Analysis for Internal Phosphorus Loading in Lake Allegan

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In 1999, the Michigan Department of Environmental Quality (MDEQ) developed a phosphorus (P) TMDL for Lake Allegan. The TMDL targets a reduction of lake P levels so that water quality standards can be met in the lake (Heaton, 1999). This TMDL was developed based on a water quality monitoring effort conducted from April to September 1998, during which once per month sampling was conducted at five stations in the lake and 15 stations on selected tributaries of the Kalamazoo River. Twice per month sampling was also conducted on 13 selected sites on the main stem of the Kalamazoo River and its tributaries. The specific water quality goals (TP, chl-*a*, Secchi depth, and DO) were based on the conditions in Morrow Lake, another reservoir impoundment upstream of Lake Allegan that has "desirable water quality characteristics" (Heaton, 2001). Internal loading was not considered, however, in developing the load allocations, although concerns were raised and the MDEQ acknowledged the need of additional monitoring to determine "if P release from sediments plays a significant part in the recycling of P in Lake Allegan" (Heaton, 1999). Currently, water quality monitoring is continuing on Lake Allegan, the Kalamazoo River, and Morrow Lake by the MDEQ on a once per month schedule each year from April through September.

Using available MDEQ data, a data analysis revealed signs of internal loading in Lake Allegan. According to Granéli (1999), a clear sign of internal loading is an increase in total P (TP) and soluble reactive P (SRP) during the course of the summer when external loading is low and P consumption by algae is high. Figure F-1 shows that for the four years (1998-2001) during which monthly TP and SRP (referred to as orthophosphorus [Ortho-P] by the MDEQ[1]) concentrations were measured from April to September, TP rapidly increased from April, peaked in July, and then decreased equally rapidly in August and September. Year 2000 is an exception most likely because of, as pointed out by the MDEQ (Heaton, 2001), heavy precipitation two days prior to the April and September sampling dates. Increasing summer TP coupled with low external loading suggests: 1) P loads from internal sources; 2) increasingly efficient P retention by the lake biota; or 3) a combination of the two effects. Distinguishing the first two processes is not possible with available monitoring data. Nonetheless, even if the second process is the dominant force, an efficient summer P retention may well mean a high P accumulation rate and thus a high potential for internal loading in the future. The increasing trend of Ortho-P is less pronounced in Figure F-1 probably due to the low Ortho-P concentrations that frequently dropped below 10 μg/L in the lake, limiting the growth of algae. Thus,

[1] To be consistent with the MDEQ terminology, SRP will be termed Ortho-P hereafter.

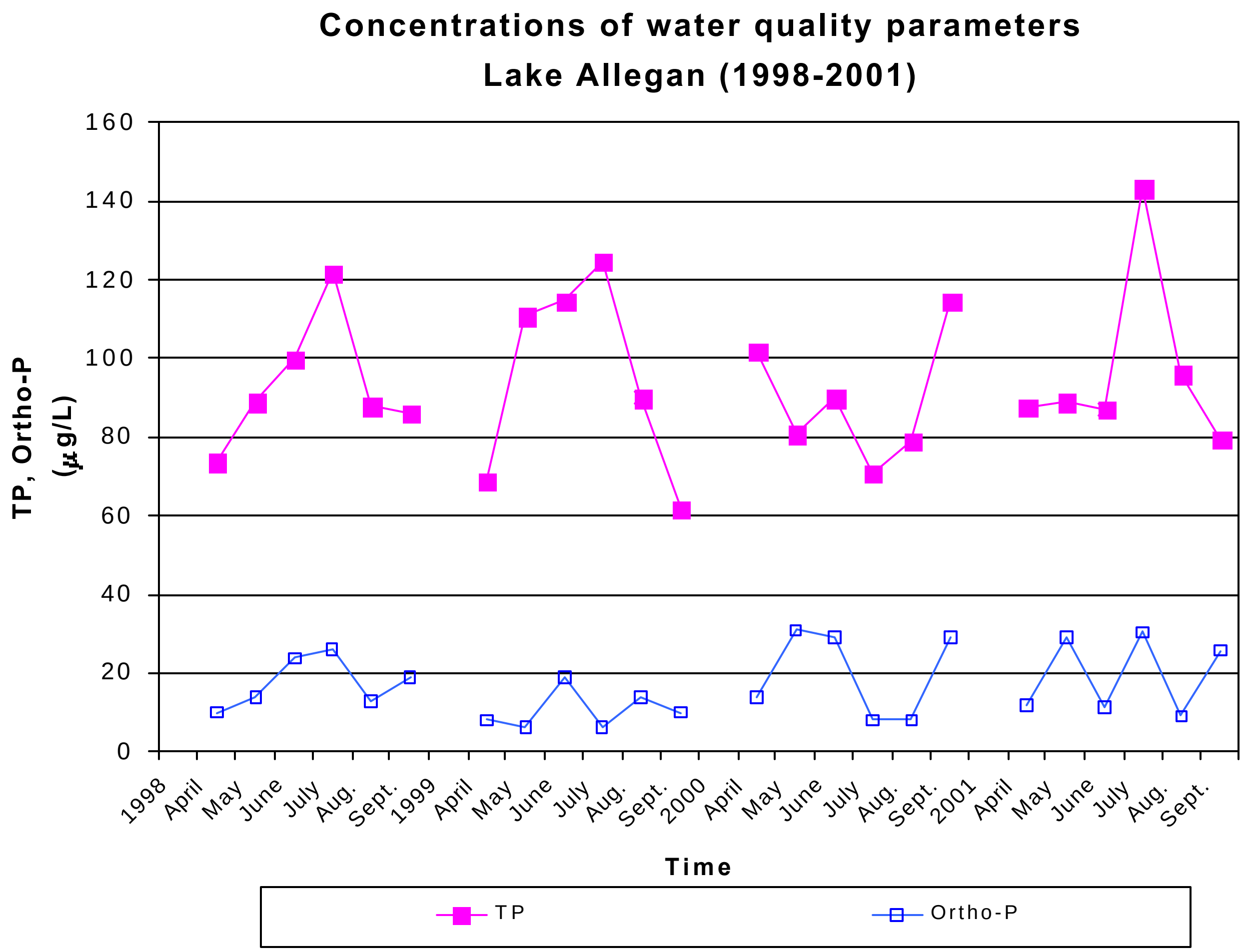

Figure F-1. Average monthly TP and Ortho-P (SRP) concentrations of Lake Allegan

it is possible that Ortho-P from internal sources was consumed by algae as soon as it became available. This conclusion is supported by the reverse correlation found between Ortho-P and chl-*a* concentrations (r = -0.57, $p < 0.01$) in 1998, indicating an active consumption of Ortho-P by algae in the lake. Similar, albeit weak, correlations were also found in Lake Allegan (r = -0.39, p = 0.05) and Morrow Lake (r = -0.54, $p < 0.05$) in 1999[2].

Sampling station analyses also suggest internal loading in Lake Allegan and Morrow Lake. Available depth profile data from the MDEQ's monitoring program provide clues to the presence of internal loading caused by different mechanisms. Figure F-2 shows the depth profiles of P related parameters at sampling station no. 2 in Lake Allegan on a calm day of June 25, 2001. Station 2 has a maximum depth of 14 ft (4.3 m), one of the two deeper stations of the five MDEQ sampling sites in the lake. A clear temperature stratification was present as the thermocline was well established between the 2 and 8 foot depths. Both TP, Ortho-P (especially the percentage of Ortho-P as part of the TP)

[2] Data from later years have not been analyzed.

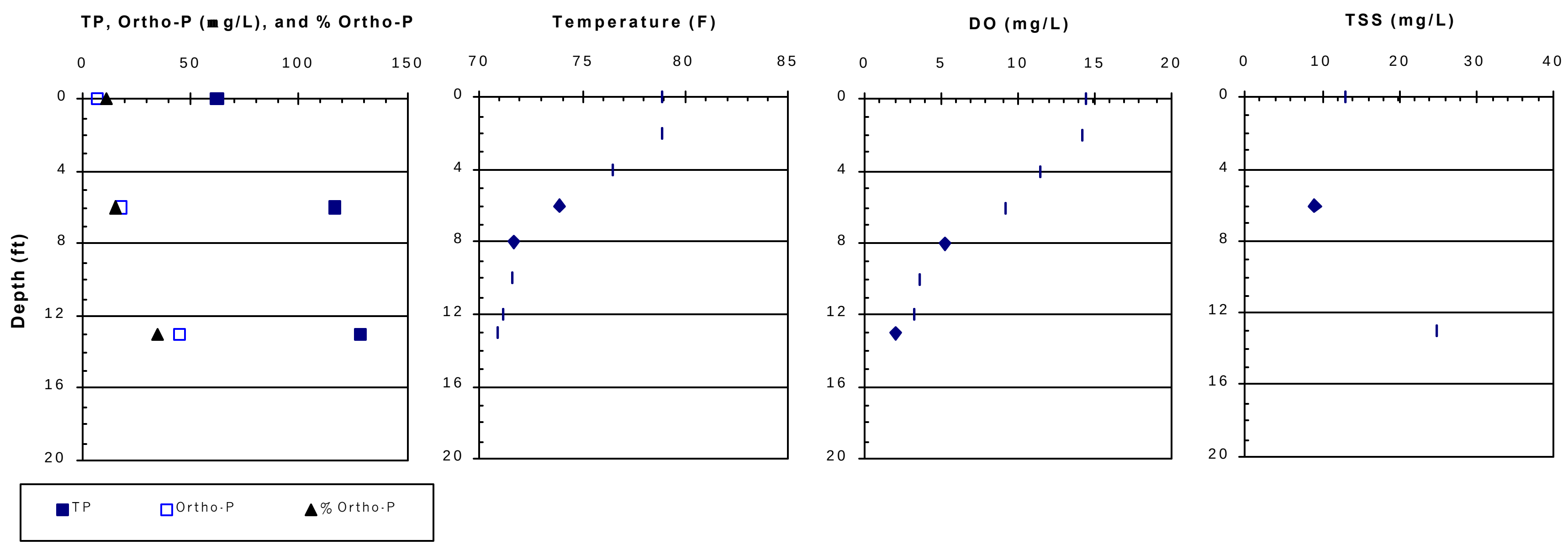

Figure F-2. Depth profiles of selected water quality parameters at sampling Station 2 in Lake Allegan on June 25, 2001.

showed a remarkable increasing trend throughout the depth profile, indicating a bottom-to-top injection of Ortho-P. An increase in TSS partially explained the increase of TP but cannot account for the rise of Ortho-P level because Ortho-P is a soluble form. The DO profile provides a possible explanation for the increase of Ortho-P. The bottom (13 ft) sample had a low DO of only 2.1 mg/L, very close to the 2 mg/L threshold found by Mortimer (1941 and 1971) for anoxic release of P from lake sediment. Consequently, a release of P from the bottom sediment was likely in progress at the time that the water samples and measurements were taken.

Figure F-3 is similar to Figure F-2 except that it shows monitoring results from Station 4 in Lake Allegan on June 16, 1999. With a maximum depth of only 7.2 ft (2.2 m) on the sampling day, Station 4 is the shallowest one among all the five stations. The DO profile indicates the water was well oxygenated throughout, and no temperature stratification was present. However, there was a 148% increase of TSS from the surface to the bottom in a mere 7.2 ft distance, suggesting a disturbance of the bottom sediments. TP also increased 40% while Ortho-P increased only slightly (the Ortho-P percentage decreased slightly). The absolute values of Ortho-P remained high (> 25% of TP). Combined, the plots in Figure F-3 suggest a situation where disturbance in the bottom sediment layer increased both TP and soluble Ortho-P in the water column. Mechanisms causing this disturbance could be physical or biological. Carp bioturbance is suspected. Similar P related parameter depth profiles have also been found at Station 5 on June 25, 2001 and Station 4 on May 29, 1998 in the lake.

Lake Allegan fish community surveys conducted by the Fisheries Division of the Michigan Department of Natural Resources (MDNR) in 1996 revealed that common carp dominated the fish community in terms of numbers (63.7%) and biomass (61.3%) (unpublished data). The 1996 survey series was extensive, incorporating electrofishing effort (2 hours), trapnetting (14 net lifts), and gill netting (6 net nights). The report stated that the combination of frequent low dissolved oxygen conditions and continued high nutrient loads likely contributed to the dominance of carp. Results and conclusions were said to agree with a similar survey conducted in 1987 (unpublished data, Surface Water Quality Division). A less extensive fish collection was conducted during June 1999 (1-h electrofishing) for contaminant analysis. This revealed that carp made up 86.7% of the catch in terms of numbers and 97.2% in terms of biomass. We are unaware of any fish community surveys conducted directly in Morrow Lake, the reference lake for the Lake Allegan TMDL.

In summary, there are strong indications of internal P loading in Lake Allegan. Thus, there is possibility that after external sources are reduced, P levels in the lake will not follow this reduction immediately. As a result, internal loading may become the major component of the total P loads, leading to a delay of water quality improvement.

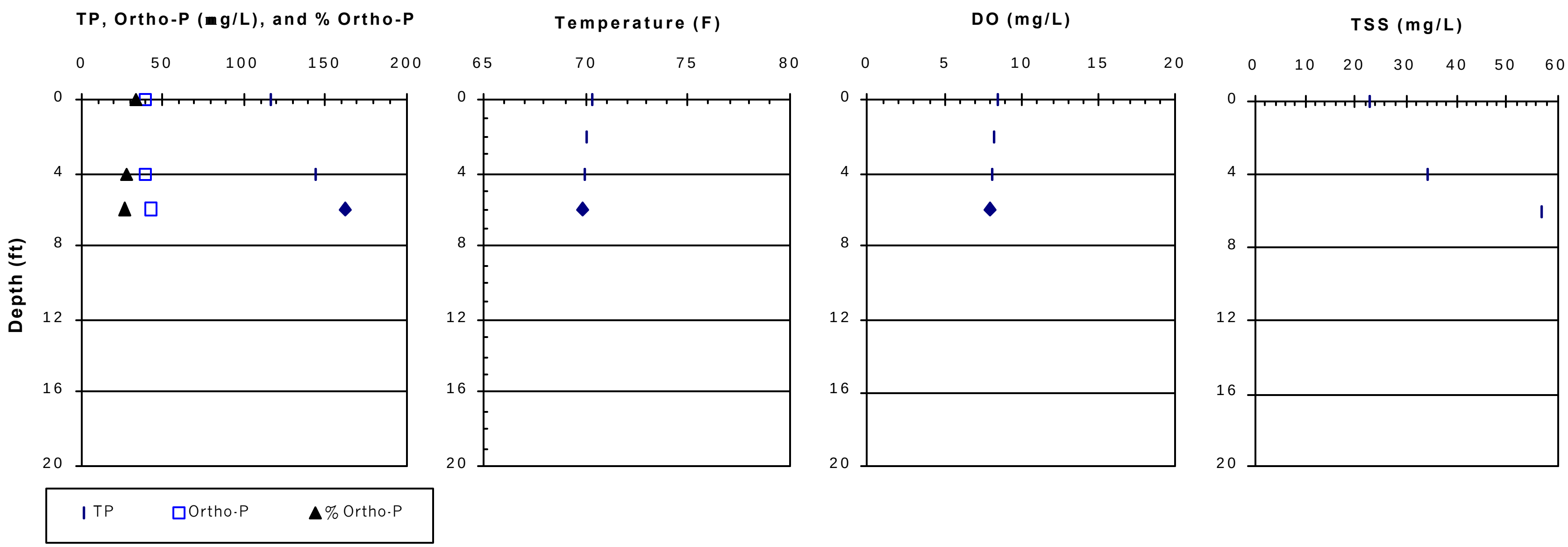

Figure F-3. Depth profiles of selected water quality parameters at sampling Station 4 in Lake Allegan on June 16, 1999.

Contributions of P associated with in-stream sources also include streambank erosion. As a source of sediments as well as P, eroding streambanks associated with human alterations of original stream channels and floodways additionally impact the habitat quality of streams and rivers. Thus, there are multiple benefits in addressing these types of contributing sources. A recent stream corridor survey in two highly urbanized streams to the Kalamazoo River (Portage and Arcadia Creeks) identified numerous erosion sites (http://www.kalamazooriver.net/pa319/arcadia/arcadiaero.htm). A recent demonstration project on P credit trading in the Kalamazoo River Basin studied P losses to the river due to bank erosion (Kieser, 2000). It estimated that P loads from three erosion sites on the Kalamazoo River alone contributed 247 pounds of P in total to the river every year along with tons of sediment. This P load, although small compared to the overall non-point source loads of P to Lake Allegan (96,244 lbs as estimated by the MDEQ in 1999 [Heaton, 1999]), already exceeds the 150 pound Margin of Safety from July through September in the Lake Allegan TMDL and is very close to the 300 pound Margin of Safety set from April through June. In view of the many erosion sites on the Kalamazoo River and its tributaries, P loading from bank erosion is considered a direct source of P to the river and the lake.

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