

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
SURFACE WATER QUALITY DIVISION
APRIL 2002

STAFF REPORT

WATER QUALITY MONITORING OF LAKE ALLEGAN
AND TRIBUTARIES, 2001

INTRODUCTION

Water quality monitoring of Lake Allegan is conducted on an annual basis to determine the progress toward meeting the phosphorus goal established by the Lake Allegan Total Maximum Daily Load (TMDL) and to document the effectiveness of phosphorus reduction efforts. This report presents the results of sampling efforts in 2001, and compares the results with previous sampling conducted in 1998, 1999, and 2000 as part of the phosphorus TMDL developed for Lake Allegan. The report also includes sampling results for Morrow Lake for comparison of water quality conditions with Lake Allegan.

SUMMARY

The in-lake concentration of total phosphorus in Lake Allegan averaged 90 micrograms per liter (ug/l) in 2001. Phosphorus concentrations in the lake continue to be higher than the TMDL goal of 60 ug/l for Lake Allegan. The inlet phosphorus concentration in the Kalamazoo River at the M-89 location was reported to be 91 ug/l in 2001. This concentration continues to be higher than the TMDL goal of 72 ug/l for the inlet location at M-89. However, this is the lowest concentration that has been reported for the inlet to Lake Allegan. No change in the average transparency across the lake was observed from 1998 to 2001, nor were any visual algae blooms observed during the summer sampling period. Dissolved oxygen concentrations across Lake Allegan in 2001 remain above the TMDL goal of 5 milligrams per liter (mg/l).

BACKGROUND

Lake Allegan is a 1,587-acre impoundment on the Kalamazoo River and is located in Allegan County in southwestern Michigan. Lake Allegan and the Kalamazoo River watershed drain approximately 2,020 square miles from ten counties: Calhoun, Kalamazoo, Allegan, Barry, Eaton, Hillsdale, Jackson, and Van Buren Counties. Lake Allegan has a volume of 17,200 acre-feet, and a mean hydraulic retention time of 7 days. Depths in the lake range from 3 to 20 feet, with a mean depth of 10 feet (USEPA, 1975). Natural areas of upland forest dominate the shoreline of Lake Allegan. Much of the immediate surrounding land is designated as the Allegan State Game Area. Residential areas make up a small portion of the lake's shoreline.

Major tributaries to Lake Allegan are the Kalamazoo River and Dumont Creek. Several small perennial and ephemeral streams also discharge directly to the lake. Six dams (Trowbridge, Plainwell, Otsego, Otsego City, Allegan City, and Lake Allegan) were originally constructed on the stretch of river from Plainwell to Allegan (three have been partially removed – Trowbridge, Otsego, and Plainwell). Lake Allegan was created in 1936 as a result of the Caulkins Dam built on the Kalamazoo River for providing hydroelectric power.

Section 305(b) of the 1972 federal Clean Water Act (CWA) requires the Michigan Department of Environmental Quality (MDEQ) to biennially develop and submit to the United States Environmental Protection Agency (USEPA) a list of waterbodies that do not attain water quality

standards (WQS). Section 303(d) of the CWA requires the submittal of a list of water quality limited or threatened waters needing established pollutant TMDLs. Lake Allegan was identified as an impaired waterbody not meeting WQS due to nutrient enrichment and was included on the “nonattainment” list submitted to the USEPA (Kosek, 1997 and Wuycheck, 1998). Lake Allegan is currently classified as a hypereutrophic lake (Wuycheck, 1998) with extremely high nutrient and chlorophyll *a* levels, low transparency, periodic nuisance algal blooms, low dissolved oxygen levels with occasional exceedance of the 5 mg/l dissolved oxygen standard, and an unbalanced fish community dominated by carp and channel catfish.

The MDEQ received a Section 104(b)(3) grant from the USEPA in July 1998 to develop a phosphorus TMDL for Lake Allegan. Phosphorus loadings from throughout the Lake Allegan watershed were quantified and related to Lake Allegan’s in-lake phosphorus concentration. Heaton (1999) summarized the sampling efforts, sampling results, and outlined the methods used to develop a phosphorus TMDL that will result in Lake Allegan meeting WQS. The TMDL document was public noticed on October 25, 1999, submitted to the USEPA on March 23, 2001, and approved by the USEPA on April 12, 2001.

METHODS

Sampling was conducted once per month from April through September 2001, at 5 stations in Lake Allegan (Figure 1) and from 1 to 3 stations in Morrow Lake (Figure 2), depending on flow conditions and accessibility. As part of the process in evaluating site-specific characteristics in the Kalamazoo River watershed, an analysis of the conditions in Morrow Lake, an impoundment on the Kalamazoo River upstream of the city of Kalamazoo, was conducted in 1999. Morrow Lake and Lake Allegan share similar land use characteristics with the majority of land use being agriculture and forestlands. Morrow Lake is of similar size (1,000 acres) and depth (5-10 foot depth) as Lake Allegan, and has desirable water quality characteristics. The conditions in Morrow Lake were used as the basis to establish the specific desired attributes for Lake Allegan in the TMDL. Monitoring of Morrow Lake continued in 2001 for comparing results of Morrow Lake with Lake Allegan, and to assess changes in the water quality of both systems as the TMDL is implemented.

Grab samples were collected at the surface, bottom, and mid-depth at each lake station. A depth integrated sample of the photic zone was also collected at each station for chlorophyll *a* analysis. Additional sampling at each station included a measurement of secchi transparency and a profile, at 2-foot increments, of temperature, dissolved oxygen, conductivity, and pH from the surface to the lake bottom.

Grab samples were also collected once per month, on the same day the lake sampling was conducted, at up to 5 tributary stations on the Kalamazoo River, depending on flow conditions, to monitor phosphorus concentrations at the inlet and outlet of Lake Allegan and Morrow Lake (Figures 1 and 2).

All of the samples from the lake and tributaries were collected, preserved (if necessary), stored at 4°C, and transported to the MDEQ’s Environmental Laboratory for chemical analysis using standard protocols (MDNR, 1994). Samples for April, August, and a portion of samples in September were analyzed by TriMatrix Laboratories, Inc. The samples were analyzed for total phosphorus, orthophosphorus, nitrates, nitrites, ammonia, dissolved solids, and suspended solids.

SAMPLING RESULTS

Monthly water quality sampling results collected in 2001 for Lake Allegan, Morrow Lake, and the tributary sites are presented in Tables 1 through 12. Results of total phosphorus and suspended solids for April, August, and September may be higher than the actual results

reported due to different laboratory methods used by TriMatrix Laboratories, Inc. Average monthly sampling results collected in 2001 for total phosphorus in Lake Allegan and Morrow Lake, and historic data taken at the same locations (Heaton, 1999) are displayed in Figures 3 and 4. A summary of the average monthly water quality sampling results in Lake Allegan and Morrow Lake for 1998, 1999, 2000, and 2001 are shown in Table 13.

A comparison of average monthly water quality results for Lake Allegan with the TMDL goals from 1998 to 2001 are reported in Table 14. The average in-lake concentration of total phosphorus in 2001 at the 5 stations sampled in Lake Allegan was 90 ug/l. This is slightly higher than the seasonal average phosphorus concentration of 89 ug/l reported in 2000. Average monthly concentrations reported in 2001 continue to be higher than the TMDL goal of 60 ug/l for Lake Allegan. Phosphorus concentrations in Lake Allegan have typically been the lowest in spring (April) and late summer (September). This was observed in 1998, 1999, and 2001. Phosphorus concentrations in 2000 revealed the highest concentrations of phosphorus in April and September. The higher levels were likely a result of heavy precipitation two days prior to the April and September sampling dates. The highest average phosphorus concentration (149 ug/l) in 2001 was observed in the month of July. The highest monthly average phosphorus concentrations from 1998 to 2001 have typically been reported in July.

The inlet phosphorus concentration in the Kalamazoo River at the M-89 location was reported to be 91 ug/l in 2001. The inlet concentration in 2001 continued to be higher than the TMDL goal of 72 ug/l for the inlet location at M-89. However, this is the lowest concentration that has been reported for the inlet to Lake Allegan. The average inlet and lake average concentrations from 1998 to 2001 are compared to the TMDL goals in Table 15. A comparison of the 1998 through 2001 Kalamazoo River tributary sampling data for total phosphorus is presented in Table 16. Phosphorus concentrations were the lowest in 2001 for all tributary stations except Highway M-40/89 as compared to previous sampling years.

Overall, average in-lake chlorophyll *a* levels reported for Lake Allegan in 2001 have increased from average in-lake concentrations reported in 2000 as reported in Table 14. Monthly average chlorophyll *a* concentrations observed in 2001 were lower in April and May, and higher from June to September, than those concentrations reported in 2000 for the same periods. Secchi depth readings collected in Lake Allegan in 2001 ranged from 1.9 to 2.2 feet, with an average depth of 2.1 feet. However, no change in the average transparency across the lake was observed from 1998 to 2001. The TMDL goal for secchi transparency in Lake Allegan is 3.5 feet. No visual algae blooms were observed during the sampling period in 2001.

Dissolved oxygen concentrations across Lake Allegan in 2001 remain above the TMDL goal of 5 mg/l. Dissolved oxygen concentrations were depressed near the lake bottom at stations 2 and 3 in June, and at all other stations in July. Phosphorus concentrations were elevated in several water samples collected when dissolved oxygen was depressed. Supersaturation of dissolved oxygen was not as apparent as had occurred in July and August 2000, when dissolved oxygen concentrations were in the range of 20 to 29 mg/l.

As previously discussed, the conditions in Morrow Lake were used as the basis to establish the specific desired attributes for Lake Allegan in the TMDL. Monitoring of Morrow Lake continued in 2001 for comparing results of Morrow Lake with Lake Allegan, and to assess changes in the water quality of both systems as the TMDL was implemented. The average phosphorus concentration in Morrow Lake in 2000 was 68 ug/l. Phosphorus concentrations have decreased from those levels reported in 1999 and 2000. Chlorophyll *a* levels for Morrow Lake have decreased slightly from those reported in 1999 and 2000. Secchi transparency has slightly increased to levels observed in 1999.

REFERENCES

Heaton, S. 1999. Loading Assessments of Phosphorus Inputs to Lake Allegan, 1998. MDEQ, SWQD, Report No. MI/DEQ/SWQ-99/125.

Heaton, S. 2000. Water Quality Monitoring of Lake Allegan and Tributaries, 2001. MDEQ, SWQD, Report No. MI/DEQ/SWQ-01/082.

USEPA. 1975. National Eutrophication Survey. 1975. Report on Lake Allegan, Allegan County, Michigan, EPA Region V, Working Paper No. 182.

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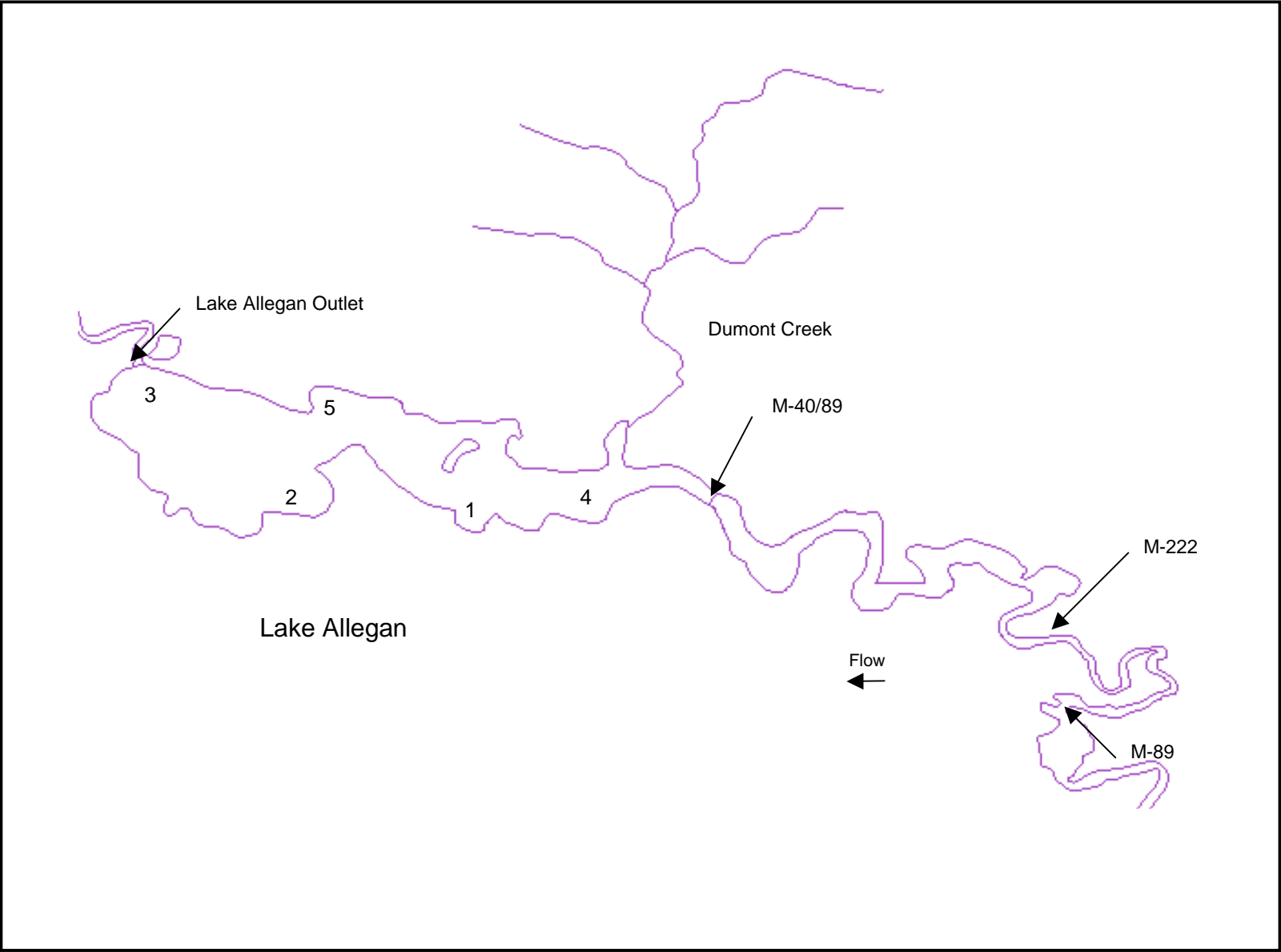


Figure 1. Water quality sampling stations in Lake Allegan and the Kalamazoo River, 2000.

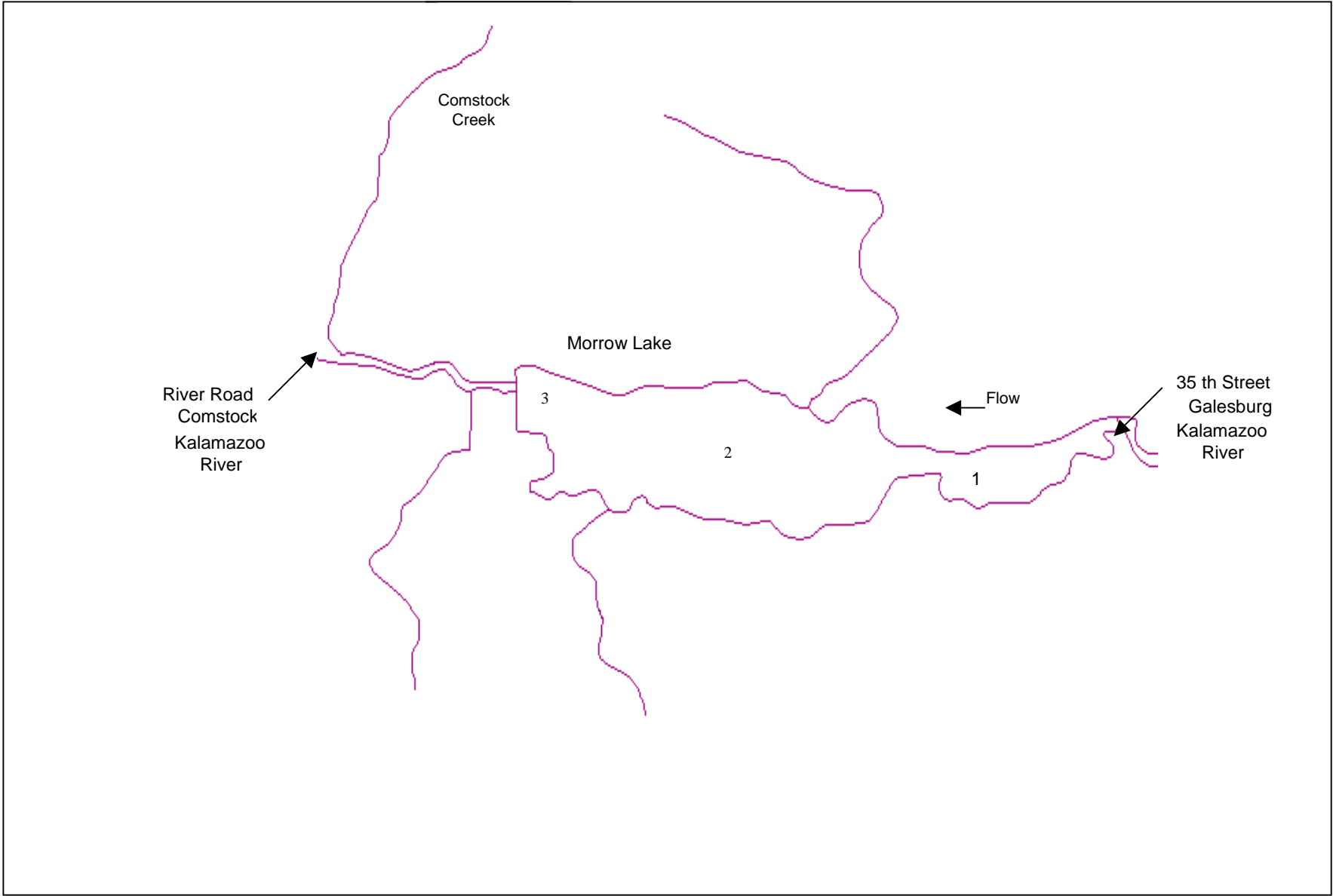


Figure 2. Water quality sampling stations in Morrow Lake and the Kalamazoo River, 2000.

Table 1. Water quality data for Lake Allegan, April 24, 2001.

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	NITRITE (mg/l)	NITRATE+ NITRITE (mg/l)	AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL* PHOS. (mg/l)	TSS* (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)
Station #2	Surface(S)	58.2	11.3	616	8.2	33		1.3	0.09	0.73	0.01	0.07	18	366	17	8.1
Depth (ft): 13.5	2	58.2	11.2	617	8.2											
Secchi	4	58.2	11.2	617	8.2											
Depth (ft): 2.0	(M)6	58.2	11.2	617	8.2											
	8	58.2	11.2	617	8.2											
	10	58.1	8.7	618	8.2											
	(B)12	58.7	4	622	7.8			1.3	0.07	0.7	0.02	0.07	18	508		7.6
Station #3	Surface(S)	59	11.9	620	8.3	36		1.2	0.07	0.71	0.01	0.06	11	370	16	7.6
Depth (ft): 17	2	59.1	11.6	620	8.3											
Secchi	4	58.7	11.6	623	8.3											
Depth (ft): 2.5	6	58.6	11.7	625	8.3											
	(M)8	58.4	11.8	627	8.4											
	10	58.1	12	630	8.4											
	12	57.8	12.2	635	8.4											
	14	57	12.4	642	8.4											
	16	56.8	12.2	643	8.4											
	(B)18	56.7	7.3	643	8.3			1.1	0.06	0.72		0.05	12	372	16	8
Station #4	Surface(S)	59.2	10.7	611	7.8	32		1.3	0.07	0.8	0.01	0.09	22	336	19	7.7
Depth (ft): 5	2	58.8	10.5	610	7.9											
Secchi	4	58.9	10.5	612	8											
Depth (ft): 2.0	6	59	10.4	616	8											
	8	59.1	10.4	618	8.1											
	(B)10	58.7	8.5	620	8.1			1.2	0.08	0.94	0.01	0.11	38	368	22	7.4
Averages			10.63			33		1.23	0.07	0.77	0.01	0.08	20	387	18	7.7

Note* Results may be higher than actually reported due to different laboratory techniques being used.

Table 2. Water quality data for Lake Allegan, May 29, 2001.

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	NITRATE+		AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL PHOS. (mg/l)	TSS (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)
							NITRITE (mg/l)	NITRITE (mg/l)								
Station #1	Surface(S)	59.77	8.5	510	7.8	7	0.023	1.5	0.08	0.91	0.029	0.121	21	360	31	11
Depth (ft): 7	2	59.45	8.45	510	7.8											
Secchi	(M)4	59.19	8.4	510	7.8		0.023	1.5	0.082	0.95	0.032	0.115	13	370	32	10
Depth (ft): 1.5	6	59.08	8.38	510	7.8											
	(B)7	59.01	7.58	510	7.6		0.023	1.51	0.079	1.01	0.034	0.12	22	360	34	8.9
Station #2	Surface(S)	60.96	8.64	500	7.88	9	0.025	1.21	0.1	1.01	0.032	0.091	4	350		8.9
Depth (ft): 13.5	2	60.73	8.52	499	7.87											
Secchi	4	60.18	8.52	501	7.88											
Depth (ft): 2.0	(M)6	59.69	8.52	503	7.87		0.025	1.2	0.099	0.29	0.032	0.031	4	360	30	8.8
	8	59.61	8.42	503	7.86											
	10	59.57	8.27	503	7.84											
	(B)11	59.56	7.32	505	7.61		0.024	1.2	0.102	0.22	0.031	0.024	11	360	30	8.9
Station #3	Surface(S)	61.64	9.5	500	8.01	15	0.025	1.18	0.051	0.91	0.021	0.088	4	340	31	9.6
Depth (ft): 18	2	60.72	9.22	500	7.95											
Secchi	4	59.74	8.86	502	7.9											
Depth (ft): 3.0	6	59.68	8.71	502	7.89											
	(M)8	59.61	8.59	502	7.88		0.023	1.24	0.068	0.74	0.027	0.071	9	360	27	8.8
	10	59.51	8.45	501	7.89											
	12	59.5	8.39	500	7.88											
	14	59.47	8.35	502	7.87											
	16	59.37	8.19	501	7.86											
	(B)18	58.85	6.86	510	7.71		0.024	1.18	0.08	0.08	0.025	0.075	7	360	33	9
Station #4	Surface(S)	58.98	9.14	513	7.48	6	0.022	1.41	0.059	0.86	0.027	0.095	12	350	32	8.8
Depth (ft): 8	2	58.85	8.86	513	7.72											
Secchi	4	58.83	8.8	513	7.76		0.022	1.45	0.058	0.93	0.029	0.103	20	350	35	9.3
Depth (ft): 1.5	(B)6	58.83	8.77	513	7.77		0.022	1.45	0.058	1.02	0.03	0.115	25	360	34	8.8
Station #5	Surface(S)	61.75	8.75	513	7.87	7	0.023	1.48	0.061	0.82	0.031	0.08	11	360	32	8.8
Depth(ft): 9.5	2	59.64	8.65	514	7.86											
Secchi	4	59.48	8.64	513	7.85											
Depth(ft): 2.0	(M)6	59.23	8.51	512	7.84		0.023	1.48	0.063	0.92	0.029	0.1	9	360	33	8.8
	8	59.2	8.49	512	7.84											
	10	59.19	8.49	512	7.84											
	(B)12	59.12	8.48	511	7.83	36	0.023	1.48	0.064	0.93	0.029	0.107	22	370	33	9.6
Averages			8.49			13	0.023	1.36	0.074	0.77	0.029	0.089	13	358	32	9.2

Table 3. Water quality data for Lake Allegan, June 25, 2001.

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	NITRATE+		AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL PHOS. (mg/l)	TSS (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)
							NITRITE (mg/l)	NITRITE (mg/l)								
Station #1	Surface (S)	75.4	11.9	591	8.2	23	0.016	1.01	0.032	1.03	0.012	0.097	17	440	26	8.4
Depth (ft): 7	2	74.2	11.5	592	8.2											
Secchi	4	72.4	9.8	587	8.2											
Depth (ft): 1.5	(B)6	71.5	8.7	598	8.2		0.017	1.03	0.049	0.9	0.012	0.094	18	460	30	9.2
Station #2	Surface(S)	78.9	14.5	572	8.4	32	0.022	0.86	0.017	0.82	0.007	0.062	13	430		8.3
Depth (ft): 14	2	78.9	14.2	573	8.5											
Secchi	4	76.5	11.4	581	8.3											
Depth (ft): 2.2	(M)6	73.9	9.1	589	8.1		0.024	0.99	0.17	1.19	0.018	0.117	9	430	24	7.3
	8	71.7	5.3	594	7.8											
	10	71.6	3.6	594	7.7											
	12	71.2	3.3	597	7.7											
	(B)13	70.9	2.1	599	7.6		0.03	1.03	0.31	1.13	0.045	0.129	25	410	26	7.8
Station #3	Surface(S)	80.6	15.9	563	8.4	45	0.023	0.83	0.015	0.91	0.008	0.057	19	400	26	7.6
Depth (ft): 19	2	80	16.1	561	8.4											
Secchi	4	76.2	15.4	566	8.4											
Depth (ft): 3.0	6	74.6	13.6	573	8.3											
	(M)8	74	11.4	580	8.2		0.021	0.92	0.015	0.86	0.006	0.055	15	420	25	7.3
	10	73.2	9.8	587	8.1											
	12	72.7	8.4	588	8											
	14	72.3	7.9	585	8											
	16	71.6	5.9	589	7.8											
	(B)17	71.4	4.9	592	7.7		0.02	1.1	0.054	0.75	0.005	0.058	14	400	21	7.3
Station #4	Surface(S)	73.1	9.8	603	8.2	46	0.012	1.25	0.01	0.77	0.006	0.077	12	400	23	7.4
Depth (ft): 9	2	73	9.5	595	8.2											
Secchi	(M)4	71.9	9.1	591	8.2		0.011	1.23	0.014	0.85	0.006	0.092	19	420	24	7.6
Depth (ft): 2	6	71.7	8.8	587	8.2											
	8	71.6	8.7	574	8.2											
	(B)9	71.5	8.4	573	8.2		0.012	1.13	0.022	0.9	0.005	0.109	29	410	26	7.2
Station #5	Surface(S)	77	12.4	599	8.4	55	0.014	1.18	0.012	0.91	0.01	0.078	14	450	26	8
Depth(ft): 8	2	74.4	12.2	598	8.4											
Secchi	(M)4	73	11.4	599	8.3		0.014	1.2	0.012	0.94	0.009	0.085	16	430	26	7.1
Depth(ft): 2	6	71.9	10	603	8.2											
	8	71.6	8.7	602	8.1											
	(B)10	71.5	7.8	603	8.1	36	0.012	1.27	0.027	0.93	0.009	0.108	35	440	26	7.7
Averages			9.75			40	0.018	1.07	0.054	0.92	0.011	0.087	18	424	25	7.7

Table 4. Water quality data for Lake Allegan, July 24, 2001.

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	NITRATE+		AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL PHOS. (mg/l)	TSS (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)
							NITRITE (mg/l)	NITRITE (mg/l)								
Station #1	Surface (S)	78.2	7	606	7.8	72	0.022	0.7	0.183	1.22	0.013	0.141	14	410	26	6.6
Depth (ft): 7.2	2	78.7	6.4	608	7.8											
Secchi	4	78.5	5.6	604	7.7											
Depth (ft): 2.0	(B)6	78	3.4	603	7.6		0.22	0.72	0.26	1.27	0.19	0.159	19	410	25	6.4
Station #2	Surface(S)	81.2	8.8	558	7.8	67	0.023	0.21	0.198	1.21	0.012	0.109	6	370	18	6.3
Depth (ft): 13.5	2	81	8.8	559	7.8											
Secchi	4	80.4	7.7	583	7.9											
Depth (ft): 2.0	(M)6	80.3	7.3	595	7.7		0.023	0.27	0.186	1.72	0.017	0.162	11	370	29	6.3
	8	80.2	7.2	601	7.8											
	10	79.9	5.9	606	7.7											
	(B)11.5	79	2.8	622	7.6		0.022	0.55	0.166	1.25	0.008	0.118	16	470	23	5.8
Station #3	Surface(S)	81.8	11.5	555	8.1	67	0.021	0.24	0.063	1	0.007	0.072	9	440	22	5.7
Depth (ft): 17	2	81.6	11.6	557	8.1											
Secchi	4	81	10.2	572	8											
Depth (ft): 3.5	6	80.6	8.6	583	7.8											
	(M)8	80.5	7.1	591	7.7		0.022	0.41	0.22	1.29	0.008	0.108	12	440	28	6
	10	80.2	5	607	7.6											
	12	77.7	2.8	618	7.5											
	14	78.9	0.8	623	7.4											
	16	77.6	0.4	633	7.4											
	(B)17	77	0.3	640	7.3		0.039	0.23	0.78	2.1	0.031	0.27	64	460	30	6.6
Station #4	Surface(S)	77.6	5.97	578	7.6	39	0.016	0.81	0.182	1.13	0.022	0.131	20	470	22	6.5
Depth (ft): 10	2	77.3	5.6	577	7.7											
Secchi	4	77.1	5.4	571	7.7											
Depth (ft): 1.5	6	76.9	5.2	566	7.7											
	8	76.2	5	544	7.7											
	(B)8.8	76.3	4.6	541	7.7		0.017	0.8	0.185	0.99	0.024	0.153	45	430	25	5.5
Station #5	Surface(S)	78.3	5.7	569	7.8	55	0.021	0.83	0.135	0.78	0.021	0.099	19	440	20	5.1
Depth(ft): 8	2	78.2	5.5	570	7.8											
Secchi	4	77.9	4.8	570	7.6											
Depth(ft): 1.5	(M)6	77.9	4.5	569	7.7		0.019	0.78	0.172	1.1	0.021	0.156	26	430	20	5.5
	8	77.9	4.4	569	7.7											
	10	77.9	4.2	569	7.7											
	(B)12	77.9	1.45	583	7.5		0.02	0.77	0.24	1.19	0.025	0.186	43	440	24	5.6
Averages			5.63			60	0.04	0.56	0.23	1.25	0.031	0.143	25	428	24	5.9

Table 5. Water quality data for Lake Allegan, August 27, 2001.

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	NITRATE+		AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL* PHOS. (mg/l)	TSS* (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)
							NITRITE (mg/l)	NITRITE (mg/l)								
Station #1	Surface (S)	75.1	11.9	557	8	60	0.023	1.02	0.042	1.22	0.007	0.07	15		16	6.5
Depth (ft): 7.2	2	74.7	12.3	558	8											
Secchi	(M)4	73.2	11	565	7.9											
Depth (ft): 1.5	(B)6	73	8.9	568	7.6		0.021	1.21	0.101	1.47	0.011	0.153	50		12	6.1
Station #2	Surface(S)	74.7	14	54	8.2	76	0.024	0.918	0.058	1.18	0.005	0.063	10		15	6.8
Depth (ft): 13.5	2	74.6	14	546	8.2											
Secchi	4	74.6	13.9	546	8.2											
Depth (ft): 2.0	(M)6	74.5	13.7	546	8.2											
	8	74.3	12.9	547	8.2											
	10	72.9	9.6	555	8											
	(B)12	72.3	8	566	7.8		0.024	0.908	0.038	1.03	0.002	0.06	14		14	6.13
Station #3	Surface(S)	75.3	15	534	8.4	83	0.026	0.086	0.052	1.06	0.004	0.06	12		25	6.36
Depth (ft): 19	2	75.2	14.8	535	8.4											
Secchi	4	75.2	14.8	536	8.4											
Depth (ft): 2.0	6	75.2	14.8	537	8.4											
	(M)8	75.2	14.6	538	8.3		0.026	0.864	0.046	0.846	0.003	0.059	17		17	6.24
	10	75.1	13.8	541	8.3											
	12	74.3	11.6	551	8.2											
	(B)14	72.3	12	550	8.1		0.025	0.931	0.037	1.04	0.003	0.064	17		17	6.1
Station #4	Surface (S)	73.5	9.5	559	7.7	34	0.018	1.2	0.069	0.913	0.007	0.082	14		16	5.98
Depth (ft): 10	2	73	9.3	560	7.7											
Secchi	(M)4	72.9	9	563	7.7		0.018	1.28	0.075	0.823	0.012	0.081	26		12	5.85
Depth (ft): 2.25	6	72.8	8.8	576	7.7											
	(B)7	72.7	8.6	576	7.7		0.018	1.31	0.082	1.03	0.023	0.112	32		11	5.88
Station #5	Surface(S)	74.5	11.1	561	8	54	0.02	1.19	0.044	1.02	0.008	0.065	12		15	5.85
Depth(ft): 13	2	74.5	11.6	561	8											
Secchi	4	74.4	10.7	561	8											
Depth(ft): 2.0	(M)6	73.8	9.5	563	7.9		0.02	1.24	0.069	0.947	0.012	0.089	21		12	6.02
	8	72.9	8.9	564	7.8											
	10	72.9	8.7	565	7.8	36										
	(B)12	72.8	8.8	565	7.5		0.02	1.26	0.085	0.884	0.023	0.102	38		12	5.73
Averages			11.49				57	0.02	1.03	0.061	1.036	0.009	0.082	21	14.9231	6.11846

Note* Results may be higher than actually reported due to different laboratory techniques being used.

Table 6. Water quality data for Lake Allegan, September 25, 2001.

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	NITRATE+		AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL* PHOS. (mg/l)	TSS* (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)
							NITRITE (mg/l)	NITRITE (mg/l)								
Station #1	Surface (S)	57.8	9.34	575	7.97	41	0.019	1.19	0.106	0.854	0.013	0.057	19			
Depth (ft): 7.0	2	57.9	9.16	575	7.98											
Secchi	4	57.9	9.08	575	7.99											
Depth (ft): 1.5	(B)6	57.9	9.05	575	7.99		0.019	1.21	0.105	0.741	0.013	0.06	20			
Station #2	Surface(S)	61	10.02	597	8.15		0.021	0.95	0.09	0.854		0.054	29			
Depth (ft): 12.8	2	61	9.98	592	8.16											
Secchi	4	61	9.96	597	8.17											
Depth (ft): 2.3	6	61	9.92	597	8.18											
	8	61	9.9	597	8.18											
	10	61	9.88	597	8.19											
	(B)11	61	9.45	597	8.12		0.02	0.996	0.087	0.912		0.058	30			
Station #3	Surface(S)	60	9.36	587	8.03	43	0.013	1.22	0.048	0.68	0.01	0.069	11			
Depth (ft): 20	2	60	9.28	587	8.03											
Secchi	4	60	9.28	587	8.04											
Depth (ft): 2.5	6	60	9.25	587	8.04											
	(M)8	60	9.22	587	8.04		0.016	1.17	0.083	0.613		0.05	14			
	10	60	9.2	587	8.04											
	12	60	9.15	587	8.05											
	14	60	9.15	587	8.04											
	(B)16	60	9.08	587	8.05		0.016	1.17	0.088	0.628		0.053	18			
Station #4	Surface (S)	57.9	9.06	563	7.87	44	0.011	1.48	0.06	0.7	0.029	0.097	13			
Depth (ft): 9.5	2	58	9.03	562	7.75											
Secchi	(M)4	58	9	563	7.78		0.015	1.46	0.094	0.652	0.036	0.087	30			
Depth (ft): 2.0	6	58	8.98	563	7.8											
	(B)8	58	8.93	563	7.81		0.015	1.43	0.097	0.766	0.038	0.094	104			
Station #5	Surface(S)	58.4	9.1	573	7.95	15	0.011	1.42	0.064	0.59	0.027	0.084	7			
Depth(ft): 13.8	2	58.3	8.95	572	7.94											
Secchi	4	58.2	8.93	570	7.94											
Depth(ft): 2.0	(M)6	58.2	8.91	570	7.94		0.014	1.38	0.103	0.629	0.031	0.066	22			
	8	58.1	8.91	568	7.94											
	10	58	8.87	568	7.93											
	12	58	8.88	567	7.93											
	(B)13	58	8.65	567	7.82		0.015	1.39	0.117	0.634	0.033	0.065	22			
Averages			9.24			36	0.016	1.27	0.088	0.712	0.026	0.069	26			

Note* Results may be higher than actually reported due to different laboratory techniques being used.

Table 7. Water quality data for Morrow Lake and select tributaries, April 24, 2001.

Morrow Lake

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	DATE: 25-Apr-01		AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL* PHOS. (mg/l)	TSS* (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)
							NITRITE (mg/l)	NITRATE+ (mg/l)								
Dock	Surface					14	0.92	0.92	0.07	0.59	0.02	0.06	12	348	19	9.1
Secchi	3.5															

Kalamazoo River @ Galesburg (35th Street)						16	0.83	0.83	0.06	0.74	0.02	0.06	21	330	24	10
Kalamazoo River @ Comstock (River Road)						18	1	1	0.12	0.71	0.02	0.06	8	362	17	7.2
Kalamazoo River @ M-89							1.3	1.3	0.09	0.67	0.01	0.06	14	376	16	8.3
Lake Allegan Outlet						33	1.2	1.2	0.09	0.65	0.01	0.06	14	372	16	7.3

Note* Results may be higher than actually reported due to different laboratory techniques used.

Table 8. Water quality data for Morrow Lake and select tributaries, May 25, 2001.

Morrow Lake

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	DATE: 29-May-01		AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL PHOS. (mg/l)	TSS (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)
							NITRITE (mg/l)	NITRATE+ NITRITE (mg/l)								
Dock Secchi	Surface 3.5					6	0.019	0.86	0.065	0.77	0.022	0.058	4	360	29	9.9
<hr/>																
Kalamazoo River @ Galesburg (35th Street)				517		4	0.028	0.86	0.08	0.98	0.023	0.08	16	350	36	9.7
Kalamazoo River @ Comstock (River Road)				556		6	0.018	0.93	0.08	0.77	0.024	0.058	12	380	36	9.2
Kalamazoo River @ M-89				563			0.023	1.37	0.063	0.95	0.029	0.113	19	390	34	9.6
Kalamazoo River @ M-40/89				553		6	0.023	1.44	0.057	0.92	0.029	0.097	18	370	33	8.5
Lake Allegan Outlet				541			0.025	1.16	0.081	0.81	0.023	0.069	13	360	30	9

Table 9. Water quality data for Morrow Lake and select tributaries, June 25, 2001.

Morrow Lake

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	DATE:	25-Jun-01	AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL PHOS. (mg/l)	TSS (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)
							NITRITE (mg/l)	NITRATE+ NITRITE (mg/l)								
Station #2	Surface (S)	80.2	8.5	570	7.9	11	0.015	0.88	0.055	0.89	0.012	0.055	6	410	25	8
Depth (ft): 7	2	77.6	7.6	575	7.9											
Secchi	(B)4	71.7	6.9	571	7.8		0.014	0.92	0.042	0.67	0.014	0.05	4	410	28	8.3
Depth (ft): 5																
Station #3	Surface (S)	81	15	548	8.4	43	0.023	0.56	0.013	0.85	0.008	0.056	14	390	27	7.5
Depth (ft): 9.5	2	80.5	15.9	550	8.4											
Secchi	(M)4	74.6	12.8	557	8.2		0.019	0.65	0.012	1.01	0.006	0.071	6	400	24	8.4
Depth (ft): 3.0	6	73	9.1	562	8											
	8	70.1	6.1	562	7.7											
	(B)10	69.4	5.2	562	7.6		0.014	0.92	0.035	0.63	0.006	0.043	8	380	20	7.8
Averages				562	8	27	0.017	0.786	0.0314	0.81	0.009	0.055	8	398	25	8
Kalamazoo River @ Galesburg (35th Street)						3	0.013	0.93	0.046	0.76	0.02	0.077	11	410	26	8
Kalamazoo River @ Comstock (River Road)						31	0.016	0.97	0.057	0.67	0.007	0.05	6	440	21	7.9
Kalamazoo River @ M-89						33	0.011	1.25	0.021	1.01	0.014	0.147	32	420	28	7.6
Lake Allegan Outlet						40	0.023	0.94	0.064	0.93	0.009	0.07	16	400	19	8.2

Table 10. Water quality data for Morrow Lake and select tributaries, July 26, 2001.

Morrow Lake

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	DATE: 26-Jul-00		AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL PHOS. (mg/l)	TSS (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)
							NITRITE (mg/l)	NITRATE+ (mg/l)								
Station #3	Surface (S)	81.2	10	553	8.2	44	0.02	0.67	0.016	0.66	0.005	0.058	8	440	22	4.8
Depth (ft): 9.5	2	80.1	10.5	551	8.2											
Secchi	(M)4	78.8	8.4	568	8											
Depth (ft): 3.0	6	78.4	6.4	567	7.9											
	8	78.3	5.7	567	7.9											
	(B)9	78.3	4.9	568	7.8		0.021	0.69	0.196	0.77	0.016	0.09	15	400	15	4.8
Averages				562	8	44	0.02	0.68	0.106	0.72	0.011	0.07	12	420	19	4.8
Kalamazoo River @ Galesburg (35th Street)							0.016	0.91	0.082	0.56	0.023	0.067	13	440	16	5.2
Kalamazoo River @ Comstock (River Road)							0.022	0.84	0.142	0.7	0.021	0.08	21	420	16	4.7
Kalamazoo River @ M-89							0.022	1.3	0.145	0.86	0.021	0.105	13	490	18	4.8
Kalamazoo River @ M-40/89							0.018	0.99	0.157	0.93	0.022	0.134	29	420	21	5.1
Lake Allegan Outlet							0.027	0.3	0.29	1.26	0.011	0.107	19	380	25	5.5

Table 11. Water quality data for Morrow Lake and select tributaries, August 27, 2001.

Morrow Lake

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	DATE: 27-Aug-01		AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL* PHOS. (mg/l)	TSS* (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)
							NITRITE (mg/l)	NITRATE+ NITRITE (mg/l)								
Dock	Surface (S)						0.013	0.893	0.098	1.1	0.041	0.101	5		22	5.57
Secchi	3.5															

Kalamazoo River @ Galesburg (35th Street)							0.018	0.81	0.089	0.473	0.024	0.049	6		11	5.69
Kalamazoo River @ Comstock (River Road)							0.017	0.89	0.112	0.981	0.023	0.072	7		17	6.51
Kalamazoo River @ M-89							0.018	1.24	0.093	0.722	0.024	0.088	21		12	5.89
Lake Allegan Outlet						68	0.024	0.859	0.055	1.23	0.006	0.064	15		20	6.42

Note* Results may be higher than actually reported due to different laboratory techniques used.

Table 12. Water quality data for Morrow Lake and select tributaries, September 25, 2001.

Morrow Lake

STATION	DEPTH (ft)	TEMP. (F)	D.O.	COND.	pH	CHLORO A. (ug/l)	DATE: 25-Sep-01		AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TOTAL* PHOS. (mg/l)	TSS* (mg/l)	TDS (mg/l)	COD (mg/l)	TOC (mg/l)	
							NITRITE (mg/l)	NITRATE+									
Dock	Surface (S)						0.011	1.02	0.086	0.525	0.02	0.061	5.5				
Secchi	3.5																
<hr/>																	
Kalamazoo River @ Galesburg (35th Street)									0.924	0.062	0.665	0.017	0.03	6.5			
Kalamazoo River @ Comstock (River Road)								0.014	1.04	0.142	0.804	0.026	0.043	10			
Kalamazoo River @ M-89								0.014	1.34	0.084	0.498	0.035	0.034	17			
Lake Allegan Outlet									1.23	0.047	0.66		0.068	7			

Note* Results may be higher than actually reported due to different laboratory techniques used.

Table 13. Comparative results of water quality for Morrow Lake and Lake Allegan, 1998-2001.

Units	Total Phos (ug/l)	Ortho Phos (ug/l)	Secchi Depth (feet)	Chlor. A (ug/l)	NO2- (mg/l)	NO3- (mg/l)	NH4 + (mg/l)	Total Sus. Solids (mg/l)	Total Dis. Solids (mg/l)
Lake Allegan (1998)									
April	74	10.5	2.4	13	0.014	0.91	0.031	20	351
May	90	16	2.2	25	0.019	0.74	0.03	29	407
June	100	27.5	2	41.5	0.024	0.67	0.057	15	399
July	122	26.3	1.5	45.4	0.022	0.71	0.077	23	353
August	88	14	2.5	26.4	0.016	0.71	0.059	13	356
September	86	21	2.5	23.8	0.017	0.89	0.044	11	400
Average	95	19	2.2	29	0.019	0.748	0.0508	20	373.2
Lake Allegan (1999)									
April	69	7.6	2.4	43.2	0.02	1.05	0.043	10	387
May	111	5.9	1.7	80.6	0.022	0.87	0.016	27	441
June	117	20	1.9	82.2	0.024	0.78	0.066	25	437
July	125	6.3	2	86.8	0.02	0.47	0.05	26	411
August	90	13.6	2.9	41.2	0.02	0.7	0.03	18	426
September	63	10.3	2.5	52.2	0.015	0.52	0.046	12	415
Average	96	11	2.2	64.4	0.02	0.73	0.042	20	420
Lake Allegan (2000)									
April	102	14	1.8	48	0.029	1.56	0.092	20	376
May	80	31	1.4	16	0.032	1.61	0.089	20	375
June	90	29	2.5	29	0.018	1.28	0.037	18	390
July	72	8	2	58	0.016	0.81	0.034	13	430
August	77	8	3	51	0.02	0.76	0.041	15	408
September	115	29	1.6	15	0.017	1.6	0.079	16	398
Average	89	20	2.1	36	0.022	1.27	0.062	17	396
Lake Allegan (2001)									
April	75	12	2.2	34	----	1.23	0.07	19	387
May	89	29	2	9	0.023	1.36	0.074	13	358
June	87	11	2.1	40	0.018	1.07	0.054	18	424
July	143	31	2.1	60	0.04	0.56	0.23	25	428
August	82	9	1.9	61	0.022	1.03	0.061	21	----
September	65	26	2.1	36	0.016	1.27	0.088	26	----
Average	90*	20	2.1	40	0.0238	1.09	0.096	20*	399

Note* Results may be higher than actually reported due to different analytical techniques used.

Table 13 (con't). Comparative results of water quality for Morrow Lake and Lake Allegan, 1998-2001.

Units	Total Phos (ug/l)	Ortho Phos (ug/l)	Secchi Depth (feet)	Chlor. A (ug/l)	NO2- (mg/l)	NO3- (mg/l)	NH4 + (mg/l)	Total Sus. Solids (mg/l)	Total Dis. Solids (mg/l)
Morrow Lake (1999)									
April	50	11	4	10.7	0.013	1.06	0.036	6	339
May	60	17	3	11.3	0.021	1.05	0.138	12	438
June	78	23	3.5	33.7	0.022	0.7	0.101	12	424
July	83	11	3.3	30.3	0.014	0.65	0.017	15	397
August	79	9.1	3.8	32	0.012	0.71	0.017	21	440
September	71	9	3.5	32	0.015	0.71	0.017	18	440
Average	70	13	3.5	24	0.016	0.81	0.054	14	413
Morrow Lake (2000)									
April	101	23	2	10.5	0.037	2.2	0.191	18	353
May	80	28	----	7.5	0.034	1	0.109	12	390
June	88	26	3.5	14	0.017	1.2	0.051	23	345
July	54	10	3	42	0.016	----	0.013	10.5	375
August	74	4	3.5	65	0.017	----	0.014	11	427
September	52	16	----	8	0.004	----	0.025	8	400
Average	75	18	3	24	0.0208	1.5	0.067	14	382
Morrow Lake (2001)									
April	60	20	3.5	14	0.92	0.92	0.07	12	348
May	58	22	3.5	6	0.019	0.86	0.065	4	360
June	55	9	4.25	27	0.017	0.786	0.031	8	398
July	70	11	3	44	0.02	0.68	0.106	12	420
August	101	41	3.5	----	0.013	0.893	0.098	5	----
September	61	20	3.5	----	0.011	1.02	0.086	5.5	----
Average	68*	21	3.5	23	0.1667	0.860	0.076	8*	382

Note* Results may be higher than actually reported due to different analytical techniques used.

Table 14. Comparison of average monthly water quality results for Lake Allegan with the Lake Allegan TMDL goals, 1998-2001.

<u>Phosphorus (ug/l)</u>						
	April	May	June	July	August	September
Goal	60	60	60	60	60	60
2001	80	89	87	143	82	69
2000	102	80	90	72	77	115
1999	69	111	117	125	90	63
1998	74	90	100	122	88	86

<u>Chlorophyll a (ug/l)</u>						
	April	May	June	July	August	September
Goal	30	30	30	30	30	30
2001	33	13	40	60	57	36
2000	48	16	29	58	51	15
1999	43	81	82	87	41	52
1998	13	25	42	45	26	24

<u>Secchi Transparency (feet)</u>						
	April	May	June	July	August	September
Goal	3.5	3.5	3.5	3.5	3.5	3.5
2001	2.2	2.0	2.1	2.1	2.0	2.1
2000	1.8	1.4	2.5	2.0	3.0	1.6
1999	2.4	1.7	1.9	2.0	2.9	2.5
1998	2.4	2.2	2.0	1.5	2.5	2.5

<u>Dissolved Oxygen (mg/l)</u>						
	April	May	June	July	August	September
Goal	5.0	5.0	5.0	5.0	5.0	5.0
2001	10.6	8.5	9.8	5.6	11.5	9.2
2000	12.9	9.5	9.4	16.7	21.5	8.6
1999	10.6	10.5	10.2	13.6	12.8	13.5
1998	10.8	11.5	7.1	6.8	8.4	9.8

Table 15. Comparison of average water quality results for Lake Allegan and the M-89 lake inlet with the Lake Allegan TMDL goals, 1998-2001.

	<u>TMDL GOAL</u>	<u>2001</u>	<u>2000</u>	<u>1999</u>	<u>1998</u>
<u>Total Phosphorus:</u>					
M-89 Inlet	72 ug/l	91 ug/l	124 ug/l	114 ug/l	100 ug/l
Lake Allegan	60 ug/l	90 ug/l	89 ug/l	102 ug/l	95 ug/l
<u>Chlorophyll a:</u>					
Lake Allegan	30 ug/l	40 ug/l	36 ug/l	64 ug/l	29 ug/l
<u>Secchi Transparency:</u>					
Lake Allegan	3.5 feet	2.1 ug/l	2.1 feet	2.2 feet	2.2 feet
<u>Dissolved Oxygen:</u>					
Lake Allegan	5.0 mg/l	9.21 mg/l	13.1 mg/l	11.9 mg/l	9.1 mg/l

Table 16. Comparison of water quality results for total phosphorus collected for selected stations on the Kalamazoo River, 1998-2001.

	<u>1998</u>	<u>1999</u>	<u>2000</u>	<u>2001</u>
Galesburg	-----	65 ug/l	86 ug/l	61 ug/l
Comstock	66 ug/l	72 ug/l	73 ug/l	61 ug/l
Highway M-89	100 ug/l	114 ug/l	124 ug/l	91 ug/l
Highway M-40/89	-----	-----	89 ug/l	116 ug/l
Lake Outlet	70 ug/l	76 ug/l	74 ug/l	73 ug/l