Nitrogen Loading in the New Hope Arm of the Jordan Lake Watershed

Capstone Spring 2012

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Executive Summary

Project Goals: Jordan Lake has been eutrophic or hyper-eutrophic since 1983, threatening its original intended uses, such as water supply, recreation, and fish and wildlife protection. In order to comply with the Clean Water Act, the North Carolina Division of Water Quality issued Jordan Lake Rules to manage the amount of nitrogen entering the lake from Chapel Hill, Carrboro, Durham, and Orange County areas. The goal of this project was to evaluate potential input and output sources of nitrogen and incorporate them into a zeroth order nitrogen budget.

Methods: A final nitrogen budget model was conducted by calculating the percentage of nitrogen retention within the watershed. Nineteen sub-watersheds (13 from historic Chapel Hill data and 6 from group's water quality sampling locations) were identified within the watershed; for each watershed, the amount of inflowing nitrogen was calculated from the sum of the values of atmospheric deposition, wastewater, septic tank leakage, lawn and agricultural fertilizer use, denitrification, and volatilization. The output was approximated by the stream nitrogen load within each sub-watershed.

Certain input values were obtained from literature reviews and data from other agencies. Wastewater data was obtained from Orange Water and Sewer Authority, estimating that about 430.7 lb N/day were released with the wastewater. Atmospheric deposition data was obtained from North Carolina State University (NCSU) station at Finley Farm in Wake County. The monthly data was divided into 4 seasons and averaged over the past 15 years. Because the retention of atmospheric deposition differs based on the land cover, it was further scaled based on the surface within each watershed, with values taken from the Valeila et al. (1997) WBLMER model. From literature reviews, the denitrification rates were assumed to be between 0 to 0.58 mg N m^{-2} d^{-1}, and scaled based on the percentage of urban cover. Further, volatilization was assumed to be 5% based on the literature reviews. The agricultural fertilizer use was approximated based on the recommended values from NCSU and applied to corn and soybeans, the two dominant crops in the watershed.

Household lawn care and fertilizer surveys were conducted at four neighborhoods within the watershed in order to approximate the nitrogen input from lawn fertilizers. Using a survey tool, data was collected from 45 households pertaining to the amount and frequency of fertilizer application. Then, the lawn area of each of the households was approximated using remote sensing. After counting the number of houses within each sub-watershed, the total lawn area was approximated by multiplying the average lawn area by the number of houses. The total developed area was obtained as a sum of four development layers of the NLCD data cover of the watershed, and the percentage of lawn area in proportion to the total developed area was calculated.

In order to calculate the stream loads, six first- and second-order streams within Chapel Hill and Carrboro area were sampled once a week for six weeks for nitrate concentration. This data was combined with the historic Chapel Hill water quality data at 13 other locations, for which the annual nitrate concentration averages were available. The discharge for all of the streams in the 19 sub-watersheds was modeled from the SWAT moel, averaging the data over a ten-year period. Due to the seasonality of the discharge, the data was divided into four seasons, with spring having the highest discharge, and summer the lowest. As a result, stream loads for 13 historic sites were calculated by multiplying the annual nitrate average by each season discharge, and by multiplying the spring nitrate average by the seasonal discharge for the sampled water quality sites.

Results and Discussion: In this study, lawn fertilizer was the most significant nitrogen input. From the findings of the lawn care survey, it was assumed that 35% of the developed area was covered with lawns. We further assumed that 69% of households fertilizer their lawns, and of those households, 61.3% employ a company, which applies 0.134 kg N yr^{-1} m^{-2}, and 38.7% self-fertilize at the rate of 0.0181 kg N yr^{-1} m^{-2}.

Applying all of the input and output parameters as described, the output to input ratio was calculated for each of the 19 sub-watersheds. While for 17 out of 19 sub-watersheds the ratio was less than 20%, for two of them the ratio was over 100%. Excluding these two outliers, the ratio was averaged as 6.2%, meaning that 93.8% of the inflowing nitrogen was retained within the ecosystem. This value was surprisingly high, but it was used to extrapolate the nitrogen output into Jordan Lake from the entire watershed. Piecing together all the different inputs and scaling it using the retention within the watershed, a range of 278204 – 826279 kg/N/year was approximated to enter Jordan Lake from the entire watershed.

The high retention value can be partially attributed to overestimating the nitrogen input from the lawn fertilizers. The sampling bias was due to conducting surveys predominantly in the neighborhoods with large lawns, so the lawn percentage of 35% is probably too high, since it did not take into consideration more densely populated apartment complexes and townhouse neighborhoods. There is also a problem with recall bias, especially with the households that self-fertilize; the company application rates were calculated based on the NCSU recommendations, but the self-fertilize rate was based solely on the subjects' responses, which may underestimate their fertilizer application.

Finally, the output amount of nitrogen is also subject to revision. The seasonality in the nitrate concentration needs to be investigated further, since the final budget model used either the annual or spring averaged values. Therefore, the output may be underestimated, also leading to higher retention rate. Further, the interaction between the sub-watersheds was not taken into consideration, which should also be developed in the future models.