Addendum to the
Water Quality Improvement Plan
For

Meadow Lake

Adair County, Iowa

Total Maximum Daily Load for:
Algae
Addendum to include Turbidity

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2025

GENERAL REPORT SUMMARY

What is the purpose of this report?
This report serves as an addendum to the Meadow Lake Water Quality Improvement Plan (WQIP), dated November 2019, which was previously prepared by the Iowa Department of Natural Resources (Iowa DNR), submitted and partially approved by the EPA. The WQIP addressed the Total Maximum Daily Load (TMDL) for Algae and Turbidity. At the time of the initial WQIP submittal, Meadow Lake was only considered impaired for algae, and not turbidity. Therefore, only the algae portion of the WQIP was approved by the EPA. Subsequent to the Meadow Lake WQIP approval, the lake was placed on the 2022 303(d) list for a non-algal turbidity impairment. As a formality, this addendum addresses the non-algal turbidity impairment. For a full discussion please see the 2019 Meadow Lake WQIP entitled "*Water Quality Improvement Plan for Meadow Lake, Adair County, Iowa, Total Maximum Daily load for: Algae and Turbidity*" dated November 2019 and approved by the EPA on March 25, 2020.

What is wrong with Meadow Lake?
Meadow Lake is listed as impaired on the 2024 303(d) list for not supporting its primary contact recreation designated use. The impairment is due to elevated levels of algae and turbidity, which is caused by overly-abundant nutrients and sediment, including sediment-bound phosphorus in the lake.

What is causing the problem?
The amount of sediment and phosphorus transported to the lake from the surrounding watershed is sufficient to cause excessive growth of algae and excessive levels of turbidity, which reduces water clarity. Phosphorus is carried to the lake in two primary forms: (1) attached to eroded soil that is transported to the lake by rainfall runoff and stream flow, and (2) dissolved phosphorus in runoff and subsurface flow (e.g., shallow groundwater). Phosphorus and sediment within the water column and on the lake bed may become resuspended under certain conditions, which can add to algae and turbidity issues. There are no allowable discharging point sources in the Meadow Lake watershed; therefore, all phosphorus loads to the lake are attributed to nonpoint sources.

Nonpoint sources are discharged in an indirect and diffuse manner, and often are difficult to locate and quantify. Nonpoint sources of phosphorus in the Meadow Lake watershed include gully erosion, sheet and rill erosion from various land uses, runoff and subsurface flows from lands that receive fertilizer application, grazed pasture land, poorly functioning septic systems, manure deposited by wildlife, and particles carried by dust and wind (i.e., atmospheric deposition). A portion of the phosphorus carried to the lake eventually settles to the lake bottom and accumulates. Under certain conditions, this accumulated phosphorus can become available for algal uptake and growth through an internal recycling process.

What can be done to improve Meadow Lake?
Reducing phosphorus loss from pasture, row crops, and implementing or improving existing structural BMPs such as terraces, grass waterways, and constructed sediment basins in beneficial locations will significantly reduce phosphorus loads to the lake. Increasing the trapping efficiency of the existing sediment basins may be the most cost-effective structural alternative. Additionally, in-lake practices such dredging or phosphorus stabilization may be necessary in order to address algae and turbidity concerns. Consideration should be given to reductions in the population of grass carp, which graze on aquatic plants reducing the uptake of phosphorous. Finally, removal of curly-leaf pondweed will help improve water quality. Curly-leaf pondweed dies back in the summer releasing nutrients that contribute to algal blooms.

TOTAL MAXIMUM DAILY LOAD (TMDL) FOR TURBIDITY

A Total Maximum Daily Load (TMDL) is required for Meadow Lake by the Federal Clean Water Act. The WQIP for Meadow Lake quantified the maximum amount of total phosphorus (TP) the lake can assimilate and still support primary contact recreation. The TMDL for algae will also address the turbidity impairment since both are attributed to excess nutrients, particularly phosphorus. As a result, the addendum will not revisit the allowable TP load to the lake but refer to the 2019 WQIP for allowable phosphorus loads.

For convenience, a summary of the TMDL targets presented in the 2019 Meadow Lake WQIP will be provided here. For a full discussion please see the 2019 Meadow Lake WQIP entitled "*Water Quality Improvement Plan for Meadow Lake Adair County, Iowa, Total Maximum Daily load for: Algae and Turbidity*" dated November 2019. The Algae portion of the report was approved by the EPA on March 25, 2020.

The 2019 WQIP for Meadow Lake was written for algae and turbidity. However, because the turbidity impairment didn't exist prior to TMDL development, the EPA issued a correction letter in April, 2021 stating that "…no TMDLs were approved for turbidity for Meadow Lake." Consequently, this addendum to the TMDL is being written to address the turbidity impairment that was added during the 2022 assessment cycle.

Problem Identification

Meadow Lake is a Significant Publicly Owned Lake, and is protected for the following designated uses:

Primary Contact Recreational Use - Class A1
Aquatic Life - Class B(LW)
Human Health - Class HH

The 2024 Section 305(b) Water Quality Assessment Report states that the primary contact recreation designated use for Meadow Lake is assessed as "not supported due to aesthetically objectionable conditions caused by poor water transparency caused by algae and non-algal blooms." The 2024 assessment can be accessed at https://programs.iowadnr.gov/adbnet/Segments/1089/Assessment/2024.

Applicable Water Quality Standards

The State of Iowa Water Quality Standards (WQS) are published in the Iowa Administrative Code (IAC), Environmental Protection Rule 567, Chapter 61. Although the State of Iowa does not have numeric criteria for sediment, nutrients, or algae (chl-a), general (narrative) water quality criteria below do apply:

61.3(2) General water quality criteria. The following criteria are applicable to all surface waters including general use and designated use waters, at all places and at all times for the uses described in 61.3(1)"a."

a. Such waters shall be free from substances attributable to point source wastewater discharges that will settle to form sludge deposits.
b. Such waters shall be free from floating debris, oil, grease, scum and other floating materials attributable to wastewater discharges or agricultural practices in amounts sufficient to create a nuisance.
c. Such waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor or other aesthetically objectionable conditions.
d. Such waters shall be free from substances attributable to wastewater discharges or agricultural practices in concentrations or combinations which are acutely toxic to human, animal, or plant life.
e. Such waters shall be free from substances, attributable to wastewater discharges or agricultural practices, in quantities which would produce undesirable or nuisance aquatic life.

For 303(d) listing purposes, aesthetically objectionable conditions are present in a waterbody when Carlson's Trophic State Index (TSI) for the median growing season chl-a or Secchi depth exceeds 65. In order to de-list the turbidity impairment, the median growing season for chl-a TSI and Secchi depth TSI must not exceed 63 for one 303(d) listing cycle, per DNR de-listing methodology.

Problem Statement
Meadow Lake is impaired because primary contact recreation is not fully supported due to violations of WQS. High levels of non-algal turbidity cause the impairment. This turbidity is the result of sediment loads from the watershed. Because sediment is laden with phosphorus, which contributes to algal blooms when non-algal turbidity is low, reductions in phosphorus loads will reduce turbidity and also prevent future algal blooms.

Interpreting Meadow Lake Data
The 2024 305(b) assessment was based on results of the ambient monitoring program conducted from 2018-2022 by Iowa State University (ISU). All data was collected at the ambient monitoring location.

Carlson's Trophic State Index (TSI) was used to evaluate the relationships between TP, algae (chl-a), and transparency (Secchi depth) in Meadow Lake. TSI values are not a water quality index but an index of the trophic state of the water body. However, the TSI values for Secchi depth and chl-a can be used as a guide to establish water quality improvement targets.

If the TSI values for the three parameters are the same, the relationships between the TP, algae, and transparency are strong. If the TP TSI value is higher than the chl-a TSI, it suggests there are limitations to algal growth besides phosphorus. If the Secchi depth TSI value is higher than the chl-a TSI, it suggests that non-algal factors dominate water clarity. Figure 1 is a plot of the five-year running median TSI values, the 65 TSI threshold value, and the TSI de-listing value of 63. TSI values that exceed the 303(d)-listing threshold of 65 (for chl-a and Secchi depth) are contained within the red box. Table 1 lists the Meadow Lake average and median TSI values for the 2022 and 2024 305(b) assessment periods. Review of this information indicates a trend, in more recent years, that the Secchi depth TSI is greater than chl-a TSI indicating that non-algal factors dominate water clarity.

Figure 2 is a plot of the average and median TSI deviation values from the 2022 and 2024 305(b) assessment periods and illustrates a method for interpreting the meaning of the deviations between Carlson's TSI values for TP, Secchi depth, and chl-a. Each quadrant of the chart indicates the potential factors that may limit algal growth in a lake. A detailed description of this approach is available in A Coordinator's Guide to Volunteer Lake Monitoring Methods. If the deviation between the chl-a TSI and TP TSI is less than zero (Chl TSI < TP TSI), the data point will fall below the X-axis. This suggests phosphorus may not be the limiting factor in algal growth. The X-axis, or zero line, is related to TN:TP ratios of greater than 33:1 (Carlson, 1977). Because phosphorus is thought to become limiting at ratios greater than 10:1, TP deviations slightly below the X-axis do not necessarily indicate nitrogen limitation.

Points to the left of the Y-axis (Chl TSI < SD TSI) represent conditions in which transparency is reduced by non-algal turbidity. Points to the right reflect situations in which transparency is greater than chl-a levels would suggest, meaning that large particles, rather than fine clay particles, influence water clarity. Deviations to the right may also be caused by high zooplankton populations that feed on algae, keeping the algal populations lower than expected given other conditions. This data reinforces the previous statement that in more recent years non-algal factors dominate water clarity. From Figure 2 it can be seen that that all deviations lie within the lower left quadrant indicating that something other than algae dominates light attenuation and something other than phosphorus limits algae growth.

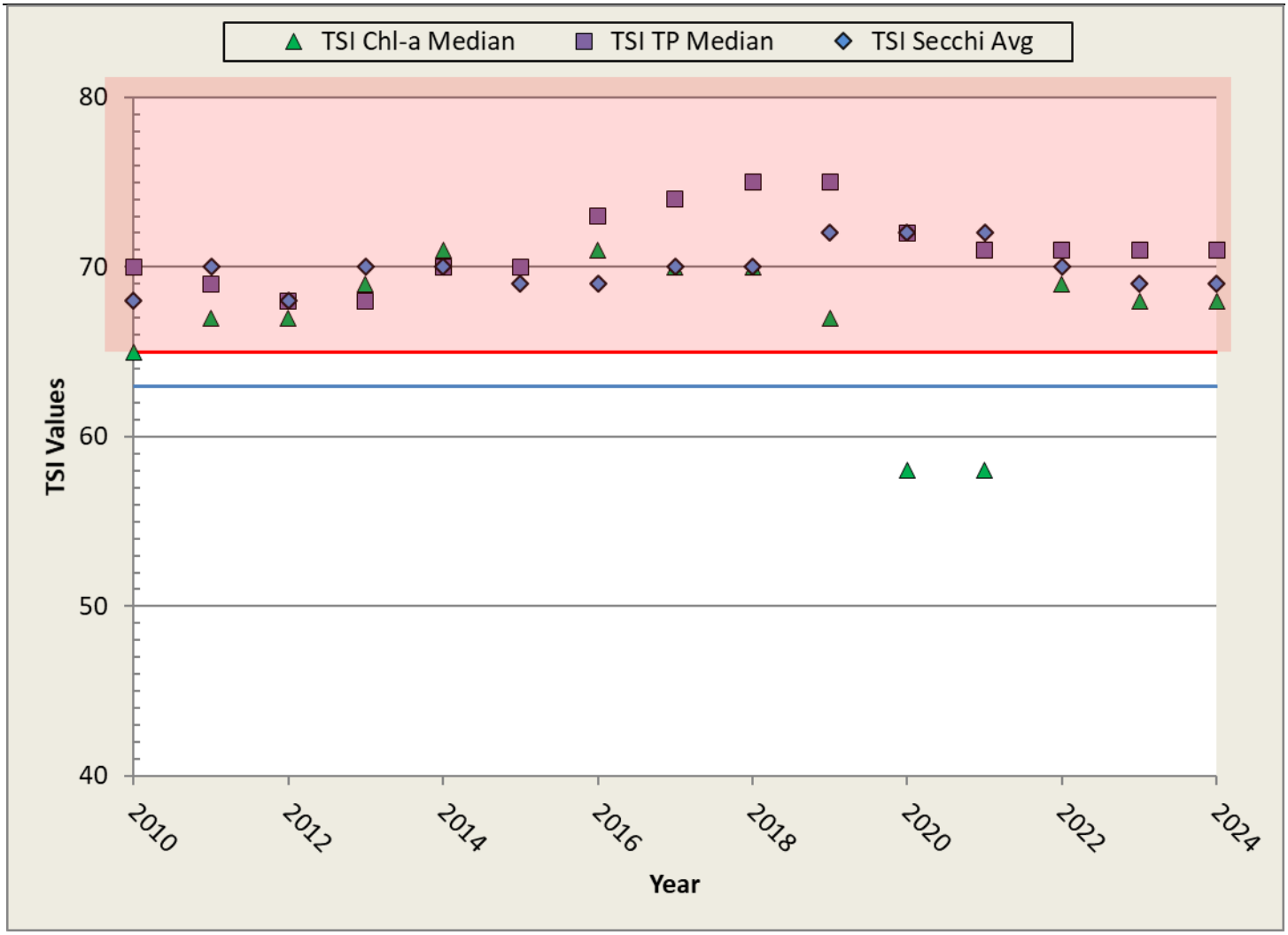

Figure 1. Five-Year Running Median TSI Values.

Table 1. Average and Median TSI Values for 2022 and 2024 Assessment Periods.

	Secchi Depth	Chl-a	Total Phosphorus
2022 Average TSI Values	70	61	72
2022 Median TSI Values	72	58	72
2024 Average TSI Values	68	65	71
2024 Median TSI Values	70	69	71

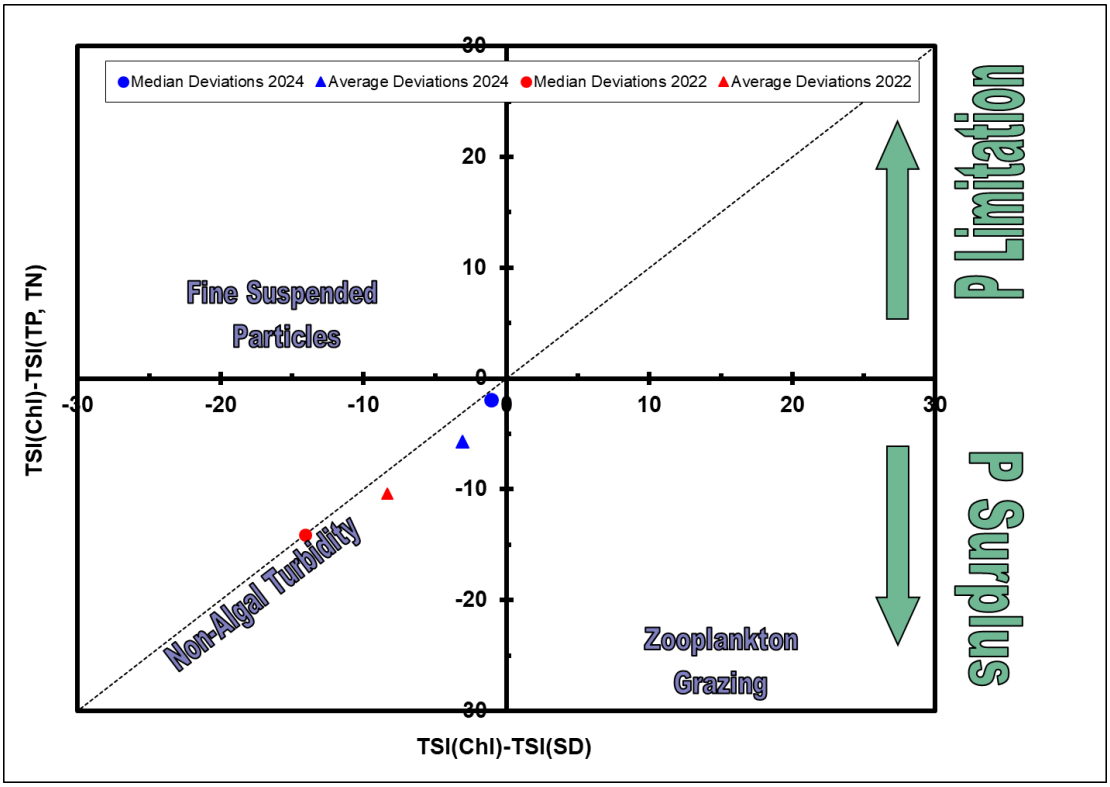

Figure 2. Average and Median TSI Deviation Values from 2022 and 2024 Assessment Periods.

TMDL Target

General Description of the Pollutant

The 2024 305(b) assessment attributes poor water quality in Meadow Lake to turbidity. From the 2019 Meadow Lake WQIP, modeling indicates that a TP reduction of 75% is needed to achieve TSI values of 63 or less for Secchi depth and chl-a.

Table 2 was copied from the 2019 Meadow Lake WQIP and reports the simulated chl-a, TP, and Secchi depth at the ambient monitoring location for both existing and target conditions. The Secchi depth and chl-a TSI target of 63 complies with the narrative "free from aesthetically objectionable conditions" criterion. Meeting this target will result in delisting Meadow Lake if attained in one 303(d) listing cycle, per Iowa DNR de-listing methodology. Note that TP values in Table 2 are not TMDL targets. Rather, they represent in-lake water quality resulting from TP load reductions required to obtain the chl-a and Secchi depth TSI targets in Meadow Lake.

Table 2. Existing and Target Water Quality (Ambient Monitoring Location).

Parameter	[1]2010-2017	[2]2010-2014	TMDL Target Conditions
Secchi Depth (meter)	0.6	0.60	1.1
TSI (Secchi Depth)	67	70	58
Chlorophyll-a (µg/L)	56.1	65	27.3
TSI (Chlorophyll-a)	70	71	63
TP (µg/L)	106.0	99	43.6
TSI (TP)	71	70	59

[1]Modeled Period, Median Values.
[2]2016 Assessment/Listing Cycle Values.
[3]This table copied from the 2019 Meadow Lake WQIP.

The allowable in-lake chl-a and Secchi depth target of 63 was translated to the TP loading by performing water quality simulations using the BATHTUB model. Based on these models the allowable annual loading capacity for TP is 205 lbs/year and the allowable maximum daily load is 1.7 lbs/day.

Waterbody Pollutant Loading Capacity (TMDL)
The TMDL establishes a chl-a and Secchi depth TSI target of 63 or less using analyses of existing water quality data and Carlson's trophic state index methodology. The allowable TP loading capacity was developed by performing water quality simulations using the BATHTUB model.

Decision Criteria for WQS Attainment
The narrative criteria in the water quality standards require that Meadow lake support primary contact for recreation. The metrics for WQS attainment for de-listing the impairments are a chl-a TSI and Secchi depth TSI of 63 or less for one 303(d) listing cycle.

Pollution Source Assessment
Existing Load
Using STEPL and BATHTUB to simulate annual average conditions between 2010-2017, the annual TP load to Meadow Lake was estimated to be 792 lbs/yr.

Identification of Pollutant Sources
The existing TP load to Meadow Lake is entirely from nonpoint sources of pollution. Sources that would contribute to non-algal turbidity are the same as those contributing to the phosphorus load as described in the 2019 WQIP.

TMDL Summary
The following general equation represents the total maximum daily load (TMDL) calculation and its components:

$$TMDL = LC = \sum WLA + \sum LA + MOS$$

Where:
- TMDL = total maximum daily load
- LC = loading capacity
- Σ WLA = sum of wasteload allocations (point sources)
- Σ LA = sum of load allocations (nonpoint sources)
- MOS = margin of safety (to account for uncertainty)

Once the loading capacity, wasteload allocations, load allocations, and margin of safety have all been determined for the Meadow Lake watershed, the general equation above can be expressed for the Meadow Lake algae and turbidity TMDL.

Expressed as the allowable annual average, which is helpful for water quality assessment and watershed management:

$$TMDL = LC = \sum WLA(0\ lbsTP/year) + \sum LA(184.5\ lbsTP/year + MOS(20.5\ lbsTP/year) = \mathbf{205.0\ lbsTP/year}$$

Expressed as the maximum daily load:

$$TMDL = LC = \sum WLA(0\ lbsTP/day) + \sum LA(1.58\ lbsTP/day + MOS(0.17\ lbsTP/day) = \mathbf{1.75\ lbsTP/day}$$

Table 3. ISU and SHL Water Quality Sampling Data (Ambient Location[1]).

Source	Date[2]	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	TN (mg/L)	pH	Secchi TSI	Chl-a TSI	TP TSI
ISU	6/16/2010	0.70	48.30	89.63	0.50	8.47	65.1	68.6	68.9
ISU	8/4/2010	0.40	62.85	138.74	8.62	7.58	73.2	71.2	75.2
ISU	9/16/2010	0.49	30.46	97.12	0.50	8.01	70.3	64.1	70.1
ISU	6/13/2011	1.18	40.24	61.45	3.08	8.17	57.6	66.8	63.5
ISU	8/1/2011	0.49	32.86	93.91	2.05	9.01	70.3	64.9	69.6
ISU	9/12/2011	0.40	94.00	92.47	1.04	8.24	73.2	75.2	69.4
ISU	6/11/2012	0.93	34.20	45.10	2.10	8.21	61.0	65.3	59.0
ISU	7/30/2012	0.43	87.52	51.50	1.93	8.34	72.2	74.5	60.9
ISU	9/10/2012	0.64	63.99	152.90	1.88	8.64	66.4	71.4	76.6
ISU	6/10/2013	0.70	52.73	62.55	2.12	8.66	65.1	69.5	63.7
ISU	7/29/2013	0.40	83.76	86.10	2.36	8.32	73.2	74.0	68.4
ISU	9/9/2013	0.43	100.32	126.70	2.33	8.20	72.2	75.8	73.9
ISU	6/16/2014	0.40	127.14	101.10	2.40	8.64	73.2	78.1	70.7
ISU	8/4/2014	0.41	64.80	156.25	3.42	8.31	72.8	71.5	76.9
ISU	9/14/2014	0.55	44.40	124.70	1.35	7.99	68.6	67.8	73.7
ISU	6/15/2015	0.78	52.80	53.55	2.01	8.26	63.6	69.5	61.5
ISU	8/3/2015	0.58	56.99	89.50	1.74	8.28	67.8	70.3	68.9
ISU	9/13/2015	0.73	30.43	93.35	1.80	8.08	64.5	64.1	69.5
ISU	6/13/2016	0.65	78.88	76.45	0.86	8.66	66.2	73.4	66.6
ISU	8/1/2016	0.33	59.76	161.90	1.56	7.85	76.0	70.7	77.5
ISU	9/13/2016	0.49	80.00	175.65	2.04	8.12	70.3	73.6	78.6
ISU	6/7/2017	1.90	5.00	39.10	1.05	8.80	50.8	46.4	57.0
ISU	7/25/2017	0.30	12.00	173.80	2.66	9.00	77.3	55.0	78.5
ISU	8/28/2017	0.20	3.30	199.50	2.21	8.60	83.2	42.3	80.5
ISU	6/5/2018	1.80	6.0	52.5	1.76	8.40	51.5	48.2	61.2
ISU	7/25/2018	0.30	82.0	162.0	2.33	8.70	77.3	73.8	77.5
ISU	8/30/2018	0.40	87.0	186.3	2.50	8.40	73.2	74.4	79.5
ISU	6/11/2019	0.45	11.8	75.3	2.75	8.90	71.5	54.8	66.4
ISU	7/31/2019	0.43	11.1	101.9	1.20	8.85	72.2	54.2	70.8
ISU	9/8/2019	0.43	8.1	215.3	1.32	8.10	72.2	51.2	81.6
ISU	6/1/2020	0.80	16.5	45.1	0.59	7.80	63.2	58.1	59.0
ISU	7/22/2020	0.30	89.7	107.6	0.74	8.60	77.3	74.7	71.6
ISU	9/23/2020	0.50	53.1	107.5	1.50	8.10	70.0	69.6	71.6
ISU	6/3/2021	1.25	86.0	99.0	1.82	9.18	56.8	74.3	70.4
ISU	7/28/2021	0.63	35.1	84.0	1.46	9.00	66.8	65.5	68.0
ISU	9/15/2021	0.53	67.9	98.0	1.05	8.04	69.3	72.0	70.2
ISU	6/26/2022	1.20	27.1	58.0		8.94	57.4	63.0	62.7
ISU	8/10/2022	0.50	49.8	125.0	2.33	8.84	70.0	68.9	73.7
ISU	9/20/2022	0.50	55.8	131.0	3.14	8.57	70.0	70.1	74.4
ISU	6/20/2023	0.80	41.9	79.0	1.97	9.25	63.3	67.2	67.1

Source	Date[2]	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	TN (mg/L)	pH	Secchi TSI	Chl-a TSI	TP TSI
ISU	8/8/2023	0.20	104.1	135.0	2.78	8.62	83.2	76.2	74.8
ISU	9/24/2023	0.41	53.3	107.0	2.71	7.94	72.8	69.6	71.5
ISU	6/25/2024	1.45	5.2	99.0	1.73	8.60	54.6	46.7	70.4
ISU	8/13/2024	0.38	127.6	173.0	1.92	7.60	74.1	78.2	78.4
ISU	9/29/2024	0.60	33.60	67.0	1.89	8.33	68.0	65.1	64.7
Average	--	0.63	52.83	111.9	1.85	8.41	68.6	66.0	70.7

[1]Ambient monitoring location = STORET ID 22010003
[2]Data between 2018-2022 were used for the 2024 Water Quality Assessment Period.

PUBLIC PARTICIPATION

Public involvement is important in the Total Maximum Daily Load (TMDL) process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in Meadow Lake.

Public Meeting

A virtual on-line presentation was prepared to present the results of the TMDL. A link to the presentation can be located on the Iowa DNR's website at https://www.iowadnr.gov/environmental-protection/water-quality/watershed-improvement/watershed-planning/water-quality-improvement-plans. The presentation will be available for viewing through the public comment period.

Public Comments

A press release was issued on May 29, 2025 to begin a 30-day public comment period which ends on June 30, 2025. All comments received by the DNR during the 30-day public notice period will be attached.