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DEPARTMENT OF
ECOLOGY

Assessment of Changes in Water Quality in the Spokane River Between Riverside State Park and the Washington-Idaho Border

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Assessment of Changes in Water Quality in the Spokane River Between Riverside State Park and the Washington-Idaho Border

by
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February 2004

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Abstract

Among the 62 long-term stations monitored by the Washington State Department of Ecology's Freshwater Monitoring Unit are 16 sets of upstream/downstream stations that delineate stream reaches. Stations at the Spokane River at Riverside State Park and at Stateline comprise one of these sets. This report is the second in a series that presents results of an analysis of water quality monitoring data from these 16 reaches.

The status and trends in water quality in the Spokane River system in Washington is mixed. Cadmium, lead, and zinc enter the system from upstream, but significant amounts of nutrients and fecal coliform bacteria are added to the mainstem Spokane River, and Hangman Creek contributes large quantities of sediment. There are preliminary indications of declining metals concentrations, and sediment in Hangman Creek declined. Though ammonia and phosphorus concentrations also fell, other nitrogen forms, including total nitrogen, increased. Fecal coliform bacteria also increased, especially during the low-flow months.

Acknowledgements

The author of this report would like to thank the following people for their contribution to this study:

- Bob Cusimano and Ken Merrill for reviewing the manuscript.
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Introduction

The purpose of this paper is to report an analysis of water quality data from Washington State Department of Ecology (Ecology) Freshwater Monitoring Unit (FMU) ambient monitoring stations on the Spokane River at Riverside (Riverside) and, upstream, at Stateline and Post Falls (Stateline) and at Hangman Creek. The focus of the analysis is on water quality conditions at the lower station, the changes that occurred between stations, and temporal trends. Data from sources other than FMU were not included.

The objective of this analysis is to identify water quality constituents exhibiting water quality degradation between upstream and downstream stations or declining trends within the reach to help guide water quality management efforts. This reach of the Spokane River is one of 16 stream reaches where Ecology's Stream Monitoring Unit has sufficient data (defined as at least five common years of data collection between October 1978 through September 2002) for a paired-station analysis (Appendix A).

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Methods and Dataset Description

Sampling

Our sampling program is based on monthly grab samples. A detailed explanation of our stream monitoring program along with specific methods and quality control procedures may be found in our annual reports (e.g., Hallock 2003a) and Quality Control Monitoring Plan (Hallock 2003b), as well as on the World Wide Web (http://www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html).

Data Record

The upper station on the Spokane River was moved from a site adjacent to the USGS gage below Post Falls, Idaho (station 57A190) to the "Stateline" Bridge (station 57A150) in December 1990. The upstream dataset, referred to as "Stateline," consists of the combined data from these two stations unless otherwise specified (see Reach Description, below).

Water samples have been collected from the Spokane River at Riverside State Park (station 54A120) and either Post Falls or Stateline from water year (WY; October through September) 1978 through WY 2002. Prior to WY 1982, however, sample collection at the upper station was spotty, and the two stations were seldom sampled within 24 hours of each other. For this reason, I have begun the data analysis with WY 1982 (October 1, 1981). This combined dataset is very consistent and complete with only a few months missing in the entire 20-year period.

We have also had a long-term station at the mouth of an intermediate tributary, Hangman (Latah) Creek (station 56A070) for the entire evaluated period. Data from this station is used to determine whether the source of differences (or trends) in the reach is the Hangman Creek watershed.

We have monitored low-level metals concentrations at Stateline since May 1994; however, metals data collected from May 1994 through February 1995 had high and variable detection limits and were not used in analyses. The detection limit was used for below detection limit results. This will not affect trends, but may impart a slightly high bias to the distributions.

Data from Spokane's Wastewater Treatment Plant effluent and influent were obtained from Ecology's Water Quality Permit Life Cycle System (WPLCS). Monthly average results were available for most months from May 1992 though September 2003. Phosphorus data were only available for April through October.

Data Analysis

General water quality was assessed by a general review of the data, by comparing results to water quality standards (Table 1; WAC 173-201A), and by a review of Water Quality Index (WQI) results (Hallock, 2002). I assessed changes in water quality between upstream and downstream stations by evaluating the average difference in constituents between upstream/downstream-paired samples. To account for changes due to Hangman Creek, I evaluated the difference between flow-weighted results at Riverside vs. Stateline/Post Fall plus Hangman Creek. I considered statistically adjusting time sensitive constituents such as temperature, pH, and dissolved oxygen to a common time (noon) if the constituent contributed to degradation or poor water quality and if there was a statistically significant relationship between the constituent and the time of sample collection.

Table 1. Water quality criteria used to evaluate monitoring results. (Results outside the ranges indicated are considered to exceed the criterion.)

				Fecal Coliform	
Class	Temperature	Oxygen	pH	10 Pct	Geo. mean
A	<=20°C[a]	>8.0 mg/L	6.5<=pH<=8.5	<=200	<=100

[a] The Spokane River from Nine Mile Bridge (RM 58) to the Idaho border had a special temperature criterion of 20˚C.

Besides conducting trend analyses on individual stations, trends were reported on the *differences* between paired results based on downstream minus upstream results. In some cases, the "upstream" concentration was calculated as a flow-weighted average of data from Stateline and Hangman Creek. There are two advantages to calculating trends on differences. First, trends (and seasonality) common to both stations are eliminated; therefore, the source of potential trends is isolated to impacts within the stream reach rather than the entire watershed. Second, the procedure reduces unexplained sources of variability common to both stations, such as laboratory bias and (to a lesser extent) changes in precision, common trends in weather and discharge, etc.

Trends were evaluated using the Seasonal Kendall test for trend, with adjustment for serial correlation when present. The Mann-Kendall trend test was used when seasonality was absent. Except for oxygen, an increasing trend in the differences between upstream results and downstream results indicates degrading water quality within the evaluated stream reach while a decreasing trend indicates an improvement. Statistical significance was assumed at the 90 percent confidence level.

Statistical analyses were performed using WQHYDRO software (Aroner, 2002).

Reach Description

The Spokane River at Riverside State Park station is located at the footbridge in the park at river mile (RM) 66, about a mile below the Spokane Wastewater Treatment Plant. The Spokane River at Stateline station is 30 miles upstream on E. Appleway Avenue near State Line Village, Idaho, about a quarter mile below the I-90 Bridge and the Idaho border. The downstream station is 1640 feet above mean sea level and the upper station elevation is 1980 feet. The average gradient is, therefore, 0.2 percent (Figure 1).

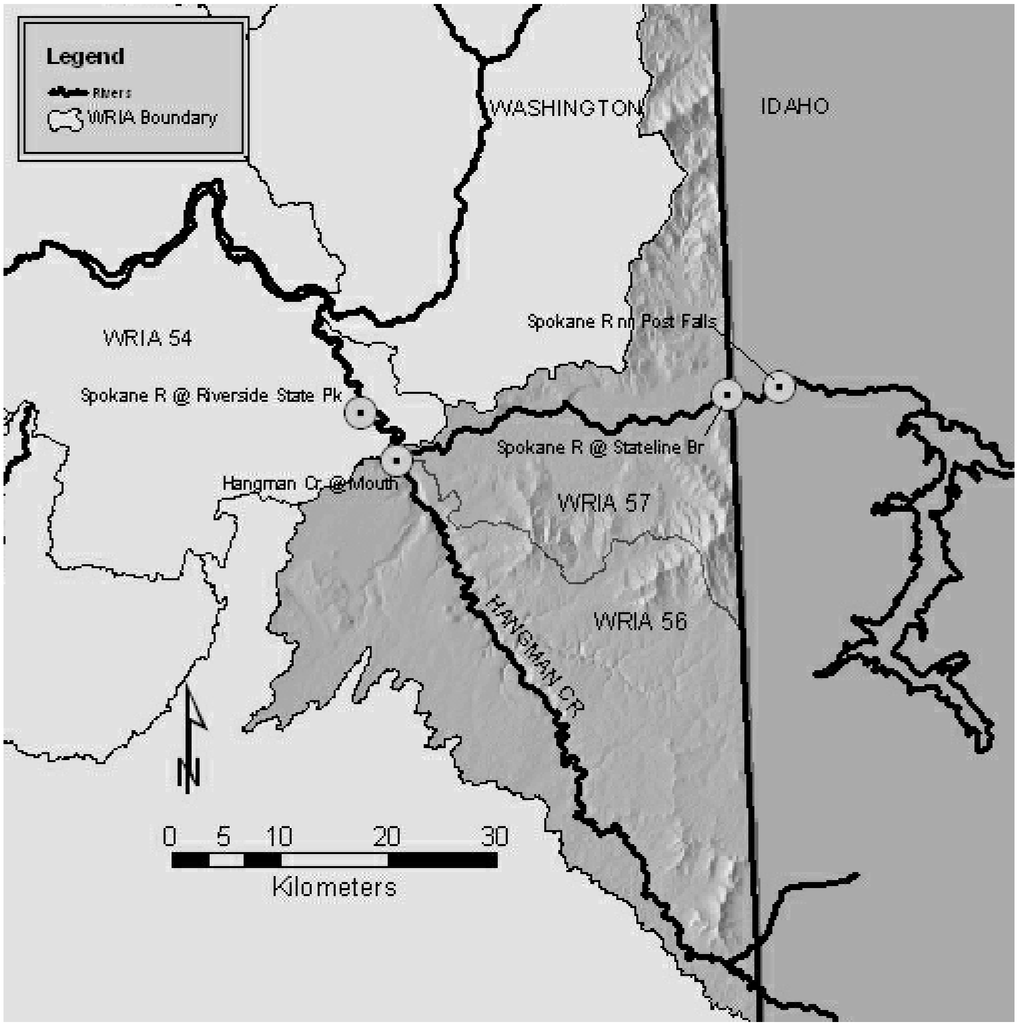

Figure 1. Map of the Spokane River showing ambient monitoring stations at Riverside, Stateline, Post Falls, and Hangman Creek. WRIA boundaries are also shown.

Prior to December 1990, we collected samples from a station near the USGS gage below Post Falls, Idaho at RM 100.7, 4.7 miles upstream of Stateline. There were few inputs between the Post Falls and Stateline stations that might affect water quality and data from these two stations have been combined.

Hangman Creek enters the Spokane River at RM 72.4. For most of the period being evaluated, we have had a long-term monitoring station near the mouth of the creek (at RM 0.6) on the West Riverside Avenue Bridge in the City of Spokane.

The watershed between Riverside and Stateline is 1140 square miles, more than half of which, 689 square miles, is drained by Hangman Creek. The watershed includes the City of Spokane, as well as several outlying communities. Besides Hangman Creek, Liberty and Newman Lakes drain to the reach. In addition, the Spokane Valley-Rathdrum Prairie Aquifer recharges portions of the reach, though the river-aquifer interaction is complex and water is lost to the aquifer in some areas and alternately lost and gained in others (Marti and Garrigues, 2001). Below Riverside, the river discharges to Long Lake and eventually to the Columbia River.

There are two hydroelectric dams in the reach between RM 66 and 99: Upriver dam (RM 79.9) and Upper Falls dam (RM 73.4). Both are run-of-the-river dams that cause shallow pooling (Cusimano, 2001).

The watershed between the two mainstem stations includes all of Water Resource Inventory Area (WRIA) 56 (Hangman) and WRIA 57 (Middle Spokane). A small portion of WRIA 54 (Lower Spokane) between Riverside State Park and Hangman Creek is also included in the reach being evaluated.

The watershed between Riverside and Stateline is mostly agricultural, especially in the Hangman Creek drainage. The upper elevations of WRIA 57 are heavily forested. The land adjacent to the river itself is mostly urban residential near the City of Spokane and agricultural east of Spokane to the Idaho border (Table 2). Point sources in the reach include public wastewater treatment facilities (Liberty Lake and City of Spokane), Kaiser Aluminum, and Inland Empire Paper Company (Cusimano, 2001). The City of Spokane treatment facility has included phosphorus removal since 1977 (Gibbons, et al., 1984).

Table 2. Land uses in WRIA 56 and 57 (http://www.ofm.wa.gov). (The reach between Riverside and Stateline includes a small portion of WRIA 54, not included below, that is mostly urban residential and forest.)

Definition	Total Acreage	WRIA 56	WRIA 57
Small Grains	126,309	122,123	4,186
Evergreen Forest	99,755	35,073	64,682
Shrubland	60,208	35,941	24,267
Fallow	58,350	50,699	7,651
Grasslands/Herbaceous	37,852	21,435	16,417
Low Intensity Residential	28,101	6,440	21,661
Pasture/Hay	21,105	7,239	13,866
Commercial/Industrial/Transportation	13,134	5,552	7,582
Mixed Forest	10,068	2,581	7,487
Transitional	5,963	284	5,679
Orchards/Vineyards/Other	4,717	1	4,716
Open Water	3,870	1,058	2,812
Urban/Recreational Grasses	2,339	1,188	1,151
Deciduous Forest	444	249	195
Bare Rock/Sand/Clay	398	312	86
Emergent Herbaceous Wetlands	398	229	169
Row Crops	389	60	329
High Intensity Residential	374	118	256
Woody Wetlands	245	108	137

The water body segment that includes Riverside is listed on Ecology's 1998 303d list for total phosphorus as an outgrowth of a Phase I Clean Lakes Restoration Project on Long Lake (Soltero, et al., 1992). This segment is also listed for dissolved oxygen (http://www.ecy.wa.gov/programs/wq/303d/1998/wrias/wria54.pdf). The Spokane River is listed for metals and other non-conventional contaminates but, except for an overview of our metals monitoring results, a review of those data is beyond the scope of this report. Hangman Creek is listed for fecal coliform, dissolved oxygen, temperature, and pH.

The population of Spokane County increased about one percent per year, on average, from 1980 to 2000, or 22% over the 20-year period. Growth in the City of Spokane has been somewhat slower at about 0.7 percent per year, or 14% overall (http://www.ofm.wa.gov).

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Results and Discussion

Water Quality Assessment

Time of Sample Collection

Through WY 1993, samples were usually collected at the lower station about a day before the upper (but never more than 24 hours apart). Since WY 1993, sample collection times at the two stations have been separated by a few hours except for 4 samples in WY 2002 taken a day apart; the station sampled first (Riverside or Stateline) was not consistent. For a description of sampling methods, see Hallock (2003a).

Of the four potentially time-sensitive constituents—temperature, ph, oxygen, and percent oxygen saturation—all exhibited statistically significant ($p<0.05$) relationships with the time of sample collection at the lower station (Table 3). However, only summer percent oxygen saturation had much of its variability explained by time ($r^2>0.10$), in spite of the fact that the time of sampling was generally mid-day during most of the data set, but early morning during several more recent years (Figure 2). At the upper station (Stateline), time did not explain much of the variability in any of the constituents, though sampling was later in the day during more recent years. (The lack of a relationship does not mean there are no diurnal changes in these constituents, of course. This analysis is based on monthly samples, not on continuous monitoring.)

Table 3. Correlations between temperature, pH, and oxygen and time of sample collection. (NS=not significant)

	All Months			Summer Months (Jun-Sep)		
Constituent	r^2	p	Model	r^2	p	Model
Spokane River at Riverside						
Temperature	0.018	<0.05	linear		NS	
pH	0.016	<0.05	linear	0.053	<0.05	linear
Oxygen	0.036	<0.05	quadratic	0.056	<0.05	linear
Pct. Oxy. Sat.	0.092	<0.05	linear	0.20	<0.05	linear
Spokane River at Stateline						
Temperature		NS			NS	
pH	0.019	<0.05	Lin-log	0.092	<0.05	quadratic
Oxygen		NS			NS	
Pct. Oxy. Sat.		NS		0.085	<0.05	hyperbolic
Hangman Creek near mouth						
Temperature	0.035	<0.05	linear	0.168	<0.05	linear
pH	0.092	<0.05	linear	0.283	<0.05	linear
Oxygen	0.066	<0.05	linear	0.337	<0.05	quadratic
Pct. Oxy. Sat.	0.134	<0.05	linear	0.355	<0.05	quadratic

Due to its much smaller volume, Hangman Creek is less buffered from diurnal affects and time was always correlated with measurements. In the summer, in particular, time of sampling explained quite a bit of the variability in the data. Riverside and Hangman Creek were generally sampled sequentially and the time of sampling plot for Hangman Creek appears nearly identical to that from Riverside.

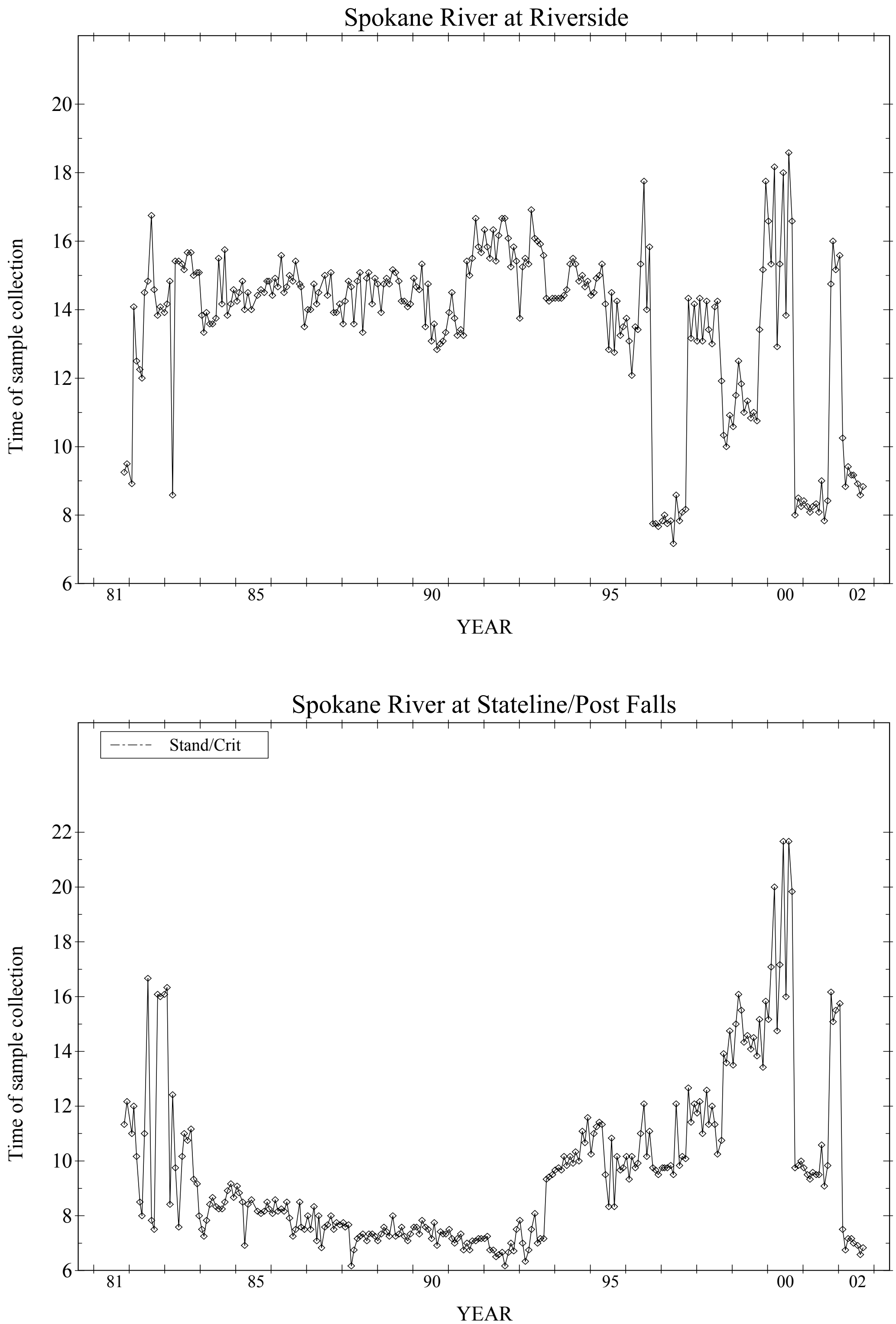

Figure 2. Time of sample collection at Spokane River at Riverside and at upstream stations (Stateline).

General Overview and Upstream/Downstream Comparisons

We have collected more than 500 samples from the Spokane River at Riverside and at Stateline since October 1981. Temperatures at the upper station exceeded the special water quality criterion of 20˚C more than ten percent of the time (Table 4). This may be due in part to the influence of Lake Coeur d'Alene, 15 miles upstream from the Washington/Idaho border, but artificially low flows due to withdrawals and impoundment by the dam at Post Falls may also be factors. Temperatures were cooler at the downstream station due to cooler groundwater recharge, especially in the reach downstream of Sullivan Road Bridge (Cusimano, 2001). The maximum seven-day average of daily maximums from 30-minute interval temperature monitoring in 2002 was 23.0 °C at Stateline; we did not monitor continuous temperature at Riverside.

Nearly ten percent of oxygen samples during the period evaluated were below the water quality criterion of 8.0 mg/L at Stateline. Low oxygen at the upstream station was likely influenced by Lake Coeur d'Alene. Only one sample was below the oxygen criterion at the downstream station. Although low dissolved oxygen was not a regular problem at the downstream station at the time we collected our samples, others have reported problems both within the reach (Pelletier, 1994a) and below the reach (Cusimano, 2001). Our monitoring design is unlikely to identify daily extreme values in constituents with large diurnal changes.

Overall, fecal coliform bacteria (FC) counts at Riverside were close to, but below the ten percent criterion of 200 colonies/100mL. FC counts at Riverside have been a problem in some years, however. Since WY 1982, more than 10 percent of the 12 monthly samples have exceeded the 200 colonies/100mL criterion during 5 years.

At the downstream station, 2002 WQI scores were low (indicating poor water quality) for total phosphorus, total nitrogen, suspended solids, and turbidity (Table 4). At the upper station, temperature and oxygen received low scores. Low nutrient and sediment scores indicate concentrations were high relative to other Northern Rockies streams; oxygen and temperature scores are based on the criteria in Washington's water quality standards. The distribution of data from the Riverside, Stateline, and Hangman Creek stations is shown in Appendix B.

All nutrients exhibited large percentage increases at the downstream station compared to the upstream station (Table 5). Fecal coliform bacteria, suspended solids, and turbidity were also much higher at Riverside, on average. For suspended solids, the median percent increase was relatively low, indicating, as might be expected, that high downstream relative to upstream suspended solids concentrations were not consistent, but flashy.

Combining flow-weighted Hangman Creek data, where water quality was quite poor (Table 4), with Stateline results, yielded much lower percentage increases, especially for FC, suspended solids, and turbidity (Table 6). (This analysis measures the affects of the reach between Riverside and Stateline, *excluding* the Hangman Creek drainage, on downstream water quality.) The contribution of Hangman Creek is even more apparent when examining average monthly flux (water quality constituent times discharge) (Table 7 and Figure 3). Hangman Creek alone may account almost entirely for the sediment flux at Riverside, as well as for a particularly disproportionate portion of nitrate plus nitrite and total nitrogen.

Table 4. Water quality summary for Spokane River at Riverside, Spokane River at Stateline, and Hangman Creek data collected from October 1981 through September 2002. Water Quality Index (WQI) scores are for WY 2002. Constituents where more than ten percent of samples exceeded water quality criteria or with WQI scores less than 80 are shown in bold.

Constituent	Station	WQI Score	Criterion	Number of Samples	Number Not Meeting Criteria	Percent Not Meeting Criteria	Notes
FC	Riverside	86	200[a]	242	21	8.7	
(col/100mL)	Stateline	93	200	239	2	0.8	
	Hangman	80	200	**225**	**36**	**16**	
Oxygen	Riverside	88	8	283	1	0.4	
(mg/L)	Stateline	**78**	8	284	28	9.9	
	Hangman	81	8	234	1	0.4	
pH	Riverside	88	6.5/8.5	287	11	3.4	Includes 1 value less than 6.5.
(std. units)	Stateline	90	6.5/8.5	280	4	1.4	Includes 4 values less than 6.5.
	Hangman	**77**	6.5/8.5	**232**	**71**	**30**	
Phosphorus, Total	Riverside	**62**	NA	272	NA	NA	
	Stateline	97	NA	273	NA	NA	
	Hangman	**70**	NA	229	NA	NA	
Suspended Solids	Riverside	**50**	NA	254	NA	NA	
	Stateline	97	NA	258	NA	NA	
	Hangman	**56**	NA	235	NA	NA	
Temperature	Riverside	90	20	290	0	0	
(˚C)	Stateline	**68**	20	283	36	**12.7**	
	Hangman	**77**	18	**233**	**48**	**21**	32 (14%) exceeded Spokane's 20˚C criterion.
Nitrogen, Total	Riverside	**53**	NA	106	NA	NA	
	Stateline	98	NA	107	NA	NA	
	Hangman	**41**	NA	103	NA	NA	
Turbidity	Riverside	**47**	NA	276	NA	NA	
	Stateline	91	NA	262	NA	NA	
	Hangman	**44**	NA	239	NA	NA	

[a] Fecal coliform bacteria are compared to the "ten percent" criterion of 200 colonies/100mL.

The higher concentrations of FC, total suspended solids (TSS), and total phosphorus (TP) at Riverside than at Stateline are evident in cumulative frequency distribution plots (Figures 4 through 6). Median TP at Riverside exceeded the 0.025 mg/L criterion set for below Nine Mile Bridge, eight miles downstream, during three of the five critical months (June through October; Figure 7).

Instantaneous monthly flows at Riverside, Stateline, and Hangman Creek are shown in Figure 8. Flows at Stateline were only slightly lower than flows at Riverside while Hangman Creek flows were a tiny fraction of the flow in the mainstem Spokane River. Hangman Creek is a much larger contributor of pollutants to the Spokane River than would be expected given its much lower flows.

Table 5. Percent increase at Riverside over Stateline ([downstream-upstream]/upstream*100) for various water quality constituents. Percentages greater than 0 indicate an increase in the constituent at the downstream station. Those constituents exhibiting more than a 100 percent change are shown in bold.

Constituent	Number of Pairs	Average Percent Change	Median Percent Change	Constituent	Number of Pairs	Average Percent Change	Median Percent Change
Ammonia	239	**420**	**118**	Phosphorus, Sol. Reac.	236	**220**	100
Conductivity	245	**137**	**110**	Phosphorus, Total	234	**198**	100
FC	234	**5154**	**334**	Suspended Solids	241	**923**	50
Flow	247	21	11	Temperature	247	18	2.3
Nitrate-Nitrite	167	**1818**	**1200**	Nitrogen, Total	106	**553**	**468**
Oxygen	248	11	9.3	Turbidity	238	**573**	16
pH	242	6.1	5.3				

Table 6. Percent increase at Riverside over the flow-weighted concentration of Stateline plus Hangman Creek for various water quality constituents. Percentages greater than 0 indicate an increase in the constituent at the downstream station. Those constituents exhibiting more than a 100 percent change are shown in bold.

Constituent	Number of Pairs	Average Percent Change	Median Percent Change	Constituent	Number of Pairs	Average Percent Change	Median Percent Change
Ammonia	207	**316**	92	Phosphorus, Sol. Reac.	200	**148**	84
Conductivity	215	**115**	88	Phosphorus, Total	202	**106**	68
FC	204	**1929**	**101**	Suspended Solids	209	47	23
Flow	218	23	14	Temperature	215	18	3.0
Nitrate-Nitrite	136	**1023**	**743**	Nitrogen, Total	89	**291**	**182**
Oxygen	216	10	8.6	Turbidity	205	16	0
pH	210	5.8	5.1				

Table 7. Average monthly flux (flow times constituent result) as a percent of flux at Spokane River at Riverside. The "unexplained" column is the net flux attributable to sources within the reach between Riverside and Stateline, excluding the Hangman Creek drainage, plus error. A negative number indicates a net loss in the reach.

Constituent	Hangman Creek	Stateline	Hangman plus Stateline	Unexplained
Ammonia	9.1%	31.2%	40.3%	59.7%
Conductivity	7.8%	55.8%	63.5%	36.5%
FC	16.0%	8.3%	24.4%	75.6%
Flow	0.7%	95.0%	95.7%	4.3%
Nitrate-Nitrite	50.1%	11.9%	62.0%	38.0%
Oxygen	4.3%	90.2%	94.5%	5.5%
pH	4.4%	90.9%	95.3%	4.7%
Phosphorus, Sol. Reac.	15.1%	46.6%	61.6%	38.4%
Phosphorus, Total	19.6%	42.6%	62.1%	37.9%
Suspended Solids	113.4%	8.7%	122.0%	-22.0%
Temperature	2.4%	83.7%	86.1%	13.9%
Nitrogen, Total	33.7%	26.0%	59.8%	40.2%
Turbidity	73.8%	10.5%	84.3%	15.7%

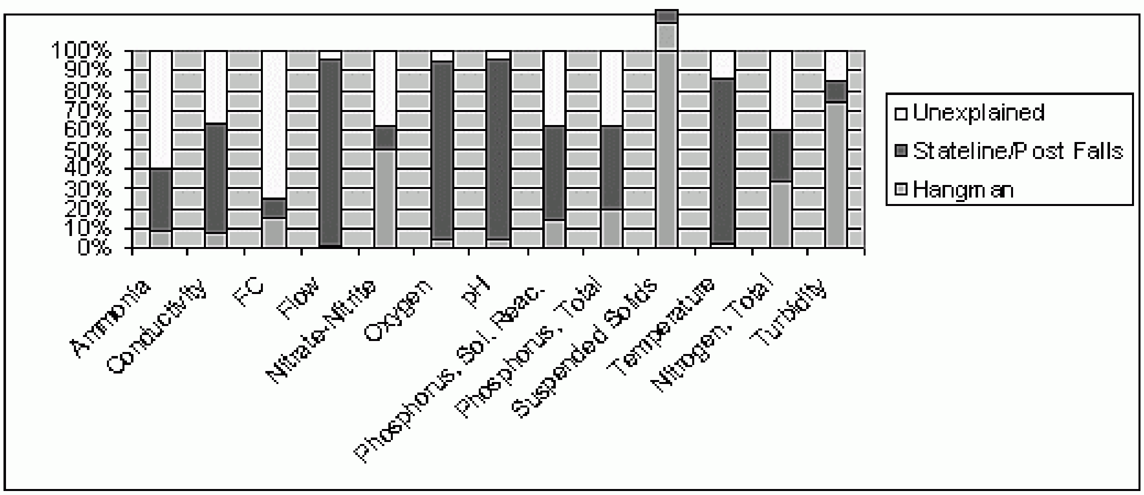

Figure 3. Average monthly flux (flow times constituent result) as a percent of Spokane River at Riverside. The "unexplained" portion is the net flux attributable to sources within the reach between Riverside and Stateline, excluding the Hangman Creek drainage, and error. Hangman Creek alone contributed 113 percent of the suspended solids at Stateline, indicating a net loss in the reach.

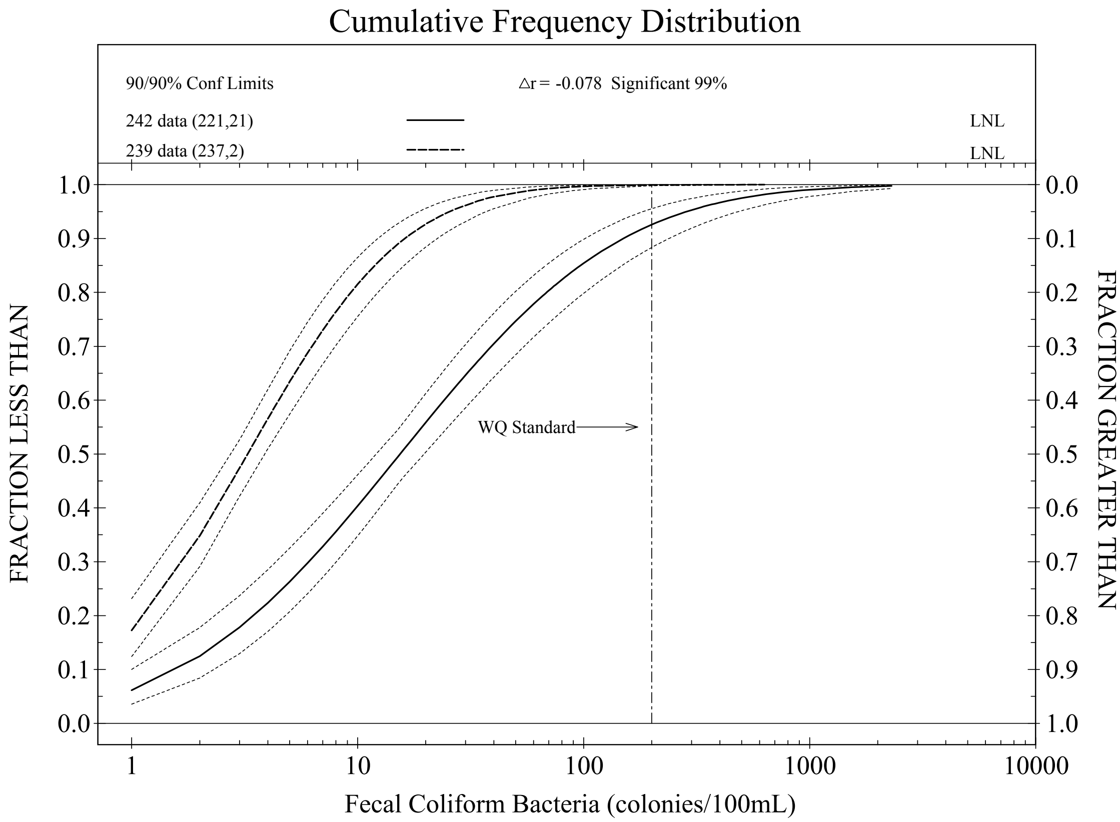

Figure 4. Cumulative frequency distribution for FC in the Spokane River at Riverside (—) and Stateline (**---**).

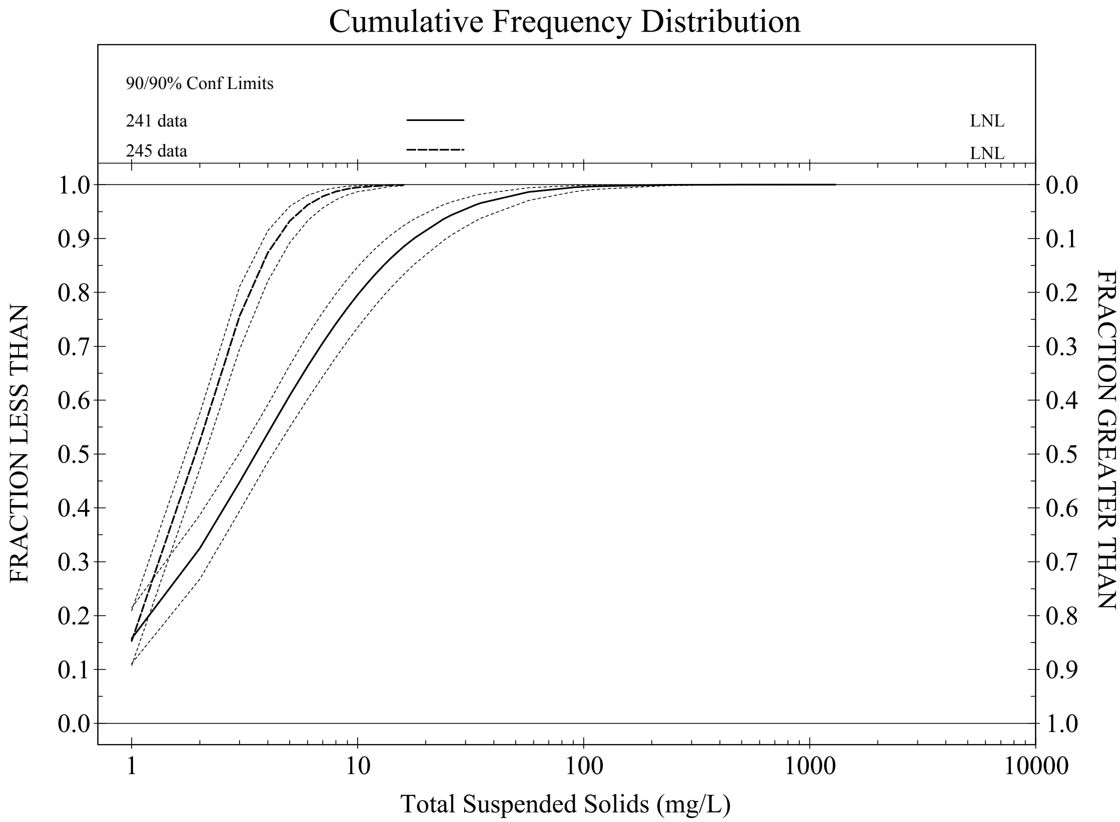

Figure 5. Cumulative frequency distribution for suspended solids in the Spokane River at Riverside (—) and Stateline (---).

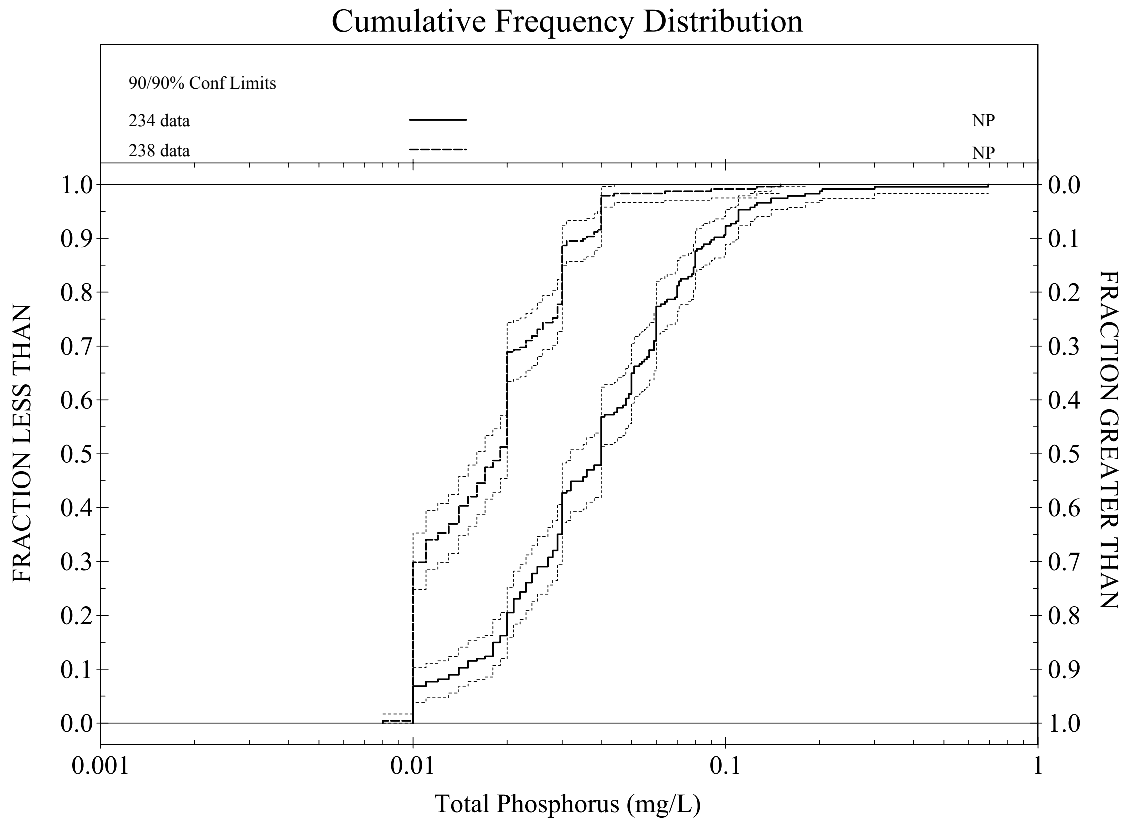

Figure 6. Cumulative frequency distribution for total phosphorus in the Spokane River at Riverside (—) and Stateline (---).

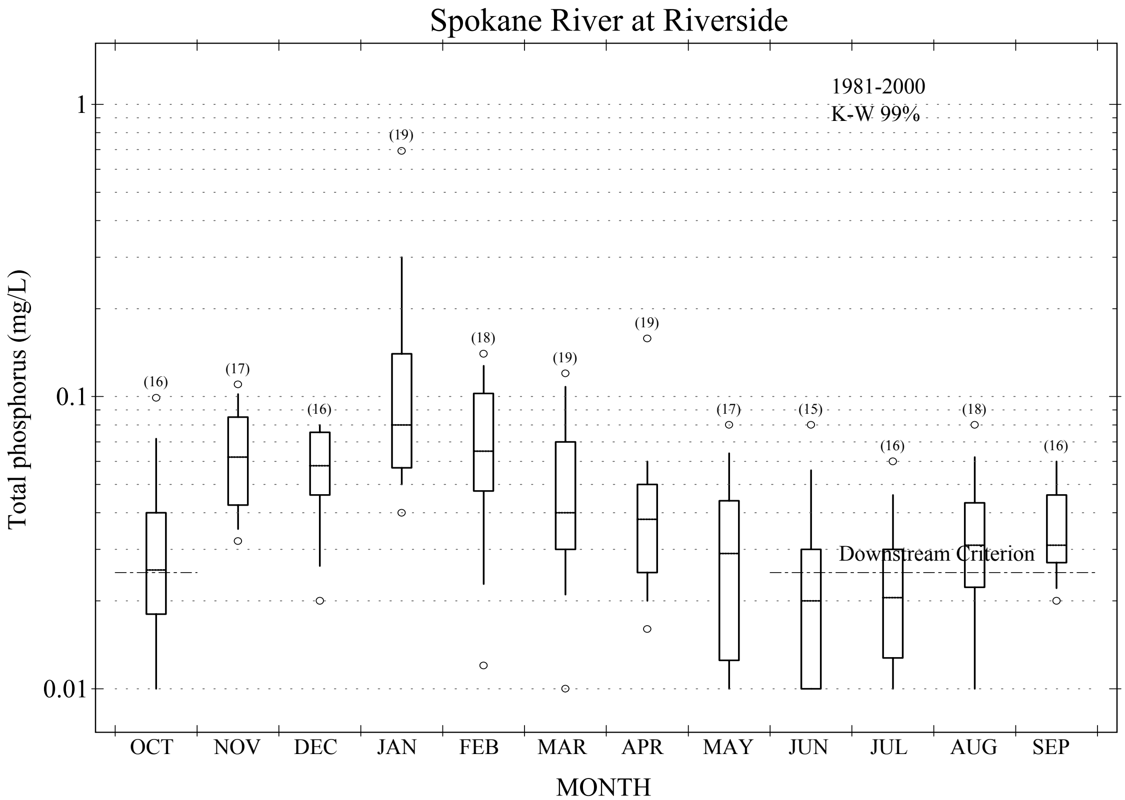

Figure 7. Seasonal distribution of total phosphorus concentrations at Spokane River at Riverside State Park. "K-W 99%" indicates the confidence level of the Kruskal-Wallis test for seasonality. The "Downstream Criterion" line does not apply at this station; it is included for comparison.

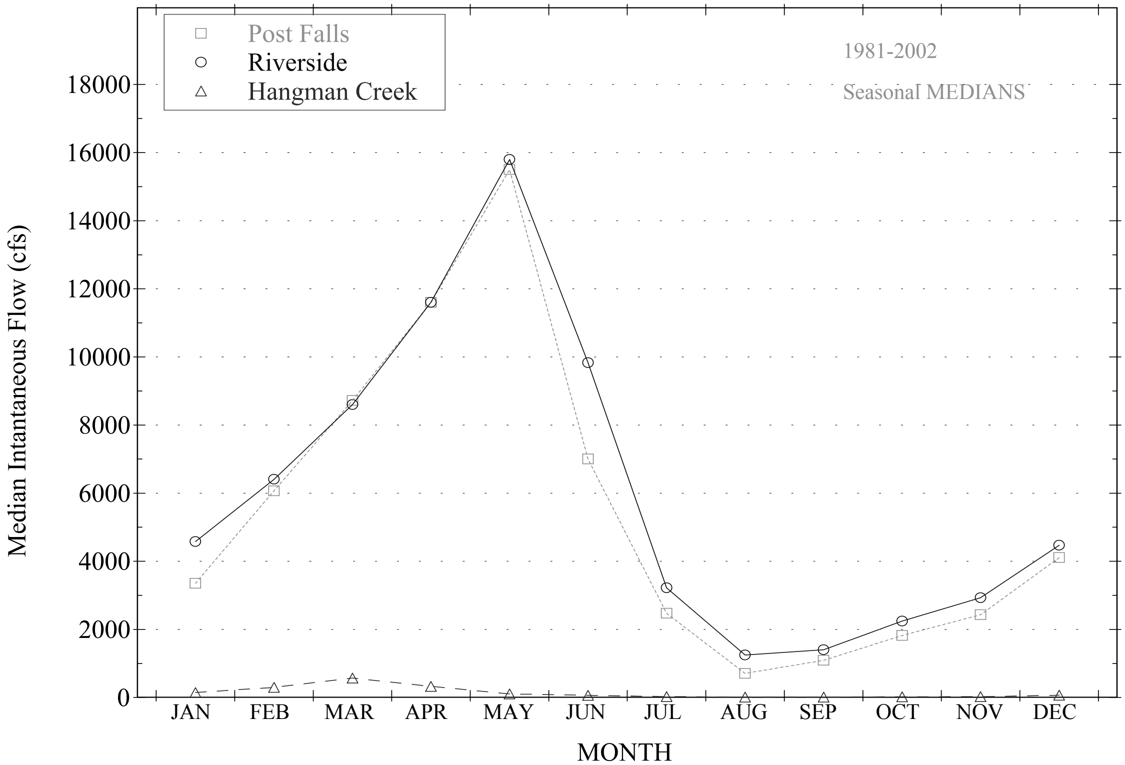

Figure 8. Median monthly instantaneous flow at Spokane River at Riverside State Park, Spokane River at Stateline, and Hangman Creek.

Trend Analysis

Flow

Instantaneous flow at the time of sampling was very stable during the period, with no significant trends overall (Table 8). The monthly average of daily flows was also stable (Figure 9), nor were there trends in particular months or seasons. However, there were indications of a decline in the 7-day low flow, which, though not important to the following trend analyses, may be important in other contexts. Flows tended to be lowest in August and highest in April and May (Figure 10).

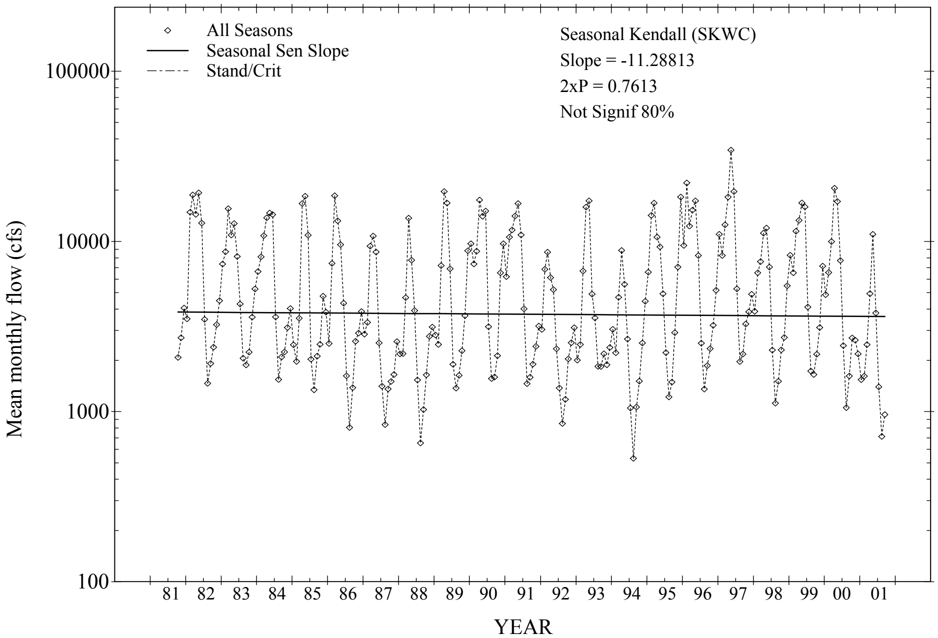

Figure 9. Monthly average of daily flows at Spokane River at Riverside State Park.

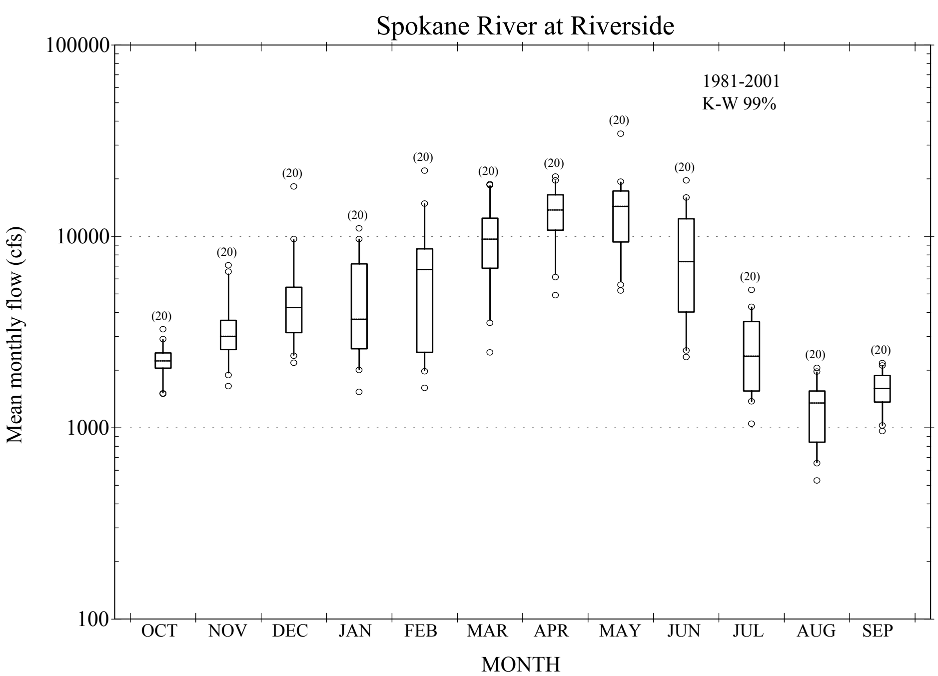

Figure 10. Monthly average of daily flows at Spokane River at Riverside State Park. “K-W 99%” indicates the confidence level of the Kruskal-Wallis test for seasonality.

Temperature

Temperatures at Riverside cooled significantly ($p<0.1$), though the trend magnitude was small (0.6 ˚C drop over ten years). However, when the data were adjusted to a common time of collection, there was no significant trend. In other words, the apparent trend was probably due to sampling earlier in the day in more recent years. There were no significant temperature trends at the other stations. There were declining trends in the “difference” datasets, both with and without the Hangman Creek drainage, but these may also be attributable to changing time of collection. There was no trend in the monthly mean of daily maximum air temperatures measured at the Spokane Airport ($p=0.94$), nor was there a trend in water temperatures at Riverside when corrected for time of day and for maximum daily air temperature ($p=0.23$).

pH

There was a possible increasing trend in pH at Stateline during the period. However, pH is a particularly difficult constituent to measure consistently over time and trends must be interpreted with caution. Direct trends on pH differences are invalid. Because pH is the negative log of the hydrogen ion (H^+) concentration, the difference between 7.0 and 7.1 is not the same, in terms of H^+, as the difference between 8.0 and 8.1. There was an increasing trend in H^+ within the reach (which corresponds to a decreasing (improving) trend in pH).

Sediment

Turbidity appeared to decline significantly at all three stations. However, the detection limit for turbidity changed from 1 to 0.5 NTUs in the early 1990s. Only Hangman Creek (where turbidity was seldom below 1 NTU anyway) showed an improvement after adjusting all turbidity data below 1 to 1. Hangman Creek was also the only station to show a significant decline in suspended solids concentrations. There were no significant changes in turbidity or total suspended solids (TSS) within the reach, either with or without the Hangman Creek drainage included. In other words, although conditions improved in Hangman Creek, no improvements were evident within the mainstem Spokane River.

TSS was strongly correlated with flow in Hangman Creek ($r^2=0.82$, $p<0.05$, linear), but the relationship between TSS and flow was poor at best in the main Spokane River (Riverside: $p>0.05$; Stateline: $r^2=0.04$, $p<0.05$, quadratic). After adjusting for flow, the TSS trend in Hangman Creek was no longer significant ($p=0.12$); that is, the decline in TSS is probably due, at least in part, to changes in flow. The declining turbidity trend remained significant even after adjusting for flow.

Table 8. Trends in ambient monitoring data collected by Ecology from WY 1982 through WY 2002 (unless otherwise specified). Statistically significant trends not shown in bold are suspect (see text).

Station	Station ID	Slope (units/yr)	2-tailed probability	Significant (90%)	Statistital Test Used[a]
Temperature (˚C)					
Spokane River at Riverside	54A120	-0.060	0.048	Yes ↓	skwc
corrected for time of collection	54A120	-0.012	0.749	N	skwc
Spokane River at Stateline	57A150	0.000	0.962	N	skwc
Hangman Creek	56A070	-0.060	0.193	N	skwc
corrected for time of collection	56A070	-0.034	0.463	N	skwc
Upstream/Downstream Difference[b]	NA	-0.045	0.003	Yes ↓	skwc
Up (incl. Hangman)/Down Diff.[b]	NA	-0.041	0.003	Yes ↓	skwc
Flow (cfs)					
Spokane River at Riverside	54A120	-3.702	0.935	N	skwc
Spokane River at Stateline	57A150	0.000	0.986	N	skwc
Hangman Creek	56A070	0.129	0.613	N	skwoc
Upstream/Downstream Difference	NA	-11.957	0.135	N	skwc
Up (incl. Hangman)/Down Diff.[b]	NA	-9.112	0.255	N	skwc
Conductivity (µsiemans/cm)					
Spokane River at Riverside	54A120	-0.063	0.834	N	skwc
Spokane River at Stateline	57A150	-0.335	0.006	**Yes ↓**	skwc
Hangman Creek	56A070	1.135	0.092	**Yes ↑**	skwc
Upstream/Downstream Difference	NA	0.376	0.231	N	skwc
Up (incl. Hangman)/Down Diff.b	NA	0.323	0.185	N	skwc
Oxygen (mg/L)					
Spokane River at Riverside	54A120	-0.040	0.004	**Yes ↓**	skwc
July-October	54A120	-0.050	0.000	**Yes ↓**	skwc
corrected for time of collection	54A120	-0.027	0.063	**Yes ↓**	skwc
corrected for time; July-October	54A120	-0.043	0.002	**Yes ↓**	skwc
Spokane River at Stateline	57A150	-0.007	0.476	N	skwc
Hangman Creek	56A070	-0.023	0.171	N	skwc
corrected for time of collection	56A070	-0.018	0.152	N	skwc
corrected for time; July-October	56A070	-0.080	0.023	**Yes ↓**	skwc
Upstream/Downstream Difference	NA	-0.025	0.126	N	skwc
Up (incl. Hangman)/Down Diff.[b]	NA	-0.024	0.147	N	skwc
corrected for time of collection	NA	-0.010	0.410	N	skwc
corrected for time; July-October	NA	-0.047	0.013	**Yes ↓**	skwc
Percent Saturation (%)					
Spokane River at Riverside	54A120	-0.500	0.003	**Yes ↓**	skwc
July-October	54A120	-0.678	0.001	**Yes ↓**	skwc
corrected for time; July-October	54A120	-0.431	0.004	**Yes ↓**	skwc
Spokane River at Stateline	57A150	0.000	0.987	N	skwc
Hangman Creek	56A070	-0.334	0.076	**Yes ↓**	skwc
Upstream/Downstream Difference	NA	-0.431	0.024	**Yes ↓**	skwc
July-October	NA	-0.809	0.003	**Yes ↓**	skwc
Up (incl. Hangman)/Down Diff.[b]	NA	-0.367	0.041	**Yes ↓**	skwc
July-October	NA	-0.811	0.005	**Yes ↓**	skwc

Station	Station ID	Slope (units/yr)	2-tailed probability	Significant (90%)	Statistital Test Used[a]
pH (standard units)					
Spokane River at Riverside	54A120	0.005	0.300	N	skwc
Spokane River at Stateline	57A150	0.021	0.003	**Yes ↑**	skwc
corrected for time of collection	57A150	0.020	0.006	**Yes ↑**	skwc
Hangman Creek	56A070	-0.003	0.389	N	skwc
Upstream/Downstream Difference: H^+	NA	0.000[c]	0.036	**Yes ↑**	skwc
Up (incl. Hangman)/Down Diff: H^+ [b]	NA	0.000	0.102	N	skwc
Suspended Solids (mg/L)					
Spokane River at Riverside	54A120	0.000	0.117	N	skwoc
Spokane River at Stateline	57A150	0.000	0.480	N	skwoc
Hangman Creek	56A070	-0.266	0.008	**Yes ↓**	skwc
Adjusted for flow (r^2=0.82)		-0.500	0.121	N	skwc
Upstream/Downstream Difference	NA	0.000	0.789	N	skwc
Up (incl. Hangman)/Down Diff.[b]	NA	0.001	0.697	N	skwc
Hangman Flux as Pct of Riverside	NA	-0.06%	0.254	N	skwc
Nitrogen, Total (mg/L) (Data collected since WY 1994)					
Spokane River at Riverside	54A120	0.019	0.099	**Yes ↑**	skwc
Adjusted for flow (r^2=0.62)		0.020	0.113	N	skwc
Adjusted for flow, Jul-Oct		0.036	0.031	**Yes ↑**	skwc
Spokane River at Stateline	57A150	-0.002	0.241	N	skwc
Hangman Creek	56A070	-0.033	0.399	N	skwc
Upstream/Downstream Difference	NA	0.018	0.033	**Yes ↑**	skwoc
Up (incl. Hangman)/Down Diff.[b]	NA	0.029	0.038	**Yes ↑**	skwc
Nitrogen, Ammonia (mg/L)					
Spokane River at Riverside	54A120	-0.003	0.000	**Yes ↓**	skwc
Spokane River at Stateline	57A150	0.000[c]	0.065	Yes ↓	skwc
Hangman Creek	56A070	-0.001	0.002	**Yes ↓**	skwc
Upstream/Downstream Difference	NA	-0.003	0.000	**Yes ↓**	skwc
Up (incl. Hangman)/Down Diff.[b]	NA	-0.003	0.000	**Yes ↓**	mkwc
Nitrogen, Nitrate+Nitrite (mg/L) (Data collected since WY 1988)					
Spokane River at Riverside	54A120	0.025	0.001	**Yes ↑**	skwc
Spokane WTP Effluent (since 1992)[d]		1.198	0.002	**Yes ↑**	skwc
Spokane River at Stateline	57A150	0.003	0.001	**Yes ↑**	skwc
Hangman Creek	56A070	0.022	0.030	**Yes ↑**	skwc
Upstream/Downstream Difference	NA	0.020	0.003	**Yes ↑**	skwc
Up (incl. Hangman)/Down Diff.[b]	NA	0.013	0.002	**Yes ↑**	skwc
Nitrogen, Organic (mg/L) (=Total Nitrogen-[nitrate+nitrite + ammonia]; Data collected since WY 1994)					
Spokane River at Riverside	54A120	-0.003	0.424	N	skwc
Spokane WTP Effluent (since 1992) [d]		0.027	0.465	N	skwc
Phosphorus, Total (mg/L) (through April 2000) [e]					
Spokane River at Riverside	54A120	-0.0009	0.100	**Yes ↓**	skwc
Spokane WTP Influent (since 1992) [d]		0.0844	0.004	**Yes ↑**	skwc
Spokane WTP Effluent (since 1992) [d]		0.0000	0.000	N	skwc
Spokane River at Stateline	57A150	-0.0003	0.053	**Yes ↓**	skwc
Hangman Creek	56A070	0.0003	0.395	N	skwc
Jul-Nov		-0.0012	0.116	N	skwc

Station	Station ID	Slope (units/yr)	2-tailed probability	Significant (90%)	Statistital Test Used[a]
Dec-Jun		0.0029	0.020	**Yes ↑**	skwc
Adjusted for flow (r^2=0.04)		0.0005	0.362	N	skwc
Upstream/Downstream Difference	NA	0.0000	0.325	N	skwc
Up (incl. Hangman)/Down Diff.[b]	NA	-0.0002	0.395	N	skwc
Phosphorus, Sol. Reactive (mg/L)					
Spokane River at Riverside	54A120	-0.0000[c]	0.003	Yes ↓	skwc
Adj. for detection limit change	54A120	-0.0003	0.003	Yes ↓	skwc
Spokane River at Stateline	57A150	-0.0001	0.001	Yes ↓	skwc
Adj. for detection limit change	54A120	-0.0000[c]	0.007	Yes ↓	skwc
Hangman Creek	56A070	-0.0009	0.005	**Yes ↓**	skwc
Adj. for detection limit change	54A120	-0.0009	0.004	**Yes ↓**	skwc
Upstream/Downstream Difference	NA	0.000	0.230	N	skwc
Up (incl. Hangman)/Down Diff.[b]	NA	0.000	0.223	N	skwc
Turbidity (NTU)					
Spokane River at Riverside	54A120	-0.022	0.045	Yes ↓	skwc
Adj. for detection limit change	54A120	0.000	0.172	No	skwc
Spokane River at Stateline	57A150	-0.022	0.035	Yes ↓	skwc
Adj. for detection limit change	57A150	0.000	0.219	No	skwc
Hangman Creek	56A070	-0.113	0.068	Yes ↓	skwc
Adjusted for flow (r^2=0.43)		-0.260	0.032	**Yes ↓**	skwc
Adj. for detection limit change		-0.112	0.069	**Yes ↓**	skwc
Upstream/Downstream Difference	NA	0.000	0.674	N	skwc
Up (incl. Hangman)/Down Diff.[b]	NA	0.002	0.693	N	skwc
Fecal Coliform Bacteria (colonies/100mL)					
Spokane River at Riverside	54A120	0.461	0.041	**Yes ↑**	skwc
July through November	54A120	1.001	0.001	**Yes ↑**	skwc
December through January	54A120	0.0715	0.666	N	skwc
Spokane WTP Effluent (since 1992)[d]		0.100	0.830	N	skwc
July through November		0.949	0.228	N	skwc
Spokane River at Stateline	57A150	0.125	0.000	**Yes ↑**	skwc
Hangman Creek	56A070	-0.100	0.820	N	skwc
Upstream/Downstream Difference	NA	0.300	0.066	**Yes ↑**	skwoc
Up (incl. Hangman)/Down Diff.[b]	NA	0.351	0.008	**Yes ↑**	skwoc
Total Nitrogen : Total Phosphorus Ratio (October 1993-April 2000)					
Spokane River at Riverside	54A120	-0.845	0.327	N	skwc
Spokane River at Stateline	57A150	-1.024	0.222	N	skwc

[a] The Seasonal Kendall test for trend (sk) was used when seasonality was present in the data (2p>0.25), otherwise, the Mann-Kendall test (mk) was used. Trend tests were corrected for serial correlation (wc) when present (2p>0.25) otherwise no correction was used (woc).

[b] Trends on downstream results minus upstream results where upstream results include flow-weighted results from Hangman Creek will exclude sources of trends in the Hangman Creek drainage (i.e., trend sources will be primarily limited to the mainstem Spokane River between Riverside and Stateline).

[c] A slope of 0 can occur even when the trend is significant if there are a large number of tied values.

[d] Spokane WTP data were available from May, 1992 through September, 2003. Effluent and influent TP were only collected from April through October.

[e] Total phosphorus trends did not include data collected after April 2000. Due to a methods change, total phosphorus data collected since then may have a positive bias that could artificially affect trends.

Fecal Coliform Bacteria

There was a significant increasing trend in bacteria counts at both mainstem stations, but not at Hangman Creek (Table 8). The increasing trend at Riverside can be seen graphically in the running geometric mean of FC data (Figure 11). Trends at Riverside were seasonal; FC concentrations increased substantially during July through November (Figure 12), but there was no trend during other months. There was no trend in FC in Spokane Wastewater Treatment Plant (WTP) effluent, either year-round or during July through November. The cause of the increase in FC is unknown, but the increase is attributable to the mainstem Spokane River, rather than Hangman Creek or sources upstream of Stateline. The lack of a declining trend in FC during wet-season months is disappointing since by 1990, the City of Spokane had reduced the volume of combined sewage overflows (CSO) by about 85 percent (http://www.spokanewastewater.org/csoinfo.asp). It's entirely possible that without the CSO reductions, bacteria would have increased during the wet months as well.

Though trends exhibited seasonality, the FC concentrations themselves did not; the distribution was similar across all months (Figure 13). Nor were FC counts correlated with discharge ($p>0.05$). In fact, flow explained less than 1 percent of the variability in the FC data. This can be indicative of both point and non-point sources.

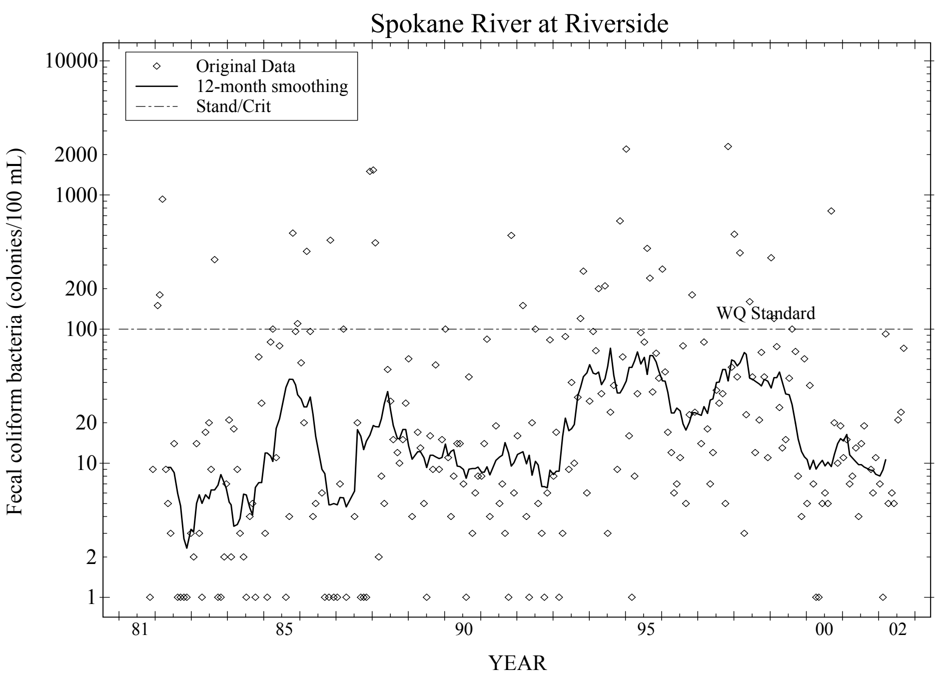

Figure 11. Twelve-month running geometric mean of FC data at Spokane River at Riverside.

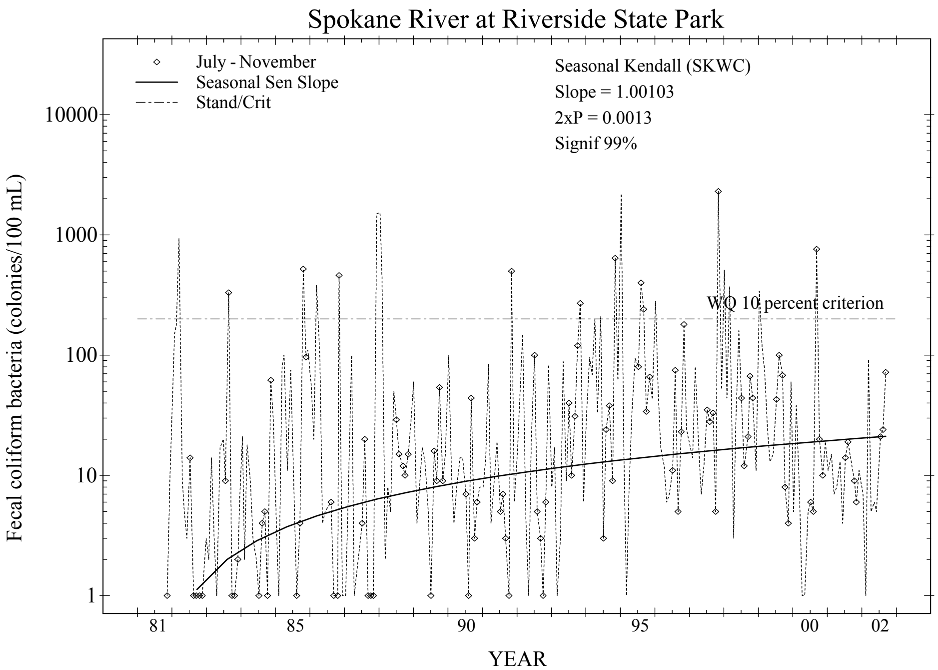

Figure 12. Trend in FC at Spokane River at Riverside, July through November months only. The trend line is curved because the y-axis is logarithmic.

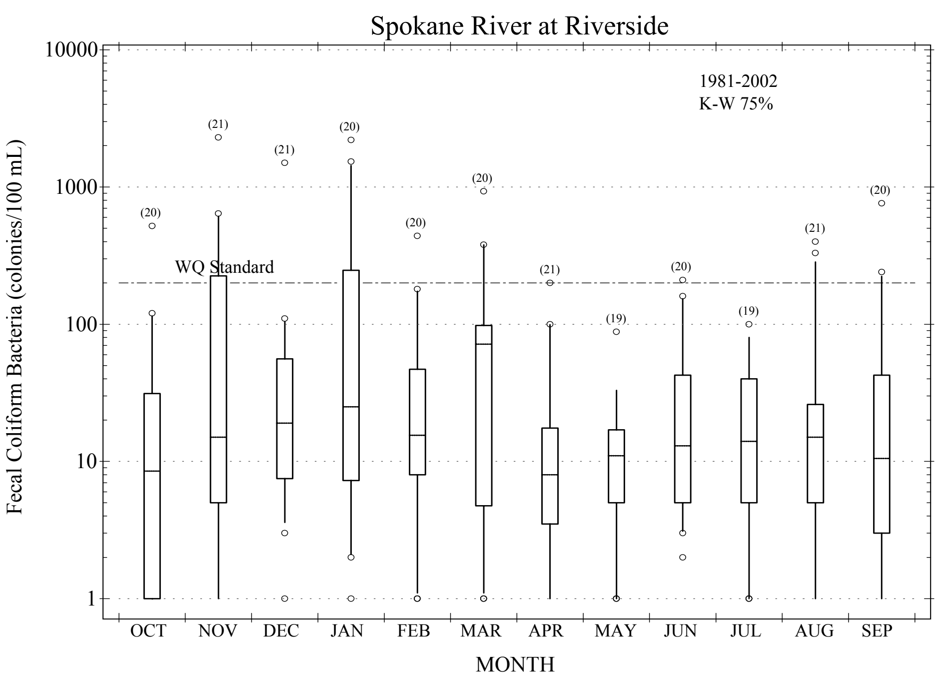

Figure 13. Seasonal distribution of FC data at Spokane River at Riverside. "K-W 75%" indicates the confidence level of the Kruskal-Wallis test for seasonality.

Oxygen

Oxygen concentrations declined at Riverside, both in absolute terms and when corrected to a common time of collection ($p<0.1$; Table 8). The trend was most pronounced during July through October (Figure 14). The declining trend during those months may be partly attributable to a declining trend in oxygen concentrations in Hangman Creek, but the trend remained significant even when the effects of Hangman Creek were removed. July through October are also the months when oxygen concentrations tended to be the lowest.

Declining oxygen concentrations may at first seem a bad thing, but these trends are based on instantaneous concentrations, collected more or less at mid-day. In fact, oxygen was frequently supersaturated and the decline in concentration (coupled with a decrease in temperature) has resulted in a reduction of the supersaturated condition (Figure 15). Oxygen trends on daily grab samples may not directly correlate with trends on daily minima. In fact, if the decrease in mid-day supersaturated concentrations is due to reduced productivity, daily minima may very well be increasing. Unfortunately, we have no data to directly test this hypothesis.

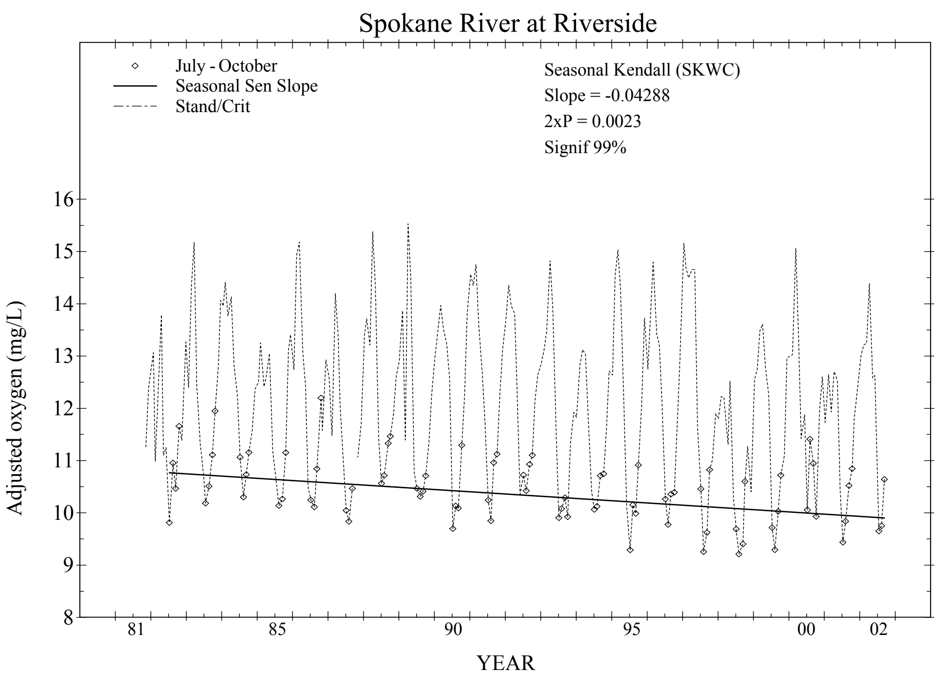

Figure 14. Trend in oxygen, adjusted to a common collection time (noon) at Spokane River at Riverside, July through October months only.

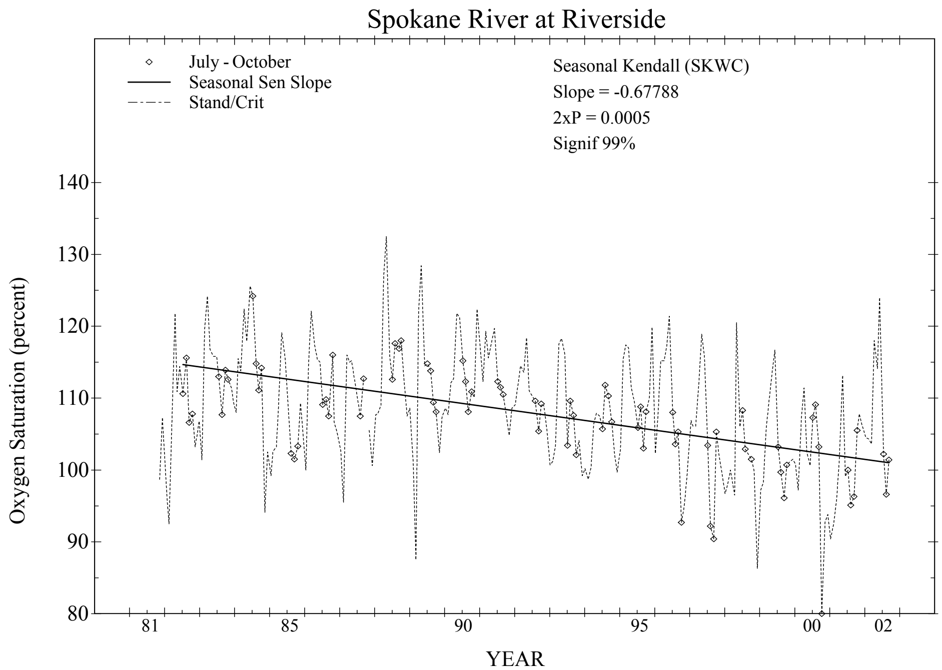

Figure 15. Trend in oxygen saturation at Spokane River at Riverside, July through October months only.

Nutrients

Total nitrogen (TN) at Riverside increased nearly 0.02 mg/L per year since we began collecting TN data in WY 1994 (Figure 16). This equates to 0.18 mg/L over the nine years evaluated, or 24% of the median (Appendix B). As large as this increase was, the trend was just barely statistically significant (p=0.099) because of variability in the data. Concentrations were strongly inversely related to flow (log-log, r^2=0.62)—indicating a point (or groundwater) source. Adjusted for flow, the overall trend was no longer significant (p=0.11) but the flow-adjusted July-October period, when TN concentrations tended to be highest and flows lowest, increased dramatically and significantly (slope=0.036 mg/L/year, p=0.03). The total nitrogen trend was not significant at either Hangman Creek or Stateline, but it was significant in both “difference” datasets indicating the source of the increase in nitrogen is neither upstream of Stateline nor in the Hangman Creek drainage. (The Spokane WTP is the most likely source.) In percentage terms, this rate of increase in nitrogen is nearly double the 20-year growth rate of Spokane’s population.

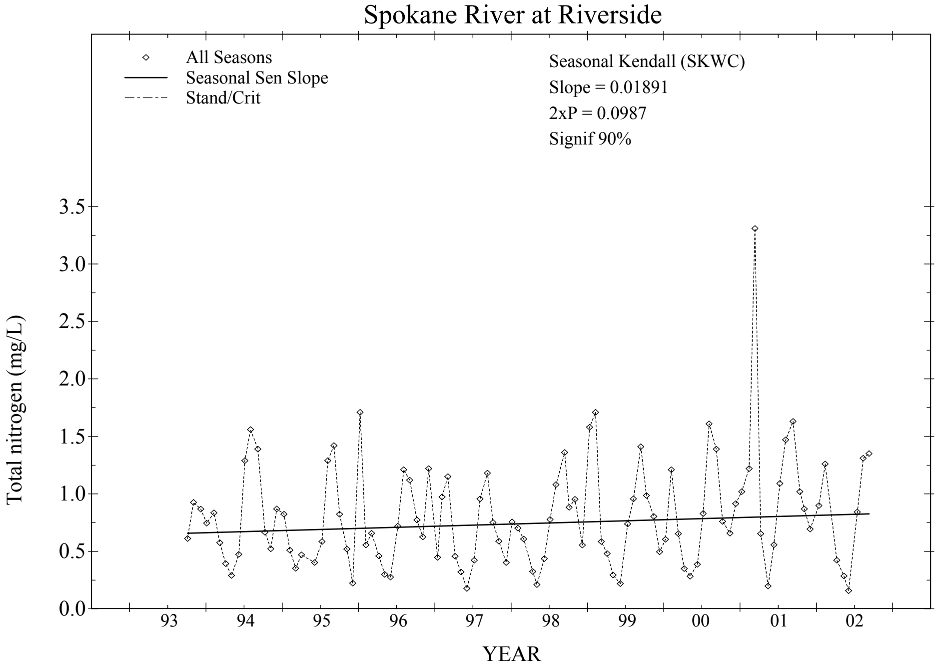

Figure 16. Trend in total nitrogen at Spokane River at Riverside. The unusually high value on March 13, 2001 was accompanied by nearly as high a nitrate+nitrite concentration.

All datasets exhibited steadily increasing trends in nitrate+nitrite-nitrogen (NO23). The absolute slope at Stateline was smallest (0.003 mg/L), but this represents an increase of 7.5 percent of the median, the largest relative increase of all three stations (Riverside and Hangman Creek increased 4.6 and 1.8 percent of the median, respectively). NO23 was not correlated with flow at Stateline ($p<0.05$). NO23 was inversely correlated with flow at Riverside (log-log, $r^2=0.54$), indicating a point source, and positively correlated at Hangman Creek (log-linear, $r^2=0.19$), indicating a non-point source. NO23 in Spokane WTP effluent, which contributed 35% of the average flux at Riverside, increased at a rate of more than 1 mg/L per year since 1992 (Figure 17).

Conversely, all datasets exhibited decreasing ammonia trends. However, the trend at Stateline was very small and concentrations were low; the ammonia trend at this station may have been influenced by imprecision/contamination that is present in most of our low-level ammonia data prior to the mid-1980s. However, ammonia concentrations were much higher at Riverside and in Hangman Creek. Based on the magnitude of the trends at these stations, the trend in the "difference" datasets, and the relative concentrations, most of the improvement can be attributed to the mainstem Spokane River. There was a sharp drop in ammonia concentrations at Riverside in 1992-93 (Figure 18).

The decrease in ammonia and increase in nitrate+nitrite and TN may be partly explained by more thorough oxidation of nitrogenous waste at the Spokane WTP (ammonia limits were imposed in the mid 1990's). There was no trend in organic nitrogen at Riverside (calculated as ON = TN -

[NO23 + ammonia]; slope=-0.003 mg/L, p=0.42) or at the WTP, indicating that most of the increasing trend in TN may be attributable to increasing NO23.

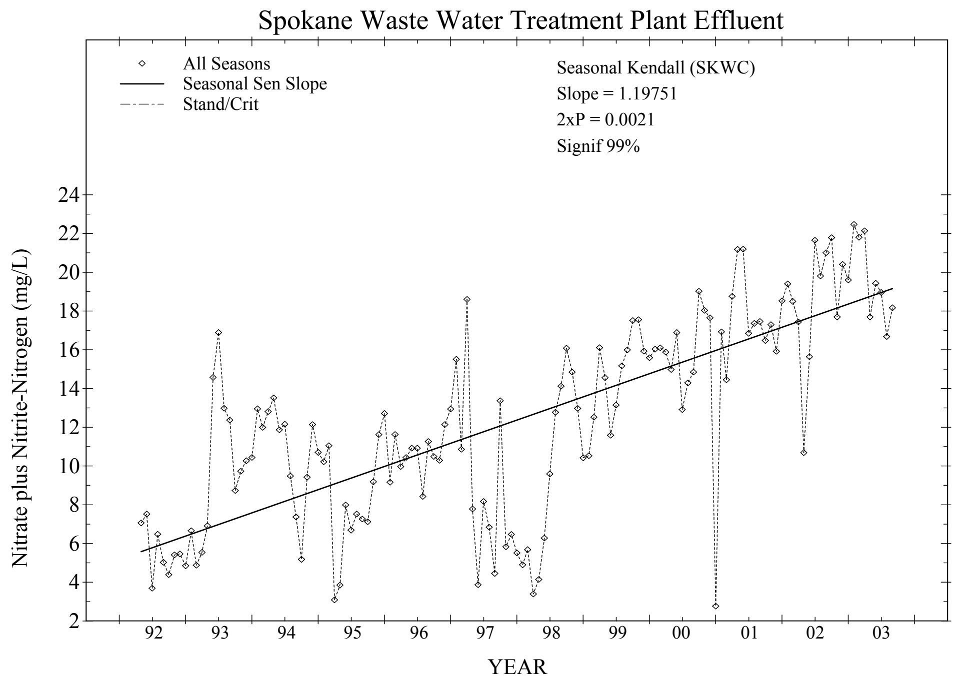

Figure 17. Trend in nitrate plus nitrite-nitrogen in Spokane WTP effluent.

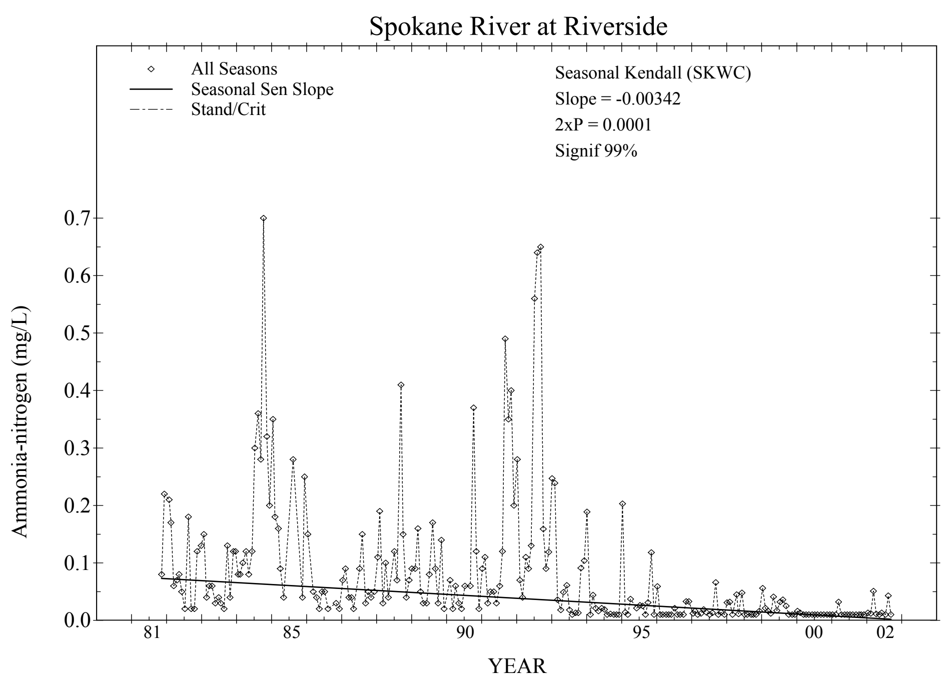

Figure 18. Trend in ammonia-nitrogen at Spokane River at Riverside.

Total phosphorus (TP) decreased significantly at Riverside, especially in the early 1990s after a phosphorus detergent ban—though concentrations appear to have increased again in the late 1990s (Figure 19). Concentrations also decreased at Stateline (the City of Coeur d'Alene began phosphorus treatment during this period). In any case, the decrease at Riverside was not dramatic and when changes at Stateline and Hangman Creek were factored out, there was no longer a significant trend at Riverside. In other words, only a portion of the trend at Riverside is attributable to changes in the mainstem Spokane River below Stateline, the remainder may be attributed to changes upstream of Stateline and in the Hangman Creek drainage.

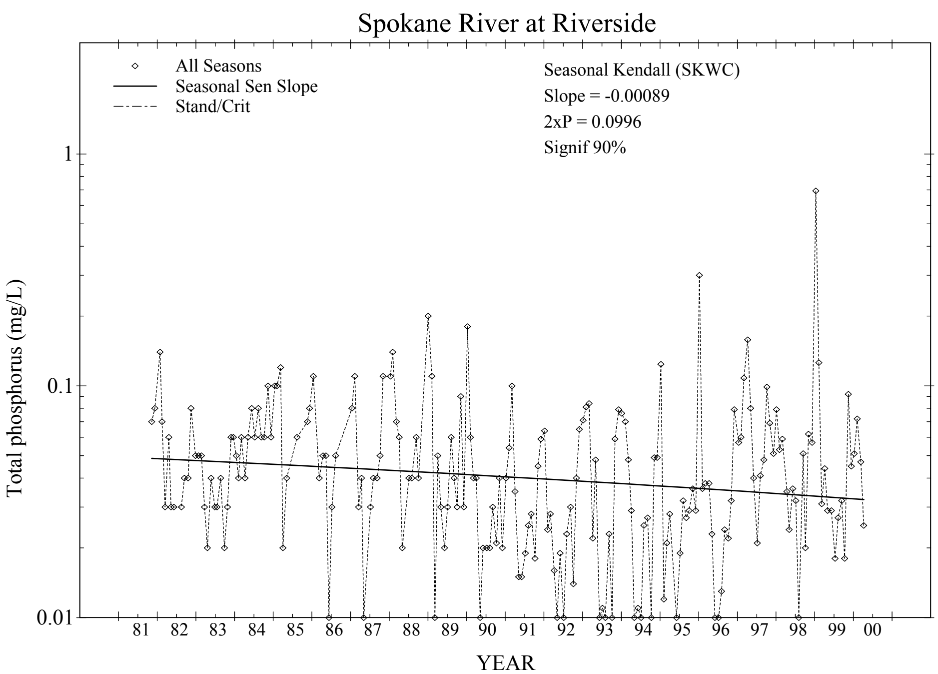

Figure 19. Trend in total phosphorus at Spokane River at Riverside.

In Hangman Creek, TP increased significantly during the high-flow months of December through June and decreased in the low-flow months of July through November, though not significantly ($p>0.1$). These opposing trends cancelled each other out and the overall TP trend in Hangman Creek was not significant. Though *concentration* trends may have cancelled out, most of the *load* carried by the stream is associated with the high-flow period when concentrations were high and increasing.

TP was not correlated with discharge at either mainstem station ($p>0.05$), and was only weakly correlated with discharge in Hangman Creek ($p<0.05$, $r^2=0.04$, log-linear).

Soluble reactive phosphorus (SRP) declined at all stations even after adjusting for changing detection limits. However, I believe the apparent declining trends at Riverside and Stateline, where concentrations were low, is an artifact caused by improved precision in the analytical method.

Advanced treatment to remove phosphorus at the Spokane WTP has been in place during the entire period evaluated. Although there was no strong declining trend in total phosphorus concentrations in the river, the Spokane WTP, in spite of a significant increasing trend in influent TP in the last 10 years, managed by increasing the percent removal to avoid an increasing trend in the effluent. Still, there are indications of higher effluent TP concentrations in recent years (Figure 20). Advanced wastewater treatment undoubtedly helped prevent an increase in phosphorus related to increasing population. New wastewater discharges to the Spokane River have been proposed, as has expanding existing discharges; point sources are currently operating well below discharge limits (Cusimano, Personal communication, 2003). As discharges increase, nutrient concentrations, especially total nitrogen but also phosphorus, may be expected to increase as well.

The ratio of TN to TP (TN:TP) indicated that on the whole, phosphorus was more likely than nitrogen to be limiting productivity at Riverside and Hangman Creek and nitrogen was the likely limiting nutrient at Stateline (Table 9). However, at Riverside TN:TP was highly seasonal. Phosphorus probably limited productivity during the low-flow months of July through October, but during other months the limiting nutrient was less clear (Figure 21). The only trend in TN:TP was at Hangman Creek, where the ratio declined indicating a reduction in nitrogen relative to phosphorus.

Table 9. Ratio of TN:TP at Spokane River and Hangman Creek based on samples collected from October 1993 through April 2000 (n~78).

Station	Mean	Std. Dev.	Seasonality[a]	Median
Riverside	25.1	23.9	99%	15.4
July-October	48.9	28.3	NA	44.1
November-June	13.9	8.6	NA	12.0
Stateline	9.8	6.4	75%	10.3
Hangman	32.9	23.6	50%	26.6

[a] Confidence level of Kruskal-Wallis test for seasonality.

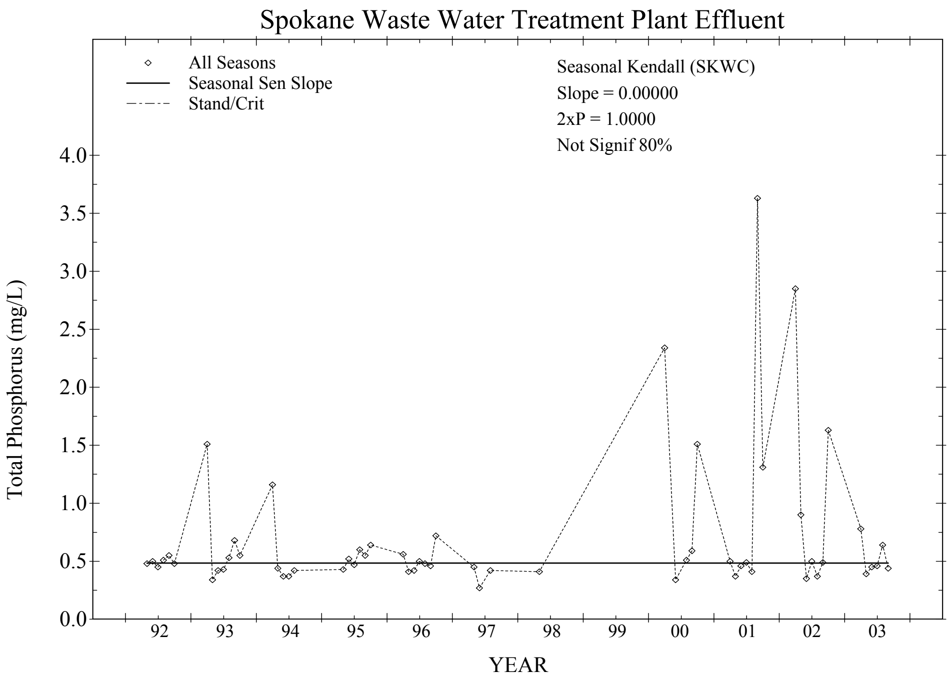

Figure 20. Trend in total phosphorus in Spokane WTP effluent (April through October only).

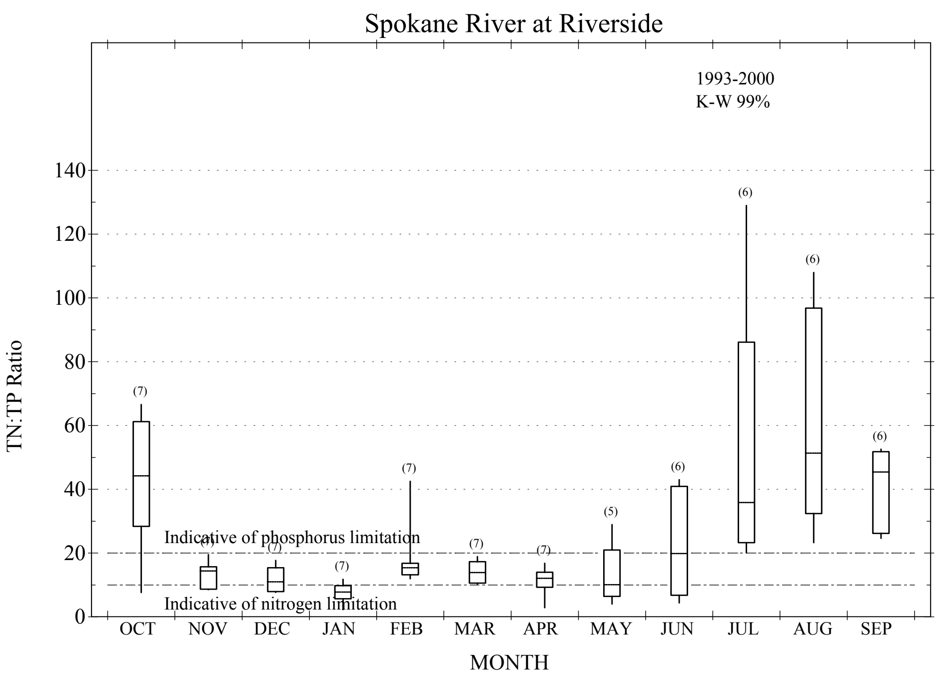

Figure 21. Seasonal distribution of the TN:TP ratio at Spokane River at Riverside. “K-W 99%” indicates the confidence level of the Kruskal-Wallis test for seasonality.

Metals

Metals contamination is a known problem in the Coeur d'Alene-Spokane River system and it will surprise no one familiar with the issue that numerous cadmium, lead, and zinc results have exceeded Washington's chronic criteria (Table 10 and Figure 22). The purpose of this section is not to characterize the problem, which has been done elsewhere (e.g., Pelletier, 1994b), but rather to present an overview of our results and a brief analysis of trends for the three problem metals: cadmium, lead, and zinc.

Table 10. Metals monitored by FMU since March 1995 exceeding Washington's chronic criteria at least once.

Metal	Total number of samples	Number exceeding chronic criteria	Percent exceeding chronic criteria
Cadmium, dissolved	39	8	21
Lead, dissolved	39	16	41
Zinc, dissolved	39	38	97

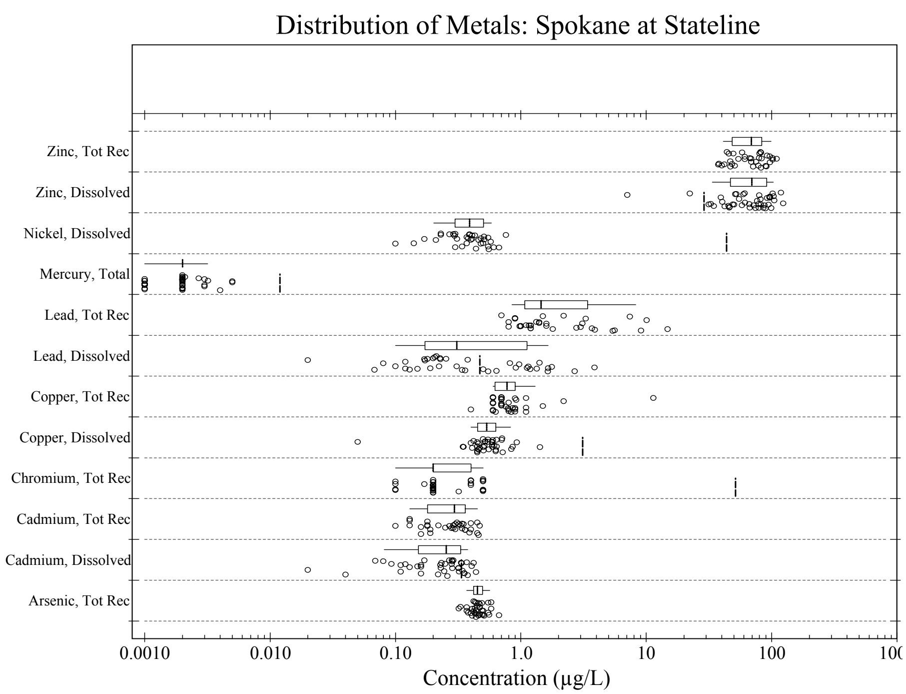

Figure 22. Distribution of metals concentrations in the Spokane River at Stateline. Vertical bars indicate the water quality standards criterion at a hardness of 22 mg/L (the average hardness during the sampled period).

Trends in dissolved cadmium, lead, and zinc are shown in Table 11. Because there were fewer than ten years data available, results were not corrected for serial correlation. Actual p-values are probably higher than the values shown and weak trends are suspect. Also, we generally prefer to have at least 60 data points (5 years of monthly data) for trend analysis, while only about 40 were available. It is easy to imagine that a few high data points in WYs 2000-2001, when metals monitoring was interrupted due to budget cuts, would have strongly affected the trend significance and slope in spite of the apparent dramatically declining trends (Figure 23). These trend results should be considered “preliminary.” Nevertheless, though concentrations still frequently exceeded standards, there are encouraging indications of declining metals trends in the upper Spokane River.

Table 11. Preliminary trends in cadmium, lead, and zinc data collected at Spokane River at Stateline by Ecology’s FMU from March 1995 through WY 2002. The Season Kendall test for trends without correction for serial correlation was used. Statistically significant trends not shown in bold are suspect (see text).

Metal	Slope (units/yr)	Slope (% of median)	2-tailed probability	Significant (90%)
Cadmium, dissolved	-0.0267	10	<0.001	**Yes ↓**
Flow-adjusted (quadratic, r2=0.36)	-0.0245	NA	<0.001	**Yes ↓**
Cadmium, total recoverable	-0.0248	8.0	<0.001	**Yes ↓**
Flow-adjusted (quadratic, r2=0.46)	-0.0238	NA	0.001	**Yes ↓**
Lead, dissolved	-0.0302	9.8	0.019	**Yes ↓**
Flow-adjusted (quadratic, r2=0.35)	-0.051	NA	0.067	Yes ↓
Lead, total recoverable	-0.1022	7.0	0.083	Yes ↓
Flow-adjusted (quadratic, r2=0.43)	-0.0432	NA	0.571	N
Zinc, dissolved	-4.01	5.6	<0.001	**Yes ↓**
Flow-adjusted (quadratic, r^2=0.27)	-4.45	NA	0.001	**Yes ↓**
Zinc, total recoverable	-3.15	4.6	<0.001	**Yes ↓**
Flow-adjusted (quadratic, r^2=0.45)	-2.68	NA	0.009	**Yes ↓**

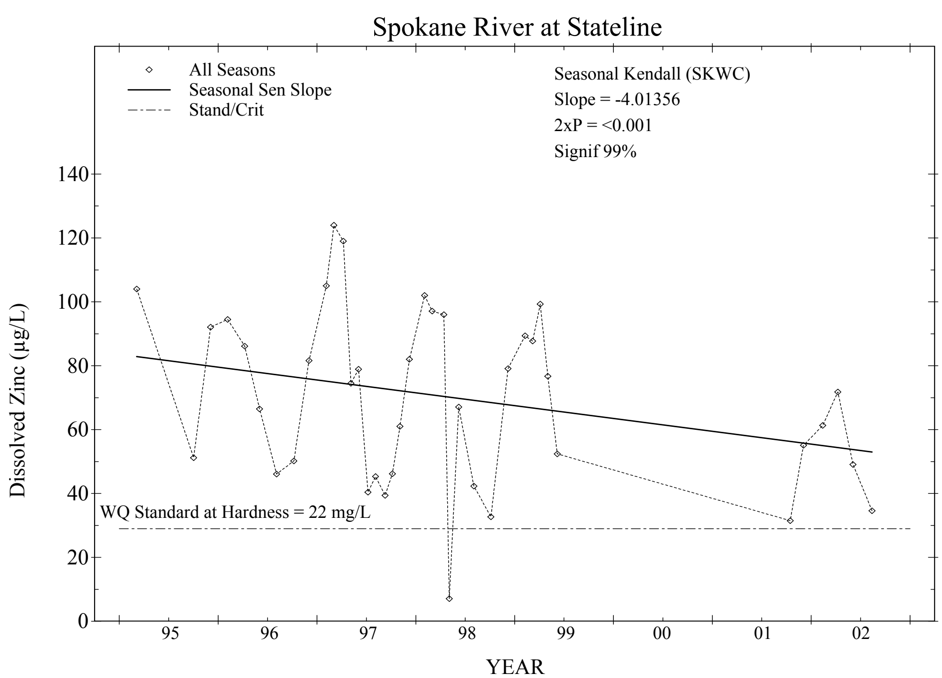

Figure 23. Trend in dissolved zinc at Spokane River at Stateline.

Summary

The status and trends in water quality in the Spokane River system in Washington is mixed. Cadmium, lead, and zinc enter the system from upstream, but significant amounts of nutrients and fecal bacteria are added to the mainstem Spokane River, and Hangman Creek contributes large quantities of sediment. There are preliminary indications of declining metals concentrations, and sediment in Hangman Creek declined. Though ammonia and phosphorus concentrations also fell, other nitrogen forms, including total nitrogen, increased. Fecal coliform bacteria also increased, especially during low-flow months. As the population of the Spokane Valley grows and wastewater discharges increase, nutrient levels in the Spokane River will likely increase as well.

Spokane River at Riverside State Park

Except for temperature and oxygen, water quality tended to be considerably worse at Riverside than upstream at Stateline. For the most part, temperatures were cool and oxygen above the criterion at Riverside, though others have reported problems with low oxygen concentrations. Our monthly grab-sample monitoring design is unlikely to catch daily minimum oxygen concentrations, however. Fecal coliform bacteria counts, on the other hand, were a borderline problem at Riverside. Over the entire evaluated period, fewer than ten percent of samples exceeded the “ten percent” criterion, however this criterion was exceeded during several individual years. Nutrients and sediment were both higher at Riverside than is typical for other long-term monitoring stations in the Northern Rockies Ecoregion. Total phosphorus concentrations typically exceeded the downstream summer criterion of 0.025 mg/L (though this criterion does not apply at Riverside).

There were no significant trends in flow, temperature, or sediment (in spite of a reduction in Hangman Creek sediment concentrations). There were indications of a declining (improving) trend in pH. Fecal coliform bacteria counts increased in the July through November period between WY 1981 and 2002. The source of the increase was the mainstem Spokane River, and not increased loading from Hangman Creek or upstream of Stateline. Daytime grab sample oxygen concentrations declined at Riverside, especially during the summer, but this decline represents a reduction in supersaturated conditions. The direction and magnitude of trends in daily minima are unknown. Ammonia-nitrogen concentrations decreased but nitrate plus nitrite-nitrogen and total nitrogen concentrations, especially during low-flow months, increased faster than the rate of population growth. The relationship between total nitrogen and flow indicates a point source. Phosphorus concentrations decreased slightly at Riverside, especially after a phosphorus detergent ban in 1990, in spite of increasing influent TP to the Spokane WTP, though concentrations appear to have increased again in the late 1990s.

Spokane River at Stateline

Concentrations of sediment, nutrients, and fecal bacteria were low at Stateline. Temperature, however, regularly exceeded the water quality standards criterion and oxygen was frequently below the criterion. The relative contributions of water withdrawal, artificial impoundment during low-flow summer months behind the Post Fall dam, and the natural impacts of Lake Coeur d'Alene, are unknown.

There were no significant trends in flow, temperature, or sediment. There were indications of increasing (worsening) trends in pH and fecal bacteria (though counts were still well within water quality standards).

Cadmium, lead, and zinc concentrations exceeded standards in 21, 41, and 97 percent of samples, respectively. There were too few data to report trends with confidence, but there are indications of declining concentrations of cadmium and zinc.

Hangman Creek

Water quality in Hangman Creek was poor. Temperature and pH failed to meet state standards. Nutrient and sediment concentrations were higher than concentrations at Riverside. Concentrations in Hangman Creek explained some of the high nutrient and fecal bacteria concentrations at Riverside, and almost all of the high sediment at Riverside may be from Hangman Creek, in spite of the much lower flows compared to the mainstem Spokane River.

There were no significant trends in flow, temperature, pH, or fecal coliform bacteria. Both turbidity and total suspended solids declined though the latter trend was not significant after accounting for flow. Ammonia-nitrogen concentrations decreased in Hangman Creek, but nitrate plus nitrite-nitrogen concentrations increased. Soluble reactive phosphorus concentrations also decreased.

The Stream Monitoring Unit continues to monitor our long-term stations at Spokane River at Riverside, Spokane River at Stateline, and at Hangman Creek.

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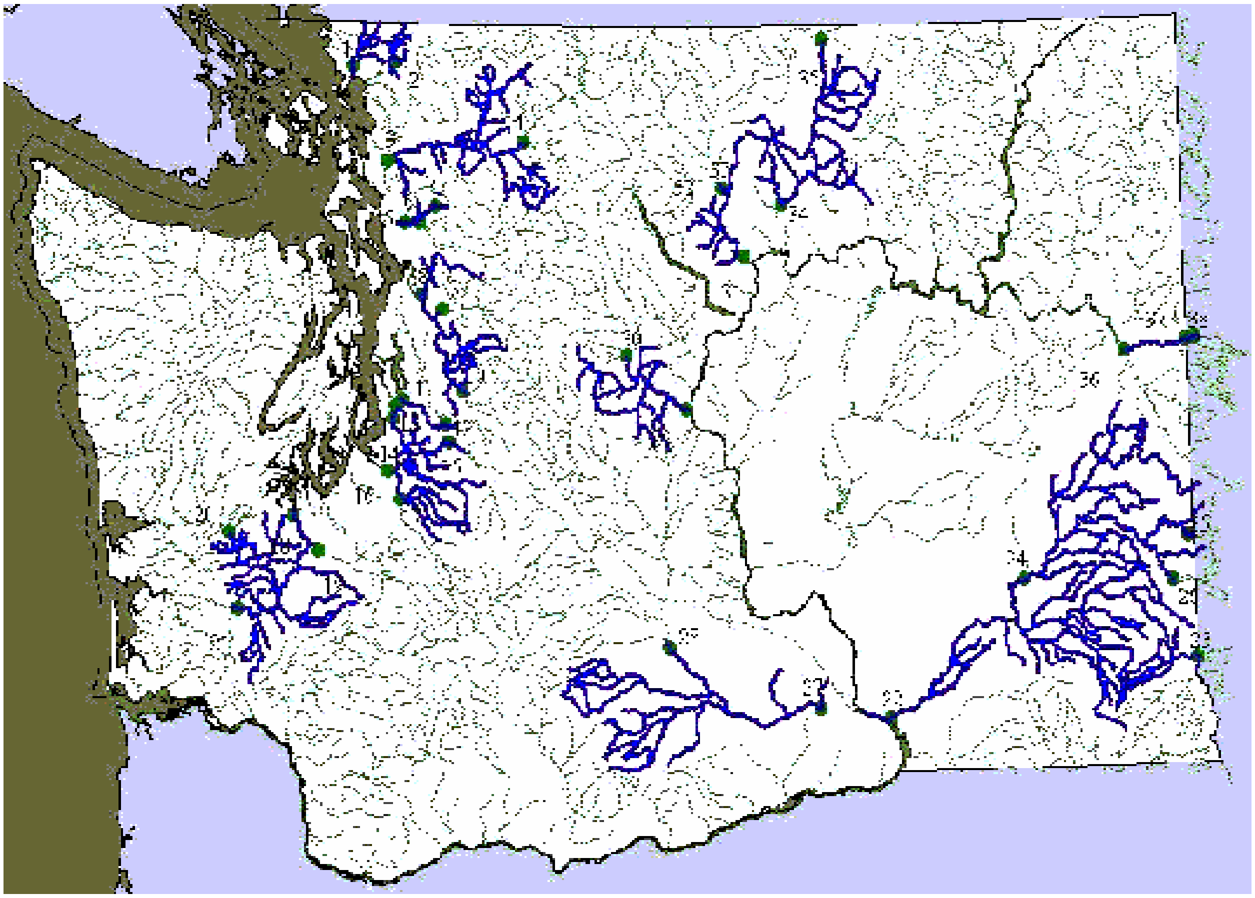
Appendix A

River and stream ambient monitoring stations defining stream reaches selected for analysis. The "Years" column indicates the number of complete water years sampled since October 1978 common to all stations in a system. The "Period" column is the range of years for which data were available for that system; not all years within the period have data for all stations in a system, however, and not all years may be included in analyses.

System	Years	Period	Station		Status
Nooksack	20	1978-2000	01A050	Nooksack R @ Brennan	Publ. Number
			01A120	Nooksack R @ No Cedarville	02-03-037
Skagit	22	1978-2000	03A060	Skagit R nr Mount Vernon	
			04A100	Skagit R @ Marblemount	
Stillaguamish	20	1978-2000	05A070	Stillaguamish R nr Silvana	
			05A090	SF Stillaguamish @ Arlington	
			05B070	NF Stillaguamish @ Cicero	
Snohomish	20	1978-2000	07A090	Snohomish R @ Snohomish	
			07C070	Skykomish R @ Monroe	
			07D130	Snoqualmie R @ Snoqualmie	
Cedar	20	1978-2000	08C070	Cedar R @ Logan St/Renton	
			08C110	Cedar R nr Landsburg	
Green	20	1978-2000	09A080 &	Green R @ Tukwila &	
			09A090	@ 212 St. nr Kent	
			09A190	Green R @ Kanaskat	
Puyallup	16		10A070	Puyallup R @ Meridian St	
			10A110	Puyallup R @ Orting	
Deschutes	15		13A060	Deschutes R @ E St Bridge	
			13A150	Deschutes R nr Rainier	
Chehalis	22		23A070	Chehalis R @ Porter	
			23A160	Chehalis R @ Dryad	
Snake	9		33A050	Snake R nr Pasco	
			35A150	Snake R @ Interstate Br	
Palouse	6		34A070	Palouse R @ Hooper	
			34A170	Palouse R @ Palouse	
			34B110	SF Palouse R @ Pullman	
Yakima	15		37A090	Yakima R @ Kiona	
			37A190	Yakima R @ Parker	
Wenatchee	22		45A070	Wenatchee R @ Wenatchee	
			45A110	Wenatchee R nr Leavenworth	
Methow	20		48A070	Methow R nr Pateros	
			48A130 &	Methow R nr Twisp &	
			48A140	Methow R @ Twisp	
Okanogan	16		49A070	Okanogan R @ Malott	
			49A190	Okanogan R @ Oroville	
Spokane	22		54A120	Spokane R @ Riverside State Pk	This report
			57A150 &	Spokane R @ Stateline &	
			57A190	Spokane R nr Post Falls	



Appendix A, Figure 1. Washington State map showing stream segments bounded by Ecology monitoring stations.

Appendix B

Distribution of data for various constituents collected at Spokane River at Riverside and at Stateline.

	Number of Obs.	Minimum	10	25	50 (median)	75	90	Maximum
Temperature (˚C)								
Riverside	249	1.0	3.4	4.8	8.8	14.4	17.6	19.9
Stateline	248	0.3	2.2	3.8	8.6	16.6	20.5	25.2
Hangman	221	-0.9	0.6	3.2	9.8	16.7	21.0	27
Flow (cfs)								
Riverside	249	302	1360	2230	3860	8445	16000	31000
Stateline	248	237	883	1760	3605	8952	15620	32000
Hangman	221	1	9	20	58	224	591	5800
Specific Conductivity (µsiemans/cm)								
Riverside	246	46	68	82	115	154	210	295
Stateline	248	23	45	50	54	57	63	94
Hangman	220	77	147	190	273	351	381	445
Oxygen (mg/L)								
Riverside	248	7.8	9.7	10.3	11.8	12.9	13.8	15.3
Stateline	249	6.2	8.1	8.9	10.8	12.3	13.1	15.1
Hangman	220	7.8	9.9	10.7	12.0	13.0	13.8	16.1
Oxygen Saturation (percent)								
Riverside	242	78.0	97.2	102.3	107.9	114.5	118.2	132.5
Stateline/	243	66.4	90.3	92.8	98.1	104.0	112.4	125.9
Hangman	218	80.8	93.3	97.5	105.5	125.1	148.3	177.2
pH (standard units)								
Riverside	246	6.8	7.4	7.7	8.0	8.3	8.4	8.9
Stateline	245	6.3	7.0	7.2	7.5	7.7	8.1	8.5
Hangman	219	7.0	7.5	7.8	8.3	8.6	8.8	9.3
Suspended Solids (mg/L)								
Riverside	241	1	1	2	3	5	12	1300
Stateline	245	1	1	1	2	3	4	16
Hangman	213	1	3	5	8	20	110	2200
Nitrogen, Total (mg/L)								
Riverside	106	0.158	0.293	0.467	0.742	1.083	1.396	3.310
Stateline	107	0.010	0.076	0.112	0.147	0.183	0.215	0.530
Hangman	91	0.444	0.874	1.080	1.520	3.970	5.830	11.500
Ammonia Nitrogen (mg/L)								
Riverside	239	0.010	0.010	0.012	0.036	0.090	0.200	0.700
Stateline	241	0.010	0.010	0.010	0.010	0.020	0.032	0.190
Hangman	211	0.010	0.010	0.010	0.022	0.052	0.100	0.320
Nitrate+Nitrite-Nitrogen (mg/L)								
Riverside	167	0.060	0.156	0.300	0.541	0.870	1.172	3.300
Stateline	168	0.010	0.010	0.020	0.040	0.072	0.106	0.253
Hangman	139	0.190	0.446	0.724	1.220	3.110	5.320	11.000
Phosphorus, Total (mg/L)								
Riverside	234	0.010	0.014	0.023	0.040	0.060	0.096	0.693
Stateline	238	0.008	0.010	0.010	0.019	0.028	0.036	0.150
Hangman	208	0.010	0.033	0.041	0.072	0.116	0.202	1.740
Phosphorus, Soluble Reactive (mg/L)								
Riverside	237	0.003	0.005	0.010	0.020	0.040	0.064	0.130

	Number of Obs.	Minimum	10	25	50 (median)	75	90	Maximum
Stateline	242	0.001	0.005	0.005	0.010	0.010	0.011	0.120
Hangman	207	0.005	0.010	0.020	0.038	0.070	0.090	0.150
Turbidity (NTU)								
Riverside	238	0.5	0.8	1.0	1.6	3.9	11.0	1000
Stateline	244	0.5	0.7	1.0	1.2	2.0	3.9	14.0
Hangman	209	0.6	1.4	2.5	6.0	32.5	110.0	2300.0
Fecal Coliform Bacteria (colonies/100mL)								
Riverside	242	1	1	5	13	53	174	2300
Stateline	239	1	1	1	3	7	16	630
Hangman	214	1	4	13	36	120	345	2400