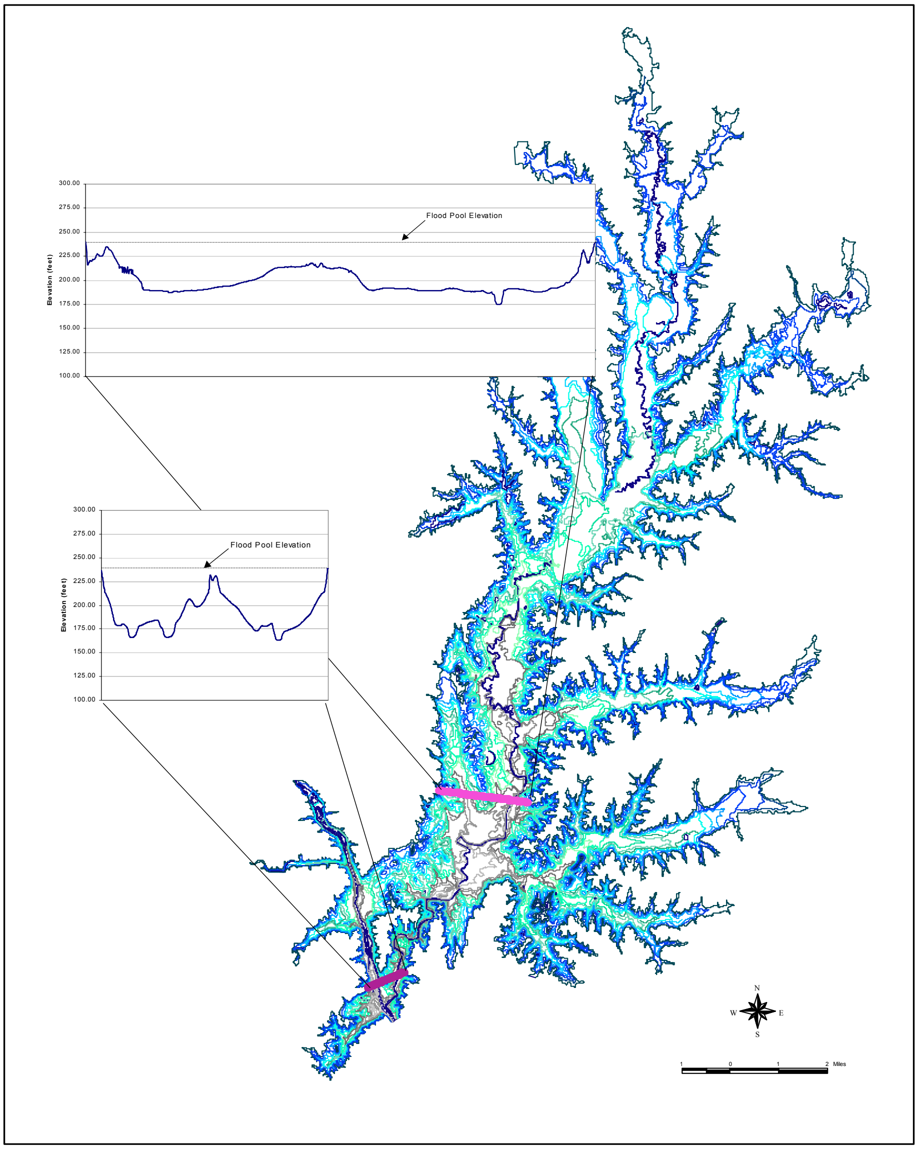
B. Everett Jordan Lake Nutrient Response Model Enhancement



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1 Introduction

This report constitutes the final deliverable under Project Number 1-1 of Tetra Tech's TMDL support contract with the North Carolina Division of Water Quality (NC DWQ). In July of 2002, Tetra Tech delivered the Jordan Lake Nutrient Response Model, developed for the Jordan Lake Project Partners, to the North Carolina Environmental Management Commission (Tetra Tech, 2002). The model is a linked system that relies on Environmental Fluid Dynamics Code (EFDC) and Water Analysis Simulation Program (WASP) model simulations. Hydrodynamic output and temperature simulation generated by EFDC (Hamrick, 1996) are input to the WASP water quality model (Ambrose et al., 1993) to account for the dynamic processes of lake mixing, seasonal changes, and nutrient cycling. The model was developed and calibrated based primarily on data collected from 1997 to 2000, and was shown to accurately predict flow of water, lake temperature profiles, pollutant concentrations, and algal response.

Also in 2002, NC DWQ placed the northern portion of the New Hope Arm of Jordan Lake on the North Carolina list of impaired waters (the §303(d) list) and identified it as a segment requiring estimation of a Total Maximum Daily Load (TMDL) to meet the water quality criterion for chlorophyll *a*. The TMDL will need to address limitations on the loading of nutrients that support excess algal growth in the lake. The Jordan Lake Nutrient Response Model was selected by NC DWQ to evaluate the impacts of several nutrient reduction scenarios and as a tool to develop the nutrient TMDL required by EPA. Additional data are now available as a result of an extensive monitoring study conducted by NC DWQ from late 2000 through 2001 to complement the initial modeling study and allow additional validation testing of the Jordan Lake Nutrient Response Model.

Section 2 of this report presents results of model extension to 2001 observations. The application to 2001 was originally intended solely as a validation test of the previous calibration. The initial 2001 validation, however, was only partially successful; that is, the model reproduced spatial and temporal trends in the observed lake data, but tended to underestimate nutrient concentrations. Observed chlorophyll *a* concentrations were also frequently underestimated.

Examination of the 2001 data suggested that several enhancements to the analysis of tributary load time series for the calibration period were desirable. In addition, internal review of the previous model calibration (Tetra Tech, 2002) suggested that re-evaluation of several kinetic parameters was desirable. As a result of these factors a constrained recalibration of the entire model was undertaken and is documented in Section 3 of this report.

The initial attempt at recalibration was submitted to NC DWQ on June 3, 2003. In this iteration, the model reproduced both spatial and temporal trends of water quality in the lake. However, the 2001 simulation did not meet the pre-specified criteria for average absolute prediction error at all monitoring stations, and tended to under-predict nutrient and algal concentrations during portions of the year.

In the June 3, 2003 submission, the lack of accuracy in predicted nutrient concentrations was attributed to uncertainty in the tributary load estimates from FLUX. This was deduced from the fact that the discrepancies are greatest in the inflow segments (New Hope Creek, Morgan Creek, Haw River), and that the nutrient speciation observed in these segments often differed markedly than that predicted from the tributary observations. Underestimation of chlorophyll *a* was in part a result of inaccuracy in the nutrient simulation, but was also thought to be due in part to the fact that observations were of uncorrected chlorophyll *a* (including pheophytin) and thus may be biased high relative to actual concentrations of chlorophyll *a* in living algae.

Following submission of the draft model validation memo, NC DWQ determined that 2001 chlorophyll *a* results were indeed "corrected" chlorophyll *a* – that is, not including a "dead" pheophytin component – and not uncorrected results as reported previously. Thus, pheophytin interference is apparently not the cause of poor fit to observed chlorophyll *a* in 2001.

At the request of NC DWQ, Tetra Tech revisited the model calibration/validation to see if results could be improved. Unfortunately, diagnosis of the sources of model uncertainty is complicated by changes in analytical laboratories and procedures, which call into question the comparability of results between years. Problems with NC DWQ analyses for chlorophyll *a* through 2000 are well documented, and caused the corrected chlorophyll *a* results to be rejected, for which reason the modeling had to use uncorrected chlorophyll *a*. The 2001 chlorophyll *a* results do not have this problem. They were, however, analyzed by a different, non-acidification method with narrow-band filters that produce only "corrected" numbers. Apparently, no inter-method comparisons have been reported by the laboratory, so we do not know the extent to which the change in method introduced a bias relative to the older results.

There are also data comparability issues for the in-lake and tributary monitoring for 2001. The NC DWQ laboratory went through a thorough internal quality control update for nutrients in 2001, and some procedures may have changed. The 2001 tributary self-monitoring was undertaken by Symalab for the Upper Cape Fear River Basin Association (UCFRBA), in contrast to self-monitoring data reported by individual wastewater treatment plants and analyzed by a variety of laboratories in earlier years. These changes in methods and laboratories may have introduced some consistent changes into reported results.

In sum, there are multiple sources of uncertainty. It is difficult to ascertain to what extent the differences in model fit between 1997-1999 and 2001 reflect actual differences in model performance, and to what extent they reflect differences in analytical methods. However, a second round of recalibration was undertaken and reported to NC DWQ on June 23, 2003 with the intention of obtaining the best fit to both the 1997-1999 and 2001 results. This resulted in a "compromise" model that essentially splits the difference between 1997-1999 and 2001 results.

Despite some inaccuracies in the simulation, the model continues to provide a good representation of nutrient response in Jordan Lake, and is an appropriate tool with which to analyze nutrient reduction scenarios. The recalibrated model continues to indicate that inorganic nitrogen is the most commonly limiting nutrient in the Upper New Hope Arm (the listed portion of the lake), while both nitrogen and phosphorus may limit algal growth in most of the remainder of the lake.

After presenting the recalibrated model results to NC DWQ and watershed stakeholders, Tetra Tech was instructed to use the model to evaluate load reduction scenarios for the lake. These scenarios address the question, "What degree of reduction in existing nutrient loads, from all sources, would be required to achieve water quality standards in the listed portions of the lake?" Results of these scenarios, which are reported in Section 4, will be used by NC DWQ to help formulate nutrient loading targets for the 303(d)-listed portion of the lake. The loading targets will in turn provide a basis for developing the Jordan Lake TMDL.

2 Extension of Input Data to 2001

The EFDC and WASP input files require extensive amounts of data to predict nutrient cycling in Jordan Lake. Meteorology, hydrology, and nutrient loading must be considered simultaneously to predict impacts on the algal community. Thus, data from several agencies were required to construct the year 2001 input files. In addition, certain data previously used for 2000 were incomplete or in draft form at the time of the earlier report. These data have also been updated.

The meteorological input files contain daily values of precipitation, wind speed and direction, and temperature obtained from the National Climatic Data Center (NCDC) station at RDU airport, along with solar radiation and atmospheric conditions reported from the NC Agnet station. These data are used by both the EFDC and WASP models.

Input flows for the four major tributaries were obtained from USGS gage stations at the Haw River near Bynum, Morgan Creek at Farrington, New Hope Creek, and Northeast Creek. Flows from the ungaged portions of the watershed were obtained by area weighting Morgan Creek flows based on drainage area, as with the 1997 through 2000 model runs (Tetra Tech, 2002). Outflows from the dam were obtained from the U.S. Army Corps of Engineers (USACOE). The USACOE also provided the initial lake level conditions, which define the initial water level grids used to initiate the EFDC model.

Pollutant loads from monitored tributaries were estimated by an integration of observed water quality and flow series using the FLUX model (see Section 2.2). For unmonitored tributary areas, the average annual loading rates documented in Tetra Tech (2002) were retained.

2.1 LAKE DATA FOR 2001

The focus of the present effort is on extending the model to 2001 conditions. During 2001, NC DWQ continued the intensive sampling effort begun in 2000, obtaining physical and water quality data at 16 stations in the lake (Figure 1). Vertical profiles were collected for temperature and DO, while chemical water quality was analyzed for photic zone composites as well as from middle and bottom depths at many stations.

Unlike the calibration period, data were collected throughout the year during 2001, not just for the growing season. However, laboratory quality control issues resulted in some of the data from the beginning of the year being lost. In addition, some of the samples, particularly from the late spring, were reported with higher than typical detection limits, as discussed in Section 2.3.

Average annual spatial patterns in the 2001 sampling results are summarized in Table 1. Note that average chlorophyll *a* concentrations reported for four of the five monitoring stations located in the upper part of the New Hope Arm (above SR 1008) exceeded the state water quality criterion of 40 µg/L.

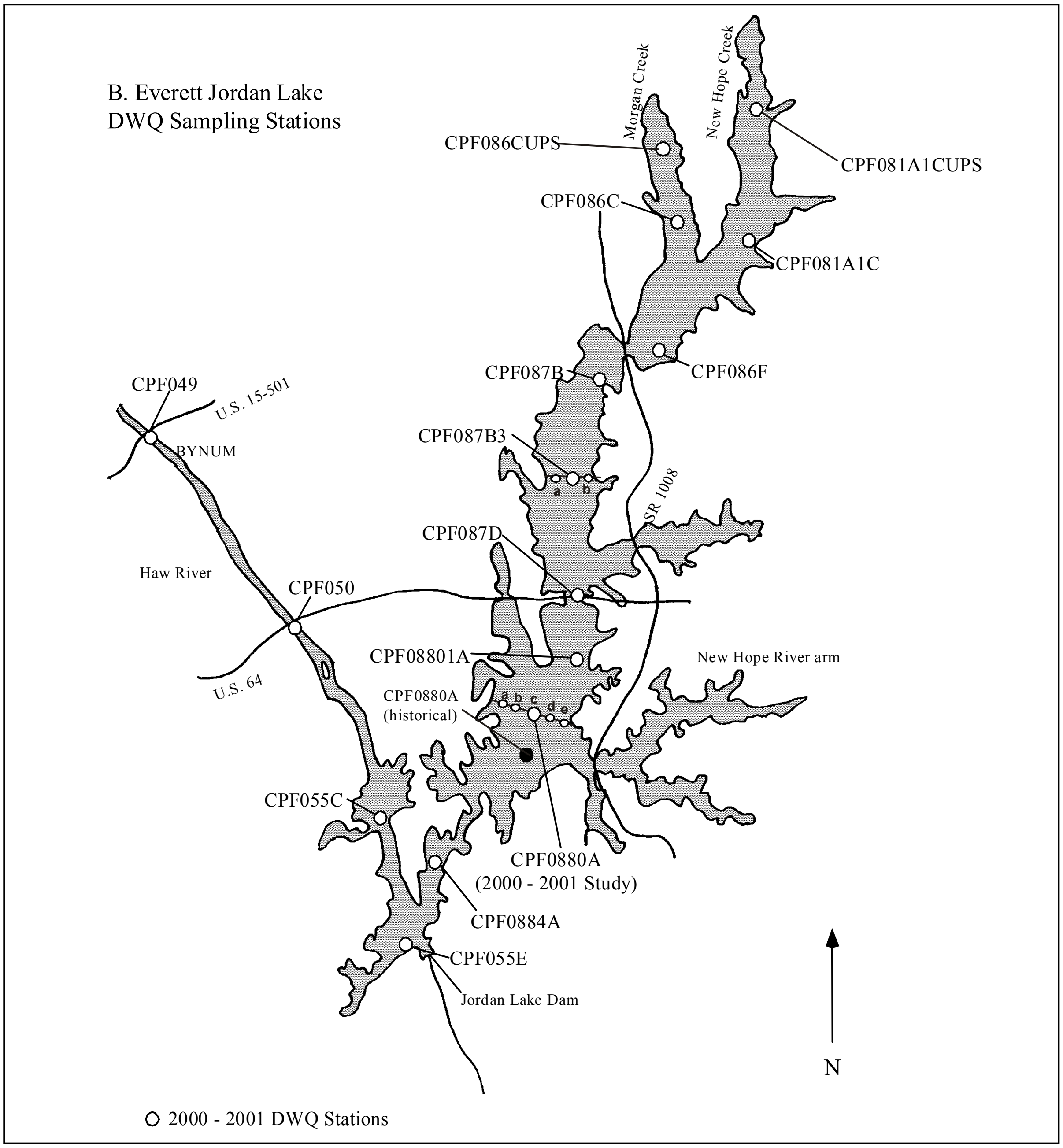


Figure 1. NC DWQ Sampling Stations in Jordan Lake

Table 1. Annual Average Results for 2001 Jordan Lake Sampling

Station		CPF050	CPF055C	CPF055E	CPF081AC	CPF081CUPS	CPF086C	CPF086CUPS	CPF086F	CPF087B	CPF087B3	CPF087D	CPF08801A	CPF0880Aa-c	CPF0884A
DO (mg/L)	Surface	10.2	11.3	10.4	10.3	10.4	10.2	10.7	9.1	8.9	8.8	8.8	9.2	9.1	9.7
	Bottom	–	3.4	2.2	6.2	7.9	5.8	8.3	4.5	4.4	3.2	3.8	3.7	3.1	2.4
Total Inorganic N (mg/L)	Surface	1.19	0.34	0.22	0.19	0.30	0.22	0.46	0.21	0.17	0.17	0.15	0.14	0.17	0.16
	Bottom	–	0.89	0.80	0.21	0.18	0.27	0.24	0.28	0.25	0.38	0.42	0.60	0.44	0.85
Total Organic N (mg/L)	Surface	0.56	0.80	0.53	0.76	0.96	0.80	0.80	0.57	0.50	0.50	0.56	0.52	0.50	0.56
	Bottom	–	0.64	0.53	0.93	1.01	0.88	0.98	0.70	0.61	0.60	0.56	0.60	0.58	0.54
Total Inorganic P (mg/L)	Surface	0.16	0.04	0.03	0.04	0.05	0.04	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.03
	Bottom	–	0.07	0.08	0.04	0.05	0.04	0.04	0.03	0.03	0.03	0.04	0.05	0.04	0.07
Total Organic P (mg/L)	Surface	0.06	0.05	0.03	0.07	0.11	0.06	0.07	0.05	0.04	0.02	0.02	0.02	0.02	0.03
	Bottom	–	0.11	0.15	0.10	0.14	0.10	0.09	0.06	0.05	0.07	0.05	0.09	0.06	0.14
Secchi Depth (m)		–	0.7	0.8	0.3	0.3	0.4	0.4	0.50	0.7	0.8	0.9	1.0	1.0	0.9
Chlorophyll *a* (corrected, µg/L)	Average	2.1	27.2	18.7	47.2	58.8	45.8	50.4	21.8	26.1	23.4	22.1	19.2	17.9	25.8
	Count	10	13	13	11	12	13	12	13	13	13	13	13	37	13
	Standard Deviation	0.7	16.2	13.0	13.7	18.6	16.2	13.5	14.7	11.2	12.6	12.3	11.1	12.4	13.3

2.2 MODIFICATIONS TO FLUX ANALYSIS OF TRIBUTARY LOADS

FLUX (Walker, 1987) integrates observed concentration data and continuous flow series to create time series of loads and is used to establish the tributary boundary loads for the Jordan Lake Nutrient Response Model. The original FLUX analyses were performed for time periods ending in 1999, then updated to 2000, and data files with interpolated loads were generated from those analyses. The current application required load series extending through 2001. To update the load series, the FLUX analyses were performed again through 2001, with a few modifications.

Stream flow and water quality data were obtained for each of the four tributaries for the 2000 – 2001 time period. Flow data were downloaded from the USGS National Water Information System (NWIS) website. Water quality data came from NC DWQ, UCFRBA Wastewater Treatment Plant (WWTP) instream compliance monitoring data, and from UCFRBA tributary storm event sampling performed during 2001. Water quality parameters reported as being less than the detection limit were set equal to half the reported detection limit. A few data were discarded that appeared to be clearly erroneous. With the exception of most of the UCFRBA storm sampling data, instantaneous flow observations were not available with the water quality data, so flow observations from the daily USGS dataset were paired with the water quality observations within the FLUX water quality sample input files. These flow and water quality data from 2000 – 2001 were appended to the original FLUX input files.

For 2000 the tributary data are quite sparse compared to other years, consisting only of the approximately monthly NC DWQ ambient samples. During 2000, the Durham City, Durham County, and the Orange Water and Sewer Authority (OWASA) WWTPs ceased doing their own downstream monitoring, which provided an important supplement to the NC DWQ ambient monitoring. This monitoring was scheduled to be taken over by UCFRBA, with the addition of storm event sampling. However, the data generated by the analytical laboratory selected by UCFRBA during 2000 were rejected due to serious quality control issues.

For 2001, the UCFRBA data passed quality assurance checks. In addition to the compliance monitoring, these included a series of "event" samples consisting of multiple samples on a single day or set of days. (These were intended to focus on storm events, but, due to the infrequent rainfall in this very dry year, many of the attempted "event" samples did not actually coincide with high runoff events.) Multiple samples generated in a single day (which often vary significantly in magnitude) had to be treated differently in the FLUX analysis of loads. The FLUX procedure adopted for Jordan Lake includes use of interpolated loads, in which the load estimate for a given day is adjusted based on the deviation from expected concentration of other observations within a plus or minus 12-day window. The event samples are associated with specific intra-day flows, but the load and concentration estimates generated by FLUX are based on daily average flows. Thus, use of the raw event data can generate misleadingly large deviations for use in the FLUX interpolation. To avoid this problem, multiple observations from a single day were converted to a flow-weighted average concentration.

FLUX analyses were performed to estimate loads of ammonia nitrogen, nitrate-plus-nitrite nitrogen (NO_X), total Kjeldahl nitrogen (TKN), and total phosphorus (TP) for each of the four tributaries using the updated input files. Two of the analyses were adjusted from the approach used in Tetra Tech (2002), as discussed subsequently. Otherwise, each analysis was performed according to the methodology used during model calibration through 1999. However, since FLUX dynamically produces a best fit using the available data, it was impossible to duplicate the previous analysis exactly when 2001 data are included. The new data added information to each analysis, resulting in a regression with slightly different parameters. The resulting interpolated loads for the time period prior to 2000 differed somewhat from the loads generated originally during model calibration. In order to maintain continuity for model validation, the original interpolated loads were retained in the data files, and the loads from the new analyses from 2000 – 2001 were appended to the original load files. The result is that the interpolated loads are identical for the time period through 1999, and the loads for 2000 – 2001 are based on analyses with only a slight modification in regression parameters.

The analyses for TP and NO_X in New Hope Creek were adjusted substantially due to an observed poor fit between modeled and observed concentrations (Figures 2 and 3).

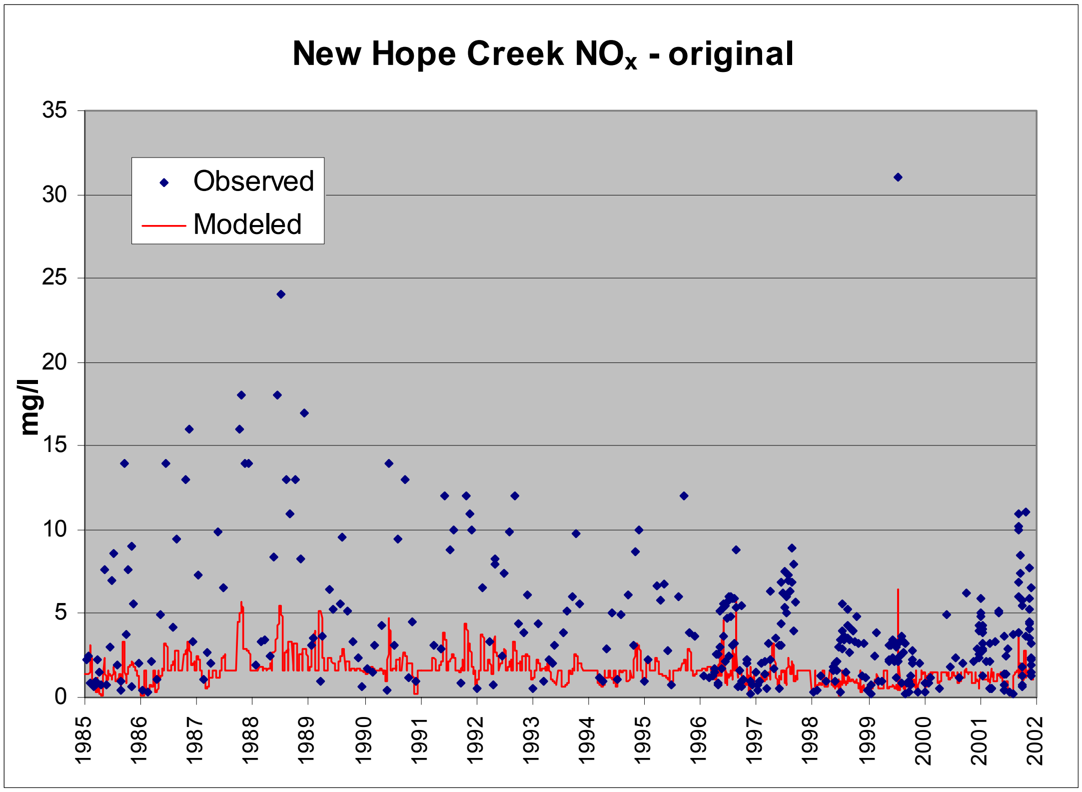


Figure 2. **Observed and Modeled NOx for New Hope Creek (Original FLUX Model)**

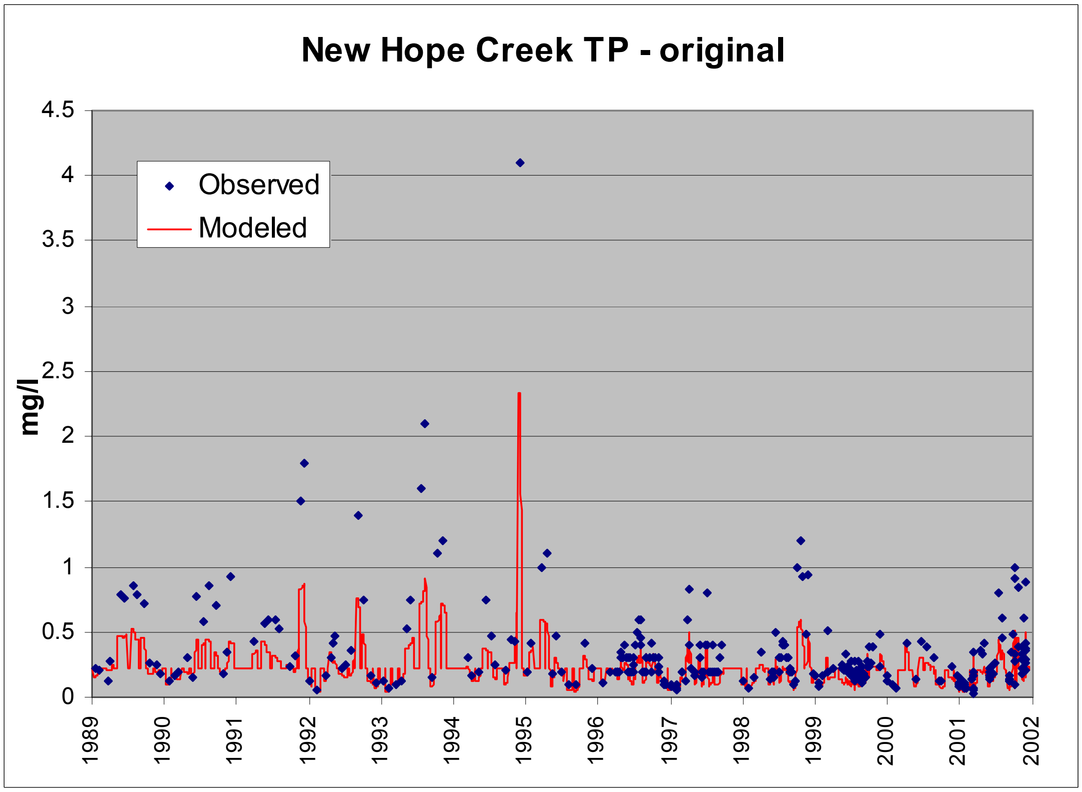


Figure 3. **Observed and Modeled TP for New Hope Creek (Original FLUX Model)**

New Hope NO_X FLUX Model

The original FLUX NO_X model for New Hope Creek was performed as follows:

- Time frame beginning 1/1/1985
- Method #4 (Regression 1)
- No stratification
- Max days for interpolation: 12

A new model was developed with a time frame beginning 1/1/1995, flow stratification at 60 hm^3/yr, seasonal stratification from June-Sept and Oct-May, and no other changes. The reduced time frame was selected based on an apparent visual change in the observed values beginning in 1995. A comparison of original and new interpolated concentrations is shown in Figure 4. FLUX statistics showed the following significance level on the fit of the regression slope for the four strata:

0 to 60 hm^3/yr, June – Sept:	<0.001
0 to 60 hm^3/yr, Oct – May:	<0.001
>60 hm^3/yr, June – Sept:	<0.001
>60 hm^3/yr, Oct – May:	0.004

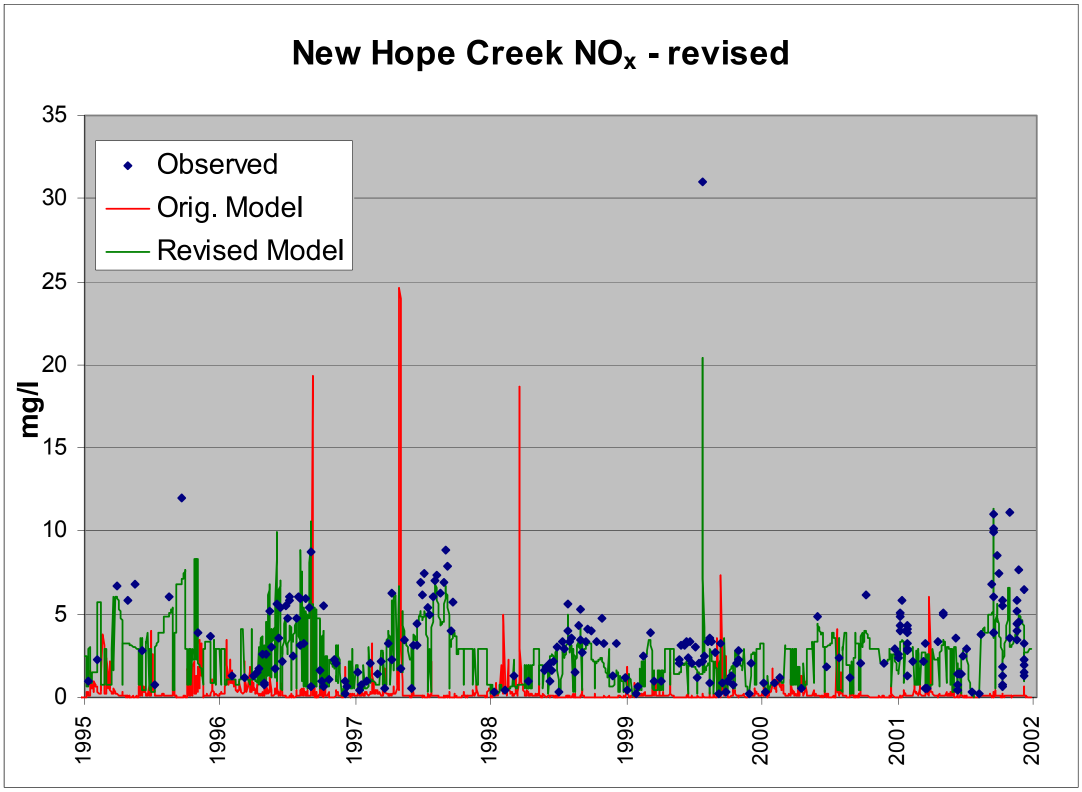


Figure 4. Revised FLUX Model for NO_X in New Hope Creek

New Hope TP FLUX Model

The original FLUX TP model for New Hope Creek was performed as follows:

- Time frame beginning 1/1/1989
- Method #4 (Regression 1)
- No stratification
- Max days for interpolation: 12

A new model was developed with flow stratification at 100 hm^3/yr, and no other changes. A comparison of original and new interpolated concentrations is shown in Figure 5. Values are shown beginning in 1997 for clarity. FLUX statistics showed the following significance level on the fit of the two strata:

0 to 100 hm^3/yr:	0.006
>100 hm^3/yr:	0.006

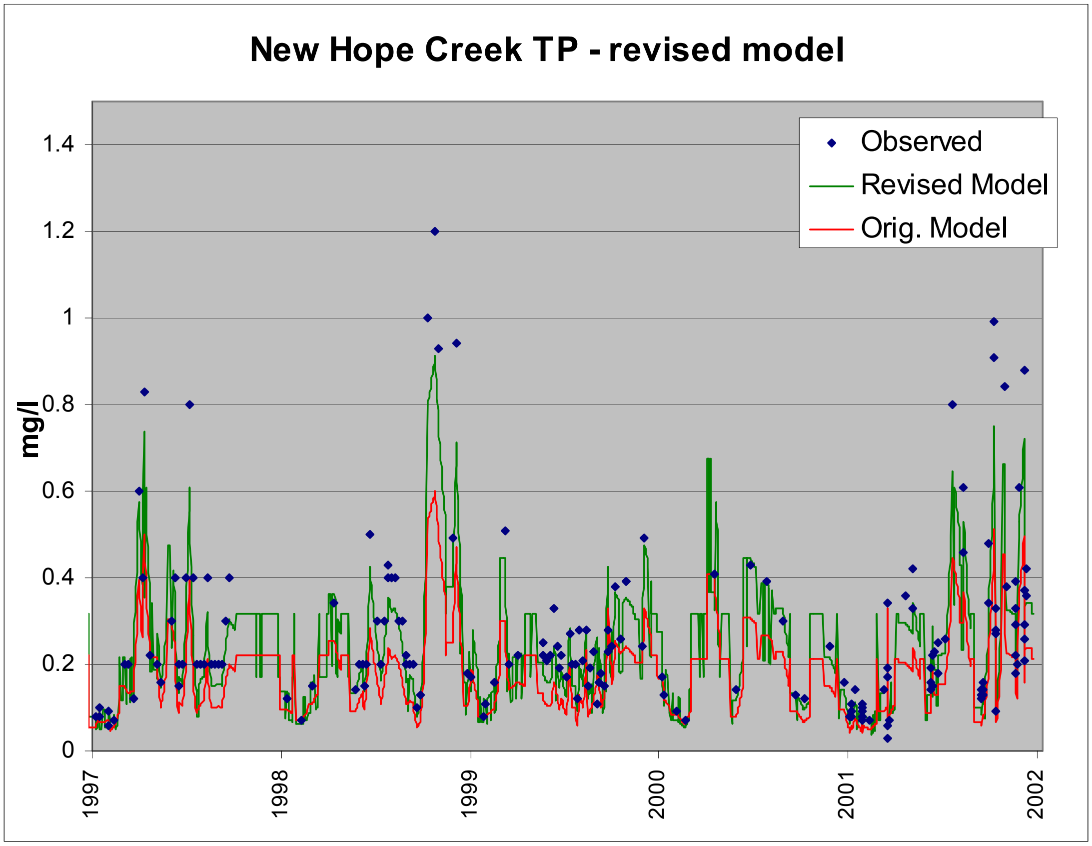


Figure 5. Revised FLUX Model for TP in New Hope Creek

Detailed diagnostics were undertaken on the FLUX tributary load estimates for 2001. This revealed potential problems in the nitrate representation for New Hope Creek and the total phosphorus representation in Northeast Creek. The FLUX load estimates used to drive the model were generated using a 12-day interpolation window. This means that each prediction is adjusted to reflect the average deviation from predictions of observations within the interpolation window. Use of the interpolated loads was previously recommended as a way to insure that smaller-scale temporal changes in tributary loads (e.g., from WWTP operations) were honored by the model. However, in 2001 this approach led to some dubious results. Figure 6 shows the interpolated and uninterpolated FLUX estimates of nitrite/nitrate load in New Hope Creek for 2001. The two series are in general agreement except during the July-August period. During this period the uninterpolated dry-weather loads amount to about 150 kg/day, while the interpolated loads decline to 10 kg/day. The 10 kg/day estimate is highly unlikely, as the Durham New Hope WWTP was discharging greater than 200 kg/day of nitrite/nitrate during this time period (although not all is expected to be transported through the system until storm flushing occurs).

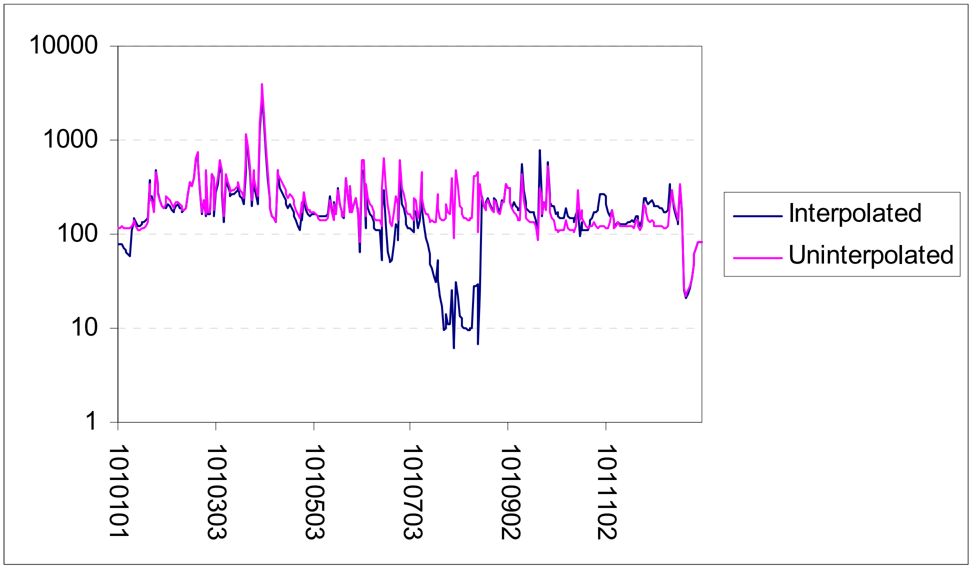


Figure 6. Interpolated and Uninterpolated FLUX Nitrite/Nitrate Load Estimates for New Hope Creek, 2001

This problem occurs due to an anomaly in the data. UCFRBA did not collect instream data between July 10 and August 26. The tributary concentration data in this period is thus dominated for interpolation by NC DWQ measurements on July 26 and August 15. Both these observations had very low values for nitrite/nitrate (0.2 and 0.3 mg/L), versus typical values (in excess of 1 mg/L). Further, NC DWQ analyses for nitrite/nitrate on these dates also appear anomalously low in Haw River, Northeast Creek, and Morgan Creek, resulting in a similar underestimation of interpolated loads during the July-August time period that appear inconsistent with wastewater treatment plant loading. This suggests that there may have been analytical issues with NC DWQ nitrite/nitrate data for these two dates. Whatever the cause, the fortuitous placement of these observations in the time series results in an apparent underestimation of nitrite/nitrate load during a critical part of the summer growing season.

All of the other FLUX nutrient series were examined in each of the tributaries, and similar problems were not evident for other nutrients, except in one case. Total Kjeldahl nitrogen results are very similar for the interpolated and uninterpolated estimates. Ammonia and total phosphorus interpolated and uninterpolated estimates differ somewhat, but likely reflect actual differences for the year. The one exception is total phosphorus in Northeast Creek. Here, some June observations were reported as non-detect, which again seems unreasonable given the presence of the Durham Triangle WWTP and results in a low bias in the interpolated values.

To address these issues, uninterpolated FLUX load results were substituted for 2001 nitrite/nitrate in all monitored tributaries and for total phosphorus in Northeast Creek. All other inputs continued to use the interpolated results.

The revised analyses were used to generate interpolated loads for 2000 – 2001 for all tributaries. The interpolated loads from the original FLUX analyses through 1999 were retained as discussed previously to maintain consistency with the previous calibration and the 2000 – 2001 results were appended to the original files. Only in the case of nitrite/nitrate in New Hope Creek was there sufficient difference in the new analysis to reject the earlier results. Therefore, the New Hope nitrite/nitrate FLUX loading file was replaced in its entirety. This represented a potentially significant change in the estimated nutrient load to the upper portion of the lake, and required a re-examination of the adequacy of the existing calibration.

2.3 DATA QUALITY ISSUES

The apparent quality of fit of the calibrated model cannot be any better than the accuracy of the data available for calibration. Unfortunately, there are serious issues regarding the accuracy of the in-lake calibration data, both for 2001 and for earlier years.

The primary data quality challenge facing the entire calibration exercise is the accuracy of NC DWQ chlorophyll *a* measurements. It is worth repeating the discussion contained in Tetra Tech (2002) in this context:

> In January of 2001, NC DWQ became aware of a variety of problems with their chlorophyll *a* monitoring data. Specifically, split samples from the Neuse MODMON project revealed that DWQ results were apparently biased high, and that "corrected" chlorophyll *a* results on occasion exhibited a very large bias. Subsequently, DWQ discovered that there were a variety of analytical problems with chlorophyll *a* data statewide, starting in/or about September 1996. Quality problems with chlorophyll *a* data, and their potential resolution, have a variety of implications for Jordan Lake modeling. It appears, however, that the problems are not fatal, and should not preclude the ability to create a calibrated nutrient response model for Jordan Lake.
>
> To understand the data quality issues, it is first necessary to summarize a few facts about chlorophyll *a* analysis. First, chlorophyll *a* may be analyzed in three major ways: by high-pressure liquid chromatography (HPLC), by spectrophotometry, and by fluorometry. Of these methods, HPLC is the most accurate, but also the most expensive and time-consuming. Fluorometry is the quickest and least expensive method of analysis, but potentially yields reasonably accurate results when the instrument is calibrated against a spectrophotometer using a known chlorophyll *a* standard.
>
> Both spectrophotometry and fluorometry are subject to interference from other pigments, including breakdown products from "dead" chlorophylls (e.g., pheophytin). The North Carolina water quality standard is based on a corrected estimate of chlorophyll *a* that is designed to estimate only the concentration associated with living cells. The correction for pheophytin *a* is used because it absorbs and fluoresces light in the same range of the spectrum as chlorophyll *a* (APHA, 1985). For fluorometric determination of chlorophyll *a* concentration, measurements are taken before and after acidification of the sample. The ratio of these two measurements (the acid ratio) is then used to calculate corrected chlorophyll *a* concentrations (without interference from pheophytin *a*). Because of this adjustment procedure, corrected values will always be less than or equal to uncorrected values depending on the amount of pheophytin *a* in each sample. Unfortunately, the acid ratio can only be calculated at the time of lab analysis: "the acid ratio is instrument specific and must be determined for each instrument at the time of calibration" (Baker et al., 1983). DWQ reports both an uncorrected, and a corrected chlorophyll *a* concentration.
>
> DWQ has relied on fluorometry for chlorophyll *a* since June 1981. (Previous to this, a spectrophotometer was used.) Problems with the fluorometric analyses began in 1996 and primarily involved choice of chlorophyll *a* standards, calculation/calibration of the acidification ratio, and computer calculation problems. Key points are summarized as (NC DWQ memo of February 26, 2001):

- DWQ chlorophyll *a* data (both uncorrected and corrected) should be useable *as is* up through August 1996.
- Data from September 1996 through January 1999 used correct standards, but had poor calibration quality assurance on the acidification ratio. For this time period, the uncorrected chlorophyll *a* results are relatively accurate, but the corrected data may be inaccurate.
- From February 1999 through January 2001, both standards and analytical procedures were in error. There are also issues with use of incorrect filters beginning in May 1999. For this time period, the corrected chlorophyll *a* results are inaccurate and cannot be recovered. DWQ went back to the original laboratory documentation to generate revised "uncorrected" chlorophyll *a* concentrations.

> In sum, for the period in which the best data are available for flow, temperature, and tributary loads, reliable corrected chlorophyll *a* data are not available. The DWQ *uncorrected* chlorophyll *a* data are useable throughout the calibration period, but may be subject to increased uncertainty in the period beginning in May 1999 due to filtration issues.

During the remainder of 2001 NC DWQ worked to address these problems, as well as other laboratory analytical data quality issues. Starting with the results for April 2001, Jordan Lake chlorophyll *a* samples were analyzed using a new analytical procedure, based on EPA Method 445.0, Revision 1.2 (Arar and Collins, 1997). Method 445 is also based on fluorometry, but uses narrow band interference filters that eliminate pheophytin interference. As implemented by DWQ, no acidification step is employed with Method 445; thus only corrected chlorophyll *a* is reported. The method is still subject to minor interferences by chlorophyll *b* and *c*. Welschmeyer (1994) found that, for typical chlorophyll *a* to chlorophyll *b* molar ratios, the new method estimated the true chlorophyll *a* concentration by 0 to 4 percent, whereas the acidification method used previously underestimated the true concentration by 6 to 23 percent. Thus, the change in methods could result in systematically higher determinations of chlorophyll *a* concentrations, but ones that should be closer to results obtained by high-pressure liquid chromatography (HPLC). Interlaboratory comparisons on unialgal cultures reported by Arar and Collins (1997) suggest that both Method 445 and standard fluorometry with pheophytin corrections have relative standard deviations on the order of 20 percent.

Corrected chlorophyll *a* measurements (only) are thus available for 2001. However, prior to 2001 only uncorrected chlorophyll *a* estimates are available. The upshot of these issues is that the model must be calibrated to uncorrected, rather than corrected chlorophyll *a*. This is undesirable, as the output of the model is chlorophyll *a* associated with living algae. It appeared, however, that this did not introduce a major problem for the original model calibration period (1997-1999), as most observations during this time interval are for the summer growing season, and corrected and uncorrected chlorophyll *a* measurements are expected to be close during these periods of low inflows and active algal growth.

In January of 2002, NC DWQ provided re-estimated values for uncorrected chlorophyll *a* results from Jordan Lake for 1996-2000. For some results, primarily in 1997, DWQ was not able to recover revised uncorrected estimates. Tetra Tech originally converted the old "corrected" values for 1997 to approximate revised uncorrected estimates using a regression equation supplied by DWQ (Jay Sauber, NC DWQ, email to Trevor Clements, Tetra Tech, May 10, 2001). Over the whole range of data (1-225 µg/L original "uncorrected" chlorophyll *a*, 1996-2000) there is a strong linear relationship ($R^2 = 77\%$) of the form:

$$\text{revised uncorrected chlorophyll } a = 2.336 + 0.562 \text{ Original corrected chlorophyll } a.$$

However, the strength of this relationship is largely due to data from 1999-2000. In contrast, data from 1996 show revised uncorrected values nearly identical to the original corrected chlorophyll *a* values. Further, the linear relationship appears relatively weak in the range of 10-40 µg/L, which is where most of the 1997 original corrected chlorophyll *a* results fall. Based on these observations, the DWQ results for "corrected" chlorophyll *a* from 1997 for which revised uncorrected values could not be calculated are assumed to be equivalent to uncorrected chlorophyll *a*. This assumption differs from that in Tetra Tech (2002), as well as earlier drafts of the current report, where the regression equation was applied to the 1997 results, resulting in an apparent underestimation of observed chlorophyll *a* concentrations.

For 2000 and 2001, NC DWQ's expanded monitoring provides chlorophyll *a* observations throughout the year, including a number of fall and winter samples. For 2000, these are uncorrected results and the assumption that uncorrected chlorophyll *a* is a good approximation of corrected chlorophyll *a* is more suspect, as pheophytin levels may increase due to senescence of algae, decay of macrophytes, and input of terrestrial chlorophylls to the lake.

Figure 7 summarizes the ratio of uncorrected to corrected chlorophyll *a* in NC DWQ samples from all stations in Jordan Lake prior to the onset of data quality problems in September 1996. As expected, the ratio tends to be close to one during the prime growing season, with larger values present during the fall and winter. In all seasons, ratios up to about two are not uncommon, and much higher ratios are occasionally observed. (The ratio scales shown in the figure are arbitrarily truncated at 5; a few outlying values as high as 15 are present.)

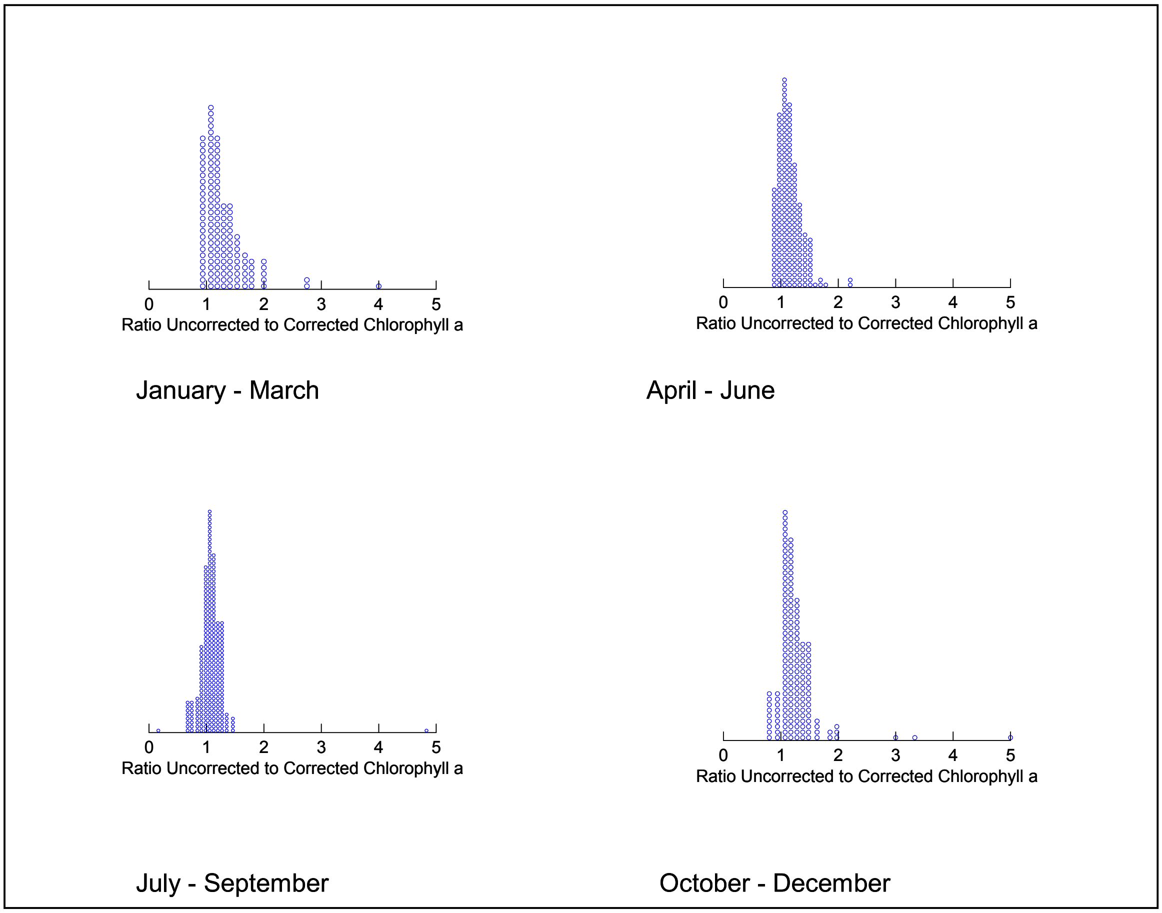


Figure 7. Ratio of Uncorrected to Corrected Chlorophyll *a* in Jordan Lake Water Quality Data Collected Prior to September 1996

The conclusion drawn from this analysis is that available uncorrected chlorophyll *a* data do not constitute a hard calibration target for model simulation of algae. Rather, they provide an approximate upper bound, and individual observations, particularly in the fall and winter, may be expected to be much higher than model predictions. For this reason, the previous (and current) model calibrations must focus on achieving an accurate representation of nutrient concentrations and speciation.

There are some other data quality issues that affect the 2001 sampling. In-lake samples (analyzed by NC DWQ) collected in April through June apparently had generally higher detection limits during 2001 than in earlier time periods. As a result, many of the nutrient results are reported for 2001 as non-detect. In addition, throughout the model application period many of the observations for inorganic phosphorus, nitrate/nitrite, and ammonia are at or below detection limits.

As discussed in Section 2.2, data quality issues are also present for the tributary monitoring that is used to set the boundary loads for WASP. In sum, there are important limitations and uncertainties in both the lake data used for calibration/validation and in the tributary data that provides external forcing to the model. These issues, which are common in any complex environmental monitoring program, do not preclude development of a calibrated nutrient response model. However, it is important to be aware of these issues during the development and interpretation of the model. For example, the unavailability of corrected chlorophyll *a* observations means that the calibration must treat chlorophyll *a* as a semi-qualitative bound and provide more emphasis on a quantitative calibration to organic nutrient concentrations. Inaccuracies and uncertainty in tributary data are particularly important because observations in the tributary segments of the lake are strongly driven by tributary concentrations, and lake model predictions in these segments cannot be any more accurate than the interpolated tributary conditions.

3 Model Recalibration and Validation

The Jordan Lake Nutrient Response Model consists of two linked models: EFDC and WASP. The EFDC code provides the simulation of hydrodynamics and water temperature on a fine spatial and temporal grid. Results of the EFDC model simulation are aggregated to a coarser spatial and temporal scale to drive the WASP water quality model. Extension to 2001 data resulted in validation of the existing EFDC calibration without modification of parameters. On the other hand, extension to 2001 resulted in some changes to the WASP calibration, primarily due to refinements in the input forcing data. As a result, 2001 was incorporated into the recalibration dataset for WASP, and 2000 used as a qualitative validation test. Validation (and, for WASP, recalibration) of the constituent models is described below.

3.1 EFDC HYDRODYNAMIC AND TEMPERATURE SIMULATIONS

The EFDC hydrodynamic model underlies the water quality model and simulates the movement of water and the thermal profile. Data on water surface elevations and temperature are used to test model performance for general mass balance and internal movement respectively. No data on flow velocities within the lake are available; however, successful representation of the temperature profile implies that the movement of water within the lake is adequately simulated.

The initial calibration of the EFDC model was based on observations from 1997 to 1999, with year 2000 data used for model refinement. Hydrodynamic model validation was conducted for 1992 to 1995 conditions. In the course of the present work, the external flow and meteorological forcings for 2000 were updated, while 2001 was added. Therefore, the performance of the model can be checked for both 2000 and 2001.

Water surface elevation simulations are compared to data reported by the USACOE for 2000 and 2001 in Figure 8. The fit for 2000 remains close despite the changes in external flows and meteorology. For 2001, the model achieves mass balance closure across the year, although the simulated water elevations differ from reported elevations during the late summer, with a maximum discrepancy less than 1 m. As discussed in Tetra Tech (2002), these discrepancies result from a combination of imprecision in the measurements of inflows and outflows and the approximations inherent in representation of the lake by the EFDC grid. Because mass balance closure over the course of the year 2001 is attained, no modifications to input/output flows were made to improve calibration; however, some error may be introduced into water quality simulations during this period. Table 2 displays the statistical results for all model simulation years, and shows that the results for 2000 and 2001 remain within the pre-specified error bounds.

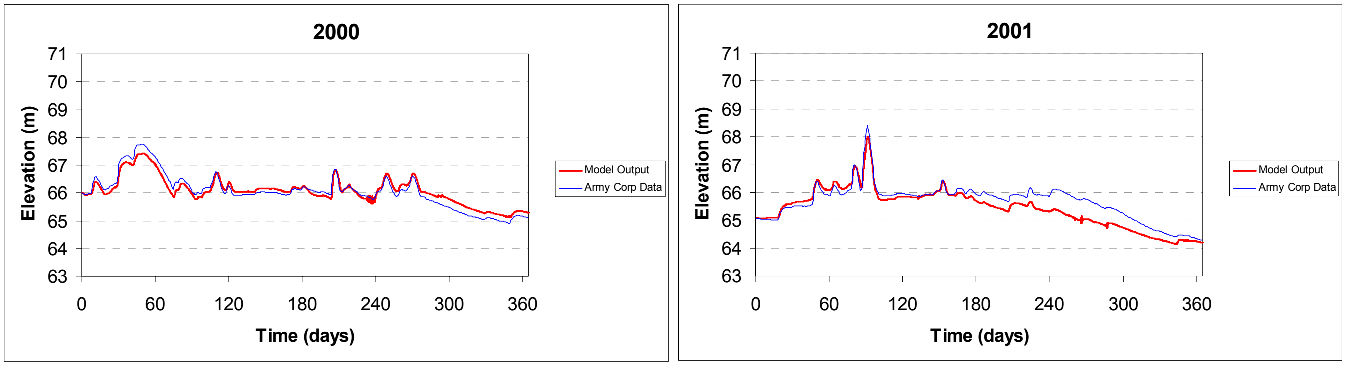


Figure 8. Water Surface Elevation Validation for 2000 – 2001

Table 2. Calibration Statistics for Hydrologic Calibration of the EFDC Model

	Average Absolute Error in Elevation (m)	99th Percentile Absolute Error in Elevation (m)
Criterion	***< 0.50***	***< 1.00***
1992	0.13	0.33
1993	0.37	0.85
1994	0.09	0.35
1995	0.18	0.63
1997	0.48	0.86
1998	0.19	0.64
1999	0.14	0.58
2000	0.17	0.36
2001	0.28	0.76

The EFDC temperature simulation also provides satisfactory results for 2000 and 2001. Figure 9 compares the simulated and observed water temperatures (multiple observed values are shown when more than one observation intersects one of the four EFDC vertical layers). The error statistics for all years of simulation are reported in Table 3. In general, results from 2000 and 2001 are similar to other years, with small discrepancies due to uncertainties in tributary inflow temperatures and inaccuracies in the simulation of flows. While there is some discrepancy in results for individual years and locations, the annual average errors all fall within the desired bounds of plus or minus 2° C.

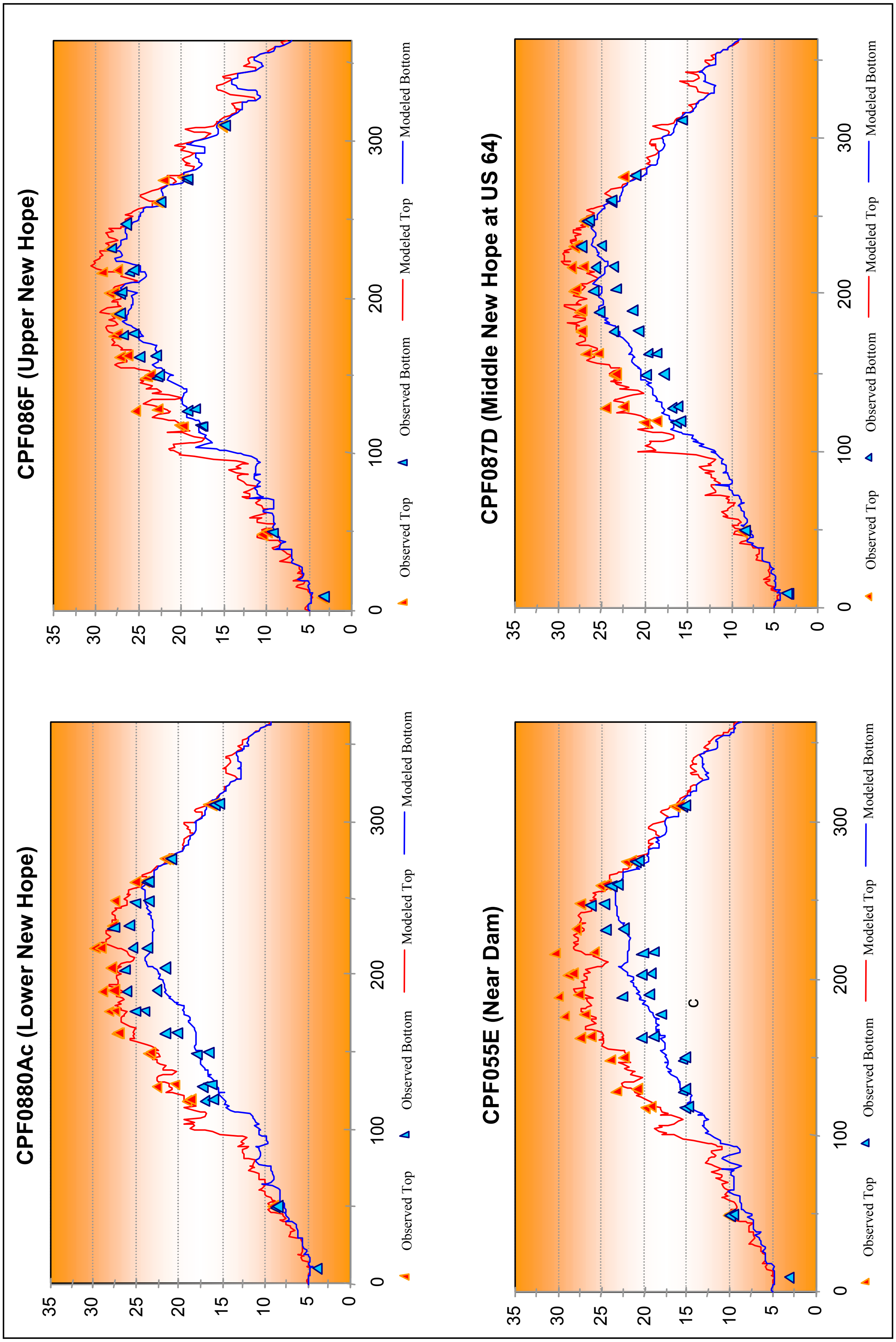


Figure 9. Jordan Lake Temperate Validation, 2001 (˚ C)

Table 3. Annual Average Error in Temperature Prediction (Predicted Minus Observed in Degrees Celsius)

Year	Count	CPF0880A		CPF055E		CPF086F		CPF087D	
		Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Calibration Period									
1997	5-10	-0.14	-1.30	-1.31	-1.82	+0.03	-1.15	+0.07	-0.55
1998	2-5	+0.55	-1.23	-0.21	-0.17	+1.07	-0.87	+0.51	+0.32
1999	6	+1.36	+0.80	+1.06	+0.07	+0.97	-0.31	+1.57	+1.31
2000	13	+0.62	+0.87	+0.99	+0.54	-0.11	+0.54	+0.04	-0.96
Validation Period									
1992	0-1	–	–	-1.54	-1.35	+0.18	+1.33	-0.27	-1.77
1993	1-5	-0.58	+2.52	-0.65	+0.08	+0.06	-1.24	+0.35	+1.27
1994	1-6	-1.06	+2.51	-0.58	+0.05	-0.23	-1.09	-0.25	-0.59
1995	0-4	–	–	-1.46	-2.34	+0.06	-2.11	+0.30	-1.31
2001	15	-0.11	-0.54	-0.07	+0.56	+0.72	-0.28	+0.56	+1.19

Notes: Negative values indicate under-prediction by model.
Shaded cells have less than two observations.

3.2 WASP RECALIBRATION AND VALIDATION

3.2.1 Recalibration Approach

After completion of the EFDC model runs, the output was aggregated in space and time to provide the flow/transport and water temperature series used by the WASP model. The external hydrodynamic files generated for 2001 and 2000 (revised) were concatenated to the 1997 through 1999 files to provide a continuous simulation.

In addition to the hydrodynamic and water temperature input, WASP also requires external forcing series for nutrients and pollutants delivered to each model segment. Tributary loads were summarized using the FLUX model, as described in Section 2, to construct the WASP input files. The light attenuation time series for 2001 was constructed from Secchi depth and light penetration data observed by NC DWQ.

As noted in Section 2, the FLUX application through 2001 resulted in significant changes in the estimated loading time series for nitrite/nitrate nitrogen in New Hope Creek. Because New Hope Creek is a major load source to the upper part of Jordan Lake, the changes to the nitrite/nitrate load series necessitated recalibration of the water quality model. In addition, several other issues were raised during internal review of the previous modeling effort:

- An inexact conversion factor was used to compute total daily insolation for 1997-1999 in the previous modeling effort. Because the error introduced is a constant factor and algal light limitation depends on the product of insolation and the parameter IS1, this can be remedied without perturbing the previous calibration by altering the value of IS1.

- The previous calibration relied on an *ad hoc* redistribution among organic and inorganic nitrogen forms, applied to the FLUX time series at the inflow segments. This approach was judged to be sub-optimal, as it bypasses the parametric representation of water quality in the WASP model. Therefore, a revised calibration was attempted without any alteration of nitrogen species distribution in the external load time series. This recalibration focused on specification of settling rates and dissolved fraction of nutrients in the input segments of the lake.
- The maximum algal growth rate and the Michaelis-Menton nutrient half-saturation constants in the previous model calibration differed significantly from values most commonly reported in the literature. Both the growth rate and the half-saturation constant for inorganic nitrogen, determined through optimization, were higher than literature values. As the maximum growth rate and half-saturation constant for nitrogen interact inversely, the previous results may be an artifact of the optimization process, and similar results for nutrient-limiting conditions could be obtained with lower values of both parameters more in keeping with values reported in the literature. However, the algal respiration rate must also be adjusted to maintain the previous fit for non-nutrient-limiting conditions.

The majority of the model parameters, other than those discussed above, were left at the previously determined values,

Thus, the entire simulation period was initially subjected to limited recalibration, with 2001 reserved as a validation period. Results for 2000 were analyzed and presented graphically, but not included in the calibration/validation statistics because the very limited tributary data available for this year is expected to reduce the accuracy of simulation results.

In the second round of recalibration, extensive efforts were pursued to improve model calibration to the 1997-1999 time period while better fitting the 2001 results using a consistent set of parameters determined through both automated and manual calibration. Some small improvements were achieved, yielding a slightly better fit to 2001 without significantly degrading the 1997-1999 calibration. However, after considerable effort it was concluded that it is not possible to find a single set of parameters that both maintains the excellent fit to 1997-1999 observations while also fitting the 2001 results within the desired tolerances. In general, the best fit to the 1997-1999 data continues to underestimate nutrient and chlorophyll *a* results for 2001. This reflects the uncertainty in tributary load estimates, coupled with potential biases introduced by changes in analytical methods.

Neither the 1997-1999 or 2001 data can be taken as a true, unbiased baseline. There are, however, some reasons to prefer the 2001 data as these were obtained after improvements in quality control at the NC DWQ laboratory, cover a greater span of the year than just the summer growing season, and possess a relatively high density of tributary samples. On the other hand, 2001 is only a single year, and results for any single year could be affected by factors not accounted for in the model, such as atypical algal species composition. In addition, the hydraulic simulation for any year has some inherent inaccuracies that are best addressed by averaging over multiple years.

Given these concerns, it appeared that the best approach was to undertake a joint calibration to 1997-1999 and 2001, seeking a good compromise fit to both sets of data. This has the disadvantage of removing 2001 as an independent validation test. However, the 2000 lake data can still be used for validation.

Results of the WASP application are presented in terms of WASP model segments, as in Tetra Tech (2002). The numbering of the surface segments of the lake is shown in Figure 10.

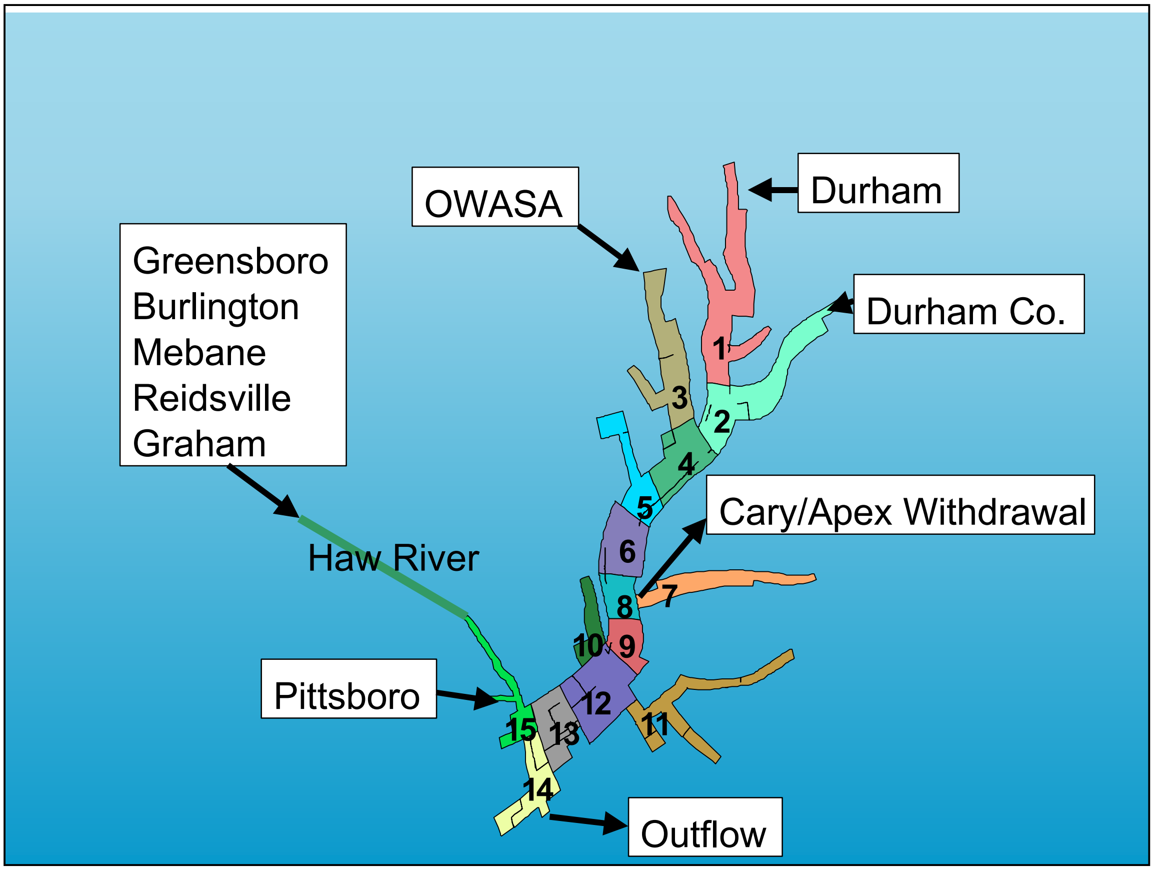


Figure 10. WASP Model Surface Segments for Jordan Lake (outline at flood pool elevation)

3.2.2 Modifications to WASP Model

During the course of the sensitivity analysis, a shortcoming in the original WASP model was detected. Under high nutrient and light availability and low settling rates, the algal simulation may become unstable, oscillating between high growth and zero growth in alternate time steps and introducing an accumulating error into the simulation of nutrients produced by algal respiration and death. To address this problem a modification was made to the code so that algal growth is suppressed at chlorophyll *a* concentrations in excess of 100 µg/L (the selection of the cutoff value is arbitrary as long as it is set above the range of observed concentrations).

3.2.3 WASP Recalibration

Recalibration of the model was accomplished with aid of the Parameter ESTimation (PEST) parameter estimation software (Watermark Numerical Computing, 2002), which helps to automate the process of varying multiple parameters simultaneously. However, final recalibration adjustments were made manually.

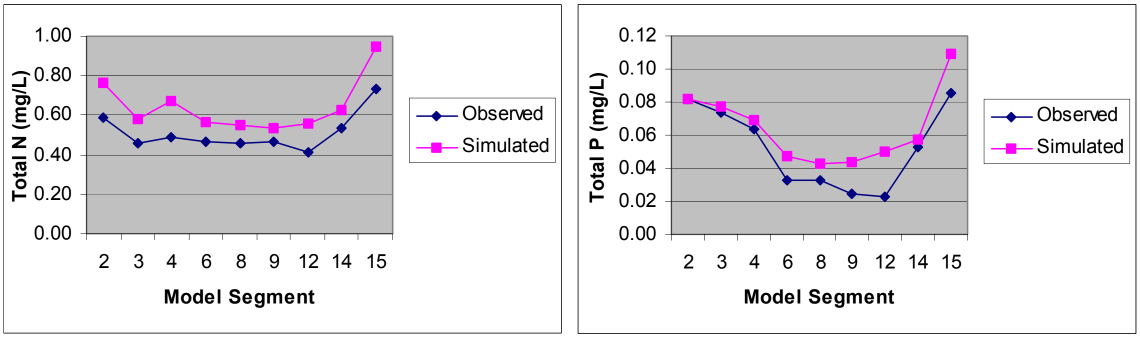
The initial recalibration was done on the 1997-1999 observations, with 2001 used for validation. As the validation results were not entirely satisfactory, a recalibration across the full time period was done to create a compromise model, as noted above. Recalibration to achieve the compromise model explored many different parameters, but ended with adjustments to a relatively small number of parameters. The major changes involved in achieving a reasonable compromise model were as follows:

- Dispersive exchange coefficients were increased significantly among Segments 1 through 4.

- Organic matter settling velocities were modified in Segments 13 and 14.
- Algal settling velocities were adjusted; most notably settling velocities were decreased in Segments 1 and 2.
- The seasonal pattern of the assumed sediment ammonia generation time series (FNH4) was altered.
- Fractions of dead/respired algae going to the organic nutrient pool rather than directly to inorganic forms were reduced for both nitrogen (fon) and phosphorus (fop). Fon was reduced from 0.95 to 0.75 and fop was reduced from 0.95 to 0.60.
- The temperature coefficient on organic phosphorus decay was increased from 1.08 to 1.10.

Following these changes, the model truly does represent a compromise between fit to 1997-1999 and 2001 conditions. This can be seen in the spatial pattern of total nitrogen and total phosphorus, shown in Figure 11. The simulated and observed results are relatively close, but the model over-predicts 1997-1999 results, while under-predicting 2001 results. In contrast, the original model calibration provided a close fit to 1997-1999 concentrations, but concentrations observed in 2001 were significantly under-predicted.

1997-1999 Results



2001 Results

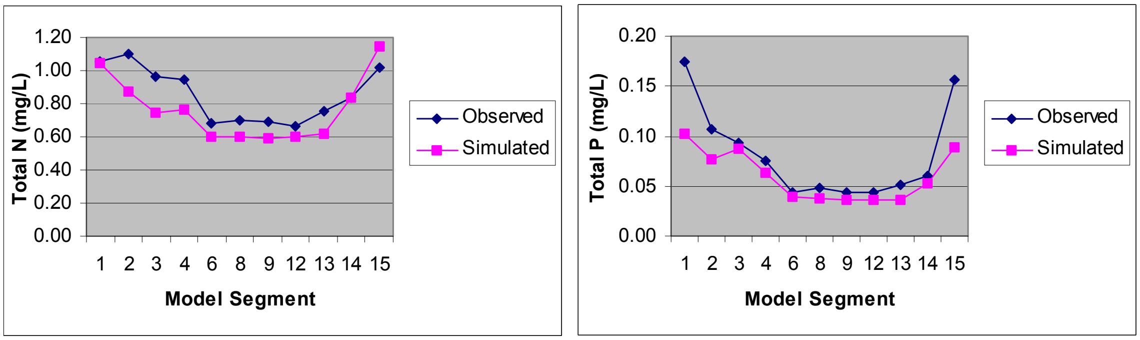


Figure 11. Summary Comparison of Predicted versus Observed Total Nitrogen and Total Phosphorus for Compromise Model Fit to 1997-1999 and 2001 Observations in Lake Jordan

The revised set of water quality model parameters is summarized in Tables 4 and 5, which are modified versions of Tables 3-14 and 3-15 in Tetra Tech (2002). Modifications made during the re-calibration are described in the notes column of the tables. The majority of the parameters have not changed. The most significant changes are in organic nutrient settling rates. Changes in settling in the upper New Hope Arm were required to adjust for the changes in the FLUX input series. In addition, segments were broken out at a finer scale (e.g., specifying Segment 4 separately) for the recalibration effort, while some improvements in model fit were realized by adjusting settling rates in the Haw Arm in accompaniment to recalibration of the organic nutrient mineralization rates. It should be noted that the determination of the settling rates is conditional on assumptions for the dissolved fraction of each component, as settling only acts on the sorbed (non-dissolved) fraction.

As noted above, one objective of the recalibration was to use default Michaelis-Menton constants for algal nutrient requirements while adjusting algal saturated growth rates into the range recommended in the literature. This was compensated for by reducing the algal respiration rate.

In addition to parameter adjustments, one new parameter was added to the model: a lower-bound cutoff for algal growth. The distribution version of WASP models the saturated algal growth rate via a rate applicable at 20° Celsius and an Arrhenius temperature adjustment. However, the growth of most algal species is expected to stop as temperatures approach freezing. Therefore, a lower bound temperature for active algal growth was added as a specification to the model, using the approach instituted in the HSPF model (Bicknell et al., 1996).

Table 4. Revised Parameter Values for Jordan Lake WASP/EUTRO Model – Dispersion and Settling Parameters

Parameter	Value	Notes
Horizontal Dispersion Coefficient (m^2/s)	0.002 to 20	Multiplied by interfacial area divided by characteristic length to obtain dispersion. Shows range; high values assigned to Segments 1-4.
Vertical Dispersion Coefficient (m^2/s)	6.4 · 10-5	Optimized. Thomann and Mueller (1987) cite a range of 10-6 to 10-1.
Porewater Exchange Coefficient (m^2/s)	4.4 · 10-8	Represents dispersive exchange only; a porewater flux is also specified in Group D.2.
Settling Rate, Organic Nutrients, Segments 1-2, 7, 10, 11 (m/d)	0.4554	Optimized (previously 0.34).
Settling Rate, Organic Nutrients, Segment 3 (m/d)	0.90	Optimized (previously 0.34).
Settling Rate, Organic Nutrients, Segment 4 (m/d)	0.065	Optimized (previously 0.30).
Settling Rate, Organic Nutrients, Segments 5, 6, 8, 9, 12 (m/d)	1.02	Optimized (previously 0.73).
Settling Rate, Organic Nutrients, Segments 13-14 (m/d)	0.65	Optimized (previously 1.0).
Settling Rate, Organic Nutrients, Segment 15 (m/d)	1.0	Optimized.
Settling Rate, Algae, Segments 1-2 (m/d)	0.060	Optimized, was 0.064.
Settling Rate, Algae, Segments 3, 7, 10, 11 (m/d)	0.064	Optimized. USEPA (1997) cites range of 0.0 to 30.0.
Settling Rate, Algae, Segment 4 (m/d)	0.080	Optimized, was 0.075.
Settling Rate, Algae, Segments 5, 6, 8, 9, 12 (m/d)	0.065	Optimized, was 0.060.
Settling Rate, Algae, Segments 13-15 (m/d)	0.070	Optimized.
Settling Rate, Inorganic Nutrients, Segments 1-3, 7, 10, 11 (m/d)	4.1	Optimized.
Settling Rate, Inorganic Nutrients, Segments 5, 6, 8, 9 (m/d)	1.8	Optimized (previously 2.0).
Settling Rate, Inorganic Nutrients, Segment 12 (m/d)	2.33	Optimized (previously 2.0).
Settling Rate, Inorganic Nutrients, Segments 13-15 (m/d)	6.2	Optimized (previously 5.0).

Table 5. Revised Parameter Values for Jordan Lake WASP/EUTRO Model – Selected Kinetic Parameters

Parameter	Value	Notes
KESG – Scale factor on light extinction coefficients estimated from Secchi Depth	0.80	Optimized – within range of uncertainty expected on estimated extinction coefficients.
k12c – Nitrification rate at 20°C, per day	0.12	Optimized, USEPA (1997) cites range of 0.05 – 0.20.
k12t – Arrhenius temperature coefficient for nitrification	1.08	Literature value (USEPA, 1997).
k20c – Denitrification rate at 20°C	0.09	Recommended default (Ambrose et al., 1993)
k1c – Saturated growth rate of phytoplankton (per day)	2.10	Optimized value – previous value 3.87; USEPA (1997) cites range of 1-3.
k1t – Temperature coefficient for phytoplankton growth	1.08	Optimized value – Ambrose et al. (1993) cite value of 1.06; USEPA (1997) cites range of 1.01 – 1.18.
cchl – Carbon to chlorophyll ratio	50	Range 20-50 (Ambrose et al., 1993); blue-green dominance suggests high value for Jordan Lake.
is1 – Saturation light intensity for phytoplankton growth (Ly/d)	490.5	Adjusted from previous calibrated value of 568 to compensate for incorrect conversion of insolation; typically around 400-500.
kmng1 – Nitrogen half-saturation constant for phytoplankton growth (mg-N/L)	0.025	Previously set at 0.13, value cited by Ambrose et al. (1993) is 0.025.
kmpg1 – Phosphorus half-saturation constant for phytoplankton growth (mg-P/L)	0.001	Previously set at $6.47 \cdot 10^{-4}$; value cited by Ambrose et al. (1993) is $1 \cdot 10^{-3}$.
k1rc – Endogenous respiration rate for phytoplankton (per day)	0.20	Thomann and Mueller (1987) cite range of 0.05 – 0.25. Previously optimized at 0.226.
k1rt – Temperature coefficient for phytoplankton respiration	1.045	Recommended default.
k1d – Phytoplankton background death rate (per day)	0.0132	Optimized value, value cited by Ambrose et al. (1993) is 0.02.
pcrb – Phosphorus to carbon ratio in phytoplankton	0.025	Default value.
ncrb – nitrogen to carbon ratio in phytoplankton	0.25	Default value.
k71c – Mineralization rate of dissolved organic nitrogen (per day)	0.065	Optimized value, previously set at 0.15; value cited by Ambrose et al. (1993) is 0.075.
k71t – Temperature coefficient for organic nitrogen mineralization	1.186	Optimized, previously set at 1.08; cited by Ambrose et al. (1993).
fon – Fraction of dead and respired phytoplankton nitrogen recycled to organic nitrogen	0.75	Was 0.95, example values cited by Ambrose et al. (1993) range from 0.5 to 1.0.
k83c – Mineralization rate of dissolved organic P (per day)	0.177	Optimized value, previously set at 0.18; value cited by Ambrose et al. (1993) is 0.22.
k83t – Temperature coefficient for mineralization of dissolved organic P	1.10	Optimized value, previously set at 1.06; value cited by Ambrose et al. (1993) is 1.08.
fop – Fraction of dead and respired phytoplankton phosphorus recycled to organic P	0.60	Optimized, previously set at 0.95 and constrained equal to fon.
Lower bound temperature for algal growth (°C)	4.0	New parameter added to model.

3.2.4 1997-1999 and 2001 Recalibration Results

For the 1997 to 1999 original calibration period, the only changes in external forcing of the model are in the nitrite/nitrate load from New Hope Creek, phosphorus load from Northeast Creek, and the specification of daily insolation, which is compensated for by adjustment of the previously calibrated value of IS1. Therefore, application of the original calibrated model parameters yields almost no change in model fit. During the final recalibration, a compromise was made between fit for the 1997-1999 and 2001 periods. This results in a small degradation in the quality of fit. The resulting average absolute errors are often greater than the desired maxima of 0.25 for total nitrogen and 0.025 for total phosphorus. However, the errors for 1997-1999 and 2001 are generally of opposite sign and compensating (Tables 6 and 7).

Table 6. Jordan Lake Nutrient Response Compromise Model Statistics for 1997-1999

Segment	2	3	4	6	8	9	12	14	15
TN – AvObs	0.59	0.46	0.49	0.47	0.46	0.47	0.41	0.54	0.73
TN – AvSim	0.76	0.58	0.67	0.56	0.55	0.53	0.56	0.62	0.95
TP – AvObs	0.082	0.074	0.064	0.032	0.033	0.025	0.022	0.052	0.085
TP – AvSim	0.082	0.077	0.069	0.047	0.043	0.043	0.050	0.058	0.109
Chl – GMObs	31.4	28.2	14.6	13.3	14.5	15.1	12.0	11.6	15.9
Chl – GMSim	34.2	33.1	25.8	20.5	18.5	17.7	18.3	18.1	25.5
TN – AvErr	0.134	0.118	0.138	0.056	0.037	0.028	0.146	0.087	0.217
TP – AvErr	0.0006	0.0030	0.0055	0.0150	0.0103	0.0188	0.0277	0.0054	0.0234
Chl – AvErr	7.51	7.34	11.89	7.18	4.31	-0.17	5.51	6.05	7.34
TN - Av ABSErr	0.23	0.15	0.17	0.20	0.11	0.15	0.19	0.15	0.26
TP - Av ABSErr	0.025	0.015	0.022	0.019	0.017	0.022	0.029	0.017	0.036
Chl -Av ABSErr	12.9	8.9	12.4	7.8	5.7	9.0	9.1	8.0	17.2
TN – RMSE	0.32	0.20	0.21	0.24	0.15	0.20	0.25	0.19	0.33
TP – RMSE	0.038	0.024	0.029	0.024	0.019	0.025	0.033	0.021	0.044
Chl – RMSE	16.4	12.1	15.3	9.7	7.6	14.7	11.4	9.6	23.4

Key:

TN	Total Nitrogen	AvObs	Average Observed
TP	Total Phosphorus	AvSim	Average Simulated
Chl	Chlorophyll *a*	GMObs	Geometric Mean Observed
		GMSim	Geometric Mean Simulated
		AvErr	Average Error
		AvABSErr	Average Absolute Error
		RMSE	Root Mean Squared Error

Table 7. Jordan Lake Nutrient Response Compromise Model Statistics for 2001

Segment	1	2	3	4	6	8	9	12	13	14	15
TN - AvObs	1.0588	1.0971	0.97	0.95	0.68	0.70	0.69	0.66	0.76	0.83	1.01
TN - AvSim	1.0487	0.8691	0.75	0.77	0.60	0.60	0.59	0.60	0.62	0.83	1.14
TP - AvObs	0.1743	0.1071	0.093	0.075	0.044	0.048	0.044	0.044	0.052	0.060	0.156
TP - AvSim	0.1019	0.0765	0.087	0.064	0.040	0.038	0.036	0.036	0.037	0.052	0.088
Chl - GMObs	56.0	45.3	42.5	20.2	20.5	18.8	16.7	15.5	23.0	17.1	22.0
Chl - GMSim	35.1	25.4	25.0	18.1	11.3	9.9	9.4	8.7	9.5	11.4	14.1
TN - AvErr	-0.025	-0.241	-0.246	-0.195	-0.084	-0.102	-0.093	-0.065	-0.163	-0.044	0.067
TP - AvErr	-0.0685	-0.0286	-0.0095	-0.0082	-0.0034	-0.0094	-0.0069	-0.0072	-0.0149	-0.0098	-0.0727
Chl - AvErr	-7.51	-10.18	-10.13	5.24	-2.08	-2.60	-1.06	-1.81	-8.36	-1.32	-9.66
TN - Av ABSErr	0.52	0.39	0.39	0.25	0.13	0.13	0.11	0.12	0.23	0.20	0.38
TP - Av ABSErr	0.069	0.031	0.024	0.014	0.016	0.022	0.018	0.021	0.024	0.023	0.079
Chl -Av ABSErr	20.9	16.2	18.2	11.0	11.2	12.1	9.4	11.4	14.4	10.1	14.7
TN - RMSE	0.75	0.49	0.44	0.30	0.19	0.20	0.17	0.20	0.34	0.30	0.55
TP - RMSE	0.078	0.036	0.032	0.023	0.022	0.032	0.027	0.029	0.032	0.034	0.245
Chl - RMSE	27.5	20.7	21.9	13.1	15.7	15.8	14.1	16.0	21.2	14.1	21.0

Key:	TN	Total Nitrogen	AvObs	Average Observed
	TP	Total Phosphorus	AvSim	Average Simulated
	Chl	Chlorophyll *a*	GMObs	Geometric Mean Observed
			GMSim	Geometric Mean Simulated
			AvErr	Average Error
			AvABSErr	Average Absolute Error
			RMSE	Root Mean Squared Error

A graphical comparison of model predictions and observations shows a model fit for 1997-99 that is similar to that reported previously, despite a slight decrease in the quality of fit caused by use of the compromise model. This is shown in Figures 12 through 18, which may be compared to Figures 3-17 – 3-23 in Tetra Tech (2002). As in the original report, chlorophyll *a* observations on the plots for certain model segments (e.g., Segment 4 – see Table 3-16 in Tetra Tech, 2002) are adjusted to account for differences in the sample vertical integration depth (twice the Secchi depth) and the average vertical dimension of the WASP segment. A reverse adjustment must be applied to the model simulated values in these segments when evaluating compliance with the chlorophyll *a* water quality criterion as assessed using standard NC DWQ sampling protocols.

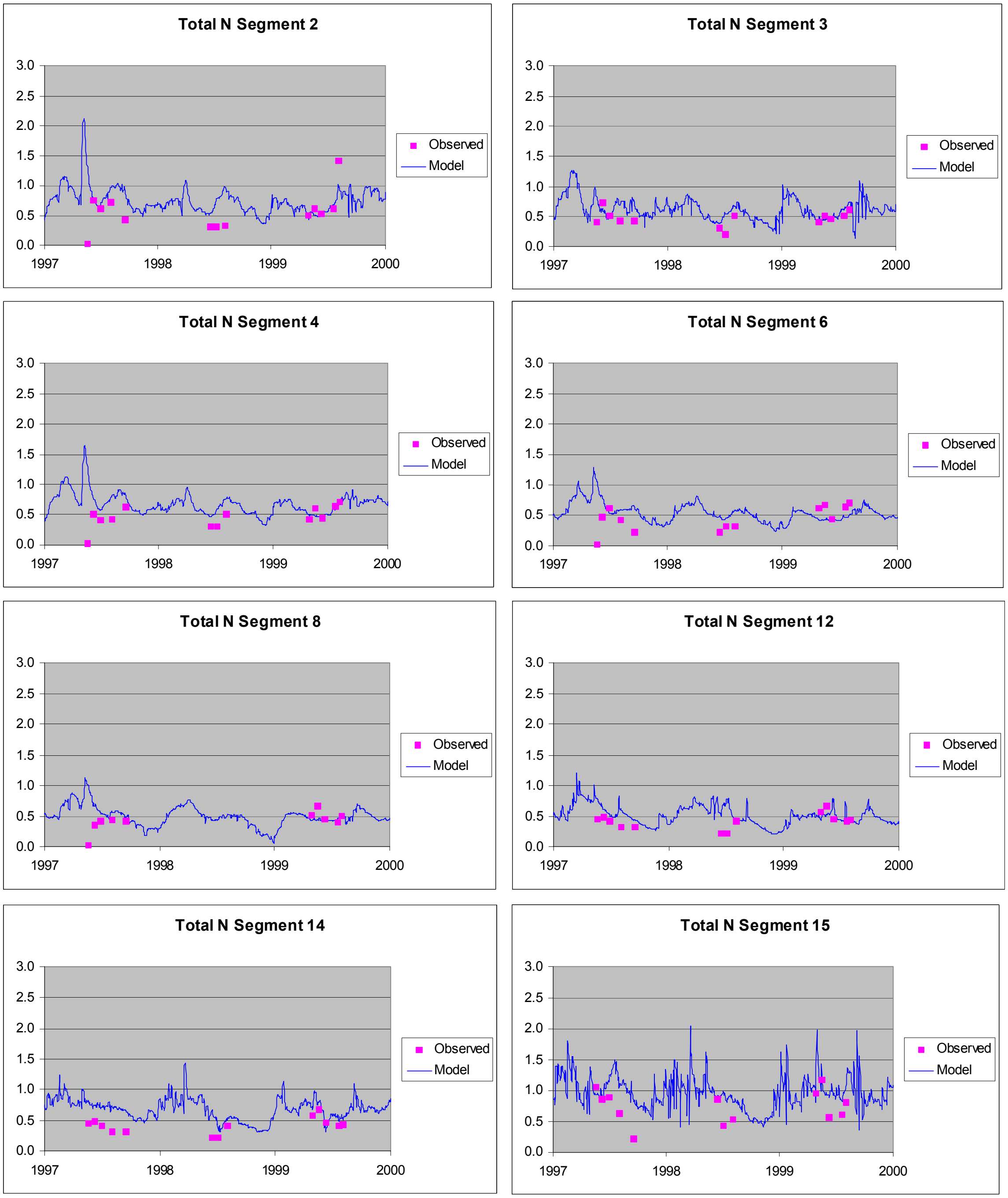


Figure 12. Total Nitrogen Calibration, 1997-1999 (mg/L)

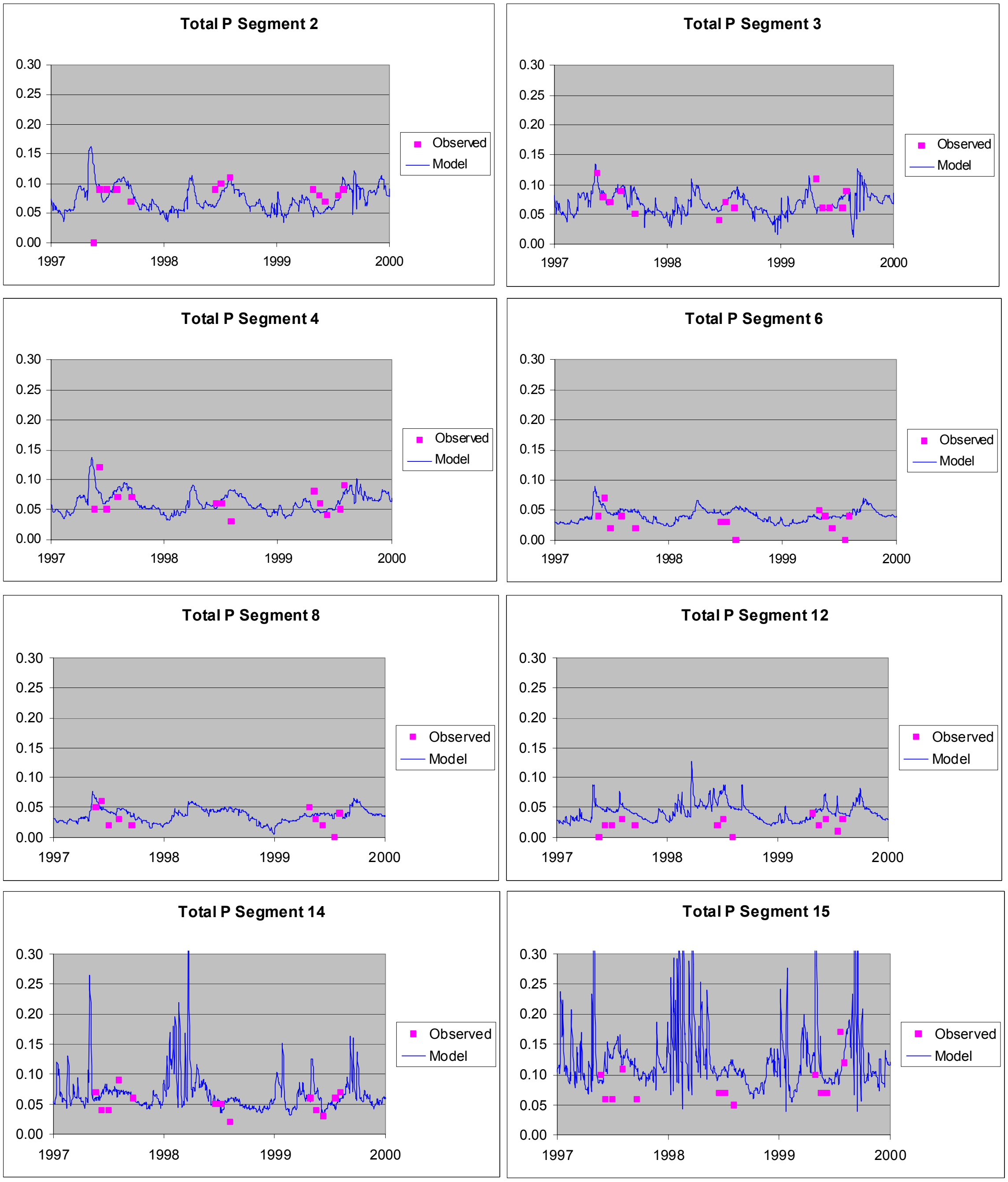


Figure 13. Total Phosphorus Calibration, 1997-1999 (mg/L)

Figure 14. Organic Nitrogen Calibration, 1997-1999 (mg/L)

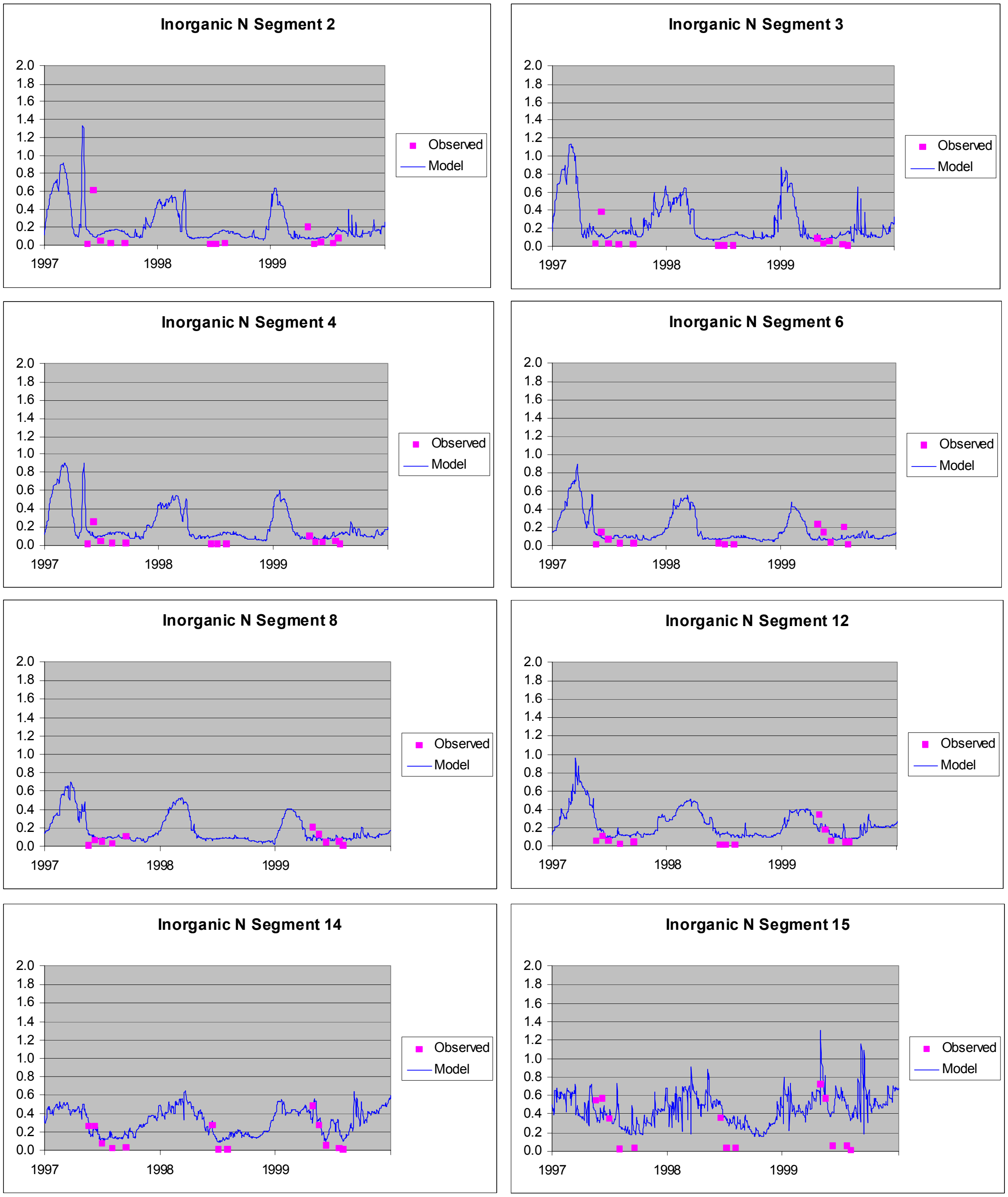


Figure 15. Inorganic Nitrogen Calibration, 1997-1999 (mg/L)

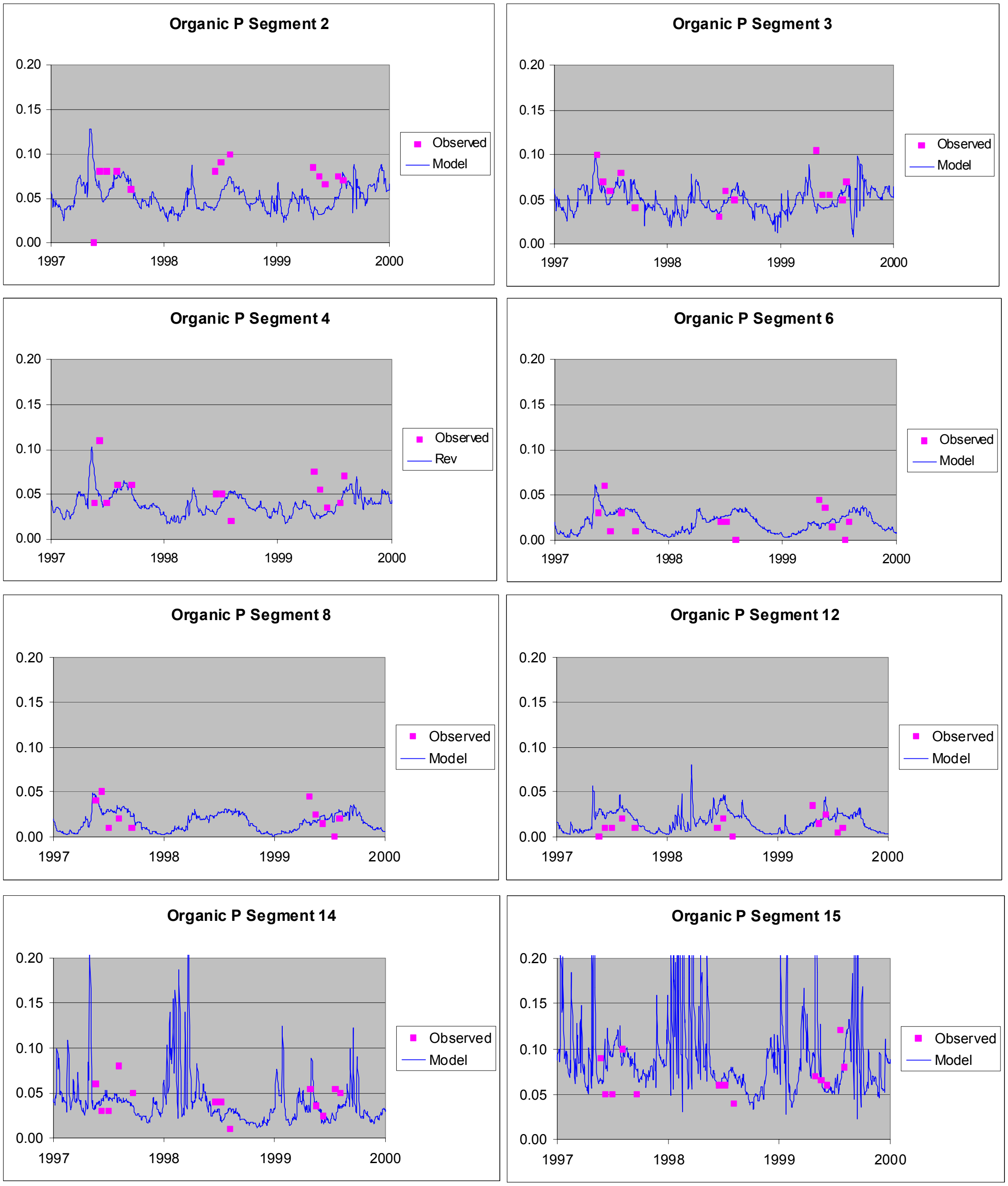


Figure 16. Organic Phosphorus Calibration, 1997-1999 (mg/L)

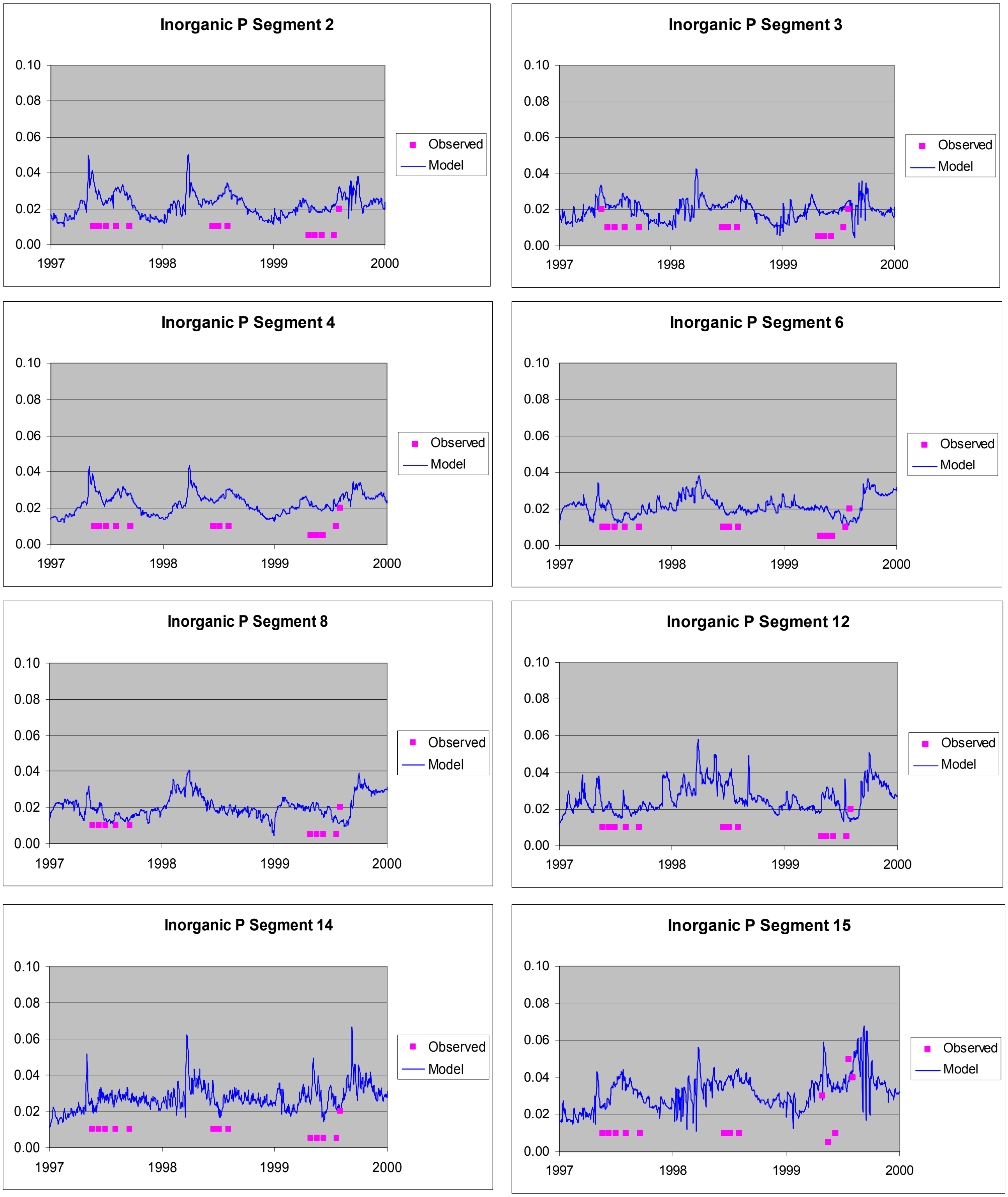


Figure 17. Inorganic Phosphorus Calibration, 1997-1999 (mg/L)

Note: Many observed values are at or below a detection limit of 0.01 mg/L. Observations reported as non-detect are plotted at 0.005 mg/L.

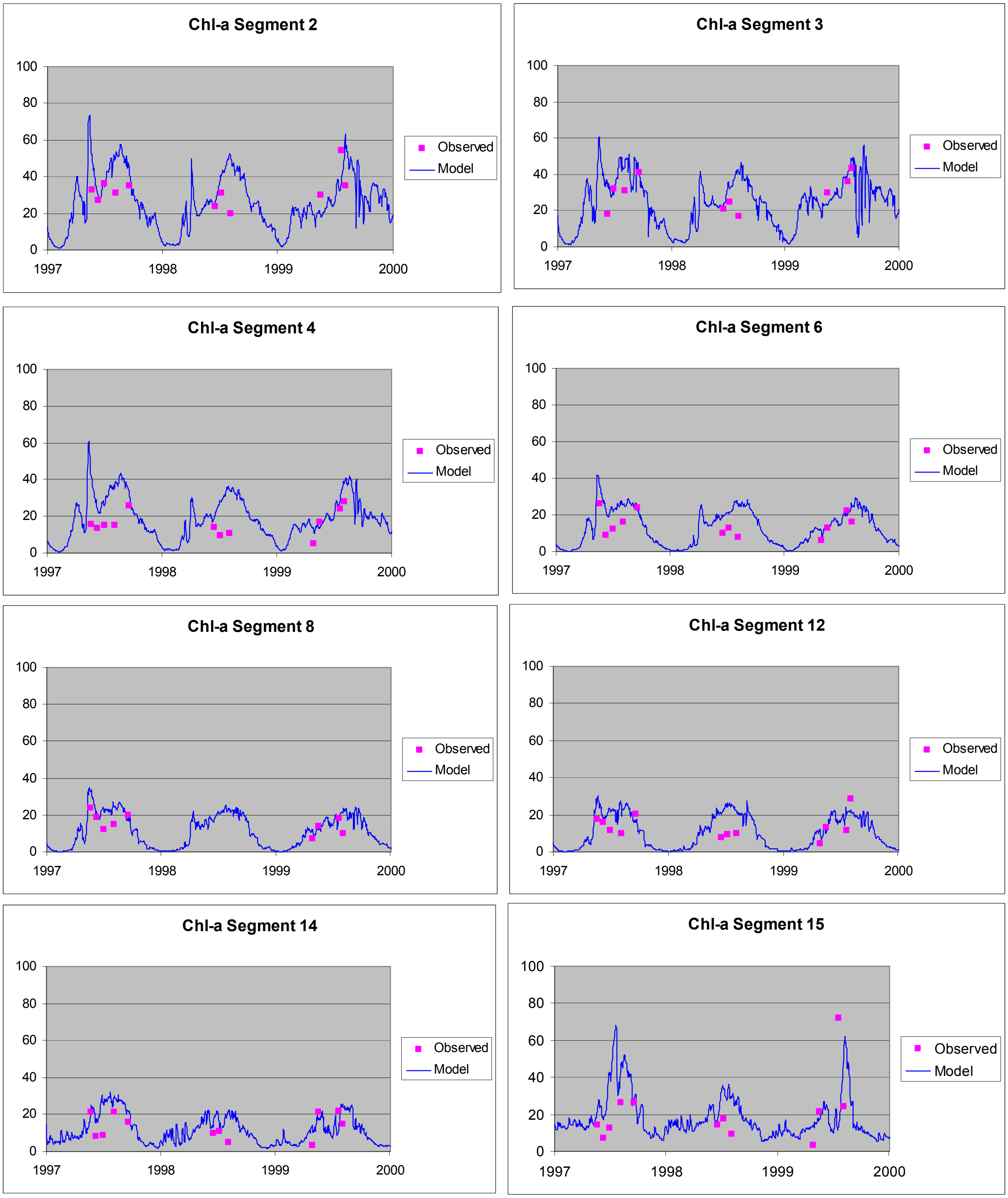


Figure 18. Chlorophyll *a* Calibration, 1997-1999 (µg/L)

Note: Observed values in Segments 4, 12, 14, and 15 are adjusted in accordance with Table 3-16 in Tetra Tech (2002) to account for depth of segment simulated versus depth of sampling. Observed values for 1997-1999 are uncorrected chlorophyll *a*.

Results for 2001 were also simulated as part of a continuous run commencing in 1997; thus the initial conditions for the year are determined by the calibration run. The year 2001 was a drought year, marked by low inflows and low lake levels throughout much of the summer and fall. As a result, there was less dilution available for tributary inflows.

Figures 19 through 25 display the daily simulation results for 2001.

For inorganic phosphorus, high detection limits were present during much of 2001, and the observed results thus have low precision. While the model appears to underestimate inorganic phosphorus at many times, this may only be an artifact of the high detection limits.

Chlorophyll *a* simulated values in 2001 are often significantly less than observed values, particularly in the fall. In addition, to the extent that inorganic nutrient concentrations are underestimated by the model a similar underestimation in algal response will be expected. For example some of the high chlorophyll *a* concentrations observed during the summer of 2001 coincide with high inorganic nitrogen concentrations that are not replicated by the lake model nor accounted for in the tributary loading series.

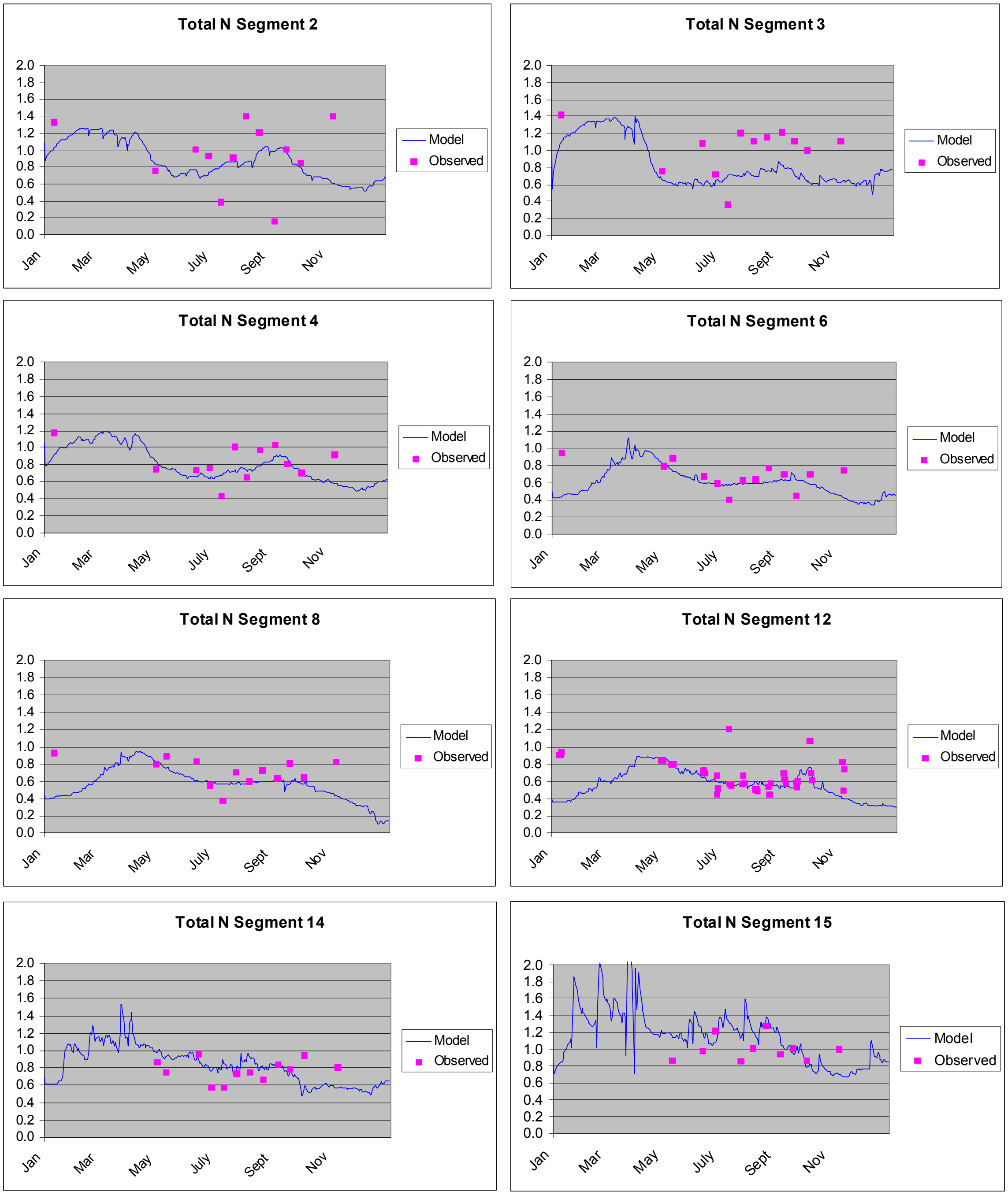


Figure 19. Total Nitrogen Calibration, 2001 (mg/L)

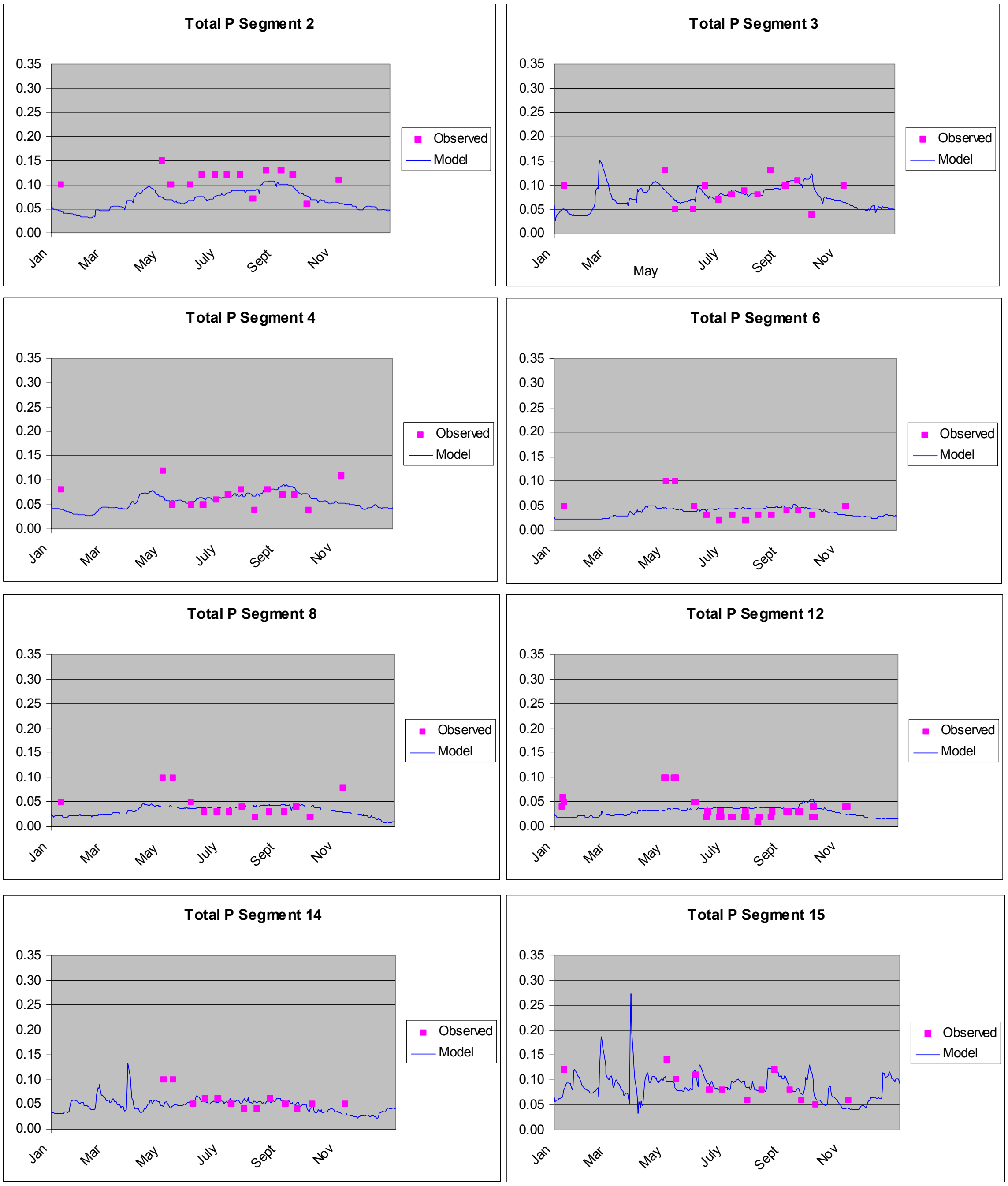


Figure 20. Total Phosphorus Calibration, 2001 (mg/L)

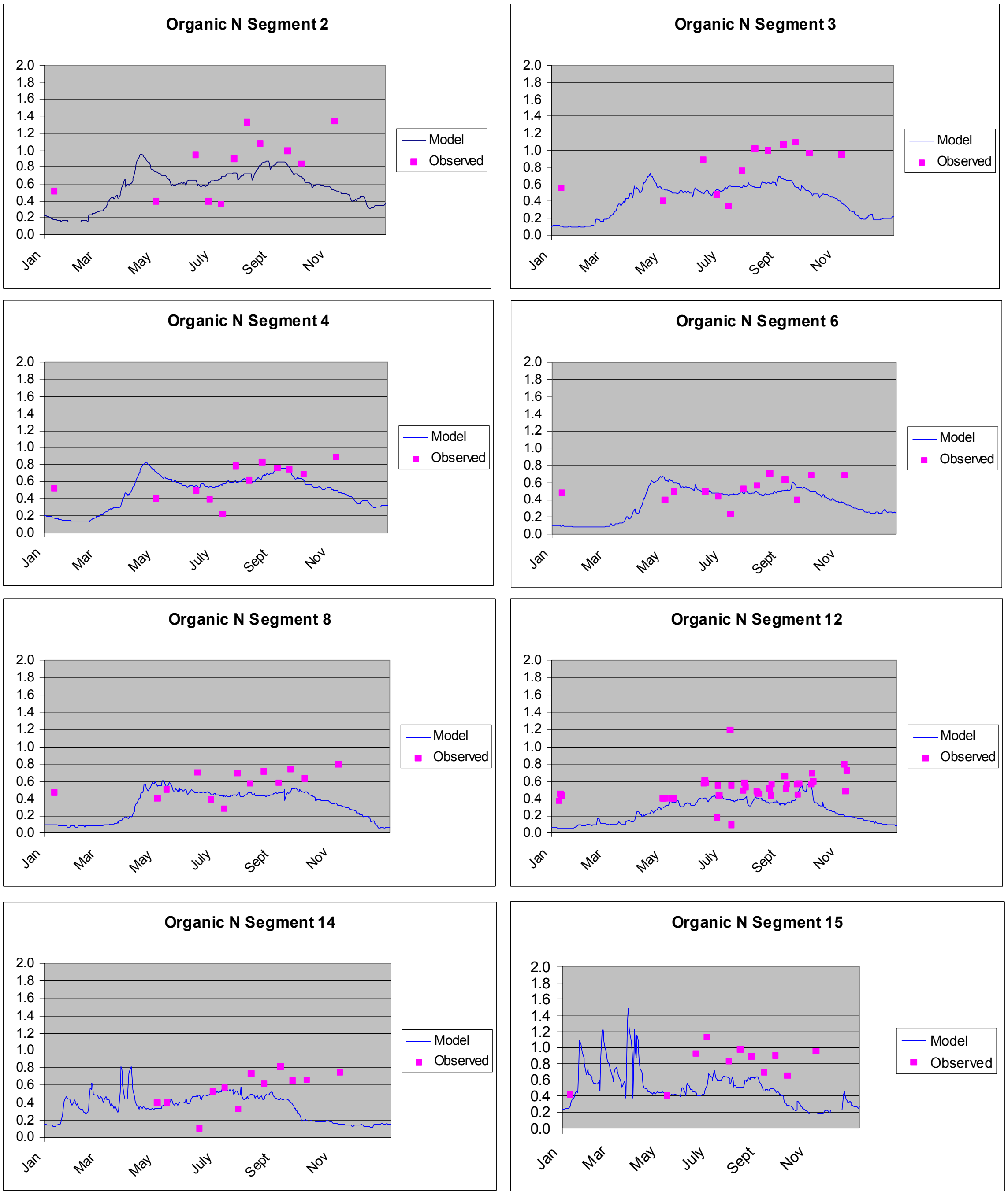


Figure 21. Organic Nitrogen Calibration, 2001 (mg/L)

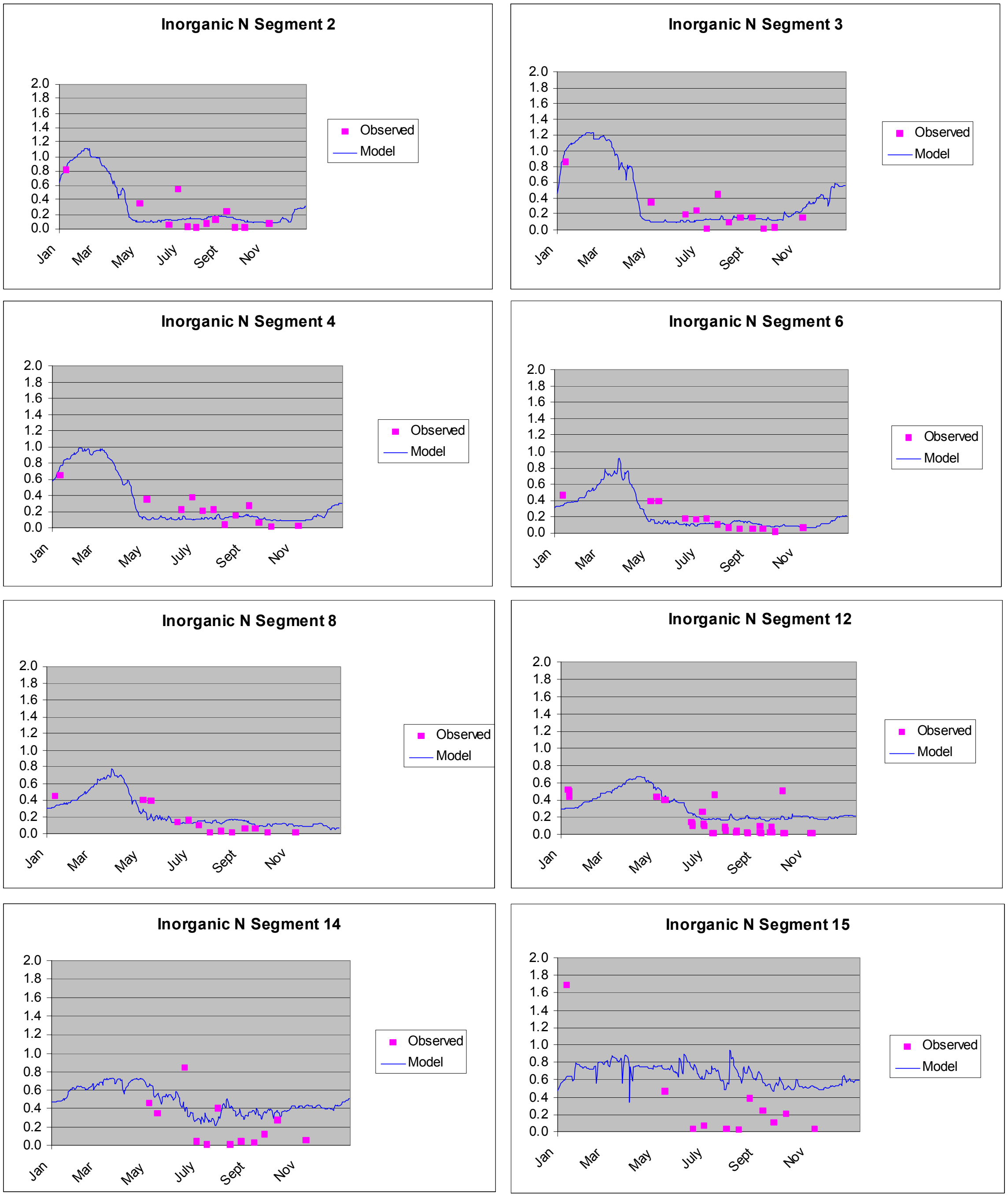


Figure 22. Inorganic Nitrogen Calibration, 2001 (mg/L)

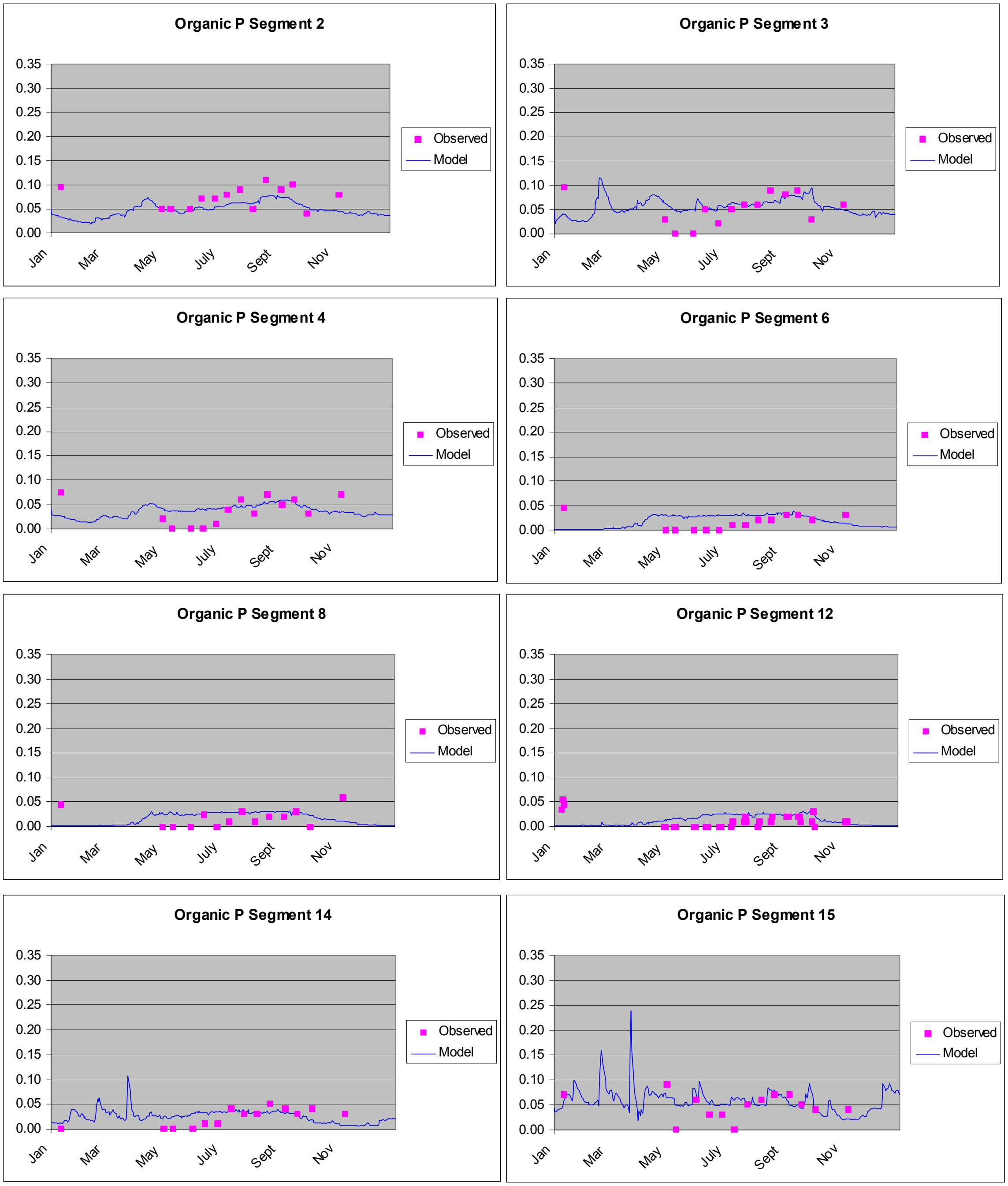

Organic P Segment 2
Organic P Segment 3
Organic P Segment 4
Organic P Segment 6
Organic P Segment 8
Organic P Segment 12
Organic P Segment 14
Organic P Segment 15

Figure 23. Organic Phosphorus Calibration, 2001 (mg/L)

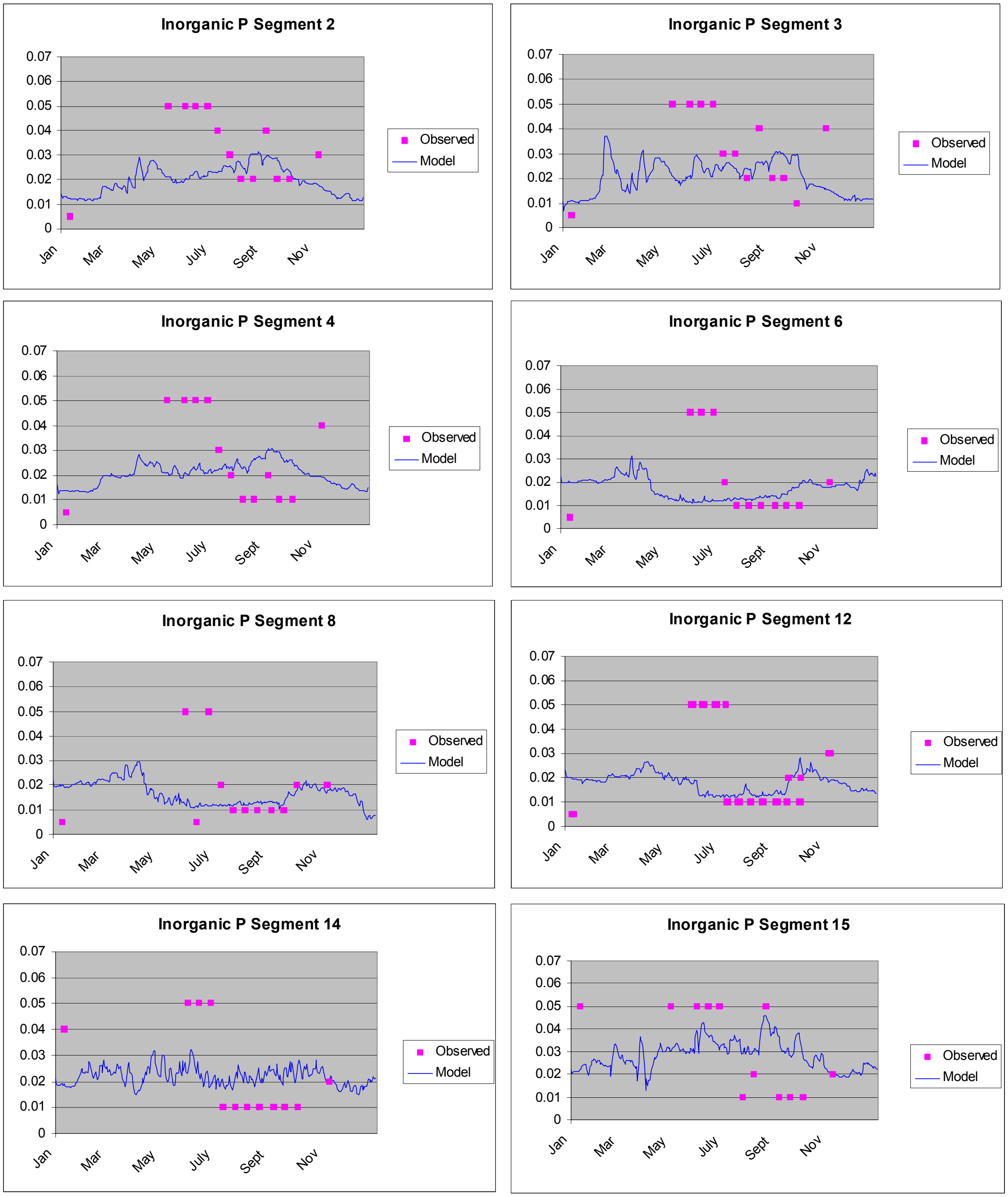


Figure 24. Inorganic Phosphorus Calibration, 2001 (mg/L)

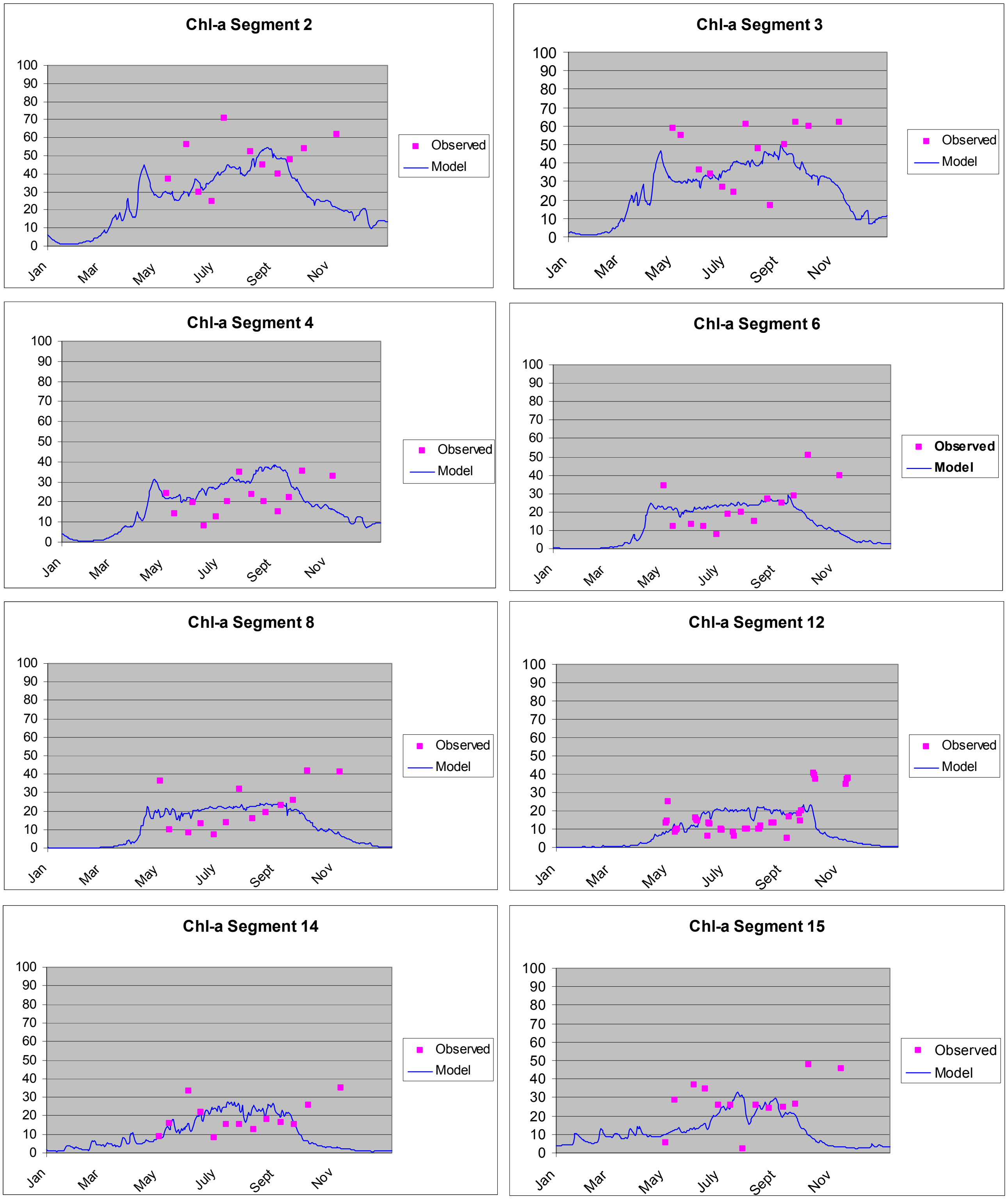


Figure 25. Chlorophyll *a* Calibration, 2001 (µg/L)

Note: Observed values in Segments 4, 12, 14, and 15 are adjusted in accordance with Table 3-16 in Tetra Tech (2002) to account for depth of segment simulated versus depth of sampling. Observed values for 2001 are corrected chlorophyll *a* by Method 445.

3.2.5 2000 Validation Results

As mentioned above, the 2000 lake data were not used in the recalibration process, and are therefore available for model validation. Unfortunately, only a limited amount of tributary data are available for 2000, so a relatively high degree of uncertainty in estimation of tributary loads is expected for this year. Nonetheless, the compromise model provides a good visual fit to the data, as shown in Figures 26 through 32. Indeed, this fit yields some noticeable improvements over the results for 2000 presented for the previous model calibration (Tetra Tech, 2002). The only major discrepancies in the 2000 results are for fall chlorophyll *a* concentrations. As with the 2001 data, this may reflect switch in species composition and reduced carbon-to-chlorophyll ratios in the fall. However, the 2000 observations are uncorrected chlorophyll *a* by the acidification method. Thus, fall observations may be inflated by the presence of pheophytin derived from both algal and terrestrial plant sources.

Figure 26. Total Nitrogen Validation, 2000 (mg/L)

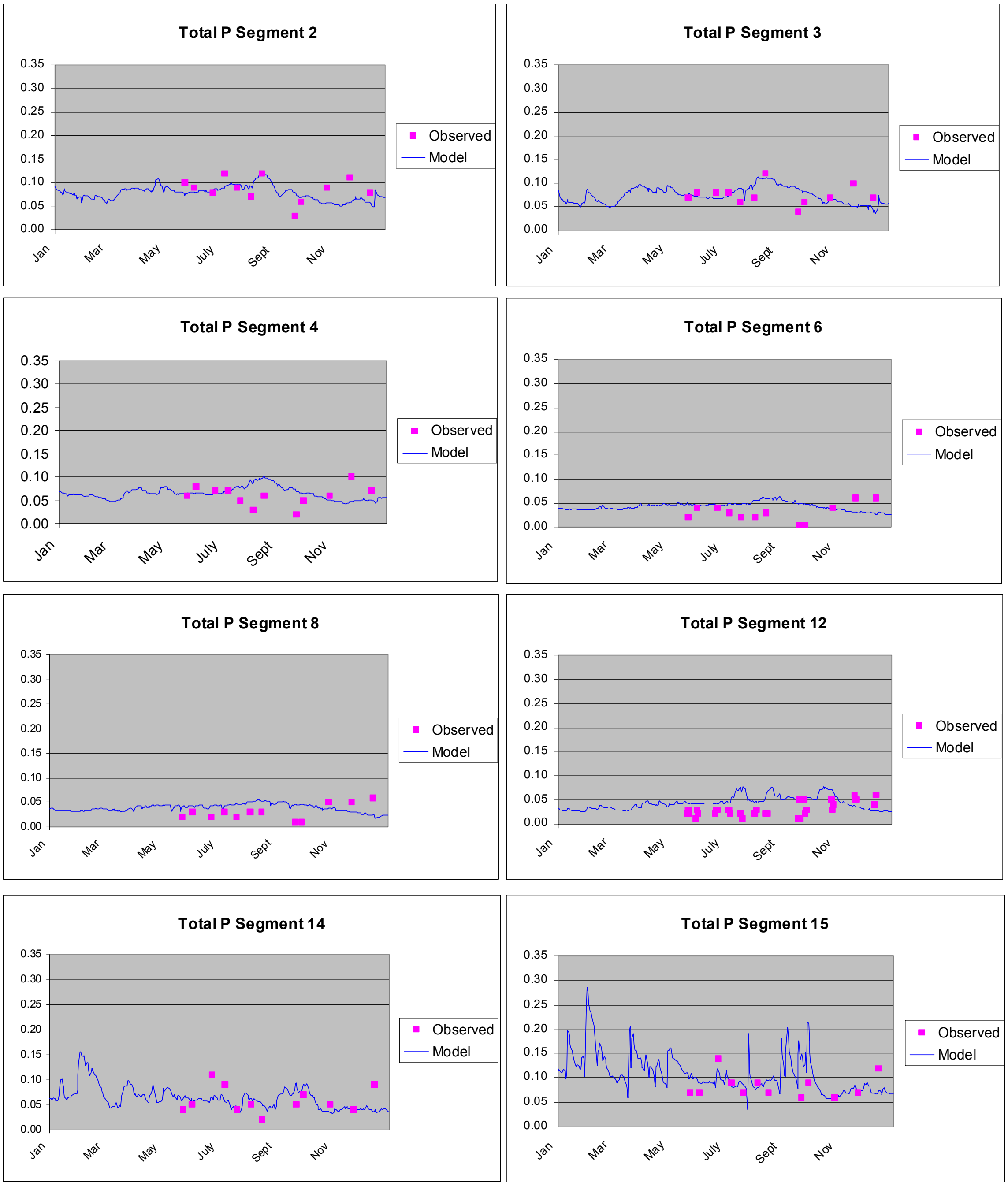


Figure 27. Total Phosphorus Validation, 2000 (mg/L)

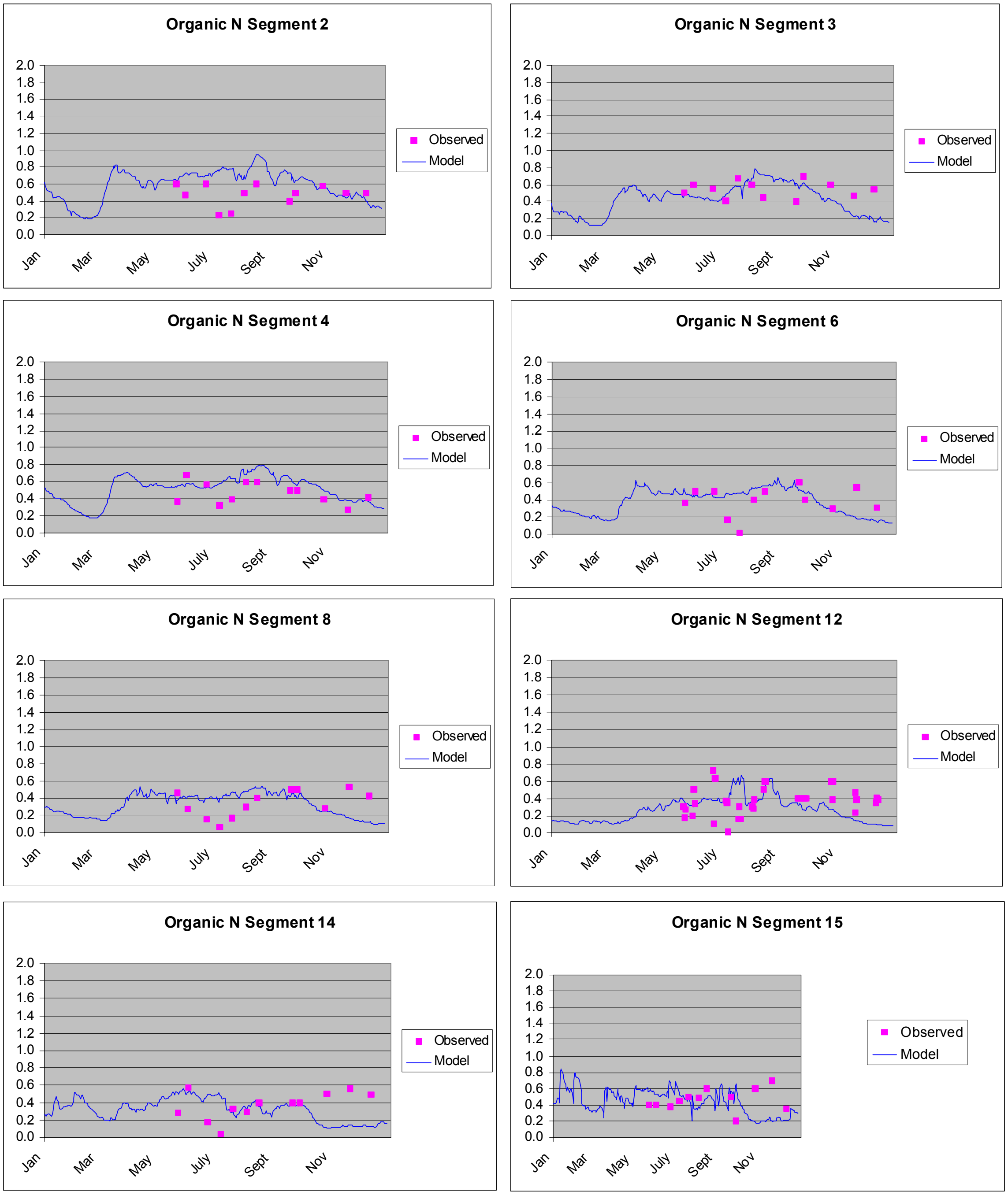


Figure 28. Organic Nitrogen Validation, 2000 (mg/L)

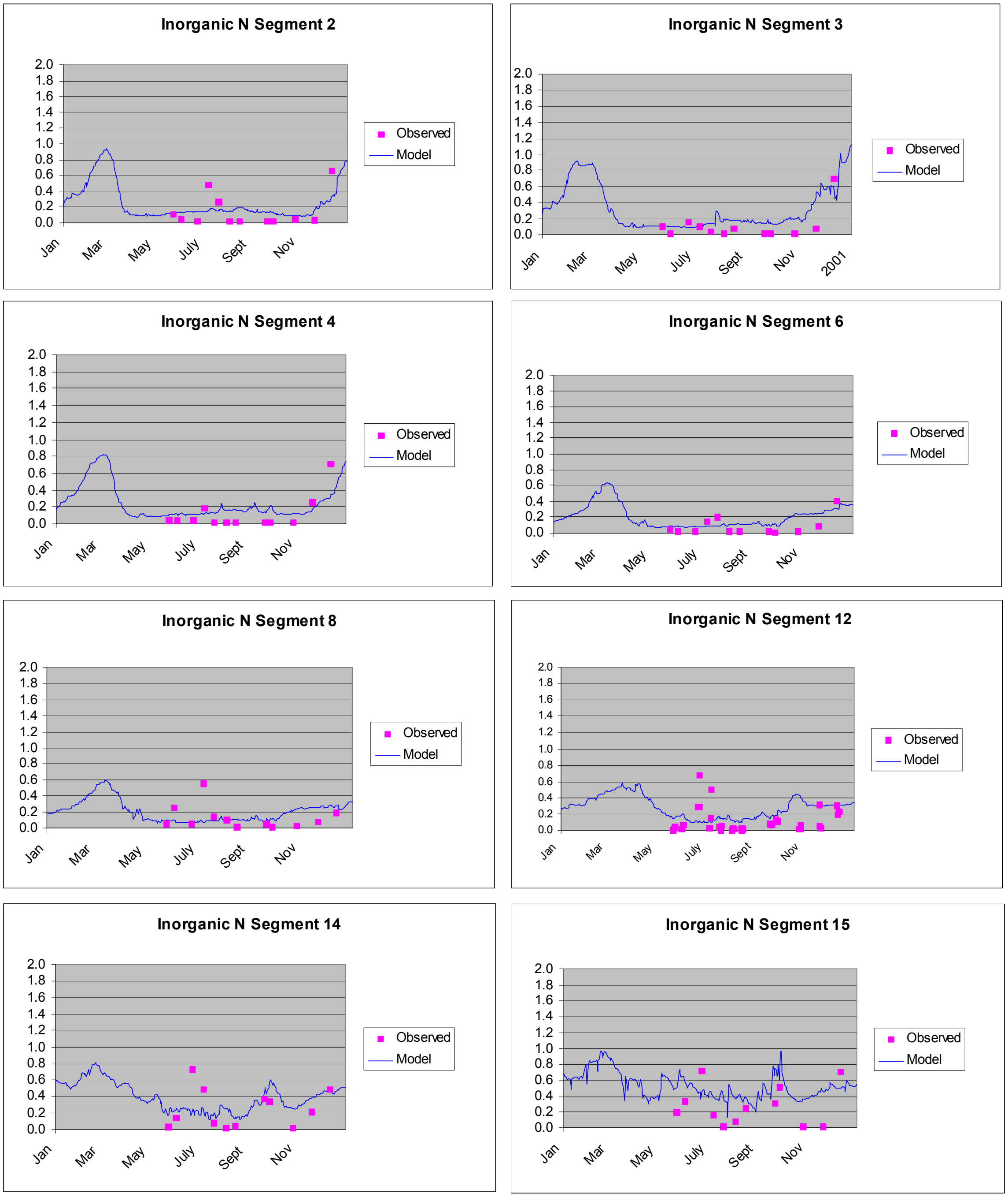


Figure 29. Inorganic Nitrogen Validation, 2000 (mg/L)

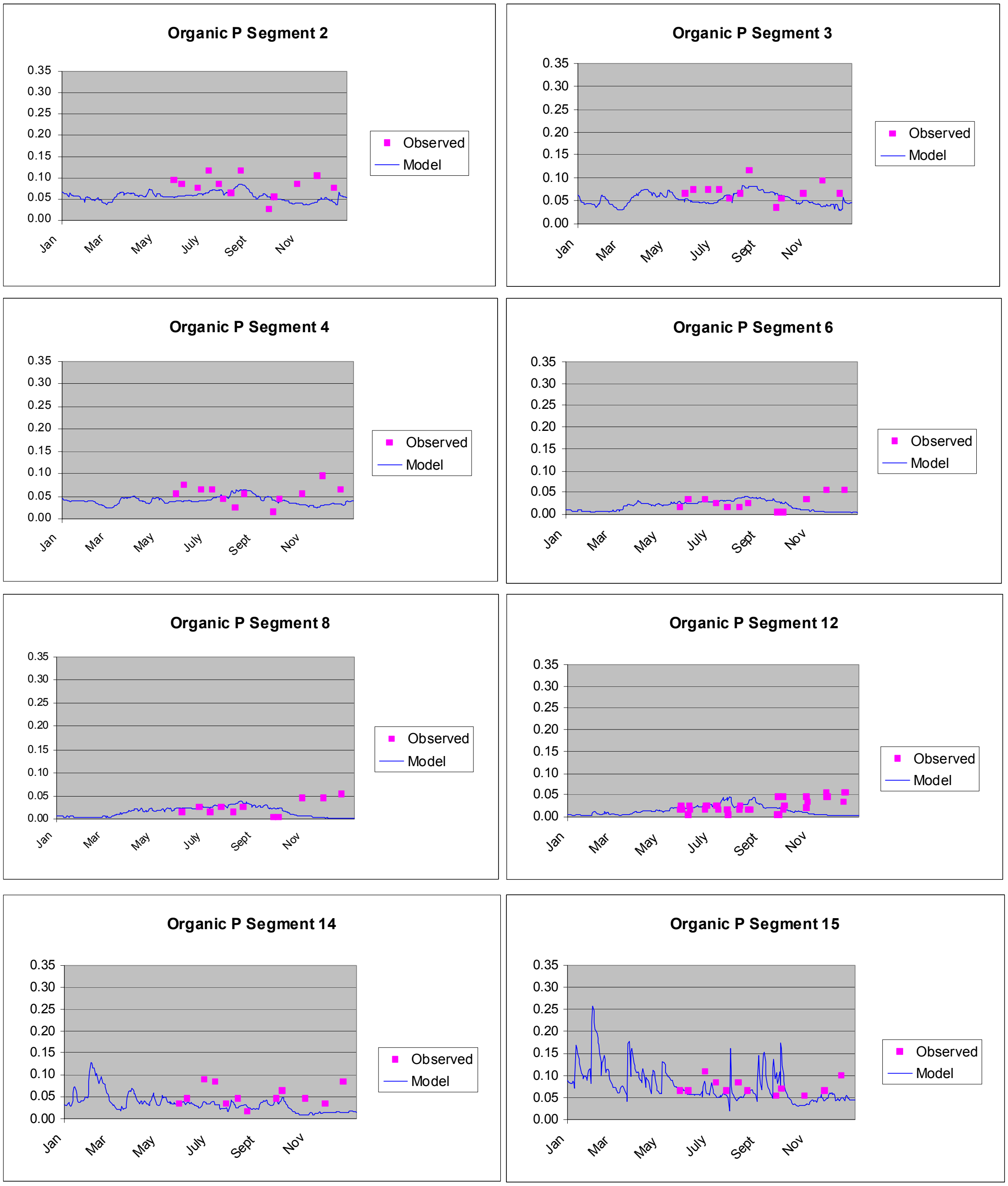


Figure 30. Organic Phosphorus Validation, 2000 (mg/L)

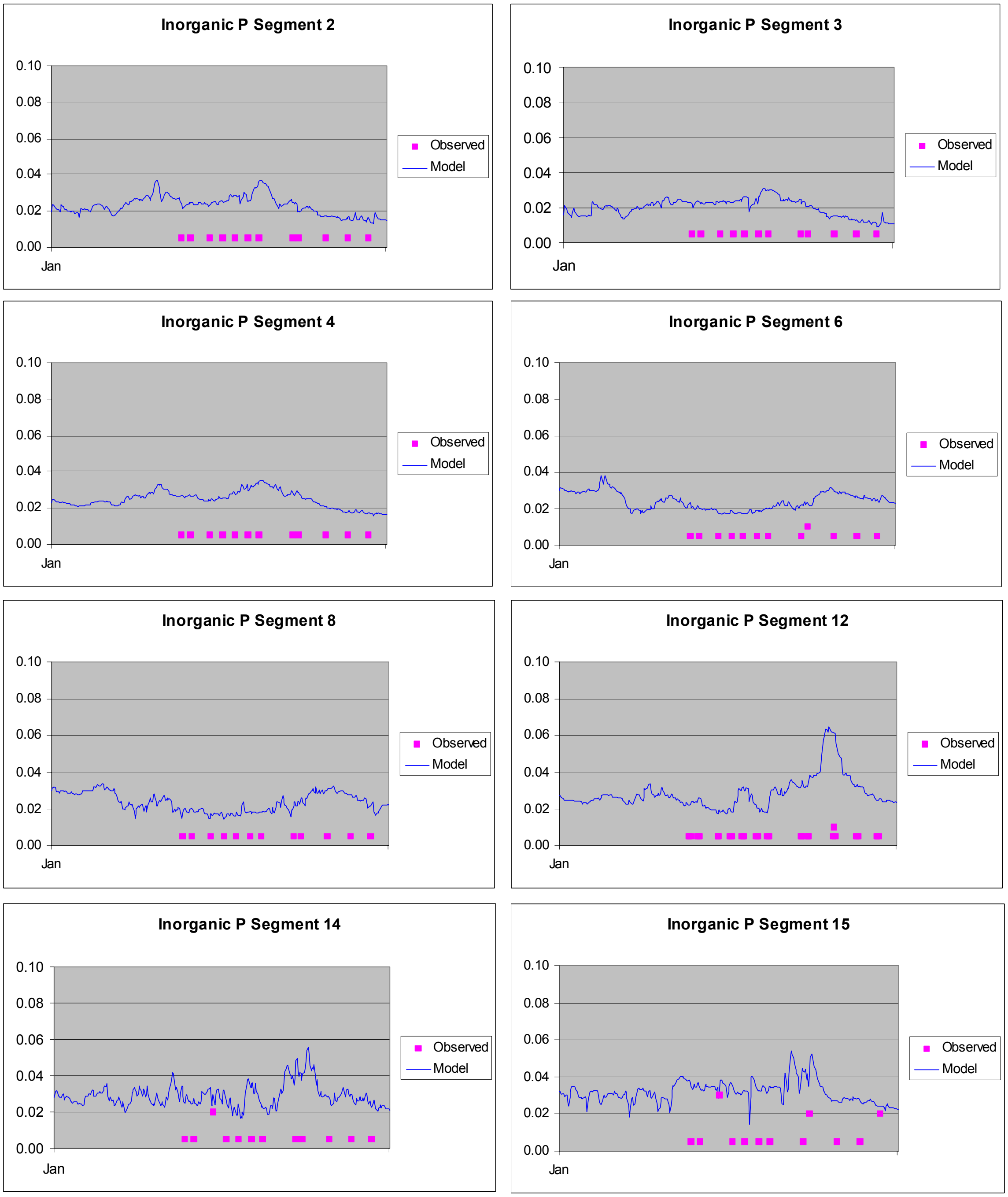
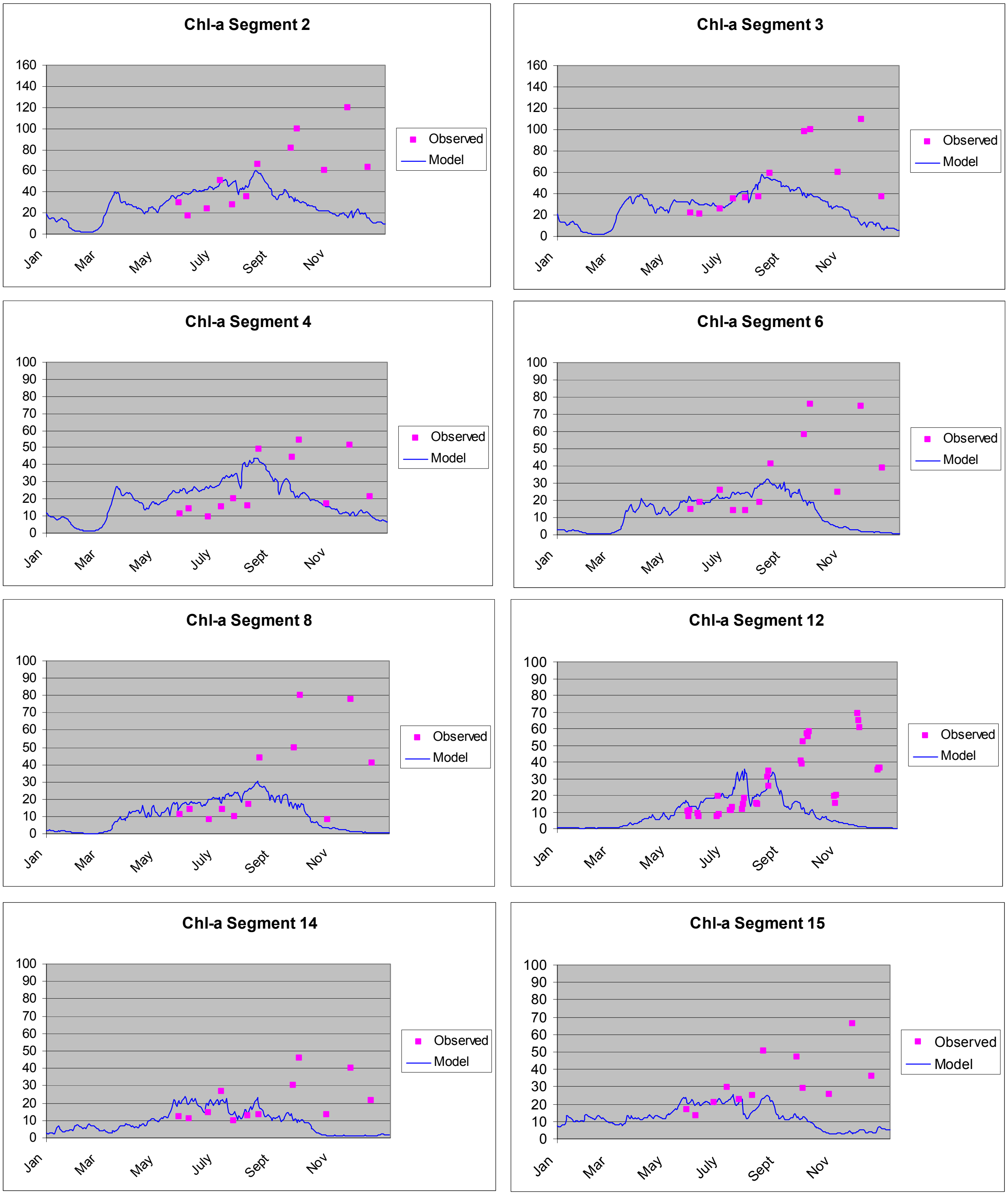


Figure 31. Inorganic Phosphorus Validation, 2000 (mg/L)



Chl-a Segment 2

Chl-a Segment 3

Chl-a Segment 4

Chl-a Segment 6

Chl-a Segment 8

Chl-a Segment 12

Chl-a Segment 14

Chl-a Segment 15

Figure 32. Chlorophyll *a* Validation, 2000 (µg/L)

Note: Observed values in Segments 4, 12, 14, and 15 are adjusted in accordance with Table 3-16 in Tetra Tech (2002) to account for depth of segment simulated versus depth of sampling. Observed values for 2000 are uncorrected chlorophyll *a*.

3.2.6 Discussion of Simulation Results

The model re-calibration and validation generally provides a good fit to nutrient concentrations, and a somewhat less accurate fit to chlorophyll *a* observations. Complete calibration statistics are presented in Tables 8 and 9 for the full simulation and the growing season only (omitting 2000, for which the dearth of tributary data increases uncertainty). Simulated data in the tables are for days matched to observations.

Table 8. WASP Calibration Statistics for 1997-1999 and 2001 Combined, Full Year

Segment	1	2	3	4	6	8	9	12	14	15
TN – AvObs	1.0588	0.8433	0.70	0.72	0.58	0.61	0.60	0.54	0.68	0.88
TN – AvSim	1.0487	0.8186	0.67	0.72	0.58	0.58	0.57	0.58	0.74	1.05
TP – AvObs	0.1743	0.0948	0.084	0.069	0.039	0.041	0.036	0.033	0.056	0.122
TP – AvSim	0.1019	0.0791	0.082	0.066	0.043	0.040	0.039	0.043	0.055	0.098
Chl – AvObs	58.8	39.8	38.3	21.6	14.1	19.4	19.0	15.7	16.2	24.1
Chl – AvSim	44.0	34.4	32.8	25.4	19.9	18.0	17.0	16.8	17.1	21.7
Chl –GMObs	56.0	37.7	35.2	17.3	12.6	16.9	16.0	13.7	14.2	18.8
Chl – GMSim	35.1	29.2	28.4	21.3	14.9	12.7	12.1	12.3	14.2	18.6
TN – AvErr	-0.025	-0.054	-0.057	-0.029	-0.019	-0.047	-0.046	0.037	0.022	0.139
TP – AvErr	-0.0685	-0.0145	-0.0035	-0.0014	0.0055	-0.0012	0.0038	0.0096	-0.0025	-0.0264
Chl – AvErr	-7.51	-1.34	-2.13	8.43	7.49	0.23	-0.70	1.71	2.21	-1.50
TN - Av ABSErr	0.52	0.31	0.27	0.21	0.16	0.12	0.13	0.16	0.18	0.32
TP - Av ABSErr	0.069	0.028	0.019	0.018	0.017	0.020	0.019	0.025	0.020	0.058
Chl -Av ABSErr	20.9	14.5	14.0	11.7	10.0	9.5	9.2	10.3	9.1	15.9
TN – RMSE	0.75	0.34	0.33	0.25	0.21	0.18	0.18	0.22	0.25	0.45
TP – RMSE	0.078	0.280	0.028	0.025	0.022	0.027	0.026	0.030	0.028	0.176
Chl – RMSE	27.5	14.3	17.7	13.9	11.5	12.8	14.0	13.7	11.9	21.7
TN – CV	0.70	0.40	0.47	0.35	0.36	0.30	0.29	0.41	0.36	0.36
TP – CV	0.45	2.96	0.33	0.37	0.58	0.65	0.72	0.91	0.50	0.50
Chl – CV	0.49	0.38	0.50	0.80	0.91	0.76	0.88	1.00	0.84	0.84

Key:	TN	Total Nitrogen	AvObs	Average Observed
	TP	Total Phosphorus	AvSim	Average Simulated
	Chl	Chlorophyll *a*	GMObs	Geometric Mean Observed
			GMSim	Geometric Mean Simulated
			AvErr	Average Error
			AvABSErr	Average Absolute Error
			RMSE	Root Mean Squared Error
			CV	Coefficient of Variation (error standard deviation divided by observed mean)

Note: Observed values in Segments 4, 12, 14, and 15 are adjusted in accordance with Table 3-16 in Tetra Tech (2002) to account for depth of segment simulated versus depth of sampling. Observed values for 2001 are corrected chlorophyll *a* by Method 445.

Table 9. WASP Calibration Statistics for 1997-1999 and 2001 Combined, Growing Season Only (May-September)

Segment	1	2	3	4	6	8	9	12	14	15
TN - AvObs	0.86	0.82	0.69	0.67	0.54	0.57	0.57	0.49	0.62	0.78
TN - AvSim	1.08	0.82	0.63	0.71	0.59	0.59	0.58	0.59	0.72	1.05
TP - AvObs	0.180	0.094	0.082	0.066	0.034	0.036	0.033	0.028	0.052	0.126
TP - AvSim	0.117	0.085	0.082	0.070	0.046	0.042	0.041	0.046	0.056	0.100
Chl – AvObs	56.4	38.0	35.4	18.0	19.6	16.7	17.7	13.6	15.8	24.0
Chl – AvSim	54.8	39.4	36.7	29.0	22.8	21.2	20.1	20.0	20.2	25.2
Chl - GMObs	53.5	36.2	32.8	16.9	17.9	15.4	15.6	13.0	14.5	20.1
Chl - GMSim	53.0	38.1	36.0	28.1	22.4	20.8	19.8	19.0	19.6	23.5
TN - AvErr	0.237	-0.012	-0.051	0.019	0.029	-0.002	-0.012	0.101	0.086	0.271
TP - AvErr	-0.0634	-0.0091	-0.0003	0.0054	0.0124	0.0066	0.0082	0.0172	0.0041	-0.0266
Chl - AvErr	-1.58	1.80	1.25	11.31	3.18	4.65	2.33	5.59	4.82	1.22
TN - Av ABSErr	0.46	0.33	0.26	0.20	0.15	0.10	0.12	0.14	0.14	0.30
TP - Av ABSErr	0.063	0.024	0.013	0.015	0.016	0.016	0.018	0.024	0.018	0.065
Chl -Av ABSErr	17.7	12.7	11.4	12.0	8.3	7.1	7.9	8.4	8.0	14.2
TN - RMSE	0.59	0.35	0.34	0.23	0.19	0.13	0.16	0.19	0.18	0.40
TP - RMSE	0.073	0.311	0.019	0.022	0.019	0.021	0.024	0.029	0.024	0.195
Chl - RMSE	24.7	10.3	15.7	14.3	9.9	8.3	11.7	9.9	9.7	19.8
TN - CV	0.68	0.42	0.50	0.35	0.34	0.22	0.27	0.40	0.29	0.29
TP - CV	0.41	3.31	0.23	0.33	0.57	0.59	0.72	1.03	0.46	0.46
Chl - CV	0.46	0.29	0.48	0.85	0.55	0.54	0.57	0.77	0.67	0.67

Key:

TN	Total Nitrogen
TP	Total Phosphorus
Chl	Chlorophyll *a*
AvObs	Average Observed
AvSim	Average Simulated
GMObs	Geometric Mean Observed
GMSim	Geometric Mean Simulated
AvErr	Average Error
AvABSErr	Average Absolute Error
RMSE	Root Mean Squared Error
CV	Coefficient of Variation (error standard deviation divided by observed mean)

Note: Observed values in Segments 4, 12, 14, and 15 are adjusted in accordance with Table 3-16 in Tetra Tech (2002) to account for depth of segment simulated versus depth of sampling. Observed values for 2001 are corrected chlorophyll *a* by Method 445.

3.2.6.1 Spatial Representation of Chlorophyll *a*

The recalibrated model provides a reasonable fit for nutrients, but appears to over-predict chlorophyll *a* in Segments 4 and 6 when paired observed and simulated values were compared. The model predicts segment-wide averages, which are not necessarily equivalent to measurements at a fixed point within a segment. For instance, the location of station CPF086F not far above the SR 1008 causeway in a generally downwind direction could result in a greater algal response than the segment average in Segment 4. In addition, the NC DWQ samples are composites over twice the Secchi depth. Segment 4 is represented by a single model cell that often has a depth greater than the sample composite depth, causing a low bias in chlorophyll *a* predictions from the model relative to observations as algal concentrations are greater in the surface layers with more light. (This issue is discussed in greater detail in Section 4.2). For Segment 6, the WASP model has two vertical segments with a fixed depth for the top segment. This fixed depth will not always correspond to the compositing depth, again leading to some bias.

In sum, the match between model segment-average predictions and sampling observations at discrete points is subject to considerable uncertainty and can be expected to result in discrepancies at some individual points. More important is the model's ability to represent trends across multiple segments.

3.2.6.2 Temporal Representation of Chlorophyll *a*

The model provides a good representation of summer algal concentrations for 1997-2001, represented as chlorophyll *a*, throughout the lake. The model, however, appears to under-predict chlorophyll *a* concentrations reported by NC DWQ during the fall of 2000 and 2001. For 2000, the fall chlorophyll *a* analyses are suspect due to laboratory quality control issues. These issues were, however, resolved for the 2001 sampling. Thus, apparent under-estimation of chlorophyll *a* in fall 2001 is a concern.

The water quality modeling tool is based on the EPA WASP5/EUTRO model. This model does not simulate chlorophyll *a* directly. Rather, it simulates phytoplankton carbon and converts this carbon concentration to a chlorophyll *a* concentration for reporting purposes based on a carbon:chlorophyll ratio. In addition, the model simulates algae as a single group.

This formulation limits the ability of the model to represent the effects of seasonal changes in algal species composition on chlorophyll *a* concentrations. Two major factors may influence the apparent difference in chlorophyll response during the fall season: First, there is a shift in species composition from summer dominance by cyanophytes to a mixed assemblage with a large proportion of diatoms; Second, available light for photosynthesis declines during the fall, causing algae to adjust their internal carbon:chlorophyll ratio.

The model is calibrated primarily to summer conditions, and thus reflects growth kinetic coefficients and a carbon:chlorophyll ratio typical of cyanophyte dominance in high light conditions (a ratio of 50 is used for calibration to observed chlorophyll *a*). Algae present in the fall typically have a lower ratio under good light conditions (more chlorophyll *a* per unit of carbon), and this ratio is likely to further decrease as available light declines.

The purpose of the discussion in this section is to investigate whether use of a theoretical calculation of carbon:chlorophyll ratios for portions of the growing season not dominated by cyanophytes would improve the apparent fit between model predictions and observations. Note that the word "apparent" is intentionally chosen; interpretation with an alternate ratio does not affect the internal simulation, which uses algal carbon as a state variable. That this approach is an appropriate one is suggested by the fact that nutrient concentrations appear to fit reasonably well in the fall, suggesting that the discrepancies in chlorophyll *a* do not represent an actual change in algal density and algal activity that would alter the nutrient balance.

Methods

Quantitative representations of the carbon:chlorophyll *a* ratio (C:Chl *a*) are provided by Smith (1980) and Cloern et al. (1995). Both equations related C:Chl *a* to light intensity, temperature, and growth rate. The main assumption of Smith's approach (Equation 9-11 in Wool et al., 2003) was that phytoplankton regulates chlorophyll *a* concentrations to achieve a saturating light intensity (I_s) of 30 percent available light.

$$\Theta = 0.3 \frac{\Phi_{\max} K_c f_u}{k_{1c} X_{RT} e} I_a \left[\frac{1 - e^{-K_e D}}{K_e D} \right]$$

where Θ = carbon to chlorophyll *a* ratio, mgC -mg^{-1} Chl *a*; $\Phi_{\max}$ = the maximum photosynthetic quantum yield, mgC-mol^{-1} of light quanta absorbed; K_c = extinction coefficient per unit chlorophyll, m^2-mg^{-1} chlorophyll *a*; X_{RT} = temperature adjustment factor; k_{1c} = maximum growth rate at 20 degrees C; f_u = units conversion factor (0.083, assuming 43 percent incident light is visible and 1 mole of photons is equivalent to 52,000 cal), mol photons-m^{-2}ly^{-1}; and

$$I_a \left[\frac{1 - e^{-K_e D}}{K_e D} \right] = \text{Average daily solar radiation during daylight hours (Ly/d)}$$

where I_a = average light intensity during daylight hours just below the surface (assumed to average 0.9 I/f) ly-day^{-1}; K_e = light extinction coefficient, m^{-1}; and D = depth of model segment, m.

Cloern et al. (1995) modeled the reciprocal of C:Chl *a* according to temperature, daily irradiance, and nutrient-limited growth rate. Using experimental data on diatoms and other eukaryotes, they developed the following equation:

$$Chl{:}C = 0.003 + 0.0154 e^{(0.050T + -0.059I)} \mu'$$

where T = temperature in degrees C; I = light intensity in mol quanta-m^{-2}d^{-1}; and μ' = the nutrient limited growth rate in, d^{-1}.

Monthly averages of temperature (T) and light (I) from WASP output were used to estimate C:Chl *a* using the Smith (1980) equation. $\Phi_{\max}$ was set to 600 mg C-mol^{-1} photons according to WASP theoretical determination. The following parameter values were chosen as appropriate for diatoms:

$X_{RT} = 1.06^{T-20}$

$k_{1c} = 2.0$ day^{-1}

f_u *= 0.083 mole photons-m*$^{-2}$*ly*$^{-1}$

K_c*=0.017 m*^{2}*-mg*$^{-1}$*Chl a*

Monthly averages of temperature and light intensity were also entered in the Cloern et al. (1995) equation. The growth rate (μ') was set to 2.0, assuming no nutrient limitations.

Results and Discussion

Both equations produced similar C:Chl *a* ratios for the non-summer portion of the year (Table 10). According to Eppley and Sloane (1966), physiological factors, including the energy cost of synthesizing chlorophyll, prevent the ratio from going much below 20. Therefore, if the estimated C:Chl *a* was less than 20, a default of 20 was used. Given the similarity between the Smith and Cloern results, the Smith results (adjusted to a minimum of 20) were used to adjust model chlorophyll *a* predictions.

It will be noted from Table 10 that the C:Chl *a* ratios *do not* show an increase through the fall as light decreases. This occurs because the effect of light is outweighed by the effect of decreasing temperature, which causes a decrease in growth rate and thus a decrease in C:Chl *a*. As a result, the revised ratio is relatively constant near 20, and concentrations calculated with the revised ratio are approximately 50/20 = 2.5 times higher than those predicted with the summer model.

To approximate a transition between summer and winter algal assemblages, an adjusted chlorophyll *a* concentration was calculated from existing model output, using the summer C:Chl *a* ratio of 50 in the summer and the revised ratio from Table 10 in the winter. A gradual transition between the two ratio sets was imposed in May and September.

Figure 33 shows the observed data, existing calibration and the revised results that would result from application of the alternative C:Chl *a* ratio for 2001 results. The observed data are corrected for pheophytin. The adjustment for C:Chl *a* for the fall appears reasonable in the upper New Hope Arm of the lake; however, in Segments 8 through 15 the November chlorophyll *a* concentrations are still under-estimated. The revised model also tends to under-predict total nitrogen in the lake in November 2001, so this discrepancy could be due to imprecise estimation of loads for this period.

Results for 2000 are shown in Figure 34 (keeping in mind that there is considerable uncertainty as to the accuracy of fall chlorophyll *a* measurements for this year). Again, the correction appears to improve the fit to the data, but fails to replicate the high chlorophyll concentrations reported for November 2000. These uncorrected observations may, however, be inflated by inclusion of large amounts of pheophytin, as well as by analytical uncertainty.

Average water temperature in November is approximately 15° C. One possibility for the November discrepancy is that the algal blooms present at this time are optimized to lower temperatures and produce higher growth rates than are predicted by the temperature coefficient on growth used in the overall calibrated model. WASP uses an exponential formulation to represent the dependence of maximum algal growth rate on water temperature. This type of approach is commonly used for total algae; however, as noted by Bowie et al. (1985), some type of temperature optimum curve is generally more appropriate than the exponential function when considering a single algal species. In other words, different growth rate kinetics could be appropriate for simulation of algae in this part of the year. Representing this would require simulation of a succession of different algal groups, which is not readily feasible within the existing model.

Table 10. C:Chl *a* Ratio used in Experimental WASP Chlorophyll *a* Output Adjustment

Date	C:Chl *a* estimated from Smith (1980)	C:Chl *a* estimated from Cloern et al. (1995)	C:Chl *a* used in adjustment
2000 January	21	24	21
February	31	26	31
March	23	19	23
April	18	16	20
May	17	13	20
September	10	11	20
October	15	14	20
November	13	16	20
December	17	21	20
2001 January	23	25	23
February	22	22	22
March	23	20	23
April	20	17	20
May	16	13	20
September	12	11	20
October	18	14	20
November	19	17	20
December	18	19	20

Conclusion

The conclusion of this exercise is that a fall chlorophyll *a* prediction calculated with the theoretical carbon:chlorophyll ratio (varied by month according to environmental conditions) does tend to provide a better fit to the observed fall values. It does not, however, provide a precise fit, and appears to underestimate November observations in the lower portion of the reservoir. This conclusion is, however, uncertain due to the uncertainty in the reported 2000 results. One possibility is that some of the apparent deviation between model and observations in the fall could also be due to different algal kinetic coefficients (e.g., growth rates, cell nutrient content, Michaelis-Menton coefficients, etc.) for the algal assemblage present in the fall.

Recommendation of an appropriate response is difficult. First, there are not sufficient valid data from the fall to make an accurate determination of the actual frequency of algal blooms greater than 40 µg/L during this period (the only recent data in which we have confidence are those from 2001). Second, if fall algal blooms are occurring with different kinetics than algal response in the overall model, then the model is probably not an appropriate tool to predict response to load reductions in this portion of the year. There is a question, however, as to the degree of emphasis that should be placed on fall blooms. If these blooms represent diatoms or other species with a higher chlorophyll content than cyanophytes, then chlorophyll observations greater than 40 µg/L may not represent the same degree of nuisance algal biomass that would be associated with a summer bloom. Further, the summer blooms are generally of cyanophytes that tend to cause greater impairment of aesthetic/recreational uses than do diatom blooms.

One possible alternative would be to use the calibrated model to evaluate loading targets appropriate for the summer growing season. The issue of fall blooms could then be discussed in terms of the need for further monitoring, assessment, and adaptive management. At this time, no further adjustment to the model is recommended.

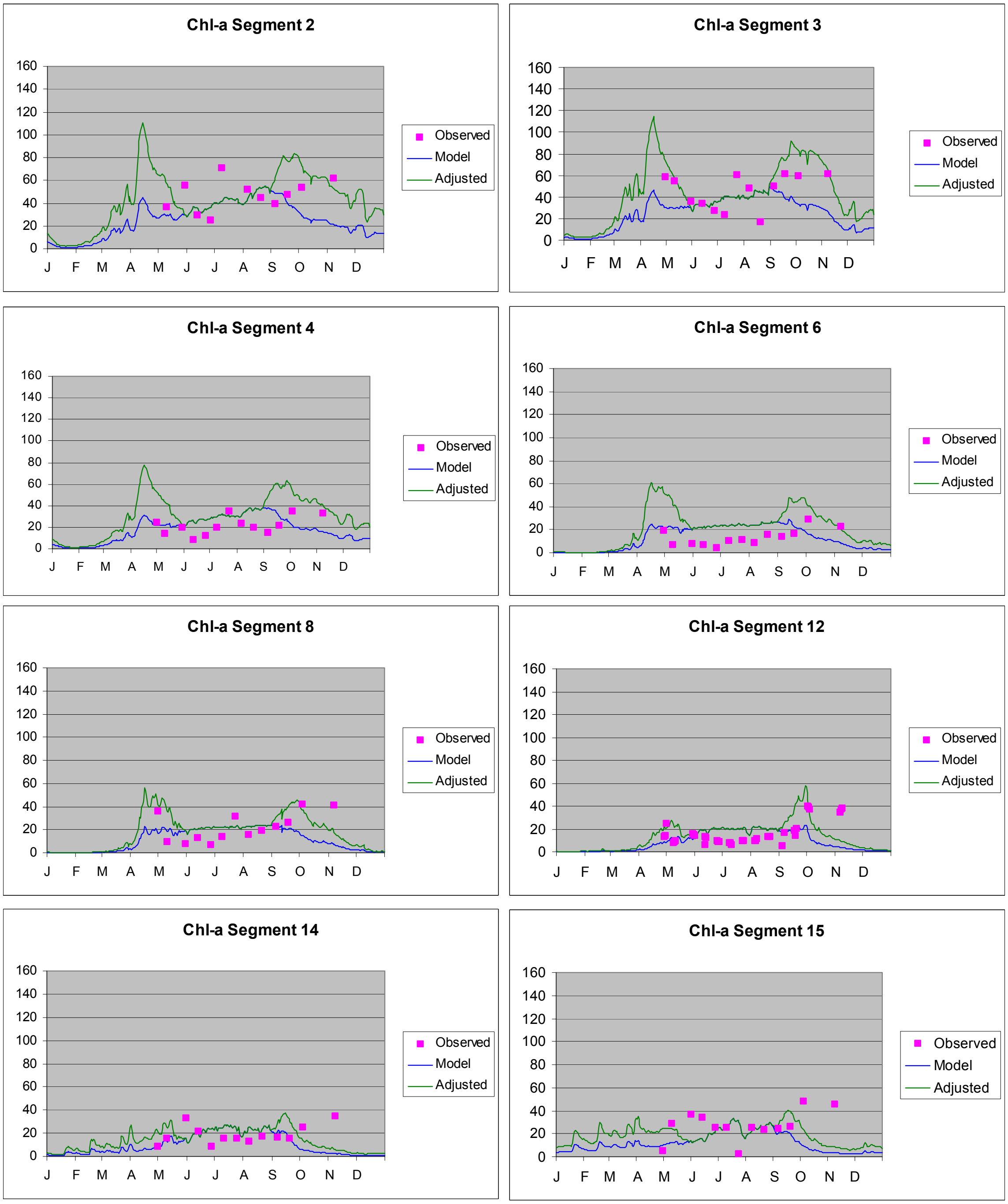


Figure 33. Comparison of Chlorophyll *a* Predictions with Modified Carbon:Chlorophyll *a* Ratios to Existing Model Calibration for 2001

Figure 34. Comparison of Chlorophyll *a* Predictions with Modified Carbon:Chlorophyll *a* Ratios to Existing Model Calibration for 2000

3.2.7 Discussion of Algal Growth Limitation

The revisions to the model calibration result in some changes in the interpretation of limits on algal growth in Jordan Lake. These changes are largely due to the revised assumption of literature default Michaelis-Menton half-saturation constants for nitrogen and phosphorus.

Tetra Tech (2002) summarizes the issue as follows:

> Consistent with the findings of the scoping model, it appears that nitrogen is most often the limiting nutrient in Jordan Lake. In the upper New Hope arm, phosphorus is the limiting nutrient at times, particularly later in the growing season. In the Haw River arm it appears that nitrogen is almost always the limiting nutrient. Light is, however, the most important factor in limiting algal growth in the reservoir. In other words, the high turbidity and color of Jordan Lake water limit the penetration of light, and thus the availability of light energy to support algal growth. Light limitation in the headwater sections of the lake serves, however, to slow the rate of uptake of inorganic nutrients by algae, and may thus spread algal blooms further down the lake.

After recalibration, the conclusions regarding the important role of light limitation remain unchanged, but some refinements of the conclusions regarding nutrient limitation are required. Figure 35 displays the limiting factors on algal growth on a daily basis, where a value of one indicates no limitation and a value of zero indicates complete inhibition. Over the course of the simulation period, the most significant nutrient limitation alternates between nitrogen and phosphorus, with neither nutrient exerting strong limitation during the cold season. During the warm season (May-September) nitrogen is estimated to remain the most limiting nutrient – although it was less limiting during 2001, when there were higher inorganic nitrogen loads relative to phosphorus loads than in earlier years, apparently associated with drought conditions in that year. Figures 36 and 37 shows the percent of time that nitrogen and phosphorus are limiting at selected stations during the warm season. For the Upper New Hope Arm (the listed segments, above Mt. Carmel Church Road), nitrogen is the predominant limiting nutrient, because most of the nitrogen is tied up in organic forms. Within the remainder of the lake, nutrient limitation alternates between nitrogen and phosphorus, indicating an approximate balance between the available inorganic fractions of nitrogen and phosphorus. As noted in Tetra Tech (2002), nitrogen appears to most often constitute the primary nutrient limit on algal growth during the early summer, with phosphorus taking on increasing importance in late summer and fall. Results for 2001 are somewhat anomalous relative to earlier years, with a much higher tendency toward limitation by phosphorus.

These results continue to suggest that control of eutrophication in the §303(d)-listed segments of the lake may be responsive to reductions in inorganic nitrogen load. However, algal concentrations in the remainder of the lake are likely to respond to reductions in either inorganic nitrogen or inorganic phosphorus loads.

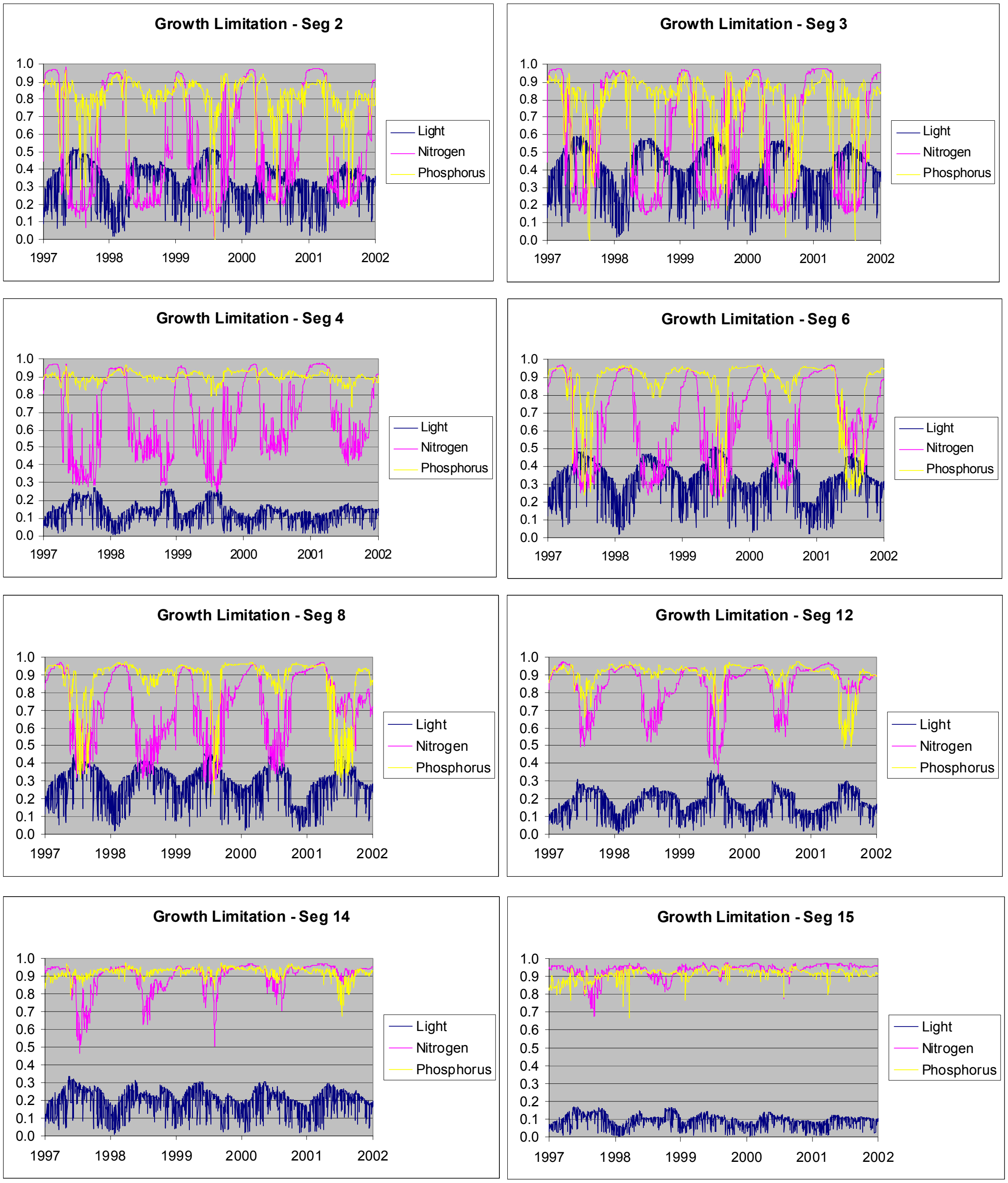


Figure 35. Time Series of Limitations on Algal Growth in Jordan Lake, 1997-2001

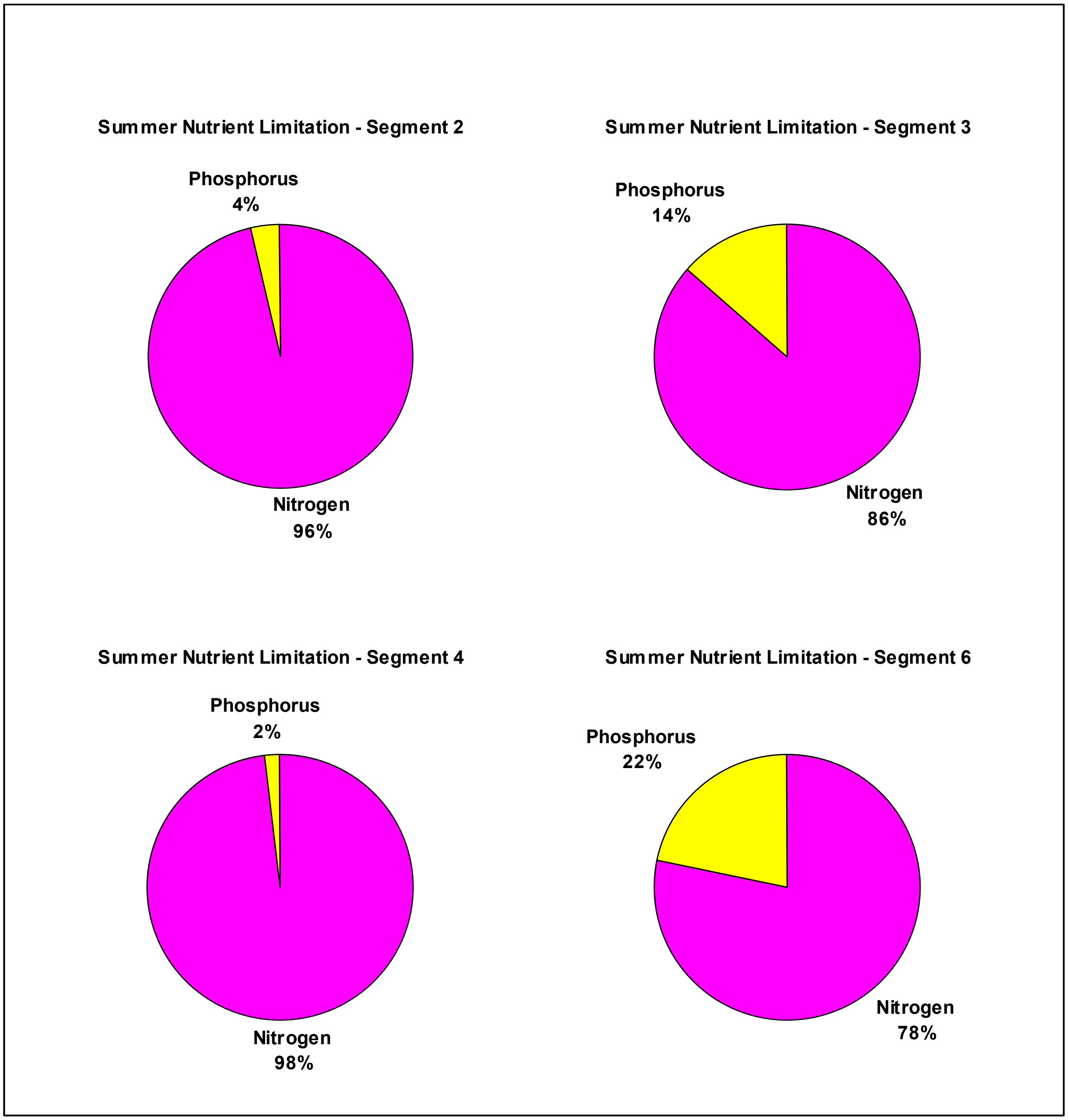


Figure 36. Percent of Time (May-Sept.) that Nitrogen or Phosphorus is the Most Limiting Nutrient on Algal Growth – Upper New Hope Arm

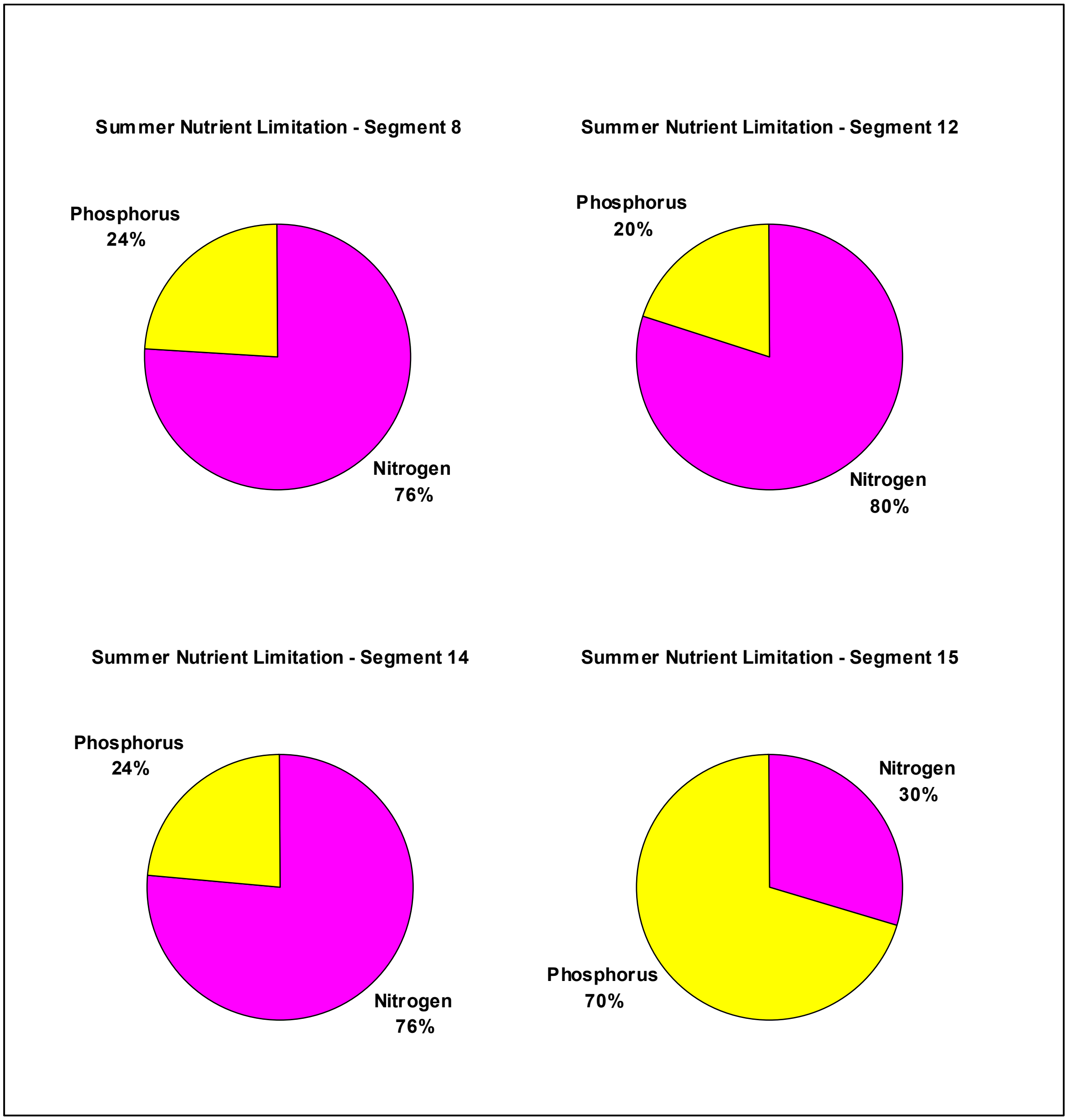


Figure 37. Percent of Time (May-Sept.) that Nitrogen or Phosphorus is the Most Limiting Nutrient on Algal Growth – Lower New Hope and Haw River Arm

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4 Model Scenarios

4.1 SCENARIO APPLICATION PROCEDURE

An objective of the project is to develop nutrient loading targets for different sections of Jordan Lake. To accomplish this, multiple loading scenarios must be evaluated.

The general strategy for scenarios was to run the calibrated water quality model for the full simulation period (1997-2001) with modifications to external loading and analyze the resulting predictions of chlorophyll *a* concentration in relation to magnitude and frequency targets (as described in Section 4.4). The model is driven by external loads that are based on FLUX-interpolated analysis of tributary flow and water quality monitoring, plus estimates for unmonitored areas. These are specified to the model through an external nonpoint source (NPS) file. Thus, a modification to the net load entering any given segment can be implemented by scaling the external loading specified in the NPS file.

This procedure yields an estimate of total loading reductions necessary to meet the target. At this stage, the analysis does not distinguish between point and nonpoint loading components. These components may have differing impacts on water quality: Nonpoint loads tend to be concentrated during storm events and may contain a significant proportion of nutrient load in forms that are not readily bioavailable, while point source loads tend to be more constant in time and often have a higher proportion of bioavailable inorganic nutrients. Further analysis of point versus nonpoint load reductions will be possible upon completion of the companion Project Number 1-2, which will result in the completion of a Jordan Lake watershed model.

While algal growth in the listed segments of Jordan Lake is most strongly limited by inorganic nitrogen, algae can be expected to respond to loads of both nitrogen and phosphorus. This means that a loading target is potentially bivariate, consisting of a paired target loading rate for both nitrogen and phosphorus.

Loads of nitrogen and phosphorus consistent with meeting the target are estimated by iterating the model across a range of reductions in nitrogen and/or phosphorus. The iterations are automated in a shell program that successively directs the following components:

1. Determine load modifications for the step in the iteration;
2. Rewrite the external NPS file for the specified load modifications;
3. Implement the WASP file using the modified NPS file;
4. Extract chlorophyll *a* concentration predictions for each model segment from the WASP output;
5. Analyze the frequency of excursions of the water quality target.

Prior to reporting scenario results, several details relevant to interpretation of the results must be covered. Section 4.2 evaluates specific adjustments to certain model segments to ensure that the modeled frequencies are consistent with observed frequencies, Section 4.3 examines the representativeness of the years included in the simulation, and Section 4.4 discusses interpretation of the water quality target.

4.2 SEGMENT ADJUSTMENTS

Analysis of results for Segments 4, 12, 14, and 15 requires adjustment of observed data before they can be compared with model results appropriately. The comparison for these four segments is complicated by the fact that the average depth in these model segments is typically more than twice the Secchi disk depth, which is the compositing depth used for regulatory compliance. In essence, the model predicts chlorophyll *a* concentrations over a depth that is often greater than the depth represented by observations and includes volume below the photic zone. Thus the model simulated chlorophyll *a* concentration is expected to be, on average, less than expected from a compliance sample.

For the purposes of model calibration, the *observed* data were adjusted to compensate for this difference. The theoretical adjustment factor was estimated as:

$$\frac{2\,SD + \alpha\left(D - 2\,SD\right)}{D}$$

where SD is the Secchi disk depth, D is the segment depth, and α is the relative proportion of the algal population found below the photosynthetic zone (2 SD). The equation for the adjustment factor is applicable only where 2 SD is less than D. Calibrated model output for these segments should, in theory, be inflated by the inverse of the adjustment factor to yield values comparable to NC DWQ observations.

For model calibration purposes in Segment 4, these adjustment factors were calculated at average summer conditions, with α assumed to be equal to 0.1. Inverse correction to model predictions should be generally valid for estimating concentration averages, as it reflects the basis of model calibration. The adjustment factor estimates are not, however, necessarily appropriate for conditions associated with individual measurements. For energetic conditions in which the algal population is unable to compensate for vertical mixing α will go to 1 and the adjustment factor will go to 1. Increases in depth during high flow periods should tend to decrease the adjustment factor unless compensated for by increases in α. Finally, as reduction scenarios decrease algal concentrations and increase Secchi depth, the adjustment factor may also increase relative to the value assumed for calibration.

The result of application of the adjustment factor during calibration is to bring model predictions and observations into closer agreement, particularly for higher chlorophyll *a* concentrations, which reflect conditions of low vertical mixing. Examination of model predictions versus adjusted observations shows that the two sets of paired observed and predicted data have both average and median ratios close to 1, as desired. Application of the inverse adjustment factor may not, however, yield an accurate estimate of the frequency of excursions of the chlorophyll *a* criterion, for the reasons discussed in the preceding paragraph, as the frequency represents a tail rather than the central tendency of the distribution. In essence, use of the inverse of the calibration adjustment factor could result in over-prediction of chlorophyll *a* concentrations during periods when observed concentrations are low. This in turn would result in an over-estimation of the frequency of excursions of the criterion, particularly in response to reduction scenarios. On the other hand, use of the unadjusted model predictions, which yield estimates of concentration over a greater depth than the compliance depth in these segments, clearly under-estimates the frequency of excursion of the criterion in measurements over twice the Secchi depth.

Of the adjusted segments, Segment 4 appears to present the greatest difficulty for comparison, partly because results for this segment are very sensitive to small changes in conditions. The adjustment factor used in calibration was 0.58. Model predictions of the frequency of concentrations greater than 40 µg/L are 3 percent without adjustment and 37 percent with application of the inverse of the adjustment factor. The observed frequency of concentrations greater than 40 in this segment is around 26 percent with the suspect data from 2000 omitted – despite the fact that the model is known to under-predict fall chlorophyll observations in 2001. Thus, an adjustment factor somewhere between 0.58 and 1 appears to be needed to produce useful frequency results for this segment.

There is not a simple resolution to this problem. Even reconfiguration of the model layers would not fully resolve the issue, as the regulatory compliance depth (twice the Secchi disk depth) varies according to ambient conditions, whereas the model layer thicknesses are fixed. Therefore, an empirical approach is used to modify the adjustment factor for calculation of frequencies if needed. The objective of this empirical approach is to ensure that the frequency of excursions of the criterion under current conditions predicted by the model is comparable to the frequency observed by NC DWQ.

Because the model is calibrated primarily to summer growing season (May-September) conditions and is believed to underpredict fall concentrations, the need for modification is based on comparison of the observed frequency of growing season concentrations greater than 40 µg/L with model predictions of the average frequency of growing season concentrations over 40 for the 1997-2001 simulation period. Examination of the results for Segment 4 shows that use of a modified adjustment factor of 0.84 puts the model into approximate agreement with the observed frequency of growing season concentrations greater than 40 µg/L of 24 percent. Without modification to the adjustment factor, the predicted rate of excursions during the growing season would be 40 percent.

Depth adjustment factors (0.64 and 0.8) are also applied in calibration for Segments 14 and 15 (near dam and Haw River arm). However, for these segments the predicted frequencies of growing season excursions of the standard (after inverse adjustment) are similar to the observed frequencies. For these segments it is therefore appropriate to apply the inverse of the calibration adjustment factor without alteration and assess the potential differences between model predictions and observations based on model error statistics.

Results are summarized in Table 11. For the model, this shows both the complete growing season frequency and the frequency calculated only on dates for which there are paired observations and predictions.

Table 11. Comparison of Observed and Simulated Growing Season (May-September) Frequencies of Chlorophyll *a* Concentrations Greater then 40 µg/L for Jordan Lake Segments with Depth Adjustment Factors

Segment	Depth Adjustment Factor	Observed Growing Season Frequency	Simulated Growing Season Frequency (full data)	Simulated Growing Season Frequency (paired data)
4	0.84*	24%	25%	28%
14	0.64	11%	12%	4%
15	0.80	15%	16%	11%

* Modified from calibration default.

4.3 REPRESENTATIVENESS OF MODEL APPLICATION YEARS

The Jordan Lake model application covers the period from 1997 through 2001. The years 1999 through 2002 generally comprised a drought period in the Jordan watershed (NCDC, 2003a, 2003b). This raises the question of representativeness of the model years for TMDL development.

How extreme were the drought events relative to lake behavior? By the middle of 2002, the drought in central North Carolina was characterized as the most severe on record (OWASA, 2002; Jehl, 2002), due to an accumulated deficit in precipitation over the preceding years. For Jordan Lake response, the sequence of inflows and direct precipitation is more significant than the long-term moisture deficit. An examination of meteorological and hydrological records shows that, while there were deficits in precipitation and flow over this period, the low flow conditions were not extraordinary and continuous to the extent that they represent extremely rare conditions for Jordan Lake.

There are many ways to analyze the drought relative to the functioning of Jordan Lake. In terms of lake elevation, the minimum reported stage during the simulation years was 210.3 ft, near the end of 1998, which is only 6 feet below the guide curve of 216. Similar levels have been reached in other years, such as 1993. For the purpose of evaluating lake nutrient response, two additional relevant time series are the flows in the Haw River (representing the majority of inflow to the lake) and precipitation at RDU Airport (a useful index for potential runoff to the upper lake).

Inflow rates from the Haw River for the simulation years, on an average annual basis, ranged from 645 cfs in 2001 to 1,603 cfs in 1998. These may be compared to the long-term record (1928-2003) from the USGS gage on the Haw River at Bynum (since 1973) and the earlier gage slightly downstream at Pittsboro (1928-1973). The low annual flows of 2001 are the fourth lowest in the 73-year record. This is equivalent to a recurrence frequency for flows this low or lower of once in 18.5 years – which is an infrequent, but not extraordinarily rare event. The other four years have annual recurrence frequencies for flows as low or lower ranging from 3.7 years in 2000 to 1.2 years in 1998.

Monthly departures of the average flow in the Haw River from long term mean flows are shown in Figure 38 (departure is accumulated over the year, but not from year to year in this figure). This shows that 1998 was a high flow year, while 2001 was a low flow year. 1997 and 2000 were not far off from normal, but both had dry falls, while 2000 also had a small deficit in spring. 1999 had extreme drought conditions through the summer, but this was partially reversed in September by hurricane input. (Note that the hurricane runoff was much less in the Haw watershed than in the area immediately around Jordan Lake itself.)

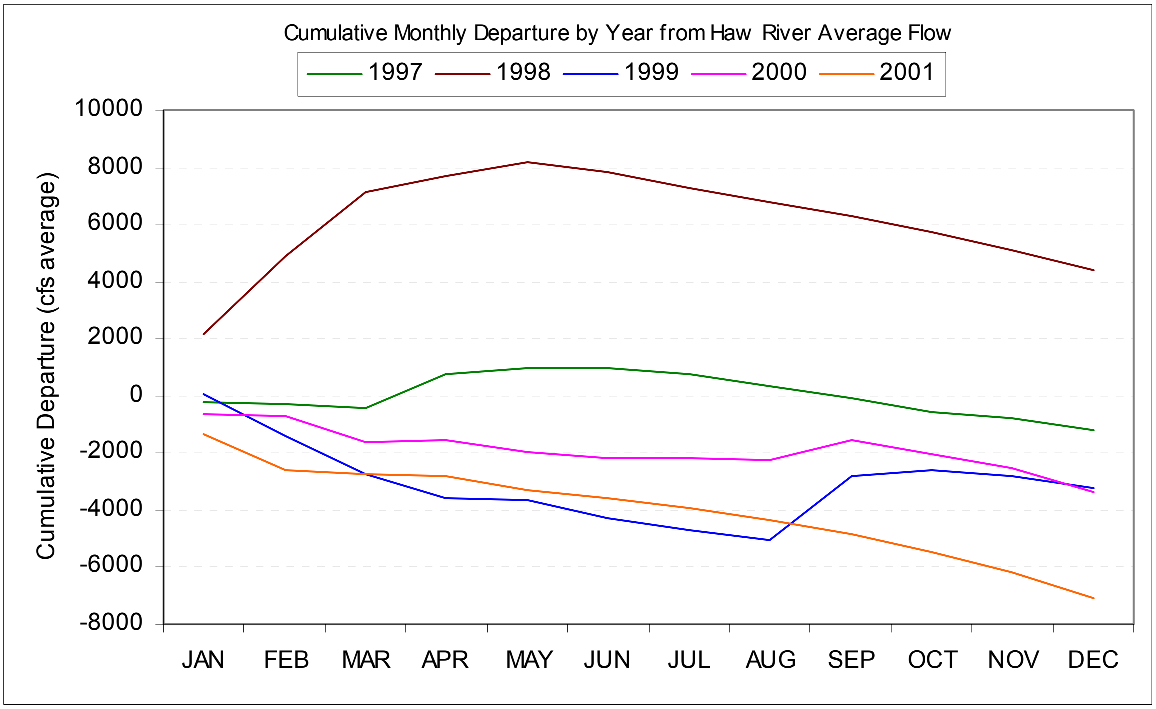


Figure 38. Departure from Long Term Average of Haw River Monthly Average Flows for 1997 through 2000

Given the variability within years, it is more informative to look at results on a seasonal basis. Recurrence frequencies (for flows less than observed) are shown on a 3-month basis in Table 12. The largest recurrence frequency (and thus the rarest event) was 24.7 years, for the Oct.-Dec. period in 2001. 1998 had the wettest Jan.-Mar. period on record and above-average total flows, but was extremely dry in the second half of the year, with recurrence frequencies of 10.6 and 12.3 years. All other seasons have recurrence frequencies of less than 10 years.

Table 12. Seasonal Recurrence Intervals for Haw River Average Flows, 1997-2001 (Recurrence Interval in Years for Flow Less than Observed)

Year	Jan-Mar	Apr-Jun	July-Sep	Oct-Dec
1997	2.0	1.2	4.1	3.1
1998	1.0	1.4	10.6	12.3
1999	6.2	5.7	1.2	1.9
2000	3.1	2.4	1.4	7.4
2001	5.7	3.4	4.6	24.7

Precipitation data from RDU Airport tells a generally similar story. Monthly total precipitation during the model simulation period can be compared to the normals at this station for 1948-2001. Cumulative departures over the course of each year are shown in Figure 39. Here we see a wet spring in 1998, an extremely dry summer in 1999, and very dry falls in 2000 and 2001. The maximum precipitation deficit over the course of a year occurred in 2001, amounting to 7.6 inches, or about 17 percent of total annual average precipitation.

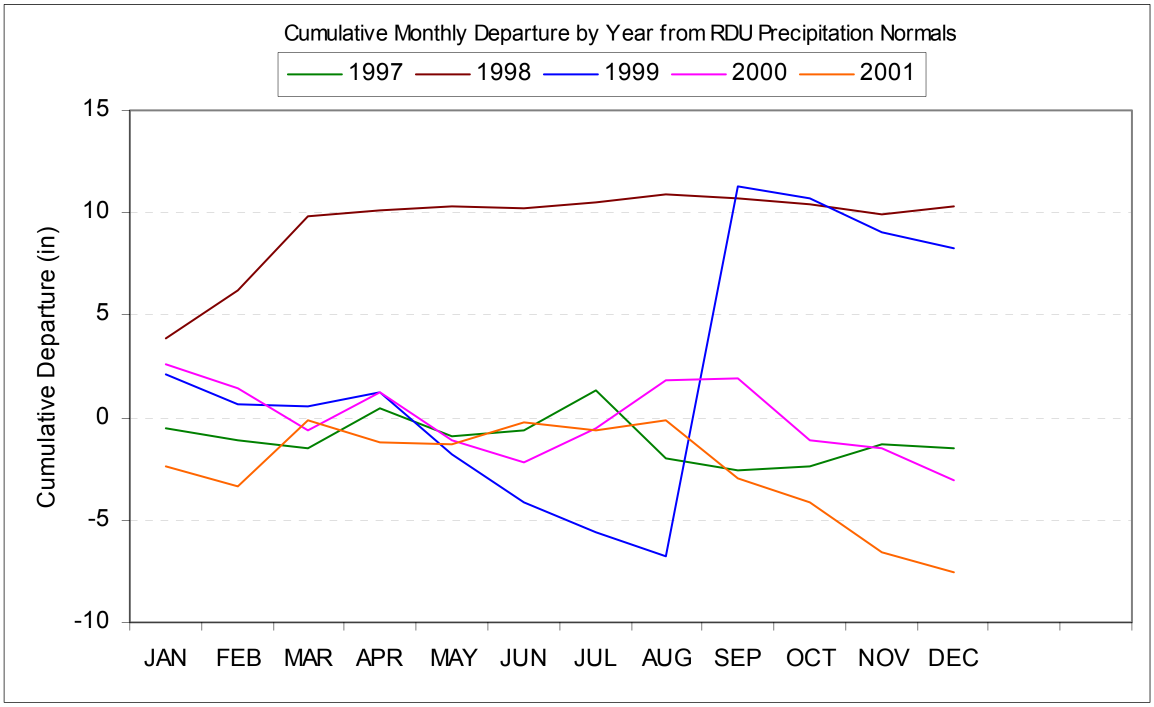


Figure 39. Departure from Long Term Precipitation Normals at RDU Airport for 1997 through 2000

Recurrence intervals by season for RDU precipitation are shown in Table 13. The majority of the 20 seasonal results have recurrence intervals of less than 10 years. The exceptions are April-June of 1999, October-December of 2000, and October-December of 2001, which have recurrence intervals of 27.5, 27.5, and 18.3 years, respectively.

Table 13. Seasonal Recurrence Intervals for RDU Precipitation, 1997-2001 (Recurrence Interval in Years for Precipitation Less than Observed)

	Jan-Mar	Apr-Jun	July-Sep	Oct-Dec
1997	3.67	1.53	2.62	1.53
1998	3.06	1.72	1.62	2.29
1999	1.02	27.50	1.02	6.88
2000	1.72	3.06	1.22	27.50
2001	2.39	1.96	3.67	18.33

In sum, the model simulation period contains a wet year (1998) a normal year (1997) and three years that were drier than normal, although each with different characteristics (1999-2001). However, the seasonal analysis shows that Haw River inflows and precipitation were not extraordinarily low, except for local precipitation during the summer of 1999. The drought, in terms of water supply availability, was the cumulative effect of several years of below normal precipitation and flow, and conditions, when examined on a seasonal basis, were generally not so extraordinarily rare as to be unrepresentative of the expected range of lake response. The years on which the model is developed are indeed biased toward drier conditions, but these conditions are not so extraordinary as to be rejected for development of a TMDL. The bias toward lower flows could, however, be used as part of a margin of safety argument in the development of point source wasteload allocations, as these low flow conditions should exacerbate the impacts of point source loads in the listed segments.

4.4 WATER QUALITY TARGETS

This section presents and describes the target against which potential load reductions are evaluated.

4.4.1 Chlorophyll *a* Criterion

The portions of Jordan Lake lying north and east of SR 1008 were identified by NC DWQ on their 2002 submission of the Clean Water Act §303(d) list (NC DENR, 2003) as impaired waters for which TMDLs are required. This portion of the lake officially consists of three waterbody segments, identified as shown in Table 14.

Table 14. Segments of Jordan Lake for which TMDLs are Required

Description	Segment (Assessment Unit)	Acres	Cause of Impairment
New Hope River Arm of B. Everett Jordan Lake, from source at confluence of Morgan Cr. and New Hope Cr. Arms of B. Everett Jordan Lake (an east-west line across the southern tip of the formed peninsula) to Chatham County SR 1008	16-41-(0.5)	1205	Chlorophyll *a*
New Hope Creek, from a point 0.8 miles downstream of Durham County SR1107 to confluence with Morgan Creek Arm of New Hope River Arm of B. Everett Jordan Lake	16-41-1-(14)	1377	Chlorophyll *a*
Morgan Creek (including the Morgan Creek Arm of Jordan Lake), from Chatham County SR 1726 (Durham County SR1109) to New Hope Creek Arm of New Hope River Arm of B. Everett Jordan Lake	16-41-2-(9.5)	851	Chlorophyll *a*

Each of these segments is listed for excursions of the NC water quality standard for chlorophyll *a*. The North Carolina Administrative Code (15A NAC 02B .0211(3)(a)) specifies the following quality standard as applicable to all fresh surface waters:

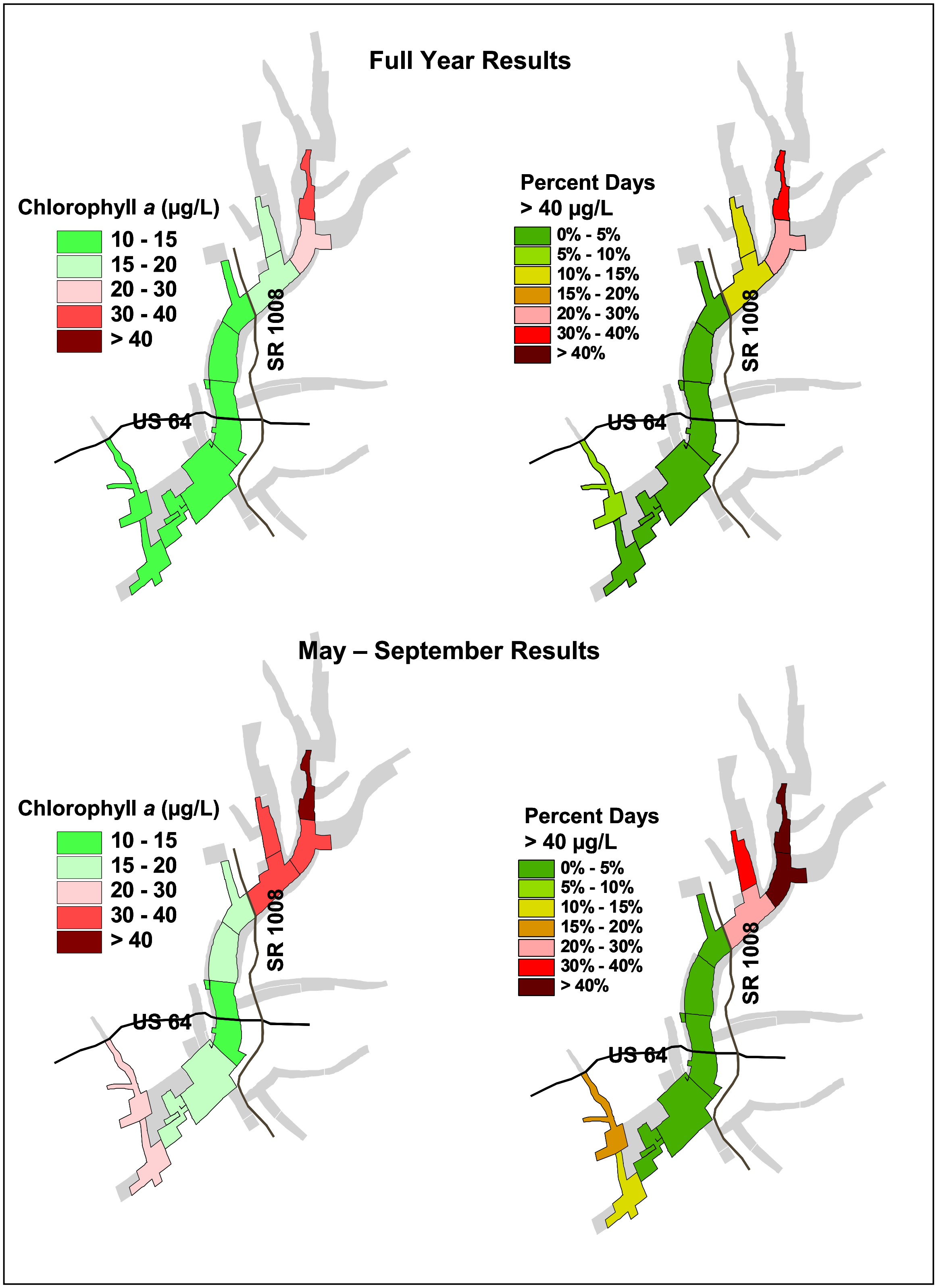
> *Chlorophyll a (corrected): not greater than 40 µg/l for lakes, reservoirs, and other waters subject to growths of macroscopic or microscopic vegetation not designated as trout waters… the Commission or its designee may prohibit or limit any discharge of waste into surface waters, if, in the opinion of the Director, the surface waters experience or the discharge would result in growths of microscopic or macroscopic vegetation such that the standards established pursuant to this Rule would be violated or the intended best usage of the waters would be impaired;*

Existing conditions relative to the water quality standard are summarized in Figure 40. This displays results of the simulation for 1997 through 2001. The top left portion of the figure shows the annual average concentration by segment predicted by the calibrated model. The annual average chlorophyll *a* concentration is less than 15 µg/L in most of the lake, but as high as 35 µg/L in Segment 1 of the upper New Hope arm. The upper right portion of the figure shows the frequency of time that concentrations are greater than the water quality standard of 40 µg/L on an annual basis. In general, the listed segments (1 through 4) lying upstream of SR 1008 in the New Hope Arm of Jordan Lake are predicted to have chlorophyll *a* concentrations greater than the water quality standard more than 10 percent of the time, while the remainder of the lake is predicted to exceed 40 µg/L less than 10 percent of the time.

The bottom portion of Figure 40 displays similar results, but calculated only for the May – September growing season. In all cases, chlorophyll *a* concentrations predicted for the growing season are greater than concentrations on annual basis, as expected. Average growing season concentrations in the listed segments range from 34 to 52 µg/L, consistent with DWQ observations. Frequency of days during the growing season with concentrations greater than 40 µg/L ranges from 30 to 75 percent in the listed segments. In the main body of the lake, the average growing season frequencies of excursions are much lower (less than 5 percent throughout the remainder of the New Hope Arm). However, the frequency of concentrations greater than 40 µg/L in segments 14 and 15 (Haw River arm) are between 11 and 17 percent. The data corresponding to Figure 40 are summarized in Table 15. Results are not shown for the tributary arms for which no monitoring data are available, as the model performance has not been tested in these areas.

Table 15. Model Predictions of Average Chlorophyll *a* Concentrations and Frequency of Concentrations Greater than 40 µg/L for Individual Segments of Jordan Lake, Based on Simulations for 1997-2001

Jordan Lake WASP Model Segment	Annual Average Chlorophyll *a* Concentration (µg/L)	Average Annual Frequency of Concentrations > 40 µg/L	Growing Season Average Chlorophyll *a* Concentration (µg/L)	Average Summer Frequency of Concentrations > 40 µg/L
1	35.2	36.5%	52.6	74.5%
2	26.1	21.0%	38.5	48.4%
3	25.0	14.8%	35.6	33.7%
4	22.5	12.5%	34.0	29.6%
5	14.8	0.6%	23.9	1.3%
6	13.1	0.4%	22.3	0.8%
8	11.2	0.0%	20.0	0.0%
9	10.3	0.0%	19.6	0.0%
12	11.4	1.2%	22.1	2.8%
13	11.6	0.1%	20.6	0.1%
14	16.9	5.0%	28.5	11.8%
15	19.8	6.9%	29.8	16.3%



Full Year Results

May – September Results

Figure 40. Simulated Chlorophyll *a* Concentrations and Frequency of Concentrations Greater than 40 µg/L for Jordan Lake, 1997-2001

4.4.2 Frequency Interpretation

Neither the North Carolina Administrative Code nor the state's 305(b) assessment methodology contains a precise statement of the frequency of excursions of the chlorophyll *a* standard sufficient to cause impairment of uses. The listing methodology for eutrophication promotes a weight-of-evidence approach, and states that it is "not appropriate to determine eutrophication related use impairment with the quantitative assessment of an individual water quality variable (i.e., chlorophyll *a*)." For ambient water quality criteria associated with aquatic life/secondary recreation use, a frequency of excursions of criteria up to 10 percent of the time within the past 5 years of data is deemed consistent with full use support (NC DENR, 2003).

Chlorophyll *a* concentrations naturally tend to be highly variable, and occasional blooms with greater than 40 µg/L can be expected in many waterbodies that otherwise support uses. It is thus not reasonable to set a management target that precludes any excursions of the chlorophyll *a* criterion. Use of a 10 percent frequency as a target for completion of a chlorophyll *a* TMDL in North Carolina is supported by EPA's approval of the nitrogen TMDL for the Neuse estuary. This document (NC DENR, 2001) states "…the TMDL target is to have less than or equal to 10% of the samples collected in a specified area and time (EPA guidance for use support determination) above the chlorophyll-a standard of 40 µg/l. Hereafter, this will be referred to as the 10/40 criterion."

Based on this precedent, a 10 percent or less frequency of predicted (daily average) chlorophyll *a* concentrations greater than 40 µg/L is taken as the frequency target for management.

4.4.3 Spatial and Temporal Applicability

The Neuse Estuary precedent establishes a 10 percent frequency target that can be applied to "a specified area and time." This leaves considerable remaining flexibility for interpretation.

For spatial applicability, results could be analyzed for individual model segments, or as an aggregate frequency across some or all of the listed segments. As the issue of appropriate area of application of the frequency target had not been resolved at the time of this document, results are developed for the four individual model segments constituting the listed area, and for various combinations of these segments.

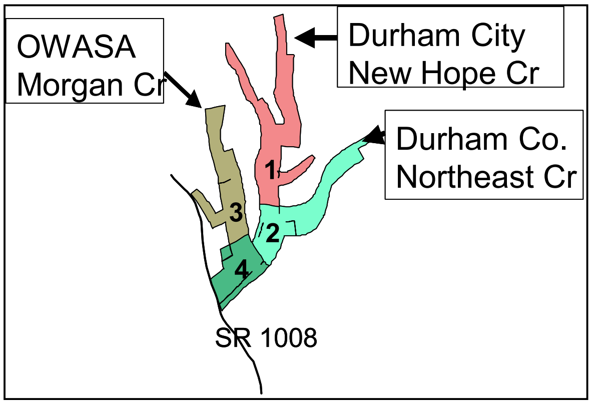
Temporal applicability is also subject to interpretation. Four potential options were evaluated for the listed segments of Jordan Lake:

1. Long-term (five-year) frequency of excursions over all seasons,
2. Long-term (five-year) frequency of excursions for growing season (May-September) only,
3. Worst-case (individual 12-month window) annual frequency of excursions, and
4. Worst-case (individual year) frequency of excursions for growing season only.

Options 3 and 4 (the worst-case analyses) were subsequently dropped as overly restrictive and unreliable. The worst-case analyses tend to focus on extreme conditions (such as extreme low flow conditions associated with the drought experienced in this area in 2000-2002) that are not representative of more general trends. Further, the 305(b) listing guidance supports use of five-year averages. Finally, a finding of non-compliance from the model using a worst-case approach runs a distinct risk of being caused by anomalies in the model forcing data, such as anomalies in the estimates of tributary load, rather than reflecting actual conditions.

The two long-term analyses (options 1 and 2) were both carried forward for further analyses. Option 1 (frequency over the entire simulation period) is consistent with the approach taken in the Neuse Estuary TMDL, and is likely to be less restrictive than requiring a 10 percent or less frequency during the summer growing season (because lower algal concentrations are expected in winter and early spring). However, this option has a drawback in that the model appears to underestimate chlorophyll *a* concentrations during the fall (see Section 4.2). Application of the 10 percent frequency target to the summer growing season (Option 2) is likely to be more restrictive than Option 1, but is consistent with the recent draft TMDL proposed for phosphorus in Roberson Creek (NC DENR, 2003b). Use of this option has the advantage of focusing on the period for which the model performs best, while avoiding the fall period in which the model may under-predict chlorophyll *a* concentrations.

4.5 RESULTS FOR LISTED SEGMENTS (UPPER NEW HOPE ARM OF JORDAN LAKE)



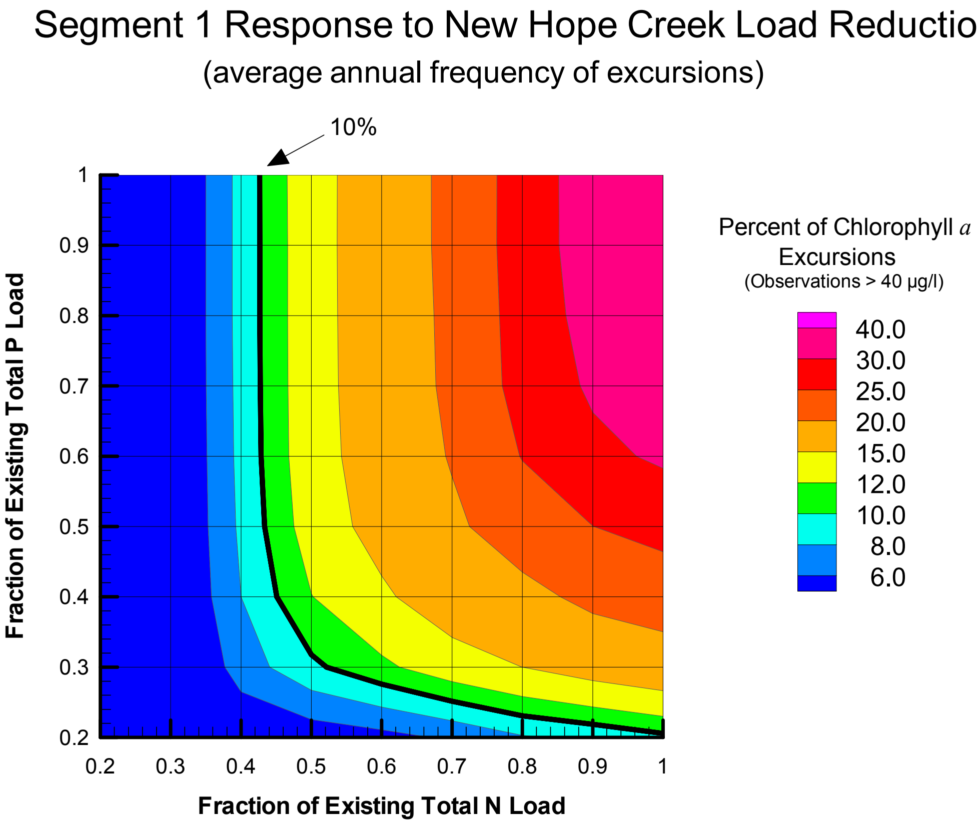
For the listed segments (see inset), the model scenarios examined the effects of load reductions from New Hope Creek, Northeast Creek, and Morgan Creek, as well as the additional impact of load reductions from the Haw River. Frequencies were tabulated for both the full simulation period and the growing season, as described above, and for individual and grouped segments. The frequency results are presented graphically in Figures 40 through 47, and tables of results are presented in Appendix B. Where frequencies are given for aggregated or "lumped" sets of segments these frequencies are calculated as the number of individual observations greater than 40 µg/L in all the aggregated segments divided by the total number of observations in those segments for the appropriate averaging period.

It is important to note that the loading reduction targets are evaluated relative to the loads observed in 1997-2001. This approach is necessary to maintain the temporal correlation between hydrology and pollutant loading.

Each of the graphs uses color ramps to map the predicted frequency of excursions, and the 10 percent target line is highlighted. The horizontal axis shows the scale factor on the existing 1997-2001 nitrogen load series, while the vertical axis shows the scale factor on the existing phosphorus load series. For instance, Figure 40 shows that attaining the 10 percent frequency in Segment 1 in response to New Hope Creek load reductions only is consistent with loading equal to 45 percent of the existing nitrogen load and 100 percent of the existing phosphorus load. Alternatively, the 10 percent frequency is consistent with 60 percent of the existing nitrogen load and 28 percent of the existing phosphorus load.

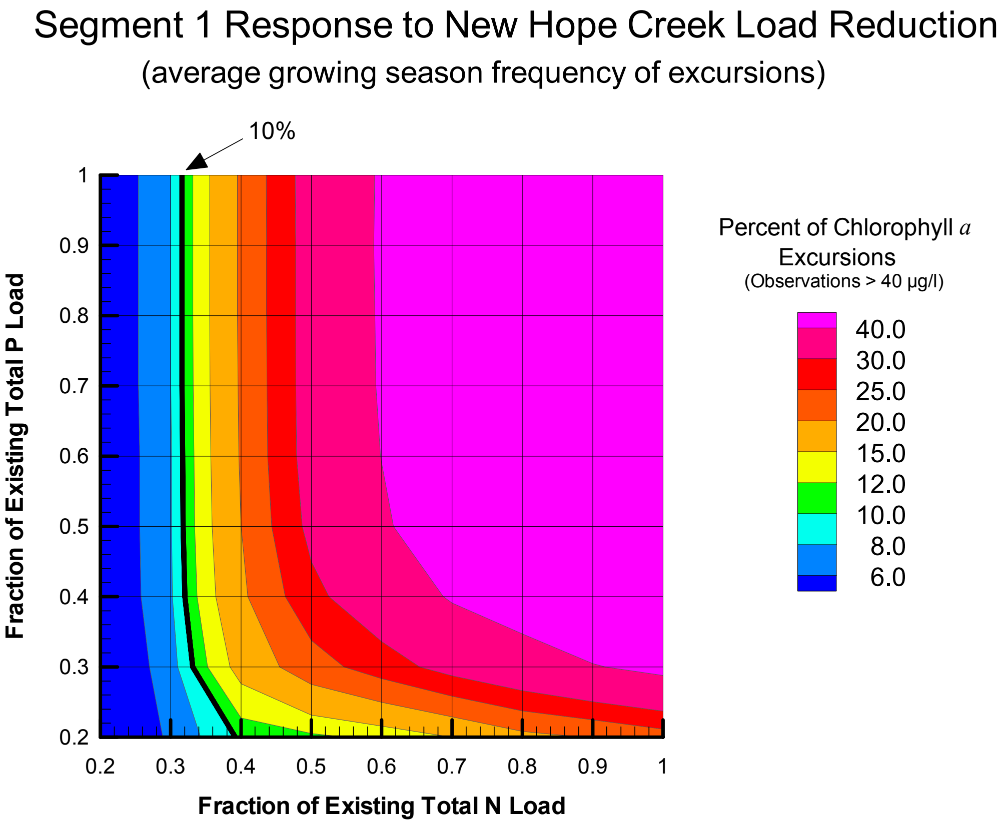
In general, attaining the desired frequency of excursions of the chlorophyll *a* standard in Segment 1 – which is dominated by Durham City sewage effluent during low flow conditions – would require large reductions in existing loads, despite the fact that this WWTP already achieves nitrogen removal close to that required under the NSW rule. In contrast, achieving the desired frequency on an aggregate basis over Segments 1-4 requires significantly less stringent reductions.

Results in Segment 4, and to a lesser extent in Segment 2, are sensitive to reductions in all three tributary areas. On the other hand, conditions in Segments 1 (New Hope) and 3 (Morgan Creek) are dominated by load from the local tributary. Figure 47 is included to show the effects on the listed segments of adding reductions in the Haw Arm loads. This produces a negligible change in the upper New Hope Arm of the lake.



Segment 1 Response to New Hope Creek Load Reduction

(average annual frequency of excursions)

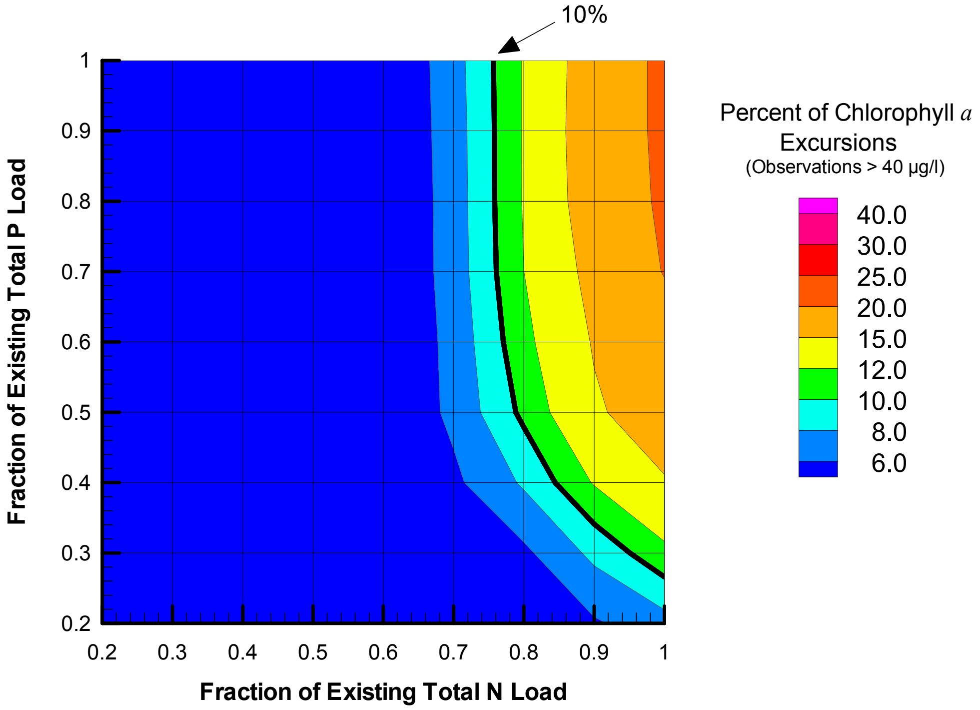


Segment 1 Response to New Hope Creek Load Reduction

(average growing season frequency of excursions)

Figure 41. Segment 1 Response to New Hope Creek Load Reduction

Segment 2 Response to New Hope Creek and Northeast Creek Load Reductions
(average annual frequency of excursions)



Segment 2 Response to New Hope Creek and Northeast Creek Load Reductions
(average growing season frequency of excursions)

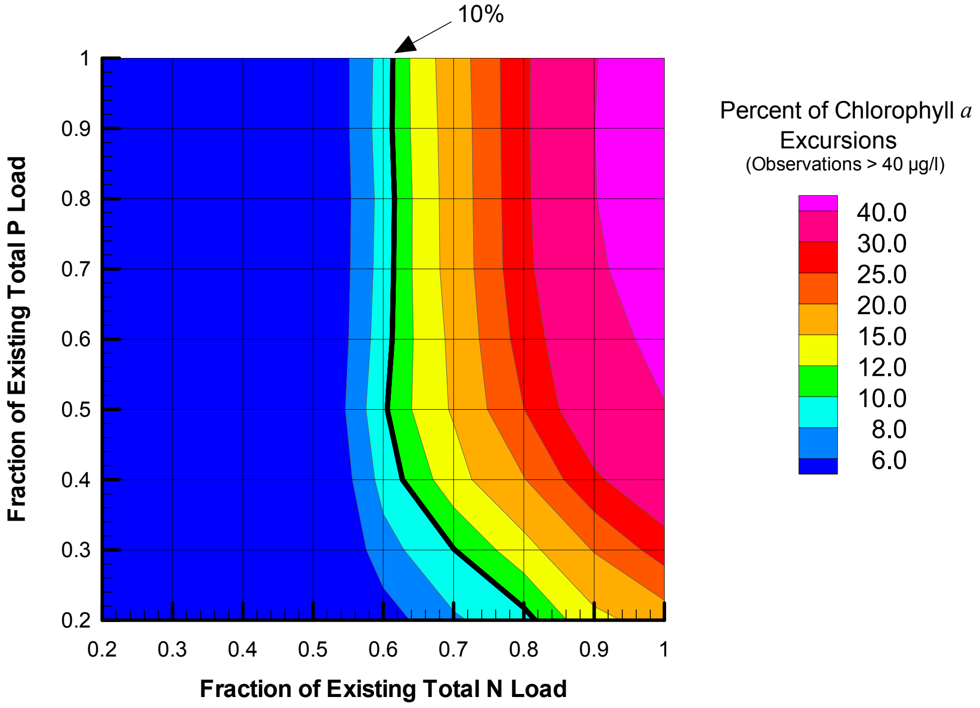
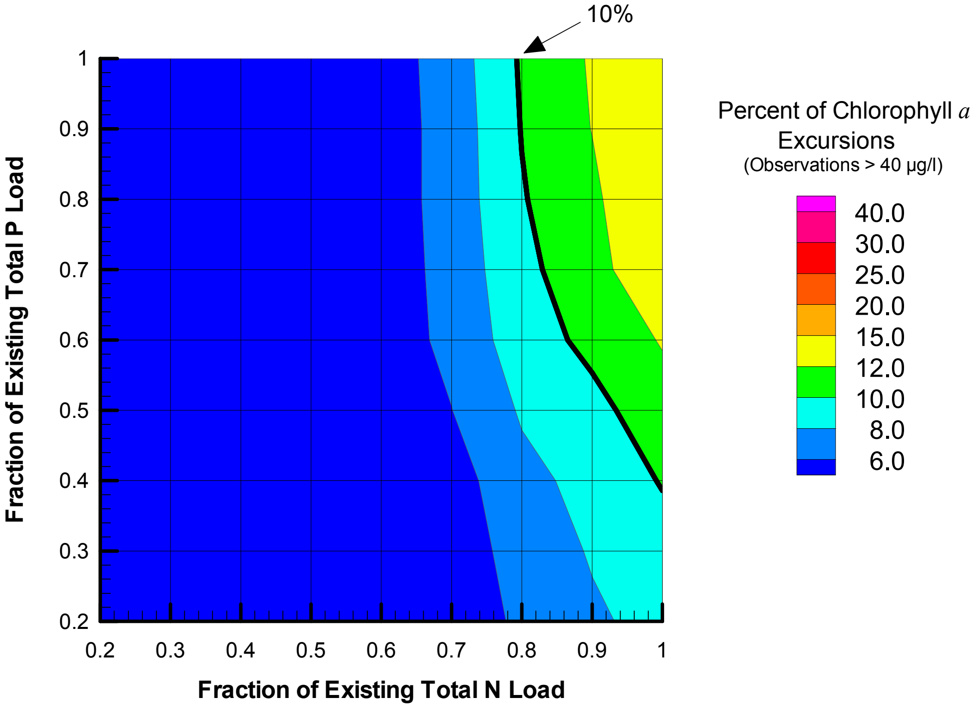


Figure 42. Segment 2 Response to New Hope Creek and Northeast Creek Load Reductions

Segment 3 Response to Morgan Creek Load Reduction

(average annual frequency of excursions)



Segment 3 Response to Morgan Creek Load Reduction

(average growing season frequency of excursions)

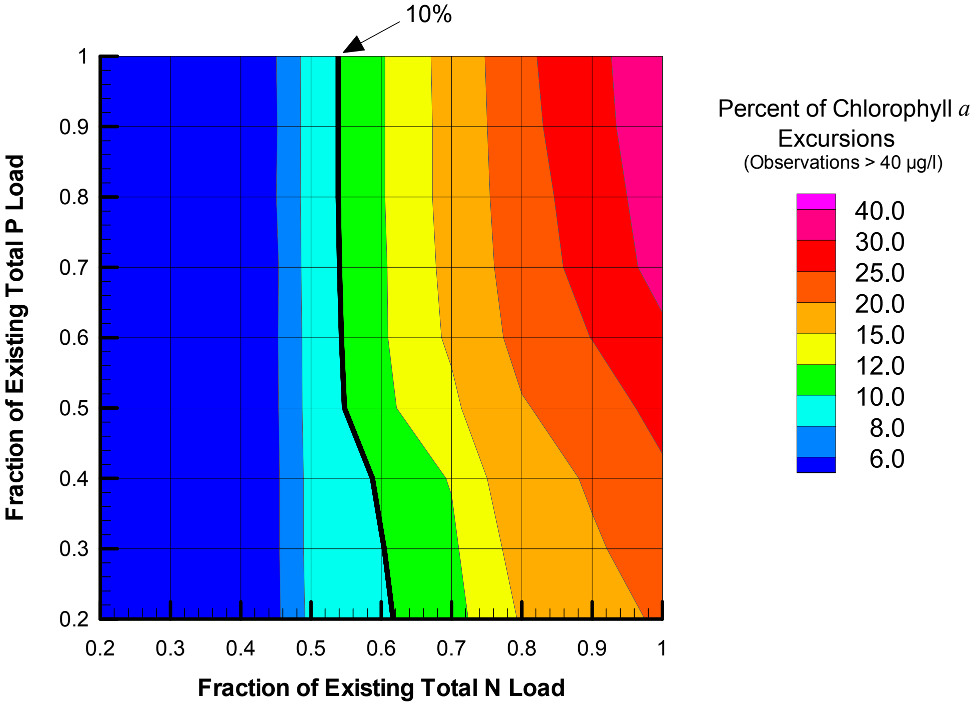
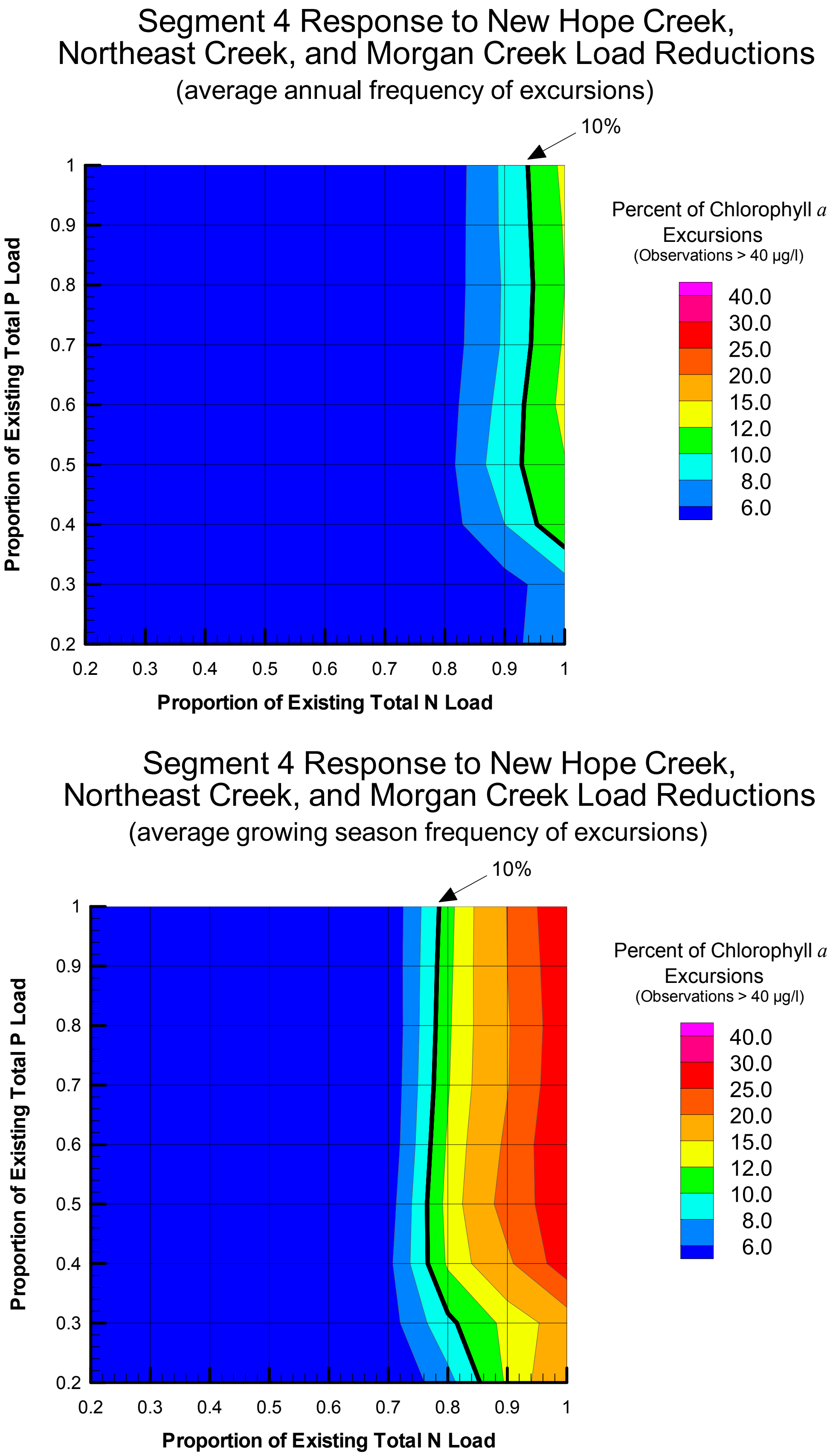
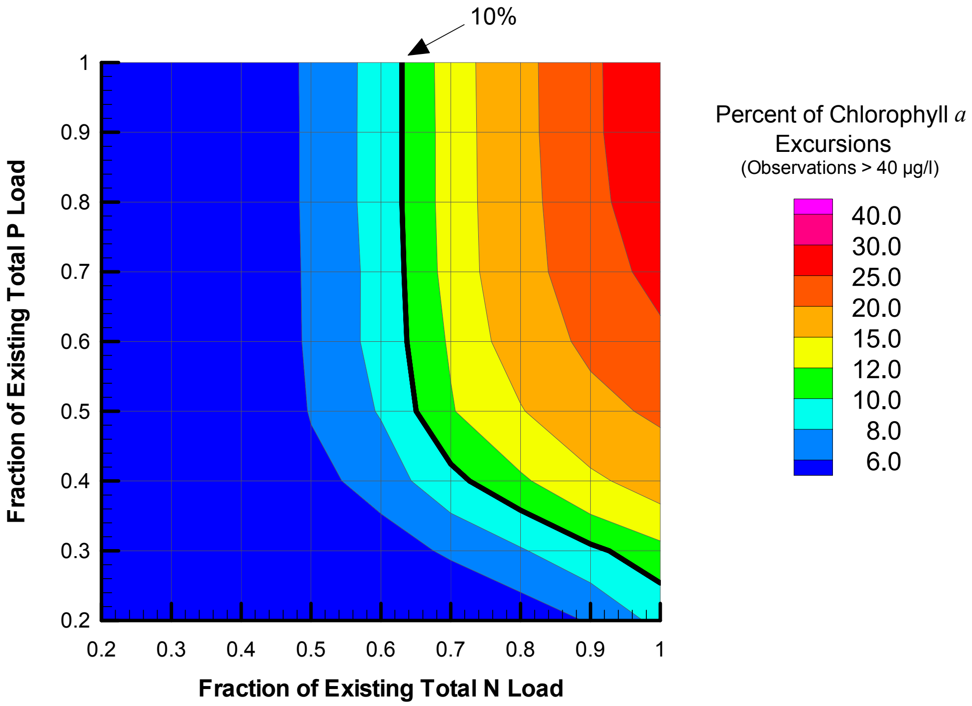


Figure 43. Segment 3 Response to Morgan Creek Load Reduction


Segment 4 Response to New Hope Creek, Northeast Creek, and Morgan Creek Load Reductions (average annual frequency of excursions)

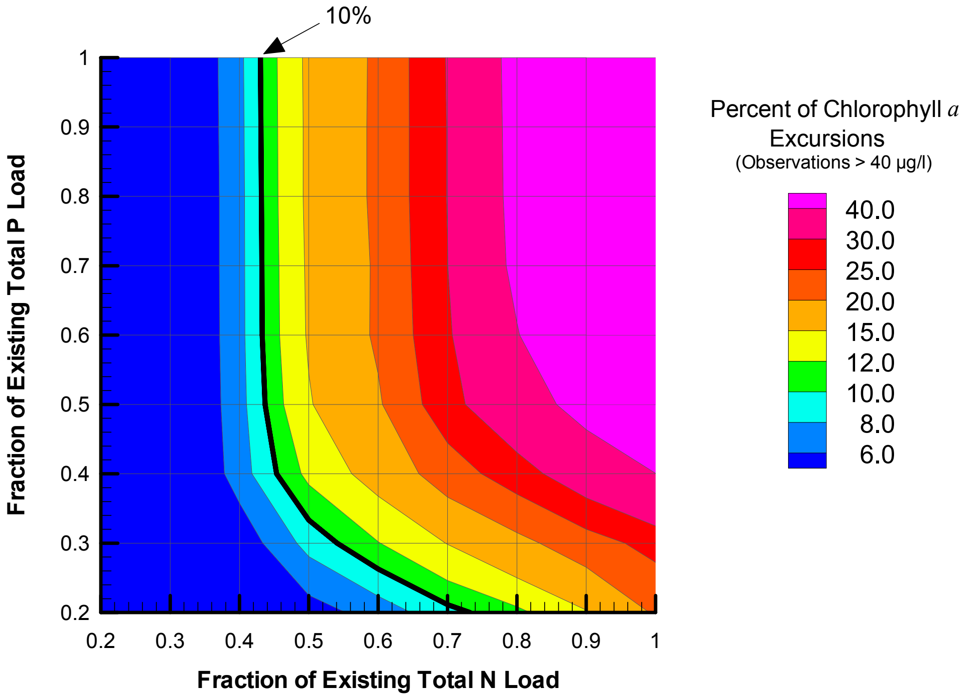
Segment 4 Response to New Hope Creek, Northeast Creek, and Morgan Creek Load Reductions (average growing season frequency of excursions)

Figure 44. Segment 4 Response to New Hope, Northeast, and Morgan Creek Load Reductions



Lumped Segments 1 & 2 Response to Load Reductions

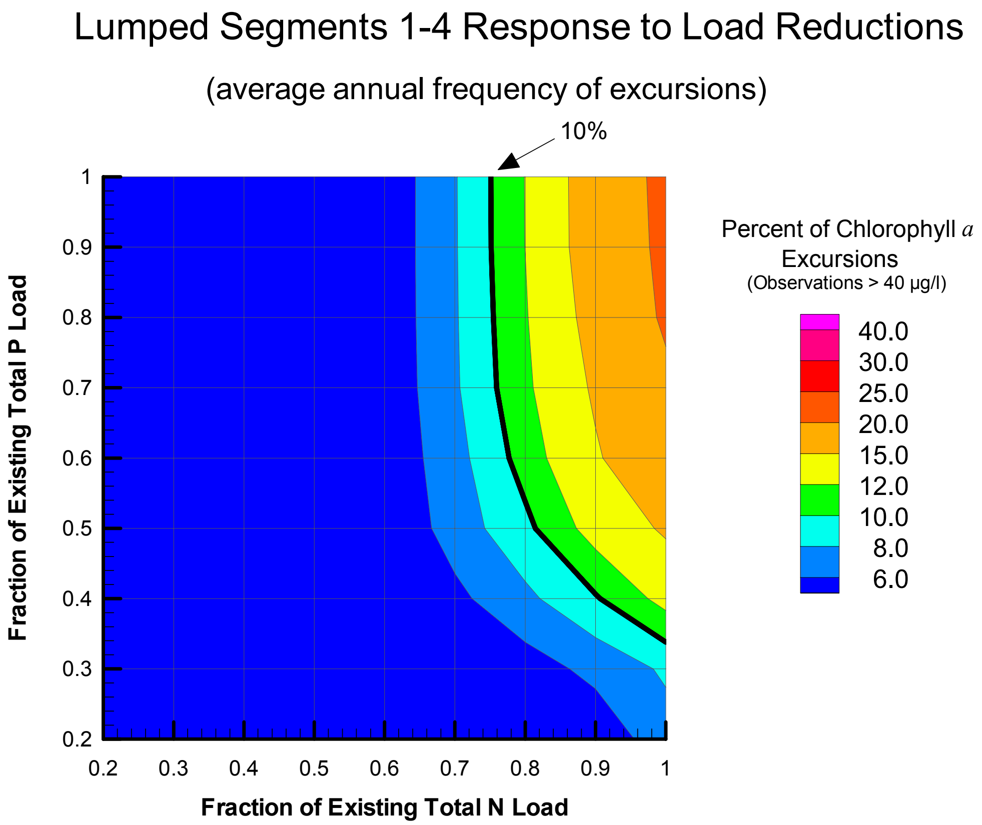
(average annual frequency of excursions)



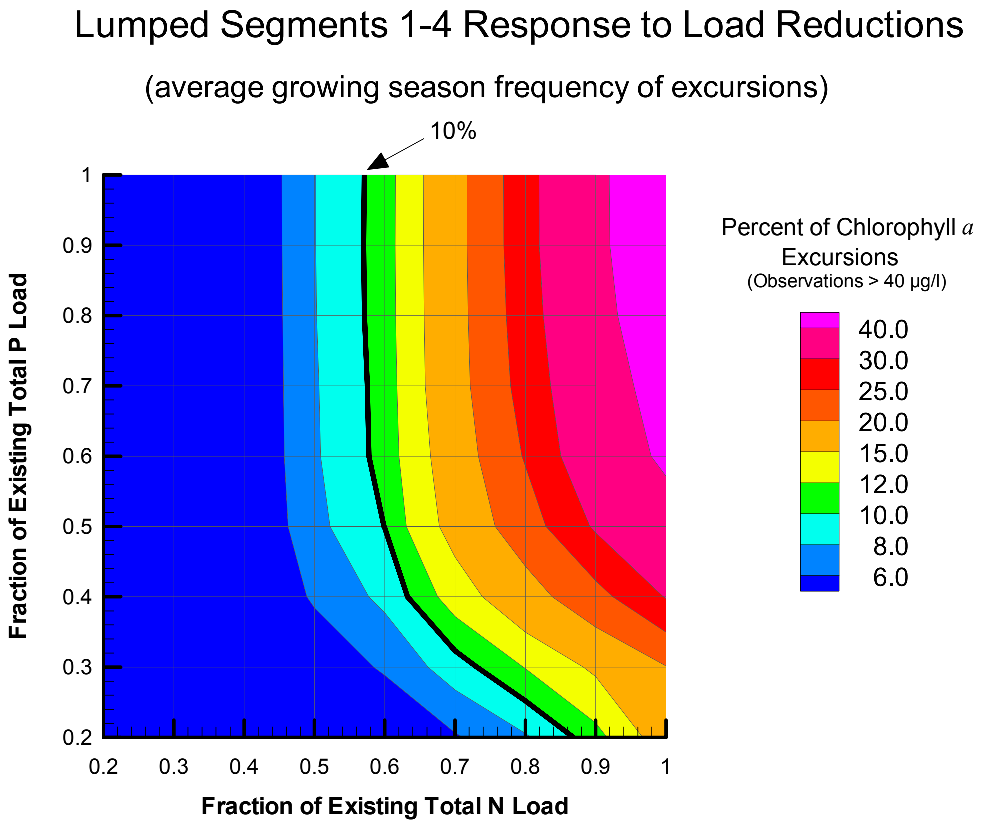
Lumped Segments 1 & 2 Response to Load Reductions

(average growing season frequency of excursions)

Figure 45. Aggregate Response of Segments 1 and 2 to New Hope, Northeast, and Morgan Creek Load Reductions


Lumped Segments 1-4 Response to Load Reductions

(average annual frequency of excursions)

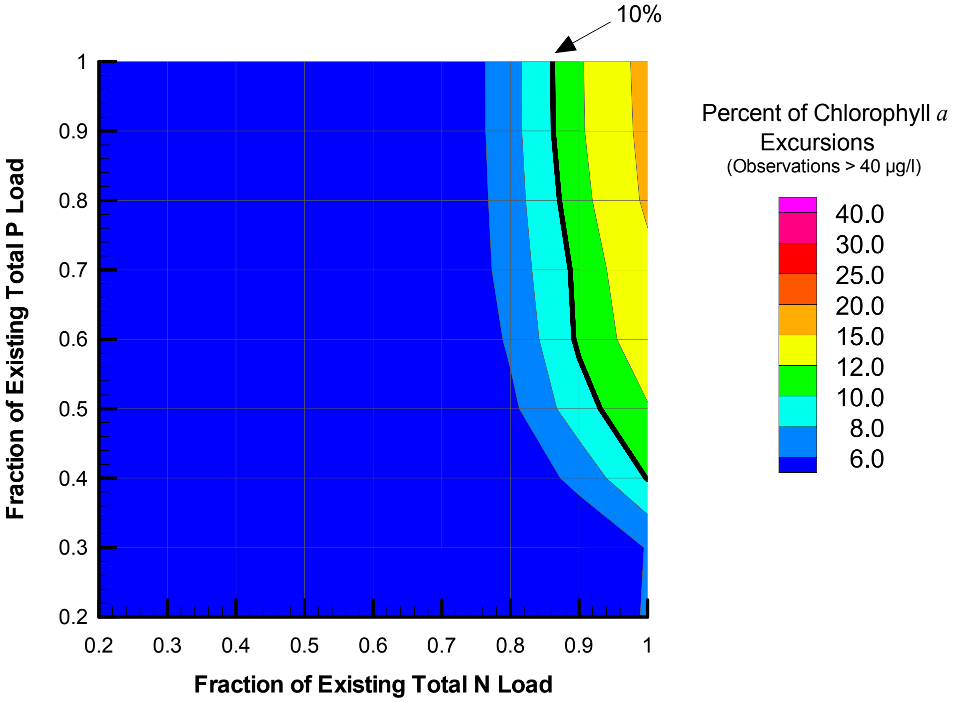

Lumped Segments 1-4 Response to Load Reductions

(average growing season frequency of excursions)

Figure 46. Aggregate Response of Segments 1-4 to New Hope, Northeast, and Morgan Creek Load Reductions

Lumped Segments 2 - 4 Response to New Hope, Northeast, and Morgan Load Reductions

(average annual frequency of excursions)



Lumped Segments 2 - 4 Response to New Hope, Northeast, and Morgan Load Reductions

(average growing season frequency of excursions)

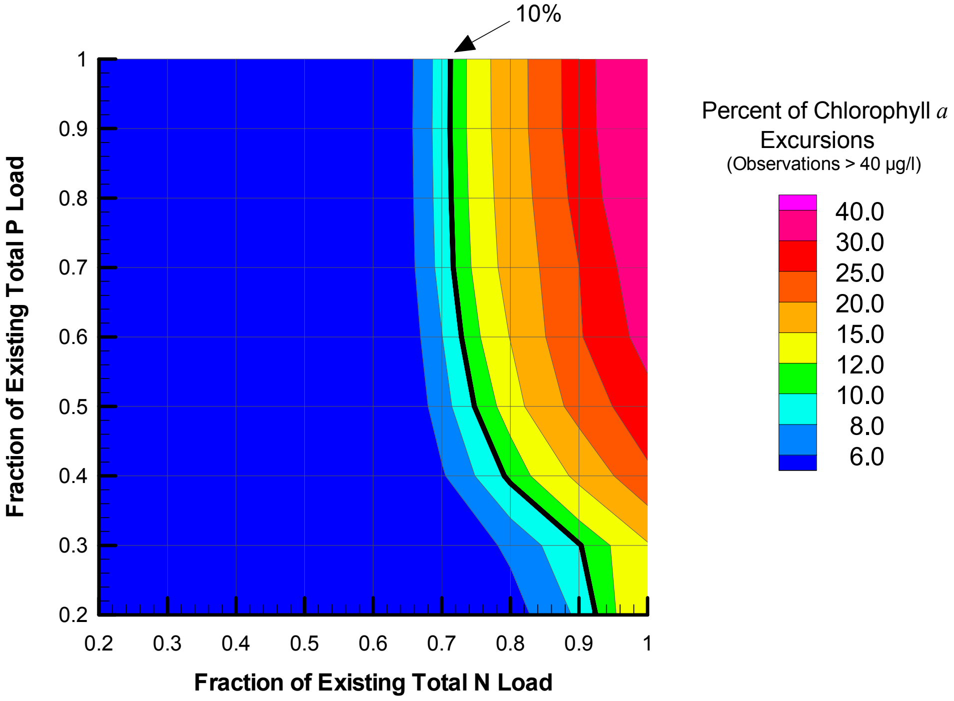
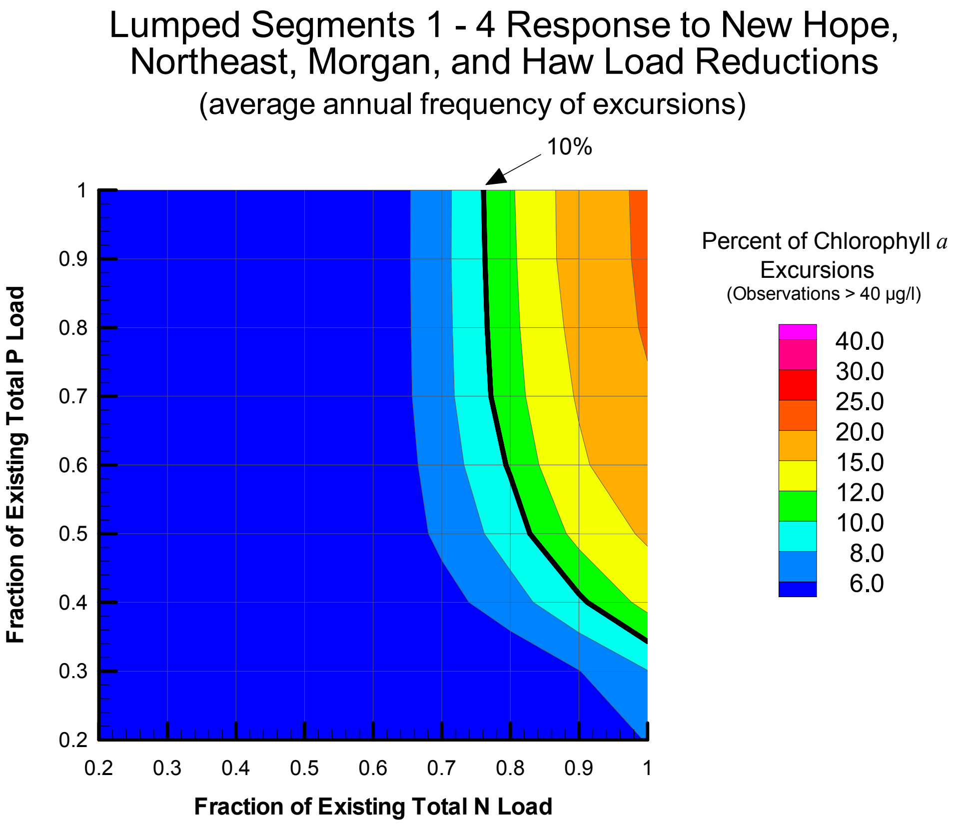


Figure 47. Aggregate Response of Segments 2-4 to New Hope, Northeast, and Morgan Creek Load Reductions


Lumped Segments 1 - 4 Response to New Hope, Northeast, Morgan, and Haw Load Reductions
(average annual frequency of excursions)

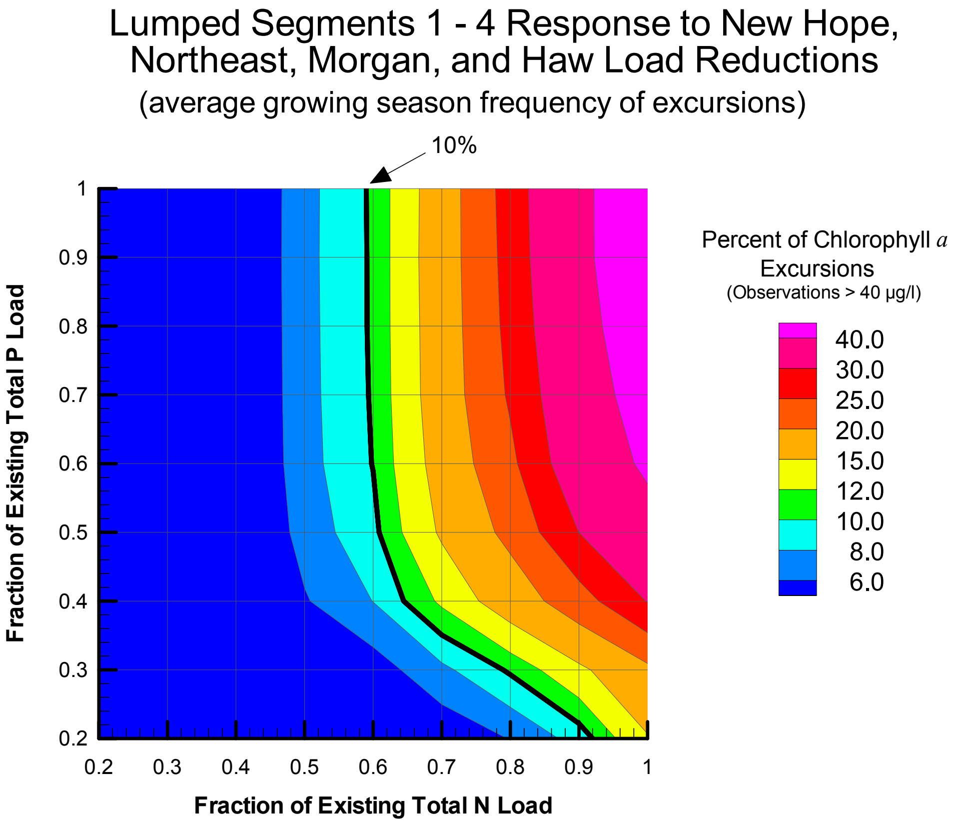

Lumped Segments 1 - 4 Response to New Hope, Northeast, Morgan, and Haw Load Reductions
(average growing season frequency of excursions)

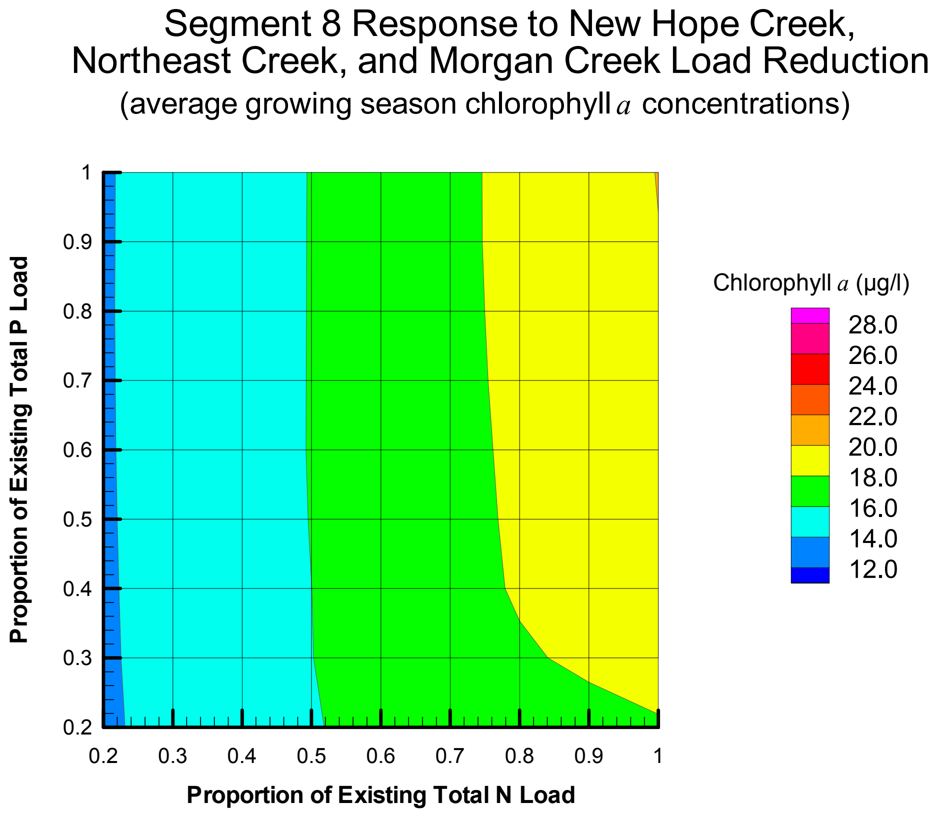
Figure 48. Aggregate Response of Segments 1-4 to New Hope, Northeast, Morgan Creek, and Haw River Load Reductions

4.6 RESULTS FOR OTHER SEGMENTS OF JORDAN LAKE

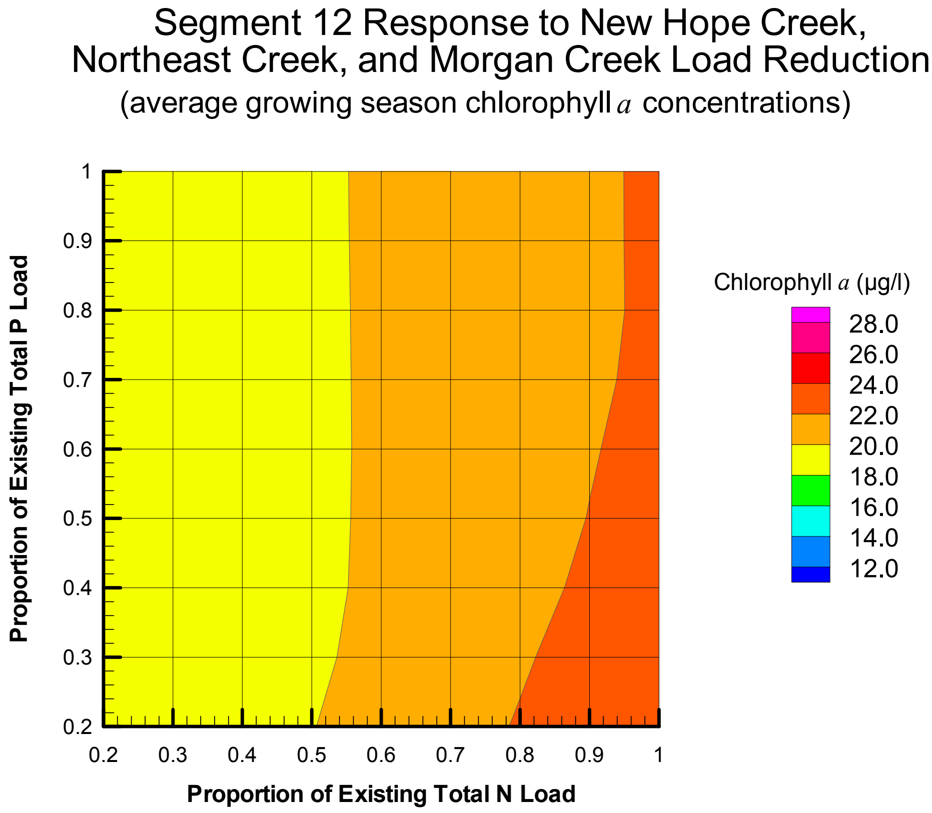
4.6.1 Response in the Middle New Hope Arm to Reductions in the Listed Segments

In the Middle New Hope Arm of Jordan Lake, chlorophyll *a* concentrations greater than 40 µg/L are predicted to occur rarely, if at all. This portion of the lake contains the Cary-Apex water supply intake (Segment 8) and major recreation areas, such as those in Segment 12. Reductions in loads to meet targets in the listed segments are expected to produce secondary benefits of lowered chlorophyll *a* concentrations in these segments as well.

The responses of Segments 8 and 12 to upstream load reductions are shown in Figure 48. Because concentrations greater than 40 µg/L are not expected, results for these segments are shown in terms of growing season average chlorophyll *a* concentration, rather than frequency. Segment 8 shows the expected response; reductions in upstream loading translate into a reduction in summer chlorophyll *a* concentrations at the water supply segment. A more complex result is seen in Segment 12. Here, large reductions in upstream phosphorus loading can actually result in a small predicted increase in Segment 12 summer chlorophyll *a* concentration. This occurs because imposition of phosphorus limitation in the Upper New Hope results in greater transport of nitrogen to Segment 12, where it can interact with the phosphorus supply from the Haw River arm to produce a heightened algal response.



Segment 8 Response to New Hope Creek, Northeast Creek, and Morgan Creek Load Reductions
(average growing season chlorophyll *a* concentrations)



Segment 12 Response to New Hope Creek, Northeast Creek, and Morgan Creek Load Reductions
(average growing season chlorophyll *a* concentrations)

Figure 49. Chlorophyll *a* Concentration Response of Middle New Hope Segments to Upper New Hope Load Reductions

4.6.2 Nutrient Response in the Haw River Arm of Jordan Lake

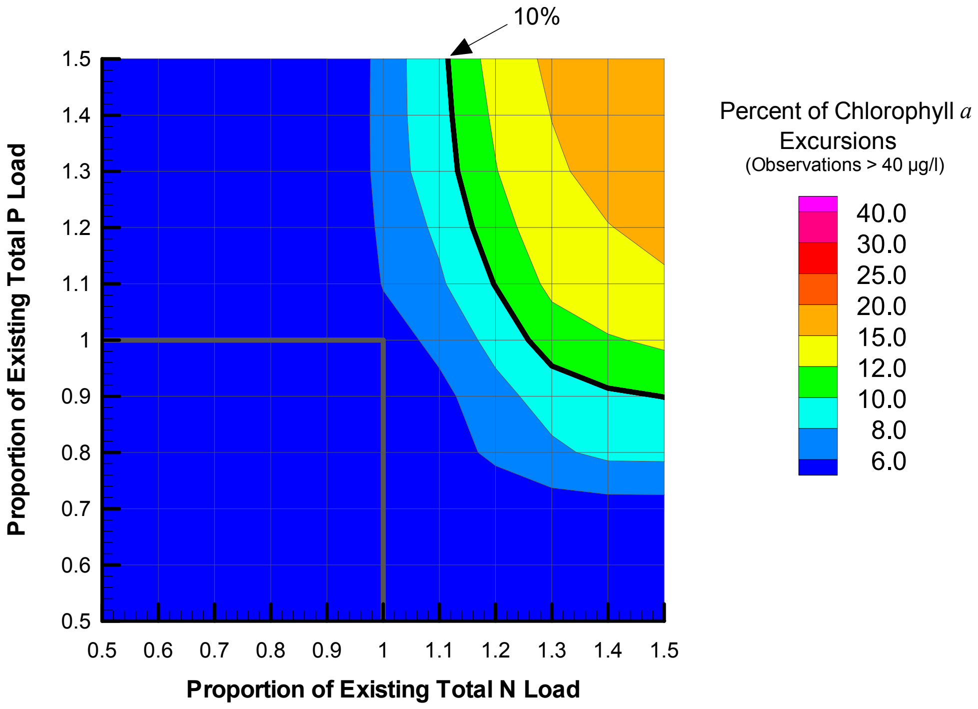
Only the upper segments of the New Hope Arm of Jordan Lake are currently listed as requiring a TMDL to address chlorophyll *a* concentrations. However, the entire lake is subject to Nutrient Sensitive Water (NSW) rules. The other portion of the lake in which chlorophyll *a* concentrations greater than 40 µg/L are observed is the Haw River arm, consisting of surface Segments 15 (upper Haw River arm) and 14 (near dam segment).

These segments have not been listed as impaired, despite occasional excursions of the chlorophyll *a* standard. They *may* possess additional assimilative capacity, depending on how the target is evaluated. Because there is potentially additional assimilative capacity, the graphical summary of results for these segments is presented in a different format than the results for the upper New Hope Arm. Specifically, the x and y axes are displayed as a proportion of existing load, ranging from 0.5 (50 percent reduction) to 1.5 (50 percent increase).

Results for Segments 14 and 15 individually, in response to reductions in Haw River loads only, are shown in Figures 49 and 50. For both segments, the long-term annual average frequency of concentrations in excess of 40 µg/L is well less than the target frequency of 10 percent (this is the 1:1 point at the center of the graphs). In large part this reflects the fact that residence time in these segments is very short during periods when flow in the Haw River is elevated, particularly in the spring, providing little opportunity for algal blooms. If, however, the frequency is evaluated on a growing season basis, the frequencies associated with existing conditions appear to be slightly over 10 percent in both segments. This fits with the 2001 monitoring results, in which observed chlorophyll *a* concentrations at CPF055C (Segment 15) ranged from 7 to 60 µg/L with a median of 32, and observed concentrations at CPF055E (Segment 14) ranged from 14 to 55 µg/L with a median of 25.

Aggregating the results for Segments 14 and 15 (Figure 51) produces little change, because the response in these two segments is similar. Finally, Figure 52 examines the aggregated results when loads to the New Hope Arm are also reduced. These results are almost indistinguishable from those in Figure 51, showing that the frequency of excursions of the chlorophyll *a* standard in this portion of the lake is insensitive to nutrient loading in the Upper New Hope Arm.

Segment 14 Response to Haw River Load Changes
(average annual frequency of excursions)



Segment 14 Response to Haw River Load Changes
(average growing season frequency of excursions)

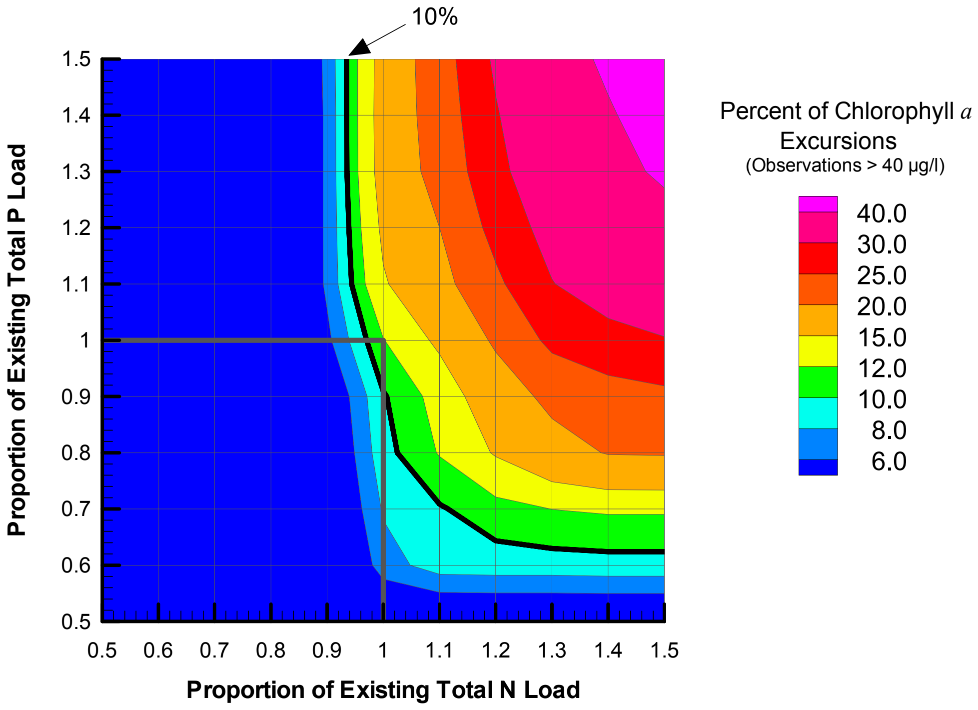
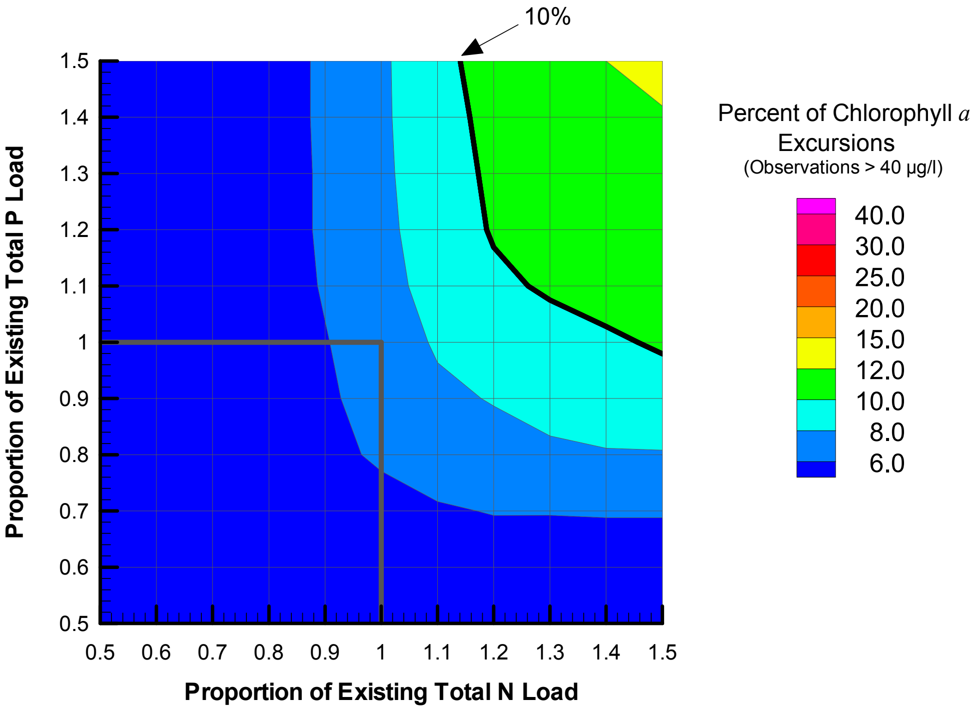
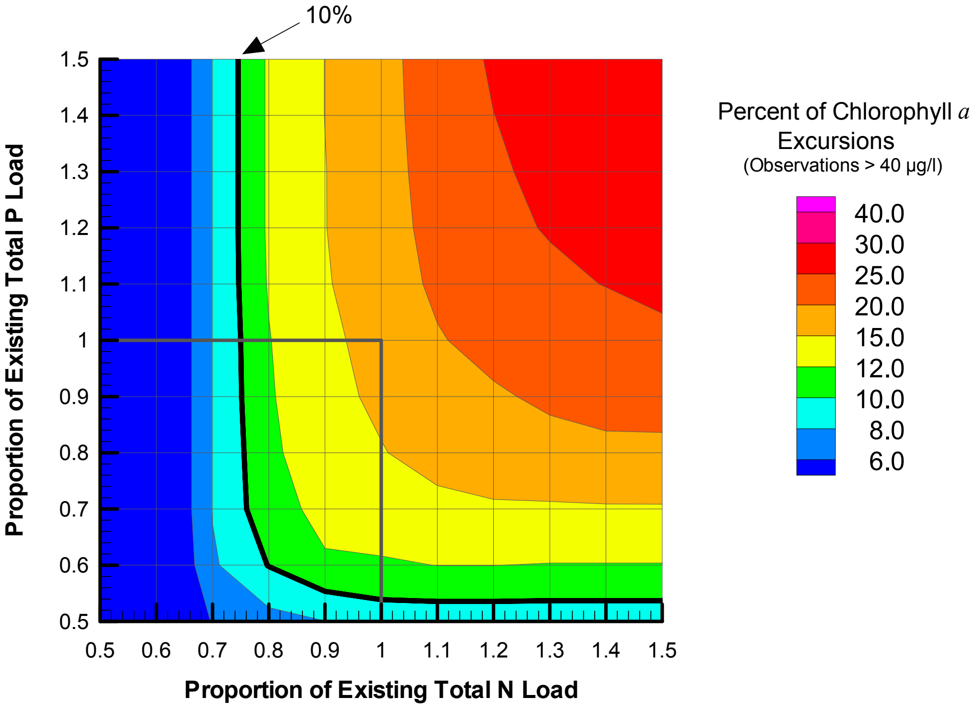


Figure 50. Segment 14 (Near Dam) Response to Haw River Load



Segment 15 Response to Haw River Load Changes

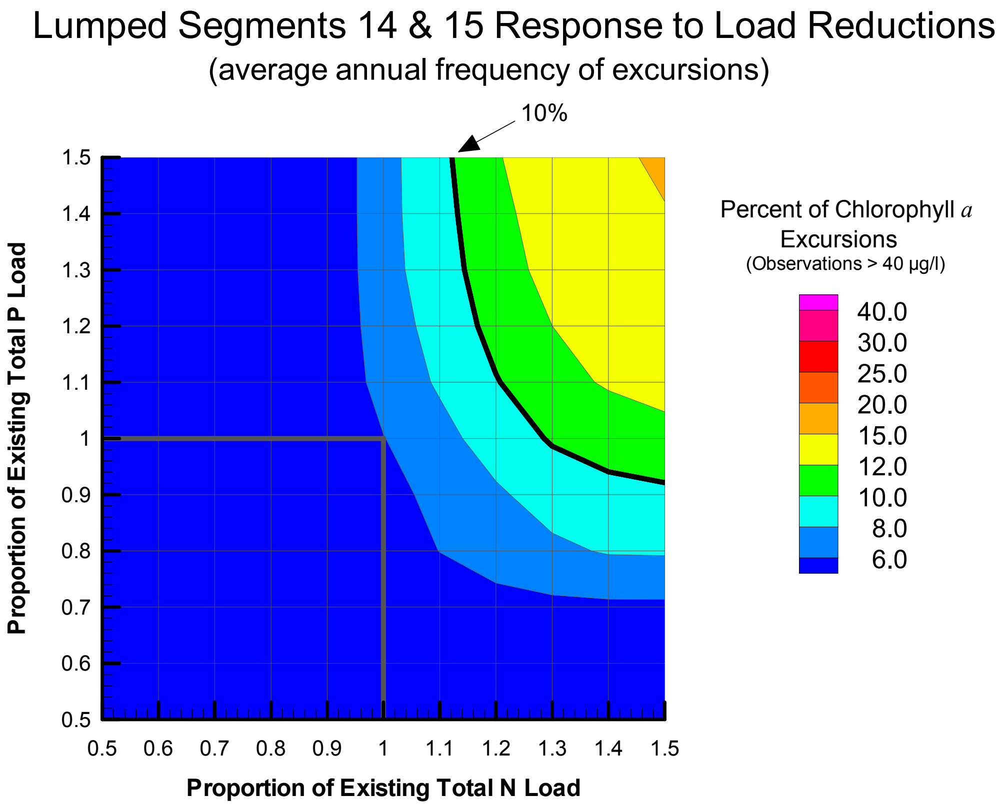
(average annual frequency of excursions)



Segment 15 Response to Haw River Load Changes

(average growing season frequency of excursions)

Figure 51. Segment 15 (Haw River Arm) Response to Haw River Load


Lumped Segments 14 & 15 Response to Load Reductions
(average annual frequency of excursions)

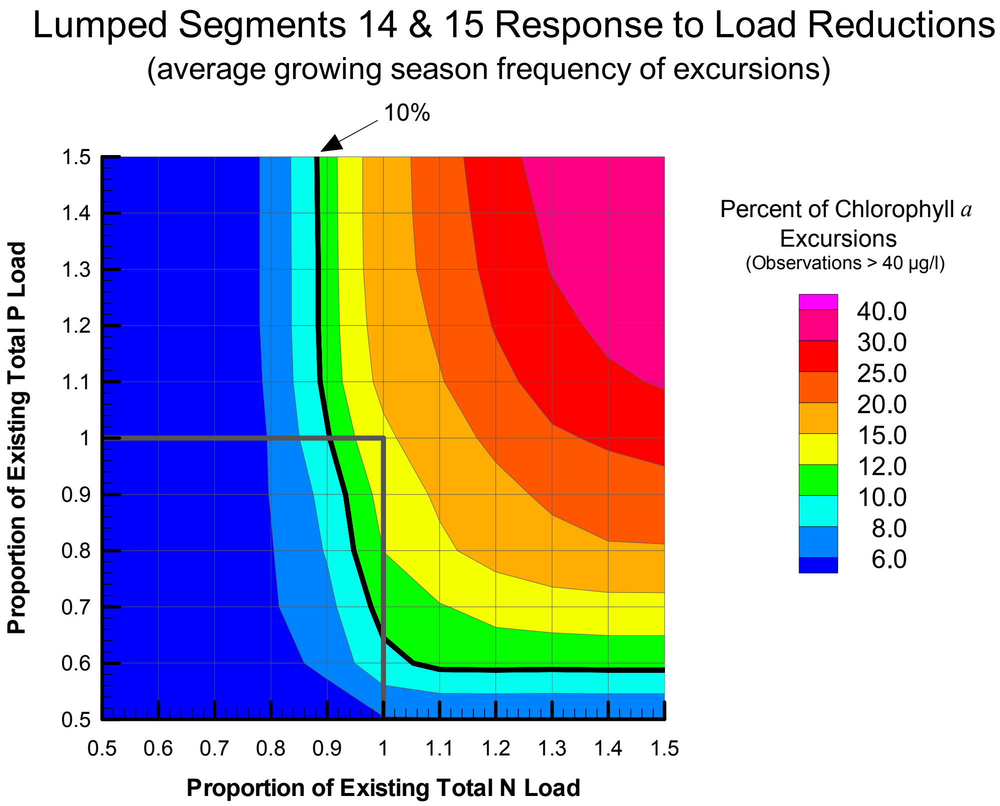
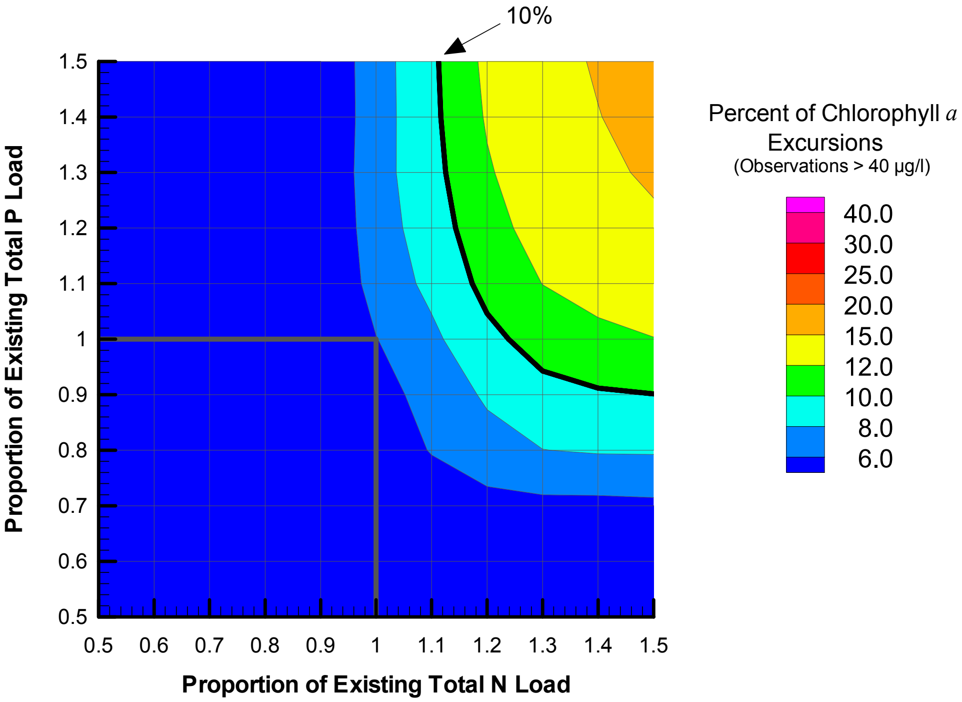

Lumped Segments 14 & 15 Response to Load Reductions
(average growing season frequency of excursions)

Figure 52. Segments 14 and 15 Aggregated Response to Haw River Load

Lumped Segments 14 & 15 Response to Morgan, Northeast, New Hope, and Haw Load Changes
(average annual frequency of excursions)



Lumped Segments 14 & 15 Response to Morgan, Northeast, New Hope, and Haw Load Changes
(average growing season frequency of excursions)

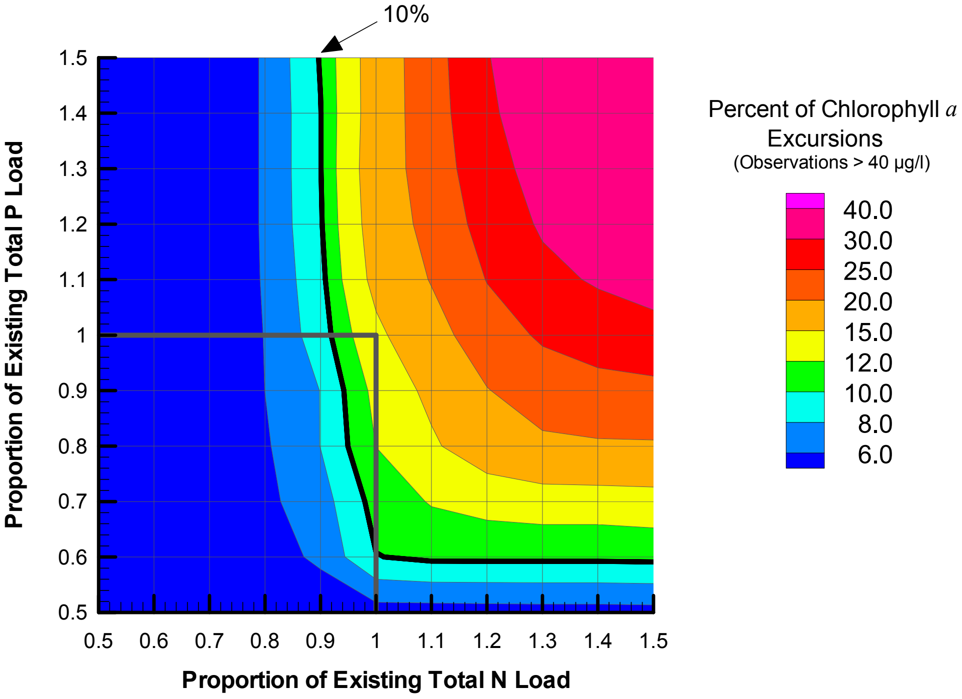


Figure 53. Segments 14 and 15 Aggregated Response to Haw River, New Hope Creek, Morgan Creek, and Northeast Creek Loads

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Appendix A. Revised Jordan Lake WASP Input File

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```
EUTRO
 JORDAN LAKE 97-01 - using uninterpolated NOx and TP for 2001
 NSEG NSYS ICFL MFLG JMAS NSLN INTY ADFC   DD HHMM MODEL OPTIONS
   41    8    0    0    4    0    0  0.0   0. 0.0.    0.00
    1    3    4   15   14   25
    8
    .03125      180.    .03125      410.    .03125      450.    .03125      520.
    .03125      690.   .015625      731.    .03125      841.    .03125     1826.
    1
       1.0    1826.                       change to 1826
    0    0    0    0    0    0    0    0
    2          DATA GROUP B: EXCHANGE COEFFICIENTS
    5  0.20D-01        1.
    3
    805.00   3450.00    2    1
   3029.00   2980.00    4    2
   1188.00   3230.00    3    4
    2
    1000.0    0.0000    1000.0 1826.0000
    8
    324.00   2340.00    5    4
     68.00   2340.00   16    4
    324.00   2400.00    9    8
    312.00   2400.00   20   19
    180.00   3440.00   12   11
    113.00   3440.00   23   22
    180.00   2795.00    8    7
    204.00   2795.00   19   18
    2
       1.0    0.0000       1.0 1826.0000
   10
   1132.00   3180.00    6    5
   3397.00   3180.00   17   16
   2198.00   2660.00    8    6
   6594.00   2660.00   19   17
   2739.00   2580.00   12    9
   8218.00   2580.00   23   20
    848.00   2940.00   10   12
   2545.00   2940.00   21   23
   1458.00   2620.00   13   12
   4375.00   2620.00   24   23
    2
       0.1    0.0000       0.1 1826.0000
    6
   2261.00   2460.00   14   13
   6784.00   2460.00   25   24
   1720.00   4905.00   15   14
   1720.00   4905.00   15   25
      1.00   1000.00   15   13
      1.00   1000.00   15   24
    2
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   10
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4435316.00      2.90    6   17
1989902.00      2.90    7   18
2704982.00      2.90    8   19
```

```
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 365051.00      2.90   10   21
3479557.00      2.90   11   22
8487744.00      2.90   12   23
2453471.00      2.90   13   24
3589474.00      2.90   14   25
    2
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    1  0.19D+02        1.
   15
 2426609.0       1.0    1   26
 3426040.0       1.0    2   27
 2660280.0       1.0    3   28
 4882959.0       1.0    4   29
 2362953.0       1.0   16   31
 4435316.0       1.0   17   32
 1989902.0       1.0   18   33
 2704982.0       1.0   19   34
 3128214.0       1.0   20   35
  365051.0       1.0   21   36
 3479557.0       1.0   22   37
 8487744.0       1.0   23   38
 2453471.0       1.0   24   39
 3589474.0       1.0   25   40
 2498592.0       1.0   15   30
    2
 0.231E-08    0.0000 0.231E-08  1826.0000
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         3        28        1 .26903E+07       1.0       0.0       1.0       0.0
         4        29        1 .16923E+08       1.0       0.0       1.0       0.0
         5        16        1 .75280E+07       1.0       0.0       1.0       0.0
         6        17        1 .82004E+07       1.0       0.0       1.0       0.0
         7        18        1 .37984E+07       1.0       0.0       1.0       0.0
         8        19        1 .55560E+07       1.0       0.0       1.0       0.0
         9        20        1 .66200E+07       1.0       0.0       1.0       0.0
        10        21        1 .24869E+07       1.0       0.0       1.0       0.0
        11        22        1 .10750E+08       1.0       0.0       1.0       0.0
        12        23        1 .22199E+08       1.0       0.0       1.0       0.0
        13        24        1 .65473E+07       1.0       0.0       1.0       0.0
        14        25        1 .99260E+07       1.0       0.0       1.0       0.0
        15        30        1 .13269E+08       1.0       0.0       1.0       0.0
        16        31        2 .57901E+07       1.0       0.0       1.0       0.0
        17        32        2 .13532E+08       1.0       0.0       1.0       0.0
        18        33        2 .54898E+07       1.0       0.0       1.0       0.0
        19        34        2 .12002E+08       1.0       0.0       1.0       0.0
        20        35        2 .12739E+08       1.0       0.0       1.0       0.0
        21        36        2 .70606E+06       1.0       0.0       1.0       0.0
        22        37        2 .52520E+07       1.0       0.0       1.0       0.0
        23        38        2 .46141E+08       1.0       0.0       1.0       0.0
        24        39        2 .12616E+08       1.0       0.0       1.0       0.0
        25        40        2 .28030E+08       1.0       0.0       1.0       0.0
        26        41        3 .15604E+07       1.0       0.0       1.0       0.0
        27        41        3 .11627E+07       1.0       0.0       1.0       0.0
```

```
        28        41         3 .97844E+06       1.0       0.0       1.0       0.0
        29        41         3 .70467E+06       1.0       0.0       1.0       0.0
        30        41         3 .40000E+06       1.0       0.0       1.0       0.0
        31        41         3 .54301E+06       1.0       0.0       1.0       0.0
        32        41         3 .62213E+06       1.0       0.0       1.0       0.0
        33        41         3 .60303E+06       1.0       0.0       1.0       0.0
        34        41         3 .34048E+06       1.0       0.0       1.0       0.0
        35        41         3 .35241E+06       1.0       0.0       1.0       0.0
        36        41         3 .29670E+06       1.0       0.0       1.0       0.0
        37        41         3 .75885E+06       1.0       0.0       1.0       0.0
        38        41         3 .96823E+06       1.0       0.0       1.0       0.0
        39        41         3 .57812E+06       1.0       0.0       1.0       0.0
        40        41         3 .59202E+06       1.0       0.0       1.0       0.0
        41         0         4 .10461E+08       1.0       0.0       1.0       0.0
    3    51997-01.hyd     Data Group D: Flows
    1 0.000E+00     1.000    Data Block D.2 Pore Water Flows               in m3/s
   15
      0.10   26    1      0.10  27     2      0.10   28    3      0.10   29    4
      0.10   30   15      0.10  31    16      0.10   32   17      0.10   33   18
      0.10   34   19      0.10  35    20      0.10   36   21      0.10   37   22
      0.10   38   23      0.10  39    24      0.10   40   25
    2
0.15D+01       0.0    0.15D+01    1826.0
    7 1.000E+00 1.157E-05    Data Block D.3 Sed. #1 Transport Field - Organics
    8
0.2427E+07    1   260.3426E+07    2   270.1990E+07    7   180.3651E+06   10   21
0.3480E+07   11   220.1990E+07   18   330.3651E+06   21   360.3480E+07   22   37
    4
 0.4550000     0.0   0.4550000    1824.0 0.0500000    1825.0 0.0500000    1826.0
    1
0.4883E+07    3   28
    4
      0.90     0.0        0.90    1826.0
    1
0.4883E+07    4   29
    4
      0.08     0.0        0.08    1824.0      0.04    1825.0      0.04    1826.0
   10
0.2364E+07    5   160.4435E+07    6   170.2705E+07    8   190.3128E+07    9   20
0.8488E+07   12   230.2364E+07   16   310.4435E+07   17   320.2705E+07   19   34
0.3128E+07   20   350.8488E+07   23   38
    2
   1.02000     0.0     1.02000    1826.0
    4
0.2453E+07   13   240.3589E+07   14   250.2453E+07   24   390.3589E+07   25   40
    2
      0.65       0.0      0.65    1826.0
    1
0.2499E+07   15   30
    4
      1.00     0.0        1.00    1824.0      0.00    1825.0      0.00    1826.0
   15
0.2427E+07   26   410.3426E+07   27   410.2660E+07   28   410.1990E+07   33   41
0.3651E+06   36   410.4883E+07   29   410.2364E+07   31   410.4435E+07   32   41
0.2705E+07   34   410.3128E+07   35   410.8488E+07   38   410.2499E+07   30   41
0.2453E+07   39   410.3589E+07   40   410.3480E+07   37   41
    2
```

```
0.001          0.0    0.001       1826.0
    6 1.000E+00 1.157E-05    Data Block D.4 Sed. #2 Transport Field - Algae
    2
0.2427E+07    1   260.3426E+07    2   270.2660E+07
    2
.060000000     0.0  .060000000    1826.0
    7
0.2660E+07    3   280.1990E+07    7   180.3651E+06   10   210.3480E+07   11   22
0.1990E+07   18   330.3651E+06   21   360.3480E+07   22   37
    2
0.64D-01       0.0    0.64D-01    1826.0
    1
0.4883E+07    4   29
    2
0.80D-01       0.0    0.80D-01    1826.0
    2
0.2364E+07    5   160.4435E+07    6   17
    2
0.65D-01       0.0    0.65D-01    1826.0
    8
0.2705E+07    8   190.3128E+07    9   200.8488E+07   12   230.2364E+07   16   31
0.4435E+07   17   320.2705E+07   19   340.3128E+07   20   350.8488E+07   23   38
    2
0.65D-01       0.0    0.65D-01    1826.0
    5
0.2453E+07   13   240.3589E+07   14   250.2499E+07   15   300.2453E+07   24   39
0.3589E+07   25   40
    2
      0.07       0.0      0.07    1826.0
    6 1.000E+00 1.157E-05    Data Block D.5 Sed. #3 Transport Field - inorganics
    9
0.2427E+07    1   260.3426E+07    2   270.1990E+07    7   180.3651E+06   10   21
0.3480E+07   11   220.1990E+07   18   330.3651E+06   21   360.3480E+07   22   37
0.4883E+07    4   29
    4
0.41D+01       0.0    0.41D+01    1824. 0.01D+01    1825.0    0.01D+01    1826.0
    1
0.2660E+07    3   28
    2
0.50D+01       0.0    0.50D+01    1826.0
    9
0.2364E+07    5   160.4435E+07    6   170.2705E+07    8   190.3128E+07    9   20
0.2364E+07   16   310.4435E+07   17   320.2705E+07   19   340.3128E+07   20   35
0.8488E+07   23   38
    2
       1.8     0.0         1.8    1826.0
    1
0.8488E+07   12   23
    2
  2.325470     0.0    2.325470    1826.0
    5
0.2453E+07   13   240.3589E+07   14   250.2499E+07   15   300.2453E+07   24   39
0.3589E+07   25   40
    2
   6.20000       0.0  6.200000    1826.0
   15
0.2427E+07   26   410.3426E+07   27   410.2660E+07   28   410.1990E+07   33   41
```

```
0.3651E+06   36   410.4883E+07   29   410.2364E+07   31   410.4435E+07   32   41
0.2705E+07   34   410.3128E+07   35   410.8488E+07   38   410.2499E+07   30   41
0.2453E+07   39   410.3589E+07   40   410.3480E+07   37   41
    2
       .002       0.0      .002    1826.0
    0    0    0    0    0    0    0    0
        17 *** Data Group E, System:  1
        1.        1.
   15    2
        0.        0.        0.     1826.
    3    2
        0.        0.        0.     1826.
    1    2
        0.        0.        0.     1826.
    2    2
        0.        0.        0.     1826.
   14    2
        0.        0.        0.     1826.
   11    2
        0.        0.        0.     1826.
    7    2
        0.        0.        0.     1826.
    4    2
        0.        0.        0.     1826.
    5    2
        0.        0.        0.     1826.
   10    2
        0.        0.        0.     1826.
    8    2
        0.        0.        0.     1826.
   25    2
        0.        0.        0.     1826.
   22    2
        0.        0.        0.     1826.
   18    2
        0.        0.        0.     1826.
   16    2
        0.        0.        0.     1826.
   21    2
        0.        0.        0.     1826.
   19    2
        0.        0.        0.     1826.
        17 *** Data Group E, System:  2
        1.        1.
   15    2
        0.        0.        0.     1826.
    3    2
        0.        0.        0.     1826.
    1    2
        0.        0.        0.     1826.
    2    2
        0.        0.        0.     1826.
   14    2
        0.        0.        0.     1826.
   11    2
        0.        0.        0.     1826.
    7    2
```

```
          0.        0.        0.     1826.
     4    2
          0.        0.        0.     1826.
     5    2
          0.        0.        0.     1826.
    10    2
          0.        0.        0.     1826.
     8    2
          0.        0.        0.     1826.
    25    2
          0.        0.        0.     1826.
    22    2
          0.        0.        0.     1826.
    18    2
          0.        0.        0.     1826.
    16    2
          0.        0.        0.     1826.
    21    2
          0.        0.        0.     1826.
    19    2
          0.        0.        0.     1826.
         17 *** Data Group E, System:  3
          1.        1.
    15    2
          0.        0.        0.     1826.
     3    2
          0.        0.        0.     1826.
     1    2
          0.        0.        0.     1826.
     2    2
          0.        0.        0.     1826.
    14    2
          0.        0.        0.     1826.
    11    2
          0.        0.        0.     1826.
     7    2
          0.        0.        0.     1826.
     4    2
          0.        0.        0.     1826.
     5    2
          0.        0.        0.     1826.
    10    2
          0.        0.        0.     1826.
     8    2
          0.        0.        0.     1826.
    25    2
          0.        0.        0.     1826.
    22    2
          0.        0.        0.     1826.
    18    2
          0.        0.        0.     1826.
    16    2
          0.        0.        0.     1826.
    21    2
          0.        0.        0.     1826.
    19    2
          0.        0.        0.     1826.
```

```
      17 *** Data Group E, System:  4
       1.        1.
  15   2
      15.        0.       10.     1826.
   3   2
       3.        0.        3.     1826.
   1   2
       3.        0.        3.     1826.
   2   2
       3.        0.        3.     1826.
  14   2
       3.        0.        3.     1826.
  11   2
       3.        0.        3.     1826.
   7   2
       3.        0.        3.     1826.
   4   2
       3.        0.        3.     1826.
   5   2
       3.        0.        3.     1826.
  10   2
       3.        0.        3.     1826.
   8   2
       3.        0.        3.     1826.
  25   2
       3.        0.        3.     1826.
  22   2
       3.        0.        3.     1826.
  18   2
       3.        0.        3.     1826.
  16   2
       3.        0.        3.     1826.
  21   2
       3.        0.        3.     1826.
  19   2
       3.        0.        3.     1826.
      17 *** Data Group E, System:  5
       1.        1.
  15   2
       0.        0.        0.     1826.
   3   2
       0.        0.        0.     1826.
   1   2
       0.        0.        0.     1826.
   2   2
       0.        0.        0.     1826.
  14   2
       0.        0.        0.     1826.
  11   2
       0.        0.        0.     1826.
   7   2
       0.        0.        0.     1826.
   4   2
       0.        0.        0.     1826.
   5   2
       0.        0.        0.     1826.
  10   2
```

```
        0.        0.        0.     1826.
    8   2
        0.        0.        0.     1826.
   25   2
        0.        0.        0.     1826.
   22   2
        0.        0.        0.     1826.
   18   2
        0.        0.        0.     1826.
   16   2
        0.        0.        0.     1826.
   21   2
        0.        0.        0.     1826.
   19   2
        0.        0.        0.     1826.
       17 *** Data Group E, System:  6
        1.        1.
   15   2
        0.        0.        0.     1826.
    3   2
        0.        0.        0.     1826.
    1   2
        0.        0.        0.     1826.
    2   2
        0.        0.        0.     1826.
   14   2
        0.        0.        0.     1826.
   11   2
        0.        0.        0.     1826.
    7   2
        0.        0.        0.     1826.
    4   2
        0.        0.        0.     1826.
    5   2
        0.        0.        0.     1826.
   10   2
        0.        0.        0.     1826.
    8   2
        0.        0.        0.     1826.
   25   2
        0.        0.        0.     1826.
   22   2
        0.        0.        0.     1826.
   18   2
        0.        0.        0.     1826.
   16   2
        0.        0.        0.     1826.
   21   2
        0.        0.        0.     1826.
   19   2
        0.        0.        0.     1826.
       17 *** Data Group E, System:  7
        1.        1.
   15   2
        0.        0.        0.     1826.
    3   2
        0.        0.        0.     1826.
```

```
   1    2
        0.        0.        0.     1826.
   2    2
        0.        0.        0.     1826.
  14    2
        0.        0.        0.     1826.
  11    2
        0.        0.        0.     1826.
   7    2
        0.        0.        0.     1826.
   4    2
        0.        0.        0.     1826.
   5    2
        0.        0.        0.     1826.
  10    2
        0.        0.        0.     1826.
   8    2
        0.        0.        0.     1826.
  25    2
        0.        0.        0.     1826.
  22    2
        0.        0.        0.     1826.
  18    2
        0.        0.        0.     1826.
  16    2
        0.        0.        0.     1826.
  21    2
        0.        0.        0.     1826.
  19    2
        0.        0.        0.     1826.
        17 *** Data Group E, System:  8
        1.        1.
  15    2
        0.        0.        0.     1826.
   3    2
        0.        0.        0.     1826.
   1    2
        0.        0.        0.     1826.
   2    2
        0.        0.        0.     1826.
  14    2
        0.        0.        0.     1826.
  11    2
        0.        0.        0.     1826.
   7    2
        0.        0.        0.     1826.
   4    2
        0.        0.        0.     1826.
   5    2
        0.        0.        0.     1826.
  10    2
        0.        0.        0.     1826.
   8    2
        0.        0.        0.     1826.
  25    2
        0.        0.        0.     1826.
  22    2
```

```
        0.        0.        0.     1826.
   18    2
        0.        0.        0.     1826.
   16    2
        0.        0.        0.     1826.
   21    2
        0.        0.        0.     1826.
   19    2
        0.        0.        0.     1826.
         0         *    +    *    +    *    (NH3)  *    +    *    F: LOADS
         0                                (NO3)
         0                                (PO4)
         0                                (PHYT)
         0                                (CBOD)
         0                                (DO)
         0                                (ON)
         0                                (OP)
         1          valun6.nps                                      (NPS
LOADS)valun6 is flow-weighted to days and uniterpolated in 2001 for NOx and TP NE
        10    +    *    +    *    +    *    +    *    +    *    G: PARAMETERS
TMPSG    3       1.0TMPFN    4       1.0  SAL    2       0.0SOD1D    9       1.0
scale factors
SODTA   12       1.0 KESG    5  8.00D-01 KEFN    6       1.0 FNH4    7      50.0
TOTLM   13       1.0 FPO4    8       2.0DUMMY    0       0.0DUMMY    0       0.0
         1
segments
TMPSG    3      1.10TMPFN    4       2.0  SAL    2       0.0SOD1D    9       0.5
SODTA   12     1.028 KESG    5       1.0 KEFN    6       4.0 FNH4    7       1.0
TOTLM   13     0.750 FPO4    8       1.0
         2
TMPSG    3      1.10TMPFN    4       2.0  SAL    2       0.0SOD1D    9       0.4
SODTA   12     1.028 KESG    5       1.0 KEFN    6       4.0 FNH4    7       0.8
TOTLM   13     1.000 FPO4    8       1.0
         3
TMPSG    3      1.05TMPFN    4       2.0  SAL    2       0.0SOD1D    9       0.5
SODTA   12     1.028 KESG    5       1.0 KEFN    6       4.0 FNH4    7       0.8
TOTLM   13     0.750 FPO4    8       1.0
         4
TMPSG    3       1.0TMPFN    4       2.0  SAL    2       0.0SOD1D    9       3.5
SODTA   12     1.028 KESG    5       1.0 KEFN    6       4.0 FNH4    7       0.5
TOTLM   13     0.800 FPO4    8       1.0
         5
TMPSG    3       1.0TMPFN    4       2.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5       1.0 KEFN    6       3.0 FNH4    7       0.2
TOTLM   13     0.900 FPO4    8       0.0
         6
TMPSG    3       1.0TMPFN    4       2.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5       1.0 KEFN    6       3.0 FNH4    7       0.2
TOTLM   13     1.000 FPO4    8       0.0
         7
TMPSG    3       1.0TMPFN    4       2.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       3.0 FNH4    7       0.2
TOTLM   13       1.0 FPO4    8       0.0
         8
TMPSG    3       1.0TMPFN    4       2.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       3.0 FNH4    7       0.2
TOTLM   13       1.0 FPO4    8       0.0
```

```
         9
TMPSG    3        1.0TMPFN    4       2.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12      1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.2
TOTLM   13        1.0 FPO4    8       0.0
        10
TMPSG    3        1.0TMPFN    4       2.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12      1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.0
TOTLM   13        1.0 FPO4    8       0.0
        11
TMPSG    3        1.0TMPFN    4       2.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12      1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.0
TOTLM   13        1.0 FPO4    8       0.0
        12
TMPSG    3        1.0TMPFN    4       2.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12      1.028 KESG    5     1.500 KEFN    6       2.0 FNH4    7       0.0
TOTLM   13        0.9 FPO4    8       0.0
        13
TMPSG    3        1.0TMPFN    4       1.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12      1.028 KESG    5     1.500 KEFN    6       1.0 FNH4    7       0.0
TOTLM   13        0.9 FPO4    8       0.0
        14
TMPSG    3        1.0TMPFN    4       1.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12      1.028 KESG    5     1.500 KEFN    6       1.0 FNH4    7       0.0
TOTLM   13        0.8 FPO4    8       0.0
        15
TMPSG    3        1.0TMPFN    4       1.0  SAL    2       0.0SOD1D    9       2.5
SODTA   12      1.028 KESG    5     2.000 KEFN    6       1.0 FNH4    7       0.0
TOTLM   13        0.8 FPO4    8       0.0
        16
TMPSG    3        1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       3.5
SODTA   12      1.028 KESG    5     1.000 KEFN    6       3.0 FNH4    7       .30
TOTLM   13        1.0 FPO4    8       1.0
        17
TMPSG    3        1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       3.5
SODTA   12      1.028 KESG    5     1.000 KEFN    6       3.0 FNH4    7       .30
TOTLM   13        1.0 FPO4    8       1.0
        18
TMPSG    3        1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       3.5
SODTA   12      1.028 KESG    5     1.000 KEFN    6       3.0 FNH4    7       .30
TOTLM   13        1.0 FPO4    8       1.0
        19
TMPSG    3        1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       3.5
SODTA   12      1.028 KESG    5     1.000 KEFN    6       3.0 FNH4    7       .30
TOTLM   13        1.0 FPO4    8       1.0
        20
TMPSG    3        1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       2.5
SODTA   12      1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.2
TOTLM   13        1.0 FPO4    8       1.0
        21
TMPSG    3        1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       2.5
SODTA   12      1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.2
TOTLM   13        1.0 FPO4    8       1.0
        22
TMPSG    3        1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       2.5
SODTA   12      1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.2
TOTLM   13        1.0 FPO4    8       1.0
        23
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TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       2.5
SODTA   12     1.028 KESG    5     1.500 KEFN    6       2.0 FNH4    7       0.2
TOTLM   13       0.9 FPO4    8       1.0
        24
TMPSG    3       1.0TMPFN    4       3.0  SAL    2       0.0SOD1D    9       2.5
SODTA   12     1.028 KESG    5     1.500 KEFN    6       2.0 FNH4    7       0.2
TOTLM   13       0.9 FPO4    8       0.0
        25
TMPSG    3       1.0TMPFN    4       3.0  SAL    2       0.0SOD1D    9       2.5
SODTA   12     1.028 KESG    5     1.500 KEFN    6       2.0 FNH4    7       0.0
TOTLM   13       0.8 FPO4    8       0.0
        26                                     start sediment segments
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       4.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        27
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       4.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        28
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       4.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        29
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       4.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        30
TMPSG    3       1.0TMPFN    4       3.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       1.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        31
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       3.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        32
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       3.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        33
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       3.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        34
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       3.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        35
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        36
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        37
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
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SODTA   12     1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        38
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        39
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        40
TMPSG    3       1.0TMPFN    4       4.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       2.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
        41
TMPSG    3       1.0TMPFN    4       3.0  SAL    2       0.0SOD1D    9       0.0
SODTA   12     1.028 KESG    5     1.000 KEFN    6       4.0 FNH4    7       0.0
TOTLM   13       1.0 FPO4    8       0.0
    +    *    +    *    +    *    +    *    +    *    +    *    H: CONSTANTS
   GLOBALS         0         *         *         *         *
       NH3         1         *         *         *         *
  nitrific         3
      k12C        11 1.200D-01      k12t        12      1.08
      knit        13       2.0
       NO3         1         *         *         *         *
  denitrif         3
      k20c        21      0.09      k20t        22     1.045
      kno3        23       0.0
       PO4         0         *         *         *         *
      PHYT         1         *         *         *         *
      chla        19
       k1c        41      2.10       k1t        42      1.08
     lghts        43        1.      cchl        46       50.
       is1        47     490.5     kmng1        48     0.025           !is1
changed to compensate for calib w incorrect factor on Solar
     kmpg1        49    0.0010      k1rc        50   0.20000
      k1rt        51     1.045       k1d        52 1.320D-02
       k1g        53        0.    nutlim        54        0.
     kpzdc        55      0.02     kpzdt        56      1.08
      pcrb        57     0.025      ncrb        58      0.25
     kmphy        59  0.00D+00     phimx        44     720.0
       xkc        45     0.017
       BOD         1         *         *         *         *
 deoxygent         5
       kdc        71      0.16       kdt        72     1.047
      kdsc        73    0.0004      kdst        74      1.08
      kbod        75       0.5
        DO         1
   oxygent         1
      ocrb        81    2.6667
        ON         1
   onrates         5
      k71c        91 .06500000      k71t        92   1.18612
     kondc        93 1.000D-03     kondt        94      1.08
       fon        95  0.75D+00
        OP         1
   oprates         5
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      k83c       100.176831145     kopdc       102 1.000D-03
     kopdt       103      1.10       fop       104 6.000D-01
      k83t       1011.07408936
        13         ************************************I: Kinetic Time Functions
TEMP1 1826    1
       5.0        1.       5.3        2.       5.4        3.       6.1        4.
       6.7        5.       7.5        6.       7.9        7.       7.6        8.
       7.1        9.       6.9       10.       6.7       11.       6.1       12.
       5.7       13.       5.2       14.       4.8       15.       4.7       16.
       3.7       17.       3.2       18.       3.0       19.       2.3       20.
       2.5       21.       2.8       22.       3.3       23.       3.7       24.
       3.8       25.       3.8       26.       3.9       27.       4.7       28.
       5.1       29.       4.9       30.       4.9       31.       5.1       32.
       5.4       33.       5.4       34.       5.2       35.       5.6       36.
       6.1       37.       6.2       38.       6.3       39.       6.3       40.
       6.3       41.       6.4       42.       6.2       43.       6.1       44.
       5.9       45.       5.8       46.       5.7       47.       5.5       48.
       5.4       49.       5.3       50.       6.3       51.       6.5       52.
       7.2       53.       8.5       54.       8.6       55.       8.3       56.
       8.2       57.       8.4       58.       9.2       59.       9.9       60.
      11.2       61.      11.1       62.      11.6       63.      11.5       64.
      11.6       65.      11.3       66.      11.3       67.      11.0       68.
      11.0       69.      11.9       70.      11.8       71.      11.1       72.
      10.8       73.      11.6       74.      11.2       75.      11.0       76.
      11.1       77.      10.9       78.      11.1       79.      10.8       80.
      11.1       81.      11.5       82.      11.3       83.      11.2       84.
      11.7       85.      11.7       86.      12.0       87.      12.7       88.
      13.3       89.      14.1       90.      13.9       91.      13.8       92.
      13.7       93.      13.7       94.      13.9       95.      14.6       96.
      15.0       97.      15.6       98.      15.5       99.      14.9      100.
      14.0      101.      13.8      102.      14.4      103.      14.0      104.
      13.6      105.      13.8      106.      14.2      107.      14.6      108.
      14.0      109.      13.9      110.      13.7      111.      13.9      112.
      13.4      113.      12.8      114.      12.4      115.      12.4      116.
      12.5      117.      12.8      118.      12.4      119.      11.8      120.
      13.2      121.      14.0      122.      14.4      123.      15.1      124.
      15.0      125.      15.1      126.      15.7      127.      16.4      128.
      16.9      129.      19.1      130.      18.5      131.      18.2      132.
      18.5      133.      18.6      134.      18.3      135.      19.8      136.
      19.6      137.      19.4      138.      20.4      139.      20.7      140.
      21.9      141.      22.0      142.      22.1      143.      22.4      144.
      21.2      145.      22.1      146.      21.3      147.      20.6      148.
      20.4      149.      21.8      150.      21.8      151.      21.8      152.
      22.8      153.      22.9      154.      21.6      155.      20.0      156.
      19.2      157.      19.6      158.      19.0      159.      18.4      160.
      18.7      161.      19.2      162.      20.4      163.      20.5      164.
      21.3      165.      21.0      166.      21.4      167.      21.8      168.
      22.0      169.      23.1      170.      24.1      171.      24.6      172.
      25.5      173.      26.3      174.      27.1      175.      27.5      176.
      28.2      177.      27.4      178.      27.1      179.      25.5      180.
      26.1      181.      26.4      182.      26.5      183.      26.4      184.
      26.7      185.      27.2      186.      27.9      187.      28.2      188.
      27.6      189.      27.3      190.      27.7      191.      27.7      192.
      27.7      193.      27.9      194.      28.2      195.      28.3      196.
      28.7      197.      29.0      198.      28.8      199.      29.0      200.
      29.4      201.      29.3      202.      29.1      203.      28.9      204.
      28.0      205.      27.2      206.      26.9      207.      27.2      208.
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   27.8       209.       28.6       210.       28.7       211.       27.4       212.
   26.3       213.       26.6       214.       27.0       215.       27.5       216.
   27.8       217.       27.6       218.       26.8       219.       27.1       220.
   26.8       221.       26.8       222.       26.9       223.       26.8       224.
   27.6       225.       27.5       226.       27.8       227.       28.0       228.
   28.8       229.       28.8       230.       29.0       231.       28.5       232.
   28.5       233.       27.5       234.       27.4       235.       27.0       236.
   26.6       237.       26.2       238.       26.2       239.       26.5       240.
   26.8       241.       26.7       242.       26.8       243.       26.9       244.
   27.1       245.       27.3       246.       27.3       247.       26.3       248.
   26.0       249.       25.9       250.       25.8       251.       26.0       252.
   25.8       253.       25.6       254.       24.6       255.       24.2       256.
   24.4       257.       24.7       258.       24.7       259.       24.5       260.
   24.5       261.       25.1       262.       25.4       263.       25.5       264.
   24.6       265.       24.5       266.       24.0       267.       23.8       268.
   22.9       269.       22.3       270.       22.0       271.       21.9       272.
   21.4       273.       21.9       274.       21.6       275.       21.2       276.
   21.1       277.       21.2       278.       21.5       279.       21.9       280.
   22.2       281.       22.4       282.       22.7       283.       22.5       284.
   22.5       285.       22.1       286.       22.3       287.       22.5       288.
   21.6       289.       20.6       290.       19.9       291.       19.1       292.
   18.3       293.       17.1       294.       17.0       295.       16.7       296.
   16.1       297.       16.3       298.       16.2       299.       16.7       300.
   16.0       301.       15.2       302.       14.8       303.       14.8       304.
   15.3       305.       15.3       306.       15.0       307.       14.9       308.
   14.5       309.       14.3       310.       14.3       311.       14.0       312.
   13.8       313.       13.5       314.       13.2       315.       13.2       316.
   12.9       317.       12.6       318.       12.2       319.       12.0       320.
   11.6       321.       11.0       322.       10.7       323.       10.5       324.
   10.3       325.       10.5       326.       10.4       327.       10.2       328.
    9.8       329.        9.6       330.        9.4       331.        9.2       332.
    9.1       333.        9.3       334.       10.0       335.        9.7       336.
    9.4       337.        9.4       338.        9.8       339.        9.5       340.
    9.0       341.        8.6       342.        8.4       343.        8.3       344.
    8.1       345.        7.9       346.        7.8       347.        7.6       348.
    7.3       349.        7.1       350.        7.0       351.        6.9       352.
    7.2       353.        7.3       354.        7.1       355.        6.9       356.
    7.2       357.        7.0       358.        7.2       359.        7.1       360.
    7.3       361.        7.2       362.        6.8       363.        6.7       364.
    6.4       365.        5.0       366.        5.2       367.        5.3       368.
    6.0       369.        6.4       370.        6.4       371.        7.0       372.
    7.5       373.        9.5       374.        9.7       375.        9.5       376.
    9.6       377.        9.6       378.        9.7       379.        9.3       380.
    8.9       381.        8.1       382.        7.5       383.        7.2       384.
    6.7       385.        6.7       386.        6.8       387.        6.7       388.
    6.6       389.        6.1       390.        6.2       391.        6.3       392.
    5.8       393.        5.3       394.        6.1       395.        6.5       396.
    6.7       397.        7.2       398.        7.2       399.        7.1       400.
    6.8       401.        6.0       402.        5.7       403.        5.0       404.
    5.4       405.        6.1       406.        6.4       407.        6.2       408.
    7.2       409.        7.5       410.        7.5       411.        7.2       412.
    7.2       413.        7.9       414.        8.2       415.        9.0       416.
    9.7       417.       10.0       418.       10.0       419.        9.7       420.
    9.7       421.       10.6       422.       11.0       423.       11.0       424.
   11.1       425.       11.6       426.       12.3       427.       11.9       428.
   11.3       429.       10.7       430.       10.4       431.       10.3       432.
   10.3       433.       10.7       434.       10.5       435.       10.5       436.
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10.6	437.	10.6	438.	11.2	439.	11.3	440.
10.7	441.	10.3	442.	8.9	443.	8.4	444.
9.0	445.	8.5	446.	9.1	447.	9.6	448.
10.3	449.	11.1	450.	11.8	451.	12.5	452.
13.2	453.	14.9	454.	16.0	455.	16.2	456.
17.0	457.	17.7	458.	17.7	459.	17.1	460.
17.3	461.	17.7	462.	17.5	463.	17.9	464.
17.5	465.	16.9	466.	17.1	467.	17.6	468.
18.0	469.	16.7	470.	18.0	471.	17.3	472.
16.2	473.	16.1	474.	15.8	475.	15.7	476.
16.7	477.	16.9	478.	17.1	479.	17.9	480.
18.7	481.	18.7	482.	18.5	483.	18.8	484.
18.8	485.	18.7	486.	19.0	487.	18.8	488.
18.0	489.	18.2	490.	19.1	491.	19.6	492.
19.5	493.	19.6	494.	20.3	495.	20.5	496.
19.9	497.	19.2	498.	19.3	499.	20.2	500.
21.3	501.	22.1	502.	22.8	503.	23.5	504.
23.9	505.	24.3	506.	24.2	507.	24.1	508.
23.4	509.	23.0	510.	23.8	511.	24.6	512.
24.9	513.	24.6	514.	24.5	515.	24.7	516.
24.9	517.	25.7	518.	26.0	519.	26.6	520.
26.2	521.	25.5	522.	23.9	523.	23.9	524.
23.7	525.	23.2	526.	23.0	527.	24.0	528.
25.0	529.	25.7	530.	24.8	531.	24.8	532.
25.6	533.	26.3	534.	27.3	535.	27.2	536.
27.8	537.	28.1	538.	28.5	539.	28.9	540.
28.8	541.	29.0	542.	29.3	543.	29.6	544.
29.7	545.	29.8	546.	29.4	547.	29.4	548.
29.5	549.	29.3	550.	29.3	551.	28.2	552.
28.9	553.	29.3	554.	28.8	555.	28.8	556.
28.9	557.	28.7	558.	28.3	559.	28.2	560.
28.5	561.	28.7	562.	28.7	563.	28.6	564.
28.9	565.	28.8	566.	28.8	567.	29.2	568.
29.6	569.	29.6	570.	29.9	571.	29.1	572.
28.9	573.	28.2	574.	28.7	575.	29.2	576.
28.9	577.	28.1	578.	28.1	579.	27.8	580.
27.7	581.	27.9	582.	27.9	583.	28.1	584.
27.9	585.	28.2	586.	28.1	587.	27.2	588.
27.5	589.	27.8	590.	27.8	591.	28.2	592.
28.3	593.	27.9	594.	27.7	595.	27.9	596.
28.0	597.	28.0	598.	27.9	599.	28.1	600.
28.1	601.	28.1	602.	28.1	603.	28.1	604.
27.6	605.	28.4	606.	28.5	607.	28.8	608.
28.5	609.	28.4	610.	28.2	611.	27.1	612.
26.6	613.	26.7	614.	27.4	615.	27.2	616.
26.2	617.	25.7	618.	25.7	619.	25.7	620.
26.0	621.	26.5	622.	26.9	623.	27.0	624.
27.0	625.	26.9	626.	26.7	627.	26.8	628.
26.8	629.	26.4	630.	26.2	631.	26.0	632.
25.6	633.	25.5	634.	25.8	635.	25.9	636.
25.9	637.	25.6	638.	25.3	639.	25.2	640.
24.9	641.	24.5	642.	23.9	643.	23.4	644.
23.0	645.	22.9	646.	22.4	647.	22.2	648.
22.3	649.	22.1	650.	22.0	651.	21.8	652.
21.6	653.	21.3	654.	21.1	655.	21.0	656.
21.0	657.	20.7	658.	20.8	659.	20.0	660.
19.6	661.	19.1	662.	18.9	663.	19.0	664.

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      19.0      665.      19.0      666.      18.9      667.      19.2      668.
      19.0      669.      19.0      670.      18.7      671.      18.2      672.
      17.6      673.      17.0      674.      16.4      675.      15.9      676.
      15.3      677.      14.7      678.      14.4      679.      14.8      680.
      14.5      681.      14.4      682.      14.2      683.      13.9      684.
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26.2	1669.	25.3	1670.	24.9	1671.	24.3	1672.
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27.9	1681.	28.3	1682.	28.1	1683.	27.7	1684.
27.8	1685.	28.2	1686.	27.6	1687.	27.6	1688.
27.9	1689.	28.1	1690.	28.2	1691.	27.3	1692.
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25.7	1709.	25.7	1710.	26.2	1711.	26.1	1712.
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24.0	1721.	23.9	1722.	23.6	1723.	23.7	1724.
23.7	1725.	24.0	1726.	24.0	1727.	24.0	1728.
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21.2	1737.	21.4	1738.	21.5	1739.	21.2	1740.
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19.2	1745.	19.5	1746.	19.3	1747.	19.0	1748.
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18.0	1769.	17.8	1770.	17.2	1771.	16.8	1772.
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14.0	1801.	14.3	1802.	14.2	1803.	14.1	1804.

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       9.5     1825.       9.1     1826.
TEMP2 1826    2
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      25.3       909.      25.4       910.      26.4       911.      25.8       912.
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TEMP3 1826   3
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     8.0     1157.        8.1     1158.        8.4     1159.        9.0     1160.
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    11.7     1169.       12.2     1170.       12.2     1171.       12.3     1172.
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    10.9     1177.       10.4     1178.       10.3     1179.       10.2     1180.
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    22.5     1325.       22.5     1326.       22.5     1327.       22.3     1328.
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     15.7      1593.      15.6      1594.      15.7      1595.      16.0      1596.
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     17.5      1609.      17.3      1610.      17.3      1611.      17.5      1612.
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     17.9      1617.      17.6      1618.      17.7      1619.      17.6      1620.
     17.6      1621.      17.7      1622.      17.8      1623.      17.9      1624.
     17.7      1625.      17.5      1626.      18.0      1627.      18.4      1628.
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     17.5      1757.      17.4      1758.      17.4      1759.      17.4      1760.
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       9.0     1825.       8.7     1826.
TEMP4 1826   4
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       7.0        9.       7.2       10.       7.0       11.       6.6       12.
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      24.6      181.      24.9      182.      25.0      183.      25.1      184.
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        27.0       201.       27.1       202.       27.7       203.       28.0       204.
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        26.0       213.       25.1       214.       25.0       215.       24.9       216.
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        27.1       229.       27.8       230.       27.7       231.       27.8       232.
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       7.4     1825.       6.9     1826.
ITOT  1826    5
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     826.8      173.     787.6      174.     886.5      175.     825.8      176.
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   559.1      449.      676.8      450.      698.1      451.      676.8      452.
   666.9      453.      675.8      454.      534.0      455.      233.4      456.
   774.4      457.      291.4      458.      187.6      459.      773.2      460.
   807.0      461.      723.4      462.      648.5      463.      432.2      464.
   292.9      465.      822.5      466.      824.6      467.      780.0      468.
   102.8      469.      771.9      470.      512.9      471.      301.1      472.
   131.5      473.      305.1      474.      835.7      475.      731.5      476.
   271.6      477.      441.3      478.      700.3      479.      806.8      480.
   776.9      481.      377.9      482.      857.6      483.      719.7      484.
   358.3      485.      341.2      486.      587.0      487.      576.1      488.
   466.7      489.      682.4      490.      792.2      491.      287.3      492.
   631.4      493.      606.4      494.      416.5      495.      336.8      496.
   257.2      497.      366.0      498.      903.2      499.      903.6      500.
   741.2      501.      613.0      502.      878.4      503.      879.5      504.
   581.6      505.      688.4      506.      600.2      507.      333.8      508.
   388.7      509.      766.6      510.      799.8      511.      681.5      512.
   400.6      513.      664.2      514.      686.1      515.      768.6      516.
   768.0      517.      761.2      518.      822.7      519.      478.9      520.
   330.5      521.      242.1      522.      700.1      523.      704.0      524.
   292.5      525.      436.3      526.      601.5      527.      753.0      528.
   681.3      529.      737.5      530.      661.7      531.      632.8      532.
   793.0      533.      902.2      534.      451.4      535.      912.3      536.
   772.2      537.      705.9      538.      818.4      539.      702.2      540.
   749.9      541.      811.6      542.      773.2      543.      661.1      544.
   833.7      545.      681.3      546.      751.1      547.      833.2      548.
   759.4      549.      687.1      550.      545.1      551.      835.1      552.
   858.4      553.      510.0      554.      518.5      555.      703.2      556.
   712.5      557.      606.2      558.      693.9      559.      855.1      560.
   702.8      561.      410.3      562.      481.9      563.      784.5      564.
   757.5      565.      763.3      566.      835.1      567.      738.9      568.
   738.7      569.      629.3      570.      402.9      571.      560.4      572.
   246.2      573.      618.6      574.      755.4      575.      444.6      576.
   464.0      577.      695.4      578.      602.3      579.      830.6      580.
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   710.2      589.      652.6      590.      667.3      591.      541.2      592.
   421.7      593.      624.8      594.      701.8      595.      717.2      596.
   813.4      597.      776.3      598.      753.2      599.      672.9      600.
   709.8      601.      602.9      602.      211.4      603.      204.1      604.
   700.1      605.      647.3      606.      620.2      607.      412.8      608.
   619.8      609.      599.8      610.      131.9      611.      485.3      612.
   647.3      613.      608.9      614.      630.1      615.      257.2      616.
   661.9      617.      716.8      618.      702.0      619.      668.7      620.
   652.2      621.      641.3      622.      576.3      623.      570.7      624.
   576.5      625.      560.4      626.      355.0      627.      502.0      628.
   290.4      629.      488.8      630.      609.9      631.      626.8      632.
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      598.8        633.       566.6        634.       609.5        635.       504.9        636.
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      559.8        641.       188.9        642.       251.6        643.       168.0        644.
      370.3        645.       192.6        646.       493.9        647.       557.5        648.
      552.5        649.       501.4        650.       473.9        651.       492.9        652.
      525.5        653.       505.3        654.       505.9        655.       496.0        656.
      358.1        657.       451.4        658.       200.4        659.       354.0        660.
      493.3        661.       484.8        662.       480.7        663.       466.7        664.
      445.0        665.       421.5        666.       452.6        667.       387.2        668.
      431.6        669.       432.8        670.       273.3        671.        39.0        672.
       83.6        673.       391.8        674.       320.1        675.       425.4        676.
      175.0        677.       287.7        678.       272.2        679.       105.1        680.
      392.8        681.       164.1        682.        78.2        683.       345.9        684.
      247.1        685.       349.0        686.       359.6        687.       165.9        688.
      170.7        689.       341.4        690.       363.3        691.       337.1        692.
      328.0        693.       260.3        694.       347.0        695.       351.5        696.
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      300.1        705.       303.4        706.       187.6        707.       249.1        708.
      321.4        709.       231.0        710.       123.2        711.        47.3        712.
      318.7        713.       210.3        714.       287.3        715.       132.9        716.
      317.4        717.        99.1        718.       177.9        719.       186.0        720.
      111.3        721.        48.5        722.        36.9        723.       247.9        724.
      117.2        725.       298.5        726.       152.7        727.        42.1        728.
      306.1        729.       205.6        730.       318.5        731.        43.8        732.
      110.6        733.       295.6        734.       341.6        735.       294.9        736.
      317.2        737.        83.0        738.       144.7        739.       351.7        740.
      331.9        741.       336.6        742.       289.8        743.       234.5        744.
      324.7        745.       348.0        746.       260.5        747.       145.5        748.
      365.5        749.       323.2        750.       250.4        751.       184.9        752.
      225.2        753.        77.8        754.       374.8        755.       380.4        756.
      301.3        757.       383.5        758.       313.9        759.       269.1        760.
      239.8        761.        86.1        762.       180.4        763.       363.5        764.
      277.2        765.       447.7        766.       322.6        767.       270.0        768.
      456.1        769.       343.7        770.       451.6        771.       378.1        772.
      210.9        773.       415.9        774.       511.7        775.       495.4        776.
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      509.2        781.       509.6        782.       561.0        783.       194.4        784.
      491.9        785.       159.5        786.       556.7        787.       382.1        788.
      163.3        789.       413.8        790.       573.2        791.       321.0        792.
      606.6        793.       534.6        794.       389.9        795.       630.8        796.
      592.2        797.       103.8        798.       264.2        799.       641.9        800.
      652.2        801.       319.5        802.        35.9        803.       169.5        804.
      649.8        805.       629.1        806.       642.9        807.       638.8        808.
      632.8        809.       138.7        810.       695.0        811.       604.1        812.
      492.9        813.       390.3        814.       398.2        815.       534.8        816.
      715.2        817.       585.4        818.       706.3        819.       616.5        820.
      131.3        821.       575.4        822.       564.5        823.       539.7        824.
      529.6        825.       364.3        826.       682.2        827.       687.7        828.
      583.5        829.       677.8        830.       363.1        831.       563.3        832.
      808.9        833.       814.9        834.       250.2        835.       793.2        836.
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      771.3        841.       771.9        842.       660.5        843.       497.2        844.
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      108.4        849.       292.5        850.       542.0        851.       498.3        852.
      855.7        853.       835.1        854.       411.2        855.       559.1        856.
      628.5        857.       703.4        858.       833.5        859.       838.2        860.
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     664.8      929.     783.7      930.     710.2      931.     660.3      932.
     720.3      933.     711.5      934.     552.5      935.     789.1      936.
     796.3      937.     645.0      938.     716.4      939.     625.0      940.
     764.1      941.     792.8      942.     674.3      943.     808.1      944.
     816.5      945.     811.0      946.     592.8      947.     671.8      948.
     698.3      949.     653.3      950.     320.5      951.     652.2      952.
     696.0      953.     718.7      954.     531.9      955.     423.7      956.
     453.9      957.     553.4      958.     527.8      959.     609.9      960.
     488.1      961.     276.2      962.     668.7      963.     652.4      964.
     544.9      965.     506.7      966.     330.2      967.     470.0      968.
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     565.3     1005.     269.8     1006.     303.0     1007.     248.9     1008.
     541.6     1009.     470.0     1010.     527.4     1011.     362.4     1012.
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     462.8     1021.     299.7     1022.      44.0     1023.     427.9     1024.
     476.0     1025.     459.7     1026.     410.3     1027.     468.5     1028.
     462.3     1029.     451.6     1030.     432.4     1031.     414.0     1032.
     415.7     1033.     418.8     1034.     371.5     1035.     249.5     1036.
     437.6     1037.     430.3     1038.     410.3     1039.     392.4     1040.
     416.5     1041.     390.9     1042.     346.8     1043.     358.1     1044.
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   324.3     1137.      31.0     1138.      78.0     1139.     244.8     1140.
   475.1     1141.     397.7     1142.     447.1     1143.     108.2     1144.
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   257.8     1153.     560.2     1154.     566.2     1155.     479.5     1156.
   545.9     1157.     514.8     1158.     138.5     1159.     569.9     1160.
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   539.7     1165.     457.0     1166.     492.1     1167.     627.9     1168.
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   152.5     1185.     700.1     1186.     698.3     1187.     206.4     1188.
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   793.0     1221.     780.4     1222.     812.2     1223.     775.5     1224.
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   771.1     1229.     691.7     1230.     824.4     1231.     791.8     1232.
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     260.9     1413.     184.3     1414.     341.8     1415.     136.0     1416.
      94.3     1417.     203.9     1418.      20.2     1419.     180.2     1420.
     338.7     1421.     345.1     1422.     309.4     1423.     251.4     1424.
      22.9     1425.      76.2     1426.     294.3     1427.     317.0     1428.
     229.7     1429.     322.8     1430.     310.0     1431.      55.7     1432.
      87.5     1433.     324.9     1434.     315.6     1435.     233.9     1436.
     304.4     1437.     290.8     1438.     272.2     1439.      48.3     1440.
      63.0     1441.     214.5     1442.     215.1     1443.      54.1     1444.
     259.0     1445.      53.5     1446.     200.2     1447.     298.0     1448.
      83.4     1449.     304.2     1450.     272.7     1451.     302.4     1452.
     300.3     1453.     285.9     1454.     282.2     1455.     263.8     1456.
     106.5     1457.     182.9     1458.     270.2     1459.     149.8     1460.
     211.8     1461.     273.7     1462.     315.4     1463.     327.1     1464.
     306.9     1465.     193.2     1466.     319.3     1467.     252.0     1468.
      35.7     1469.     291.4     1470.     333.1     1471.     307.3     1472.
     118.3     1473.     273.3     1474.      94.1     1475.     255.1     1476.
     254.5     1477.     158.5     1478.      59.7     1479.     130.2     1480.
      31.0     1481.     358.5     1482.     353.6     1483.     366.4     1484.
     307.1     1485.     288.3     1486.     371.3     1487.     358.5     1488.
     374.8     1489.     318.7     1490.     243.3     1491.     355.2     1492.
     197.9     1493.     157.3     1494.     394.0     1495.      99.9     1496.
     329.0     1497.     418.6     1498.     403.7     1499.     380.2     1500.
     291.0     1501.     339.3     1502.     432.6     1503.      31.2     1504.
     264.2     1505.      61.7     1506.     154.0     1507.     242.7     1508.
     454.1     1509.     464.0     1510.     409.5     1511.     369.0     1512.
     186.0     1513.      32.6     1514.     493.5     1515.     497.4     1516.
      72.7     1517.     462.1     1518.     482.6     1519.     205.2     1520.
     523.2     1521.     322.4     1522.      80.5     1523.      64.2     1524.
     414.7     1525.     381.6     1526.     543.9     1527.     574.6     1528.
     576.1     1529.     599.0     1530.     567.4     1531.     272.0     1532.
     438.8     1533.     524.1     1534.      44.0     1535.      95.4     1536.
     506.1     1537.     559.4     1538.     649.8     1539.      94.5     1540.
     123.0     1541.     617.6     1542.     647.7     1543.     635.3     1544.
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      44.6     1549.     602.5     1550.     418.4     1551.      91.0     1552.
     699.1     1553.     194.8     1554.     194.4     1555.     655.1     1556.
     586.0     1557.     587.4     1558.     641.9     1559.     659.9     1560.
     601.0     1561.     359.1     1562.     503.4     1563.     378.7     1564.
     658.6     1565.     313.7     1566.     733.8     1567.     241.5     1568.
     698.7     1569.     740.6     1570.     545.7     1571.     593.6     1572.
     688.1     1573.     721.2     1574.     636.3     1575.     148.0     1576.
     785.8     1577.     774.2     1578.     660.1     1579.     660.1     1580.
     756.9     1581.     692.5     1582.     710.4     1583.     744.7     1584.
     736.9     1585.     733.8     1586.     419.6     1587.     747.8     1588.
     647.7     1589.     530.7     1590.     585.6     1591.     708.0     1592.
     609.1     1593.     759.8     1594.     779.4     1595.     336.2     1596.
     196.9     1597.     126.9     1598.     491.0     1599.     747.4     1600.
     436.5     1601.     328.4     1602.     534.4     1603.     758.5     1604.
     779.6     1605.     633.2     1606.     509.4     1607.     699.3     1608.
     230.1     1609.     496.0     1610.     773.4     1611.     637.4     1612.
     207.6     1613.     542.2     1614.     798.2     1615.     677.0     1616.
     738.3     1617.     674.9     1618.     525.9     1619.     353.2     1620.
     520.1     1621.     710.8     1622.     517.7     1623.     609.5     1624.
     277.8     1625.     160.2     1626.     350.3     1627.     613.4     1628.
     846.0     1629.     787.2     1630.     772.2     1631.     659.7     1632.
     638.4     1633.     619.2     1634.     498.3     1635.     665.0     1636.
     603.7     1637.     709.4     1638.     576.5     1639.     706.3     1640.
     756.3     1641.     660.5     1642.     589.9     1643.     669.6     1644.
     397.9     1645.     539.5     1646.     774.2     1647.     714.2     1648.
     812.0     1649.     250.2     1650.     656.8     1651.     776.5     1652.
     685.5     1653.     762.5     1654.     280.1     1655.     798.0     1656.
     668.5     1657.     654.7     1658.     740.0     1659.     493.7     1660.
     411.2     1661.     663.2     1662.     831.8     1663.     802.5     1664.
     463.0     1665.     401.7     1666.     569.3     1667.     286.9     1668.
     176.9     1669.     319.5     1670.     203.7     1671.     331.3     1672.
     675.8     1673.     737.5     1674.     769.3     1675.     654.1     1676.
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     556.5     1685.     347.8     1686.     637.4     1687.     643.4     1688.
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     409.3     1697.     648.5     1698.     653.3     1699.     599.6     1700.
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     516.2     1709.     649.5     1710.     656.8     1711.     498.9     1712.
     381.6     1713.     502.8     1714.     575.0     1715.     626.4     1716.
     511.5     1717.     366.0     1718.     576.3     1719.     634.9     1720.
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     452.2     1725.     481.3     1726.     461.7     1727.     120.7     1728.
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     556.9     1741.     540.4     1742.     540.6     1743.     453.1     1744.
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     452.6     1753.     457.0     1754.     357.1     1755.     438.8     1756.
     413.4     1757.     410.7     1758.     420.9     1759.     468.9     1760.
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     401.2     1765.     354.2     1766.     388.4     1767.     386.6     1768.
     404.1     1769.     411.6     1770.     416.7     1771.     401.5     1772.
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     132.7     1785.     339.1     1786.     333.1     1787.     206.8     1788.
      81.9     1789.      85.0     1790.     200.8     1791.     261.3     1792.
     284.0     1793.     203.9     1794.     112.7     1795.     316.0     1796.
     252.8     1797.     298.7     1798.     311.7     1799.     306.1     1800.
     292.7     1801.     245.6     1802.     258.4     1803.     121.2     1804.
      48.7     1805.      61.3     1806.      47.3     1807.      59.7     1808.
     142.4     1809.     287.7     1810.     280.1     1811.     255.7     1812.
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     309.2     1817.     158.3     1818.     304.6     1819.     258.4     1820.
     302.6     1821.     311.9     1822.     232.6     1823.     258.2     1824.
     315.6     1825.     315.2     1826.
****F 1826     6
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      0.41        9.      0.41       10.      0.41       11.      0.41       12.
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      0.43       33.      0.43       34.      0.43       35.      0.44       36.
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      0.46       53.      0.46       54.      0.46       55.      0.46       56.
      0.47       57.      0.47       58.      0.47       59.      0.47       60.
      0.47       61.      0.47       62.      0.48       63.      0.48       64.
      0.48       65.      0.48       66.      0.48       67.      0.48       68.
      0.49       69.      0.49       70.      0.49       71.      0.49       72.
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      0.50       77.      0.50       78.      0.50       79.      0.50       80.
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      0.51       85.      0.51       86.      0.52       87.      0.52       88.
      0.52       89.      0.52       90.      0.52       91.      0.52       92.
      0.53       93.      0.53       94.      0.53       95.      0.53       96.
      0.53       97.      0.53       98.      0.54       99.      0.54      100.
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0.60	193.	0.60	194.	0.60	195.	0.60	196.
0.59	197.	0.59	198.	0.59	199.	0.59	200.
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0.59	205.	0.59	206.	0.59	207.	0.58	208.
0.58	209.	0.58	210.	0.58	211.	0.58	212.
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0.49	269.	0.49	270.	0.49	271.	0.49	272.
0.49	273.	0.48	274.	0.48	275.	0.48	276.
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0.43	313.	0.43	314.	0.43	315.	0.42	316.
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0.59	1661.	0.59	1662.	0.59	1663.	0.59	1664.
0.59	1665.	0.59	1666.	0.59	1667.	0.59	1668.
0.58	1669.	0.58	1670.	0.58	1671.	0.58	1672.
0.58	1673.	0.58	1674.	0.58	1675.	0.58	1676.
0.58	1677.	0.57	1678.	0.57	1679.	0.57	1680.
0.57	1681.	0.57	1682.	0.57	1683.	0.57	1684.
0.57	1685.	0.56	1686.	0.56	1687.	0.56	1688.
0.56	1689.	0.56	1690.	0.56	1691.	0.56	1692.
0.55	1693.	0.55	1694.	0.55	1695.	0.55	1696.
0.55	1697.	0.55	1698.	0.54	1699.	0.54	1700.
0.54	1701.	0.54	1702.	0.54	1703.	0.54	1704.
0.54	1705.	0.53	1706.	0.53	1707.	0.53	1708.
0.53	1709.	0.53	1710.	0.53	1711.	0.52	1712.
0.52	1713.	0.52	1714.	0.52	1715.	0.52	1716.
0.52	1717.	0.51	1718.	0.51	1719.	0.51	1720.
0.51	1721.	0.51	1722.	0.50	1723.	0.50	1724.
0.50	1725.	0.50	1726.	0.50	1727.	0.50	1728.
0.49	1729.	0.49	1730.	0.49	1731.	0.49	1732.
0.49	1733.	0.49	1734.	0.48	1735.	0.48	1736.
0.48	1737.	0.48	1738.	0.48	1739.	0.48	1740.
0.47	1741.	0.47	1742.	0.47	1743.	0.47	1744.
0.47	1745.	0.47	1746.	0.46	1747.	0.46	1748.
0.46	1749.	0.46	1750.	0.46	1751.	0.46	1752.
0.46	1753.	0.45	1754.	0.45	1755.	0.45	1756.
0.45	1757.	0.45	1758.	0.45	1759.	0.45	1760.
0.44	1761.	0.44	1762.	0.44	1763.	0.44	1764.

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      0.44     1765.       0.44     1766.       0.44     1767.       0.43     1768.
      0.43     1769.       0.43     1770.       0.43     1771.       0.43     1772.
      0.43     1773.       0.43     1774.       0.43     1775.       0.43     1776.
      0.42     1777.       0.42     1778.       0.42     1779.       0.42     1780.
      0.42     1781.       0.42     1782.       0.42     1783.       0.42     1784.
      0.42     1785.       0.42     1786.       0.42     1787.       0.41     1788.
      0.41     1789.       0.41     1790.       0.41     1791.       0.41     1792.
      0.41     1793.       0.41     1794.       0.41     1795.       0.41     1796.
      0.41     1797.       0.41     1798.       0.41     1799.       0.41     1800.
      0.41     1801.       0.41     1802.       0.41     1803.       0.41     1804.
      0.41     1805.       0.41     1806.       0.40     1807.       0.40     1808.
      0.40     1809.       0.40     1810.       0.40     1811.       0.40     1812.
      0.40     1813.       0.40     1814.       0.40     1815.       0.40     1816.
      0.40     1817.       0.40     1818.       0.40     1819.       0.40     1820.
      0.40     1821.       0.40     1822.       0.41     1823.       0.41     1824.
      0.41     1825.       0.41     1826.
 WIND 1826    7
      6.20        1.       7.50        2.       7.30        3.       4.40        4.
     11.00        5.       4.50        6.       3.10        7.       3.00        8.
      1.80        9.      14.00       10.       7.10       11.       2.40       12.
      2.00       13.       0.00       14.       3.70       15.       6.60       16.
      7.10       17.       6.60       18.       3.70       19.       5.10       20.
      3.90       21.       8.50       22.       3.20       23.       4.70       24.
      6.90       25.       0.40       26.       4.40       27.       3.90       28.
      5.50       29.       6.60       30.       5.40       31.       4.40       32.
      4.00       33.       1.00       34.       7.40       35.       2.10       36.
      1.30       37.       3.00       38.       6.10       39.       1.30       40.
      1.10       41.       1.30       42.       1.30       43.       7.90       44.
      1.80       45.       3.20       46.       2.60       47.       1.60       48.
      6.70       49.      10.00       50.       4.80       51.       9.80       52.
     10.00       53.       0.90       54.       1.90       55.       2.10       56.
      2.60       57.      12.00       58.       1.80       59.       2.60       60.
      3.60       61.       2.60       62.       1.60       63.       2.00       64.
      2.90       65.       1.40       66.       2.50       67.       2.30       68.
      1.80       69.       1.60       70.       0.70       71.       1.20       72.
      1.70       73.       2.40       74.       1.90       75.       1.80       76.
      2.10       77.       3.10       78.       1.60       79.       1.90       80.
      3.10       81.       1.60       82.       1.80       83.       2.50       84.
      2.80       85.       1.40       86.       1.80       87.       3.40       88.
      1.90       89.       2.60       90.       2.90       91.       1.50       92.
      1.20       93.       1.60       94.       1.80       95.       2.40       96.
      2.10       97.       2.20       98.       2.40       99.       1.70      100.
      1.30      101.       1.00      102.       2.80      103.       1.70      104.
      0.80      105.       1.40      106.       1.90      107.       1.90      108.
      1.80      109.       1.60      110.       2.10      111.       2.20      112.
      4.00      113.       1.40      114.       1.10      115.       1.40      116.
      1.00      117.       1.70      118.       2.90      119.       1.10      120.
      2.90      121.       1.50      122.       3.00      123.       1.50      124.
      1.50      125.       0.40      126.       0.20      127.       0.30      128.
      0.20      129.       0.30      130.       0.20      131.       0.40      132.
      0.20      133.       0.30      134.       0.50      135.       0.30      136.
      0.30      137.       0.20      138.       0.50      139.       0.30      140.
      0.10      141.       0.10      142.       0.10      143.       0.30      144.
      0.40      145.       0.30      146.       0.30      147.       0.30      148.
      0.20      149.       0.10      150.       0.10      151.       0.10      152.
      0.10      153.       0.20      154.       0.10      155.       0.30      156.
      5.60      157.       4.70      158.       2.40      159.       2.60      160.
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2.10      161.      3.10      162.      5.80      163.      6.50      164.
3.50      165.      4.10      166.      2.00      167.      4.90      168.
7.20      169.      4.00      170.      1.60      171.      3.90      172.
4.20      173.      2.80      174.      1.90      175.      6.60      176.
8.10      177.      1.40      178.      3.30      179.      3.70      180.
2.20      181.      2.30      182.      1.60      183.      5.40      184.
4.00      185.      2.40      186.      2.10      187.      2.10      188.
2.50      189.      3.50      190.      3.80      191.      4.10      192.
1.70      193.      2.60      194.      2.70      195.      4.20      196.
3.90      197.      3.60      198.      4.90      199.      2.60      200.
2.70      201.      2.40      202.      2.70      203.      1.30      204.
2.00      205.      1.30      206.      1.30      207.      2.60      208.
2.10      209.      1.50      210.      1.70      211.      1.60      212.
1.10      213.      1.50      214.      2.60      215.      2.00      216.
1.10      217.      1.00      218.      1.50      219.      0.90      220.
1.00      221.      1.00      222.      1.00      223.      1.90      224.
3.60      225.      2.20      226.      1.90      227.      2.50      228.
3.10      229.      2.50      230.      1.50      231.      2.30      232.
1.40      233.      1.10      234.      0.90      235.      1.00      236.
1.00      237.      1.20      238.      0.90      239.      1.20      240.
1.40      241.      1.40      242.      1.20      243.      1.20      244.
1.20      245.      1.80      246.      1.70      247.      0.80      248.
2.20      249.      2.20      250.      1.50      251.      1.30      252.
1.30      253.      1.40      254.      0.80      255.      1.00      256.
1.40      257.      1.00      258.      1.00      259.      0.90      260.
1.30      261.      1.10      262.      2.90      263.      2.20      264.
1.20      265.      1.50      266.      2.50      267.      1.70      268.
0.90      269.      2.70      270.      1.70      271.      3.20      272.
3.70      273.      1.10      274.      1.50      275.      1.00      276.
1.90      277.      1.60      278.      1.00      279.      0.80      280.
0.90      281.      1.20      282.      2.40      283.      1.50      284.
1.30      285.      1.10      286.      1.70      287.      1.50      288.
1.40      289.      1.20      290.      1.60      291.      1.20      292.
1.30      293.      1.30      294.      1.00      295.      1.10      296.
1.70      297.      2.20      298.      2.00      299.      3.10      300.
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2.60      305.      3.30      306.      3.00      307.      1.70      308.
1.50      309.      1.40      310.      1.30      311.      1.30      312.
2.20      313.      1.00      314.      0.90      315.      0.80      316.
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1.20      321.      1.30      322.      1.70      323.      1.10      324.
1.10      325.      1.80      326.      1.10      327.      1.70      328.
1.40      329.      4.00      330.      1.70      331.      2.40      332.
1.50      333.      1.80      334.      2.10      335.      1.00      336.
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2.40      357.      2.20      358.      1.80      359.      0.80      360.
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1.20      369.      1.20      370.      1.40      371.      2.10      372.
3.40      373.      4.00      374.      0.70      375.      0.80      376.
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1.20      385.      1.00      386.      2.10      387.      2.00      388.
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3.10	393.	2.20	394.	2.20	395.	1.50	396.
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1.00	409.	1.80	410.	2.10	411.	4.10	412.
4.00	413.	4.30	414.	2.20	415.	2.40	416.
2.20	417.	1.70	418.	2.90	419.	4.50	420.
3.30	421.	1.20	422.	1.50	423.	1.50	424.
2.10	425.	1.70	426.	3.10	427.	2.60	428.
1.50	429.	2.00	430.	1.60	431.	2.40	432.
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2.00	437.	3.80	438.	1.70	439.	2.80	440.
2.80	441.	1.20	442.	1.20	443.	2.10	444.
2.80	445.	2.60	446.	1.40	447.	1.10	448.
1.80	449.	3.00	450.	3.60	451.	3.50	452.
2.80	453.	3.10	454.	3.50	455.	4.00	456.
3.50	457.	1.70	458.	2.40	459.	1.60	460.
1.60	461.	2.50	462.	3.80	463.	4.20	464.
1.90	465.	1.20	466.	1.20	467.	2.10	468.
3.50	469.	3.50	470.	3.40	471.	3.80	472.
2.20	473.	2.10	474.	1.50	475.	2.20	476.
1.60	477.	1.60	478.	3.00	479.	2.70	480.
4.10	481.	2.50	482.	0.90	483.	1.70	484.
1.60	485.	1.60	486.	3.60	487.	2.80	488.
1.90	489.	2.20	490.	1.20	491.	1.80	492.
1.80	493.	1.10	494.	1.40	495.	1.20	496.
1.10	497.	1.50	498.	1.30	499.	0.90	500.
1.40	501.	0.90	502.	1.20	503.	2.80	504.
2.50	505.	1.90	506.	1.60	507.	1.60	508.
1.30	509.	1.60	510.	1.50	511.	1.30	512.
1.20	513.	1.50	514.	2.10	515.	3.00	516.
1.80	517.	3.10	518.	2.70	519.	1.20	520.
1.00	521.	1.30	522.	1.50	523.	2.20	524.
1.40	525.	1.90	526.	1.10	527.	2.40	528.
2.60	529.	2.50	530.	3.10	531.	4.10	532.
2.50	533.	1.70	534.	2.20	535.	1.60	536.
1.00	537.	0.90	538.	1.00	539.	0.90	540.
0.80	541.	2.30	542.	1.80	543.	1.30	544.
1.80	545.	3.40	546.	1.70	547.	1.00	548.
0.80	549.	2.20	550.	1.50	551.	1.80	552.
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1.60	557.	1.40	558.	1.30	559.	1.50	560.
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2.20	577.	2.40	578.	2.50	579.	2.00	580.
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1.10	597.	1.00	598.	1.40	599.	1.90	600.
2.20	601.	1.80	602.	3.40	603.	2.80	604.
1.90	605.	2.30	606.	0.90	607.	0.90	608.
1.20	609.	1.80	610.	2.70	611.	2.40	612.
1.20	613.	1.70	614.	3.50	615.	2.30	616.

1.20	617.	1.00	618.	1.20	619.	1.60	620.
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2.70	741.	3.80	742.	3.10	743.	1.70	744.
2.30	745.	2.20	746.	1.30	747.	4.00	748.
2.10	749.	1.50	750.	1.30	751.	1.30	752.
2.50	753.	1.90	754.	1.70	755.	1.70	756.
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3.20	761.	2.40	762.	2.80	763.	1.50	764.
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4.40	773.	2.80	774.	1.60	775.	2.10	776.
3.00	777.	2.80	778.	2.00	779.	2.60	780.
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3.60	789.	3.50	790.	1.60	791.	5.40	792.
4.80	793.	1.40	794.	3.70	795.	2.90	796.
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2.20	801.	1.40	802.	2.60	803.	2.20	804.
2.50	805.	2.80	806.	4.20	807.	1.60	808.
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2.20	813.	2.00	814.	3.40	815.	1.80	816.
2.80	817.	2.00	818.	1.60	819.	2.00	820.
2.20	821.	1.40	822.	1.90	823.	3.70	824.
2.80	825.	2.10	826.	2.70	827.	2.70	828.
5.00	829.	1.80	830.	2.00	831.	2.50	832.
1.80	833.	1.70	834.	1.90	835.	4.70	836.
3.70	837.	2.40	838.	2.00	839.	2.50	840.
2.20	841.	3.70	842.	4.80	843.	2.20	844.

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      3.10      857.      3.80      858.      1.50      859.      1.30      860.
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      1.30      905.      1.40      906.      1.20      907.      2.50      908.
      3.10      909.      3.30      910.      1.90      911.      2.80      912.
      2.50      913.      2.70      914.      3.10      915.      2.00      916.
      1.90      917.      2.80      918.      2.00      919.      3.60      920.
      3.60      921.      1.80      922.      2.10      923.      1.50      924.
      1.30      925.      0.90      926.      0.90      927.      1.90      928.
      2.80      929.      3.20      930.      1.60      931.      1.30      932.
      1.20      933.      1.00      934.      1.60      935.      2.20      936.
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      2.00      945.      1.70      946.      2.40      947.      1.20      948.
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      0.90      969.      0.90      970.      1.60      971.      3.10      972.
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      2.20      977.      3.00      978.      2.10      979.      1.50      980.
      1.50      981.      1.50      982.      1.00      983.      0.80      984.
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      1.20     1005.      1.20     1006.      1.80     1007.      1.20     1008.
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      1.70     1017.      1.50     1018.      1.70     1019.      1.90     1020.
      1.40     1021.      1.30     1022.      1.00     1023.      1.00     1024.
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      3.40     1037.      1.40     1038.      2.20     1039.      2.90     1040.
      0.90     1041.      1.10     1042.      2.10     1043.      3.70     1044.
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      2.80     1069.      2.80     1070.      1.30     1071.      0.90     1072.
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      1.80      1081.         1.30      1082.         2.50      1083.         2.10      1084.
      1.40      1085.         1.30      1086.         1.10      1087.         1.60      1088.
      1.70      1089.         3.30      1090.         1.80      1091.         1.70      1092.
      1.90      1093.         1.90      1094.         1.90      1095.         1.00      1096.
      1.00      1097.         2.40      1098.         2.80      1099.         4.80      1100.
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      1.60      1125.         1.40      1126.         2.00      1127.         2.90      1128.
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      0.90      1137.         2.60      1138.         2.70      1139.         1.10      1140.
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      1.00      1349.        0.80      1350.        1.20      1351.        1.10      1352.
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      1.70      1385.        1.90      1386.        1.40      1387.        1.30      1388.
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     0.85      1681.       1.52      1682.       3.67      1683.       2.91      1684.
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      2.10     1793.      3.71     1794.      4.29     1795.      1.61     1796.
      2.59     1797.      0.76     1798.      0.00     1799.      0.58     1800.
      2.59     1801.      1.70     1802.      1.30     1803.      2.46     1804.
      2.82     1805.      2.24     1806.      1.79     1807.      1.61     1808.
      5.01     1809.      1.70     1810.      0.72     1811.      2.06     1812.
      3.40     1813.      0.85     1814.      2.68     1815.      0.40     1816.
      0.00     1817.      2.46     1818.      1.92     1819.      0.22     1820.
      0.00     1821.      1.79     1822.      3.35     1823.      3.08     1824.
      0.31     1825.      0.09     1826.
  KE1   30    8
   1.52088        1.     1.521      150.     1.574      152.     1.574      273.
   1.41350      274.     1.414      365.     1.521      366.     1.521      515.
   2.10801      517.     2.108      638.     1.414      639.     1.414      730.
   1.52088      731.     1.521      880.     2.167      882.     2.167     1003.
   1.41350     1004.     1.414     1095.     1.521     1096.     1.521     1246.
   1.76        1248.     1.76      1369.     1.85      1370.     1.85      1461.
   1.52088     1462.     1.521     1612.     1.59      1614.     1.59      1734.
   1.71        1735.     1.71      1826.
  KE2   30    9
  2.090049        1.     2.090      150.     1.427      152.     1.427      273.
  1.460534      274.     1.461      365.     2.090      366.     2.090      515.
  1.433968      517.     1.434      638.     1.461      639.     1.461      730.
  2.090049      731.     2.090      880.     1.062      882.     1.062     1003.
  1.460534     1004.     1.461     1095.     2.090     1096.     2.090     1246.
  1.21         1248.     1.21      1369.     2.25      1370.     2.25      1461.
  2.090049     1462.     2.090     1612.     1.08      1614.     1.08      1734.
  1.85         1735.     1.85      1826.
  KE3   30   10
  2.150553        1.     2.151      150.     1.811      152.     1.811      273.
  1.699176      274.     1.699      365.     2.151      366.     2.151      515.
  1.834483      517.     1.834      638.     1.699      639.     1.699      730.
  2.150553      731.     2.151      880.     1.571      882.     1.571     1003.
  1.699176     1004.     1.699     1095.     2.151     1096.     2.151     1246.
  1.50         1248.     1.50      1369.     4.64      1370.     4.64      1461.
  2.150553     1462.     2.151     1612.     1.35      1614.     1.35      1734.
  2.21         1735.     2.21      1826.
  KE4   30   11
  3.107417        1.     3.107      150.     2.712      152.     2.712      273.
  2.185969      274.     2.186      365.     3.107      366.     3.107      515.
  4.013138      517.     4.013      638.     2.186      639.     2.186      730.
  3.107417      731.     3.107      880.     2.522      882.     2.522     1003.
  2.185969     1004.     2.186     1095.     3.107     1096.     3.107     1246.
  3.50         1248.     3.50      1369.     3.21      1370.     3.21      1461.
  3.107417     1462.     3.107     1612.     2.60      1614.     2.60      1734.
  3.03         1735.     3.03      1826.
TFNH4   47   13
      0.00        1.      0.00      120.       0.4      121.       0.4      181.
       1.0      182.       1.0      258.       0.4      259.      0.40      304.
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      0.00      305.       0.0      365.       0.0      485.      0.40      486.
      0.40      546.       1.0      547.      1.00      623.      0.40      624.
       0.4      669.       0.0      670.      0.00      730.      0.00      850.
       0.4      851.       0.4      911.      1.00      912.      1.00      988.
       0.4      989.      0.40     1034.      0.00     1035.       0.0     1095.
       0.0     1215.      0.40     1216.      0.40     1276.       1.0     1277.
      1.00     1353.      0.40     1354.       0.4     1399.       0.0     1400.
      0.00     1461.      0.00     1580.      0.40     1581.       0.4     1641.
       1.0     1642.       1.0     1718.       0.4     1719.       0.4     1764.
      0.00     1765.      0.00     1825.       0.0     1826.
TFPO4   17   14
      0.00        1.      1.00      220.       0.0      330.       0.0      366.
      1.00      585.      0.00      695.       0.0      731.       1.0      950.
      0.00     1060.      0.00     1096.       1.0     1315.       0.0     1425.
      0.00     1461.      0.00     1462.      1.00     1681.       0.0     1791.
       0.0     1826.
NH3                                         3  0.0    1.0E08    J:INITIAL CONC.
   1:      0.01      0.95   2:      0.01      0.95  3:       0.01      0.90
   4:      0.01      0.95   5:      0.01      0.90  6:       0.01      0.90
   7:      0.01      0.87   8:      0.01      0.87  9:       0.01      0.87
  10:      0.01      0.85  11:      0.01      0.85 12:       0.01      0.80
  13:      0.01  0.837376  14:      0.01  0.837376 15:       0.01      0.50
  16:      0.05      0.95  17:      0.05      0.95 18:       0.05      0.95
  19:      0.05      0.95  20:      0.05      0.95 21:       0.05      0.95
  22:      0.05      0.95  23:      0.05      0.95 24:       0.05      0.95
  25:      0.05      0.95  26:      9.00      0.10 27:       9.00       0.1
  28:      9.00       0.1  29:      9.00       0.1 30:       9.00       0.1
  31:      9.00       0.1  32:      9.00       0.1 33:       9.00       0.1
  34:      9.00       0.1  35:      9.00       0.1 36:       9.00       0.1
  37:      9.00       0.1  38:      9.00       0.1 39:       9.00       0.1
  40:      9.00       0.1  41:      9.00       0.1
NO3                                         5  0.0    1.0E08
   1:      0.01       1.0   2:      0.01       1.0   3:      0.01       1.0
   4:      0.10       1.0   5:      0.10       1.0   6:      0.10       1.0
   7:      0.10       1.0   8:      0.10       1.0   9:      0.10       1.0
  10:      0.10       1.0  11:      0.10       1.0  12:      0.10       1.0
  13:      0.10       1.0  14:      0.50       1.0  15:      0.50      0.70
  16:      0.10       1.0  17:      0.10       1.0  18:      0.10       1.0
  19:      0.10       1.0  20:      0.10       1.0  21:      0.10       1.0
  22:      0.10       1.0  23:      0.10       1.0  24:      0.10       1.0
  25:      0.10       1.0  26:      0.50       1.0  27:       0.5       1.0
  28:      0.50       1.0  29:      0.50       1.0  30:       0.5       1.0
  31:      0.50       1.0  32:      0.50       1.0  33:       0.5       1.0
  34:      0.50       1.0  35:      0.50       1.0  36:       0.5       1.0
  37:      0.50       1.0  38:      0.50       1.0  39:       0.5       1.0
  40:      0.50       1.0  41:      0.50       1.0
PO4                                         5  0.0    1.0E08
   1:      0.01      0.70   2:      0.01      0.70   3:      0.01      0.85
   4:      0.01      0.75   5:      0.01      0.85   6:      0.01      0.85
   7:      0.01      0.85   8:      0.01      0.85   9:      0.01      0.85
  10:      0.01      0.70  11:      0.01      0.70  12:      0.01     0.612
  13:      0.01     0.612  14:      0.01     0.612  15:      0.01     0.500
  16:      0.01      0.90  17:      0.01      0.90  18:      0.01      0.90
  19:      0.01      0.90  20:      0.01      0.90  21:      0.01      0.90
  22:      0.01      0.90  23:      0.01      0.90  24:      0.01      0.90
  25:      0.01      0.90  26:      2.50      0.50  27:       2.5       0.5
  28:      2.50       0.5  29:      2.50       0.5  30:       2.0       0.5
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  31:      2.00       0.5  32:      2.00       0.5  33:       2.0       0.5
  34:      2.00       0.5  35:      2.00       0.5  36:       2.0       0.5
  37:      2.00       0.5  38:      2.00       0.5  39:       2.0       0.5
  40:      2.00       0.5  41:      2.00       0.5
PHYT                                        4  0.0    1.0E08
   1:     25.00       0.0   2:     15.00       0.0   3:      25.0       0.0
   4:      5.00       0.0   5:      5.00       0.0   6:       5.0       0.0
   7:      5.00       0.0   8:      5.00       0.0   9:       5.0       0.0
  10:      5.00       0.0  11:      5.00       0.0  12:       5.0       0.0
  13:      5.00       0.0  14:     15.00       0.0  15:      15.0       0.0
  16:      4.00       0.0  17:      4.00       0.0  18:       4.0       0.0
  19:      4.00       0.0  20:      4.00       0.0  21:       4.0       0.0
  22:      4.00       0.0  23:      4.00       0.0  24:       4.0       0.0
  25:      0.00       0.0  26:      0.00       0.0  27:       0.0       0.0
  28:      0.00       0.0  29:      0.00       0.0  30:       0.0       0.0
  31:      0.00       0.0  32:      0.00       0.0  33:       0.0       0.0
  34:      0.00       0.0  35:      0.00       0.0  36:       0.0       0.0
  37:      0.00       0.0  38:      0.00       0.0  39:       0.0       0.0
  40:      0.00       0.0  41:      0.00       0.0
CBOD                                        3  0.0    1.0E08
   1:      5.00       0.8   2:      5.00       0.8   3:       5.0       0.8
   4:      5.00       0.8   5:      5.00       0.8   6:       5.0       0.8
   7:      5.00       0.8   8:      5.00       0.8   9:       5.0       0.8
  10:      5.00       0.8  11:      5.00       0.8  12:       5.0       0.8
  13:      5.00       0.8  14:      5.00       0.8  15:       5.0       0.8
  16:      5.00       0.9  17:      5.00       0.9  18:       5.0       0.9
  19:      5.00       0.9  20:      5.00       0.9  21:       5.0       0.9
  22:      5.00       0.9  23:      5.00       0.9  24:       5.0       0.9
  25:      9.00       0.9  26:      9.00       0.3  27:       9.0       0.3
  28:      9.00       0.3  29:      9.00       0.3  30:       9.0       0.3
  31:      9.00       0.3  32:      9.00       0.3  33:       9.0       0.3
  34:      9.00       0.3  35:      9.00       0.3  36:       9.0       0.3
  37:      9.00       0.3  38:      9.00       0.3  39:       9.0       0.3
  40:      9.00       0.3  41:      9.00       0.3
DO                                          5  0.0    1.0E08
   1:      10.0       1.0   2:      10.0       1.0   3:      10.0       1.0
   4:      10.0       1.0   5:      10.0       1.0   6:      13.0       1.0
   7:      13.0       1.0   8:      12.0       1.0   9:      12.0       1.0
  10:      12.0       1.0  11:      12.0       1.0  12:      12.0       1.0
  13:      11.0       1.0  14:      11.0       1.0  15:      13.0       1.0
  16:      14.0       1.0  17:      13.0       1.0  18:      13.0       1.0
  19:      12.0       1.0  20:      12.0       1.0  21:      12.0       1.0
  22:      12.0       1.0  23:      12.0       1.0  24:      11.0       1.0
  25:      11.0       1.0  26:      0.00       1.0  27:       0.0       1.0
  28:      0.00       1.0  29:      0.00       1.0  30:       0.0       1.0
  31:      0.00       1.0  32:      0.00       1.0  33:       0.0       1.0
  34:      0.00       1.0  35:      0.00       1.0  36:       0.0       1.0
  37:      0.00       1.0  38:      0.00       1.0  39:       0.0       1.0
  40:      0.00       1.0  41:      0.00       1.0
ON                                          3  1.5    1.0E08
   1:      0.20      0.50   2:      0.20      0.50   3:       0.2      0.50
   4:      0.20      0.40   5:      0.20      0.80   6:       0.2      0.80
   7:      0.20      0.80   8:      0.20      0.80   9:       0.2      0.80
  10:      0.20      0.70  11:      0.20      0.70  12:       0.2      0.70
  13:      0.20      0.70  14:      0.20      0.70  15:       0.2      0.70
  16:      0.50      0.85  17:      0.50      0.85  18:       0.5      0.85
  19:      0.50      0.85  20:      0.50      0.85  21:       0.5      0.85
```

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  22:      0.50      0.85  23:      0.50      0.70  24:      0.5      0.70
  25:      0.50      0.40  26:     15.00      0.10  27:     15.0      0.1
  28:     15.00      0.1   29:     15.00      0.1   30:     15.0      0.1
  31:     15.00      0.1   32:     15.00      0.1   33:     15.0      0.1
  34:     15.00      0.1   35:     15.00      0.1   36:     15.0      0.1
  37:     15.00      0.1   38:     15.00      0.1   39:     15.0      0.1
  40:     15.00      0.1   41:     15.00      0.1
OP                                             3  0.0    1.0E08
   1:      0.05.992176627   2:      0.05.992176627   3:      0.05      0.99
   4:      0.04      0.99   5:      0.02      0.99   6:      0.02      0.70
   7:      0.02      0.70   8:      0.02      0.70   9:      0.02      0.70
  10:      0.02      0.75  11:      0.01      0.70  12:      0.01      0.60
  13:      0.01      0.85  14:      0.04      0.85  15:      0.07      0.90
  16:      0.02      0.65  17:      0.02      0.55  18:      0.02      0.50
  19:      0.02      0.50  20:      0.02      0.50  21:      0.02      0.50
  22:      0.02      0.50  23:      0.02      0.50  24:      0.02      0.50
  25:      0.04.561981676  26:      2.00      0.10  27:      2.0       0.1
  28:      2.00      0.1   29:      2.00      0.1   30:      2.0       0.1
  31:      2.00      0.1   32:      2.00      0.1   33:      2.0       0.1
  34:      2.00      0.1   35:      2.00      0.1   36:      2.0       0.1
  37:      2.00      0.1   38:      2.00      0.1   39:      2.0       0.1
  40:      2.00      0.1   41:      0.50      0.1
```

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Appendix B. Response of Listed Segments to Load Reductions

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Table B-1. Segment 1 Response to New Hope Creek Load Reduction (Annual Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	1.0	1.53	3.34	8.66	13.75	17.14	21.20	27.16	32.64	36.47
	0.9	1.53	3.34	8.66	13.69	17.25	21.14	27.22	32.53	36.08
	0.8	1.53	3.34	8.66	13.69	17.20	20.98	26.94	31.87	35.76
	0.7	1.53	3.34	8.60	13.69	17.09	20.87	26.67	30.72	33.73
	0.6	1.53	3.29	8.55	13.64	16.81	20.32	25.19	28.80	30.72
	0.5	1.53	3.29	8.38	13.20	16.27	19.22	22.35	24.97	26.56
	0.4	1.53	3.23	8.00	11.94	14.46	17.09	18.73	21.09	22.23
	0.3	1.48	2.96	6.90	9.58	11.50	13.47	15.01	16.54	17.75
	0.2	1.59	2.63	4.33	4.77	5.32	6.30	7.78	8.49	9.53
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-2. Segment 1 Response to New Hope Creek Load Reduction (Growing Season Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	1.0	3.66	7.97	20.65	32.81	40.78	48.76	61.83	71.24	75.29
	0.9	3.66	7.97	20.65	32.68	40.92	48.76	61.31	71.24	75.03
	0.8	3.66	7.97	20.65	32.68	40.78	48.50	61.05	70.33	74.51
	0.7	3.66	7.97	20.52	32.68	40.65	48.37	60.39	68.89	72.29
	0.6	3.66	7.84	20.39	32.55	40.13	47.97	57.91	66.41	69.28
	0.5	3.66	7.84	20.00	31.50	38.82	45.88	52.81	58.69	61.57
	0.4	3.66	7.71	19.09	28.50	34.51	40.78	44.71	50.33	52.68
	0.3	3.53	7.06	16.47	22.88	27.45	32.16	35.82	39.48	42.35
	0.2	3.79	6.27	10.33	11.37	12.68	15.03	18.56	20.26	22.75
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-3. Segment 2 Response to New Hope Creek Load and Northeast Creek Reduction (Annual Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	**1.0**	0.00	0.00	0.27	1.21	3.73	7.17	12.16	16.76	21.03
	0.9	0.00	0.00	0.33	1.15	3.78	7.01	12.16	16.92	20.97
	0.8	0.00	0.00	0.27	1.15	3.67	6.96	12.16	16.70	20.75
	0.7	0.00	0.00	0.27	1.15	3.72	6.90	11.99	15.94	20.21
	0.6	0.00	0.00	0.27	1.15	3.83	6.63	11.39	15.23	17.85
	0.5	0.00	0.00	0.27	1.21	4.05	6.46	10.46	14.62	16.60
	0.4	0.00	0.00	0.16	1.04	3.67	5.59	8.27	12.16	14.79
	0.3	0.00	0.00	0.16	0.93	3.01	4.16	5.59	8.49	11.45
	0.2	0.00	0.00	0.33	0.93	2.08	3.23	3.89	5.75	7.18
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-4. Segment 2 Response to New Hope Creek Load and Northeast Creek Reduction (Growing Season Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	**1.0**	0.00	0.00	0.65	2.88	8.89	17.12	29.02	39.48	48.76
	0.9	0.00	0.00	0.78	2.75	9.02	16.73	29.02	39.87	49.02
	0.8	0.00	0.00	0.65	2.75	8.76	16.60	28.89	39.61	49.15
	0.7	0.00	0.00	0.65	2.75	8.89	16.47	28.63	37.91	47.84
	0.6	0.00	0.00	0.65	2.75	9.15	15.82	27.19	36.34	42.61
	0.5	0.00	0.00	0.65	2.88	9.67	15.42	24.97	34.90	39.61
	0.4	0.00	0.00	0.39	2.48	8.76	13.33	19.74	29.02	35.29
	0.3	0.00	0.00	0.39	2.22	7.19	9.93	13.33	20.26	27.32
	0.2	0.00	0.00	0.78	2.22	4.97	7.71	9.28	13.73	17.12
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-5. Segment 3 Response to Morgan Creek Load Reduction (Annual Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	**1.0**	0.44	0.55	1.26	3.72	4.93	6.95	10.24	12.21	14.78
	0.9	0.44	0.55	1.21	3.72	4.93	6.79	10.08	12.05	14.68
	0.8	0.44	0.55	1.26	3.72	4.93	6.79	9.86	11.61	14.18
	0.7	0.44	0.55	1.10	3.72	4.87	6.68	9.47	11.28	13.69
	0.6	0.44	0.55	1.21	3.67	4.87	6.52	9.03	10.51	12.16
	0.5	0.44	0.55	1.15	3.67	4.76	5.97	8.21	9.42	11.12
	0.4	0.44	0.55	1.15	3.61	4.27	5.09	7.45	8.60	10.13
	0.3	0.44	0.55	1.15	3.61	4.16	4.82	6.85	8.16	9.20
	0.2	0.38	0.55	1.15	3.56	4.11	4.60	6.41	7.72	8.60
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-6. Segment 3 Response to Morgan Creek Load Reduction (Growing Season Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	**1.0**	1.05	1.31	3.01	8.89	11.76	16.34	24.05	28.50	33.99
	0.9	1.05	1.31	2.88	8.89	11.76	16.21	23.66	28.10	33.59
	0.8	1.05	1.31	3.01	8.89	11.76	16.21	23.14	27.19	32.81
	0.7	1.05	1.31	2.61	8.89	11.63	15.95	22.61	26.67	31.76
	0.6	1.05	1.31	2.88	8.76	11.63	15.56	21.57	25.10	29.02
	0.5	1.05	1.31	2.75	8.76	11.37	14.25	19.61	22.48	26.54
	0.4	1.05	1.31	2.75	8.63	10.20	12.16	17.78	20.52	24.18
	0.3	1.05	1.31	2.75	8.63	9.93	11.50	16.34	19.48	21.96
	0.2	0.92	1.31	2.75	8.50	9.80	10.98	15.29	18.43	20.52
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-7. **Segment 4 Response to New Hope, Northeast, and Morgan Creek Load Reductions (Annual Average)**

Fraction of Existing Total P Load		Percent of Chlorophyll *a* Excursions								
	1.0	0.00	0.00	0.00	0.11	0.44	1.81	4.60	8.43	12.49
	0.9	0.00	0.00	0.00	0.16	0.44	1.81	4.71	8.38	12.16
	0.8	0.00	0.00	0.00	0.11	0.38	1.75	4.82	8.22	11.99
	0.7	0.00	0.00	0.00	0.11	0.38	1.81	4.93	8.27	12.21
	0.6	0.00	0.00	0.00	0.11	0.38	1.86	5.15	8.76	12.60
	0.5	0.00	0.00	0.00	0.11	0.38	2.08	5.31	9.26	11.88
	0.4	0.00	0.00	0.00	0.00	0.44	2.30	5.15	8.00	11.72
	0.3	0.00	0.00	0.00	0.00	0.60	2.14	4.00	5.26	7.18
	0.2	0.00	0.00	0.00	0.00	0.49	1.64	3.07	5.15	7.95
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-8. **Segment 4 Response to New Hope, Northeast, and Morgan Creek Load Reductions (Growing Season Average)**

Fraction of Existing Total P Load		Percent of Chlorophyll *a* Excursions								
	1.0	0.00	0.00	0.00	0.26	1.05	4.31	10.98	20.13	29.80
	0.9	0.00	0.00	0.00	0.39	1.05	4.31	11.24	20.00	29.02
	0.8	0.00	0.00	0.00	0.26	0.92	4.18	11.50	19.61	28.63
	0.7	0.00	0.00	0.00	0.26	0.92	4.31	11.76	19.74	29.15
	0.6	0.00	0.00	0.00	0.26	0.92	4.44	12.29	20.92	30.07
	0.5	0.00	0.00	0.00	0.26	0.92	4.97	12.68	22.09	28.37
	0.4	0.00	0.00	0.00	0.00	1.05	5.49	12.29	19.09	27.97
	0.3	0.00	0.00	0.00	0.00	1.44	5.10	9.54	12.55	17.12
	0.2	0.00	0.00	0.00	0.00	1.18	3.92	7.32	12.29	18.95
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-9. Aggregate Response of Segments 1 and 2 to New Hope, Northeast, and Morgan Creek Load Reductions (Annual Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	1.0	0.27	1.10	3.15	6.60	8.71	13.01	18.57	24.20	28.75
	0.9	0.27	1.10	3.12	6.57	8.74	12.93	18.48	24.18	28.61
	0.8	0.27	1.10	3.10	6.57	8.74	12.93	18.35	23.60	28.34
	0.7	0.27	1.10	3.10	6.49	8.63	12.79	18.16	22.81	26.48
	0.6	0.27	1.07	3.10	6.44	8.65	12.27	16.95	21.17	24.12
	0.5	0.27	1.07	3.04	6.16	8.16	11.80	14.76	18.43	20.95
	0.4	0.27	1.01	2.93	5.29	6.90	9.42	11.58	14.21	16.87
	0.3	0.27	1.01	1.95	3.64	4.98	6.33	7.81	9.56	11.20
	0.2	0.27	0.79	1.40	2.14	2.85	3.92	4.77	6.16	8.60
		0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
		Fraction of Existing Total N Load								

Table B-10. Aggregate Response of Segments 1 and 2 to New Hope, Northeast, and Morgan Creek Load Reductions (Growing Season Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	1.0	0.65	2.61	7.52	15.75	20.78	30.26	42.81	54.31	62.03
	0.9	0.65	2.61	7.45	15.69	20.85	30.13	42.61	54.38	62.09
	0.8	0.65	2.61	7.39	15.69	20.85	30.13	42.42	53.40	61.96
	0.7	0.65	2.61	7.39	15.49	20.59	29.93	41.83	52.09	58.95
	0.6	0.65	2.55	7.39	15.36	20.65	29.28	39.61	49.48	55.75
	0.5	0.65	2.55	7.26	14.71	19.48	28.17	35.23	43.53	49.09
	0.4	0.65	2.42	6.99	12.61	16.47	22.48	27.65	33.79	39.93
	0.3	0.65	2.42	4.64	8.69	11.90	15.10	18.63	22.81	26.73
	0.2	0.65	1.90	3.33	5.10	6.80	9.35	11.37	14.71	20.52
		0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
		Fraction of Existing Total N Load								

Table B-11. Aggregate Response of Segments 1-4 to New Hope, Northeast, and Morgan Creek Load Reductions (Annual Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	**1.0**	0.14	0.55	1.58	3.33	4.55	7.86	12.05	16.84	21.19
	0.9	0.14	0.55	1.56	3.33	4.56	7.85	12.02	16.78	20.97
	0.8	0.14	0.55	1.55	3.31	4.55	7.80	11.82	16.20	20.58
	0.7	0.14	0.55	1.55	3.27	4.49	7.72	11.56	15.43	19.17
	0.6	0.14	0.53	1.55	3.25	4.46	7.26	10.82	14.68	17.76
	0.5	0.14	0.53	1.52	3.11	4.20	6.89	9.50	12.93	15.40
	0.4	0.14	0.51	1.47	2.64	3.56	5.50	7.52	9.80	12.75
	0.3	0.14	0.51	0.97	1.82	2.64	3.79	5.07	6.55	8.31
	0.2	0.14	0.40	0.70	1.07	1.55	2.42	3.25	4.63	7.11
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-12. Aggregate Response of Segments 1-4 to New Hope, Northeast, and Morgan Creek Load Reductions (Growing Season Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	**1.0**	0.33	1.31	3.76	7.94	10.85	18.37	28.01	38.33	46.96
	0.9	0.33	1.31	3.73	7.94	10.88	18.37	27.94	38.30	46.63
	0.8	0.33	1.31	3.69	7.91	10.85	18.27	27.52	37.19	46.11
	0.7	0.33	1.31	3.69	7.81	10.72	18.14	26.83	35.65	43.63
	0.6	0.33	1.27	3.69	7.75	10.65	17.32	25.39	34.51	41.47
	0.5	0.33	1.27	3.63	7.42	10.03	16.44	22.68	30.62	36.31
	0.4	0.33	1.21	3.50	6.31	8.50	13.14	17.94	23.33	30.26
	0.3	0.33	1.21	2.32	4.35	6.31	9.05	12.09	15.62	19.84
	0.2	0.33	0.95	1.67	2.55	3.69	5.78	7.75	11.05	16.96
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-13. Aggregate Response of Segments 2-4 to New Hope, Northeast, and Morgan Creek Load Reductions (Annual Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	**1.0**	0.00	0.00	0.04	0.24	0.80	3.74	7.30	11.68	16.10
	0.9	0.00	0.00	0.02	0.24	0.82	3.76	7.27	11.65	15.90
	0.8	0.00	0.00	0.02	0.22	0.79	3.72	7.08	11.15	15.50
	0.7	0.00	0.00	0.02	0.18	0.75	3.65	6.86	10.46	14.24
	0.6	0.00	0.00	0.04	0.20	0.71	3.32	6.33	10.30	13.36
	0.5	0.00	0.00	0.00	0.18	0.68	2.98	5.53	9.17	11.85
	0.4	0.00	0.00	0.00	0.11	0.68	2.41	4.36	6.61	10.08
	0.3	0.00	0.00	0.00	0.15	0.60	1.68	2.70	4.13	6.10
	0.2	0.00	0.00	0.00	0.13	0.51	1.26	2.12	3.51	6.30
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-14. Aggregate Response of Segments 2-4 to New Hope, Northeast, and Morgan Creek Load Reductions (Growing Season Average)

		Percent of Chlorophyll *a* Excursions								
Fraction of Existing Total P Load	**1.0**	0.00	0.00	0.09	0.57	1.92	8.93	17.43	27.58	37.52
	0.9	0.00	0.00	0.04	0.57	1.96	8.98	17.34	27.54	37.12
	0.8	0.00	0.00	0.04	0.52	1.87	8.89	16.91	26.54	36.60
	0.7	0.00	0.00	0.04	0.44	1.79	8.71	16.38	24.97	33.94
	0.6	0.00	0.00	0.09	0.48	1.70	7.93	15.12	24.58	31.90
	0.5	0.00	0.00	0.00	0.44	1.61	7.10	13.20	21.87	28.28
	0.4	0.00	0.00	0.00	0.26	1.61	5.75	10.41	15.77	24.05
	0.3	0.00	0.00	0.00	0.35	1.44	4.01	6.45	9.85	14.55
	0.2	0.00	0.00	0.00	0.31	1.22	3.01	5.05	8.37	15.03
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-15. Aggregate Response of Segments 1-4 to New Hope, Northeast, Morgan Creek, and Haw River Load Reductions (Annual Average)

Fraction of Existing Total P Load		Percent of Chlorophyll *a* Excursions								
	1.0	0.11	0.47	1.37	3.08	4.31	7.39	11.68	16.72	21.19
	0.9	0.11	0.47	1.37	3.09	4.30	7.44	11.51	16.69	21.03
	0.8	0.11	0.47	1.36	3.08	4.30	7.38	11.34	16.03	20.60
	0.7	0.11	0.47	1.36	3.07	4.27	7.31	11.06	15.32	19.37
	0.6	0.11	0.45	1.36	3.03	4.22	6.94	10.21	14.49	17.74
	0.5	0.11	0.45	1.32	2.85	3.97	6.49	8.93	12.69	15.51
	0.4	0.10	0.42	1.18	2.44	3.37	5.22	7.19	9.63	12.72
	0.3	0.11	0.44	0.85	1.58	2.10	3.14	4.31	5.94	7.94
	0.2	0.10	0.33	0.58	0.85	1.11	1.90	2.55	3.70	6.16
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-16. Aggregate Response of Segments 1-4 to New Hope, Northeast, Morgan Creek, and Haw River Load Reductions (Growing Season Average)

Fraction of Existing Total P Load		Percent of Chlorophyll *a* Excursions								
	1.0	0.26	1.11	3.27	7.35	10.29	17.29	27.12	38.04	46.96
	0.9	0.26	1.11	3.27	7.39	10.26	17.39	26.76	38.07	46.76
	0.8	0.26	1.11	3.24	7.35	10.26	17.26	26.37	36.80	46.21
	0.7	0.26	1.11	3.24	7.32	10.20	17.16	25.65	35.39	44.15
	0.6	0.26	1.08	3.24	7.22	10.07	16.57	23.95	34.09	41.41
	0.5	0.26	1.08	3.14	6.80	9.48	15.49	21.31	30.03	36.57
	0.4	0.23	1.01	2.81	5.82	8.04	12.45	17.16	22.91	30.20
	0.3	0.26	1.05	2.03	3.76	5.00	7.48	10.29	14.18	18.95
	0.2	0.23	0.78	1.37	2.03	2.65	4.54	6.08	8.82	14.71
		0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
		Fraction of Existing Total N Load								

Table B-17. Segment 14 (Near Dam) Response to Haw River Load (Annual Average)

		Percent of Chlorophyll *a* Excursions										
Fraction of Existing Total P Load	**1.5**	0.00	0.00	0.00	0.27	2.74	6.96	9.48	12.93	15.72	17.15	18.51
	1.4	0.00	0.00	0.00	0.27	2.68	7.01	9.31	12.38	15.06	16.54	17.86
	1.3	0.00	0.00	0.00	0.27	2.68	6.96	9.10	11.89	14.52	15.99	17.14
	1.2	0.00	0.00	0.00	0.27	2.68	6.58	8.38	11.12	13.42	14.90	15.83
	1.1	0.00	0.00	0.00	0.22	2.68	6.14	7.73	10.08	12.49	13.80	14.57
	1.0	0.00	0.00	0.00	0.16	2.30	4.99	6.58	8.66	10.96	11.78	12.44
	0.9	0.00	0.00	0.00	0.16	1.48	4.11	5.42	7.34	8.88	9.70	10.03
	0.8	0.00	0.00	0.00	0.11	1.21	3.89	5.10	6.41	7.62	8.49	8.55
	0.7	0.00	0.00	0.00	0.11	0.99	3.45	4.11	4.66	5.04	5.15	5.15
	0.6	0.00	0.00	0.00	0.00	0.66	2.96	3.78	3.84	3.84	3.89	3.89
	0.5	0.00	0.00	0.00	0.00	0.27	1.15	1.15	1.15	1.15	1.15	1.15
		0.5	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
		Fraction of Existing Total N Load										

Table B-18. Segment 14 (Near Dam) Response to Haw River Load (Growing Season Average)

		Percent of Chlorophyll *a* Excursions										
Fraction of Existing Total P Load	**1.5**	0.00	0.00	0.00	0.65	6.54	16.60	22.61	30.85	37.52	40.92	44.18
	1.4	0.00	0.00	0.00	0.65	6.41	16.73	22.22	29.54	35.95	39.48	42.61
	1.3	0.00	0.00	0.00	0.65	6.41	16.60	21.70	28.37	34.64	38.17	40.92
	1.2	0.00	0.00	0.00	0.65	6.41	15.69	20.00	26.54	32.03	35.56	37.78
	1.1	0.00	0.00	0.00	0.52	6.41	14.64	18.43	24.05	29.80	32.94	34.77
	1.0	0.00	0.00	0.00	0.39	5.49	11.90	15.69	20.65	26.14	28.10	29.67
	0.9	0.00	0.00	0.00	0.39	3.53	9.80	12.94	17.52	21.18	23.14	23.92
	0.8	0.00	0.00	0.00	0.26	2.88	9.28	12.16	15.29	18.17	20.26	20.39
	0.7	0.00	0.00	0.00	0.26	2.35	8.24	9.80	11.11	12.03	12.29	12.29
	0.6	0.00	0.00	0.00	0.00	1.57	7.06	9.02	9.15	9.15	9.28	9.28
	0.5	0.00	0.00	0.00	0.00	0.65	2.75	2.75	2.75	2.75	2.75	2.75
		0.5	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
		Fraction of Existing Total N Load										

Table B-19. Segment 15 (Haw River Arm) Response to Haw River Load (Annual Average)

		Percent of Chlorophyll *a* Excursions										
Fraction of Existing Total P Load	**1.5**	0.00	1.04	3.40	5.15	6.30	7.67	9.53	10.69	11.23	12.00	12.22
	1.4	0.00	1.04	3.40	5.15	6.30	7.67	9.37	10.47	11.01	11.73	11.95
	1.3	0.00	1.04	3.40	5.15	6.25	7.62	9.21	10.30	10.79	11.45	11.62
	1.2	0.00	1.04	3.40	5.15	6.25	7.51	9.04	10.14	10.58	11.18	11.34
	1.1	0.00	1.04	3.40	5.10	6.14	7.29	8.77	9.70	10.19	10.63	10.96
	1.0	0.00	1.04	3.40	4.99	5.92	6.90	8.22	9.10	9.42	9.75	10.19
	0.9	0.00	1.04	3.40	4.93	5.75	6.63	7.62	8.11	8.77	9.26	9.26
	0.8	0.00	1.04	3.40	4.82	5.64	6.19	6.96	7.29	7.62	7.84	7.89
	0.7	0.00	1.04	3.40	4.71	5.26	5.53	5.81	6.08	6.08	6.14	6.14
	0.6	0.00	0.99	3.23	4.22	4.93	4.93	5.04	5.04	4.99	4.99	4.99
	0.5	0.00	0.99	2.58	3.07	3.34	3.73	3.73	3.73	3.73	3.73	3.73
		0.5	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
		Fraction of Existing Total N Load										

Table B-20. Segment 15 (Haw River Arm) Response to Haw River Load (Growing Season Average)

Fraction of Existing Total P Load		Percent of Chlorophyll *a* Excursions										
	1.5	0.00	2.48	8.10	12.29	15.03	18.30	22.75	25.49	26.80	27.97	28.24
	1.4	0.00	2.48	8.10	12.29	15.03	18.30	22.35	24.97	26.27	27.32	27.71
	1.3	0.00	2.48	8.10	12.29	14.90	18.17	21.96	24.58	25.75	26.67	27.06
	1.2	0.00	2.48	8.10	12.29	14.90	17.91	21.57	24.18	25.23	26.14	26.41
	1.1	0.00	2.48	8.10	12.16	14.64	17.39	20.92	23.14	24.31	25.10	25.75
	1.0	0.00	2.48	8.10	11.90	14.12	16.47	19.61	21.70	22.48	23.27	24.31
	0.9	0.00	2.48	8.10	11.76	13.73	15.82	18.17	19.35	20.92	22.09	22.09
	0.8	0.00	2.48	8.10	11.50	13.46	14.77	16.60	17.39	18.17	18.69	18.82
	0.7	0.00	2.48	8.10	11.24	12.55	13.20	13.86	14.51	14.51	14.64	14.64
	0.6	0.00	2.35	7.71	10.07	11.76	11.76	12.03	12.03	11.90	11.90	11.90
	0.5	0.00	2.35	6.14	7.32	7.97	8.89	8.89	8.89	8.89	8.89	8.89
		0.5	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
		Fraction of Existing Total N Load										

Table B-21. Segments 14 and 15 Aggregated Response to Haw River Load (Annual Average)

Fraction of Existing Total P Load	Percent of Chlorophyll *a* Excursions										
1.5	0.00	0.52	1.70	2.71	4.52	7.32	9.51	11.81	13.48	14.57	15.37
1.4	0.00	0.52	1.70	2.71	4.49	7.34	9.34	11.42	13.04	14.13	14.90
1.3	0.00	0.52	1.70	2.71	4.47	7.29	9.15	11.09	12.66	13.72	14.38
1.2	0.00	0.52	1.70	2.71	4.47	7.04	8.71	10.63	12.00	13.04	13.59
1.1	0.00	0.52	1.70	2.66	4.41	6.71	8.25	9.89	11.34	12.22	12.76
1.0	0.00	0.52	1.70	2.58	4.11	5.95	7.40	8.88	10.19	10.77	11.31
0.9	0.00	0.52	1.70	2.55	3.62	5.37	6.52	7.73	8.82	9.48	9.64
0.8	0.00	0.52	1.70	2.47	3.42	5.04	6.03	6.85	7.62	8.16	8.22
0.7	0.00	0.52	1.70	2.41	3.12	4.49	4.96	5.37	5.56	5.64	5.64
0.6	0.00	0.49	1.62	2.11	2.79	3.95	4.41	4.44	4.41	4.44	4.44
0.5	0.00	0.49	1.29	1.53	1.81	2.44	2.44	2.44	2.44	2.44	2.44
	0.5	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
	Fraction of Existing Total N Load										

Table B-22. Segments 14 and 15 Aggregated Response to Haw River Load (Growing Season Average)

		Percent of Chlorophyll *a* Excursions										
Fraction of Existing Total P Load	**1.5**	0.00	1.24	4.05	6.47	10.78	17.45	22.68	28.17	32.16	34.77	36.67
	1.4	0.00	1.24	4.05	6.47	10.72	17.52	22.29	27.26	31.11	33.73	35.56
	1.3	0.00	1.24	4.05	6.47	10.65	17.39	21.83	26.47	30.20	32.75	34.31
	1.2	0.00	1.24	4.05	6.47	10.65	16.80	20.78	25.36	28.63	31.11	32.42
	1.1	0.00	1.24	4.05	6.34	10.52	16.01	19.67	23.59	27.06	29.15	30.46
	1.0	0.00	1.24	4.05	6.14	9.80	14.18	17.65	21.18	24.31	25.69	26.99
	0.9	0.00	1.24	4.05	6.08	8.63	12.81	15.56	18.43	21.05	22.61	23.01
	0.8	0.00	1.24	4.05	5.88	8.17	12.03	14.38	16.34	18.17	19.48	19.61
	0.7	0.00	1.24	4.05	5.75	7.45	10.72	11.83	12.81	13.27	13.46	13.46
	0.6	0.00	1.18	3.86	5.03	6.67	9.41	10.52	10.59	10.52	10.59	10.59
	0.5	0.00	1.18	3.07	3.66	4.31	5.82	5.82	5.82	5.82	5.82	5.82
		0.5	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
		Fraction of Existing Total N Load										

Table B-23. Segments 14 and 15 Aggregated Response to Haw River, New Hope Creek, Morgan Creek, and Northeast Creek Loads (Annual Average)

		Percent of Chlorophyll *a* Excursions										
Fraction of Existing Total P Load	**1.5**	0.00	0.11	1.59	2.63	4.25	7.10	9.64	12.46	14.13	15.23	16.22
	1.4	0.00	0.11	1.59	2.63	4.16	7.10	9.56	12.19	13.86	14.93	15.91
	1.3	0.00	0.11	1.59	2.63	4.16	7.21	9.40	11.78	13.37	14.49	15.37
	1.2	0.00	0.11	1.59	2.63	4.11	7.04	9.04	11.26	12.82	13.80	14.57
	1.1	0.00	0.11	1.62	2.60	3.95	6.74	8.49	10.55	12.03	12.85	13.48
	1.0	0.00	0.11	1.62	2.55	3.78	5.95	7.59	9.53	10.74	11.45	11.94
	0.9	0.00	0.11	1.62	2.52	3.37	5.31	6.63	8.30	9.45	9.81	9.97
	0.8	0.00	0.11	1.64	2.41	3.37	5.04	6.08	7.18	7.97	8.16	8.19
	0.7	0.00	0.11	1.53	2.33	2.99	4.49	5.10	5.37	5.51	5.51	5.62
	0.6	0.00	0.47	1.48	2.05	2.71	4.16	4.36	4.36	4.36	4.36	4.38
	0.5	0.00	0.44	1.12	1.51	1.81	2.14	2.14	2.16	2.19	2.19	2.22
		0.5	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
		Fraction of Existing Total N Load										

Table B-24. Segments 14 and 15 Aggregated Response to Haw River, New Hope Creek, Morgan Creek, and Northeast Creek Loads (Growing Season Average)

		Percent of Chlorophyll *a* Excursions										
Fraction of Existing Total P Load	**1.5**	0.00	0.26	3.79	6.27	10.13	16.93	23.01	29.74	33.73	36.01	38.23
	1.4	0.00	0.26	3.79	6.27	9.93	16.93	22.81	29.09	33.07	35.29	37.52
	1.3	0.00	0.26	3.79	6.27	9.93	17.19	22.42	28.10	31.90	34.25	36.27
	1.2	0.00	0.26	3.79	6.27	9.80	16.80	21.57	26.86	30.59	32.68	34.44
	1.1	0.00	0.26	3.86	6.21	9.41	16.08	20.26	25.16	28.69	30.52	31.90
	1.0	0.00	0.26	3.86	6.08	9.02	14.18	18.10	22.75	25.62	27.32	28.43
	0.9	0.00	0.26	3.86	6.01	8.04	12.68	15.82	19.80	22.55	23.40	23.79
	0.8	0.00	0.26	3.92	5.75	8.04	12.03	14.51	17.12	19.02	19.48	19.54
	0.7	0.00	0.26	3.66	5.56	7.12	10.72	12.16	12.81	13.14	13.14	13.40
	0.6	0.00	1.11	3.53	4.90	6.47	9.93	10.39	10.39	10.39	10.39	10.46
	0.5	0.00	1.05	2.68	3.59	4.31	5.10	5.10	5.16	5.23	5.23	5.29
		0.5	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
		Fraction of Existing Total N Load										