MEMO

SUBJECT: Reduction curve model analysis using proposed Water Quality Criteria for High Rock Lake

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Proposed Water Quality Standard for High Rock Lake:

15A NCAC 02B .0211FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS C WATERS

(4) Chlorophyll a (corrected):

(a)Site-specific High Rock Lake Reservoir Chlorophyll a (corrected): not greater than a growing season geometric mean of 35 ug/L in the photic zone based on all samples collected in a minimum of five different months during the growing season. For the purpose of this Sub-Item, the growing season is April 1 through October 31 and the photic zone is represented by a composite sample taken from the water surface down to twice the measured Secchi depth. Chlorophyll a shall not occur in amounts that result in an adverse impact as defined in 15A NCAC 02H .1002.

Methodology

EFDC and WASP models were used to simulate chlorophyll a responses to nutrient load reductions in High Rock Lake. The model report can be downloaded from DWR website. Thirty-six model scenario runs were conducted to examine water quality conditions in High Rock Lake when total loadings of nitrogen and phosphorus are reduced at a combination of 0%, 10%, 20%, 30%, 40%, and 50% levels.

Model results were output 4 times daily, evenly distributed throughout the day. The model simulated chlorophyll a concentrations were extracted from April 1 to October 30th of the modeling time period 2005-2009. Each data point is then log transformed and averaged according to station and the year, the overall average was then transformed back to provide the corresponding geomean.

Model Results

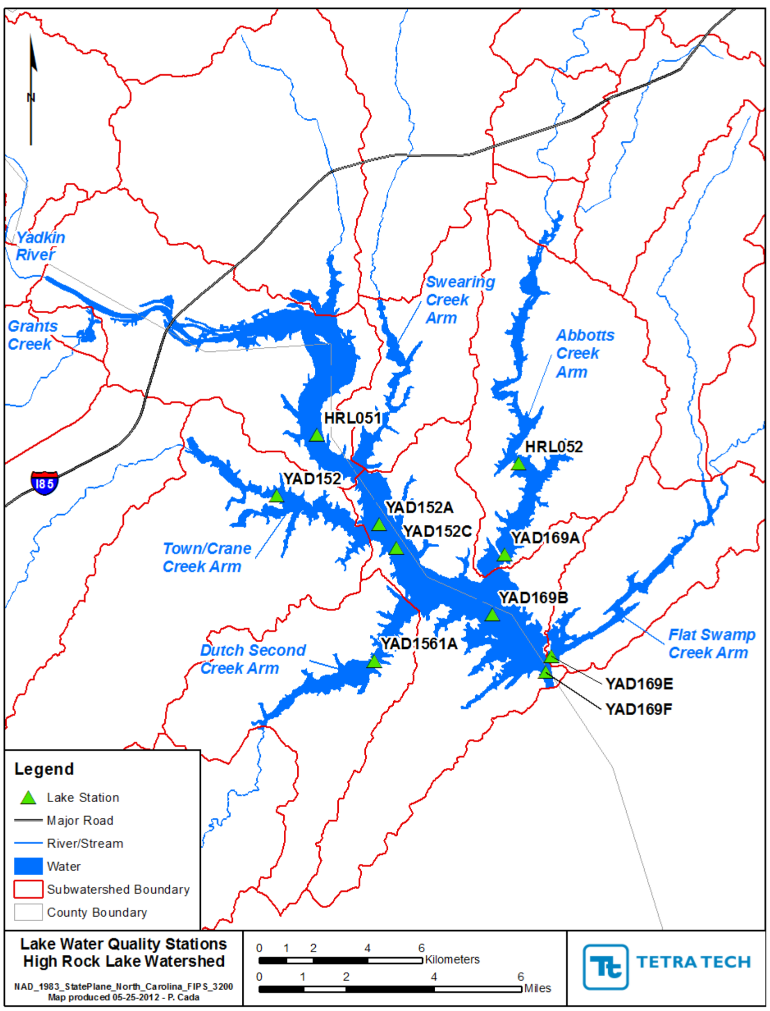
Spatial and temporal differences of model simulated chlorophyll-a growing season geomean

Figure 1 shows the model simulated growing season geomeans for choloraphyll a concentrations at different stations and for different years in High Rock Lake. In general, YAD152A and YAD152C are the two stations have relatively higher geomeans in High Rock Lake. The year of 2005 appeared to have the most stations with growing season geomeans exceeded the proposed criteria of 35 µg/L. The year of 2006, on the other hand, have the highest growing season geomean (at station YAD152A).

For comparison, growing season (mathematical) averages of chlorophyll a concentrations were also calculated (Figure 2). Mathematical averages are typically higher than the corresponding geomean values. The most differences occurred at station HRL051, where event-driven high peaks as well as generally lower chlorophyll a concentrations were observed during growing season.

Field observations of chlorophyll a concentrations were also calculated for growing season geomeans at different stations and for the years of 2005 and afterwards (Figure 3). Similar to model simulated results, YAD152C appeared to be the station having relatively higher chlorophyll a values in High Rock Lake, except during 2009, when higher chlorophyll a values were observed in Town/Crane Creek and Dutch Second Creek arms. Although highest chlorophyll a concentrations were observed during 2006 within the 2005-2009 baseline period, however, most recent data suggested that similar or even higher chlorophyll a concentrations were observed during 2011 and 2016.

Long term flow records are also obtained at USGS station 2116500 Yadkin River at Yadkin College from 1963 to 2019. The drainage area to this station is about 63% of the total drainage area of High Rock Lake. The annual mean and growing season mean discharges of 2005 and forward from this station are presented here together with their corresponding long term (1963-2019) and recent year (2005-2019) medians (Figure 4). 2008 appear to be dry among recent years while 2013 and 2018 are the wet years. Compare with long term median, relatively drier years occur more frequently in recent years.



From "Figure 1-2. High Rock Lake Water Quality Sampling Stations" in "High Rock Lake Hydrodynamic and Nutrient Response Models" (Tetra Tech 2012 / DWR 2016)

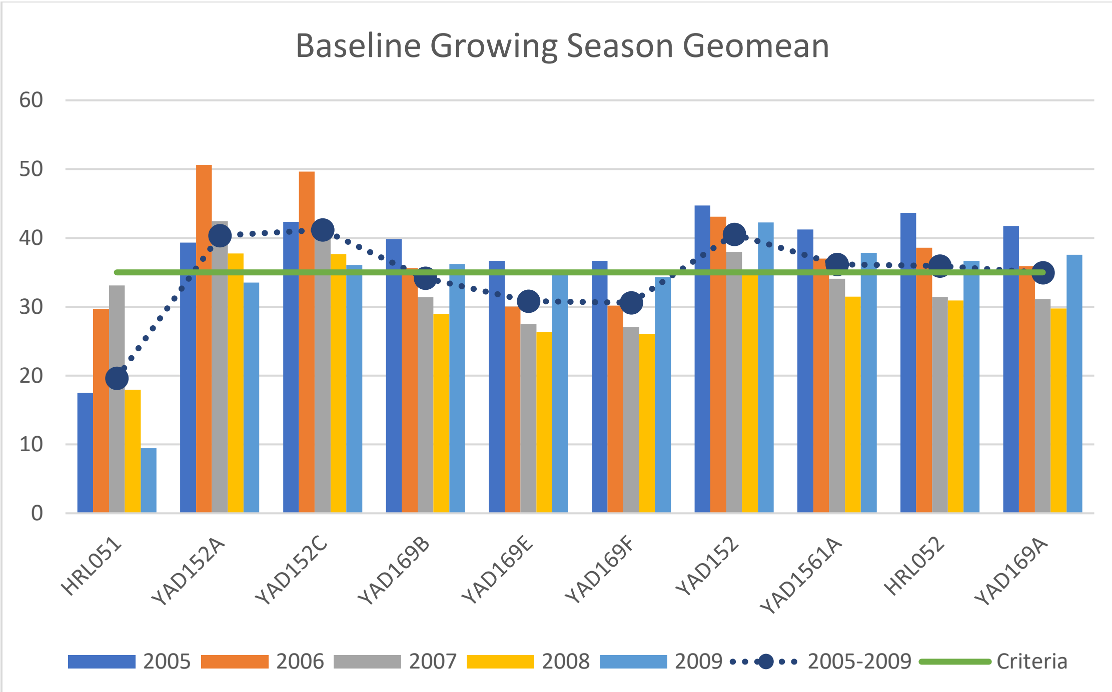


Figure 1. Model simulated chlorophyll a growing season geomeans (µg/L) at different stations and in different years in High Rock Lake.

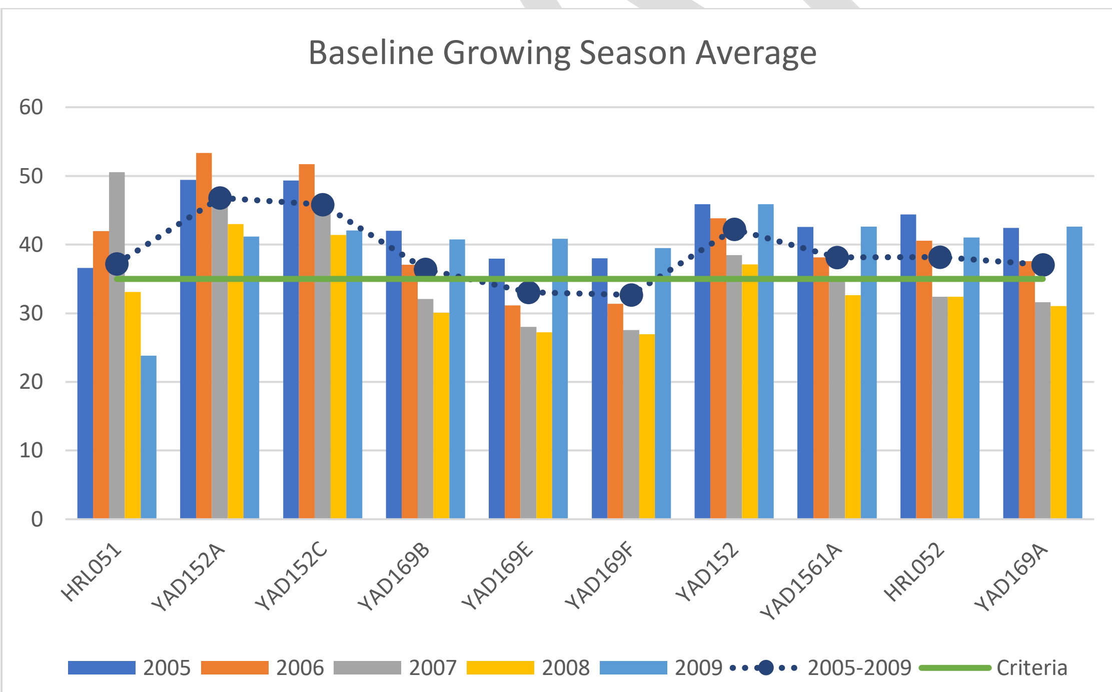


Figure 2. Model simulated chlorophyll a growing season mathematical averages (µg/L) at different stations and in different years in High Rock Lake.

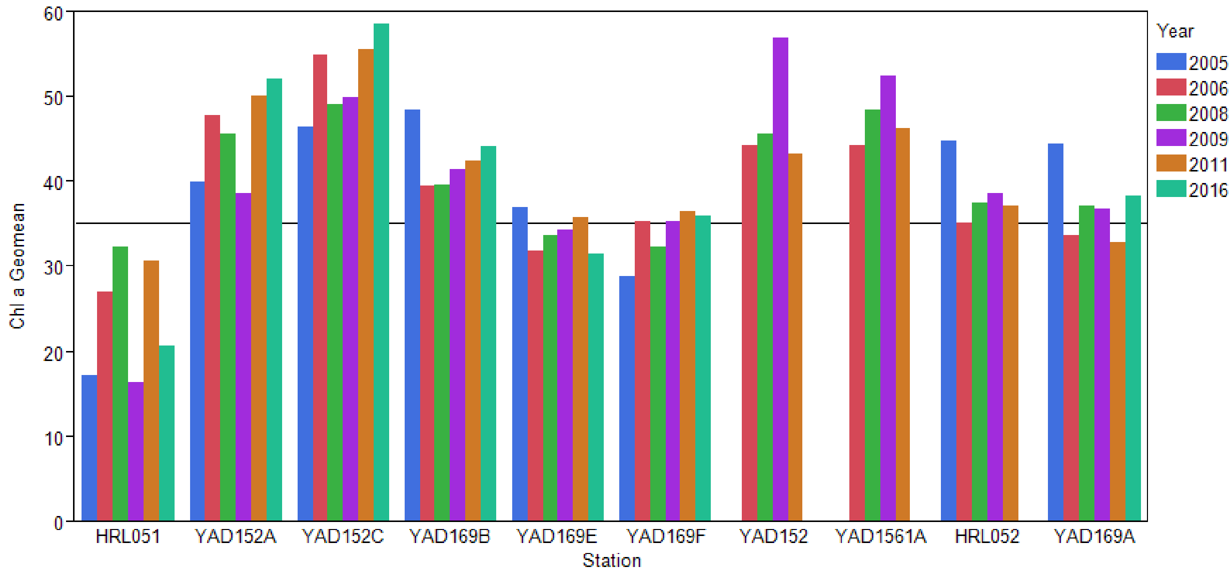
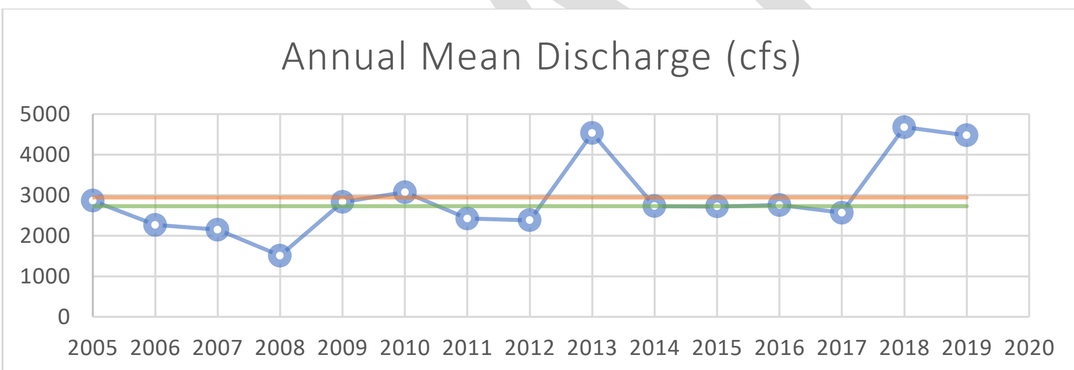


Figure 3. Field observations of chlorophyll a growing season geomeans (µg/L) at different stations and for different years (the horizontal reference line is at 35 µg/L).



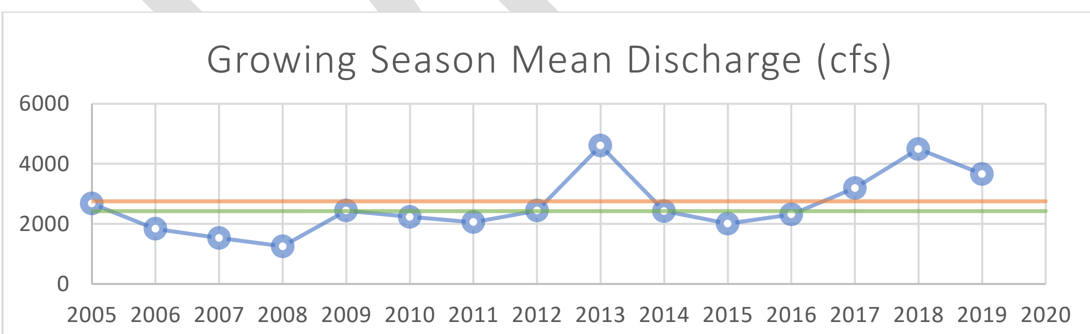


Figure 4. Annual mean and growing season (April to October) mean of river discharge at USGS station 2116500 Yadkin River at Yadkin College (dotted blue line). The orange reference lines are the long term (1963-2019) median and the green reference lines are the recent year (2005-2019) median.

Model simulated reduction curve

Both model results and field data suggest that chlorophyll a growing season geomeans appear to be relatively higher at station YAD152C in High Rock Lake, although higher values may occur in other places in some year. For the purposes of nutrient reduction goal calculation, model results at YAD152C were selected to represent critical area in High Rock Lake. Model results are analyzed at station 152C in response to nutrient reduction scenarios. Figures 4 to 8 present the reduction curves of chlorophyll a growing season geomean for each individual year. Figure 9 shows the responses of the entire 5-year (2005-2009) growing season geomean at YAD152C to different nutrient reduction levels.

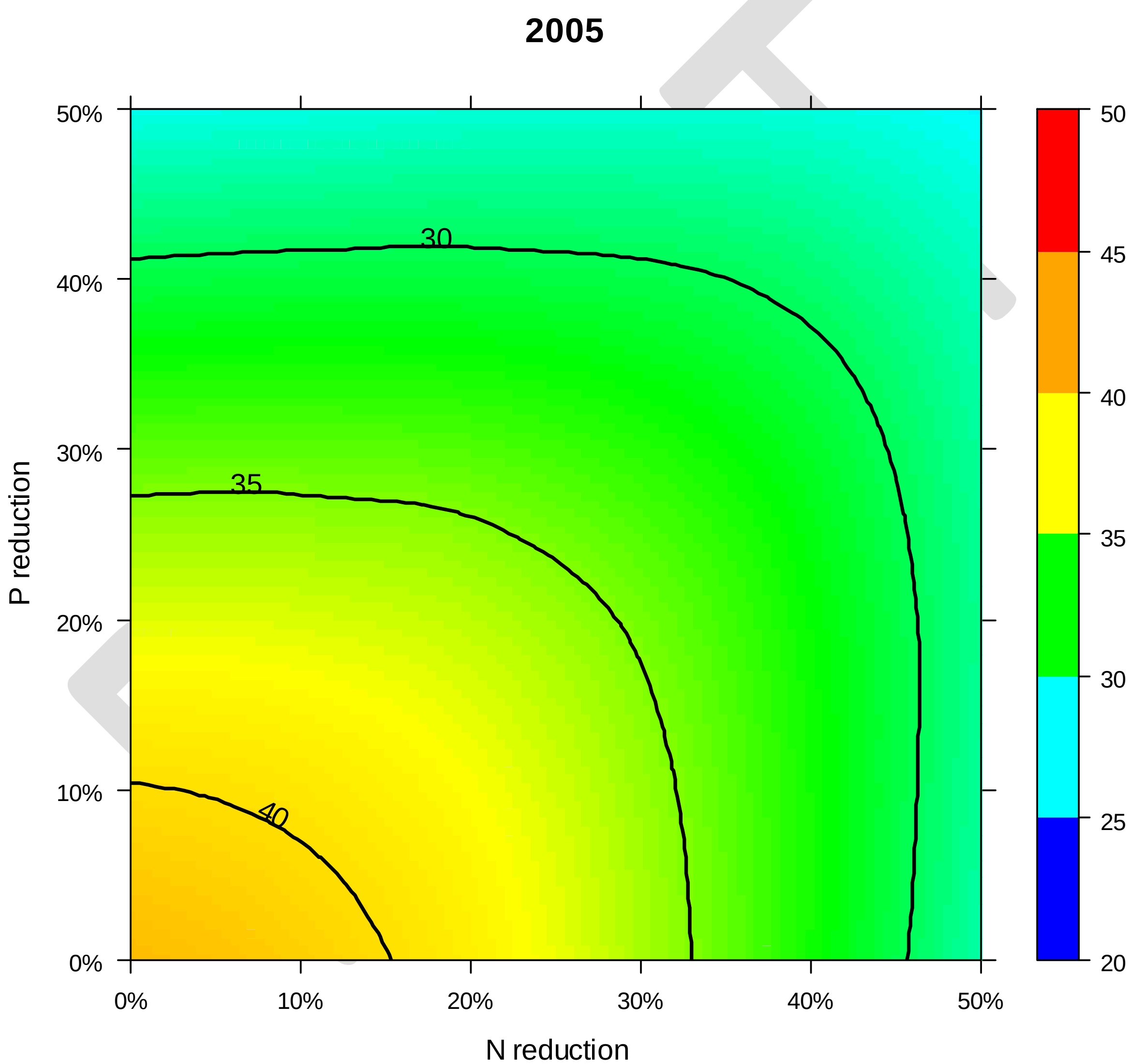


Figure 5. Model results of 2005 growing season geomean of chlorophyll a concentrations at YAD152C in response to nutrient reductions.

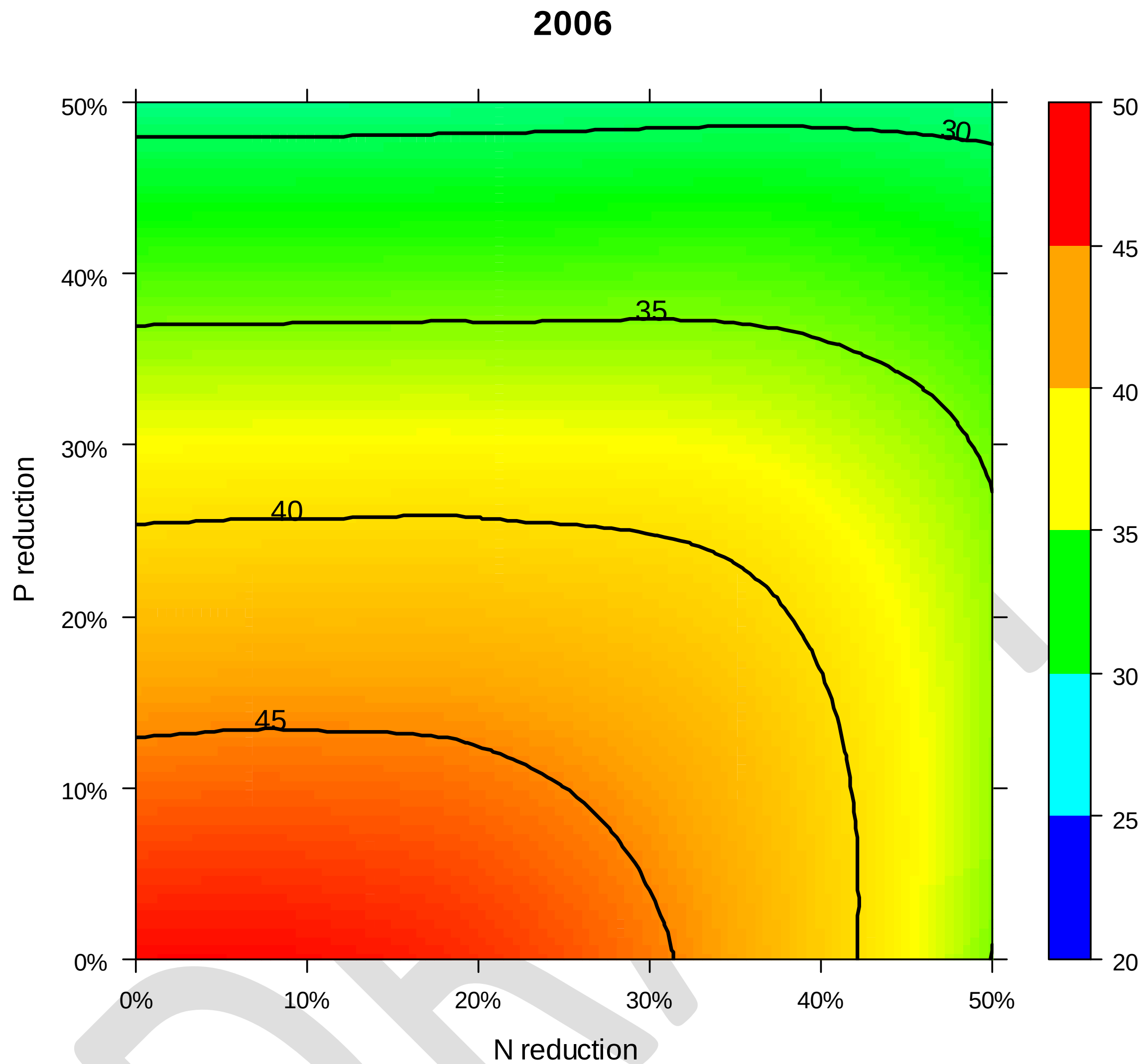


Figure 6. Model results of 2006 growing season geomean of chlorophyll a concentrations at YAD152C in response to nutrient reductions.

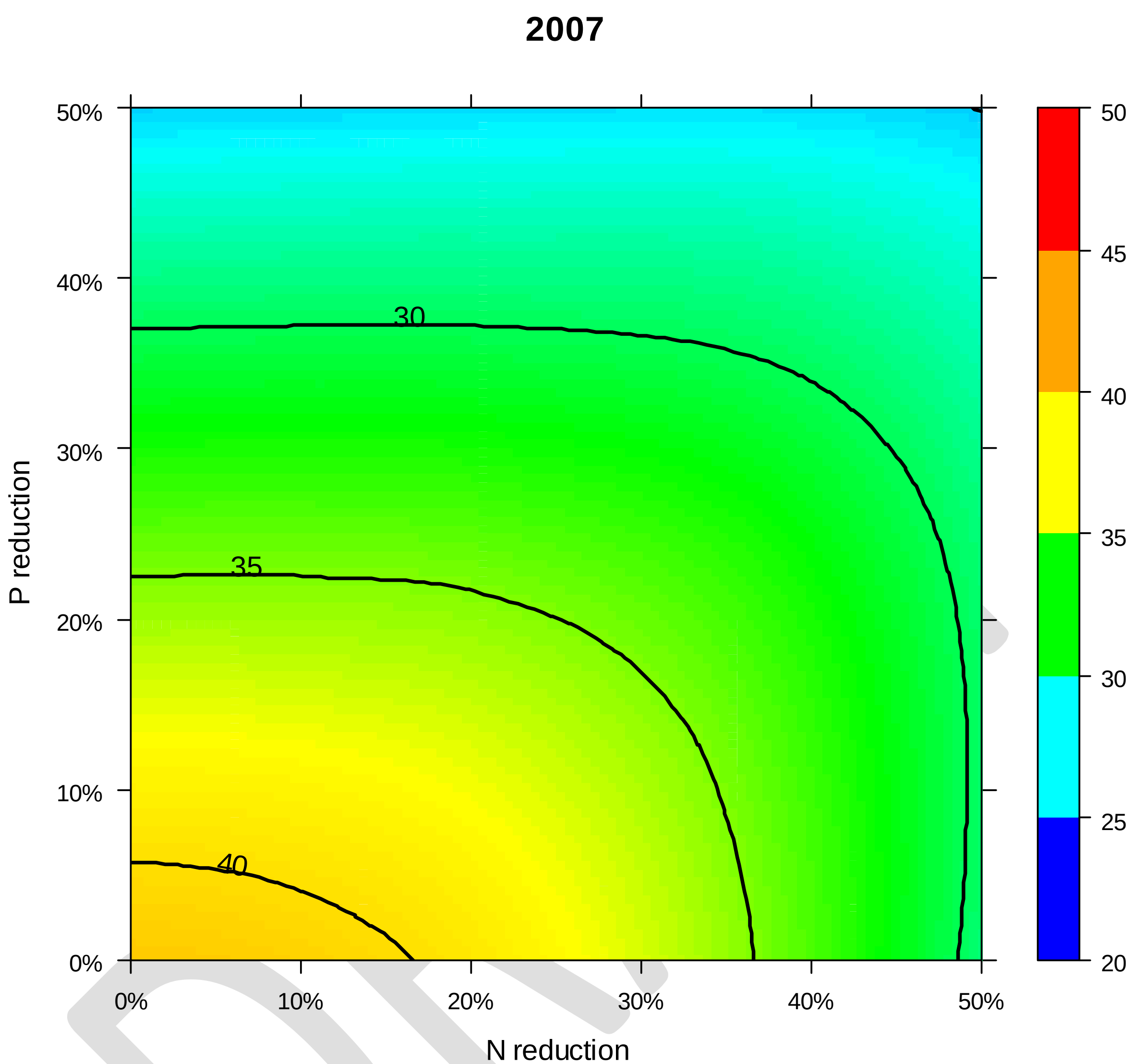


Figure 7. Model results of 2007 growing season geomean of chlorophyll a concentrations at YAD152C in response to nutrient reductions.

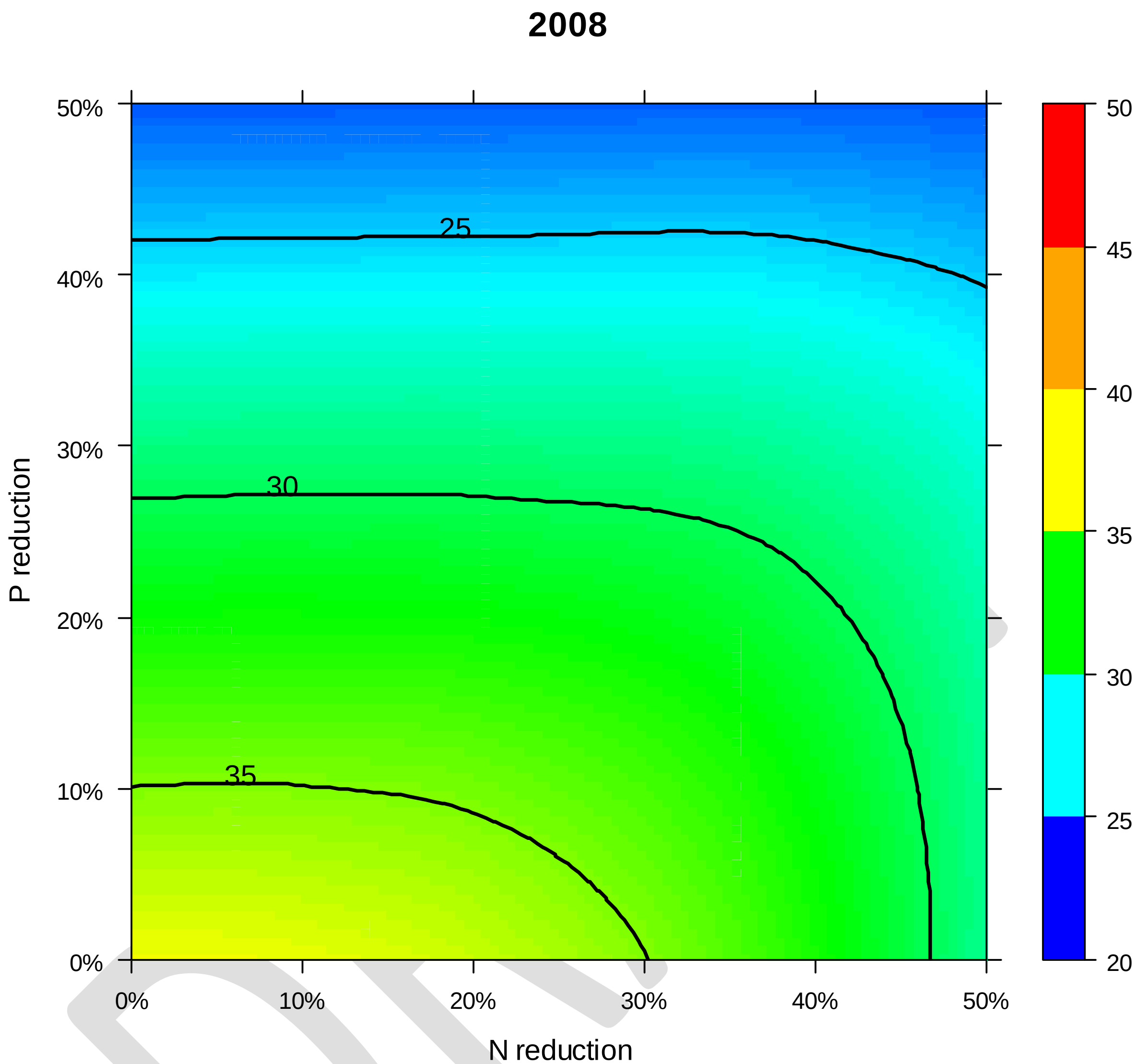


Figure 8. Model results of 2008 growing season geomean of chlorophyll a concentrations at YAD152C in response to nutrient reductions.

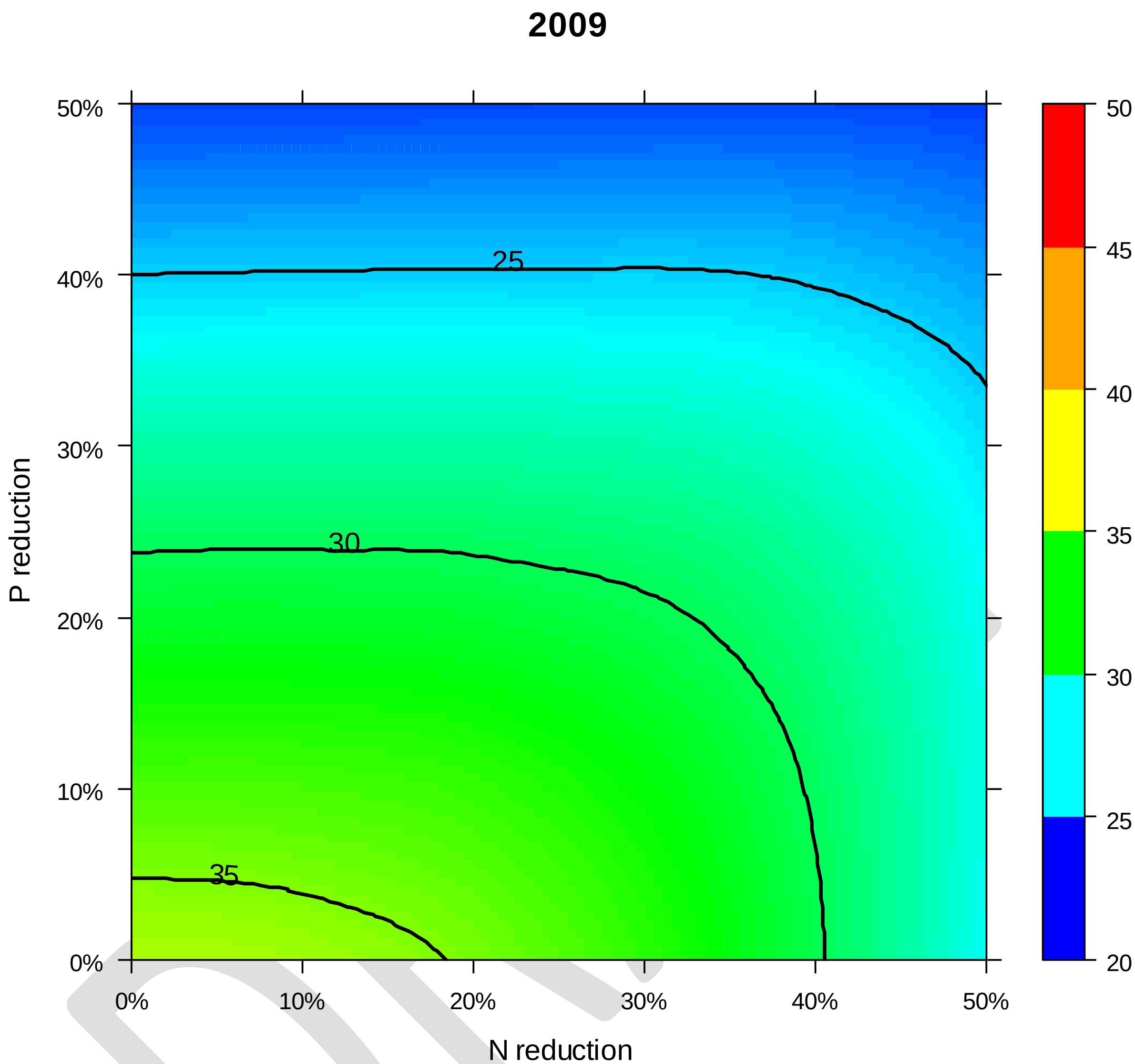


Figure 9. Model results of 2009 growing season geomean of chlorophyll a concentrations at YAD152C in response to nutrient reductions.

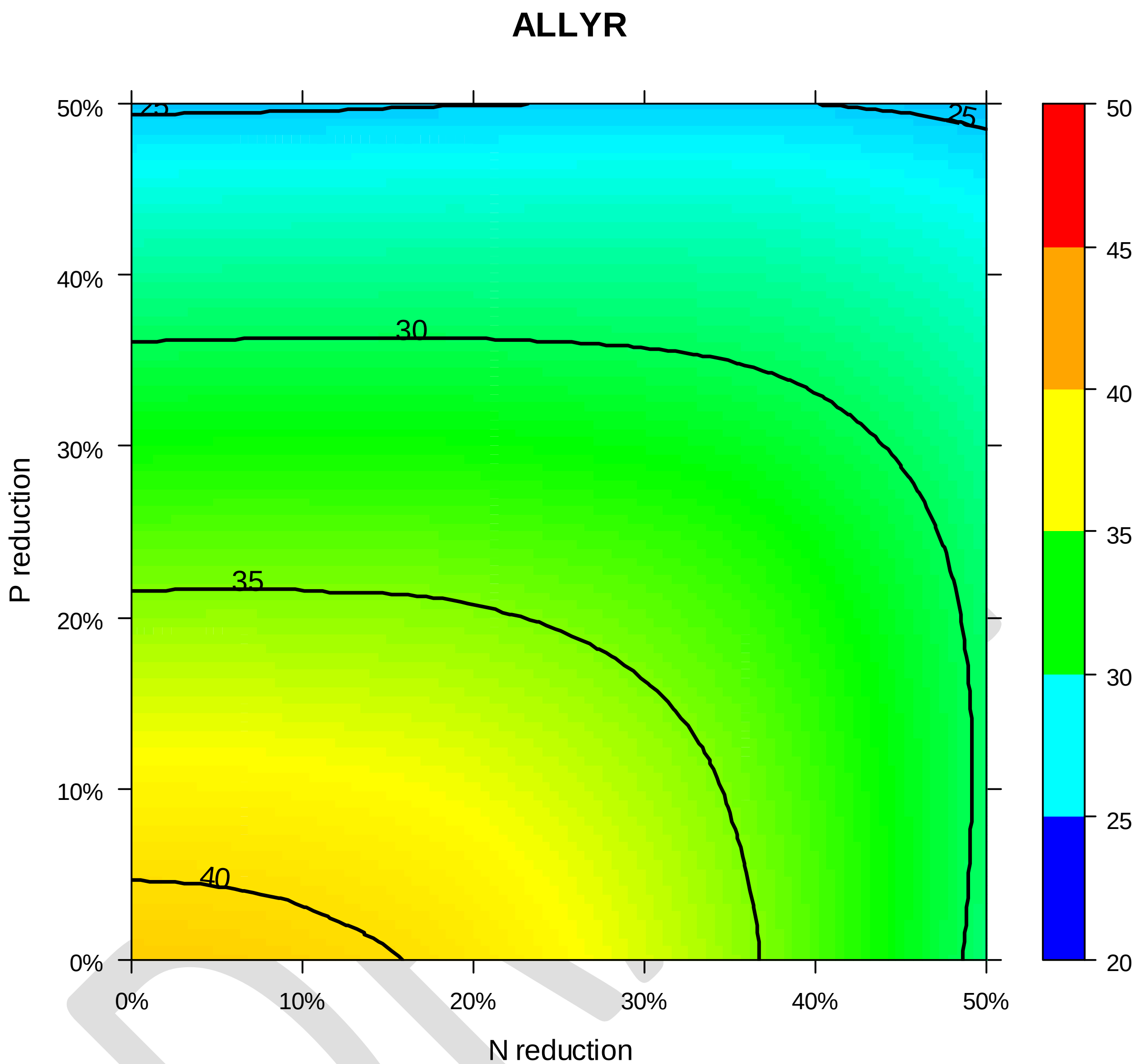


Figure 10. Model results of 5-yr growing season geomean of chlorophyll a concentrations at YAD152C in response to nutrient reductions.

Discussion

Scenario runs were conducted with High Rock Lake Model to simulate chlorophyll a responses to different levels of nutrient loading reductions. Nutrient reduction goal is the nutrient load reduction level under which water quality standard would be met in High Rock Lake. Two major factors need to be considered to calculate the nutrient loading reduction goal: the compliance point (the location where the nutrient reduction curve will be generated) and which model year will be used to calculate the chlorophyll a growing season geomean.

Compliance Point

Compliance point is the place where water quality standard compliance need to be met. It typically resides in critical area of chlorophyll a distributions. Based on data from both field observations and modeling results, station YAD152C, located in the middle part of the lake, is chosen to be the compliance point.

Year

The High Rock Lake model was run for five years: 2005 to 2009. The model simulated chlorophyll a growing season geomean is highest in 2006. However, field data show that at YAD152C chlorophyll a growing season geomean in most recent years (2011 and 2016) are as high as, if not higher than, in 2006 (Figure 3). In addition, model simulated chlorophyll a concentrations are extracted 4 times per day and evenly distributed throughout the day for the geomean calculation, while field observations are normally conducted during day time when chlorophyll a concentrations are around daily high. The geomeans estimated from model results are hence likely lower than those calculated from field data. Moreover, model uncertainty also requires a margin of safety being added into nutrient reduction goal.

Considering all the factors listed above, we propose to use 2006 model results to generate nutrient reduction curve (Figure 6). This would give an approximately 37% TP reduction goal when TN kept the same as the baseline. Model results (interpolated from the graphs) also suggest that with 37% TP reduction, chlorophyll a growing season geomean would be around 32, 35, 30, 27, 26 µg/L, for the years of 2005, 2006, 2007, 2008 and 2009, respectively.

Model Limitation

Scenario model runs conducted in this project assume model parameterization are kept the same as the ones obtained from the model calibration. Some critical model parameters such as the model representation of different phytoplankton groups and their characteristics may change as nutrient load reductions occur. Especially when N only or P only load reductions may lead to very different N:P ratios than those represented in the calibrated model. The effects of such differences on phytoplankton dynamics in High Rock Lake is beyond the model capability. Model limitations need to be considered when nutrient management strategies are being developed.

Conclusion

Our initial analysis suggests that using 2006 as the target year and YAD152C as the compliance point, an approximately 37% TP reduction (TN kept the same as the baseline) would reduce growing season geomean of Chl-a concentration at YAD152C to be at or below 35ug/L. This is slightly lower than an approximately 42% TP reduction goal suggested by using the chlorophyll a criteria of no more than 10% exceeding 40 µg/L. If TP load is kept the same as the baseline, then an approximately 50% TN reduction would be needed to set growing season geomean of Chl-a at YAD152C to be at or below 35 ug/L, by contrast, an approximately 48.5% TN reduction would be needed using the chlorophyll a criteria of no more than 10% exceeding 40 µg/L.

A combination of N/P reduction would also work, that may reduce slightly the reduction level needed for TN only or TP only approach. Considering model limitations and uncertainties especially on N only or P only approach, and the potential impact on downstream uses, a combined N/P reduction goal may work better in High Rock Lake. Figure 6 is repeated in the following as our recommended nutrient reduction curve to be used for High Rock Lake.

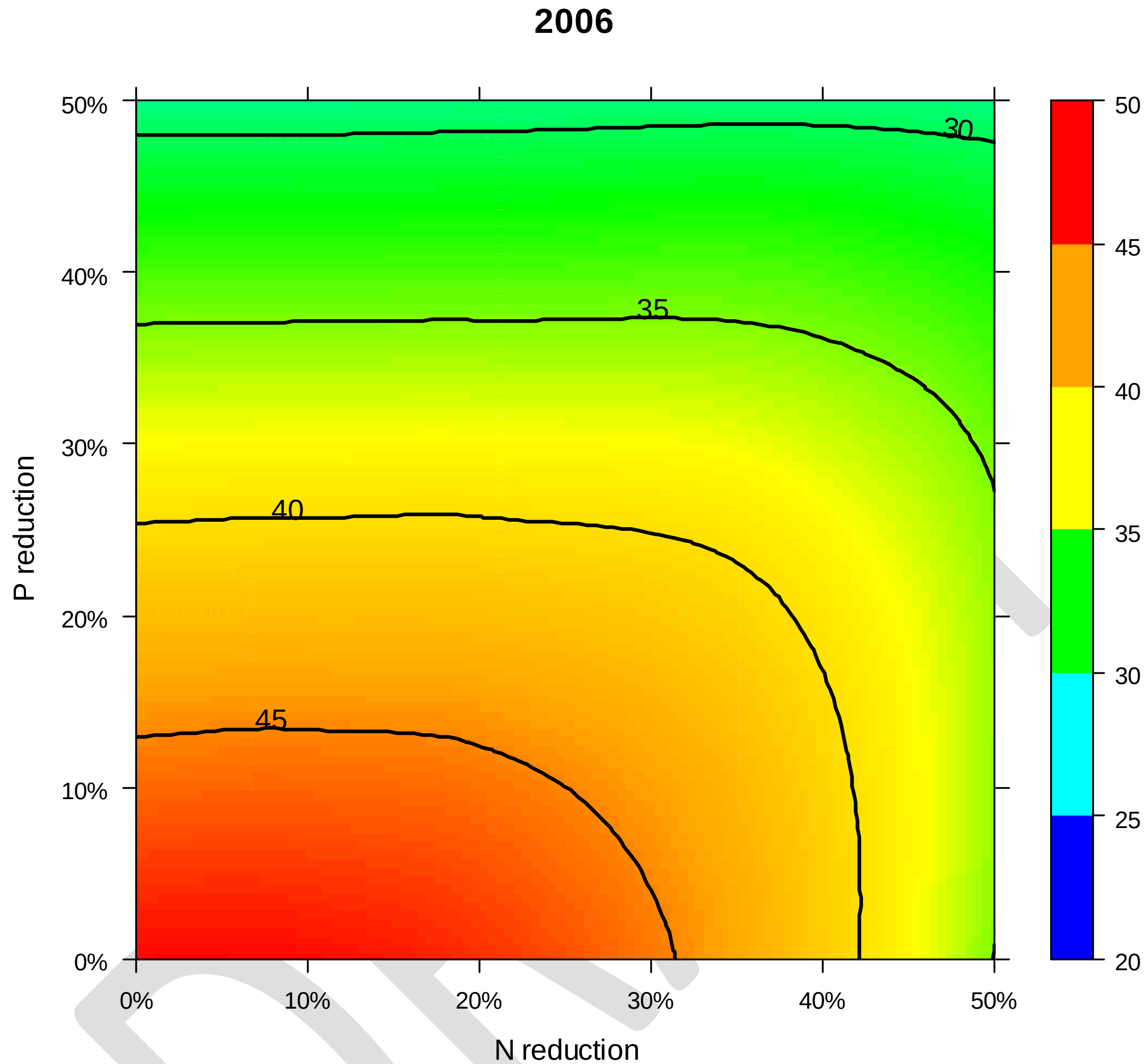


Figure 6. Model results of 2006 growing season geomean of chlorophyll a concentrations at YAD152C in response to nutrient reductions.