Spokane River TMDL Model Simulations

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Spokane River Total Maximum Daily Load (TMDL) scenarios were simulated using the CE-QUAL-W2 model developed for the Washington Department of Ecology by Portland State University (Berger et al., 2003). The output of a newly calibrated Idaho section model had recently become available, necessitating new simulations which employed the Idaho model's output as the Washington model's upstream boundary condition (Cope, 2006).

The scenarios were run with varying dissolved phosphorus inputs for Washington tributaries to determine the amount of additional phosphorus that would reduce Long Lake dissolved oxygen by 0.2 mg/l with respect to background conditions. Phosphorus rather than ammonia was varied because it has more of a significant impact on algal production. Background conditions are defined as the water quality without human caused pollution sources. The adjusted Washington tributaries were Hangman Creek, Coulee Creek, and the Little Spokane River. Input files at the upstream boundary condition, located at the Washington-Idaho state line, were provided by EPA. These input files were the output of the upstream model that was developed for the Idaho section of the Spokane River. The Idaho simulation included point source loads corresponding to the proposed Idaho permits (Cope, 2006).

The Washington scenarios were listed in Table 1. The scenarios had Washington point source nutrient and CBOD loadings set to groundwater conditions. Scenario A had tributary inputs at background levels. Scenario B had CBOD concentrations at 2001 levels and dissolved phosphorus at background levels. For Scenario C the CBOD concentrations remained at 2001 levels, but dissolved phosphorus was increased 2.5 times from background levels. Scenario D used CBOD and phosphorus loadings which were equivalent to 2001 levels.

Table 1. Descriptions of model scenarios and their tributary loads.

Scenario	Description of tributary loads	Dissolved P	CBOD
A	Background inputs	Background	Background
B	CBOD at 2001 levels, dissolved P at background levels	Background	2001 levels
C	CBOD at 2001 levels, dissolved P at 2.5 times background levels	2.5X background concentrations	2001 levels
D	CBOD and dissolved P at 2001 levels	2001 levels	2001 levels

For each scenario, the model cell weighted average dissolved oxygen concentration for the model segment adjacent to the Lake Spokane dam (segment 188) was calculated, selecting only cells that had values below 8.0 mg/l. At a time step of 0.02 days, the algorithm would scan the model cells adjacent to Lake Spokane dam for concentrations less than 8.0 mg/l. For each time step, the concentrations of cells satisfying the "less than 8.0 mg/l concentration" criterion would be averaged. To permit comparisons between simulations having slightly different hydrodynamics, the model predictions were smoothed for each scenario by calculating the running average of the concentrations using a window of one-fifth of a day. The difference in the "smoothed" cell weighted concentrations of the scenarios relative to the background conditions scenario were

calculated and plotted in Figure 2. Increasing the dissolved phosphorus 2.5 times in tributaries reduces the cell weighted average of the dissolved oxygen concentrations at the dam by approximately 0.2 mg/l, compared to background conditions.

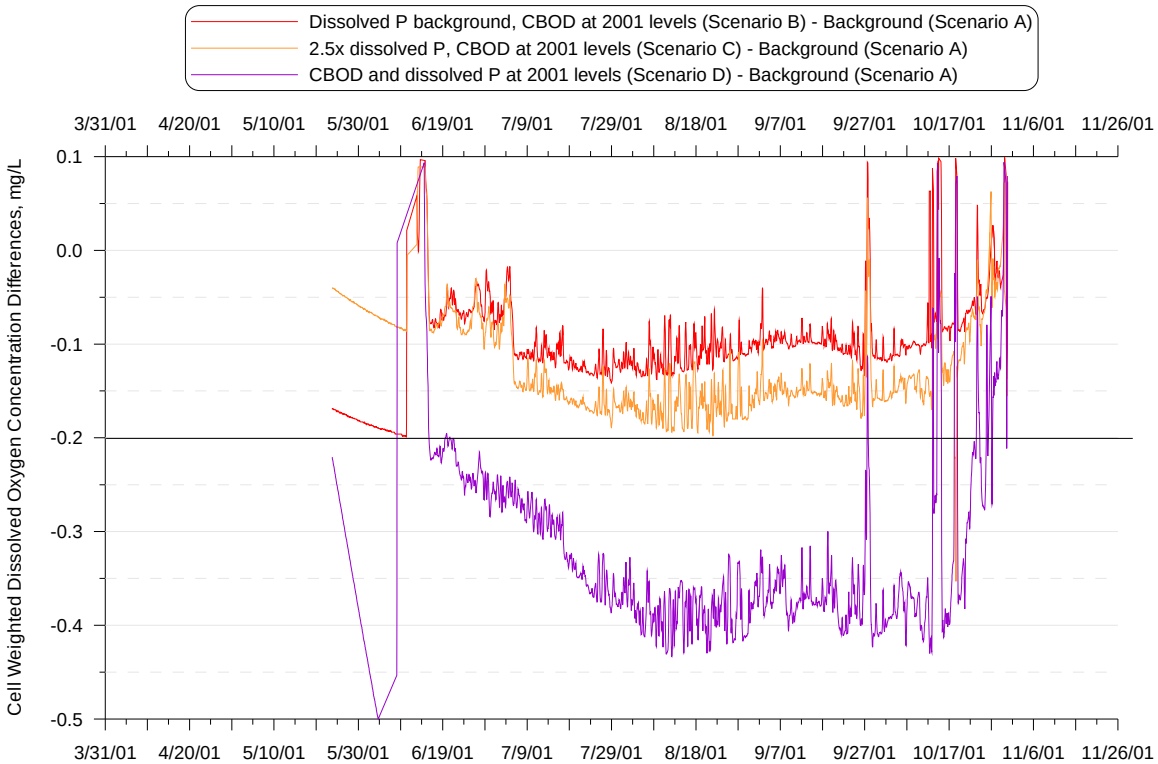


Figure 1. Plot of cell weighted dissolved oxygen differences for model segment adjacent to dam (segment 188) and considering only cell concentrations less than 8.0 mg/l. The linear nature of the plots prior to June 19 is due to lack of variation and the low number of model cells being used in the calculation. The dissolved oxygen differences were not plotted before May 20 because there were not any model cells predicting concentrations less than 8.0 mg/l. The dynamic fluctuations occurring after September 27 were caused by differences in the hydrodynamics in the model runs. The different nutrient loadings in the scenarios caused differing amounts algae growth, which slightly affected temperature predictions by changing the water transparency. The different temperature predictions affected the timing of turnover events during Fall, leading to the fluctuations in the predicted dissolved oxygen differences.

The April/May tributary phosphorus loadings for the current conditions scenario, the background conditions scenario, and 2.5X background P concentration in tributaries scenario were shown in Table 2. The June through October and the April through October tributary phosphorus loadings for these scenarios were shown in Table 3 and Table 4, respectively. For the May/April period, the 2.5X background P in tributaries scenario corresponds to a 22% reduction of phosphorus loadings from 2001 levels. The reduction in phosphorus loadings for the June through October period was 6% and for the April through October period was 15%.

Table 2. April/May phosphorus loadings of tributaries for current conditions (2001) scenario, background conditions scenario, and 2.5X background P concentration scenario. Loadings from the current conditions scenario have to be reduced 22% to be equivalent to the P loadings of the 2.5X background P concentration scenario.

Average pounds/day of TP				
	Current 2001 Scenario D	Background Scenario A	TMDL, or 2.5x P concentration Scenario C	Percent Reduction from 2001 levels
Hangman	53.71	12.26	32.71	39%
Coulee	14.02	3.20	8.54	39%
Little Spokane	131.47	59.30	114.62	13%
Total	199.20	74.76	155.87	22%

Table 3. June through October phosphorus loadings of tributaries for current conditions (2001) scenario, background conditions scenario, and 2.5X background P concentration scenario. Loadings from the current conditions scenario have to be reduced 6% to be equivalent to the P loadings of the 2.5X background P concentration scenario.

Average pounds/day of TP				
	Current 2001 Scenario D	Background Scenario A	TMDL, or 2.5x P concentration Scenario C	Percent Reduction from 2001 levels
Hangman	4.04	1.29	3.21	21%
Coulee	1.05	0.34	0.84	20%
Little Spokane	58.21	36.04	55.75	4%
Total	63.30	37.67	59.80	6%

Table 4. April through October phosphorus loadings of tributaries for current conditions (2001) scenario, background conditions scenario, and 2.5X background P concentration scenario. Loadings from the current conditions scenario have to be reduced 15% to be equivalent to the P loadings of the 2.5X background P concentration scenario.

Average pounds/day of TP				
	Current 2001 Scenario D	Background Scenario A	TMDL, or 2.5x P concentration Scenario C	Percent Reduction from 2001 levels
Hangman	18.23	4.42	11.64	36%
Coulee	4.76	1.16	3.04	36%
Little Spokane	79.14	42.69	72.57	8%
Total	102.13	48.27	87.25	15%

Simulation with Washington Point Sources having total phosphorus concentrations of 50 micrograms/liter

An additional Spokane River scenario was modeled with Washington point sources having total phosphorus concentrations of 50 micrograms/liter. Ammonia-nitrogen, BOD5, nitrate, dissolved oxygen, and temperature were set to the values shown in Table 5. BOD5 was converted to CBOD ultimate using the CBOD decay rate for each discharger. The stoichiometric equivalent between CBOD mass and phosphorus were also set to values applicable to each discharger. The decay rate and stoichiometric equivalent between CBOD mass and phosphorus for the Spokane Country WTP were assumed to be the same as that of the City of Spokane WTP.

Table 5. Concentrations, average flow rate and temperatures used for point sources

Discharger	Total P	BOD5	Nitrate	Ammonia	DO	Flow	Temp

	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	Avg. (cms)	(°C)
City of Spokane	0.050	2.0	8.0	0.20	7.0	1.63 (57.5 cfs)	20.0
Spokane County	0.050	2.0	8.0	2.0	5.0	0.35 (12.4 cfs)	20.0
Inland Empire Paper	0.050	6.0	0.10	1.0	6.0	0.19 (6.7 cfs)	27.8
Liberty Lake	0.050	2.0	8.0	0.10	5.0	0.03 (0.9 cfs)	18.0
Kaiser	0.050	2.0	1.0	0.05	(used 2001 values)	0.70 (24.6 cfs)	21.9

The simulation was run with constituent concentrations in Hangman Creek, Coulee Creek, and the Little Spokane River set to values corresponding to background conditions. Input files at the upstream boundary condition were provided by EPA. These input files were the output of the model developed for the Idaho section of the Spokane River. The Idaho simulation included point source loads corresponding to the proposed Idaho permits (Cope, 2006).

The difference in the "smoothed" cell weighted concentrations of the scenario relative to the background conditions scenario were calculated and plotted in Figure 2.

With constituent concentrations in Hangman Creek, Coulee Creek, and the Little Spokane River being set to background condition values, the simulation with Washington point sources having total phosphorus concentrations of 50 micrograms/liter slightly exceeded the standard of 0.2 mg/l on several occasions.

References:

Berger, C.J., R.L. Annear, S.A. Wells, and T. Cole, 2003. "Upper Spokane River Model: Model Calibration 2001." Technical Report EWR-01-03. Department of Civil Engineering, Portland State University, Portland, OR.

Cope, B. (2006). "Assessment of the water quality impact of Idaho wastewater treatment plants on the Spokane River and Long Lake." *Technical Report*, Office of Environmental Assessment, EPA Region 10 Seattle, Washington.

Merrill, K. and B. Cusimano (2004). " Total maximum daily load to restore and maintain dissolved oxygen in the Spokane River and Lake Spokane (Long Lake), DRAFT." Water Quality Program, Washington State Department of Ecology, Olympia, Washington.

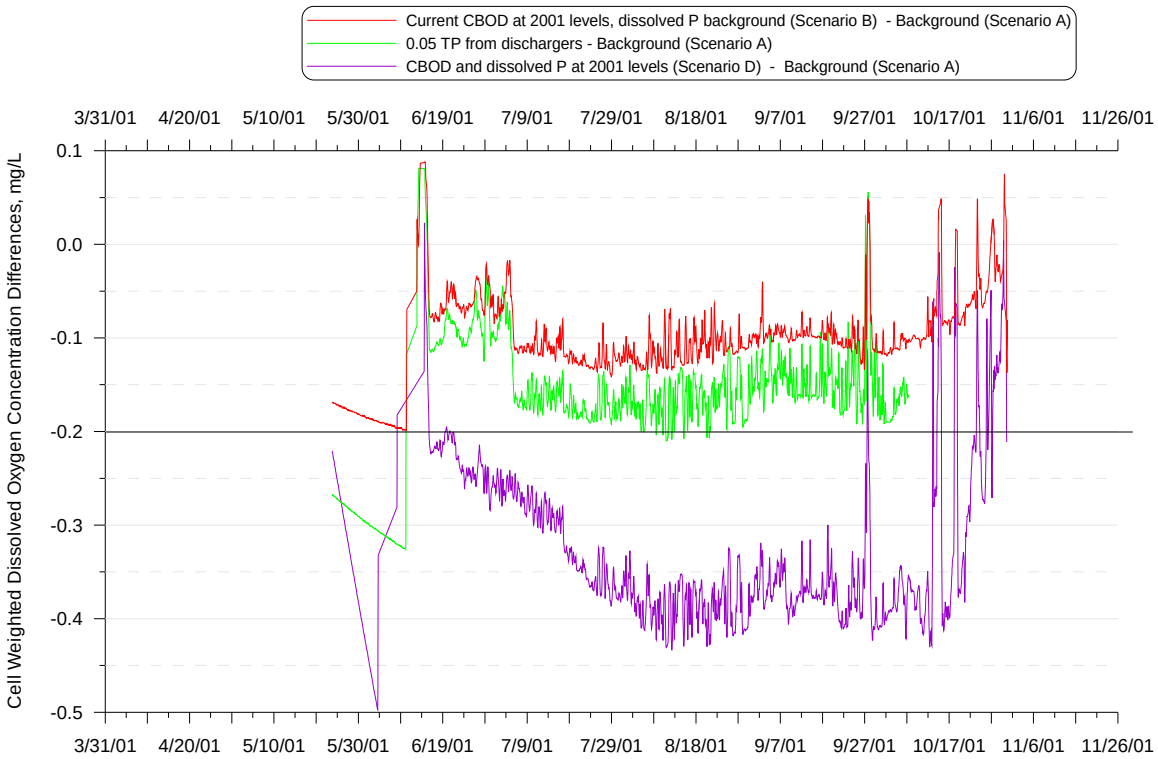


Figure 2. Plot of cell weighted dissolved oxygen differences for model segment adjacent to dam (segment 188) and considering only cell concentrations less than 8.0 mg/l. The linear nature of the plots prior to June 19 is due to lack of variation and the low number of model cells being used in the calculation. The dissolved oxygen differences were not plotted before May 20 because there were not any model cells predicting concentrations less than 8.0 mg/l. The dynamic fluctuations occurring after September 27 were caused by differences in the hydrodynamics of the model runs. The different nutrient loadings in the scenarios caused differing amounts algae growth, which slightly affected temperature predictions by changing the water transparency. The different temperature predictions affected the timing of turnover events during Fall, leading to the fluctuations in the predicted dissolved oxygen differences.

Appendix A – Vertical Profiles

Model scenarios were simulated to created vertical profiles of dissolved oxygen similar to those shown in the 2004 Total Maximum Daily Load report (Merrill and Cusimano, 2004). The following scenarios were simulated:

- **Current**: The 2001 calibration run using data at the upstream boundary (state line).
- **No Point:** The current case without the point source loads. The upstream boundary constituent files were provided by EPA (Cope, 2006).
- **No Source:** The current case with tributary loads set at background concentrations. The upstream boundary constituent files were provided by EPA.
- **Treatment:** The current 2001 case except effluent quality was improved for all dischargers so that total phosphorus concentration was 0.020 mg/L TP, 0.1 mg /L NH3 and 2 mg/L CBOD. The upstream boundary constituent files were provided by EPA.
- **SOD:** The current case without the point source loads, tributary loads set at background concentrations, and the maximum sediment oxygen demand set at 0.25 g O_2 m^{-2} per day. The upstream boundary constituent files were those provided by EPA.

In Figure 3 simulated vertical profiles of dissolved oxygen are compared on selected dates for the model segment adjacent to Lake Spokane dam. The above scenarios (except for the SOD scenario) were also simulated using a minimum allowable flow of 745 cfs released from Post Falls Dam. Figure 4 compares the dissolved oxygen profiles from these scenarios.

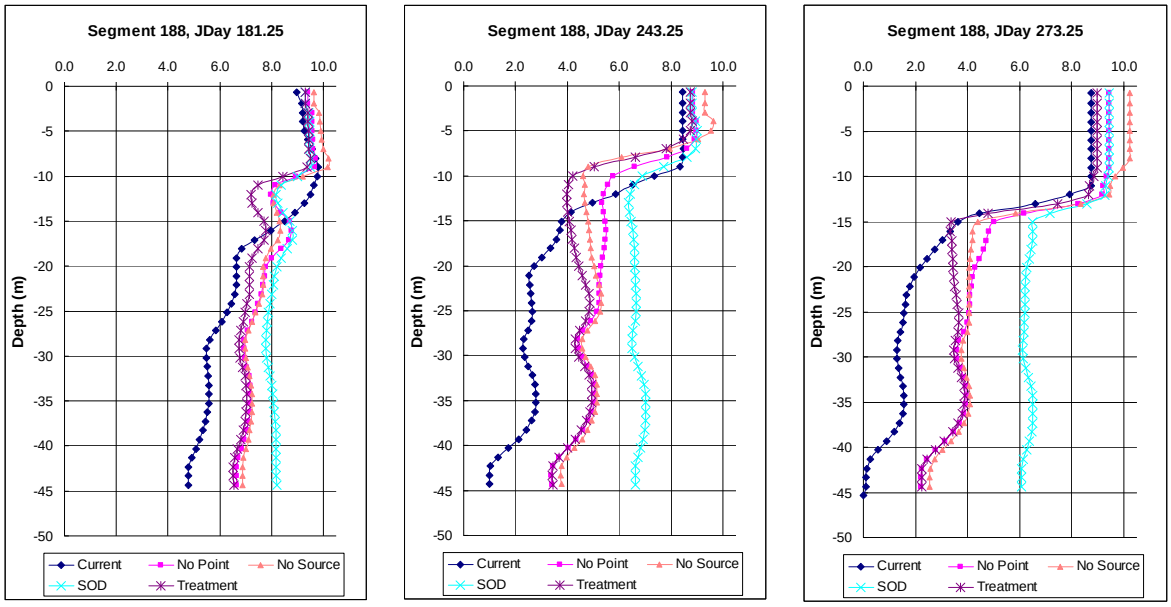
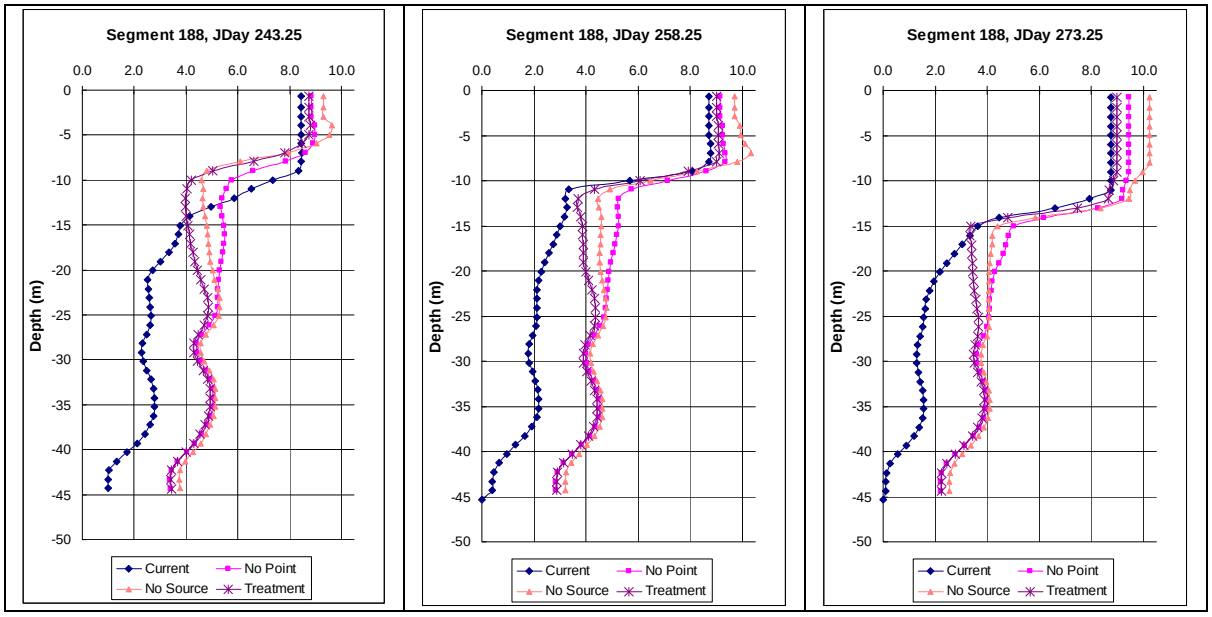
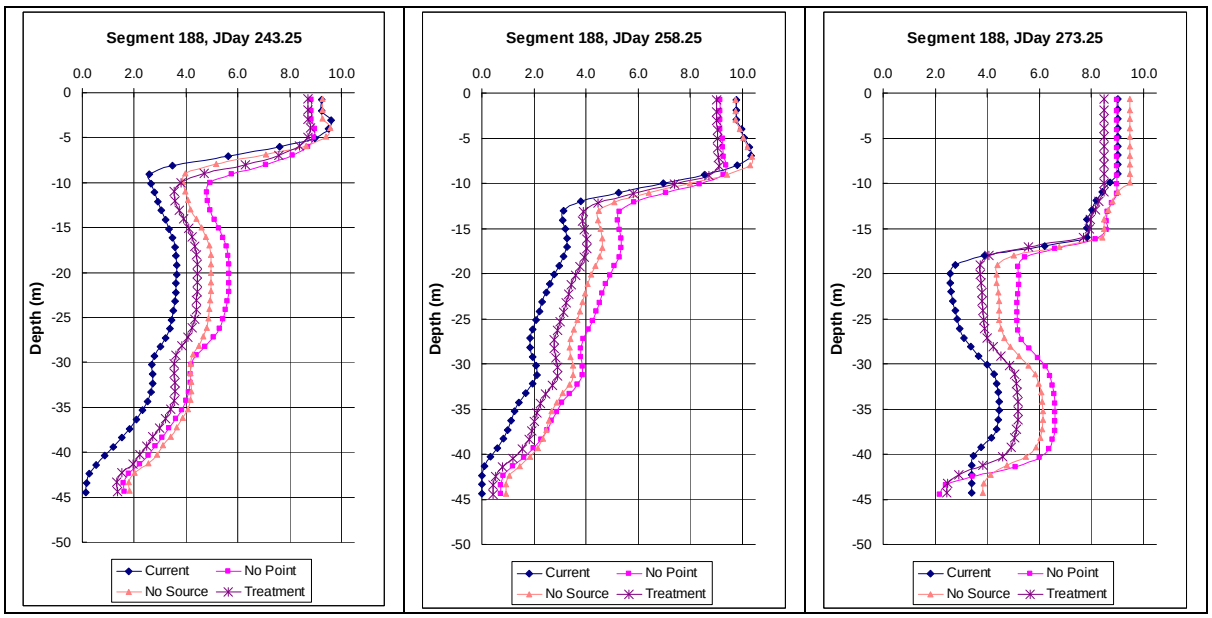


Figure 3. Model predicted dissolved oxygen profiles for Lake Spokane at model segments 188 for the CURRENT, NO-POINT, NO-SOURCE, PERMIT, and SOD scenarios on Julian days 181.25 (Jun 15), 243.25 (Sep 1), 273.25 (Oct 1).

Figure 4. Comparison of model predictions for Lake Spokane dissolved oxygen (DO) near Dam (segment 188) during 2001 flows and augmented minimum flows (745 cfs @ Post Falls).

2001 Flows



Augmented Minimum Flow (745 cfs @ Post Falls)