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Data Summary:

Spokane River and Lake Spokane (Long Lake) Pollutant Loading Assessment for Protecting Dissolved Oxygen

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Data Summary:

Spokane River and Lake Spokane (Long Lake) Pollutant Loading Assessment for Protecting Dissolved Oxygen

by
Bob Cusimano

Environmental Assessment Program
Olympia, Washington 98504-7710

August 2003

Waterbody Numbers:
WA-54-1010 (QZ45UE), WA-54-1020 (QZ45UE), WA-54-9040 (QZ45UE)
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Abstract

As part of the project, *Spokane River and Lake Spokane (Long Lake) Pollutant Loading Assessment for Protecting Dissolved Oxygen*, the Washington State Department of Ecology compiled historical data and conducted a series of water quality surveys in 1999 and 2000. In addition, the Spokane River Phosphorus Technical Advisory Committee discharger members collected data during the summer of 2001. This report provides a summary of the field measurements and chemical data.

The data provided in this report – and flow, water level, meteorological, and bathymetry data from other sources – were used to develop and calibrate a hydrodynamic and water quality computer model of the Spokane River and Lake Spokane. Ecology will use the model to recommend Total Maximum Daily Load pollutant limitations for the Spokane River and Lake Spokane.

Acknowledgements

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- Rob Annear, Portland State University, School of Engineering, for developing sampling site information as well as collecting and compiling data.
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Introduction

Background

The Washington State Department of Ecology (Ecology) is concerned about the pollutant loading capacity of the Spokane River system, including the Lake Spokane (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 waterbodies for dissolved oxygen. The dissolved oxygen concentrations in the bottom waters of Lake Spokane during the summer stratification period have been identified as impaired (URS, 1981; Patmont et al., 1987). The federal Clean Water Act requires Water Cleanup Plans, also known as Total Maximum Daily Loads (TMDLs), to be done for waterbodies on the 303(d) list. A TMDL for this waterbody was identified as a high priority during the water quality scoping process for the Spokane Water Quality Management Area (Knight, 1998).

Ecology's Eastern Regional Office requested that Ecology's Environmental Assessment Program Watershed Studies Unit determine minimum dissolved oxygen concentrations during critical conditions in the Spokane River and Lake Spokane, and establish TMDLs and pollutant loading allocations to control sources of oxygen-consuming substances (i.e., Biochemical Oxygen Demand or BOD).

The Eastern Regional Office also requested that the Watershed Studies Unit reassess the nutrient loading to Lake Spokane and, if needed, update the Phosphorus (P)-Attenuation Model developed for the river in the mid 1980s (Patmont et al., 1985). Nutrient enrichment and eutrophication of Lake Spokane has been one of the major water quality concerns for the area. In the early 1980s Ecology established a total phosphorus TMDL for the lake. The P-Attenuation Model was developed to predict and allocate phosphorus loads into the lake from the Spokane River (and Little Spokane River).

The two project requests were linked because nutrient loading and biochemical oxygen demand (BOD) both affect dissolved oxygen concentrations. Eutrophication increases plant growth and decreases dissolved oxygen due to plant respiration and decay of the organic material produced. (The direct loading of BOD from point and nonpoint sources also can decrease dissolved oxygen concentrations.) Both of these water quality issues can be exacerbated during periods of low river flow and warm temperatures, especially in the deep slow moving water segments of the river system like Lake Spokane. The results of this study may require allocations for both BOD and nutrients to mitigate the impact of these pollutants on dissolved oxygen.

Study Area

The Spokane River upstream of Lake Spokane drains over 6,000 square miles of land in Washington and Idaho (Figure 1). 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.

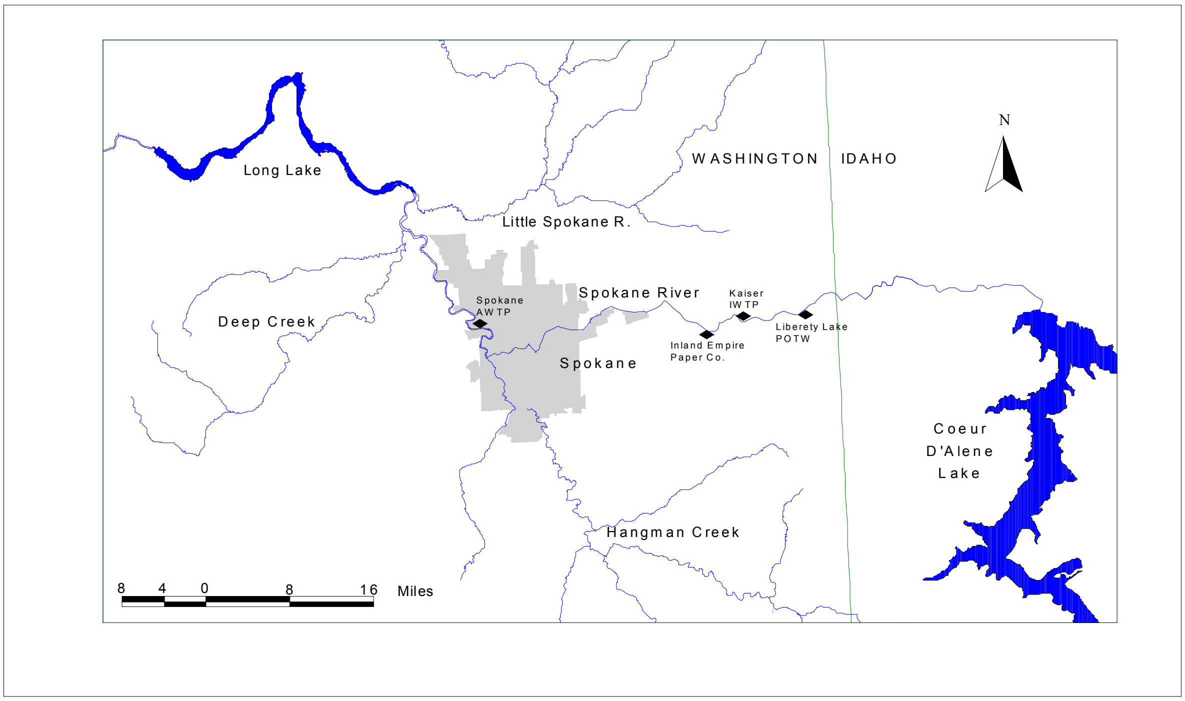

Figure 1. Study area map.

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. The study area for this project extends from the Stateline Bridge at approximately river mile (RM) 96.0 to Lake Spokane Dam at RM 33.9. The study area does not include the Idaho portion of the river.

There are four hydroelectric dams located in the proposed study area: Upriver dam (RM 79.9), Monroe Street dam (RM 73.4), Nine-Mile Dam (RM 57.6), and Lake Spokane Dam (RM 33.9). There is also a dam at Post Falls, Idaho (RM 100.8) that influences the hydrodynamics of the river. All of the Washington dams are run-of-the-river types except Lake Spokane dam (Long Lake dam), which creates Lake Spokane (Long Lake), a 24-mile long reservoir.

Sources of Oxygen-Consuming Substances and Nutrients

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

Idaho

- City of Coeur d'Alene Advanced Wastewater Treatment Plant (AWTP)
- Hayden Area Regional Sewer Board Publicly-owned Treatment Works (POTW)
- City of Post Falls POTW

Washington

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

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

- Latah Creek (or Hangman Creek). The cities of Cheney, Spangle, Rockford, Tekoa, and Fairfield all have small seasonal POTW discharges to creeks in the watershed.
- Little Spokane River. The Kaiser IWTP discharges to the Spokane River.
- Coulee/Deep Creeks. The city of Medical Lake discharges to Deep Creek. In Knight (1998) it states that "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 Creek and a potential for a new growing season phosphorus load to the Spokane River."

The Spokane aquifer also 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.

In addition, nonpoint sources along the length of the river system may be contributing BOD and nutrients. However, other than the tributary and groundwater loads, nonpoint sources along the mainstem of the river were relatively small during the period of concern for this project because stormwater and combined sewer overflow discharge to the river have been greatly reduced over the last 15-20 years. The contributions of BOD and nutrients from small discharges to the tributaries of the Spokane River were included as part of the tributary loading to the river, and not assessed as "discrete" loads for this study.

Classification and Water Quality Criteria

The Spokane River classifications and dissolved oxygen criteria are listed in Table 1.

Table 1. Waterbody classification and dissolved oxygen criteria for the Spokane River system.

Portion Of Study Area	Classification	Dissolved Oxygen Criterion
Lake Spokane or Lake Spokane (from Lake Spokane Dam to Nine Mile Bridge)	Lake Class	No measurable decrease from natural conditions.
Spokane River (from Nine Mile Bridge to the Idaho border)	Class A	Dissolved oxygen shall exceed 8.0 mg/L. If "natural conditions" are less than the criteria, the natural conditions shall constitute the water quality criteria.

In addition, the Spokane River has the following specific water quality criteria (Ch. 173-201A-130 WAC):

- Spokane River from Lake Spokane Dam (RM 33.9) to Nine Mile Bridge (RM 58.0). Special conditions:

  (a) The average euphotic zone concentration of total phosphorus (as P) shall not exceed 25 ug/L during the period of June 1 to October 31.

  (b) Temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9). ("t" represents the maximum permissible temperature increase measured at a mixing zone boundary; and "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.)

Spokane River from Nine Mile Bridge (RM 58.0) to the Idaho border (RM 96.0) temperature shall not exceed 20.0°C due to human activities. When natural conditions exceed 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9).

Project Goals

Ecology's Eastern Regional Office requested a study of the Spokane River partly because the city of Spokane is currently finalizing their 20-year facility plan, and the total assimilative capacity of the Spokane River to receive wastewater is not well understood. The major pollutants of concern that affect dissolved oxygen for NPDES permits are carbonaceous biochemical oxygen demand (CBOD) and ammonia. Nutrient loading is also of concern because of its indirect impact on dissolved oxygen through potential increased primary productivity and the resultant plant respiration and decay processes.

The primary goal of this project was to assess the assimilative capacity of the Spokane River system, including Lake Spokane, for CBOD and ammonia from point and nonpoint loading sources, and recommend pollutant limits based on the assimilative capacity of the river system.

Another goal of this study was to evaluate and update the P-attenuation model and associated Total Phosphorus Lake Spokane TMDL with respect to the original assumptions used to develop the model and its use to predict water quality responses in Lake Spokane.

Project Objectives

- Develop a hydrodynamic and water quality model (CE-QUAL-W2) that can be used to determine the capacity of the Spokane River and Lake Spokane to assimilate point and nonpoint sources of oxygen-consuming substances and meet water quality criteria.

- Gather existing and historical data, and conduct water quality sampling investigations that can be used to calibrate the CE-QUAL-W2 model.

- Use the CE-QUAL-W2 model to determine the potential to violate water quality criteria during critical conditions.

- Identify potential waste load allocations for point sources and load allocations for nonpoint sources of oxygen-consuming substances that will meet dissolved oxygen criteria.

- Assess the current conditions in the Spokane River and Lake Spokane, including the gain and loss of total phosphorus within the river system from the state line to Nine-Mile Dam.

- Evaluate and update the existing P-attenuation model used to predict water quality responses in Lake Spokane and compare prediction estimates to the CE-QUAL-W2 model developed for this project.

The original set of objectives listed in the Quality Assurance Project Plan (Cusimano, 1999) did not identify a specific model or models for simulating the Spokane River and Lake Spokane. However, after reviewing the capabilities of CE-QUAL-W2 Version 2 and its application in other reservoirs, it was selected for modeling Lake Spokane. During 2000, the model was upgraded to Version 3.0 (now 3.1). The new version includes modifications that enable simulations of river systems and a number of hydraulic structures (e.g., weirs, spillways, tainter gates, and pipes). The Version 3.0 modifications also made CE-QUAL-W2 the best choice for modeling the river portion of the study area.

In the fall of 2000, Ecology contracted with the U.S. Corps of Engineers (through a joint cost share grant) to have Tom Cole, one of the model developers and Corps scientists, apply the model to the Spokane River and Lake Spokane. The Corps collaborated with Scott Wells, Professor of Engineering at Portland State University, to apply the model to 1991 and 2000 conditions. Subsequent to the 1991 and 2000 model calibration, the NPDES permittees collected additional ambient and effluent data during 2001 and contracted directly with Scott Wells to apply the model to 2001 conditions.

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Methods

Study Design

Dissolved Oxygen Assessments

It was expected that wasteload allocations for NPDES permits would be applied seasonally. Based on an analysis of streamflow statistics, three potential seasonal permit periods were identified:

- Summer – July through October. This season has the lowest streamflows and will likely have the lowest river assimilative capacity. The critical period for this season is late August to early September.

- Winter – November through March. This season will have a higher assimilative capacity than the summer, but may still require water quality-based discharge limits for point sources. The critical period for this season is November.

- Spring – April through June. This season has the highest streamflows and is least likely to experience dissolved oxygen problems. However, loading of oxygen-consuming substances from point and nonpoint sources could be the highest during this period and may have effects on the water quality of Lake Spokane during the summer period.

The summer period was the focus of the sampling program because it was expected to be the most limiting time of the year and the most difficult to model.

Phosphorus Attenuation Assessments

The surveys used to develop the P-Attenuation Model were conducted from mid-July to mid-September. The critical period for P-loading to Lake Spokane was identified as June-November by Singleton (1981) and June-October by Patmont et al. (1985). In order to assess the model performance, make modifications to the model, and compare the model results to those predicted by the CE-QUAL-W2 model, the summer period was also the focus for assessing phosphorus attenuation and loading.

The following data collection approaches were used to gather data to meet the objectives of this study:

1. Field measurement surveys to collect discrete *in situ* water column data at river and lake sampling sites, and to collect continuous data from selected river and lake sites.

2. Synoptic sampling surveys that consisted of comprehensive and concurrent sampling of mainstem river sites, tributaries, and major point source discharges.

3. Diagnostic limnological sampling of Lake Spokane.

4. Monthly ambient monitoring at model boundary and tributaries.

5. Monthly and/or daily effluent measurements provided by the specific permitted facilities.

6. Historical data gathered from other studies of the river and lake.

Historical data, existing data, and Ecology survey data were used to calibrate a CE-QUAL-W2 model that will be used to predict dissolved oxygen levels during critical conditions.

The CE-QUAL-W2 water quality model is based on eutrophication processes that include the interaction of nutrients, phytoplankton, carbonaceous material, and dissolved oxygen. If dissolved oxygen levels are predicted to be below 8 mg/L in the river or less than "natural" levels in Lake Spokane during critical conditions, the model will be used to determine the amount of pollutant loading reduction needed to meet the criterion. Pollution reductions will be identified for point sources in terms of waste load allocations, and for nonpoint sources in terms of load allocations. All phosphorus and limnological data collected also will be used to compare the performance of the existing P-attenuation model with that of the CE-QUAL-W2 model developed for this project.

Data Quality Objectives and Analytical Procedures

Analytical methods and the target precision or reporting limits for field measurements and laboratory analyses are listed in Table 2. The goal for this study was to have total precision (includes sampling and analytical precision) for all variables not exceed 15%, and analytical bias not exceed the expected level for the specified analytical method.

Table 2. Summary of field and laboratory parameters, precision or reporting limits, and analytical methods.

Parameter	Precision Limit (for field measurements and turbidity) or Reporting Limit (all others)	Method[a]
Field Measurements		
Velocity	± 0.05 f/s	Current Meter
Temperature (Temp)	± 0.2° C	Alcohol Thermometer
pH	± 0.1 standard pH units	Field Meter/Electrode
Dissolved Oxygen (DO)	± 0.06 mg/L	Winkler Titration
Specific Conductivity (Cond)	± 20 µmhos/cm	Field Meter/Conductivity Bridge
Secchi Disc Depth	± 0.5 m	Secchi Disc
Light Attenuation	0.0014 µW/cm^2	Irradiameter
General Chemistry		
Specific Conductance	1 µmhos/cm	SM16 2510
Ammonia Nitrogen (NH3)	0.01 mg/L	EPA 350.1
Alkalinity (ALK)	1.0 mg/L	EPA 310.1
Nitrate + Nitrite Nitrogen (NO2-NO3)	0.01 mg/L	EPA 353.2
Total Persulfate Nitrogen (TPN)	0.01 mg/L	SM 4500 NO3-F Modified
Total Kjeldahl Nitrogen (TKN)	0.01 mg/L	SM 4500
Orthophosphate (Ortho-P or SRP)[c]	0.005 mg/L	EPA 365.3
Total Phosphorus[b] (TP)	0.003 mg/L	EPA 365.3
Chloride (Cl)	0.1 mg/L	EPA 300.0
Total Organic Carbon (TOC)	1.0 mg/L	EPA 415.1
Total Dissolved Solids (TDS)	1.0 mg/L	EPA 2540B
Dissolved Organic Carbon[c] (DOC)	1.0 mg/L	EPA 415.1
5-day Biochemical Oxygen Demand (BOD5)	2 mg/L	EPA 405.1
Ultimate Carbonaceous BOD (CBODU)	2 mg/L	NCASI (1987a and 1987b)[d]
Phytoplankton ID/Biovolume	NA	SM18 10200F; Sweet (1987)
Chlorophyll *a* (Chloro-a)	0.05 µg/L	Fluorometer, SM 10200H(3)

[a] SM = Standard methods for the examination of water and wastewater. 20th edition (1998). American Public Health Association, American Water Works Association, and Water Environmental Federation. Washington, D.C.

[b] Low level phosphorus analysis.

[c] Filter in field with Nalgene or Whatman PURADISC™ 0.45 µm pore size syringe filter. Reported as Soluble Reactive Phosphorus (SRP)

[d] A procedure for estimation of ultimate oxygen demand. National Council of the Paper Industry for Air and Stream Improvement, Inc. Special Report No. 87-06. May 6, 1987.

Sample Collection and Field Measurement Methods

The following is a description of sample collection and field measurement methods for data collected by Ecology. Figure 2 shows all of the sampling site locations. Table 3 lists the river mile and latitude and longitude of the sampling sites, as well as the general type of data collected at each site. Figures 3-6 are smaller scale maps that also show the sampling site locations. Information about the methods used to collect the historical or existing data presented in this report (i.e., data not collected by Ecology) can be found in the associated source references or acquired directly from the reported source (e.g., information about the effluent monitoring data collected by a facility can be acquired by contacting the manager of the facility).

Ecology field personnel collected water quality data during surveys conducted in 1999 and 2000. The methods used in these surveys were initially described in the Quality Assurance Project Plan (Cusimano, 1999). However, because the river flow during the summer of 1999 was extremely high, the sampling surveys that were originally scheduled for the summer of 1999 were delayed until 2000. An abbreviated sampling effort was conducted on August 25, 1999 to collect ambient and effluent data. The parameter concentrations and physical characteristics of the river and lake found during the August 1999 survey were used in designing the 2000 data surveys. Although the 1999 data are reported here, the river and Lake Spokane data were not used to calibrate the CE-QUAL-W2 model. The 1999 effluent data were used to help establish effluent characteristics for the point sources.

Intensive synoptic surveys were conducted for three days each on August 14-16 and September 25-27, 2000. During these surveys all river, lake, and effluent sites were sampled.

In addition, samples were collected from the Spokane River at the Stateline Bridge (upstream model boundary at RM 96.0), the Spokane River at Riverside State Park (RM 66.0), near the mouth at Latah Creek (tributary at RM 72.0), the Spokane River below Nine Mile Dam (RM 58.1), and near the mouth of the Little Spokane River (tributary at RM 56.4) on most or all of the following 2000 dates: January 9, February 6, March 12, April 9, May 7, June 11, July 5, 9, and 26, August 2 and 6, September 7 and 10, October 10, November 14, and December 12.

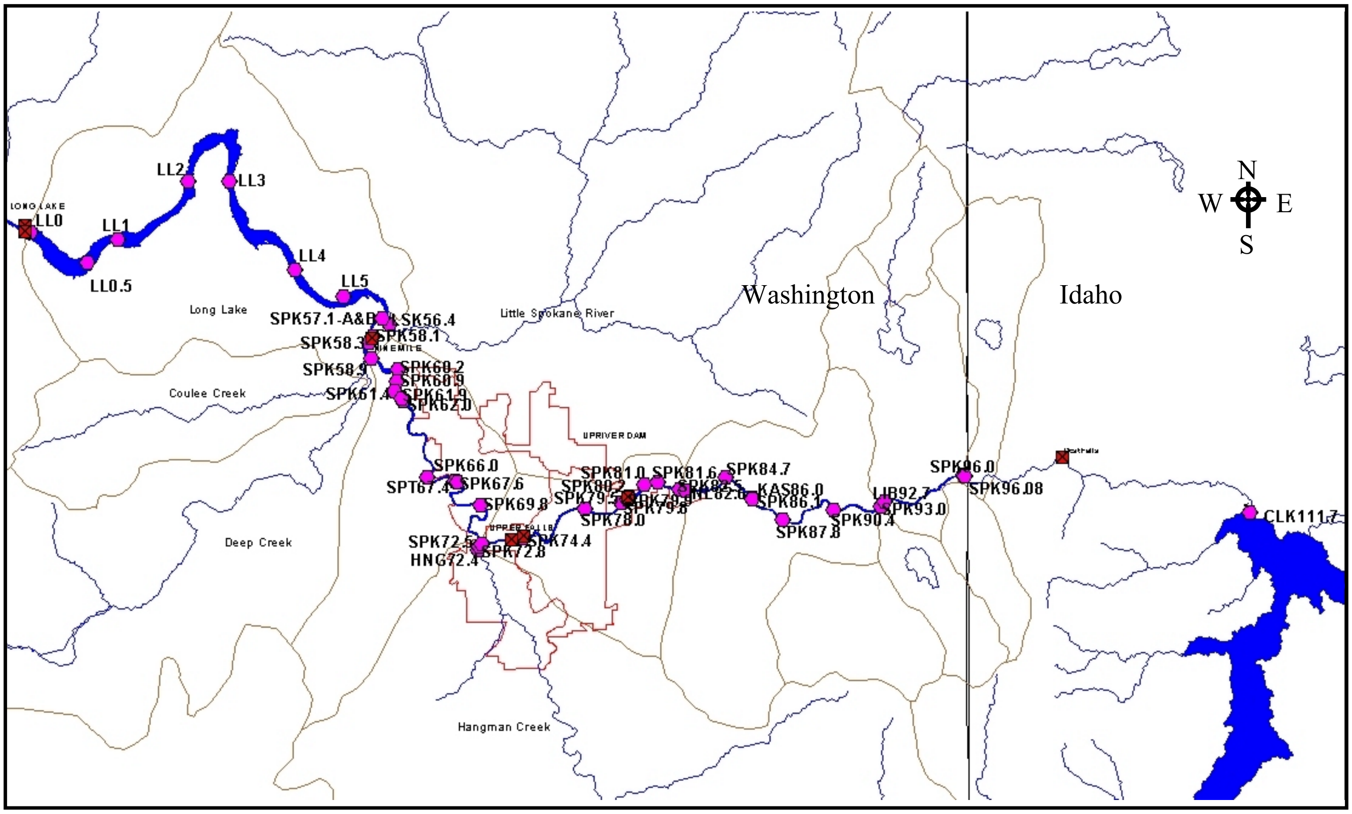

Figure 2. Sample site locations

Table 3. Sample site identification, description, and location.

Site ID	Description	Data Category	RM	Longitude	Latitude
LL0	Lake Spokane @ Station 0 (near dam)	Vertical Profiles, Grab samples	32.66	117.83381	47.83400
LL0.5	Lake Spokane @ Station 0.5	Vertical Profiles	35.90	117.78503	47.81681
LL1	Lake Spokane @ Station 1	Vertical Profiles, Grab samples	37.62	117.76011	47.83060
LL2	Lake Spokane @ Station 2	Vertical Profiles, Grab samples	42.06	117.70030	47.86374
LL3	Lake Spokane @ Station 3	Vertical Profiles, Grab samples, Continuous data	46.42	117.66569	47.86416
LL4	Lake Spokane @ Station 4	Vertical Profiles, Grab samples	51.47	117.60955	47.81382
LL5	Lake Spokane @ Station 5	Vertical Profiles, Grab samples, Continuous data	54.20	117.56812	47.79866
LSK56.4	Little Spokane River @ Lake Spokane (near mouth): near HWY 291 Bridge	Grab samples, Continuous data	56.40	117.52963	47.78284
SPK57.1-A	Spokane River @ Lake Spokane: 1 mile downstream of Nine Mile Dam	Continuous data	57.10	117.53551	47.78625
SPK57.1-B	Spokane River @ Lake Spokane: 1 mile downstream of Nine Mile Dam	Continuous data	57.10	117.53551	47.78625
SPK58.1	Just downstream of Nine Mile Dam at the road bridge	Grab samples	58.10	117.54363	47.77594
SPK58.3	Spokane River above Nine Mile Dam: about 0.2 miles upstream of Nine Mile Dam	Vertical Profiles, Continuous data	58.30	117.54606	47.77280
SPK58.9	Spokane River above Nine Mile Dam: about 0.8 miles upstream of Nine Mile Dam	Vertical Profiles	58.90	117.54468	47.76370
SPK60.2	Spokane River above Nine Mile Dam: about 2.1 miles upstream of Nine Mile Dam	Vertical Profiles	60.20	117.52177	47.75785
SPK60.9	Spokane River above Nine Mile Dam: about 2.8 miles upstream of Nine Mile Dam	Vertical Profiles, Continuous data	60.90	117.52247	47.75069
SPK61.4	Spokane River above Nine Mile Dam: about 3.3 miles upstream of Nine Mile Dam	Vertical Profiles	61.40	117.52473	47.74506
SPK61.9	Spokane River above Nine Mile Dam: about 3.8 miles upstream of Nine Mile Dam	Vertical Profiles	61.90	117.51748	47.73982
SPK62.0	Spokane River @ Seven Mile Bridge	Grab samples, Continuous data	62.00	117.51855	47.74080
SPK66.0	Spokane River @ Riverside State Park	Grab samples	66.00	117.49679	47.69645
SPT67.4	Spokane AWTP effluent discharge	Composite samples	67.40	117.47267	47.69413
SPK67.6	Spokane River upstream Spokane AWTP	Grab samples, Continuous data	67.60	117.47139	47.69353
SPK69.8	Spokane River near Fort Wright Bridge	Grab samples	69.80	117.45140	47.68044
HNG72.4	Latah Creek at mouth, upstream with confluence with Spokane River	Grab samples	72.40	117.45334	47.65477
SPK72.5	Spokane River Upstream of Hangman Creek	Grab samples	72.50	117.45243	47.65679

Table 3 (cont.). Sample site identification, description, and location information.

Site ID	Description	Data Category	RM	Longitude	Latitude
SPK72.8	USGS gauging station, Spokane River at Spokane	Grab samples	72.80	117.45021	47.65818
SPK74.4	Spokane River @ Walkbridge behind Spokane Center	Grab samples, Continuous data	74.40	117.41516	47.66161
SPK78.0	Spokane River @ Green St. Bridge	Grab samples	78.00	117.36272	47.67863
SPK79.5	Downstream of Upriver Dam Powerhouse	Grab samples	79.50	117.33217	47.68226
SPK79.8	Spokane River Upstream Upriver Dam Powerhouse	Grab samples	79.80	117.32704	47.68400
SPK79.9	Spokane River above Upriver Dam: about 0.1 miles upstream of Upriver Dam Powerhouse.	Continuous data	79.90	117.32672	47.68532
SPK80.2	Spokane River above Upriver Dam: about 0.4 miles upstream of Upriver Dam Powerhouse.	Vertical Profiles	80.20	117.32596	47.68558
SPK81.0	Spokane River above Upriver Dam: about 1.2 miles upstream of Upriver Dam Powerhouse.	Vertical Profiles	81.00	117.31324	47.69269
SPK81.6	Spokane River above Upriver Dam: about 1.8 miles upstream of Upriver Dam Powerhouse.	Vertical Profiles	81.60	117.30147	47.69392
SPK82.5	Spokane River above Upriver Dam: about 2.7 miles upstream of Upriver Dam Powerhouse.	Vertical Profiles	82.50	117.28325	47.69021
INL82.6	Inland Empire Paper Co discharge	Composite samples	82.60	117.27844	47.68896
SPK84.7	Spokane River Foot Bridge @ Plante Ferry Park	Grab samples	84.70	117.24466	47.69714
KAS86.0	Kaiser Aluminum	Composite samples	86.00	117.22189	47.68540
SPK86.1	Spokane River Upstream Kaiser IWTP	Grab samples	86.10	117.22186	47.68473
SPK87.8	Spokane River @ Sullivan Rd. Bridge	Grab samples	87.80	117.19596	47.67284
SPK90.4	Spokane River @ Barker Rd. Bridge	Grab samples	90.40	117.15298	47.67846
LIB92.7	Liberty Lake POTW	Composite samples	92.70	117.11372	47.68088
SPK93.0	Spokane River @ Harvard Rd. Bridge	WQ Data3	93.00	117.11040	47.68326
SPK96.0	Spokane River @ Stateline Bridge	Grab samples	96.00	117.04391	47.69867
SPK96.08	Spokane River about 400 feet upstream of Stateline Bridge.	Continuous data	96.10	117.04242	47.69789
CLK111.7	Lake Coeur d'Alene outlet	Grab samples	111.70	116.80146	47.67717

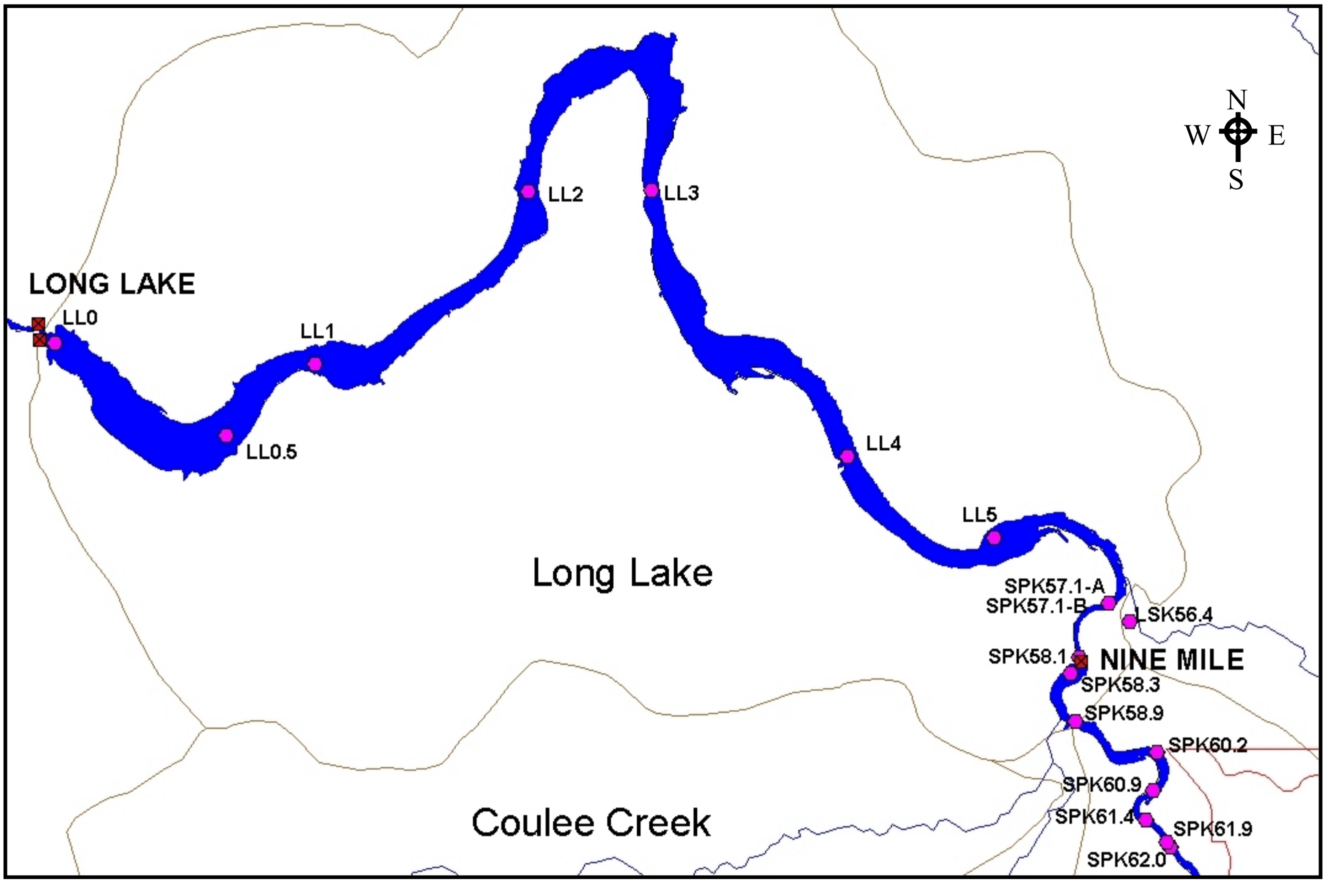

Figure 3. Long Lake sample site locations.

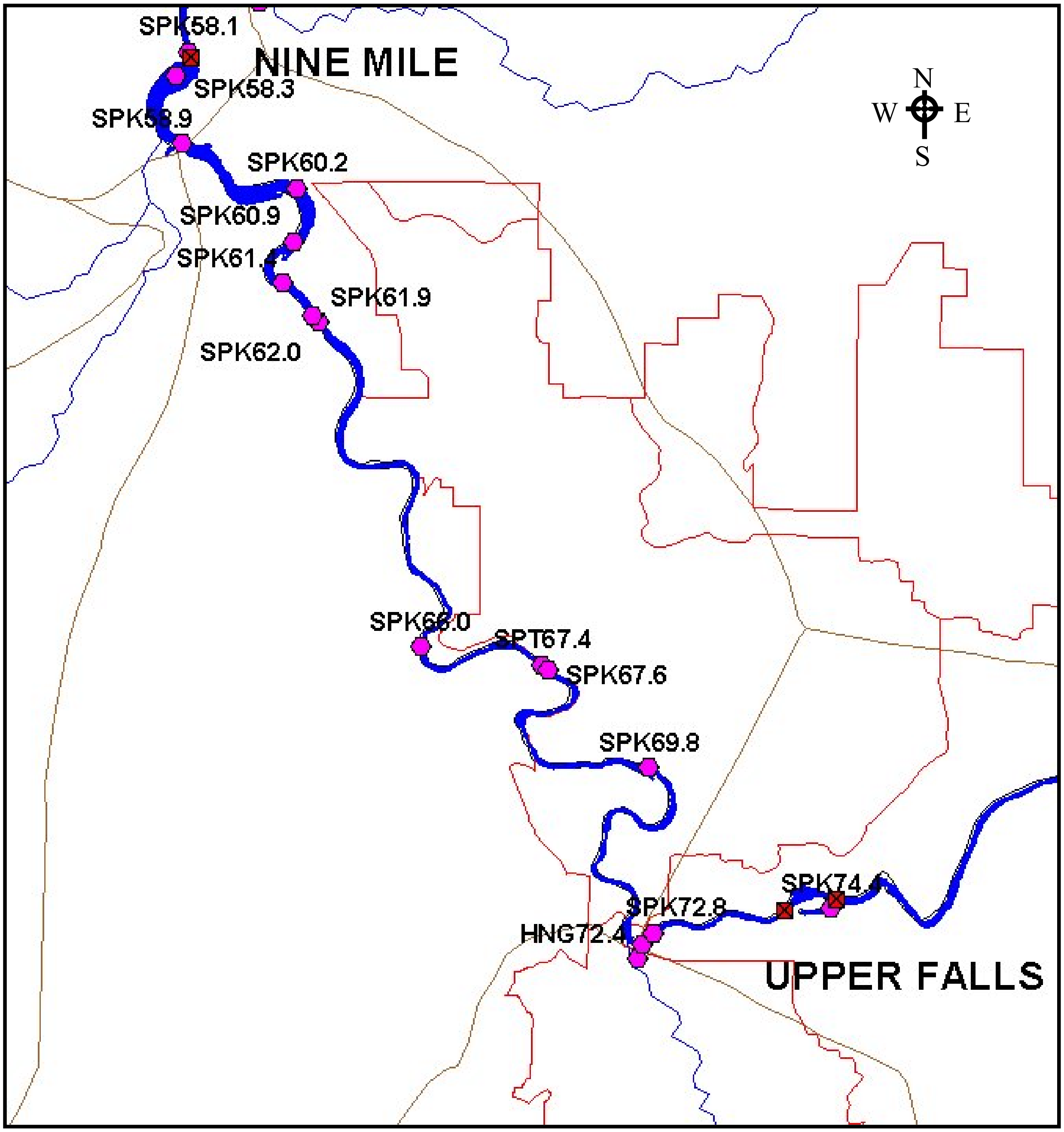

Figure 4. Nine Mile Dam and Upper Falls river segment sample site locations.

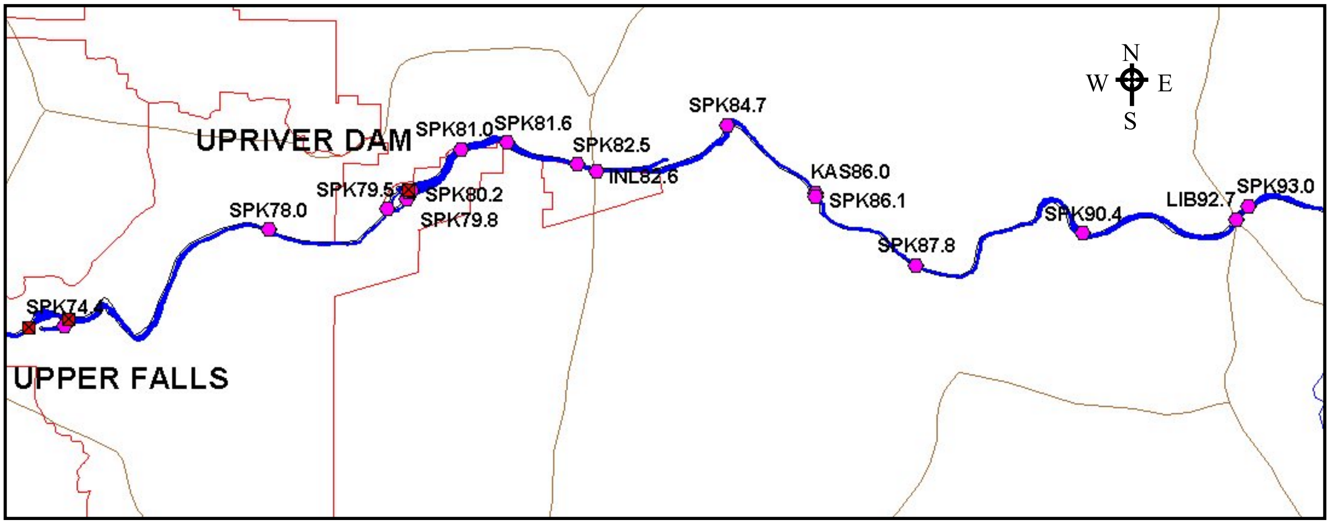

Figure 5. Upriver Dam river segment sample site locations.

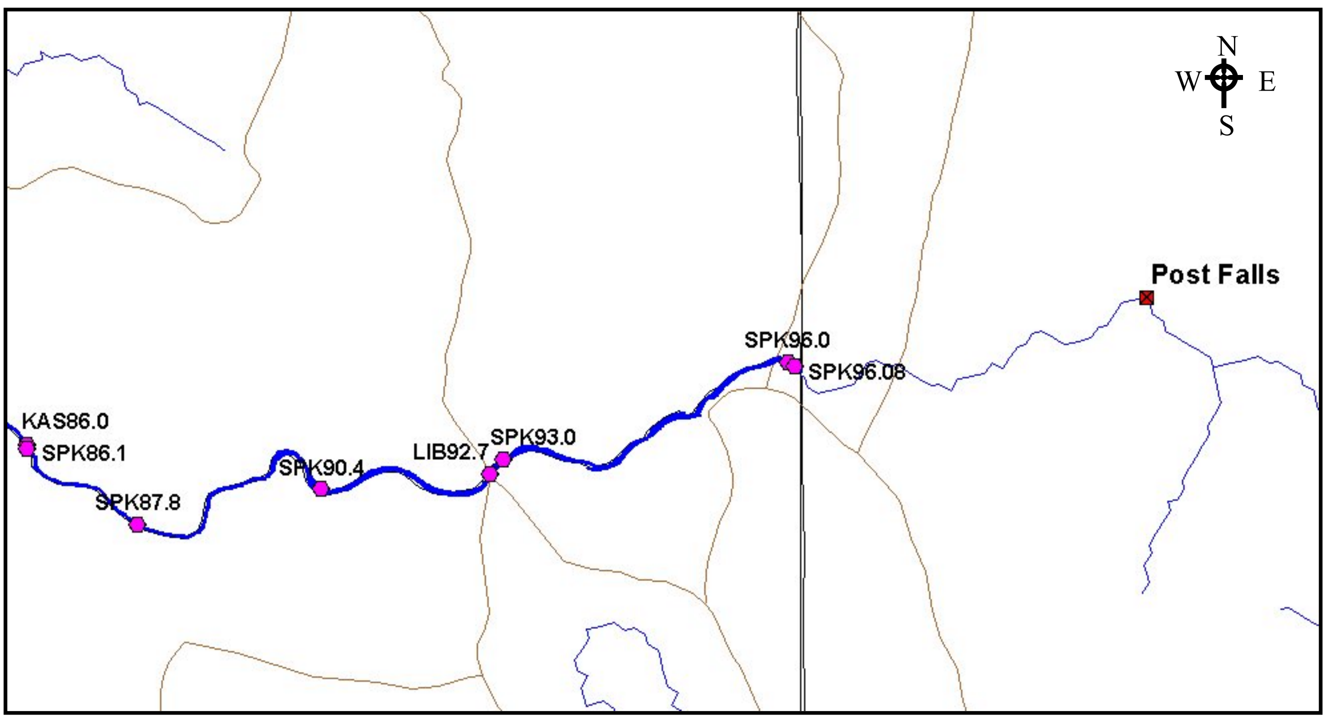

Figure 6. Washington and Idaho State line river segment sample site locations.

All river water quality samples collected for laboratory analysis were grab samples taken just below the water surface from the main body of flow. Samples were collected either by using samplers lowered from bridges or by wading into the river. During the synoptic surveys, grab samples were collected twice a day (morning and afternoon) for two days from the river and tributary sites.

Final effluent grab and 24-hr composite samples were collected from the point sources during the abbreviated August 25, 1999 survey, on January 25 and April 25, 2000, and during the synoptic surveys on August 15 and September 26, 2000. The composite samples were collected with ISCO® automatic composite samplers. The composite sampler water collection bottles were kept iced during the 24-hr sample period.

River and effluent temperature was measured using an alcohol thermometer; dissolved oxygen by the azide modified Winkler method, and pH using an Orion® pH meter.

In situ multi-parameter data loggers (Hydrolab® Datasonde 3s and 4s) were deployed at different locations in the river and lake during the summer months of both 1999 and 2000 to collect continuous diurnal data for dissolved oxygen, temperature, pH, and conductivity. The dates and locations that the diurnal data were collected are listed in the data files noted in section *CE-QUAL-W2 Model Calibration DATA: Diurnal Data*. These data were used to assess diurnal changes in the parameters measured.

Water quality grab samples also were collected from Lake Spokane during surveys on June 6 and 27, July 18, August 29, and September 13 at sites 1 and 3 (LL1 and LL3); and on August 15-16 and September 25-27 at sites 0-5 (LL0, LL1, LL2, LL3, LL4, and LL5). Sites 0-4 were the same as those sampled during previous studies outlined in Soltero et al. (1992). Ecology added one site approximately 2.5 miles upstream of site 4 (i.e., site LL5). During the lake surveys, grab samples were collected using a Van Dorn sample bottle at 3-meter intervals from the top to the bottom at each site.

During the lake surveys, field measurements for temperature, pH, conductivity, and dissolved oxygen water column data were collected at all sites using a Hydrolab® Surveyor II. Secchi disk depth was also measured at all sites. Vertical profiles of light extinction were measured at selected sites during the lake surveys on June 6, August 15, and September 25.

The city of Spokane, in cooperation with the other regional stakeholders, completed sampling surveys of the Spokane River, Lake Spokane, tributaries, and the point source effluents during the summer of 2001. As part of their surveys, Ecology collected profile data from Lake Spokane during two August surveys and collected additional diurnal data from three sites in the river. The chemistry data are not yet available, but the profile and diurnal data are included as part of this report.

Sampling and Quality Control Procedures

All water samples for laboratory analysis were collected in pre-cleaned containers supplied by the Ecology's Manchester Environmental Laboratory (MEL), except dissolved organic carbon and ortho-phosphorus which were collected in a syringe and filtered into a pre-cleaned container. The syringe was rinsed with ambient water at each sampling site two-three times before filtering. All samples for laboratory analysis were preserved as specified by MEL (2000) and delivered to MEL within 24 hours of collection. Laboratory analyses listed in Table 2 were performed in accordance with MEL (2000).

Field sampling and measurement protocols followed those specified in WAS (1993) for temperature (alcohol thermometer), pH (Orion Model 250A meter and Triode™ pH electrode), conductivity (Beckman Model RB-5 and YSI 33), dissolved oxygen (Winkler titration), and *in situ* temperature, dissolved oxygen, pH, and specific conductance (Hydrolab® multi-parameter meters). All meters were calibrated and post-calibrated per manufacturer's instructions.

Effluent samples from the point sources were collected in pre-cleaned ISCO 24-hour composite samplers. Effluent sampling was conducted according to standard operating procedures for Class II inspections by Ecology as documented in Glenn (1994). Groundwater data collected by Ecology followed protocols defined in Garrigues (1999).

Replicate samples were collected to assess total field and laboratory variation. In addition, field blanks and laboratory standards (for total phosphorus) were collected to determine the presence of any positive bias in the analytical method. Blanks were also used to assess possible sample contamination. The phosphorus standards were included because ambient concentrations of phosphorus are low and assessing the existing phosphorus TMDL for Lake Spokane was one of the objectives of this study. Replicate, blank, and standard quality assurance samples were introduced in the field and submitted "blind" with the routine batches of samples to the laboratory.

Phytoplankton samples were preserved with 1% Lugol's solution immediately after collection and sent to Jim Sweet, Aquatic Analysts, Wilsonville, Oregon, for plankton analyses. Aquatic Analysts laboratory quality control procedures for plankton analysis are summarized in *Algae_QC.doc* (see CE-QUAL-W2 Model Calibration DATA: 1999-2000 Data section for file location).

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Data Quality Results

Laboratory quality control samples (blank, spike, duplicate, and laboratory control) were within acceptable limits (reference MEL 2001 for quality control sample requirements). Most of the laboratory data were performed within specified holding times and can be used without qualification. The laboratory did qualify some sample analytes with a "J" qualifier. The laboratory "J" qualifier is defined as "The analyte was positively identified. The associated numerical result is an estimate."

The qualified results and the reasons for qualifying the specific analytes were as follows:

- TPN result for SPK79.8 collected on August 25, 1999 exceeded holding time.
- Chlorophyll *a* sample results for all of the sites collected on August 16, 2000 were not on ice and possibly exposed to light when they were transported to the laboratory (about a one hour drive). These samples were filtered, preserved, the filter placed in acetone, covered with aluminum foil, and held in a walk-in cooler before they were transported to the laboratory. It is unlikely the handling of these samples affected the results.
- Alkalinity sample results for SPK96.0, SPK93.0, and SPK90.4 collected on September 26, 2000, and SPK90.4 collected on September 27, 2000, were qualified because quantities of alkalinity less than 20 mg $CaCO_3$/L are considered unstable.
- Chlorophyll sample results for SPK73.4 collected on September 26, 2000, and LL2-0.5, LL2-3, LL2-6 and LL2-9 collected on September 27, 2000, exceeded holding times by a maximum of 30 minutes.
- TPN sample results for CLK111.7 (one of the two samples), SPK96.0, SPK93.0, and SPK90.4 collected on September 27, 2000 were analyzed two days after the holding time.
- Total phosphorus sample results for SPK90.4, LIB92.7, and LL2-9 collected on September 27, 2000 exceeded holding time.

Analyte results not detected at or above the reporting limits listed in Table 2 were qualified by MEL with a "U." These data were included in the study data sets at a value of one-half the reporting limit. The laboratory reported results for total organic carbon (TOC) and dissolved organic carbon (DOC) at 0.5 mg/L (i.e., lower than the target limit listed in Table 2). All qualified data were considered "usable" and included as part of the model calibration data set.

Table 4 lists the pooled standard deviations and the root mean square (RMS) of the percent relative standard deviations (%RSD) for the replicate results for each analyte separated by ambient and effluent samples. (CBODU replicate results are not included in Table 4, but are reviewed at the end of this section). The pooled standard deviations for the ambient nutrient analyses are very low because many of the samples were below the reporting limits. The effluent NH3 was the only analyte listed in Table 4 that exceeded the 15% precision goal for the study with a RMS%RSD of 21%. However, the results were strongly influenced by one of the 12 sample pairs such that the calculated RMS%RSD excluding the one pair is 14.5%. Overall, the replicate results suggest that total sampling and analytical variability for all analytes was less than 15%.

Table 4. Pooled standard deviations ($Stdev_P$) and root mean square of the percent relative standard deviation (RMS%RSD) for replicate sample results.

Ambient Samples				Effluent Samples			
n Pairs	Analyte	$Stdev_P$	RMS%RSD	n Pairs	Analyte	$Stdev_P$	RMS%RSD
17	ALK	0.28	0.5	12	ALK	0.54	1.1
21	CHLORO-a	0.59	11.3	5	BOD5	0.26	6.4
16	CL	0.018	1.0	11	CL	1.43	4.3
17	COND	0.92	0.8	5	COND	3.68	0.8
18	DO	0.08	1.2	12	DOC	0.326	3.6
21	DOC	0.120	11.6	12	NH3	0.0705	21.0
28	NH3	0.0006	10.1	12	NO2-NO3	0.4386	4.0
28	NO2-NO3	0.0090	2.6	12	SRP	0.0312	7.2
28	SRP	0.0009	7.4	12	TKN	0.0941	7.7
17	TDS	8.4	13.7	12	TNVS	16.0	8.1
21	TOC	0.052	6.8	12	TNVSS	0.0	0.0
28	TP	0.0009	9.6	2	TOC	0.422	3.8
28	TPN	0.0127	9.9	2	TP	0.0252	6.8
				2	TS	3.2	1.0
				2	TSS	0.0	0.0
16	TDS[c]	7.2	6.8	11	NH3[c]	0.0736	14.5

[C]= TDS and NH3 pooled STdev and RMS%RSD estimates excluding one replicate pair from the calculations.

Blank sample results are presented in Table 5. NO2-NO3 and TPN were measured in a few of the blank samples, and TOC and DOC were measured in one other blank sample. However, in reviewing all of the field and laboratory quality control data it does not appear that there was any contamination or positive bias in either the sampling or analytical procedures such that the results for these few samples are unexplained.

Table 6 lists the phosphorus concentrations for the standards and the associated laboratory measurement result. The RMS%RSD for the pairs was 9.0% and for those values <0.060 mg/L it was 8.4%. Figure 7 shows a 1:1 plot of the standards versus measurements for the values <0.060 mg/L. The results suggest that the laboratory was able to measure phosphorus accurately.

Water blanks, check standards, and replicates were used to determine the data quality of CBODU measurements and the associated estimates used to establish ambient and effluent CBODU concentrations (i.e., BOD_5 estimates, CBODU:BOD_5 ratios, and decay coefficients "k"). All of the 35- and 55-day water blank CBODU and BOD_5 values fell below the expected values. However only one of the sugar checks standards fell within the expected range of 314.5 mg/L ±2.1%. The sugar checks range was –18.0% to +11.0% from the target of 314.5 mg/L.

Table 5. Blank sample laboratory analysis results.

QA TYPE	Station Name	Date	Time	Sample #	NO2-NO3 (mg/L)		NH3 (mg/L)		TPN (mg/L)		SRP (mg/L)		TP (mg/L)		TOC (mg/L)		DOC (mg/L)	
Blank	SPK78.0	8/15/2000	16:15	00338426	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U	0.5	U	0.5	U
Blank	LSK56.4	8/15/2000	15:55	00338436	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U	0.5	U	0.5	U
Blank	SPK78.0	8/16/2000	11:50	00338469	0.01	U	0.01	U	0.01	U			0.003	U			0.5	U
Blank	LSK56.4	8/16/2000	15:50	00338479	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U	0.5	U	0.5	U
Blank	LL0	8/16/2000	19:25	00338543	0.01	U	0.01	U	0.01	U	0.005	U	0.0036		0.5	U	0.5	U
Blank	SPK78.0	8/15/2000	12:25	00338550	0.135	J	0.01	U	0.043		0.005	U	0.003	U				
Blank	LSK56.4	8/15/2000	11:10	00338551	0.058		0.01	U	0.045		0.005	U	0.003	U				
Blank	SPK78.0	8/16/2000	15:55	00338552	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U				
Blank	LSK56.4	8/16/2000	10:10	00338553	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U				
Blank	SAM999	8/15/2000	11:10	00338554	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U	0.5	U	0.5	U
Blank	SAM999	8/15/2000	11:12	00338555	0.082		0.01	U	0.066		0.005	U	0.003	U	0.5	U	0.5	U
Blank	SAM999	8/15/2000	11:14	00338556	0.076		0.01	U	0.054		0.005	U	0.003	U	0.5	U	0.5	U
Blank	SPK78.0	9/26/2000	15:30	00398626	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U	0.5	U	0.5	U
Blank	LSK56.4	9/26/2000	15:40	00398636	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U	0.5	U	0.5	U
Blank	SPK78.0	9/27/2000	14:35	00398669	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U	0.5	U	0.5	U
Blank	LSK56.4	9/27/2000	14:55	00398679	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U	0.64		0.71	
Blank	LL0	9/27/2000	16:00	00398743	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U	0.5	U	0.5	U
Blank	SPK78.0	9/26/2000	11:25	00398750	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U				
Blank	LSK56.4	9/26/2000	10:28	00398751	0.01	U	0.01	U	0.01	U	0.005	U	0.003	UJ				
Blank	SPK78.0	9/27/2000	11:05	00398752	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U				
Blank	LSK56.4	9/27/2000	9:55	00398753	0.01	U	0.01	U	0.01	U	0.005	U	0.003	U				

U = Laboratory Reporting Limit

Table 6. Phosphorus standard laboratory analysis results.

Station Name	Date	Sample #	TP Standard (mg/L)	TP Sample (mg/L)
SPK69.8	9/27/2000	00398680	0.0046	0.003
SPK69.8	9/26/2000	00398637	0.0046	0.004
SPK62.0	8/16/2000	00338483	0.00558	0.0048
SPK67.6	8/16/2000	00338438	0.0056	0.0066
SPK67.6	9/27/2000	00398681	0.0093	0.0074
SPK67.6	9/26/2000	00398638	0.0093	0.0096
SPK66.0	8/16/2000	00338439	0.014	0.013
SPK58.1	8/16/2000	00338484	0.014	0.013
SPK66.0	9/27/2000	00398682	0.014	0.014
SPK66.0	9/26/2000	00398639	0.014	0.016
SPK62.0	9/27/2000	00398683	0.023	0.025
SPK62.0	9/26/2000	00398640	0.0223	0.027
SPK58.1	9/27/2000	00398684	0.0349	0.040
SPK66.0	8/16/2000	00338482	0.0558	0.053
SPK69.8	8/16/2000	00338437	0.0558	0.054
SPK67.6	8/16/2000	00338481	0.279	0.289
SPK58.1	8/16/2000	00338441	0.279	0.339
SPK69.8	8/16/2000	00338480	0.698	0.741
SPK62.0	8/16/2000	00338440	0.698	0.784

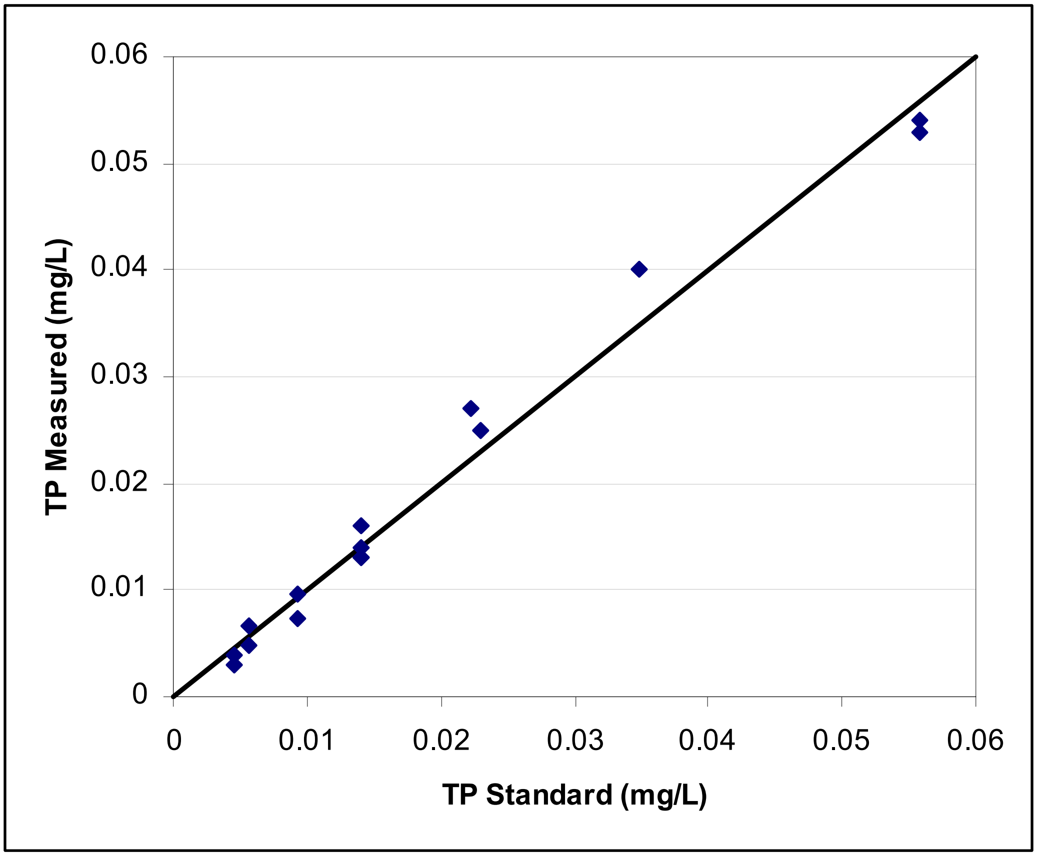

Figure 7. Total phosphorus standard concentration versus laboratory measured concentration.

Table 7 lists the pooled standard deviations and the RMS%RSD for the CBODU replicate samples separated by ambient and individual and combined effluent replicate samples. All field and laboratory replicate samples including different laboratory dilutions were included in the estimates. The RMS%RSDs indicate that the CBODU estimates and the associated parameters are highly variable and only the ambient replicate samples met the data quality objectives for this project. However, for modeling water quality, only the mean estimates were used for defining effluent CBODU characteristics (i.e., the variability of the measurements were not included in characterizing the effluents). In addition, CBODU mean values reported by Pelletier (1994, 1997) were used for modeling the Inland Empire Paper Company (IEPC) effluent characteristics for this study (i.e., not the 1999 and 2000 mean values). The 1999 and 2000 mean CBODU concentrations measured by Ecology fell within the range of values reported in Pelletier (1997).

Table 7. Pooled standard deviations ($Stdev_P$) and root mean square of the percent relative standard deviations (RMS%RSD) for ultimate carbonaceous biochemical oxygen demand (CBODU) replicate measurements.

	$Stdev_P$ BOD5	RMS%RSD BOD5	$Stdev_P$ CBODU	RMS%RSD CBODU	$Stdev_P$ U:5 ratio	RMS%RSD U:5 ratio	$Stdev_P$ k	RMS%RSD k
Ambient	0.040	8.0	0.206	10.3	0.118	4.9	0.013507	25.5
IEPC	0.846	31.2	11.329	21.6	8.816	33.8	0.006156	28.2
Kaiser	0.127	9.2	0.890	17.9	0.595	21.7	0.026252	24.3
Liberty Lake	0.646	10.5	6.231	24.7	1.386	31.5	0.005504	19.7
Spokane	3.800	26.8	4.152	23.9	0.593	28.0	0.023021	25.1
All Effluent Reps	2.572	20.8	6.705	22.0	4.349	27.5	0.023573	24.4

Ambient = Spokane River and Tributaries
IEPC = Inland Empire Paper Company IWTP
Kaiser = Kaiser Aluminum IWTP
Liberty Lake = Liberty Lake POTW
Spokane = City of Spokane AWTP

Hydrolab® Datasonde 3s and 4s and Surveyor IIs post calibration standard checks were within 5 percent of the expected value for pH and conductivity, and temperature was always within 0.5 ^{o}C of alcohol thermister readings. The battery pack failed in the Datasondes deployed near the mouth of the Little Spokane River during August 2000, and no data were collected. Dissolved oxygen and conductivity were evaluated by meter and survey grab samples. Winkler titrations for dissolved oxygen were judged to have greater accuracy than meter measurements. If necessary, Winkler titration dissolved oxygen measurements were used to adjust meter data for data analyses.

The quality assurance and quality control procedures for the long-term ambient monitoring data included in the Spokane Study data sets are described in Ehinger (1996).

Except for the CBODU results, the quality assurance and quality control procedures/sample results reviewed suggest that the Ecology data are of good quality.

CE-QUAL-W2 Model Calibration DATA

A combination of historical and current water quality data were used to calibrate the CE-QUAL-W2 model. The data are contained in electronic files that can be downloaded from the web site listed on the back of the cover of this report.

Following is a brief summary of the contents of the data files.

Historical Data

Previous investigations by Eastern Washington University of the Lake Spokane impoundment have described surface hydrology, point source nutrient loading, and potential trophic response. The most recent study by Soltero et al. (1992) was used together with Ecology long-term ambient data and point source data to calibrate the CE-QUAL-W2 model to 1991 conditions in the river and Lake Spokane. The 1991 surface water and groundwater chemical data are contained in the file *Chem_1991.xls* in the folder *1991*.

The Soltero et al. (1992) report provides a detailed description of the study area, methods, and results and discussion of the study, including quality assurance and quality control. Although only the chemistry data are provided here, the report also provides data for bacteriology; phytoplankton standing crop, chlorophyll *a*, and primary productivity; zooplankton standing crop; phytoplankton/zooplankton relationships; macrophyte standing crop; fisheries characteristics; and wetland characteristics for Lake Spokane. These data and information in the Soltero et al. report also were used for calibrating the CE-QUAL-W2 model.

There are 10 worksheets contained in *Chem_1991.xls*. The worksheet *Dictionary* provides a description of the worksheets' contents and parameter codes. In the worksheet *River-Tribe,* the data are listed as either "Ecology" or "Soltero." The data noted as "Ecology" are from Ecology's long-term Ambient Water Quality Monitoring Program. The long-term ambient sites are located in the study area at the state line and Riverside State Park on the Spokane River, near the mouth of Latah Creek, and near the mouth of the Little Spokane River.

The effluent data contained in the worksheets *Spokane_WTP, IEPC, Kaiser, and Liberty_WTP* were either provided by the dischargers or were from other Ecology reports (Das, 1994a, 1994b, 1994c, 1994d; Hallinan et al., 1991; and Das and Zinner, 1991). Some values are annotated as "estimates" and were calculated based on relationships with other variables. In the worksheet *Spokane_WTP*, the City of Spokane provided the effluent data in columns A-Z and the data in columns Z-AX were collected by Soltero et al. (1992).

1999 and 2000 Data

In addition to calibrating the CE-QUAL-W2 model to 1991 conditions, Ecology's long-term ambient monitoring data, groundwater data, survey data (river, lake, point source), and existing effluent data were used to calibrate the CE-QUAL-W2 model to 2000 conditions. Groundwater and effluent data collected during August 1999 were also used to establish the characteristics of these sources for modeling the 2000 conditions. The referenced files below are in the folder *1999-2000*.

Chemistry Data

The 2000 surface water and 1999 and 2000 effluent chemical data are contained in the file *Chem_2000.xls* in the folder *1999-2000*. The worksheet *Dictionary* provides a description of the worksheets contents and parameter codes. The effluent data contained in the worksheets *Spokane_WTP, IEPC, Kaiser, and Liberty_WTP* were either provided by the dischargers, other reports, or collected by Ecology. The Ecology data are in the first block of data (15 rows) in each worksheet.

The 1999 surface water data are in the file *Chem_1999*. The parameter codes are the same as those defined in the 2000 data file dictionary.

Diurnal Data

The files *Diurnal_1999.xls* and *Diurnal_2000.xls* in the folder *1999-2000* contain diurnal data. The worksheet names (e.g., SPK96.0) are the sample site locations as listed in Table 3.

Phytoplankton Data

The folder *Phyto* contains the phytoplankton data for samples Ecology collected in the Spokane River and Lake Spokane. The folders *Aug1999*, *Aug2000*, and *Sep2000* contain data collected in those months. The contents of the general file categories in the folder are as follows:

*.DOC files contain a cover letter from the analyst Jim Sweet, Aquatic Analysts. In the cover letters, he provides a general description of the species present, phytoplankton abundance, and comparison between samples for each batch.

*.TXT files define the headers contained in the *.PRN files

*.PRN files contain phytoplankton analysis results for each sample. The *Sidoe.prn* files contain a "similarity indices" matrix for all of the samples for a batch.

*.XLS files contain a summary table of the results for each batch of samples.
The file *Algae_QC.doc* reviews the laboratory quality control procedures followed by Aquatic Analysts for plankton analysis.

Groundwater Data

Groundwater data collected during the summer of 1999 are contained in the file *GW_data.xls* in the folder *GW*. The groundwater data were collected under a separate project and are reported (including sample locations information) in Marti and Garrigues (2001). The file *Well.ppt* contains a map showing the sample locations (wells)

2001 Data

The folder *2001* contains 2001 data collected by Ecology and the Spokane River Phosphorus Technical Advisory Committee (SRPTAC). The city of Spokane submitted a "Post-Project" Quality Assurance Project Plan for the 2001 SRPTAC data collection. However, Ecology submitted a letter on January 6, 2003 to Dr Scott Wells, Portland State University, a contractor working with SRPTAC to compile 2001 data and apply the CE-QUAL-W2 model to 2001 conditions. The letter discusses potential problems with some of the data collected (see copy of letter in Appendix A). Today, Ecology has not received any response to the concerns raised in the letter.

Although most of the data collected during 2001 appear to be of good quality, a few of the major model calibration variables are suspect (i.e., chlorophyll *a* and total and dissolved organic carbon). In addition, data for total and soluble reactive phosphorus were reported to only two decimal places for data >0.010 mg/L (e.g., 0.02 to 0.03 mg/L) which was less than the three decimal places needed to monitor changes in the river and lake. Therefore, further calibration of the CE-QUAL-W2 model rates and constants to 2001 data, except CBODU characteristics, was not attempted. However, the model was set up to simulate 2001 conditions, and model comparisons to data were presented.

Chemistry Data

The 2001 river, lake, and point source chemistry data were compiled by Scott Wells at Portland State University, Department of Engineering as part of a contract with the SRPTAC. The river, lake, and point source data are in the file *2001_Data.xls*. The original data from Columbia Analytical Services (CAS) laboratory is also included in *CAS_Data.xls*. The methods and analytical results for 2001 CBODU data analyzed by Dr. David Yonge, Washington State University, Chemistry Department are summarized in the file *CBODU_Data_Summary.doc*.

Diurnal and Profile Data

The profile data for Lake Spokane are in the file *Profile_2001.xls,* and the diurnal data collected at three different locations in the river are in *Diurnal_2001*. These data were collected by Ecology.

Periphyton Data

Dr. Michael Falters, University of Idaho, collected periphyton data along the Spokane River. The periphyton data are in the files *Periphyton_Chla_2001.xls* and *Periphyton_Biomass_2001.xls*.

Groundwater Data

Groundwater data collected by Spokane County during 2001 from 12 wells near the river are contained in the file *2001_GW_Data.xls*.

Data Results and Discussion

Spokane River and Tributary Data

Appendix B tables B1-B3 list the mean and standard deviation for the ambient data collected during the critical water quality period of June through October 1991, 2000, and 2001. The data were summarized for the Spokane River sampling stations located at the state line (RM 96.0), Riverside State Park at Bowl and Pitcher (RM 66.0), and downstream of Nine Mile Dam (RM 58.1), as well as from stations near the mouth of Latah Creek and the Little Spokane River. The results were consistent with historical data collected at these locations.

Table B4 list statistics for the ultimate carbonaceous biochemical oxygen demand (CBODU) to 5-day BOD ratios and decay rates (k) for data collected by Ecology during 1999-2000 and by SRPTAC during 2001. The data indicate that there was not a significant difference between the average results, but that the SRPTAC data analyzed by Washington State University were less variable than the Ecology data.

Two of the major parameters of concern for this project are dissolved oxygen and total phosphorus concentrations. The following is a brief review of the data results for these parameters and temperature. The water quality of the Spokane River and Lake Spokane are discussed in more detail in the final project report (Cusimano, 2003).

Dissolved Oxygen

The diurnal data show that the dissolved oxygen concentrations in the Spokane River can violate the dissolved oxygen criterion of 8 mg/L at the Washington and Idaho state line, in the Upriver Dam pool, above Upper Falls, and in the Nine Mile Dam pool.

Figures 8-14 present some of the diurnal data for these areas. The data logger readings of dissolved oxygen were corrected by the grab sample Winkler titration results collected at the meter site. In all cases the dissolved oxygen corrections were <0.4 mg/L. The diurnal changes in dissolved oxygen concentrations (and pH) are mostly due to photosynthesis and respiration of floating and attached algae. It should be noted that low river flows exacerbate the diurnal changes. For example, the diurnal data collected at the state line in Figures 8-10 show that the dissolved oxygen and pH diurnal changes were greatest during 2001 which was a lower river flow year than 2000.

Figures 15 and 16 are graphs of August dissolved oxygen profile data collected from Lake Spokane at site LL1 and LL3 for the period 1977 to 2001. The Department of Biology at Eastern Washington University provided the historical profile data (1977-91).

- The 1977 profile data reflect the typical August dissolved oxygen profiles found in the lake before the City of Spokane wastewater treatment plant was upgraded (in December 1977) to secondary treatment with phosphorus removal.
- The 1978 profile data show a significant improvement in lake hypolimnetic dissolved oxygen concentrations following the City's treatment plant upgrade. Wagstaff and Soltero (1982) reported that dissolved oxygen concentrations declined throughout the summer of 1981 with minimum values occurring in August. They also noted that the extent and duration of anoxic conditions during 1981 appeared to be less than that in the previous post treatment plant upgrade summers.
- The August 1991 through 2001 profiles are probably typical of the lake minimum dissolved oxygen concentrations since the treatment plant upgrade and the phosphorus TMDL was adopted in the late 1980s.

The minimum dissolved oxygen concentrations in the lake improved immediately after 1977 and appear to have continued to improve until 1991, but the 2000 and 2001 data suggest that the lake may not improve further without further management. It should be noted that annual variations in lake dissolved oxygen concentrations (and water quality in general) are partly due to changes in the river flows. The years 1977 and 2001 were very low flow years, and the other years shown in Figures 15 and 16 were closer to median flow years.

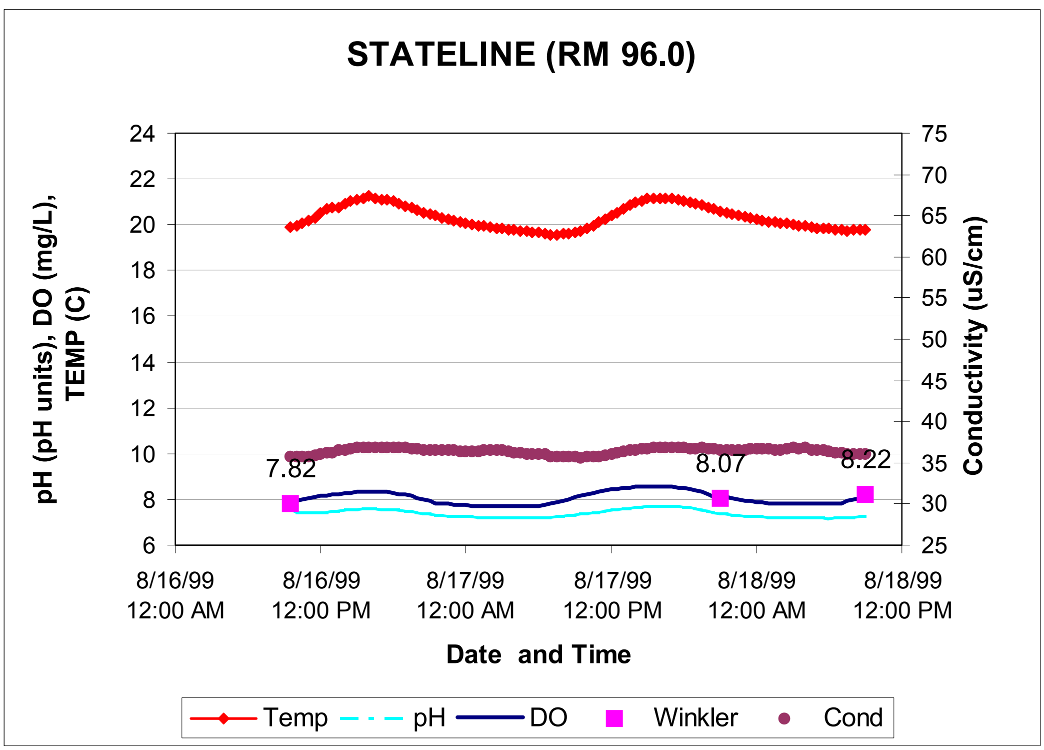

Figure 8. Diurnal data collected at the Washington/Idaho state line during August 1999.

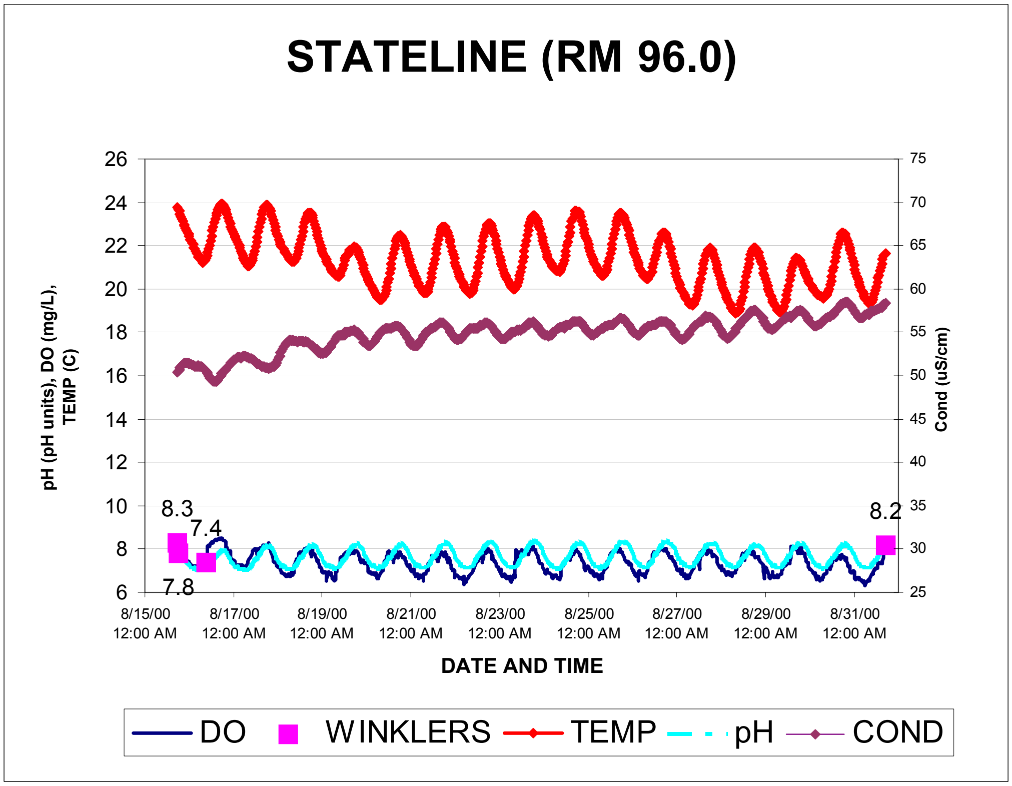

Figure 9. Diurnal data collected at the Washington/Idaho state line during August 2000.

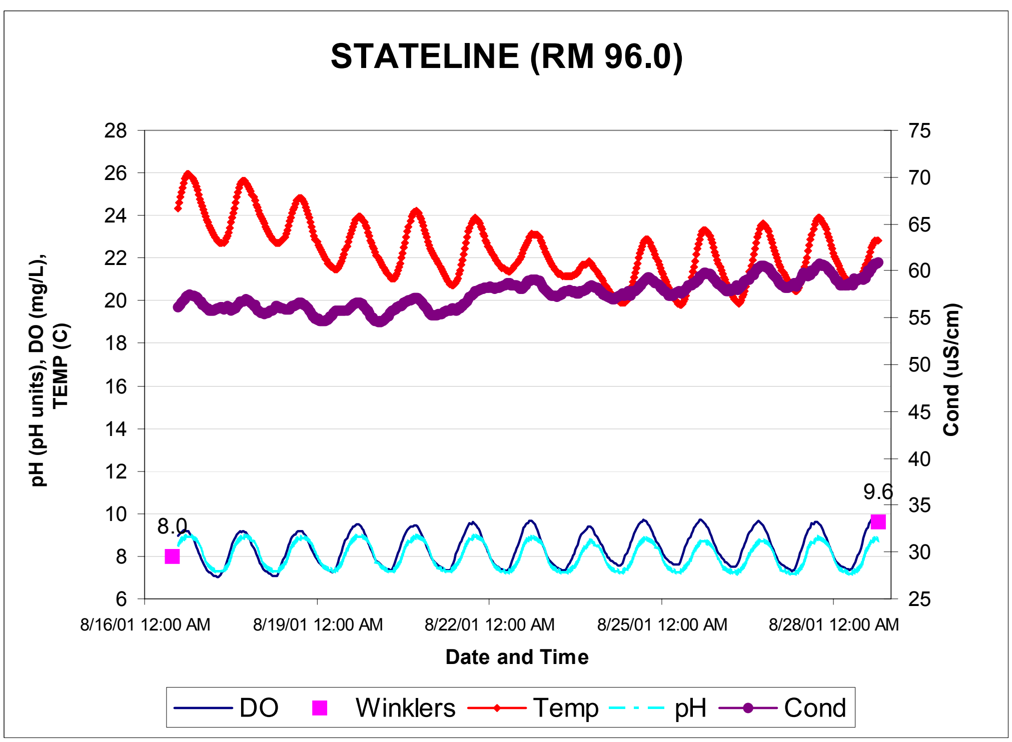

Figure 10. Diurnal data collected at the Washington/Idaho state line during August 2001.

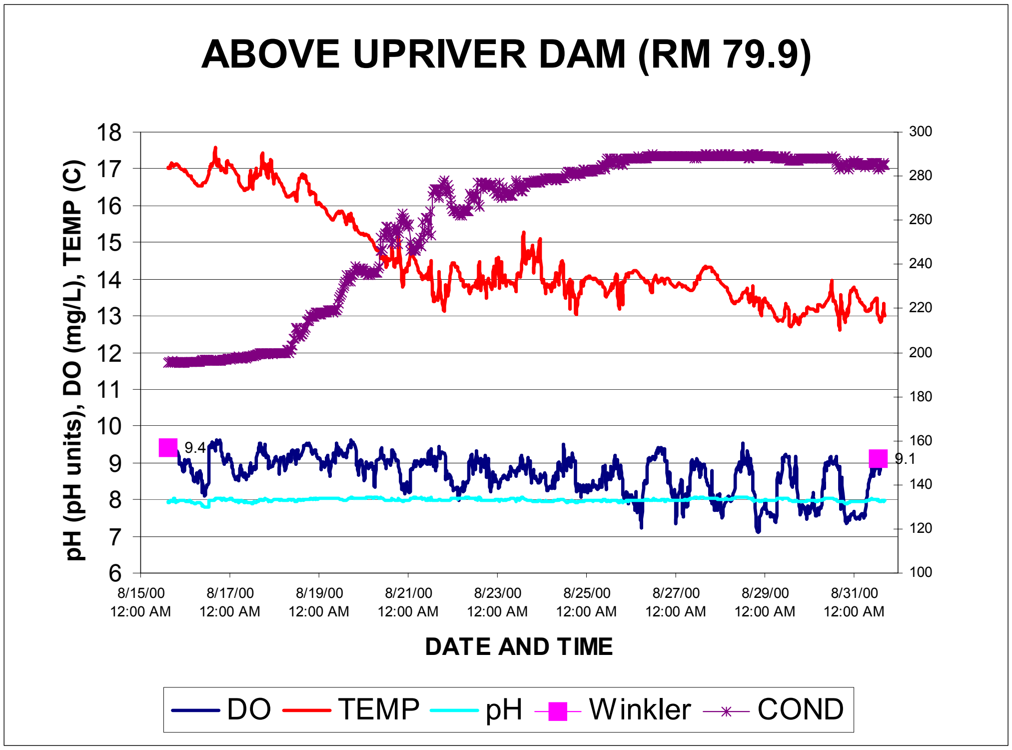

Figure 11. Diurnal data collected in the Upriver Dam pool during August 2000.

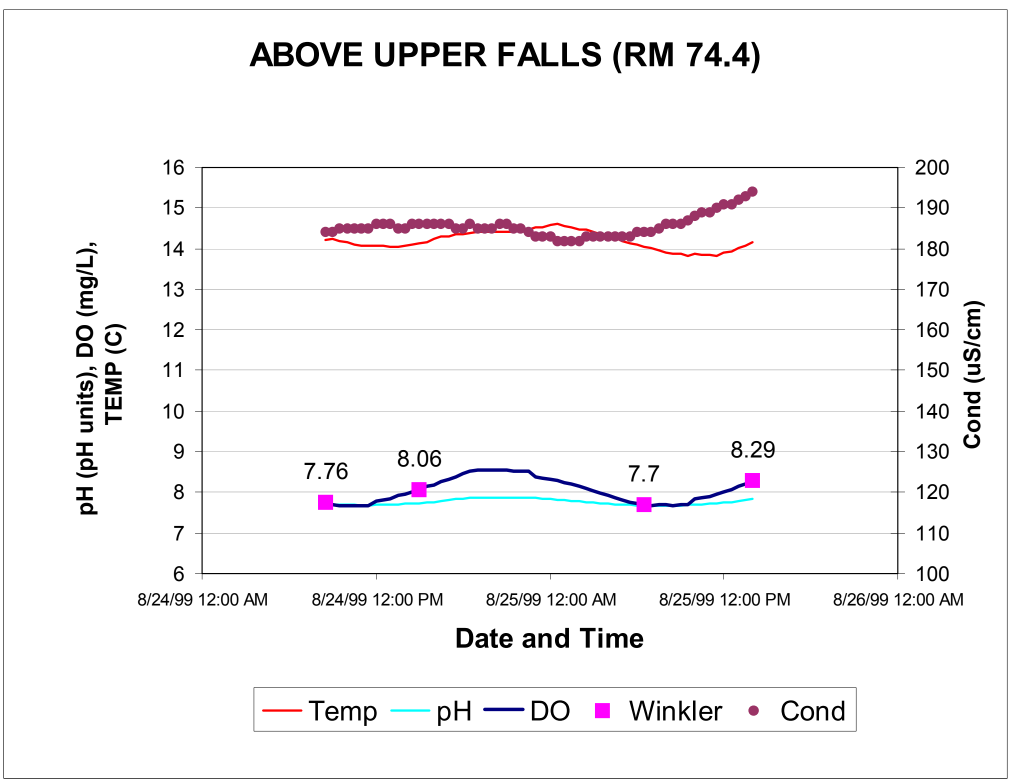

Figure 12. Diurnal data collected from the pool above Upper Falls during August 1999.

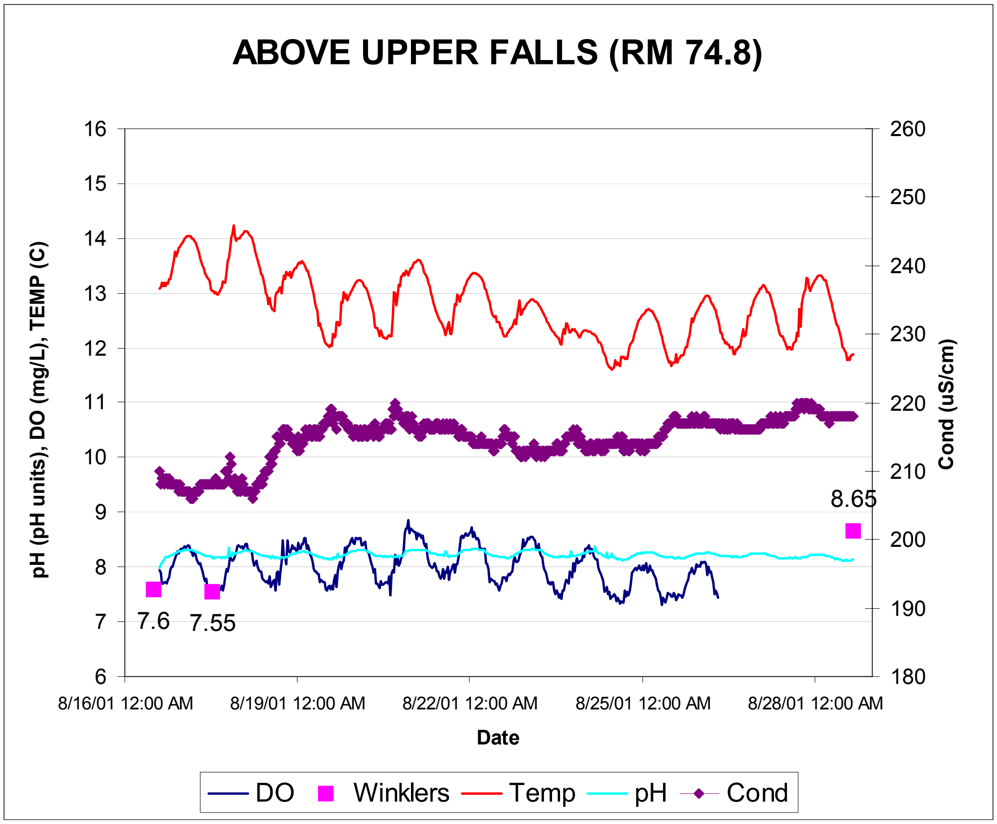

Figure 13. Diurnal data collected from the pool above Upper Falls during August 2001.

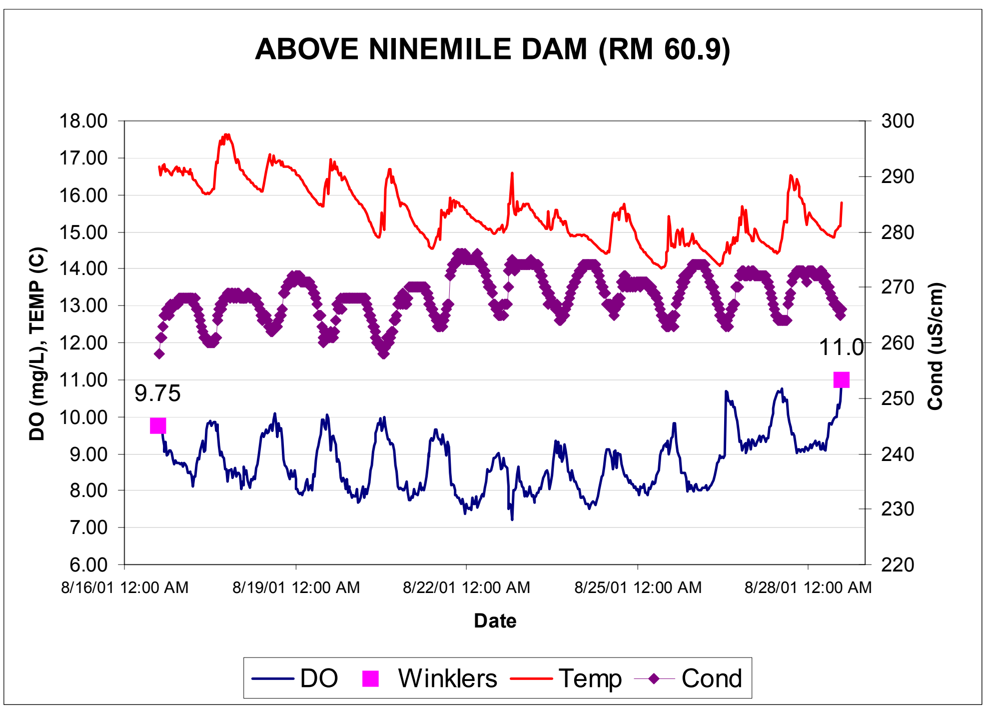

Figure 14. Diurnal data collected from the pool above Nine Mile Dam during August 2001.

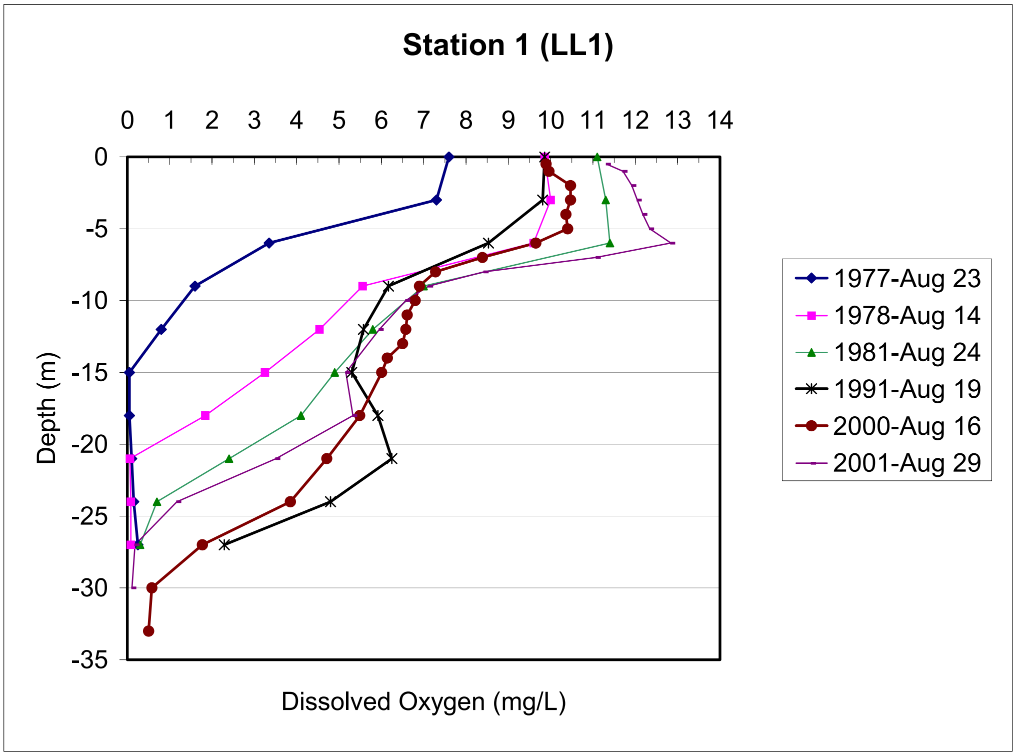

Figure 15. Long Lake Station 1 (LL1) dissolved oxygen profile data collected during August.

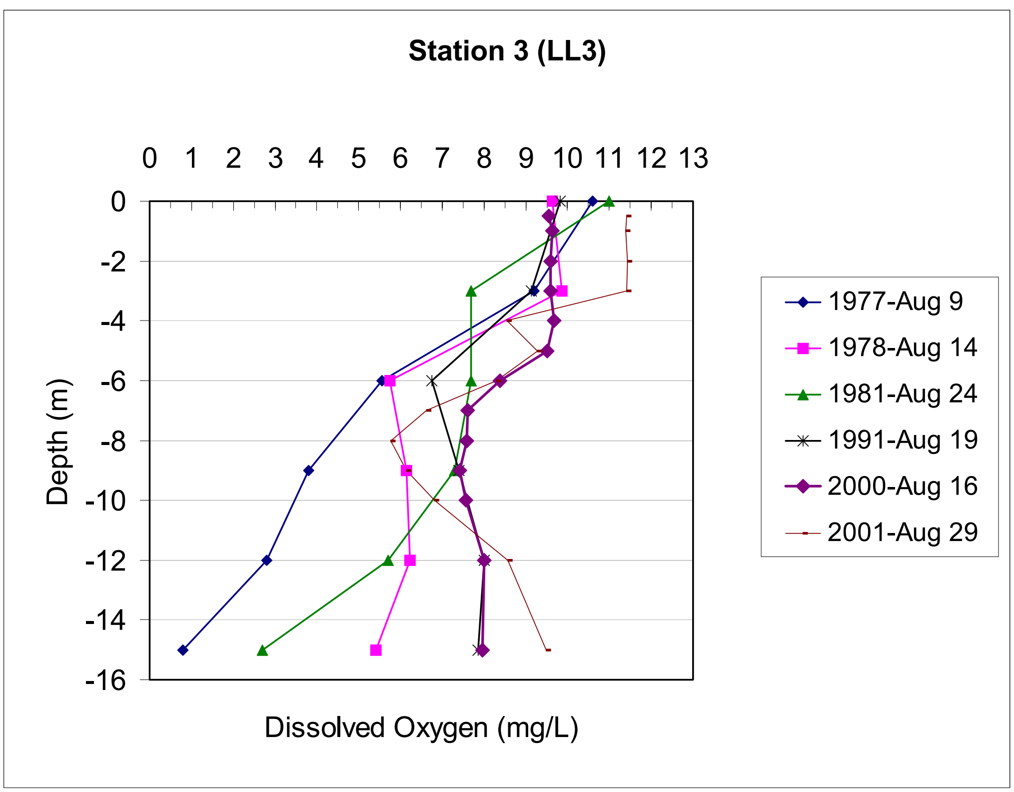

Figure 16. Long Lake Station 3 (LL3) dissolved oxygen profile data collected during August.

Total Phosphorus

The Lake Spokane total phosphorus TMDL set phosphorus limits for the euphotic zone of the lake at 25 ug/L. A total phosphorus loading limit of 259± 43 kg/day was recommended for the Spokane River and Little Spokane River to meet the TMDL, and load and wasteload allocations to meet the total phosphorus limit were determined (Patmont et al., 1987).

Figure 17 shows the total phosphorus concentrations (mean ± stdev) for the August 15-16 and September 26-27, 2000 surveys by river mile (n = 4 at each sampling station for each survey), from the state line (RM 96.0) to just below Nine-Mile Dam (RM 58.1). Figure 18 shows the total phosphorus concentrations for the August 8-9 and August 29-30, 2001 surveys (n = 1 or 2 for each sampling station for each survey). Figure 19 and 20 present estimated total phosphorus loads for the 2000 and 2001 survey data by river mile. The graphs show that the total phosphorus concentrations and loads were low in the river from the state line to the City of Spokane AWTP, then significantly increase below the plant.

Figure 21 presents the estimated total phosphorus loads for the Spokane River just below Nine Mile Dam, the state line, and for the Little Spokane River near the confluence with Lake Spokane for the June through September 2000 data. The combined loading for the Little Spokane and Spokane River (i.e., Total Load in the graph), and TMDL limit are also plotted. The results show that the total phosphorus loading limit for the Spokane River and Lake Spokane was met during most of the sampling days.

Figure 22 presents the 1991 estimated loading for the Spokane and Little Spokane rivers to Lake Spokane. Again, the total phosphorus loading limit was met in 1991. The phosphorus loading to Lake Spokane in 1991 and 2000 was less than the recommended loading allocations for the Spokane and Little Spokane rivers.

Years 1991 and 2000 were approximately median river flow years during the June-October period, and 2001 was a low flow year (i.e., 2001 was approximately a lower 10^{th} percentile flow year).

The existing total phosphorus TMDL is discussed in more detail in the final report (Cusimano, 2003).

Temperature

The diurnal data at the state line also show that temperatures exceed the numeric criterion at this point in the river. Figure 23 shows that the special criterion of 20^{o} C is exceeded downstream to near the Sullivan Road Bridge. Cooler groundwater starts to enter the river downstream of this point in the river, and river temperatures stay below the criteria, except in the Upriver Dam pool which exceeded the criterion during 2001 (i.e., 2001 was a low river flow year).

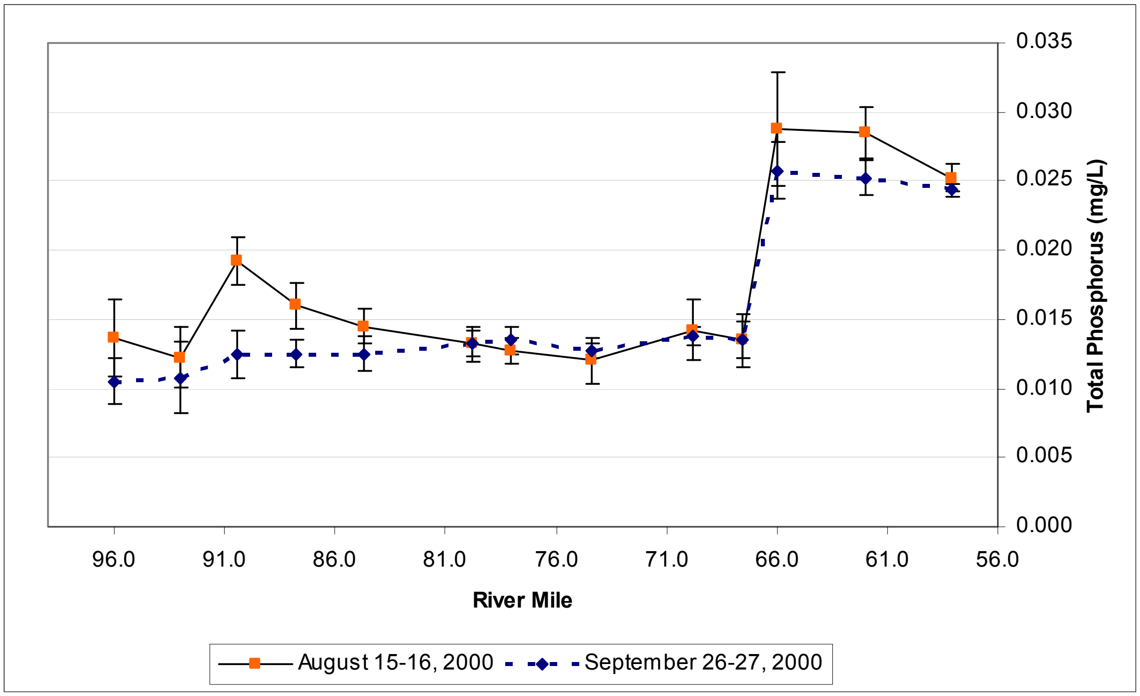

Figure 17. August 15-16 and September 26-27, 2000 survey data for the total phosphorus concentrations (mean ± stdev) in the Spokane River from the state line (river mile 96.0) to just below Nine Mile Dam (river mile 58.1).

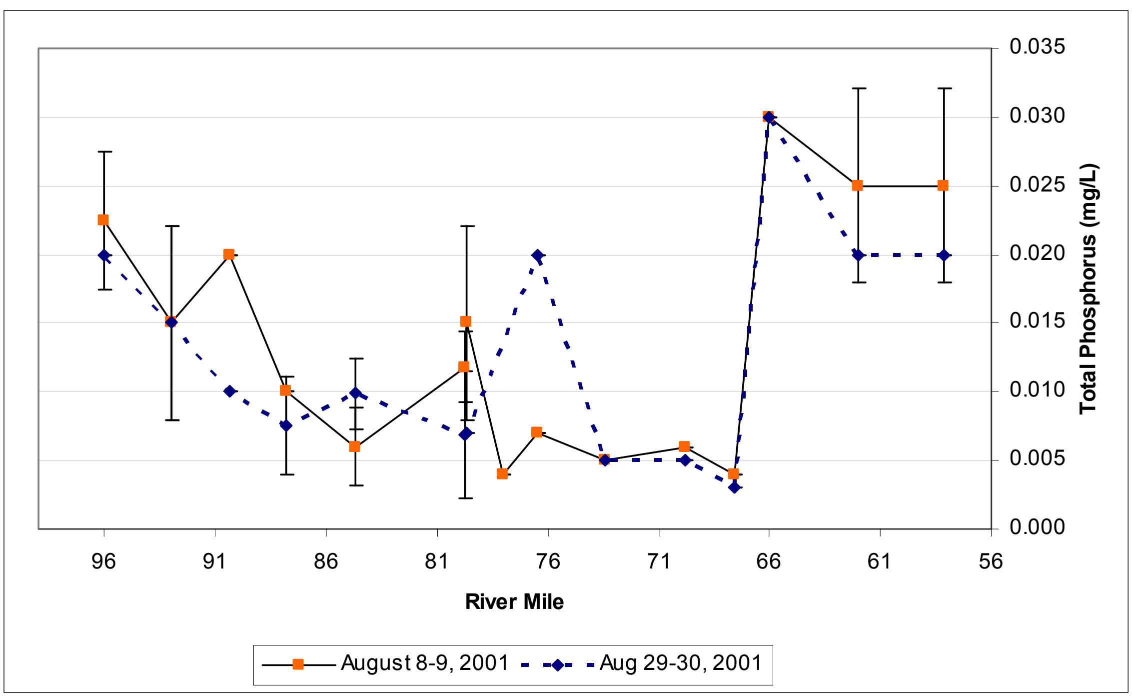

Figure 18. August 8-9 and August 29-30, 2001 survey data for the total phosphorus concentrations (mean ± stdev) in the Spokane River from the state line (river mile 96.0) to just below Nine Mile Dam (river mile 58.1).

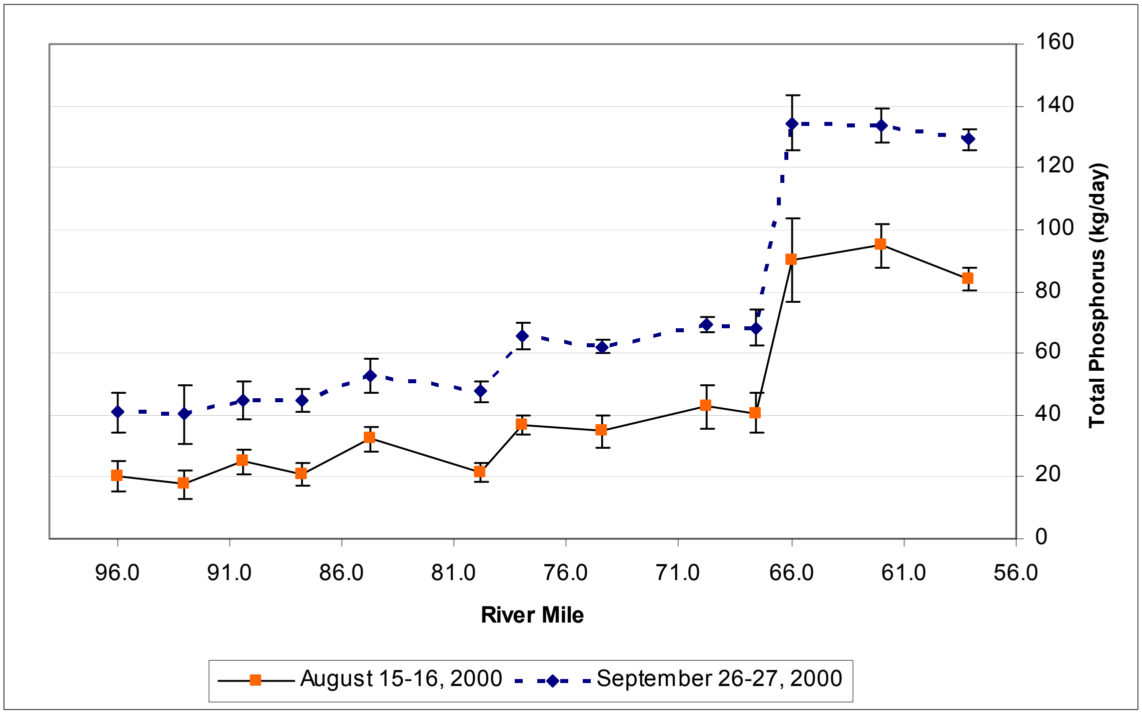

Figure 19. August 15-16 and September 26-27, 2000 estimated total phosphorus loads (mean ± stdev) in the Spokane River from the state line (river mile 96.0) to just below Nine Mile Dam (river mile 58.1).

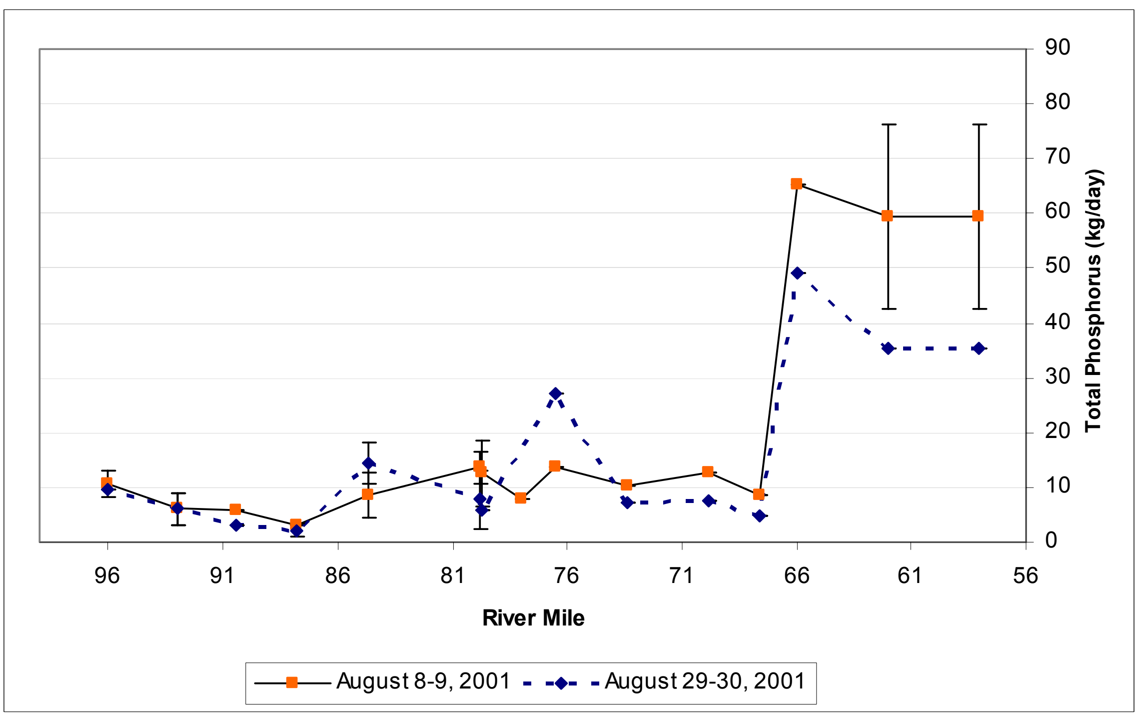

Figure 20. August 8-9 and August 29-30, 2001 estimated total phosphorus loads (mean ± stdev) in the Spokane River from the state line (river mile 96.0) to just below Nine Mile Dam (river mile 58.1).

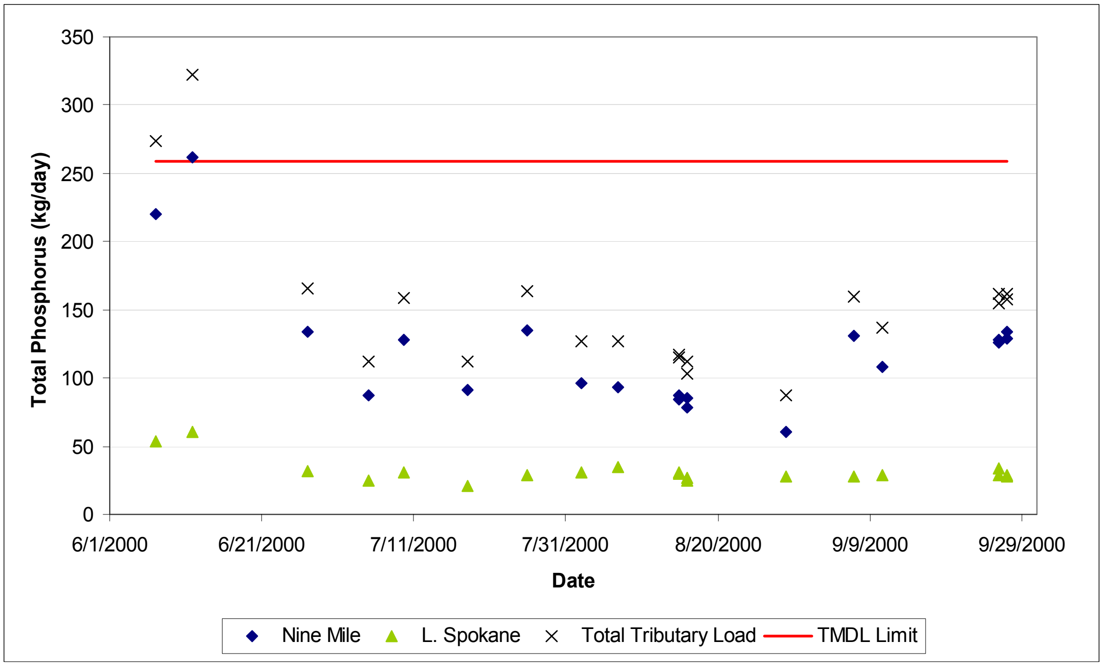

Figure 21. 2000 estimated total phosphorus loads for the Spokane River just below Nine Mile Dam, the Little Spokane River near the confluence with Lake Spokane, and the total tributary load to Lake Spokane; and the total phosphorus load allocation limit for the tributaries to Lake Spokane (TMDL Limit).

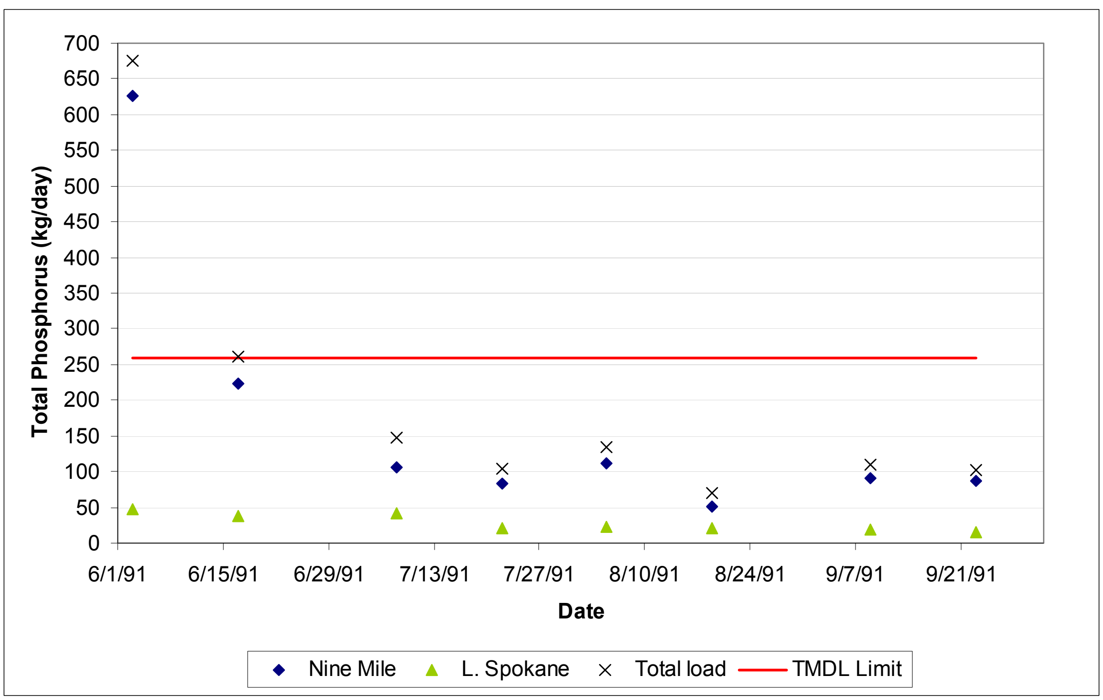

Figure 22. 1991 estimated total phosphorus loads for the Spokane River just below Nine Mile Dam and the Little Spokane River near the confluence with Lake Spokane, and the total phosphorus load allocation limit for the tributaries to Lake Spokane (TMDL Limit).

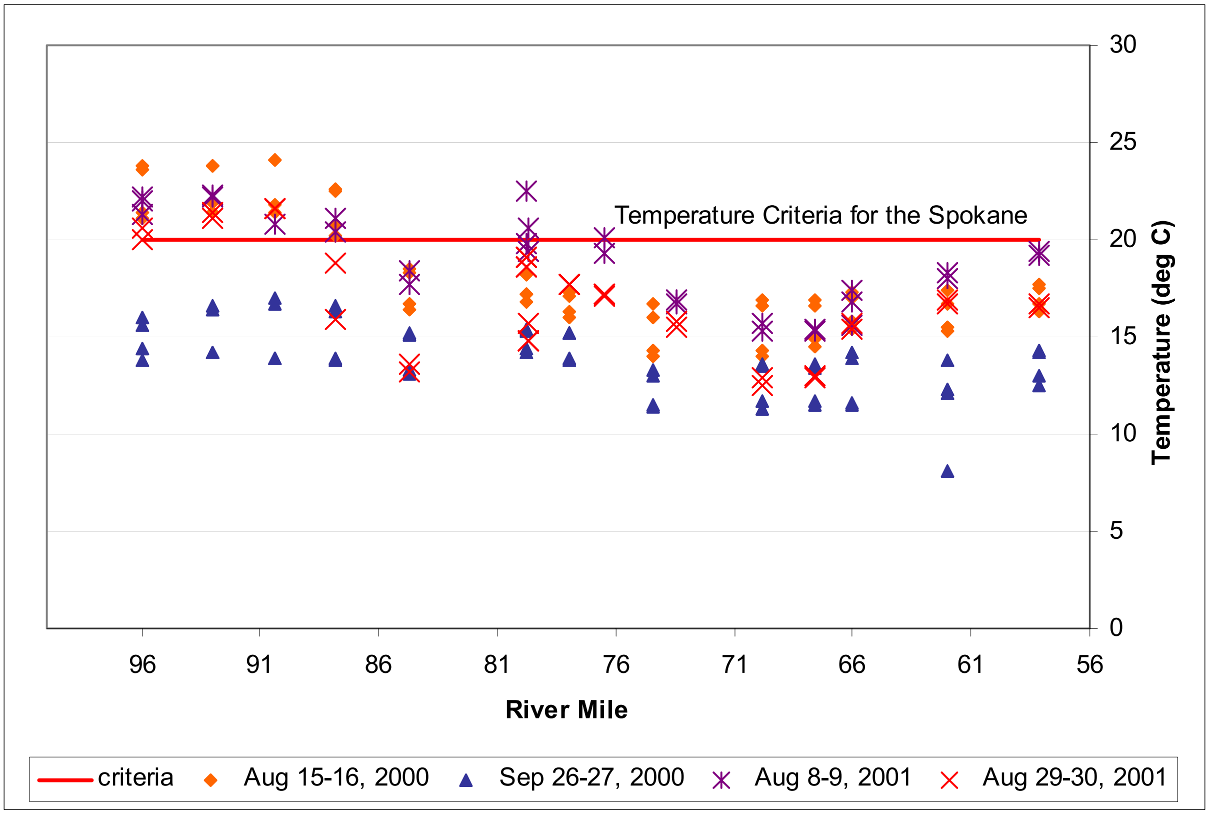

Figure 23. August 15-16 and September 26-27, 2000, and August 8-9 and 29-30, 2001 temperature data for the Spokane River from the state line (river mile 96.0) to just below Nine Mile Dam (river mile 58.1).

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Conclusions and Recommendations

Overall, the data collected by Ecology for this project met the data quality objectives. The Ecology ultimate carbonaceous biochemical oxygen demand (CBODU) data did not meet the data quality objectives. However, only the mean characteristics – CBODU:BOD_5 ratios and decay coefficients “k” – of the CBODU measurements will be used to estimate effluent CBODU (i.e., variability in the measurements will not be included in establishing CBODU effluent characteristics). In addition, the Ecology CBODU results were verified during 2001 by the Spokane River Phosphorus Technical Advisory Committee CBODU data (i.e., 2001 data were not significantly different than those reported by Ecology for 1999-2000 data).

The diurnal and some grab sample data suggest that the dissolved oxygen criterion of 8 mg/L was violated in the river at the state line and in the Upriver Dam, Upper Falls Dam, and Nine Mile Dam pools in one or more of the data collection surveys. Although the dissolved oxygen concentrations in Lake Spokane appear to have improved in the 1980s, further improvement may be unlikely given the current loading of total phosphorus and organic matter to the lake.

The data provided in this report – and flow, water level, meteorological, and bathymetry data from other sources – were used to build and calibrate a CE-QUAL-W2 model of the river system. Ecology will use the model to recommend TMDL pollutant limitations to protect the water quality of the Spokane River and Lake Spokane.

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Appendices

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Appendix A

2001 Data Quality

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STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
P.O. Box 47600 • Olympia, Washington 98504-7600
(360) 407-6000 • TDD Only (Hearing Impaired) (360) 407-6006

January 6, 2003

Dr. Scott Wells
Department of Civil Engineering Environmental Engineering
Portland State University
P.O. Box 751
Portland, Oregon 97207-0751

Dear Dr. Wells:

As you know, during the summer of 2001, the city of Spokane in cooperation with Spokane County and Ecology collected field and laboratory data from the Spokane River, Lake Spokane, and the facilities that discharge effluent to the Spokane River. The goal was to collect data during the summer of 2001 that could be used to further calibrate the hydrodynamic and water quality model (CEQUALW2) that has been developed for the river system.

Columbia Analytical Services (CAS), Dr David Yonge at Washington State University, and Dr. Michael Falter at the University of Idaho were used to provide laboratory analysis support for the project. Fourteen samples were "split" and analyzed by both CAS and Ecology's Manchester Environmental Laboratory (MEL). Data were also collected by Spokane County, as part of the county's groundwater and surface water sampling program, and analyzed by North Creek Analytical Laboratory in their labs located in Spokane and Bothell, Washington.

I have completed a review of the 2001 field and laboratory data. Since Ecology has not received a quality assurance plan for the data collection or a report summarizing the quality of the 2001 data, it is not possible to provide a complete assessment of the 2001 data. However, the following are my observations and recommendations for using the data to calibrate the CEQUALW2 model to 2001 conditions:

1. The CBODU and epiphyton data provided by Dr. David Yonge and Dr. Michael Falter, respectively, appear to be of high quality based on analysis procedures and results summaries they provided.

2. The Lake Spokane 2001 profile data were collected by Ecology following the same protocols as those used to collect data during 2000 and should be comparable. Calibration and post calibration of the HYDROLAB SURVEYOR meter met specifications.

3. The Ecology *in situ* datalogger data were collected following the same protocols as those used to collect data during 2000 and should be comparable. Calibration and post calibration of the HYDROLAB DATASONDE meters met specifications.

4. The Ecology chlorophyll data reported for Lake Spokane sample station LL2 were collected at LL4. Data were not collected at LL2 during the 2001 surveys.

5. Sample collection times were not recorded by the discharger's field sample teams. Without the sampling times, it is difficult to calibrate (or check) the model with respect to the diurnal variability of dissolved oxygen, pH, and other variables associated with photosynthesis and respiration of algae. In addition, it will not be possible to closely associate ambient and predicted diurnal water temperature data without sampling times.

6. All of the lake and most of the river chlorophyll data were reported by CAS as ND (not detected) at a method detection limit (MDL) of 0.3 ug/L. These results are not possible for August river or lake data. There should be measurable chlorophyll in the river and lake >0.3 ug/L. The Ecology "split" chlorophyll samples averaged 6-7 ug/L and 3-4 ug/L in the lake stations (LL1 and LL3) and river stations, respectively. (At LL4, the surface chlorophyll was 70 ug/L during the August 29-30, 2001 survey.)

7. The laboratory reporting limits for the CAS phosphorus data (Total and Ortho-P) appears to be 0.010 mg/L, which is higher than the Ecology reporting limits for the 2000 and 2001 survey data of 0.003 mg/L for Total-P and 0.005 for Ortho-P. The reporting limits for phosphorus should be considered when comparing model predictions to ambient data.

8. Nutrients were reported by CAS with only one or two significant digits. It would be better to have two or three significant numbers for calibrating the CEQUALW2 model, because the difference between 0.01 and 0.02 mg/L of Ortho-P is a significant amount with respect to the availability of SRP for phytoplankton productivity. The rounding of the results will make it difficult to assess the accuracy of model predictions.

   The significant numbers associated with the CAS data also make it difficult to compare the Ecology lab split results because in most cases the MEL data are reported with more significant numbers. MEL reported Nitrite-Nitrate values with three significant numbers (e.g., 1.29, or 0.657 mg/L), and CAS reported values with one or two significant numbers (e.g., 1, 1.1, or 0.7 mg/L).

   If the result is less than ten times the reporting limit, MEL uses two significant figures. If the result is ten times the reporting limit or greater, they use three significant figures. In our Laboratory QA Manual it states "As a general guide, it is suggested that, whenever possible, 3 significant figures be used in reporting results. This will ensure that rounding-off errors do not exceed 0.5%, an accuracy sufficient for all general needs. At concentrations approaching the limit of detection, it is often impractical to measure the responses of the analytical measurement systems to more than 2 significant figures. However, provided the limits of detection are suitably small for the purposes of analysis, the greater the relative inaccuracy (maximum error 5%) consequent on the use of only 2 significant figures is considered tolerable."

9. Conductivity measured by the different groups (i.e., different meters by CAS lab, CAS field, Spokane County field, Ecology lab, and Ecology field) are biased. Figure 1 shows the conductivity relationships (the intercept was forced through zero because most of the low concentrations were close to the same value and zero conductivity should be zero).

   Ecology lab vs. field conductivity data collected during the 2000 surveys were very close to 1:1 (i.e., y = 1.0096x).

10. In most cases, CAS reported total organic carbon (TOC) values that were less than the corresponding dissolved organic carbon (DOC) values. TOC should be about the same or greater than the DOC values. Figure 2 shows the Ecology, CAS, and County TOC and DOC data. The accuracy of the CAS TOC and DOC data appear to be uncertain and suggest that comparisons to model predictions will also be uncertain. The overall ratio of DOC:TOC was 0.9 for the Ecology data and 1.3 for the CAS data. Again, TOC should be equal to or greater than the DOC values such that the ratio of DOC:TOC should be <1.0.

    Figure 3 shows the CAS vs. Ecology TOC and DOC split data. Overall, CAS data are negatively biased relative to the Ecology data.

11. Figure 4 shows the CAS vs. Ecology Total Nitrogen and Nitrite-Nitrate Nitrogen split data results. CAS data are positively biased relative to the Ecology data. Total Nitrogen was measured by Ecology using the Total Persulfate Nitrogen (TPN) method. TPN measures all organic and inorganic nitrogen, and CAS values are the sum of Total Kjeldahl Nitrogen (TKN) and Nitrate-Nitrate Nitrogen (i.e., TKN only measures ammonia and organic nitrogen). Most of the Nitrite-Nitrate Nitrogen split data fall close to the 1:1 line; however, there is still a positive bias for the CAS data.

12. Figure 5 shows the CAS vs. Ecology Total Phosphorus and Ortho-Phosphorus split data results. As with nitrogen, the CAS data show a positive bias relative to the Ecology data.

13. Figure 6 shows the CAS vs. Ecology Alkalinity split sample results. Although most of the results are close to the 1:1 line, for a few samples the CAS data show a positive bias.

Overall, the data collected during 2001 can be used to calibrate the CEQUALW2 model. However, the reporting limits and relative bias associated with the laboratory and field data discussed here should be considered when calibrating the model. In addition, the significant digits associated with the CAS nutrient data should also be noted. If possible, it would be good if CAS could provide data with an additional significant digit for the nutrient analyses.

The CAS TOC data appear to underestimate the ambient total carbon. The ND chlorophyll data reported by CAS should be considered gross errors and not useable.

Sincerely,

Robert F. Cusimano, Environmental Specialist
Watershed Ecology Section
Environmental Assessment Program

RC:cn
Enclosures: Figures 1-6

cc: James Bellatty, Water Quality Program, ERO
Karol Erickson, Environmental Assessment Program, HQ
Will Kendra, Environmental Assessment Program, HQ
Ken Merrill, Water Quality Program, ERO

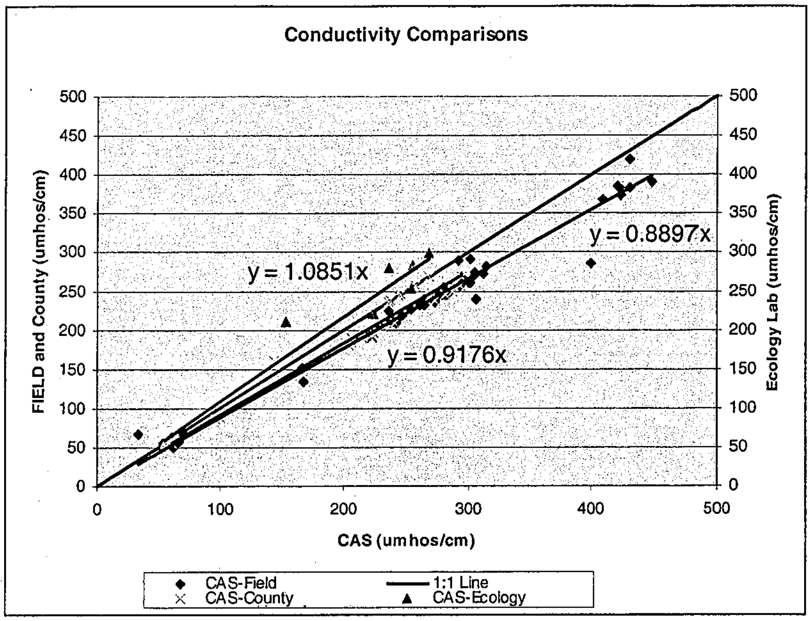

Figure 1. Shows the Comparisons of 2001 Conductivity Data Reported by the Different Groups.

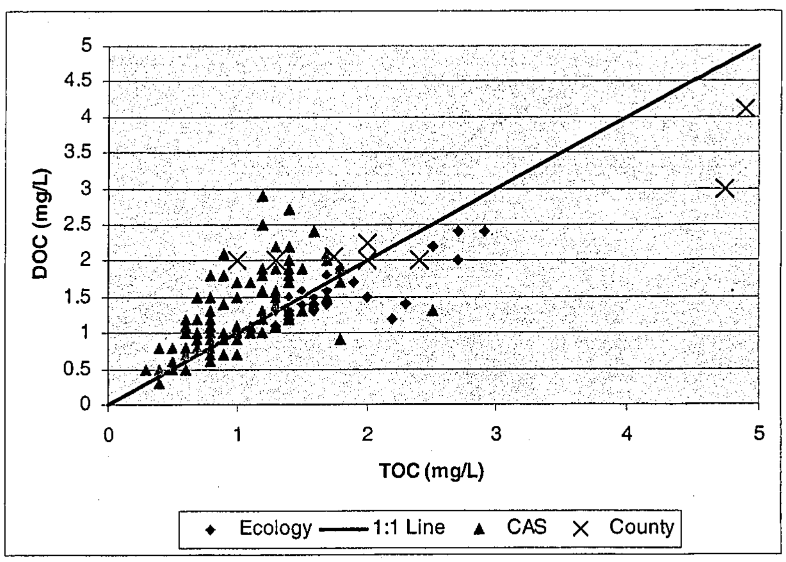

Figure 2. Ecology, CAS, and County TOC vs. DOC.

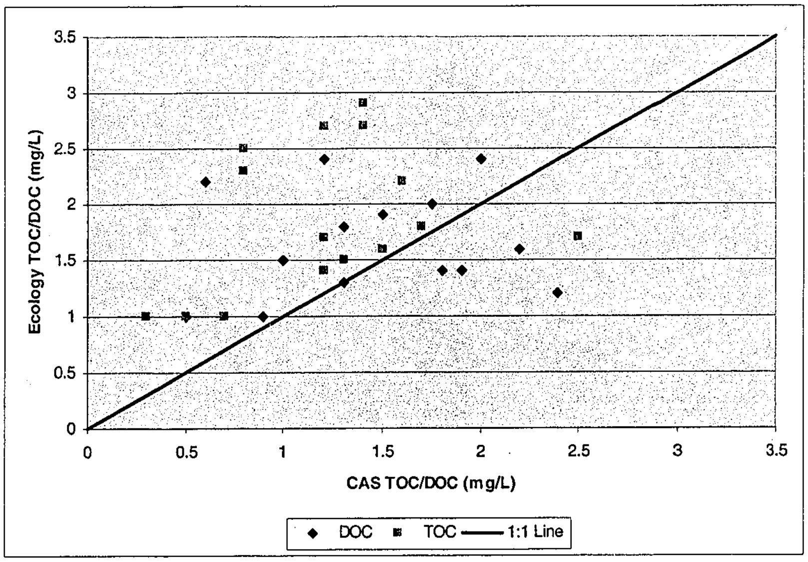

Figure 3. TOC and DOC CAS vs. Ecology.

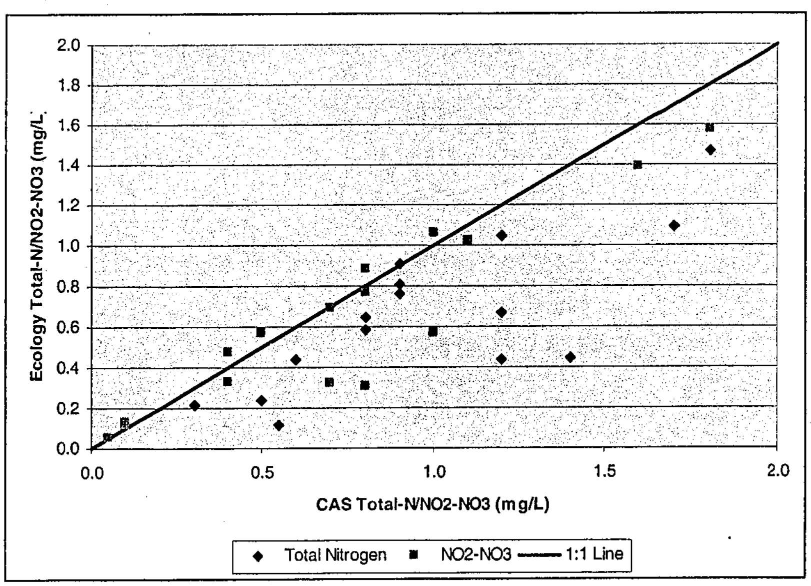

Figure 4. Total Nitrogen and Nitrite-Nitrate Nitrogen CAS vs. Ecology.

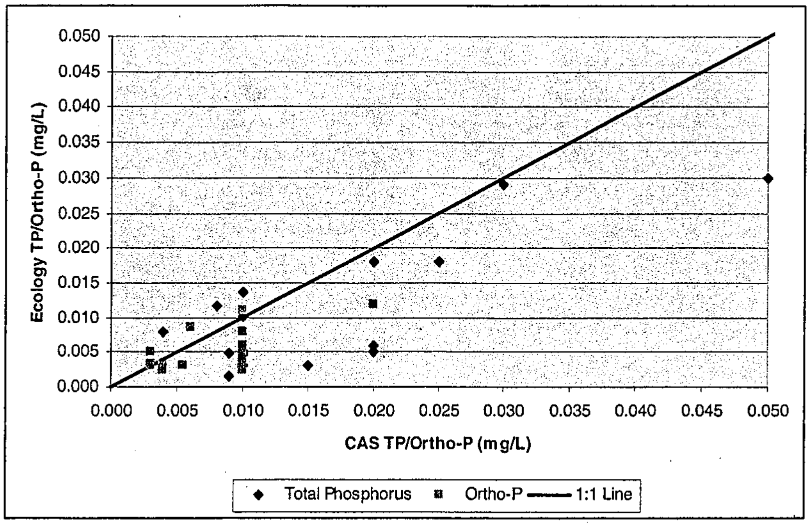

Figure 5. Total Phosphorus and Ortho-Phosphorus CAS vs. Ecology.

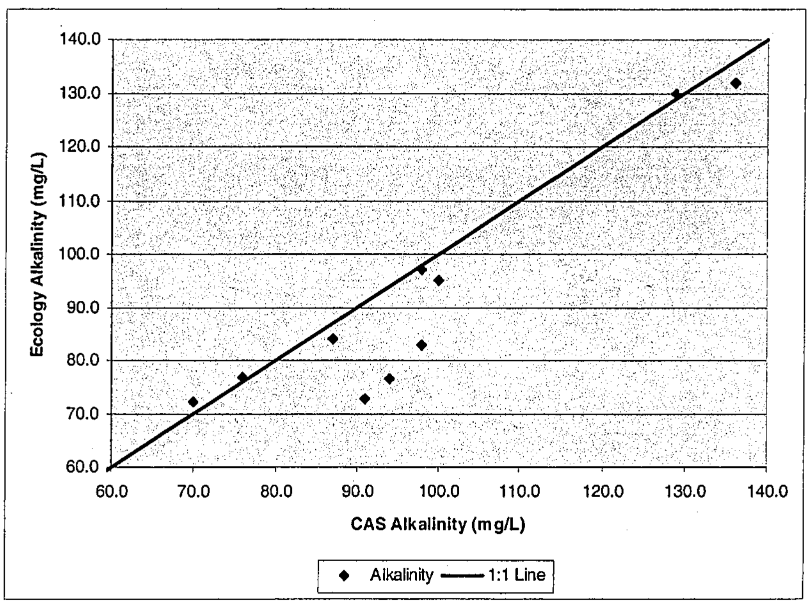

Figure 6. Alkalinity CAS vs. Ecology.

Appendix B

Data Summary Tables

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Table B1. Means and standard deviations (Stdev) for data collected during June through October 1991 at four locations in the study area.

Year 1991	Units	WA/ID Stateline (RM 96.0)		Riverside Park (RM 66.0)		Downstream of Nine-Mile Dam (RM 58.1)		Latah Creek (RM 72.4)		Little Spokane River (RM 56.4)	
		Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
TEMP	(C)	17.3	4.18	15.7	2.80	14.9	2.48	17.0	3.96	14.9	1.65
COND	(µmhos/cm)	52.0	4.85	138.6	96.50	271.8	54.09	307.1	100.68	271.8	26.09
pH	pH Units	7.5	0.37	8.1	0.18	8.2	0.16	8.1	0.35	8.2	0.25
DO	(mg/L)	8.4	1.42	10.5	0.85	9.5	1.18	10.3	1.94	9.5	0.63
CL	(mg/L)					3.37	0.75	8.16	6.02	3.37	0.25
NO2_NO3	(mg/L)	0.061	0.084	0.514	0.421	1.006	0.27	0.834	0.337	1.006	0.273
NO3	(mg/L)					0.990	0.27	0.866	0.358	0.990	0.328
NO2	(mg/L)					0.001	0.00	0.004	0.003	0.001	0.002
NH3	(mg/L)	0.013	0.012	0.210	0.201	0.043	0.03	0.056	0.047	0.043	0.030
TKN	(mg/L)					0.692	0.19	0.861	0.227	0.692	0.119
SRP	(mg/L)	0.003	0.000	0.005	0.006	0.007	0.00	0.020	0.016	0.007	0.009
TP	(mg/L)	0.017	0.006	0.021	0.005	0.025	0.01	0.055	0.020	0.025	0.008
SiO2	(mg/L)					12.5	4.45	20.6	6.58	12.5	4.24
TURB	(NTU)	1.7	0.57	1.5	0.75	2.2	0.32	4.7	7.19	2.2	1.35
TSS	(mg/L)	2.2	0.84	2.4	0.89	7.8	0.44	7.6	5.09	7.8	3.63

Table B2. Means and standard deviations (Stdev) for data collected during June through October 2000 at four locations in the study area.

Year 2000	Units	WA/ID Stateline (RM 96.0)		Riverside Park (RM 66.0)		Downstream of Nine-Mile Dam (RM 58.1)		Latah Creek (RM 72.4)		Little Spokane River (RM 56.4)	
		Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
TEMP	(C)	18.4	6.25	15.0	3.77	15.8	2.34	13.9	4.28	13.7	2.48
COND	(µmhos/cm)	49.8	4.33	200.9	58.54	195.5	61.53	366.0	49.94	256.6	44.77
pH	(pH Units)	7.8	0.39	8.1	0.23	8.1	0.33	8.3	0.22	8.0	0.34
DO	(mg/L)	8.5	1.29	9.8	0.47	10.0	0.44	10.8	1.32	9.4	0.60
CL	(mg/L)	0.86	0.06	4.58	1.12	4.29	0.50	11.13	0.76	4.06	0.08
NO2_NO3	(mg/L)	0.070	0.038	1.155	0.437	1.169	0.464	0.948	0.193	1.206	0.146
NH3	(mg/L)	0.006	0.002	0.007	0.006	0.006	0.002	0.012	0.007	0.005	0.000
TPN	(mg/L)	0.130	0.048	1.196	0.408	1.215	0.445	1.126	0.141	1.269	0.106
SRP	(mg/L)	0.003	0.003	0.012	0.005	0.011	0.005	0.023	0.006	0.011	0.002
TP	(mg/L)	0.011	0.005	0.034	0.044	0.022	0.007	0.057	0.011	0.027	0.005
CHLa	(ug/L)	2.39	0.57	1.95	0.60	2.38	0.63	3.20	0.80	2.28	1.38
TOC	(mg/L)	1.40	0.20	1.09	0.42	1.08	0.29	2.17	0.14	1.15	0.54
DOC	(mg/L)	1.41	0.29	1.09	0.44	1.15	0.47	2.16	0.12	1.20	0.72
ALK	(mg/L)	19.8	0.67	80.3	22.26	83.6	26.44	179.5	4.12	123.2	7.66
TDS	(mg/L)	40.8	5.19	127.4	40.63	123.0	36.86	259.3	9.07	165.5	11.41
TURB	(NTU)	1.2	0.68	1.1	0.13	2.9	3.62	3.2	1.52	2.5	0.87
TSS	(mg/L)	1.4	0.82	2.0	0.71	2.3	1.26	5.8	3.27	6.8	1.79
CBODU	(mg/L)	2.3	0.73			1.7	0.39	3.0	0.06	1.2	0.17

Table B3. Means and standard deviations (Stdev) for data collected during June through October 2001 at four locations in the study area.

Year 2001	Units	WA/ID Stateline (RM 96.0)		Riverside Park (RM 66.0)		Downstream of Nine-Mile Dam (RM 58.1)[a]		Latah Creek (RM 72.4)		Little Spokane River (RM 56.4)	
		Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
TEMP	(C)	15.6	7.4	13.0	4.8	17.2	1.8	17.6	3.7	13.6	1.9
COND	(umhos/cm)	60.1	5.4	213.8	61.1	258.4	39.7	371.6	43.7	271.4	18.0
pH	(pH Units)	7.6	0.3	7.8	0.4	7.9	0.4	8.2	0.4	8.0	0.4
DO	(mg/L)	9.1	1.8	10.1	1.0	9.9	0.5	9.8	2.2	9.0	0.5
CL	(mg/L)	1.39	0.30	4.23	1.73	5.56	1.19	11.95	2.17	3.52	0.16
NO2-NO3	(mg/L)	0.103	0.052	1.373	0.717	1.720	0.368	0.906	0.222	1.276	0.077
NH3	(mg/L)	0.009	0.004	0.010	0.010	0.023	0.006	0.018	0.014	0.008	0.005
TPN	(mg/L)	0.149	0.048	1.217	0.850			0.974	0.290	1.326	0.083
TKN	(mg/L)	0.269	0.149	0.348	0.204	0.308	0.163	0.333	0.122	0.338	0.288
SRP	(mg/L)	0.008	0.004	0.020	0.021	0.011	0.004	0.016	0.008	0.010	0.003
TP	(mg/L)	0.019	0.007	0.036	0.024	0.024	0.005	0.033	0.013	0.017	0.006
CHLa	(ug/L)	0.00	0.00	0.00	0.00			4.60	3.01	2.63	2.12
TOC	(mg/L)	1.55	0.52	1.32	0.62	0.95	0.19	2.53	0.81	1.05	0.64
DOC	(mg/L)	1.74	0.53	1.42	0.52	1.14	0.33	2.41	0.74	1.08	0.48
ALK	(mg/L)	23.1	2.1	98.2	19.8	106.5	20.1	174.8	10.2	130.1	3.6
TDS	(mg/L)	42.3	10.1	257.6	388.5	143.8	32.2	245.9	26.3	167.3	12.0
TURB	(NTU)	1.04	0.39	2.14	2.67						
TSS	(mg/L)	2.7	2.78	3	2.11						
CBODU		2.4	0.59	2.5	0.71	2.7	0.75	3.2	0.46	1.7	0.59

[a] Data only collected July through September.

Table B4. Ultimate carbonaceous biochemical oxygen demand (CBODU) to 5-day BOD ratios and decay rates (*k*) for data collected by Ecology during 1999-2000 and by SRPTAC during 2001.

Source		Ecology CBODU:BOD5 (ratio)	Ecology *k* (day^{-1})	Dischargers CBODU:BOD5 (ratio)	Dischargers *k* (day^{-1})
Ambient	Average (n=28&55)	3.36	0.0704	3.64	0.0590
	Stdev	2.08	0.0318	1.34	0.0202
	95% confidence	0.76	0.0116	0.35	0.0053
	lower limit	2.61	0.0588	3.29	0.0537
	upper limit	4.12	0.0820	3.99	0.0643
Spokane POTW	Average (n=10&7)	2.82	0.0880	3.46	0.0531
	Stdev	2.09	0.0561	1.12	0.0169
	95% confidence	1.30	0.0347	0.83	0.0125
	lower limit	1.52	0.0532	2.63	0.0406
	upper limit	4.12	0.1227	4.29	0.0657
Liberty Lake POTW	Average (n=5&5)	5.27	0.0418	4.69	0.0518
	Stdev	1.55	0.0089	1.78	0.0215
	95% confidence	1.36	0.0078	1.56	0.0188
	lower limit	3.91	0.0354	3.13	0.0330
	upper limit	6.63	0.0510	6.25	0.0706
Kaiser IWTP	Average (n=7&5)	2.71	0.1302	1.96	0.1232
	Stdev	1.62	0.0765	0.21	0.0448
	95% confidence	1.20	0.0567	0.18	0.0393
	lower limit	1.52	0.0735	1.78	0.0839
	upper limit	3.91	0.1869	2.15	0.1625
IEPC	Average (n=8&5)	13.01	0.0175	9.68	0.0204
	Stdev	4.67	0.0061	3.10	0.0027
	95% confidence	3.23	0.0042	2.72	0.0024
	lower limit	9.77	0.0133	6.96	0.0180
	upper limit	16.24	0.0217	12.39	0.0228
IEPC (1995)	Average (n=8)			6.36	0.0469
	stdev			1.85	0.0106
	95% confidence			1.62	0.0093
	lower limit			4.74	0.0376
	upper limit			7.98	0.0562