focus on only this subwaterhed. The subwatershed draining to Linwood Lake through Rice and Boot Lakes is of low concern.

Given the significantly high levels of particulate phosphorus at the *Linwood Lake Inlet @ AMA*, the drainage area to the DNR's aquatic management area is the primary area of concern. The nearly 2,000 acre drainage area is mostly wetland, and drainage is primarily through vast wetlands. Only the downstream end is ditched, and those ditches are in poor repair (mostly filled in or vegetated). At the end of this drainage is a 8.5 acre pond. One might presume that the wetlands would yield little phosphorus however this is clearly not the case. Nor is the pond sufficiently settling or capturing phosphorus.

Further investigation is needed to determine why the pond is not settling solids or assimilating phosphorus. Reasons may include that the pond is too shallow and easily mixed by wind, or that is already nutrient enriched and producing excessive amounts of algae. In order to assess the area and develop concepts that might achieve phosphorous retention, additional information such as depth, TSS, and TP are required, as well as collaboration with DNR. We recommend exploring project types that might enhance nutrient capture and providing secondary benefits for fisheries such as aeration, iron filings or spent lime to inactivate phosphorus, alum dosing, excavation, habitat improvements, or improved fish passage through the outlet culvert at Viking Blvd.

Given that most phosphorous particulate, a settling pond retrofit would likely be more feasible and cost-effective. Practices targeting dissolved phosphorus, such as an iron-enhanced sand filter, are unlikely to be appropriate.

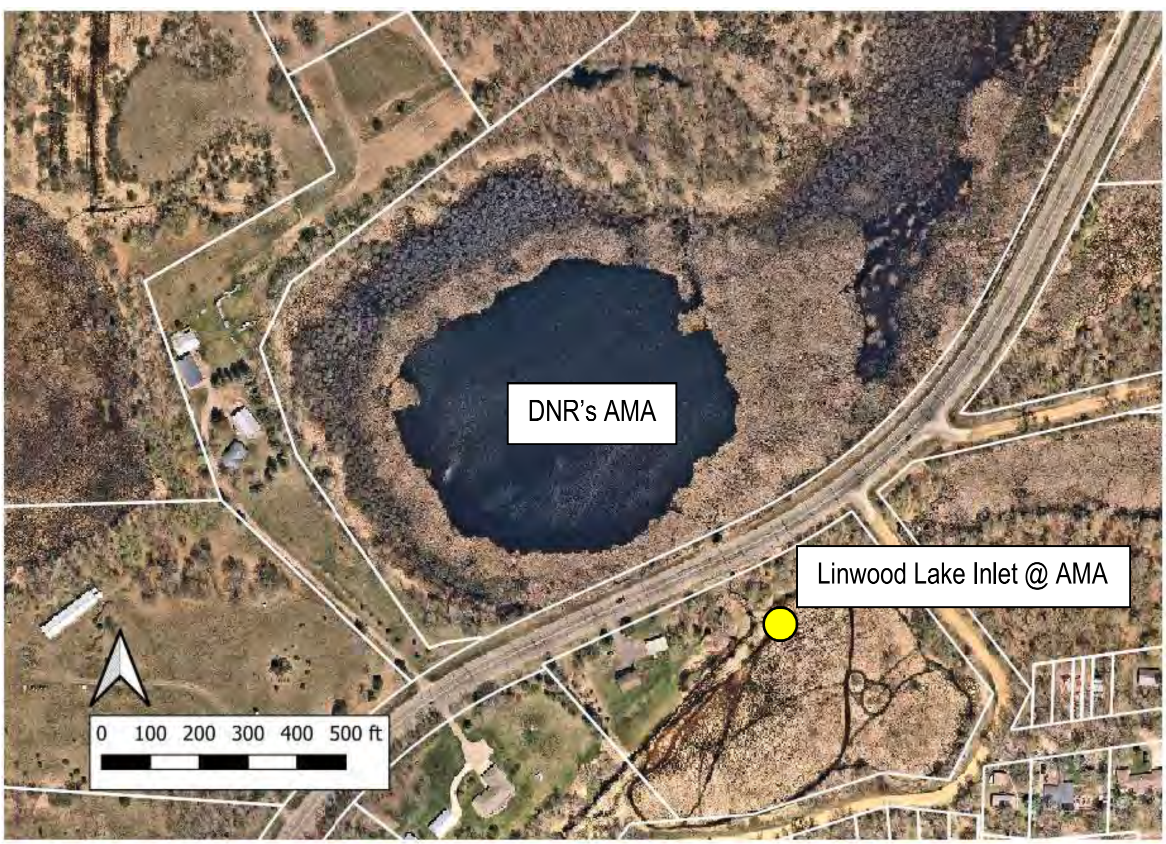


Figure 5: Overview of DNR's aquatic management area.

Another potential practice is ditch blocks within the wetland-complex upstream of the DNR's aquatic management area. As shown in Figure 6 below, this area had a history of being cropped or harvested for sod or hay. Those ditch-dependent land uses have been abandoned. The scope and extent of drainage of the wetland soils could be reduced with ditch blocks, particularly for lateral ditches. This could reduce phosphorus export from those partially drained wetland soils. These ditches are on private lands, and willingness from all affected landowners would be needed.

Figure 6: Historical 1960 photo of ditch network upstream of DNR's aquatic management area.

Figure 7: Modern 2024 photo of ditch network upstream of DNR's aquatic management area.

Several other practices were considered but ruled out. Agricultural practices such as no-till, reduced till, and cover crops were considered, but available sites are limited given the limited number of agricultural fields and the fact that they drain through wetlands. Enhanced street sweeping was considered, but most of the roads are rural residential and lack stormwater conveyance systems. The areas with curb and gutter near the lake already have enhanced street sweeping. Given the lack of stormwater infrastructure throughout the area, potential urban stormwater retrofit sites are limited.