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Upper Spokane River Model in Idaho: Boundary Conditions and Model Setup for 2001

By

Scott A. Wells

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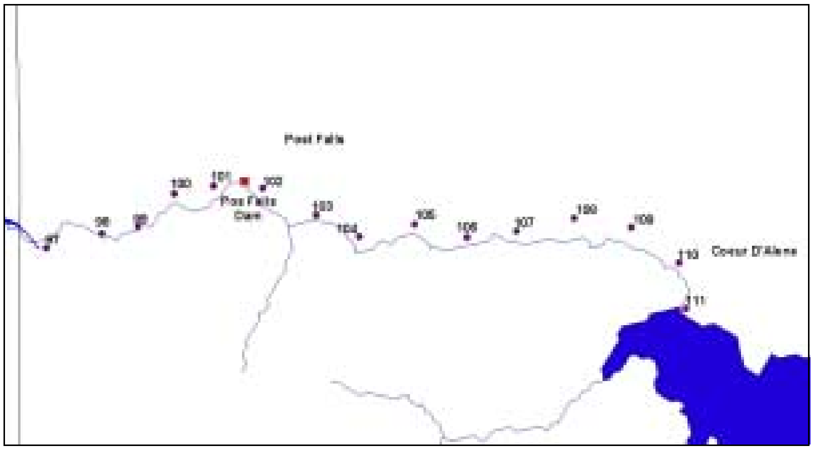

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Technical Report EWR-02-03

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April 2003

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Introduction

The Spokane River in Idaho originates in Coeur d'Alene Lake (Figure 1 and Figure 2). The section of the Spokane River from Coeur d'Alene Lake to the Washington state line is the subject of a water quality study for the US Environmental Protection Agency. The objective of this study is to create a water quality and hydrodynamic model of the Spokane River in Idaho using CE-QUAL-W2 Version 3.1 (Cole and Wells, 2002).

Since the Spokane River is water quality limited, a hydrodynamic and water quality model for the Spokane River in Washington was developed by Portland State University for the Corps of Engineers and the Washington Department of Ecology from the Idaho border to the outlet of Long Lake.

Prior reports prepared for the Spokane River modeling in Washington include:

- Annear et al. (2001) - Upper Spokane River Model: Boundary Conditions and Model Setup for 1991 and 2000
- Berger et al. (2002) - Upper Spokane River Model: Calibration for 1991 and 2000
- Slominski et al. (2002) - Upper Spokane River Model: Boundary Conditions and Model Setup for 2001 where information such as the following were detailed:
    1. Inflows, temperatures, and water quality
    2. Meteorological conditions
    3. Bathymetry of the Spokane River and Long Lake and the model grid
    4. Reservoir operations and structure information
- Berger et al. (2003) - Upper Spokane River Model: Calibration for 2001

An earlier study of the Spokane River was undertaken by Limno-Tech (2001a, 2001b) for the domain shown in Figure 3. Limno-Tech used an earlier version of CE-QUAL-W2, Version 2, for the Reservoir portion of the Spokane River from Post Falls Dam to Coeur d'Alene Lake and a steady-state EPA model, QUAL2E, for the riverine section from Post Falls Dam to the Idaho-Washington border. The steady-state QUAL2E model was not adequate to deal with flow and water quality dynamics. Hence, the riverine portion of the model and the reservoir portion were both upgraded to CE-QUAL-W2 Version 3.1.

Because of the necessity of looking at the entire water basin, a model using CE-QUAL-W2 Version 3.1 of the Idaho portion of the Spokane River model was developed to assess water quality management strategies for the Idaho side of the Spokane River.

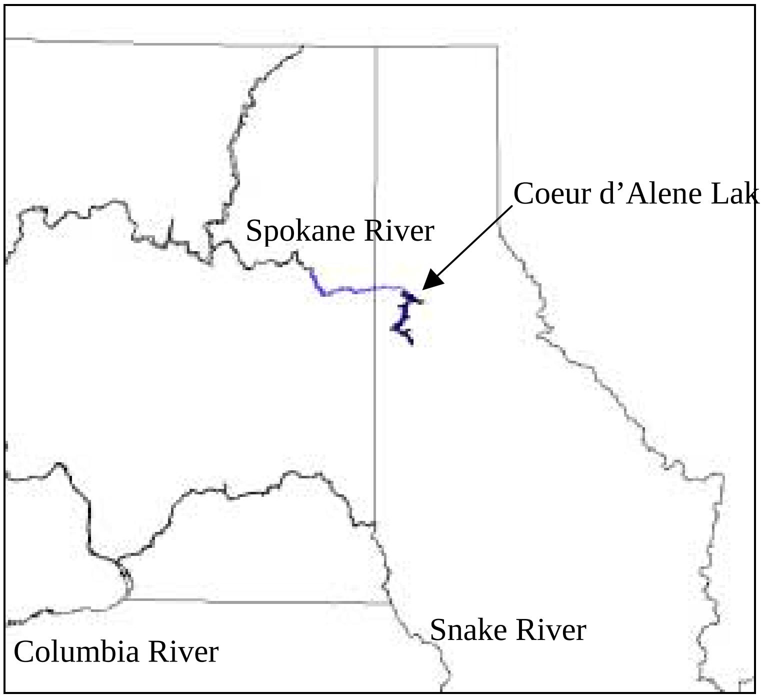


Figure 1. Spokane River study area in Idaho.

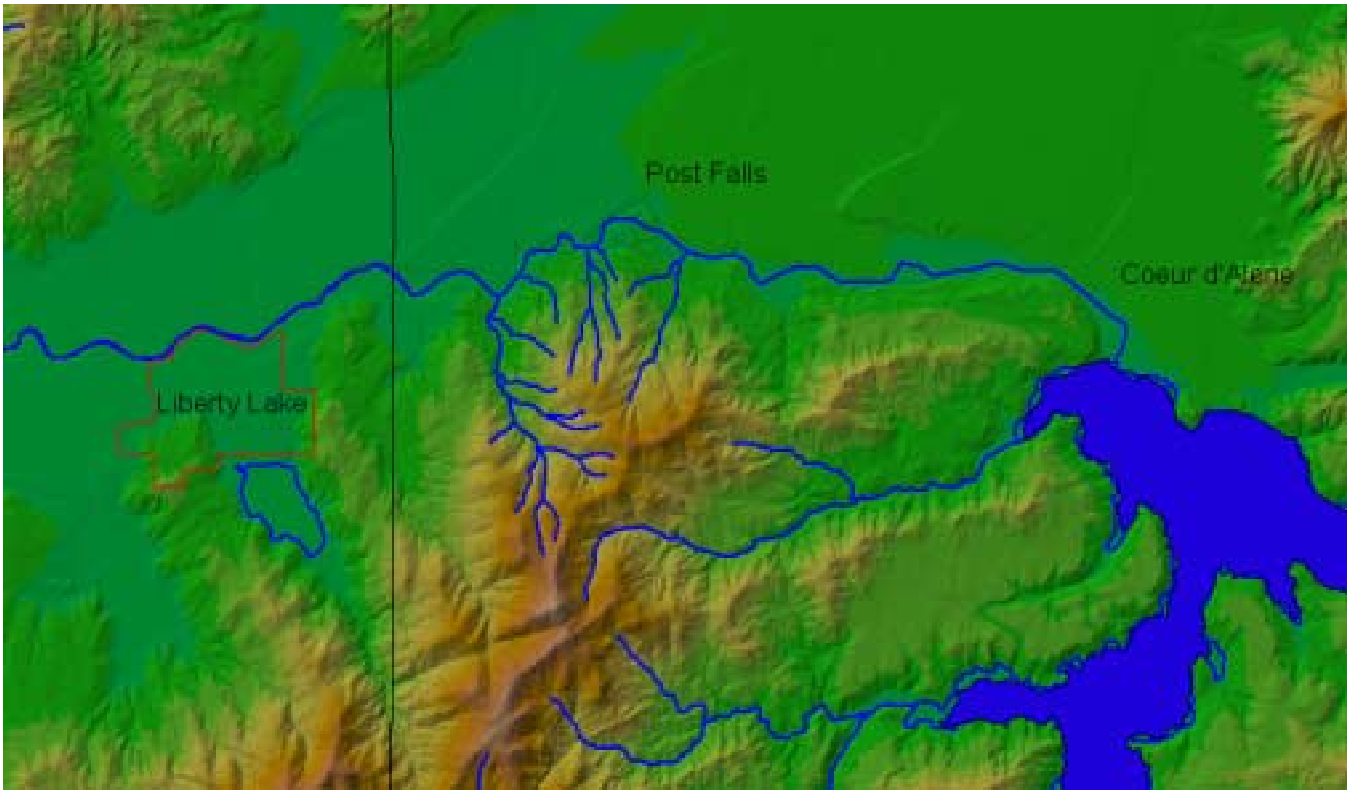


Figure 2. Detailed study area from Coeur d'Alene Lake to the Washington-Idaho border on the Spokane River.

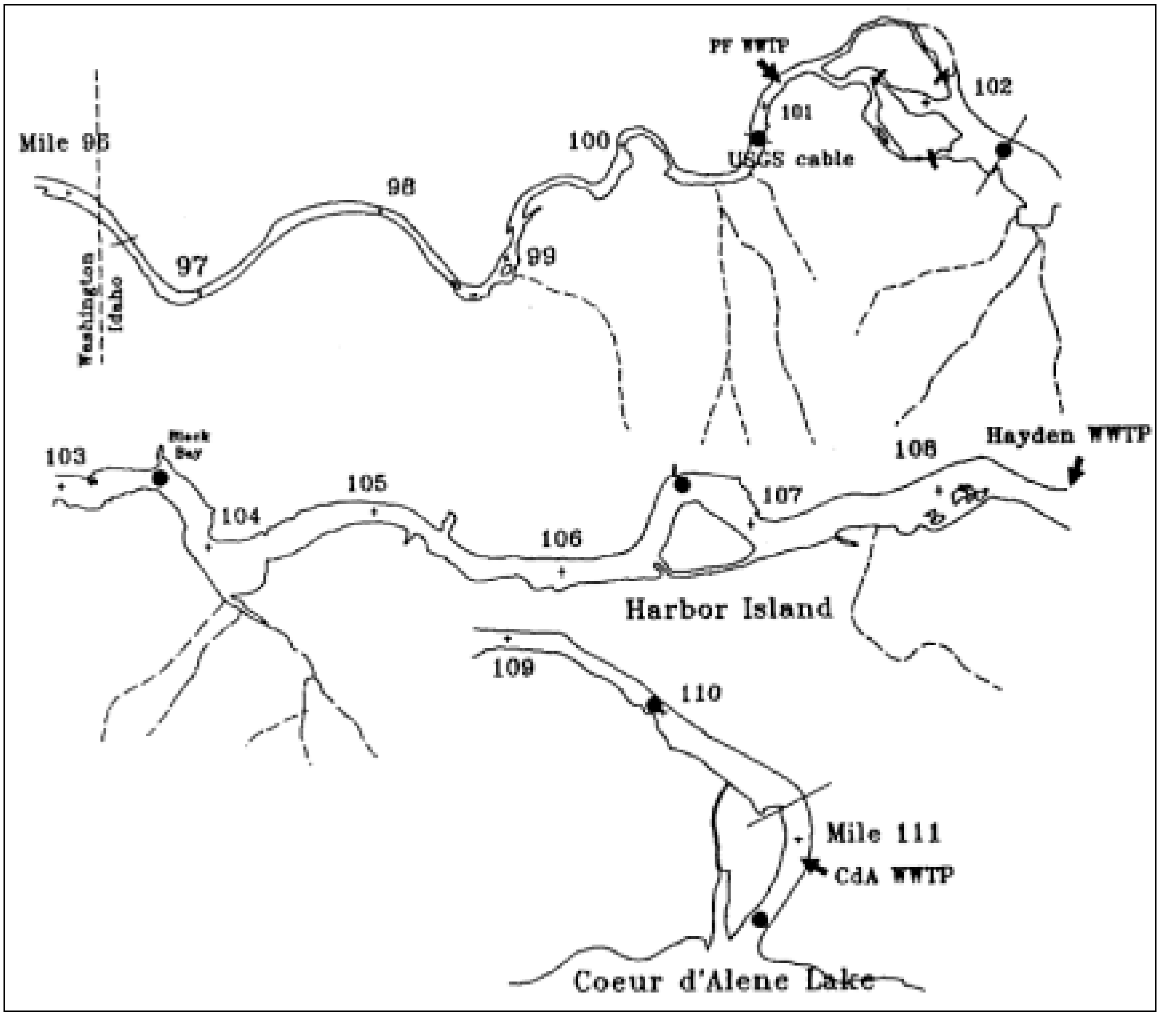


Figure 3. Map of study area from Limno-Tech, Inc. (2001).

Background

Washington Department of Ecology described the background of the Spokane River study area (Cusimano, 2002):

> The Spokane River upstream of Long Lake (Figure 4) drains over 6,000 square miles of land in Washington and Idaho. The Spokane River flows west from Lake Coeur d'Alene in Idaho, across the State Line to the City of Spokane. From Spokane, the river flows northwesterly to its confluence with the Columbia River at Lake Roosevelt. Most of the people in the watershed live in the Spokane metropolitan area. However, the incorporated area of Liberty Lake east of Spokane and the Cities of Coeur d'Alene and Post Falls in Idaho are growing in population.
>
> Ecology is concerned about the pollutant loading capacity of the Spokane River system, including the Long Lake impoundment, which has a long history of water quality problems. The Spokane River exhibits low dissolved oxygen levels during the summer months, in violation of Washington State water quality standards. Segments of the river are included on Ecology's 1998 303 (d) list of impaired water bodies for dissolved oxygen. A TMDL for this water body was

identified as a high priority during the water quality scoping process for the Spokane Water Quality Management Area.

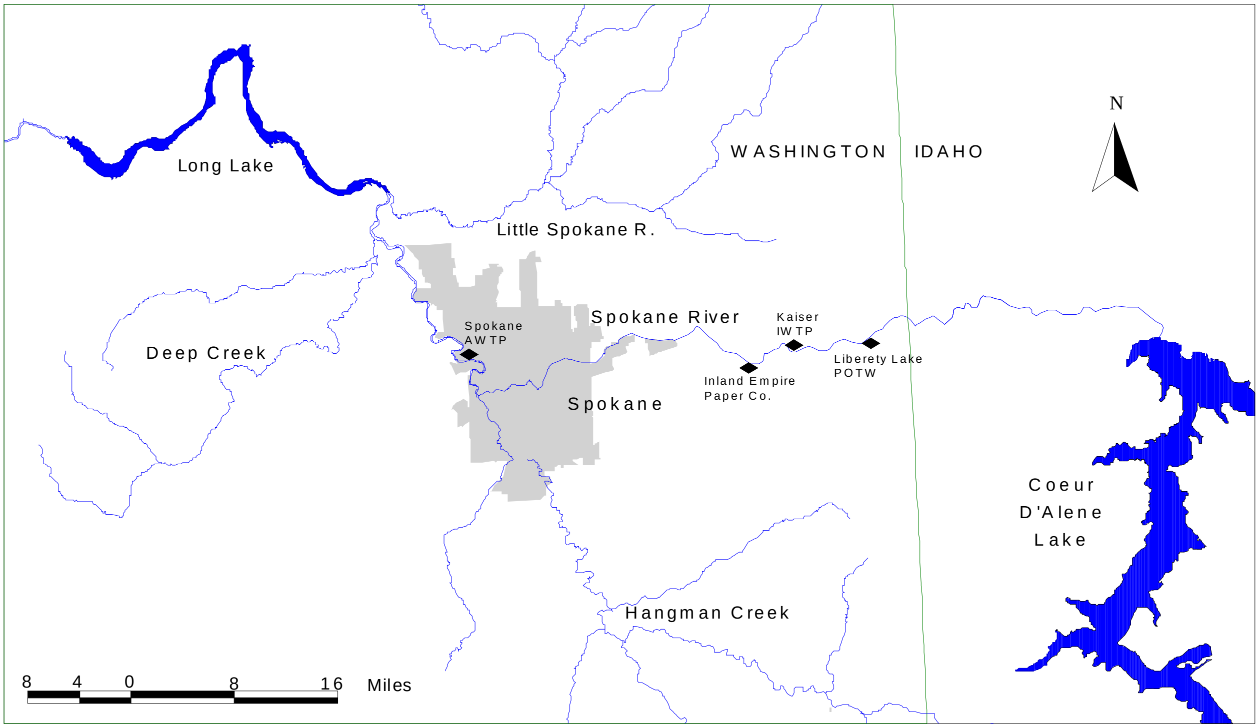


Figure 4. Current TMDL study area for the Spokane River.

The following facilities have National Pollutant Discharge Elimination System (NPDES) permits for discharging BOD, ammonia, and phosphorus to the Spokane River study area, in order of upstream to downstream:

Washington:

- Liberty Lake Publicly Owned Treatment Works (POTW)
- Kaiser Aluminum Industrial Wastewater Treatment Plant (IWTP)
- Inland Empire Paper Company IWTP
- City of Spokane AWTP

Idaho:

- Coeur d'Alene Wastewater Treatment Plant (WTP)
- Hayden Area Regional Sewer Board WTP (land discharge during the summer)
- Post Falls WTP

The following tributaries affect dissolved oxygen levels and nutrient concentrations in the Spokane River study area:

- Latah Creek (formerly Hangman Creek) (note – City of Cheney, Spangle, Rockford, Tekoa, and FairField all have small seasonal POTW discharges to creeks in the watershed.)
- Little Spokane River (note – Kaiser-Mead discharges to the Spokane River)

- Deep Creek (note – City of Medical Lake discharges to Deep Creek. In Knight, 1998 it was stated, “at current proposed design flows the discharge will probably not affect the Spokane River. However, as the system is expanded there may be some winter hydraulic capacity issues in Deep Cr. and a potential for a new growing season P load to the Spokane River.”)

The Spokane aquifer also potentially affects dissolved oxygen levels and nutrient concentrations in the river. The aquifer discharges to the river in some reaches, and is recharged by the river in other reaches.

The TMDL study area is currently from the Washington/Idaho State Line at river mile (RM) 96.0 to Long Lake Dam at RM 33.9. The PSU group developed a CE-QUAL-W2 model of the river-lake system for 1991 and 2000 from the Washington State line to the outlet of Long Lake. This further work would extend the model into Idaho. Ecology will use the model developed by PSU to recommend TMDL pollutant allocations to protect the water quality of the Spokane River and Long Lake. However, there are interstate water quality issues with Idaho that are currently not being addressed since the model does not extend past the Washington-Idaho border.

Water quality at the State Line with Idaho is not meeting Washington State’s dissolved oxygen criterion, and the upstream impacts of point sources (e.g., Lake Coeur d’Alene WTP and Post Falls WTP) of oxygen consuming substances on water quality in the river are unknown.

Model Boundary Condition and Forcing Data

This section describes the model set-up and boundary condition data. These data include:

- ☐ Model bathymetry
- ☐ Model grid
- ☐ Model inflows – point sources
- ☐ Dam operations at Post Falls Dam
- ☐ Upstream boundary condition at Coeur d’Alene Lake

Model Bathymetry

The model geometry was developed primarily in two sections:

- ☐ Coeur d’Alene Lake to Post Falls Dam
- ☐ Post Falls Dam to the Washington-Idaho border

Existing information from both sections was used to develop the grid for CE-QUAL-W2. This section explains the background data sources for the grid.

Post Falls Dam to the Washington-Idaho Border

The river section from Post Falls Dam to the Washington-Idaho state line was developed using (1) Surface DEMs of the area, and (2) two river cross-sections – one at the USGS gage and the other near the state line as shown in Figure 5. These 2 cross-sections are shown in Figure 6 and Figure 7.

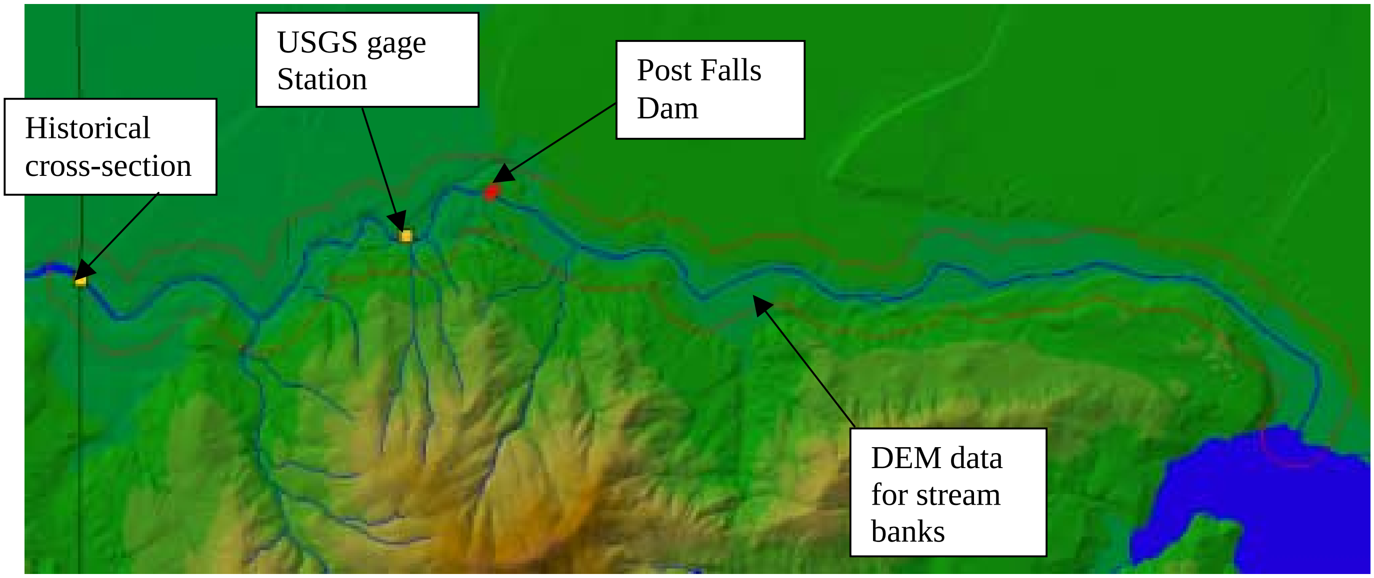


Figure 5. Spokane River study area showing DEM coverage and location of 2 cross-sections below Post Falls Dam.

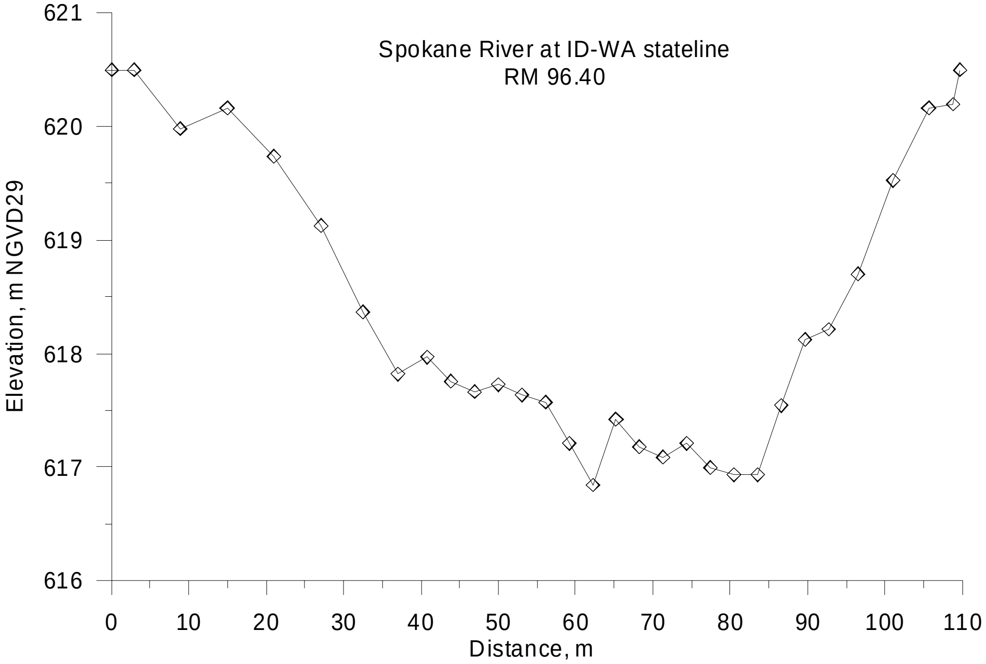


Figure 6. Spokane River cross-section at RM 96.4.

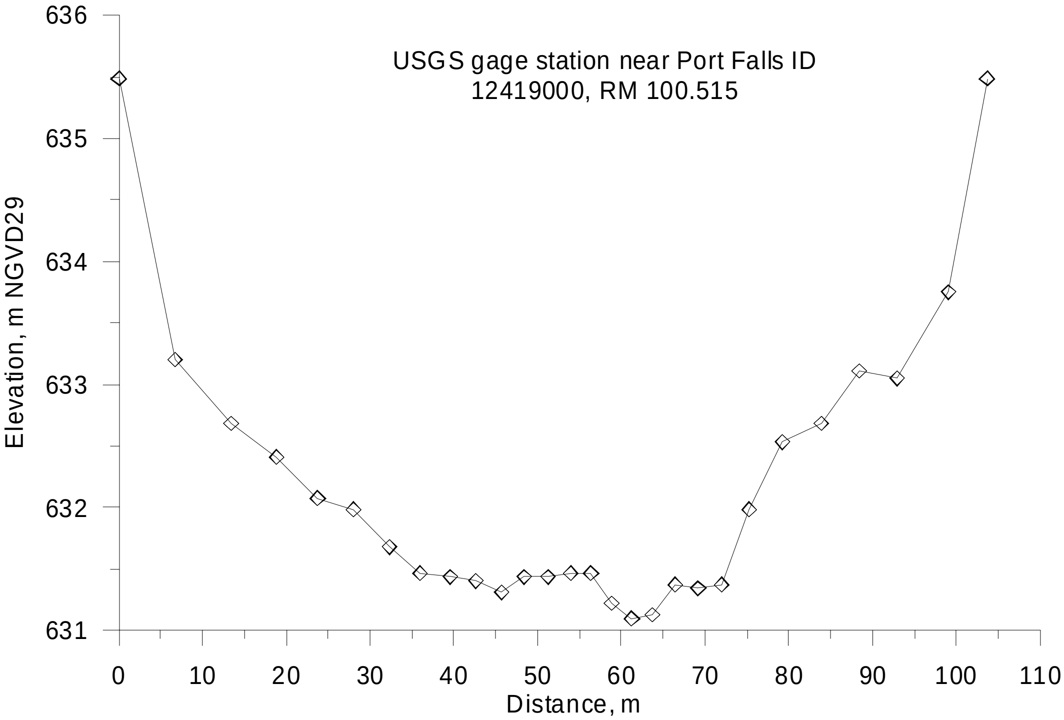


Figure 7. Spokane River cross-section at RM 100.515.

The cross-section at RM 96.401 was based on an older historical cross-section. The maximum elevations of the cross-section matched DEM data on the banks, so the cross-section was deemed accurate.

The cross-section elevations at RM 100.515 were obtained by adding the gage height to the datum and then subtracting off the water depths measured. The cross section taken by USGS does not match the DEM terrain elevations. The cross section had to adjusted vertically by 18.9 m upward. This was based on recognizing that the contour line on the stream bank at the Post Falls gage station was 2080ft based on the DRG, 633.9917 m, the water surface based on the DEM was 634 m NGVD, and that the DEM elevation on the 2080 contour line itself ranged from 634 to 636 m NGVD.

The process for generating the bathymetry consisted of using the thalweg point every 30 m to generate cross sections of points for the wetted channel. Elevations for these points were generated by interpolating between the two data cross sections at RM 96.401 and 100.515. If the generated cross section were upstream or downstream of the data cross sections then the nearest cross section was used with adjustments made for the channel width and the elevation by using the stream gradient, which was developed using the elevation change over the ricer channel. The cross section data was then combined with the 10m resolution DEM data our to 500 m away from the stream channel to create a contour plot of the river channel. Using the slope computed by the Ttools GIS tool for the river resulted in too high slopes and resulted in bottom elevations above the water surface. Hence, Ttools was not used. The slope of the section between the state line and Post Falls Dam is shown in Figure 8.

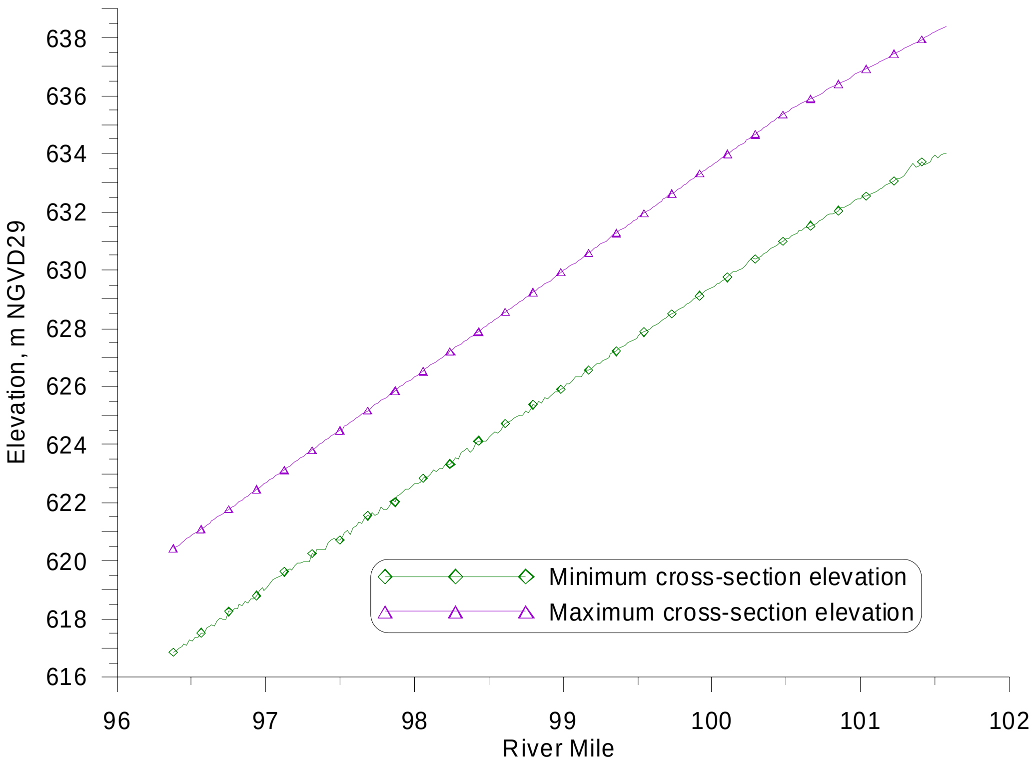


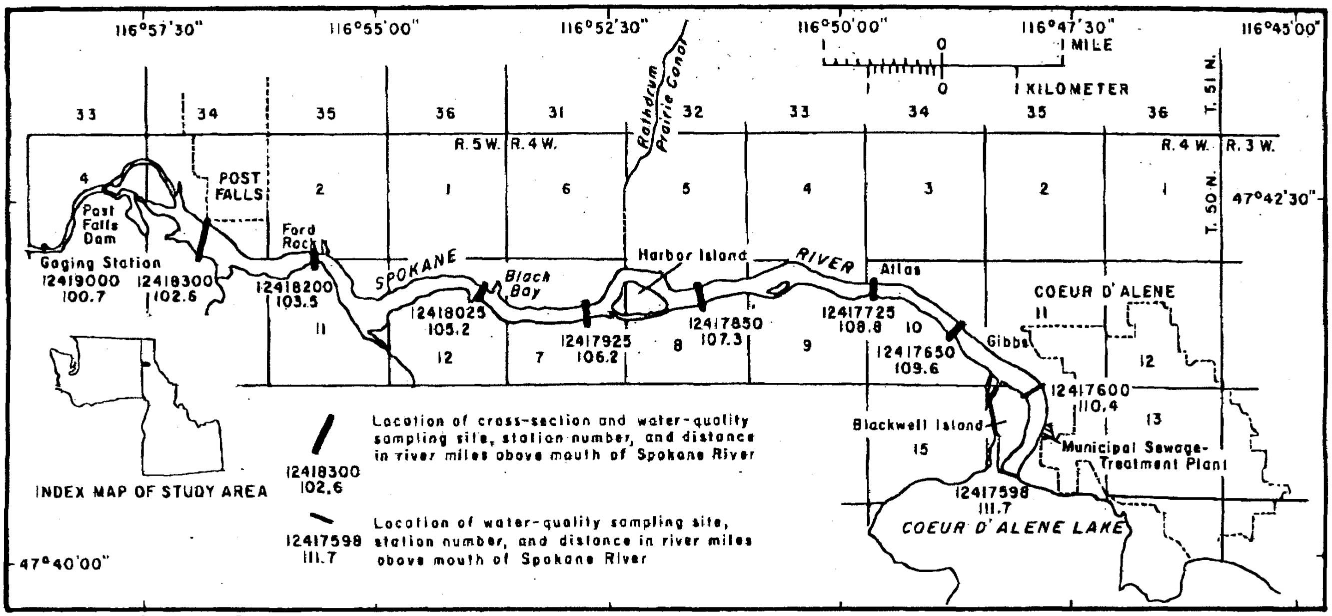
Figure 8. Elevation versus River mile for the Spokane River below Post Falls Dam showing the maximum elevation and minimum elevation of the 2 cross-sections.

Coeur d'Alene Lake to Post Falls Dam

This section of the model was constructed based on an earlier W2 Version 2 model development by Limno-Tech, Inc. (2001). The section of the model developed by Limno-Tech, Inc. (2001) was based on a set of 8 cross-sections taken at locations noted in Figure 9 and Table 1 done in 1980 (Seitz and Jones, 1981). Individual cross-section data are shown in Figure 10, Figure 11, Figure 12, and Figure 13. Seitz and Jones (1981) also estimated the Manning's friction factors for this reach as shown in Table 1. Also, another 5 cross-sections were taken in 1991 by Falter and Riggers (Cusimano, 2002) above Post Falls Dam. These data are summarized in Table 2. Apparently, these data were also used by Limno-Tech (2001) to develop their model grid.

Table 1. Cross-sections surveyed by Seitz and Jones (1981) in 1980 at 8 locations above Post Falls Dam, as well as estimated friction factors.

Cross-section ID#	RM location	Estimated Manning's friction, n
12417600	110.4	0.027-0.028
12417650	109.6	0.026-0.027
12417725	108.8	0.027-0.028
12417850	107.3	0.027-0.028
12417925	106.2	0.029-0.030
12418025	105.2	0.030-0.032
12418200	103.5	0.034-0.036
12418300	102.6	0.029-0.030



Base from U.S. Geological Survey
Coeur d' Alene NE 1:24,000, 1975 and
Coeur d' Alene NW 1:24,000, 1975

Figure 9. Map showing survey locations for 1980 study of Seitz and Jones (1981).

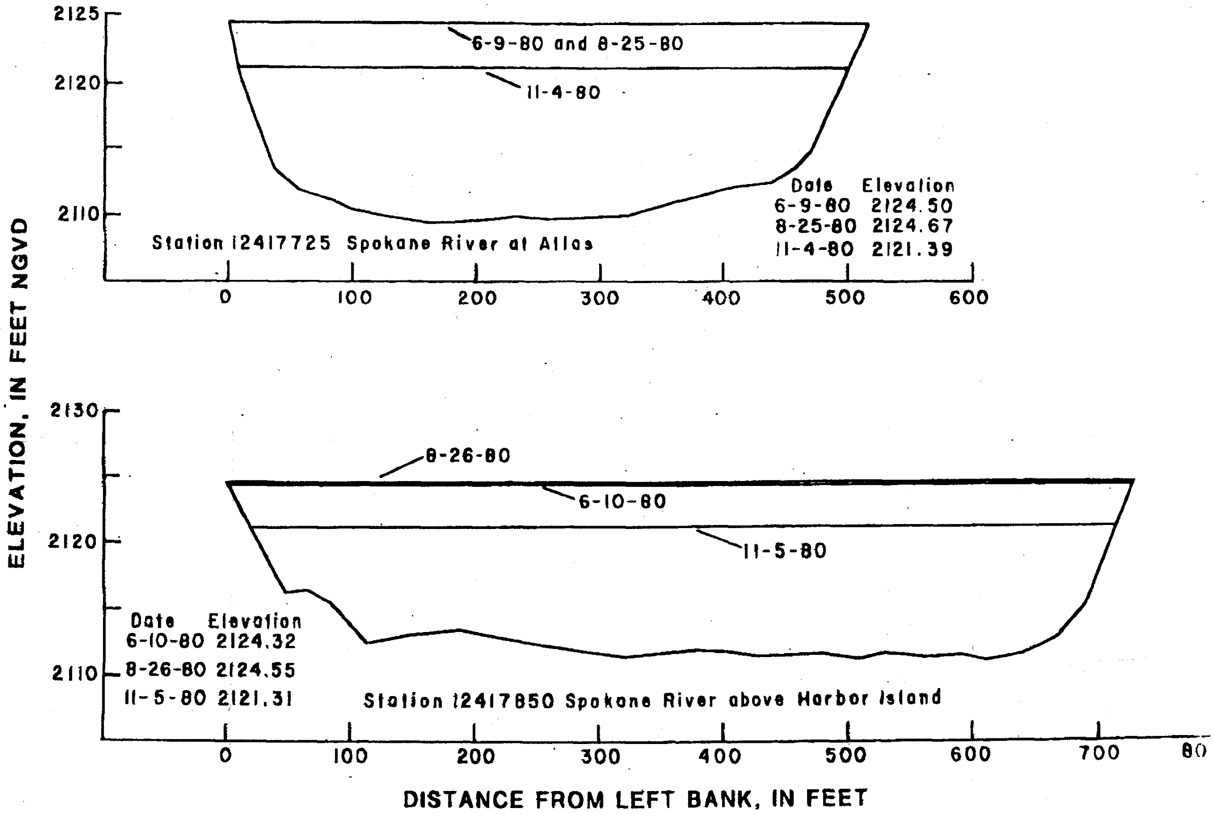


Figure 10. Survey information from Seitz and Jones (1981) for stations 12417725 and 12417850.

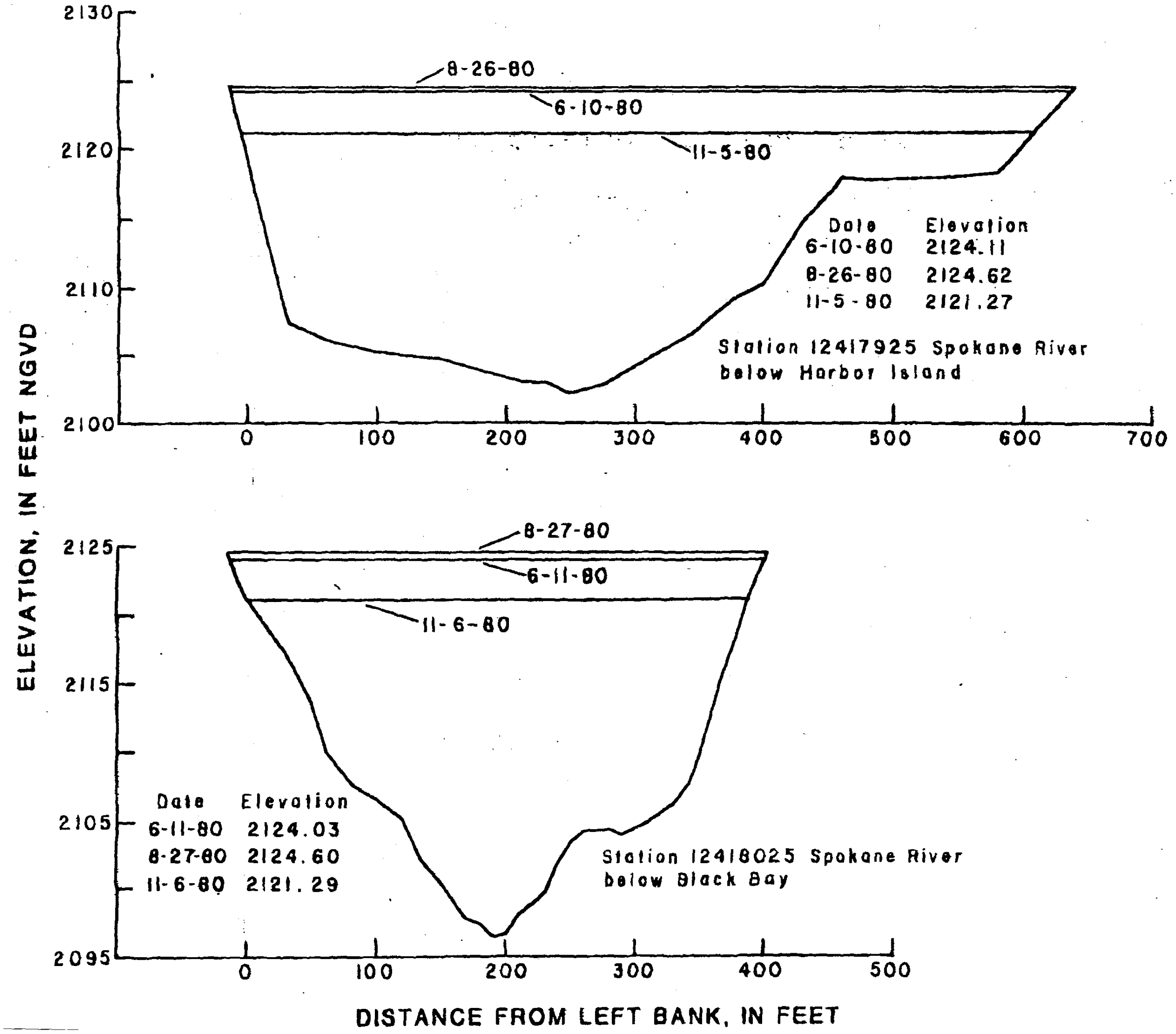


Figure 11. Survey information from Seitz and Jones (1981) for stations 12417925 and 12418025.

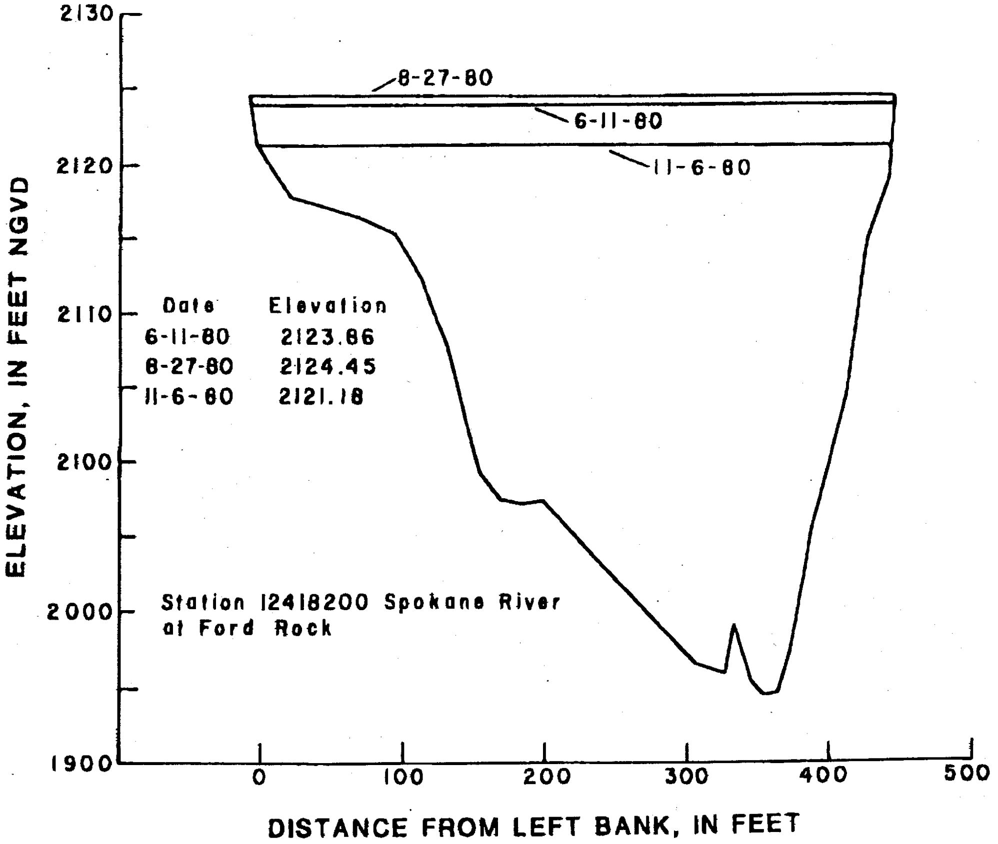


Figure 12. Survey information from Seitz and Jones (1981) for stations 12418200.

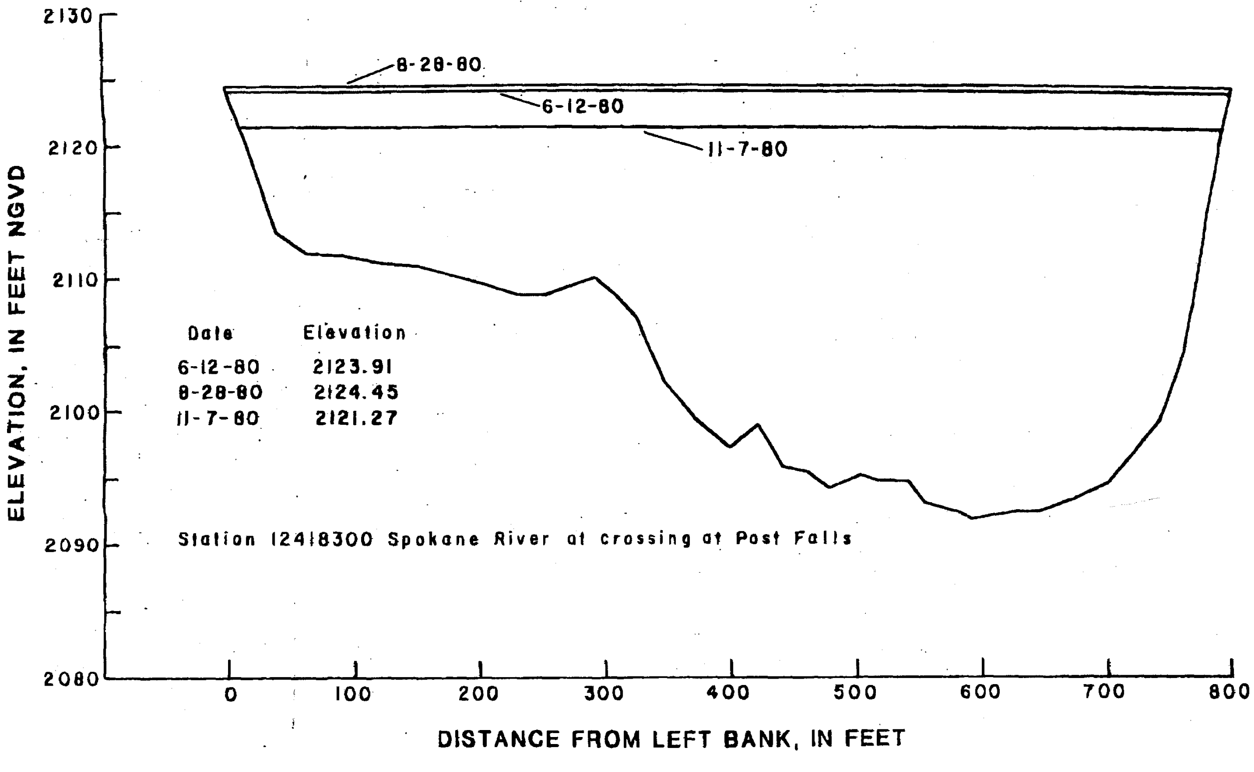


Figure 13. Survey information from Seitz and Jones (1981) for stations 12418300.

Table 2. Cross-section depths (ft) taken August 13, 1991 when water level was at a datum of 2128 ft.

Distance from Right bank, ft	Station 1, RM 111.1	Station 2, RM 108.8	Station 3, RM 106.2	Station 4, RM 103.5	Station 5, RM 102.5
0	0	0	0	0	0
19.0	1.9	4.7	5	14	15
38.1	3.8	5.3	5.6	16.9	20
57.1	5.8	8.9	8	19.1	23
76.1	6.7	11.2	17.1	19.4	24.5
95.5	7.5	12	19	27.9	26
114.5	8	12.6	20.1	28.8	27.2
133.5	8.9	13	21.2	34.9	28
152.6	8.6	13.6	21.7	32	29.2
171.6	9.3	14.4	22.1	31.8	29.6
190.6	9	15	22.2	31.9	28.6
209.7	9.7	15.3	22.1	30	28
228.7	10.2	16	21.7	27.5	26.2
247.7	10.7	16.8	20.8	24.7	24
267.1	11	15	20.5	22.4	19.5
286.1	10.9	11	20.4	13	16.2
305.1	10.4	10.2	19	11.1	14.2
324.2	10	9	16.9	10.7	15.9
343.5	10	2.7	15	10.7	16
362.2	9.8	0 (at 361 ft)	12.2	9.9	14.9
381.3	9.3		10.3	7	14.3
400.3	9.1		7.8	4.8	13.7
419.6	8.5		7.7	2.3	13.3
438.7	6.9		6.1	0 (at 440 ft)	12.9
457.7	5.2		4.9		12
476.7	4		3.2		12.2
495.8	2.9		2.1		11.7
514.8	0 (at 515 ft)		0 (at 515 ft)		10.8
533.8					10.5
552.8					10
571.9					0 (at 571 ft)
Mean depths	*7.43*	*10.34*	*13.31*	*17.95*	*17.66*

Model Grid

The model grid was divided into 2 separate water bodies: the Post Falls to Coeur d'Alene reservoir-like stretch and the Post Falls Dam to the Washington-Idaho border riverine stretch. For the first water body, the existing grid developed by S. Wells for Limno Tech, Inc. (2001b) for the earlier CE-QUAL-W2 Version 2 model was used with minor file revisions. These segment numbers from Limno Tech, Inc. (2001b) are shown in Figure 14 with segment spacing of 643.7 m and no channel slope.

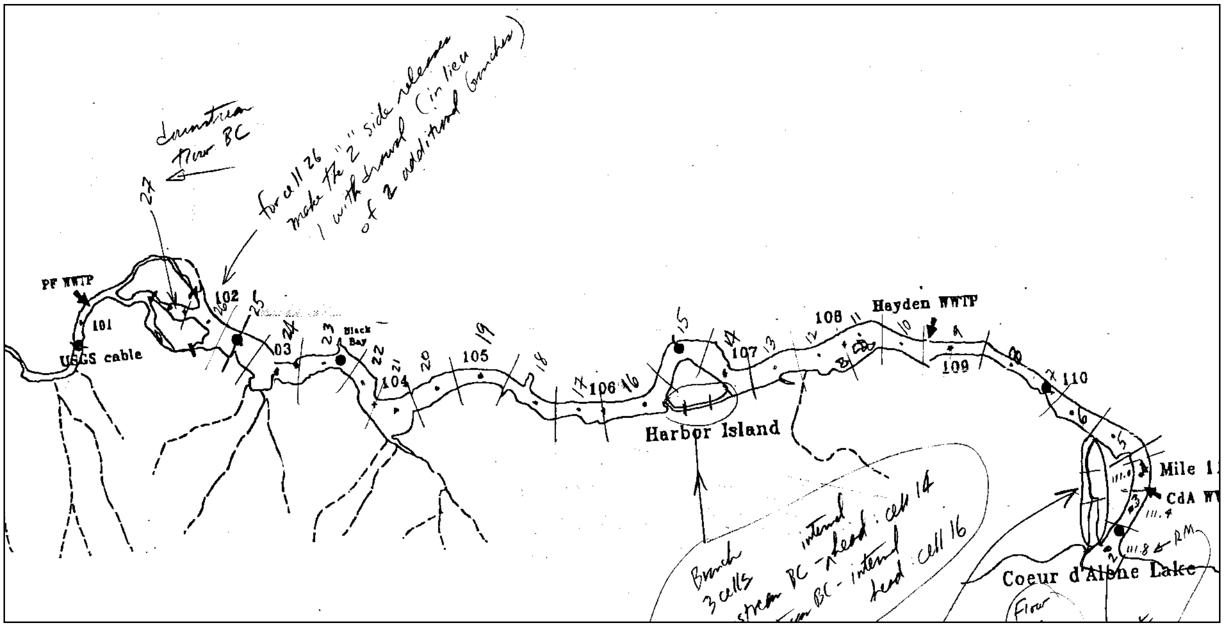


Figure 14. Model segment layout from Wells in work done for Limno-Tech, Inc. (2001).

For the riverine stretch, the grid was developed using data from the 2 cross-sections mentioned above. The process of developing the river grid consisted of the following steps:

- ☐ Creation of a topographic map of the river channel using x,y,z information from the 2 cross-sections, DEMs and interpolated points
- ☐ Dividing the river channel into model segments (consisting of polygons)
- ☐ Creating for each segment a model volume versus elevation relationship
- ☐ Computing the segment widths from the volume versus elevation relationship for each segment
- ☐ Constructing a model file compatible with CE-QUAL-W2

This procedure is also detailed in the CE-QUAL-W2 user's manual (Cole and Wells, 2002).

The slope of the riverine section is shown in Figure 15. Figure 16 shows the segment layout using a segment spacing of 252 m with a channel slope of 0.00198.

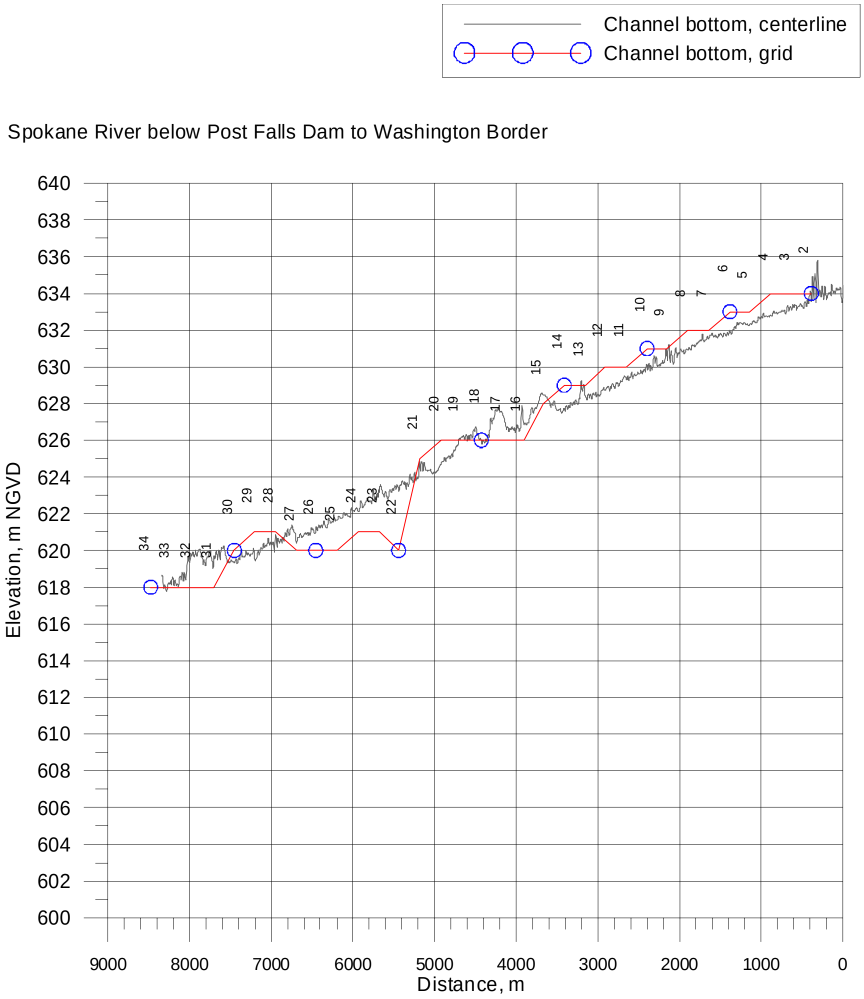


Figure 15. Channel bottom elevations from Post Falls Dam to Idaho-Washington state line.

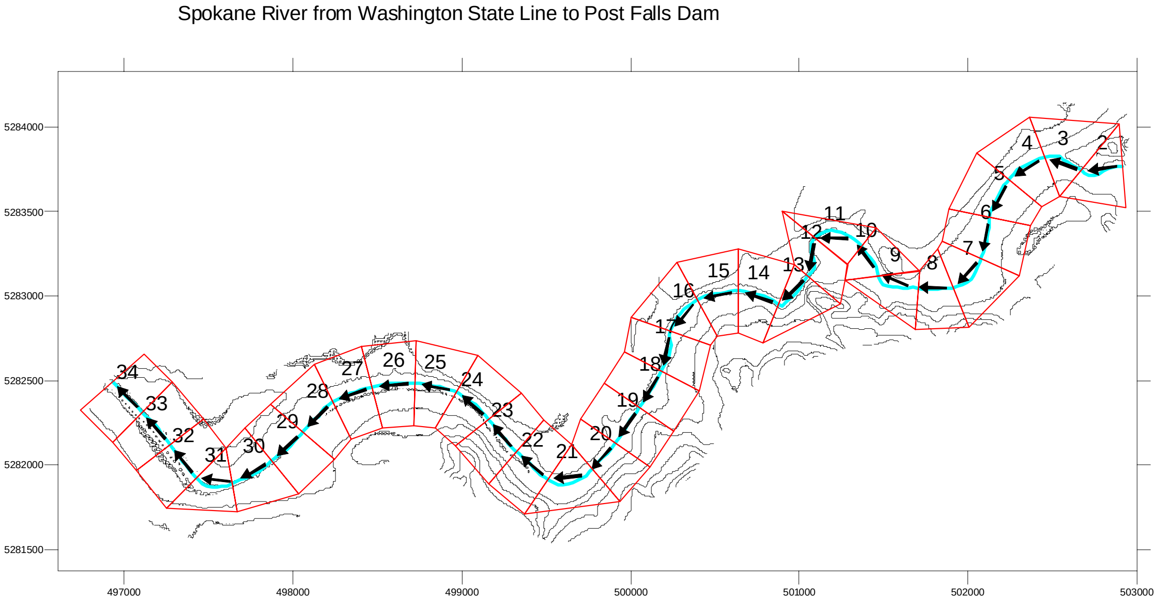


Figure 16. Segment number layout for model segments below Post Falls Dam.

The overall segment numbering and grid characteristics are shown in Figure 17 and Table 3. The side view of the grid for Branch 1 (also water body 1) and for Branch 2 (also water body 2) is shown in Figure 18 and Figure 19, respectively. Representative cross-sections of segments in each branch are shown in Figure 20 and Figure 21 for Branch 1 and 2, respectively. A listing of the segment numbers and their corresponding river miles is shown in Appendix A.

Table 3. Model grid characteristics

Branch #	**Up stream cell #**	**Down stream cell #**	**Cell longitudinal spacing, m**	**Slope [-]**	**Vertical layer spacing, m**	**Elevation of bottom of grid, m NGVD**	**Up stream BC**	**Down stream BC**
1	2	27	643.75	0.0	0.6 to 1.2	636.73	Flow or head	Flow
2	30	62	252.82	0.00198	1.0	618.00	Flow	Flow (weir)

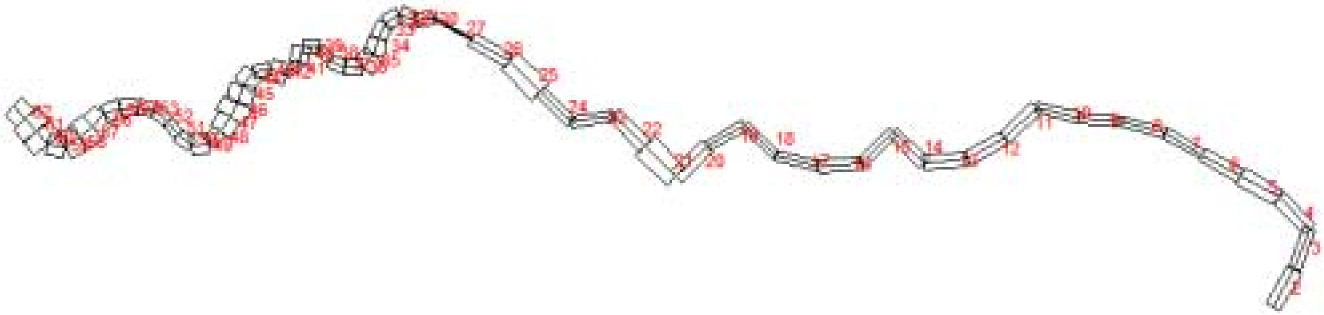


Figure 17. Model segment layout for W2 model.

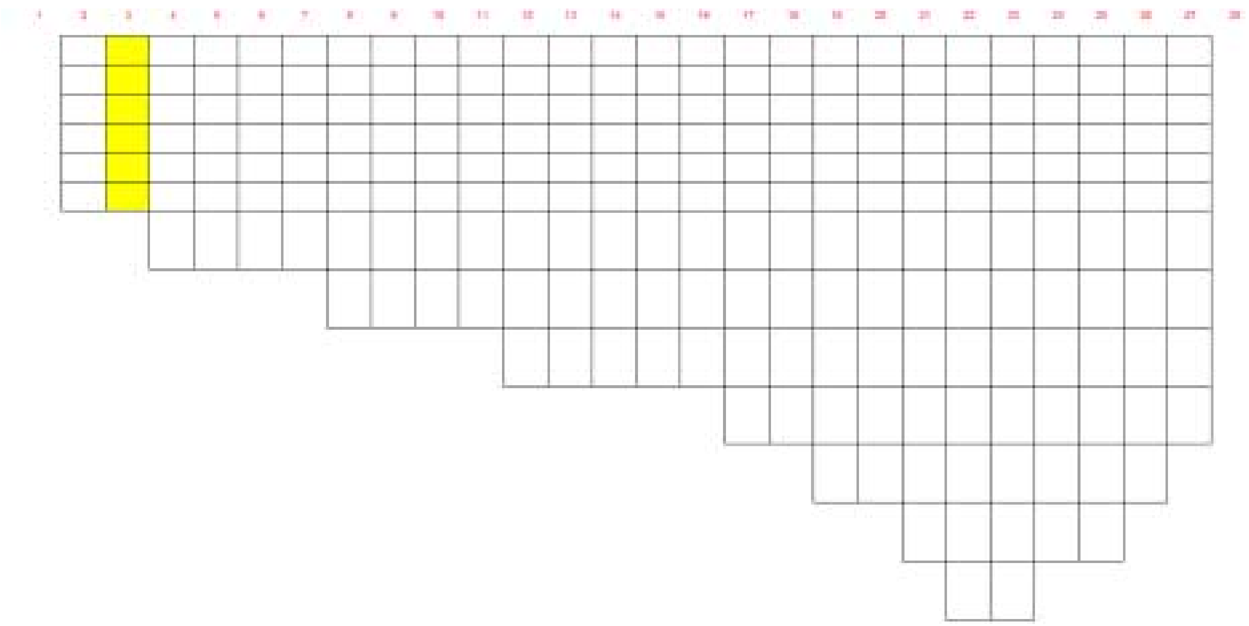


Figure 18. Side view of bathymetry grid for Branch 1 to Post Falls Dam.

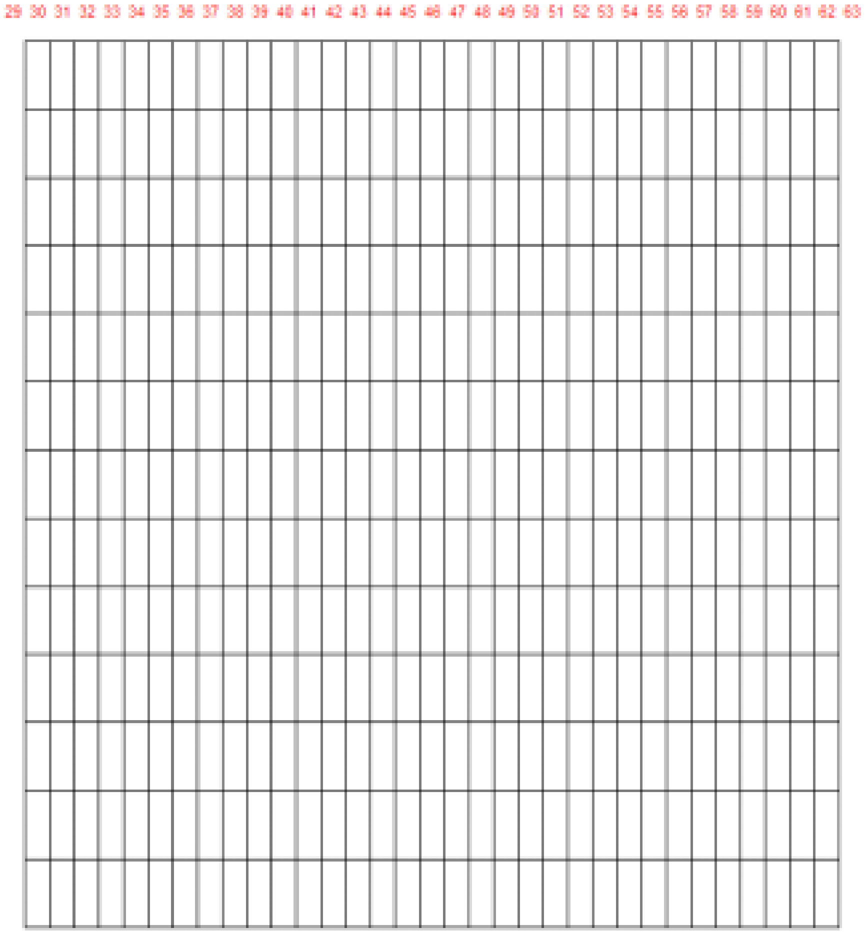


Figure 19. Side view of grid for Branch 2, river section.

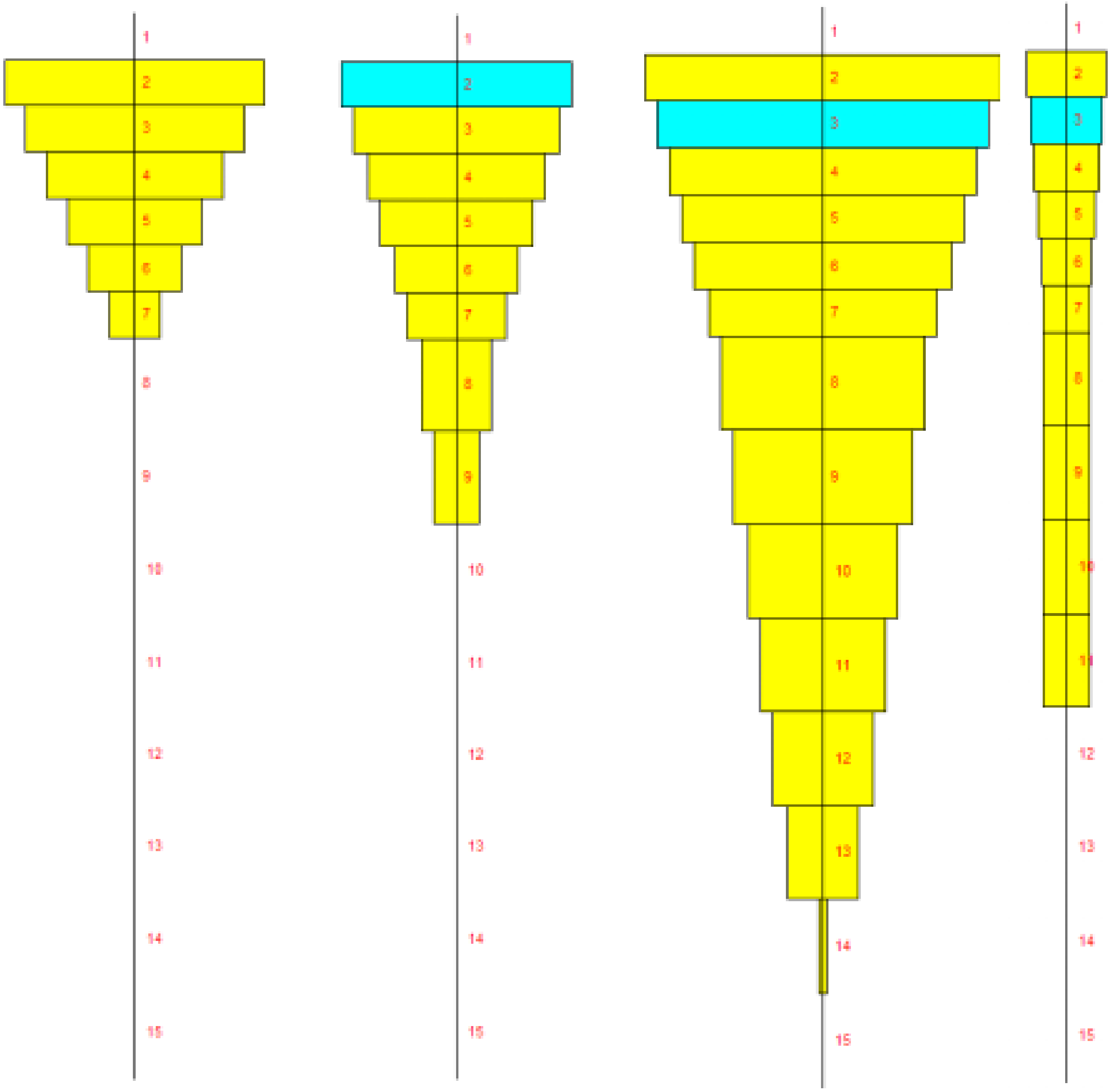


Figure 20. Segment 2, 9, 22, and 27 width versus layer for Branch 1.

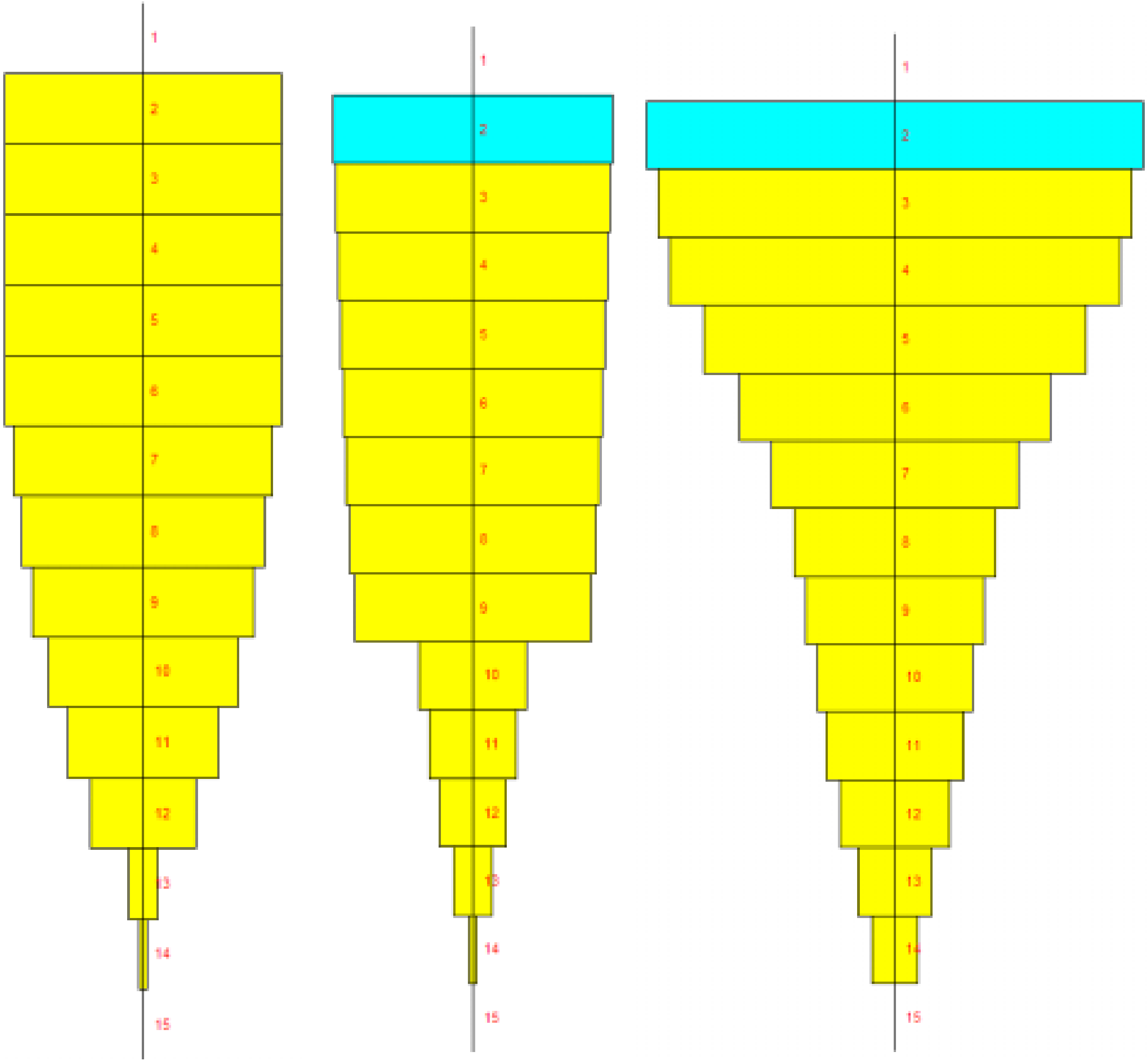


Figure 21. Segments 30, 39, and 62 width vs. layer for Branch 2. Note that the upper layers are never used; the river channel is defined by the lowest layers, for example 14, 13, and 12.

Boundary Conditions

The upstream boundary condition on the Spokane River was set at the outlet of Lake Coeur d'Alene. The model time period was from January to October 2001. The boundary conditions consisted of flow, water temperature and water quality characteristics. The model used internal interpolation to fill in the boundary conditions between the data.

The flow rates used for the upstream boundary condition were shown in Figure 22. Lake Coeur d'Alene outflows were back calculated using Post Falls flow data, groundwater loss estimates, and tributary inflow data. The groundwater losses from the Post Falls Dam to the Lake were estimated by LimnoTech (2001b) as 0.657 m^3/s/mile. Using the turbine flow data and the estimated spillway flow, the flow from the lake was determined by $Q_{LAKE} = Q_{turbine} + Q_{spillway} + Q_{groundwater\_loss}$. This section of the model then had water loss from evaporation implicitly included in the water balance and hence was not turned on for Waterbody 1.

There was little temperature and water quality data available in 2001 to characterize the upstream boundary condition. Historical data from previous was utilized in developing the upstream boundary conditions.

Monthly average temperatures were used to characterize the upstream boundary condition temperature file. The data used for the monthly averages were collected at two sampling sites, the Spokane River at the Lake outlet (RM 111.0) and the Spokane River 50 meters above Coeur d'Alene WWTP outflow (RM 110.6). Monthly averages were chosen because comprehensive temperature data for the Lake Coeur d'Alene outflow were unavailable for 2001. Figure 23 shows the plot of the upstream boundary condition temperatures.

Water quality of the upstream boundary condition was described using pH, conductivity, dissolved oxygen, total dissolved solids, nitrite-nitrate nitrogen, ammonia nitrogen, chloride, soluble reactive phosphorus, alkalinity, chlorophyll a and carbonaceous BOD ultimate ($CBOD_u$) data. These data were measured at sampling site CLK111.7 located near the outflow of Lake Coeur d'Alene into the Spokane River. Data were sparse and existed only during August 2001.

Alkalinity, pH and temperature data were used to estimate inorganic carbon concentration by applying equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981). Algae concentrations were estimated using chlorophyll *a* data and assuming a ratio of 130 mg/l algae to 1 mg/l chlorophyll a. Organic matter was simulated using a CBOD compartment. $CBOD_u$ data were used to characterize CBOD concentrations.

Constituent concentrations of LDOM (labile dissolved organic matter), RDOM (refractory dissolved organic matter), LPOM (labile particulate organic matter) and RPOM (refractory particulate organic matter) were set to zero. Inorganic suspended solids concentrations were assumed to be 0.1 mg/l.

Figure 24, Figure 25, and Figure 26 show the water quality concentrations used in the model for the upstream boundary condition.

Note that Limno-Tech, Inc. (2001b) used the following water quality parameter values based on September 1998 data: Temperature = 21.7^{o}C, SS=1.2 mg/l, LDOM=0.455 mg/l; RDOM=0 mg/l; Algae=0.070 mg/l (using a chlorophyll a/algae ratio of 11 μg chlorophyll a/mg algae); LPOM=0 mg/l; PO_4-P=0.001 mg/l; NH_4-N=0.003 mg/l; NO_3-N=0.005 mg/l; DO=7.66 mg/l; CBOD5=1.0 mg/l.

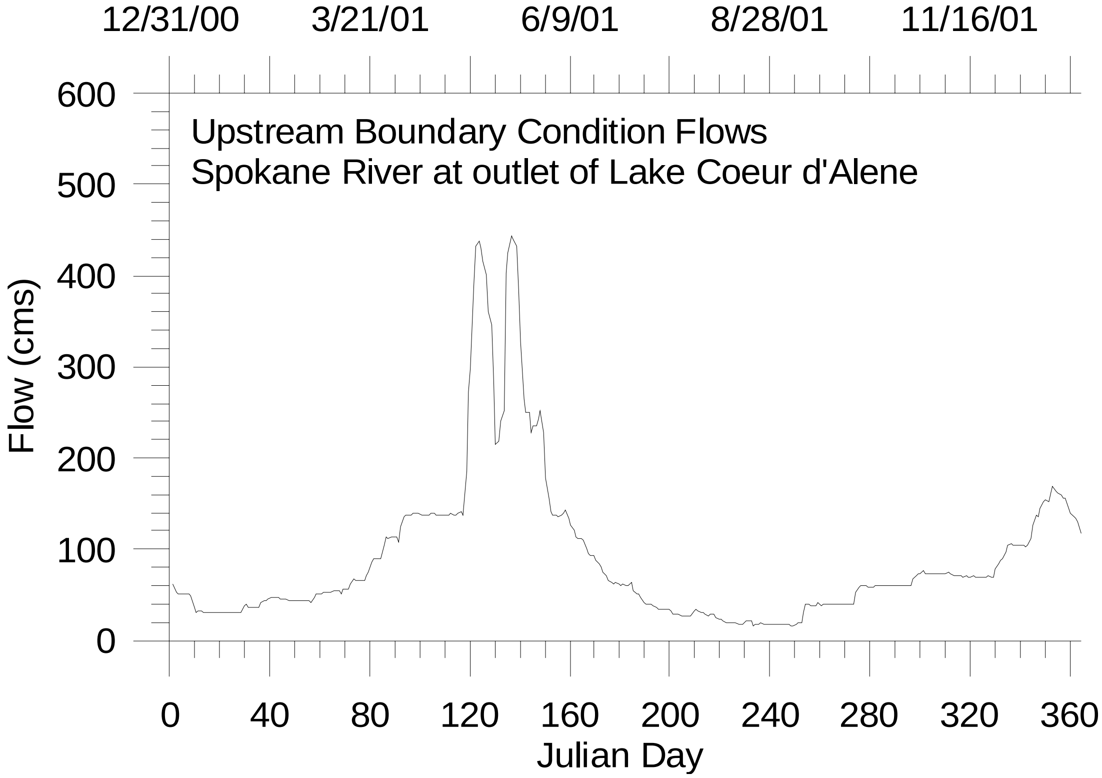


Figure 22. Flow rates used to simulate upstream boundary condition at outlet to Lake Coeur d'Alene.

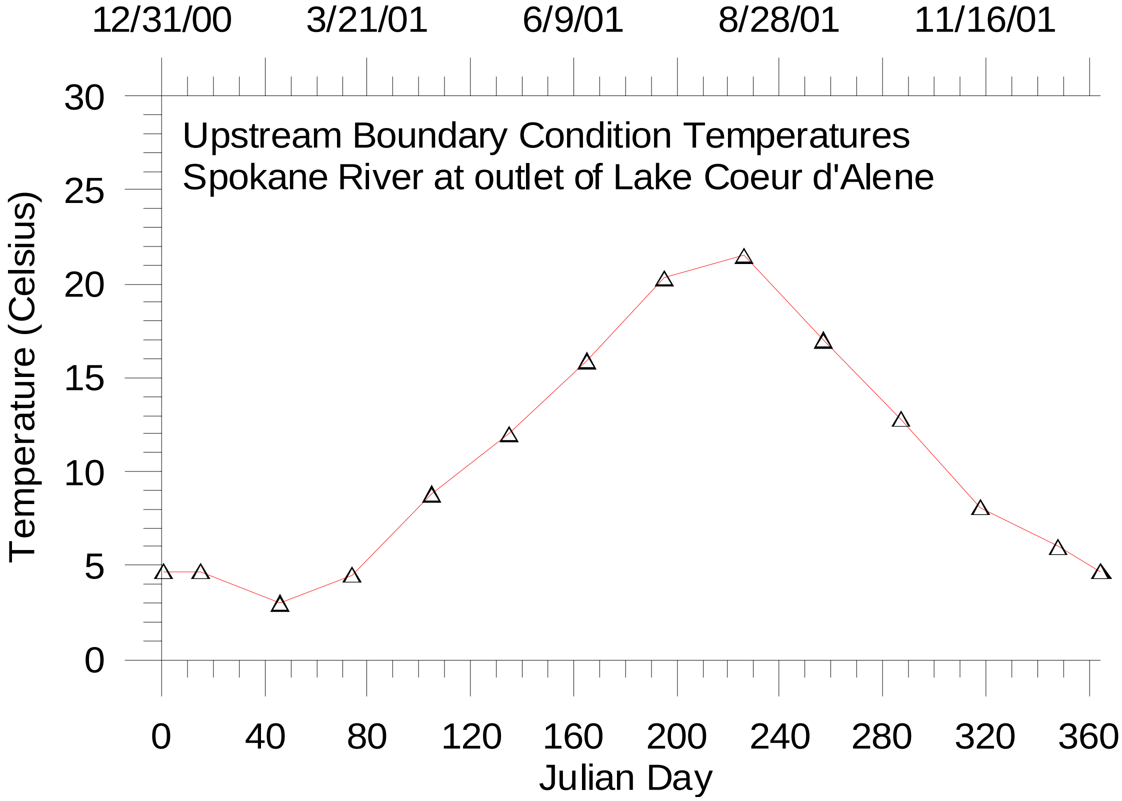


Figure 23. Temperatures used to simulate upstream boundary condition at outlet to Lake Coeur d'Alene.

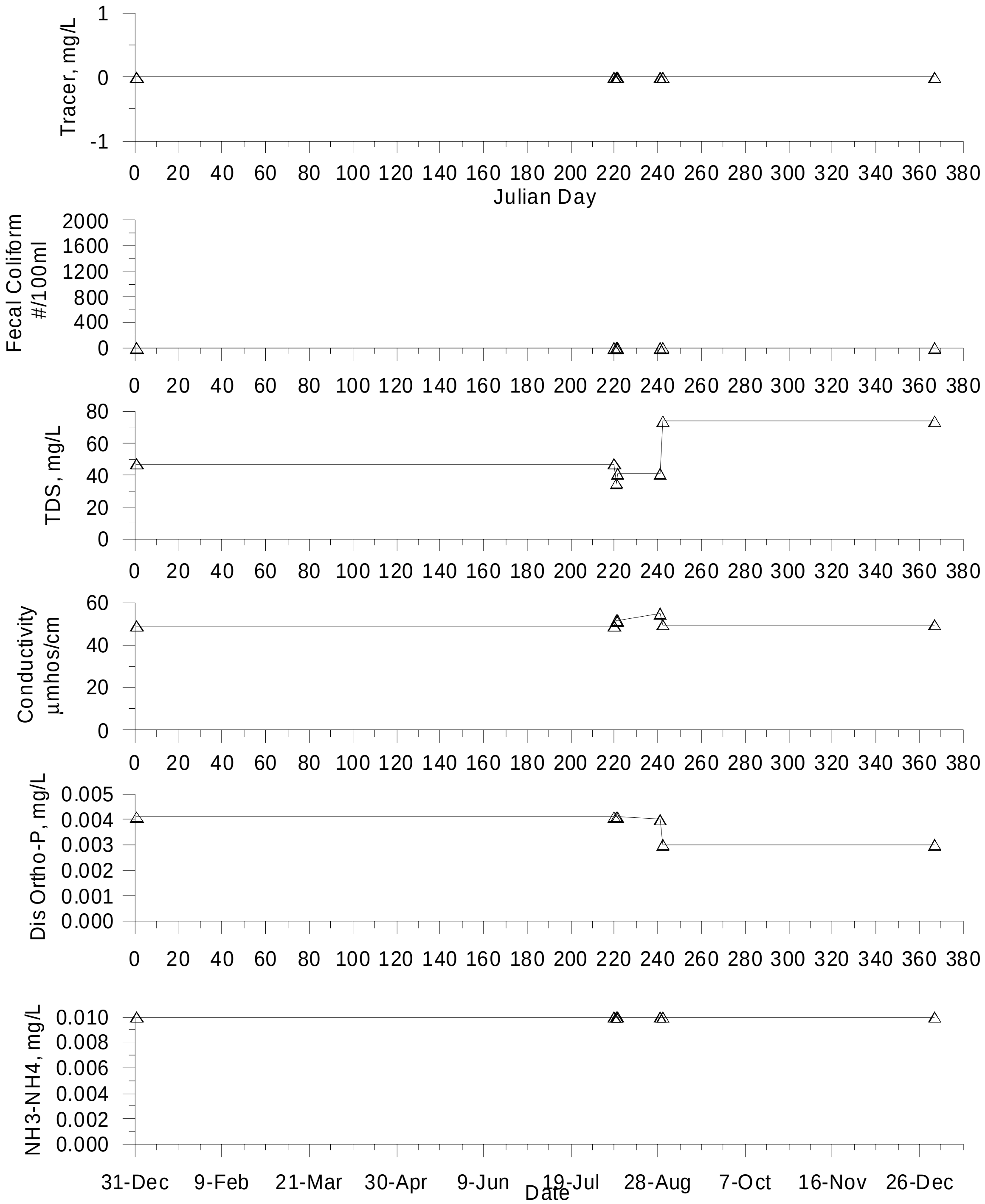


Figure 24. Upstream boundary water quality conditions (Part 1).

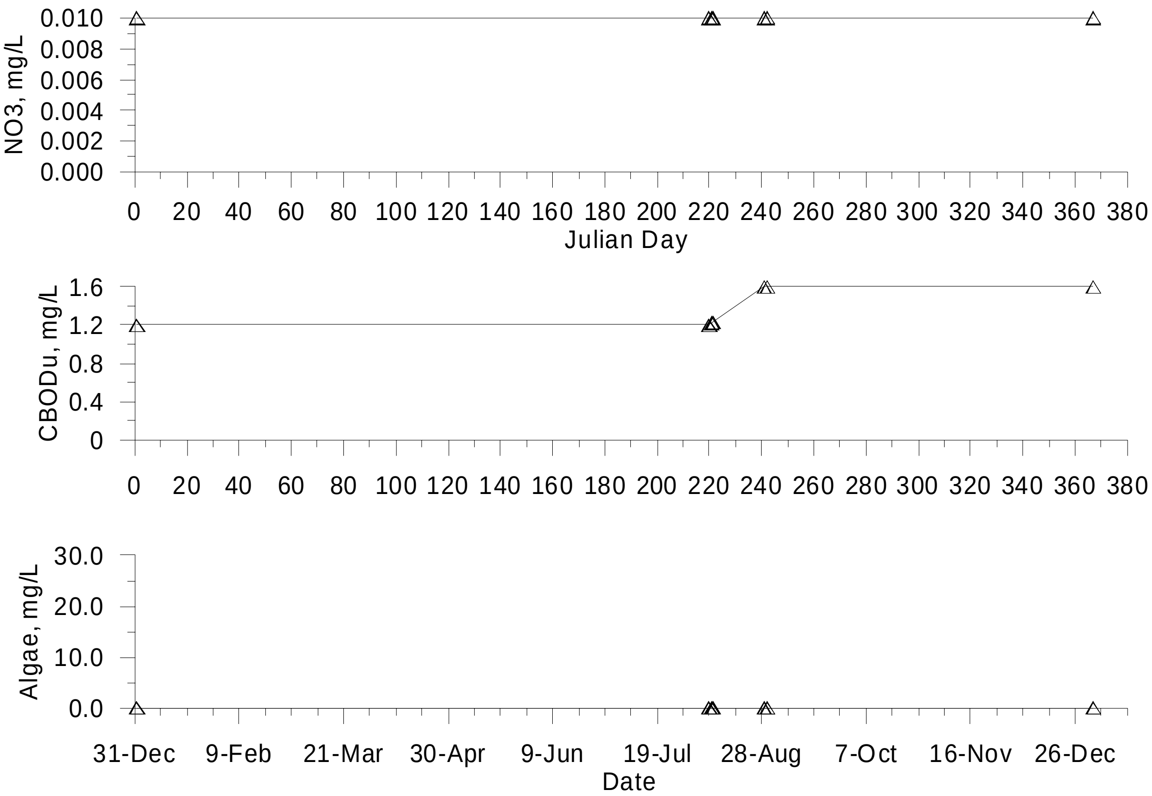


Figure 25. Upstream boundary water quality conditions (Part 2).

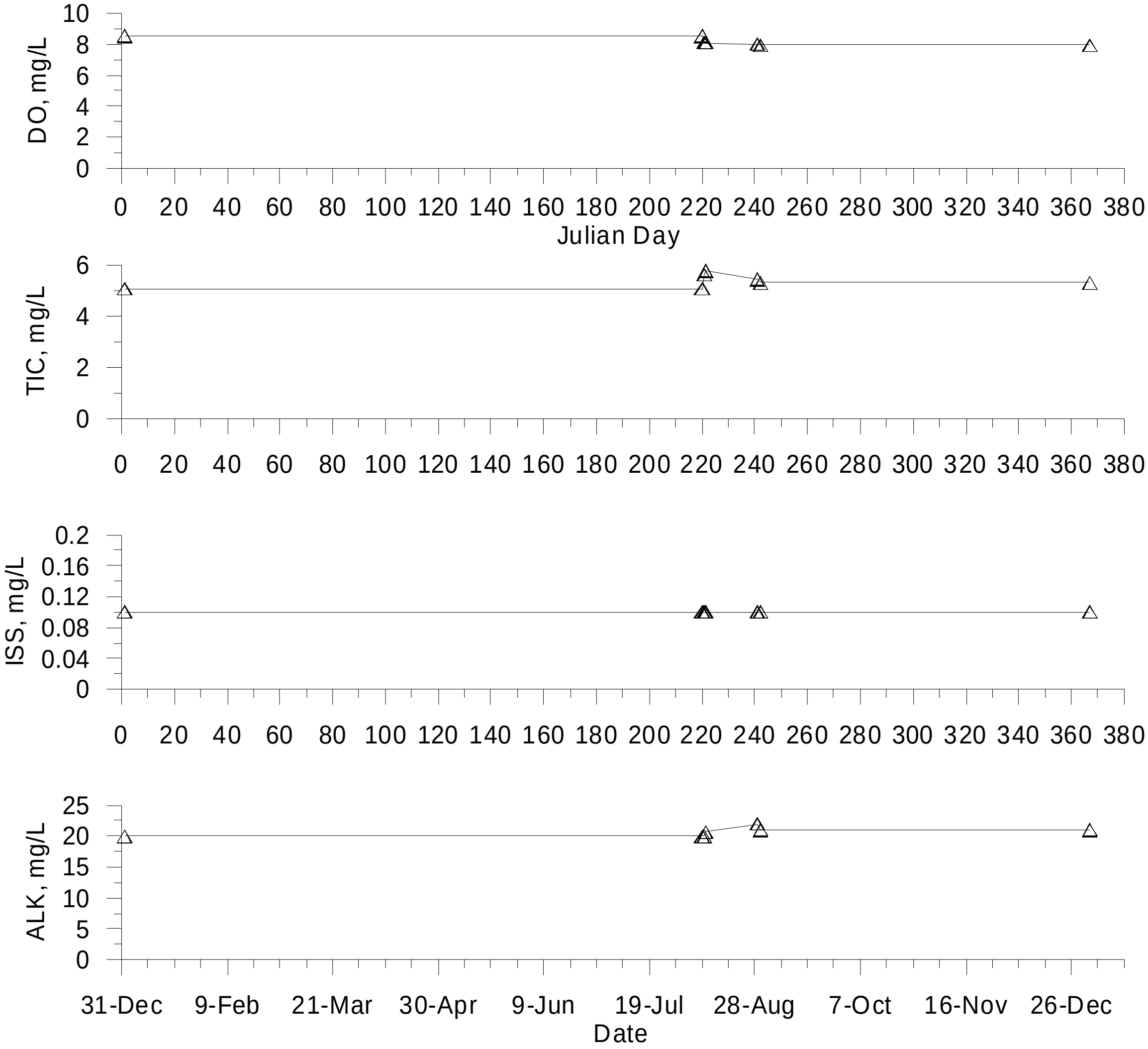


Figure 26. Upstream boundary water quality conditions (Part 3).

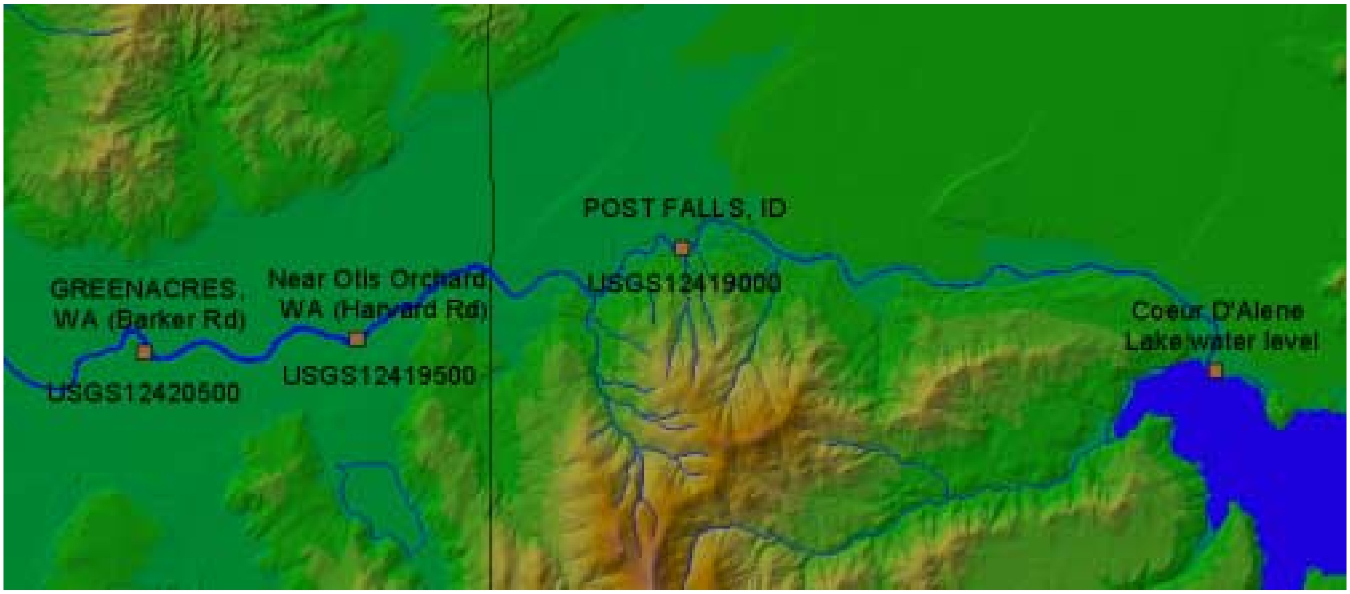


Figure 27. USGS gage station locations and water level on the Spokane River.

Tributaries and Point Dischargers

There are three point source discharges to the Spokane River between Coeur d'Alene and the ID-WA state line. There are several small tributaries and one larger tributary called Skalan Creek. Table 4 lists the locations of the point sources and the tributary inflow. Skalan Creek, although large is relatively small and is not expected to contribute much flow to Spokane River model. There has been no data collected on the creek to assess its flow contribution. The flow would be expected to be negligible compared to the groundwater gain and loss in this reach of the river. Although the model incorporates the creek as a tributary inflow the flow has been set to zero and could be used to check the sensitivity of a possible inflow at this location.

Table 4. Tributaries to the Spokane River in Idaho.

Tributaries	Segment Number	River Mile
Post Falls WWTP	30	101.186
Skalan Creek	47	98.465
Coeur D'Alene WWTP	4	110.563
Hayden Area POTW	9	109.500 (other maps show RM 108.5)

Organic matter in the upstream boundary condition, tributaries, and point sources were simulated using CBOD ultimate data and multiple CBOD compartments in CE-QUAL-W2. Each point source was represented by a separate CBOD compartment and decay rate, and the upstream boundary condition and tributary BOD were grouped into a single CBOD compartment. These CBOD compartments were summarized in Table 5. CBOD compartments 1 to 4 correspond to dischargers that do not exist in the Idaho section of the model, but have been included to facilitate model linkage to the rest of the Upper Spokane River model. The first-order decay rates of the CBOD compartments were developed from laboratory data supplied by the Washington Department of Ecology.

Table 5. CBOD compartments and decay rates used in model.

CBOD compartment	Description	Decay rate, day^{-1}
1	Liberty WTP	0.0456
2	Kaiser Aluminum	0.1275
3	Inland Empire Paper	0.0186
4	Spokane WTP	0.0736
5	Compartment simulating organic matter from tributaries; Includes Coulee Creek, Hangman Creek, Little Spokane River and Upstream Boundary Condition	0.0660
6	Coeur d'Alene WWTP	0.7920
7	Hayden POTW	0.0838
8	Post Falls	0.0660

Hayden Area POTW

The Hayden Area Regional Sewer Board manages the effluent from the regional treatment plant, which discharges to the Spokane River. During the summer months the treatment plant does not discharge effluent to the Spokane River. The effluent is discharged to a lagoon and then land applied to crops. Figure 28 shows the Hayden discharge flow for 2001 and illustrates the time periods when the effluent was not discharged to the Spokane River. Figure 29 shows the effluent temperature with a seasonal warming trend.

The Hayden Area POTW (Publicly Owned Treatment Works) point source water quality was characterized using conductivity, total dissolved solids, dissolved oxygen, chloride, ammonia nitrogen, nitrite-nitrate nitrogen, soluble reactive phosphorus, alkalinity, BOD5, pH, and non-volatile suspended solids data.

A separate CBOD compartment was used to simulate organic matter originating from the Hayden Area POTW. $CBOD_u$ concentrations were estimated from BOD5 data using a decay rate of 0.0838 day^{-1}. The decay rate was obtained from the Washington Department of Ecology. Since organic matter was accounted for in the CBOD compartment, constituent concentrations of LDOM (labile dissolved organic matter), RDOM (refractory dissolved organic matter), LPOM (labile particulate organic matter) and RPOM (refractory particulate organic matter) were set to zero.

Inorganic carbon concentrations were estimated from pH, alkalinity and temperature data using equations based on the carbonate-bicarbonate equilibrium reaction (Stumm and Morgan, 1981). Algae concentrations were set to zero. Inorganic suspended solids concentrations were assumed to be equivalent to the non-volatile suspended solids data.

The 2001 constituent concentrations for the Hayden Area POTW are plotted in Figure 30, Figure 31, and Figure 32.

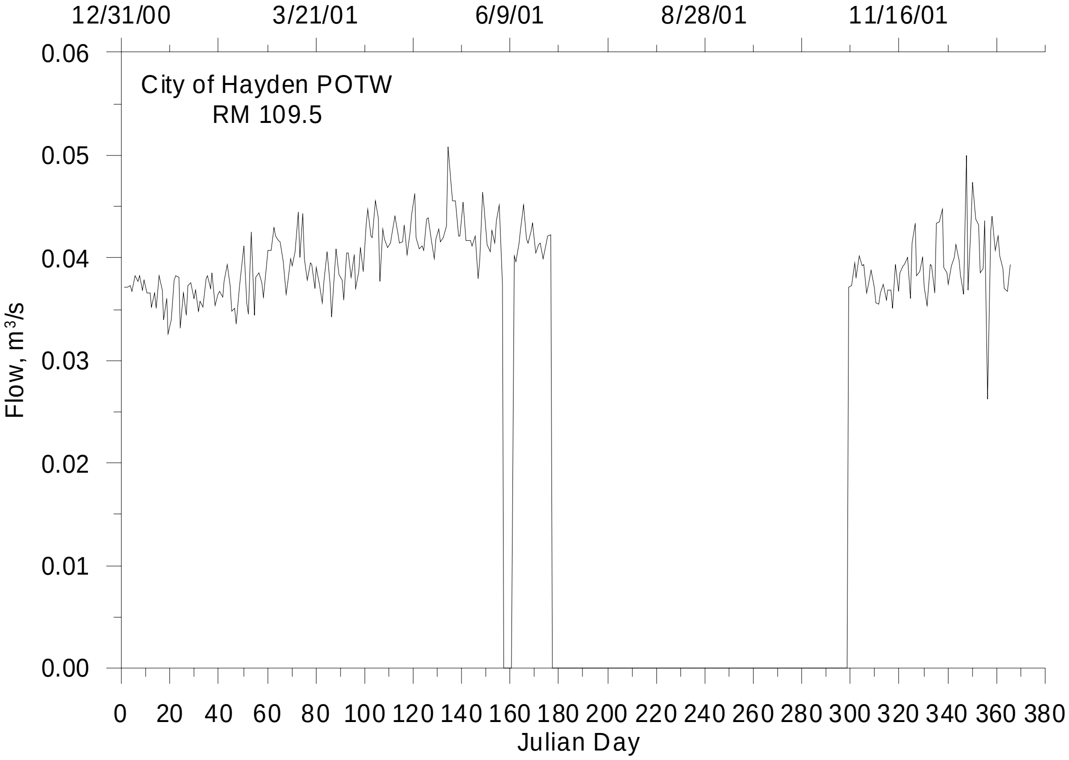


Figure 28. Hayden Area POTW flow rate for 2001.

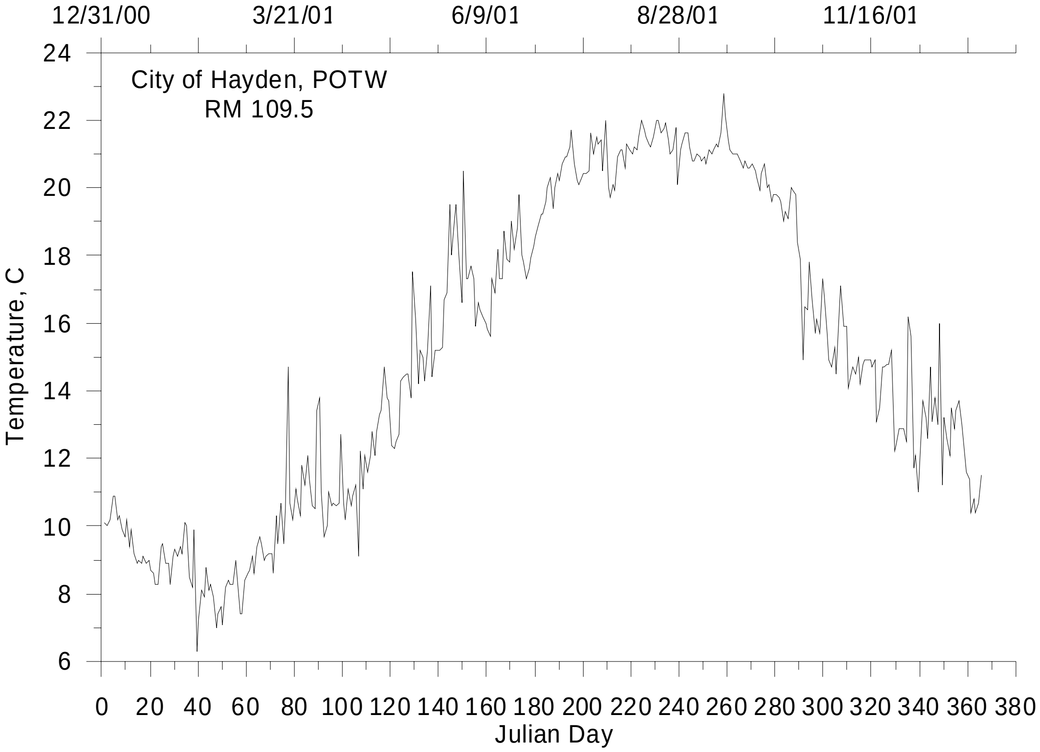


Figure 29. Hayden Area POTW temperature for 2001.

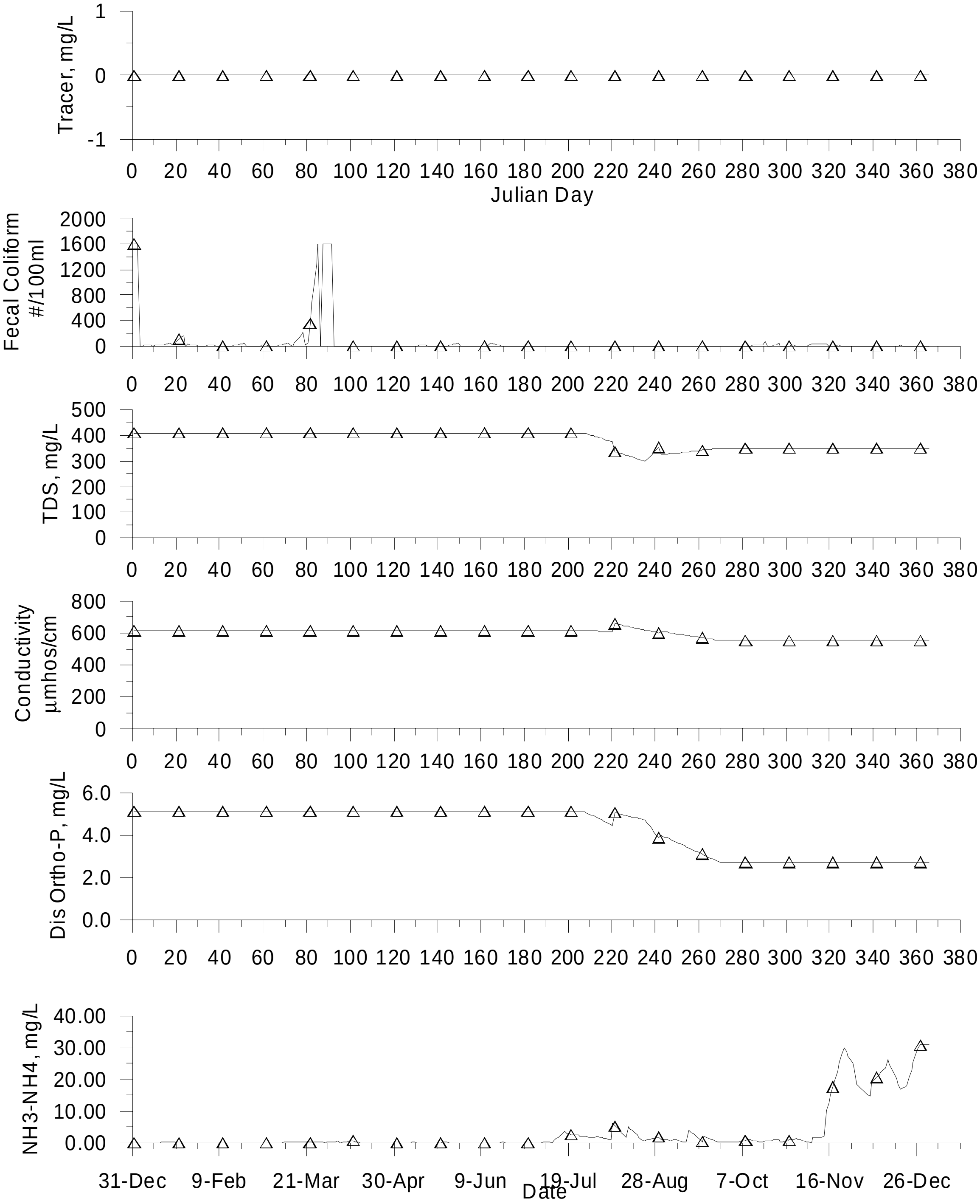


Figure 30. Hayden discharge water quality conditions (Part 1).

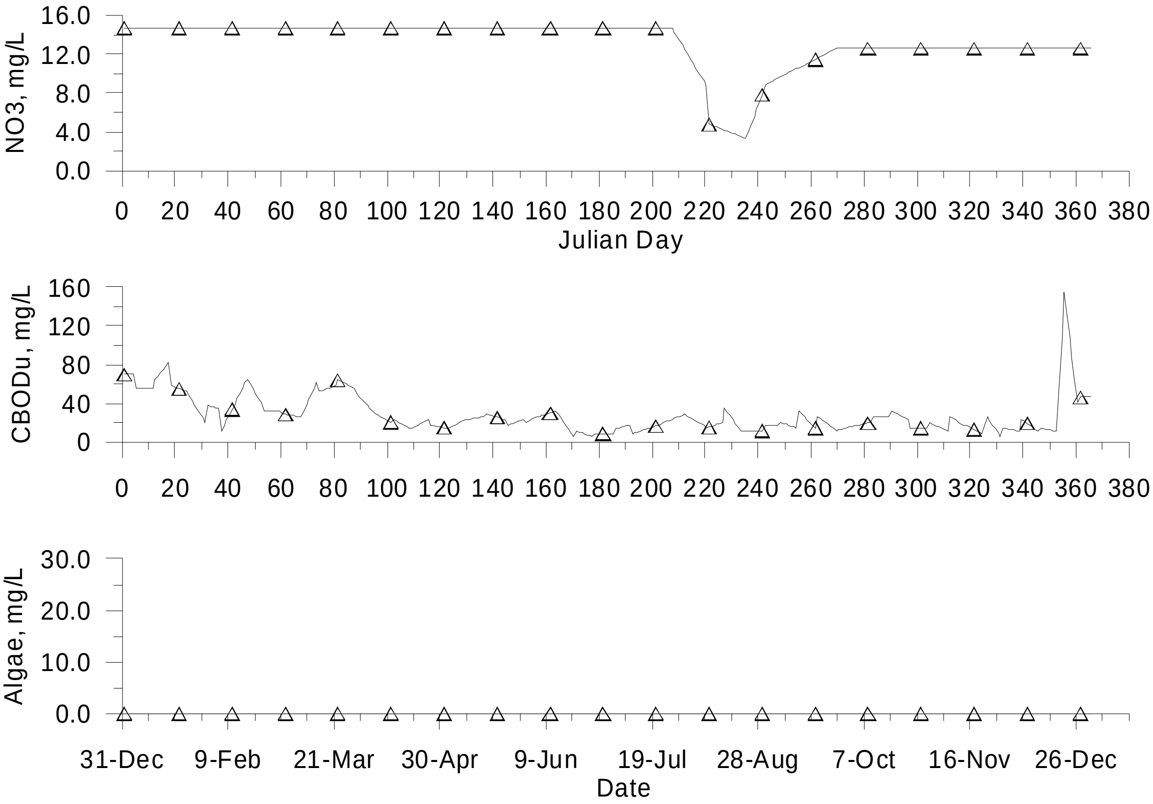


Figure 31. Hayden discharge water quality conditions (Part 2).

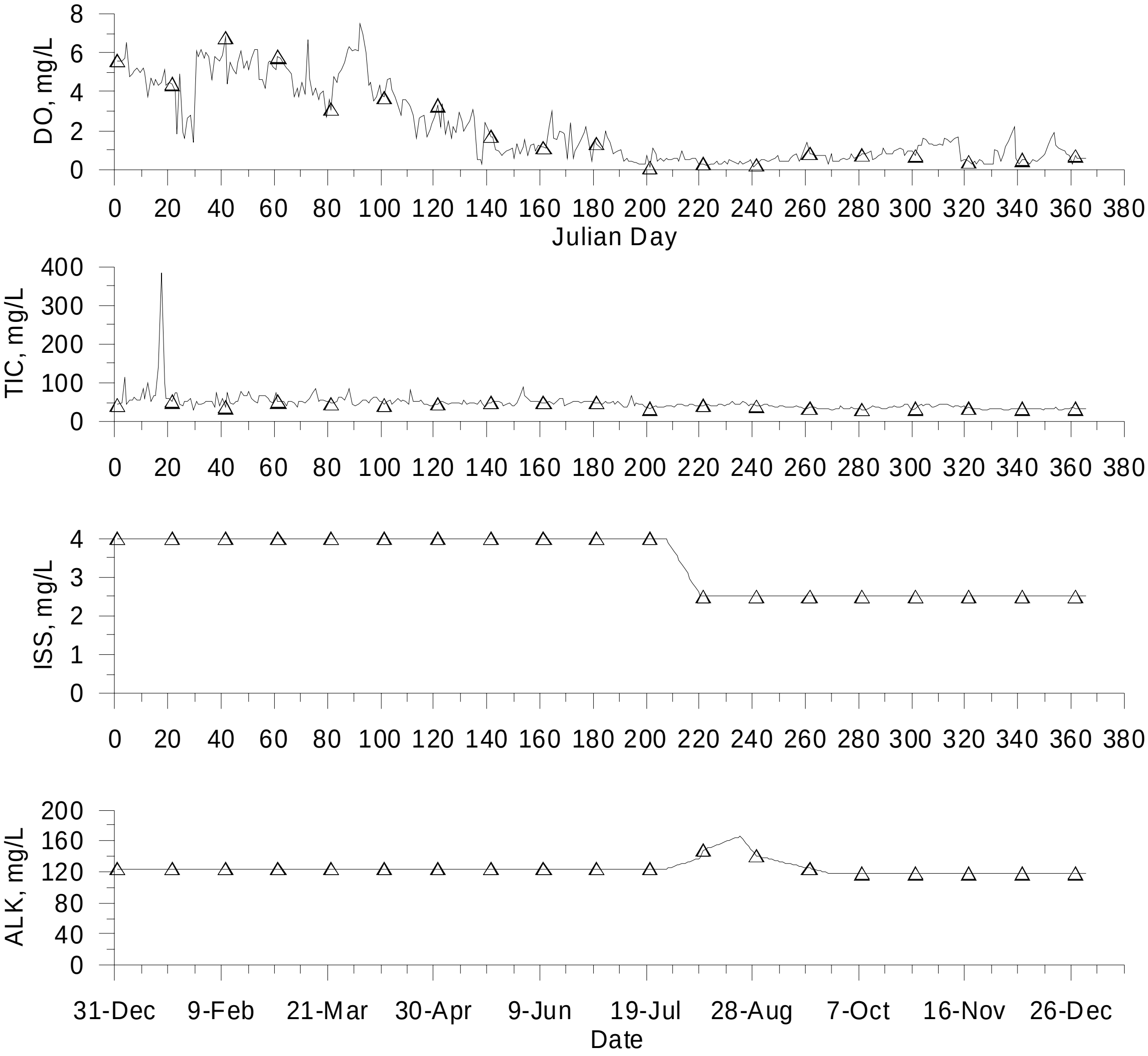


Figure 32. Hayden discharge water quality conditions (Part 3).

Post Falls WWTP

The City of Post Falls wastewater treatment plant discharge flow is shown in Figure 33. The flows are relatively low and consistent over the course of the year. There is a data gap in the flow record for the month of November as shown in the figure by a straight horizontal line. This should not influence the modeling effort as the critical time period for the model simulation is from April to October 2001. Figure 34 shows the discharge temperature for 2001 and shows a general seasonal warming trend with a data gap in November.

The Post Falls WWTP water quality constituent file was developed from dissolved oxygen, BOD5, alkalinity, total dissolved solids, pH, chloride, conductivity, nitrite-nitrate nitrogen, ammonia nitrogen, soluble reactive phosphorus, and total non-volatile suspended solids data. Fecal Coliform data did not exist and concentrations were set to zero. The methods used to develop the constituent file were equivalent to those used to develop the Hayden Area POTW file (discussed above). A decay rate of 0.0598 day^{-1} was used to estimate CBODu concentrations from BOD5 data. This decay rate was estimated using Washington Department of Ecology data.

The constituent concentrations of the Post Falls WWTP point source are shown in Figure 35, Figure 36, and Figure 37.

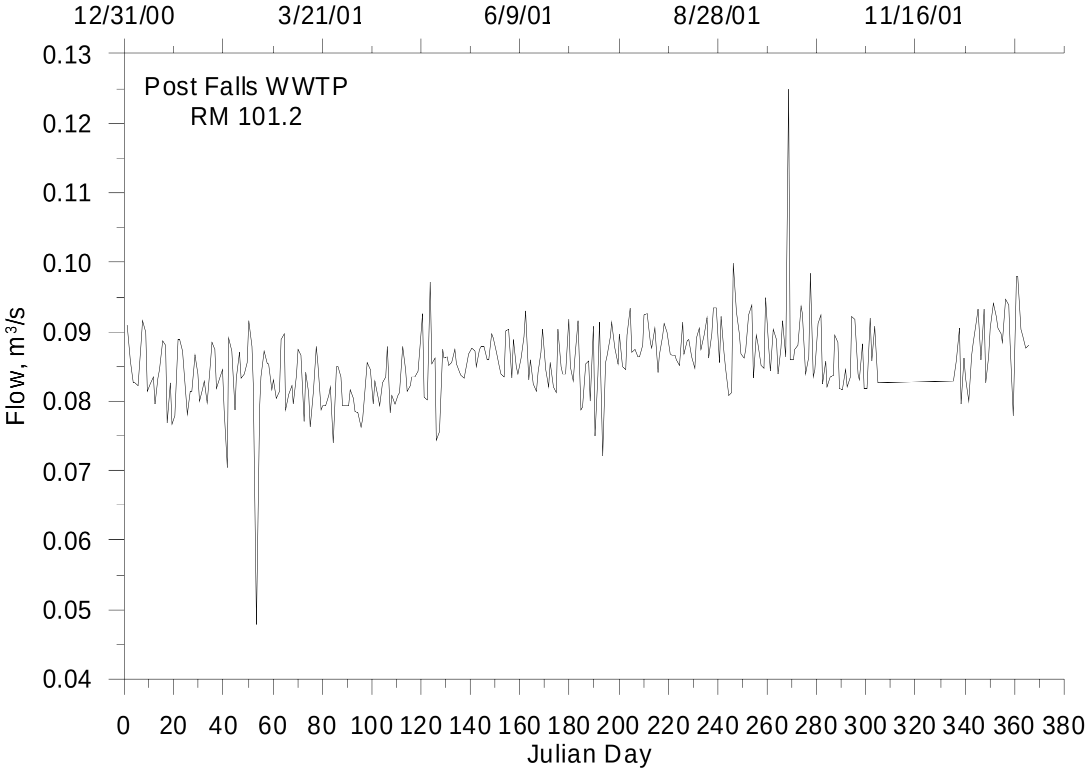


Figure 33. Post Falls WWTP flow rate for 2001.

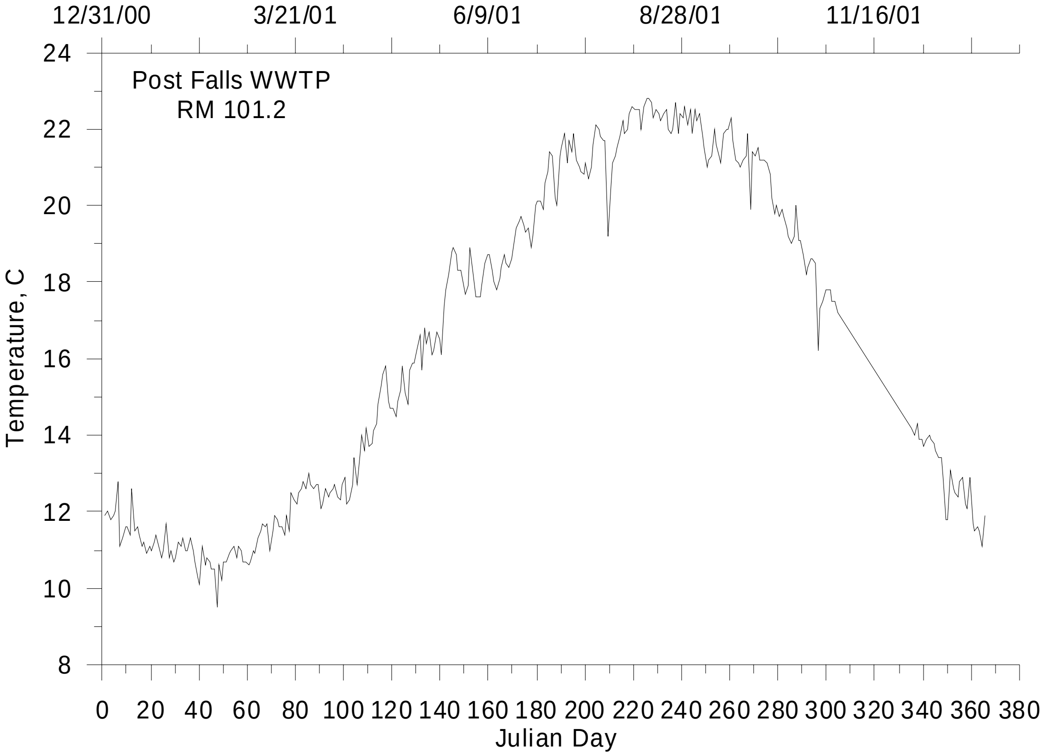


Figure 34. Post Falls WWTP temperatures for 2001.

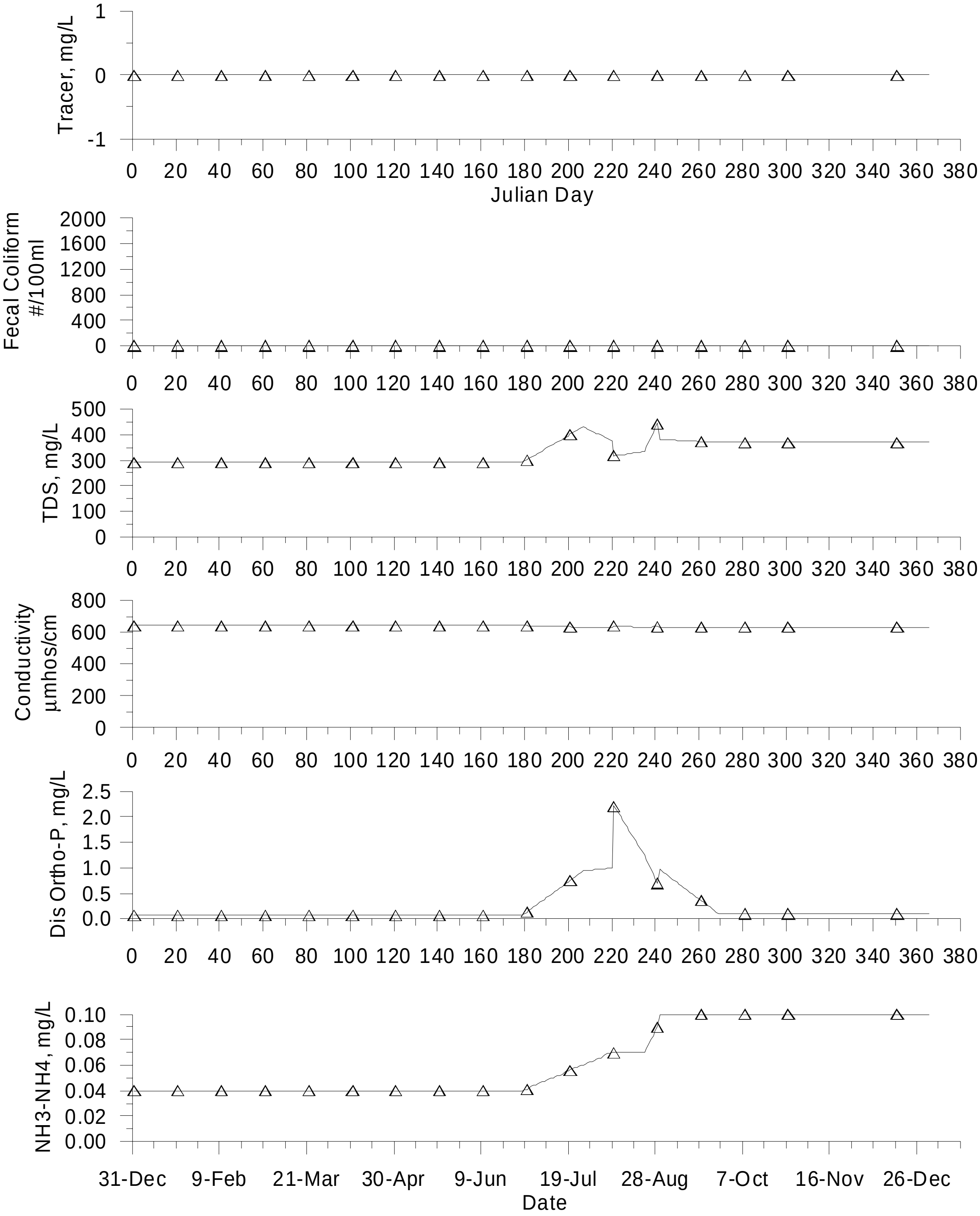


Figure 35. Post Falls discharge water quality conditions (Part 1).

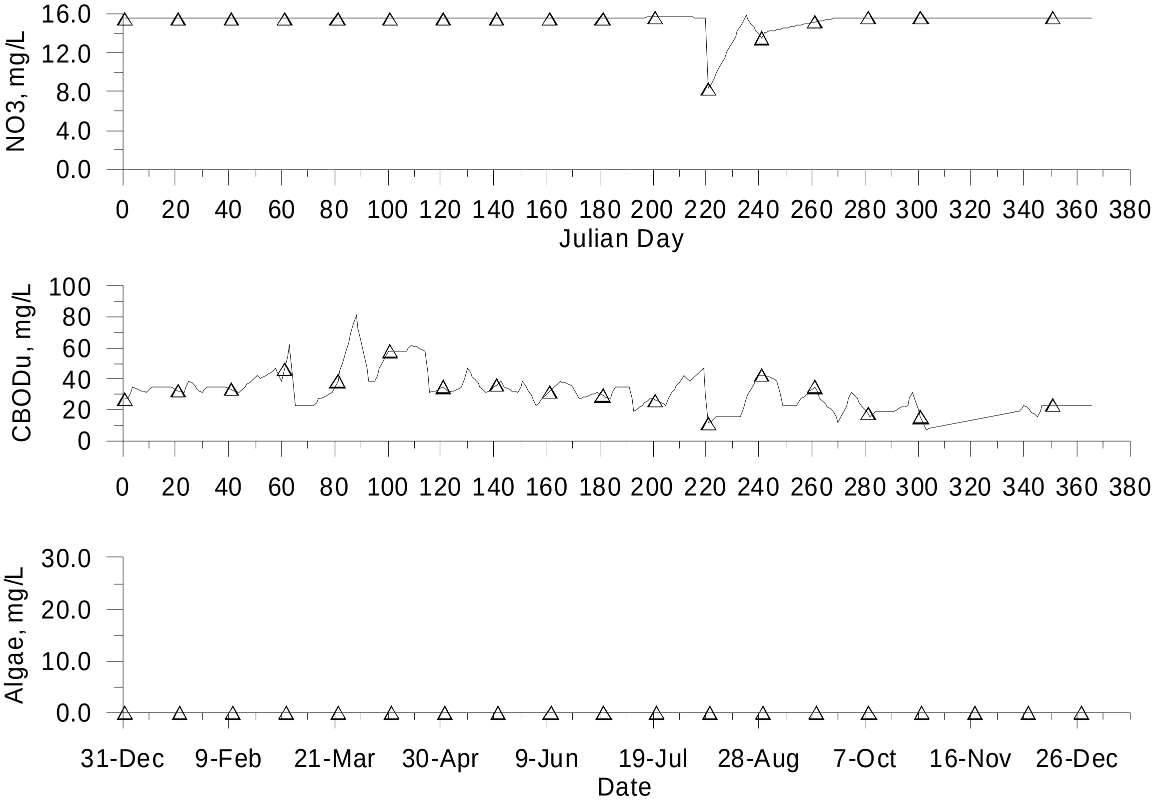


Figure 36. Post Falls discharge water quality conditions (Part 2).

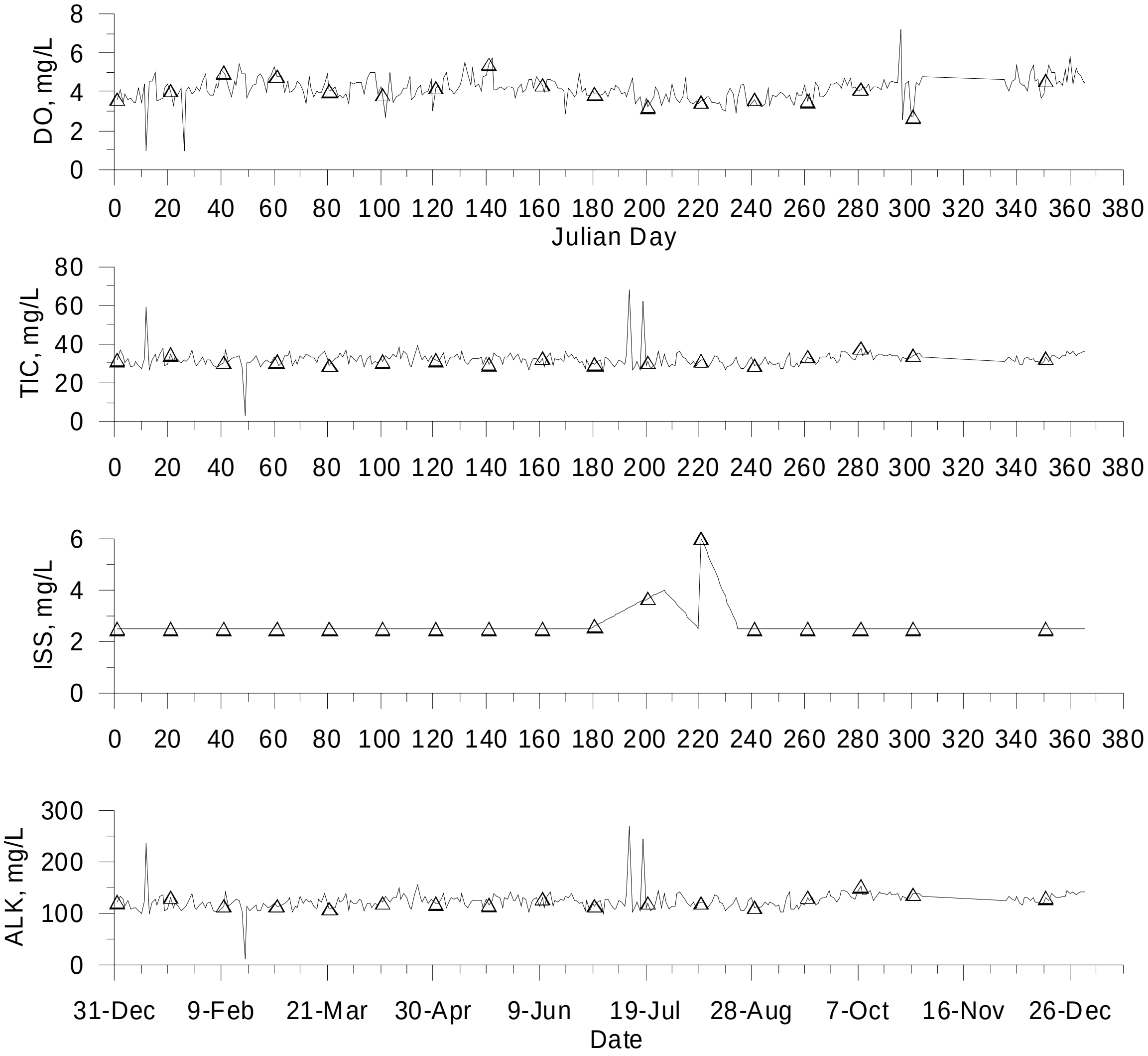


Figure 37. Post Falls discharge water quality conditions (Part 3).

Coeur d'Alene WWTP

The City of Coeur d'Alene wastewater treatment plant discharge flow is shown in Figure 38. The flows are relatively low but higher than Post Falls as expected with slightly flows later in the year. Figure 39 shows the discharge temperature for 2001 and shows a general seasonal warming trend into August and then decreasing temperatures from September through the end of the year.

The water quality constituent file for Coeur d'Alene WWTP was developed from pH, dissolved oxygen, CBODu, total phosphorus, ammonia nitrogen, chloride, conductivity, alkalinity, nitrite-nitrate nitrogen, soluble reactive phosphorus, total dissolved solids, and total non-volatile suspended solids data. Because total phosphorus data were more frequent than soluble reactive phosphorus (SRP) data, for time periods when SRP data were sparse total phosphorus data were used to estimate SRP concentrations by assuming a ratio of 0.594 mg/l SRP per 1 mg/l Total Phosphorus. This ratio was the average of coincidental SRP and total phosphorus Coeur d'Alene WWTP data. Fecal coliform data did not exist and concentrations were set to zero. CBODu data did exist for the Coeur d'Alene discharge so a conversion from BOD5 data was unnecessary. All other constituent concentrations were developed using methods equivalent to those applied to develop the Hayden Area POTW file (described above).

The water quality concentrations used to simulate the Coeur d'Alene WWTP point source are shown in Figure 40, Figure 41, and Figure 42.

Note that Limno-Tech, Inc. (2001b) used the following discharge values based on September 1998 data: Temperature = 23.15°C, SS=2.9 mg/l, LDOM=15.6 mg/l; RDOM=0 mg/l; Algae=0 mg/l; LPOM=0 mg/l; PO_4-P=0.52 mg/l; NH_4-N=3.86 mg/l; NO_3-N=15.9 mg/l; DO=3.67 mg/l; CBOD5=4.2 mg/l. It is unclear why LimnoTech used LDOM and CBOD5 since there is the possibility of counting O_2 demand more than once.

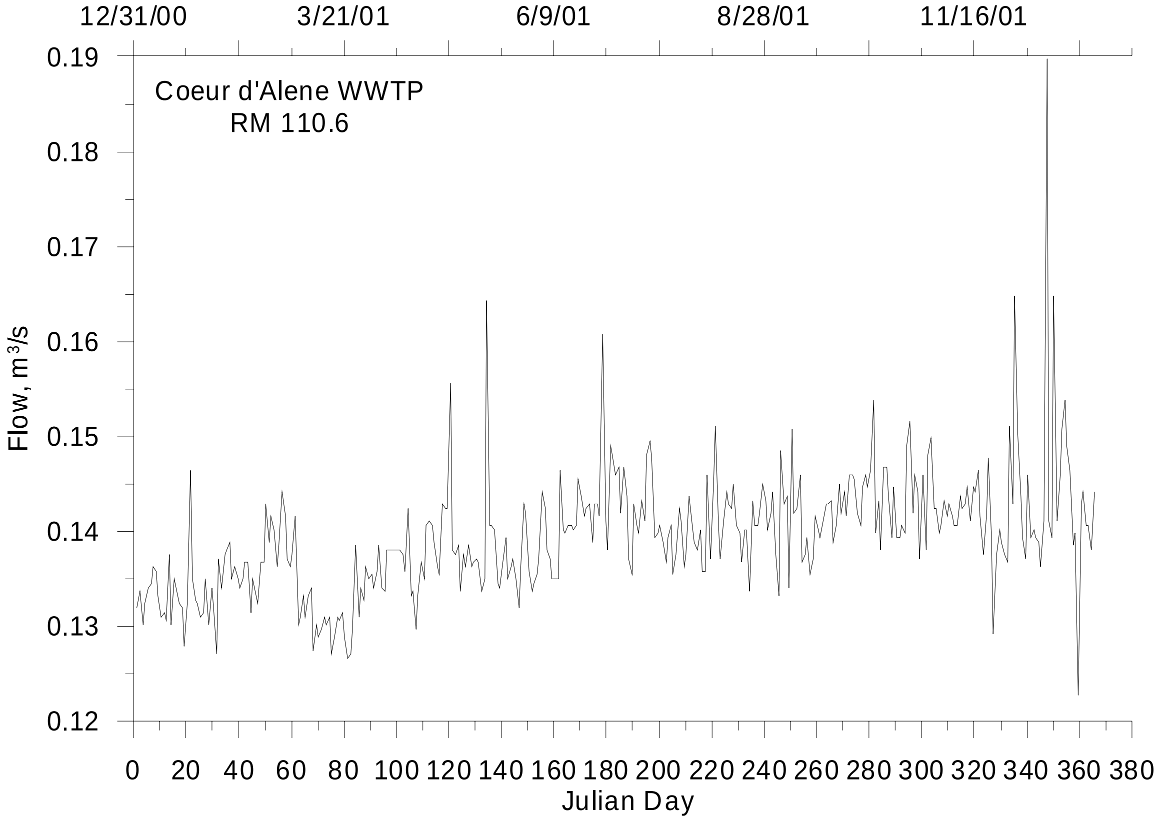


Figure 38. Coeur d'Alene WWTP flow rate for 2001.

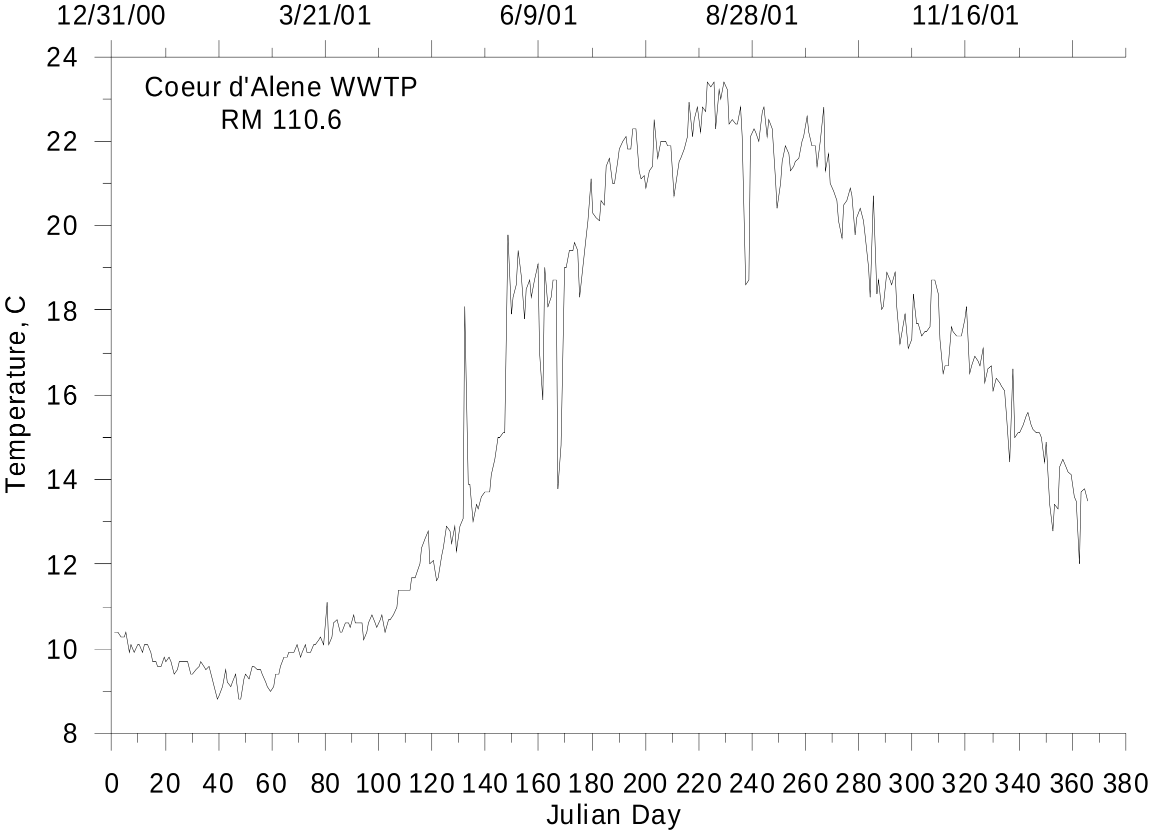


Figure 39. Coeur d'Alene WWTP temperatures for 2001.

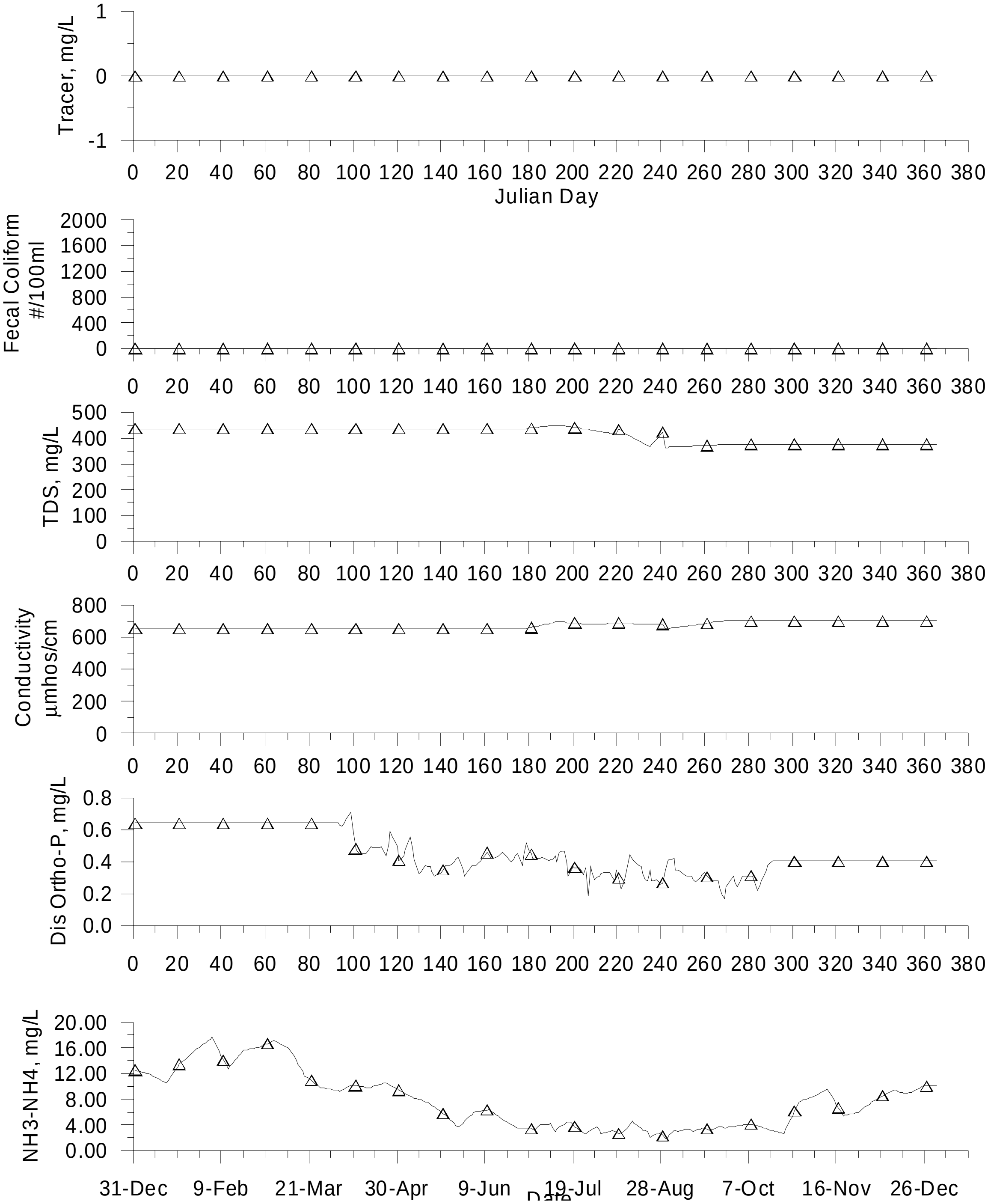


Figure 40. Coeur d'Alene WWTP discharge water quality conditions (Part 1).

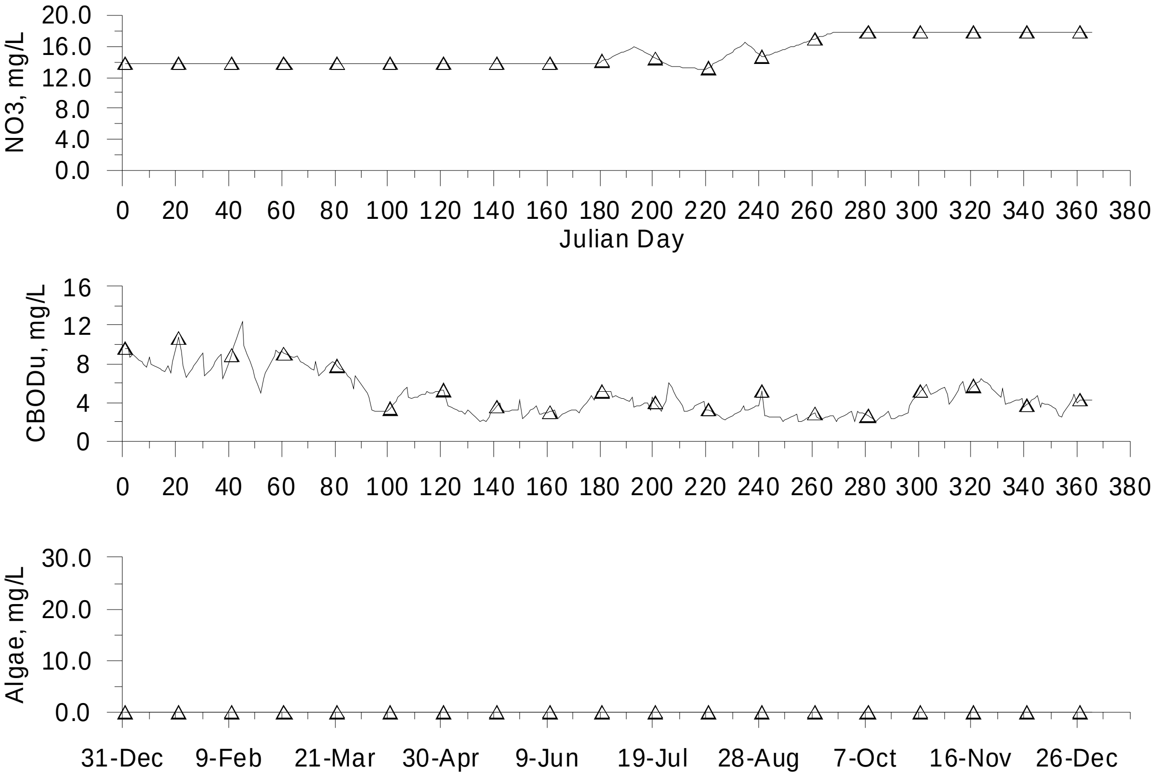


Figure 41. Coeur d'Alene WWTP discharge water quality conditions (Part 2).

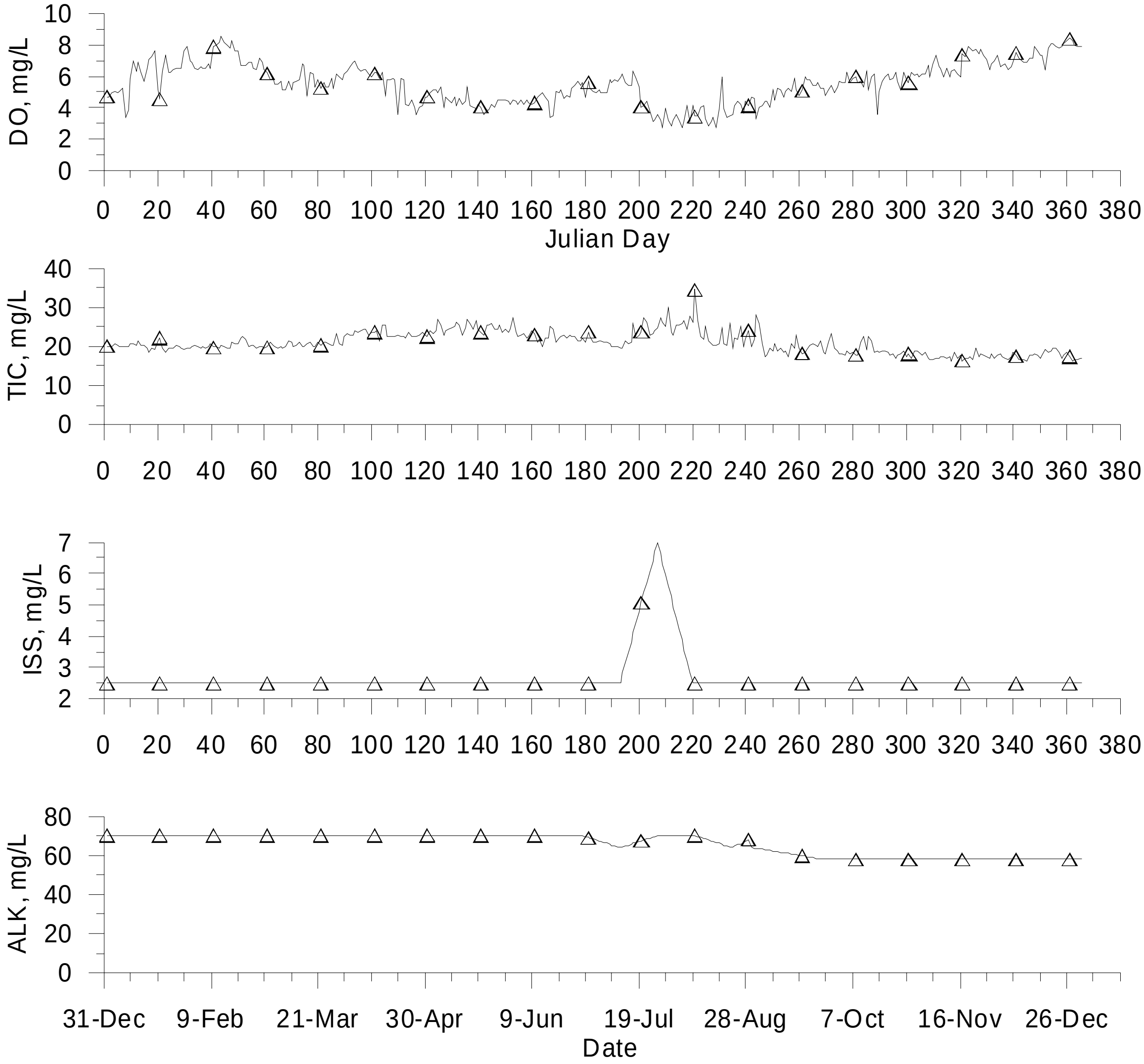


Figure 42. Coeur d'Alene WWTP discharge water quality conditions (Part 3).

Post Falls Reservoir Operations

The Post Falls Dam consists of turbine and spillway discharges. The six turbines each had 4.57 m x 4.53 m (15 ft x 14.85 ft) gates at a centerline elevation of 643.5 m NGVD. The active spillway on another part of the dam has a crest elevation of 645.27 m NGVD. Figure 43 shows the turbine flows for 2001. The plot shows a large spring freshet passing downstream and then reduced flows during the summer and early fall. The spillway flow is shown in Figure 44 with flows only occurring during the spring freshet. Figure 45 shows the water surface elevation of Lake Coeur d’Alene during 2001. The plot shows the water level remained relatively constant over the summer and higher than during the fall through spring period.

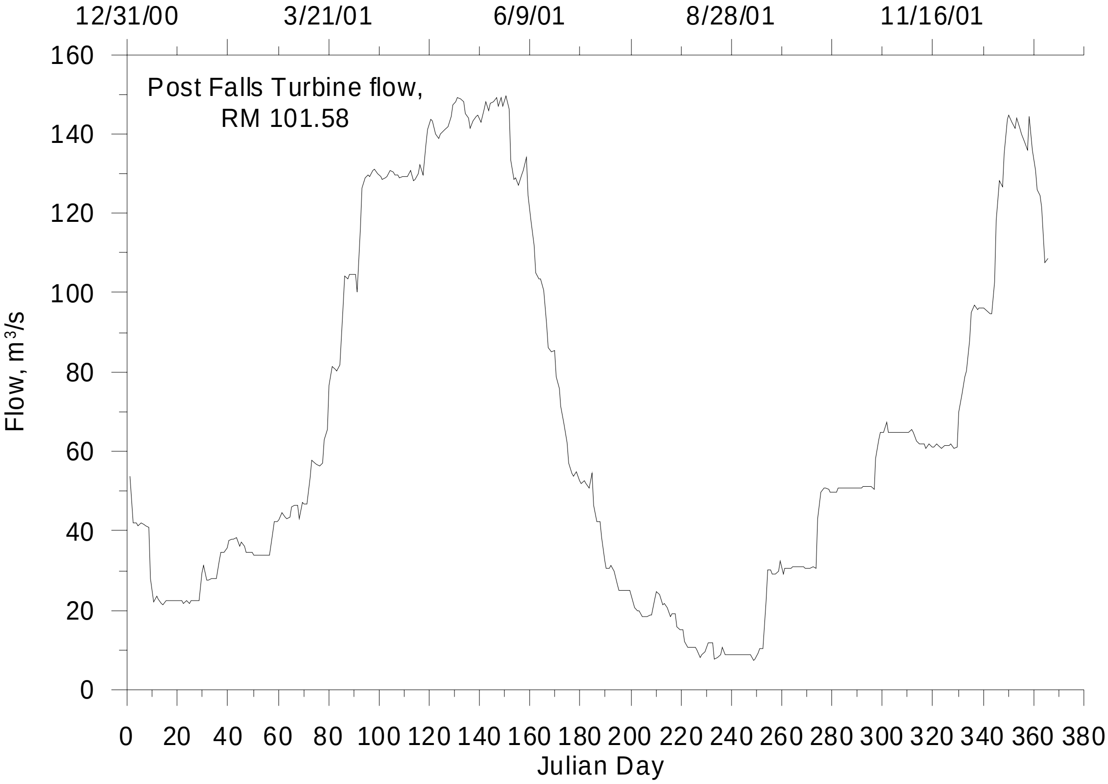


Figure 43. Post Falls Dam turbine flows for 2001.

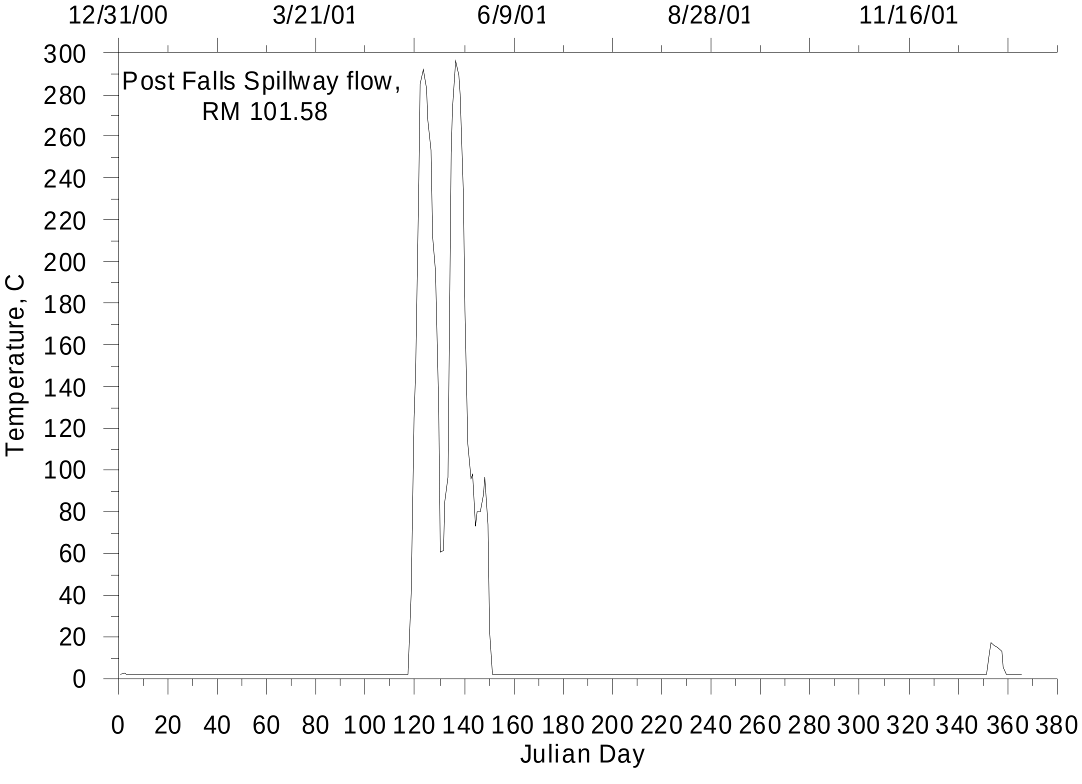


Figure 44. Post Falls Dam spillway flows for 2001.

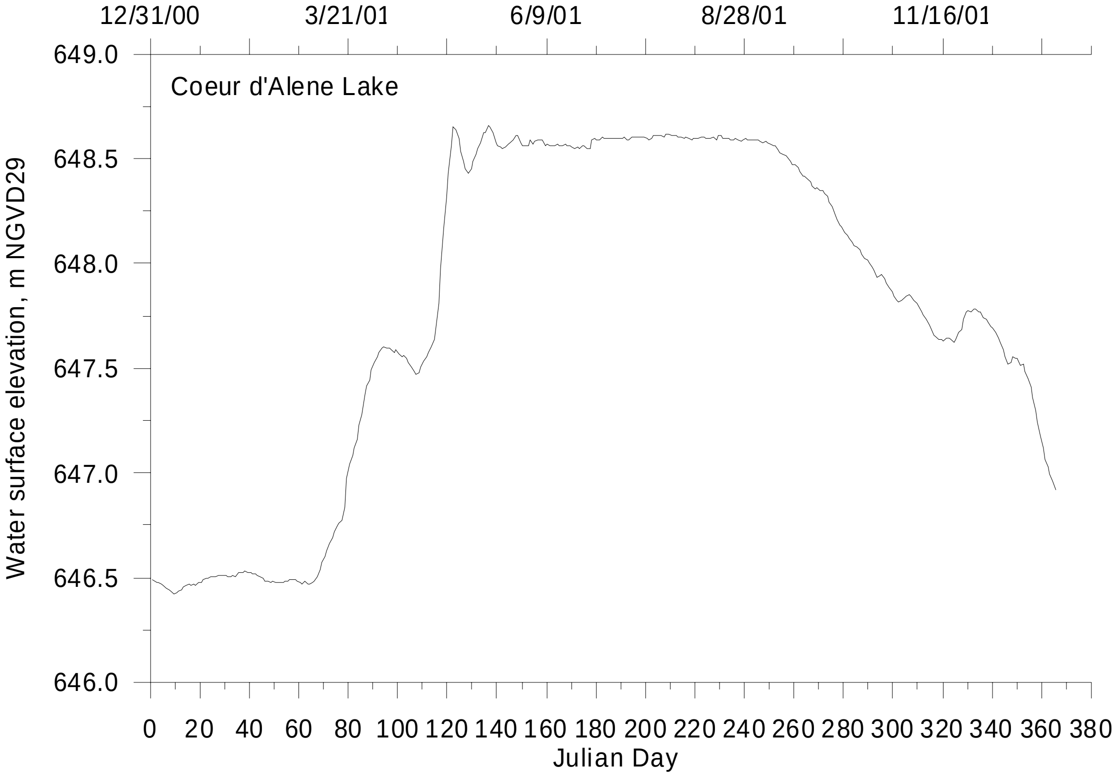


Figure 45. Coeur d'Alene Lake water surface elevations for 2001.

Groundwater

Figure 46 shows the distributed inflow between the ID-WA state line and the U.S. Geological Survey (USGS) gage station near Post Falls, ID (USGS: 12419000) for 2001. The change in flow occurring between Post Falls and the state line was estimated by using flow data from Harvard Road (RM 93.7). Flow rates at Harvard Road were typically less than those at Post Falls due to losses to the aquifer. The difference in flow between Post Falls and Harvard Road was then used to estimate the flow at the state line, which lay 4.7 miles downstream of Post Falls. The total distance between Post Falls and Harvard Bridge is 7.7 miles, and the loss/gain to the aquifer occurring between Post Falls and the state line was estimated by multiplying the difference in flow between Post Falls and Harvard Road by the fraction f of river miles between Post Falls and state line (f = 4.7 miles/7.7 miles). The gain/loss to the aquifer Q_{aquifer} (typically a loss) between Post Falls and State Line was estimated from

$$Q_{\text{aquifer}} = \left(Q_{\text{Harvard}} - Q_{\text{Post Falls}}\right)\frac{4.7\text{ miles}}{7.7\text{ miles}}$$

This was the same method used to develop the upstream boundary condition for the Spokane River model for 1991, 2000 and 2001 (Annear et al, 2001; Slominski et al, 2002).

Losses to the aquifer for the model branch located between Lake Coeur d'Alene and Post Falls Dam (branch 1) were also modeled using a distributed tributary inflow. Losses were set at a constant outflow rate of –6.57 cms (LimnoTech, Inc., 2001b from Yearsley).

Since the river section between Lake Coeur d'Alene and Post Falls dam was always an outflow reach, temperature and water quality of the distributed tributary for this model branch has no impact on model predictions. Dummy files for temperature and water quality were included in the model.

The reach between Post Falls dam was also generally a losing reach, but there were brief periods of groundwater inflows. Temperature and water quality of these inflows were based on well data collected in the Sullivan Road area of the Upper Spokane River (Slominski et al., 2002).

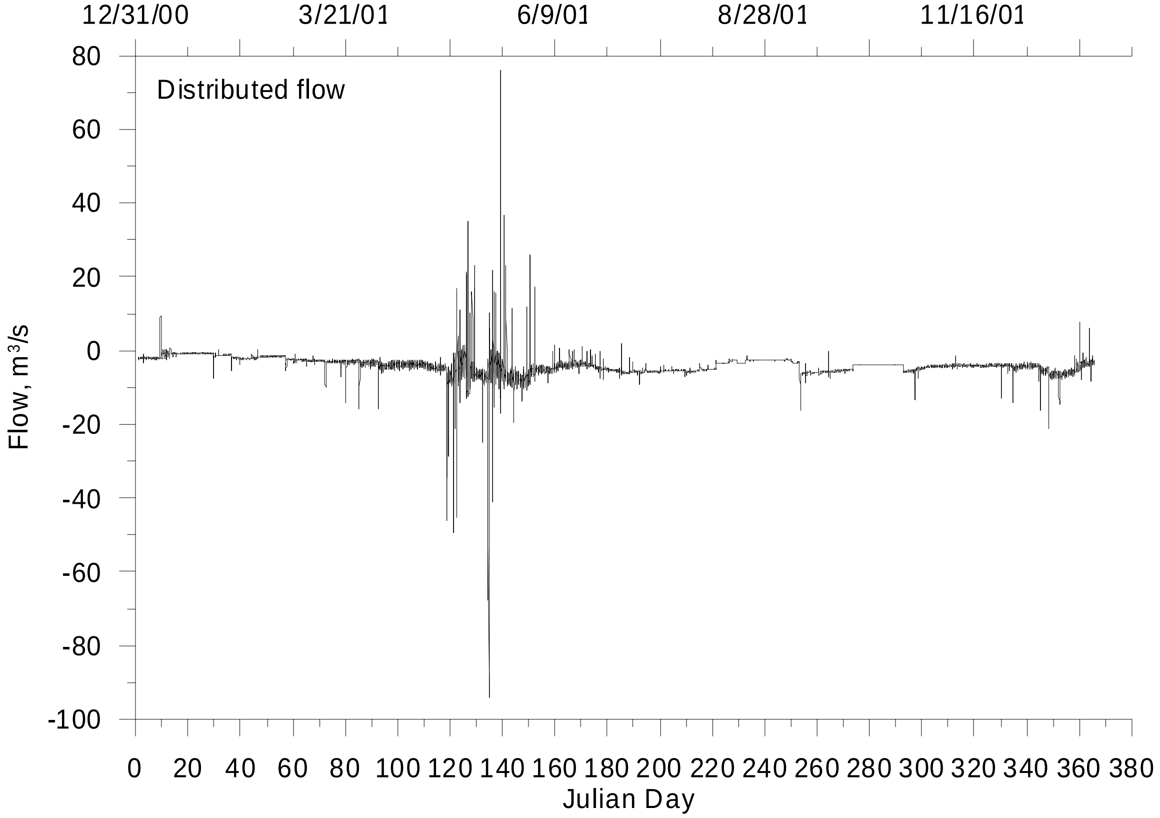


Figure 46. Distributed groundwater flow for 2001 for the Spokane River below Post Falls Dam.

Meteorological Data

Meteorological data for the CE-QUAL-W2 model was taken from the Coeur d’Alene airport, even though other sites were also available, such as the Spokane International Airport and the Spokane Felts Field (Figure 47). The model utilizes air and dew point temperature, wind speed and direction, and cloud cover or solar radiation. The airport sites did not have solar radiation data available. Solar radiation data from Odessa, WA was available, but for the Idaho portion of the Spokane model, the cloud cover from Coeur d’Alene was used to estimate short wave solar radiation . The model used interpolation to fill in the meteorological information between input data.

The following sections summarize the different meteorological data in the project area:

- Spokane International Airport
- Spokane Felts Field
- Coeur d’Alene Airport
- Odessa Solar Radiation

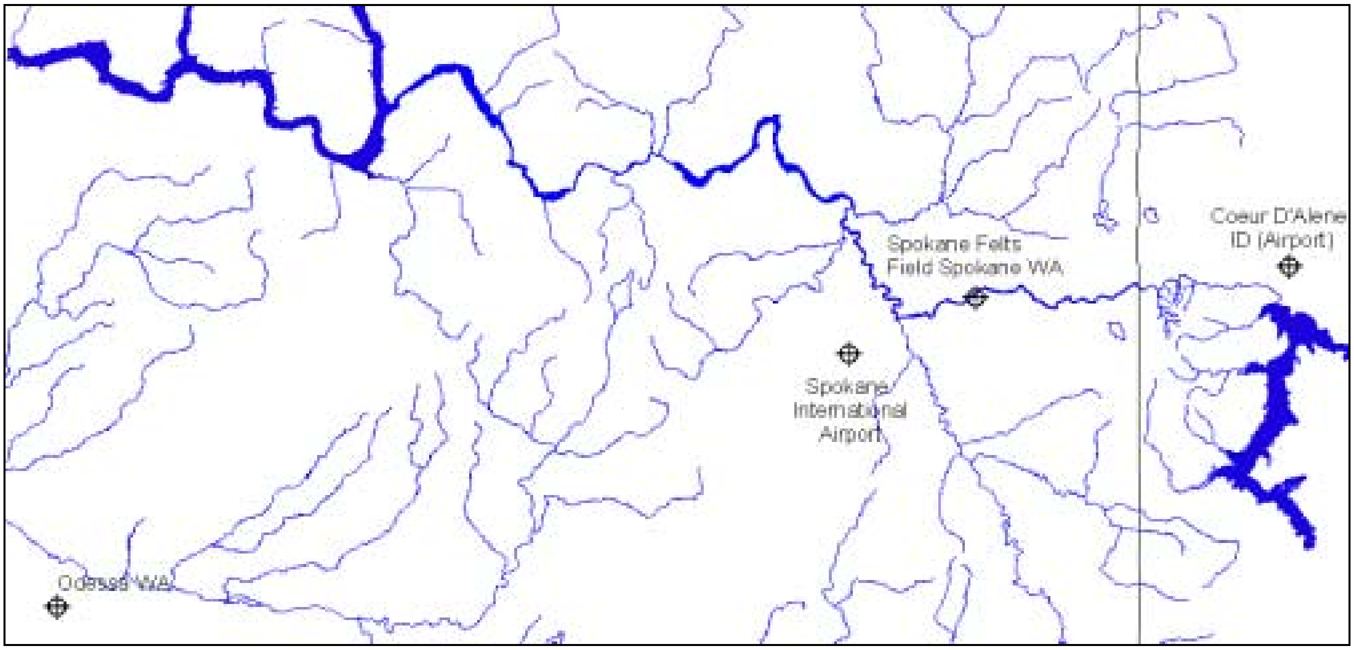


Figure 47. Meteorological stations near the Spokane River

Spokane International Airport

Air temperatures for 2001 are shown in Figure 48. Dew point temperatures are shown in Figure 49. Air and dew point temperatures were similar to 2000. Figure 50 shows wind speed and Figure 51 shows wind direction recorded at the airport for 2001. The Spokane International Airport uses a high-speed wind gauge that only records wind speeds greater then 1.5 m/s. Wind direction is only noted for speeds greater then 1.5 m/s. As in 1991 and 2000, the predominant wind directions were from 150 to 250 degrees from the North and from 0 to 70 degrees from the North. Figure 52 shows the cloud cover reported at the airport. It should be noted that the National Weather Service (NWS) started recording cloud cover differently in 1996. Prior to 1996 the NWS used a 0 to 10 scale for recording cloud density with 0 indicating no cloud cover and 10 indicating full cloud cover. After 1996, the scale was switched to 1 to 8. In order to compare the data to the previous data record, the cloud cover from 2001 was converted to a scale of 0 to 10.

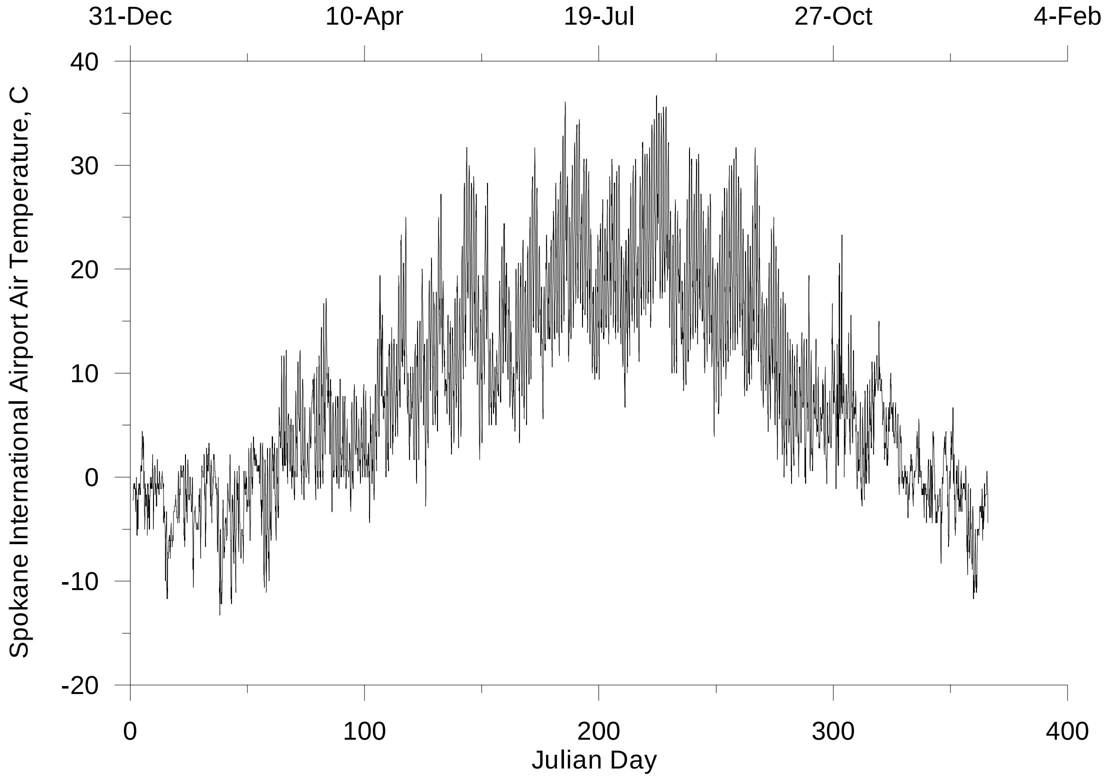


Figure 48. Air temperature, °C, at the Spokane International Airport

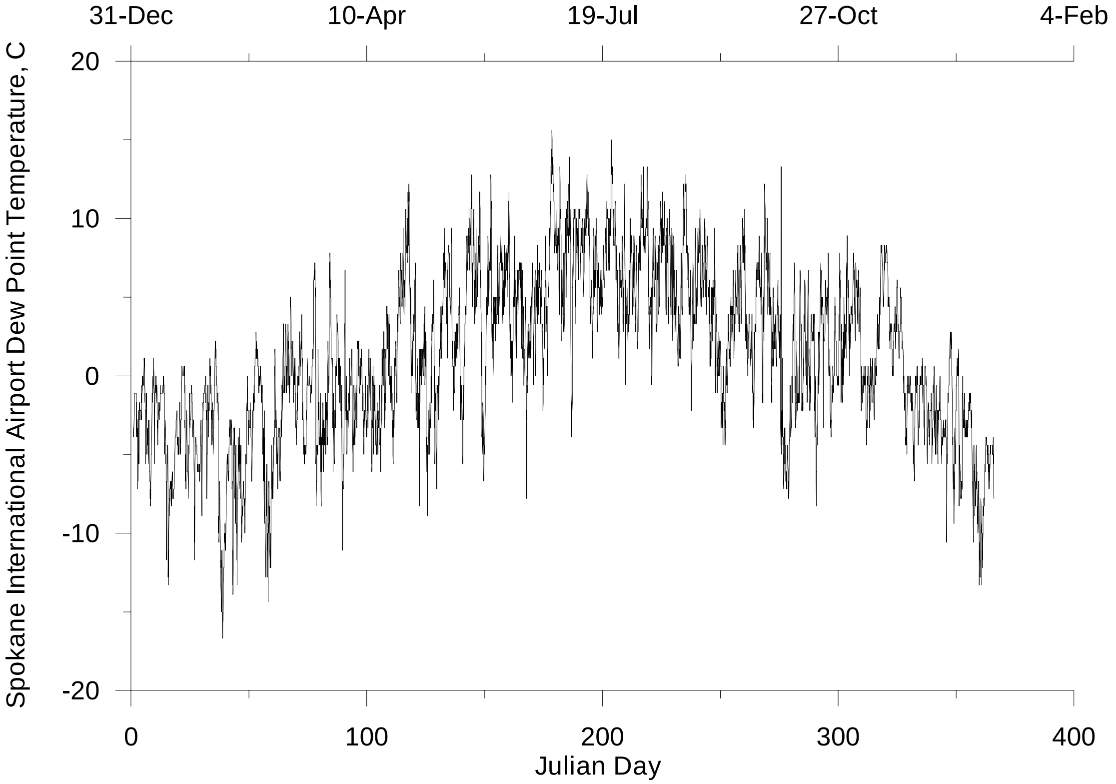


Figure 49. Dew point temperature, °C, at the Spokane International Airport

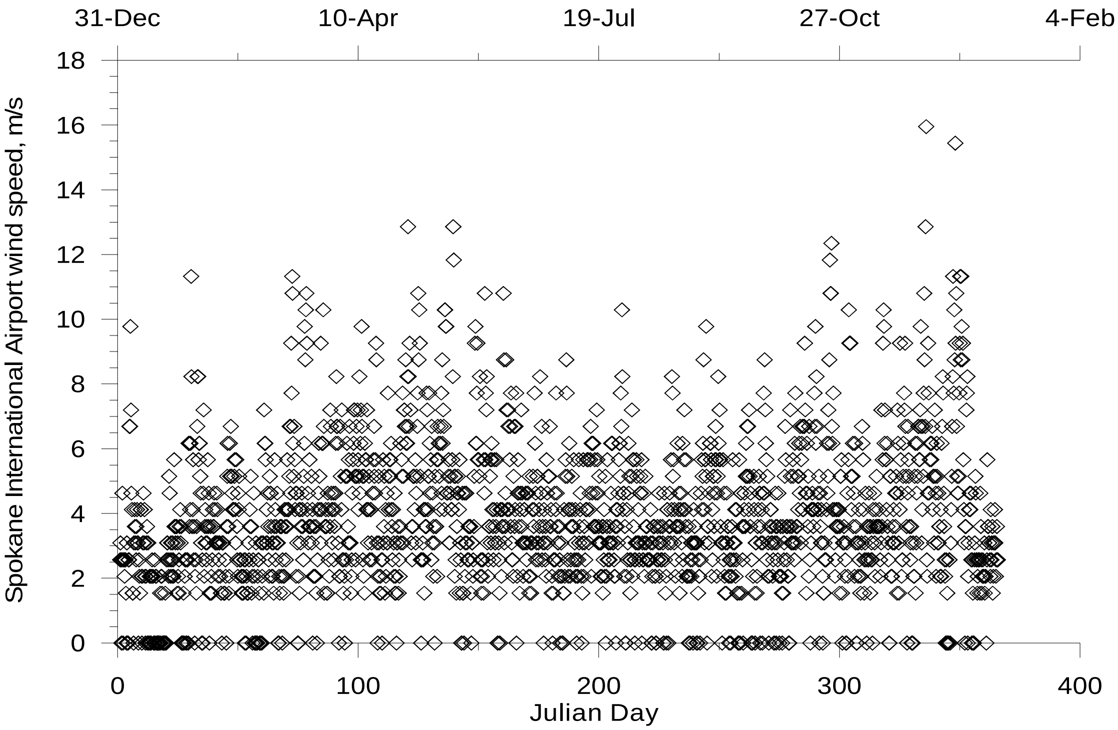


Figure 50. Wind Speed, m/s, at the Spokane International Airport

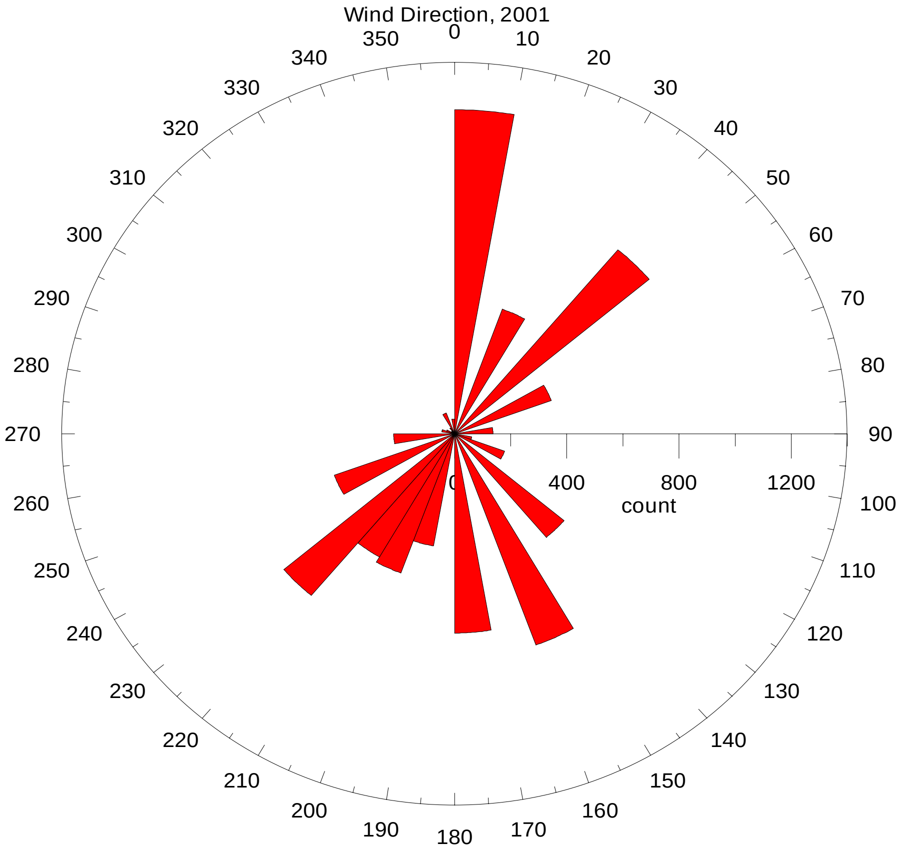


Figure 51. Wind direction, degrees from North, at the Spokane International Airport, 2001

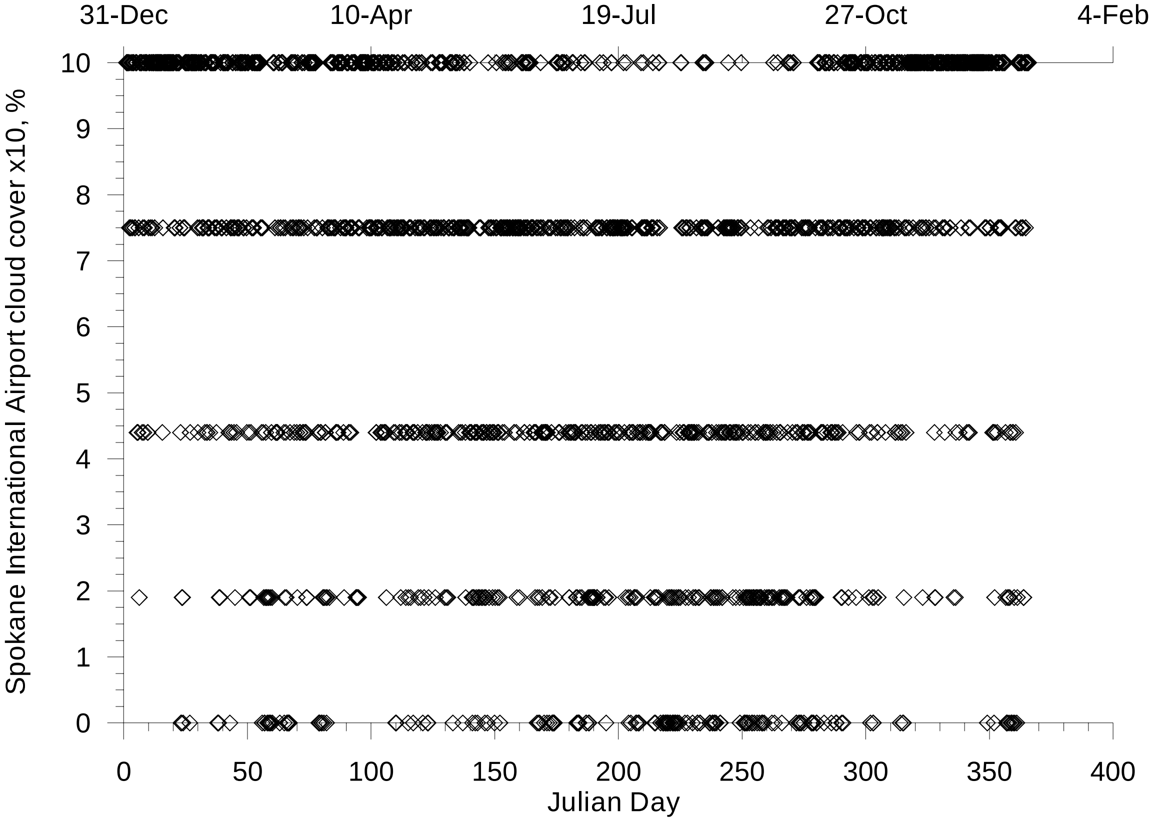


Figure 52. Cloud Cover, x10, at the Spokane International Airport

Spokane Felts Field

Air temperatures for 2001 are shown in Figure 53 with the highest temperatures in July and August similar to temperatures shown for the Spokane International Airport. Dew point temperatures are shown in Figure 54. Figure 55 shows the wind speeds, which were lower than wind speeds at the Spokane International Airport. Figure 56 shows a rose diagram of the wind directions recorded where the predominant wind direction was 170 to 260 degrees from the North. Figure 57 shows the cloud cover reported for the year. Felts Field has a high-speed wind gauge as well, only recording speeds greater then 1.5 m/s. Similar to the Spokane International Airport, the cloud cover data recorded by the National Weather Service (NWS) were switched to 1 to 8 scale after 1996. In order to compare data from years prior to 1996 and for use in the model, the cloud cover information from 2000 was converted to a scale of 0 to 10.

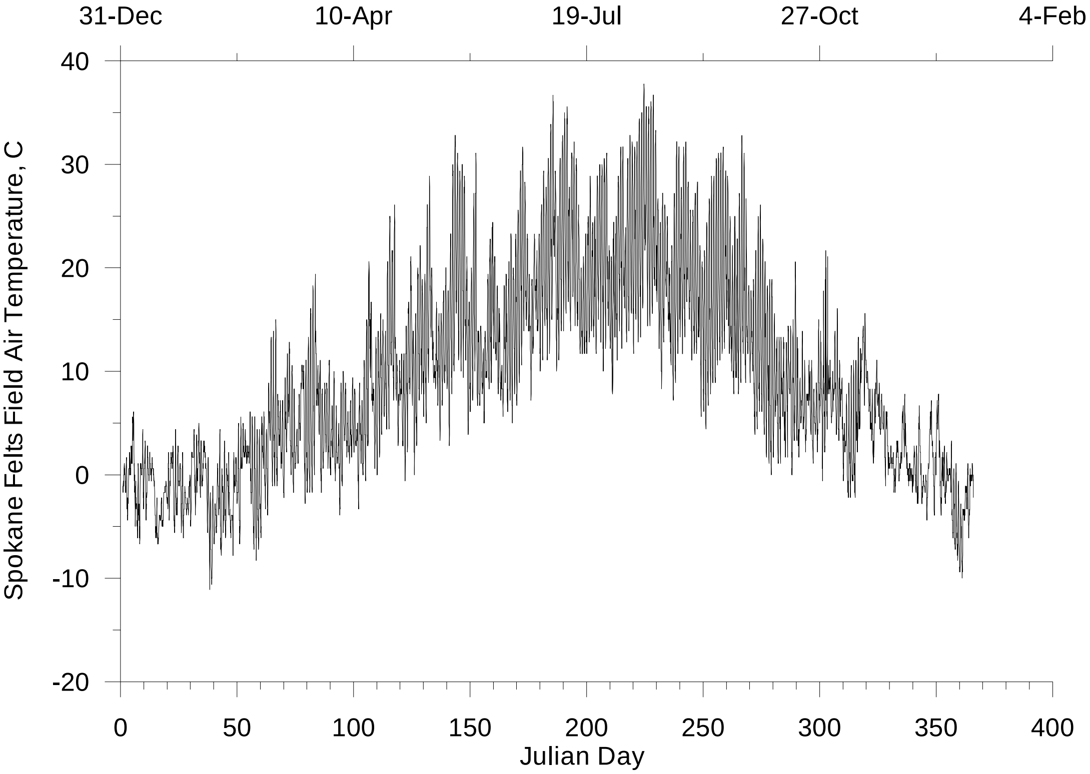


Figure 53. Air temperature, °C, at Spokane Felts Field

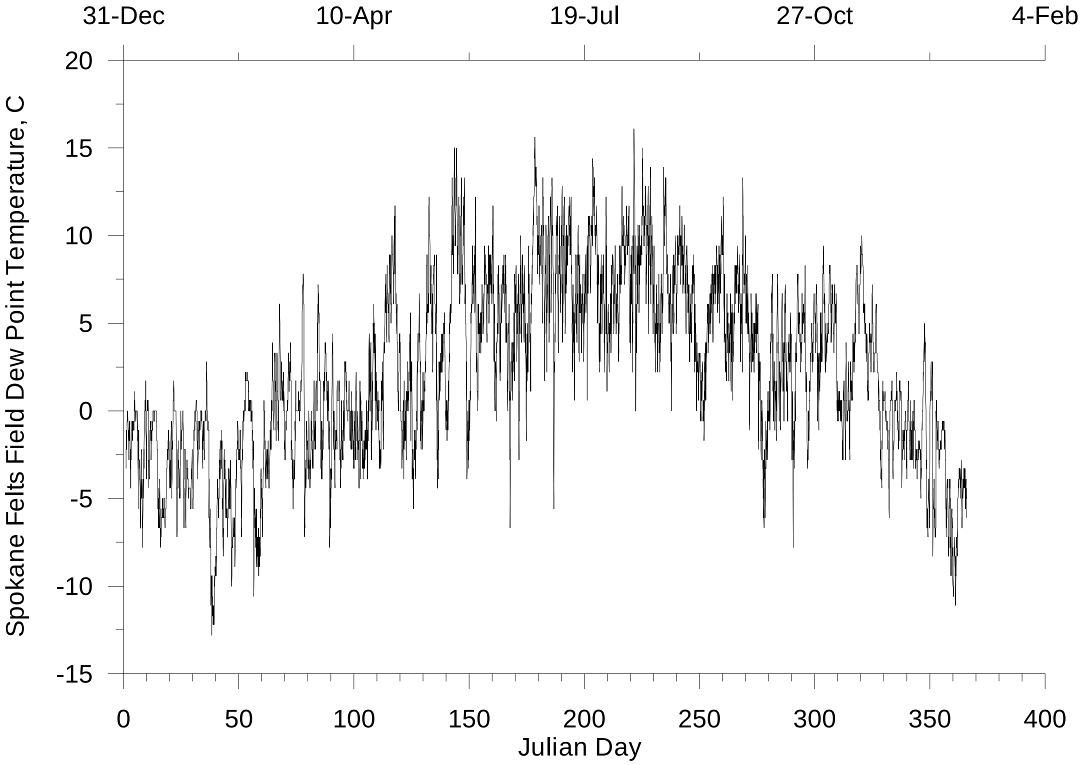


Figure 54. Dew point temperature, °C, at Spokane Felts Field

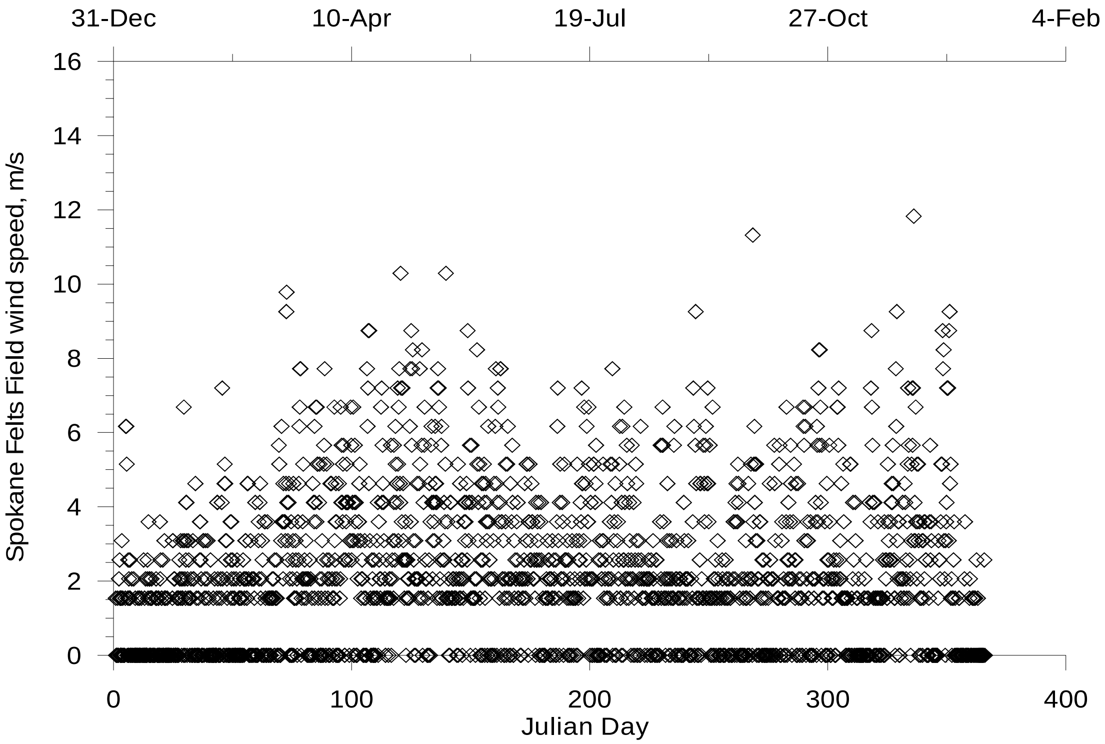


Figure 55. Wind speed, m/s, at Spokane Felts Field

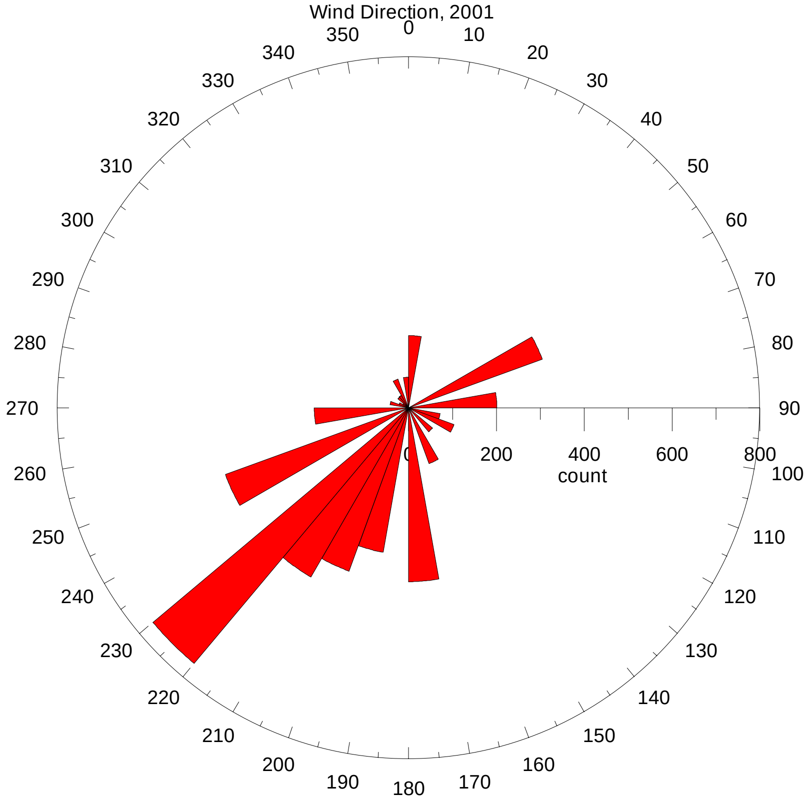


Figure 56. Wind direction, degrees from North, at Spokane Felts Field

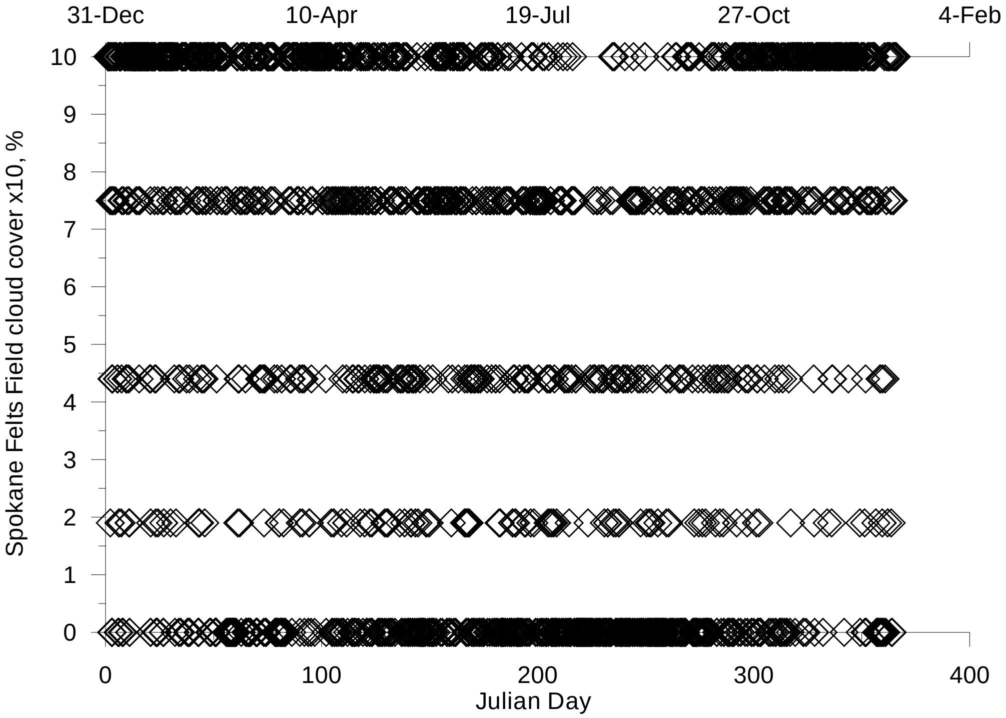


Figure 57. Cloud Cover, x10, at Spokane Felts Field

Coeur d'Alene

The meteorological station at the airport in the City of Coeur D'Alene, ID, as shown in Figure 47, monitored air temperature, dew point temperature, wind speed and direction, cloud cover, visibility and barometric pressure. Figure 58 shows the air temperature recorded at the airport showing a general warming trend into August and cooler in the fall and diurnal fluctuations throughout. Figure 59 shows the dew point temperature throughout 2001 with muted diurnal fluctuations and a slight general increase into late summer. Figure 60 shows the wind speed data, which is highly variable. It should be noted that the measurement instrument was designed for high-speed wind measurements so any wind speed below approximately 1.5 m/s were set to zero. Figure 61 plots the wind direction data in a rose diagram and indicates the predominant wind direction was from the north (0.0 to 5 degrees). This bias is mostly likely because the high-speed wind instrument measure the wind direction at zero when the wind speed is measured at zero. Ignoring this aspect of the rose diagram shows the predominant wind directions were form the Northeast and from the Southwest, which is similar to the wind directions measured at Spokane Felts Field airport and the International Airport. Figure 62 shows the cloud cover data measured at the airport in Coeur d'Alene. Similar to the Spokane International Airport and Spokane Felts Field, the cloud cover data recorded by the National Weather Service (NWS) were switched to 1 to 8 scale after 1996. In order to compare data from years prior to 1996 and for use in the model, the cloud cover information from 2000 was converted to a scale of 0 to 10.

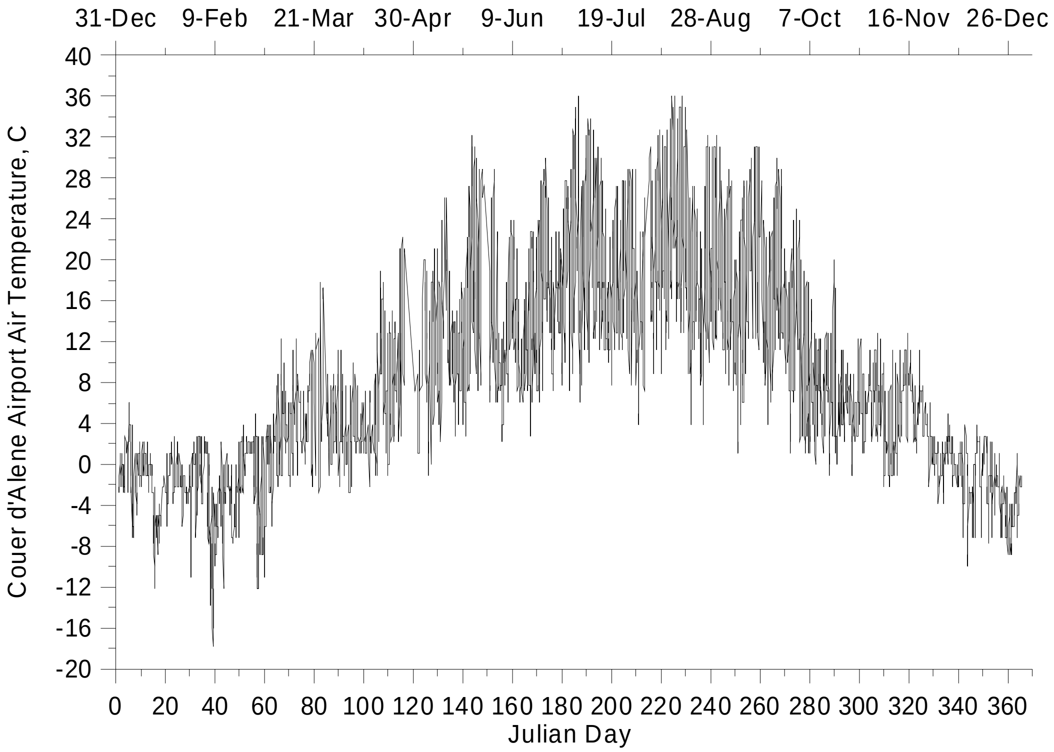


Figure 58. Air temperature, ^{o}C, at City of Coeur d'Alene Airport

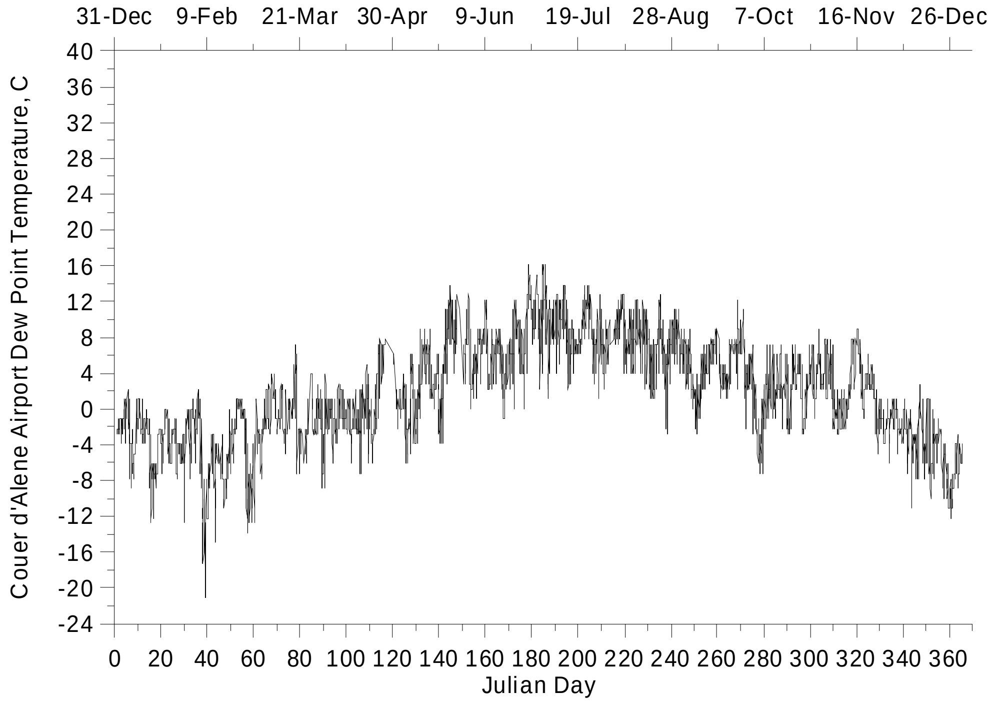


Figure 59. Dew point temperature, ^{o}C, at City of Coeur d'Alene Airport

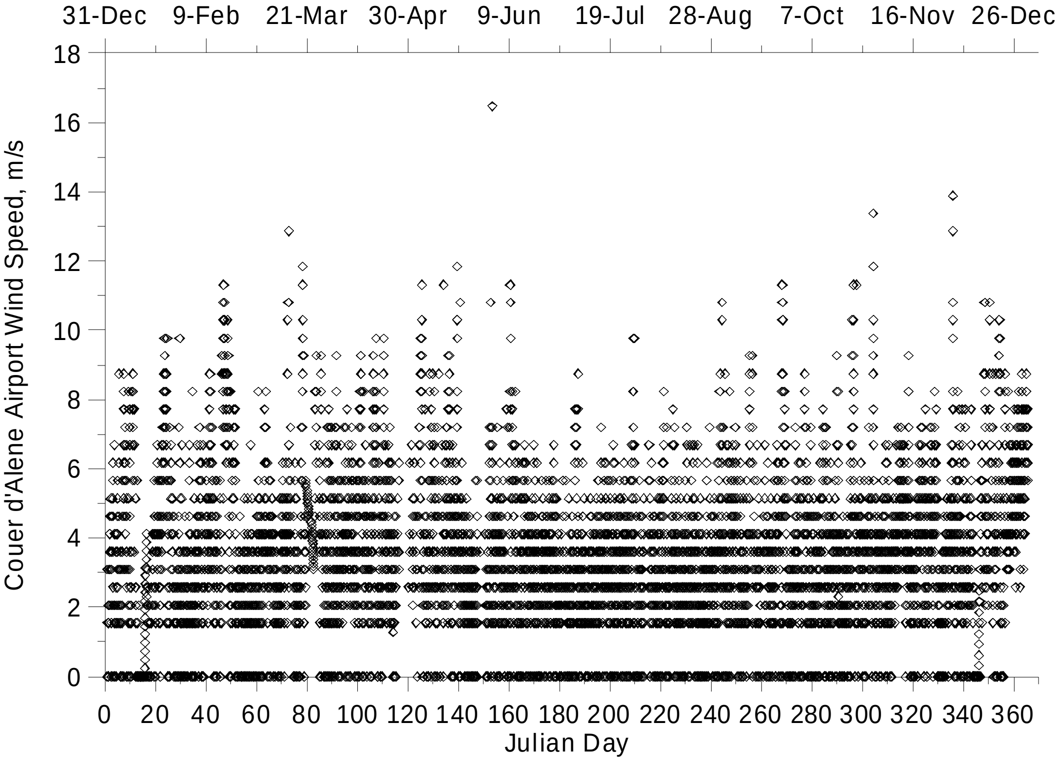


Figure 60. Wind speed, m/s, at City of Coeur d'Alene Airport

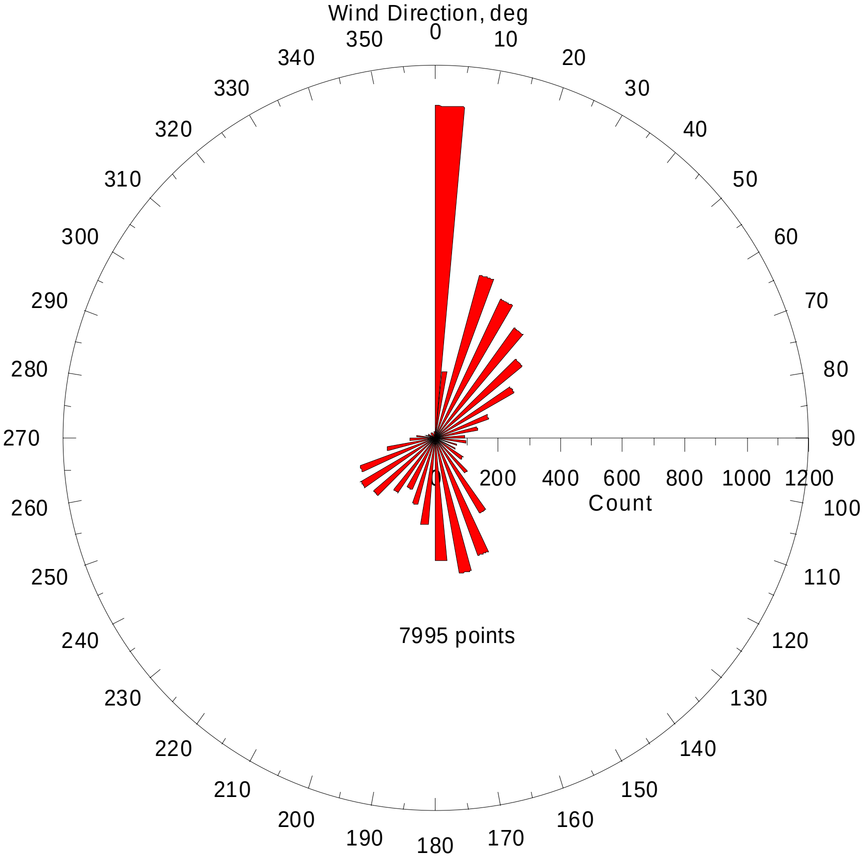


Figure 61. Wind direction, degrees from North, at City of Coeur d'Alene Airport

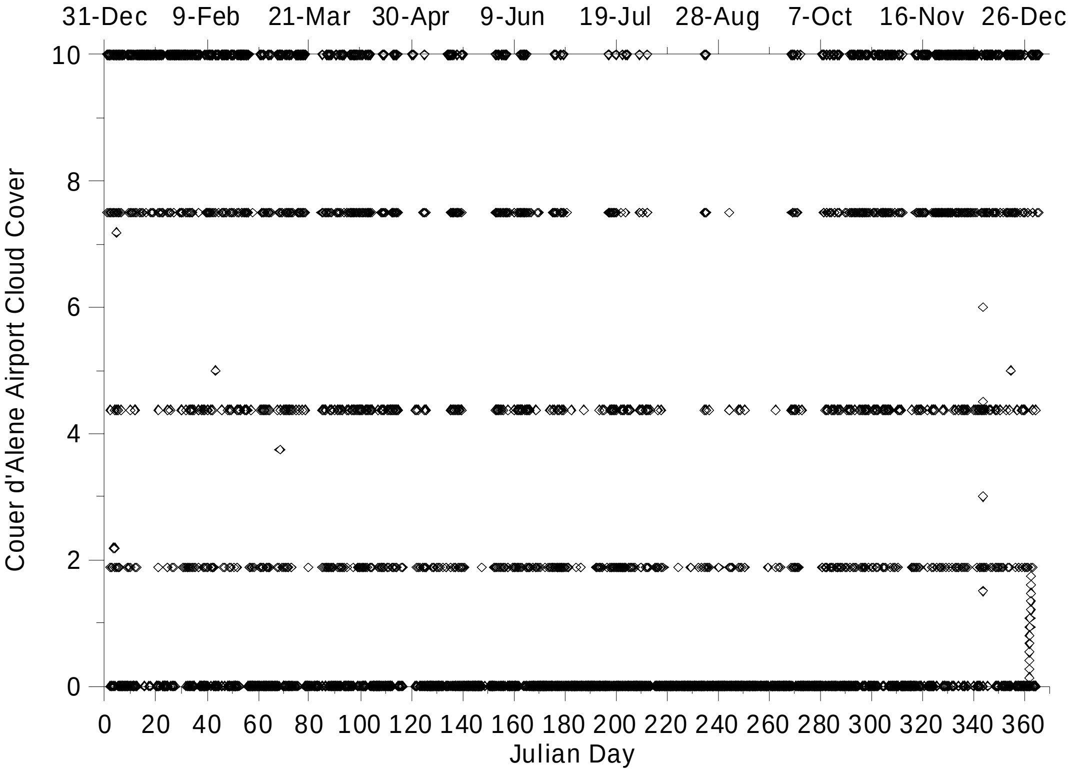


Figure 62. Cloud Cover, x10, at City of Coeur d'Alene Airport

Odessa, WA

The meteorological site in Odessa, WA (see Figure 47) collected solar radiation data. This was far from the Idaho project area and was not used in the model. The solar radiation data collected at Odessa in 2001 is shown in Figure 63.

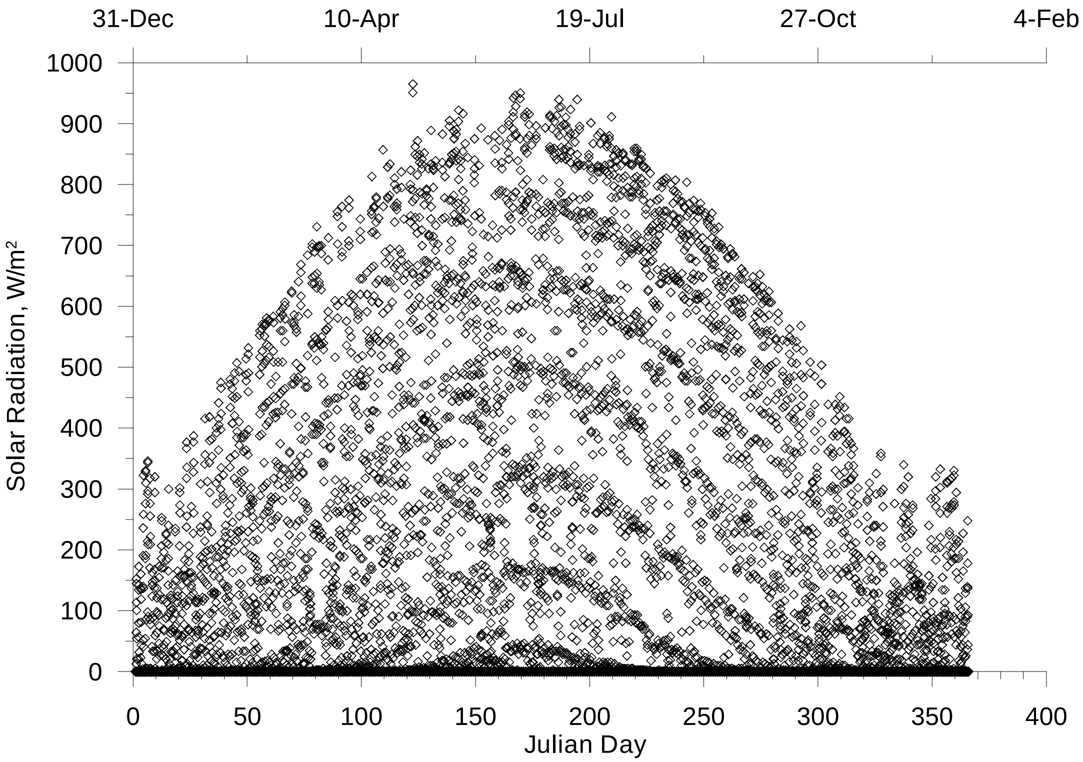


Figure 63. Solar radiation, W/m^2, at Odessa, WA 2001

Periphyton Data

A periphyton algorithm was developed for the model to incorporate important nutrient and dissolved oxygen changes in the Spokane River. Samples were collected at 8 sites on the Spokane River in WA as listed in Table 6 in August and September 2001. Table 7 and Table 8 show the mean biomass and chlorophyll data from August 2001 for each site based on several samples collected. Table 9 and Table 10 show the mean biomass and chlorophyll data from September 2001 for each site based on several samples collected. Table 11 and Table 12 show the mean biomass and chlorophyll data for each site based on new growth over 28 days from incubated substrates at each site.

Table 6. Periphyton Data Sites

Site Code	Description	River Mile
SL	Stateline Bridge	96.0
BSB	Barker Road Bridge	90.4
TI	Trent Road Bridge	85.3
BGS	Green St. Bridge	78.0
CPS	Clark Pump Station	72.7
ASP	Above Spokane WWTP	67.6
BGC	Below Gun Club	64.6
BNM	Below Nine Mile Dam	58.1

Table 7. August 2001 Site Mean Biomass from Natural Substrates

RM	Depth	ODW	AFODW	Autotrophic	Autotrophic

	(m)	(g/m2)	(g/m2)	Index (Mono Chl a)	Index (Tri Chl a)
96.0	1.17	120.24	8.49	244.51	222.74
90.4	1.47	13.15	3.33	358.46	334.78
85.3	1.21	20.75	4.93	418.41	386.32
78.0	0.69	129.19	22.95	283.53	259.21
72.7	0.71	24.37	8.86	215.76	202.55
67.6	0.93	41.94	9.33	276.97	263.53
64.6	0.65	39.43	15.42	196.19	190.08
58.1	0.79	279.24	11.63	162.86	153.99

Table 8. August 2001 Site Mean Chlorophyll from Natural Substrates

RM	Temp. (C)	Elec. Cond. (m-siemens)	Depth (m)	Flow Velocity (ft/sec)	Mono-Chromatic Chl a (mg/m2)	Pheophyton (mg/m2)	Tri-Chromatic Chl a (mg/m2)	Tri-Chromatic Chl b (mg/m2)	Tri-Chromatic Chl c (mg/m2)
96.0	24.2	140	1.1	0.0	36.6	4.3	40.4	3.1	1.6
90.4	22.5	175	1.3	0.0	10.8	0.8	11.6	1.3	0.3
85.3	12.5	280	1.2	0.1	14.4	0.8	15.4	0.9	1.0
78.0	14.3	271	0.7	0.4	26.8	2.3	28.9	4.5	1.4
72.7	15.7	270	0.7	0.3	44.0	3.0	47.0	5.2	4.9
67.6	15.2	210	0.9	0.4	43.4	2.0	45.9	4.7	1.8
64.6	16.0	329	0.6	0.3	77.9	-0.1	80.6	1.6	4.9
58.1	18.1	326	0.8	0.0	80.0	4.8	85.7	2.1	5.5

Table 9. September 2001 Sites Mean Biomass from Natural Substrates

RM	Depth (m)	ODW (g/m2)	AFODW (g/m2)	Autotrophic Index (Mono Chl a)	Autotrophic Index (Tri Chl a)
96.0	1.39	172.10	9.46	236.79	211.01
90.4	1.78	21.61	5.08	413.41	382.36
85.3	0.97	36.75	5.01	436.66	404.29
78.0	0.78	67.81	8.59	312.56	288.26
72.7	0.62	75.91	8.15	347.10	303.12
67.6	0.79	26.88	8.80	320.92	292.22
64.6	0.72	47.65	19.89	192.81	185.45
58.1	0.68	557.08	12.21	306.63	278.79

Table 10. September 2001 Site Mean Chlorophyll from Natural Substrates

RM	Temp. (C)	Elec. Cond. (m-siemens)	Depth (m)	Flow Velocity (ft/sec)	Mono-Chromatic Chl a (mg/m2)	Pheophyton (mg/m2)	Tri-Chromatic Chl a (mg/m2)	Tri-Chromatic Chl b (mg/m2)	Tri-Chromatic Chl c (mg/m2)
96.0	20.5	135	1.5	0.0	44.2	7.4	50.0	5.4	1.9
90.4	17.5	90	1.8	0.0	11.6	1.0	12.6	1.7	0.6
85.3	10.7	240	1.0	0.1	12.6	1.2	13.6	1.8	0.6
78.0	11.5	230	0.8	0.5	30.3	2.3	32.4	5.3	1.0
72.7	13.4	250	0.6	0.2	27.9	5.4	32.0	3.7	2.0
67.6	14.0	220	0.8	0.3	29.4	2.9	32.0	3.0	1.8
64.6	13.9	240	0.7	0.1	103.3	1.7	107.7	6.4	4.4
58.1	15.1	268	0.7	0.1	43.9	3.3	47.3	3.1	2.6

Table 11. September 2001 Sites Mean Biomass, New Growth Over 28 days on Incubated Substrates

RM	Depth (m)	ODW (g/m2)	AFODW (g/m2)	Autotrophic Index (Mono Chl a)	Autotrophic Index (Tri Chl a)
96.0	1.39	96.87	15.42	176.35	153.27
90.4	1.65	21.18	2.96	362.73	284.44
85.3	0.97	34.29	4.60	327.87	301.46
78.0	0.77	40.79	9.08	276.48	256.77
72.7	0.62	19.94	5.86	291.91	266.61
67.6	0.79	22.90	5.05	351.24	308.10
64.6	0.71	29.81	10.43	180.35	172.28
58.1	0.61	68.20	7.31	200.76	185.50

Table 12. September 2001 Site Mean Chlorophyll, New Growth Over 28 days on Incubated Substrates

RM	Temp. (C)	Elec. Cond. (m-siemens)	Depth (m)	Flow Velocity (ft/sec)	Mono-Chromatic Chl a (mg/m2)	Pheophyton (mg/m2)	Tri-Chromatic Chl a (mg/m2)	Tri-Chromatic Chl b (mg/m2)	Tri-Chromatic Chl c (mg/m2)
96.0	20.5	135	1.5	0.0	90.2	18.1	103.5	13.9	4.0
90.4	17.5	90	1.6	0.0	9.0	2.1	10.5	2.1	0.0
85.3	10.7	240	1.0	0.1	14.9	1.6	16.3	2.5	0.7
78.0	11.5	230	0.8	0.6	34.9	2.4	37.2	5.8	1.7
72.7	13.4	250	0.6	0.2	20.9	2.2	22.9	1.2	1.5
67.6	14.0	220	0.8	0.3	16.4	1.1	17.5	1.1	1.6
64.6	13.9	240	0.7	0.1	67.2	0.5	69.9	1.6	4.1
58.1	15.1	268	0.6	0.1	43.4	3.5	46.9	3.1	3.2

Initial results at the State Line WA-ID

Data available for calibration from the state line site includes flow, temperature, dissolved oxygen, pH, conductivity, soluble reactive phosphorus, ammonia nitrogen, nitrite-nitrate nitrogen, chlorophyll a, CBODu, total organic carbon and dissolved organic carbon data. Dissolved oxygen, temperature, pH and conductivity continuous data from a 13-day period in August were also available. The system model was run once and compared to data at the ID-WA state line. No model calibration was conducted. The model kinetic coefficients used were those used in Berger et al. (2003) as shown in Table 13.

Table 13. W2 Model Water Quality Parameters

Variable	Description	Units	Typical values*	Calibration Values
Hydrodynamics and Longitudinal Transport				
AX	Longitudinal eddy viscosity (for momentum dispersion)	m^2/sec	1	1
DX	Longitudinal eddy diffusivity (for dispersion of heat and constituents)	m^2/sec	1	1
Temperature				

Table 13. W2 Model Water Quality Parameters

Variable	Description	Units	Typical values*	Calibration Values
CBHE	Coefficient of bottom heat exchange	Wm^2/sec	7.0 x 10-8	7.0 x 10-8
TSED	Sediment (ground) temperature	^oC	12.8	11.5
WSC	Wind sheltering coefficient		0.85	0.2-1.4
BETA	Fraction of incident solar radiation absorbed at the water surface		0.45	0.45
Water Quality				
EXH20	Extinction for water	/m	0.25	0.25
EXSS	Extinction due to inorganic suspended solids	$m^3/m/g$	0.01	0.01
EXOM	Extinction due to organic suspended solids	$m^3/m/g$	0.17	0.10
EXA	Extinction due to organic algal type 1	$m^3/m/g$	0.10	0.10
SSS	Suspended solids settling rate	m/day	2	1.5
AG1	Algal growth rate for algal type 1	/day	1.1	1.5
AM1	Algal mortality rate for algal type 1	/day	0.01	0.1
AE1	Algal excretion rate for algal type 1	/day	0.01	0.04
AR1	Algal dark respiration rate for algal type 1	/day	0.02	0.04
AS1	Algal settling rate for algal type 1	/day	0.14	0.2
ASAT1	Saturation intensity at maximum photosynthetic rate for algal type 1	W/m^2	150	40
APOM1	Fraction of algal biomass lost by mortality to detritus for algal type 1		0.8	0.8
AT11	Lower temperature for algal growth for algal type 1	^oC	10	8
AT21	Lower temperature for maximum algal growth for algal type 1	^oC	30	10
AT31	Upper temperature for maximum algal growth for algal type 1	^oC	35	20
AT41	Upper temperature for algal growth for algal type 1	^oC	40	30
AK11	Fraction of algal growth rate at ALGT1 for algal type 1		0.1	0.1
AK21	Fraction of maximum algal growth rate at ALGT2 for algal type 1		0.99	0.99
AK31	Fraction of maximum algal growth rate at ALGT3 for algal type 1		0.99	0.99
AK41	Fraction of algal growth rate at ALGT4 for algal type 1		0.1	0.1
ALGP-A1	Stoichiometric equivalent between organic matter and phosphorus for algal type 1		0.011	0.005
ALGN-A1	Stoichiometric equivalent between organic matter and nitrogen for algal type 1		0.08	0.08
ALGC-A1	Stoichiometric equivalent between organic matter and carbon for algal type 1		0.45	0.45
EG1	Periphyton growth rate for Periphyton type 1	/day	1.1	1.5
EM1	Periphyton mortality rate for Periphyton type 1	/day	0.01	0.10
EE1	Periphyton excretion rate for Periphyton type 1	/day	0.01	0.04
ER1	Periphyton dark respiration rate for Periphyton type 1	/day	0.02	0.04

Table 13. W2 Model Water Quality Parameters

Variable	Description	Units	Typical values*	Calibration Values
EB1	Periphyton burial rate for Periphyton type 1	/day	0.001	0.001
ESAT1	Saturation intensity at maximum photosynthetic rate for Periphyton type 1	W/m^{2}	150	150
EPOM1	Fraction of Periphyton biomass lost by mortality to detritus for Periphyton type 1		0.8	0.8
ET11	Lower temperature for Periphyton growth for Periphyton type 1	^{o}C	10	1
ET21	Lower temperature for maximum Periphyton growth for Periphyton type 1	^{o}C	30	3
ET31	Upper temperature for maximum Periphyton growth for Periphyton type 1	^{o}C	35	20
ET41	Upper temperature for Periphyton growth for Periphyton type 1	^{o}C	40	30
EK11	Fraction of Periphyton growth rate at ALGT1 for Periphyton type 1		0.1	0.1
EK21	Fraction of maximum Periphyton growth rate at ALGT2 for Periphyton type 1		0.99	0.99
EK31	Fraction of maximum Periphyton growth rate at ALGT3 for Periphyton type 1		0.99	0.99
EK41	Fraction of Periphyton growth rate at ALGT4 for Periphyton type 1		0.1	0.1
EP-E1	Stoichiometric equivalent between organic matter and phosphorus for Periphyton type 1		0.011	0.005
EN-E1	Stoichiometric equivalent between organic matter and nitrogen for Periphyton type 1		0.08	0.08
EC-E1	Stoichiometric equivalent between organic matter and carbon for Periphyton type 1		0.45	0.45
LDOMDK	Labile DOM decay rate	/day	0.12	0.08
LRDDK	Labile to refractory decay rate	/day	0.001	0.001
RDOMDK	Maximum refractory decay rate	/day	0.001	0.001
LPOMDK	Labile Detritus decay rate	/day	0.06	0.08
POMS	Detritus settling rate	m/day	0.35	0.1
RPOMDK	Refractory Detritus decay rate	/day		0.001
OMT1	Lower temperature for organic matter decay	^{o}C	4	4
OMT2	Lower temperature for maximum organic matter decay	^{o}C	20	30
OMK1	Fraction of organic matter decay rate at OMT1		0.1	0.1
OMK2	Fraction of organic matter decay rate at OMT2		0.99	0.99
SDK	Sediment decay rate	/day	0.06	0.1
PARTP	Phosphorous partitioning coefficient for suspended solids		1.2	0
AHSP	Algal half-saturation constant for phosphorous	g/m	0.009	0.003
NH4DK	Ammonia decay rate (nitrification rate)	/day	0.12	0.40
AHSN	Algal half-saturation constant for ammonia	g/m^{3}	0.014	0.014
NH4T1	Lower temperature for ammonia decay	^{o}C	5	5
NH4T2	Lower temperature for maximum ammonia decay	^{o}C	20	25

Table 13. W2 Model Water Quality Parameters

Variable	Description	Units	Typical values*	Calibration Values
NH4K1	Fraction of nitrification rate at NH4T1		0.1	0.1
NH4K2	Fraction of nitrification rate at NH4T2		0.99	0.99
NO3DK	Nitrate decay rate (denitrification rate)	/day	0.102	0.05
NO3T1	Lower temperature for nitrate decay	^oC	5	5
NO3T2	Lower temperature for maximum nitrate decay	^oC	20	25
NO3K1	Fraction of denitrification rate at NO3T1		0.1	0.1
NO3K2	Fraction of denitrification rate at NO3T2		0.99	0.99
O2NH4	Oxygen stoichiometric equivalent for ammonia decay		4.57	4.57
O2OM	Oxygen stoichiometric equivalent for organic matter decay		1.4	1.4
O2AR	Oxygen stoichiometric equivalent for dark respiration		1.4	1.1
O2AG	Oxygen stoichiometric equivalent for algal growth		1.4	1.4
BIOP	Stoichiometric equivalent between organic matter and phosphorus		0.011	0.005
BION	Stoichiometric equivalent between organic matter and nitrogen		0.08	0.08
BIOC	Stoichiometric equivalent between organic matter and carbon		0.45	0.45
O2LIM	Dissolved oxygen concentration at which anaerobic processes begin	g/m^3	0.05	0.1

* Cole and Wells (2000)

Hydrodynamics

Model flow predictions were compared with flow estimates based on flow data from Post Falls and Harvard Bridge (Figure 64). These flow estimates were made by considering the decrease in flows occurring between Post Falls and Harvard Bridge and the distance between Post Falls and State Line relative to the distance between Post Falls and Harvard Bridge (see “groundwater” section). Model predictions were fairly close to flow estimates.

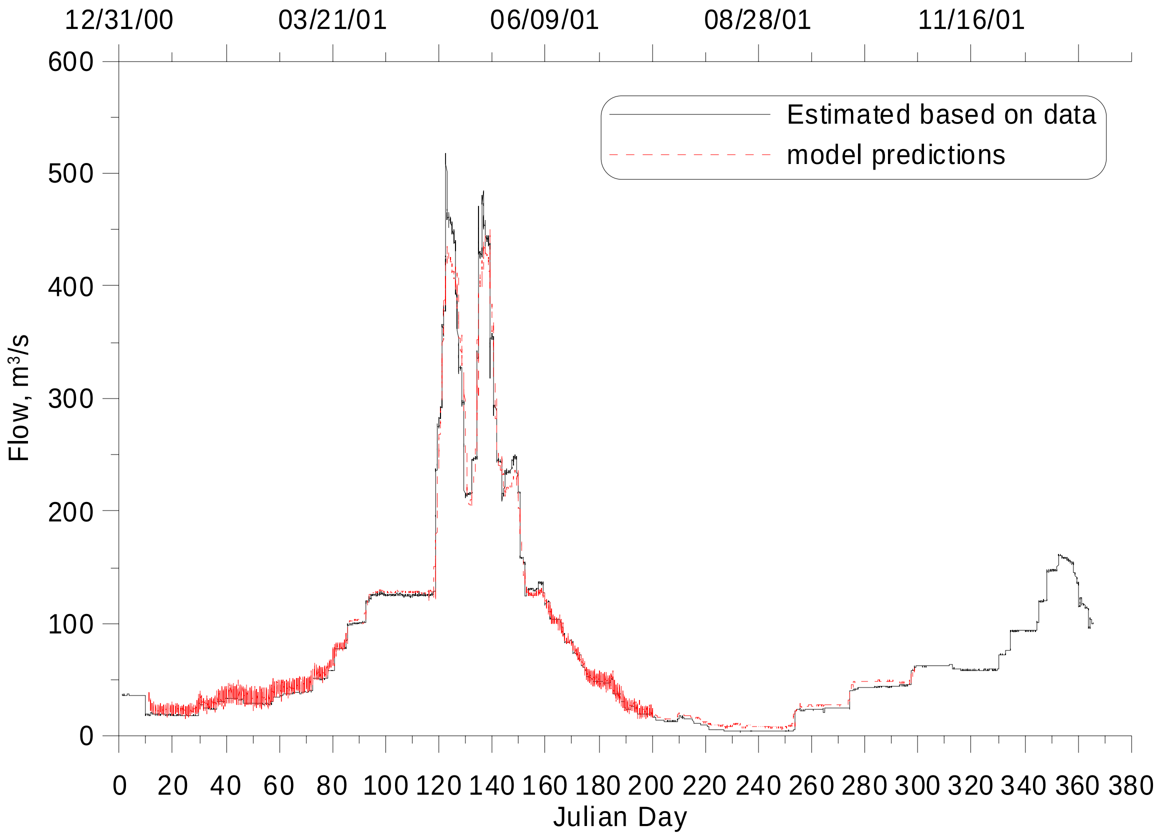


Figure 64. Comparison of model predicted flows at the state line with flow estimates. The flow estimates were based on flow rate data collected at Post Falls and Harvard Bridge.

Water Quality

Model predicted temperatures were compared with data collected at the state line in Figure 65. Differences between model predictions and data most likely can be attributed to using historical monthly average temperatures at the upstream boundary condition. A potential calibration knob would be wind sheltering.

Figure 66 shows the comparison between model predicted conductivity and data. Conductivity was modeled as a conservative constituent and provides a way to help confirm the accuracy of the water balance.

Dissolved oxygen and pH predictions were compared with continuous and grab sample data in Figure 67 and Figure 68. Diurnal fluctuations in D. O. and pH evident in the data and model predictions were most likely due to epiphyton growth and respiration.

Nutrient model-data comparisons were plotted for soluble reactive phosphorus (Figure 69), ammonia nitrogen (Figure 70), and nitrite-nitrate nitrogen (Figure 71). Model predicted diurnal fluctuations of nutrients were due to uptake and release by epiphyton.

Model predicted chlorophyll a concentrations were compared with data in Figure 72. CE-QUAL-W2 models algae using dry weight concentration. Model predicted concentrations were converted to chlorophyll a by assuming a ratio of 130 mg/l algae to 1 mg/l chlorophyll a. This ratio can be varied in the model control file if necessary.

The total model predicted carbonaceous BOD ultimate model predictions were compared with data in Figure 73. The total $CBOD_u$ represents the sum of all $CBOD_u$ compartments simulated in the model.

The comparisons of model predicted total organic carbon and dissolved organic carbon were shown in Figure 74 and Figure 75, respectively.

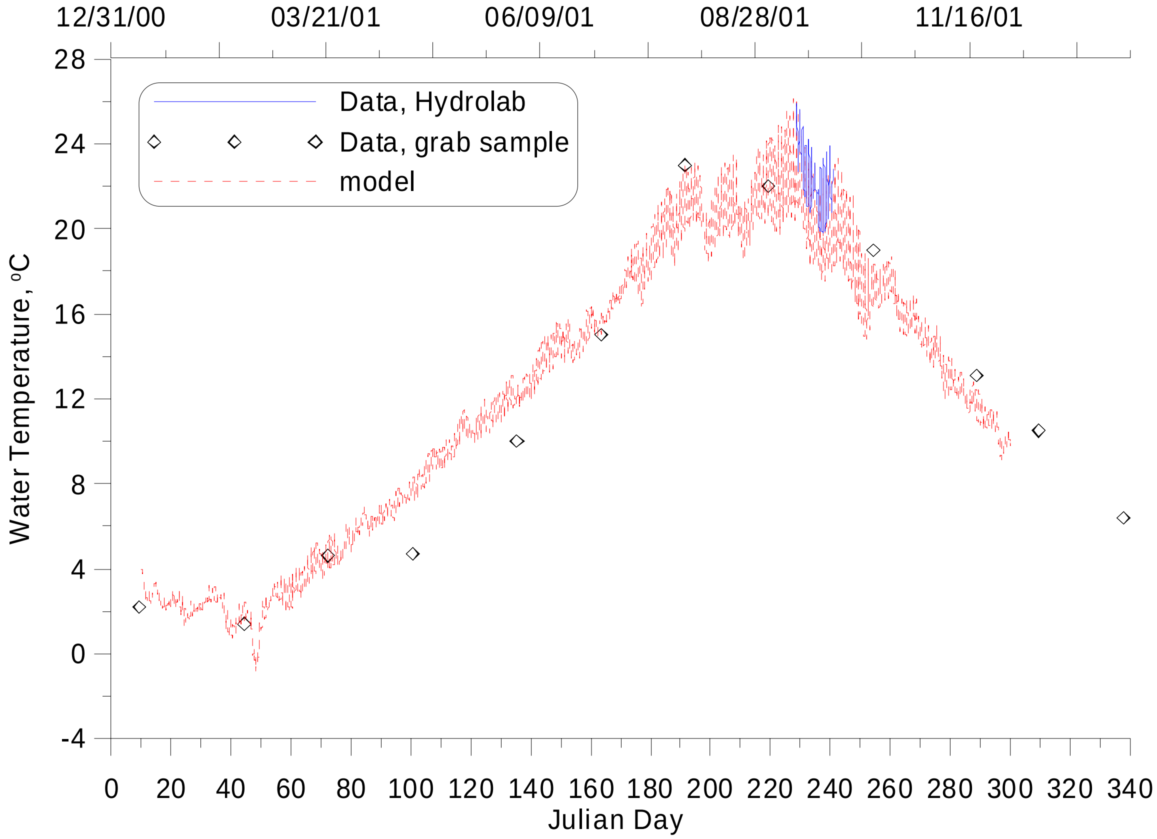


Figure 65. Comparison of model predicted temperatures and data at the state line.

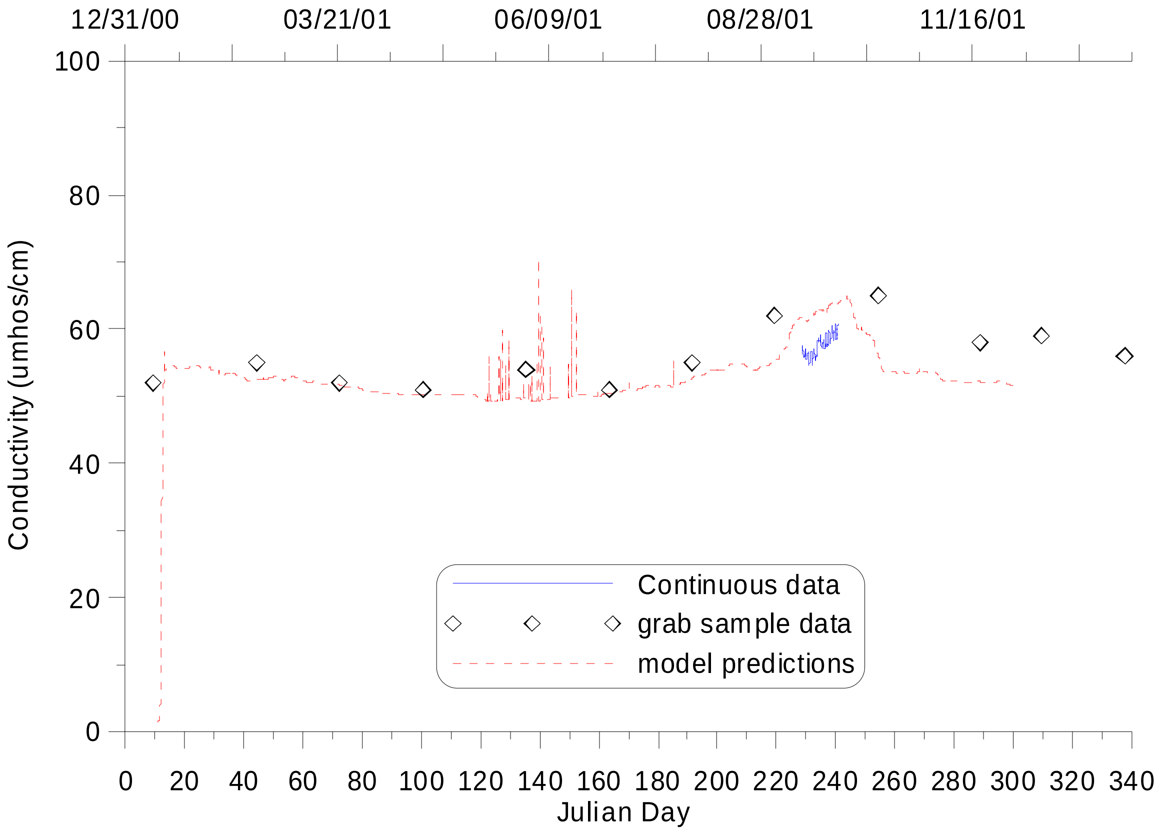


Figure 66. Comparison of model predicted conductivity and data at the state line.

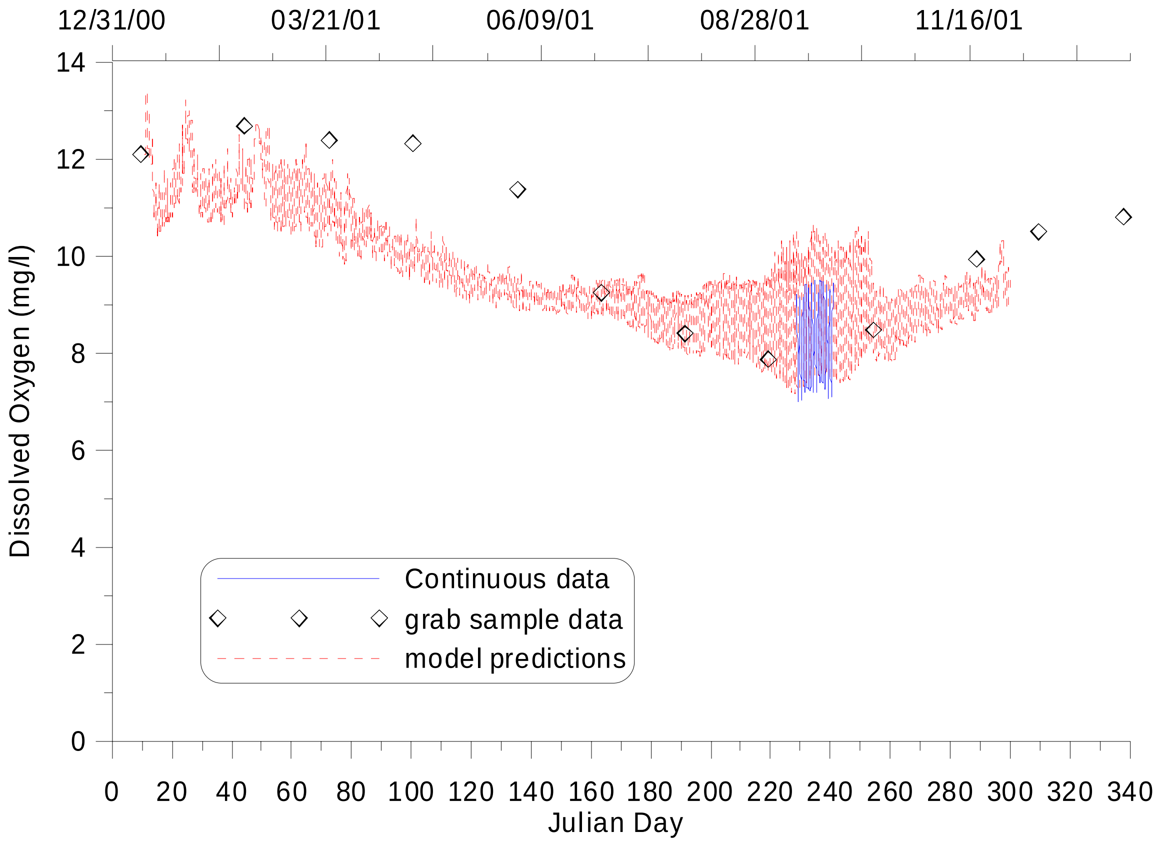


Figure 67. Comparison of model predicted dissolved oxygen and data at the state line.

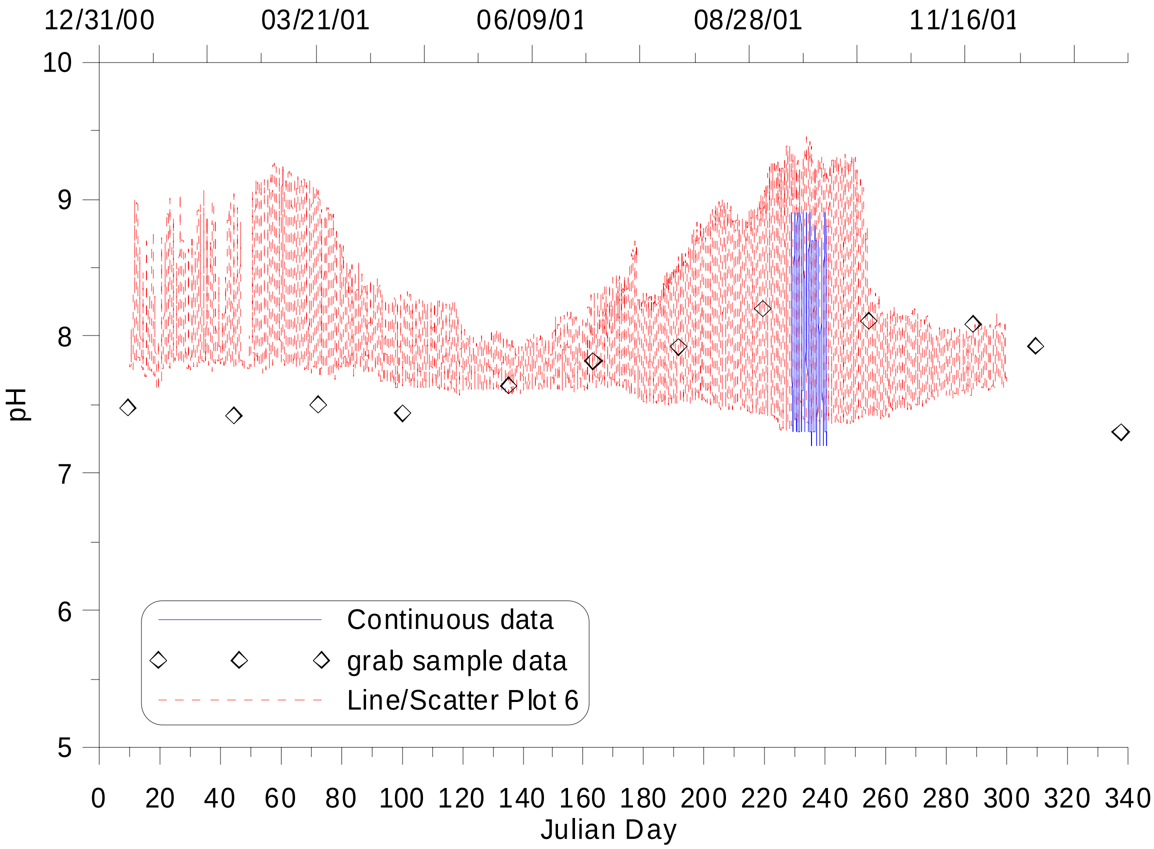


Figure 68. Comparison of model predicted pH and data at the state line.

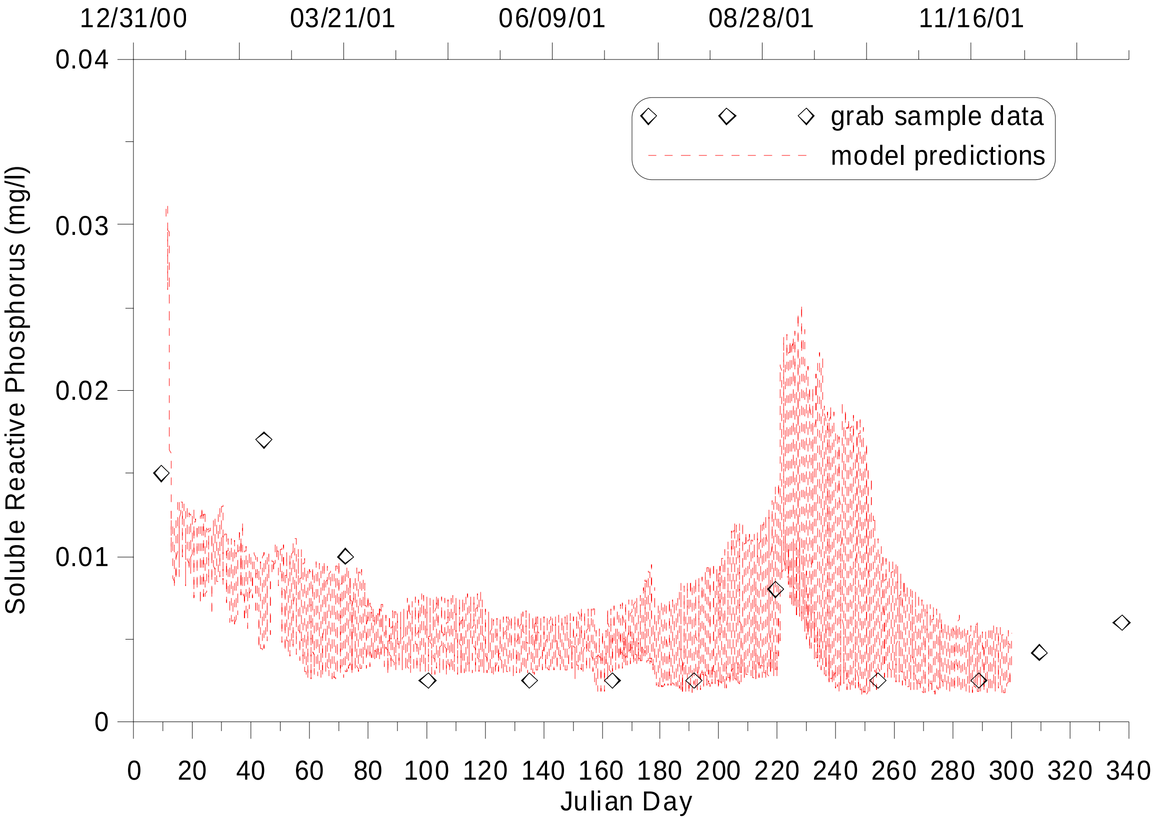


Figure 69. Comparison of model predicted soluble reactive phosphorus and data at the state line.

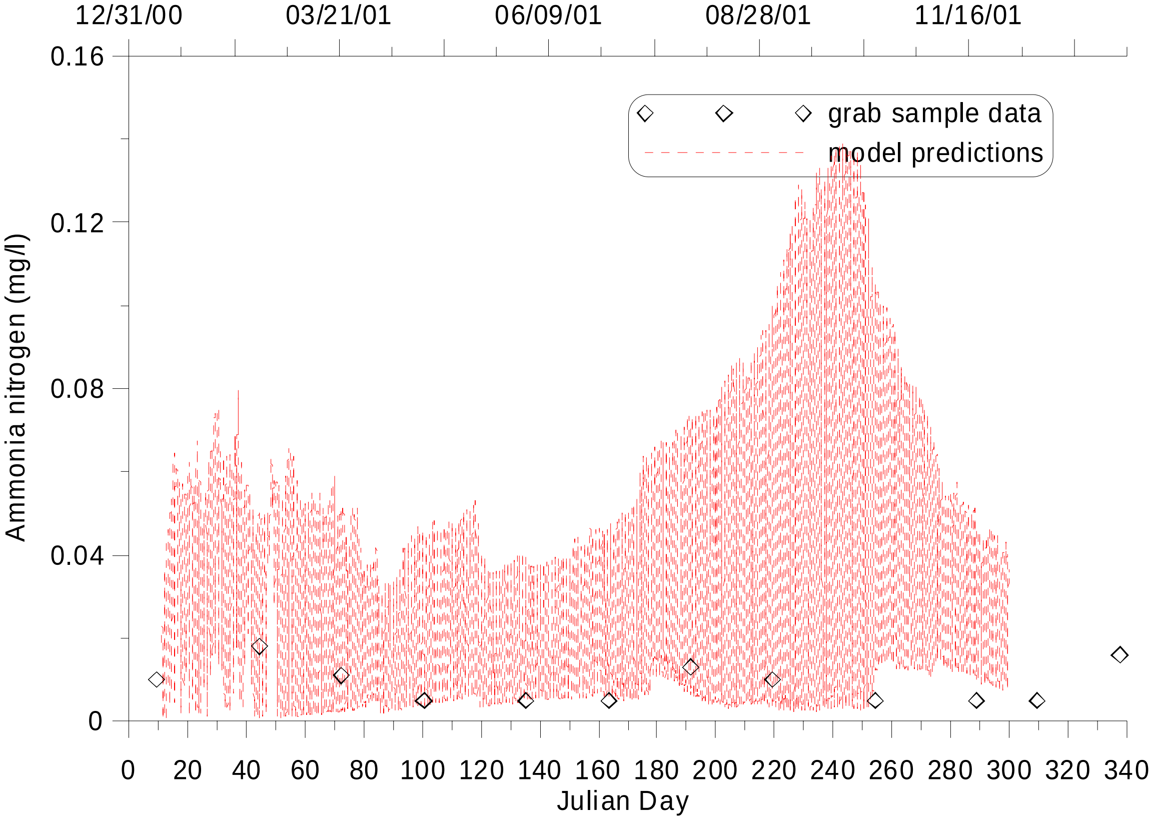


Figure 70. Comparison of model predicted ammonia nitrogen and data at the state line.

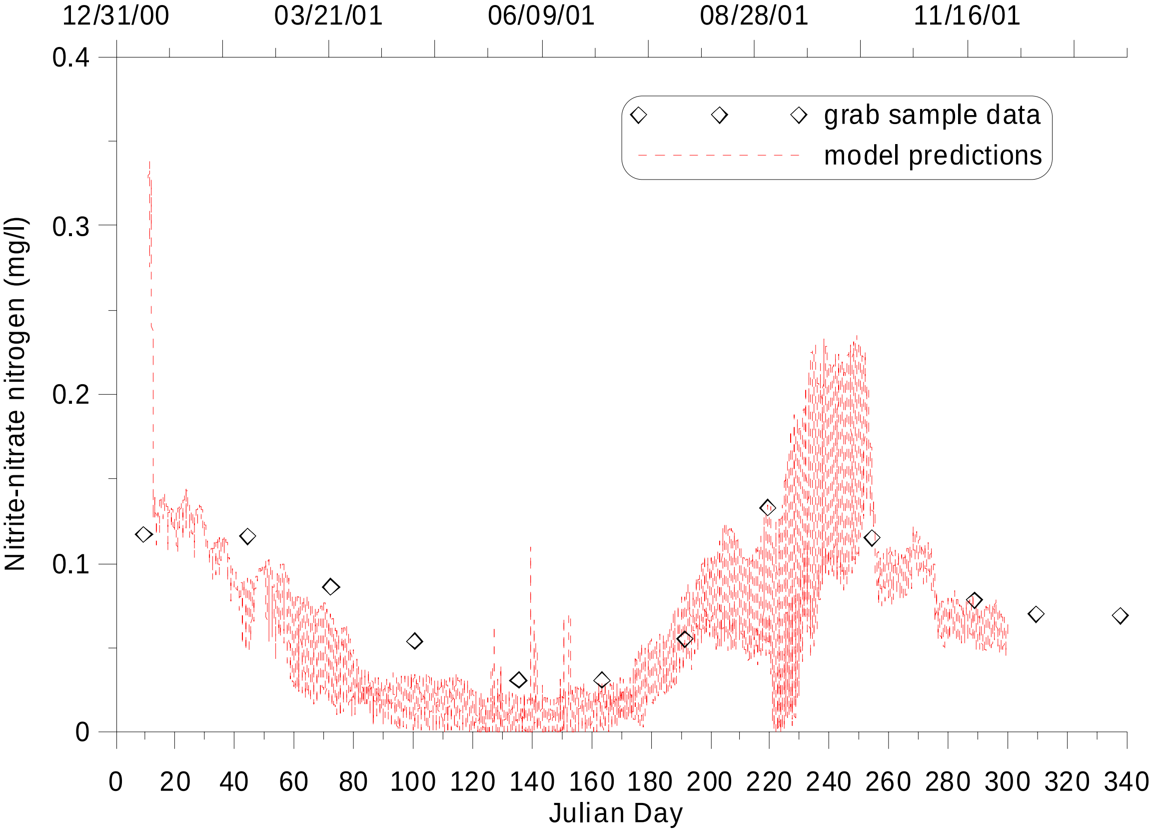


Figure 71. Comparison of model predicted nitrite-nitrate nitrogen and data at the state line.

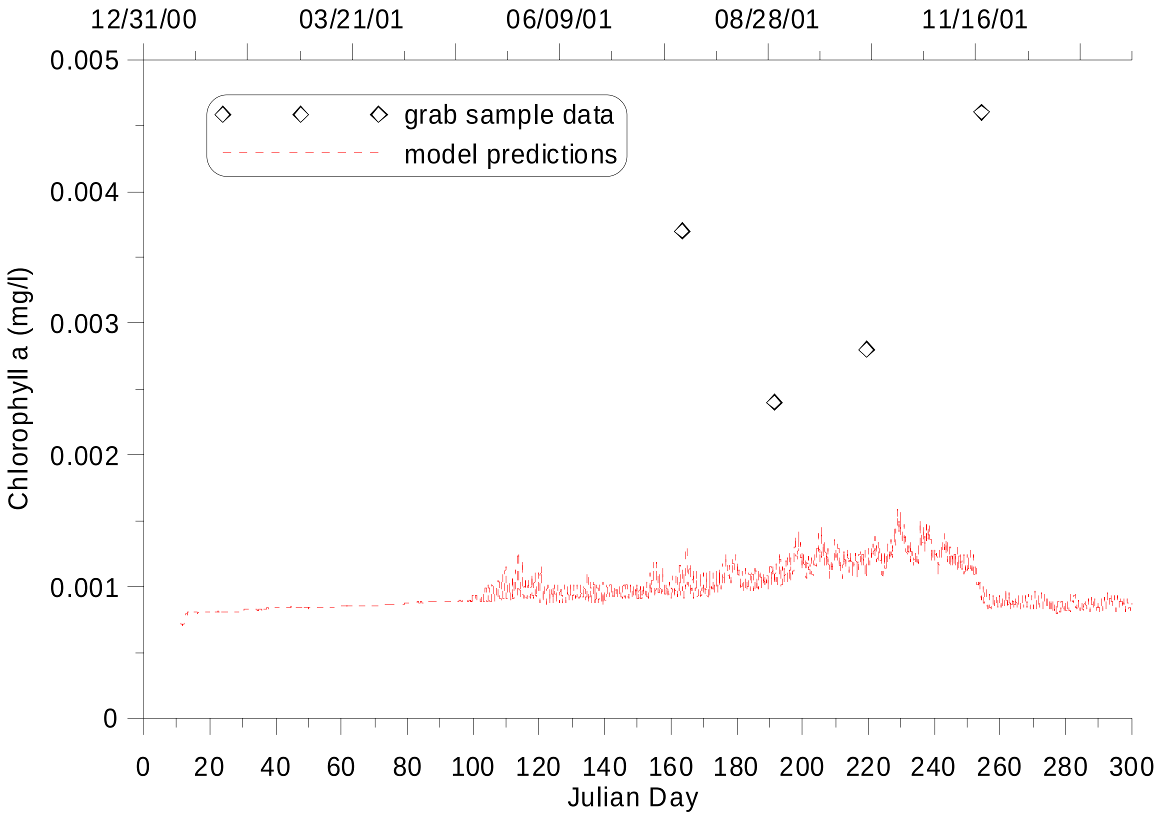


Figure 72. Comparison of model predicted chlorophyll a and data at the state line.

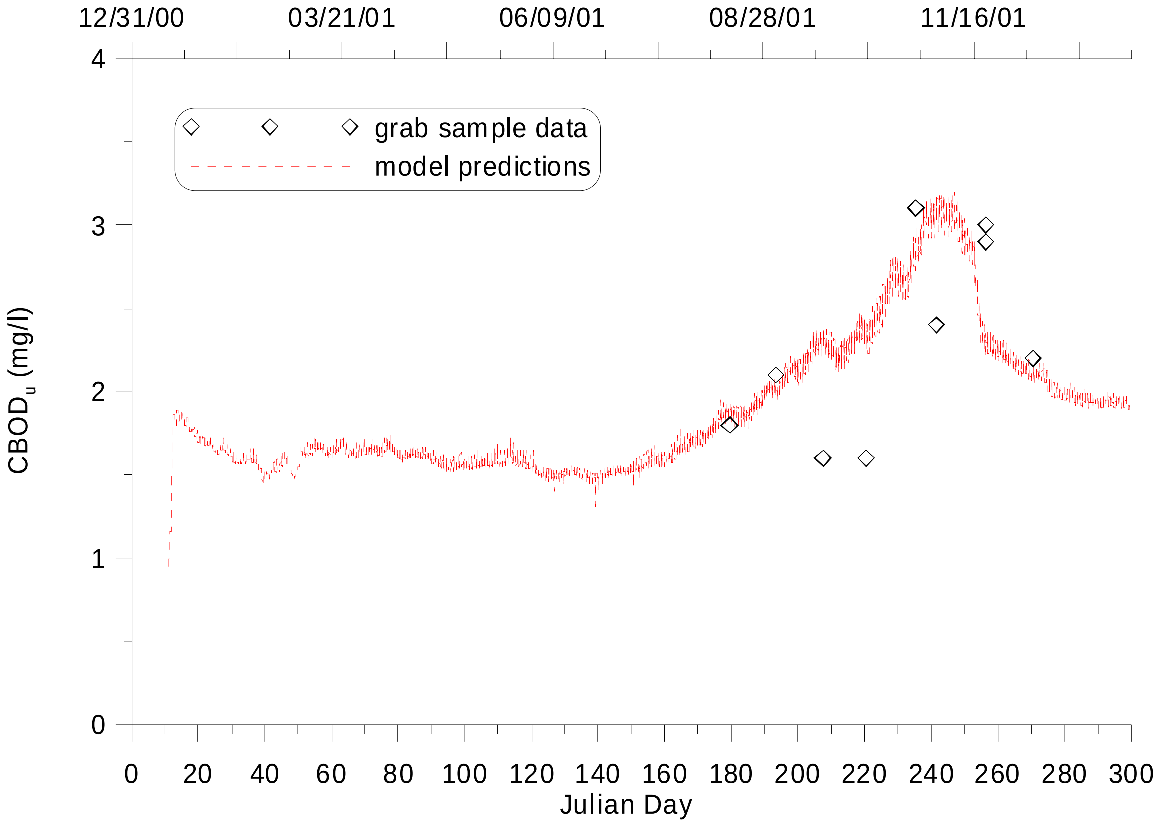


Figure 73. Comparison of model predicted carbonaceous BOD ultimate and data at the state line.

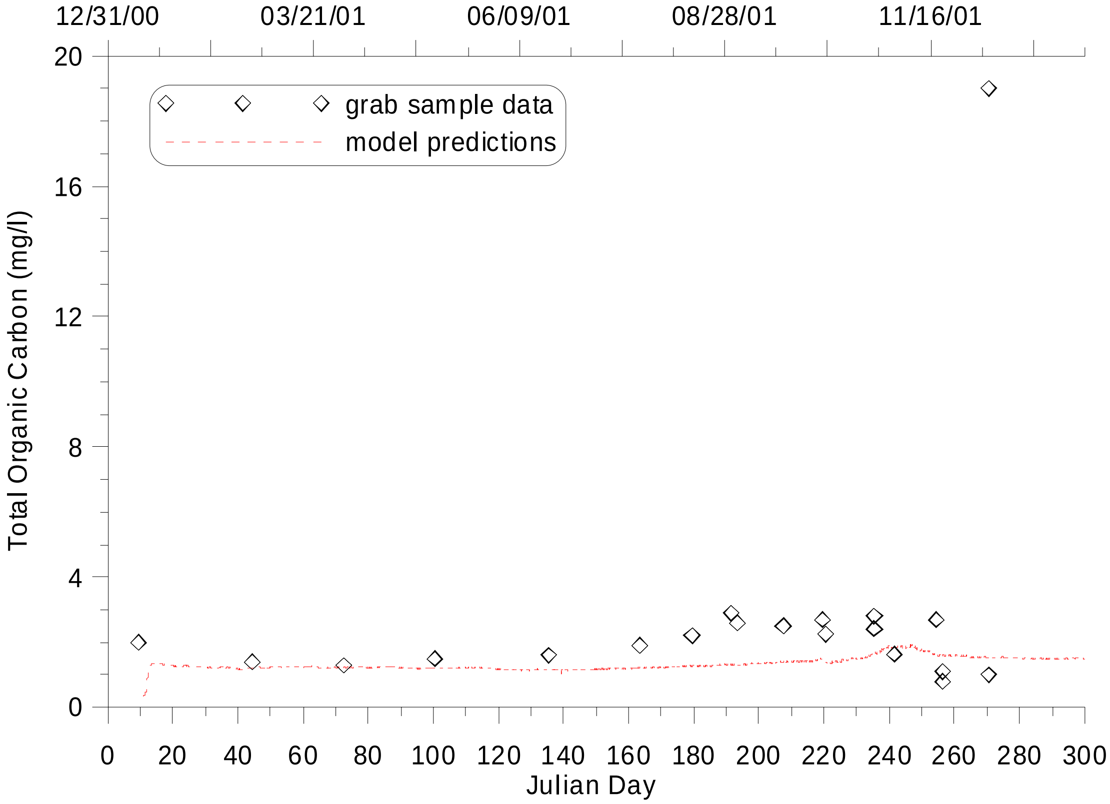


Figure 74. Comparison of model predicted total organic carbon and data at the state line.

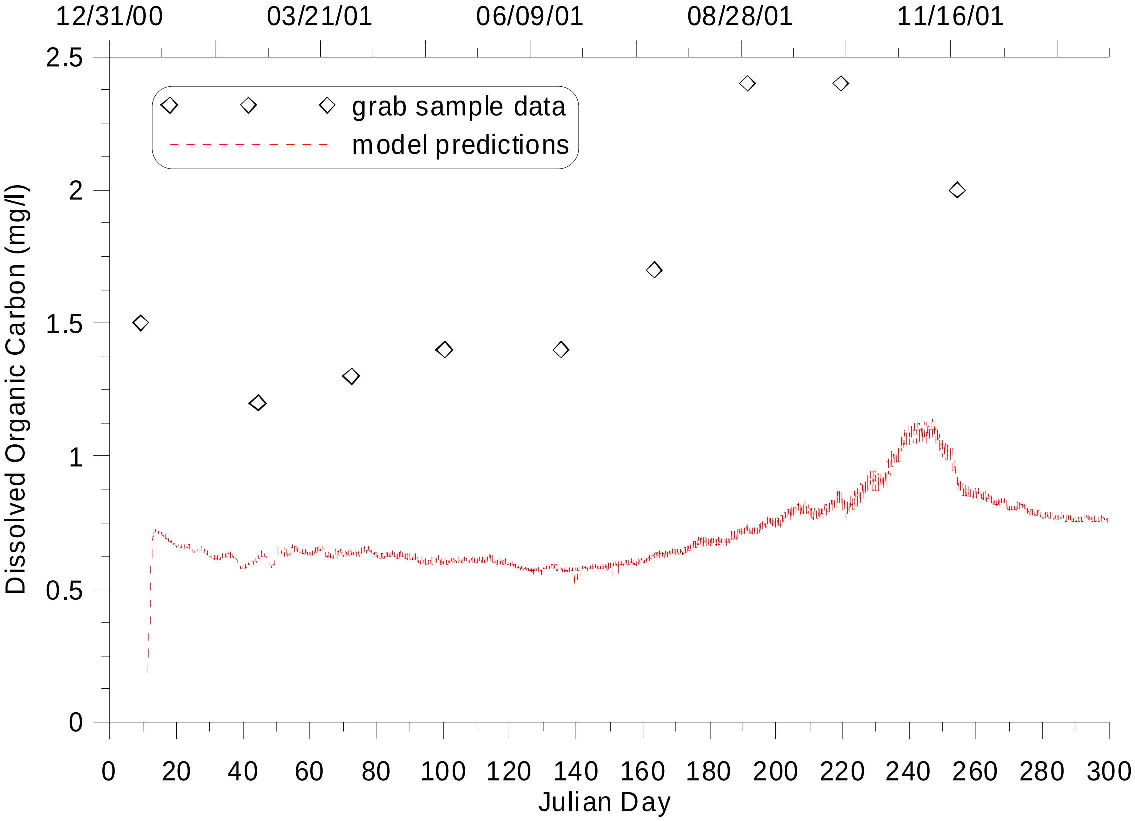


Figure 75. Comparison of model predicted dissolved organic carbon and data at the state line.

Calibration Recommendations

In order to improve the model foundation, the bathymetry of the Spokane River above and below Post Falls Dam should be updated by fieldwork. Below the Post Falls Dam, only 2 cross-sections have been taken over about a 6-mile stretch. More frequent cross-sections, 2-4 per mile would be necessary to accurately model this stretch of the river. Above Post-Falls Dam, the most recent bathymetry was done in 1991, and that at only 5 cross-sections over almost a 10-mile stretch of river. A complete 3-D mapping of the River above Post Falls Dam needs to be made using GIS or other format to catalog the updated bathymetry information.

Temperature predictions might be improved by replacing the historic monthly averages with 2001 temperature data at the upstream boundary. Beyond a few data points in August, no temperature data could be found to represent the upstream boundary. The model's temperature sensitivity to wind sheltering could also be tested. The evaporation formulation could be examined as well to help further calibrate temperatures.

Keys to improving dissolved oxygen predictions include experimenting with different reaeration equations and varying epiphyton growth rates. Important parameters for epiphyton growth include the biomass limitation factor (EHS) and maximum growth rate (EG). Sediment oxygen above Post Falls dam might also be adjusted to improve the dissolved oxygen predictions.

Nutrient concentrations are likely to be strongly affected by epiphyton uptake and release. Varying the half saturation parameters for phosphorus and nitrogen will limit epiphyton growth and impact nutrient concentrations. Also important for nitrogen calibration would be the selection of an appropriate ammonia nitrogen preference equation for epiphyton. Another factor in improving ammonia-nitrogen calibration could be selecting the appropriate nitrification rate.

Chlorophyll a data suggest relatively low phytoplankton populations, but increasing the maximum growth rate could increase populations. Half saturation coefficients for phosphorus and nitrogen may also be important. It may also be reasonable to adjust the chlorophyll a to algae ratio.

In work done by Cusimano (2003), by adjusting the algal maximum growth rate to 2.5 day^{-1} and adjusting the DO hydrolab data up by 0.30 mg/L (based on last Winkler collected by Washington Ecology), the dissolved oxygen results and chlorophyll a results are shown in Figure 76 and Figure 77, respectively.

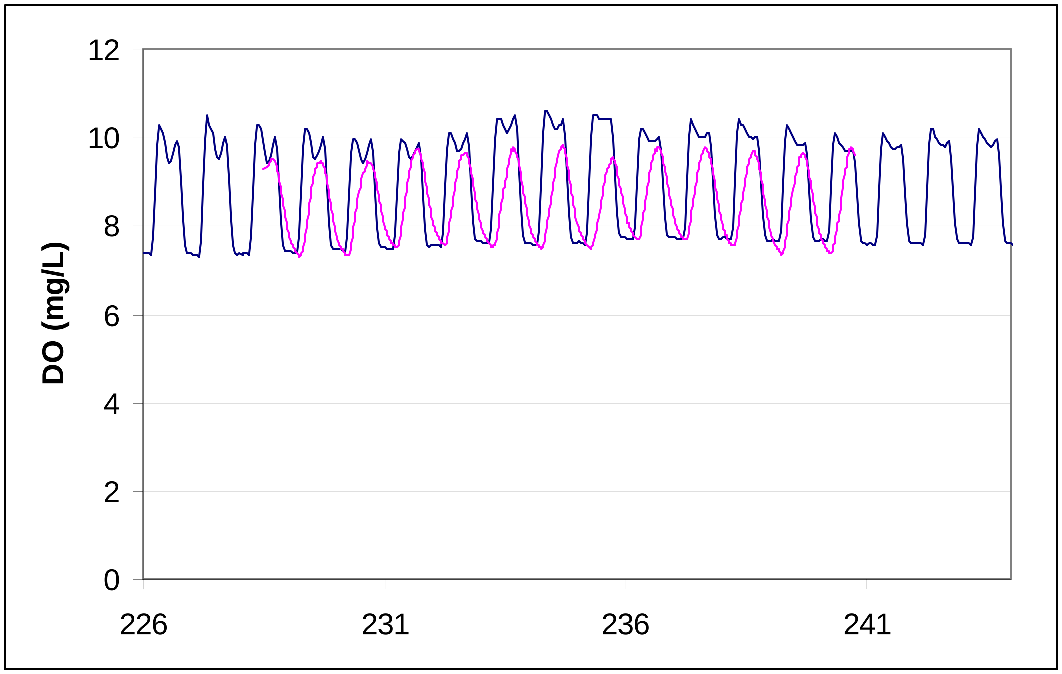


Figure 76. Dynamic dissolved oxygen data at Washington state line compared to model predictions as a function of Julian day for 2001 after re-examination of DO data (Cusimano, 2003).

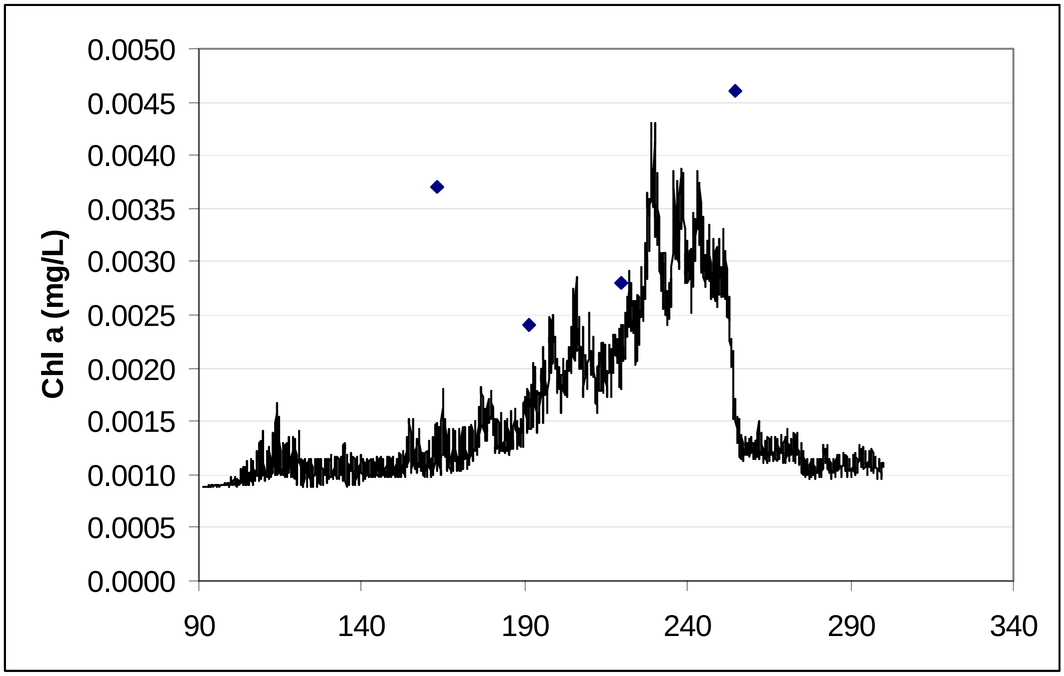


Figure 77. Chlorophyll a data at Washington state line compared to model predictions as a function of Julian day for 2001 after adjusting the maximum algae growth rate (Cusimano, 2003).

Summary

This report summarizes boundary conditions for a water quality model of the Spokane River from the outlet of Lake Coeur d'Alene to the Idaho-Washington state-line for 2001. The model uses the U. S. Army Corps of Engineers CEQUALW2 Version 3.1 river-reservoir-estuary code. Since the CE-QUAL-W2 model allows the user to separate the river basin into separate branches (collections of model longitudinal segments or computational cells) and water bodies (collections of branches with similar kinetic coefficients, turbulence closure, and meteorological forcing) the W2 model was composed of both riverine and reservoir sections, such as

- The Spokane River
- Post Falls Dam pool to Lake Coeur d'Alene outlet

The system model required that boundary conditions and the topography of river and reservoir sections be determined. Data in support of this modeling effort were shown in this report. This includes data such as:

- Dynamic inflow/discharge rates
- Dynamic inflow/discharge temperatures
- Dynamic inflow/discharge water quality constituents
- Dynamic meteorological data (air temperature, dew point temperature, wind speed, wind direction and cloud cover or short wave solar radiation)
- Model bathymetry

Comparisons were also made of meteorological data in the Long Lake Spokane River area at the Spokane International Airport, Spokane Felts Field, Coeur d'Alene Airport and at Odessa, Washington. The meteorological data used in the model was developed from the meteorological data from the Coeur d'Alene Airport.

The water quality model of the Spokane River from Lake Coeur d'Alene to the Idaho-Washington was not calibrated. Parameters simulated include flow, water level, temperature, dissolved oxygen, phytoplankton, epiphyton, pH, soluble reactive phosphorus, ammonia nitrogen, nitrite-nitrate nitrogen and carbonaceous BOD ultimate. Discharges located along this river section have been modeled using individual CBOD compartments and decay rates.

Model calibration was not complete but initial calibration results have been shown for the state line sampling site. Calibration can be improved with better upstream boundary temperature data, experimentation using different reaeration equations, and the variation of parameters affecting the growth of epiphyton. Wind sheltering may also have a significant effect on temperature predictions.

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Appendix A – Location of Model Segments according to River Mile

Table 14 below gives x, y coordinates, segment orientation, and River Miles of each model segment in the CE-QUAL-W2 model of the Spokane River in the State of Idaho.

Table 14. Segment numbers and RM for W2 model.

X, m	Y, m	Segment Orientation, RADIANS	Segment Orientation, Deg	Seg #	RM	RM start	111.5			
				63						
497018.4	5282402	2.36	135.4	62	96.12	End BR 2 Washington-Idaho border				
497189.1	5282217	2.43	139.4	61	96.27					
497349.4	5282022	2.47	141.7	60	96.43					
497542.1	5281911	1.67	95.7	59	96.59					
497765.4	5281962	1.05	60.3	58	96.74					
497966.1	5282110	0.82	46.8	57	96.90					
498145.7	5282286	0.78	44.5	56	97.06					
498351.8	5282419	1.22	69.7	55	97.22					
498595.3	5282473	1.49	85.1	54	97.37					
498844.1	5282459	1.76	101.1	53	97.53					
499062.1	5282353	2.29	131	52	97.69					
499238.6	5282174	2.44	139.6	51	97.84					
499415.9	5281997	2.28	130.5	50	98.00					
499626.1	5281929	1.45	83.3	49	98.16					
499824.8	5282036	0.73	41.7	48	98.32					
499980	5282235	0.6	34.3	47	98.47	Skalan Creek				
500117.3	5282447	0.55	31.5	46	98.63					
500209.9	5282673	0.22	12.6	45	98.79					
500315.3	5282886	0.7	39.9	44	98.94					
500517.1	5283005	1.37	78.4	43	99.10					
500758.1	5282991	1.9	108.6	42	99.26					
500962.6	5283033	0.82	46.7	41	99.41					
501070.7	5283229	0.18	10.5	40	99.57					
501206	5283342	1.6	91.6	39	99.73					
501391.9	5283238	2.52	144.3	38	99.89					
501563.7	5283094	1.98	113.5	37	100.04					
501788.4	5283049	1.58	90.7	36	100.20					
501994.6	5283135	0.75	43.1	35	100.36					
502101.7	5283345	0.21	11.9	34	100.51					
502185.4	5283578	0.48	27.6	33	100.67					
502347.3	5283756	1	57.3	32	100.83					
502564.5	5283781	1.93	110.5	31	100.99		DLX	253	m	
502795.1	5283755	1.43	82.1	30	101.14	Start BR1 Lower Spokane River				
				29			Post Falls WWTP			
		2.09		28		Post Falls Dam				
		2.09		27	101.30					

		2.09		26	101.70					
		2.36		25	102.10					
		2.36		24	102.50					
		1.4		23	102.90					
		2.36		22	103.30					
		2.36		21	103.70					
		0.79		20	104.10					
		1.05		19	104.50					
		2.36		18	104.90					
		1.83		17	105.30					
		1.48		16	105.70					
		0.79		15	106.10					
		2.36		14	106.50					
		1.48		13	106.90					
		1.05		12	107.30					
		0.79		11	107.70					
		1.83		10	108.10					
		1.66		9	108.50	Hayden Lake POTW				
		1.83		8	108.90					
		2.09		7	109.30					
		2.09		6	109.70					
		2.09		5	110.10					
		2.36		4	110.50	Coeur d'Alene WWTP				
		3.49		3	110.90		DLX=	644	m	
		3.67		2	111.30	BR 1 Lake Coeur D'Alene-Spokane River				
		3.67		1						