Marion Lake
Water Quality Status, Trends, and Management

Marion Lake is located between the cities of Marion and Hillsboro in central Kansas. It was constructed by the U.S. Army Corps of Engineers (USACE) in 1968. The reservoir was created by damming the North Cottonwood River to control flooding and reached its conservation pool level in 1969. Marion Lake (mean depth 3.4 m, maximum depth 9.0 m) is a multiple-use and relatively young reservoir that serves as the major source of drinking water for people in Marion County and surrounding communities. Normal pool surface area is 2,509 ha (6,200 acres) that can extend to 3,716 ha (9,183 acres) during flood control operations.

Marion Lake lies within a 52,836-ha (204-sq. mile) watershed that is predominantly cultivated row crop (43%) and grassland (40%). The North Cottonwood River drains 82% of the watershed while French Creek watershed comprises 18% of the remaining drainage area.

The trophic conditions of Marion Lake were compared to other federal reservoirs. Typically, Marion Lake has higher trophic levels than other reservoirs in the state and has much higher nutrients and chlorophyll *a* concentrations than the nutrient benchmarks proposed by the state.

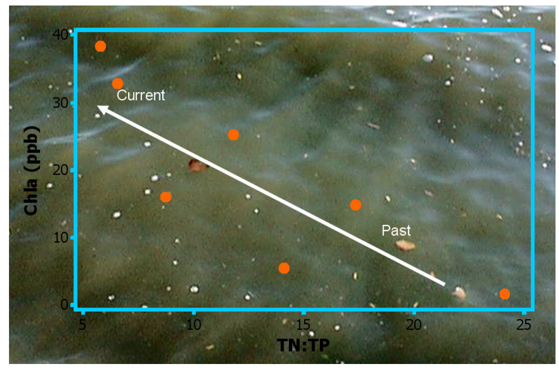
Cultural eutrophication is an important water-quality problem in Marion Lake and reservoirs throughout the Midwest. Although eutrophication occurs naturally, cultural eutrophication is an anthropogenic process that causes reservoirs to become more productive or eutrophic due to excessive nutrient additions from their associated watersheds.

One of the most detrimental consequences of eutrophication is the development of nuisance cyanobacterial blooms. Cyanobacteria, also referred to as blue-green algae, are photosynthetic prokaryotes that frequently dominate the phytoplankton communities of lakes and reservoirs that receive high nutrient loads from their surrounding watersheds. Abundant cyanobacterial blooms and the resulting appearance of dense surface accumulations are not only aesthetically unappealing, but they can also have negative effects on water quality conditions. Many taxa produce objectionable odor substances (e.g., geosmin) when they die and decay and/or chemicals that are toxic to humans or animals.

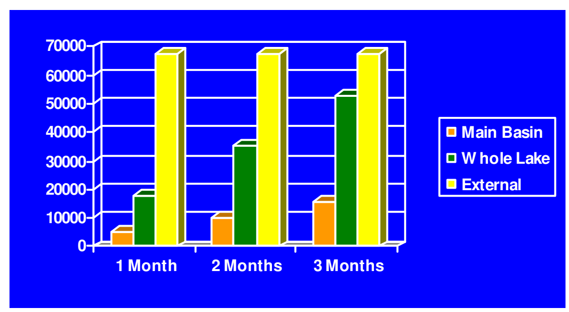
Marion Lake frequently experiences cyanobacterial blooms in the recent years. In July 10 of 2003, total algal cell count [*Anabaena* sp. (121,647 cells/ml) and *Microcystis* sp. (33,765,339 cells/ml)] in drinking water intake far exceeded the World Health Organization's recommended guidelines of very high risk level (100,000 cells/ml).

Low TN:TP ratios and warm, dry weather, accompanying by the prolonged dissolved oxygen (DO) stratification, create the favorable conditions for excessive cyanobacterial blooms.

More specifically, extensive agricultural activities (e.g., animal feeding operations) imbalance nutrient export (i.e., increased TP levels in conjunction with decreased TN level) from the watershed. Soil test results from the Kansas State University indicated that on average the top 6″ soil in Marion County had 36 mg/L of available P.



Because Marion Lake has a long hydrological residence time (2.2 years) and approximately 93% of the TP load is retained annually in the lake, internal P released from lake



sediment may play an important role of fueling the undesired algal blooms when the lake undergoes extensive DO stratification. A recent study conducted by the Kansas Biological Survey revealed that the average internal P releasing rate was 21mg/m^2/day, ranging from 17 to 24 mg/m^2/day. The figure above shows the internal P load (kg) released from the sediment at the main basin area and whole lake under 1, 2, and 3 months of anoxic condition, in comparison with the external TP load estimated by Generalized Watershed Loading Function (GWLF) and USACE BATHTUB model.

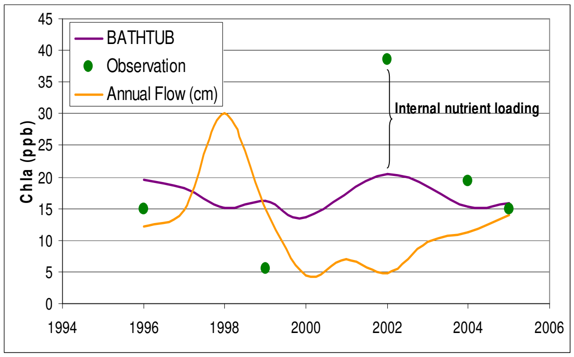
Median trophic values of Marion Lake in comparison with other reservoirs and Kansas trophic benchmarks (reference conditions). The Kansas benchmark values were derived from 105 lakes and reservoirs, based on the data collected between 1985 and 2002.

Trophic Indicator	Marion Lake	Federal Reservoirs	Kansas Benchmarks
Secchi depth (cm)	64	95	129
TN (µg/L)	1,190	903	625
TP (µg/L)	80	76	23
Chlorophyll *a* (µg/L)	15	12	8

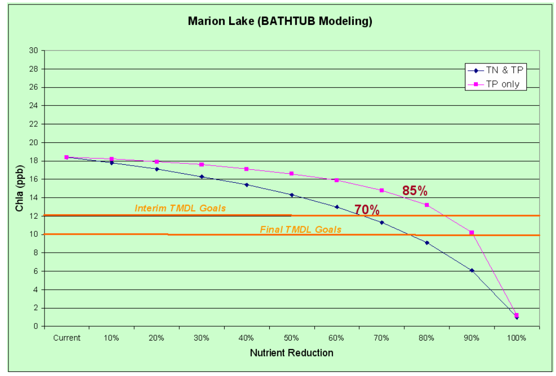
Understanding what environmental factors contribute to cultural eutrophication and the subsequent appearance of algal blooms has been at the center of total watershed management. Specifically, nutrient loading, thermal stratification, hydrological condition (e.g., residence times and flushing rates), and land use/land cover patterns have all been identified as important factors contributing to water quality problems that occur in Marion Lake.

Eleven subwatersheds were modeled using GWLF, and the 10-yr modeling results indicate that in average of 263 tons of TN and 67 tons of TP are exported annually from the watershed to the lake. Of which, about 81% of the TN (213 tons) and 80% of the TP (54 tons) come from the North Cottonwood River whereas the French Creek (Basins 9 and 10) exports the remaining nutrient loads. Two municipal wastewater treatment plants (Canton and Lehigh) together contribute 1.4 tons of TN and 0.4 tons of TP per year. Nutrient losses from streambank erosion only contribute about 1% of the total watershed nutrient loads. Among the 11 subwatersheds, Basins 9, 10, 1, 4 and 11 are the top five subwatersheds having a higher TN load per unit of area. Similarly, Basins 9 10, 8, 4, and 1 are the top five subwatersheds that have a higher TP load per unit of area.

To improve water quality, a 70% nutrient reduction (TN and TP) is required in order to reach the desired designated Primary Contact Recreation Use (chlorophyll a = 12 µg/L). However, a 85% nutrient reduction is needed if only managing TP load. Additional reductions are necessary to reach 10 µg/L of Chla



The results of a 10-yr BATHTUB simulation show that the internal nutrients from the sediment are an important source of causing algal blooms in the lake (e.g., 2002). This is because excess P is released into the water column, which lowers the TN:TP ratio. As a result, algal species shifts to cyanobacteria that can fix N from the atmosphere, and out compete more desired algae.



For future perspective in terms of changes in water quality, the U.S. Global Change Research Program indicates that possible future climate changes in the Central Great Plains region are higher temperatures with much drier growing seasons, but warmer and wetter winter and spring months, and higher intensity rainfall events. Therefore, predicted changes in the future climate are very likely to accelerate the eutrophication of this specific aquatic ecosystem and increase the possibility of the occurrence of cyanobacterial dominance.

To abate water quality problems, here are several recommended agricultural practices: (1) Apply nutrient best management practices (BMPs) to reduce nutrient additions from excess fertilization; (2) Promote and adopt continuous no-till cultivation to minimize soil erosion and nutrient transports; (3) Install grass buffer strips along streams; (4) Reduce activities within riparian areas; (5) Setback both confined and non-confined animal feeding operation sites; (6) Evaluate a lake application of chelating agents to bond phosphorus to sediments; and (7) Construct ponds/detention basins, erosion control structures and/or wetlands to reduce soil erosion and to trap sediment and lower peak runoff rates. In addition, a watershed management team needs to work with research agencies and/or institutes to develop new technologies to effectively and efficiently remove P from the watershed.