Appendix 8.B. Effect of Water Withdrawal on Phytoplankton Biomass in Lake Poinsett

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I. Introduction

Lake Poinsett is a 13.6 km^2 run-of-the-river lake located in river segment 8 of the Upper Basin of the St. Johns River at approximately river kilometer 380 (Figure 1). One of the proposed water withdrawal locations is located just downstream of the lake. The water withdrawal could potentially alter the lake's hydrology, particularly its hydraulic residence time (HRT), and thereby alter the lake's phytoplankton community. The purpose of this study is to evaluate whether any of the proposed water withdrawal scenarios will cause an increase in algal biomass in the lake. The approach used is similar to that used for downstream segments of the river (Chapter 8. Plankton). The assumption is that water withdrawal would affect lake elevation and/or discharge, alter HRT, and thereby potentially alter algal bloom dynamics.

Several algal bloom metrics were developed for downstream reaches of the SJR (Chapter 8. Plankton). Of these metrics, thresholds for marine algae were not evaluated here as this portion of the river is not marine, and change in nitrogen load was not evaluated for lack of data on N-fixation rates and the generally low algal biomass in Lake Poinsett. A statistical summary of relevant water quality parameters is shown in Table 1.

II. Methods

Water quality data were obtained from two stations on Lake Poinsett, one at the outlet of the lake (LPO) and another at the lake's center (LPC) from 1979 to 2008. Water quality analyses followed the same methods used by the Plankton Working Group (Chapter 8. Plankton). In particular, chlorophyll-a (chl-a) was examined to evaluate algal bloom intensity. Each year, the maximum chl-a concentration at either sampling location was determined. This approach does not utilize the spatial averaging used in the larger downstream lakes.

Unlike in downstream segments of the river, the SJRWMD hydrodynamic model (EFDC) has not been developed for the Upper Basin (river segments 7 – 9) which precludes the use of water age as a primary variable to evaluate hydrologic conditions in the lake. However, as has been done in the rest of the river's watershed, the SJRWMD has modeled the Upper Basin watersheds using the HSPF model for the years 1975 to 2008 (Chapter 3. Watershed Hydrology). The water withdrawal scenarios modeled in the Upper Basin are a sub-set of those evaluated downstream for two reasons. First, the effect of sea level rise has not been incorporated since this portion of the river is too distant and topographically too high (Lake Poinsett mean elevation ~ 3.28 m NAVD 1988) to be affected. Second, the effects of withdrawals from the Ocklawaha River have not been evaluated since Lake Poinsett is approximately 230 river kilometers upstream of the confluence of the St. Johns and Ocklawaha rivers.

The HSPF model simulates and outputs daily lake water level, volume (V), and discharge (Q) data (Chapter 3. Watershed Hydrology), from which daily HRT values were calculated by the equation.

$$\mathrm{HRT} = \frac{\mathrm{V}}{\mathrm{Q}}$$

On the few days when discharge was negative, HRT was not calculated. Daily HRT values were then used in place of water age in analyses similar to those used in the downstream river segments . Specifically, the same bloom and hydrologic statistics for various periods of each year were calculated as calculated by the Plankton Working Group (Chapter 8. Plankton). The maximum annual chl-a data were filtered so that only years with more than six sampling events were included in the regression analysis. SAS was used to perform multiple linear regression analyses using the HRT statistics for the baseline scenario (Base1995NN) as independent variables and the observed bloom statistics as dependent variables.

As was done in the analyses of the downstream river segments, the bloom predictions for withdrawal scenarios were calculated and then compared to the baseline using two metrics:

1. The percent change in the median response (withdrawal minus baseline) of the bloom metric

2. The change in annual frequency (withdrawal minus baseline) that thresholds were exceeded (e.g. two in 30 years (0.067) minus one in 30 years (0.033) = +0.033)

III. Results and Discussion

A. Chlorophyll a

The site LPC was sampled for only portions of four years (2002 – 2005) on the same date as the LPO site. There was no statistical difference between the chl-a values for the sites (Paired T-test $p = 0.64$).

Bloom duration was not evaluated as was done for downstream segments of the river because there were only seven sampling events when chl-a exceeded the 40 $\mu g\ L^{-1}$ threshold which defined bloom conditions. Only one of these occasions was the result of consecutive monthly samples exceeding the bloom duration threshold of 50 days. Other blooms were defined by a single value exceeding the threshold, sometimes with more than a month between sampling events. Some of these potential blooms exceeded the duration threshold only when linear interpolation to adjacent sampling events was included. Based upon professional judgment it was determined that there were too few blooms exceeding 40 $\mu g\ L^{-1}$ for at least 50 days and they were too poorly defined to allow the development of predictive bloom duration models.

B. Predicted magnitude of algal blooms (maximum annual chl-a)

The results of the multiple regression analysis using Max_A, Max_E and Inv_Min_D of HRT statistics as the independent variables and maximum annual chl-a concentration as the dependent variable are presented in Figure 2. The model's three independent variables were each significant ($p < 0.05$), and the overall model had an adjusted $R^2 = 0.85$.

In the downstream segments of the river two thresholds were utilized to evaluate the magnitude of freshwater algal blooms, one at 50 $\mu g\ L^{-1}$ and the other at 138 $\mu g\ L^{-1}$, with the latter based upon the role of algal blooms in driving periods of low dissolved oxygen (DO). Work by the Biogeochemistry Working Group (Jian Di and Lawrence Keenan, SJRWMD, pers. comm.) has demonstrated that periods of low DO in Lake Poinsett are driven by inundation patterns of the lake's extensive floodplain wetlands, and not decomposition of algae; therefore, this threshold will not be applied in Lake Poinsett. The 50 $\mu g\ L^{-1}$ threshold was based upon a shift in the plankton community toward cyanobacteria dominance, which has a variety of consequences, (Chapter 8. Plankton) and is appropriate here as cyanobacteria dominate Lake Poinsett (Fisher et al. 2009).

The multiple regression model was used to predict the annual maximum chl-a for each year under the baseline and each water withdrawal scenario. Because chl-a data first are available in 1979, model predictions of annual maximum chl-a were made for the years 1979 – 2008, inclusive.

C. Effects of Water Withdrawals on Algal Biomass (chl-a)

The predicted maximum annual chl-a for the baseline scenario (Base1995NN) is similar to the observed data (Figure 3). The results of the pair-wise comparisons between the baseline scenario (Base1995NN) and all withdrawal scenarios are presented in Figure 4. There are only three years (2000, 2001 and 2008) out of the 30 modeled years when any scenario predicts annual maximum chl-a concentrations to exceed the bloom threshold of 50 $\mu g\ L^{-1}$. The years 2000 and 2001 were during a record drought in the watershed.

The effect of the Upper Basin project is particularly noticeable in the scenario results; scenarios with the project in place (PN) have much lower predicted annual maximum chl-a during the drought years (2000 & 2001) than scenarios without the project in place (NN). Other than the drought years, the predicted differences in annual maximum chl-a are slight (Figure 4). When the Upper Basin project is in place the difference (withdrawal minus baseline) in the probability of blooms exceeding the threshold is negative, indicating that blooms are predicted to be less frequent, no matter the withdrawal magnitude. Without the project, there are no changes in frequency. The median percent change in annual maximum chl-a ranges from + 1.56% to – 1.71% (Table 2). With the Upper Basin project in place all withdrawals with 1995 land use have negative percent median change, i.e. lower annual maximum chl-a. With the project in place, the

2030 scenarios predict a slight increase in annual maximum chl-a, either + 0.67% (half withdrawal) or + 1.56% (full withdrawal). All predicted withdrawal effects fall within the negligible effect category (see Chapter 8. Plankton) since all differences in bloom frequency are less than 0.09, and median percent changes are less than 10%.

D. Potential Effects of Nutrient Enrichment

The Biogeochemistry Working Group assessed the potential for altered nutrient runoff from the adjacent floodplain wetlands to Lake Poinsett due to water withdrawals (Chapter 7. Biogeochemistry). Nitrogen and phosphorus runoff from the floodplain wetlands contributing to Lake Poinsett was modeled using release rates and a range of reduction coefficient estimates and the predicted changes in inundation due to withdrawals. The median loading from these predictions was tabulated daily from 1976 through 2008. For direct comparison with the years of bloom prediction (1979 – 2008), the annual average increase in total phosphorus and total Kjeldahl nitrogen over the baseline caused by the most extreme withdrawal scenario (Full1995NN) was 0.00159 mg TP L^{-1} and 0.0104 mg TKN L^{-1}. The median observed total phosphorus concentration for sites LPO and LPC for 1979 – 2008 was 0.074 mg P L^{-1} and therefore the most extreme scenario results in a 2.15% increase in the median concentration. The median observed total Kjeldahl nitrogen concentration for the sites LPO and LPC for 1979 – 2008 was 1.70 mg N L^{-1} and therefore the most extreme scenario results in a 0.61% increase in the median concentration. Both these concentration increases are deemed negligible (less than 10%). This conclusion is supported by the relative insensitivity of algal biomass to nutrients in blackwater lakes in the Upper Basin of the SJR (Aldridge and Schelske 1999). As the increase for the most extreme scenario resulted in negligible effects, all other scenarios are considered to have a negligible effect on nutrient availability. Thus, changes in nutrient availability are not considered to alter the previous assessment of bloom metrics based solely on hydrologic changes.

IV. Uncertainty in Assessment of Effects

As was done by the Plankton Working Group (Chapter 8. Plankton), uncertainty was assessed using a common set of criteria based upon three types of evidence: predictive models, supporting evidence, and understanding of the mechanisms. Like uncertainty, strength of evidence was also expressed in five ordinal categories (1 – strong to 5 – weak).

Unlike in downstream river segments, the uncertainty could not be based upon the SJRWMD hydrodynamic model output, but rather on the watershed modeling (HSPF) of discharge, volume and stage. The Watershed Hydrology Working Group evaluated the HSPF model uncertainty by river segment and considered segment 8, including Lake Poinsett, to have low uncertainty (Chapter 3. Watershed Hydrology). In our assessment, HRT was utilized in a hydroecological multiple regression predictive model as water age was used in downstream segments to predict annual maximum chl-a. This model was judged to have very low uncertainty since it demonstrated good fit, each independent variable contributed significantly, and the regression was based upon 30 years of data (Figure 2).

We rated both supporting evidence and understanding of mechanisms as strong (1) since the relationships between HRT and bloom characteristics are well understood (see main chapter and Appendix 1). Thus, the final expression of uncertainty for the Lake Poinsett predictions as used in Table 21 of the main chapter is 2-1|1|1 which is consolidated to an overall rating of ** (HSPF-Hydroecological models | supporting evidence | understanding of mechanisms and ** for the highest rated individual uncertainty of 2).

V. References

Aldridge, F.J. and C.L. Schelske. 1999. Study of light and nutrient limitation in Lake Washington. Draft final report to the St. Johns River Water Management District.

Fisher, M.M., S.J. Miller, A.D. Chapman and L.W. Keenan. 2009. Phytoplankton dynamics in a chain of subtropical blackwater lakes: the Upper St. Johns River, Florida, USA. Lake Reserv. Manage. 25:73-86.

Table 1. Statistical summary for selected water quality parameters in Lake Poinsett.

Parameter (Unit)	**Mean**	**Median**	**Min**	**Max**	**St. Dev.**	**n**
Chlorophyll-a ($\mu g\ L^{-1}$)	11	6	0	155	16	220
Color (pcu)	190	150	30	700	120	228
Secchi Depth (m)	0.68	0.64	0.10	1.78	0.30	189
Total Phosphorus ($mg\ L^{-1}$)	0.098	0.077	0.009	0.483	0.073	230
Dissolved Ortho-Phosphate ($mg\ L^{-1}$)	0.043	0.020	-0.001	0.316	0.059	71
Total Kjeldahl Nitrogen ($mg\ L^{-1}$)	1.845	1.700	0.050	6.573	0.682	216
Dissolved Nitrate & Nitrite ($mg\ L^{-1}$)	0.106	0.050	-0.009	0.494	0.131	64
Dissolved Ammonium ($mg\ L^{-1}$)	0.066	0.036	0.005	0.493	0.088	71
Total Organic Carbon ($mg\ L^{-1}$)	27	27	16	44	5	187
Dissolved Organic Carbon ($mg\ L^{-1}$)	27	27	17	43	5	50
Total Dissolved Solids ($mg\ L^{-1}$)	508	410	12	2330	317	230
Total Suspended Solids ($mg\ L^{-1}$)	12	5	-2	211	23	235
Field pH (S.U.)	7.59	7.56	5.73	9.93	0.61	230
Dissolved Oxygen ($mg\ L^{-1}$)	7.18	7.24	0.82	17.70	2.02	235

Table 2. Summary of differences between baseline scenario (Base1995NN) and water withdrawal scenarios for Lake Poinsett. As discussed in text, this list of scenarios is a subset of but equivalent to the longer list in Chapter 8. Plankton. Because of the upstream location of Lake Poinsett, sea level rise was not important ("xxxN" and "xxxS" scenarios were equivalent) and effects of water withdrawal from the Ocklawaha River were not important ("FULLxxx" scenarios were equivalent to "FwORxxx" scenarios).

USJRB Project	Year	SJR Withdrawal	Scenario Compared to Base1995NN	Bloom Characteristic	Scenario Bloom Probability	Difference in Bloom Probability	Median % Change in Max Chl-a
No	1995	Half	HALF1995NN	Max Chl-a	0.09	0	0.56%
		Full	FULL1995NN	Max Chl-a	0.09	0	1.32%
Yes	1995	Half	HALF1995PN	Max Chl-a	0	-0.09	-1.71%
		Full	FULL1995PN	Max Chl-a	0.03	-0.06	-0.29%
	2030	Half	HALF2030PN	Max Chl-a	0.03	-0.06	0.67%
		Full	FULL2030PN	Max Chl-a	0.03	-0.06	1.56%

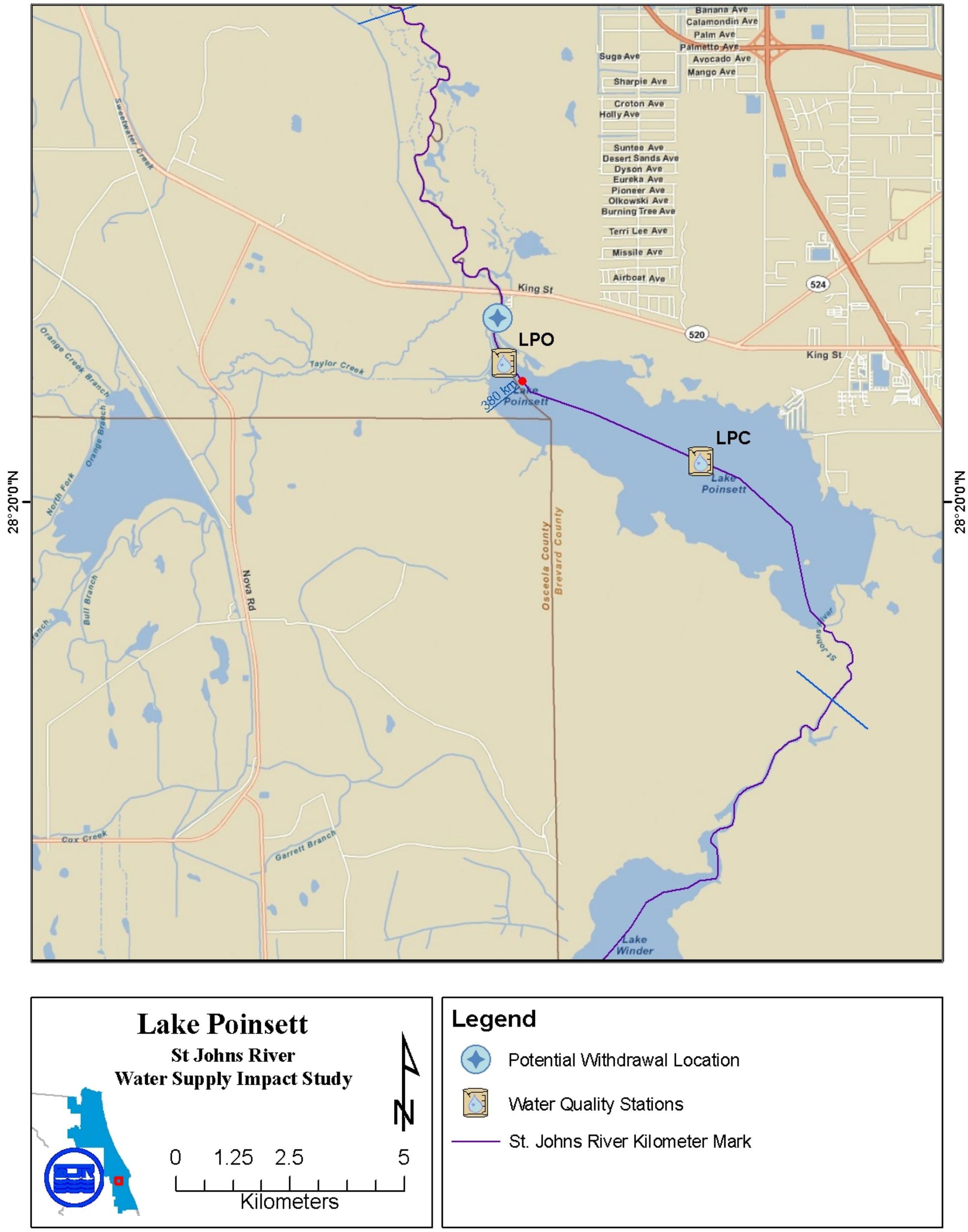

Figure 1. Map of Lake Poinsett indicating potential withdrawal location and location of two water quality sampling sites (LPC and LPO).

Appendix 8.B.

Analysis of Variance					
Source	*DF*	*Sum of Squares*	*Mean Square*	*F Value*	*Pr > F*
Model	3	19558	6519.23119	34.35	<.0001
Error	14	2657.34594	189.81042		
Corrected Total	17	22215			

Root MSE	13.77717	*R-Square*	0.8804
Dependent Mean	39.43343	*Adj R-Sq*	0.8547
Coeff Var	34.93780		

Parameter Estimates						
Variable	*Label*	*DF*	*Parameter Estimate*	*Standard Error*	*t Value*	*Pr > |t|*
Intercept	Intercept	1	6.29068	8.52876	0.74	0.4729
Max_A		1	0.03906	0.00458	8.52	<.0001
Max_E		1	0.02410	0.00465	5.18	0.0001
Inv_Min_D		1	166.61142	64.98100	2.56	0.0225

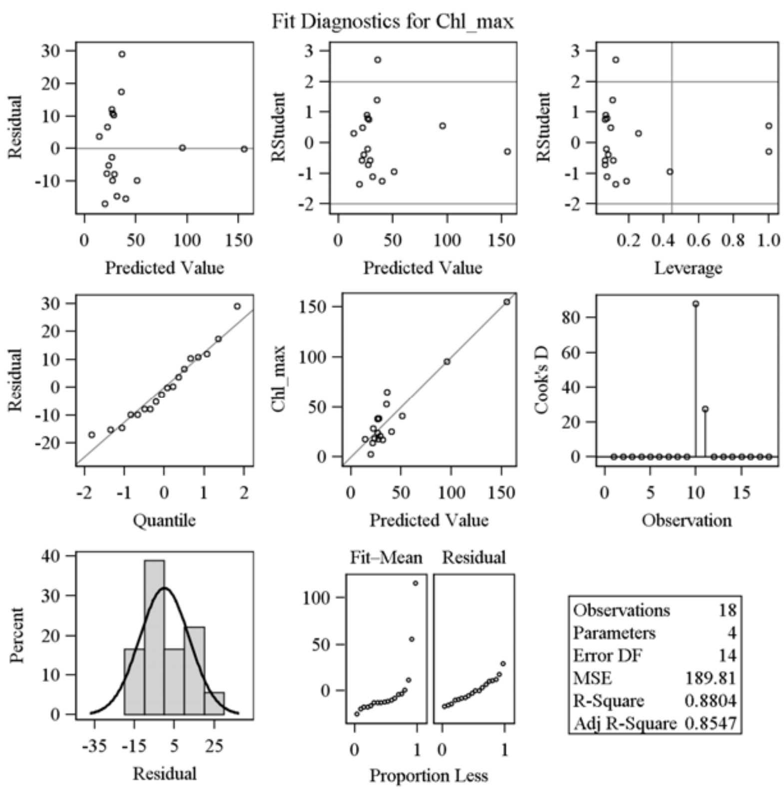

Figure 2. Multiple regression output for predictive model between HRT and annual maximum chl-a. The letter designations in variable names refer to the same time periods used in Chapter 8. Plankton, namely, A: Oct-Dec of previous year, D: July-Dec, and E: Oct-Dec. Thus the variable Max_A is the maximum HRT predicted during Oct-Dec of the previous year, Max_E is the maximum HRT predicted during Oct-Dec of current year and Inv_Min_D is the inverse of the minimum HRT predicted during July-Sept.

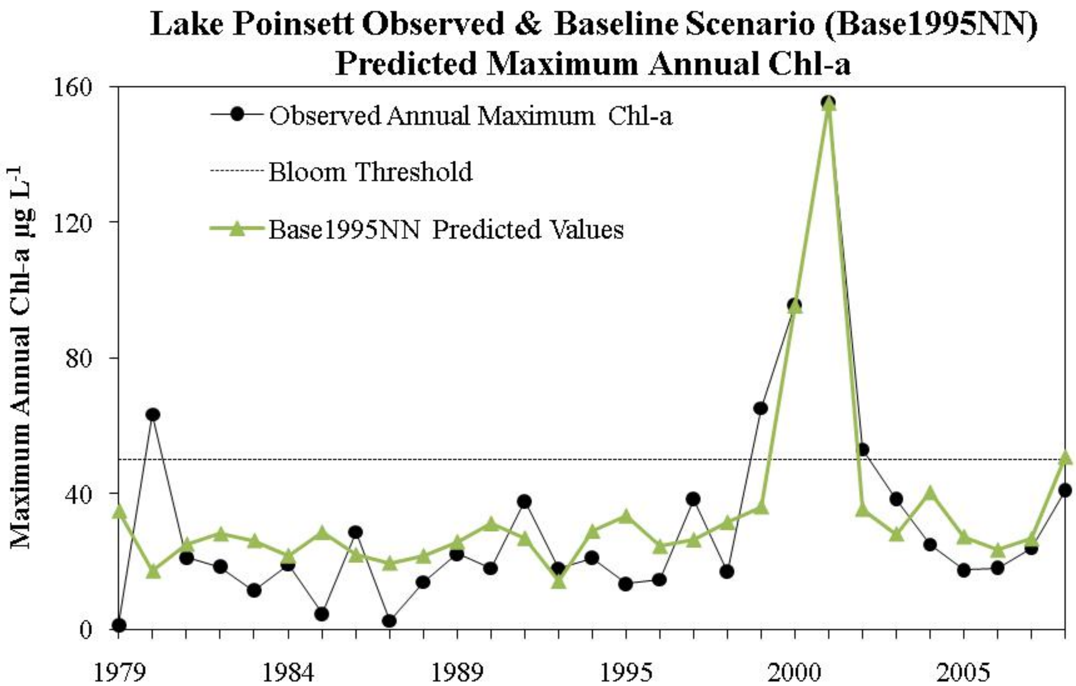

Figure 3. Observed and predicted baseline scenario (Base1995NN) annual maximum chl-a in Lake Poinsett.

Appendix 8.B.

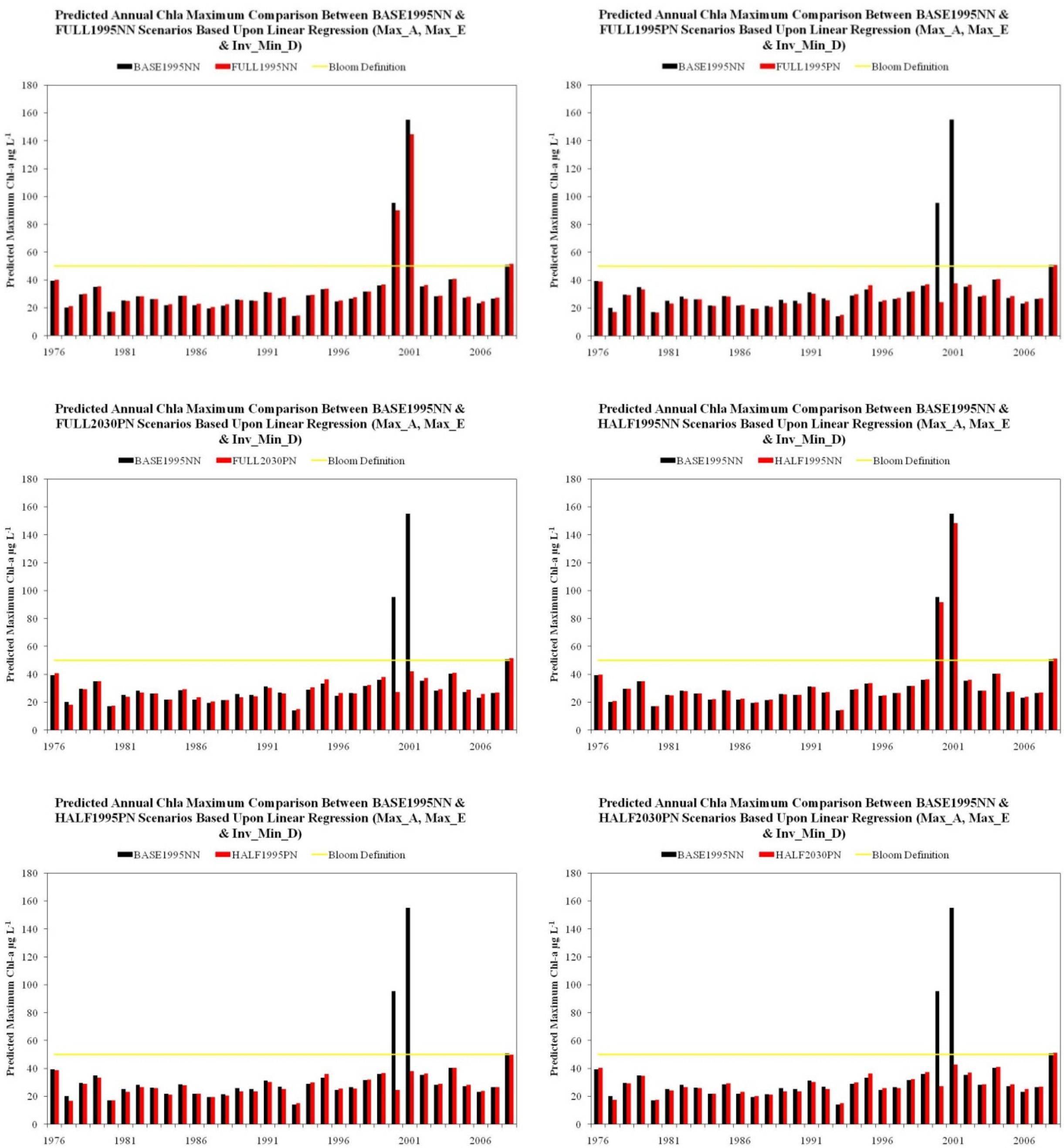

Figure 4. Pair-wise comparisons of predicted annual maximum chl-a of the baseline scenario (Base1995NN) with each water withdrawal scenario.