Preliminary Study of Nitrate Levels in Groundwater at Lime Lake, NY

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1. Background

Lime Lake is located near the town of Machias, New York, which is approximately 60 km southeast of Buffalo, New York. Lime Lake is a spring-fed lake with much of the lake having a depth less than three meters and a maximum depth of 11.5 m (Stewart and Markello, 1974). The lake, encompasses an area of approximately 640,000 m^2, has no inlets and drains north through a single outlet towards the Cattaraugus Creek which eventually discharges into Lake Erie. There are approximately 500 residences located on the banks of the lake, which consist of primarily seasonal cottages and homes. Approximately 20-30% of residents live there year round.

Lime Lake currently suffers from excess plant and algae growth possibly resulting from excess nutrients. Because of this, the Lime Lake Cottage Owners Association (LLCOA) applies a herbicide on a yearly basis (late summer) in order to control plant growth so as to preserve the aesthetics of the lake for the enjoyment of residents. Currently, the majority of homes in the vicinity of the lake use septic systems to treat their waste water. Because the lake is used by residents for swimming, fishing, and boating, monitoring of lake quality for the purposes of taking preventative action to preserve it was undertaken. The LLCOA, since 1997, has participated in the The Citizens Statewide Lake Assessment Program (CSLAP) which a volunteer lake monitoring program conducted by the NYS Department of Environmental Conservation (NYS DEC) and the NYS Federation of Lake Associations. The CSLAP program collects data related to trophic state of a lake in order to assess the aesthetic and ecological health of a lake.

An important conclusion of the CSLAP reports since at least the 1997 report, is that algal growth appears to be limited by phosphorus and not nitrogen. Starting from 2002, the reports use the total nitrogen to total phosphorus ratio as an quantitative indicator of whether nitrogen or phosphorus is limiting. According to the reports, a TN/TP value greater than 10 indicates a phosphorus limiting condition (i.e., nitrogen is in excess), although other sources (Florida Lakewatch, 2000) suggest that a value

greater than 17 should indicate phosphorus limiting conditions. For the sampling period from 2002 to 2005 (except the final two samples from 2005), the TN/TP ratio ranged from 33 to 77[1]. According to the 2005 report (NYS Department of Environmental Conservation, 2006), nitrate levels have decreased since 1997 while phosphorus has remained roughly the same. This would help explain the decreasing TN/TP trend from 2002 to 2005. The 2011 report[2] (NYS Department of Environmental Conservation, 2012) shows a large increase in the TN/TP ratio (more than double the 2002 to 2005 values) due to an increase in nitrate and organic nitrogen. Although the 2011 report does not discuss the TN/TP ratio (even though it presents numbers for it), it would appear that phosphorus continues to be the limiting factor in the lake.

2. Nitrates in Groundwater at Lime Lake

Although it appears that nitrate is currently likely not the dominant nutrient that controls algal and plant growth in the lake, nitrate levels in groundwater remain a concern, mainly due to the fact that the majority of homes surrounding the lake rely on on-site wells for their water. The CSLAP report rates the nitrate + nitrite level in the lake as "high", but still within the normal range for the lake, compared to previous sampling years (NYS Department of Environmental Conservation, 2012). Because the lake is spring fed, it is very likely that nitrate enters the lake via groundwater discharge. In August 2012, I conducted groundwater sampling from the wells of several volunteers. This preliminary sampling study revealed that nitrate is present in groundwater extracted from the surficial aquifer that is used as a potable water supply. A total of seven wells, located at various points around the lake, were sampled. Three were located on the eastern shore of the lake, one on the northern shore, two on the north-western shore, and one on the western shore. The wells on the eastern and northern shores did not contain any detectable nitrate. Nitrate levels in the wells on the north-western and western shores were between 2 and 5

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[1]The method of calculation of the TN/TP ratio in the CSLAP reports is not clear. Simply dividing the given TN by the given TP does not produce the TN/TP numbers given.

[2]No CSLAP sampling was performed at Lime Lake from 2006 to 2010.

mg/l NO3-N (the regulatory threshold set by the EPA is 10 mg/l). The source of nitrate is not currently known as it could originate from septic systems or from agricultural sources (there are agricultural fields in the vicinity of the lake). Therefore, one avenue of research is determining whether septic systems are contributing nitrate to the lake via groundwater or if agricultural sources are more likely.

3. Determining the Origin of Nitrates in the Groundwater Discharging into Lime Lake

There are several approaches that can be taken in order to determine the origin of the nitrates present in groundwater which discharges into Lime Lake. These approaches can be predominantly modeling oriented or field work oriented. The modeling oriented approach uses computer models of groundwater flow and contaminant transport, along with some field and literature data in order to provide support for or against a particular hypothesis. In the field oriented approach, a large quantity of field data is gathered which gives a clear enough picture of the groundwater hydrology and behavior of the contaminant of interest such that the role of models is minimal.

Due to the high resources necessary to conduct a large amount of field data collection, as well as difficulties related to sampling at locations of interest[3], the modeling approach is proposed as a way to provide insight into the source of the nitrates present in groundwater. In order to use models to help determine the source of nitrates over the long term, an inverse modeling approach using a numerical groundwater model and ArcNLET (Rios et al., 2013) is proposed. Uncertainty and sensitivity of the inputs will be assessed using the methods outlined in this report. The proposed approach will use measurements of nitrate concentration in groundwater along with groundwater levels in order to estimate contributions from septic systems and agriculture (assumed to be the dominant sources). Typical rates of nitrate contribution for septic systems and agricultural fields, denitrification rates, and hydrologic parameters will be obtained from literature in order to obtain baseline estimates of nitrate movement and fate. Using the observed and literature-sourced data, it should be possible to determine whether agriculture or septic systems are the dominant source of nitrates. However, it is anticipated that the model will not be detailed enough to have a predictive capacity.

Although the proposed study is modeling oriented, additional information that provides clues to the sources of nitrates would be useful. For example, testing sampled groundwater for pharmaceuticals or caffeine would provide strong evidence for the presence of septic system effluent in groundwater. Although the presence of pharmaceutical or caffeine does not imply that any nitrates found in groundwater came from a septic system, it would provide supporting evidence that, in the absence of other sources, any nitrates present above background levels originated from the septic system. In contrast, the absence of pharmaceuticals does not imply the absence of septic effluent. Another method that can provide evidence for a particular nitrate source is one using stable the isotopes of oxygen and nitrogen, ^{18}O and ^{15}N. By plotting $\delta^{18}O$ (a ratio of ^{18}O to ^{16}O) and $\delta^{15}N$ (a ratio of ^{15}N to ^{14}N) and examining the clustering of the points, it is possible to draw stronger conclusions regarding the source of nitrate. Although these methods are useful, collecting the data required to use them is outside the scope of the proposed work.

4. Acknowledgments

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[3]Because the lake is surrounded by homes, it is very difficult to obtain permission to drill a borehole on private property. It proved difficult enough to recruit volunteers that would allow groundwater samples to be taken from their wells.