WATER QUALITY MODELING

Scenarios to Address Nuclear Regulatory Commission RAI

Prepared for:

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RAI Question

The time series of the following metrics are to be provided. Time increments should be a minimum of monthly. The maximum (or minimum) values to be provided are those that occur within the monthly increment.

- Normalized Cape Fear water quality response. The normalization is with respect to the 0 ft rise condition with existing inflows and existing consumptive uses. Variability of Cape Fear River water quality is to be included at a monthly time interval, as supported by the available data.
  - For total phosphorous, total nitrogen and a conservative tracer, provide a maximum of the volumetric-weighted average concentrations for Harris Reservoir for each time increment.
  - For chlorophyll a, provide the maximum concentration wherever it occurs outside the mixing zone in Harris Reservoir for each time increment.
  - For dissolved oxygen, provide the minimum surface layer concentration wherever it occurs in Harris Reservoir.

Water Quality Modeling Objectives

The objective of this water quality modeling analysis of Harris Lake was to provide information necessary to address the specific questions pertaining to water quality impacts in Nuclear Regulatory Commission RAI 9.4-3. This modeling examined existing water quality conditions in Harris Lake to establish a baseline for normalization, and the predicted water quality impacts from both high and low release strategies and the Cape Fear River make-up water pumping scenarios associated with those two release regimes. The modeling analysis simulated conventional/eutrophication water quality parameters including, but not limited to: nutrients, phytoplankton, chlorophyll a. and dissolved oxygen.

Modeling Approach

A two-dimensional, laterally-averaged, hydrodynamic and water quality model, CE-QUAL-W2 (Cole and Wells, 2003), was applied to Harris Lake to forecast the water quality conditions in the lake resulting from the combined effects of a higher pool, larger cooling water load, minimum release targets, and introduction of water from the Cape Fear River. The particular CE-QUAL-W2 model used in this analysis was previously developed to examine potential wastewater management scenarios, including the possibility of discharging municipal wastewater directly to Harris Lake, for a regional partnership of communities and for the Town of Holly Springs. Details on the development of the model for those uses are available in a Technical Memorandum produced by CH2M HILL (2008).

A thorough review was conducted of all model inputs, inputs were updated to reflect the most recent and accurate information available, and the model calibration was revised. Specific actions to revise and improve the model include:

- Revised the bathymetry, including adding layers and segments, lowering the bottom at dam, adding a layer at the top of the pool to make sure the lake could handle pools above 240 feet.
- Conducted a water balance to improve the amount of tributary inflows entering the lake. This resulted in about 15% more water entering and a much better agreement of model with observed pool elevation.
- Revised the tributary inflow temperatures to reflect a more accurate estimate of temperature versus time of year.
- Revised all of the non-point source tributary nutrient loadings including changing the splits among nutrient loadings computed by the upgraded GWLF model.
- Corrected physical descriptions for spillway and blow-down withdrawal and discharge structures.
- Corrected other errors in the model control file.
- Corrected the blow-down withdrawal and discharge flow rates and water quality characteristics of the discharge.
- Revised the model hydrodynamic and temperature parameters.
- Revised nearly all of the model kinetic rate and stoichiometric parameters for water quality.

The CE-QUAL-W2 model of Harris Lake was supported by a Generalized Watershed Loading Function (GWLF) (Haith and Shoemaker, 1987), model that predicted pollutant loads from stormwater runoff and other point and non-point sources throughout the lake's watershed. The watershed includes portions of the rapidly growing and changing jurisdictions of southwestern Wake County, and since the GWLF model was originally developed, local land use plans within these jurisdictions, as well as those for Chatham County, have evolved. To reflect the most current land use planning information available, the GWLF model was updated accordingly and the assumptions that were utilized to develop the pollutant loads in the watershed model were thoroughly reviewed and revised as deemed necessary.

The Cape Fear River make-up water pumping scenarios were developed using the Cape Fear River Basin Hydrologic Model (CFRBHM), a planning tool that was developed for the North Carolina Department of Environmental and Natural Resources (NC DENR) and is widely used by municipalities, stakeholders and the state to conduct analyses of water uses in the Cape Fear River Basin.

Scenarios Modeled

The CE-QUAL-W2 model of Harris Lake was used to examine the following scenarios to address the issues raised in the RAI:

Existing Conditions – Harris Lake at current elevation of 220' MSL (no rise condition), with exiting tributary flows (2001 – 2008 hydrologic conditions) and existing tributary non-point source pollutant loads as predicted by the updated GWLF model. The scenario also includes cooling water intake volumes and cooling tower blow-down discharges associated with the existing Shearon Harris nuclear plant. The Holly Springs WWTP discharge that enters the White Oak/Utley Creek arm of the lake from a short distance upstream (see Figure 1) was input with existing discharge volume parameters and pollutant loads. . Note that the actual discharge point for Holly Springs WWTP is further upstream than could be depicted in the extent of Figure 1.

Future Conditions – Harris Lake at planned future elevation of 240' MSL (with new spillway configuration and minimum release valve), with existing tributary flows (2001 – 2008 hydrologic conditions) and existing tributary non-point source pollutant loads. The scenario also includes future levels of cooling water intake and blow-down discharges necessary to support the two new units planned for the Harris site, HAR Unit 2 and Unit 3. The Holly Springs WWTP discharge was input with future discharge volume and pollutant load parameters associated with projected 2025 conditions.

The Future Conditions Scenario was run with both a high base flow release pattern and a low base flow release pattern, as identified through the ongoing Instream Flow Study process. The high base flow release pattern provides releases into Buckhorn Creek ranging from 17 cfs to 30 cfs depending on the month. The low base flow release pattern provides releases into Buckhorn Creek ranging from 4 cfs to 14 cfs depending on the month. Both future conditions scenarios were run with existing levels of non-point source loading to the lake tributaries to more clearly illustrate the water quality impacts specifically associated with the higher cooling water demands and Cape Fear River make-up water pumping associated with the two new units.

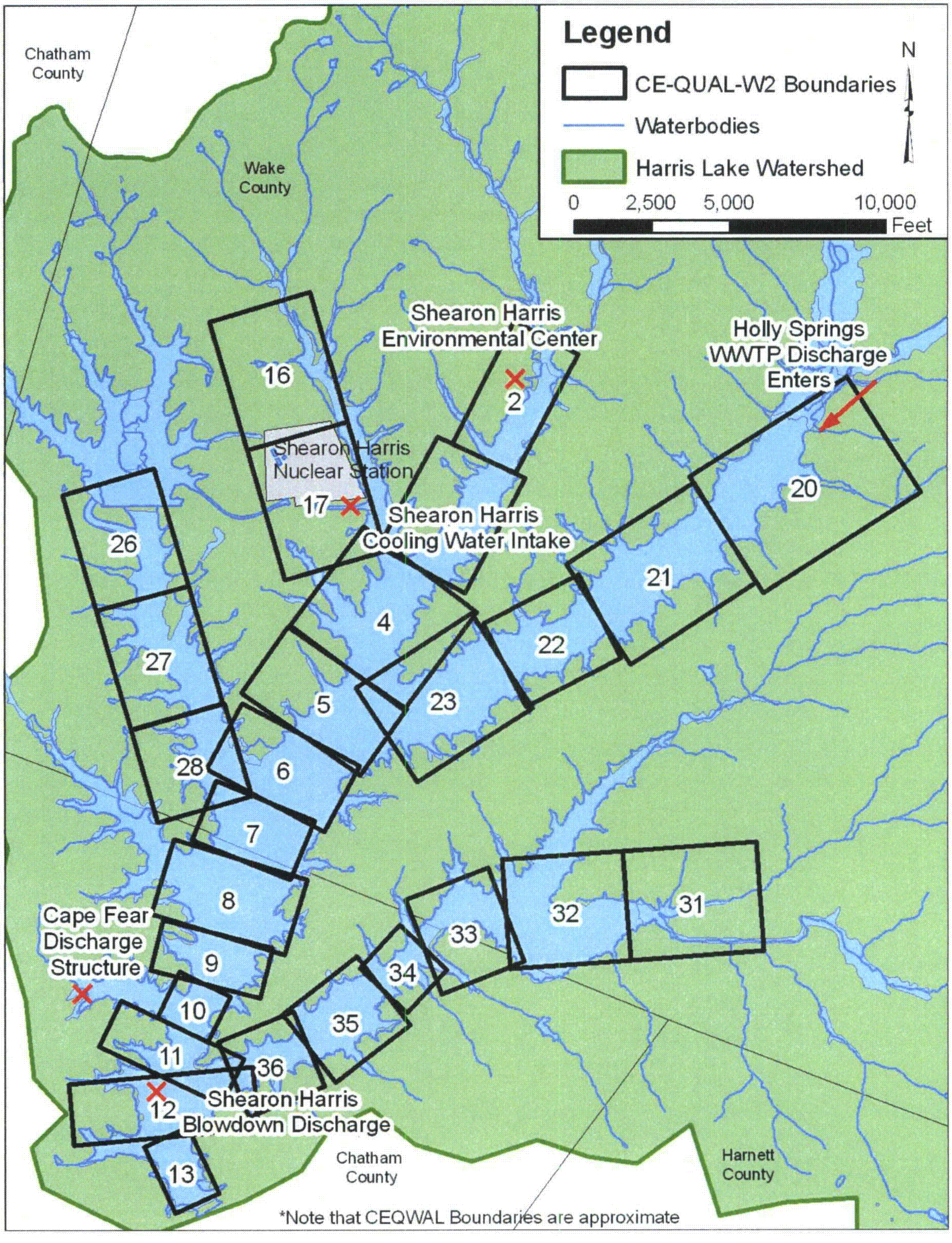


Figure 1. Map of Harris Lake with Model Schematic and Major Inputs and Withdrawals

Model Results and Discussion

Per the parameters stipulated in the RAI, model results were output for total phosphorous, total nitrogen, chlorophyll a, dissolved oxygen, and a hypothetical conservative tracer. The conservative tracer was injected into the Cape Fear River make-up water at a concentration of 100 mg/L in order to examine the resulting in-lake concentrations. Model results were output specifically for the surface layers of model segments 5 and 13 (Figure 1). As a result of the morphometry of the reservoir, these two segments are the most reflective of overall water quality conditions. Segment 5 is located where the major tributary arms of the lake have come together and where pollutants from those tributaries and upstream sources have the opportunity to exert their combined effects. Segment 13 reflects conditions at the downstream end of the main arm, where the lake has completed its transformation of incoming loads and where the best prediction of the quality of downstream releases can be derived. Model results are shown as time series for each parameter for the entire 2001-2008 hydrologic base period (Julian Day 1-2922) and are presented in the series of graphs at the end of this report.

Model results for the segment nearest to the dam (Segment 13) indicate that total nitrogen concentrations are predicted to be significantly lower in the expanded Lake, with Cape Fear River water introduced. The fluctuations of total phosphorus (TP) loads are altered and the TP graph appears to indicate a slight overall load reduction. Examination of the chlorophyll a time series clearly shows a reduction in peak levels throughout the simulation period, which would indicate an overall reduction in eutrophic productivity. Surface dissolved oxygen (DO) levels appear to remain relatively unchanged, with the potential for some lessening in severity of the minimum DO spikes. The conservative tracer is reduced to concentrations near zero at start up and increases gradually, and then fluctuates in a range of approximately 20-45 mg/l for the high base flow release condition, and 15-40 mg/l for the low base flow release condition, by the end of the simulation period.

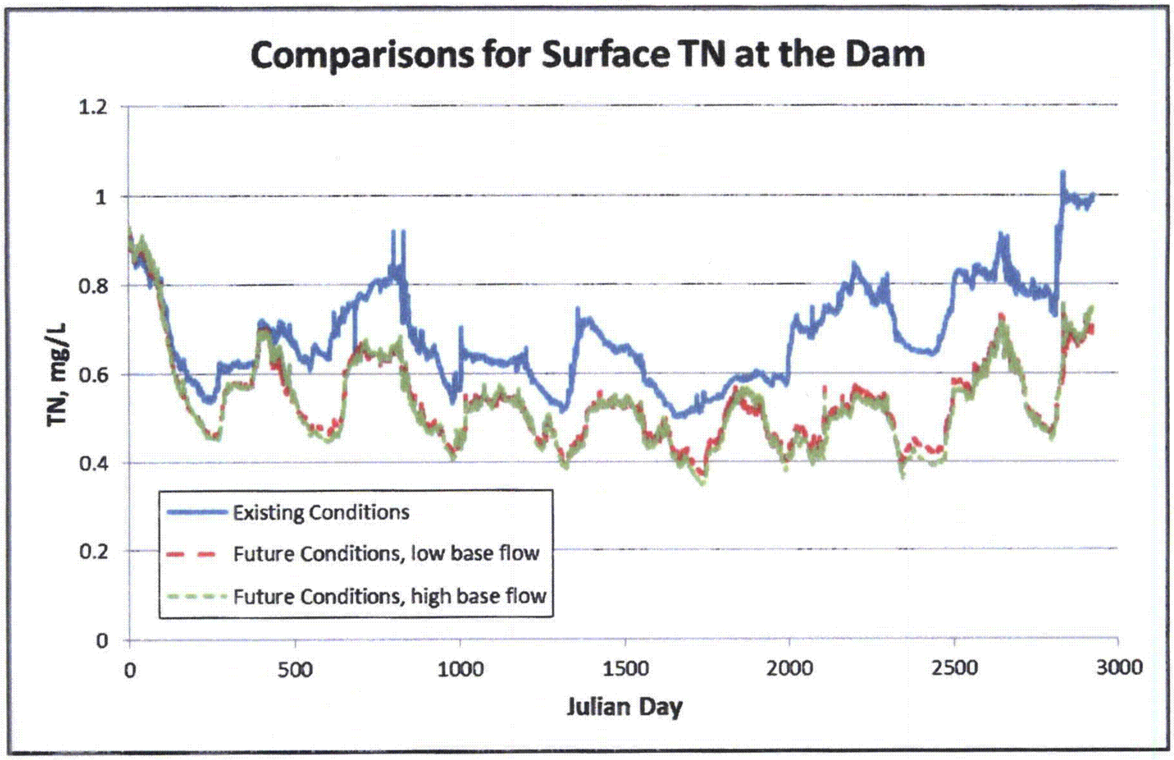
Model results for the segment at the upstream end of the main lake arm (Segment 5) also indicate that total nitrogen concentrations are predicted to be significantly lower in the expanded lake. Unlike the model results near the dam, TP in Segment 5 is predicted to be reduced significantly in the expanded lake with tangible differences in TP concentrations resulting from the two different release strategies. Examination of the chlorophyll a time series clearly shows a reduction in overall and peak levels throughout the simulation period. Just as with predicted conditions near the dam, surface dissolved oxygen (DO) levels appear to remain relatively unchanged. Just as with predictions at the dam, the conservative tracer is reduced to concentrations near zero at start up and increases gradually, then fluctuating by the end of the simulation period with significant differences between the two base flow release strategies.

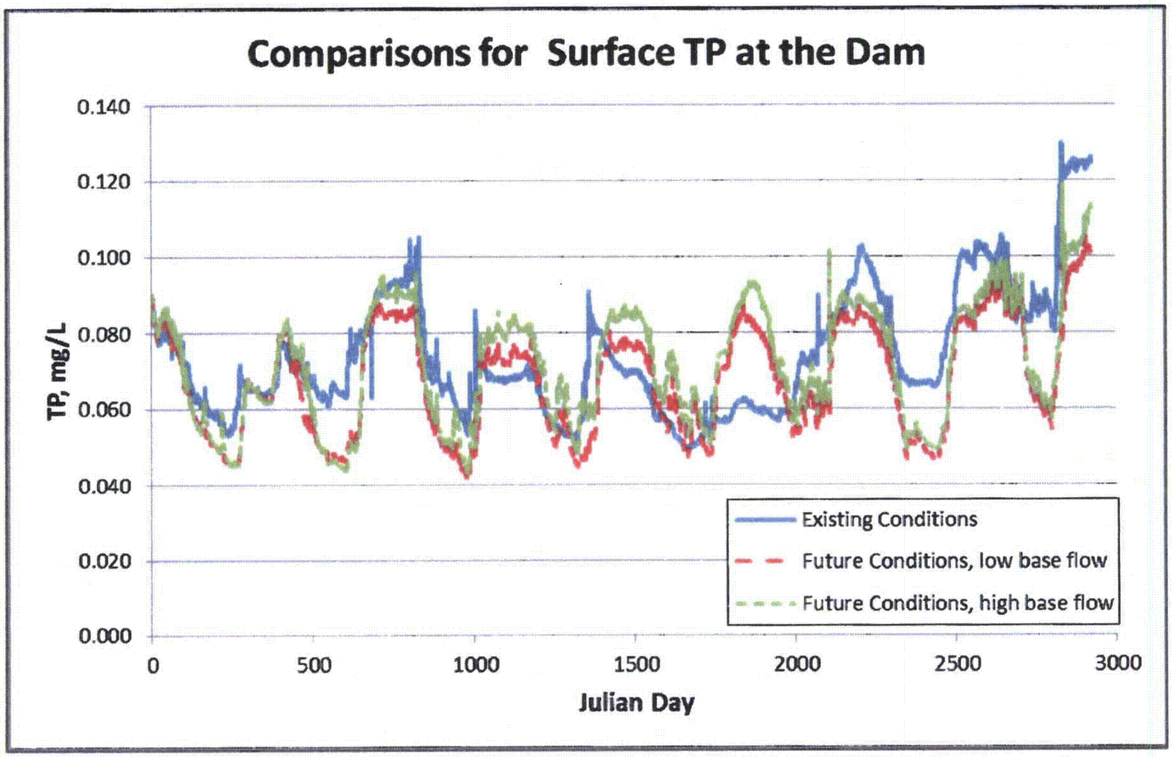
References

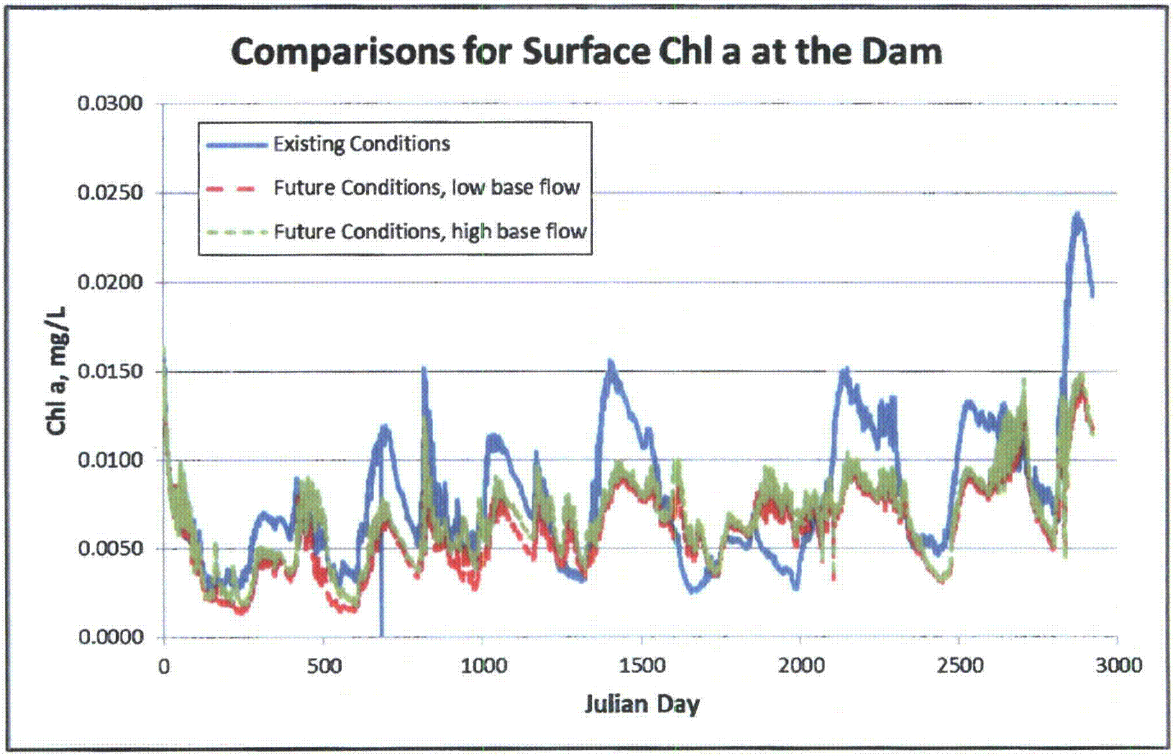
CH2M HILL. 2008. Technical Memorandum: Development and Calibration of a CE-QUAL-W2 Model for Harris Lake, prepared for Western Wake Partners.

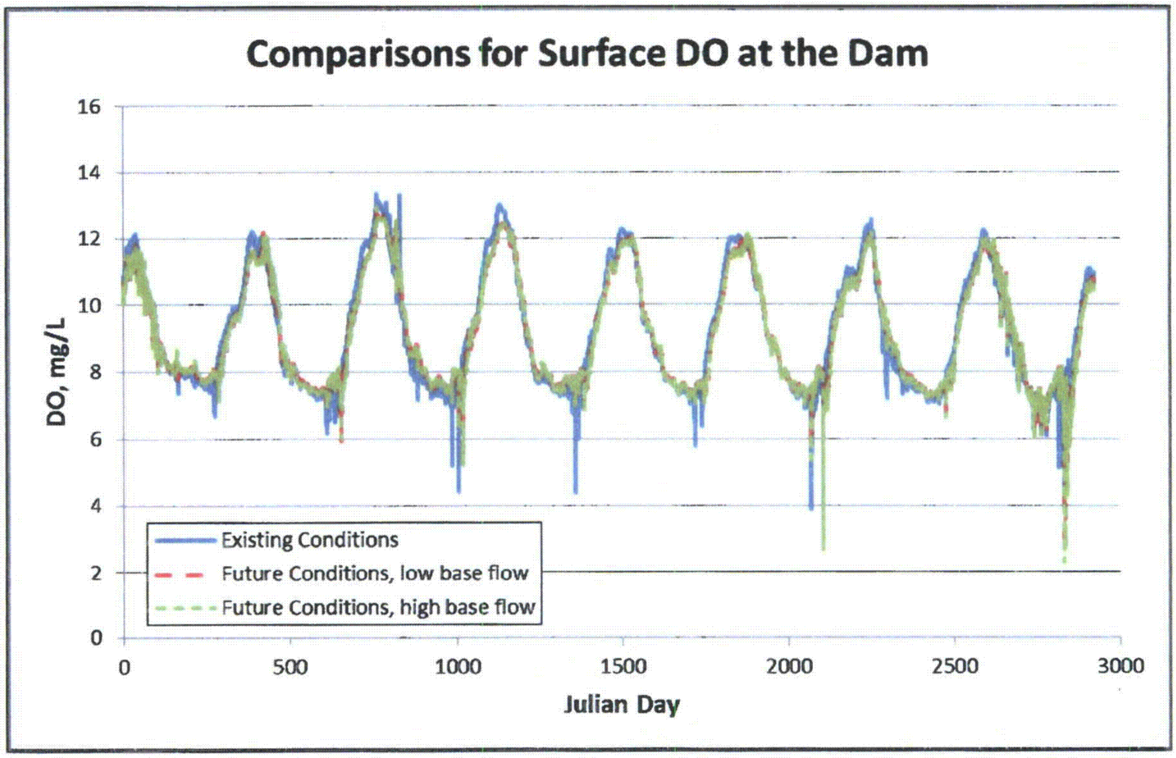
Cole, T.M., and Wells, S.A. 2003. CE-QUAL-W2: a two-dimensional, laterally-averaged, hydrodynamic and water quality model, version 3.2, user manual, Instruction report EL-03-1 (draft), prepared for U.S. Army Corps of Engineers.

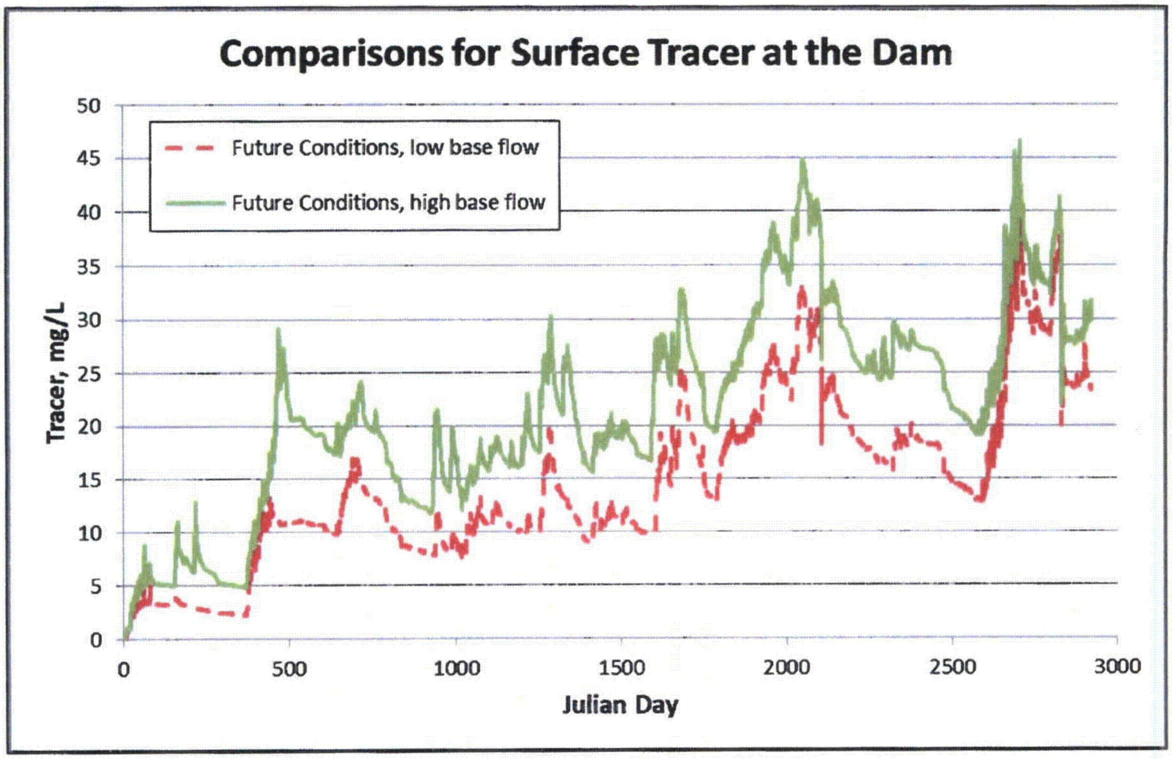
Haith, D.A. and L.L. Shoemaker, 1987. Generalized Watershed Loading Functions for Stream Flow Nutrients. Water Resources Bulletin, 23(3), pp. 471-478.

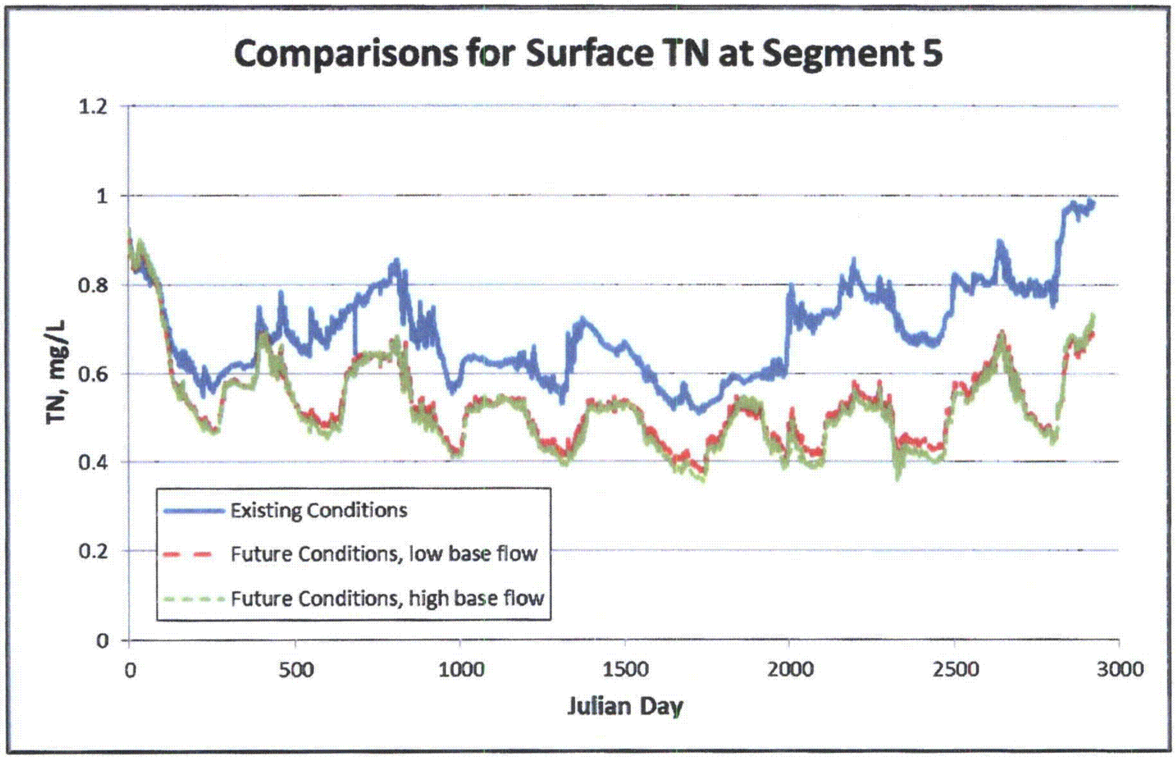

Comparisons for Surface TN at the Dam
TN, mg/L
1.2
1
0.8
0.6
0.4
0.2
0
0
500
1000
1500
2000
2500
3000
Julian Day
Existing Conditions
Future Conditions, low base flow
Future Conditions, high base flow

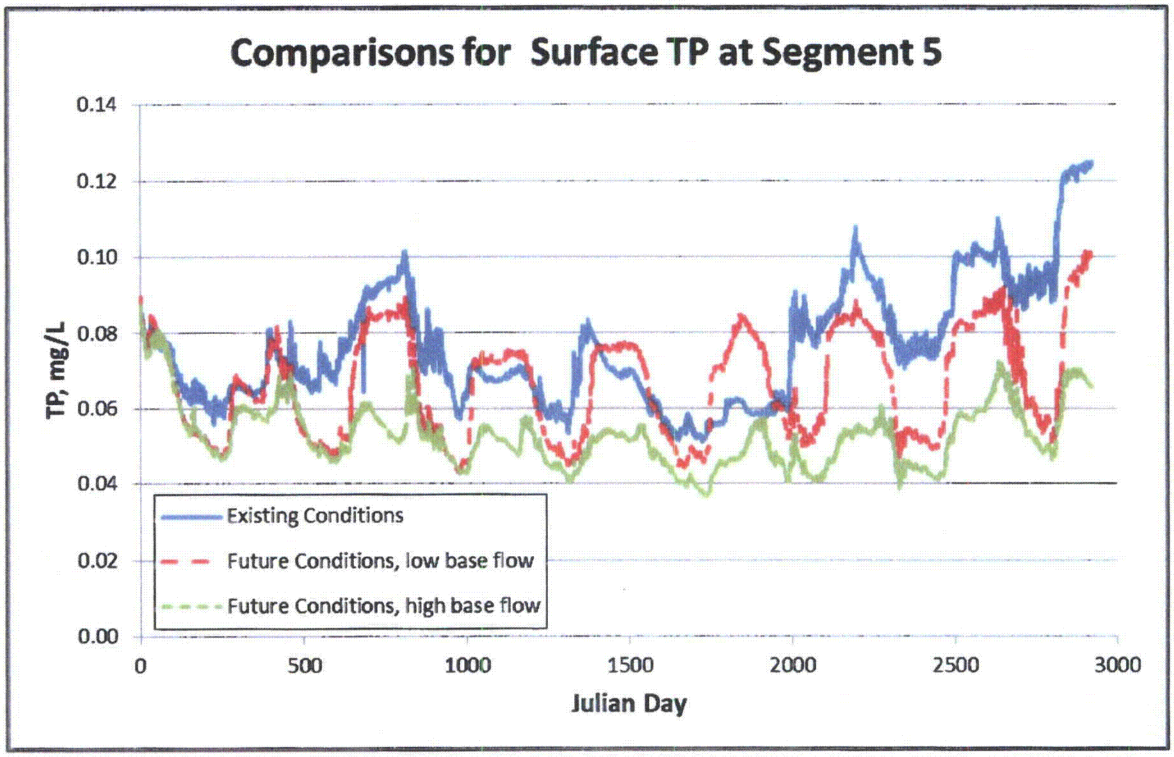

Comparisons for Surface TP at the Dam
TP, mg/L
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0
500
1000
1500
2000
2500
3000
Julian Day
Existing Conditions
Future Conditions, low base flow
Future Conditions, high base flow


Comparisons for Surface Chl a at the Dam
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
Chl a, mg/L
Existing Conditions
Future Conditions, low base flow
Future Conditions, high base flow
0
500
1000
1500
2000
2500
3000
Julian Day


Comparisons for Surface DO at the Dam
16
14
12
10
8
6
4
2
0
DO, mg/L
Existing Conditions
Future Conditions, low base flow
Future Conditions, high base flow
0
500
1000
1500
2000
2500
3000
Julian Day


Comparisons for Surface Tracer at the Dam
Future Conditions, low base flow
Future Conditions, high base flow
Tracer, mg/L
Julian Day
0
5
10
15
20
25
30
35
40
45
50
0
500
1000
1500
2000
2500
3000





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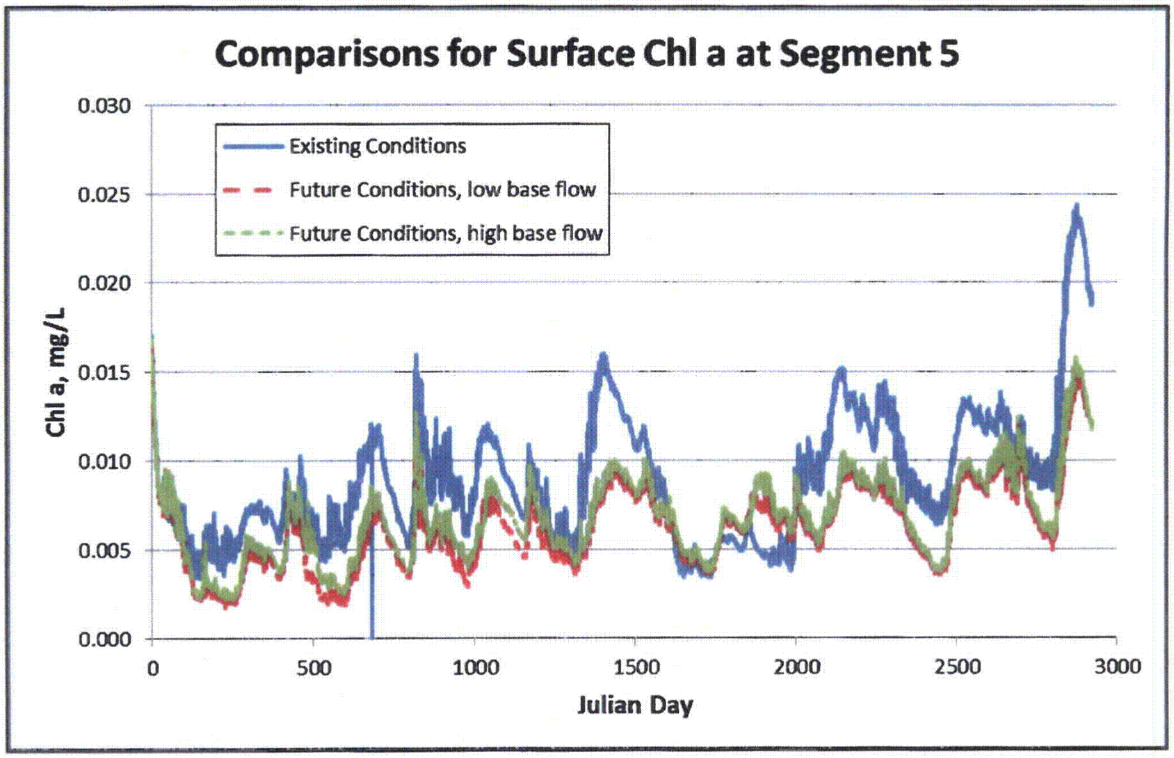
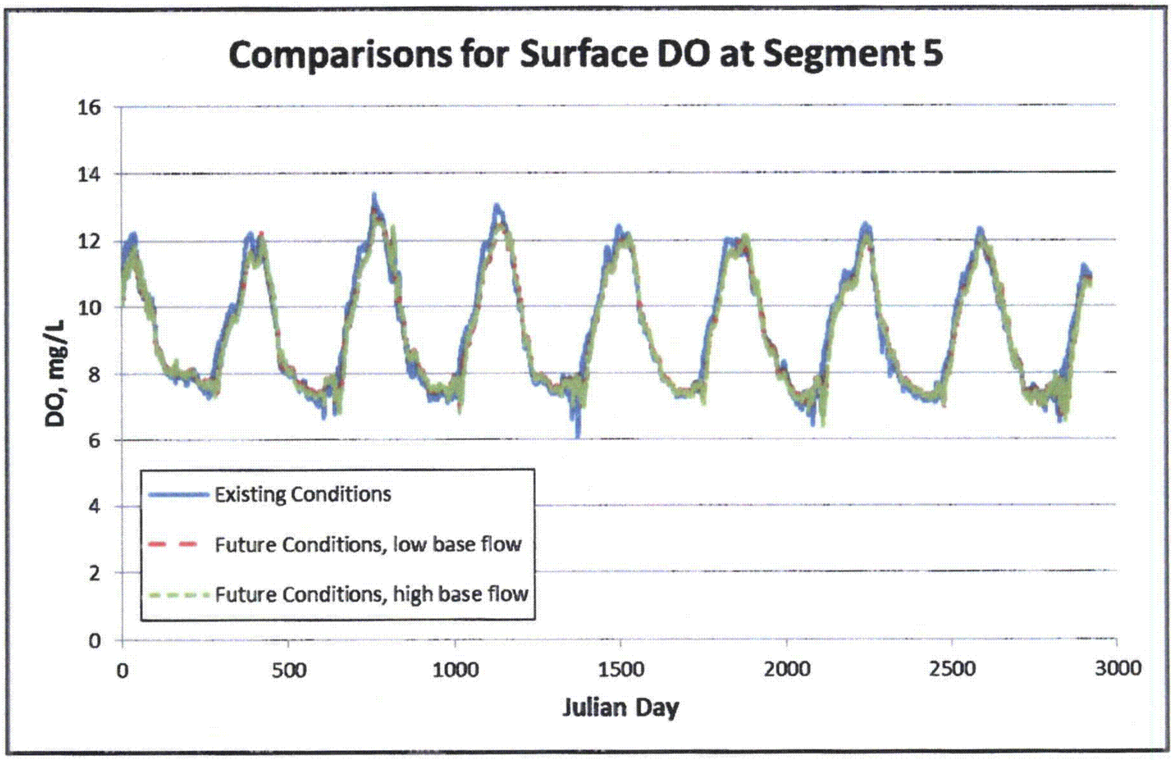
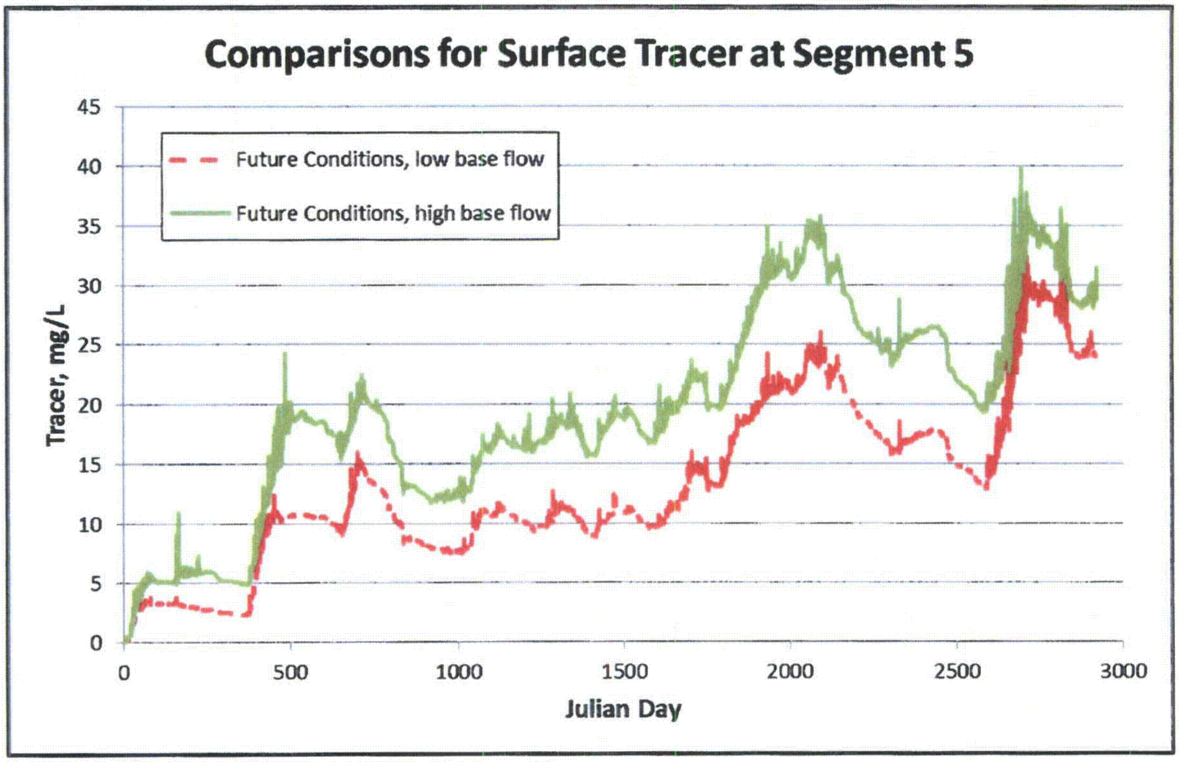

Comparisons for Surface Chl a at Segment 5
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Chl a, mg/L
Existing Conditions
Future Conditions, low base flow
Future Conditions, high base flow
0
500
1000
1500
2000
2500
3000
Julian Day


Comparisons for Surface DO at Segment 5
16
14
12
10
8
6
4
2
0
DO, mg/L
Existing Conditions
Future Conditions, low base flow
Future Conditions, high base flow
0
500
1000
1500
2000
2500
3000
Julian Day



Comparisons for Surface Tracer at Segment 5
Future Conditions, low base flow
Future Conditions, high base flow
Tracer, mg/L
Julian Day
0
5
10
15
20
25
30
35
40
45
500
1000
1500
2000
2500
3000