Addendum to the
Androscoggin River 2005 Total Maximum Daily Load
For
Gulf Island Pond
Livermore Falls Impoundment

May 2010

DEPARTMENT OF ENVIRONMENTAL PROTECTION
STATE OF MAINE

Bureau of Land and Water Quality
Division of Environmental Assessment
DEPLW- 1119

Introduction

In 2005, following issuance of new MEPDES permits for the mills and municipalities affected by this TMDL, and a Water Quality Certification issued for the continued operation of the Gulf Island-Deer Rips Hydro Project, appeals of the Department's decisions were presented to the Board of Environmental Protection. Following a public hearing of these appeals, the Board issued appeal orders on February 7, 2008 establishing additional oxygen injection requirements, water quality monitoring requirements, and final pulp and paper mill effluent limits needed to meet Class C water quality standards in Gulf Island Pond based on the Department's 2005 Androscoggin River Total Maximum Daily Load (TMDL) report.

The Board also directed the Department to revise and re-calibrate its water quality models incorporating the correction of a dispersive mixing error (which could affect oxygen injection requirements) and a recalculation of the sediment area that affects the sediment phosphorus flux in the pond (which could affect final allowable effluent limits for total phosphorus and/or ortho-phosphorus). The Department engaged the services of HydroAnalysis, Inc. of Brookline, Massachusetts to assist with the required recalibration and the recalculation of phosphorus contribution used in the QUAL2E and WASP models for this TMDL. The revised models were then used to evaluate wasteloads and supplemental oxygen injection requirements needed to attain dissolved oxygen standards and phosphorus loads needed to prevent algae blooms in Gulf Island Pond. This 2010 addendum of the 2005 TMDL provides new recommendations for allowable wasteloads and oxygen injection requirements from the 2005 TMDL. Two model outcomes are presented, one with wasteloads set at license load limits established in new draft MEPDES permits for the two mills in Maine (Rumford Paper and Verso) dated January 29, 2010 and as established in the NPDES permit for Fraser paper in NH. The second model outcome uses the same loads as above, except to use permit reductions required in the Verso permit in the event that wastewater from the Wausau-Mosinee Otis mill is no longer sent to the Verso facility for treatment. Note that Rumford Paper and Verso Paper referred to in this addendum report are the former Mead Westvaco and former International Paper facilities, respectively, identified in the 2005 TMDL.

The TSS portion (Livermore Falls impoundment) of the 2005 TMDL document is not addressed in this addendum report.

Results of HydroAnalysis Inc. and Mobley Engineering analyses are in the attached appendices:

Appendix A.	Recalibration of the Gulf Island Pond Water Quality Model (HydroAnalysis Inc., October 31, 2008)
Appendix B.	Final Model Recalibration Results (HydroAnalysis Inc., December 18, 2008)
Appendix C.	Recalibration of the Gulf Island Pond Water Quality Model and Assessment of Oxygen Injection Requirements and Allowable Phosphorus Load (HydroAnalysis, Inc., April 2, 2009)
Appendix D.	Assessment of Oxygen Injection Requirements Under Licensed Discharge Conditions (HydroAnalysis, Inc., April 13, 2009)
Appendix E.	Analyses of GIPOP Partnership Proposed Alternative Oxygen Injection Rates and Analysis of Reduced Oxygen Injection Rates Without Wausau-Mosinee Wastewater (HydroAnalysis, Inc., September 25, 2009, December 1, 2009, and February 4, 2010)
Appendix F	Evaluation of Oxygen Diffuser Replacement at Gulf Island Pond (Mobley Engineering, May 2008)
Appendix G	Oxygen Transfer Efficiency Predictions for Oxygen Diffusers Placed in Gulf Island Pond Lower Narrows (Mobley Engineering, September 25, 2009)
Appendix H	GIP 10% Factor of Safety Calculation (HydroAnalysis, Inc. May 9, 2010)
Appendix I	Response to Comments on March 2010 Draft Addendum to Androscoggin River 2005 TMDL

Summary of findings from the revised models.

- The revised modeling did not change any of the general findings of the 2005 TMDL, however, it did alter the relative source contributions of oxygen demand and phosphorus, and found a reduced need for supplemental oxygen. The nonpoint source contributions remain the same as the estimates in the 2005 TMDL. This TMDL addendum, based on corrected and recalibrated models, results in a net reduction in total phosphorus but with an increase in the ortho-phosphorus fraction. In addition, this TMDL addendum includes a reduction on $CBOD_u$ based on new BOD limits for Verso and Fraser, as established in permitting actions subsequent to issuance of the 2005 TMDL, and based on a further voluntary reduction on BOD limits for Verso. The wasteload allocations by facility are presented in the Revised Tables 6 (for phosphorus), 8 (for 7-day CBOD), and 9 (for 30-day CBOD) from the 2005 TMDL found at the end of this section.

- The revised modeling also uses a different supplemental oxygenation strategy that results in an overall reduction in total oxygenation required as a result of improved oxygen injection efficiency at Upper Narrows (54%) and the installation of a second oxygenation station at Lower Narrows with 75% efficiency.

Revised 2010 TMDL for Gulf Island Pond

Required loads (ppd)	Total-P	Ortho-P	$CBOD_u$	$CBOD_u$	TSS	Oxygen Injection	
Averaging Period	30 day	30 day	30 day	7 day	Annual	U. Narrows	L. Narrows
Season	Jun-Sep	Jun-Sep	Jun-Sep	Jun-Sep	Year	Jun-Sep	Jun-Sep
WLA - Point sources	206	52	34,477[b]	38,652 [a]	42,093	23,300	33,100
LA - Nonpoint sources	77.7	0.3	10,440	9,444	47,907		
Explicit MOS	28	4	na	na	10,000	979	1,390
Total	312	56	44,917	48,096	100,000	24,279	34,490

[a] 7-day point source $CBOD_u$ differs slightly from the value reported by HydroAnalysis, Inc. (Appendix D) since discharge limits for Gorham NH were not available at the time the modeling was conducted. As indicated in Revised Table 8, Gorham has licensed limits of 281 pounds. This amounts to less than 0.7% of the 7-day $CBOD_u$ used for modeling and would have negligible effect on model results.

[b] 30-day point source $CBOD_u$ differs slightly from values reported in revised Table 9 due to a typo in Table 9 of the May 2005 TMDL that erroneously set the allocation for Bethel for BOD_5 at 75 ppd. This has been corrected in Revised Table 9 at the correct license limit of 85 ppd. This difference amounts to less than 0.03% of the 30-day $CBOD_u$ reported above.

Revised 2010 TMDL for Gulf Island Pond without Wausau-Mosinee

Required loads (ppd)	Total-P	Ortho-P	CBOD_u	CBOD_u	TSS	Oxygen Injection	
Averaging Period	30 day	30 day	30 day	7-day	Annual	U. Narrows	L. Narrows
Season	Jun-Sep	Jun-Sep	Jun-Sep	Jun-Sep	Year	Jun-Sep	Jun-Sep
WLA - Point sources	206	52	33,896	37,216	41,579	23,300	32,333
LA - Nonpoint sources	77.7	0.3	10,440	9,444	47,907		
Explicit MOS	28	4	na	na	10,000	979	1,358
Total	312	56	44,336	46,660	99,484	24,279	33,691

Original TMDL table from 2005 TMDL for comparison.

TMDL for Gulf Island Pond in PPD

Required Loads in ppd		Total-P	Ortho-P	CBODu		TSS	Oxygen Injection Loads	
Averaging Period		30-Day	30-Day	30-Day	7-Day	Annual	U. Narrows	L.Narrows
Season		June-Sept	June-Sept	June-Sept	June-Sept	Year	June-Sept	June-Sept
WLA	Point Sources	208	45	39,818	45,673	42,093	30,000	150,000
LA	Non-Point Sources	77.7	0.3	10,440	9,444	47,907		
Explicit MOS 10%		31.7	5	5,585	6,124	10,000		
Total		317	50	55,843	61,241	100,000		

1. Instream aeration is needed as a component of the TMDL load due to sediment oxygen demand . There are no feasible reductions of WLA's and LA's that will result in full attainment of DO criteria without oxygen injection.

2. Oxygen Injection loads of 30,000 ppd at Upper Narrows and 150,000 ppd at Lower Narrows are the default requirements. Other systems are possible. See pages 27 to 51.

3. Oxygen injection loads of 50,000 ppd at Upper Narrows, 65,000 ppd at Lower Narows, and 42,000 ppd near the Deep Hole were investigated with a 3 point injection system.

4. All calculations assume a 1/3 transfer efficiency. Other systems other than those in this report may be acceptable provided they are approved by DEP.

5. Ambient monitoring is required and implemented in licensing.

Revised Table 6. TMDL Allocation of Phosphorus
Applies June to September

	Phosphorus Alloc Outfall in ppd			Assimilation Factors % P Remaining @ Twin Br.		Phosphorus Alloc Twin Br in ppd*		
Municipal	TP ppd	OP ppd	OPO4-P ppd	OP	OPO4-P	TP ppd	OP ppd	OPO4-P ppd
Berlin	19.8	2.6	17.2	60.7%	1.6%	1.9	1.6	0.3
Gorham	12.9	1.0	11.9	64.0%	3.9%	1.1	0.6	0.5
Bethel	7.6	0.7	6.9	65.5%	10.8%	1.2	0.5	0.7
Rumford-Mexico	31.4	4.4	27.0	82.8%	14.9%	7.7	3.6	4.0
Liv Falls	9.6	1.3	8.3	93.3%	98.4%	9.4	1.2	8.2
Paper Mills								
Fraser	129	47	82	62.1%	1.7%	30.6	29.2	1.4
Rumford Paper	152	55	97	79.6%	13.8%	57.2	43.8	13.4
Verso Paper	130	102	28	90.9%	97.6%	120.0	92.7	27.3
Total TMDL WLA (Point Sources)						**229.0**	**173.2**	**55.8**
Total TMDL WLA (Point Sources) reduced by clustering factor						199.1	147.2	51.9
Total TMDL LA (Non-Point Source + Natural)						77.7	77.4	0.3
Explicit MOS						28	22	4
Total TMDL						**304**	**247**	**56**

Verso Paper allocation based on final limits proposed in draft DEP MEPDES/WDL (#W000623-5N-K-M) dated January 29, 2010.

Rumford Paper allocation based on final limits as per MEPDES/WDL (#W000955-5N-G-R) dated September 21, 2005

Fraser Paper allocation for total P based on final limits as per NPDES Permit (# NH0000655) dated September 30, 2008. Loading for OP and OPO4 based on Recalibration of the GIP WQ Model and Assessment of O2 Injection Requirements and Allowable P Load, HydroAnalysis - April 2, 2009

Municipal allocations as per Mitnik 2005 modeling based on municipal dischargers at 1.5 times their measured 2004 discharge rates and OPO4 limits for Livermore Falls as per MEPDES/WDL (#W002654-5L-G-R) dated September 21, 2005.

NPS loading, clustering factor, conversion factors and assimilation rates as per Androscoggin River TMDL dated May 2005.

*Twin Bridges or Rte 219 in Turner is the upstream boundary to Gulf Island Pond

Revised Table 8. Gulf Island Pond 7-Day Average TMDL CBOD$_U$ PPD June to Sept

	Allocations at Outfall	CBODu / BOD5	Assimilation	Allocations Twin Bridges*
Source	BOD5 based on final NPDES & MEPDES/WDL llimits		% BOD Remaining Twin Bridges*	Ultimate CBOD
NPS				9444
Fraser	10298	3.6	17.4%	6451
Rumford P	12500	3.6	31.9%	14355
Verso P.	6400	3.5	63.2%	14157
Berlin	991	Municipal Discharges are grouped in the TMDL due to their de-minimus impact upon dissolved oxygen levels within Gulf Island Pond .		
Gorham	281			
Bethel	128			
Rum.-Mex	995			
Liv. Falls	750			
Munic Tot.	**3145**	3	39.1%	3689
Total TMDL WLA (Point Sources)				38652
LA = Non-point Sources + Natural				9444
TMDL Total				**48096**

Verso Paper allocation based on final limits as per BEP order (#W000623-5N-F-R) dated February 7, 2008.
Rumford Paper allocation based on final limits as per MEPDES/WDL (#W000955-5N-G-R) dated September 21, 2005
Fraser Paper allocation based on final limits as per NPDES Permit (# NH0000655) dated September 30, 2008.
Municipal allocations as per current NPDES and MEPDES/WDL.
NPS loading, conversion factors and assimilation rates as per Androscoggin River TMDL dated May 2005.
*Twin Bridges or Rte 219 in Turner is the upstream boundary to Gulf Island Pond

Revised Table 9. Gulf Island Pond 30-Day Avg. TMDL CBOD$_U$ PPD June to Sept

	Allocations at Outfall	CBODu / BOD5	Assimilation	Allocations Twin Bridges*
Source	BOD5 based on final NPDES & MEPDES/WDL llimits		% BOD Remaining Twin Bridges*	Ultimate CBOD
NPS				10440
Fraser	9149	3.6	24.7%	8135
Rumford P	8330	3.6	45.8%	13735
Verso P.	4400	3.5	65.0%	10010
Berlin	660	Municipal Discharges are grouped in the TMDL due to their de-minimus impact upon dissolved oxygen levels within Gulf Island Pond .		
Gorham	188			
Bethel	85			
Rum.-Mex	663			
Liv. Falls	500			
Munic Tot.	**2096**	3	41.3%	2597
Total TMDL WLA (Point Sources)				34477
LA = Non-point Sources + Natural				10440
TMDL Total				**44917**

Verso Paper allocation based on final limits proposed in draft DEP MEPDES/WDL (#W000623-5N-K-M) dated January 29, 2010.

Rumford Paper allocation based on final limits as per MEPDES/WDL (#W000955-5N-G-R) dated September 21, 2005

Fraser Paper allocation based on final limits as per NPDES Permit (# NH0000655) dated September 30, 2008.

Municipal allocations as per current NPDES and MEPDES/WDL.

NPS loading, conversion factors and assimilation rates as per Androscoggin River TMDL dated May 2005.

*Twin Bridges or Rte 219 in Turner is the upstream boundary to Gulf Island Pond

Oxygen Component of the Model

In draft versions of the 2002 WASP model, it was found that there was an error in the model that allowed for dispersive mixing from downstream of the dam to upstream of the dam, an obvious impossibility. The error was corrected, however, the 2002 model used for the 2005 TMDL was never recalibrated after that correction was made. At the direction of the Board of Environmental Protection, the model has been recalibrated (see Appendices A, B). This recalibration also included improving the calibration results at the 50 foot depth. The initial calibration targets of Mitnik (2002) had used 5, 35, and 60 feet but it was evident from results that model predictions at 50 feet were not representative of measured conditions. To improve model performance, vertical exchange factors for certain segments were modified, improving the model's performance (Appendix B). As a consequence, changes in wasteload and/or oxygen injection rates have been made to predict resultant attainment of water quality standards. It should be noted that this model recalibration had little effect on other calibration targets: total nitrogen, total phosphorus, chlorophyll-a, and carbonaceous biochemical demand. This TMDL addendum uses the recalibrated model to recommend wasteloads and oxygen injection rates.

Oxygen Injection Component of the Model

Following WASP model recalibration, the GIPOP Partnership offered an alternative that would (1) allow a small reduction in CBOD, (2) add an additional oxygen injection station at Lower Narrows (as advised in the 2005 TMDL), and (3) also improve the oxygen transfer efficiency from 33% to 54% at Upper Narrows (as required by in the Board Order) and at a rate of 75% at Lower Narrows (Appendices F, G). This reduces the total requirement for oxygen and puts the units within their optimal operating range. The recalibrated model assigns injection rates of 23,300 lbs per day (Upper Narrows) and 33,100 lbs per day (Lower Narrows) for critical flow, temperature, and wasteload conditions (Appendices C, D).

An additional model run was made using alternative permit limits for Verso that would become effective if Wausau-Mosinee no longer sends its wastewater to Verso (Appendix E). In that event, the Verso discharge would be reduced to 5900 ppd BOD5 (weekly average) and 14,222 ppd TSS (annual average). The resultant oxygen requirements would be reduced to 32,333 ppd (75% efficiency) at Lower Narrows while keeping Upper Narrows at 23,300 (54% efficiency), a reduction of 767 ppd of oxygen (Appendix E).

Phosphorus Component of the Models

The Gulf Island Pond water quality model was recalibrated by modifying the benthic phosphate flux rates to obtain a spatially uniform benthic flux rate (Appendix C). The allowable phosphorus load to Gulf Island Pond was estimated as the maximum orthophosphate and organic phosphate rates at the upstream end of the impoundment which will attain the 2005 TMDL targets for chlorophyll-a. The HydroAnalysis report (Appendix C) provides two alternatives for point source load contributions: 56 pounds per day of orthophosphate and 256 pounds per day of organic phosphorus, or 50 pounds per day of orthophosphate and 277 ponds per day of organic phosphate. By selecting the higher orthophosphate alternative, an additional 6 pounds per day can be assigned to the Verso discharge (noting that uptake between the discharge and the head of the impoundment is estimated at <3%). Current and draft permitted loads amount to 56 pounds of ortho-phosphorus and 229 pounds of total phosphorus. (Revised Table 6 from 2005 TMDL).

Margin of Safety

- This TMDL addendum recommends a different approach to set Margin of Safety. First, the Department is using an improved model which is expected to provide a more confident estimate of water quality response to projected wasteloads and oxygen injection. While the revised TMDL table in this addendum is no longer using a 10% explicit margin of safety for CBODu, the revised models did not use a "clustering factor" that had been used in the 2005 TMDL to acknowledge an expectation that all facilities would not be discharging at maximum allowable load at the same time. The model outputs used for this report were constructed with the conservative assumption that all dischargers could be discharging at maximum permit load simultaneously under critical low flow and temperature condition. This provides an implicit margin of safety and by comparison is relatively the same as the 10% explicit + clustering factor approach used in the 2005 TMDL . The cluster factor used in the 2005 TMDL allowed for an 8.8% reduction of CBODu in the Wasteload Allocation.

- While an explicit Margin of Safety was not added for CBODu, an explicit MOS is recommended for the oxygen injection component of the TMDL (there was no MOS in the supplemental oxygen requirement established in the 2005 TMDL). A factor of 4.2% of the model predicted supplemental oxygen requirement is added at both Upper Narrows and Lower Narrows. This additional oxygen is calculated to replace the amount of oxygen that would be required if the total CBODu load to the impoundment were increased by 10% (Appendix H). Any inaccuracies of the models can best be managed adaptively with the oxygen injection system since there will be additional capacity available.

- An explicit Margin of Safety for phosphorus is included in this TMDL addendum. The original clustering factor used in the 2005 TMDL is still being used (Revised Table 6 from 2005 TMDL).

- Margin of Safety established for TSS in the 2005 TMDL remains the same.

- As indicated in the 2005 TMDL, the Department continues to recommend ambient monitoring by the dischargers for the term of the permit or until attainment of water quality standards have been demonstrated to the satisfaction of the Department. Each permit and the water quality certification shall have a reopener clause that can allow modifications should monitoring indicate that the wasteload or supplemental oxygen injection requirements are insufficient to attain water quality standards.

Implementation

The Department intends to issue modified MEDPES permits for the Verso and Rumford mills and a modified water quality certification for the Gulf Island Pond-Deer Rips Hydro Project requiring that the partnership of FPL Energy, Verso Paper, Rumford Paper, and Fraser Paper, or their successors in interest, inject oxygen at Upper Narrows at a rate of up to 24,279 lbs/day at an oxygen transfer efficiency of 54%, and at Lower Narrows at a rate of up to 34,490 lbs/day (or 33, 691 if wastewater from the Wausau-Mosinee Otis mill is no longer sent to the Verso mill for treatment) at an oxygen transfer efficiency of 75%, or at equivalent rates and efficiencies.

Comments on Draft TMDL Addendum

A draft TMDL addendum was sent to interested parties on March 23, 2010 and was posted on the Department's website. A response to the comments received on the March 2010 draft is attached as Appendix I.

Appendix A

Recalibration of the Gulf Island Pond Water Quality Model

(HydroAnalysis, Inc., October 31, 2008)

RECALIBRATION OF THE GULF ISLAND POND WATER QUALITY MODEL

OCTOBER 31, 2008

Prepared for:

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Introduction

The Water Quality Analysis Simulation Program (WASP) (Ambrose et al., 1993) has been applied to the Gulf Island Pond impoundment of the Androscoggin River for the determination of the Total Maximum Daily Load (TMDL) of phosphorus and BOD and the analysis of oxygen injection within the pond. The model calibration and application were documented in Mitnik (2002) and Mitnik (2005). In Mitnik (2002) the model was calibrated to water quality data collected in August 2000 and verified using water quality data from August 1984. Calibration targets included both the time history of water quality parameters (dissolved oxygen, biochemical oxygen demand, total nitrogen, total phosphorus, and chlorophyll-a) over the course of the month and the spatial distribution of water quality parameters at given times during the month. Mitnik (2005) described efforts to refine the model calibration using data collected during the summer of 2004. The emphasis in the 2005 model refinement was in modification of system rates to replicate the concentrations of orthophosphate, organic phosphorus, and chlorophyll-a.

The DEP received comments from Dilks (2007), Connolly (2007), and Wiley (2007) on the Gulf Island Pond water quality model and its application. Dilks noted that the model described in Mitnik (2002) incorrectly allowed for dispersive exchange across the downstream dam. This physically unrealistic model feature was not present in the version of the model described in Mitnik (2005), however as noted by Dilks there was no effort to recalibrate to data collected in August 2000. Connolly (2007) noted that the benthic phosphate flux rate (WASP parameter FPO4 and referred to in the model documentation as the *benthic phosphorus flux*) was specified in the water quality model at a constant value for all segments. Because the portion of each segment's bottom area in contact with the sediment bed may be less than its total bottom area, specification of a constant loading rate had the unintended consequence of creating an uneven benthic phosphate flux (i.e. loading rate per unit of sediment bed area). In order to represent a uniform phosphate mass flux per unit of bed area, the loading rates should have been assigned values that were proportional to the bed area associated with each element.

The comments by Dilks (2007), Connolly (2007), and Wiley (2007) were reviewed by Jacobs and Shanahan (2007). Based on that review, the Maine DEP determined that the following tasks needed to be completed to improve the model reliability:

1. Recalibrate the model to the August 2000 water quality data time series with the model constructed such that there is no dispersive exchange across the downstream dam; and
2. Adjust the inorganic phosphorus bed loading rates so that they accurately reflect a uniform benthic phosphate flux consistent with the estimated area in contact with the sediment bed and recalibrate the model as necessary.

This document is a summary of the efforts to complete these two tasks. This document provides limited or no information on the physical system, past or proposed data collection activities, or the model application in development of the TMDL. The reader is referred to Mitnik (2002) and Mitnik (2005) for that type of background information.

Calibration Procedure

The recalibration effort was carried out as follows. Initially, the model data sets that were generated in the earlier calibration efforts were identified and run so as to replicate the earlier results presented by Mitnik (2002) and Mitnik (2005). Then the model input files used for calibration to the June/July 2004 and July/August 2004 data sets were modified to obtain a benthic flux rate that is representative of the actual area in contact with sediment. The model results were compared to the calibration targets and the phosphate bed loading flux adjusted upward to improve the calibration for inorganic phosphate. Vertical exchange coefficients were also made uniform across the model because we did not perceive sufficient evidence over the course of calibrating the model that would support the formerly uneven rate of vertical exchange coefficients. This change in the vertical exchange coefficients included an increase in the vertical exchange in the deep segments near the dam. . The model modifications made for the June/July 2004 and July/August 2004 data set were then applied to the August 2000 and August 1998 simulations. The results were found to provide a reasonable replication of the calibration targets for these data sets, serving as verification of the model modifications.

Then the modified model was run using the August 2000 flow conditions and the results were compared to the August 2000 calibration target time series previously presented by Mitnik (2002). The dispersion across the dam was eliminated and the vertical exchange coefficients were increased relative to the values in the original model described by Mitnik (2002) in order to achieve a reasonable representation of dissolved oxygen at the middle and lower depths of the model.

Correction of Benthic Phosphate Loading

The total benthic phosphate loading at each segment (in mg/day) is calculated in WASP as the product of the total segment-bottom area (in square meters) and the user-specified benthic phosphate flux (in mg/day/sq-meter). The relationship between the benthic area and the WASP calculation of the phosphate loading is illustrated in the sketch of a typical model profile in Figure 1. In this case, the flow is into the page and the vertical column is divided into three segments. The bottommost segment (segment 1) has a bottom area that is the same as the area in contact with the river bed. The overlying segment's modeled bottom area (segment 2) on the other hand is greater than the area in contact with the river bed because its bottom surface is partially in contact with the water of the segment below. In order to obtain a constant loading flux on a per bed-area basis, the user must specify a loading rate that is proportional to this estimated segment bed area. This was not done in the simulation runs described by Mitnik (2002; 2005).

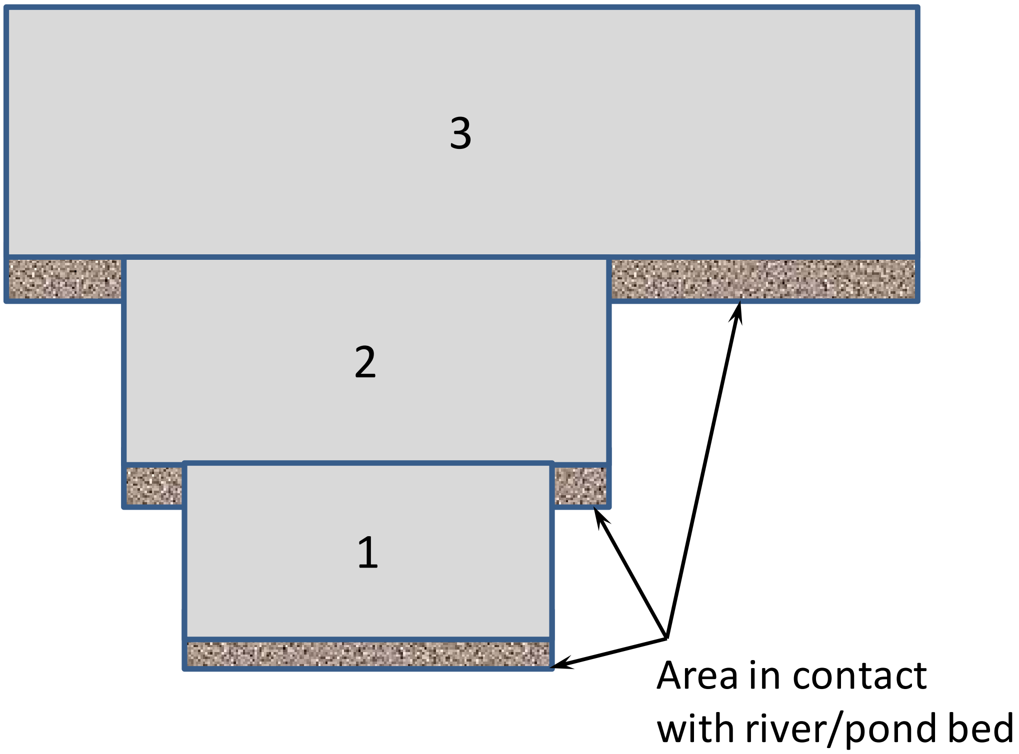


Figure 1 Schematic illustration of model segmentation with direction of flow into page.

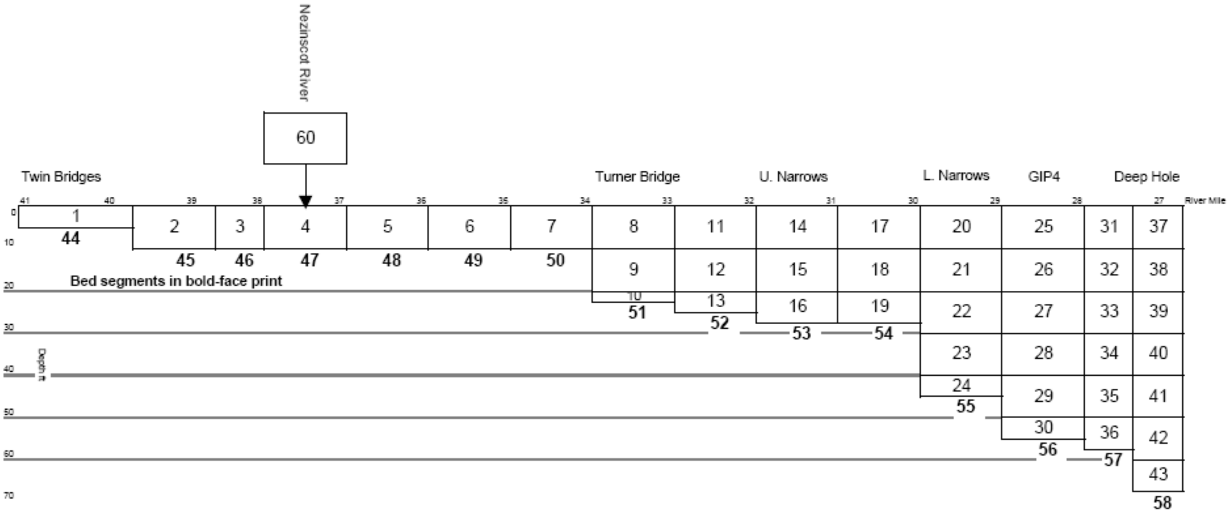


Figure 2. Gulf Island Pond WASP model segments.

The total segment bottom area was calculated as the modeled segment volume divided by the modeled segment thickness. This is based on the assumption that the model segments are rectangular in plan with a uniform thickness. The calculated segment bottom area and bed area for each model segment is shown in the table in Appendix A. Segments 1 – 7, 10 and 13 for instance have equivalent bottom area and bed area because they are the bottom water segments in their respective columns. Other segments, such as 9, 11 and 12 for instance, have a bed area that is less than their bottom area because these segments are partially underlain by the water of the segment below.

The total bottom areas of segments 21 and 29 were less than the total bottom areas of their respective underlying segments (22 and 30). This resulted in calculated river bed areas for these segments that are less than zero. In each case the benthic phosphate flux was set to zero. This is consistent with the approach employed by Mitnik in the assignment of sediment oxygen demand to these segments.

In the case of segment 21, the recorded segment volume was less than that of the underlying segment 22. We surmised that this may be an error and evaluated the sensitivity to this potential model error. The model data file representing the August 2000 flow conditions was modified using the reversed segment volumes and the new results compared to the original simulations. The changes in the simulated concentrations were insubstantial for all calibration target locations and target analytes.

Calibration Targets

The calibration effort documented in this report used the same calibration targets as documented in Figures 11, 13, 14, 15, 17, 18, and 19 by Mitnik (2002) and Figures 5–8 by Mitnik (2005). The calibration targets established by Mitnik (2002), along with the original figure numbers in that report, are:

- Ultimate BOD at four locations – August 2000 (Figure 11)
- Chlorophyll-a at four locations – August 2000 (Figure 13)
- Total nitrogen at four locations – August 2000 (Figure 14)
- Total phosphorus at four locations – August 2000 (Figure 15)
- Dissolved oxygen continuous readings at Turner Bridge and at depths of 5 feet, 35 feet and 63 feet at a point upstream of the dam – August 2000 (Figures 17 and 18)
- Dissolved oxygen at various depths at points along the stream on August 9, 15 and 31, 2000 (Figures 19a, b and c).

The calibration target locations and the associated model segments described by Mitnik (2002) are shown in Table 1. The WASP model grid, including segment numbers, is shown in Figure 2. Figures 3 and 4 show the calibration targets and simulated results for models presented by Mitnik (2002) and rerun for this investigation.

The calibration targets used by Mitnik (2005) and his original figure numbers were:

- Chlorophyll-a, orthophosphate, and organic phosphorus at six locations – June 16-July 7, 2004 (Figure 5)

- Chlorophyll-a, orthophosphate, and organic phosphorus at six locations – July 21-August 11, 2004 (Figure 6)
- Chlorophyll-a, orthophosphate, and organic phosphorus at four locations – August 1998 (Figure 7)
- Chlorophyll-a, orthophosphate, and organic phosphorus at five locations – August 2000, 2004 (Figure 8)

The calibration target locations and the associated model segments described by Mitnik (2005) are shown in Table 2.

Table 1. Calibration Targets for August 2000 Data Set.

Parameter Targets	Location or Depth Description	Figure No. from Mitnik (2002)	Model Segment No.	Notes
BOD, chl-a, total N, total P	Turner Bridge	11, 13, 14, 15	8	Surface segment
BOD, chl-a, total N, total P	Upper Narrows	11, 13, 14, 15	14	Surface segment
BOD, chl-a, total N, total P	Lower Narrows	11, 13, 14, 15	20	Surface segment
BOD, chl-a, total N, total P	Deep Hole	11, 13, 14, 15	31	Surface segment (2nd to last column)
DO	Turner Bridge	17	10	Bottom segment
DO	Above Gulf Island Dam 5 ft Depth	18	37	Surface segment in most downstream column
DO	Above Gulf Island Dam 35 ft Depth	18	40	Central segment in most downstream column
DO	Above Gulf Island Dam 63 ft Depth	18	43	Bottom segment in most downstream column
DO	Top Layer	19a, 19b, 19c		Top segment for upstream 12 columns and average of top two segments in downstream 3 columns
DO	Middle Layer	19a, 19b, 19c		Central segment or in last 4 columns is average of two segments from each column
DO	Bottom Layer	19a, 19b, 19c		Bottom segment or in last 4 columns is average of two or three segments from each column

Table 2. Calibration Targets for June/July 2004 and July/August 2004 Data Set.

Parameter Targets	Depth	Calibration Period	Figure No. from Mitnik (2005)	Notes
Chl-a, Ortho-P, Organic-P	Top Layer	June 16 – July 7, 2004	5	Surface segments at each column
Chl-a, Ortho-P, Organic-P	Top Layer	July 21 – August 11, 2004	6	Surface segments at each column
Chl-a, Ortho-P, Organic-P	Top Layer	August 1998	7	Surface segments at each column
Chl-a, Ortho-P, Organic-P	Top Layer	August 2000	8	Surface segments at each column

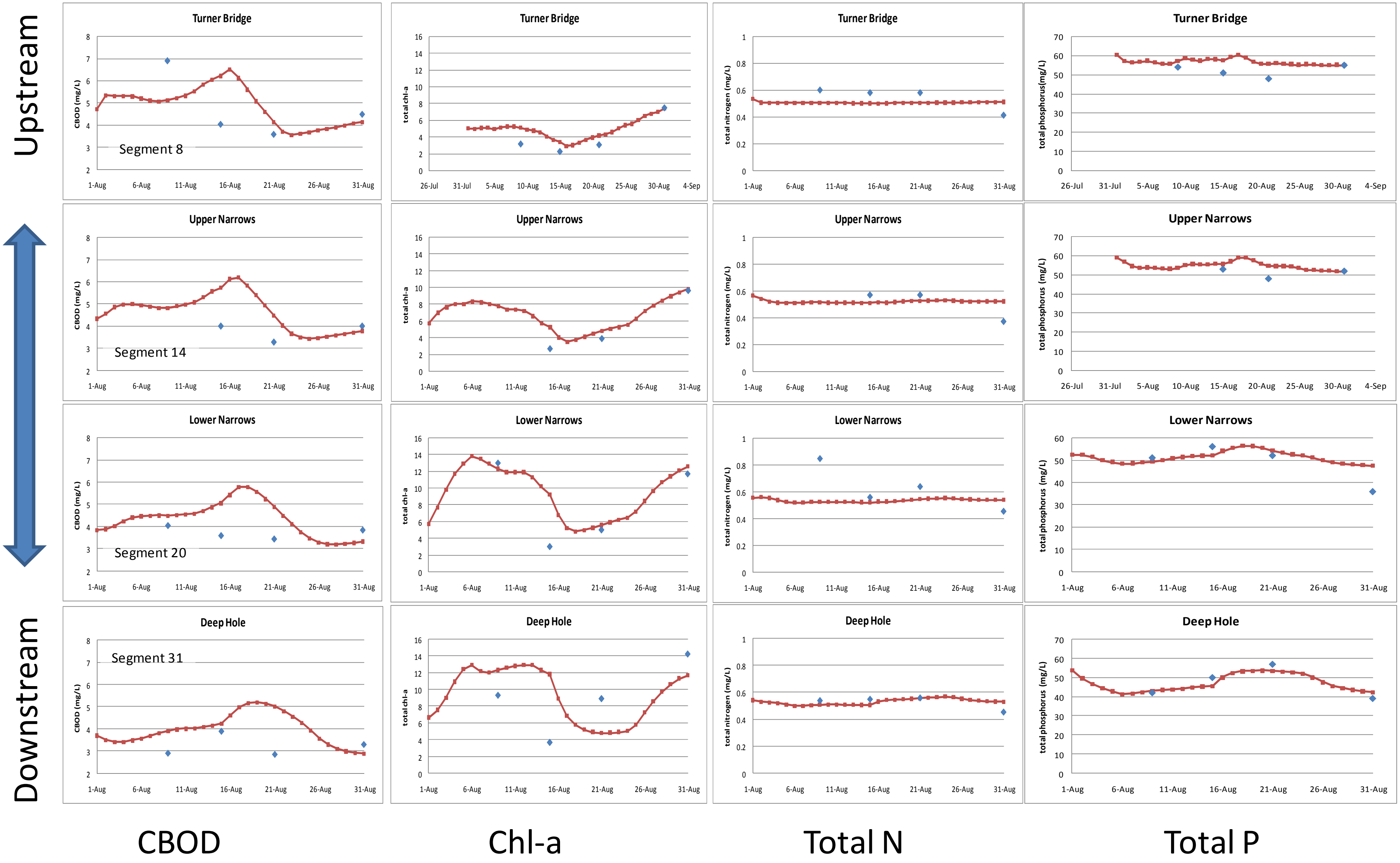


Figure 3. Calibration result and targets for August 2000 time series from Mitnik (2002).

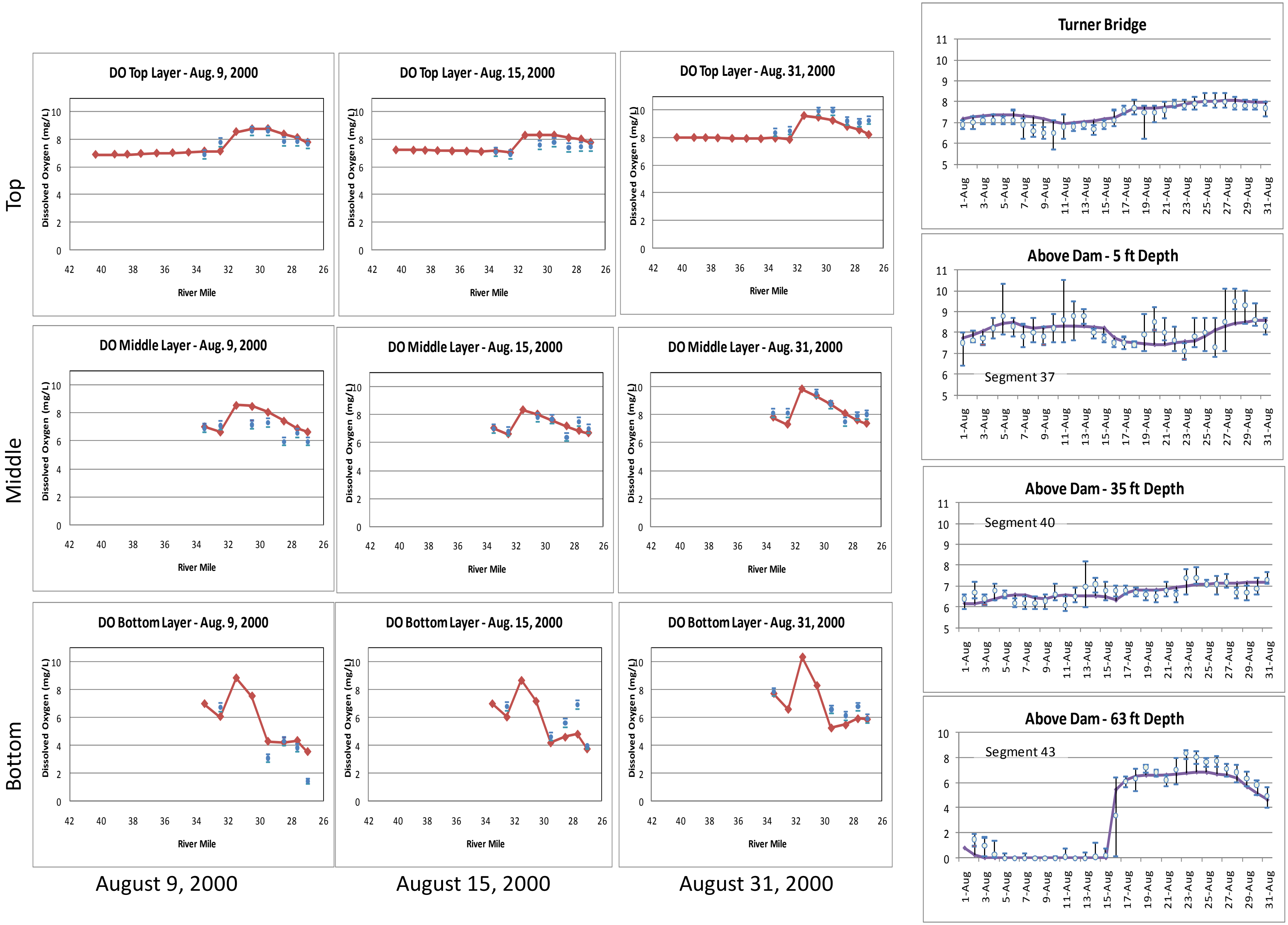


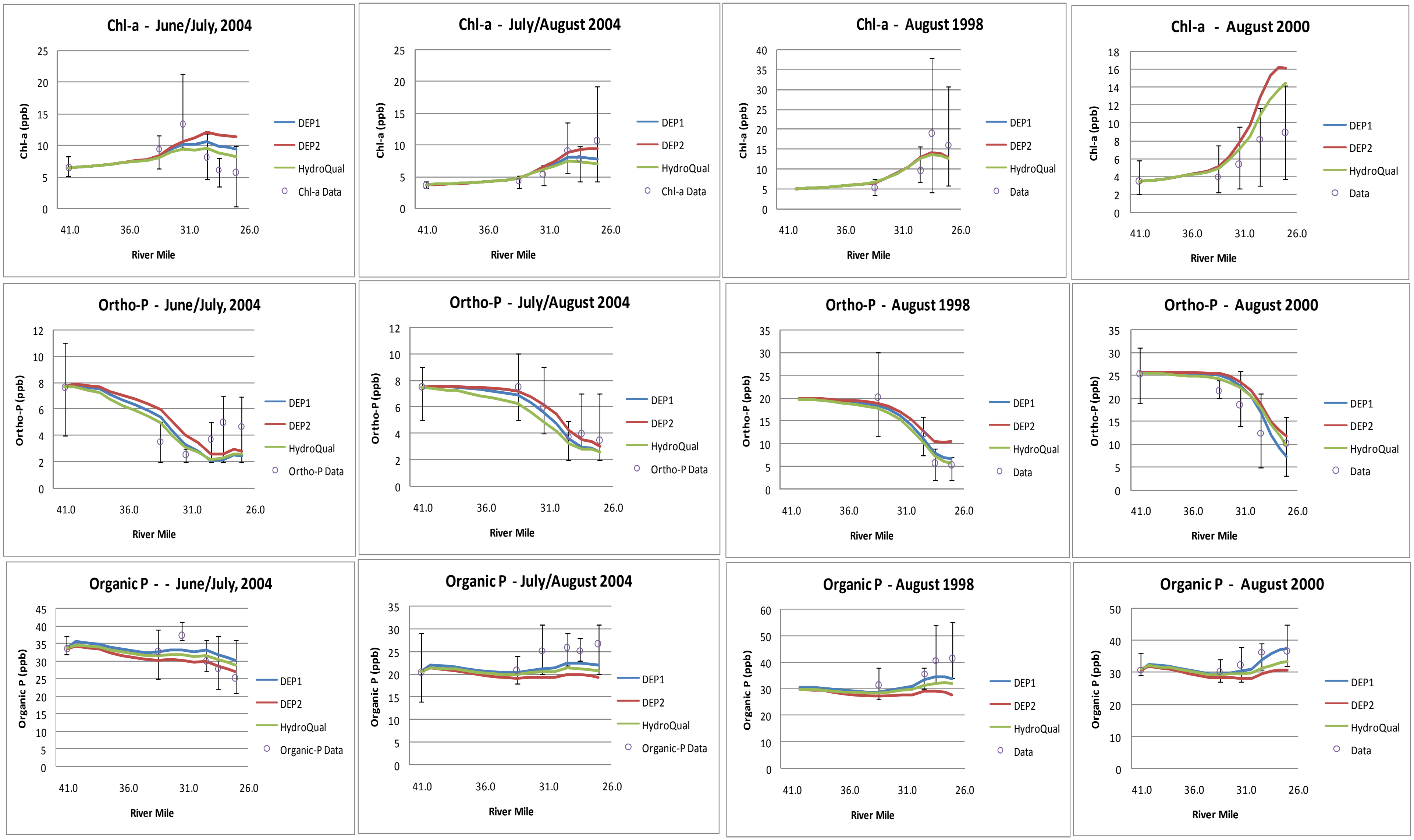
Figure 4. Dissolved oxygen calibration results and targets for August 2000 time series from Mitnik (2002).

Figure 5 shows the calibration targets and simulated results for the calibrated models described by Mitnik (2005) and rerun for this investigation. In these charts, we have retained the convention used by Mitnik of presenting results for three sets of parameters, identified as DEP1, DEP2, and HydroQual. These model runs differ in the assignment of three parameters representing: (1) the mineralization rate of dissolved organic phosphorus, (2) the fraction of dead and respired phytoplankton nitrogen recycled to organic nitrogen, and (3) the saturation light intensity for phytoplankton. The parameters associated with these variations are described in Table 2 by Mitnik (2005). Mitnik observed that it was difficult to select between these parameter sets based solely on curve fitting. Ultimately, he used the parameter set referred to as DEP2 in the TMDL simulations based on the proximity of the parameter values to values cited in the TetraTech Guidance Manual (unreferenced, but most likely Bowie et al., 1985) and the fit of the simulated results to measured chlorophyll-a concentration in Gulf Island Pond. The charts in Figure 5 recreate the results presented in Figures 5–8 by Mitnik (2005) and are provided to serve as a baseline for comparison to results presented in this report based on refinements in the model calibration.

Model Modifications

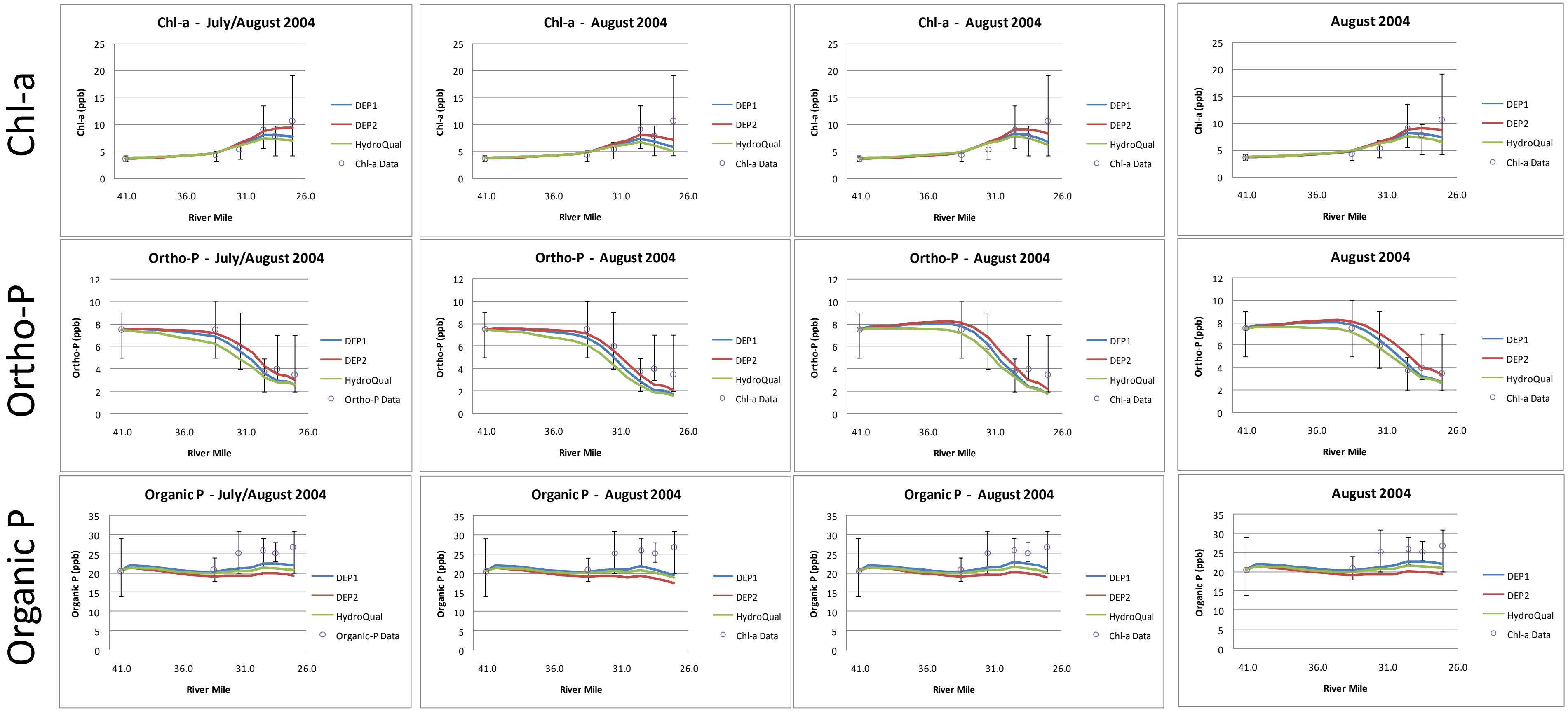
Uniform benthic phosphate flux. The phosphate bed loading was initially modified in the input files for the two summer 2004 simulations to provide for a uniform benthic phosphate flux. This was done initially by setting the benthic phosphate flux rate at each segment to the product of the original rate and the segment bed-area/segment bottom-area fraction. The seven upstream modeled water columns (WASP segments 1 through 7) consist of only one segment per column. The segment area and the area in contact with the river bed in these columns are equivalent so there was no reduction in the benthic phosphate loading from these segments between the modified and original model. In general, the more segments there are in a particular water column, the smaller is the actual bed area relative to the total bottom area. This resulted in more significant reductions to the benthic phosphate loading relative to the original model in the deepest model columns that contain as many as seven segments in a single column (see Figure 2). The model results at this stage of the calibration are presented in the second column of Figures 6 and 7. The impacts of the model change are apparent from the downward shift of orthophosphate and chlorophyll-a relative to the first set of simulations in the first column.

Increased benthic phosphate loading. The reduction in simulated orthophosphate concentration due to the correction of the benthic flux was offset by increasing the phosphate benthic flux rate. The rate was increased incrementally along with increases in the vertical exchange coefficients (see discussion in next section) to achieve a best fit to the measured phosphorus concentrations. The results from a doubling of the phosphate benthic flux rate are presented in the third column (from the left) of Figures 6 and 7. Doubling the phosphate benthic flux rate resulted in a system-wide benthic phosphate loading rate that approximates the same quantity in Mitnik’s simulations. Under these conditions, the predicted orthophosphate concentration increases through most of the pond length relative to the prior simulations, but remains too low near the downstream end of the model in both the June/July 2004 and July/August 2004 simulations.



June/July 2004 July/August 2004 August 1998 August 2000

Figure 5. Calibration result and targets from Mitnik (2005)



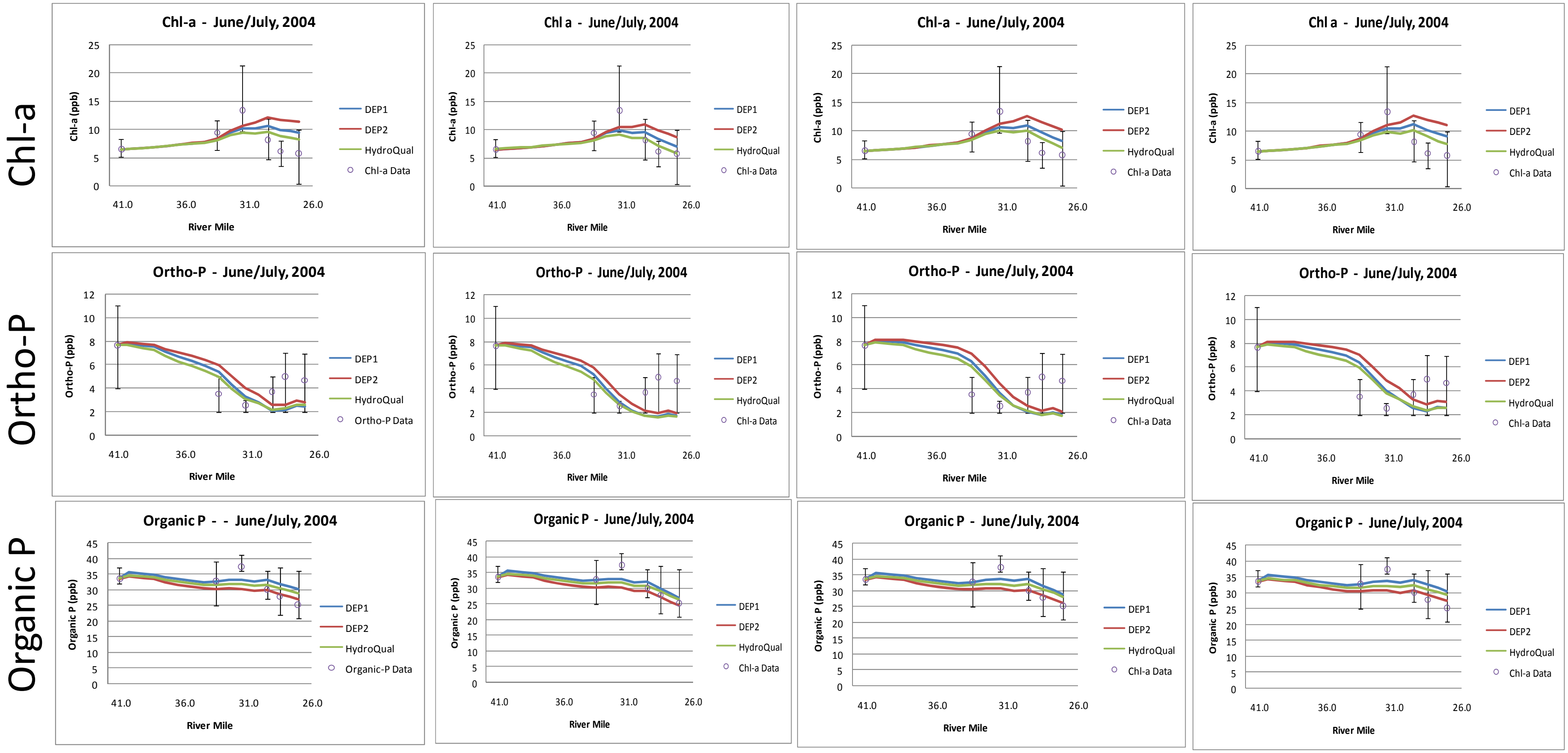
Original baseline from Mitnik (2005)

Corrected FPO4 - same rate

Corrected FPO4 – 2x rate

Corrected FPO4 – 2x rate, uniform increased vertical exchange

Figure 6. Calibration sequence for July/August 2004 water quality data set.



Original baseline from Mitnik (2005)

Corrected FPO4 - same rate

Corrected FPO4 – 2x rate

Corrected FPO4 – 2x rate, uniform increased vertical exchange

Figure 7. Calibration sequence for June/July 2004 water quality data set.

Increased vertical exchange coefficients. Increasing the benthic phosphate flux by itself results in simulated orthophosphate concentrations that are too low in some of the shallower segments in the downstream part of the model. To correct this, the vertical exchange coefficients that represent vertical mixing and dispersion were increased to allow more orthophosphate to mix into the shallower portions of the model. The coefficients were also made more spatially uniform since a physical mechanism that would result in the spatial variation of exchange coefficients has not been identified. We also failed to observe convincing evidence of variable exchange rates that could be substantiated based on the vertical distribution of the measured water quality parameters.

Table 3 show the vertical exchange coefficients in the original model from Mitnik (2005), who specified spatially varying values, and the modified uniform value reached during this calibration exercise. The simulated model results for a system that includes the correction of and increase in benthic phosphate flux described above and the increase in vertical exchange coefficients is shown in the right-hand column of Figures 6 and 7. This results in improved representations of chlorophyll-a, orthophosphate, and organic phosphorus for the July/August 2004 results. The calibration to the July/August 2004 data set was successful with respect to chlorophyll-a and orthophosphate, but tended to be too low for organic phosphorus at the downstream portion of the model. In contrast, the calibration to the June/July 2004 data set was relatively more successful for organic phosphorus than for either chlorophyll-a or orthophosphate.

After these changes in the model calibration, the June/July 2004 simulated orthophosphate concentration is still too high in the central portion of the model (river miles 30 – 35) and too low in the downstream portion of the model (river miles 26 – 30). The measured orthophosphate concentration in the June/July 2004 data is anomalous in that it increases significantly in the downstream direction. This feature is not repeated in the other data sets, so the model calibration was not modified to better represent the measured June/July 2004 spatial distribution of orthophosphate.

Table 3. Vertical Exchange Coefficients

Segment Pairs	Vertical Exchange Coefficient from Mitnik (2005) (sq-m/sec)	Modified Vertical Exchange Coefficient (sq-m/sec)
41-42, 42-43, 18-19, 22-23, 23-24	1×10^{-5}	6×10^{-5}
All Others	3.5×10^{-5}	6×10^{-5}

Consistency of constants and rate parameters. In our review of the WASP model input files, we noted that different values were assigned in different calibration runs to the phytoplankton nitrogen-carbon ratio (parameter NCRB in the WASP model input data) and orthophosphate half-saturation rate constant (parameter KMPG). These changes were not documented in the model reports. In this recalibration, these model parameters were assigned consistent values in all runs. The phytoplankton nitrogen-carbon ratio was assigned a value of 0.2 and the half saturation rate constant was assigned a value of

0.02 mg PO_4-P/L. Modification of these parameters was found to have negligible impacts on the simulated results for analytes used in model calibration.

Calibration of August 2000 water quality time series. The calibration to the August 2000 time series described by Mitnik (2002) included an effort to match the temporal distribution of water quality parameters over the course of the month. Mitnik did this by including the measured daily flow rate and calibrated, temporally variable rates of vertical exchange in the input file. The dissolved oxygen concentration at depth near the dam was initially nil up through August 16. As noted by Mitnik (2002), "in the middle of August, a large runoff event occurred which resulted in a nearly complete mixing of the pond." The dissolved oxygen concentration remained at values above 6 mg/L after that time until tailing off gradually in the last four days of the month. Temporally variable rates of vertical exchange were found to be necessary in order to represent this variability in oxygen concentration. WASP does not have the capability to dynamically calculate the vertical exchange coefficient so the exchange coefficients were manually modified to replicate the distribution of oxygen at various depths.

In the current study, the model was recalibrated to the August 2000 time series calibration targets that were previously used by Mitnik (2002). The recalibrated model utilized the modified biochemical rates and constants that had been arrived at in calibration of the summer 2004 data set as described above. Also, the current model no longer contains the exchange node pairs that allowed for mixing between model segments and the segment downstream of the dam as had been the case for Mitnik (2002). The vertical exchange coefficients were also modified to make them more spatially uniform.

As anticipated, increases in the value of the vertical exchange coefficients were required in order to obtain a reasonable representation of the dissolved oxygen at depth during the latter part of the month. In the early part of the month, the vertical exchange coefficients were increased slightly from the values used by Mitnik (2002). This increase represents a kind of upper limit on vertical exchange coefficient values—higher values were found to cause non-zero dissolved oxygen concentrations at depth near the dam, contrary to field observations. The vertical exchange coefficients arrived at in calibration of the August 2000 simulations are described in Table 4. The result of the calibration to August 2000 water quality values is shown in Figures 8 and 9.

Table 4. Vertical Exchange Coefficients for August 2000 Model Recalibration

Segments	Vertical Exchange Coefficient from Mitnik (2002) (sq-m/sec)	Modified Vertical Exchange Coefficient (sq-m/sec)
18-19, 22-23, 23-24	1×10^{-5} initially 6×10^{-5} at end	3×10^{-5} initially 1×10^{-4} at end
41-42, 42-43	0 initially 2×10^{-3} at peak 1×10^{-5} at end	3×10^{-5} initially 2×10^{-3} at peak 1×10^{-4} at end
All Others	1×10^{-5} initially 4×10^{-4} at peak 5×10^{-5} at end	3×10^{-5} initially 4×10^{-4} at peak 1×10^{-4} at end

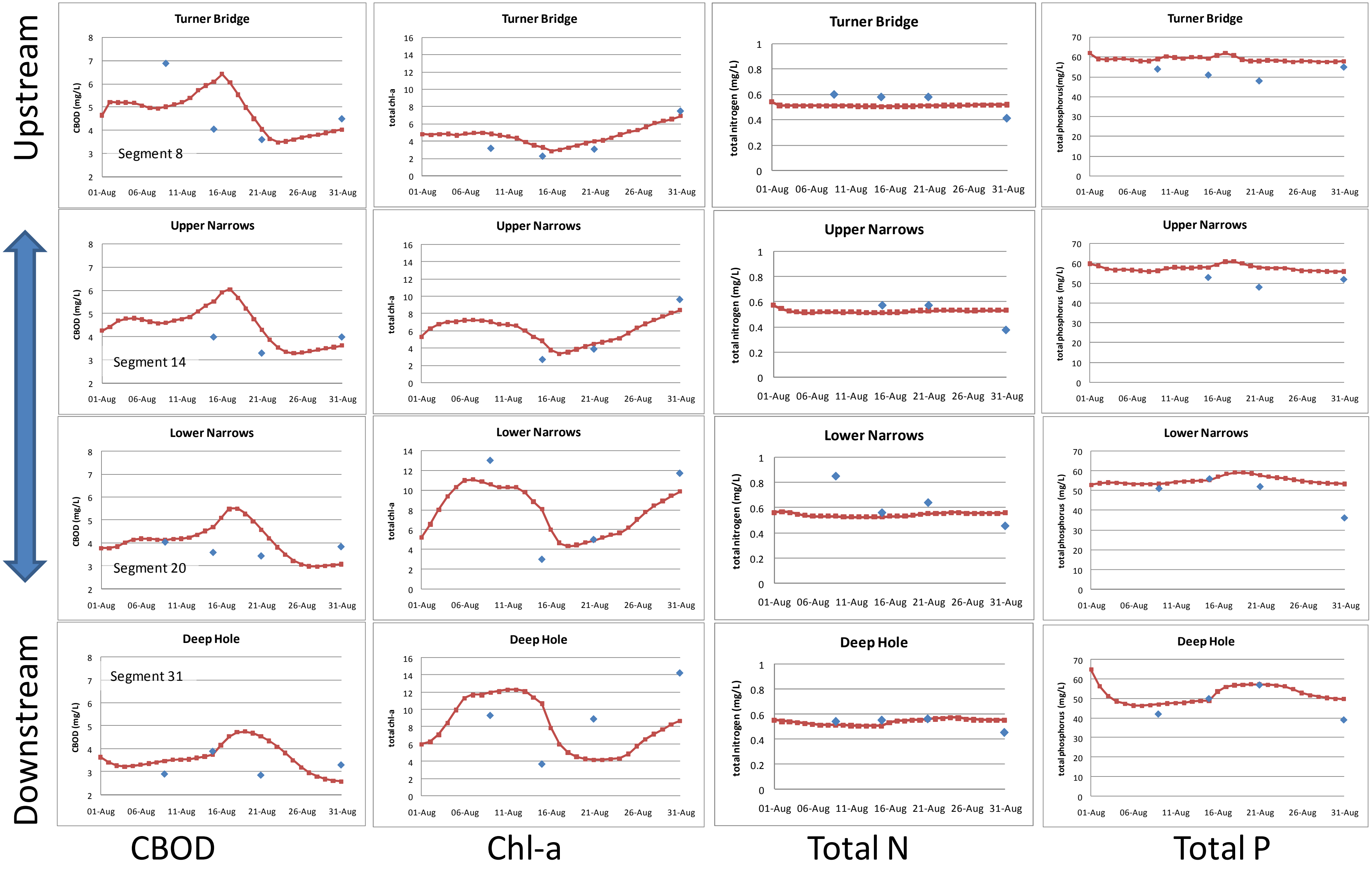
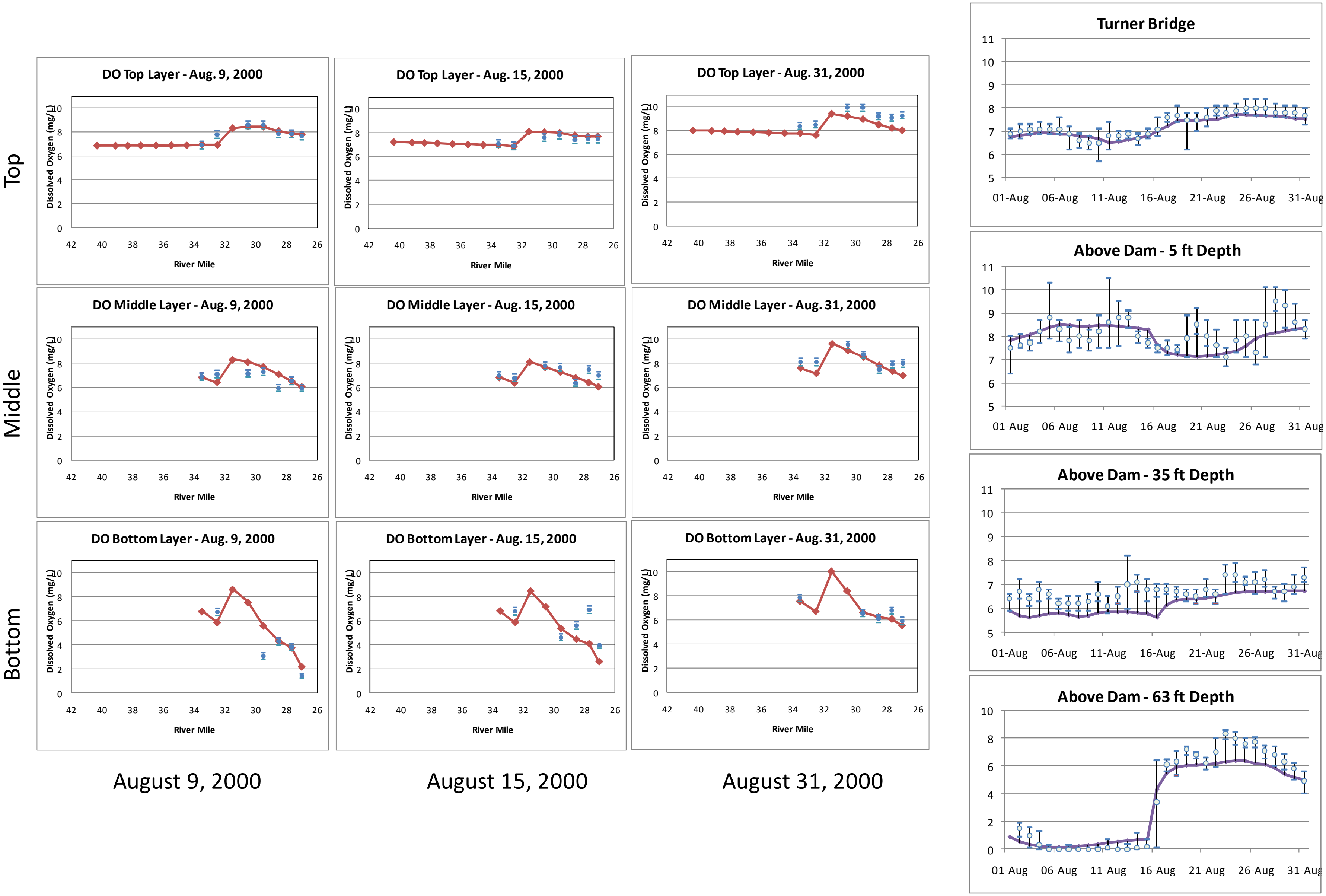


Figure 8. Calibration results of recalibrated model for August 2000 simulation using calibration targets from Mitnik (2002).



DO Top Layer - Aug. 9, 2000

DO Top Layer - Aug. 15, 2000

DO Top Layer - Aug. 31, 2000

DO Middle Layer - Aug. 9, 2000

DO Middle Layer - Aug. 15, 2000

DO Middle Layer - Aug. 31, 2000

DO Bottom Layer - Aug. 9, 2000

DO Bottom Layer - Aug. 15, 2000

DO Bottom Layer - Aug. 31, 2000

Turner Bridge

Above Dam - 5 ft Depth

Above Dam - 35 ft Depth

Above Dam - 63 ft Depth

Figure 9. Dissolved oxygen calibration results of recalibrated model for August 2000 simulation using calibration targets from Mitnik (2002).

Model Verification

The model adjustments described above—namely the correction of the benthic phosphate flux, the increase in the benthic phosphate flux rate, the increase in the vertical exchange rate, and the assignment of consistent rate parameters—were incorporated into the model input files for the August 1998 and August 2000 equilibrium simulations which had been reserved as verification datasets. The results of the two verification simulations—August 1998 and August 2000—are in the two right-hand columns of Figure 10. The model simulations do a reasonably good job of matching the growth in chlorophyll-a and its dependence on orthophosphate concentrations. The notable exception is the August 2000 simulation, in which the model chlorophyll-a concentrations are significantly greater than the measured values in the downstream portion of the system. This is consistent with the simulated orthophosphate concentrations in that same simulation that are in excess of measured values.

As noted above in the description of the August 2000 time-series data, the month consisted of two distinctly different phases. The pond was stratified over the first two weeks of the month, with zero or near-zero dissolved oxygen concentrations in the deepest portion of the pond near the dam. A large storm occurred half-way through the month that resulted in substantial mixing and high dissolved oxygen concentrations at all depths. The August 2000 simulations used in the verification are based on average flow values and environmental conditions. It is run out over a period of 30 days in order to approach a near-steady-state condition. It may be the case that the deficiencies in the model calibration data set are due to the fact that the steady-state model is unable to match the average behavior of the non-linear, dynamic system.

Segment 10 Modeled Thickness

In the course of editing a final draft of this document, Dave Courtemanch of the Maine DEP noted an inconsistency in the reported segment 10 vertical thickness. In Figure 2, which is a reproduction of a similar figure by Mitnik (2000), the segment 10 thickness is on the order of 1 meter. That is inconsistent with the 3.05-meter modeled segment thickness as reported in the table in Appendix A of this report. A spreadsheet was found in the project files by Maine DEP staff that shows a segment 10 vertical thickness of 0.91 meters that is consistent with the thickness shown in Figure 2. The original bathymetric data on which the vertical thicknesses were determined could not be found. Paul Mitnik was contacted by DEP staff, but was unable to provide information that would clear up this inconsistency.

The sensitivity of model results to the segment 10 thickness was evaluated by modifying the segment's vertical thickness in the input file representing the calibrated simulation of August 2000 conditions. The results were compared to the measured concentrations and the previously simulated concentrations at the calibration targets. The change in segment thickness resulted in a negligible difference in all of the calibration target analytes at all calibration targets except for the dissolved oxygen concentration at segment 10 itself. At this location, the dissolved oxygen concentration was reduced by up to 0.3 mg/L relative to its simulated value for the case of a 3.05-m segment thickness. The simulated concentration at Turner Bridge and the range of measured concentrations are plotted in Figure 11. Based on the results of the sensitivity analysis, we are confident that the uncertainty in the segment 10 vertical thickness will not compromise the predictive capacity of the model in the area of concern.

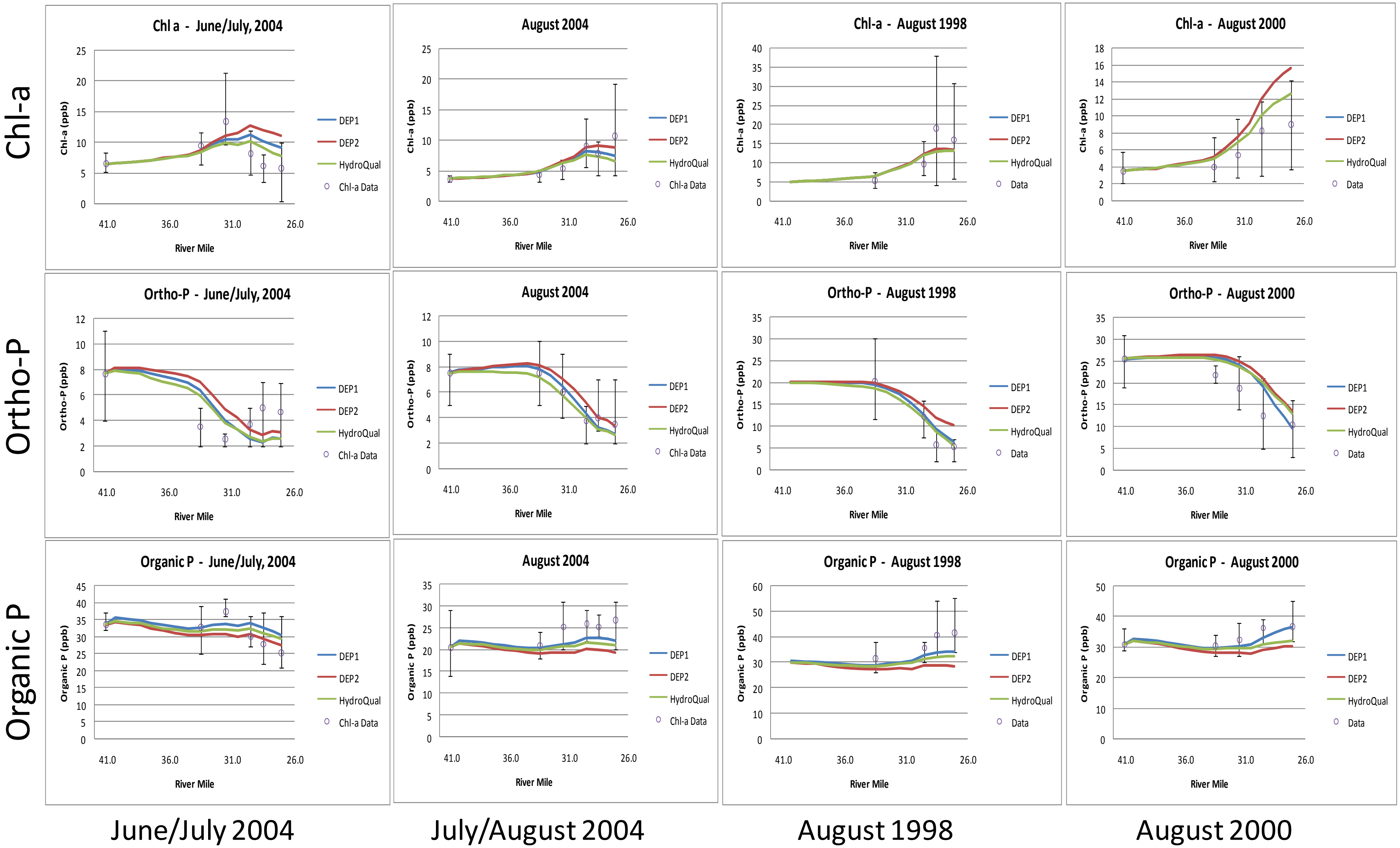
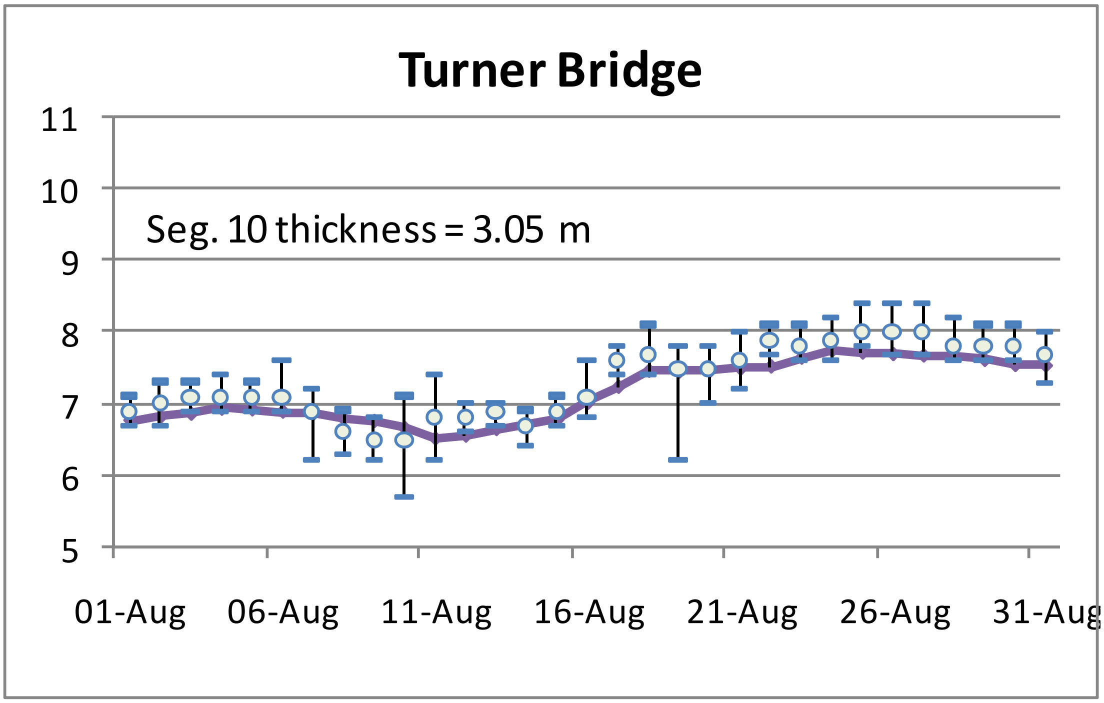


Figure 10. Calibration and verification results of recalibrated model for data sets used as calibration targets in Mitnik (2005).



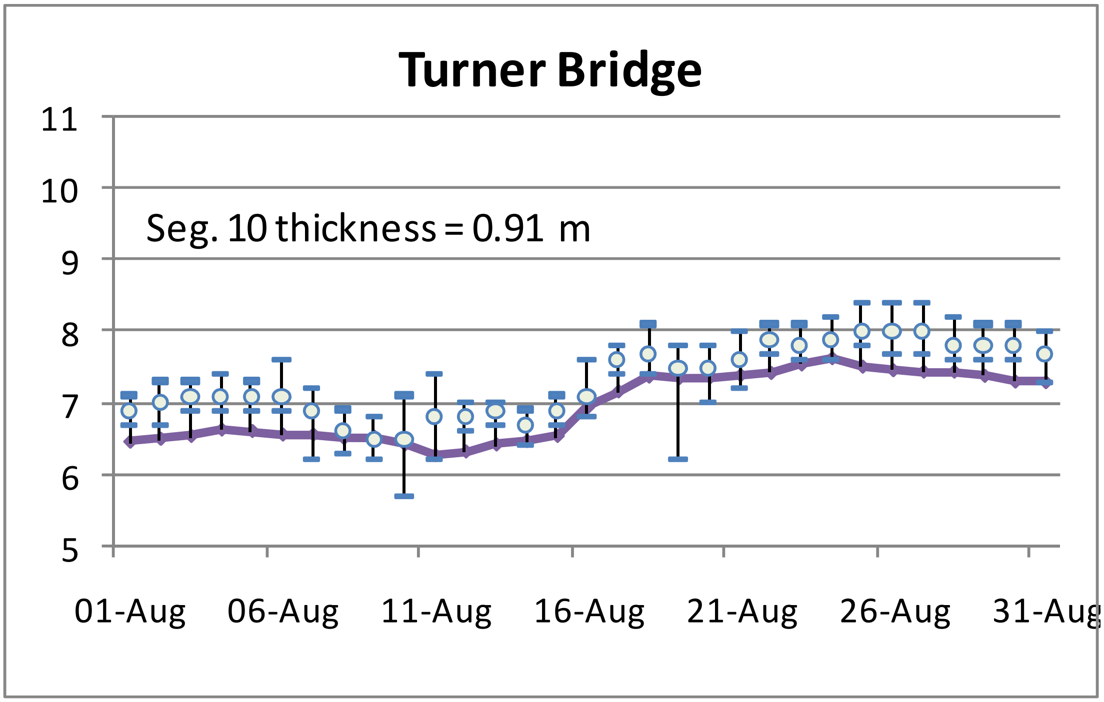


Figure 11. Dissolved oxygen at segment 10 during August 2000 simulation, with segment 10 thickness at 3.05 meters (top) and 0.91 meters (bottom).

Summary of Findings

The Gulf Island Pond water quality model was recalibrated by modifying the benthic phosphate flux rates to obtain a spatially uniform benthic flux rate and to eliminate non-physical dispersion exchanges through the downstream dam. Calibration targets used by both Mitnik (2002) and Mitnik (2005) were used in this recalibration exercise. Initially, the average conditions for four water quality data sets collected during the summers of 1998, 2000, and 2004 were calibrated. This effort focused on the concentrations of orthophosphate, organic phosphorus, and chlorophyll-a. The benthic phosphate loading flux rate was set so as to obtain a uniform flux rate at all segments on a per-area basis. The flux rate was then increased to offset reductions in the simulated orthophosphate concentrations, and vertical exchange coefficients were increased to increase the orthophosphate concentrations in the overlying shallow segments in the downstream portion of the model.

Next, the temporally variable model of the August 2000 conditions was calibrated to time series measurements originally described by Mitnik (2002). These measurements include dissolved oxygen at various depths and times over the course of August 2000. The biochemical rates and constants calibrated to the 2004 dataset were introduced into this model and the downstream dispersion exchanges through the dam were eliminated. The vertical exchange coefficient was then increased to obtain a reasonable match of dissolved oxygen. The deepest measurement of non-zero dissolved oxygen near the dam was used as the principal calibration target in varying the vertical exchange coefficients. Time-varying exchange coefficients were implemented to achieve a representation of the nil dissolved oxygen at this location during the first two weeks of the month and the relatively high dissolved oxygen at this same location during the final two weeks.

A satisfactory calibration of the time-variable oxygen, total phosphorus, total nitrogen and chlorophyll-a was achieved for the August 2000 scenario using time-variable vertical exchange coefficients. The selection of a specific set of vertical exchange coefficients to be used in applications of the model for projection of future impacts will require some additional consideration. A conservative approach from the aspect of achieving satisfactory dissolved concentrations at all depths would be to use the low-end vertical exchange rates that were calibrated to the first two weeks of August 2000. These exchange rates are most likely to coincide with the low-flow conditions for which TMDLs are typically calculated. Another approach would be to examine the velocity dependence of the vertical exchange coefficient to determine whether some physically based dependence could be used to estimate a vertical exchange coefficient that is also reasonably consistent with the calibrated values. Under this approach, the vertical exchange coefficients could be assigned to a physically reasonable value for the flow conditions for which the TMDL is to be calculated.

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Appendix A. Segment Bed Area Calculation

Segment	Volume (cu-m)	Depth (m)	Total Area (sq-m)	Bed Area (sq-m)	Bed Area - Total Area Fraction
1	628000	1.83	343169	343169	1.00
2	665000	3.05	218033	218033	1.00
3	392000	3.05	128525	128525	1.00
4	1130000	3.05	370492	370492	1.00
5	1059000	3.05	347213	347213	1.00
6	864000	3.05	283279	283279	1.00
7	954000	3.05	312787	312787	1.00
8	908000	3.05	297705	128525	0.43
9	516000	3.05	169180	140000	0.83
10	89000	3.05	29180	29180	1.00
11	1611000	3.05	528197	303607	0.57
12	685000	3.05	224590	104853	0.47
13	182000	1.52	119737	119737	1.00
14	1657000	3.05	543279	190492	0.35
15	1076000	3.05	352787	79547	0.23
16	582000	2.13	273239	273239	1.00
17	2456000	3.05	805246	174426	0.22
18	1924000	3.05	630820	72134	0.11
19	1190000	2.13	558685	558685	1.00
20	2003000	3.05	656721	425902	0.65
21	704000	3.05	230820	-81639	-0.35
22	953000	3.05	312459	145574	0.47
23	509000	3.05	166885	18798	0.11
24	271000	1.83	148087	148087	1.00
25	1849000	3.05	606230	81639	0.13
26	1600000	3.05	524590	102623	0.20
27	1287000	3.05	421967	112787	0.27
28	943000	3.05	309180	74426	0.24
29	716000	3.05	234754	-84325	-0.36
30	485000	1.52	319079	319079	1.00
31	1608000	3.05	527213	89508	0.17
32	1335000	3.05	437705	39344	0.09
33	1215000	3.05	398361	92787	0.23
34	932000	3.05	305574	67541	0.22
35	726000	3.05	238033	43142	0.18
36	534000	2.74	194891	194891	1.00
37	1444000	3.05	473443	44262	0.09
38	1309000	3.05	429180	45902	0.11
39	1169000	3.05	383279	40000	0.10
40	1047000	3.05	343279	48525	0.14
41	899000	3.05	294754	99344	0.34
42	596000	3.05	195410	85921	0.44
43	300000	2.74	109489	109489	1.00

Appendix B

Final Model Recalibration Results including Simulations at 50 Feet

(HydroAnalysis, Inc., December 18, 2008)

Hydro Analysis

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December 18, 2008

Ref: J418-007

Mr. Dave Courtemanch
Maine Department of Environmental Protection
Bureau of Land and Water Quality
17 Statehouse Station
Augusta, Maine 04333-0017

Dear Mr. Courtemanch:

HydroAnalysis carried out a recalibration of the Gulf Island Pond water quality model (HydroAnalysis, 2008) in response to concerns expressed by Dilks (2007), Connolly (2007), and Wiley (2007) regarding the model used in calculation of the TMDL for Androscoggin River. This recalibrated model was presented to the Maine Department of Environmental Protection on October 31, 2008. On November 24, 2008, the Maine DEP received a letter from Dave Dilks of Limnotech regarding the model recalibration. Dilks' letter noted that the recalibration had failed to address the model's ability to reliably simulate the measured dissolved oxygen at a point immediately upstream of the dam at a depth of 50 feet. The letter emphasized the importance of demonstrating that the model could reliably simulate the dissolved oxygen at this depth due to its importance in evaluating compliance with water quality standards.

The recalibration by HydroAnalysis had utilized the same calibration targets as previously utilized by Mitnik (2002). This included dissolved oxygen measurements immediately upstream of the dam at depths of 5 feet, 35 feet and 60 feet. Measurements at a depth of 20 feet and 50 feet at this same location were not used as a calibration target. HydroAnalysis agrees that the recalibrated model did not achieve a satisfactory representation of dissolved oxygen at a depth of 50 feet for the August 2000 simulations. The recalibrated model has been further modified in order to address this concern. These modifications are described in this letter.

The initial strategy employed to increase the simulated oxygen concentration at the 50-foot depth was to increase the simulated vertical exchange coefficients. Spatially uniform increases in the vertical exchange coefficients proved to be incapable of increasing the dissolved oxygen at depth so as to achieve a satisfactory calibration at all depths.

Modification of the simulated flow field was next explored as an alternative to modifying the vertical exchange coefficients exclusively. Mitnik (2002) noted that the temperature of water in the upstream Androscoggin River influences the depth of mixing within Gulf Island Pond. When the inflow water is cold or comparable to the water temperature in the Gulf Island Pond, then the river water penetrates deeper and depresses the elevation of the interface between the well-mixed surface waters and the more isolated, deeper waters. Figure 1 presents the August 2000 daily-average dissolved oxygen concentration at depths of 5 feet, 20 feet, 35 feet, 50 feet and 63 feet. It is readily apparent from examination of Figure 1 that the dissolved oxygen declines gradually with depth down to 50 feet. It is also apparent that there is an abrupt decrease in the dissolved oxygen concentration between the depths of 50 and 63 feet during the first two weeks of August 2000. These observations motivated a strategy to increase the advective flow in the lower segments of the model to increase the simulated dissolved oxygen concentrations at a depth of 50 feet.

WASP represents advective flows using specified segment-to-segment transfers, referred to in the WASP model documentation as unit flow responses. In some modeling projects, the unit flow responses are based on either hydraulic modeling or flow velocity measurements. The Gulf Island Pond model reports (Mitnik, 2002; 2005) do not describe how the unit flow responses were originally calculated. Presumably, engineering judgment was exercised in setting these values.

Figure 2 shows the simulated unit flow responses as represented in the model documented in Mitnik (2002) and Mitnik (2005). The response values in Figure 2 are expressed as percentages of water relative to the total outflow from each column. For instance, in the model column consisting of segments 14, 15 and 16, the segment 15 to 18 flow represents 35 percent of the outflow from that column. In all cases, the percent unit flow responses sum to 100 percent in a given column. In the simulated flow field, the segment immediately below the 50-foot depth (segment 42) receives no flow from upstream segments while the segment immediately above the 50-foot depth (segment 41) receives 15 percent of the flow from the upstream column of model segments. The low simulated flow at-depth effectively isolates segment 42, although the measured dissolved oxygen concentrations at a depth of 50 feet indicate that the segment should be included in the mixed upper layer.

Based on these observations, the model flow field was modified to increase the flow at depth while reducing the flow in overlying model segments. The final calibrated version of the flow field is shown in Figure 3. The vertical exchange factors—which represent vertical dispersive mixing—were also generally increased in order to further improve the calibrated dissolved oxygen time history at all depths. Unless otherwise cited below, vertical exchange factors were increased by a factor of 3, except during day 15 and 16 where they were reduced by 25 percent to make them constant over the last two weeks of the month.

- Vertical exchange factors between segments 41 and 42 were doubled from their prior value during the first 15 days of the simulation and left at their initial value over the remainder of the simulation.

- Vertical exchange factors between segments 42 and 43 were reduced by a factor of 30 during days 1 through 14 and left at their initial value over the remainder of the simulation.

Figure 4 shows the simulated and measured August 2000 dissolved oxygen at the five measurement depths immediately upstream of the dam. The measurement at a depth of 50 feet lies between model segments 41 and 42, so the average concentration in these two segments was calculated for comparison to the measured value at a depth of 50 feet. The measurement at a depth of 20 feet also lies between segments. It was represented by the average concentration in segments 37 and 38. The dissolved oxygen concentration at a depth of 50 feet is now a reasonable representation of the measured values. There is also improvement in the calibration at the 35-foot depth relative to the recalibrated model described by HydroAnalysis (2008). The other August 2000 calibration targets, dissolved oxygen by river mile, total nitrogen, total phosphorus, chlorophyll-a, and carbonaceous biochemical demand are shown in Figures 5, 6 and 7. The simulated concentrations for these other targets have changed minimally from the values originally reported in HydroAnalysis (2008).

The model changes described in this letter had little impact on the simulated water quality in surface or near-surface segments for the August 2000 simulations. In order to determine whether the flow field changes would have an impact on the other calibration targets, the modified flow field was introduced into the steady-state simulations of August 2004 that were described in HydroAnalysis (2008). No other changes were made to the model input file. Figure 8 shows the simulated concentrations of organic phosphorus, orthophosphate, and chlorophyll-*a* using the recalibrated version of the parameter set identified in Mitnik (2005) as *DEP2*. The results are nearly identical to the simulated concentrations prior to the imposition of the flow field modifications as presented in HydroAnalysis (2008). Based on this result, we determined that it is not necessary to repeat all of the other simulations that were previously used in calibrating the model.

We are confident that these changes have addressed the comments provided by Dilks (2008) and look forward to continuing with the project.

Sincerely,

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Peter Shanahan

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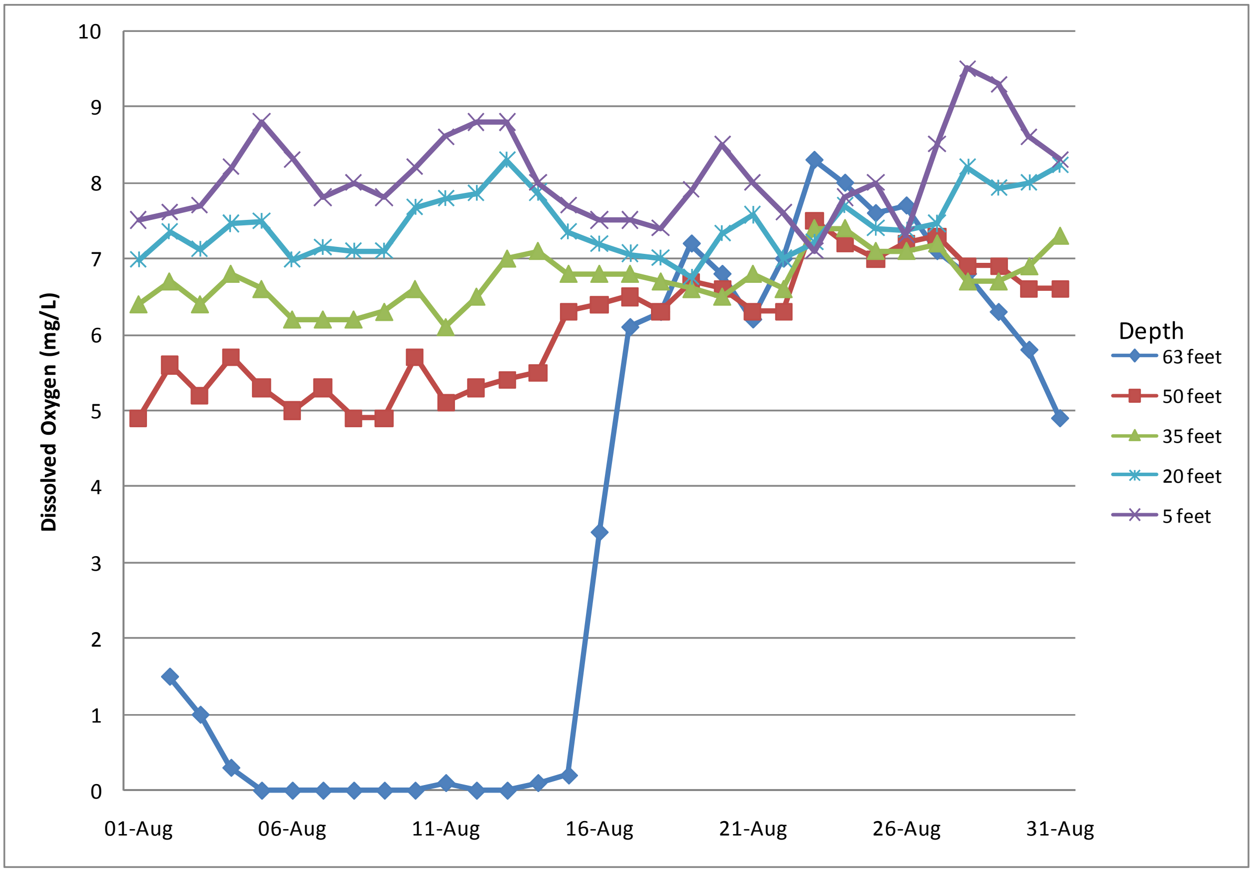


Figure 1. Daily average dissolved oxygen concentration at measurement points upstream of Gulf Island Pond dam.

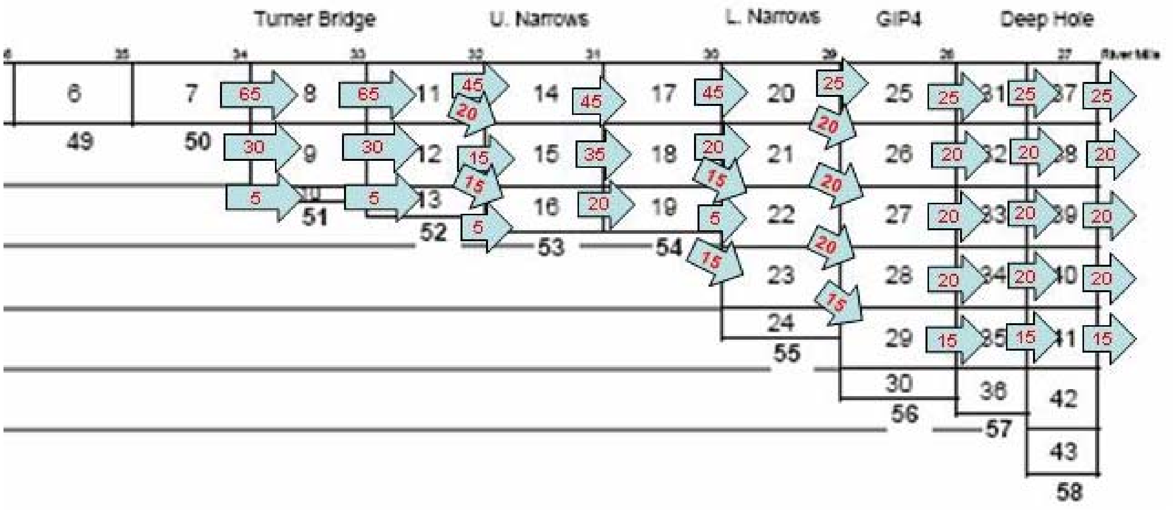


Figure 2. Percentage of model segment column flow that is transferred by advection between segment pairs in original flow field as specified by Mitnik (2000). The segment transfers sum to 100 across all the segment pairs in a single column.

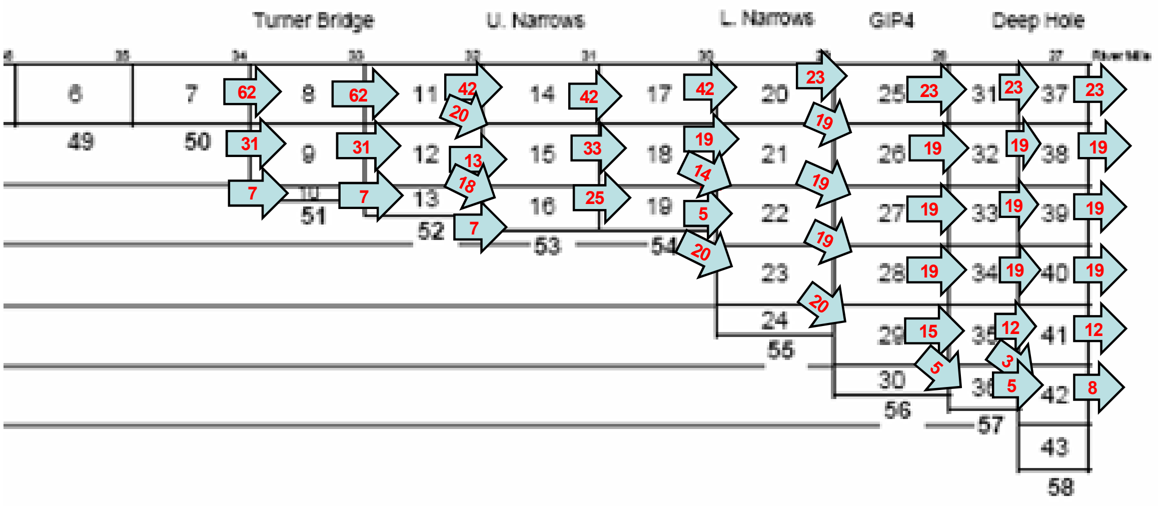


Figure 3. Percentage of model segment column flow that is transferred by advection between segment pairs in newly calibrated model.

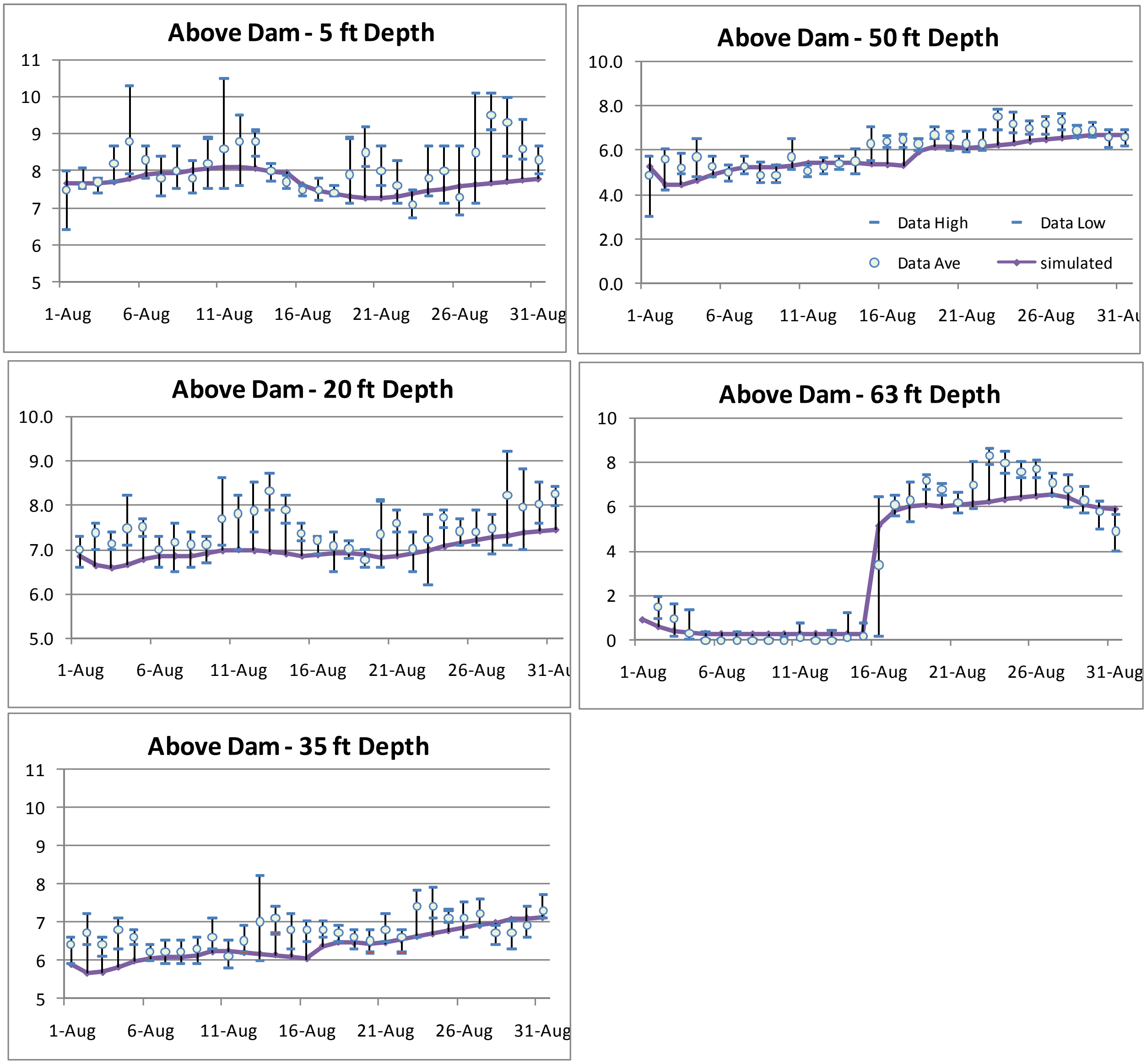


Figure 4. Simulated (purple lines) and measured August 2000 dissolved oxygen concentration at measurement points upstream of Gulf Island Pond dam. The daily average is shown as an open circle and the blue bands denote the daily minimum and maximum for measurements recorded on the hour.

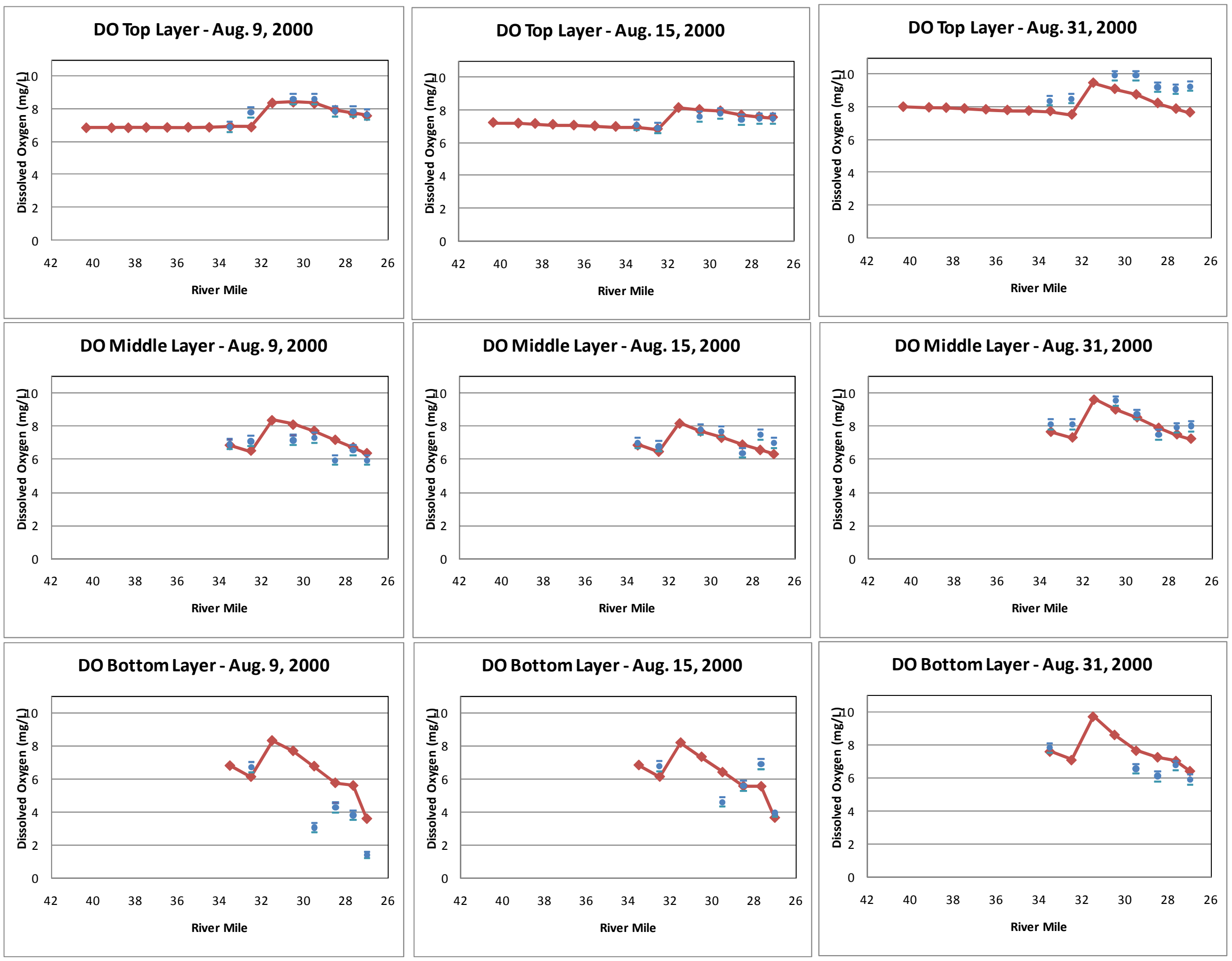


Figure 5. Simulated (red lines) and measured (blue dots) dissolved oxygen during August 2000 by river mile in Gulf Island Pond.

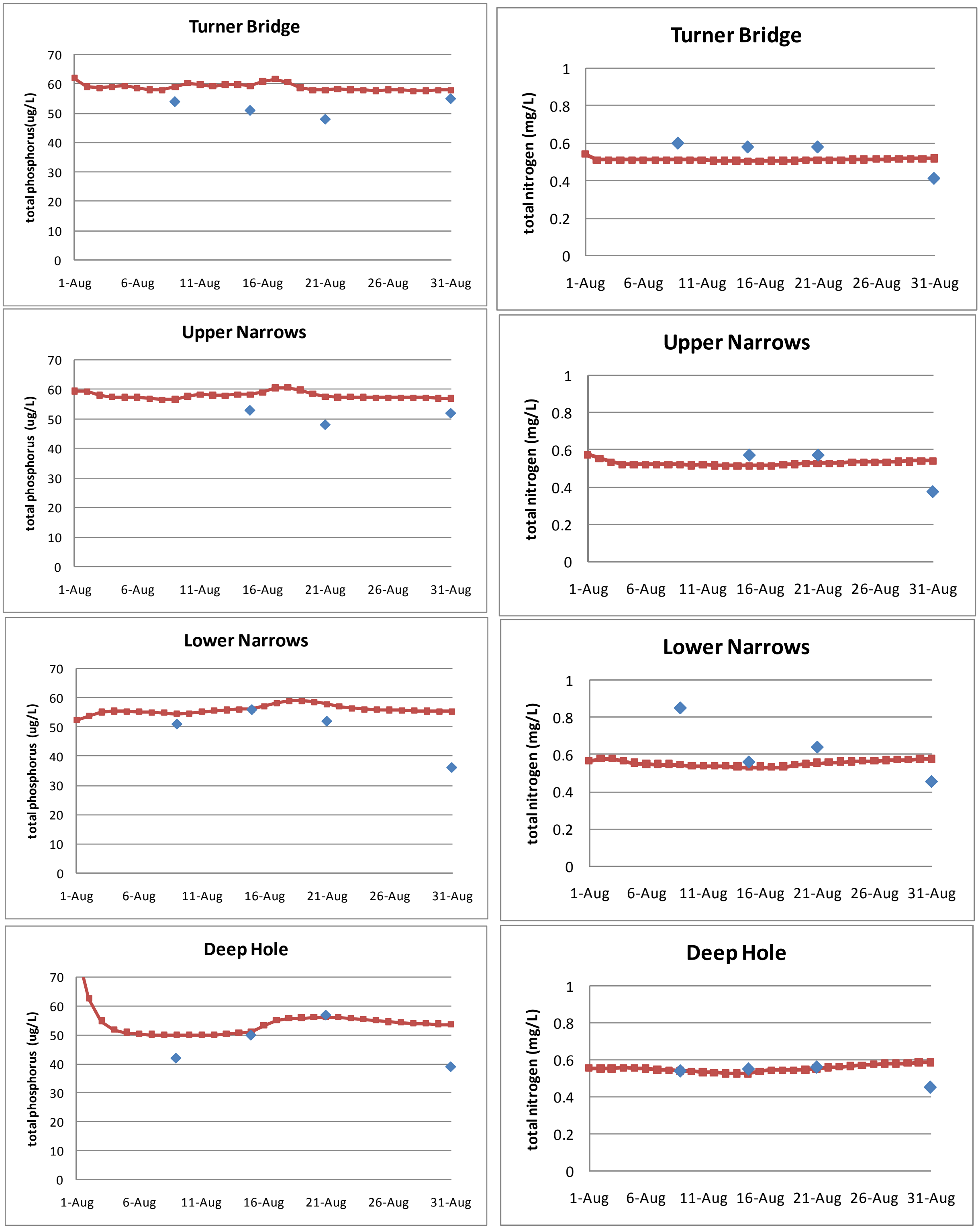


Figure 6. August 2000 simulated (red lines) and measured (blue dots) total phosphorus and total nitrogen in Gulf Island Pond.

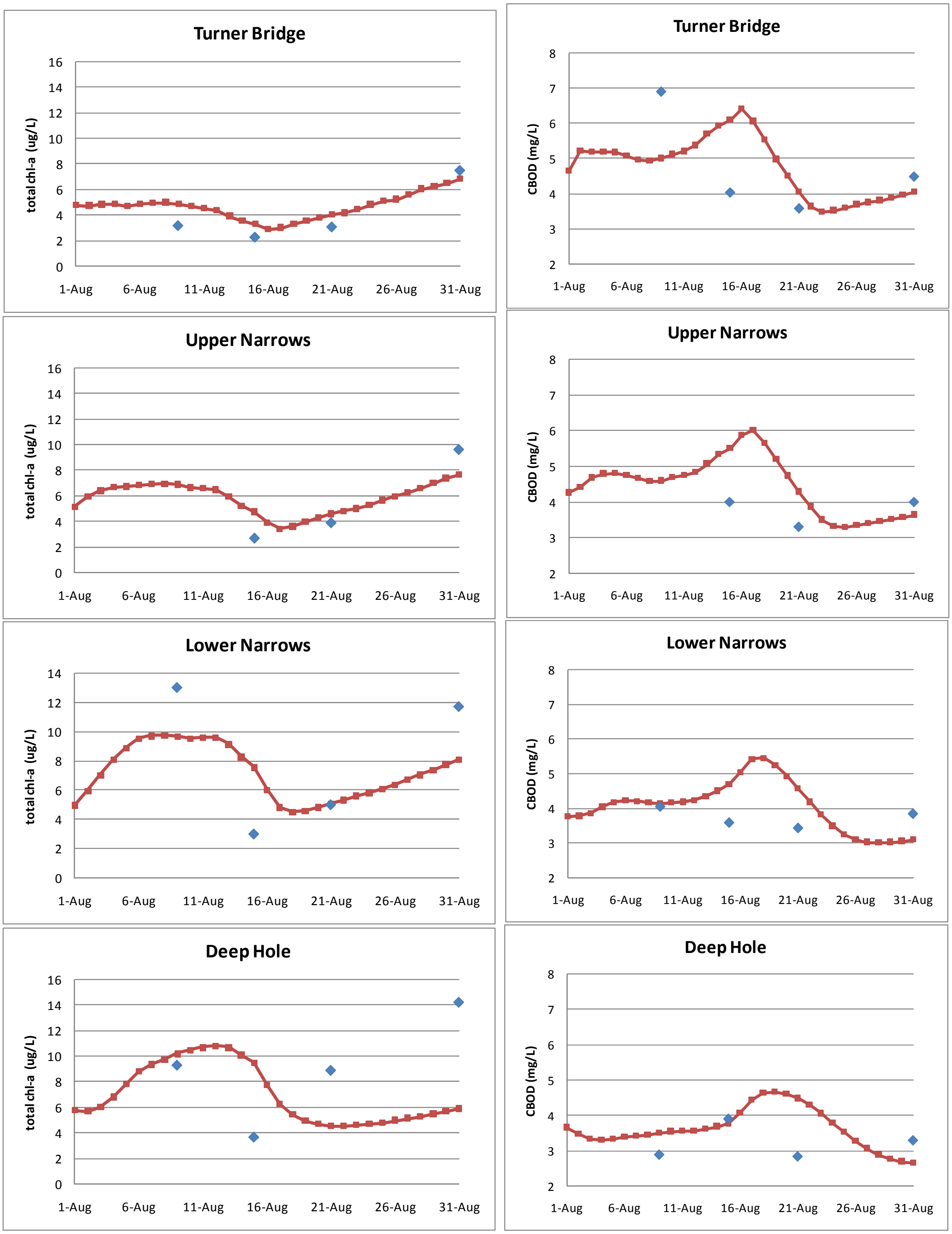
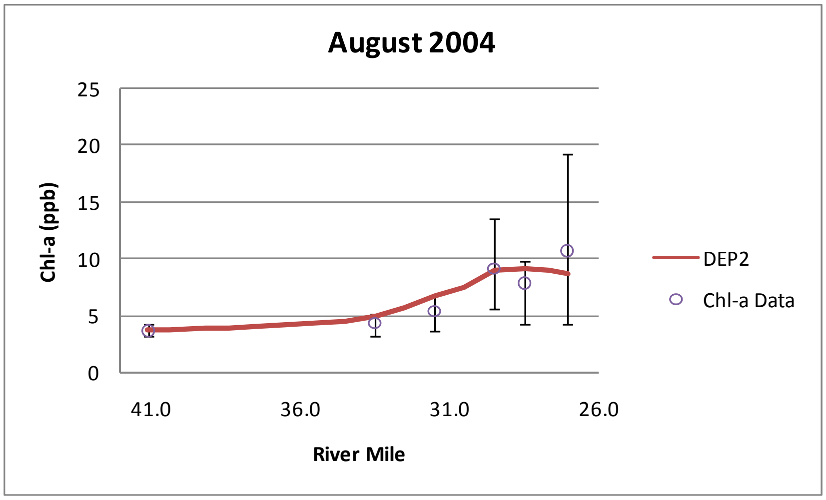
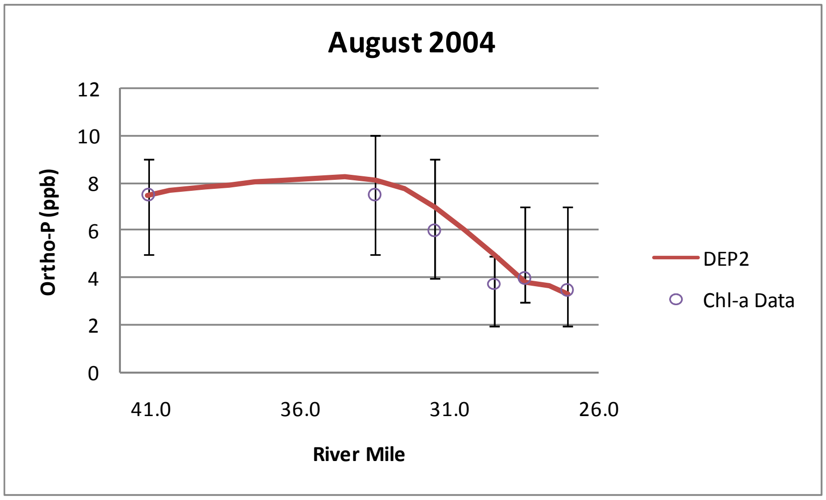


Figure 7. August 2000 simulated (red lines) and measured (blue dots) concentrations of chlorophyll-*a* and carbonaceous biochemical oxygen demand in Gulf Island Pond.





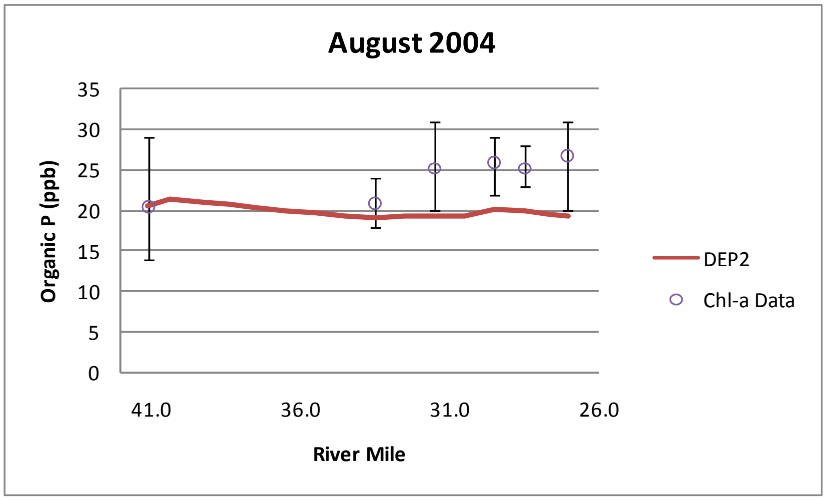


Figure 8. August 2004 average, minimum, and maximum measured concentrations and steady-state simulated concentrations of chlorophyll-*a*, orthophosphate, and organic phosphorus.

Appendix C

Recalibration of the Gulf Island Pond Water Quality Model and Assessment of Oxygen Injection Requirements and Allowable Phosphorus Load

(HydroAnalysis, Inc., April 2, 2009)

RECALIBRATION OF THE GULF ISLAND POND WATER QUALITY MODEL AND ASSESSMENT OF OXYGEN INJECTION REQUIREMENTS AND ALLOWABLE PHOSPHORUS LOAD

APRIL 2, 2009

Prepared for:

State of Maine
Dept. of Environmental Protection

Prepared by:

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1 Introduction

The Water Quality Analysis Simulation Program (WASP) (Ambrose et al., 1993) has been applied to the Gulf Island Pond impoundment of the Androscoggin River for the determination of the Total Maximum Daily Load (TMDL) of phosphorus and BOD and the analysis of oxygen injection within the pond. The model calibration and application were documented in Mitnik (2002) and Mitnik (2005). In Mitnik (2002) the model was calibrated to water quality data collected in August 2000 and verified using water quality data from August 1984. Calibration targets included both the time history of water quality constituents (dissolved oxygen, biochemical oxygen demand, total nitrogen, total phosphorus, and chlorophyll-*a*) over the course of the month and the spatial distribution of water quality constituents at given times during the month. Mitnik (2005) described efforts to refine the model calibration using data collected during the summer of 2004. The emphasis in the 2005 model refinement was in modification of system rates to replicate the concentrations of orthophosphate, organic phosphorus, and chlorophyll-*a*.

The DEP received comments from Dilks (2007), Connolly (2007), and Wiley (2007) on the Gulf Island Pond water quality model and its application. Dilks noted that the model described in Mitnik (2002) incorrectly allowed for dispersive exchange across the downstream dam. This physically unrealistic model feature was corrected in the version of the model described in Mitnik (2005), however as noted by Dilks there was no effort to recalibrate the corrected model to data collected in August 2000. Connolly (2007) noted that the benthic phosphate flux rate (WASP parameter FPO4 and referred to in the model documentation as the *benthic phosphorus flux*) was specified in the water quality model at a constant value for all segments. Because the portion of each segment's bottom area in contact with the sediment bed may be less than its total bottom area, specification of a constant loading rate had the unintended consequence of creating an uneven benthic phosphate flux (i.e. loading rate per unit of sediment bed area).

HydroAnalysis addressed these comments, recalibrated the model and presented the recalibrated model to the Maine DEP (HydroAnalysis, 2008a). Subsequent to this initial recalibration of the model, Dilks (2008) noted that a set of dissolved measurement data collected at the dam at a depth of 50 feet had been incorrectly omitted from the calibration targets used by both Mitnik (2002 and 2005) and in HydroAnalysis' recalibration. The model was again modified by HydroAnalysis (2008b) in order to address these comments.

The calibrated model has been applied to an assessment of the oxygen injection requirements at the Upper Narrows and to the allowable phosphorus load for point sources within the Androscoggin River. This report describes the two phases of HydroAnalysis's recalibration of the Gulf Island Pond model and the application of the model to these two tasks. The calibration is described in the following sections in the sequence in which it was carried out. First, the recalibration efforts aimed at resolving the 2007 comments from Dilks, Connolly and Wiley are described in Sections 2.1 through 2.3. Section 2.4 describes the segment geometry inconsistencies that were discovered during recalibration. Then the follow-up work on calibrating to the dissolved oxygen measurements at a depth of 50 feet is described in Section 2.5. Sections 3 and 4 describe the model application to the assessment of oxygen injection requirements and allowable phosphorus load.

All simulations were run using a version of the WASP model that was found to reproduce the prior results presented in Mitnik (2002) and Mitnik (2005). A copy of the program executable file will be made available on request. The WASP model grid, including segment numbers, is shown in Figure 1. The model configuration was not changed from its original condition in Mitnik (2002) and Mitnik (2005).

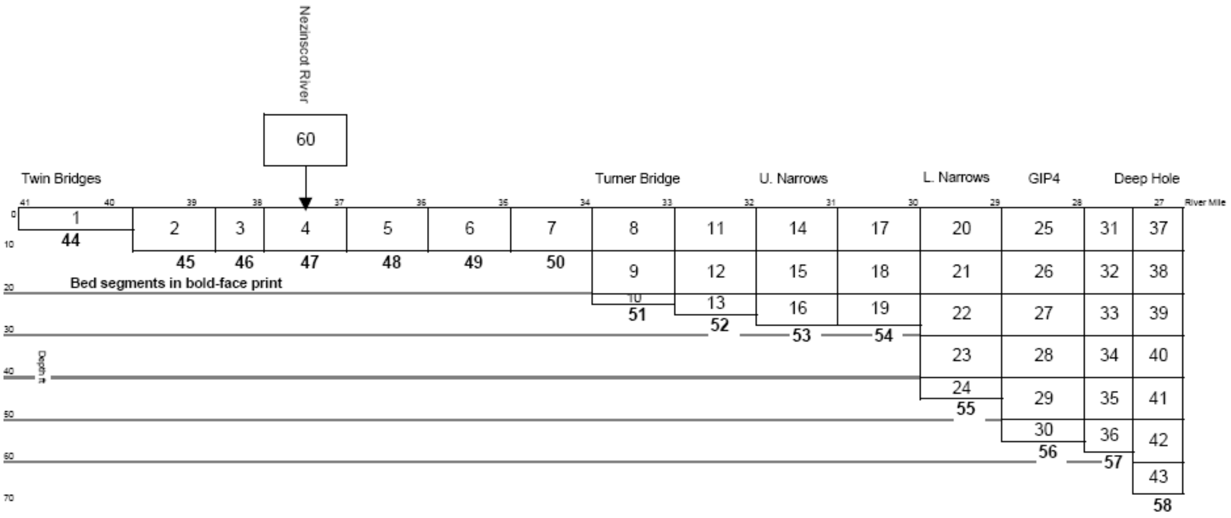


Figure 1. Gulf Island Pond WASP model segments.

2 Recalibration

The recalibration effort was carried out as follows. Initially, the model data sets that were generated in the earlier calibration efforts were identified and run so as to replicate the earlier results presented by Mitnik (2002) and Mitnik (2005). Then the model input files used for calibration to the June/July 2004 and July/August 2004 data sets were modified to obtain a benthic flux rate that is representative of the actual area in contact with sediment. The model results were compared to the calibration targets and the phosphate bed loading flux adjusted upward to improve the calibration for inorganic phosphate. Vertical exchange coefficients were also made uniform across the model because we did not perceive sufficient evidence over the course of calibrating the model that would support the formerly uneven rate of vertical exchange coefficients. This change in the vertical exchange coefficients included an increase in the vertical exchange in the deep segments near the dam . The model modifications made for the June/July 2004 and July/August 2004 data set were then applied to the August 2000 and August 1998 simulations. The results were found to provide a reasonable replication of the calibration targets for these data sets, serving as verification of the model modifications.

The modified model was run using the August 2000 flow conditions and the results were compared to the August 2000 calibration target time series previously presented by Mitnik (2002). The dispersion across the dam was eliminated and the vertical exchange coefficients were increased relative to the values in the original model described by Mitnik (2002) in order to achieve a reasonable representation of dissolved oxygen at the middle and lower depths of the model.

Following the presentation of the recalibrated model to the Maine DEP, the model was further refined to calibrate to dissolved oxygen concentrations from a point immediately upstream of the dam at a depth of 50 feet. On comparison of the measured and simulated values at this depth, it was apparent that the model segment at this depth was incorrectly isolated hydraulically from the shallower segments. The model flow field was then adjusted to increase the downward flow and thereby increase the dissolved oxygen concentration at this depth. This change in the flow field was found to have minimal consequences on the simulated water quality concentration elsewhere within the model.

2.1 Calibration Targets

The initial calibration effort originally documented in HydroAnalysis (2008a) used the same calibration targets as documented in Figures 11, 13, 14, 15, 17, 18, and 19 by Mitnik (2002) and Figures 5–8 by Mitnik (2005). In a later effort to refine the model calibration, HydroAnalysis added dissolved oxygen measurements at a depth of 50 feet as an additional calibration target. That later effort is described in Section 2.5 of this report. The calibration targets established by Mitnik (2002), along with the original figure numbers in his report, are:

- Ultimate BOD at four locations – August 2000 (Figure 11)
- Chlorophyll-*a* at four locations – August 2000 (Figure 13)
- Total nitrogen at four locations – August 2000 (Figure 14)
- Total phosphorus at four locations – August 2000 (Figure 15)
- Continuous dissolved oxygen readings at Turner Bridge and at depths of 5 feet, 35 feet and 63 feet at a point upstream of the dam – August 2000 (Figures 17 and 18)
- Dissolved oxygen at various depths at points along the stream on August 9, 15 and 31, 2000 (Figures 19a, b and c).

The calibration target locations and the associated model segments described by Mitnik (2002) are shown in Table 1.

The calibration targets used by Mitnik (2005) and his original figure numbers were:

- Chlorophyll-*a*, orthophosphate, and organic phosphorus at six locations – June 16-July 7, 2004 (Figure 4)
- Chlorophyll-*a*, orthophosphate, and organic phosphorus at six locations – July 21-August 11, 2004 (Figure 5)
- Chlorophyll-*a*, orthophosphate, and organic phosphorus at four locations – August 1998 (Figure 6)
- Chlorophyll-*a*, orthophosphate, and organic phosphorus at five locations – August 2000, 2004 (Figure 7)

The calibration target locations and the associated model segments described by Mitnik (2005) are shown in Table 2.

Table 1. Initial Calibration Targets for August 2000 Data Set.

Parameter Targets	Location or Depth Description	Figure No. from Mitnik (2002)	Model Segment No.	Notes
BOD, chl-*a*, total N, total P	Turner Bridge	11, 13, 14, 15	8	Surface segment
BOD, chl-*a*, total N, total P	Upper Narrows	11, 13, 14, 15	14	Surface segment
BOD, chl-*a*, total N, total P	Lower Narrows	11, 13, 14, 15	20	Surface segment
BOD, chl-*a*, total N, total P	Deep Hole	11, 13, 14, 15	31	Surface segment (2nd to last column)
DO	Turner Bridge	17	10	Bottom segment
DO	Above Gulf Island Dam 5 ft Depth	18	37	Surface segment in most downstream column
DO	Above Gulf Island Dam 35 ft Depth	18	40	Central segment in most downstream column
DO	Above Gulf Island Dam 63 ft Depth	18	43	Bottom segment in most downstream column
DO	Top Layer	19a, 19b, 19c		Top segment for upstream 12 columns and average of top two segments in downstream 3 columns
DO	Middle Layer	19a, 19b, 19c		Central segment or in last 4 columns is average of two segments from each column
DO	Bottom Layer	19a, 19b, 19c		Bottom segment or in last 4 columns is average of two or three segments from each column

Table 2. Calibration Targets for June/July 2004 and July/August 2004 Data Set.

Parameter Targets	Depth	Calibration Period	Figure No. from Mitnik (2005)	Notes
Chl-*a*, Ortho-P, Organic-P	Top Layer	June 16 – July 7, 2004	5	Surface segments at each column
Chl-*a*, Ortho-P, Organic-P	Top Layer	July 21 – August 11, 2004	6	Surface segments at each column
Chl-*a*, Ortho-P, Organic-P	Top Layer	August 1998	7	Surface segments at each column
Chl-*a*, Ortho-P, Organic-P	Top Layer	August 2000	8	Surface segments at each column

Table 3. Rate Parameters for Model Alternatives DEP1, DEP2, and HydroQual

Model Run	Mineralization of Dissolved Organic Phosphorus (per day)	Fraction of Dead and Respired Phytoplankton Phosphorus that is Recycled to Organic Phosphorus	Saturation Light Intensity for Phytoplankton (Ly/day)
DEP1	0.05	0.7	175
DEP2	0.05	0.5	175
HydroQual	0.02	0.5	300

Figures 2 and 3 show the calibration targets and simulated results for models presented by Mitnik (2002) and are provided to serve as a baseline for comparison to results presented in this report based on refinements in the model calibration. Figure 4 shows the calibration targets and simulated results for the calibrated models described by Mitnik (2005) and rerun for this investigation. In these charts, we have retained the convention used by Mitnik of presenting results for three sets of parameters, identified as DEP1, DEP2, and HydroQual. These three parameter sets differ in the assignment of three parameters representing: (1) the mineralization rate of dissolved organic phosphorus, (2) the fraction of dead and respired phytoplankton phosphorus recycled to organic phosphorus, and (3) the saturation light intensity for phytoplankton. The parameter values associated with these variations are described in Table 2 by Mitnik (2005) and reproduced below in Table 3.

Mitnik observed that it was difficult to select between these parameter sets based solely on curve fitting. Ultimately, he used the parameter set referred to as DEP2 in the TMDL simulations based on the proximity of the parameter values to values cited in the TetraTech Guidance Manual (unreferenced, but most likely Bowie et al., 1985) and the fit of the simulated results to measured chlorophyll-*a* concentration in Gulf Island Pond. The charts in Figure 4 recreate the results presented in Figures 5–8 by Mitnik (2005) and are provided to serve as a baseline for comparison to results presented in this report based on refinements in the model calibration.

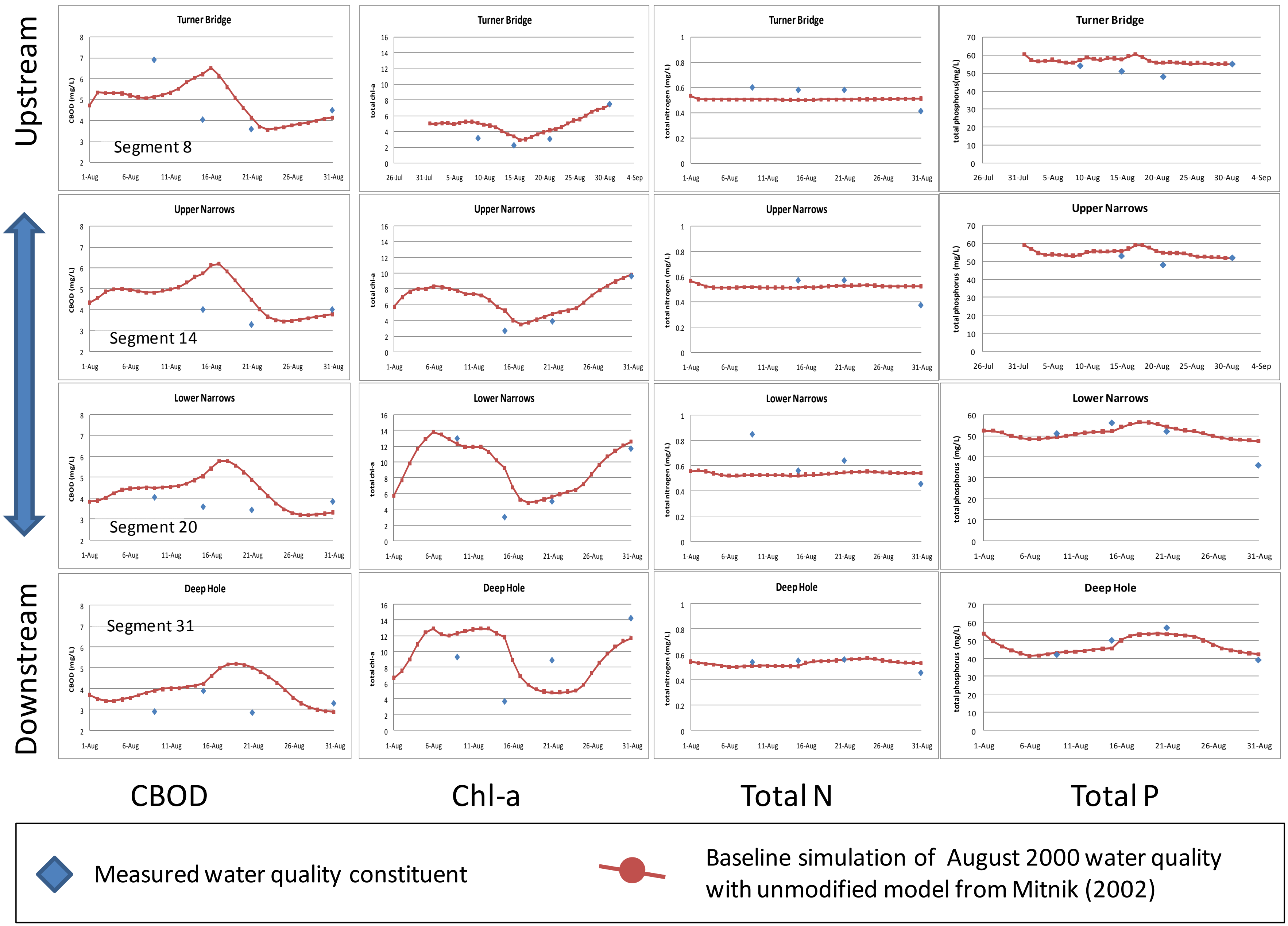


Figure 2. Calibration result and targets for August 2000 time series from Mitnik (2002).

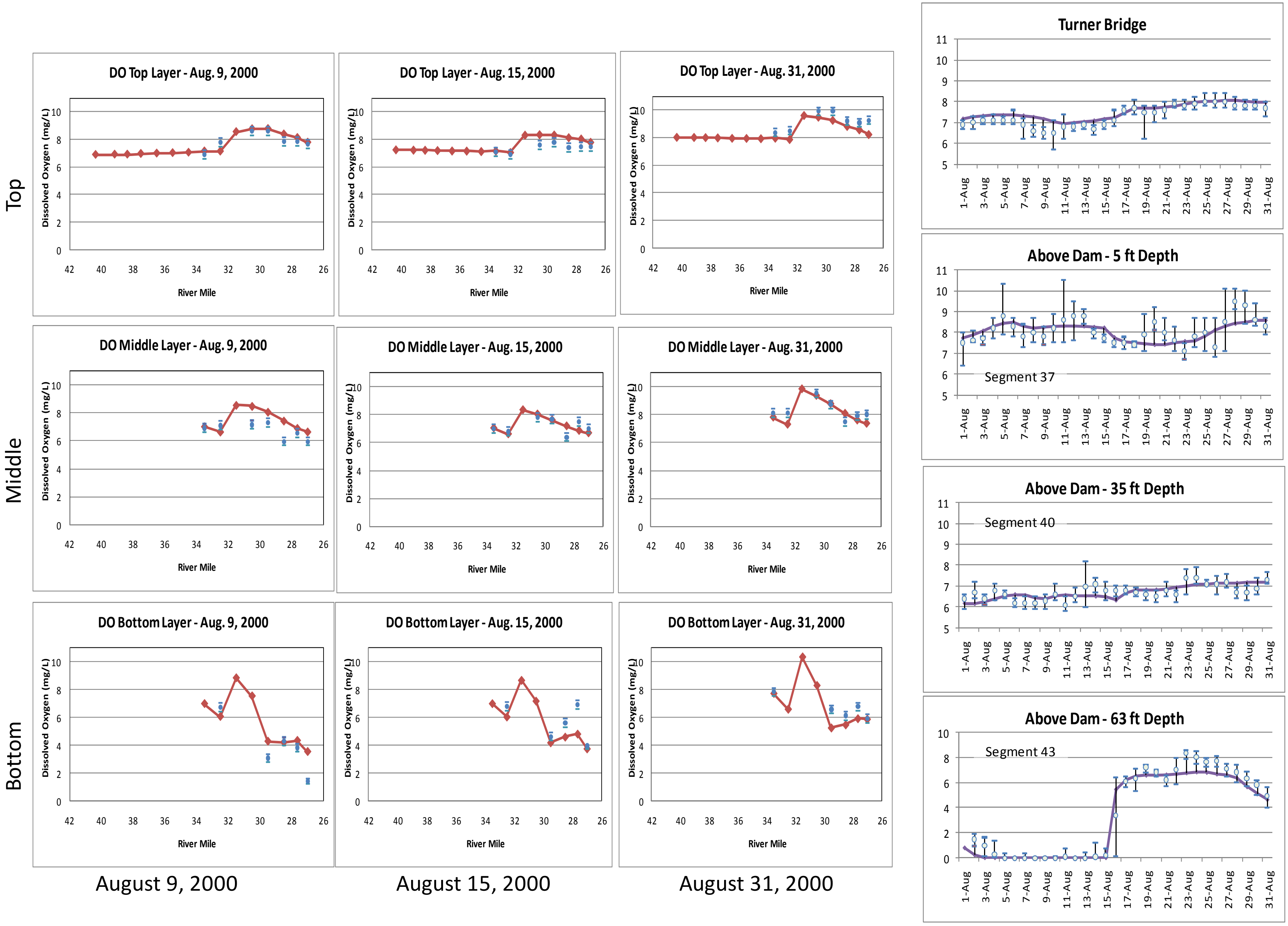
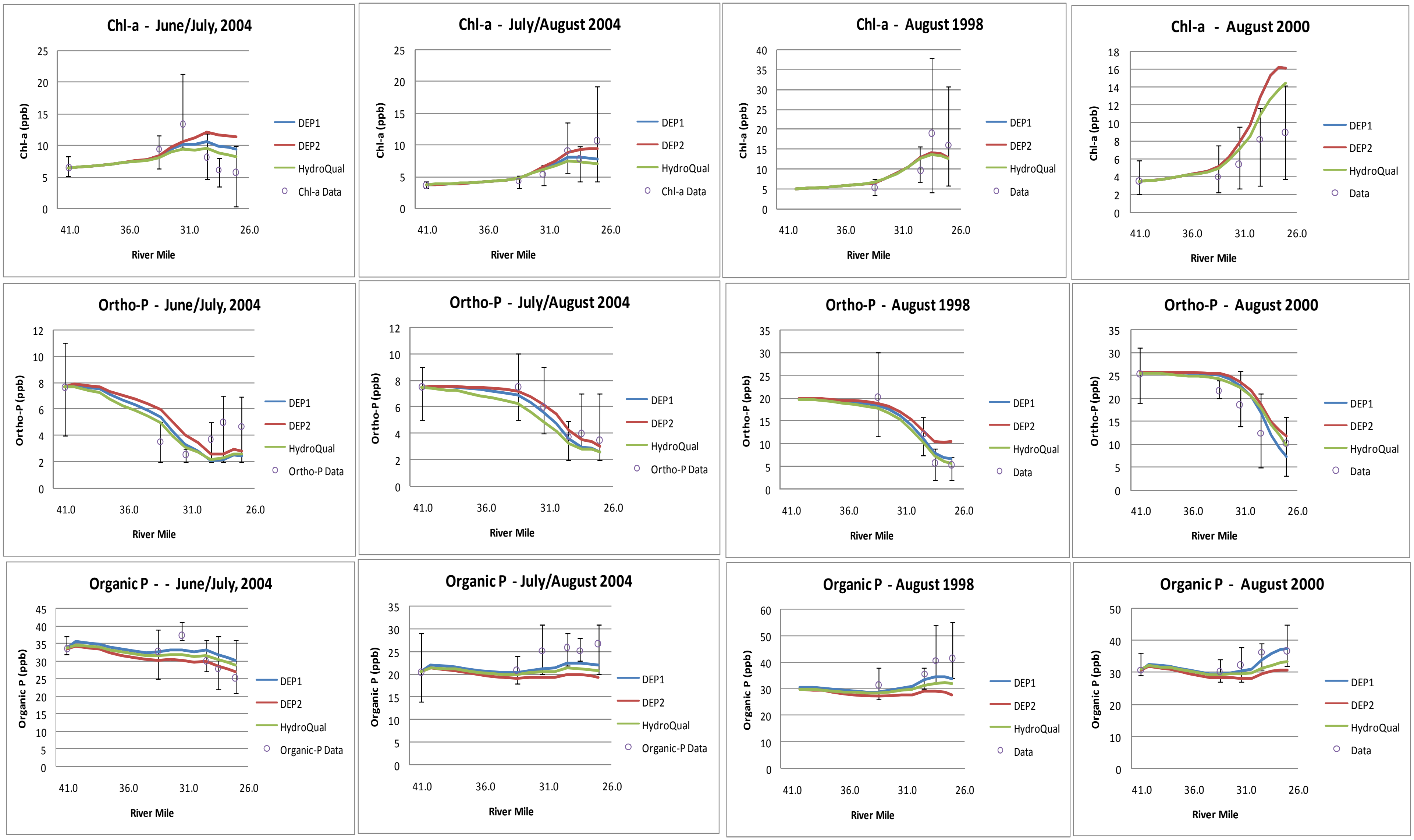


Figure 3. Dissolved oxygen calibration results and targets for August 2000 time series from Mitnik (2002).



June/July 2004 July/August 2004 August 1998 August 2000

Figure 4. Calibration result and targets from Mitnik (2005)

2.2 Model Modifications

This section describes the principal changes made in the course of calibration:

1. The benthic phosphate flux was set to a uniform rate;
2. The benthic phosphate flux was increased to calibrate to the measured phosphorus concentrations; and
3. The vertical exchange coefficients were increased.

Figures 6 and 7 show the sequence of models constructed over the course of calibration. The first column in each of these two figures shows the baseline simulated chlorophyll-*a*, orthophosphate and organic phosphorus for the models constructed by Mitnik (2002). The columns to the right present the results of the calibration steps described below.

Uniform benthic phosphate flux. The total benthic phosphate loading at each segment (in mg/day) is calculated in WASP as the product of the total segment-bottom area (in square meters) and the user-specified benthic phosphate flux (in mg/day/sq-meter). The relationship between the benthic area and the WASP calculation of the phosphate loading is illustrated in the sketch of a typical model profile in Figure 5. In this case, the flow is into the page and the vertical column is divided into three segments. The bottommost segment (segment 1) has a bottom area that is the same as the area in contact with the river bed. The overlying segment's modeled bottom area (segment 2) on the other hand is greater than the area in contact with the river bed because its bottom surface is partially in contact with the water of the segment below. In order to obtain a constant loading flux on a per bed-area basis within WASP, the user must specify a loading rate that is proportional to this estimated segment bed area. This was not done in the simulation runs described by Mitnik (2002; 2005).

The error in the assignment of benthic phosphate flux was corrected by estimating the segment bed area for each segment and assigning a flux proportional to that value. The total segment bottom area was calculated as the modeled segment volume divided by the modeled segment thickness. This is based on the assumption that the model segments are rectangular in plan with a uniform thickness. The bed area was then calculated for each segment by subtracting the area in contact with the underlying segment from the total segment area. The calculated segment bottom area and bed area for each model segment are shown in Table 4. Segments 1 – 7, 10 and 13 for instance have equivalent bottom area and bed area because they are the bottom water segments in their respective columns. Other segments, such as 9, 11 and 12 for instance, have a bed area that is less than their bottom area because these segments are partially underlain by the water of the segment below.

Table 4. Model Segment Geometry and Calculated Bed Area. (note discussion of segments 21 and 29 found on page 21)

Segment	Volume (cu-m)	Depth (m)	Total Area (sq-m)	Bed Area (sq-m)	Bed Area - Total Area Fraction
1	628000	1.83	343169	343169	1.00
2	665000	3.05	218033	218033	1.00
3	392000	3.05	128525	128525	1.00
4	1130000	3.05	370492	370492	1.00
5	1059000	3.05	347213	347213	1.00
6	864000	3.05	283279	283279	1.00
7	954000	3.05	312787	312787	1.00
8	908000	3.05	297705	128525	0.43
9	516000	3.05	169180	140000	0.83
10	89000	3.05	29180	29180	1.00
11	1611000	3.05	528197	303607	0.57
12	685000	3.05	224590	104853	0.47
13	182000	1.52	119737	119737	1.00
14	1657000	3.05	543279	190492	0.35
15	1076000	3.05	352787	79547	0.23
16	582000	2.13	273239	273239	1.00
17	2456000	3.05	805246	174426	0.22
18	1924000	3.05	630820	72134	0.11
19	1190000	2.13	558685	558685	1.00
20	2003000	3.05	656721	425902	0.65
21	704000	3.05	230820	-81639	-0.35
22	953000	3.05	312459	145574	0.47
23	509000	3.05	166885	18798	0.11
24	271000	1.83	148087	148087	1.00
25	1849000	3.05	606230	81639	0.13
26	1600000	3.05	524590	102623	0.20
27	1287000	3.05	421967	112787	0.27
28	943000	3.05	309180	74426	0.24
29	716000	3.05	234754	-84325	-0.36
30	485000	1.52	319079	319079	1.00
31	1608000	3.05	527213	89508	0.17
32	1335000	3.05	437705	39344	0.09
33	1215000	3.05	398361	92787	0.23
34	932000	3.05	305574	67541	0.22
35	726000	3.05	238033	43142	0.18
36	534000	2.74	194891	194891	1.00
37	1444000	3.05	473443	44262	0.09
38	1309000	3.05	429180	45902	0.11
39	1169000	3.05	383279	40000	0.10
40	1047000	3.05	343279	48525	0.14
41	899000	3.05	294754	99344	0.34
42	596000	3.05	195410	85921	0.44
43	300000	2.74	109489	109489	1.00

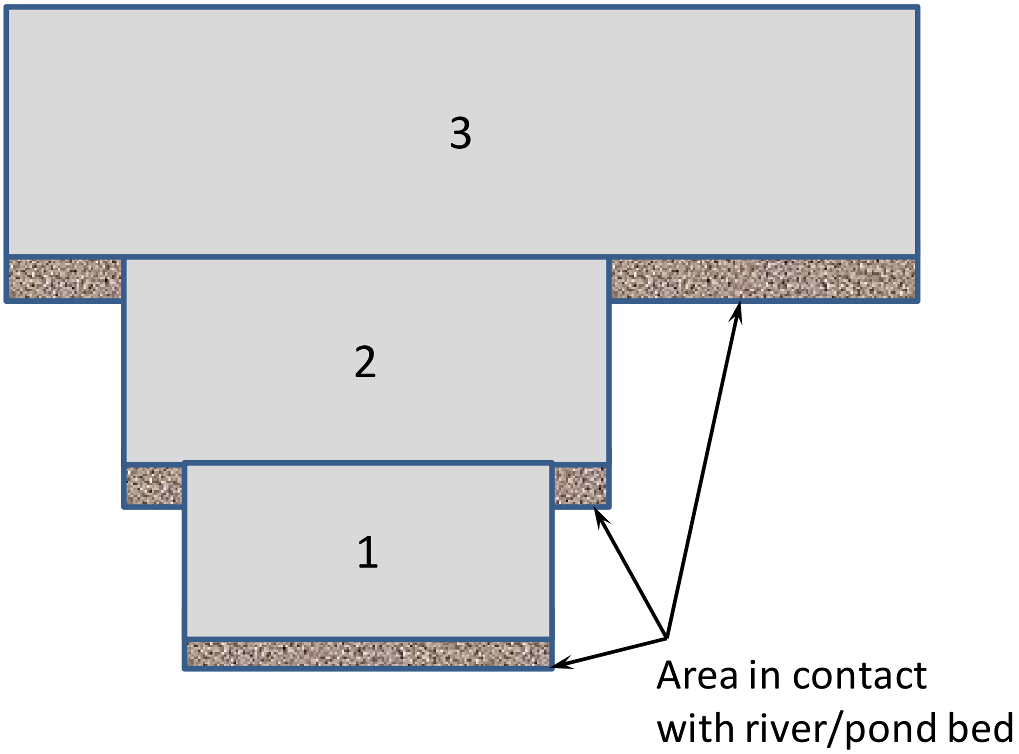


Figure 5 Schematic illustration of model segmentation with direction of flow into page.

The phosphate bed loading was modified in the input files for the two summer 2004 simulations to provide for a uniform benthic phosphate flux. This was done initially by setting the benthic phosphate flux rate at each segment to the product of the original rate and the segment bed-area/segment bottom-area fraction. The seven upstream modeled water columns (WASP segments 1 through 7) consist of only one segment per column. The segment area and the area in contact with the river bed in these columns are equivalent so there was no reduction in the benthic phosphate loading from these segments between the modified and original model. In general, the more segments there are in a particular water column, the smaller is the actual bed area relative to the total bottom area. This resulted in more significant reductions to the benthic phosphate loading relative to the original model in the deepest model columns that contain as many as seven segments in a single column (see Figure 1). The model results at this stage of the calibration are presented in the second column of Figures 6 and 7. The impacts of the model change are apparent from the downward shift of orthophosphate and chlorophyll-*a* relative to the first set of simulations in the first column.

Increased benthic phosphate loading. The reduction in simulated orthophosphate concentration due to the correction of the benthic flux was offset by increasing the phosphate benthic flux rate so as to replicate the measured phosphorus concentrations. The rate was increased incrementally along with increases in the vertical exchange coefficients (see discussion in next section) to achieve a best fit to the measured phosphorus concentrations. The results from a doubling of the phosphate benthic flux rate are presented in the third column (from the left) of Figures 6 and 7. Doubling the phosphate benthic flux rate resulted in a system-wide benthic phosphate loading rate that approximates the same quantity in Mitnik's simulations. Under these conditions, the predicted orthophosphate concentration increases through most of the pond length relative to the prior simulations, but remains too low near the downstream end of the model in both the June/July 2004 and July/August 2004 simulations.

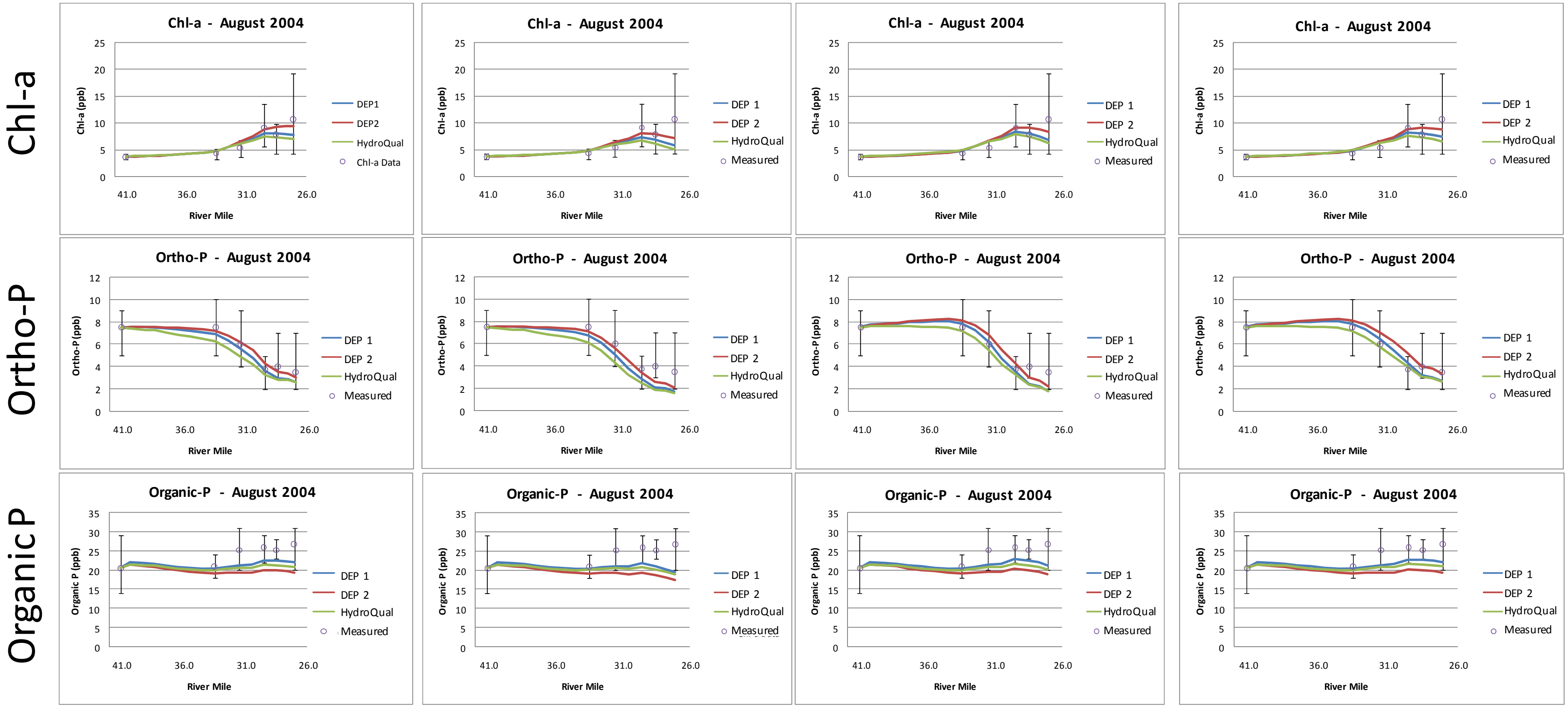
Increased vertical exchange coefficients. Increasing the benthic phosphate flux by itself results in simulated orthophosphate concentrations that are too low in some of the shallower segments in the downstream part of the model. To correct this, the vertical exchange coefficients that represent vertical mixing and dispersion were increased to allow more orthophosphate to mix into the shallower portions of the model. The coefficients were also made spatially uniform since a physical mechanism that would result in the spatial variation of exchange coefficients has not been identified. We also failed to observe convincing evidence of spatially variable exchange rates that could be substantiated based on spatial variation in the vertical distribution of the measured water quality constituents.

Table 5 show the vertical exchange coefficients in the original model from Mitnik (2005) and the modified uniform value reached during this calibration exercise. The simulated model results for a system that includes the correction of an increase in benthic phosphate flux described above and the increase in vertical exchange coefficients is shown in the right-hand column of Figures 6 and 7. This results in improved representations of chlorophyll-*a*, orthophosphate, and organic phosphorus for the July/August 2004 results. The calibration to the July/August 2004 data set was successful with respect to chlorophyll-*a* and orthophosphate, but tended to be too low for organic phosphorus at the downstream portion of the model. In contrast, the calibration to the June/July 2004 data set was relatively more successful for organic phosphorus than for either chlorophyll-*a* or orthophosphate.

After these changes in the model calibration, the June/July 2004 simulated orthophosphate concentration is still too high in the central portion of the model (river miles 30 – 35) and too low in the downstream portion of the model (river miles 26 – 30). The measured orthophosphate concentration in the June/July 2004 data is anomalous in that it increases significantly in the downstream direction below river mile 30. This feature is not repeated in the other data sets, so the model calibration was not modified to better represent the measured June/July 2004 spatial distribution of orthophosphate.

Table 5. Vertical Exchange Coefficients

Segment Pairs	Vertical Exchange Coefficient from Mitnik (2005) (sq-m/sec)	Modified Vertical Exchange Coefficient (sq-m/sec)
41-42, 42-43, 18-19, 22-23, 23-24	1×10^{-5}	6×10^{-5}
All Others	3.5×10^{-5}	6×10^{-5}



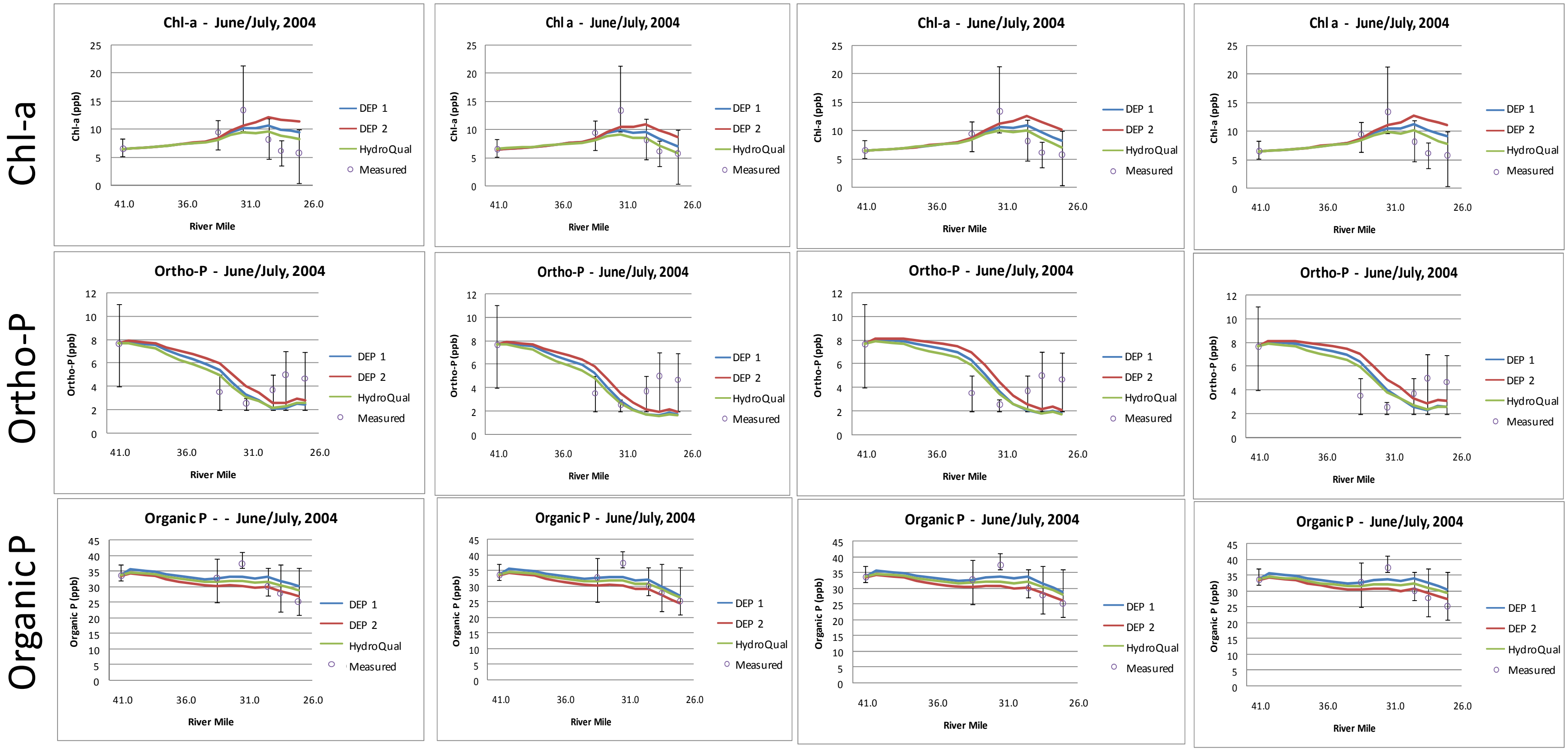
Original baseline from Mitnik (2005)

Corrected FPO4 - same rate

Corrected FPO4 – 2x rate

Corrected FPO4 – 2x rate, uniform increased vertical exchange

Figure 6. Calibration sequence for July/August 2004 water quality data set.



Original baseline from Mitnik (2005)

Corrected FPO4 - same rate

Corrected FPO4 – 2x rate

Corrected FPO4 – 2x rate, uniform increased vertical exchange

Figure 7. Calibration sequence for June/July 2004 water quality data set.

Consistency of constants and rate parameters. In our review of the WASP model input files that were used in the work described in Mitnik (2002) and Mitnik (2005), we noted that different values were assigned in different calibration runs to the phytoplankton nitrogen-carbon ratio (parameter NCRB in the WASP model input data) and orthophosphate half-saturation rate constant (parameter KMPG). These changes were not documented by Mitnik (2002, 2005). In this recalibration, these model parameters were assigned consistent values in all runs. The phytoplankton nitrogen-carbon ratio was assigned a value of 0.2 and the half saturation rate constant was assigned a value of 0.02 mg PO_4-P/L. Modification of these parameters was found to have negligible impacts on the simulated results for analytes used in model calibration.

Calibration of August 2000 water quality time series. The calibration to the August 2000 time series described by Mitnik (2002) included an effort to match the temporal distribution of water quality parameters over the course of the month. Mitnik did this by including the measured daily flow rate and calibrated, temporally variable rates of vertical exchange in the input file. Field measurements showed the dissolved oxygen concentration at depth near the dam was initially nil up through August 16. As noted by Mitnik (2002), "in the middle of August, a large runoff event occurred which resulted in a nearly complete mixing of the pond." The dissolved oxygen concentration remained at values above 6 mg/L after that time until tailing off gradually in the last four days of the month. Mitnik (2002) found that temporally variable rates of vertical exchange were necessary in order to represent this variability in oxygen concentration. WASP does not have the capability to dynamically calculate the vertical exchange coefficient so the exchange coefficients were manually modified to replicate the distribution of oxygen at various depths.

In the current study, the model was recalibrated to the August 2000 time series calibration targets that were previously used by Mitnik (2002). The recalibrated model utilized the modified biochemical rates and constants that had been arrived at in calibration of the summer 2004 data set as described above.

As anticipated, increases in the value of the vertical exchange coefficients were required in order to obtain a reasonable representation of the dissolved oxygen at depth during the mixing event during the latter part of the month. In the early part of the month, the vertical exchange coefficients were increased slightly from the values used by Mitnik (2002). This increase represents a kind of upper limit on vertical exchange coefficient values—higher values were found to cause non-zero dissolved oxygen concentrations at depth near the dam, contrary to field observations. The vertical exchange coefficients arrived at in calibration of the August 2000 simulations are described in Table 6. The result of the calibration to August 2000 water quality values is shown in Figures 8 and 9.

Table 6. Vertical Exchange Coefficients for August 2000 Model Recalibration

Segments	Vertical Exchange Coefficient from Mitnik (2002) (sq-m/sec)	Modified Vertical Exchange Coefficient (sq-m/sec)
18-19, 22-23, 23-24	1×10^{-5} initially 6×10^{-5} at end	3×10^{-5} initially 1×10^{-4} at end
41-42, 42-43	0 initially 2×10^{-3} at peak 1×10^{-5} at end	3×10^{-5} initially 2×10^{-3} at peak 1×10^{-4} at end
All Others	1×10^{-5} initially 4×10^{-4} at peak 5×10^{-5} at end	3×10^{-5} initially 4×10^{-4} at peak 1×10^{-4} at end

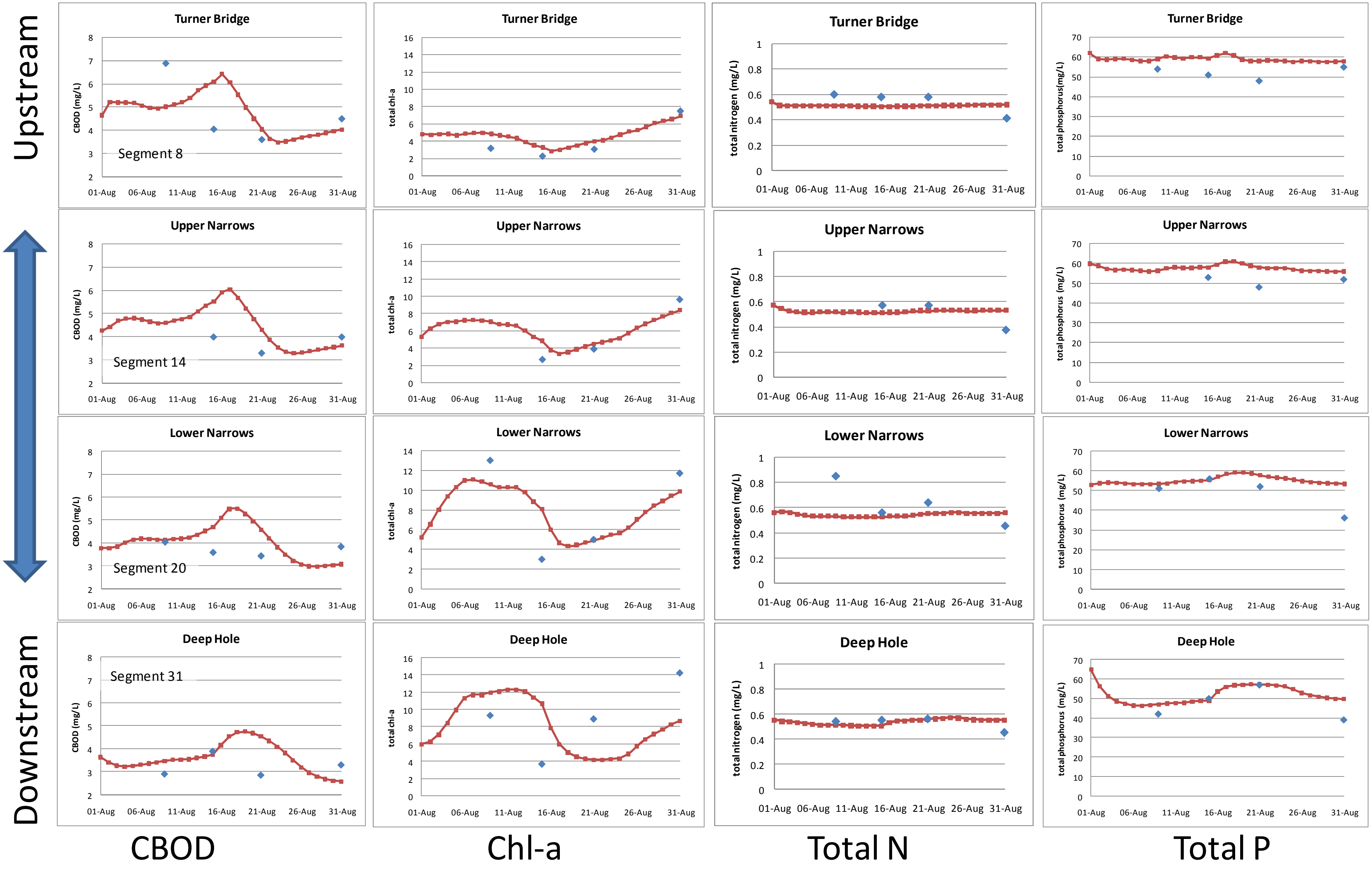


Figure 8. Calibration results of recalibrated model for August 2000 simulation using calibration targets from Mitnik (2002).

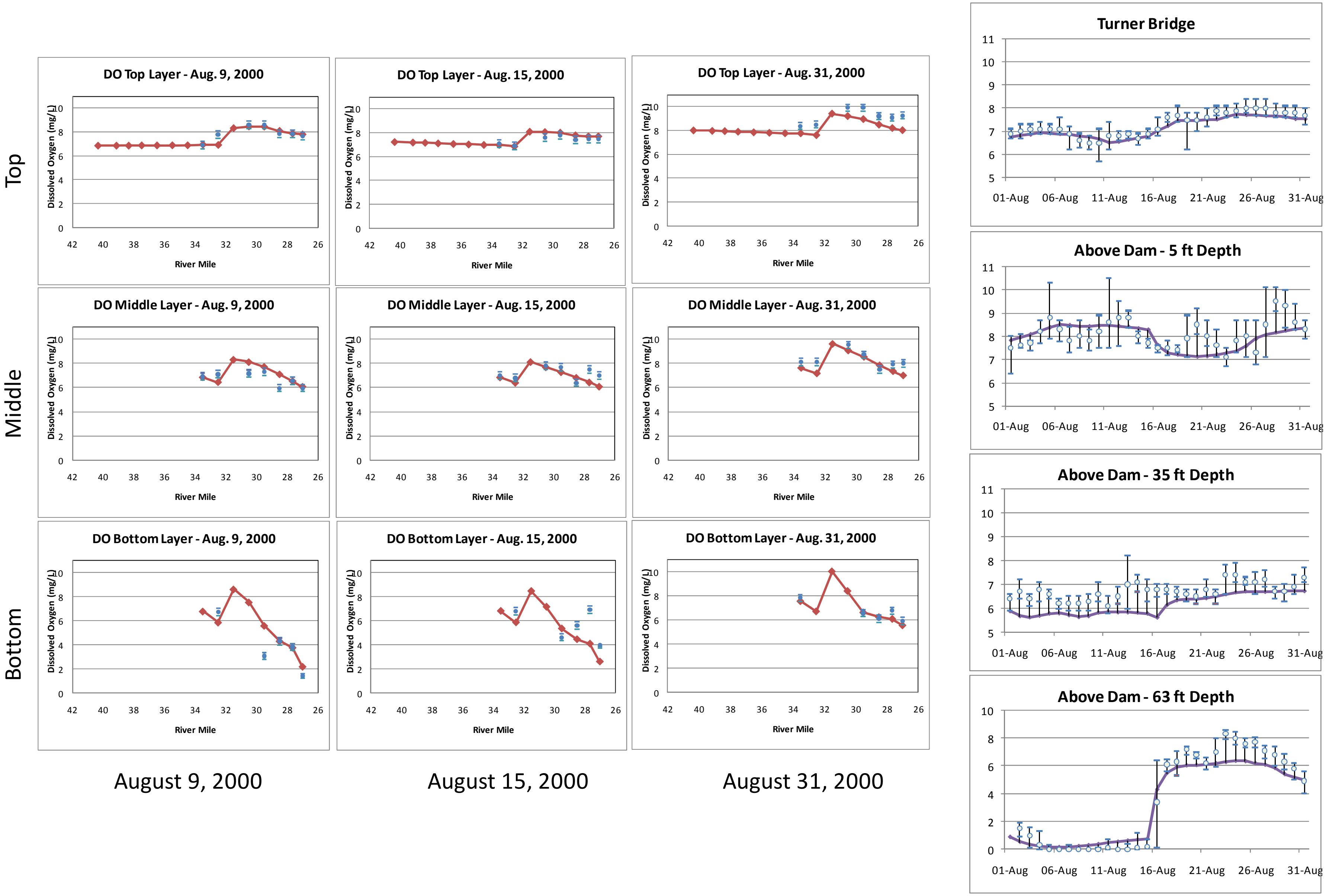


Figure 9. Dissolved oxygen calibration results of recalibrated model for August 2000 simulation using calibration targets from Mitnik (2002).

2.3 Model Verification

The model adjustments described above—namely the correction of the benthic phosphate flux, the increase in the benthic phosphate flux rate, the increase in the vertical exchange rate, and the assignment of consistent rate parameters—were incorporated into the model input files for the August 1998 and August 2000 equilibrium simulations which had been reserved as verification datasets. The results of the two verification simulations for the DEP2 parameter set—August 1998 and August 2000—are shown in Figure 10. The model simulations do a reasonably good job of matching the growth in chlorophyll-*a* and its dependence on orthophosphate concentrations. The notable exception is the August 2000 simulation, in which the model chlorophyll-*a* concentrations are significantly greater than the measured values in the downstream portion of the system. This is consistent with the simulated orthophosphate concentrations in that same simulation that are in excess of measured values.

As noted above in the description of the August 2000 time-series data, the month consisted of two distinctly different phases. The pond was stratified over the first two weeks of the month, with zero or near-zero dissolved oxygen concentrations in the deepest portion of the pond near the dam. A large storm occurred half-way through the month that resulted in substantial mixing and high dissolved oxygen concentrations at all depths. The August 2000 simulations used in the verification are based on average flow values and environmental conditions. It is run out over a period of 30 days in order to approach a near-steady-state condition. It may be the case that the deficiencies in the model calibration data set are due to the fact that the steady-state model is unable to match the average behavior of the dynamic system.

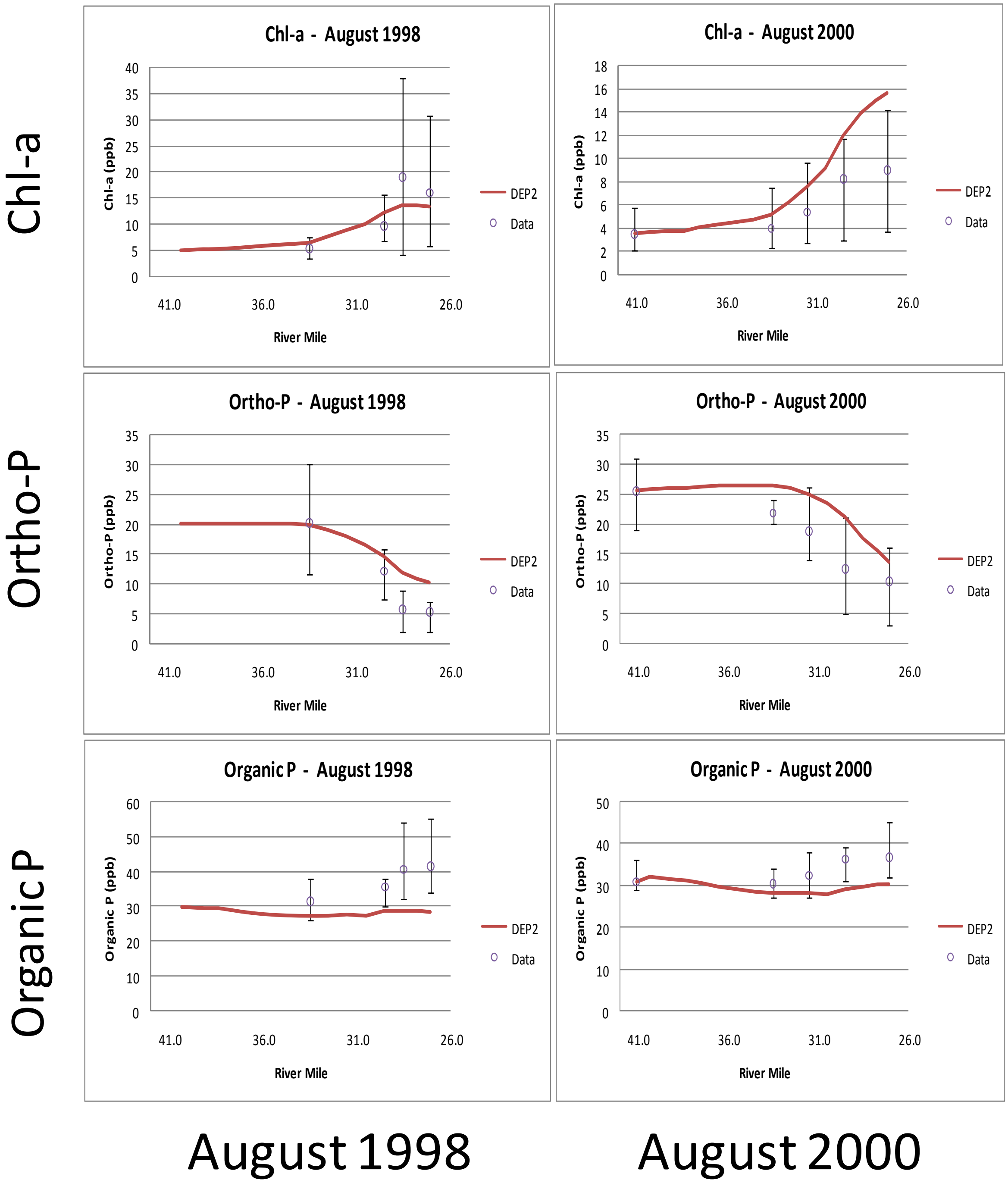


Figure 10. Calibration and verification results of recalibrated model for data sets used as calibration targets in Mitnik (2005).

2.4 Discrepancies in Model Segment Geometry

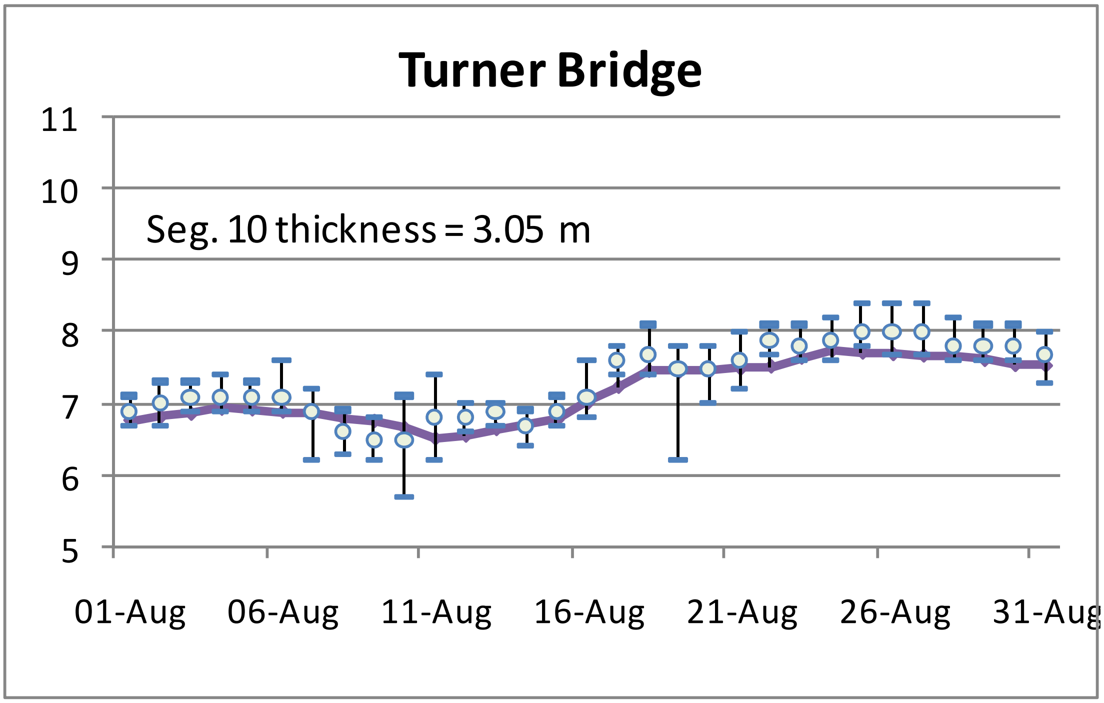
In the course of recalibrating the model, several inconsistencies were detected in the segment geometry. In particular, segment 10 was observed to have a segment thickness different from presented in the report figures and several segments had calculated segment bottom areas that were less than the underlying segment.

In Figure 1, which is a reproduction from Mitnik (2000), the segment 10 thickness is on the order of 1 meter. That is inconsistent with the modeled 3.05-meter segment thickness consistently used in the model input files prepared by Mitnik. The segment dimensions used in the model input files are reported in Table 4 of this report. A spreadsheet was found in the project files by Maine DEP staff that shows a segment 10 vertical thickness of 0.91 meters that is consistent with the thickness shown in Figure 1. The original bathymetric data on which the vertical thicknesses were determined could not be found. Paul Mitnik was contacted by DEP staff, but was unable to provide information that would clear up this inconsistency.

The sensitivity of model results to the segment 10 thickness was evaluated by modifying the segment's vertical thickness in the input file representing the calibrated simulation of August 2000 conditions. The results were compared to the measured concentrations and the previously simulated concentrations at the calibration targets. The change in segment thickness resulted in a negligible difference in all of the calibration target analytes at all calibration targets except for the dissolved oxygen concentration at segment 10 itself. At this location, the dissolved oxygen concentration was reduced by up to 0.3 mg/L relative to its simulated value for the case of a 3.05-m segment thickness. The simulated concentration at Turner Bridge and the range of measured concentrations are plotted in Figure 11. Based on the results of the sensitivity analysis, we are confident that the uncertainty in the segment 10 vertical thickness will not compromise the predictive capacity of the model in the area of concern. The model thickness was ultimately not changed from its original 3.05-m thickness.

The calculation of segment bed area based on the Mitnik WASP model data files resulted in the detection of total bottom areas at segments 21 and 29 that were less than the total bottom areas of their respective underlying segments (segments 22 and 30). See Figure 1 for a depiction of the relative positions of these segments within the model. This is a physically unrealistic, previously undetected discrepancy resulting from increasing calculated total segment area moving vertically upward in the model columns. This resulted in calculated river bed areas for these segments that are less than zero. The benthic phosphate flux for segments 22 and 30 were set to zero. This is consistent with the approach employed by Mitnik in the assignment of sediment oxygen demand to these segments.

We evaluated the sensitivity to the newly detected error in segment area by reversing the modeled volumes of segment 21 and segment 22 and then rerunning the August 2000 model. The changes in the simulated concentrations were insubstantial for all calibration target locations and target analytes.



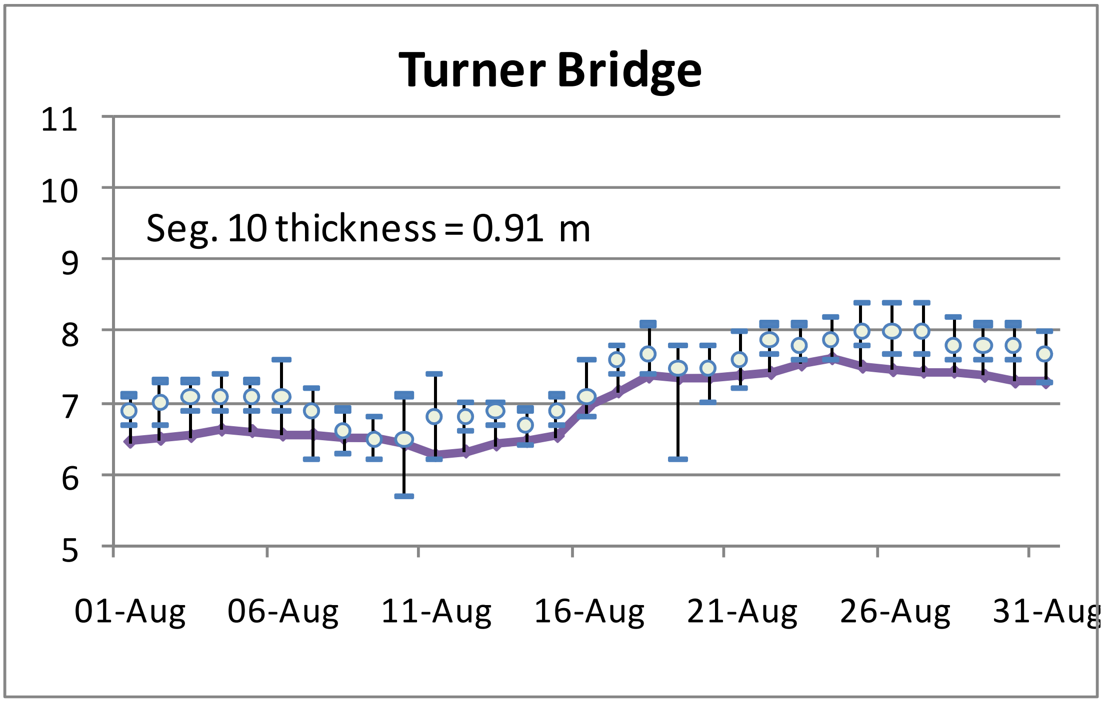


Figure 11. Dissolved oxygen at segment 10 during August 2000 simulation, with segment 10 thickness at 3.05 meters (top) and 0.91 meters (bottom).

2.5 Calibration to Measurements at Depth of 50 Feet

Following the preparation of a report documenting the recalibration tasks described in Section 2.1 through 2.4 of this document (HydroAnalysis, 2008a), Dilks (2008) forwarded comments that the HydroAnalysis recalibration as well as the prior calibration described in Mitnik (2002) and Mitnik (2005) had inappropriately failed to include the dissolved oxygen measurements at the dam at a depth of 50 feet as a calibration target. Figure 12 shows the measured dissolved oxygen concentration at a depth of 50 feet along with the simulated dissolved oxygen using the calibrated model reported by HydroAnalysis (2008a). In this case, the average of the segment 41 and segment 42 dissolved oxygen concentrations are used because the 50-foot depth lies between these two segments. It is apparent on examination of Figure 12 that the model is not successful in representation of dissolved oxygen at this depth.

The initial strategy employed to increase the simulated oxygen concentration at the 50-foot depth was to increase the simulated vertical exchange coefficients. However, spatially uniform increases in the vertical exchange coefficients proved to be incapable of increasing the dissolved oxygen at depth so as to achieve a satisfactory calibration at all depths.

Modification of the simulated flow field was next explored as an alternative to modifying the vertical exchange coefficients exclusively. Mitnik (2002) noted that the temperature of water in the upstream Androscoggin River influences the depth of mixing within Gulf Island Pond. When the inflow water is cold or comparable to the water temperature in Gulf Island Pond, then the river water plunges deeper and depresses the elevation of the interface between the well-mixed surface waters and the more isolated, deeper waters. Figure 13 presents the August 2000 daily-average dissolved oxygen concentration at depths of 5 feet, 20 feet, 35 feet, 50 feet and 63 feet. It is readily apparent from examination of Figure 13 that the dissolved oxygen declines gradually with depth down to 50 feet and then abruptly between depths of 50 feet and 63 feet. These observations motivated a strategy to increase the advective flow in the mid-depth segments of the model so as to increase the simulated dissolved oxygen concentrations at a depth of 50 feet.

WASP represents advective flows using specified segment-to-segment transfers, referred to in the WASP model documentation as unit flow responses. In some modeling projects, the unit flow responses are based on either hydraulic modeling or flow velocity measurements. The Gulf Island Pond model reports (Mitnik, 2002; 2005) do not describe how the unit flow responses were originally calculated. Presumably, engineering judgment was exercised in setting these values.

Figure 14 shows the simulated unit flow responses as represented in the model documented in Mitnik (2002) and Mitnik (2005). The response values in Figure 14 are expressed as percentages of flow relative to the total outflow from each column. For instance, in the model column consisting of segments 14, 15 and 16, the segment 15 to 18 flow represents 35 percent of the total outflow from that column. In all cases, the percent unit flow responses sum to 100 percent in a given column. In Mitnik's original version of the simulated flow field shown in Figure 14, the segment immediately below the 50-foot depth (segment 42) receives no flow from upstream segments while the segment immediately above the 50-foot depth (segment 41) receives 15 percent of the flow from the upstream column of model segments. The lack of modeled flow at depth effectively isolates segment 42 and 43, although the measured dissolved oxygen concentrations at a depth of 50 feet indicate that segment 42 should be included in the mixed upper layer.

Based on these observations, the model flow field was modified to increase the flow at depth while reducing the flow in overlying model segments to maintain the same total flow. The final calibrated version of the flow field is shown in Figure 15. The vertical exchange factors—which represent vertical dispersive mixing—were also generally increased in order to further improve the calibrated dissolved oxygen time history at all depths. Figure 16 shows the simulated vertical exchange factors for the August 2000 calibration. Segment 43, the deepest segment, has limited vertical exchange with the overlying segment in the initial 15 days of the simulation. All of the exchange factors were increased starting at the period of high flow so as to represent the increase in dissolved oxygen at depth at that time.

Figure 17 shows the simulated and measured August 2000 dissolved oxygen at the five measurement depths immediately upstream of the dam. The measurement at a depth of 50 feet lies between model segments 41 and 42, so the average concentration in these two segments was calculated for comparison to the measured value at a depth of 50 feet. The measurement at a depth of 20 feet also lies between segments. It was represented by the average concentration in segments 37 and 38. The dissolved oxygen concentration at a depth of 50 feet is now a reasonable representation of the measured values. There is also improvement in the calibration at the 35-foot depth relative to the recalibrated model described in sections 2.1 through 2.4. The other August 2000 calibration targets, dissolved oxygen by river mile, total nitrogen, total phosphorus, chlorophyll-*a*, and carbonaceous biochemical demand are shown in Figures 18, 19 and 20. The simulated concentrations for these other targets have changed minimally from the values shown in Sections 2.1 through 2.4 of this report.

In order to determine whether the flow field changes would have an impact on the other calibration targets, the modified flow field was introduced into the steady-state simulations of August 2004 that are described in HydroAnalysis (2008a) and in prior sections of this report. No other changes were made to the model input file. Figure 21 shows the simulated concentrations of organic phosphorus, orthophosphate, and chlorophyll-*a* using the recalibrated version of the parameter set identified in Mitnik (2005) as *DEP2*. The results are nearly identical to the simulated concentrations prior to the imposition of the flow field modifications. Based on this result, we determined that it is not necessary to repeat all of the other simulations that were previously used in calibrating the model.

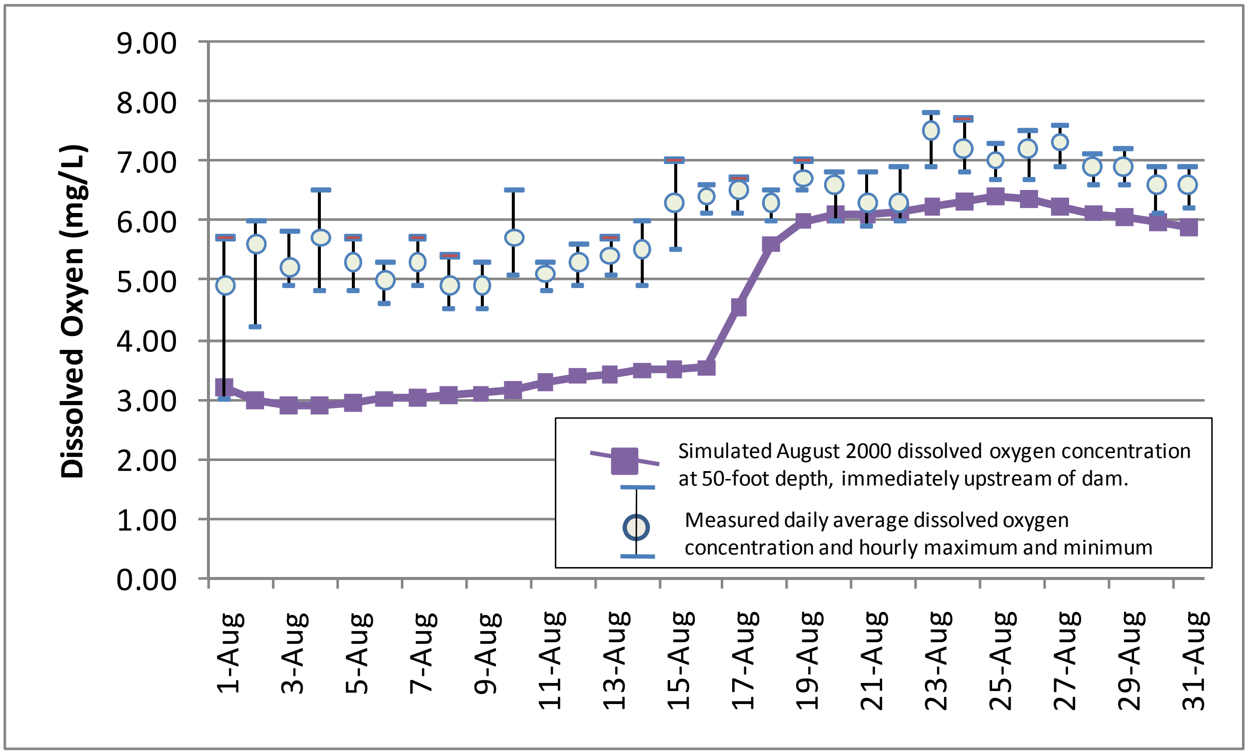


Figure 12. Measured dissolved oxygen concentration at 50-foot depth upstream of Gulf Island Pond dam and simulated dissolved oxygen concentration prior to recalibration of flow field.

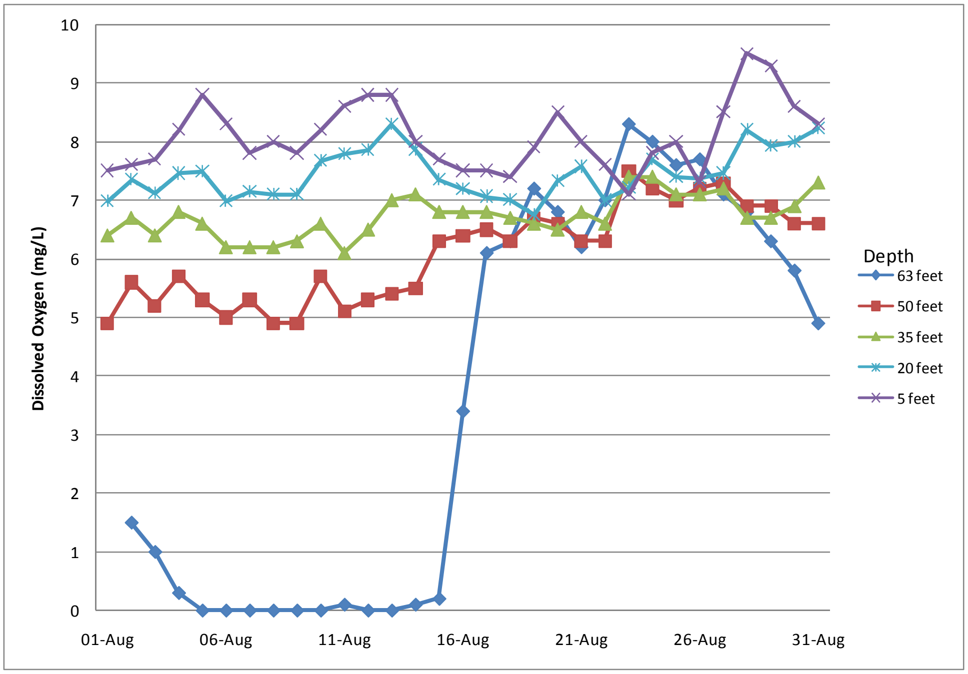


Figure 13. Measured daily average dissolved oxygen concentration upstream of Gulf Island Pond dam at depths of 5 feet, 20 feet, 25 feet, 50 feet and 63 feet.

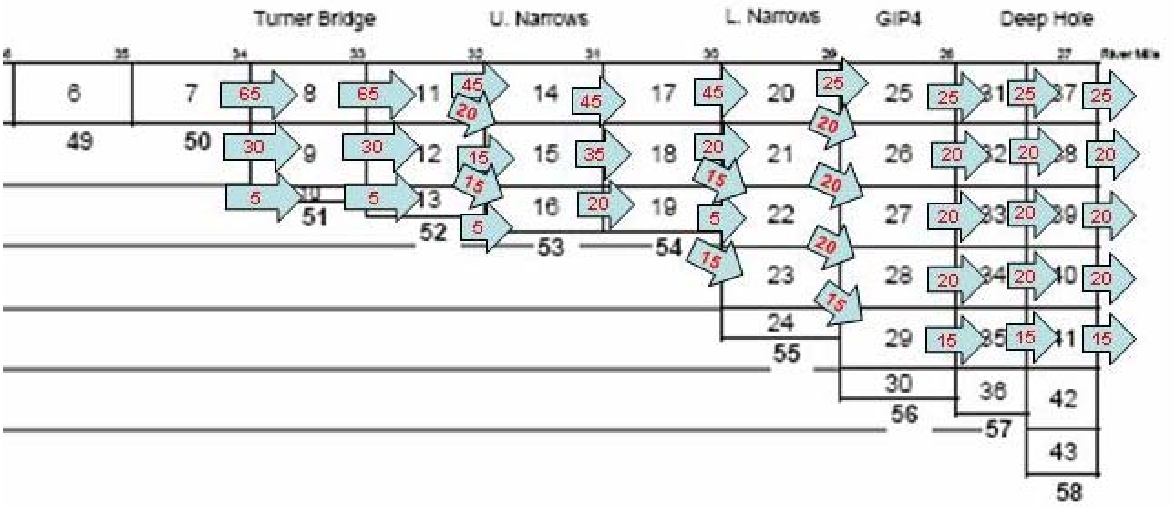


Figure 14. Percentage of model segment column flow that is transferred by advection between segment pairs in original flow field as specified by Mitnik (2000). The segment transfers sum to 100 across all the segment pairs in a single column.

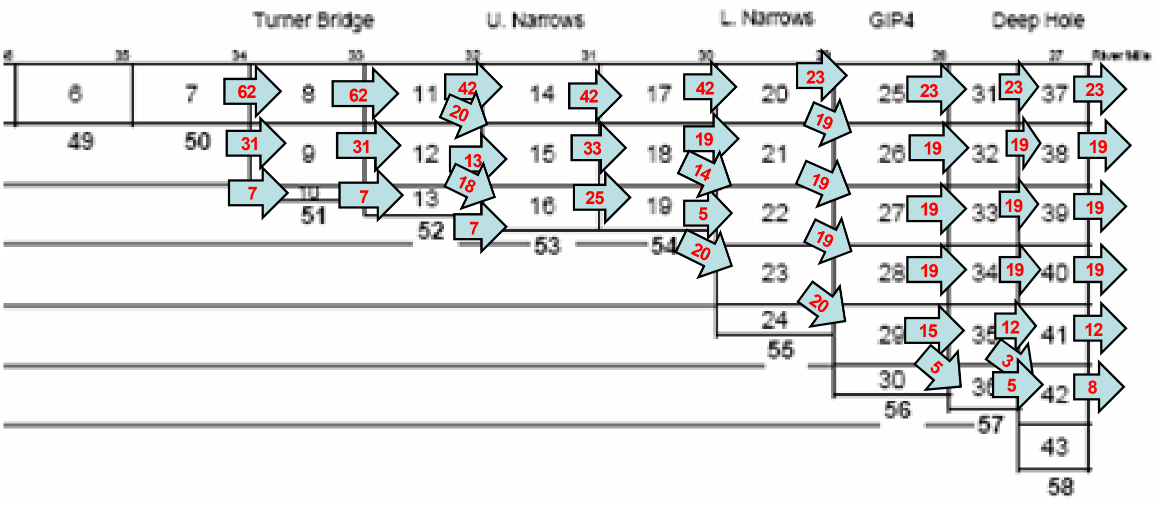


Figure 15. Percentage of model segment column flow that is transferred by advection between segment pairs in newly calibrated model.

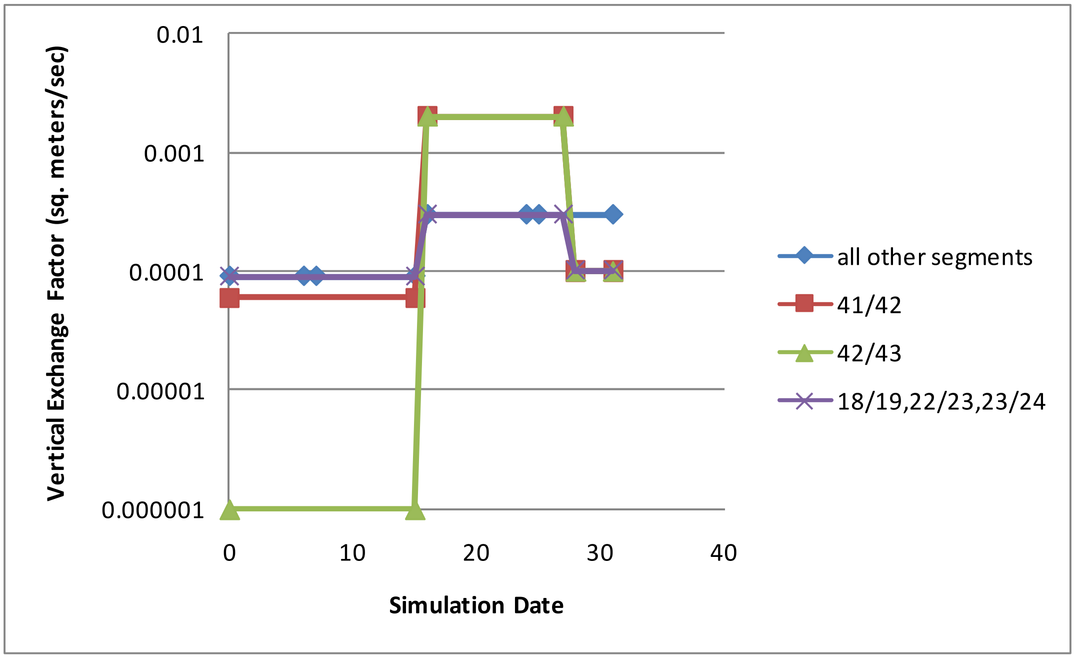


Figure 16. Simulated vertical exchange factor by segment over the course of the August 2000 simulation.

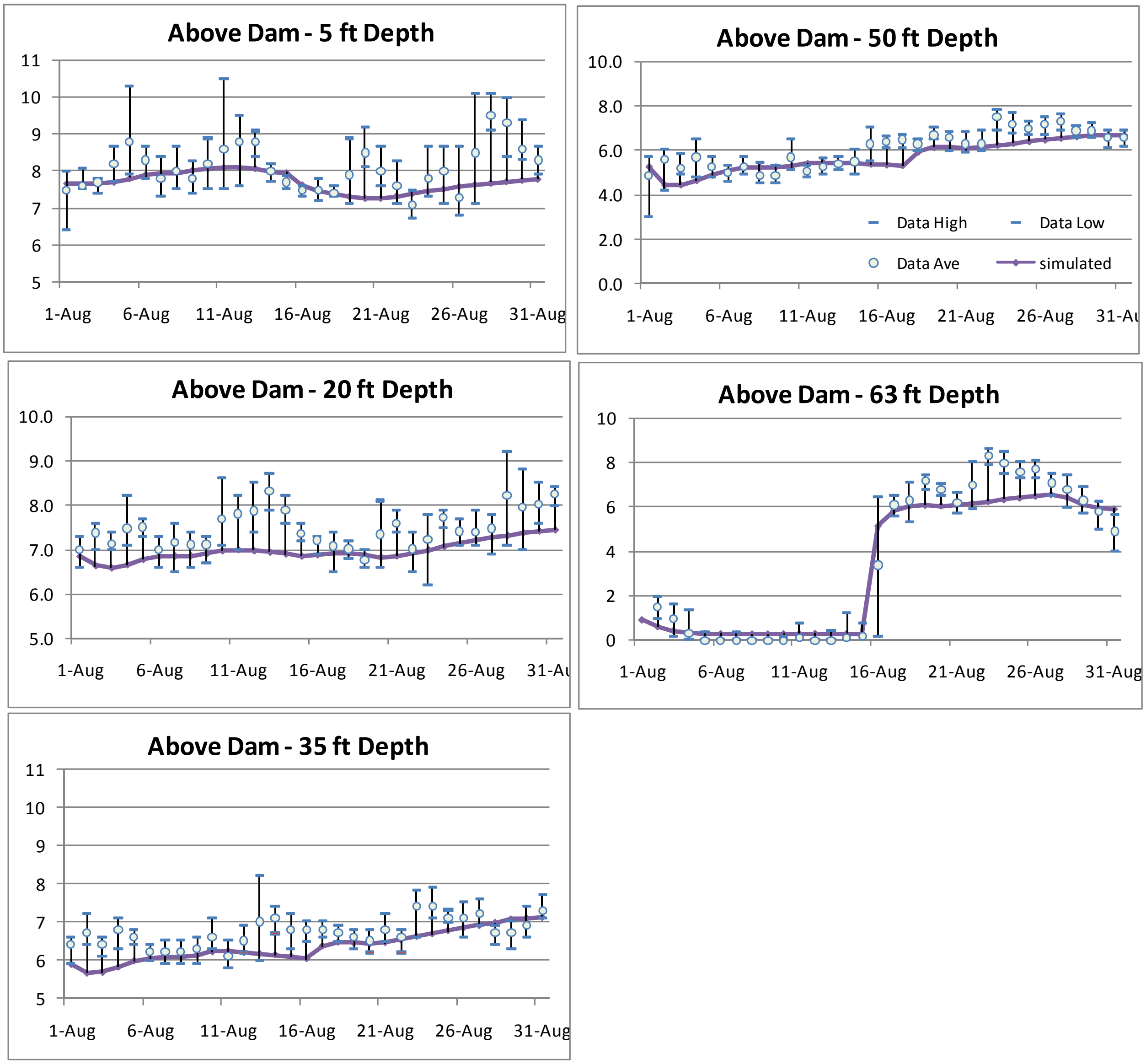
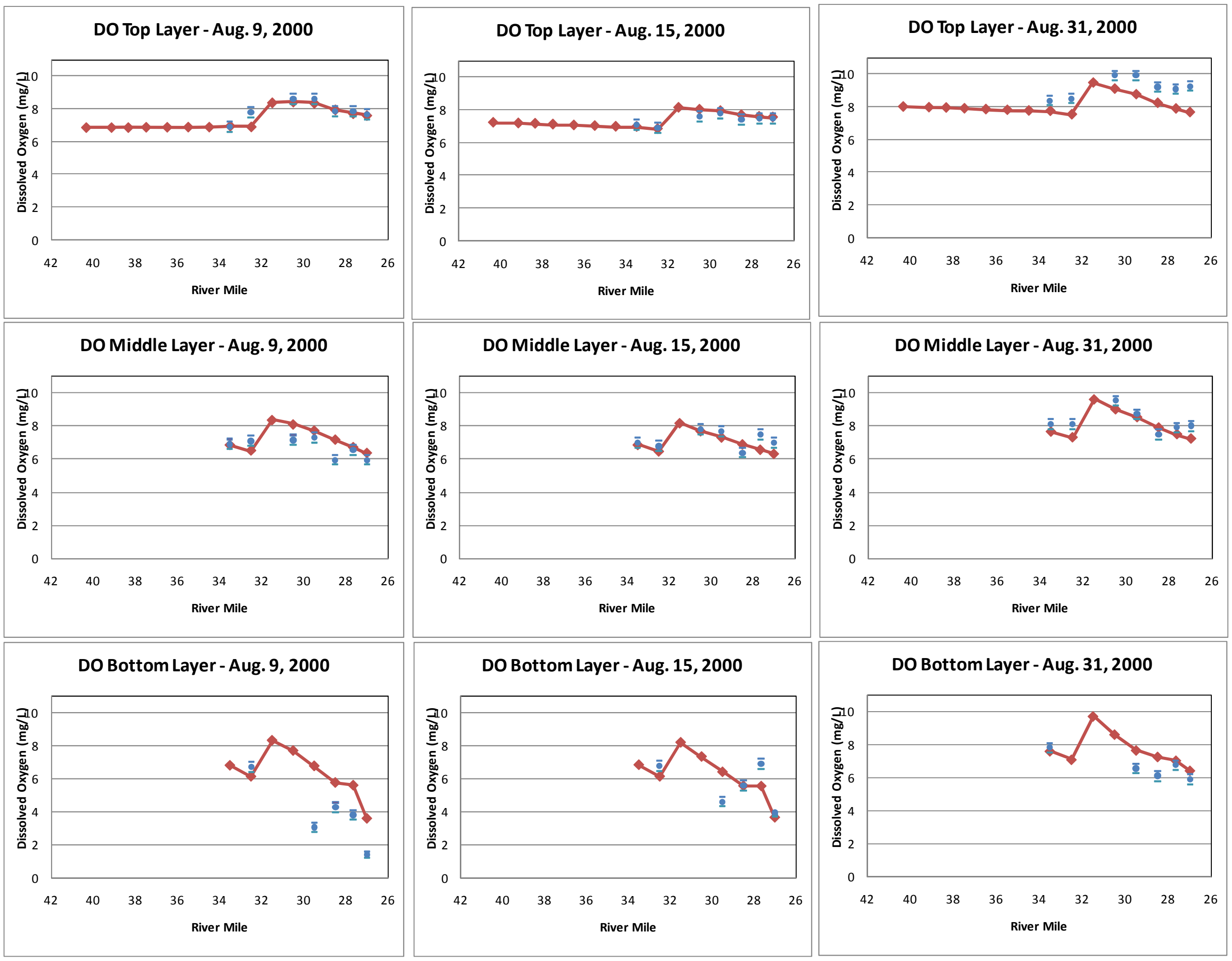


Figure 17. Simulated (purple lines) and measured August 2000 dissolved oxygen concentration at measurement points upstream of Gulf Island Pond dam. The daily average is shown as an open circle and the blue bands denote the daily minimum and maximum for measurements recorded on the hour.



DO Top Layer - Aug. 9, 2000

DO Top Layer - Aug. 15, 2000

DO Top Layer - Aug. 31, 2000

DO Middle Layer - Aug. 9, 2000

DO Middle Layer - Aug. 15, 2000

DO Middle Layer - Aug. 31, 2000

DO Bottom Layer - Aug. 9, 2000

DO Bottom Layer - Aug. 15, 2000

DO Bottom Layer - Aug. 31, 2000

Figure 18. Simulated (red lines) and measured (blue dots) dissolved oxygen during August 2000 by river mile in Gulf Island Pond.

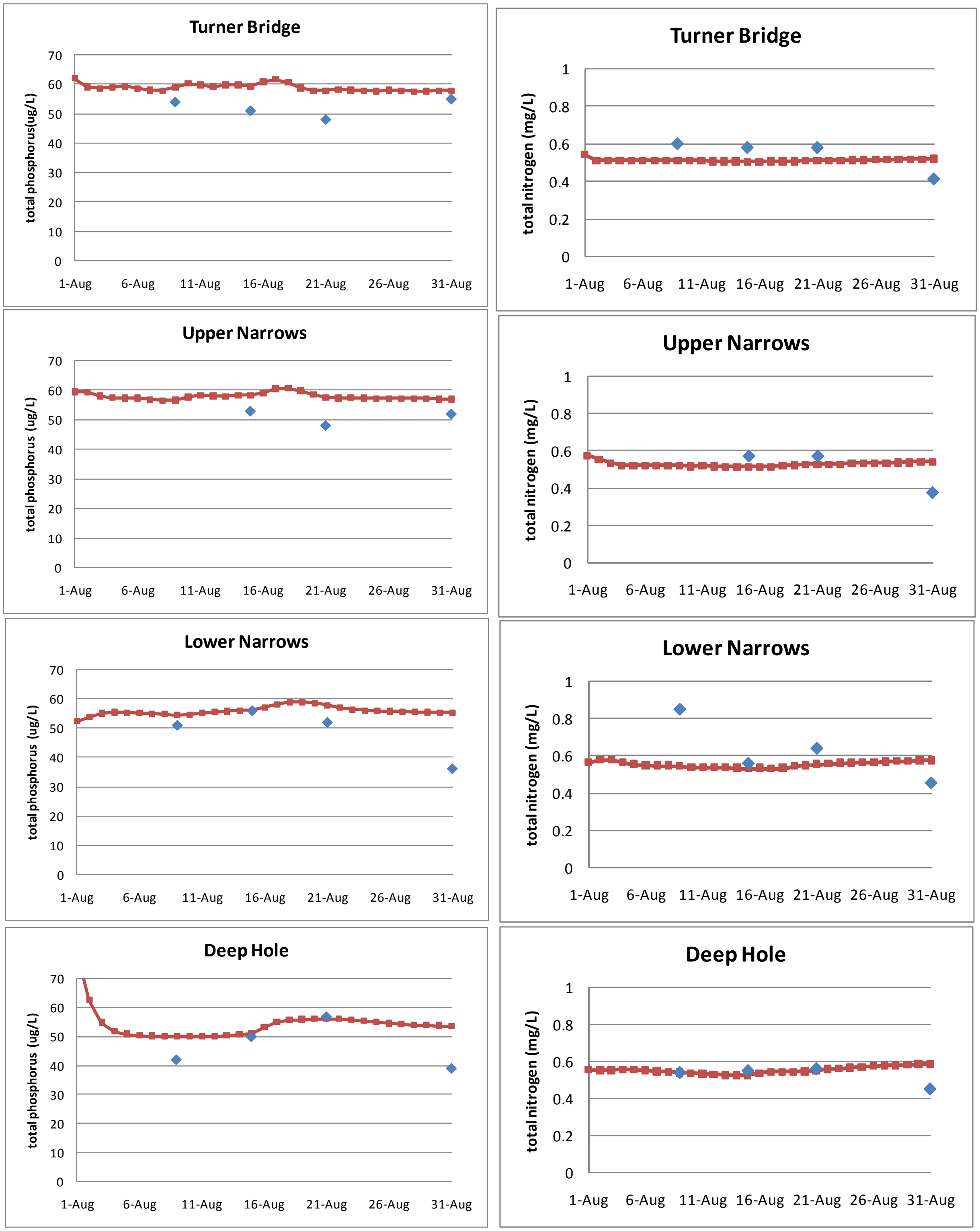


Figure 19. August 2000 simulated (red lines) and measured (blue dots) total phosphorus and total nitrogen in Gulf Island Pond.

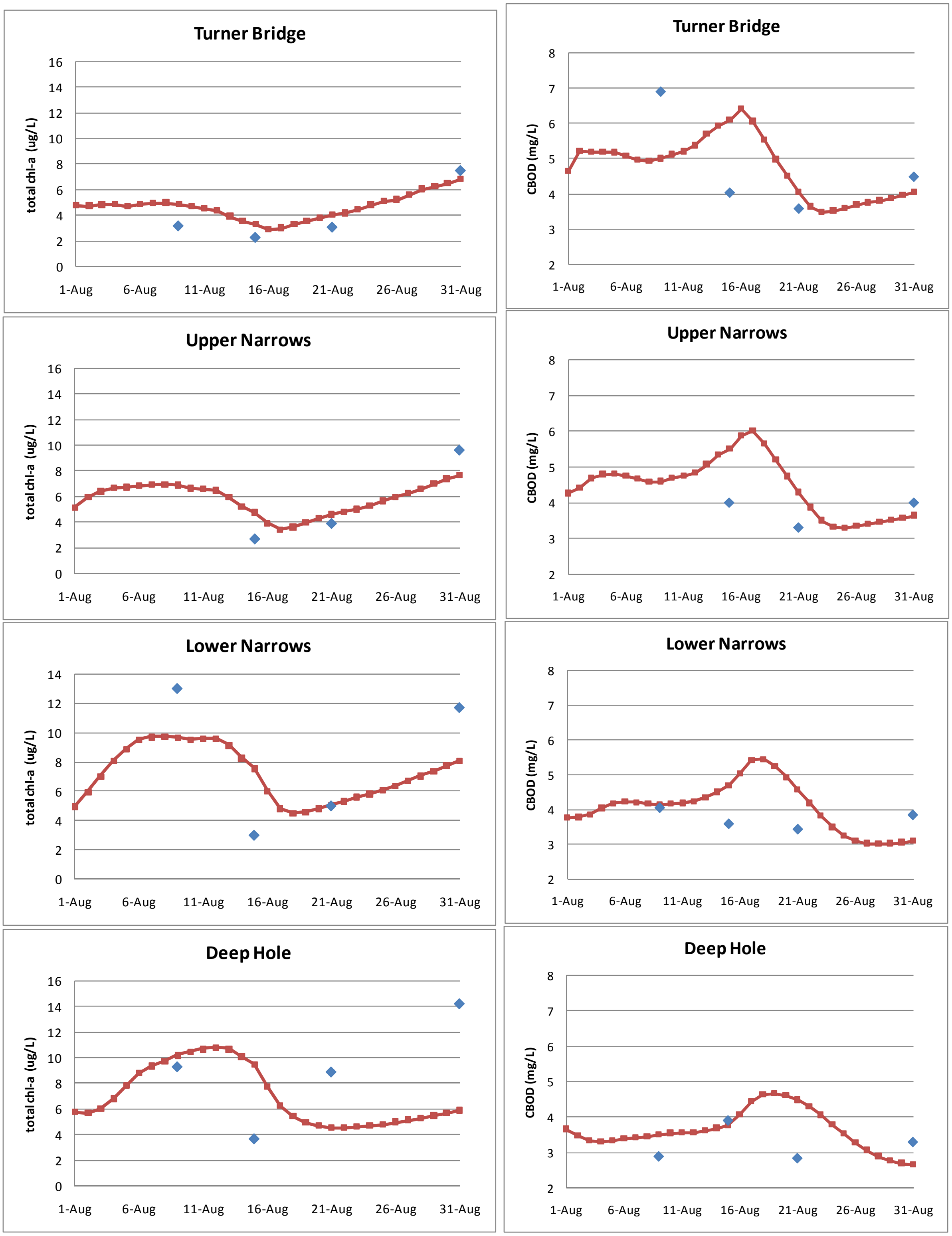


Figure 20. August 2000 simulated (red lines) and measured (blue dots) concentrations of chlorophyll-*a* and carbonaceous biochemical oxygen demand in Gulf Island Pond.

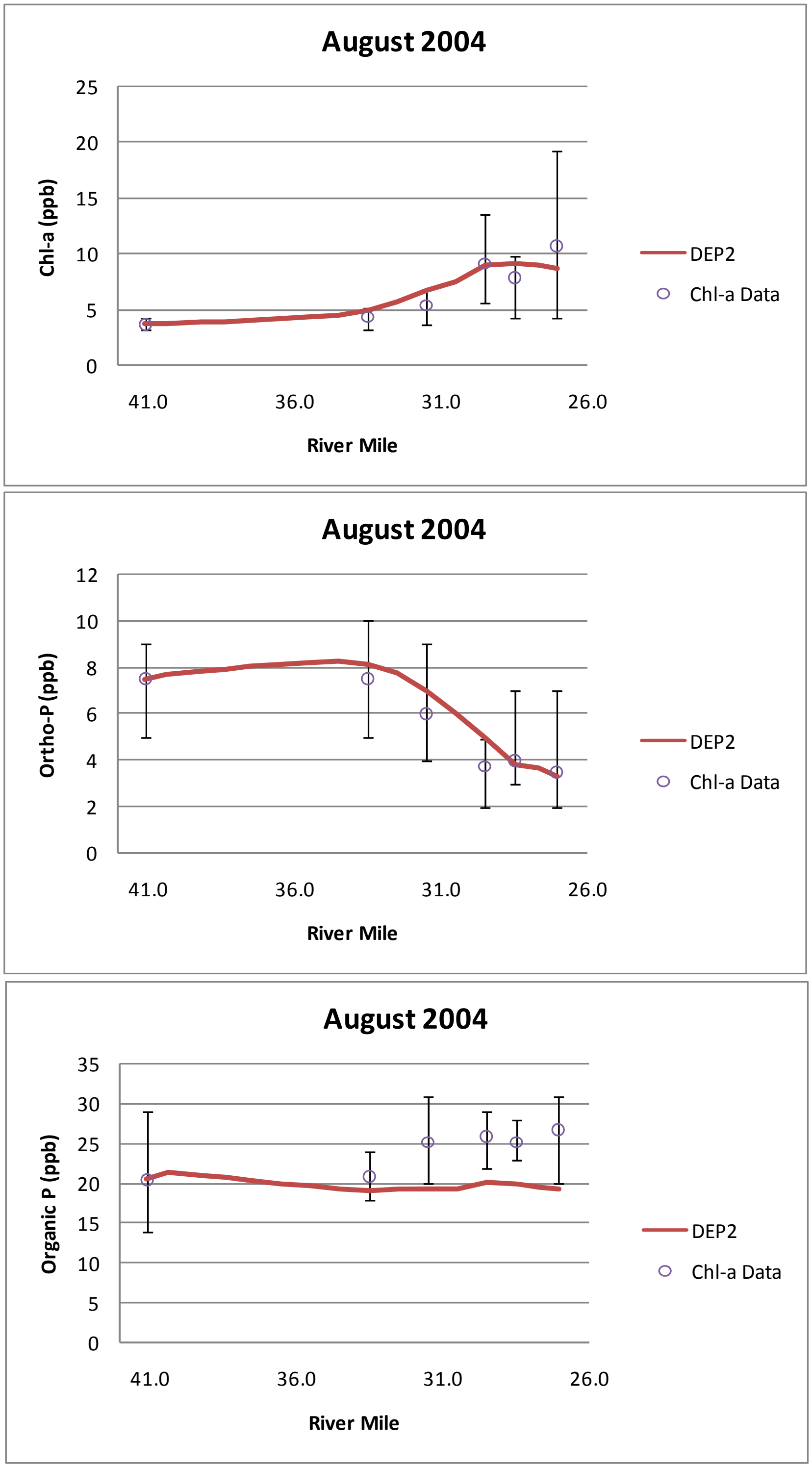


Figure 21. August 2004 average, minimum, and maximum measured concentrations and steady-state simulated concentrations of chlorophyll-*a*, orthophosphate, and organic phosphorus.

3 Oxygen Injection Requirements

The oxygen injection requirements in Gulf Island Pond for the condition of no upstream point sources in the Androscoggin River were estimated using the newly calibrated model. Oxygen injection requirements for the Upper Narrows system were analyzed as follows:

1. The dissolved oxygen concentration within Gulf Island Pond was simulated using the recalibrated WASP Gulf Island Pond model with a specified flow equivalent to the estimated 7Q10 rate of flow (1704 cfs). Upstream water quality boundary conditions were set to values representative of no upstream point sources within the Androscoggin River. These were obtained from results of the Androscoggin River QUAL2E model with zero discharge at all point sources. After execution of the WASP model, compliance with a dissolved oxygen water quality standard of 5 mg/L above a depth of 60 feet was assessed for the simulated dissolved oxygen in each of the model segments.

2. The WASP model was then modified to represent an oxygen injection of 105,000 pounds per day at the Upper Narrows (model segments 14, 15 and 16), while the upstream boundary conditions and rate of flow were left unchanged from the scenario described in (1) above. Again, the simulated dissolved oxygen concentrations in each segment less than 60 feet in depth were compared to the 5 mg/L standard.

3. Finally, the minimum rate of oxygen injection at the Upper Narrows for which the GIP would still meet the 5 mg/L dissolved oxygen concentration was evaluated by running the model at different rates of oxygen injection and comparing the model results to the 5 mg/L standard.

As in the case of prior TMDL simulations described in Mitnik (2005):

- WASP calculations were carried out for a simulation time of 30 days with a fixed rate of flow and fixed upstream boundary conditions. The day-30 result was taken to be representative of the steady-state result under the specified conditions.

- The regulatory limit for dissolved oxygen was applied to an estimate of the daily minimum dissolved oxygen concentration. To convert the simulated dissolved oxygen concentration to a daily minimum, the simulated dissolved oxygen concentration was adjusted downward using a method based on the statistical analysis of measurements of dissolved oxygen diurnal variability from the summers of 1998, 1999 and 2000. The method is described in Mitnik (2002) and was previously implemented in TMDL simulations in Mitnik (2005). For surface segments, the dissolved oxygen concentration was adjusted as a linear function of the chlorophyll concentration in ppb: Δ(dissolved oxygen) = 0.015 x (chl-*a*) + 0.51. For subsurface segments, the daily minimum dissolved oxygen was taken to be a value simply 0.4 ppb less than the simulated value.

The upstream boundary conditions used in this analysis were obtained from QUAL2E simulations described in Mitnik (2002). The boundary condition concentrations are shown in Table 7.

Figure 22 shows the simulated minimum dissolved oxygen values at each segment for the 7Q10 flow, no-point-source scenario with no oxygen injection. Twelve model segments above a depth of 60 feet were found to have simulated dissolved oxygen concentrations less than the 5 mg/L water quality standard.

Table 7. Upstream Boundary Concentrations Used in Simulation of Oxygen Analysis Requirements

Analyte	Concentration (mg/L)
Ammonia as N	0.02
Nitrite and Nitrate as N	0.12
Orthophosphate as P	0.004
Chlorophyll-*a*	0.0025
Carbonaceous Biochemical Oxygen Demand	2.2
Dissolved Oxygen	7.8
Organic Nitrogen as N	0.14
Organic Phosphorus as P	0.013

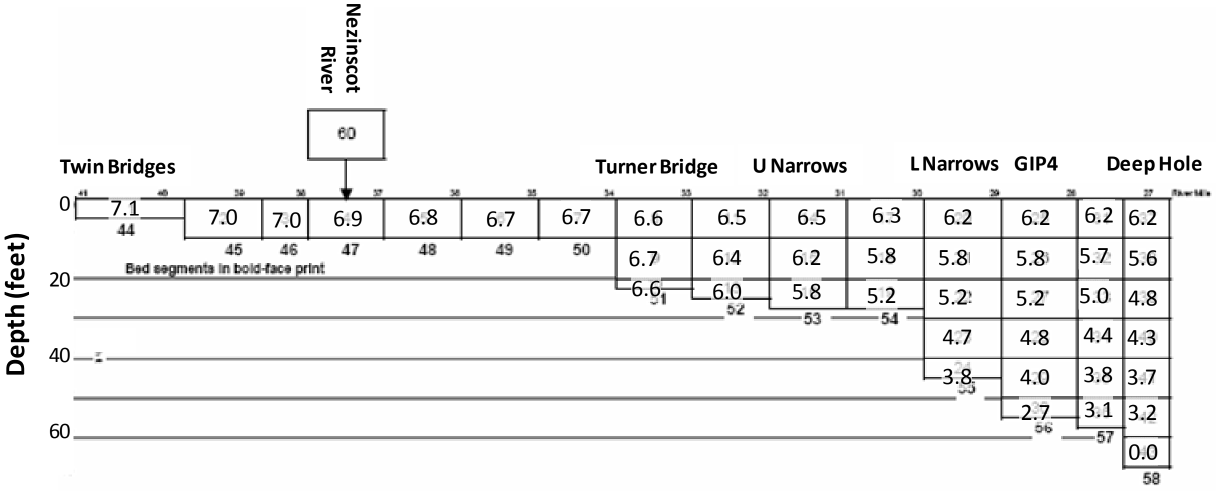


Figure 22. Simulated dissolved oxygen concentration at 7Q10 flow with no upstream point sources and no oxygen injection.

Simulations were next performed to calculate the dissolved oxygen concentration in Gulf Island Pond under the same scenario, but with oxygen injection at Upper Narrows. Initially, an injection rate of 105,000 pounds per day was simulated with a transfer efficiency of 33 percent. Per the convention utilized by Mitnik in previous simulations, one-third of the injected oxygen was assumed to be taken up by each of the three segments in the water column at that location. The uppermost two segments at that location (segments 14 and 15) have a thickness of 10 feet, while the deepest segment (segment 16) has a thickness of 7.0 feet. The location of segments 14, 15, and 16 are shown in Figure 1. Since the pounds of oxygen uptake was divided equally between the segments, the simulated water uptake rate of oxygen in pounds per unit water height is 43 percent higher in the deepest segment. Figure 23 shows the simulated minimum dissolved oxygen for this initial simulation of dissolved oxygen injection at Upper Narrows.

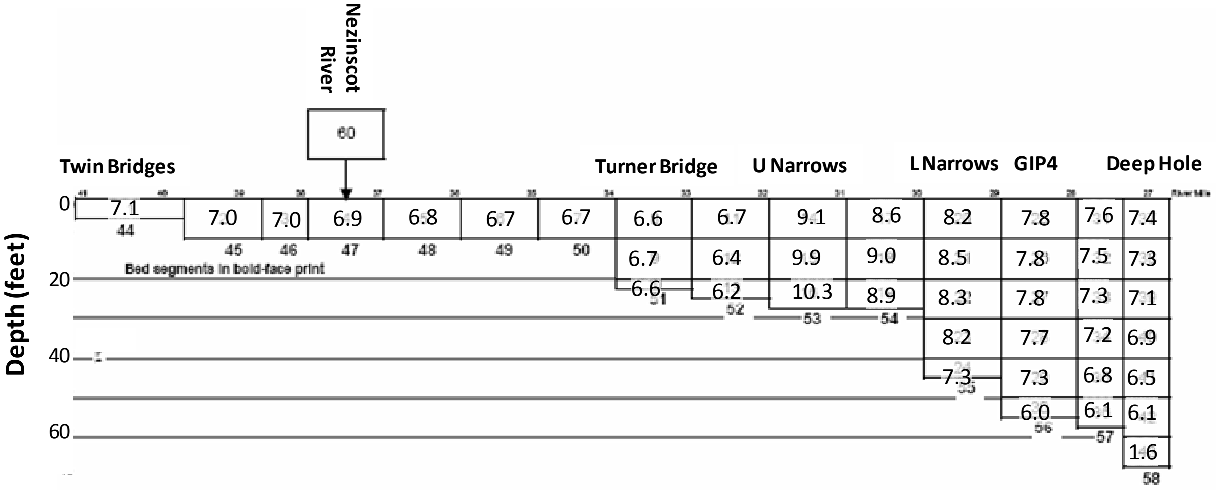


Figure 23. Simulated dissolved oxygen concentration at 7Q10 flow with no upstream point sources and dissolved oxygen injection at Upper Narrows of 105,000 pounds per day with 33 percent transfer efficiency.

In order to determine the oxygen injection requirement, the rate of injection was varied over a range of 40,000 pounds per day to 105,000 pounds per day. In each case, the simulated dissolved oxygen was adjusted as described above to convert the simulated results to an estimate of the daily minimum dissolved oxygen concentration. The minimum concentration over all segments shallower than 60 feet was then found and plotted versus the rate of oxygen injection. Figure 24 show the minimum Gulf Island Pond dissolved oxygen concentration as a function of the rate of oxygen injection at the existing 33% oxygen transfer rate. A daily minimum dissolved oxygen concentration equivalent to the regulatory standard of 5.0 mg/L was achieved at all segments at an oxygen injection rate of 73,000 pounds per day. This is equivalent to an oxygen transfer to the Gulf Island Pond of approximately 24,000 pounds per day. The model segment dissolved oxygen concentrations for this scenario are shown in Figure 25.

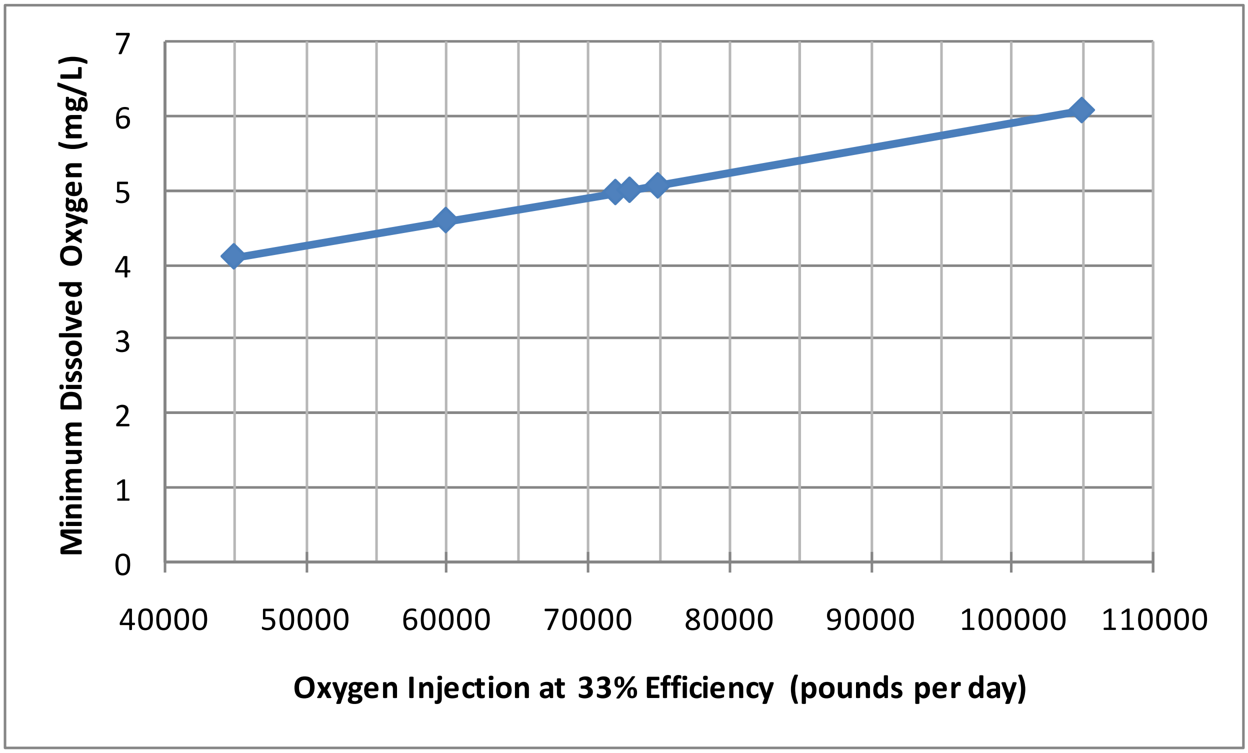


Figure 24. Model-wide minimum Gulf Island Pond dissolved oxygen as function of rate of oxygen injection at Upper Narrows.

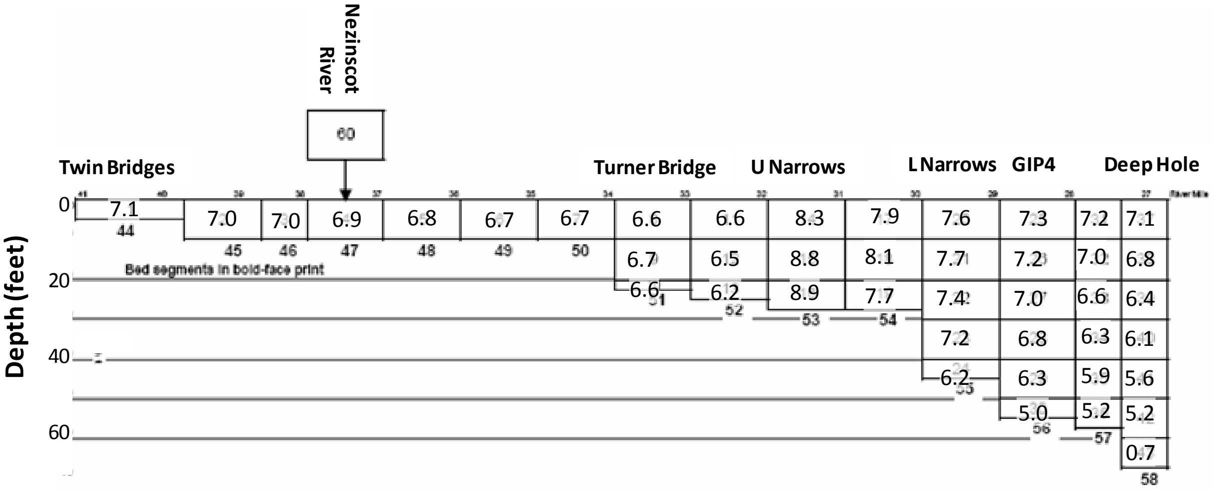


Figure 25. Simulated dissolved oxygen concentrations at 7Q10 flow with no upstream point sources and dissolved oxygen injection at Upper Narrows of 73,000 ponds per day with 33% oxygen transfer efficiency.

An alternative, high efficiency oxygen delivery system has been approved that would provide a 54 percent oxygen transfer rate. In order to achieve the same oxygen delivery of 24,000 pounds per day, this higher efficiency system would require an injection rate of 45,000 pounds per day of oxygen. This would result in compliance with the regulatory standard of 5 mg/L dissolved oxygen at all locations above a depth of 60 feet (Figures 26 and 27).

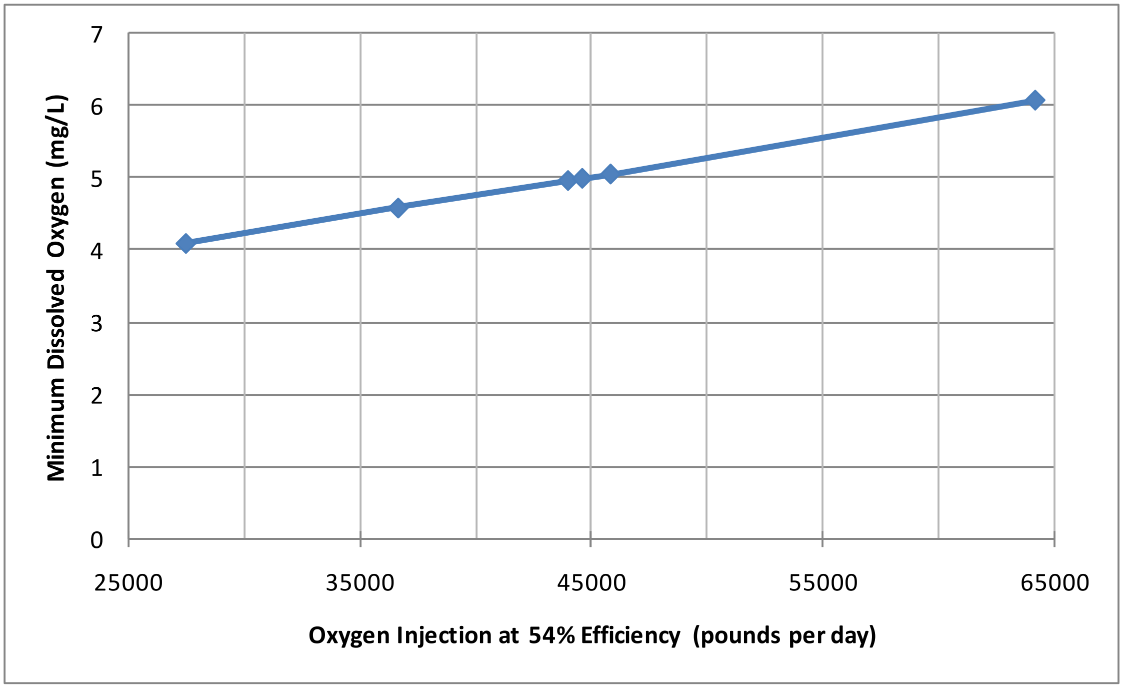


Figure 26. Model-wide minimum Gulf Island Pond dissolved oxygen as function of rate of oxygen injection at Upper Narrows.

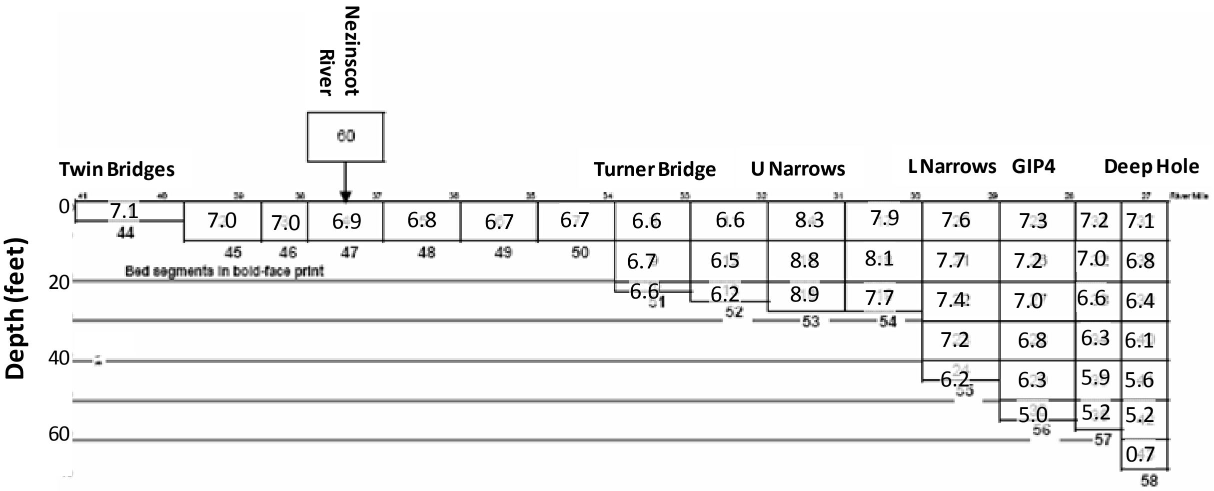


Figure 27. Simulated dissolved oxygen concentrations at 7Q10 flow with no upstream point sources and dissolved oxygen injection at Upper Narrows of 45,000 ponds per day with 54% oxygen transfer efficiency.

4 Allowable Phosphorus Load

The allowable phosphorus load to the Gulf Island Pond was reevaluated using the newly calibrated WASP model of Gulf Island Pond. First the QUAL2E model of Androscoggin River was run to obtain upstream phosphorus concentrations to the Gulf Island Pond. Then the WASP model was run with a range of phosphorus loadings to arrive at an estimate of the maximum phosphorus loading rate for which the simulated Gulf Island Pond chlorophyll-*a* concentration would still be in compliance with the adopted chlorophyll-*a* standard. The details of this procedure are as follows:

1. The QUAL2E model for Androscoggin River that had been constructed by Mitnik (2005) for the simulation of phosphorus was employed in determining the upstream phosphorus concentration in the Gulf Island Pond. At the direction of the Maine DEP the municipal phosphorus loadings in this model of the Androscoggin River were set at 1.5 times the measured 2004 discharge rates reported in Table 6 of Mitnik (2005), with the exception of the orthophosphate load from Livermore Falls, which was set at its permitted rate. This is consistent with the simulated phosphorus discharges used in TMDL simulations carried out by Mitnik (2005), who also used phosphorus loading from municipal sources at 1.5 times their measured values. The loading rates for the municipal discharges were set above their measured values in order to account for future growth and to provide for a factor of safety with respect to the phosphorus loading. The mill phosphorus loadings were set in this model to their licensed rates. The simulated point-source discharge rates are shown in Table 8.

2. The Gulf Island Pond WASP model was run using upstream water quality concentrations based on the results of the Androscoggin River QUAL2E model, with the discharge loadings as described in (1). The simulated chlorophyll-*a* concentrations in five model segments (8, 14, 20, 25, and 37) were then averaged for comparison to the adopted 10 ppb chlorophyll-*a* standard. This is consistent with the method used by Mitnik (2005) in estimation of the *pond-average* chlorophyll-*a* concentration. These five model segments are coincident with the shallow measurements of chlorophyll-*a* at locations referred to as Turner, Upper Narrows, Lower Narrows, Deep Hole, and GIP4.

3. The WASP model was then run with a range of phosphorus loading concentrations. These multiple simulations were used to estimate the upstream phosphorus loading rate that resulted in a *pond-average* chlorophyll-*a* concentration of 10 ppb. This procedure was carried out for two scenarios. In the first, the upstream organic phosphorus concentration was held constant and the orthophosphate concentration increased over some range. In the second scenario, the upstream orthophosphate concentration was held constant and the organic phosphorus concentration was increased.

Table 8. Androscoggin River Phosphorus Loading Rates Used in Allowable Phosphorus Load Calculations

Source	Discharge Flow (cfs)	Organic P Concentration (mg/L)	Orthophosphate Concentration (mg/L)	Organic P Load (pounds/day)	Orthophosphate Load (pounds/day)
Towns					
Berlin	4.09	0.12	0.78	2.6	17.2
Gorham	1.16	0.16	1.9	1.0	11.9
Bethel	0.47	0.28	2.72	0.7	6.9
Rumford-Mex	4.1	0.2	1.22	4.4	27.0
Livermore Falls	3.1	0.08	0.50	1.3	8.3
Mills					
Fraser Cascade	23.2	0.38	0.65	47.5	81.5
Rumford	52.6	0.19	0.34	55	97
Verso	78.9	0.25	0.05	106	22

In all of the phosphorus loading scenarios run using the GIP WASP model, the upstream chlorophyll-*a* concentration to Gulf Island Pond was held at a constant 6.5 ppb. This value was derived from previous QUAL2E simulations of the Androscoggin River with point sources at licensed discharge rates described in Mitnik (2005) and is consistent with the procedure employed in the phosphorus TMDL simulations in that report. The 6.5 ppb chlorophyll-*a* concentration is near the upper end of the measured concentrations at Twin Bridges during the summer of 2004. The measured values are shown in Figure 28 (reproduced from figure 1 of Mitnik (2005)). As noted in Mitnik (2005), the Androscoggin River QUAL2E model was not calibrated for chlorophyll-*a* due to the absence of measurements along its length.

Table 9 shows the phosphorus concentrations predicted by the QUAL2E Androscoggin River model at the downstream end of the Androscoggin River model for the loading rates described in Table 8. The loading rate shown in Table 9 is the loading rate to the downstream Gulf Island Pond that is derived from the QUAL2E Androscoggin River model. The resultant simulated model segment chlorophyll-*a* concentrations in Gulf Island Pond are shown in Figure 29. The shaded elements in that figure show the model segments used in the calculation of the *pond-average* chlorophyll-*a* concentration.

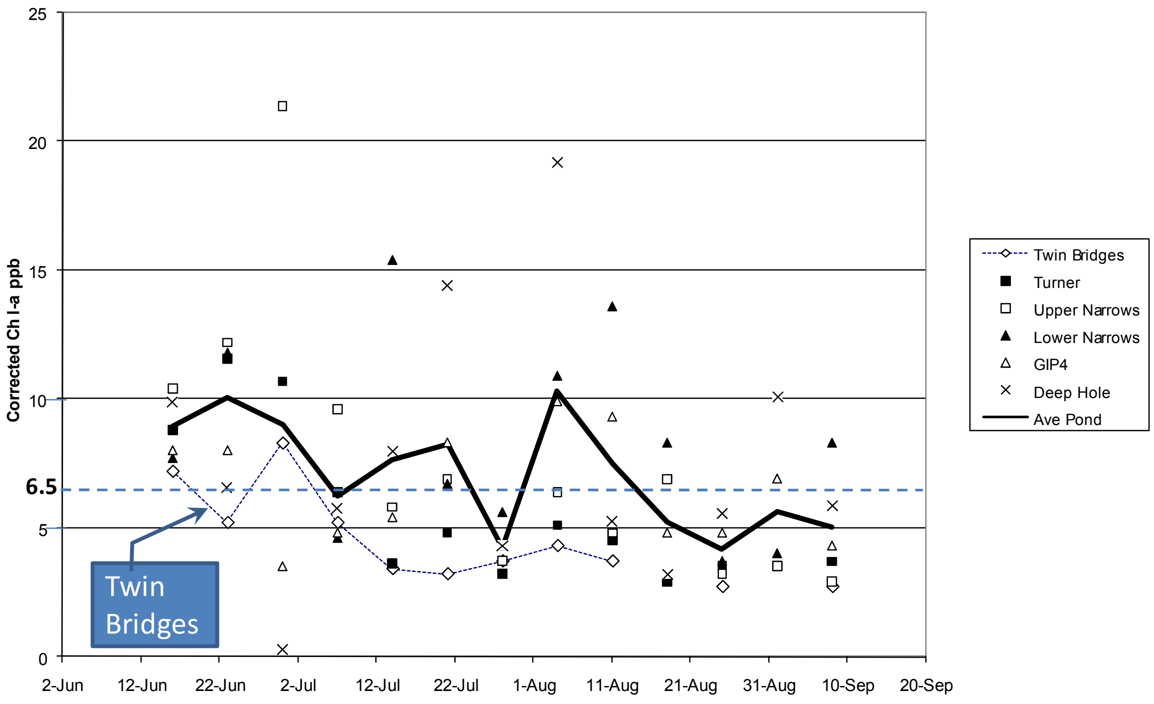


Figure 28. Measured summer 2004 chlorophyll-*a* concentration at multiple locations in Gulf Island Pond, including most upstream measurement at Twin Bridges

Table 9. Simulated Downstream Androscoggin River Phosphorus Concentrations and Loading Rates

Analyte	Concentration (mg/L)	Loading Rate (pounds/day)
Organic Phosphorus	0.0278	256
Orthophosphate	0.0055	50

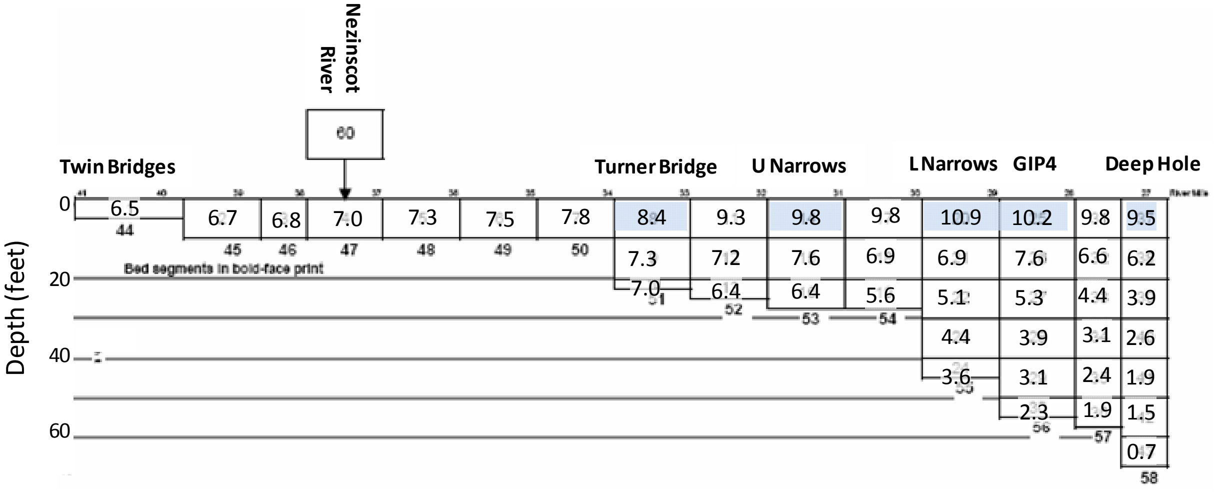


Figure 29. Simulated chlorophyll-*a* concentration at 7Q10 flow with upstream chlorophyll-*a* concentration of 6.5 ppb and phosphorus loading rates to Gulf Island Pond listed in Table 9, where shaded cells indicate cells used in calculation of *pond-average* chlorophyll-*a*.

Figure 30 shows the *pond-average* chlorophyll-*a* concentration for orthophosphate loading rates varying between 50 and 64 pounds per day, and for upstream chlorophyll-*a* concentration of 6.5 ppb. In each of these simulations, the organic phosphorus loading rate was held constant at 256 pounds per day. For an upstream chlorophyll-*a* concentration of 6.5 ppb, an orthophosphate loading rate of 56 pounds per day results in a *pond-average* chlorophyll-*a* concentration of 10 ppb.

Figure 31 shows the resultant pond average chlorophyll-*a* concentration for organic phosphorus loading rates varying from 255 to 312 pounds per day. For the scenarios presented in Figure 31, the orthophosphate concentration is held at a constant loading rate of 50 pounds per day. A *pond-average* chlorophyll-*a* concentration of 10 ppb is achieved under these circumstances at an organic phosphorus loading rate of 277 pounds per day.

Table 10 provides a summary of the allowable phosphorus calculations. The loading rates shown in this table are the phosphorus loadings to Gulf Island Pond that result in a *pond-average* chlorophyll-*a* concentration of 10 ppb. The first row, Alternative 1, was found by holding the organic phosphorus loading constant and increasing the orthophosphate loading rate, while Alternative 2 was arrived at by holding the orthophosphate loading constant and increasing the organic phosphorus loading rate. The TMDL loading rate arrived at by Mitnik (2005) is shown in the third row of this table for comparison to the results of prior TMDL calculations.

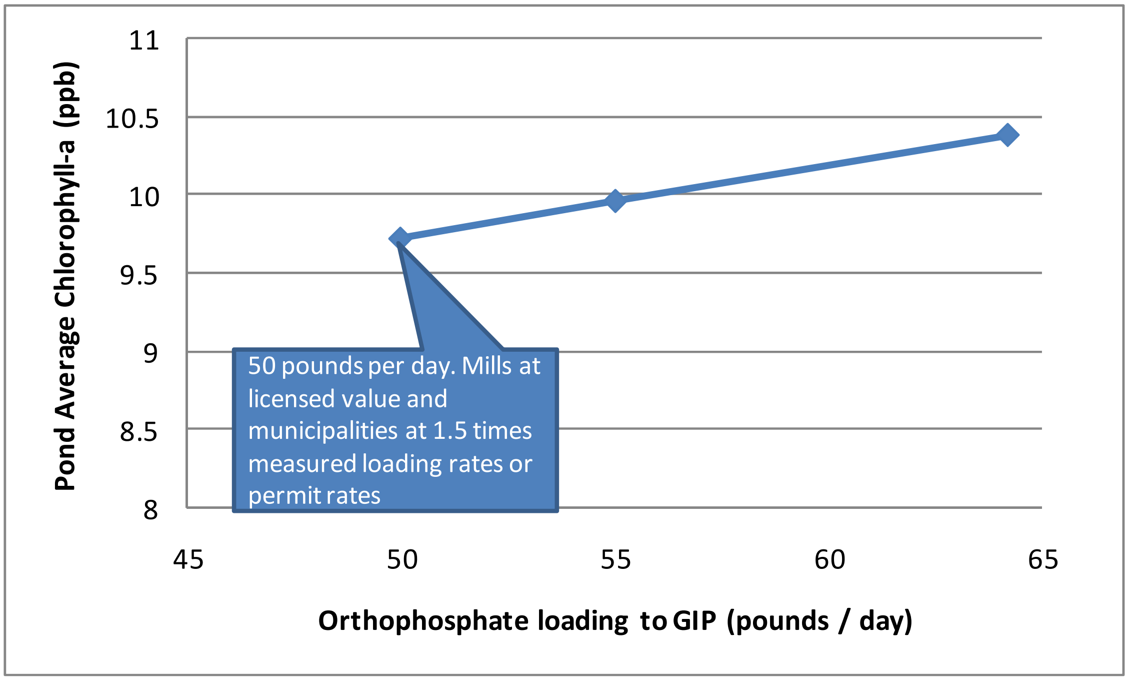


Figure 30. Simulated *pond-average* chlorophyll-*a* concentration as a function of orthophosphate loading to Gulf Island Pond in pounds per day, with organic phosphorus loading held at constant 256 pounds per day.

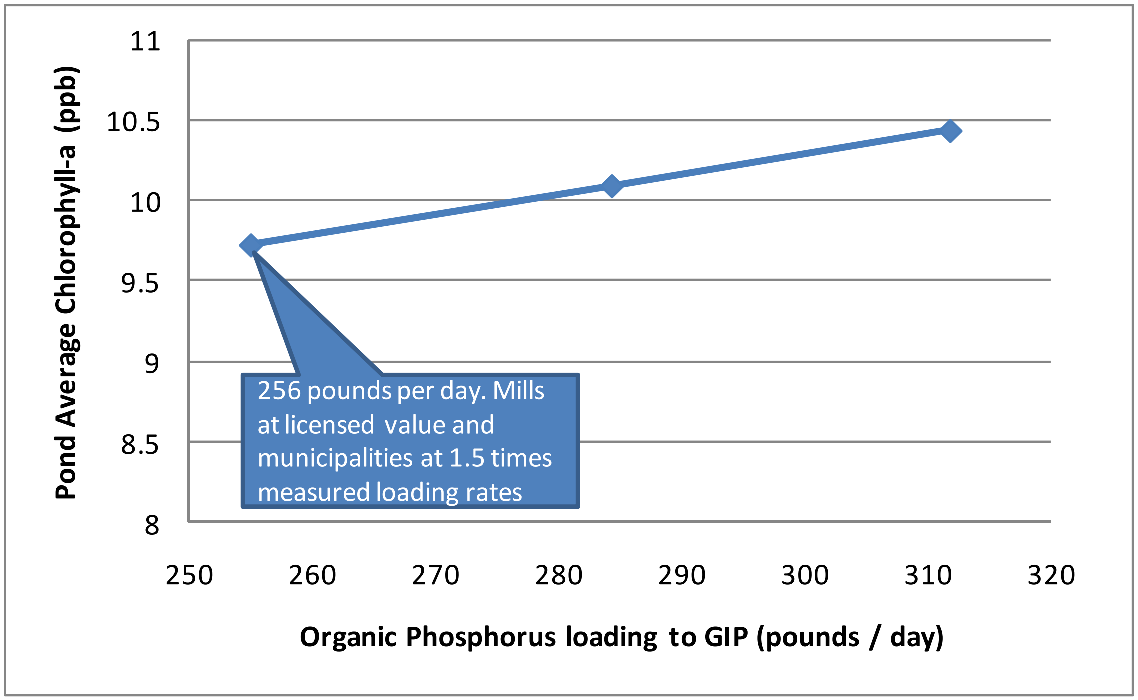


Figure 31. Simulated *pond-average* chlorophyll-*a* concentration as a function of organic phosphorus loading to Gulf Island Pond in pounds per day, with orthophosphate loading held at constant 50 pounds per day.

Table 10. Alternative Loading Scenarios to Gulf Island Pond that Meet Chlorophyll-*a* Standard

Analyte	Organic Phosphorus (pounds/day)	Orthophosphate (pounds/day)	Total Phosphorus (pounds/day)
Alternative 1	256	56	312
Alternative 2	277	50	327
TMDL from Mitnik (2005; ”Default Option” of Table 3)	267	50	317

5 Summary of Findings

The Gulf Island Pond water quality model was recalibrated by modifying the benthic phosphate flux rates to obtain a spatially uniform benthic flux rate and by recalibrating after the elimination of non-physical dispersion exchanges through the downstream dam. The calibration targets used by both Mitnik (2002) and Mitnik (2005) were used in this recalibration exercise with one additional measurement point immediately upstream of the dam at a depth of 50 feet. Initially, the model was calibrated to average conditions for four water quality data sets collected during the summers of 1998, 2000, and 2004. This effort focused on the concentrations of orthophosphate, organic phosphorus, and chlorophyll-*a*. The benthic phosphate flux rate was set so as to obtain a uniform flux rate at all segments on a per-area basis and the flux rate was then increased relative to the prior calibration to offset reductions in the simulated orthophosphate concentrations. The vertical exchange coefficients were also increased to increase the orthophosphate concentrations in the overlying shallow segments in the downstream portion of the model.

Next, the temporally variable model of the August 2000 conditions was calibrated to time series measurements originally described by Mitnik (2002). These measurements include dissolved oxygen at various depths and times during August 2000. The biochemical rates and constants calibrated to the 2004 dataset were introduced into this model. The vertical exchange coefficient was then increased to obtain a reasonable match to measured dissolved oxygen. Time-varying exchange coefficients were implemented to achieve a representation of the nil dissolved oxygen at the near-dam location during the first two weeks of the month and the relatively high dissolved oxygen at this same location during the final two weeks.

The recalibration effort was further refined by calibration to the August 2000 dissolved oxygen measurements at a depth of 50 feet, immediately upstream of the dam. This entailed the modification of the simulated Gulf Island Pond flow field in the WASP model to increase the flow through the deeper portion of the pond. This increased the dissolved oxygen concentrations at this depth resulting in a more faithful representation of the measured values.

The oxygen injection requirement for Upper Narrows was evaluated by determining the minimum oxygen injection rate that would result in compliance with the dissolved oxygen standard in Gulf Island Pond, under the condition of no upstream point sources. In this case, the QUAL2E model of the Androscoggin River was used to determine the upstream boundary condition concentrations in Gulf Island Pond. Then the Gulf Island Pond WASP model was run for a range of oxygen injection rates between 45,000 pounds per day and 105,000 pounds per day with a transfer efficiency of 33 percent. The required injection rates was determined as the rate that resulted in a simulated dissolved oxygen concentration of 5.0 mg/L or greater at all nodes less than 60 feet deep. The estimated minimum required oxygen injection is 73,000 pounds per day with a transfer efficiency of 33 percent and 45,000 pounds per day with a transfer efficiency of 54 percent.

The allowable phosphorus load to Gulf Island Pond was estimated as the maximum orthophosphate and organic phosphorus loading rates at the upstream end of Gulf Island Pond that for which the pond remains in compliance with the 10-ppb *pond-average* chlorophyll-*a* concentration water quality standard that has been adopted specifically for Gulf Island Pond. As discussed in Mitnik (2005), the *pond-average* concentration is taken as the average chlorophyll-*a* concentration at the five model segments that coincide with the location of chlorophyll-*a* measurements in Gulf Island Pond.

The allowable phosphorus load was arrived at in two stages. In the first stage, the Androscoggin River QUAL2E model and the Gulf Island Pond WASP model were run in sequence to determine the conditions in Gulf Island Pond that result from the upstream mill sources discharging at their licensed rates and the upstream municipal point sources discharging at 1.5 times the measured 2004 discharge rates. This resulted in a base case scenario.

Then in the second phase, the Gulf Island Pond upstream organic phosphorus and orthophosphate concentrations were increased relative to this base case scenario to determine the phosphorus loadings that would result in a 10-ppb *pond-average* chlorophyll-*a* concentration. This resulted in two feasible alternative phosphorus loads – one found by increasing the orthophosphate concentration relative to the base case scenario and the second found by increasing the organic phosphorus concentration relative to the base case scenario. The two alternatives were:

- 56 pounds per day of orthophosphate and 256 pounds per day of organic phosphorus and
- 50 pounds per day of orthophosphate and 277 pounds per day of organic phosphorus.

This is comparable to the TMDL load arrived at by Mitnik (2005) of 50 pounds per day of orthophosphate and 267 pounds per day of organic phosphorus.

6 References

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Appendix D

Assessment of Oxygen Injection Requirements Under Licensed Discharge Conditions

(HydroAnalysis, Inc., April 13, 2009)

Hydro Analysis

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33 Clark Road, No. 1
Brookline, Massachusetts 02445
(617) 879-0253

April 13, 2009

Ref: J418-009

Mr. Dave Courtemanch
Maine Department of Environmental Protection
Bureau of Land and Water Quality
17 Statehouse Station
Augusta, Maine 04333-0017

Dear Mr. Courtemanch:

HydroAnalysis (2009) previously carried out an analysis of the oxygen injection requirements at the Upper Narrows of the Gulf Island Pond. In that case, the required rate of oxygen injection was determined for the condition of no upstream point sources within the Androscoggin River. Subsequently, the Maine Department of Environmental Protection (DEP) has requested that HydroAnalysis expand that analysis to determine the oxygen injection requirements for a case where all upstream point sources are discharging into the Androscoggin River at their permitted rate or some other rate representative of a maximum expected condition. This memo describes the response to this request from the DEP.

The simulated point load discharge rates and concentrations in the Androscoggin River were derived from both effluent permits and measured discharge concentrations described in Tables 1 through 3. Table 1 contains the effluent permit discharge flow and loading rates for biochemical oxygen demand, total phosphorus and orthophosphate. The discharge rates in Table 1 are the weekly average limit, where available, and the monthly average limit, where no weekly limit has been specified. Table 2 contains the average discharge concentrations for the years 1998 through 2000 for three analytes from the five municipal point sources in the Androscoggin River. Table 3 shows the summer 1994 phosphorus loads in pounds per day from the municipal sources. Table 4 shows the 95th percentile discharge concentrations from mills for the years 1998 through 2000. Table 5 shows the presumed discharge concentrations that were used for municipal and mill point sources in Mitnik (2002) when no other information was available from which to determine the simulated concentration.

The simulated point-load characteristics were determined as follows:

(1) Where effluent permit values were available the simulated concentrations were set to the values laid out in the effluent permit (as contained in Table 1).

(2) For municipal sources, the simulated concentration of total Kjeldahl nitrogen, nitrate and ammonia were set to the 95th percentile of measured concentrations between 1998 and 2000 (as contained in Table 2).

(3) For municipal sources, the simulated organic phosphorus and orthophospate concentration were set to obtain a loading rate that is 50 percent greater than the summer 2004 measured phosphorus loads in pounds per day (as contained in Table 3). The one exception is Livermore Falls, which has a regulatory limit of 8.3 pounds per day of orthophosphate.

(4) For mill sources, in the event that there were no effluent limitations for particular analytes then the average concentrations measured between 1998 and 2000 (as contained in Table 4) was used as the simulated value.

(5) If neither effluent permit limits nor measured concentrations were available for particular analytes then the simulated concentration was set to the values shown in Table 5.

Table 6 shows the simulated point source concentrations resulting from the application of this procedure. Table 7 contains the simulated downstream concentrations obtained from the QUAL2E model of the Androscoggin River with the point source loads set to the values presented in Table 6.

The WASP model of Gulf Island Pond was run with the upstream boundary condition concentrations set to the values in Table 7. The oxygen injection rate was set initially to a rate of 45,000 pounds per day of oxygen at Upper Narrows with a transfer efficiency of 54 percent. The WASP model was run and the daily minimum oxygen concentration at each segment estimated based on the method described in Mitnik (2002). The resultant model segment dissolved oxygen concentrations are shown in Figure 1.

The oxygen injection rate was then incremented in order to determine the rate of oxygen injection for which the simulated dissolved oxygen concentration is at least 5 mg/L for all segments with a depth less than 60 feet. The model-wide, minimum oxygen concentration with a depth less than 60 feet is shown versus the rate of oxygen injection in Figure 2. Compliance with the regulatory standard of 5 mg/L dissolved oxygen at all locations above a depth of 60 feet is achieved for an injection rate of 94,000 pounds per day. There is a flattening of the curve in Figure 2 for injection rates greater than 94,000 pounds per day. This is due to points upstream of Upper Narrows that are not impacted by oxygen injection at that location.

Please contact me should you have any questions on the calculations described in this letter.

Sincerely,

Bruce Jacobs

Bruce L. Jacobs, Ph.D., P.E.

Table 1. Effluent Permit Discharge Rates – Weekly Average Maximum Unless Otherwise Specified

Source	Discharge Flow (cfs)	5-Day Biochemical Oxygen Demand (pounds per day)	Total Phosphorus (pounds per day)	Ortho-phosphate (pounds per day
Towns				
Berlin	4.09	991	N/A	N/A
Gorham	1.16	N/A	N/A	N/A
Bethel	0.47	128	N/A	N/A
Rumford-Mex	4.1	995	N/A	N/A
Livermore Falls	3.1	750	N/A	8.3(1)
Mills				
Fraser Cascade	23.2	10298	129	N/A
Rumford	52.6	12500	152(1)	97(1)
Verso	78.9	6400	130(1)	22(1)

(1) Monthly average discharge rate limit

Table 2. Average Municipal Discharge Concentrations for 1998 – 2000 (from Table 9 of Mitnik, 2002)

Source	Total Kjeldahl Nitrogen (mg/L)	Ammonia-N (mg/L)	Nitrate-N (mg/L)
Berlin	15.3	6.3	N/A
Gorham	N/A	N/A	N/A
Bethel	N/A	N/A	N/A
Rumford-Mex	19.7	17.2	2.7
Livermore Falls	13.6	8.87	1.18

Table 3. Average Summer 2004 Municipal Phosphorus Discharge Loads (from Table 6 of Mitnik, 2005)

Source	Organic Phosphorus (lb/day)	Ortho-phosphate (lb/day)
Berlin	1.7	11.4
Gorham	0.7	7.9
Bethel	0.5	4.5
Rumford-Mex	3.0	18.0
Livermore Falls	0.7	8.3

Table 4. 95th Percentile Mill Discharge Concentrations for 1998 – 2000 from Table 9 of Mitnik (2002)

Source	Total Kjeldahl Nitrogen (mg/L)	Ammonia-N (mg/L)	Nitrate-N (mg/L)	Ortho-phosphate (mg/L)	Organic Phosphorus (mg/L)
Fraser Cascade	4.38	1.78	N/A	0.04	0.01
Rumford	4.22	2.08	0.13	0.24	0.61
Verso	7.37	2.67	0.08	0.35	0.35

Table 5. Assumed Discharge Concentrations (from Table 9 of Mitnik, 2002)

Source	Total Kjeldahl Nitrogen(mg/L)	Ammonia-N (mg/L)	Nitrate-N (mg/L)
Mill	N/A	N/A	0.1
Municipal	16.2	10.8	2.0

Table 6. Simulated Discharge Rate and Concentration

Source	Discharge Flow (cfs)	BOD_U (3) (mg/L)	Organic N (mg/L)	Ammonia-N (mg/L)	Nitrate-N (mg/L)	Ortho-phosphate (mg/L)	Organic Phosphorus (mg/L)
Towns							
Berlin	4.09	135	9.0	6.3	2.0	0.78	0.12
Gorham	1.16	135	5.4	10.8	2.0	1.9	0.16
Bethel	0.53	135	5.4	10.8	2.0	2.72	0.28
Rumford-Mex	4.1	135	2.5	17.2	2.7	1.22	0.2
Livermore Falls	3.1	135	4.7	8.87	1.18	0.50	0.08
Mills							
Fraser Cascade	23.2	296	2.6	1.78	0.1	0.65(1)	0.38(1)
Rumford	52.6	159	2.1	2.08	0.13	0.34	0.19(2)
Verso	78.9	53	4.7	2.67	0.08	0.05	0.25(2)

(1) Fraser Cascade orthophosphate and organic phosphorus concentrations determined based on total phosphorus effluent limit and ratio of 1998 – 2000 average discharge concentrations

(2) Rumford and Verso organic phosphorus concentrations calculated based on difference between total phosphorus and orthophosphate effluent discharge limits

(3) $BOD_U/BOD_5 = 3.6$ for Fraser Cascade and Rumford; $BOD_U/BOD_5 = 3.5$ for Verso; and $BOD_U/BOD_5 = 3.0$ for all others

Table 7. Simulated Downstream Concentration in QUAL2E Model of Androscoggin River

Analyte	Simulated Concentration
DO (mg/L)	6.33
BOD (mg/L)	5.86
Organic Nitrogen as N (mg/L)	0.71
Ammonia as N (mg/L)	0.22
Nitrite as N (mg/L)	0.51
Nitrate as N (mg/L)	0.15
Organic Phosphorus as P (ug/L)	27.8
Dissolved Phosphorus as P (ug/L)	5.5
Algae as Chl-A (ug/L)	6.50

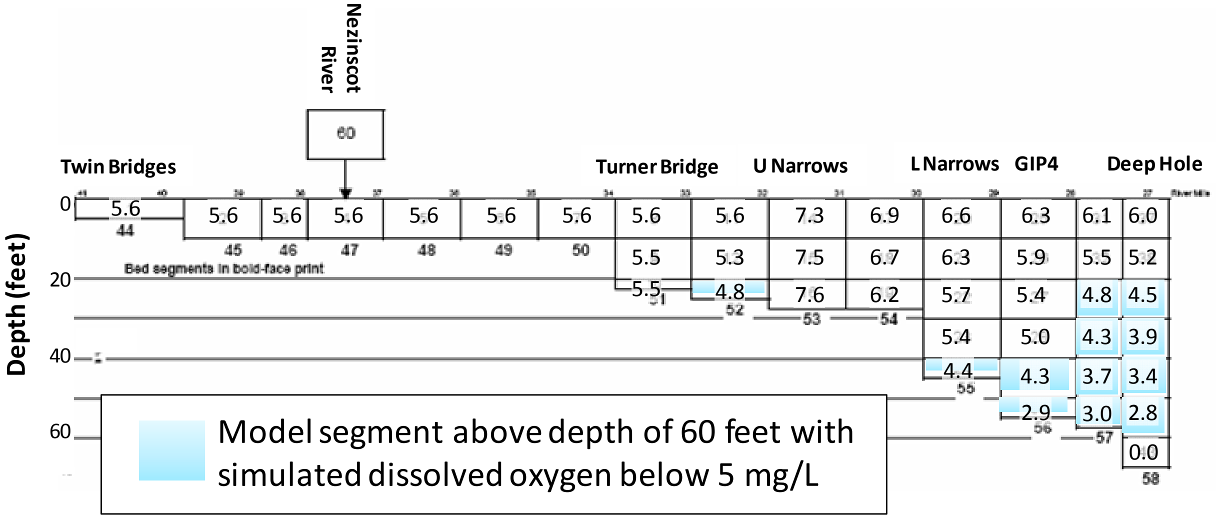

Figure 1. Simulated dissolved oxygen concentrations at 7Q10 flow with upstream point sources at maximum discharge rates and oxygen injection at Upper Narrows of 45,000 pounds per day with transfer efficiency of 54 percent

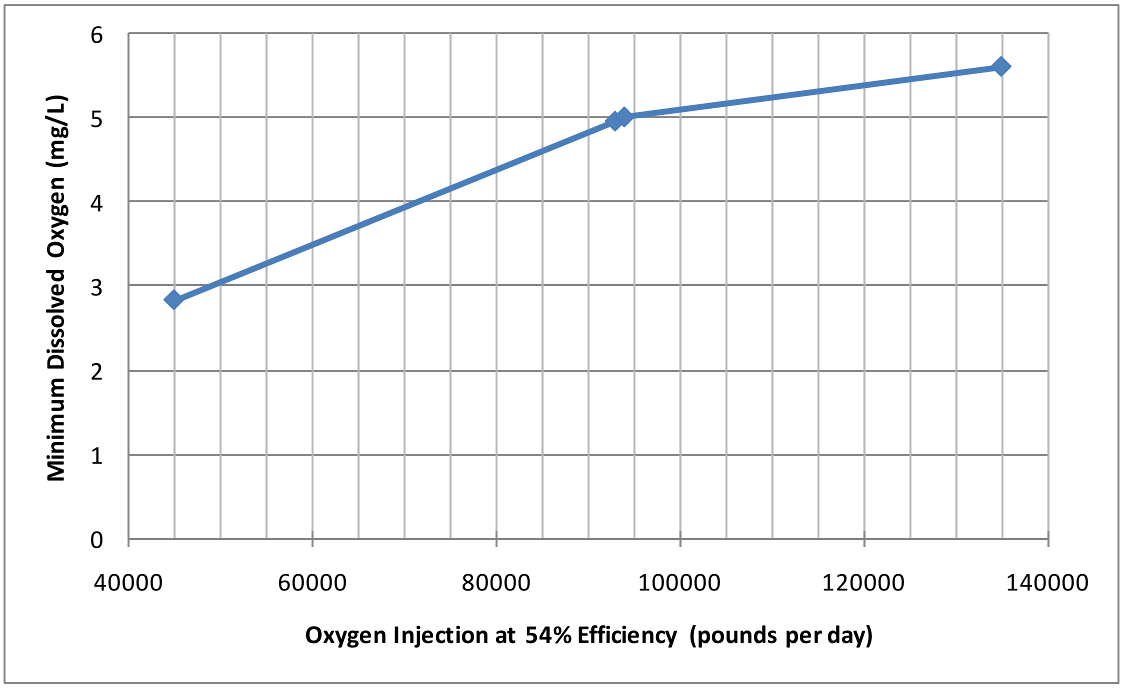

Figure 2. Model-wide minimum dissolved oxygen concentration above a depth of 60 feet as a function of rate of oxygen injection at Upper Narrows and the point sources at maximum discharge rates

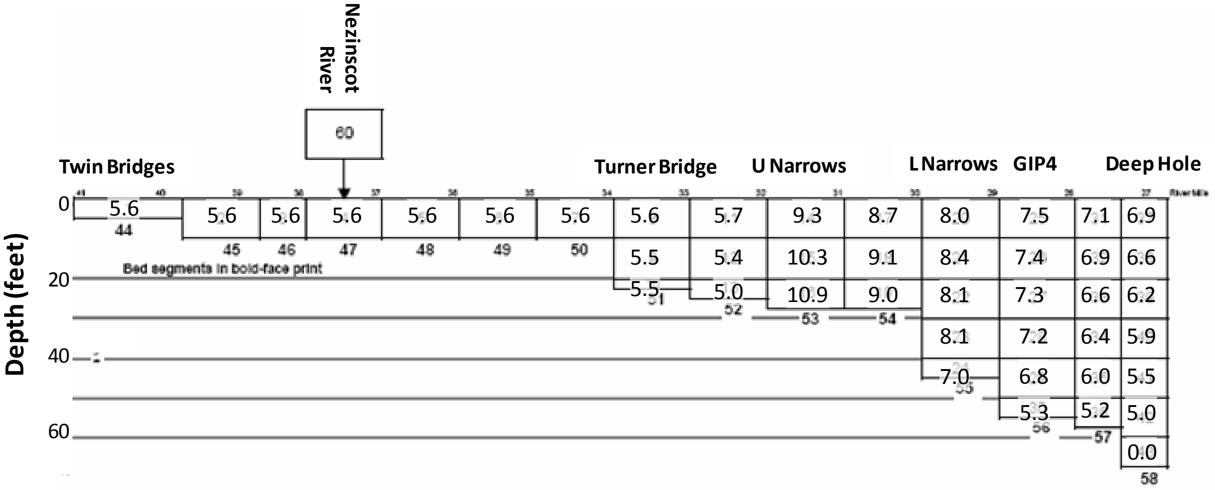

Figure 3. Simulated dissolved oxygen concentrations at 7Q10 flow with upstream point sources at maximum discharge rates and oxygen injection at Upper Narrows of 94,000 pounds per day with transfer efficiency of 54 percent

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Appendix E

Analyses of GIPOP Partnership Proposed Alternative Oxygen Injection Rates and Analysis of Reduced Oxygen Injection Rates Without Wausau-Mosinee Wastewater

(HydroAnalysis, Inc., September 25, 2009; December 1, 2009; and February 4, 2010)

MEMO
To: Dave L. Courtemanch
September 25, 2009

I have carried out the analyses of the Gulf Island Pond that you had requested in your email of September 16. Namely, you had requested:

1. A model run, with point sources set at their current license limits, and with GIPOP operating at 54% transfer efficiency, to determine the minimum amount of oxygen injection required at Upper Narrows to maintain all segments of Gulf Island Pond between Upper and Lower Narrows in attainment of the 5.0 mg/l dissolved oxygen criteria.

2. A model run, with point sources set at their current license limits, and with oxygen injected at Upper Narrows at the rate determined from the above model run, and with the balance from 73,000 lbs of oxygen injected at Lower Narrows at 54% transfer efficiency, to determine the resultant oxygen concentrations for all segments of Gulf Island Pond.

I began with a previously used model input file where the upstream concentrations had been determined based on the simulated discharge of point sources at their current license limits. I then progressively reduced the rate of injection, starting with 94,000 pounds per day, while monitoring the minimum dissolved oxygen concentration at the model segments between the Upper Narrows and Lower Narrows (segments 17, 18 and 19). The figure in the 2nd page of the attached pdf document (J418-012.pdf) shows this dissolved oxygen concentration versus the rate of oxygen injection at the Upper Narrows. The minimum concentration of 5.0 mg/L was achieved for a rate of oxygen injection of 23,300 pounds per day.

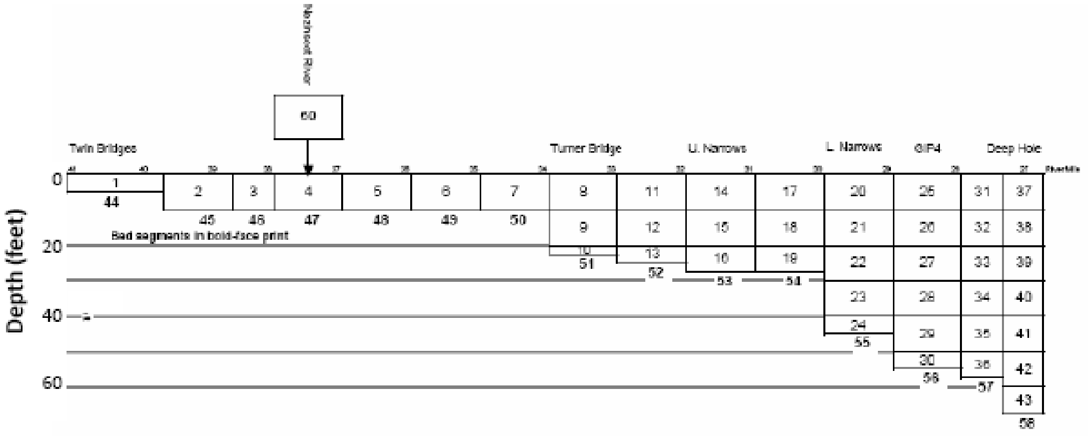
The figure in the 3rd page of the attached pdf document shows the segment-by-segment dissolved oxygen concentration for this rate of injection at the Upper Narrows. Under these conditions, the model segment immediately upstream of the Upper Narrows has a dissolved oxygen concentration of 4.8 mg/L. This is less than the 5.0 mg/L dissolved oxygen standard, although as noted in page 44 of the TMDL report (Mitnik, 2005), that non-attainment immediately upstream of the Upper Narrows was “believed to be not representative of actual conditions.” At the time, Mitnik recommended further monitoring at this location.

Assuming that the oxygen production facility, was operating at its peak rate of efficiency at 73,000 pounds per day, I simulated a case where the remainder of this injection (after injecting 23,300 pounds per day at the Upper narrows) occurred at the Lower Narrows. The figure on the fourth page of the attached pdf shows the segment-by-segment modeled concentrations for this condition. All model segments above a depth of 60 feet and downstream of the Upper Narrows and Lower Narrows have simulated concentrations greater than the standard 5 mg/L.

Please call if you have any questions on these results or wish to see any further related simulations.

Bruce Jacobs

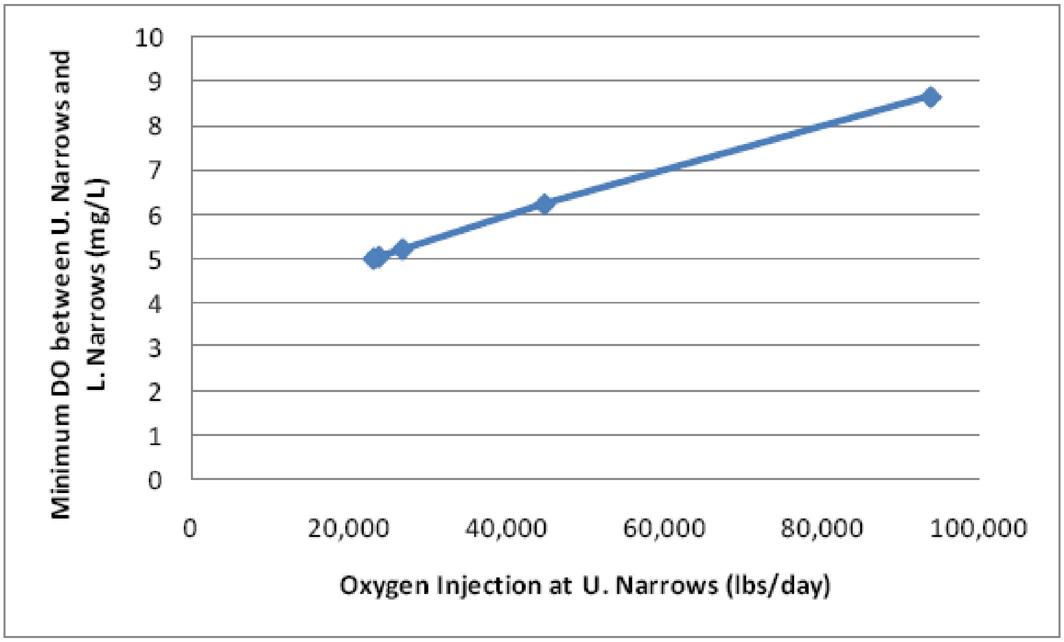
HydroAnalysis, Inc.
33 Clark Road, No. 1
Brookline, MA 02445



Model Segment Numbers

9/25/2009

1



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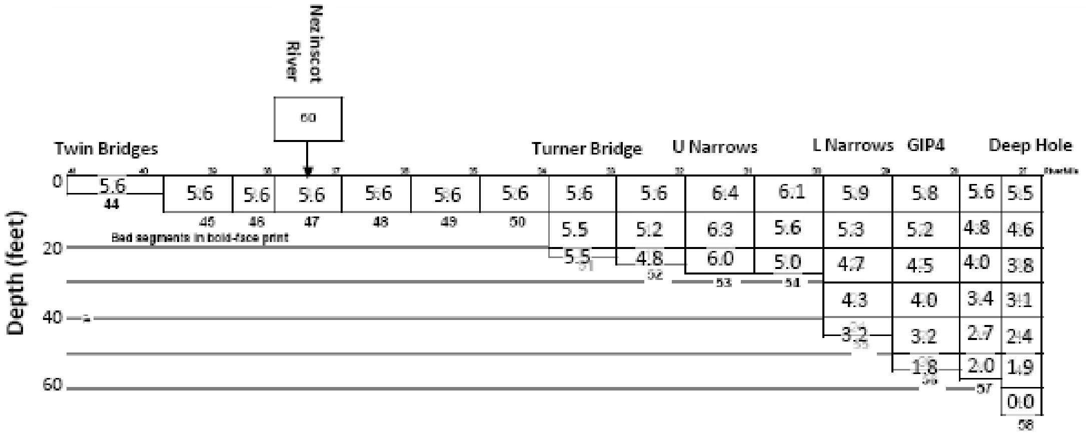
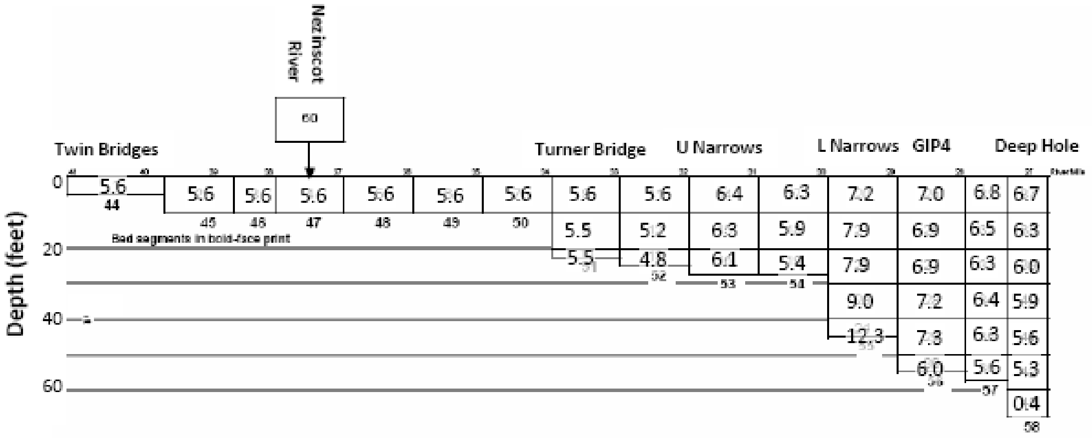
2



DO – injection of 23,300 lb/day at U. Narrows at 54% transfer efficiency



DO – injection of 23,300 lb/day at U. Narrows and
49,700 lb/day at L. Narrows at 54% transfer efficiency

MEMO:
To Dave L. Courtemanch
December 1, 2009

I have carried out the WASP and QUAL2E simulations of Androscoggin River and Gulf Island Pond per your request of November 24. Namely, I have simulated the following scenarios:

(1) Revised the oxygen injection rate to 23,300 pounds per day at 54% efficiency at Upper Narrows and 33,100 pounds per day at 75% efficiency at Lower Narrows as called for in the Nov. 20 letter from FPL Energy; and

(2) Reduced the Verso BOD5 discharge rate from 6400 pounds per day to 6258 pounds per day and then determined the minimum oxygen injection rate to meet the dissolved oxygen standard.

In the first case, under the revised oxygen injection scenario described in item (1) above, the simulated dissolved oxygen concentration results in compliance with the dissolved oxygen standard of 5.0 mg/L at all model segments up to a depth of 60 feet. Figure 1 shows the segment-by-segment dissolved oxygen concentration under this scenario.

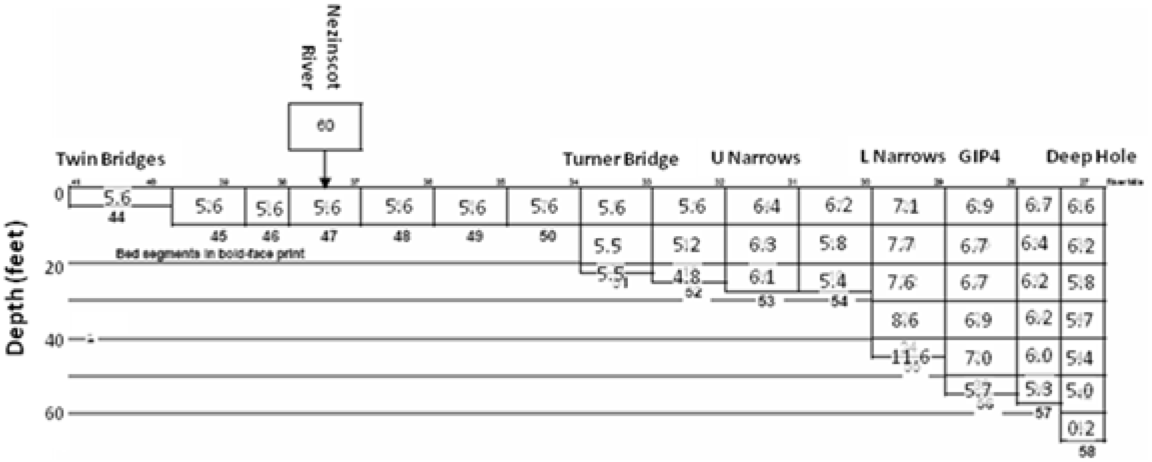


Figure 1. Simulated model segment dissolved oxygen concentration for Lower Narrows oxygen injection rate of 33,100 pounds per day and Verso BOD_5 loading rate of 6400 pounds per day.

In the second case, the revised BOD5 discharge rate resulted in relatively small changes in the simulated Androscoggin River BOD and dissolved oxygen. Table 1 shows the dissolved oxygen and BOD concentrations at the downstream end of the Androscoggin River under the initial and modified (reduced Verso discharge) conditions.

Table 1. Simulated Downstream Androscoggin River Dissolved Oxygen and BOD Concentrations

Scenario	Verso BOD5 Discharge Rate (lb per day)	WASP Model Input File Name	Dissolved Oxygen (mg/L)	BOD (mg/L)
Initial	6400	Lic10.7qt	6.33	5.86
Reduced Verso BOD discharge	6258	Lic21.7qt	6.34	5.82

The results of the QUAL2E simulations with a reduced Verso BOD discharge as shown in Table 1 were next introduced as upstream boundary conditions in the WASP Gulf Island Pond model. This resulted in an increase in the model-wide, minimum dissolved oxygen above a depth of 60 feet from 5.01 mg/L to 5.04 mg/L.

Next, the minimum oxygen injection requirements at the Lower Narrows were evaluated by carrying out two additional simulations of the Gulf Island Pond, with the Lower Narrows injection rate reduced by 1 percent and 5 percent relative to the initial rate of 33,100 pounds per day. Table 2 shows the minimum simulated dissolved oxygen concentration for segments shallower than a depth of 60 feet at these modified injection rates. In each of these simulations, the Upper Narrows rate of oxygen injection was maintained at 23,300 pounds per day with a transfer efficiency of 54%. A Lower Narrows injection rate of 32769 pounds per day – the one percent injection reduction scenario – is the estimated minimum rate of oxygen injection that resulted in compliance with the dissolved oxygen standard.

Table 2. Minimum Dissolved Oxygen Concentration in Gulf Island Pond at Depths Shallower than 60 feet

Scenario	Lower Falls Dissolved Oxygen Injection (lbs/day)	WASP Model Input File Name	Dissolved Oxygen (mg/L)
Prior Verso BOD discharge and 33,100 lb/day Injection at Lower Falls	33,100	Tsk13	5.01
Reduced Verso BOD discharge	33,100	Tsk14	5.04
Reduced Verso BOD discharge with 5% reduction in oxygen injection	31,445	Tsk15	4.88
Reduced Verso BOD discharge with 1% reduction in oxygen injection	32,769	Tsk16	5.01

Bruce Jacobs

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Brookline, MA 02445

617-879-0253
bjacobs@hydroanalysisinc.com

From: Bruce Jacobs [bjacobs@hydroanalysisinc.com]
Sent: Thursday, February 04, 2010 4:42 PM
To: Courtemanch, Dave L
Subject: RE: model run with reduced Verso loads (-Wausau)

Follow Up Flag: Follow up
Flag Status: Red

Dave,

On December 1, I reported on simulation results for the Androscoggin River and Gulf Island Pond, in which the Verso BOD5 loading had been reduced to 6258 pounds per day. At your request, I have modified the discharge rates from the Verso facility relative to the previous set of simulations. The modified Verso discharge rates are as follows:

BOD5	5,900 #/day
Total Phos	128 #/day
Ortho-P	28 #/day

I first ran the model with an injection rate of 23,300 pounds per day at the Upper Narrows and 32,769 pounds per day at the Lower Narrows. The Upper Narrows facility is assumed to have an oxygen transfer efficiency of 0.54, while the Lower Narrows facility is assumed to have an oxygen transfer efficiency of 0.75. In this first simulation, the minimum dissolved oxygen concentration above a depth of 60 feet was 5.05 mg/L. I then reduced the Lower Narrows rate of oxygen injection until the minimum dissolved oxygen concentration above a depth of 60 feet reach 5.00 mg/L. This was achieved at an injection rate of 32,333 pounds per day.

Please contact me if you have any questions on these results.

Bruce Jacobs

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33 Clark Road, No. 1
Brookline, MA 02445

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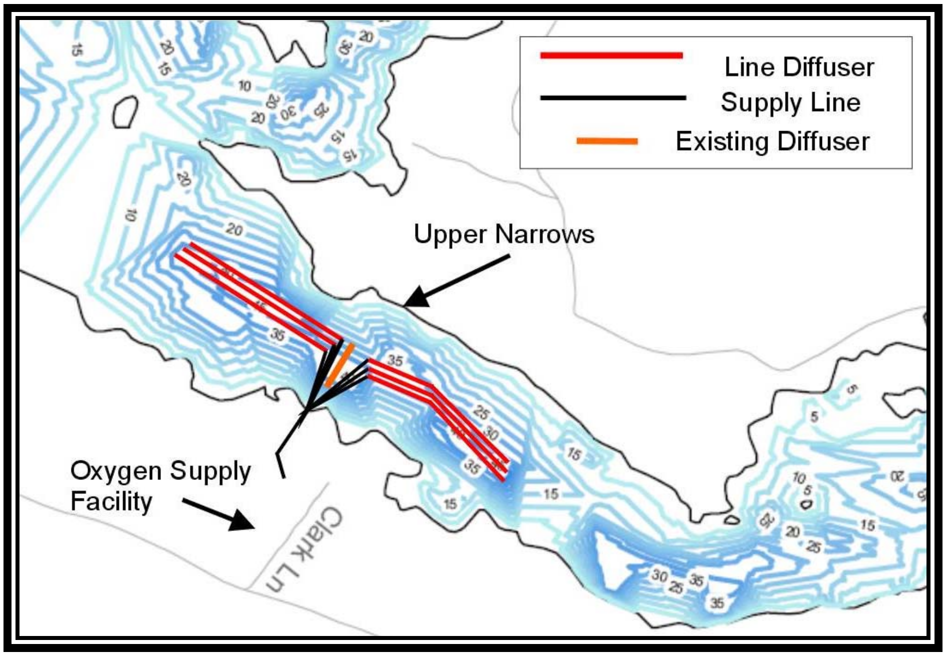
bjacobs@hydroanalysisinc.com

Appendix F

Evaluation of Oxygen Diffuser Replacement at Gulf Island Pond

(Mobley Engineering, May 2008)

Evaluation of Oxygen Diffuser Replacement at Gulf Island Pond



Prepared for:

The Gulf Island Pond Oxygenation Partnership:

Prepared by:

Mobley Engineering
Norris, Tennessee

May 2008

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Introduction

The Gulf Island Pond (GIP) Oxygenation System was installed in 1991 and has been operated to increase dissolved oxygen (DO) levels in the impoundment in an attempt to comply with the Maine Department of Environmental Protection (MEDEP) standards. Over time, measurements indicated that there were areas in the reservoir that were not attaining DO standards. In 2004, MEDEP required the Gulf Island Pond Operating Partnership (GIPOP) to conduct an engineering study to determine the effectiveness of the existing system and feasibility and cost of oxygenation alternatives. Wright Pierce was retained to conduct the study. Mobley Engineering, Inc. (MEI) provided some initial design concepts and cost estimates to Wright Pierce that were utilized in the study.

In permits recently issued, the MEDEP required the parties to upgrade the existing oxygen diffuser system. This report is intended to describe the replacement system.

The oxygenation of reservoirs has received a lot of attention since the Gulf Island Pond Oxygenation Project was installed, and dramatic technological advances have been achieved. From 1992 to 1997, the Tennessee Valley Authority invested a significant amount of resources to develop an economical and efficient line diffuser system for improving the DO content of hydropower releases and is currently maintaining oxygen diffuser operations at eight hydroelectric dams. Since 1999, MEI has further developed the diffuser design and has successfully applied diffuser systems in water supply reservoirs maintaining DO content of the entire impoundment with specific oxygen input into various elevations.

The line diffuser is a proven system that is well suited for placing oxygen uniformly over long lengths. The vertical oxygen placement into the reservoir can be modified by the height of the diffuser over the bottom and distributed oxygen flow rates. This study was conducted using the existing oxygen supply facility at Gulf Island Pond Upper Narrows to supply a replacement diffuser design near the existing diffuser.

MEI has extensive experience in applying oxygen diffuser systems to hydropower and water supply reservoirs to meet a wide variety of site-specific performance goals. MEI maintains specialized boats, equipment, and an experienced crew for such installations and has completed many evaluations similar to this GIP study for other clients.

Scope of Work

For this study at Gulf Island Pond, MEI has evaluated the feasibility and estimated costs of modifying the existing oxygenation system with a new diffuser system near the oxygen supply facility at Upper Narrows.

MEI verified the capacity and condition of the existing oxygen supply facility and supply piping. The OTE and maintenance costs of the existing system were evaluated for comparison with the costs expected for a new diffuser system. The evaluations in this study are based on a site visit, previous engineering experience, information provided by the GIPOP, and the 2004 Wright Pierce Oxygenation Study.

<u>Study Scope:</u> Develop a conceptual design and cost estimate for a new diffuser system near the supply facility at Upper Narrows. This diffuser system will be designed to place 27,000 to 35,000 pounds per day (lbs/day) of oxygen into the water column.

Site Visit Observations

On August 23, 2007, Mark and Susan Mobley visited the Gulf Island Pond oxygen supply facility accompanied by Frank Dunlap and Dick Castonguay of FPL Energy (FPLE) and John Cronin of NewPage.

Oxygen Supply Facility

The system was operating at 73,000 lbs/day and was found to be in generally very good repair. The facility is equipped with two 13,000-gallon liquid oxygen tanks, four ambient air vaporizers, and two ice racks. **Figure 1** is a picture of the oxygen supply facility storage tanks. **Figure 2** is a picture of the ambient air vaporizers. The vaporizers are operated as alternating banks to allow for freeze thaw cycles. The ice racks were added in 2002 to increase vaporization and system delivery capacity. The oxygen tanks and supply piping are maintained at about 110 psig with a delivery pressure of about 16 psi to the diffuser. The oxygen storage tanks were equipped with surprisingly small vaporizers in the pressure build circuits, but the operator reported that they had no problem maintaining tank pressure. A stainless steel pipe runs underground from the oxygen supply to a valve station several hundred feet from the reservoir. The valve station is shown in **Figure 3**. Two stainless steel pipes run underground and underwater from the valve station to feed the two diffuser banks in the reservoir. The system is operated at oxygen input flow rates based on a formula using a three-day median water temperature and a three-day average flow. The nominal oxygen delivery capacity of the facility is 73,000 lbs/day (100%) and is run up to 91,000 lbs/day (125%) typically during July and August as needed. The current equipment and maintenance contract with Air Liquide specifies maintaining and supplying the system for a nominal rate of 73,000 lbs/day, with a maximum up to 120,000 lbs/day.

Figure 1: Oxygen Supply Facility Storage Tanks

Figure 2: Oxygen Supply Facility Ambient Air Vaporizers

Figure 3: Valve Station

Diffuser

The ceramic plates for the diffuser had recently been replaced and the old plates were examined in the oxygen system operating building. The diffuser bubble pattern was visually very uniform with no obvious leaks or dead spots. The bubble plume was quite strong and was clearly moving a large volume of water to the surface that spread away from the diffuser. **Figure 4** is a picture of the diffuser bubble pattern on the water surface from the shoreline. The diffuser is probably operating at its maximum efficiency with new ceramic plates and good distribution.

Figure 4: **Surface Bubble Pattern of the Existing Oxygen Diffuser at Gulf Island Pond**

Reservoir

An FPLE boat and MEI depth finder were used to access the reservoir and verify some details of the reservoir bathymetry around the existing diffuser and elsewhere in the reservoir. The available bathymetry map provided by FPLE showed several shallow areas downstream of the diffuser and at Lower Narrows that were verified by boat.

Construction Considerations for a New Diffuser

During the site visit, several areas were evaluated for use as a diffuser construction area. The area at the Turner Bridge boat ramp would be most convenient for construction but would cause disruption in public use of the ramp. Abutment areas at the dam would provide good security but had poor access to the water. A diffuser construction site at the oxygen supply facility is considered the best option but will require some additional preparations to move the diffuser into the water from the closest available assembly area. Supply piping for the new diffuser could be tied into the existing piping at the valve station and routed through a new trench to the reservoir. A distribution manifold could be installed at the valve station to control oxygen flow to independent pipes supplying each diffuser. **Figure 5** is a picture of the shoreline access area that could be used for diffuser pipe installation and supply line trench.

Figure 5: Shoreline Access to Existing Diffuser System

GIPOP Oxygen Placement Requirement Provided for Evaluation

The new replacement diffuser is to distribute oxygen near upper narrows that is equivalent to distributing 105,000 lbs/day with the 33% OTE of the existing system.

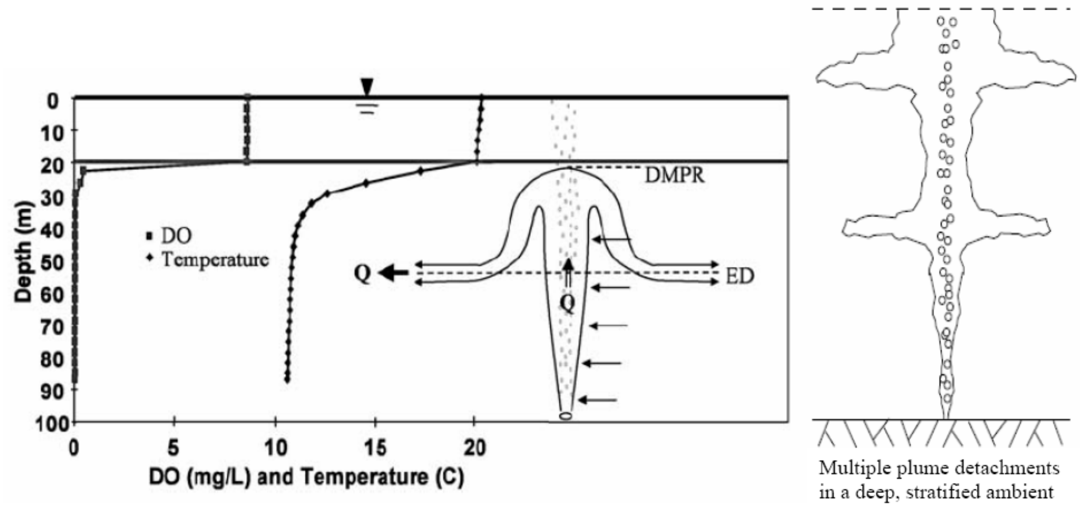
Conceptual Design Procedure

For this study, MEI developed a procedure to evaluate the oxygen placement of the replacement diffuser design. First, the oxygen required to be placed into the water column was determined by multiplying the oxygen rate by the nominal OTE of the existing diffuser system, 33%. Then, the oxygen transfer of MEI-designed line diffuser replacement was evaluated using a proprietary bubble plume model described in the next paragraph. The model results for the depth available and a range of oxygen flow rates per length of diffuser were used to determine the diffuser line lengths required for potential layouts. The diffuser line and supply piping lengths were then used to estimate installation and operating costs.

Bubble Plume Modeling and Design

The bubble plume model utilized in this study was developed by Loginetics based on plume research reported by Wuest et al. (1992). The model calculates hydrodynamic and water quality variables for a bubble plume that consists of a bubble-water inner core and an annulus of entrained water from the ambient reservoir. The model is based on integration of the governing equations for 7 fluxes (water, momentum, heat, dissolved oxygen, dissolved nitrogen, gaseous oxygen, and gaseous nitrogen) and 5 equations of state (pressure, water density, bubble-water mixture density, gas volume, bubble radius) [Wuest et al., 1992]. The model simulates upwelling associated with air or oxygen plumes in a stratified ambient based on time-variant gas flow inputs and an initial bubble size. It includes bubble size changes that result from decompression and gas transfer as the bubbles rise and exchange gases with ambient water. The model has been tested and verified in several field experiments (Hauser, 2004; Singleton et al., 2007; McGinnis et al., 2004).

A bubble plume can be designed to achieve high gas transfer efficiency or to move large quantities of water. Bubbles entrain water as they rise toward the surface as a function of the interface area of the plume – the surface area of the water moving with the plume and ambient water and the relative velocity difference. A strong plume will have a large gas flow over a small area and entrain less water as it moves to the surface. A weak plume will have a large area per volume of bubbles and will entrain more water per volume of gas than a strong plume. In a thermally stratified environment, a weak plume may have one or more detachments where the cold water entrained from deeper in the water body becomes separated from the plume due to the density differences in the water. As density differences between the entrained water and ambient water increase, the denser water falls away from the gas bubbles that continue on toward the surface, as illustrated in **Figure 6** (McGinnis et al., 2004). Similarly, the oxygen transfer from a bubble is a function of the bubble surface area, the area of the interface between the gas and the ambient water, and the time of travel to the surface. A small diameter bubble will have a larger interface area per volume of gas than a larger bubble; thus, OTE is enhanced with small bubbles. A bubble plume designed for maximum oxygen transfer will generally be a weak plume with small oxygen bubbles spread over as large an area as is practical. The MEI diffuser design has improved the OTE of diffuser installations by providing a means to economically spread small gas bubbles over a large area. In deep stratified reservoirs, a plume designed for efficient gas transfer may have detachments at or below the thermocline that spread oxygen though the reservoir at density-specific layers, as shown in the field measurements from Spring Hollow Reservoir in **Figure 7** (Gantzer, 2001).



Multiple plume detachments in a deep, stratified ambient

DMPR=depth of maximum plume rise ED=equilibrium (fallback) depth
Single plume detachment (after McGinnis, et al. 2004)

Figure 6: Conceptual Sketches of Bubble-Water Plume Dynamics

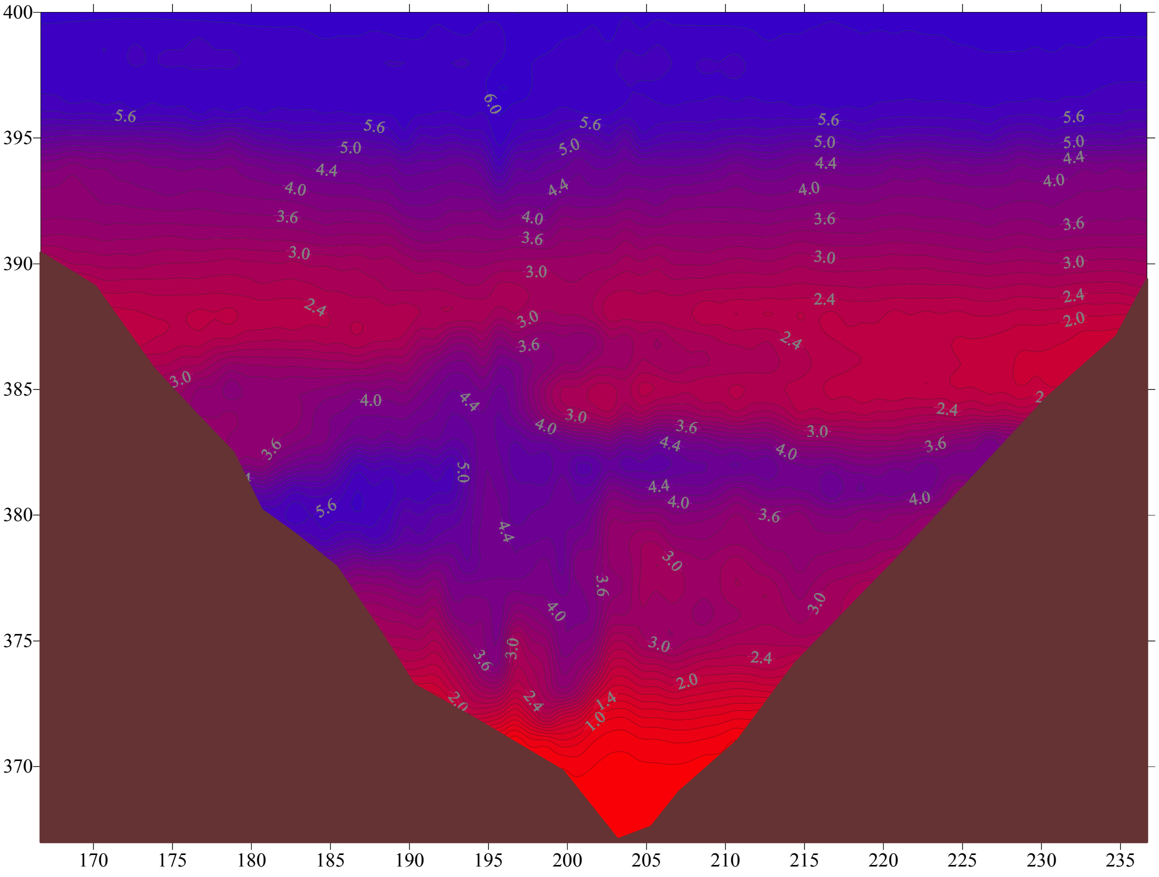
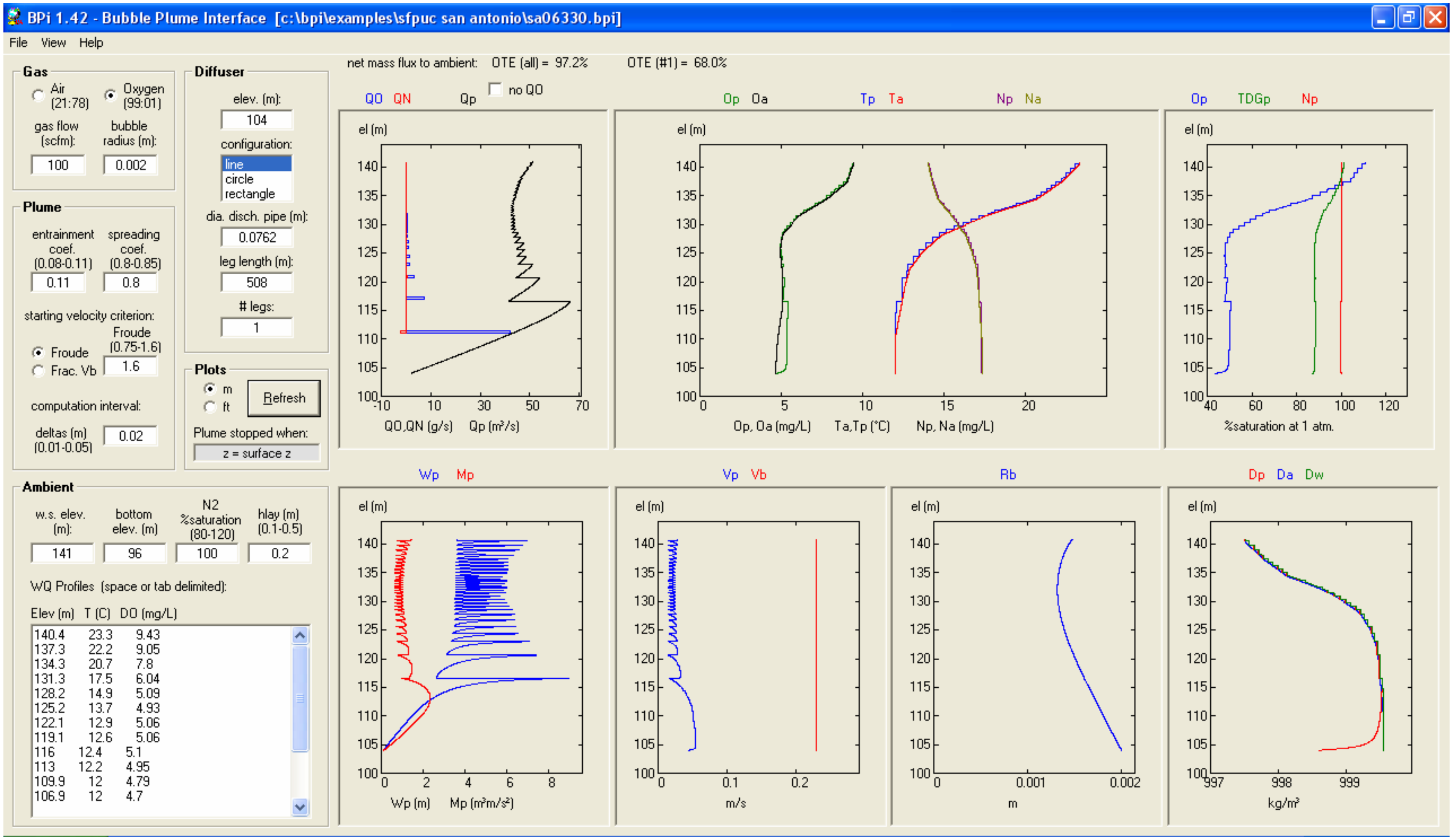


Figure 7: Oxygen Placement in a Deep Reservoir Showing Oxygen Spread at a Detachment Layer (Gantzer, 2001)

The amount of water entrained, bubble size, plume dimensions, and detachments are calculated and predicted by the BPi bubble plume model. An example of the output screen from the BPi model is shown in **Figure 8** for a typical MEI line diffuser design. All of the details of this model will not be described here but the diffuser and ambient water body characteristics are input on the left-hand side. The top left plot is the model prediction for plume water flow (Qp) in cubic meters per second. The very weak plume in this run exhibits numerous detachments shown by the saw tooth shape of the Qp line and the plume width (Wp) plot. This plume design achieves high OTE in a 120-foot deep, strongly stratified reservoir. The majority of the oxygen transfer occurs in the plume before its first detachment at elevation 116 meters, with approximately 68% of the input oxygen being placed between the detachment elevation at 116 meters and the fallback elevation at 111 meters (elevation where the ambient water temperature is equal to the average plume detachment temperature). The oxygen transfer for the entire plume is displayed near the top of the plume "OTE(all) = 97.2%". This value is used by MEI in plume design evaluations with an 11% factor of safety to provide some additional confidence in the results. For example, the OTE of this run would be 97.2% ÷ 1.11 = 87.6%. The BPi OTE prediction with the factor safety will be referred to in this report as the "design uptake efficiency". Similar plume model simulations were run for the existing GIPOP diffuser and for all of the iterative diffuser designs evaluated for each layout for each option.

Existing Diffuser OTE

The existing fine bubble diffuser system at GIP is 360 feet (109.7 meters) long and 1 foot (0.305 meters) wide at a nominal submergence depth of 30 feet (elevation 70.7 meters). The output screen from a BPi analysis of the existing GIPOP diffuser system is shown in **Figure 9**. For this and all other GIPOP plume simulations, the temperature profile that the MEDEP used in previous modeling and 6.5 mg/L dissolved oxygen was input to define ambient water conditions. This plume analysis indicates that the GIPOP diffuser forms a strong plume that penetrates directly to the surface with no detachments with a model-indicated OTE of 37.8%, or a design uptake efficiency of 34% with the factor of safety. This result matches well with visual observation of the strong plume shown in **Figure 4** and previous OTE calculations.



BPi 1.42 - Bubble Plume Interface [c:\bpi\examples\sfpuc san antonio\sa06330.bpi]

Gas

○ Air (21:78) ● Oxygen (99:01)

gas flow (scfm): 100

bubble radius (m): 0.002

Plume

entrainment coef. (0.08-0.11): 0.11

spreading coef. (0.8-0.85): 0.8

starting velocity criterion:

● Froude ○ Frac. Vb

Froude (0.75-1.6): 1.6

computation interval:

deltas (m) (0.01-0.05): 0.02

Diffuser

elev. (m): 104

configuration: line (selected), circle, rectangle

dia. disch. pipe (m): 0.0762

leg length (m): 508

legs: 1

Plots

● m ○ ft

Plume stopped when: z = surface z

Ambient

w.s. elev. (m): 141

bottom elev. (m): 96

N2 %saturation (80-120): 100

hlay (m) (0.1-0.5): 0.2

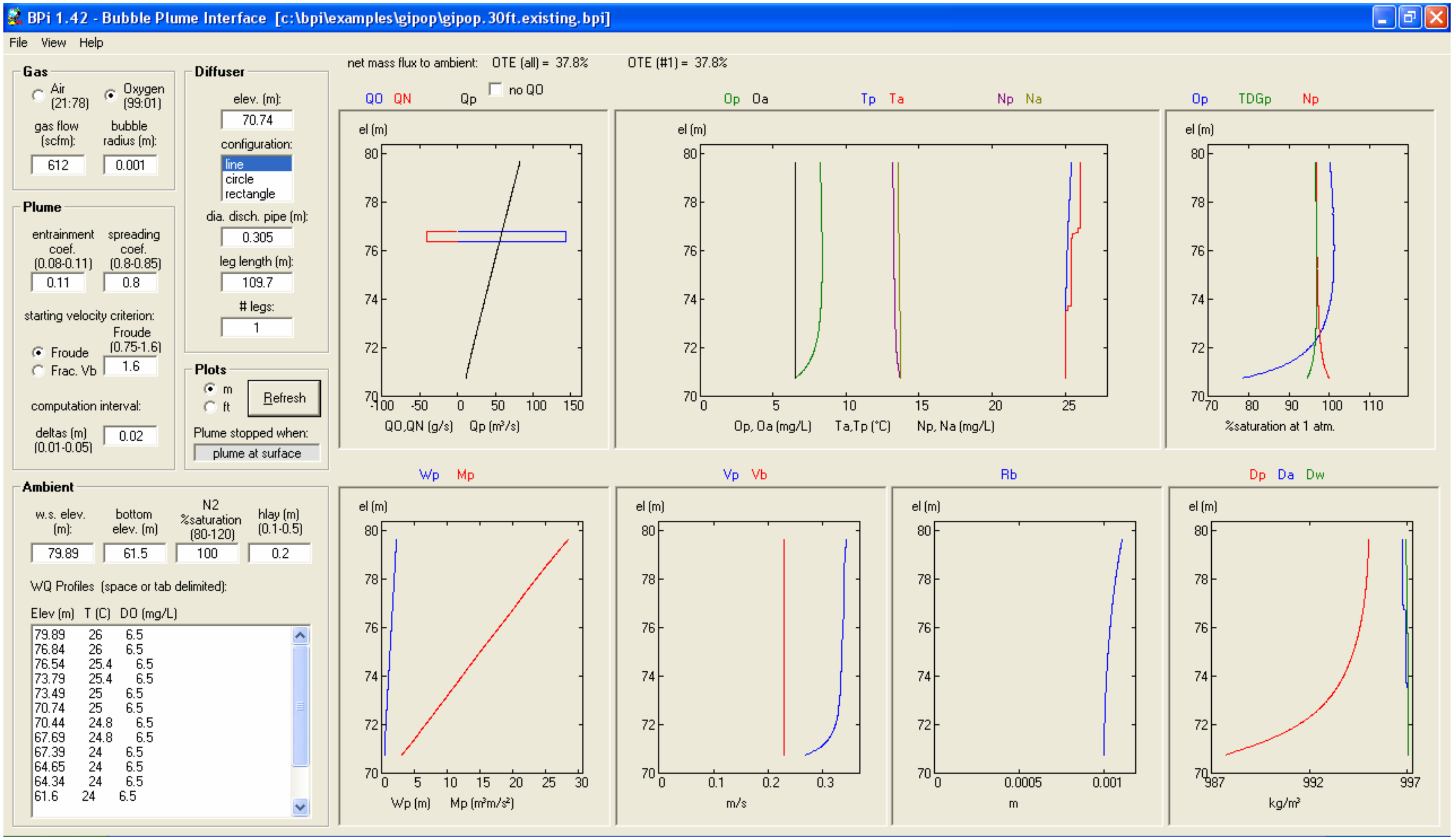
WQ Profiles (space or tab delimited):

Elev (m)	T (C)	DO (mg/L)
140.4	23.3	9.43
137.3	22.2	9.05
134.3	20.7	7.8
131.3	17.5	6.04
128.2	14.9	5.09
125.2	13.7	4.93
122.1	12.9	5.06
119.1	12.6	5.06
116	12.4	5.1
113	12.2	4.95
109.9	12	4.79
106.9	12	4.7

net mass flux to ambient: OTE (all) = 97.2% OTE (#1) = 68.0%

☐ no QO

Figure 8: BPi Model Interface Screen and Results for Typical Line Diffuser Design



BPi 1.42 - Bubble Plume Interface [c:\bpi\examples\gipop\gipop.30ft.existing.bpi]

Gas

○ Air (21:78) ● Oxygen (99:01)

gas flow (scfm): 612

bubble radius (m): 0.001

Diffuser

elev. (m): 70.74

configuration: line (selected), circle, rectangle

dia. disch. pipe (m): 0.305

leg length (m): 109.7

legs: 1

Plume

entrainment coef. (0.08-0.11): 0.11

spreading coef. (0.8-0.85): 0.8

starting velocity criterion: ● Froude ○ Frac. Vb

Froude (0.75-1.6): 1.6

computation interval: deltas (m) (0.01-0.05): 0.02

Plots

● m ○ ft

Plume stopped when: plume at surface

Ambient

w.s. elev. (m): 79.89

bottom elev. (m): 61.5

N2 %saturation (80-120): 100

hlay (m) (0.1-0.5): 0.2

WQ Profiles (space or tab delimited):

Elev (m)	T (C)	DO (mg/L)
79.89	26	6.5
76.84	26	6.5
76.54	25.4	6.5
73.79	25.4	6.5
73.49	25	6.5
70.74	25	6.5
70.44	24.8	6.5
67.69	24.8	6.5
67.39	24	6.5
64.65	24	6.5
64.34	24	6.5
61.6	24	6.5

net mass flux to ambient: OTE (all) = 37.8% OTE (#1) = 37.8%

☐ no QO

Figure 9: BPi Model Interface Screen and Results for Existing Diffuser at Gulf Island Pond

Conceptual Design for Oxygen Diffuser Replacement

The scope of this study is to modify the existing system at Upper Narrows with a new diffuser system to place the equivalent of 105,000 lbs/day at 33% OTE. Diffuser design calculations for this design are shown in **Table 1**. The diffuser lengths were chosen to fit well in the deepest channel at the Upper Narrows, extending upstream and downstream of the existing diffuser by about 1,300 feet. The conceptual diffuser layout is shown in **Figure 10. Figure 11** presents a closer view of the layout at Upper Narrows so that the dramatic difference in the line lengths of the new diffuser and the existing diffuser are more visible. For this layout, an oxygen flux rate of 0.08 scfm/ft was used instead of the more typical rate of 0.06 scfm/ft in order to reduce the total diffuser length so that the piping could be arranged in the available area at Upper Narrows that is 30 feet deep. The area available at a continuous depth of 30 feet was about 1,300 feet upstream and downstream of the existing diffuser according to the bathymetry map provided by FPLE. Boat reconnaissance verified that there were shallow areas upstream and downstream of the diffuser as indicated on the map. The layout places six diffusers in this 30-foot deep area with room to leave the existing diffuser in place. The total diffuser length, oxygen flux rate, and the nominal depth of 30 feet result in a design uptake efficiency of 54% for the new diffuser design using the MEDEP ambient temperature profile. This OTE is a considerable improvement over the 33% OTE of the existing system and allows an oxygen flow rate of 74,000 lbs/day of oxygen to achieve results similar to using 105,000 lbs/day with the existing system. The diffuser layout places oxygen in lines that are much longer than the existing system and will produce very weak plume lines that are parallel to the water flow and will be unlikely to cause the upstream flow and “short circuiting” observed with the existing system. With less mixing than the existing diffuser, the new diffuser will also be less likely to disrupt stratification by mixing the incoming water flow. Depending on ambient temperature stratification strength, oxygen placement in the water with the new diffuser may also be closer to the bottom and move downstream closer to the sediments potential improving oxygen placement in current areas of non-attainment. But the shallow (24-foot deep) area just downstream of Upper Narrow may limit the depth of oxygen distribution downstream. Costs for the installation are shown in **Table 2**. Since the overall oxygen supply flow rate required is within the range of flows currently used at GIP, no modifications are expected to be required to the oxygen supply facility. The installation cost of the replacement system is estimated to be approximately $600,000 and the annual operating costs are projected to be between $700,000 and $930,000. Operating costs are shown in **Table 2** for 90 and 122 days of operation at a current average price of $230 per ton. These operating costs include annual costs to replace the porous hose on the diffusers every 10 years. The new diffuser layout will distribute oxygen more evenly in the water column at Upper Narrows and may provide some limited benefits in the oxygen distribution downstream.

		Option 1	
DESIGN OXYGEN INPUT @ 33% OTE:	Upper Narrows	105,000	lbs/day
	Lower Narrows		lbs/day
	Deep Hole		lbs/day
		105,000	lbs/day
DESIGN OXYGEN INPUT into water:	Upper Narrows	34,650	lbs/day
	Lower Narrows	0	lbs/day
	Deep Hole	0	lbs/day
		34,650	lbs/day
DIFFUSER DESIGN:			
Design Uptake Efficiency:	30'	54%	
Safety Factor		1.15	
Flow Distribution	30'	73,915	lbs/day
		73,915	lbs/day
Number of Diffusers	30'	6	
Design Flow per Diffuser	30'	103	scfm
Flux rate	30'	0.080	scfm/ft
Diffuser Lengths	30'	1,300	feet
DESIGN OXYGEN SYSTEM CAPACITY:		73,915	lbs/day
		37	tons O2/day
		7,761	gallons/day
		1.54	tons O2/hr
		620	SCFM
		37,173	scfh
		101%	

Table 1: Oxygen Diffuser Replacement System Design Calculations

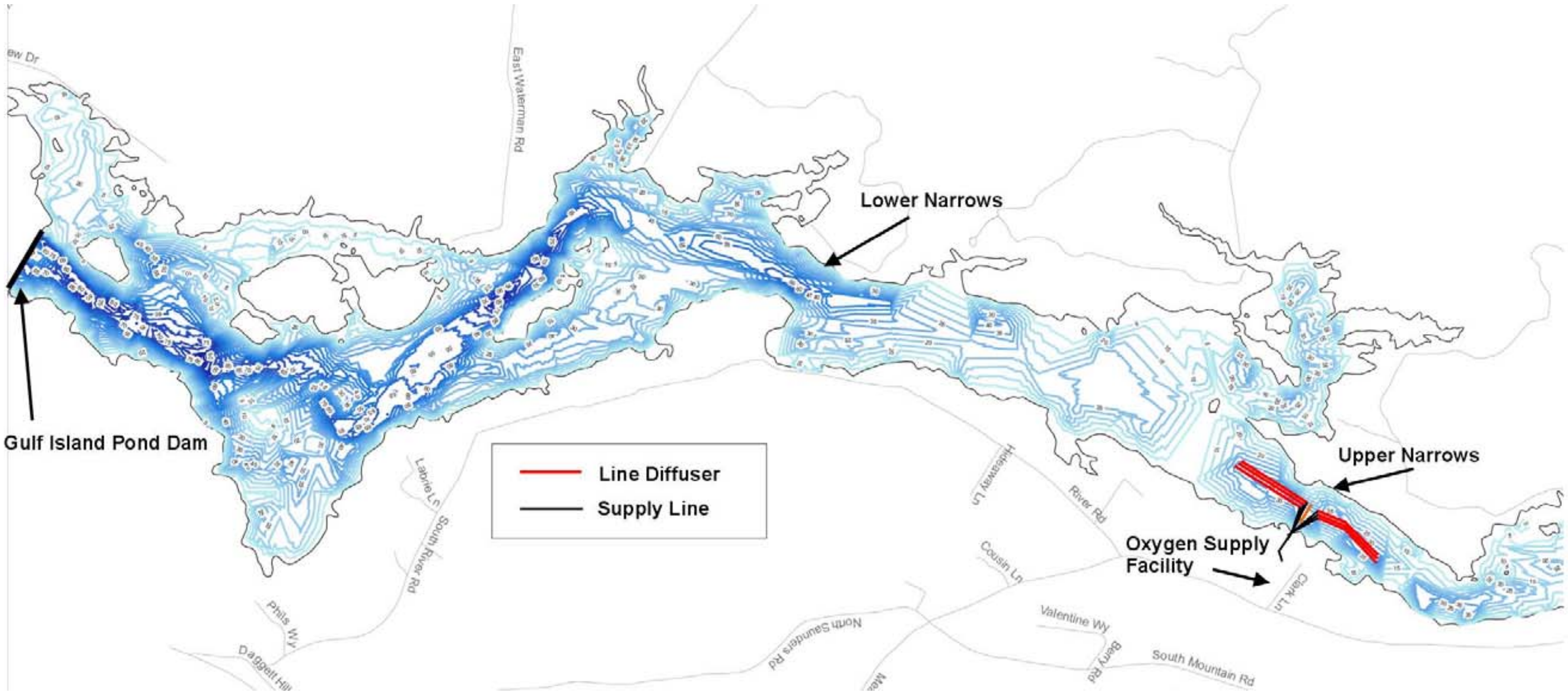


Figure 10: Replacement Diffuser Layout

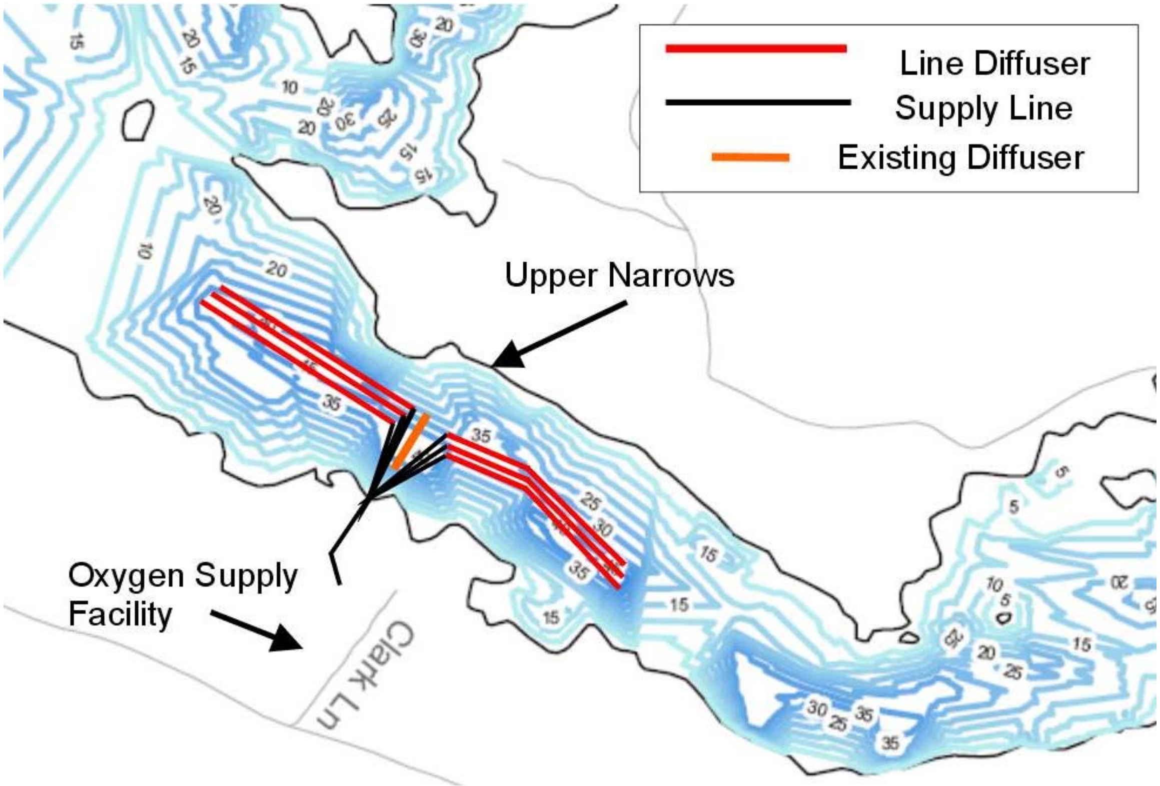


Figure 11: Replacement Diffuser Layout Close-up

Installation Budget Estimate		
Oxygen Supply Facility Modifications		
Flow Control Manifold	$80,000	
Reservoir Diffusers	$502,980	
Total Installation Budget Estimate	**$582,980**	
Operation Cost Estimate		
Annual Usage for 122 days	3,921	tons
Oxygen Annual Cost ($230 per ton)	$901,761	annually
Diffuser Maintenance	$31,200	annually
	$932,961	
Annual Usage for 90 days	2,892	tons
Oxygen Annual Cost ($230 per ton)	$665,234	annually
Diffuser Maintenance	$31,200	annually
	$696,434	

Table 2: Estimated Installation and Operation Costs

Conclusions

The diffuser evaluation in this report results in an attractive diffuser replacement design. The diffuser layout was optimized to reduce underwater supply piping and diffuser length while maintaining high oxygen transfer efficiency to minimize installation and operating costs. Keeping the diffusers as deep as possible tended to maximize OTE.

The diffuser layout was designed to place oxygen as deep as possible at Upper Narrows. However, no hydrodynamic reservoir modeling was done as a part of this evaluation and thus no oxygen distribution predictions are made except to indicate that the oxygen is placed deeper and with less mixing than is experienced with the existing diffuser.

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Hauser, G. E. (2004). Personal communication on BPi and BUBBLEP Bubble Plume Model. Loginetics, Inc.; Knoxville, Tennessee.

McGinnis, D. F., A Lorke, A. Wuest, A. Stockli, and J.C. Little (2004). “Interaction between a bubble plume and the near field in a stratified lake.” *Water Resources Research,* 40:10206, doi:10.1029/2004WR003038.

Singleton, V. L., P. Gantzer, and J. C. Little (2007). “Linear Bubble Plume Model for Hypolimnetic Oxygenation: Full-scale Validation and Sensitivity Analysis.” *Water Resources Research,* 43:W02405, doi:10.1029/2005WR004836.

Wuest, A., N. Brooks, and D. Imboden (1992). “Bubble Plume Modeling for Lake Restoration.” *Water Resources Research,* 28:12, pp 3235-3250, December.

Appendix G

Oxygen Transfer Efficiency Predictions for Oxygen Diffusers Placed in Gulf Island Pond Lower Narrows

(Mobley Engineering, September 25, 2009)

Mobley Engineering

Oxygen Transfer Efficiency Predictions for Oxygen Diffusers Placed in Gulf Island Pond Lower Narrows

September 25, 2009

Mobley Engineering Inc., (MEI) has re-visited oxygen transfer calculations at Gulf Island Pond to determine the efficiency to be expected of a potential diffuser installation located at Lower Narrows.

Diffuser Depth:
A diffuser line located at Lower Narrows could take advantage of the greater depths available to achieve better oxygen transfer than that of the existing diffuser lines at Upper Narrows. Greater depth provides increased oxygen transfer efficiency (OTE) due to greater mass transfer driving force at increased partial pressure (hydrostatic pressure), and increased bubble contact time with ambient water as the bubble has further to travel as it rises to the surface. Water depths are 50 to 55 feet at Lower Narrows compared to 30 to 35 feet at Upper Narrows.

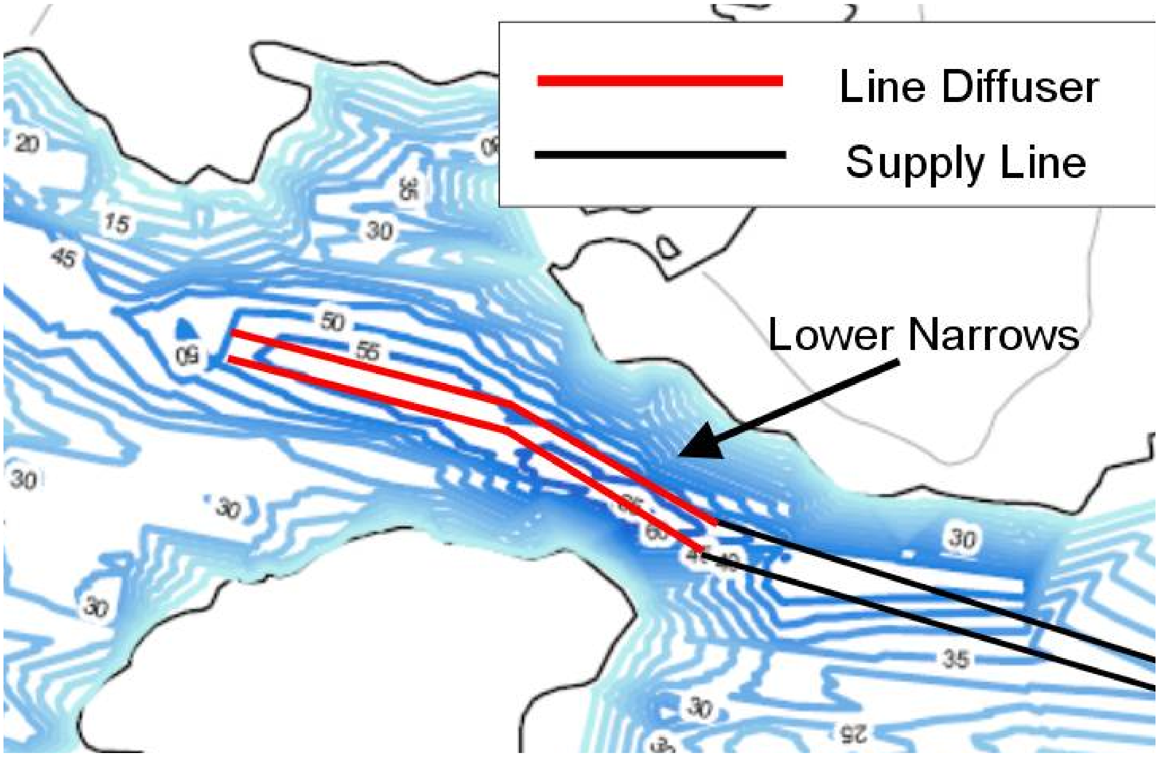


Figure 1: Conceptual Diffuser Layout at Lower Narrows

Bubble Plume Modeling:

In order to predict oxygen transfer efficiency, MEI employed the BUBBLEP bubble plume model based on the work of Wuest (1992), McGinnis (2002) and Hauser (2006). A more complete description of the plume model and interface is included as Appendix A. Model inputs include initial bubble size, ambient temperature and DO profiles, diffuser characteristics and oxygen flow rate. Using inputs to characterize the diffuser system at Lower Narrows, oxygen transfer efficiencies of 82% to 83.7% were predicted by the model for a range of oxygen flow rates. The model results indicate that the majority of the oxygen would be placed at 30 to 40 feet deep. Results from the model runs are presented in Figures 2 and 3.

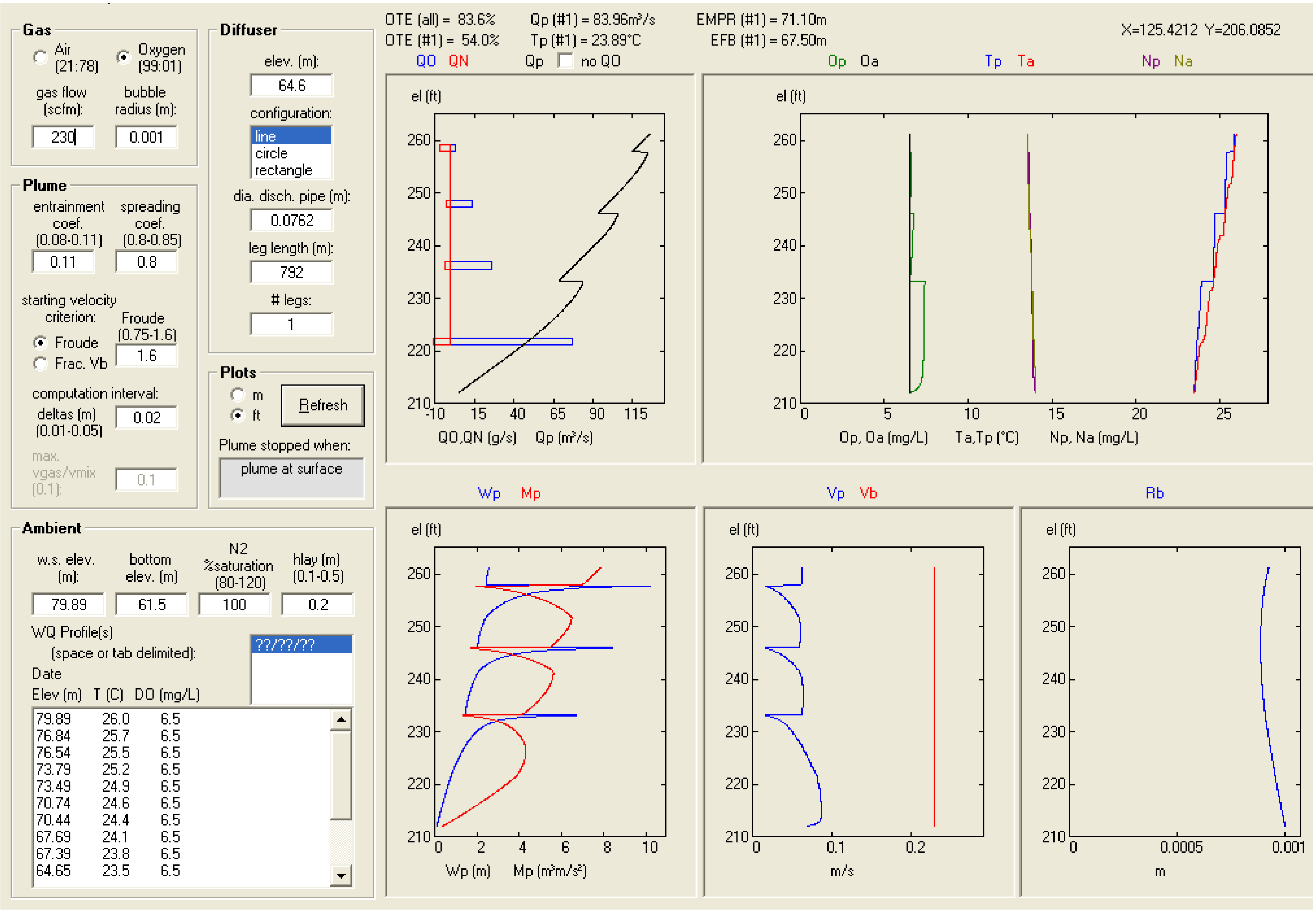
Oxygen Transfer Efficiency for Gulf Island Pond Lower Narrows

In using BUBBLEP results to predict real world applications, MEI has chosen to use a factor of 90% to take into account unknown conditions and provide some conservatism. Therefore the oxygen transfer efficiencies recommended for use by MEI are; **75%** for 2,600 foot long oxygen diffusers at Lower Narrows flowing up to 270 scfm and **74%** for the same diffusers flowing up to 350 scfm each. Two diffusers at 270 scfm each will distribute a total of 61,000 pounds per day gross.

References:

Wuest, A., N, Brooks, and D. Imboden (1992); “Bubble Plume Modeling for Lake Restoration”; Water Resources Research, vol. 28, no. 12, pp 3235-3250; December.

Daniel F. McGinnis, John C. Little Predicting diffused-bubble oxygen transfer rate using the discrete-bubble model Water Research 36 (2002) 4627–4635



Gas

○ Air (21:78) ● Oxygen (99:01)

gas flow (scfm): 230

bubble radius (m): 0.001

Plume

entrainment coef. (0.08-0.11): 0.11

spreading coef. (0.8-0.85): 0.8

starting velocity criterion: ● Froude ○ Frac. Vb

Froude (0.75-1.6): 1.6

computation interval: deltas (m) (0.01-0.05): 0.02

max. vgas/vmix (0.1): 0.1

Diffuser

elev. (m): 64.6

configuration: line (circle, rectangle)

dia. disch. pipe (m): 0.0762

leg length (m): 792

legs: 1

Plots

○ m ● ft

Plume stopped when: plume at surface

Ambient

w.s. elev. (m): 79.89

bottom elev. (m): 61.5

N2 %saturation (80-120): 100

hlay (m) (0.1-0.5): 0.2

WQ Profile(s) (space or tab delimited): ??/??/??

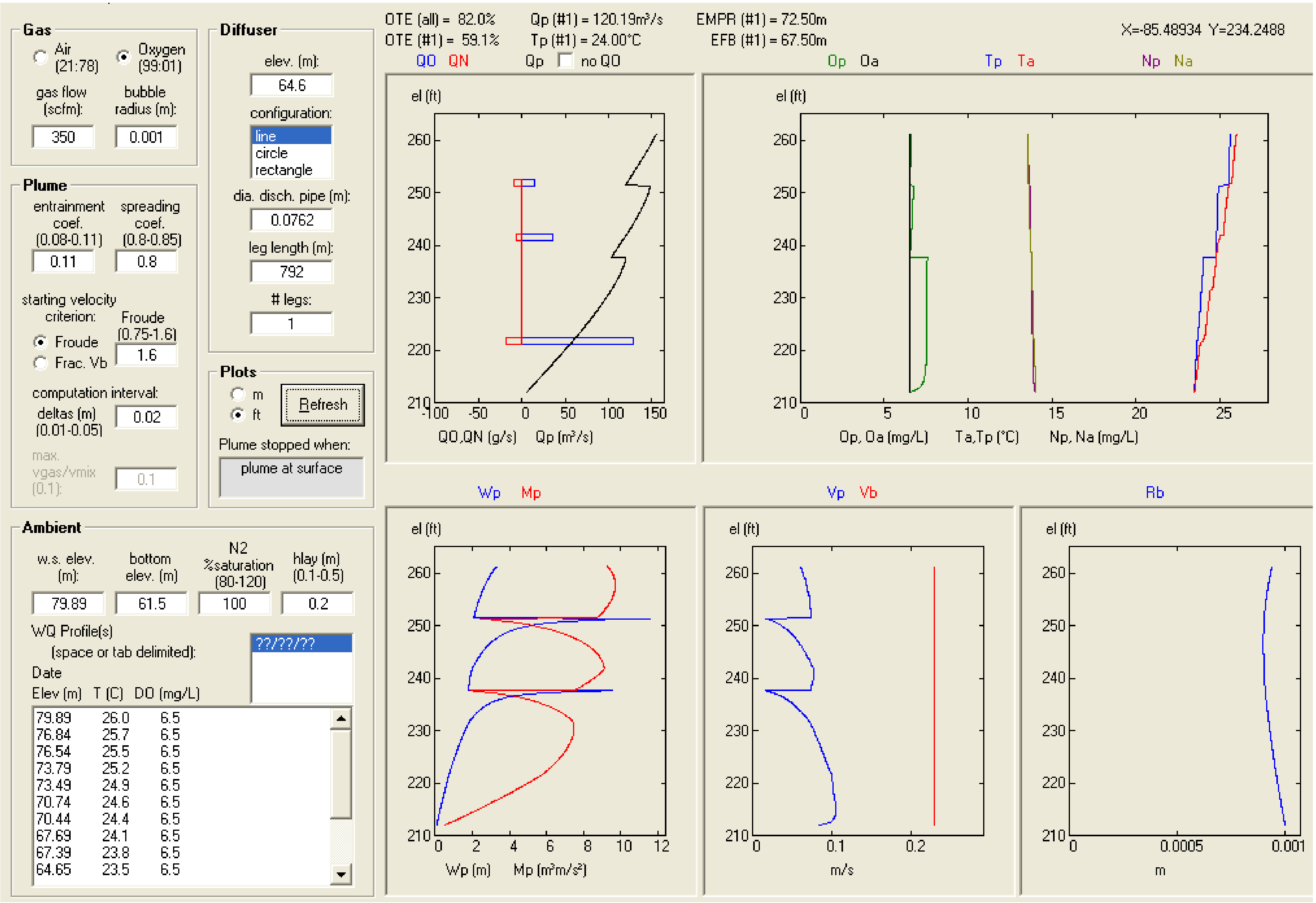
Date

Elev (m)	T (C)	DO (mg/L)
79.89	26.0	6.5
76.84	25.7	6.5
76.54	25.5	6.5
73.79	25.2	6.5
73.49	24.9	6.5
70.74	24.6	6.5
70.44	24.4	6.5
67.69	24.1	6.5
67.39	23.8	6.5
64.65	23.5	6.5

OTE (all) = 83.6%
OTE (#1) = 54.0%
Qp (#1) = 83.96m³/s
Tp (#1) = 23.89°C
EMPR (#1) = 71.10m
EFB (#1) = 67.50m
X=125.4212 Y=206.0852

Qp ☐ no QO

Figure 2: Bubble Plume Model Results for 230 scfm



Gas

○ Air (21:78) ● Oxygen (99:01)

gas flow (scfm): 350

bubble radius (m): 0.001

Plume

entrainment coef. (0.08-0.11): 0.11

spreading coef. (0.8-0.85): 0.8

starting velocity criterion: ● Froude ○ Frac. Vb

Froude (0.75-1.6): 1.6

computation interval:

deltas (m) (0.01-0.05): 0.02

max. vgas/vmix (0.1): 0.1

Diffuser

elev. (m): 64.6

configuration: line

dia. disch. pipe (m): 0.0762

leg length (m): 792

legs: 1

Plots

○ m ● ft

Plume stopped when: plume at surface

OTE (all) = 82.0%

OTE (#1) = 59.1%

Qp (#1) = 120.19m³/s

Tp (#1) = 24.00°C

EMPR (#1) = 72.50m

EFB (#1) = 67.50m

X=-85.48934 Y=234.2488

☐ no QO

Ambient

w.s. elev. (m): 79.89

bottom elev. (m): 61.5

N2 %saturation (80-120): 100

hlay (m) (0.1-0.5): 0.2

WQ Profile(s) (space or tab delimited):

Date: ??/??/??

Elev (m)	T (C)	DO (mg/L)
79.89	26.0	6.5
76.84	25.7	6.5
76.54	25.5	6.5
73.79	25.2	6.5
73.49	24.9	6.5
70.74	24.6	6.5
70.44	24.4	6.5
67.69	24.1	6.5
67.39	23.8	6.5
64.65	23.5	6.5

Figure 3: Bubble Plume Model Results for 350 scfm

Appendix A

By Gary E. Hauser, PE, ***Loginetics Inc***. 2006

BUBBLEP Bubble Plume Model

BUBBLEP is a bubble plume submodel that Loginetics has incorporated into its custom version of W2. BUBBLEP, originally developed for the BETTER reservoir model by TVA, was debugged, updated, and expanded by Loginetics to handle circular and rectangular plumes. Loginetics has successfully tested predictions of the modified bubble model against field measurements in real diffuser applications by Brown, et al. (1989) and Wuest, et al. (1992).

BUBBLEP calculates hydrodynamic and water quality variables for a bubble plume that consists of a bubble-water inner core and an annulus of entrained water from the ambient reservoir. The model is based on integration of the governing equations for 7 fluxes (water, momentum, heat, DO, dissolved nitrogen, gaseous oxygen, and gaseous nitrogen) and 5 equations of state (pressure, water density, bubble-water mixture density, gas volume, and bubble radius) based on Wuest, et al. (1992). BUBBLEP simulates upwelling associated with air or oxygen plumes in a stratified ambient based on time-variant gas flow inputs and an initial bubble size. It includes bubble size changes that result from decompression and gas transfer as the bubbles rise. Bubble slip velocity is related to bubble size. At this time, BUBBLEP does not include effects of salinity on plume density, as does the Wuest model, but this could be incorporated if needed.

BUBBLEP handles multiple detrainments of water plumes. The model initiates a new plume each time a plume loses its momentum and bubbles break away from the detraining plume. The model repeats this process until the plume reaches the surface or the bubbles dissolve completely. New plume initiation is based on an initial velocity and plume area that are established using a densimetric Froude number and a plume dimension related to the size of the previous plume prior to its rapid expansion.

BPi Interface for BUBBLEP

BPi is a graphical user interface developed by Loginetics for a stand-alone version of BUBBLEP, which functions identically to the BUBBLEP submodel embedded in W2. The BPi interface prepares inputs for and executes BUBBLEP, then plots the results on the BPi interface. BPi provides means for saving BPi inputs for efficient reuse. BUBBLEP input and output from any run can be saved as text files, so they can be used later with Excel or other programs. BPi provides the user with control over all plume parameters. BPi allows the user to visualize and understand plume characteristics that are occurring in the W2 model. Such characteristics include bubble size, bubble slip velocity, plume flow, velocity, width, momentum, fallback level, plume (and ambient) density, temperature, and quality. BPi is used assists the user in diffuser design and calibration of W2 to field observations.

References:

Brown, R. T., J. A. Gordon, and C. E. Bohac (1989); “Measurement of Upwelling Flow from an Air Diffuser”; J. Environmental Engineering, Vol. 115, No. 6, December.

McGinnis, D. F., A. Lorke, A. Wuest, A. Stockli, and J. C. Little (2004); Interaction between a bubble plume and the near field in a stratified lake; Water Resources Research; 40: 10206; doi:10.1029/2004WR003038.

Wuest, A., N, Brooks, and D. Imboden (1992); “Bubble Plume Modeling for Lake Restoration”; Water Resources Research, vol. 28, no. 12, pp 3235-3250; December.

Appendix H

GIP 10% Factor of Safety Calculation (J418)
(HydroAnalysis, Inc. May 9, 2010)

From: Bruce Jacobs [bjacobs@hydroanalysisinc.com]
Sent: Sunday, May 09, 2010 9:29 AM
To: Courtemanch, Dave L
Subject: GIP 10% factor of safety calculation (J418)

Dave,

You had asked in your May 7 email for me to calculate the additional oxygen at Lower Narrows that would be required to attain the 5 m/L DO compliance, in the event that the amount of BOD entering Gulf Island Pond increased by 10%. I have carried out this calculation and found that this would require an increase in the Lower Narrows oxygen injection of 5.7%.

I noticed that in your email from April 22, related to the 10% factor of safety that you had asked me to look at increases in the oxygen injection at both the Lower Narrows and Upper Narrows. The present calculation asked me to look at only Lower Narrows. Just in case this was an error on your part, I repeated the calculation of increasing the BOD entering Gulf Island Pond by 10% and then calculated the increase in dissolved oxygen injection that would be required if both the Upper Narrows and Lower Narrows oxygen injection were to be increased by the same factor. In this case, the oxygen injection at the two locations would need to be increased by 4.2%.

Bruce Jacobs

HydroAnalysis, Inc.
33 Clark Road, No. 1
Brookline, MA 02445

617-879-0253
bjacobs@hydroanalysisinc.com

-----Original Message-----
From: Courtemanch, Dave L [mailto:Dave.L.Courtemanch@maine.gov]
Sent: sexta-feira, 7 de maio de 2010 14:51
To: bjacobs@hydroanalysisinc.com
Cc: Kavanah, Brian W; Murch, Dana P
Subject: RE: new CBOD run

Bruce,
One more iteration - could you calculate the additional oxygen that would be required at Lower Narrows if the amount of BOD, entering the impoundment, is increased by 10%?

Dave

-----Original Message-----
From: Bruce Jacobs [mailto:bjacobs@hydroanalysisinc.com]
Sent: Monday, April 26, 2010 5:05 PM
To: Courtemanch, Dave L
Subject: RE: new CBOD run

Dave,

I have calculated that a ten percent increase in the injected oxygen into Gulf Island Pond results in a 23 percent increase in the amount of BOD that can be accepted by the pond while staying at or above 5 mg/L DO. Did you want me to write this up as a memo documenting the runs?

Bruce Jacobs

HydroAnalysis, Inc.
33 Clark Road, No. 1
Brookline, MA 02445

617-879-0253
bjacobs@hydroanalysisinc.com

-----Original Message-----
From: Bruce Jacobs [mailto:bjacobs@hydroanalysisinc.com]
Sent: Monday, April 26, 2010 3:03 PM
To: 'Courtemanch, Dave L'
Subject: RE: new CBOD run

Dave,

The increased oxygen injection rates that you listed in your email from last week (2330 lbs of oxygen at Upper Narrows and 3277 lbs at Lower Narrows) are 10% of the rates that I had calculated for the scenario of voluntary reductions in BOD discharge by Verso in my simulations from December of last year. In that case the simulated BOD5 discharge from Verso was 6258 pounds per day. These results were sent to you in a December 1 email.

There were some subsequent simulations that I did in February of this year in which I had simulated BOD5 discharge rates of 5900 pounds per day from Verso. These resulted in a slightly lower required oxygen injection rate at the Lower Narrows (32,333 pounds per day instead of 32,770 pounds per day from last year's simulations). Since the increases in oxygen are not 10% of these oxygen injection rates, I'm going to move ahead on the premise that you knew what you were doing and wanted me to use last December's simulations as the base case for this latest set of simulations. We're only talking about a difference of a couple of percent, but I wanted to me double-sure of what base case I should be working from.

Bruce Jacobs

HydroAnalysis, Inc.
33 Clark Road, No. 1
Brookline, MA 02445

617-879-0253
bjacobs@hydroanalysisinc.com

-----Original Message-----
From: Courtemanch, Dave L [mailto:Dave.L.Courtemanch@maine.gov]
Sent: Thursday, April 22, 2010 10:03 AM
To: bjacobs@hydroanalysisinc.com
Subject: new CBOD run

Bruce,
Could you make another run(s) with the model? In the revised TMDL, I added a Margin of Safety to the oxygen injection requirements. EPA would like to know how those might be translated into an increased CBOD load.

Therefore could you add 2330 lbs of oxygen at Upper Narrows and 3277 lbs at Lower Narrows and then calculate how much CBOD load could be increased and still attain 5ppm dissolved oxygen in the impoundment?

Appendix I

Response to Comments on March 2010 Draft Addendum to Androscoggin River 2005 TMDL

Response to Comments on March 2010 Draft Addendum to Androscoggin River 2005 TMDL

Verso Paper Corp. (Verso)
Letter dated April 22, 2010 from Ken Gallant, Manager, Environmental Services

Comment: Verso points out that the additional model run using alternative permit limits for the Jay mill, as described in the draft TMDL addendum, was based on Verso's proposed BOD reduction and not on the limits that would become effective if the Wausau-Mosinee mill no longer sends its wastewater to the Jay mill for treatment. Verso suggests that the distinction between these issues be made clear.

Response: Verso is correct, and the final TMDL addendum has been revised to include the results of the model run made to determine oxygen injection requirements based on the reduced effluent limits required for the Jay mill in the event that there is a permanent cessation in the treatment of wastewater from the Wausau-Mosinee mill.

Comment: Verso notes that the draft TMDL addendum incorrectly assumes that Verso was proposing to reduce its weekly average BOD limit. Verso states that it clarified in its March 1, 2010 comments on the draft permit modification for the Jay mill discharge that it was proposing to reduce its monthly average BOD limit only.

Response: Verso is correct, and the final TMDL addendum has been revised accordingly.

Comment: Verso notes that the draft TMDL addendum references incorrect effluent limits that would become effective in the event that the Wausau-Mosinee mill no longer sends its wastewater to the Jay mill for treatment.

Response: Verso is correct, and the final TMDL addendum has been revised to make reference to the correct effluent limits (a weekly average BOD5 limit of 5,900 pounds per day and an annual average TSS limit of 14,222 pounds per day) that will become effective in the event that the Wausau-Mosinee mill no longer sends its wastewater to the Jay mill for treatment.

Rumford Paper Company (Rumford)
Letter dated April 22, 2010 from Scott Reed, Environmental Manager

Comment: Rumford suggests that the summary tables in the TMDL addendum be revised to be consistent with the way loads were expressed in the 2005 TMDL, which expressed a waste load allocation for point sources as the CBODu remaining at Twin Bridges (the upper end of Gulf Island Pond).

Response: The Department agrees with Rumford's suggestion. The summary tables in the final TMDL addendum have been revised to express both 7-day and 30-day CBODu as loads to Gulf Island Pond. These CBODu loads were calculated using the same methodology as was used in the 2005 TMDL (see Tables 8 and 9 in the 2005 TMDL).

FPL Energy Maine Hydro LLC (FPL Energy)
Letter dated April 22, 2010 from Chad P. Clark, Vice President

Comment: FPL Energy makes various suggestions for language changes and corrections in the draft TMDL addendum.

Response: The final TMDL addendum includes FPL Energy's suggested changes and corrections, where appropriate.

Comment: FPL Energy notes that there is already an implicit margin of safety in the model and that, as a result, a 10% explicit margin of safety added to the model-predicted oxygen injection requirements is unnecessary and redundant.

Response: The Clean Water Act and EPA's regulations require that a TMDL include a margin of safety to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality. This margin of safety must be above and beyond the appropriate use of conservative assumptions in the development of the model. So, a margin of safety must be added to the model results. Since a margin of safety was not added to the final BOD limits for point sources, the Department proposed in the draft TMDL addendum to add an explicit 10% margin of safety to the modeled oxygen injection requirements. Upon further consideration of FPL Energy's comment, the Department determined that this methodology would result in a 23% margin of safety for BOD. This is much more than is needed. Therefore, in the final TMDL addendum, the Department has re-calculated a margin of safety based on the additional oxygen injection needed to meet standards if the total CBODu load to Gulf Island Pond were increased by 10%. This has the effect of reducing the additional oxygen injection needed to provide the needed margin of safety by over 50%.

Androscoggin River Alliance (ARA)
Letter dated April 22, 2010 from Neil A. Ward, Program Director

Comment: ARA comments that it feels strongly that the current condition of Gulf Island Pond caused by excessive phosphorus discharge from the paper mills violates Maine's Class C water quality narrative standards, in that the waters of the pond are not "swimmable and fishable."

Response: In its 2005 TMDL, the Department concluded that, based on the available monitoring data, a pond-average chlorophyll-a concentration of 10 ppb is a good predictor of algal blooms that would impair the designated uses of Gulf Island Pond. Phosphorus limits have been established by the Department and the Board of

Environmental Protection based on the conclusions reached in the 2005 TMDL. Those limits are not subject to change at this time.

Comment: ARA states its belief that the nutrient criteria rules (Chapter 583: Use Attainment Evaluation Using Nutrient Criteria for Surface Waters) would require a lower standard for phosphorus. ARA further states its belief that the Department should postpone issuance of the final TMDL addendum until final nutrient criteria rules has been adopted by the Board of Environmental Protection.

Response: There is no conflict between the Department's determination of phosphorus loading limits for Gulf Island Pond and the Department's draft nutrient criteria rules. The apparent discrepancy is due to the way the model outputs are reported and the way that nutrient criteria are proposed to be measured in the rules. The model segments are each 10 feet deep. As a consequence of averaging chlorophyll-a in the surface segments of the pond, it could be possible that surface chlorophyll-a would exceed 8 ug/l. However, the draft rule sets a surface water spatial mean chlorophyll-a of 8 ug/l based on the epilimnetic depth for determining "surface" water. The result of averaging the epilimnetic chlorophyll-a for Gulf Island Pond is that chlorophyll-a concentrations are calculated to be less than 8 ug/l. Also, the draft rule sets a maximum chlorophyll-a concentration of 10 ug/l for any sample. Model results indicate that chlorophyll-a concentrations will not exceed 10 ug/l in any segment of the pond.

Verso Paper Corp.
Androscoggin Mill
PO Box 20
Jay, ME 04239

Kenneth R. Gallant
Manager, Environmental Services

T 207 897 1633
F 207 897 1783
E kenneth.gallant@versopaper.com
W www.versopaper.com

April 22, 2010

Mr. Dana Murch
Division of Water Quality Management
Bureau of Land and Water Quality
State House Station 17
Augusta, Maine 04333

RE: Verso Comments on Draft Addendum to 2005 Androscoggin River TMDL

Dear Dana:

Please accept the following comments pertaining to the above referenced addendum to the 2005 Androscoggin River TMDL. These comments are narrow in scope and correct what we believe to be either typos or references to unintentional waste discharge limits.

The discussion in the 2005 TMDL Addendum pertaining to Verso's TSS, and particularly the BOD5 license limits, is somewhat confusing in that it combines two separate and distinct regulatory actions. The first is the reference to Appendix E of the TMDL Addendum. Appendix E is an Analysis of the GIPOP Partnership Proposed Alternative Oxygen Injection Rates – where HydroAnalysis ran a second distinct scenario based on a proposed reduction of Verso's weekly BOD5 license limit from 6,400 lbs/day to 6258lb/day (a 2.2% reduction). The second regulatory action is the reference to the Wausau-Mosinee permanent cessation of discharge. This is addressed in the February 7, 2008 Board Order under Special Condition (A)(2). This condition provides that Verso's discharge limits be lowered to 14,222 lbs/day of TSS annual average and 5,900lbs/day of BOD5 weekly average if certain conditions are met.

Specifically, under the section entitled *Oxygen Injection Component of the Model*, in the 2005 TMDL addendum, the Department describes an additional model run using alternative permit limits for Verso that would become effective if Wausau-Mosinee no longer sends its wastewater to Verso. ***In reality the additional model run has nothing to do with the Wausau – Mosinee discharge cessation issue.*** The second model run was conducted to determine the necessary oxygen feed rate corresponding to a proposed 2.2% reduction in Verso's weekly BOD5 license limit. This 2.2 % reduction in weekly BOD5 was based on a proposal that Verso made to voluntarily reduce its average *monthly* BOD5 by 2.2% from 4,500 lbs/day to 4,400/lbs per day. Correspondingly the Department proposed to reduce Verso' *weekly* BOD5 limit from 6400lbs/day to 6258lbs/day and requested HydroAnalysis Inc. to perform a second model run to reflect this.

In a related matter, based on a response to comments submitted by Verso on March 1, 2010 pertaining to the January 29 draft permit, the Department has stated in an email dated March 8, 2010, that it intends to keep the current weekly BOD5 limit in place which is 6400 lbs/day and does not intend to lower the weekly limit BOD5 limit to 6,258lbs/day.

The language as written in the TMDL Addendum under the Introduction section, the section entitled *Oxygen Injection Component of the Model* as well as the tables under the *Summary of Findings from the Revised Models* confuses the two issues and should be struck from the document or re-written to accurately reflect the reason why the second model run was conducted.

Furthermore there are some typos that need should be corrected for the record. First of all the Verso BOD5 weekly average discharge would be 6,258 lbs/day not 6,248 lbs/day and secondly the annual average TSS should be 14,222 lbs/day not 12,222 lbs/day.

Thank you for the opportunity to comment on this TMDL Addendum Verso looks forward to working with the Department and appreciates the effort the Department has made in bringing this issue to resolution.

Please contact me if you have any questions or require clarification.

Sincerely,

Ken Gallant
Manager, Environmental Services

cc:
Nehl Aldridge, VP
Marc Connor, VP
Vickie Gammon, VP
Mike Rowland, VP
Chad Clark, FPL
Frank Dunlap, FPL
Ryan Carrier, Fraser
Gregg Wood
Scott Reed, RPC
file

NewPage®

April 22, 2010

Mr. Dana Murch
Division of Water Quality Management
Bureau of Land and Water Quality
Maine Department of Environmental Protection
17 State House Station
Augusta, ME 04333-0017

Dear Mr. Murch:

Rumford Paper Company appreciates the opportunity to comment on the draft addendum to the 2005 TMDL. Our comments are intended to clarify the information provided in the Summary of Findings for the draft addendum.

Based on our review of the draft addendum, the CBOD information presented in the summary tables titled, "Revised 2010 TMDL for Gulf Island Pond" and Revised 2010 TMDL for Gulf Island Pond without Wausau-Mosinee" should be revised to ensure they are on a consistent basis with the Table 8 of the 2005 TMDL. The tables in the draft addendum present the CBOD Waste Load Allocation for point sources as a sum of the 7-Day BOD$_5$ license limits for each point source. Although the WLA ultimately translates to these license limits, we believe that the WLA itself should be expressed as the BODu remaining at Twin Bridges. The conversion to CBODu is presented in the Table below (the conversion factors were obtained from Table 8 of the 2005 TMDL). A similar calculation could be performed for the alternate scenario (without Wausau-Mosinee).

Updated CBOD for draft TMDL Addendum

	Source	7- Day BOD$_5$ (lbs)	CBODu/ BOD$_5$	% BOD remaining at Twin Bridges	Ultimate CBOD (lbs)
	Fraser	10,298	3.6	17.4%	6,451
	Rumford Paper	12,500	3.6	31.9%	14,355
	Verso	6,400	3.5	63.2%	14,157
	Berlin	991	3	39.1%	1,162
	Bethel	128	3	39.1%	150
	Rum-Mex	995	3	39.1%	1,167
	Liv Falls	750	3	39.1%	880
WLA - point					38,322
LA - non point					9,444
Explicit Margin of Safety					n/a
Total					47,766

Please note that the water quality modeling was performed on a consistent basis with the 2005 TMDL and no further changes are needed. This correction is intended to ensure that the Waste Load Allocation in the 2010 TMDL Addendum is approved in a consistent manner with the previous TMDL.

Please feel free to contact me at (207) 369-2203 if you have any questions or would like to discuss these comments further.

Sincerely,

Scott Reed
Environmental Manager

cc:
Gregg Wood - DEP
Chad Clark – FPL Energy
Frank Dunlap – FPL Energy
Ken Gallant – Verso
Ryan Carrier – Fraser
Michael Kaplan – Preti Flaherty
Virginia Davis – Preti Flaherty

NEXTera ENERGY RESOURCES

April 22, 2010

Dana Paul Murch
Bureau of Land and Water Quality
Department of Environmental Protection
17 State House Station
Augusta, ME 04330-0017

FPL Energy Maine Hydro LLC Comments
March 2010 Draft Addendum to the Androscoggin River 2005 TMDL

Dear Mr. Murch:

FPL Energy Maine Hydro LLC (FPL Energy) has reviewed the March 2010 Draft Addendum to the Androscoggin River 2005 Total Maximum Daily Load for Gulf Island Pond (TMDL Addendum). Our primary comment on the draft relates to the redundant Margin of Safety (MOS) proposed by the Department. Additionally, we suggest several corrections to the TMDL Addendum.

General Comments and Corrections

There are several corrections that should be made in order to finalize the TMDL Addendum.

Title - This addendum does not directly address the Livermore Falls Impoundment and this reference would appropriately be removed from the title.

Summary of findings from the revised models. - The first bullet states that the revision to the models "... found a reduced need for supplemental oxygen using different proposed injection techniques." This gives the impression that it was only the injection techniques that changed the model results, when in fact the recalibration and correction of the model in and of itself significantly changed the results, and lowered the anticipated supplemental oxygen requirements. The last phrase, starting at "using" should therefore be deleted. This would better allow recognition that the modified injection strategy provided reduction in the oxygenation needs separately from the model corrections.

The second bullet correctly includes the revised oxygenation strategy but is an incomplete sentence. It should read to the effect that, "The revised model runs also used a different supplemental oxygenation strategy that results in an overall reduction in total oxygenation required, this includes improved ... ."

Oxygen Component of the Model - The third sentence should read "At the direction of the Board of Environmental Protection, the model was recalibrated ... ." this better emphasizes the incumbent need to fix the model.

The next to the last sentence should be corrected by removing the phrase "dissolved oxygen by river mile," because the recalibration and correction of the model did in fact affect anticipated oxygen levels.

Oxygen Injection Component of the Model - The first sentence is incomplete and it would appear that it should read "Following WASP model recalibration, the GIPOP Partnership offered an alternative that would 1) allow a reduction in CBOD, 2) add an additional oxygen injection station at Lower Narrows and 3) would improve the oxygen transfer efficiency .... ." In reference to the addition of an injection station at Lower Narrows, we would suggest deleting the phrase "(As advised in the 2005 TMDL.)" since that reference is in relation to adding a second oxygenation facility and system which is not the current proposal (i.e. reconfiguring and adding to the existing diffusers).

Margin of Safety - The first sentence of the second bullet should be modified to read, "While an explicit MOS was not added for CBOD, ...", this would recognize the implicit MOS that is included in the model for CBOD.

The last sentence of last bullet should be amended to recognize that the proposed reopener clauses in the permits and water quality certification "can allow modifications should monitoring indicate that the wasteload or supplemental oxygen injection requirements are insufficient, or more than sufficient, to attain water quality standards. This is appropriate especially in consideration that the modeling and TMDL Addendum contain implicit and explicit margins of safety that effectively overestimate the amount of supplemental oxygen required for injection.

Margin of Safety Requirements

The TMDL Addendum includes three separate margins of safety that affect the supplemental oxygenation requirement. The first bullet in the section states that, even with the Department's revised approach to applying a margin of safety, the implicit margin in the model is "relatively the same as the 10% explicit + clustering factor approach used in the 2005 TMDL." The second bullet then adds an explicit 10% factor if safety to the model predicted supplemental oxygen requirements. The third bullet also adds a 10% factor of safety for the phosphorus component which partially affects the oxygen requirement. Considering the confidence that the Department states in the improved model, and the MOS included implicitly in the modeling, the additional 10% MOS added to the oxygen requirement is unnecessary and redundant. Additionally, as the Department notes in the addendum, the adaptive management provided for in the operations plan, the ambient sampling, and the reopener clauses provide adequate ability to adjust the oxygen injection rate requirements to meet standards without adding a redundant MOS. We would request that the additional 10% MOS for the oxygenation system not be required.

FPL Energy appreciates this opportunity to comment on the Draft TMDL Addendum, and looks forward to expeditious approvals of both the TMDL Addendum and the permit modifications required for the installation of the reconfigured oxygen diffusers to move forward. If you have any questions please feel free to contact either me or Frank Dunlap.

Sincerely,

Chad P. Clark

Chad P. Clark, Vice President
FPL Energy Maine Hydro LLC

Cc: GIPOP Partners

Androscoggin
River Alliance
P. O. Box 177
Lewiston, Maine 04240

April 22, 2010

Mr. Dana Murch
Department of Environmental Protection
17 State House station
Augusta, ME 04330-0117

Dear Mr. Murch:

The Androscoggin River Alliance ("ARA") submits the following comments regarding the Maine Department of Environmental Protection's ("DEP") draft addendum to the May 2005 Total Maximum Daily Load Report ("TMDL") for the Androscoggin River.

As an initial matter, ARA hereby restates and incorporates by reference all prior comments, testimony, motions, and other filings provided by ARA and its co-appellants in the recent appeals of the permits and certifications (the "Androscoggin River Appeals").

Addendum to the TMDL

While these proposed revisions to the TMDL are the result of the revised and recalibrated water quality model for Gulf Island Pond ordered by the Maine Board of Environmental Protection ("BEP"), much remains to be done to protect our river. The existing condition of Gulf Island Pond, caused by excessive discharge of pollutants from the paper mills decade after decade and exacerbated by Gulf Island Pond Dam, prevent the use and enjoyment of this resource by ARA members and local citizens alike.

Therefore, the ARA feels strongly that the current condition of Gulf Island Pond, during bloom and sub-bloom algal growth conditions creating odor and slime in July and August, caused by excessive phosphorous discharge from the paper mills violates Maine's class "C" water quality narrative standards. Under Maine's class "C" water quality narrative standards designated uses are "swimmable and fishable" but the current conditions prevents those designated uses.

The ARA also feels that the present effort to issue a final Androscoggin River 2005 TMDL for Gulf Island Pond and the Livermore Falls Impoundment is premature as the DEP is currently making final revisions for Chapter 583: Use Attainment Evaluation Using Nutrient Criteria for Surface Waters. A final BEP adoption hearing for those rules was just recently postponed, and a rescheduled hearing appears imminent.

It appears to the ARA that the Chapter 583: Use Attainment Evaluation Using Nutrient Criteria for Surface Waters would require a lower standard for phosphorus that would be beneficial to the Gulf Island Pond Impoundment. We believe it would be more appropriate for the DEP to postpone the issuance of a final TMDL until the BEP adoption hearing has been held and final rules have been adopted.

As the final TMDL has taken nearly 5 years to develop into final action it stands to reason that the final Androscoggin River 2005 TMDL criterion should be based on the newly developed standards.

We appreciate the opportunity to comment on the draft Addendum to the Androscoggin River 2005 Total Maximum Daily Load. If you have any questions, please feel free to contact me or ARA's attorney Steve Hinchman.

Sincerely,

Neil A. Ward
Program Director