Water Quality Special Study Report
Addendum

U.S. Army Corps of Engineers
Omaha District

Summary of Water Quality Conditions Monitored at the Williston Marsh during the Period April 2012 through January 2017

May 2017

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Summary of Water Quality Conditions Monitored at the Williston Marsh during the Period April 2012 through January 2017

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PREFACE

This report is an addendum to the previously prepared Water Quality Special Study Report, "Summary of Water Quality Conditions Monitored at the Williston Area Protective Works and Levee Project during the 3-Year Period April 2012 through March 2015" (USACE, 2015). The previous report should be referenced for background information and specific water quality assessments at the Williston Area Protective Works and Levee Project from 2012 through 2015. The current report extends the assessment of water quality conditions in the Williston Marsh at three in-marsh monitoring sites through January of 2017. The expansion of the wastewater treatment facilities at the Williston Wastewater Treatment Facility (WWTF) was completed and the expanded treatment facilities went online on November 17, 2015. At that time, the ongoing wastewater discharge from the North and South Finishing Ponds to the Williston Marsh ceased, and the discharge of treated effluent from the WWTF is now to the Missouri River/Lake Sakakawea.

1 SAMPLING AND ANALYSES METHODS

(Note: Cited Tables, Figures, and Plates are located at the end of the Chapter where there are initially cited.)

1.1 WATER QUALITY MONITORING OBJECTIVES

The following two objectives guided the Omaha District's (District) water quality monitoring at the Williston Marsh (Marsh) over the period April-2015 through January-2017:

1) Document ambient water quality conditions present in the Marsh.
2) Determine if appropriate water quality standards are being met in the Marsh.

These objectives were carried over from the previous monitoring of the Marsh during the period of April-2012 through February-2015, and thus are applicable to the monitoring period of April-2012 through January-2017.

1.2 WATER QUALITY MONITORING LOCATIONS

Water quality monitoring at the Marsh during the period April-2015 through January-2017 occurred at three in-marsh locations: 1) LOWMSH, 2) MIDMSHN, and 3) UPMSH (Table 1-1 and Figure 1-1). With this latest water quality monitoring, the period of ongoing monitoring at site LOWMSH is 2012-2017, site MIDMSHN is 2013-2016, and site UPMSH is 2012-2016. Only site LOWMSH was sampled in January-2017. The water quality monitoring results at the three sites are indicative of ambient water quality conditions that were present in the Marsh during the period April-2012 through January-2017.

1.3 WATER SAMPLE COLLECTION AND ANALYSES

Table 1-1 lists the number of water quality observations that were taken at each water quality monitoring site and the period they were taken. Table 1-2 lists, by monitoring site, the water quality parameters that were measured in the field and that were analyzed in the laboratory from collected water samples.

1.3.1 <u>Field Measurements</u>

A Hydrolab equipped with a DataSonde5 probe (Hydrolab) was used to field measure: water temperature (°C); dissolved oxygen (mg/L and % saturation); pH (SU); specific conductance (µS/cm); oxidation-reduction potential, ORP (mV); and turbidity (NTU). Whenever possible, the Hydrolab was immersed directly into the marsh just below the water surface to record measurements. The alternative was to collect a water sample at the site in a plastic bucket and immediately immerse the Hydrolab into the bucket to obtain the measurements. When sampling was done in the winter during ice-cover a hole was augered through the ice, and the Hydrolab was lowered to just below the bottom ice surface to obtain measurements.

1.3.2 Collection of Water Samples

Water samples for laboratory analyses were collected from the shore as a "near-surface" grab sample. A plastic bucket attached to a rope was casted out and retrieved at the water surface. During winter ice-cover a hole was augered through the ice, and a plastic sampling tube was used to collect a grab sample from just below the bottom ice surface. The collected water was transferred to a plastic churn bucket which was used to fill the appropriate sample bottles. The sample bottles were appropriately preserved, labeled, and transported to the laboratory for analyses.

1.4 WATER QUALITY DATA ASSESSMENT

1.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards

Statistical analyses were performed on the collected water quality data using the utilities in Microsoft Excel. Descriptive statistics were calculated to describe central tendencies and the range of observations during the period April-2012 through January-2017. Monitoring results were compared to applicable water quality standards criteria established by the State of North Dakota pursuant to the Federal Clean Water Act. Tables were constructed that list the parameters measured; number of observations; and the mean, median, minimum, and maximum of the data collected. The constructed Tables also list the water quality standards criteria applicable to the individual parameters and the frequency that these criteria were not met.

1.4.2 Temporal and Spatial Plots

Time series plots for selected parameters were constructed comparing water quality conditions in the Marsh (sites UPMSH, MIDMSHN, and LOWMSH) over the period April-2012 through January-2017.

1.4.3 Phytoplankton

Assessment of the phytoplankton community present in the Marsh was based on near-surface grab samples collected at sites LOWMSH, MIDMSHN, and UPMSH. Laboratory analyses consisted of identification of phytoplankton taxa to the lowest practical level and quantification of taxa biovolume. These results were used to identify dominant taxa present and to determine the relative abundance of phytoplankton taxa at the division level based on the measured biovolumes.

1.5 WILLISTON WASTEWATER TREATMENT FACILITY DISCHARGE MONITORING REPORTS

Discharges from the Williston Wastewater Treatment Facility's (WWTF) South and North Finishing Ponds to the Marsh, and the temporary treatment facility and expanded facilities to the Missouri River/Lake Sakakawea are documented in Discharge Monitoring Reports (DMR) submitted by the City of Williston to the North Dakota Department of Health (NDDoH) in accordance with the WWTF's North Dakota Discharge Elimination System (NDPDES) permit. Copies of the submitted DMRs were obtained from the City of Williston for the period January-2012 through March-2015 and from the NDDoH for the period April-2105 through January-2017. Information obtained from the DMRs was compiled and is provided in Table 1-3 and Table 1-4. The expanded facilities were brought online on November 17, 2015 and regular discharges to the Missouri River/Lake Sakakawea commenced (Table 1-4). No discharges to the Marsh from the South and North Finishing Ponds occurred after November 2015 (Table 1-3).

Table 1-1. Locations where water quality monitoring was conducted at the Williston Marsh during the period April-2012 through January-2017.

Site Location	Site Number	Sampling Period	Number of Samples
Williston Marsh Sites:			
Upper Reaches of Marsh	UPMSH	2012 -2016	36
Middle Reaches of Marsh – North Side	MIDMSHN	2013-2016	29
Lower Reaches of Marsh – Corps Pumping Plant Intake	LOWMSH	2012-2017	44

Table 1-2. Parameters measured and analyzed at the Williston Marsh monitoring sites during the period April-2012 through January-2017.

Parameter	Sampling Site		
	UPMSH	**MIDMSHN**	**LOWMARSH**
Alkalinity (Total)	X	X	X
Anions, Simple (Chloride)	X	X	X
Carbon, Total Organic (TOC)	X	X	X
Chlorophyll-a, Total	X	X	X
Colorized Dissolved Organic Matter (CDOM)	X	X	X
Dissolved Solids, Total	X	X	X
Microcystin, Total (Immunoassay)	X	X	X
Nitrogen, Total Ammonia	X	X	X
Nitrogen, Total Kjeldahl	X	X	X
Nitrogen, Total Nitrate/Nitrite	X	X	X
Phosphorus, Dissolved	X	X	X
Phosphorus, Orthophosphate	X	X	X
Phosphorus, Total	X	X	X
Phytoplankton*	X	X	X
Sulfate	X	X	X
Suspended Solids, Total	X	X	X
Field Measurements**	X	X	X

* Phytoplankton samples collected in May, July, and September.

** Field measurements included: water temperature, dissolved oxygen (mg/l and % saturation), pH, conductivity, ORP, and turbidity.

Table 1-3. Summary of DMR reported discharges from the Williston Wastewater Treatment Facility's North and South Finishing Ponds (Outfall 001) to the Williston Marsh during the period January-2012 through January-2017.

	Discharge				BOD mg/l)		pH (SU)		Ammonia as N (mg/l)		E. coli (org/100ml)		Discharge Flow (MGD)		Drain (MG)
Month	Pond	Days	Start	Stop	30-day Average	Maximum	Minimum	Maximum	30-day Average	Daily Maximum	30-day Average Geomean	Daily Maximum	30-day Average	Daily Maximum	Total
2012															
January	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
February	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
March	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
April	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
May	North	18	5-May	25-May	7.6	12.8	7.59	7.95	22.2	23.6	26.3	30	8.42	16.51	151.52
June	South	18	1-Jun	18-Jun	16	22.2	7.15	8.19	28.1	29.5	74.8	80	8.34	10..08	150.08
July	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
August	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
September	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
October	North	14	15-Oct	28-Oct	5.06	6.1	7.86	7.96	13.2	13.6	153.3	500	6.62	11.00	92.62
November	South	19	12-Nov	19-Nov	7.4	8.4	7.59	7.91	25.2	26.7	NA	NA	7.87	11.42	149.59
December	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
														TOTAL	**543.81**
2013															
January	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
February	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
March	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
April	North	13	11-Apr	23-Apr	29.3	31.4	7.43	7.46	27.9	34.8	1320.8	1600	10.88	15.2	141.40
May	South	21	7-May	27-May	20.4	28.3	7.26	7.70	20.3	25.3	125.5	900	6.75	11.65	141.67
June	North	7	24-Jun	30-Jun	8.4	9.1	6.81	7.78	24.0	24.5	26.0	30	11.05	16.61	77.36
July	North	10	1-Jul	10-Jul	2.3	3.8	7.62	7.88	25.7	28.2	24.7	50	7.30	9.25	65.75
August	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
September	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
October	North	17	15-Oct	31-Oct	3.95	6.3	7.55	7.94	13.9	14.9	40.76	80	8.52	16.64	144.79
November	South North	10 7	1-Nov 20-Nov	20-Nov 26-Nov	11.3	20.4	7.21	7.60	23.5	25.6	NA	NA	6.91	11.70	186.71
December	South	7	9-Dec	15-Dec	29.3	33.8	7.17	7.32	31.1	32.3	NA	NA	5.49	7.33	38.46
														TOTAL	**796.14**

Table 1-3. (Continued).

Month	Discharge				BOD mg/l)		pH (SU)		Ammonia as N (mg/l)		E. coli (org/100ml)		Discharge Flow (MGD)		Drain (MG)
	Pond	Days	Start	Stop	30-day Average	Maximum	Minimum	Maximum	30-day Average	Daily Maximum	30-day Average Geomean	Daily Maximum	30-day Average	Daily Maximum	Total
2014															
January	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
February	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
March	North	11	21-Mar	31-Mar	32.5	36.3	7.47	7.70	35.2	38.9	NA	NA	2.18	4.76	24.00
April	North	11	7-Apr	21-Apr	29.7	31	7.50	7.56	31.2	34.5	1600	1600	1.92	4.79	21.12
May	North	19	1-May	19-May	19.5	28.5	7.50	8.37	26.4	28	122.5	1600	4.64	6.54	88.24
June	North	16	19-Jun	28-Jun	12.2	13.8	8.07	8.83	19.5	20.4	26.3	30	3.11	9.41	53.08
July	North	20	1-Jul	23-Jul	13.2	18.6	7.68	8.17	17.6	21.8	15.7	80	3.00	10.84	57.06
August	North	20	4-Aug	28-Aug	7.8	9.9	7.83	8.36	18.2	19.4	26.3	30	3.49	11.09	69.88
September	North	22	2-Sep	30-Sep	5.8	8.9	7.74	8.21	20.9	21.8	38.7	50	3.07	7.80	67.69
October	North	22	1-Oct	31-Oct	3.4	5.2	7.57	8.27	22.5	24.56	25.8	80	6.36	10.87	139.97
November	South North	15 4	10-Nov 3-Nov	28-Nov 6-Nov	8.5	9.7	8.00	8.29	28.4	31.2	NA	NA	5.87	10.64	111.58
December	South	7	9-Dec	15-Dec	29.3	33.8	7.17	7.32	31.1	32.3	NA	NA	5.49	7.33	38.46
														TOTAL	**671.08**
2015															
January	North	10	1-Jan	23-Jan	28.8	29.5	7.38	7.60	33.0	34.5	NA	NA	3.50	7.59	35.03
February	North	14	9-Feb	26-Feb	31.2	33.0	6.96	7.55	33.6	34.5	NA	NA	4.03	10.86	56.47
March	North	17	2-Mar	31-Mar	32.9	37.7	7.37	8.10	29.0	33.3	NA	NA	6.58	10.83	111.90
April	North	3	27-Apr	30-Apr	15.2	17.8	7.83	8.75	23.6	24.5	11.8	19	0.24	0.50	1.21
May	North	22	4-May	31-May	11.7	16.1	7.94	9.08	21.1	22.7	5.2	20	2.95	6.38	65.06
June	North	20	2-Jun	30-Jun	14.6	20.9	7.89	8.41	22.6	25.0	3.8	328	3.09	6.16	61.97
July	North	23	1-Jul	31-Jul	19.2	21.4	8.02	8.53	19.3	21.4	12.7	105	3.17	4.47	72.9
August	North	17	4-Aug	28-Aug	13.8	19.4	7.83	8.51	18.8	19.7	5.1	9	3.39	4.76	57.78
September	North	22	1-Sep	30-Sep	14.8	18.3	8.06	8.42	16.8	17.6	12.2	47	3.66	6.23	80.55
October	North	24	1-Oct	30-Oct	12.7	15.1	7.61	8.07	16.1	16.8	11.1	17	4.80	9.09	115.17
November	South	12	2-Nov	17-Nov	10.4	12.1	8.32	8.78	9.6	9.9	11.8	19	5.21	12.25	62.46
December	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
														TOTAL	**720.50**

Table 1-3. (Continued).

Month	Discharge				BOD mg/l)		pH (SU)		Ammonia as N (mg/l)		E. coli (org/100ml)		Discharge Flow (MGD)		Drain (MG)
	Pond	Days	Start	Stop	30-day Average	Maximum	Minimum	Maximum	30-day Average	Daily Maximum	30-day Average Geomean	Daily Maximum	30-day Average	Daily Maximum	Total
2016															
January	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
February	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
March	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
April	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
May	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
June	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
July	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
August	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
September	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
October	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
November	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
December	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
														TOTAL	0
2017															
January	0	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
														TOTAL	0

Table 1-4. Summary of DMR reported discharges from the Williston Wastewater Treatment Facility's temporary (2013-2015) and expanded (2015-2017) system (Outfall 002) to the Missouri River/Lake Sakakawea during the period April-2013 through January-2017.

	Discharge			BOD mg/l)		pH (SU)		Ammonia as N (mg/l)		E. coli (org/100ml)		Discharge Flow (MGD)		Drain MG)
Month	Days	Start	Stop	30-day Average	Maximum	Minimum	Maximum	30-day Average	Daily Maximum	30-day Average Geomean	Daily Maximum	30-day Average	Daily Maximum	Total
2013 – Temporary System														
April	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
May	3	29-May	31-May	33.5	33.5	7.28	7.28	24.8	24.8	500.0	500	0.66	0.81	1.98
June	30	1-Jun	30-Jun	20.1	31.3	6.74	7.67	23.6	25.6	82.3	1600	1.47	1.83	44.20
July	22	1-Jul	22-Jul	23	42.9	7.26	7.65	28.1	29.5	104.8	140	0.97	1.64	21.49
August	3	28-Aug	30-Aug	21.3	21.3	6.83	6.83	30.4	30.4	23.0	23	0.07	0.15	0.20
September	16	9-Sep	28-Sep	17.7	25.4	6.56	7.39	27.2	29.5	46.2	80	0.18	0.32	2.81
October	23	1-Oct	31-Oct	18.3	21.6	6.99	7.34	28.8	29.5	44.8	63	0.16	0.74	3.60
November	2 4 1	1-Nov 5-Nov 13-Nov	2-Nov 8-Nov 13-Nov	28.8	33.7	6.82	7.21	26.7	27.4	NA	NA	0.58	0.65	4.09
December	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
													TOTAL	**78.37**
2014 – Temporary System														
January	21	4-Jan	24-Jan	48.48	52.0	7.42	7.87	28.0	28.8	NA	NA	1.2	1.57	25.26
February	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
March	15	15-Mar	29-Mar	46.6	52.3	7.46	7.75	28.8	30.4	NA	NA	1.70	2.50	25.60
April	22	1-Apr	30-Apr	46.6	63.0	7.30	8.00	31.1	32.7	680.0	1600	0.46	1.12	10.33
May	19	1-May	19-May	56.1	67.7	7.46	7.84	30.0	33.3	1318.0	1600	1.50	2.48	28.58
June	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
July	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
August	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
September	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
October	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
November	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
December	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
													TOTAL	**89.77**

Table 1-4. **(**Continued).

Month	Discharge			BOD mg/l)		pH (SU)		Ammonia as N (mg/l)		E. coli (org/100ml)		Discharge Flow (MGD)		Drain (MG)
	Days	Start	Stop	30-day Average	Maximum	Minimum	Maximum	30-day Average	Daily Maximum	30-day Average Geomean	Daily Maximum	30-day Average	Daily Maximum	Total
2015 – Temporary System														
January	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
February	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
March	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
April	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
May	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
June	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
July	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
August	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
September	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
October	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	0	0
2015 – Expanded System														
November	26	5-Nov	30-Nov	2.3	2.5	7.3	8.08	0.27	0.95	NA	NA	1.578	1.983	41.04
December	31	1-Dec	31-Dec	2.5	3.31	7.21	7.71	0.11	0.15	NA	NA	1.751	2.108	52.53
													TOTAL	**93.57**
2016 – Expanded System														
January	31	1-Jan	31-Jan	2	2	7.1	7.4	0.21	0.32	NA	NA	1.934	2.228	59.97
February	29	1-Feb	29-Feb	2.7	3.46	7.2	7.38	0.25	1.02	NA	NA	1.911	2.163	55.43
March	31	1-Mar	31-Mar	2.6	3.22	7.28	7.65	0.14	0.22	NA	NA	1.7	2.01	52.73
April	30	1-Apr	30-Apr	3.9	7.96	7.17	7.62	0.12	0.14	1.9	3	1.784	2.435	53.55
May	31	1-May	31-May	7.8	11.6	6.67	7.38	0.12	0.12	5.8	8	1.956	2.304	60.66
June	30	1-Jun	30-Jun	4.2	4.88	7.21	7.4	0.12	0.16	2.9	5	2.123	2.441	61.55
July	31	1-Jul	31-Jul	3.9	4.94	7.09	7.64	0.11	0.13	2.3	15	2.143	2.389	66.46
August	31	1-Aug	31-Aug	4.1	5.77	7.19	7.8	0.79	1.91	3.2	8	1.625	2.253	50.39
September	30	1-Sep	30-Sep	3.1	4.78	7.15	7.45	0.17	0.22	1.1	1	1.964	2.192	58.93
October	31	1-Oct	31-Oct	2.3	2.77	7.4	7.65	0.16	0.2	16.3	55	1.666	2.154	52.06
November	30	1-Nov	30-Nov	7.63	4.4	7.4	7.67	0.18	0.14	NA	NA	1.925	2.382	57.75
December	31	1-Dec	31-Dec	4.6	5.245	7.22	7.56	0.11	0.12	NA	NA	1.682	1.992	52.16
													TOTAL	**681.64**
2017 – Expanded System														
January	31	-Jan	31-Jan	4.9	8.44	7.34	7.4	0.14	0.18	NA	NA	1.83	2.088	56.76
													TOTAL	**56.76**

Figure 1-1. Aerial view of the Williston Marsh, City of Williston's Wastewater Treatment Facilities, and location of the three in-marsh water quality monitoring sites (UPMSH, MIDMSHN, and LOWMSH). *(Imagery Date: 2016)*

2 RESULTS – WILLISTON MARSH WATER QUALITY

2.1 STATISTICAL SUMMARY OF MONITORED WATER QUALITY CONDITIONS AND COMPARISON TO APPLICABLE WATER QUALITY STANDARDS

Water quality conditions that were monitored in the Marsh at sites LOWMSH, MIDMSHN, and UPMSH during the period April-2012 through January-2017 are respectively summarized in Plate 2-1, Plate 2-2, and Plate 2-3.

2.2 DISSOLVED OXYGEN

Dissolved oxygen (DO) levels (mg/L and percent saturation) monitored in the Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017 are plotted in Figure 2-1 and Figure 2-2. DO concentrations below the water quality standard criterion of 5 mg/L were measured in the Marsh during 2012 through 2016 (Figure 2-1). The greatest number of exceedances below 5 mg/L DO occurred in 2013, 2014, and 2015; years when effluent discharges occurred from the Finishing Ponds to the Marsh. During 2016, only one value (3.9 mg/L) was measured below 5 mg/L during the ice-free period at site UPMSH in May. Measured DO levels varied from 0.0 mg/L and 0% saturation (LOWMSH, Feb 2015 and Jan 2016) to 23.9 mg/l and 323% saturation (UPMSH Jun 2016).

2.3 OXIDATION-REDUCTION POTENTIAL (ORP)

ORP levels measured in the Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017 are plotted in Figure 2-3. Measured ORP levels were above 200 mV on most occasions. Exceptions were ORP measurements taken during the winter when ice-cover was present (Figure 2-3). The lowest ORP level measured in the Marsh was -51 mV in January-2015. At that time, a strong hydrogen sulfide odor (i.e. rotten egg smell) was emanating from the Corps Pumping Plant outfall to the Missouri River.

2.4 PH

Figure 2-4 plots the pH levels that were measured in the Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017. Unlike 2012 through 2015, during the growing season of 2016 the measured pH levels regularly exceeded the maximum water quality standard of 9.0 SU for Class III streams. No measured pH value was below the minimum water quality standard of 6.0 SU for Class III streams, with the lowest measured pH level being the 6.8 SU value measured in January-2016 (Figure 2-4).

2.5 TOTAL ALKALINITY

Total alkalinity concentrations sampled in the Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through March-2015 are plotted in Figure 2-5.

2.6 AMMONIA

Total ammonia concentrations sampled in the Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017 are plotted in Figure 2-6. Acute and chronic water quality standards criteria for ammonia were exceeded on various occasions at the three sites during 2012 through 2015, but not during 2016 and 2017 (Plate 2-1, Plate 2-2, and Plate 2-3). The exceedances of ammonia water quality standards criteria only occurred in the years that the Finishing Ponds were discharging effluent to the Marsh (2012-2015). During the growing seasons of the years effluent discharges occurred (2012-2015), the ammonia concentrations measured in the upper reaches of the Marsh (site UPMSH), nearer the WWTF discharge, were appreciably higher than the ammonia levels measured in the lower reaches of the Marsh (site LOWMSH) (Figure 2-6).

2.7 NITRATE-NITRITE

Figure 2-7 plots the nitrate-nitrite concentrations that were sampled in the Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017. Overall, the sampled nitrate-nitrite levels were quite low in the Marsh

2.8 TOTAL NITROGEN

Total nitrogen was quantified as total Kjeldahl nitrogen plus nitrate-nitrite nitrogen. Figure 2-8 plots the total nitrogen concentrations that were sampled in the Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017.

2.9 ORTHOPHOSPHATE

Figure 2-9 plots the orthophosphate concentrations sampled in the Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017. Orthophosphate levels monitored in the Marsh were appreciably lower in 2016 and 2017 as compared to the 2012 through 2015 period when effluent discharges were occurring. As indicated by the "paired" sample results during the period of effluent discharges (2012-2015), orthophosphate levels were generally higher in the upper reaches of the Marsh (site UPMSH) then in the lower reaches (site LOWMSH) (Figure 2-9). In the lower reaches of the Marsh (site LOWMSH) when effluent discharges were occurring, orthophosphate levels tended to be higher in during the ice-covered period than during the growing season (Figure 2-9).

2.10 TOTAL PHOSPHORUS

Total phosphorus concentrations monitored in the Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017 are plotted in Figure 2-10.

2.11 ALGAE

2.11.1 <u>Phytoplankton Chlorophyll-a</u>

Phytoplankton chlorophyll-a concentrations monitored in the Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017 are plotted in Figure 2-11. Sampled phytoplankton chlorophyll-a levels in the Marsh were seemingly lower in 2016 than during the period 2012 through 2015.

2.11.2 <u>Phytoplankton</u>

Phytoplankton grab samples were collected from the Marsh in May, July, and September during 2012, 2013, 2015, and 2016. Plate 2-4 lists the taxa and the biovolume of the phytoplankton collected at site LOWMSH in 2012, 2013, 2015, and 2016. Plate 2-5 lists the taxa and the biovolume of the phytoplankton collected at site MIDMSHN in 2015 and 2016. Plate 2-6 lists the taxa and the biovolume of the phytoplankton collected at site UPMSH in 2012, 2013, 2015, and 2016. Taxa identified in the collected phytoplankton samples were from seven taxonomic divisions: Bacillariophyta (diatoms), Chlorophyta (green algae), Chrysophyta (golden algae), Cryptophyta (cryptomonad algae), Cyanobacteria (blue-green algae), Pyrrophyta (dinoflagellate algae), and Euglenophyta (euglenoid algae). Major phytoplankton species present in the samples collected from the Marsh during 2012, 2013, 2015, and 2016 (i.e. species comprising more than 10% of the total biovolume of at least one sample) included:

Bacillariophyta

Achnanthidium helveticum, Aulacoseira granulata, Cocconeis placentula, Cyclotella meneghiniana, Fragilaria capucina, Gomphonema parvulum, Melosira varians, Nitzschia inconspicua, Nitzschia perminuta, Stephanocyclus meneghiniana, Stephanodiscus hantzschii, Stephanodiscus parvus, and *Synedra ulna*

Chlorophyta

Chlamydomonas globose, Chlorella spp., Closterium spp., Pandorina spp., Pyramimonas tetrarhynchus, Scenedesmus quadricauda, and *Sphaerocystis schroeteri*

Chrysophyta

Dinobryon spp., Mallomonas spp., and Synura spp.

Cryptophyta

Cryptomonas curvata, Cryptomonas erosa, Cryptomonas marssonii, Cryptomonas ovata, Cryptomonas platyuris, and *Rhodomonas spp.*

Cyanobacteria

Aphanizomenon flos-aquae, Dolichospermum spp., Microcystis spp., Phormidium spp., Planktolyngbya limnetica

Pyrrophyta

Glenodinium palustre and *Gymnodinium palustre*

A complete listing of phytoplankton species sampled in the Marsh during 2012, 2013, 2015, and 2016 is provided in Plate 2-7.

The relative abundances of phytoplankton, based on biovolume, in samples collected from the Marsh over the period 2012 through 2016 at sites UPMSH, MIDMSHN, and LOWMSH are respectively plotted in Figure 2-12, Figure 2-13, and Figure 2-14. A significant cyanobacteria bloom occurred in the Marsh during the summer of 2015, especially in the upper reaches of the Marsh. The primary cyanobacteria present during the 2015 bloom conditions was *Aphanizomenon flos-aquae*.

2.12 MICROCYSTINS

Microcystins are cyanobacterial toxins produced by the cyanobacteria *Anabaena, Fisherella, Gloeotrichia, Nodularia, Nostoc, Osicillatoria, Microcystis,* and *Planktothrix.* Water quality samples collected at the Marsh were analyzed for the presence of microcystins (Total and Dissolved). No microcystins concentrations above 2 ug/L were sampled during the period April-2012 through January-2017 (Plate 2-1, Plate 2-2, and Plate 2-3). It is noted that the primary cyanobacteria present during the 2015 bloom conditions in the Marsh was *Aphanizomenon flos-aquae*. *Aphanizomenon flos-aquae* does not produce microcystins, but does produce the cyanobacterial toxin cylindrospermopsin which was not analyzed.

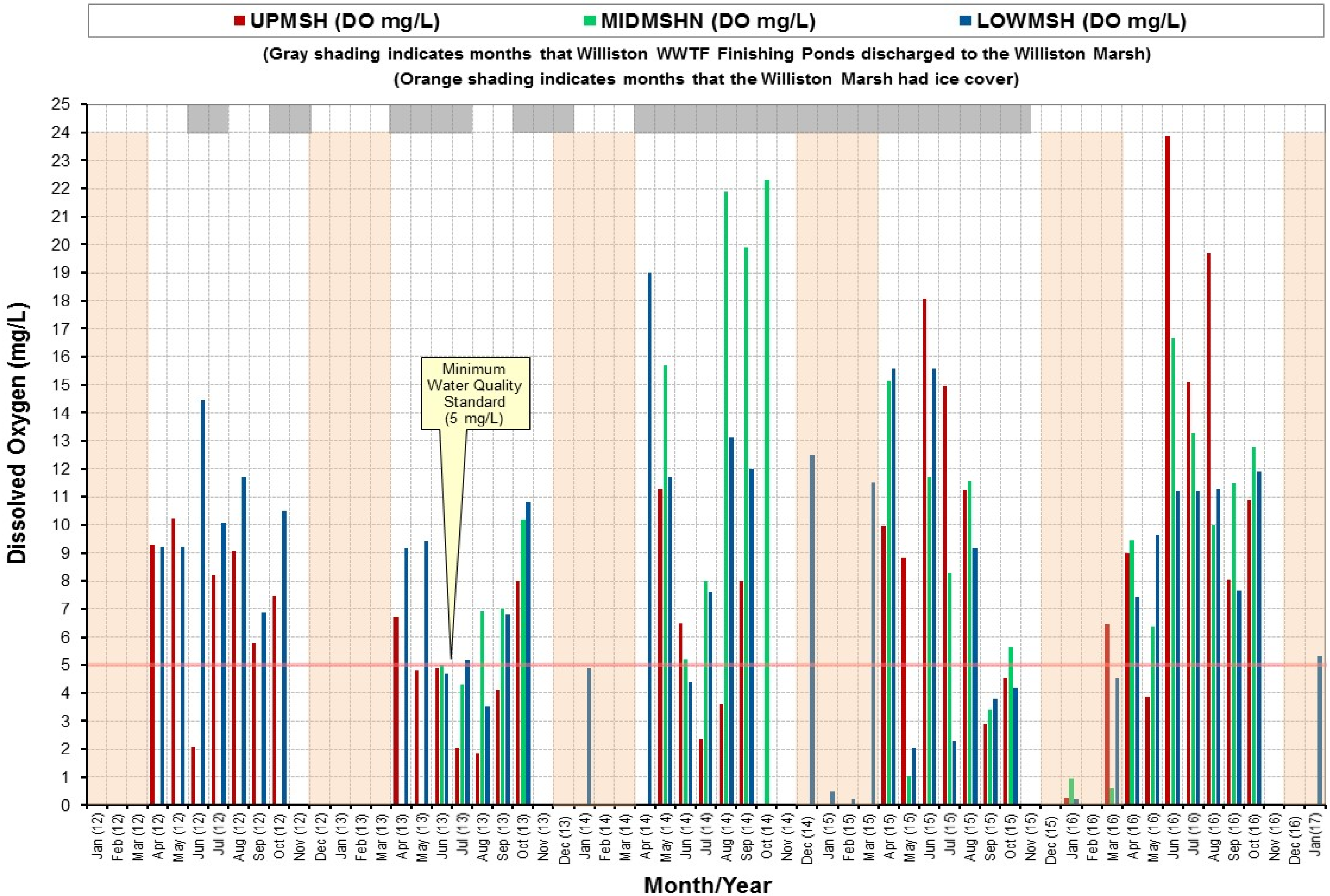

Figure 2-1. Dissolved oxygen concentrations (mg/L) monitored in the Williston Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the 5-year period April-2012 through January-2017.

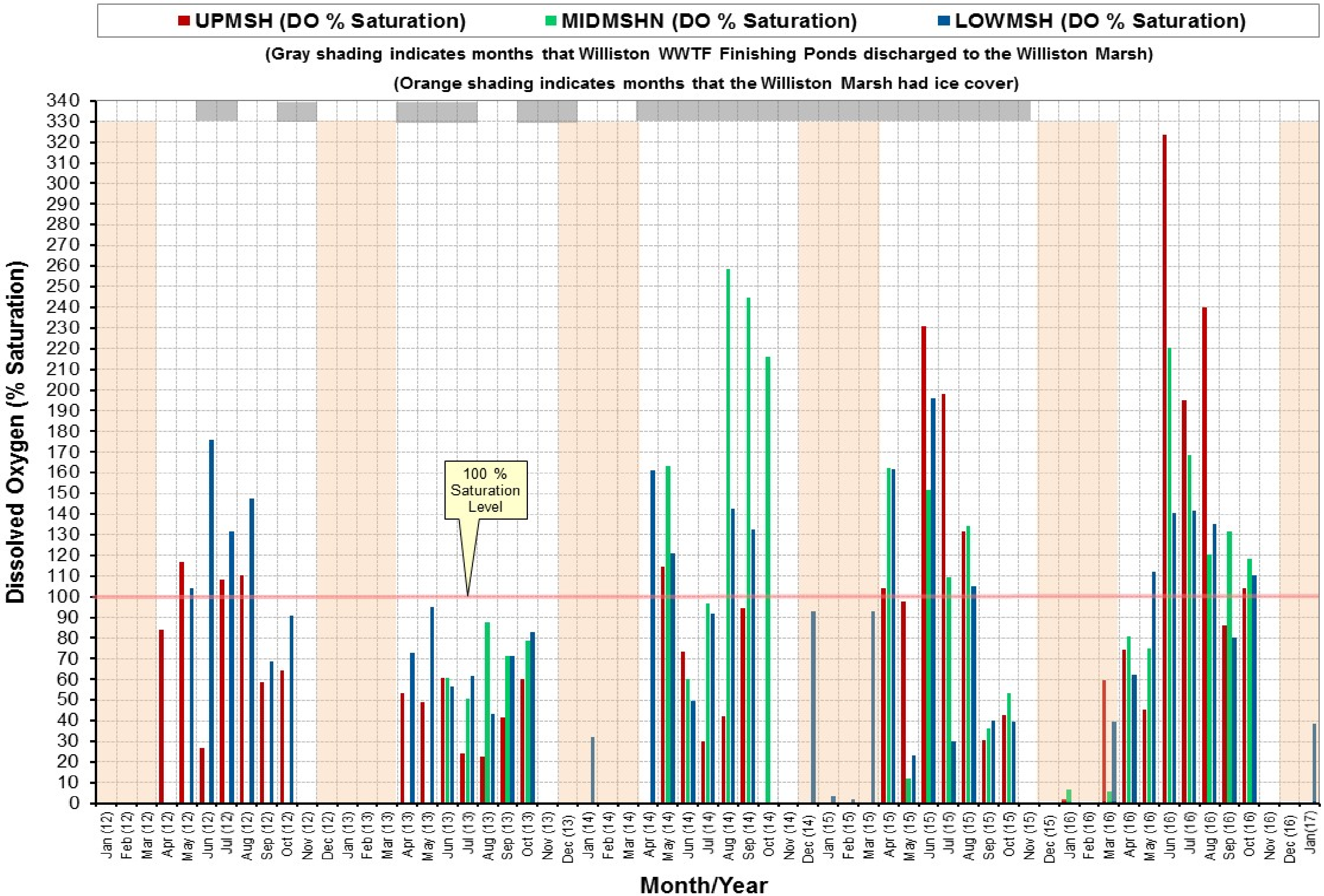

Figure 2-2. Dissolved oxygen levels (% saturation) monitored in the Williston Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the 5-year period April-2012 through January-2017.

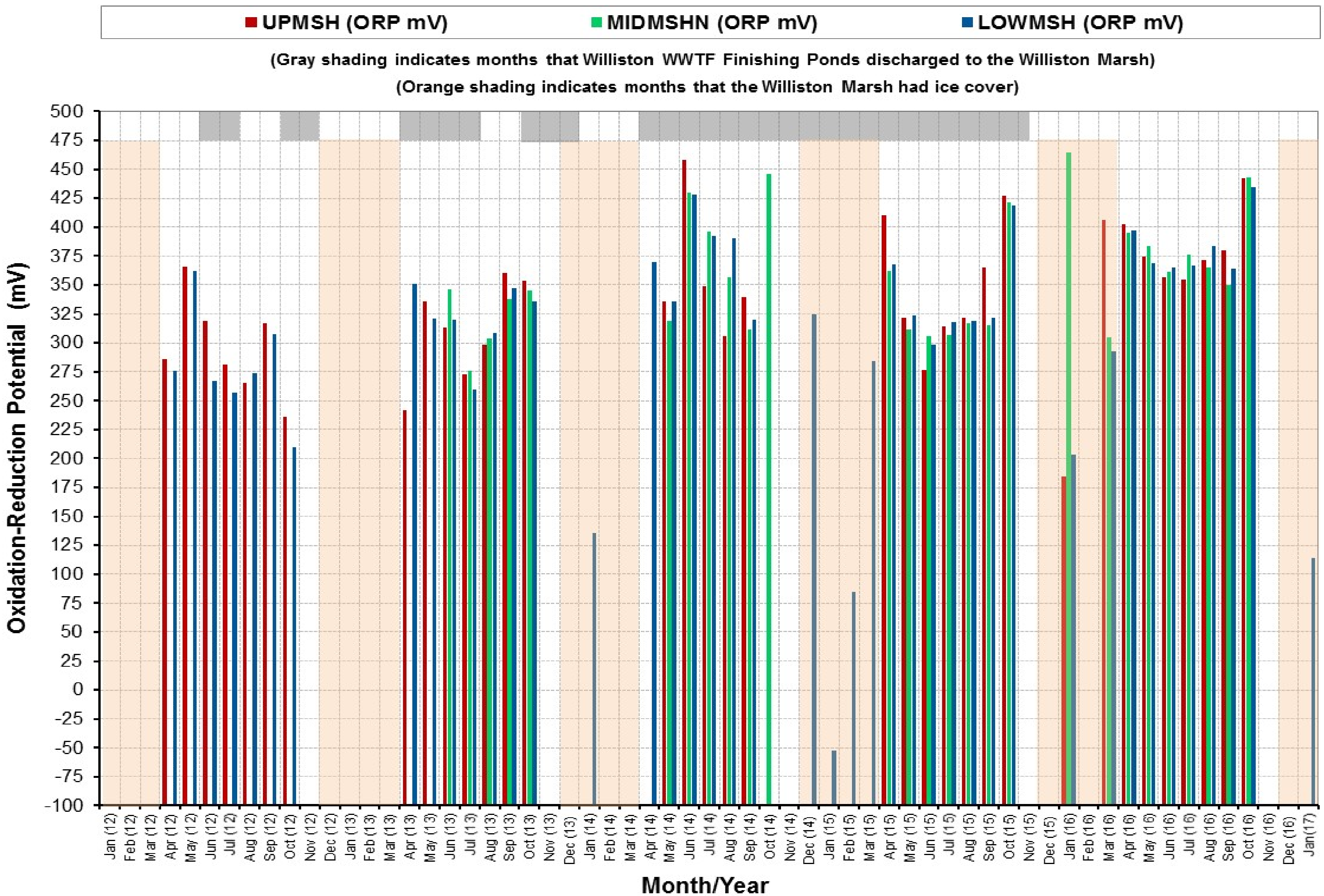

Figure 2-3. Oxidation-Reduction Potential levels (mV) monitored in the Williston Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017.

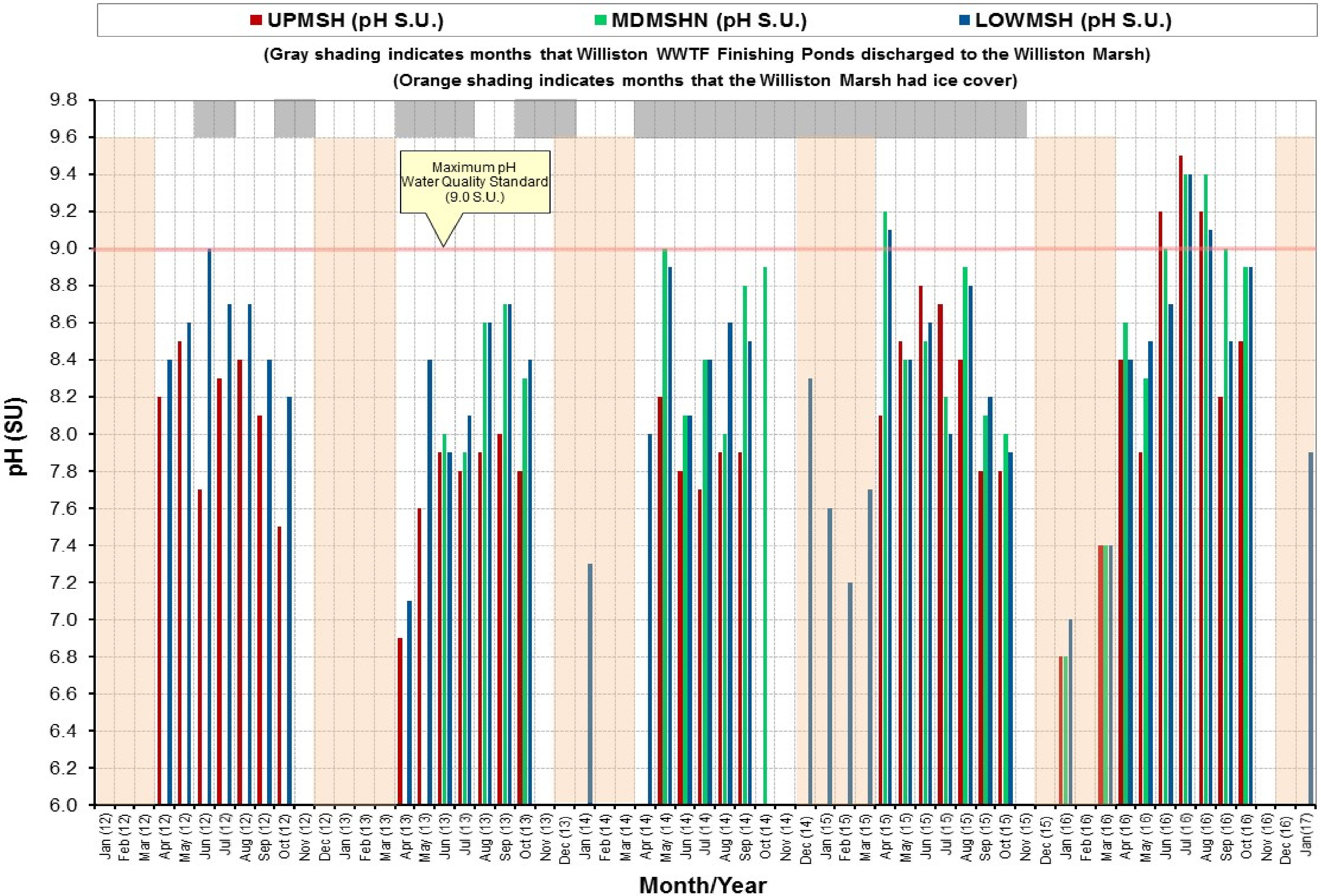

Figure 2-4. pH levels (SU) monitored in the Williston Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017.

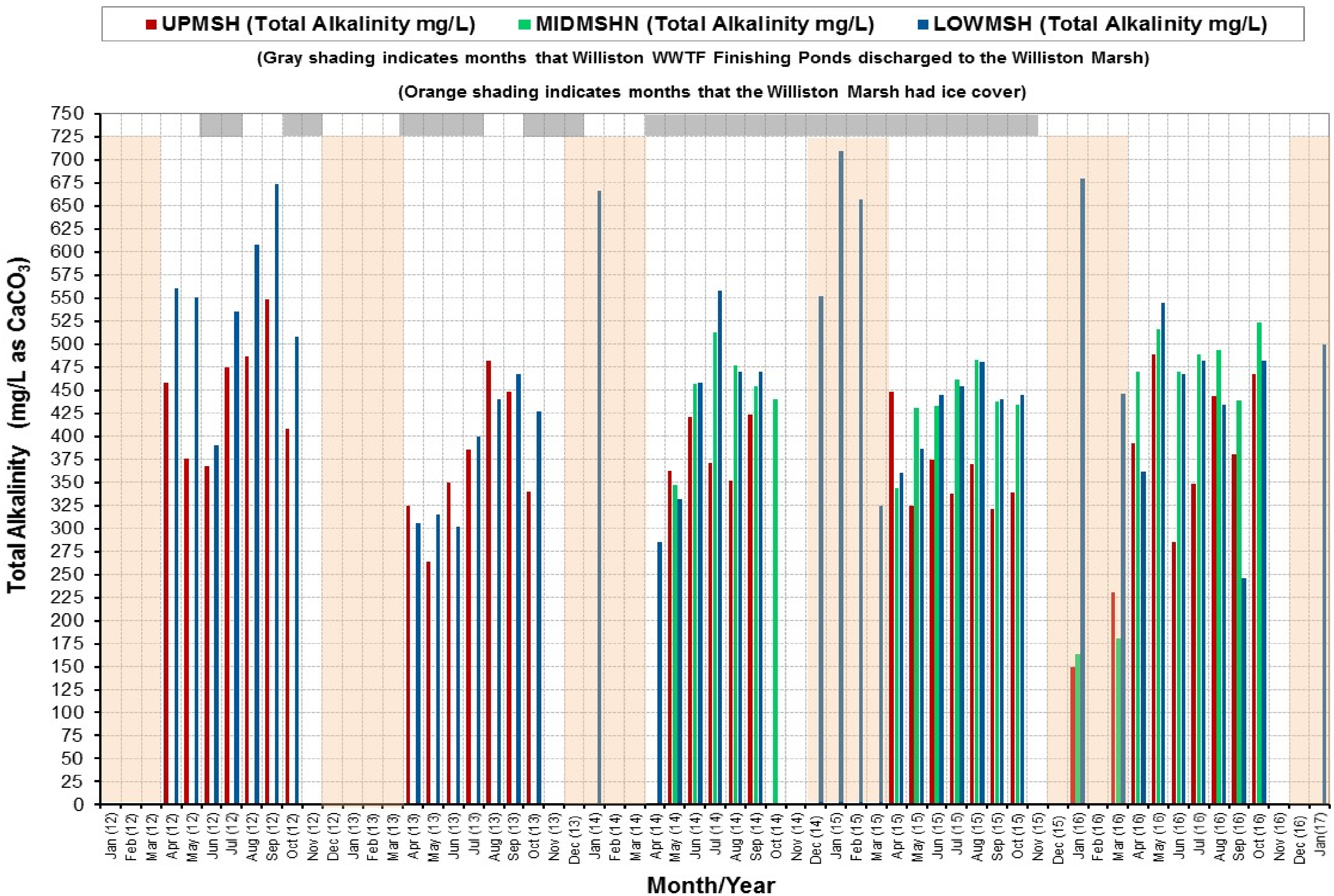

Figure 2-5. Alkalinity levels (mg/L as $CaCO_3$) monitored in the Williston Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017.

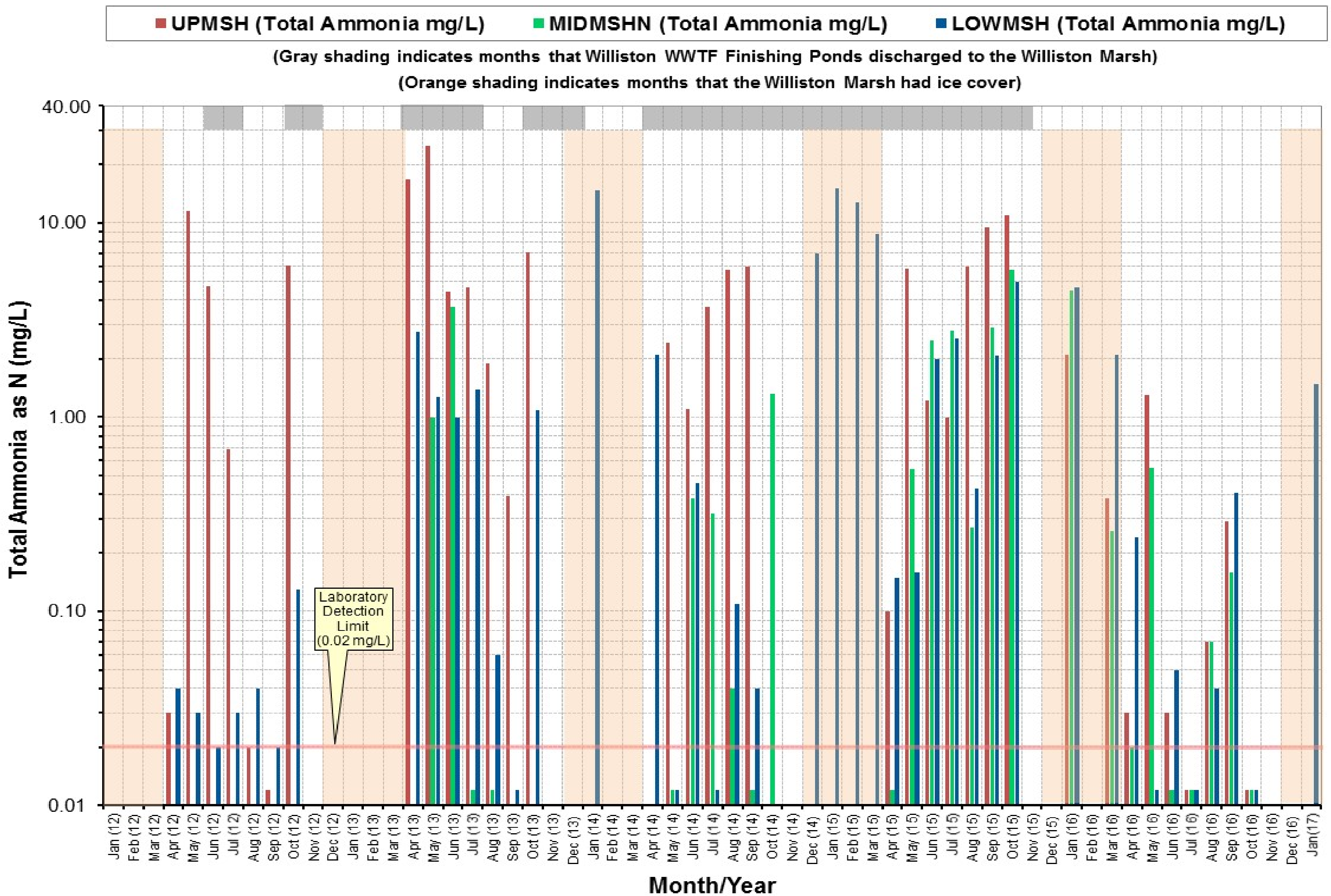

Figure 2-6. Ammonia concentrations (mg/L as N) monitored in the Williston Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017.

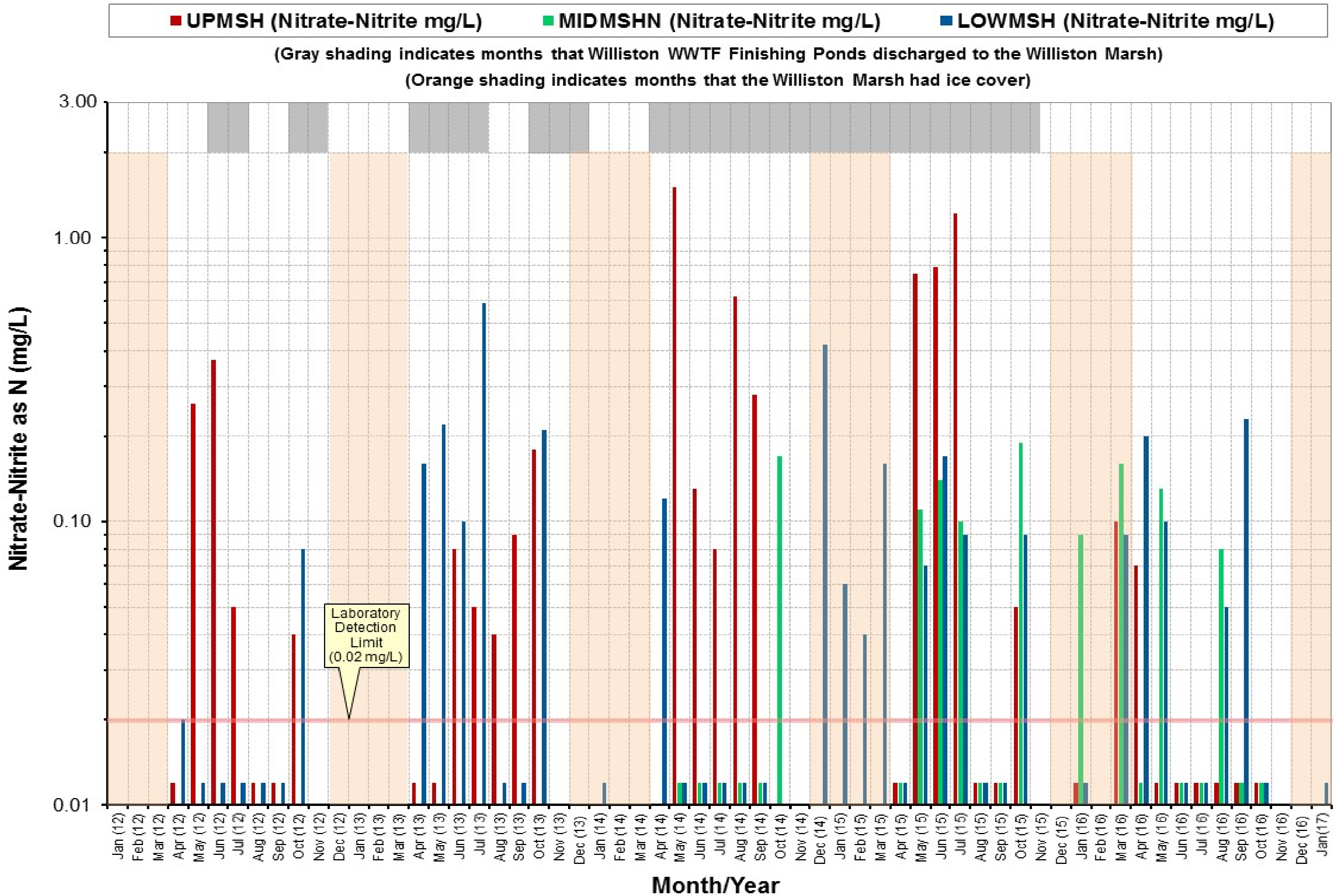

Figure 2-7. Nitrate-Nitrite concentrations (mg/L as N) monitored in the Williston Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017.

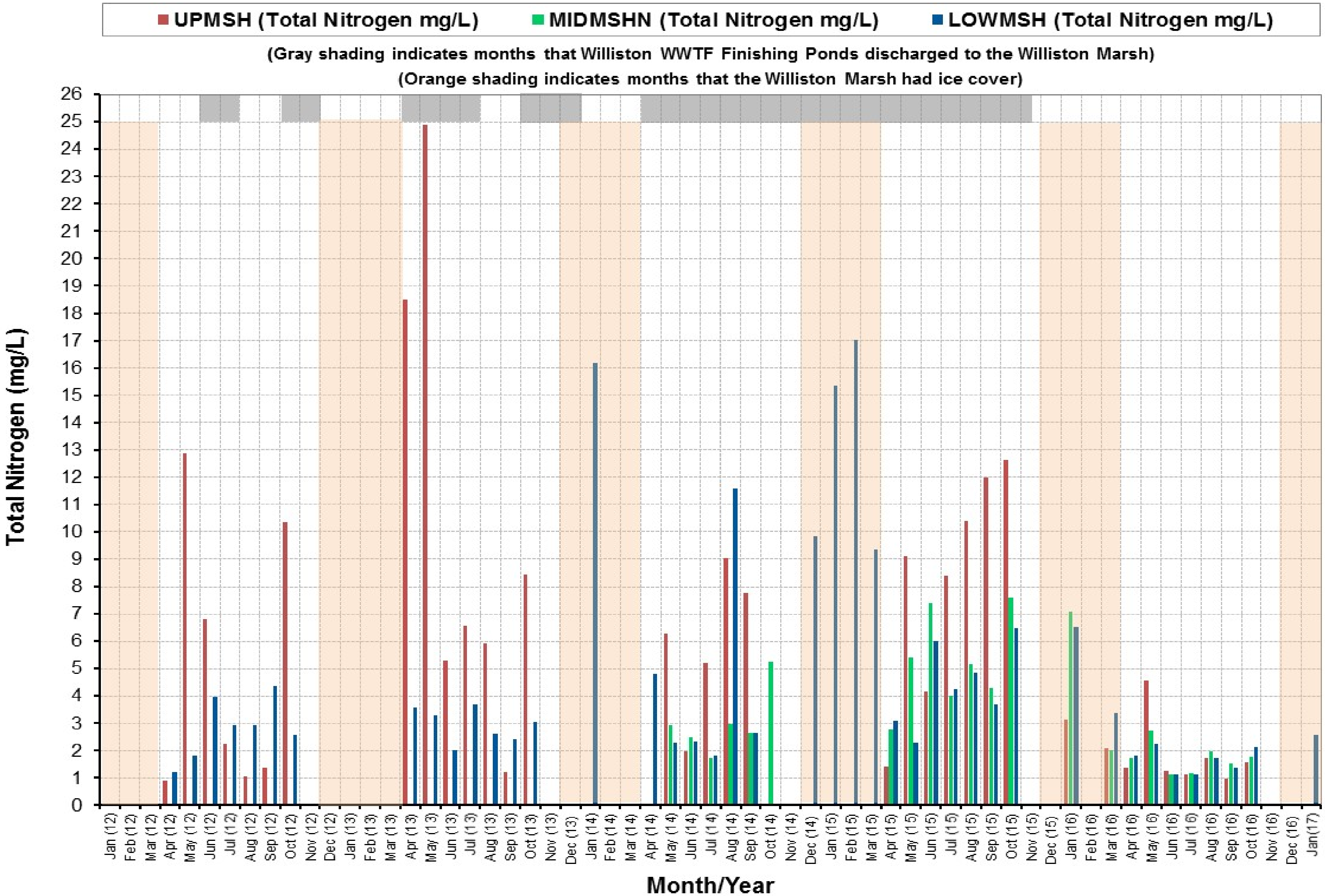

Figure 2-8. Total Nitrogen (mg/L) monitored in the Williston Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017.

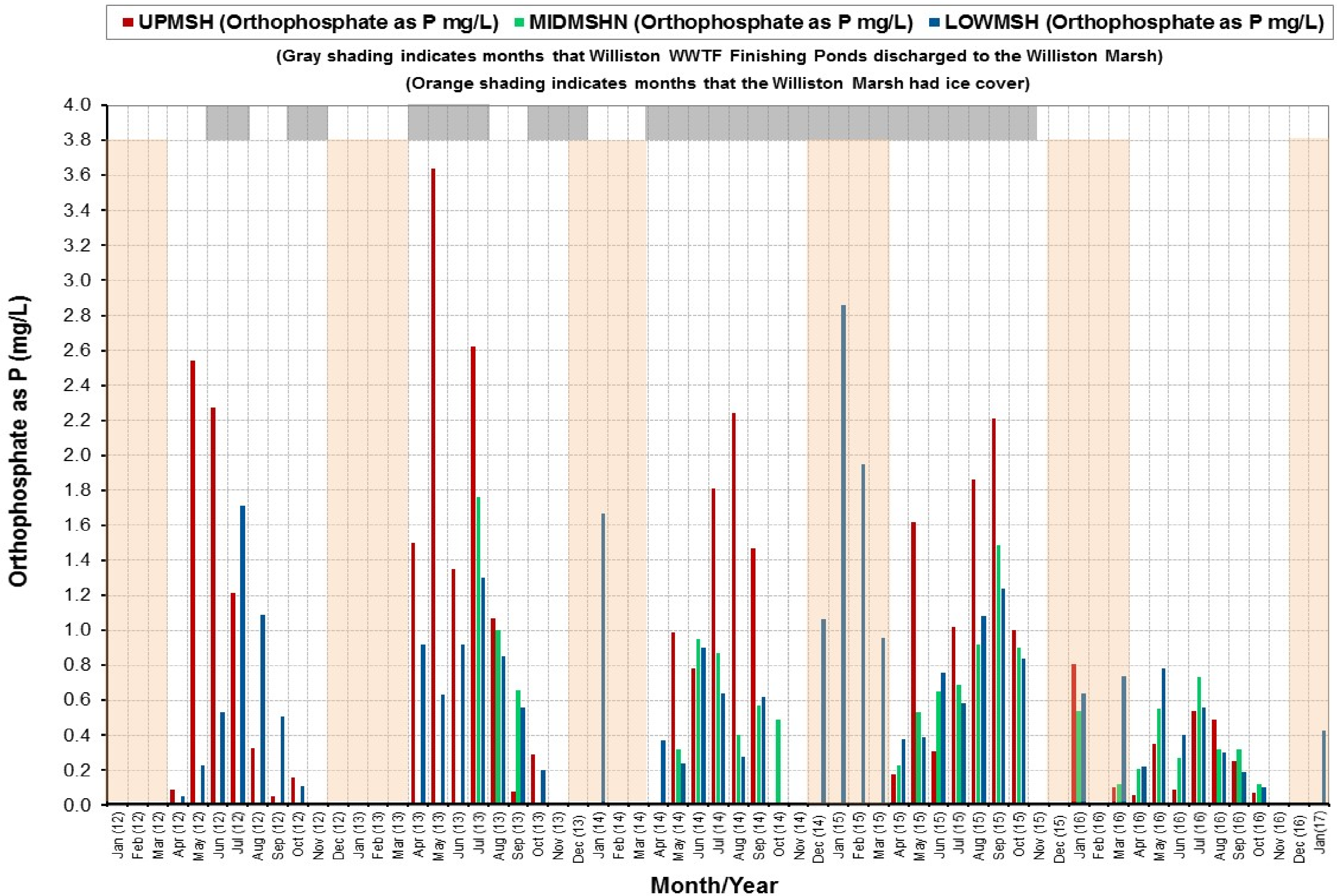

Figure 2-9. Orthophosphate (mg/L as P) monitored in the Williston Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017.

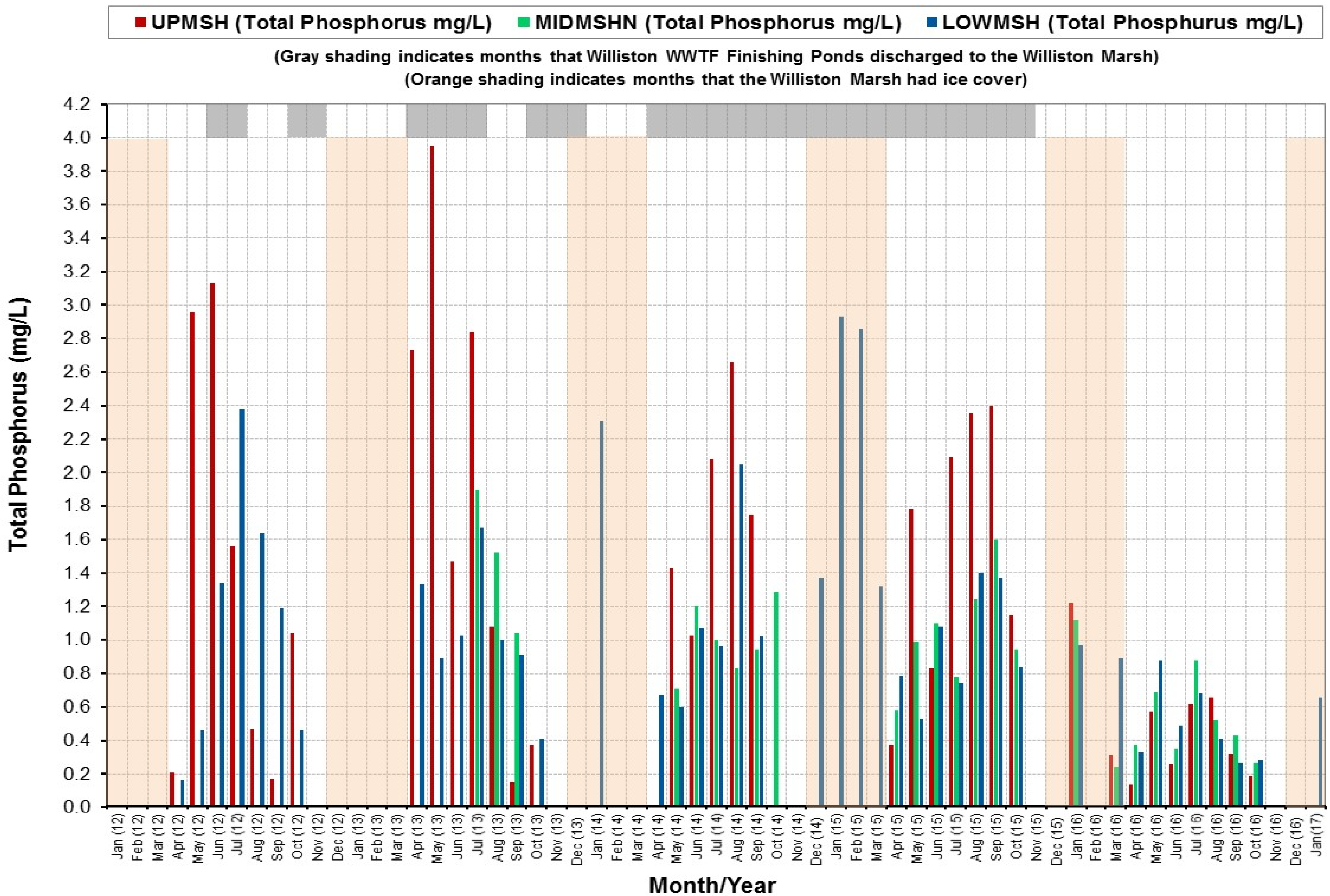

Figure 2-10. Total Phosphorus (mg/L) monitored in the Williston Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017.

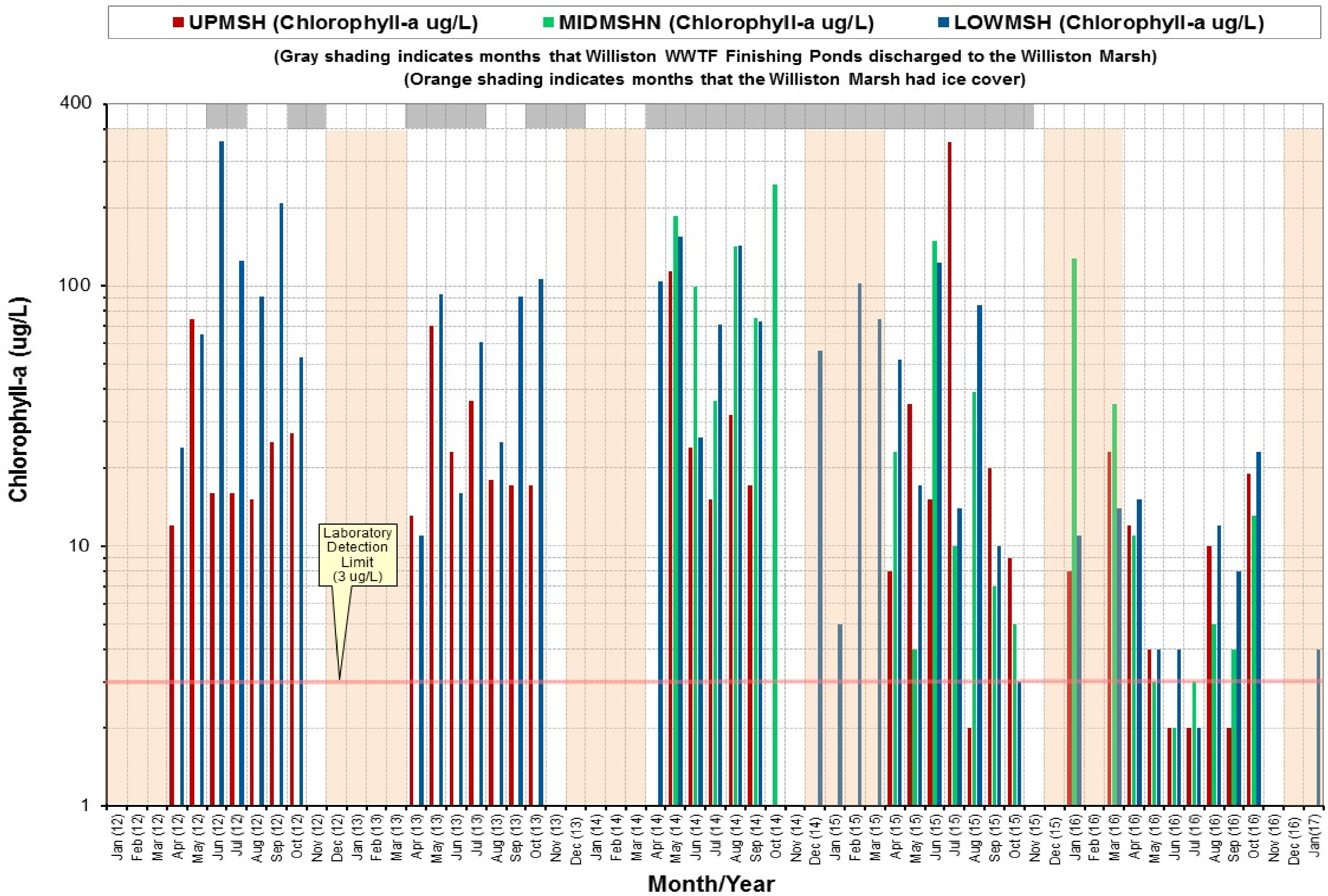

Figure 2-11. Phytoplankton Chlorophyll-a concentrations (ug/L) monitored in the Williston Marsh at sites UPMSH, MIDMSHN, and LOWMSH over the period April-2012 through January-2017.

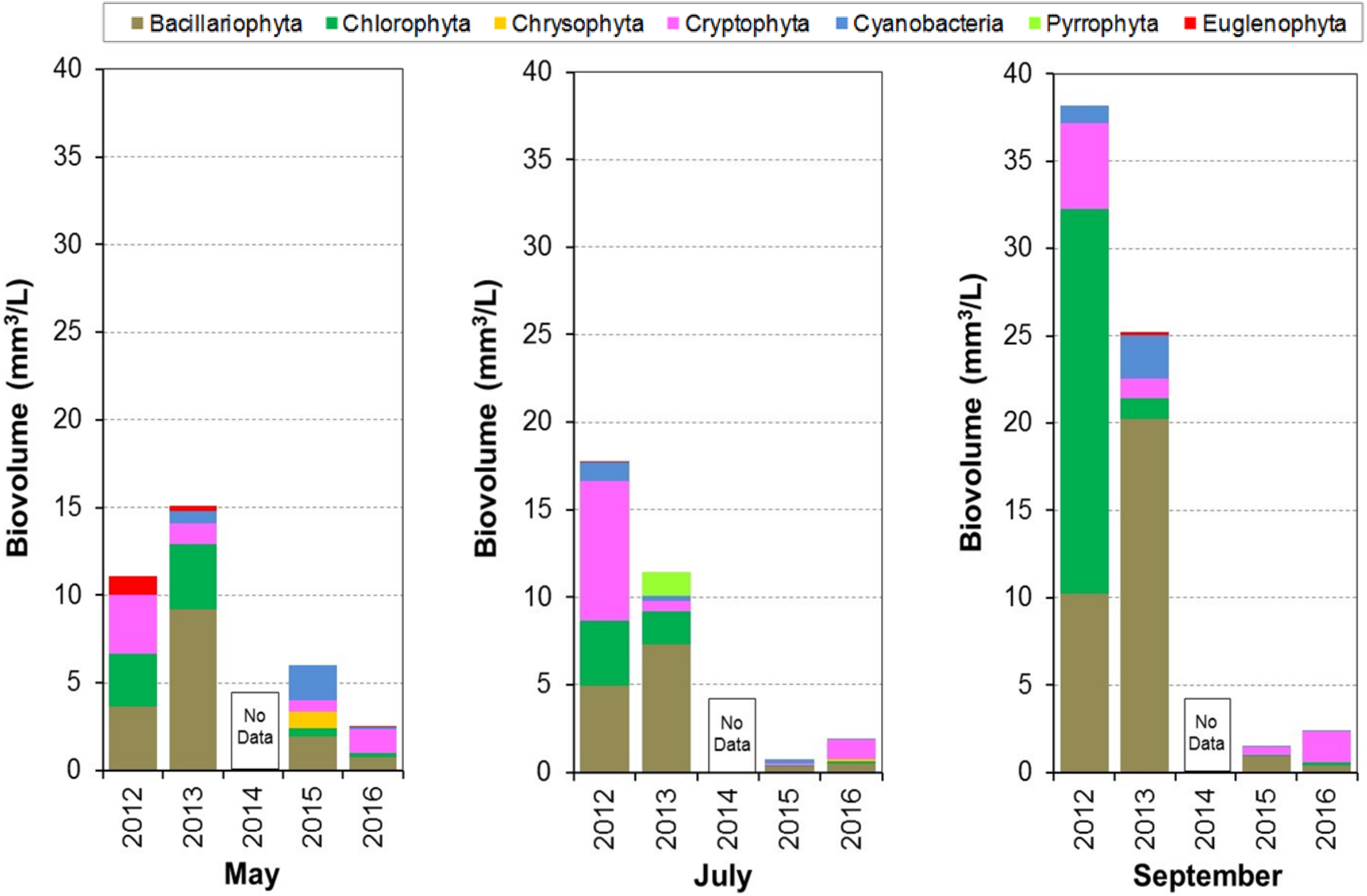

Figure 2-12. Relative abundance of phytoplankton in samples collected from the Williston Marsh at site LOWMSH in May, July, and September of 2012, 2013, 2015, and 2016.

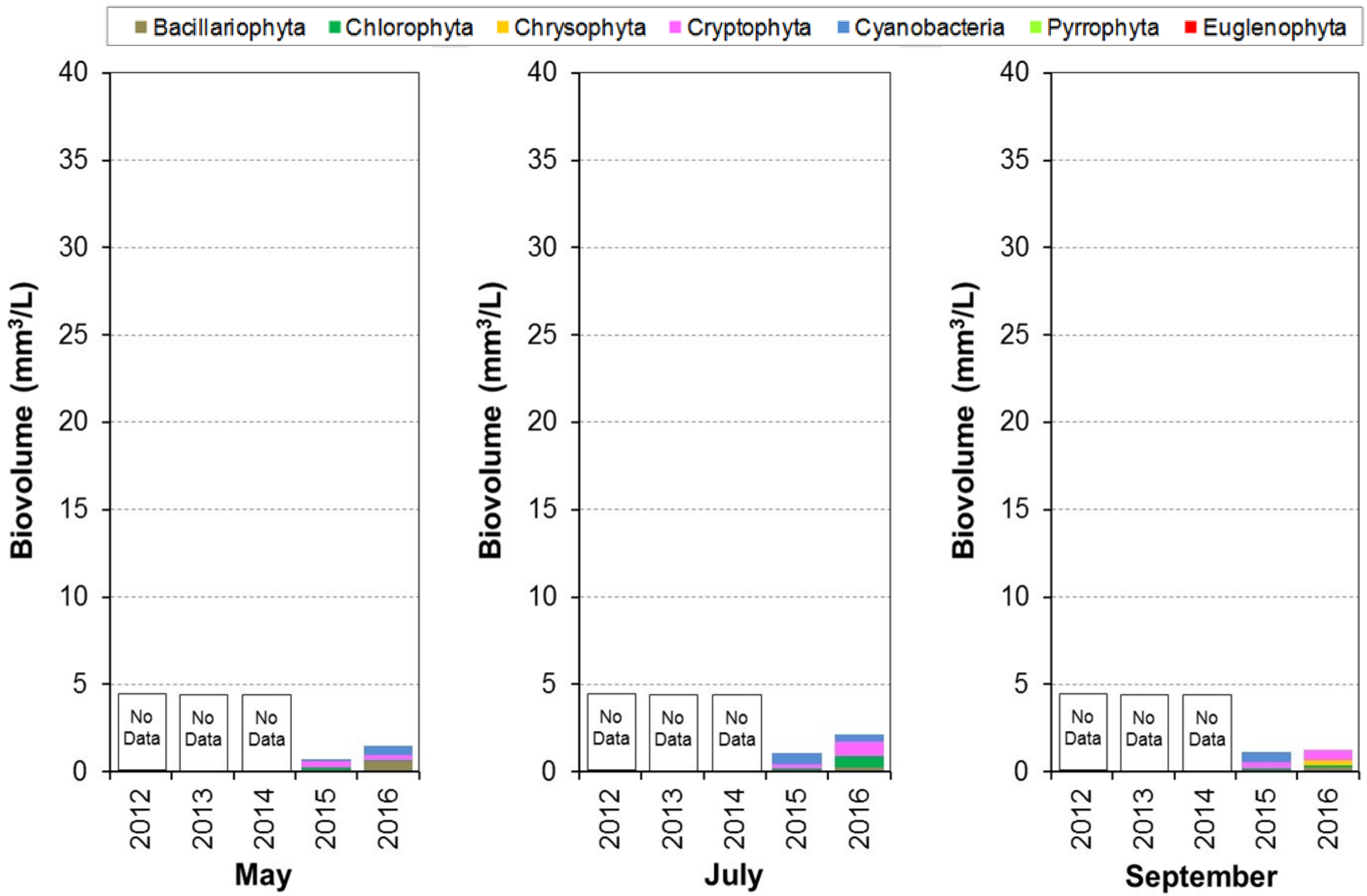

Figure 2-13. Relative abundance of phytoplankton in samples collected from the Williston Marsh at site MIDMSHN in May, July, and September of 2015, and 2016.

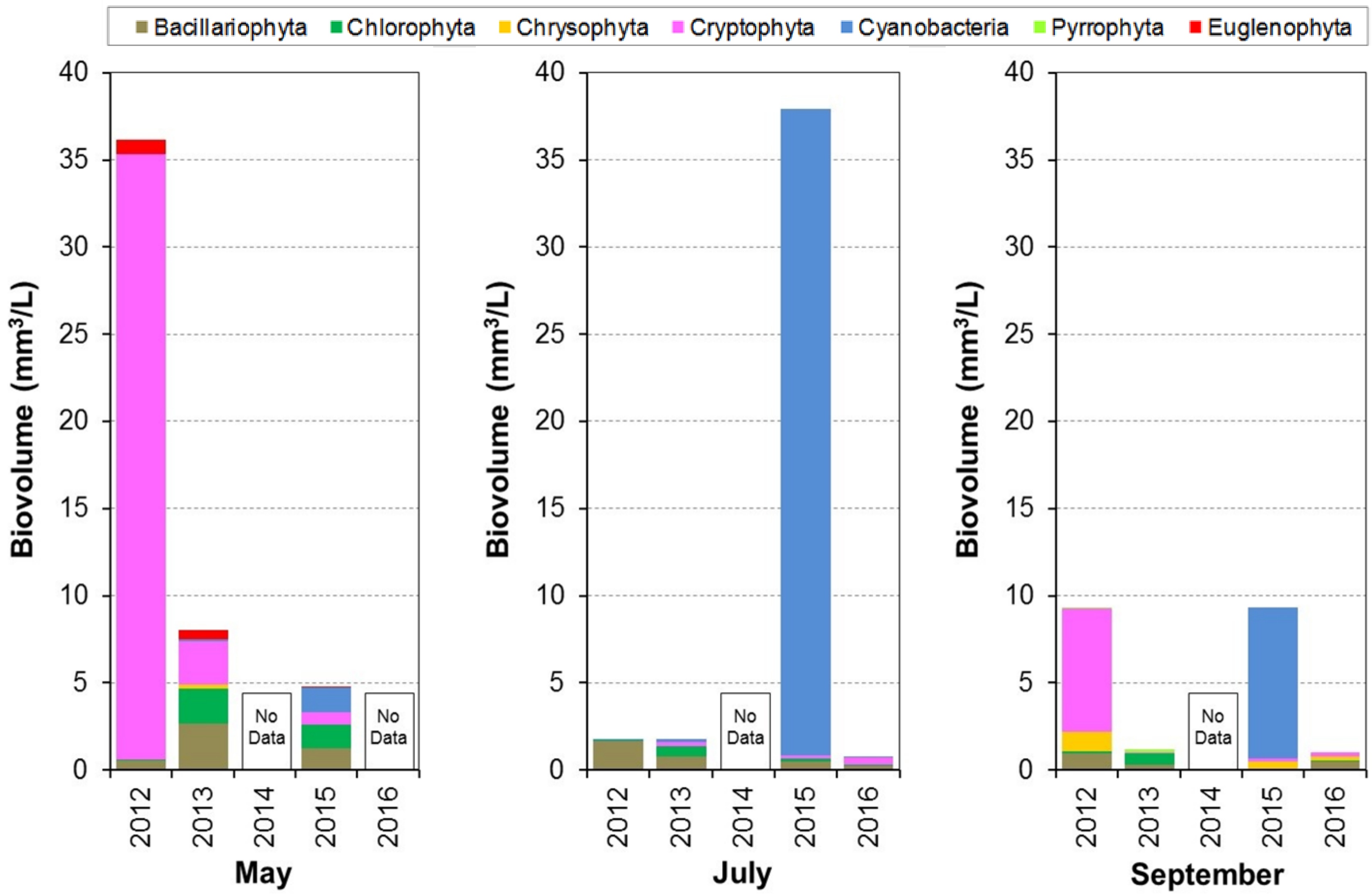

Figure 2-14. Relative abundance of phytoplankton in samples collected from the Williston Marsh at site UPMSH in May, July, and September of 2012, 2013, 2015, and 2016.

Plate 2-1. Summary of near-surface water quality conditions monitored in the Williston Marsh at monitoring site LOWMSH during the 5-year period April-2012 through March-2017.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Field Measurements:									
Dissolved Oxygen (mg/L)	0.1	44	8.2	9.2	0.0	19.0	5[1,3,6]	14	32%
Dissolved Oxygen (% Sat.)	0.1	43	85.3	82.8	0.0	196.3	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	44	309	323	-52	435	-----	-----	-----
pH (SU)	0.1	44	8.3	8.4	7.0	9.4	6[3,9], 7[1,3], 9[1,2,6]	0, 0, 3	0%, 0%, 7%
Specific Conductance (uS/cm)	1	44	1,628	1,607	822	2,531	-----	-----	-----
Temperature, Water (°C)	0.1	44	14.7	15.9	0.3	27.3	29.4[1,2,6]	0	0%
Turbidity (NTU)	1	44	18	10	2	140	-----	-----	-----
Laboratory Analyses – General Chemistry:									
Alkalinity, Total (mg/L)	1	42	467	463	246	709	-----	-----	-----
Carbon, Total Organic (mg/L)	0.3	42	14.7	14.5	9.2	20.5	-----	-----	-----
Chloride (mg/L)	0.5	35	44	40	25	88	100[1,5], 250[5,6]	0	0%
Chlorophyll *a* (ug/L)	3	41	62	52	n.d.	359	-----	-----	-----
Colorized Dissolved Organic Matter (ug/L)	10	42	141	129	77	240	-----	-----	-----
Dissolved Solids, Total (mg/L)	10	41	1,256	1,260	562	1,920	-----	-----	-----
Microcystin, Dissolved (ug/L)	0.1	28	-----	0.1	n.d.	1.7	-----	-----	-----
Microcystin, Total (ug/L)	0.1	8	-----	n.d.	n.d.	1.1			
Nitrogen, Ammonia Total (mg/L)	0.02	43	2.12	0.41	n.d.	15.10	See Footnote[4]	2, 12	5%, 28%
Nitrogen, Kjeldahl Total (mg/L)	0.08	42	4.4	2.9	1.1	17.0	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/L)	0.02	42	-----	n.d.	n.d.	0.59	1.0[1,2,7]	0	0%
Phosphorus, Dissolved (mg/L)	0.008	41	0.82	0.73	0.06	2.87	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.005	42	0.73	0.63	0.03	2.86	-----	-----	-----
Phosphorus, Total (mg/L)	0.008	42	1.07	0.94	0.16	2.93	-----	-----	-----
Sulfate (mg/L)	1	39	385	369	200	693	250[1,5], 750[5,6]	37	95%
Suspended Solids, Total (mg/L)	4	41	27	18	n.d.	230	-----	-----	-----

(A) Detection limits given for the parameters Dissolved Oxygen (mg/L and % Sat.), Oxidation-Reduction Potential, pH, Specific Conductance, Temperature, and Turbidity are resolution limits for field measured parameters. n.d. = not detected

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e. log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for Class 1 streams.

(2) Daily maximum criterion (monitoring results directly comparable to criterion).

(3) Daily minimum criterion (monitoring results directly comparable to criterion).

(4) North Dakota's criteria for ammonia are pH and temperature dependent. See Plate addendum for a separate assessment of water quality standards attainment.

(5) 30-day average criterion (monitoring results not directly comparable to criterion).

(6) Criteria for Class III streams.

(7) The standard for nitrates (N) is intended as an interim guideline limit and is subject to review by the NDDoH. In no case shall the concentration for nitrate plus nitrite N exceed 10 mg/L for any waters used as a municipal or domestic drinking water supply.

Plate 2-1 Addendum. Comparison of sampled ammonia conditions at site LOWMSH to calculated total ammonia (as N) criteria based on measured field conditions at sample collection.

Date	Time	Total Ammonia (as N, mg/L)	pH (SU)	Temperature (°C)	Ammonia Criteria (mg/L)		Criteria Exceedances	
					Acute	Chronic	Acute	Chronic
4/18/2012	12:00	0.04	8.4	9.1	3.88	1.20		
5/22/2012	13:50	0.03	8.6	18.9	2.65	0.63		
6/26/2012	11:40	0.02	9.0	22.9	1.32	0.25		
7/31/2012	13:10	0.03	8.7	27.3	2.20	0.33		
8/28/2012	12:40	0.04	8.7	24.7	2.20	0.38		
9/26/2012	9:30	0.02	8.4	14.4	3.88	1.21		
10/23/2012	11:30	0.13	8.2	6.7	5.73	1.71		
4/24/2013	8:30	2.75	7.1	3.8	32.86	5.65		
5/22/2013	11:10	1.27	8.4	14.1	3.88	1.23		X
6/25/2013	11:00	0.99	7.9	22.4	10.13	1.66		
7/25/2013	8:10	1.38	8.1	22.2	6.95	1.25		X
8/29/2013	8:15	0.06	8.6	23.7	2.65	0.48		
9/25/2013	8:10	<0.02	8.7	15.9	2.20	0.63		
10/29/2013	10:30	1.08	8.4	2.5	3.88	1.20		
1/16/2014	9:00	14.7	7.3	0.3	26.21	5.05		X
4/8/2014	12:00	2.11	8.0	5.9	8.41	2.36		
5/20/2014	16:00	<0.02	8.9	15.4	1.56	0.44		
6/24/2014	14:25	0.46	8.1	20.5	6.95	1.39		
7/29/2014	18:40	<0.02	8.4	25.5	3.88	0.62		
8/27/2014	11:40	0.11	8.6	16.8	2.65	0.72		
9/23/2014	16:30	0.04	8.5	18.5	3.20	0.78		
12/10/2014	9:20	6.94	8.3	1.5	4.71	1.44	X	X
1/27/2015	12:30	15.1	7.6	2.0	17.03	3.93		X
2/25/2015	10:50	12.8	7.2	0.9	29.54	5.36		X
3/24/2015	9:10	8.77	7.7	4.4	14.44	3.52		X
4/28/2015	16:30	0.15	9.1	15.1	0.76	0.31		
5/28/2015	10:10	0.16	8.4	19.7	2.59	0.87		
6/23/2015	17:20	1.99	8.6	24.9	1.77	0.45	X	X
7/21/2015	17:40	2.53	8.0	26.5	5.62	1.11		X
8/25/2015	19:00	0.43	8.8	19.7	1.23	0.42		X
9/22/2015	20:40	2.08	8.2	15.8	3.83	1.58		X
10/20/2015	10:50	5.00	7.9	10.8	6.77	2.73		X

Plate 2-1 Addendum. (Continued).

Date	Time	Total Ammonia (as N, mg/L)	pH (SU)	Temperature (°C)	Ammonia Criteria (mg/L)		Criteria Exceedances	
					Acute	Chronic	Acute	Chronic
1/26/2016	11:20	4.66	7.0	0.8	24.10	5.89		
3/1/2016	8:00	2.11	7.4	2.6	15.34	4.70		
4/26/2016	11:00	0.24	8.4	6.6	2.59	1.20		
5/24/2016	19:10	<0.02	8.5	20.9	2.14	0.68		
6/28/2016	14:50	0.05	8.7	25.1	1.47	0.37		
7/26/2016	16:20	<0.02	9.4	25.4	0.52	0.12		
8/23/2016	15:40	0.04	9.1	22.6	0.76	0.21		
9/27/2016	17:10	0.41	8.5	15.9	2.14	0.92		
10/27/2016	11:00	<0.02	8.9	9.1	1.04	0.46		
1/31/2016	9:10	1.48	7.9	0.8	6.77	2.73		
Total Number Of Water Quality Criteria Exceedances							**2**	**12**
Percent Exceedance Of Water Quality Criteria (No. of Observations = 43)							**5%**	**28%**

Plate 2-2. Summary of near-surface water quality conditions monitored in the Williston Marsh at monitoring site MIDMSHN during the 4-year period 2013 through 2017.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Field Measurements:									
Dissolved Oxygen (mg/L)	0.1	27	9.8	9.5	0.6	22.3	5(1,3,6)	5	19%
Dissolved Oxygen (% Sat.)	0.1	27	110.1	96.9	5.6	258.2	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	27	357	350	276	465	-----	-----	-----
pH (SU)	0.1	27	8.5	8.6	6.8	9.4	6(3,9), 7(1,3), 9(1,2,6)	0, 0, 5	0%, 0%, 19%
Specific Conductance (uS/cm)	1	27	1,653	1,645	1,343	2,149	-----	-----	-----
Temperature, Water (°C)	0.1	27	17.8	20.9	0.8	27.9	29.4(1,2,6)	0	0%
Turbidity (NTU)	1	27	12	10	n.d.	32	-----	-----	-----
Laboratory Analyses – General Chemistry:									
Alkalinity, Total (mg/L)	1	22	430	456	164	524	-----	-----	-----
Carbon, Total Organic (mg/L)	0.3	22	14.5	14.6	11.4	17.1	-----	-----	-----
Chloride (mg/L)	0.5	22	38	35	26	67	100(1,5), 250(5,6)	0	0%
Chlorophyll *a* (ug/L)	5	22	55	18	n.d.	244	-----	-----	-----
Colorized Dissolved Organic Matter (ug/L)	10	22	133	130	102	227	-----	-----	-----
Dissolved Solids, Total (mg/L)	10	21	1,173	1,150	612	1,620	-----	-----	-----
Microcystin, Dissolved (ug/L)	0.1	16	-----	0.1	n.d.	2.0	-----	-----	-----
Microcystin, Total (ug/L)	0.1	7	-----	n.d.	n.d.	0.6	-----	-----	-----
Nitrogen, Ammonia Total (mg/L)	0.02	26	-----	0.27	n.d.	5.70	See Footnote(4)	2, 6	8%, 23%
Nitrogen, Kjeldahl Total (mg/L)	0.08	22	3.4	2.7	1.1	7.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/L)	0.02	22	-----	n.d.	n.d.	0.19	1.0(1,2,7)	0	0%
Phosphorus, Dissolved (mg/L)	0.008	21	0.64	0.64	0.12	1.51	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.005	25	0.62	0.55	0.12	1.76	-----	-----	-----
Phosphorus, Total (mg/L)	0.008	25	0.90	0.89	0.24	1.90	-----	-----	-----
Sulfate (mg/L)	1	20	382	380	311	468	250(1,5), 750(5,6)	20, 0	100%, 0%
Suspended Solids, Total (mg/L)	4	22	25	24	n.d.	56	-----	-----	-----

(A) Detection limits given for the parameters Dissolved Oxygen (mg/L and % Sat.), Oxidation-Reduction Potential, pH, Specific Conductance, Temperature, and Turbidity are resolution limits for field measured parameters. n.d. = not detected

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e. log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for Class 1 streams.

(2) Daily maximum criterion (monitoring results directly comparable to criterion).

(3) Daily minimum criterion (monitoring results directly comparable to criterion).

(4) North Dakota's criteria for ammonia are pH and temperature dependent. See Plate addendum for a separate assessment of water quality standards attainment.

(5) 30-day average criterion (monitoring results not directly comparable to criterion).

(6) Criteria for Class III streams.

(7) The standard for nitrates (N) is intended as an interim guideline limit and is subject to review by the NDDoH. In no case shall the concentration for nitrate plus nitrite N exceed 10 mg/L for any waters used as a municipal or domestic drinking water supply.

Plate 2-2 Addendum. Comparison of sampled ammonia conditions at site MIDMSHN to calculated total ammonia (as N) criteria based on measured field conditions at sample collection.

Date	Time	Total Ammonia (as N, mg/L)	pH (SU)	Temperature (°C)	Ammonia Criteria (mg/L)		Criteria Exceedances	
					Acute	Chronic	Acute	Chronic
6/27/2013	10:50	0.99	8.0	22.7	5.62	1.41		
7/25/2013	10:40	3.72	7.9	21.7	6.77	1.73		X
8/29/2013	10:20	<0.02	8.6	25.0	1.77	0.44		
9/25/2013	9:00	<0.02	8.7	14.8	1.47	0.67		
5/20/2014	18:20	<0.02	9.0	15.7	1.30	0.35		
6/24/2014	16:25	0.38	8.1	21.0	6.69	1.30		
7/31/2014	9:40	0.32	8.4	22.5	3.88	0.74		
8/27/2014	13:50	0.04	9.0	20.9	1.32	0.27		
9/23/2014	17:20	<0.02	8.8	23.8	1.78	0.32		
10/21/2014	12:30	1.31	8.9	11.6	1.46	0.43		X
4/28/2015	19:50	<0.02	9.2	21.2	0.66	0.19		
5/28/2015	11:50	0.54	8.4	26.3	2.59	0.59		
6/23/2015	17:40	2.47	8.5	27.3	2.14	0.47	X	X
7/21/2015	20:00	2.78	8.2	20.6	3.83	1.17		X
8/25/2015	20:00	0.27	8.9	16.5	1.04	0.42		
9/22/2015	20:05	2.91	8.1	10.8	4.64	2.02		X
10/20/2015	12:30	5.7	8.0	0.8	5.62	2.36	X	X
1/26/2016	10:40	4.5	6.8	4.6	28.05	6.28		
3/1/2016	9:30	0.26	7.4	7.0	15.34	4.70		
4/26/2016	10:30	0.02	8.6	21.4	1.77	0.55		
5/24/2016	18:50	0.55	8.3	27.9	3.15	0.63		
6/28/2016	14:30	<0.02	9.0	25.7	0.88	0.22		
7/26/2016	16:00	<0.02	9.4	22.8	0.52	0.14		
8/23/2016	16:30	0.07	9.4	19.9	0.52	0.15		
9/27/2016	18:00	0.16	9.0	8.9	0.88	0.38		
10/27/2016	10:30	<0.02	8.9	21.2	1.04	0.32		
Total Number Of Water Quality Criteria Exceedances							**2**	**6**
Percent Exceedance Of Water Quality Criteria (No. of Observations = 26)							**8%**	**23%**

Plate 2-3. Summary of near-surface water quality conditions monitored in the Williston Marsh at monitoring site UPMSH during the 5-year period April-2012 through March-2017.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Field Measurements:									
Dissolved Oxygen (mg/L)	0.1	36	8.0	7.7	0.3	23.9	5[1,3,6]	13	36%
Dissolved Oxygen (% Sat.)	0.1	36	90.4	68.9	2.0	323.6	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	36	336	338	184	458	-----	-----	-----
pH (SU)	0.1	36	8.1	8.0	6.8	9.5	6[3,9], 7[1,3], 9[1,2,6]	0, 2, 3	0%, 6%, 8%
Specific Conductance (uS/cm)	1	36	1,500	1,499	990	2,180	-----	-----	-----
Temperature, Water (°C)	0.1	36	17.5	19.7	1.7	29.3	29.4[1,2,6]	0	0%
Turbidity (NTU)	1	36	15	5	n.d.	156	-----	-----	-----
Laboratory Analyses – General Chemistry:									
Alkalinity, Total (mg/L)	1	35	381	375	150	548	-----	-----	-----
Carbon, Total Organic (mg/L)	0.3	35	11.9	11.7	5.0	19.6	-----	-----	-----
Chloride (mg/L)	0.5	28	42	38	17	87	100[1,5], 250[5,6]	0	0%
Chlorophyll *a* (ug/L)	5	35	31	17	n.d.	356	-----	-----	-----
Colorized Dissolved Organic Matter (ug/L)	10	35	126	128	64	204	-----	-----	-----
Dissolved Solids, Total (mg/L)	10	34	1,084	1,065	644	1,720	-----	-----	-----
Microcystin, Dissolved (ug/L)	0.1	25	-----	n.d.	n.d.	0.2	-----	-----	-----
Microcystin, Total (ug/L)	0.1	7	-----	n.d.	n.d.	0.2	-----	-----	-----
Nitrogen, Ammonia Total (mg/L)	0.02	36	3.98	2.00	n.d.	24.90	See Footnote[4]		
Nitrogen, Kjeldahl Total (mg/L)	0.08	35	5.9	4.8	0.9	24.9	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/L)	0.02	35	-----	0.05	n.d.	1.51	1.0[1,2,7]	2	6%
Phosphorus, Dissolved (mg/L)	0.008	34	1.16	1.09	0.05	3.57	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.005	35	1.01	0.81	0.02	3.64	-----	-----	-----
Phosphorus, Total (mg/L)	0.008	35	1.34	1.15	0.14	3.95	-----	-----	-----
Sulfate (mg/L)	1	33	360	350	179	551	250[1,5], 750[5,6]	29	88%
Suspended Solids, Total (mg/L)	4	34	31	16	n.d.	161	-----	-----	-----

(A) Detection limits given for the parameters Dissolved Oxygen (mg/L and % Sat.), Oxidation-Reduction Potential, pH, Specific Conductance, Temperature, and Turbidity are resolution limits for field measured parameters. n.d. = not detected

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e. log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for Class 1 streams.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).
(4) North Dakota's criteria for ammonia are pH and temperature dependent. See Plate addendum for a separate assessment of water quality standards attainment.
(5) 30-day average criterion (monitoring results not directly comparable to criterion).
(6) Criteria for Class III streams.
(7) The standard for nitrates (N) is intended as an interim guideline limit and is subject to review by the NDDoH. In no case shall the concentration for nitrate plus nitrite N exceed 10 mg/L for any waters used as a municipal or domestic drinking water supply.

Plate 2-3 Addendum. Comparison of sampled ammonia conditions at site UPMSH to calculated total ammonia (as N) criteria based on measured field conditions at sample collection.

Date	Time	Total Ammonia (as N, mg/L)	pH (SU)	Temperature (°C)	Ammonia Criteria (mg/L)		Criteria Exceedances	
					Acute	Chronic	Acute	Chronic
4/18/2012	11:30	0.03	8.2	9.0	5.73	1.71		
5/22/2012	13:20	11.50	8.5	19.4	3.53	0.81	X	X
6/26/2012	12:50	4.71	7.7	25.6	13.48	1.67		X
7/31/2012	12:20	0.68	8.3	27.9	4.71	0.63		X
8/28/2012	12:00	0.02	8.4	23.4	3.96	0.71		
9/26/2012	9:05	<0.02	8.1	14.8	7.08	2.02		
10/23/2012	11:10	6.07	7.5	6.7	20.49	4.40		X
4/24/2013	9:30	16.80	6.9	3.8	38.56	6.06		X
5/22/2013	11:40	24.90	7.6	14.3	17.86	4.10	X	X
6/25/2013	11:30	4.44	7.9	24.2	9.58	1.42		X
7/25/2013	9:20	4.64	7.8	21.9	13.02	2.05		X
8/29/2013	9:20	1.90	7.9	23.8	9.76	1.48		X
9/25/2013	8:40	0.39	8.0	14.8	7.94	2.22		
10/29/2013	9:30	7.04	7.8	1.7	11.51	3.00		X
5/20/2014	5:20	2.42	8.2	14.7	6.07	1.78		X
6/24/2014	15:05	1.10	7.8	20.0	12.36	2.23		
7/29/2014	20:00	3.72	7.7	24.4	15.19	1.94		X
8/27/2014	13:15	5.72	7.9	20.7	11.10	1.97		X
9/23/2014	16:00	6.00	7.9	21.4	9.95	1.74		X
4/28/2015	17:35	0.10	8.1	15.4	4.64	1.91		
5/28/2015	9:30	5.84	8.5	18.4	2.14	0.79	X	X
6/23/2015	16:20	1.22	8.8	25.9	1.23	0.30		X
7/21/2015	19:00	0.99	8.7	27.7	1.47	0.35		X
8/25/2015	18:15	6.00	8.4	20.8	2.59	0.82	X	X
9/22/2015	18:40	9.49	7.8	16.1	8.11	2.82	X	X
10/20/2015	12:20	11.00	7.8	10.8	8.11	3.12	X	X

Plate 2-3 Addendum. (Continued).

Date	Time	Total Ammonia (as N, mg/L)	pH (SU)	Temperature (°C)	Ammonia Criteria (mg/L)		Criteria Exceedances	
					Acute	Chronic	Acute	Chronic
1/26/2016	9:50	2.09	6.8	1.9	28.05	6.28		
3/1/2016	9:10	0.38	7.4	4.6	15.34	4.70		
4/26/2016	10:00	0.03	8.4	6.1	2.59	1.20		
5/24/2016	18:30	1.30	7.9	21.1	6.77	1.80		
6/28/2016	15:10	0.03	9.2	29.3	0.66	0.14		
7/26/2016	16:40	<0.02	9.5	26.6	0.47	0.11		
8/23/2016	16:00	0.07	9.2	23.4	0.66	0.18		
9/27/2016	17:40	0.29	8.2	16.4	3.83	1.52		
10/27/2016	11:30	<0.02	8.5	10.2	2.14	1.00		
Total Number of Water Quality Criteria Exceedances							**6**	**20**
Percent Exceedance Of Water Quality Criteria (No. of Observations = 36)							**17%**	**56%**

Plate 2-4. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Williston Marsh at site LOWMSH during 2012, 2013, 2015, and 2016.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.
May 2012	11.09	12	0.33	13	0.27	1	<0.01	3	0.30	2	<0.01	0	-----	3	0.10
Jul 2012	17.70	5	0.28	13	0.21	1	<0.01	3	0.45	3	0.06	0	-----	1	<0.01
Sep 2012	38.20	10	0.27	12	0.58	0	-----	2	0.13	2	0.03	0	-----	0	-----
May 2013	15.08	14	0.61	13	0.25	0	-----	1	0.08	5	0.05	0	-----	1	0.02
Jul 2013	11.44	20	0.64	11	0.17	0	-----	1	0.05	4	0.03	1	0.12	0	-----
Sep 2013	25.20	15	0.80	10	0.05	0	-----	1	0.04	7	0.10	0	-----	2	0.01
May 2015	6.03	7	0.32	10	0.08	1	0.16	2	0.11	3	0.33	0	-----	0	-----
Jul 2015	0.77	12	0.46	4	0.04	0	-----	2	0.13	4	0.38	0	-----	0	-----
Sep 2015	1.45	7	0.65	5	0.05	0	-----	3	0.30	2	<0.01	0	-----	0	-----
May 2016	2.49	17	0.31	13	0.10	1	<0.01	3	0.54	5	0.05	0	-----	1	<0.01
Jul 2016	1.88	9	0.29	8	0.05	1	0.05	2	0.61	1	0.01	0	-----	0	-----
Sep 2016	2.38	6	0.16	8	0.08	0	-----	2	0.76	1	0.01	0	-----	0	-----
Mean*	**11.14**	**11.2**	**0.43**	**10.0**	**0.16**	**0.4**	**0.04**	**2.1**	**0.29**	**3.3**	**0.09**	**0.1**	**0.12**	**0.7**	**0.03**

Cyanobacteria the highest percentage of phytoplankton biomass.

* Mean percent composition represents the mean when taxa of that division are present.

Plate 2-5. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Williston Marsh at site MIDMSHN during 2015, and 2016.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.
May 2015	0.72	3	0.04	10	0.29	0	-----	2	0.48	4	0.19	0	-----	0	-----
Jul 2015	1.08	8	0.08	4	0.07	0	-----	2	0.24	4	0.61	0	-----	0	-----
Sep 2015	1.10	3	<0.01	2	0.19	0	-----	2	0.31	2	0.50	0	-----	0	-----
May 2016	1.49	13	0.40	5	0.06	0	-----	2	0.20	5	0.35	0	-----	0	-----
Jul 2016	2.11	5	0.12	4	0.30	0	-----	2	0.40	2	0.18	0	-----	0	-----
Sep 2016	1.23	5	0.21	8	0.09	1	0.22	2	0.48	0	-----	0	-----	0	-----
Mean*	**1.29**	**6.2**	**0.14**	**5.5**	**0.17**	**0.2**	**0.22**	**2.0**	**0.35**	**2.8**	**0.37**	**0**	**-----**	**0**	**-----**

Cyanobacteria the highest percentage of phytoplankton biomass.

* Mean percent composition represents the mean when taxa of that division are present.

Plate 2-6. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Williston Marsh at site UPMSH during 2012, 2013, 2015, and 2016.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.
May 2012	36.15	11	0.01	5	<0.01	0	-----	5	0.96	2	<0.01	0	-----	1	0.02
Jul 2012	1.78	6	0.95	3	0.02	0	-----	2	0.01	1	0.02	0	-----	0	-----
Sep 2012	9.29	11	0.11	2	0.01	2	0.12	3	0.76	0	-----	1	<0.01	0	-----
May 2013	8.05	12	0.33	12	0.25	1	0.03	2	0.31	3	0.01	0	-----	2	0.07
Jul 2013	1.76	12	0.43	8	0.34	0	-----	1	0.14	3	0.08	0	-----	0	-----
Sep 2013	1.20	11	0.28	5	0.50	1	0.01	1	0.04	0	-----	1	0.17	0	-----
May 2015	4.72	5	0.26	5	0.29	0	-----	2	0.15	2	0.29	0	-----	1	<0.01
Jul 2015	37.93	6	0.01	5	<0.01	0	-----	2	0.01	1	0.98	0	-----	0	-----
Sep 2015	9.33	0	<0.01	4	0.01	1	0.04	2	0.02	1	0.93	0	-----	0	-----
May 2016	No Sample	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Jul 2016	0.75	7	0.35	3	0.09	0	-----	2	0.49	3	0.07	0	-----	0	-----
Sep 2016	1.01	9	0.45	3	0.08	2	0.25	2	0.22	0	-----	0	-----	0	-----
Mean*	**10.18**	**8.2**	**0.29**	**5.0**	**0.18**	**0.6**	**0.09**	**2.2**	**0.28**	**1.5**	**0.30**	**0.2**	**0.09**	**0.4**	**0.03**

Cyanobacteria the highest percentage of phytoplankton biomass.

* Mean percent composition represents the mean when taxa of that division are present.

Plate 2-7. Taxa listing of phytoplankton species identified from samples collected at the Williston Marsh during 2012, 2013, 2015, and 2016.

Division	Genus/Species	Genus/Species
Bacillariophyta	*Achnanthidium helveticum*	*Navicula capitatoradiata*
	Achnanthidium minutissimum	*Navicula cryptocephala*
	Amphora copulata	*Navicula cryptotenella*
	Asterionella formosa	*Navicula gregaria*
	Aulacoseira ambigua	*Navicula lanceolata*
	Aulacoseira granulata	*Navicula phyllepta*
	Cocconeis placentula	*Navicula subminuscula*
	Craticula acidoclinata	*Nitzschia acicularis*
	Craticula ambigua	*Nitzschia amphibia*
	Cyclotella meneghiniana	*Nitzschia constricta*
	Cyclotella ocellata	*Nitzschia draveillensis*
	Cymbella obscura	*Nitzschia fruticosa*
	Diatoma elongatum var. Tenuis	*Nitzschia inconspicua*
	Diatoma vulgare	*Nitzschia linearis*
	Diploneis spp.	*Nitzschia palea*
	Encyonema minutum	*Nitzschia perminuta*
	Eunotia spp.	*Nitzschia reversa*
	Fragilaria brevistriata	*Planothidium minutissimum*
	Fragilaria capucina	*Rhoicosphenia abbreviata*
	Fragilaria crotonensis	*Rhoicosphenia curvata*
	Gomphoneis eriense	*Sellaphora laevissima*
	Gomphoneis olivacea	*Staurosirella pinnata*
	Gomphonema acuminatum	*Stephanocyclus meneghiniana*
	Gomphonema angustatum	*Stephanodiscus hantzschii*
	Gomphonema gracile	*Stephanodiscus parvus*
	Gomphonema parvulum	*Synedra delicatissima*
	Gomphonema truncatum	*Synedra tenera*
	Gyrosigma spp.	*Synedra ulna*
	Hippodonta hungarica	*Tabellaria flocculosa*
	Lindavia ocellata	*Tryblionella hungarica*
	Melosira varians	*Ulnaria ulna*
Cyanobacteria	*Anabaena flos-aquae*	*Limnothrix redekei*
	Anabaena planctonica	*Microcystis aeruginosa*
	Anabaena spiroides	*Oscillatoria tenuis*
	Anabaenopsis circularis	*Phormidium spp.*
	Aphanizomenon flosaquae	*Planktolyngbya limnetica*
	Aphanocapsa spp.	*Planktothrix spp.*
	Chroococcus microscopicus	*Pseudanabaena limnetica*
	Dolichospermum spp.	*Raphidiopsis cuvata*
	Leptolyngbya spp.	*Raphidiopsis mediterranea*
Euglenophyta	*Euglena spp.*	*Phacus spp.*
	Lepocinclis spp.	*Trachelomonas spp.*
Pyrrophyta	*Glenodinium palustre*	*Gymnodinium palustre*
	Gymnodinium discoidale	

Plate 2-7. (Continued).

Division	Genus/Species	Genus/Species
Chlorophyta	*Actinastrum hantzschii*	*Monoraphidium arcuatum*
	Ankistrodesmus falcatus	*Monoraphidium convolutum*
	Ankyra	*Monoraphidium mirabile*
	Characium ambiguum	*Monoraphidium tortile*
	Chlamydomonas	*Mougeotia spp.*
	Chlamydomonas globosa	*Oocystis parva*
	Chlamydomonas grovei	*Pandorina morum*
	Chlorella minutissima	*Pediastrum duplex*
	Closteriopsis acicularis	*Pyramimonas tetrarhynchus*
	Coelastrum astroideum	*Scenedesmus acuminatus*
	Coelastrum microporum	*Scenedesmus bernardii*
	Coelastrum sphaericum	*Scenedesmus bijuga*
	Cosmarium spp.	*Scenedesmus dimorphus*
	Crucigenia quadrata	*Scenedesmus quadricauda*
	Crucigenia tetrapedia	*Selenastrum bibraianum var. Gracile*
	Dictyosphaerium chlorelloides	*Sphaerocystis schroeteri*
	Dictyosphaerium pulchellum	*Tetraedron incus*
	Kirchneriella contorta	*Tetraedron minimum*
	Kirchneriella lunaris	*Tetrastrum glabrum*
	Kirchneriella obesa	*Ulothrix spp.*
	Korshikoviella michailovskoensis	*Westella botryoides*
Chrysophyta	*Dibobryon spp.*	*Synura sp.*
	Mallomonas sp.	
Cryptophyta	*Chroomonas sp.*	*Cryptomonas ovata*
	Cryptomonas curvata	*Cryptomonas platyuris*
	Cryptomonas erosa	*Rhodomonas spp.*
	Cryptomonas marssonii	

3 DISCUSSION – WILLISTON MARSH WATER QUALITY

3.1 WATER QUALITY CONDITIONS

3.1.1 Dissolved Oxygen

The extreme variation in monitored DO in the Marsh during non-ice-covered periods is attributed to the prolific aquatic vegetation that was present in the Marsh during the growing season. The hypoxic/anoxic DO levels monitored under ice-cover conditions is attributed to the decomposition of the abundant residual organic matter that resulted from the winter dry-back of aquatic vegetation. The nutrient-laden effluent discharge from the WWTF's Finishing Ponds to the Marsh during 2012 through 2015 led to a prolific growth of aquatic vegetation, especially watermilfoil. This influenced DO levels during the growing season through photosynthesis and aerobic respiration, and during the winter through decomposition of accumulated dead vegetative matter (watermilfoil) under ice-cover. With the cessation of the WWTF effluent discharges to the Marsh in November-2015, minimum DO levels seemingly improved in the Marsh in latter 2016 and January 2017 (Figure 2-1). In 2016 there also seemingly appears to be an increase in DO saturation levels throughout the year, and super-saturated DO conditions during the growing season (Figure 2-2). The super-saturated DO conditions monitored in 2016 seem to indicate that extensive photosynthetic activity likely occurred.

3.1.2 Oxidation Reduction Potential (ORP)

ORP measures an aqueous system's capacity to either release or accept electrons from chemical reactions. An ORP probe contains a sensor that measures electrical charges from ions and these charges are converted to millivolts (mV) that can be either negatively or positively charged (YSI, 2008). On the ORP scale the presence of an oxidizing agent such as oxygen increases the ORP value while the presence of a reducing agent decreases the value. ORP is a measurement of the ability or potential of aqueous systems to permit the occurrence of specific biological (oxidation-reduction) reactions (Gerardi, 2007). Important oxidation-reduction reactions in a wastewater setting (i.e. high nutrients and organic matter) include: nitrification, dentrification, biological phosphorus removal, biological malodor production, and the breakdown of carbon- and hydrogen- containing compounds (Gerardi, 2007). These reactions involve carbon (C), phosphorus (P), sulfur (S), and nitrogen (N) and their change from oxidized states (containing oxygen) such as nitrate (NO_3^-) and sulfate (SO_4^{-2}) to reduced states (containing hydrogen) such as ammonia (NH_3) and sulfides (H_2S) (Gerardi, 2007). Biological malodor production occurs through two major biochemical reactions, sulfide formation and acid formation (fermentation). Hydrogen sulfide (H_2S) is produced in large quantity when sulfate-reducing bacteria degrade organic matter using sulfate (SO_4^{-2}). H_2S is very toxic to aquatic life (USEPA, 1976). Biochemical reactions and corresponding ORP values are shown below (YSI, 2008):

Biochemical Reaction	ORP, mV
Nitrification	+100 to +350
cBOD degradation with free molecular oxygen	+50 to +250
Biological phosphorus removal	+25 to +250
Denitrification	+50 to -50
Sulfide (H_2S) formation	-50 to -250
Biological phosphorus release	-100 to -250
Acid formation (fermentation)	-100 to -225
Methane production	-175 to -400

The -51 mV ORP value measured in the Marsh during January-2015 corresponded with the significant malodorous conditions (i.e. rotten egg smell) that occurred at that time. The situation attests to the degraded water quality that was present in the Marsh during January-2015. The conditions were a result of the worst-case scenario of ongoing WWTF effluent discharge to the Marsh and decomposition of accumulated residual vegetative matter under ice cover. With the cessation of WWTF effluent discharges to the Marsh in November-2015, ORP values measured in the Marsh under ice cover during 2016 and 2017 were above 100 mV.

3.1.3 pH

Factors that are believed to have influenced the pH levels monitored in the Marsh are: 1) CO_2 uptake by plants during daytime photosynthesis (leads to higher pH), 2) CO_2 release during nighttime aerobic respiration (leads to lower pH), 3) CO_2 release via decay of dead vegetative matter under winter ice-cover (leads to lower pH), 4) discharge of lower pH water from the WWTF's Finishing Ponds (leads to lower pH in the vicinity of the discharge), and 5) the buffering capacity of the water present in the Marsh (higher buffering capacities attenuates the magnitude of pH changes due to CO_2 additions).

The nutrient-laden effluent discharge from the WWTF's Finishing Ponds to the Marsh during 2012 through 2015 led to a prolific growth of aquatic vegetation, especially watermilfoil. This influenced pH levels during the growing season through the uptake and release of CO_2 during photosynthesis and aerobic respiration, and during the winter through decomposition of accumulated dead vegetative matter under ice-cover. The higher pH levels measured in 2016 seemingly indicate elevated photosynthetic activity occurred during the growing season of 2016.

3.1.4 Ammonia

Ammonia levels monitored in the Marsh during the period April-2012 through January-2017 exhibited appreciable seasonal and spatial variation. Factors believed to have influenced the levels of ammonia monitored in the Marsh are: 1) ammonia discharged to the Marsh by the WWTF's Finishing Ponds, 2) uptake of ammonia by aquatic vegetation (i.e. watermilfoil) during the growing season, 3) nitrification of ammonia to nitrate nitrogen under aerobic conditions in the Marsh, and 4) ammonification of organic-nitrogen in accreted dead vegetative matter. The WWTF's Finishing Pond discharges to the Marsh during the period 2012 through 2015 had average monthly total ammonia-nitrogen concentrations of 10-35 mg/L (Table 1-3).

Figure 3-1 plots the ammonia concentrations of the effluent discharged to the Marsh and the ammonia concentrations sampled in the Marsh at sites UPMSH and LOWMSH. The plotted monthly ammonia concentrations for the WWTF effluent discharges are the DMR reported 30-day averages (Table 1-3). Ammonia concentrations plotted for the monitoring sites are the monthly grab-sample results (Figure 2-6). During the growing season when effluent discharges occurred, the ammonia concentrations in the upper end of the Marsh (site UPMSH) were usually appreciably higher than the ammonia concentrations at the lower end of the Marsh (site LOWMSH) (Figure 3-1). When effluent discharges occurred during the non-growing season ice-covered period, higher ammonia concentrations were present throughout the Marsh (sites UPMSH and LOWMSH) (Figure 3-1). Numerous exceedances of the ammonia water quality standards criteria were monitored in the Marsh during the period 2012 through 2015 when the WWTF discharged effluent to the Marsh (Plate 2-1, Plate 2-2, and Plate 2-3). With the cessation of the WWTF effluent discharges to the Marsh in November-2015, ammonia levels monitored in the Marsh appreciably declined (Figure 3-1). No exceedances of the ammonia water quality standards criteria were monitored in the Marsh after November 2015 (Plate 2-1, Plate 2-2, and Plate 2-3).

During the period 2012 through 2015 when WWTF effluent discharges were occurring to the Marsh, the seasonal and spatial variation in monitored ammonia levels was seemingly associated with the growing season and the presence of dense watermilfoil growth. During the growing season the ammonia loading from the effluent discharges was seemingly assimilated by watermilfoil as the discharged ammonia flowed through the Marsh. This resulted in higher ammonia levels in the upper reaches of the Marsh near the discharge (site UPMSH), and reduced levels of ammonia in the lower reaches of the Marsh near the Pumping Plant intake (site LOWMSH). During the winter ice-covered period high ammonia levels were present throughout the Marsh as limited watermilfoil growth was occurring in the Marsh to attenuate the ammonia loading from the discharged effluent. This is exemplified by the water quality monitoring data collected at site LOWMSH where the "winter" levels of ammonia are much higher than the growing season levels during the period effluent discharges occurred.

3.1.5 <u>Nitrate-Nitrite</u>

The low nitrate-nitrite levels monitored in the Marsh are likely due to the following: 1) the low levels of nitrate-nitrite in the effluent discharge; 2) during the growing season ammonia was likely being directly utilized as a nitrogen source for plant (watermilfoil) growth, thus reducing its availability for nitrification; and 3) the lower DO levels present in the Marsh when the WWTF's Finishing Ponds were discharging likely limited the oxidation and nitrification process of converting ammonia to nitrate-nitrite.

3.1.6 <u>Orthophosphate</u>

The lower orthophosphate levels monitored in 2016 and 2017 are mainly attributed to the cessation of the effluent discharges to the Marsh. Also, it is hypothesized that any increased internal loading of orthophosphate from accumulated vegetative organic matter on the bottom of the Marsh was likely immediately utilized by ongoing phytoplankton growth during the growing season.

3.2 OCCURRENCE OF NUISANCE AQUATIC VEGETATION

The effluent discharges from the WWTF's Finishing Ponds during the period 2012 through 2015 greatly increased the nutrient loading to the Marsh. The increased availability of nutrients (i.e. nitrogen and phosphorus) led to excessive vegetative growth in the Marsh. Excessive growth of submerged macrophytes, especially watermilfoil, occurred and was attributed to the increase in the ammonia loadings from the effluent discharges. The excessive growth of watermilfoil in the Marsh during 2012 through 2015 required extensive efforts by the Corps to remove the vegetation from the intake channel to the Pumping Plant in order to maintain the flowage required for project water management. Antidotal observations indicated that the watermilfoil density in the Marsh appreciably decreased in 2016 (Jeff Keller – Williston Field Office, personal communication, March 14, 2017). This is believed a reflection of the cessation of effluent discharges from the Finishing Ponds to the Marsh in November 2015, and the concurrent reduction of ammonia loading to the Marsh. Although harmful algal blooms (HABs) were not an ongoing occurrence in the Marsh during the period of effluent discharge, a significant cyanobacteria bloom (i.e. *Aphanizomenon flos-aquae*) occurred in the Marsh during 2015 (Figure 2-14, Plate 2-4, Plate 2-5, and Plate 2-6).

3.2.1 <u>Watermilfoil</u>

The watermilfoil present in the Marsh is believed to be the native Northern watermilfoil (*Myriophyllum exalbescens*) and not the invasive Eurasian watermilfoil (*Myriophyllum spicatum*). The Northern and Eurasian watermilfoils are similar in appearance and have been known to hybridize (MCIAP, 2007). Hundreds of millions of dollars have been spent to control the invasive Eurasian watermilfoil and its biology has been extensively studied (CLEANFLO, 2010 and Smith and Barko, 1990). The findings of these studies are inferred to also apply to the biology of the Northern watermilfoil.

Watermilfoil prefers nutrient-rich, lentic waters where it can form thick underwater stands of tangled stems and vast mats of vegetation at the water's surface (MDNR, 2015 and CLEANFLO, 2010). Stagnant, oxygen-depleted conditions are often found in association with dense beds of watermilfoil. The dense mats of vegetation can inhibit wind mixing at the surface and the aeration of subsurface waters. Widespread, dense growth of watermilfoil can also dielly impact dissolved oxygen levels in a water body. Dissolved oxygen super-saturation conditions can occur during the day due to oxygen production from watermilfoil photosynthesis, and hypoxic conditions can develop during the night from the uptake of oxygen through watermilfoil aerobic respiration. The same daily photosynthesis and respiration cycle can significantly affect pH levels in a water body through the uptake and production of CO_2 by watermilfoil.

The two primary nutrients needed for growth of watermilfoil are phosphorus (P) and nitrogen (N). It is generally agreed that the uptake of P from the sediment by roots constitutes the primary mode of uptake for Eurasian watermilfoil in the majority of aquatic systems (Smith and Barko, 1990). Fine-textured lake sediments contain large pools of available P; thus, in most lakes it's unlikely that the availability of P would often limit the growth of Eurasian watermilfoil (Smith and Barko, 1990). Unlike P, the availability of N may under some circumstances limit the growth of Eurasian watermilfoil (Smith and Barko, 1990). Nitrogen can be absorbed by Eurasian watermilfoil either as ammonium from the sediment or as ammonium and nitrate from the overlying water (Nichols and Keeney, 1976). Ammonium is preferred over nitrate by Eurasian watermilfoil (Nichols and Keeney, 1976). *In situ* fertilization of sediment by the addition of ammonium-N has been demonstrated to significantly increase the growth of Eurasian watermilfoil (Anderson and Klaff, 1986). To manage a watermilfoil infestation it has been found that the continual oxidation of littoral sediments and overlying waters negatively impacts the health and growth of watermilfoil by limiting ammonia-N availability (SolarBee, 2010). The concentration of ammonium in sediments is usually much greater than in the overlying water in most aquatic systems. However, this was not the case in the Marsh during the period large amounts of ammonia were discharged directly to the Marsh in the effluent from the WWTF's Finishing Ponds.

The excessive growth of watermilfoil in the Marsh during 2012 through 2015 is attributed to the excessive ammonia loadings delivered to the Marsh from the WWTF's Finishing Pond effluent discharges. Watermilfoil needs high levels of ammonia to thrive and it can utilize ammonia from the water column as well as from the sediment. It is estimated from the submitted DMRs for the WWTF that 521,660 pounds (260.83 tons) of ammonia were discharged to the Marsh during the period January 2012 through November 2015. The majority of the ammonia loading occurred during growing season months (Table 1-3). Removing the ammonia loading that occurred in the non-growing season months, November through March, leaves an estimated growing season ammonia loading of 338,370 pounds (169.18 tons). Using plant stoichiometry, the mass of watermilfoil that theoretically could have resulted from the ammonia discharged from the WWTF during the growing season can be estimated. The mass ratios of carbon to nitrogen to phosphorus for plant material is 1272 : 224 : 31, and plant protoplasm is about 1% phosphorus on a dry-weight basis (Chapra, 1997). Thus a gram dry weight of plant organic matter contains approximately 10 mg of phosphorus, 72 mg of nitrogen, and 400 mg of carbon (Chapra, 1997). The wet-weight biomass of aquatic vegetation is about 90% water (Chapra, 1997). Converting 169.18 tons of ammonia-N to plant material gives an estimated 23,498 tons wet weight of watermilfoil that resulted from the ammonia discharged to the Marsh during the growing season.

3.2.2 <u>Cyanobacteria and Cyanotoxins</u>

Cyanobacteria, also referred to as blue-green algae, are frequently found in freshwater systems. Similar to green algae, cyanobacteria can produce nuisance growth, odor problems, and oxygen depletion;

however, cyanobacteria are unique in their ability to produce powerful cyanotoxins. Cyanotoxins are harmful to animals and there have been many documented reports of impacts to birds, dogs, livestock, and humans (USEPA 2012). Adverse health outcomes from exposure to cyanotoxins may range from a mild skin rash to serious illness or death (EPA, 2012 and EPA, 2017). The cyanotoxins include neurotoxins (affect the nervous system), hepatoxins (affect the liver), and dermatoxins (affect the skin). Cyanotoxins are produced by a wide variety of planktonic cyanobacteria and are contained within the cyanobacterial cells (intracellular). The release of these toxins in an algal bloom into the surrounding water occurs mostly during cell death and lysis (i.e. cell rupture) as opposed to continuous excretion from the cyanobacterial cells. However, some cyanobacteria species are capable to release toxins (extracellular) into the water without rupture or death. Microcystins are the most widespread cyanobacterial toxins and can bioaccumulate in common aquatic vertebrates and invertebrates such as fish, mussels, and zooplankton (EPA, 2017). Microcystins primarily affect the liver, but also can affect the kidney and reproductive system. Microcystins are produced by the cyanobacteria *Anabaena, Fischerella, Gloeotrichia, Nodularia, Nostoc, Oscillatoria, Microcystis,* and *Planktothrix* (EPA, 2017). The cyanotoxin cylindrospermpsin is produced by the cyanobacteria *Cylindrospermopsis reaciborskii, Aphanizomenon flos-aquae, Aphanizomenon gracile, Aphanizomenon ovalisporum, Umezakia natans, Anabaena bergii, Anabaena lapponica, Anabaena planctonica, Lyngbya wollei, Rhaphidiopsis curvata,* and *Rhaphidiopsis mediterranea* (EPA, 2017). The primary toxic effects of cylindrospermpsin is damage to the liver and kidney. Anatoxins are cyanotoxins that bind to neuronal nicotinic acetylcholine receptors and affect the central nervous system. Anatoxins are mainly associated with the cyanobacteria *Aphanizomenon, Cuspidothrix, Cylindrospermopsis, Cylindrospermum, Dolichospermum, Microcystis, Oscillatoria, Planktothrix, Phormidium, Anabaena, Tychonema* and *Woronichinia* (EPA, 2017). Cyanobacteria blooms are encouraged by warmer or stagnant waters that are enriched with nutrients, especially phosphorus (USEPA, 2012 and OSU, 2013)

The nutrient enrichment of the Marsh from the WWTF's effluent discharges resulted in extremely high phosphorus levels in the water column of the Marsh (Figure 2-9 and Figure 2-10). This seemingly enhanced conditions for the occurrence of cyanobacteria blooms in the Marsh. A bloom of the cyanobacteria *Aphanizomenon flos-aquae* was monitored in the Marsh during 2015. This was the only occasion during 2012, 2013, 2015, and 2016 that a significant cyanobacteria bloom was monitored. It may be that the dense watermilfoil growth in the Marsh shaded the water column during the growing season to the detriment of phytoplankton. Dense duckweed (*Lemna sp.*) growth observed in the Marsh could also have shaded the water column. The high CDOM values measured in the Marsh, and the associated stained water color, could also have limited light penetration within the water column to the degree that phytoplankton growth was inhibited. Much of the phosphorus discharged to the Marsh was incorporated into vegetative growth and has been deposited on the Marsh bottom as dead vegetative matter. There may be a future concern that this pool of residual phosphorus could contribute to future cyanobacteria blooms in the Marsh. It is noted that supersaturated DO and high pH conditions were monitored in 2016 and could be indicative of high phytoplankton photosynthetic activity.

3.3 POOR WATER QUALITY PRESENT DURING THE 2014/2015 ICE-COVER PERIOD

Very poor water quality was monitored in the Marsh in front of the Pumping Plant intake during January and February of 2015. Anoxic conditions were monitored at site LOWMSH on 27-Jan and 25-Feb 2015. The "strength" of the anoxic conditions is reflected in the -51 mV ORP level measured on 27-Jan-2015. An ORP of this level indicates that sulfates were likely being reduced to hydrogen sulfide. When sampling was conducted at the Marsh on 27-Jan there was a severe malodorous condition (i.e. rotten egg smell) at the Williston Field Office. The malodorous condition was attributed to H_2S off-gassing from the agitation of the Pumping Plant discharge to the Missouri River. The field office was downwind of the discharge and H_2S gas was seemingly being carried over the levee and accumulating in the lower area at the field office location. To address the malodorous condition, the Pumping Plant discharge was shut down and the malodorous condition ceased.

3.4 EXTREME FOAM CONDITIONS – MARCH 2015

Foam is created when the surface tension of water is reduced and air is mixed in, causing the formation of bubbles that congregate as foam (Courtemanch, 1979; IDEM, 2001). Certain substances decrease the surface tension of water – some are manmade and some occur naturally (Courtemanch, 1979; IDEM, 2001; Davis, 2005; Manitoba, 2015). These substances are called surface active agents or surfactants (Davis, 2005). Soaps are derivatives of fatty acids, and many soaps are commercially made from vegetable oils. When aquatic plants decompose, fatty acids can be produced that are very similar to those found in common soap products (Manitoba, 2015).   Foam occurs in water bodies when these natural fatty acids are agitated by wave action. Some differences in the appearance and persistence of foam may indicate whether it is a natural occurrence or caused by human activity. General guidelines include (IDEMN, 2001; Manitoba, 2015):

“Natural” Foam:

- Light tan or brown in color, but may be white.
- An “earthy” or “fishy” or “fresh cut grass” odor.
- Dissipates fairly quickly when not agitated.

Foam from Human Activity:

- Usually white in color.
- A fragrant, perfumed or soapy odor.
- Foam persists for a longer period of time.

A situation of extreme foam occurred along the windward shore of the Marsh in March-2015 right after ice-out (Photo 1).   A possible reason for the foam build-up was the discharge of surfactants (soap or detergents) from WWTF’s Finish Ponds to the Marsh. However, the timing and appearance of the foam suggests that it was due to the accumulation of “natural” surfactants from vegetative decomposition in the Marsh and their exposure to wave action at ice-out. As discussed earlier, a tremendous amount of vegetative growth (i.e. watermilfoil) occurred in the Marsh as a result of the nutrient loadings to the Marsh from the WWTF’s effluent discharges. This created an excessive pool of residual dead vegetation on the bottom of the Marsh that was available for decomposition during the winter. During the winter ice-cover period, just prior to March-2015, it’s likely that prolonged anoxia and significantly reduced biochemical conditions occurred. The biochemical reactions that form fatty acids occur when ORP values are -100 to -225 mV (YSI, 2008). These conditions were seemingly present during the ice-covered period, and attest to the poor water quality that was present in the Marsh during that period.

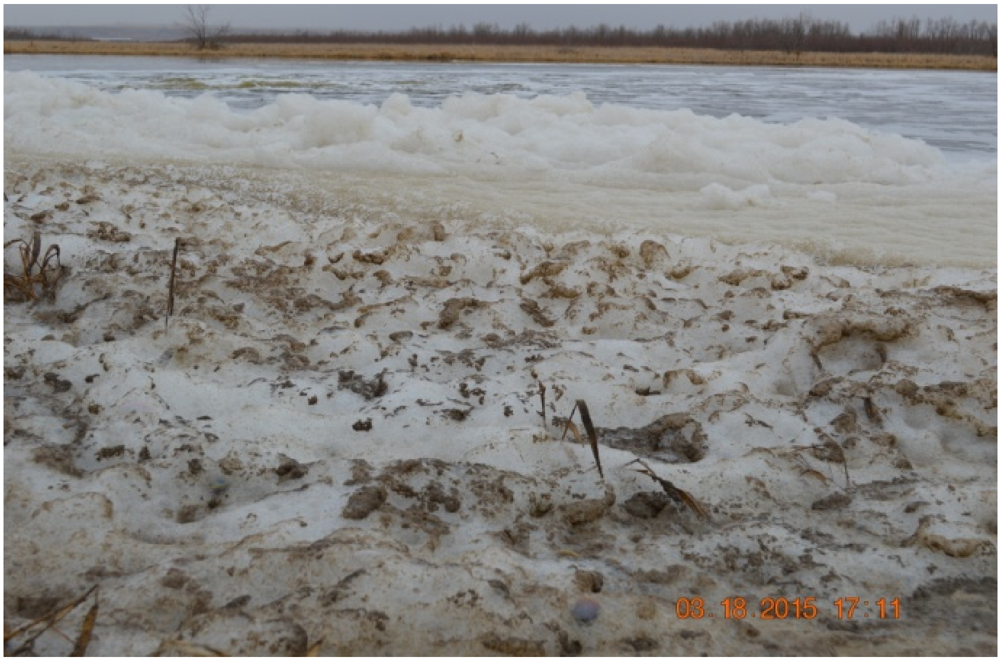

Photo 1. Foam build-up along the windward shore of the Williston March during March 2015 (photo taken 18-Mar-2015, by Jeff Keller, USACE, Williston Field Office).

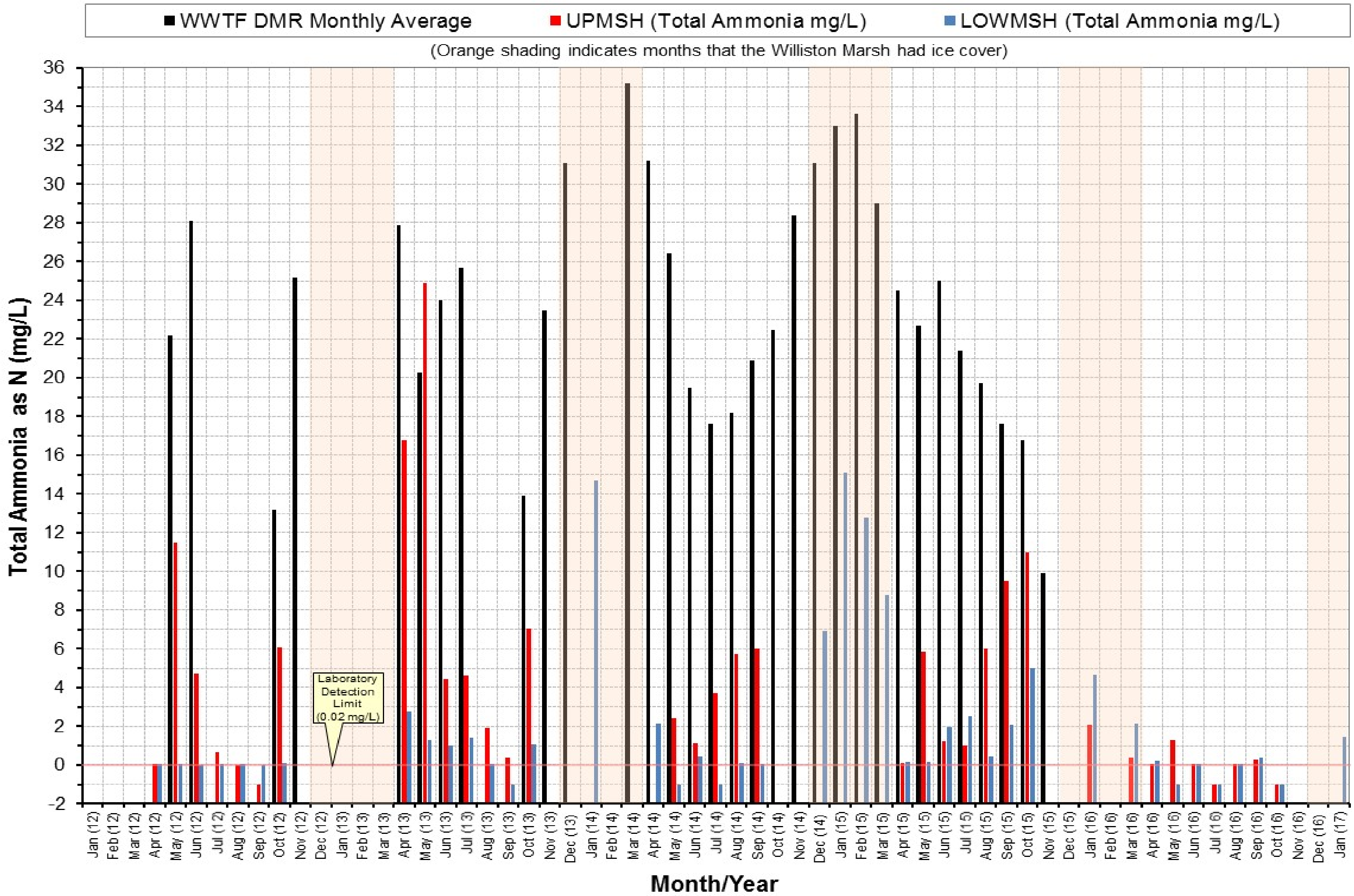

Figure 3-1. Ammonia concentrations reported for the WWTF effluent discharge (30-day average) and monitored monthly in the Williston Marsh at sites UPMSH and LOWMSH over the period April-2012 through January-2017. (*Note: Non-detect values plotted as -1.)*

4 SUMMARY AND CONCLUSIONS

4.1 POSSIBLE DEGRADATION OF THE EXISTING USE OF THE WILLISTON MARSH

The Federal Clean Water Act's (CWA) antidegradation provisions require that existing uses must be protected. Specifically, 40 CFR 131.12(a)(1) requires the protection of existing uses and the level of water quality to protect those uses. Pursuant to the CWA, existing uses are those uses actually attained in a water body on or after November 28, 1975, whether or not they are included in the applicable water quality standards (40CFR 131.3). The State of North Dakota's water quality standards and antidegradation procedure states, "Existing use means a use that was actually attained in the water body on or after 1967, whether or not it is included in the water quality standards." North Dakota's water quality standards for Class III streams state the quality of these waters must be maintained to protect secondary contact recreation uses, fish and aquatic biota, and wildlife uses. They also state that "wetlands" (including isolated ponds, sloughs, and marshes) are to be considered waters of the state and are to be protected. It is possible that the degradation of the Marsh's existing uses has occurred due to the excessive effluent discharges from the WWTF's Finishing Ponds during the period 2012 through 2015.

4.2 HAS THE EXISTING USE OF THE WILLISTON MARSH BEEN DEGRADED?

The existing water quality of the Marsh has improved with the cessation of effluent discharges from the WWTF Finishing Ponds. However, there remains a concern that the extreme nutrient loading to the Marsh from the effluent discharges has resulted in the extensive deposition of residual vegetative matter on the bottom of the Marsh. The possibility exists that this residual organic matter has sequestered significant phosphorus levels that could be released under hypoxic conditions and fuel future HABs in the Marsh. Enhanced phytoplankton productivity in the Marsh during the summer of 2016 is suggested by the monitored DO super-saturation and high pH conditions, but refuted by the monitored lower chlorophyll-a levels and phytoplankton standing crop. No HABs were monitored in the Marsh during 2016.

4.3 FUTURE WATER QUALITY MONITORING

At this time, the District plans to continue its water quality monitoring of the Marsh at the three in-marsh sites (LOWMSH, MIDMSHN, and UPMSH) for the same parameters monitored in 2015 and 2016. The collected water quality data will be used to extend the water quality assessment of the Marsh through January 2018.

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