Spokane River Non-Point Source Analysis Project Supplemental Phase 1 Surface Water Orthophosphorus Data Analysis

Supplemental Phase 1 Study
February 2010

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Introduction

The following discussion presents the results of the Supplemental Phase 1 surface water analysis of the Spokane River watershed orthophosphorus dataset. The total phosphorus data analysis is described in a separate document (HDR, 2009a). The non-point source phosphorus analysis is one of many activities related to the Spokane River Dissolved Oxygen Total Maximum Daily Load (TMDL). The ultimate goal of the non-point source analysis project is to identify and prioritize locations for non-point phosphorus reductions activities such as best management practice (BMP) implementation projects.

The Washington State Department of Ecology has stated "Phosphorus and other nutrients and organic matter have polluted the Spokane River, causing it to violate water-quality standards. These pollutants deplete dissolved oxygen in the river and Lake Spokane. To address the problem, a cleanup plan, also known as a total maximum daily load (TMDL), will set allocations for how much of the pollutants (such as phosphorus and ammonia) each of the major dischargers and other sources will be allowed to discharge at very low levels. The amounts will be set to protect water quality and bring the river into compliance with state water-quality standards and the federal Clean Water Act" (Ecology, 2009).

Approach to Supplemental Phase 1 Surface Water Analysis

This analysis includes technical approaches completed for select locations in the Spokane River watershed. The analyses and locations were limited in Supplemental Phase 1 to meet multiple objectives including the following:

1. Compliment the Phase 1 total phosphorus analysis
2. Provide a basis for prioritizing and selecting more detailed approaches for Phase 2 analyses
3. Summarize orthophosphorus concentrations and loads from a large area (approximately 6,580 square mile watershed)
4. Summarize orthophosphorus concentrations and loads from a large dataset (approximately 15,000 data points)
5. Meet Supplemental Phase 1 schedule constraints; and provide a relatively rapid assessment of the data
6. Meet Supplemental Phase 1 budget constraints

Total phosphorus concentrations, such as those previously evaluated (HDR, 2009a), includes all phosphorus fractions including the dissolved, particulate and organic forms of phosphorus. The particulate and organic forms have traditionally been thought of as less mobile in groundwater and groundwater/surface water interfaces (such as occur in the Spokane River watershed) and less readily available for biological uptake. Orthophosphorus, as used herein, primarily consists of orthophosphate and refers to the dissolved phosphorus component traditionally thought of as most available for biological uptake. Therefore, this complimentary orthophosphorus analysis is appropriate for further evaluation and understanding of the phosphorus dynamics within the Spokane River watershed as part of the nonpoint source study.

The locations for the Supplemental Phase 1 surface water analysis were the same as in Phase 1 and were downstream points in the subbasins and intermediate locations along the mainstem of the Spokane River. The analyses generally used data from the vicinity of the following six locations, as shown in Figure 1.

1. Spokane River at Lake Coeur d'Alene (downstream of Lake Coeur d'Alene)
2. Spokane River at Stateline (the border between Idaho and Washington separating the Upper Spokane subbasins)
3. Spokane River at Spokane
4. Spokane River at Long Lake headwaters (downstream of Nine Mile Dam and upstream of the confluence with the Little Spokane River)
5. Hangman Creek at Spokane River
6. Little Spokane River at Spokane River

These locations were selected as generally recognized reference points within the Spokane River watershed. As such, various agencies have also selected these locations or similar locations for water quantity (flow) and water quality monitoring. Those single point monitoring stations may coincide within the selected locations as the selected locations were examined more broadly than one single point. Data from the non-point source database from multiple sampling points within the vicinity of the selected locations were examined.

The analyses selected for the Supplemental Phase 1 surface water study were the same as in Phase 1 and were those that could be completed relatively rapidly, with minimal intermediate data computational steps, and provide a basis for a simple and straightforward presentation. The results provide insights into changes in phosphorus concentration and/or loads both temporally and spatially. Comparisons of the graphs indicate where and when the greatest orthophosphorus loads occur. The six analyses selected for the Supplemental Phase 1 surface water study are as follows:

1. Times Series Plots
2. Data Charts
3. Average Monthly Phosphorus Loadings
    a. Average Monthly Phosphorus Loadings by Year
4. Average Monthly Phosphorus Loadings for 2001
    a. Average Monthly Phosphorus Loading by Flows
5. Average Seasonal Phosphorus Concentrations and Loadings
6. Land Use to Phosphorus Correlation. (This analysis is included in a separate document.)

This combination of selected locations and analyses allows for initial observations about the dataset to be made, along with questions and hypotheses to be posed about the cause and effect relationships that may be occurring. These questions and hypotheses will be useful for prioritizing and selecting the Phase 2 analyses. The Phase 2 analyses may include some of the same analytical approaches used in Phase 1 and Supplemental Phase 1, but in new locations and with additional techniques including those previously identified such as: stream segment analysis, load analysis by subbasin or sub-subbasin, and episodic or event-based loading analysis (HDR, 2009b).

Presented in the sections below are the surface water analyses selected for Supplemental Phase 1. Each section begins with a description of the objectives that were identified as part of the options analysis. The process used for the analysis and observations from the results are then presented followed by tables and figures. Additional text and/or tables and figures are then presented for simple follow-up analysis for initial basic questions about the results. More complex questions were deferred to the more detailed analysis that can be completed in Phase 2.

Summary of Supplemental Phase 1 Surface Water Data Analysis

A review of the Supplemental Phase 1 surface water analyses is useful to make observations about where and when concentrations and loads of phosphorus are higher or lower, trends over space and time, when and where data are available and not available and other inferences about phosphorus movement through the watershed. A summary of observations from the Supplemental Phase 1 surface water analyses include the following:

- Hangman Creek has the greatest orthophosphorus concentrations and the greatest maximum and average orthophosphorus loads (Table 1.1 and Figure 1.5).
    - Hangman Creek has the greatest total phosphorus concentration and loads as well.
- March is the month with the greatest orthophosphorus loads for Coeur d'Alene, Hangman Creek and Little Spokane River while for Stateline and Spokane it is May (Figures 3.1 through 3.6).
    - May is the month with the greatest total phosphorus loads.
- Orthophosphorus loads are greater than the Spokane River total phosphorus TMDL 2001 and target loads in January, February, May and June for Spokane River at Stateline (Figure 4.1) (Ecology, 2008).
    - Total phosphorus loads are greater than the TMDL in multiple locations and multiple months.
- Monthly orthophosphorus loads decrease between Lake Coeur d'Alene and Stateline (Figure 3.1 and 3.2).
    - Total phosphorus loads also decreased.
- The orthophosphorus to total phosphorus averages about 50-percent but varies widely from 0 to 100-percent.

Considerations for Further Data Analysis

Many of the same questions resulting from the total phosphorus analysis are also relevant to the orthophosphorus analysis. Additional questions for further exploration, potentially as part of Phase 2 detailed analysis, are:

- Why is the orthophosphorus to total phosphorus ratio so varied?
- Why does the timing of the greater orthophosphorus concentration appear to occur earlier in the spring than for total phosphorus?
- Why does the Stateline to Long Lake reach appear to have more orthophosphorus from both surface water and groundwater?

Citations

Ecology. 2008. Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load, Water Quality Improvement Report. Publication No. 07-10-073. May 2008. Department of Ecology, State of Washington, Olympia, WA.

Ecology. 2009. Frequently Asked Questions about Protecting Oxygen in the Spokane River. 04-10-073, September 2004. Washington State Department of Ecology, Olympia, WA. http://www.ecy.wa.gov/biblio/0410073.html

Ecology. 2010. Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load, Water Quality Improvement Report. Publication No. 07-10-073. February 2010. Department of Ecology, State of Washington, Spokane, WA.

HDR. 2009a. Spokane River Non-Point Source Analysis Project, Phase 1 Surface Water Total Phosphorus Data Analysis, June, 2009.

HDR. 2009b. HDR Memorandum, Subject: Spokane River Non-Point Source Analysis Project, Options for Phosphorus Data Analysis Draft, March 31, 2009.

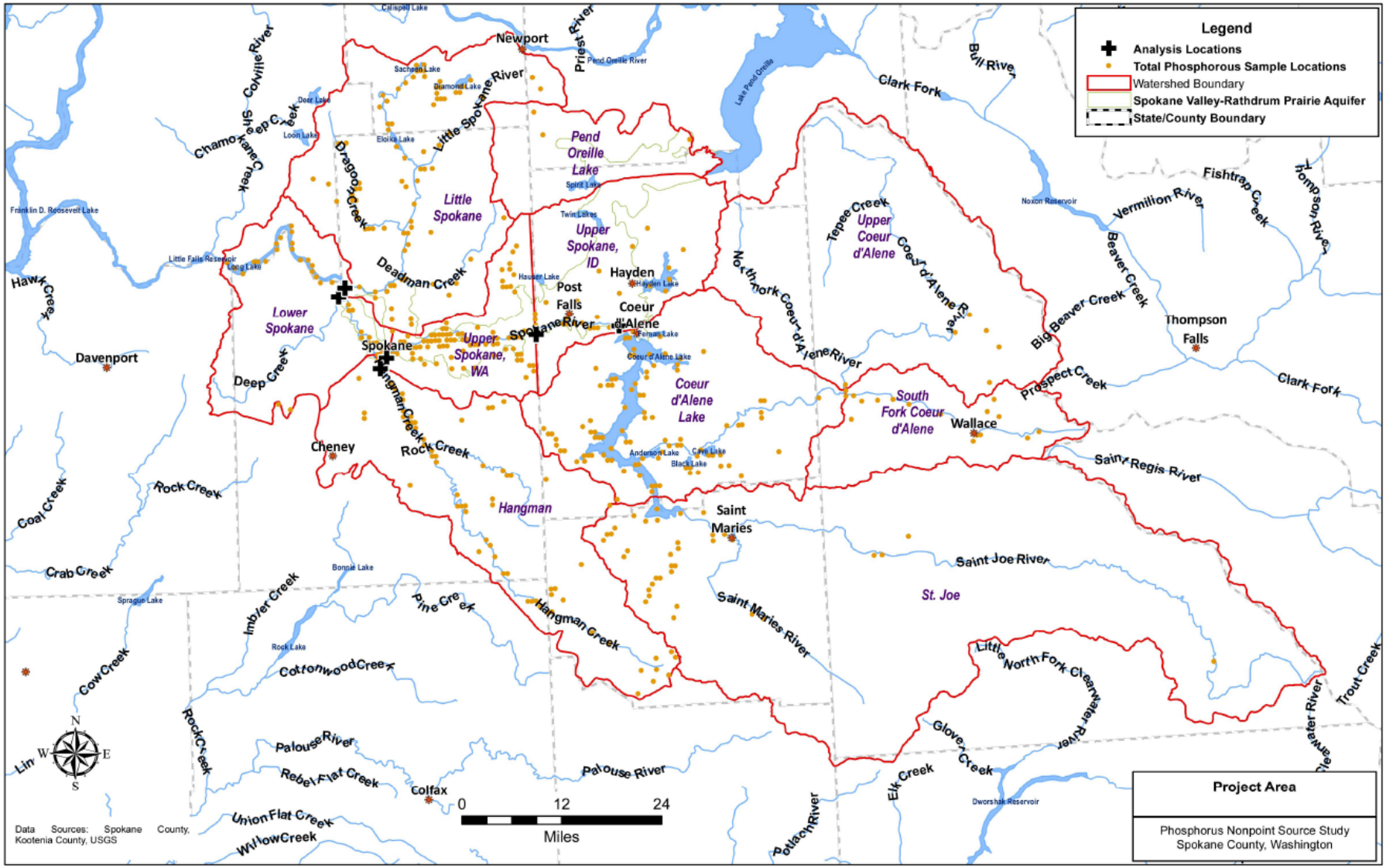

Figure 1. Project Location Map with Subbasins and Analysis Locations

1. TIMES SERIES PLOTS OF FLOW, PHOSPHORUS CONCENTRATIONS AND LOADS

Objective

The time series plots provide an overview of the dataset values for flow, orthophosphorus concentrations and loads. The Supplemental Phase 1 locations selected for scatter plot graphs are the Spokane River at Lake Coeur d'Alene, Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.

Linkage to TMDL

The time series may be compared with the TMDL load allocations and the fraction of orthophosphorus to total phosphorus.

Results

Plots of the orthophosphorus load, concentration and flow from 1990 through 2008 for the selected locations are shown in Figures 1.1 through 1.6. (These figures have the y-axis scale set to the maximum value at the monitoring location to best show the data range and trends. No statistics or validity of the trend lines was completed.) All surface water monitoring locations within the vicinity of the selected sites were examined (identified using the GIS maps of the monitoring locations and by the station location codes shown in the legends of the figures). Only paired data, i.e., dates with both flow and orthophosphorus concentrations, are shown and used for the analysis. The loads were calculated as the flow multiplied by the concentrations. The data are summarized in Table 1.1 and the following bullet points summarize observations from this analysis. (Concentrations reported as non-detect were graphed at the detection limit; however, the variability in detection limits over time (upward or downward) influences the graphing of the data and potentially the trends in concentration and loading.)

- Data from the Spokane River at Lake Coeur d'Alene are only from the 2000's.
    - The data trends indicate loads, concentrations, and flows are increasing.
    - The sampling location at the outlet of Lake Coeur d'Alene changed in 2006.
- Data from the Spokane River at Stateline are from throughout the period of interest (1990 to 2008).
    - The data trends indicate loads, concentrations, and flows are decreasing.
    - Comparing Lake Coeur d'Alene to Stateline, the average load for the period of record decreased by almost 25 percent (Table 1.1).
    - The dataset includes samples from high runoff in the spring of 1997. These few high values during spring runoff may skew analyses if included.
- Few data exist from Spokane River at Spokane. The data are mostly from the late 1990s.
    - The data trends are not clearly increasing or decreasing; however, there are few data points to clearly establish any trend.
    - Comparing Stateline to Spokane, the loads and concentrations are generally greater.
- There are only five data points from Spokane River at Long Lake headwaters (Nine Mile) and these are from middle 2007.
    - There is insufficient data to evaluate trends at Long Lake headwaters or differences from Spokane upstream.

- Data from Hangman Creek at Spokane River are from throughout the period of interest.
    - The data trend shows loads are steady (not clearly increasing or decreasing) although concentrations are decreasing.
    - Concentrations are three, or more, times greater than concentrations in the Spokane River.
    - Loads are usually about a tenth of the load in the Spokane River with the exception of occasional high loads that are similar, or greater, than high loads in the Spokane River.
- Data from the Little Spokane River at Spokane River are from throughout the period of interest.
    - The data trend shows loads and concentrations are steady (not clearly increasing or decreasing).
    - Concentrations are about 1.5 to 2 times greater than concentrations in the Spokane River.
    - Loads are usually about a fifth of the load in the Spokane River with the exception of occasional high loads that are similar to the high loads in the Spokane River.

Table 1.1. Summary of Time Series Data

Sites	Period and Count	Maximum (lb/day) (mg/L)	Average (lb/day) (mg/L)	Median (lb/day) (mg/L)	90th Percentile (lb/day) (mg/L)
Spokane River at Lake Coeur d'Alene	11/02–11/08 91	2,724 0.020	238 0.006	122 0.006	566 0.011
Spokane River at Stateline	12/90-9/08 217	1,003 0.020	182 0.007	119 0.005	398 0.010
Spokane River at Spokane	10/98-4/00 35	777 0.015	235 0.006	186 0.005	647 0.014
Spokane River at Long Lake headwaters	5/07-9/07 5	436 0.015	178 0.009	213 0.009	334 0.014
Hangman Creek at Spokane River	1/90-9/07 205	3,470 0.221	125 0.043	8 0.030	296 0.089
Little Spokane River at Spokane River	1/90-9/07 186	812 0.090	52 0.014	30 0.012	110 0.024

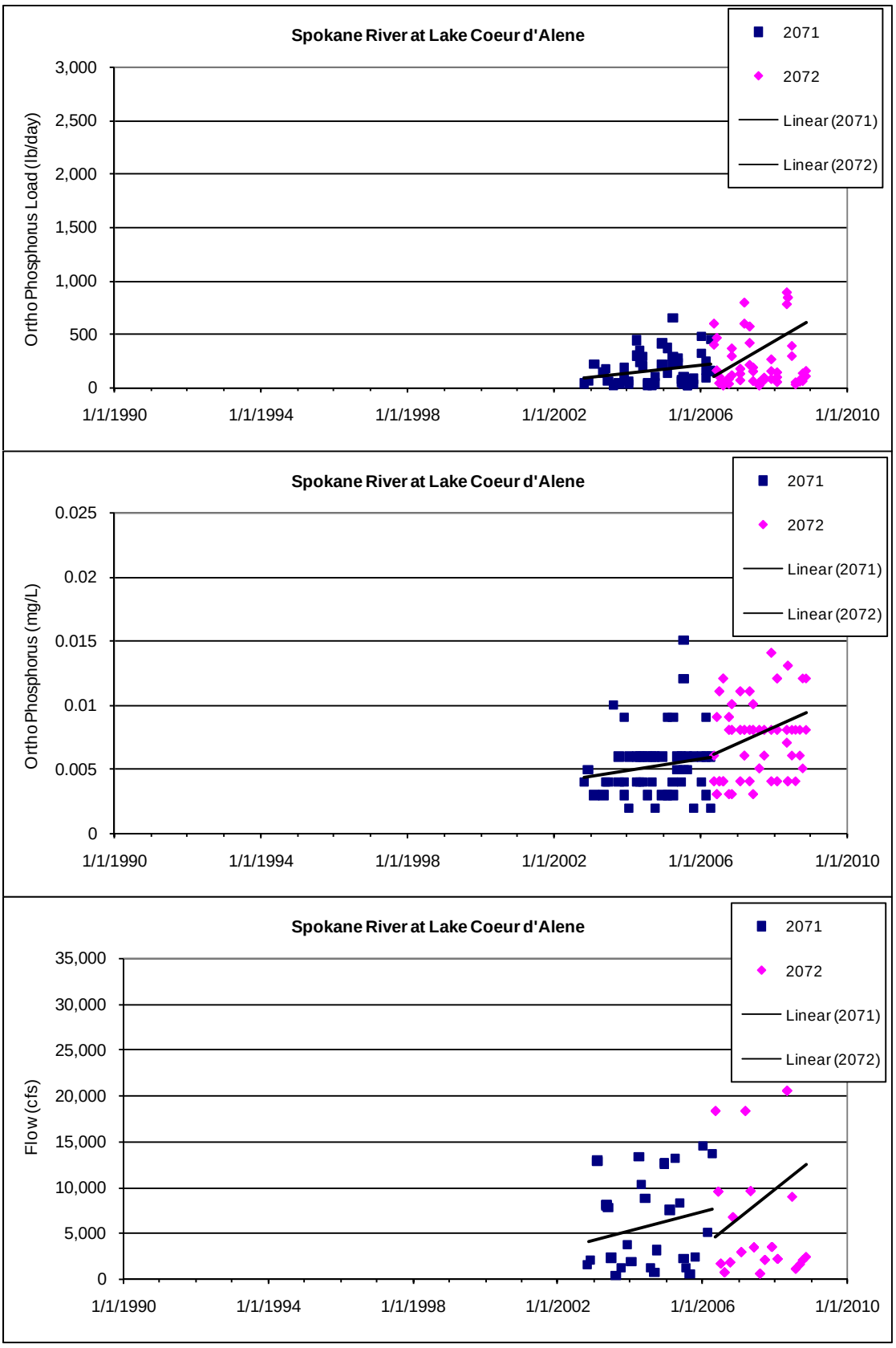

Figure 1.1. Spokane River at Lake Coeur d'Alene Time Series

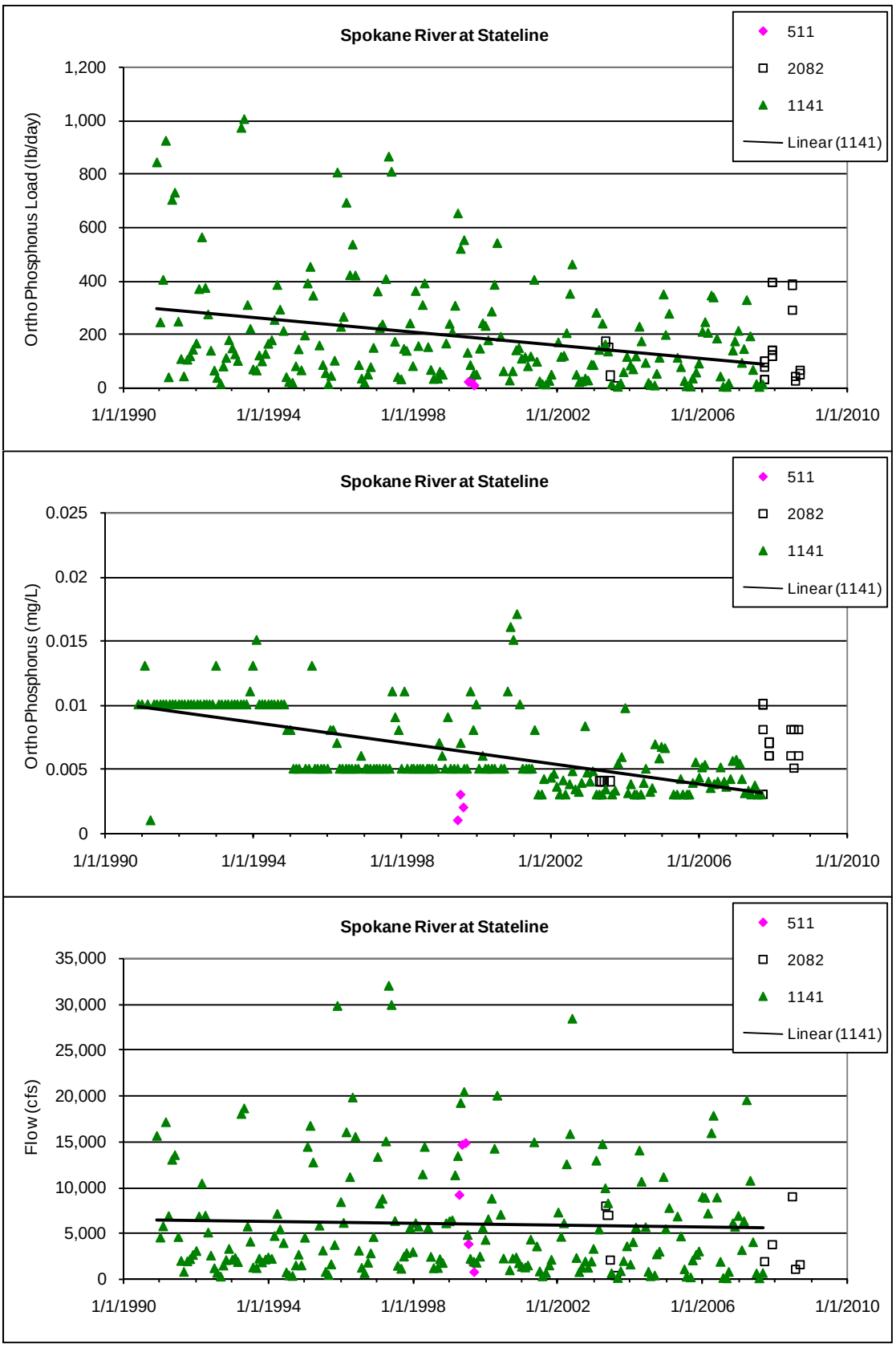

Figure 1.2. Spokane River at Stateline Time Series

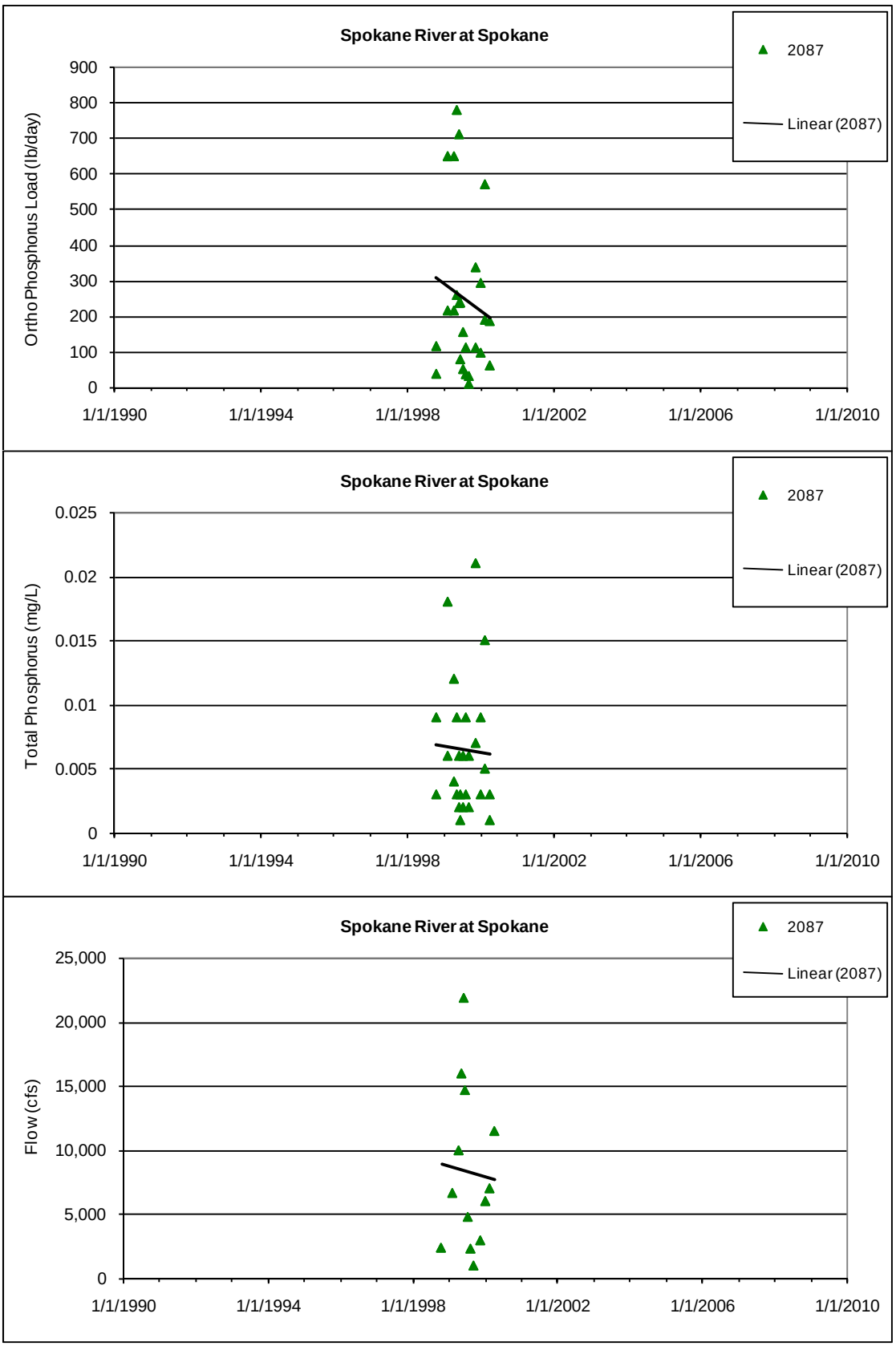

Figure 1.3. Spokane River at Spokane Time Series

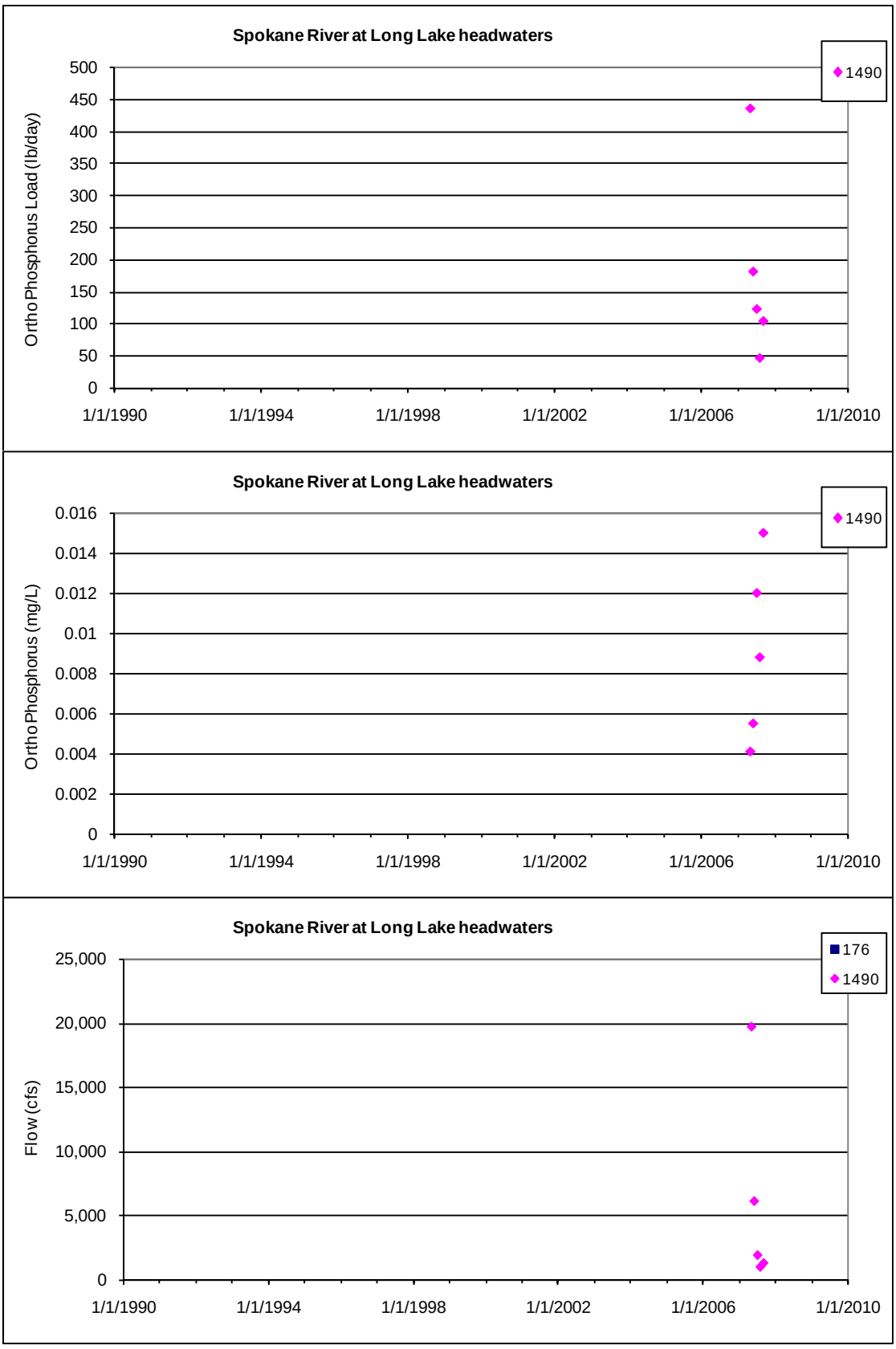

Figure 1.4. Spokane River at Long Lake headwaters (Nine Mile) Time Series

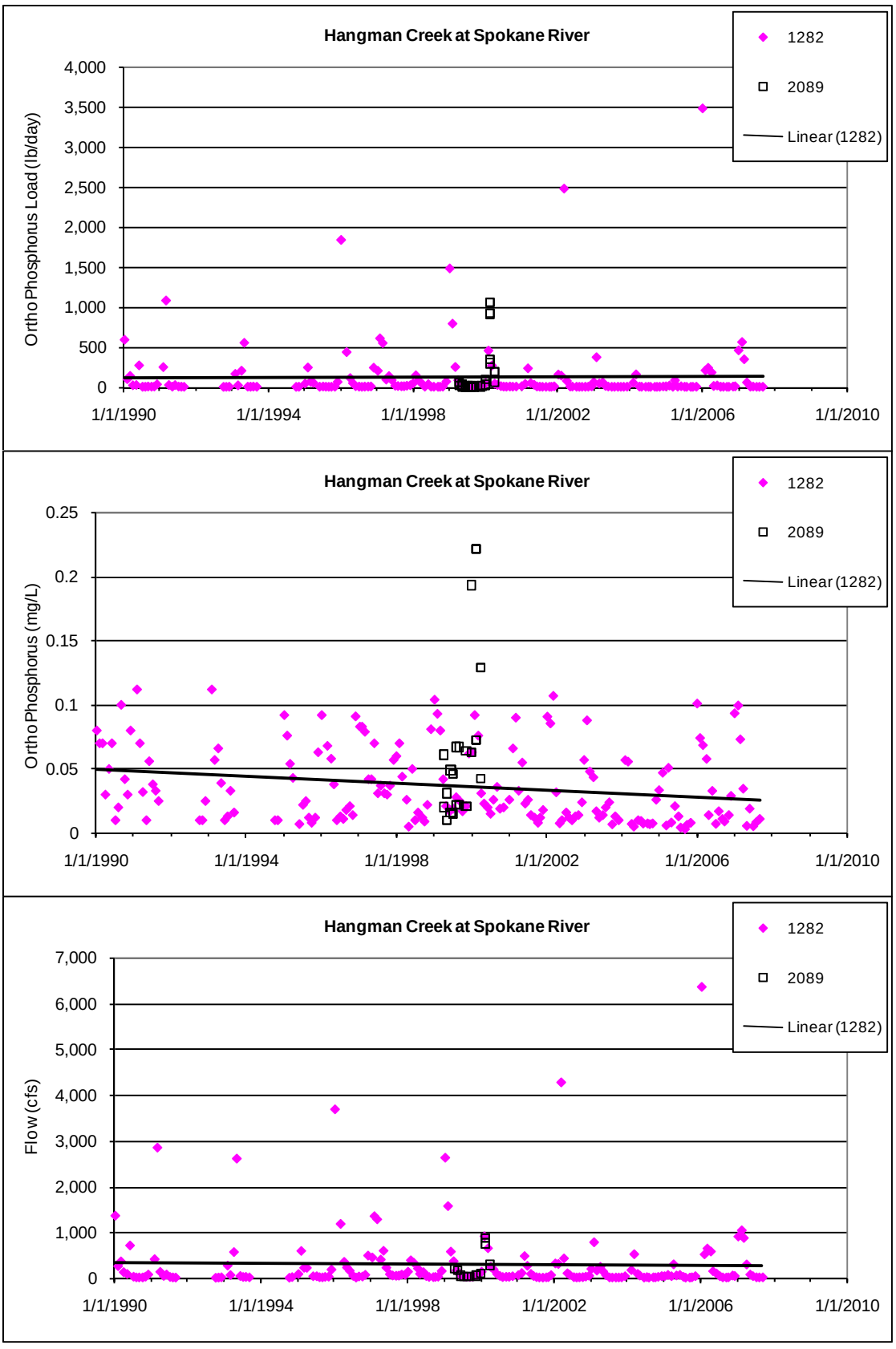

Figure 1.5. Hangman Creek at Spokane River Time Series

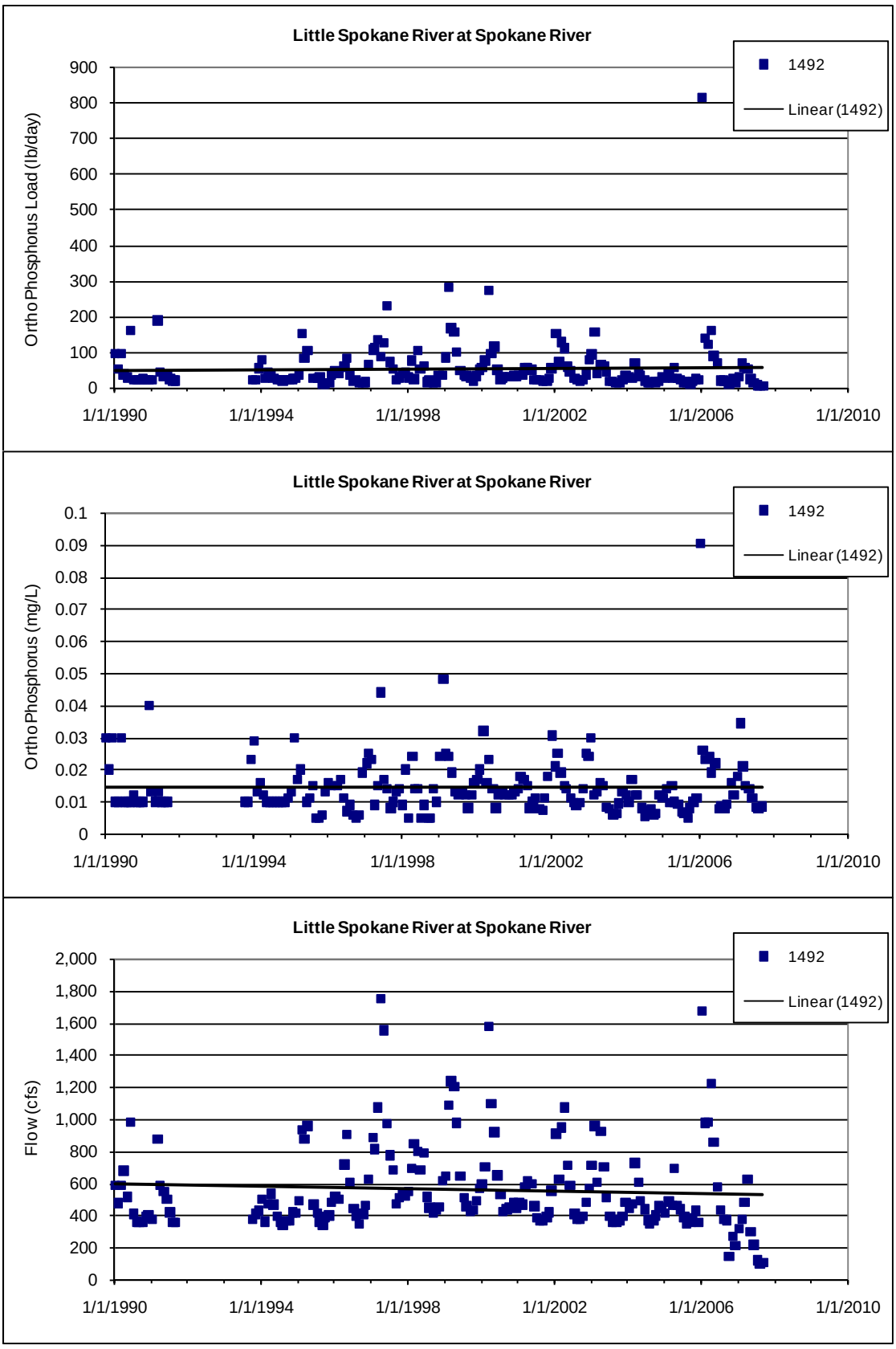

Figure 1.6. Little Spokane River at Spokane River Time Series

The differences in flows and loads in the Spokane River between Coeur d'Alene to Stateline and Stateline to Spokane are shown in Figures 1.7 and 1.8, respectively. From Coeur d'Alene to Stateline, flows decreased an average of 360 cfs, while from Stateline to Spokane flows increased an average of 480 cfs. From Coeur d'Alene to Stateline orthophosphorus loads decreased an average of 70 lbs/day while from Stateline to Spokane orthophosphorus loads decreased an average of 3 lbs/day for the comparison dataset. The groundwater, withdrawal, and inflow interactions need to be explored further in these reaches to understand why orthophosphorus concentrations and loadings appear to vary.

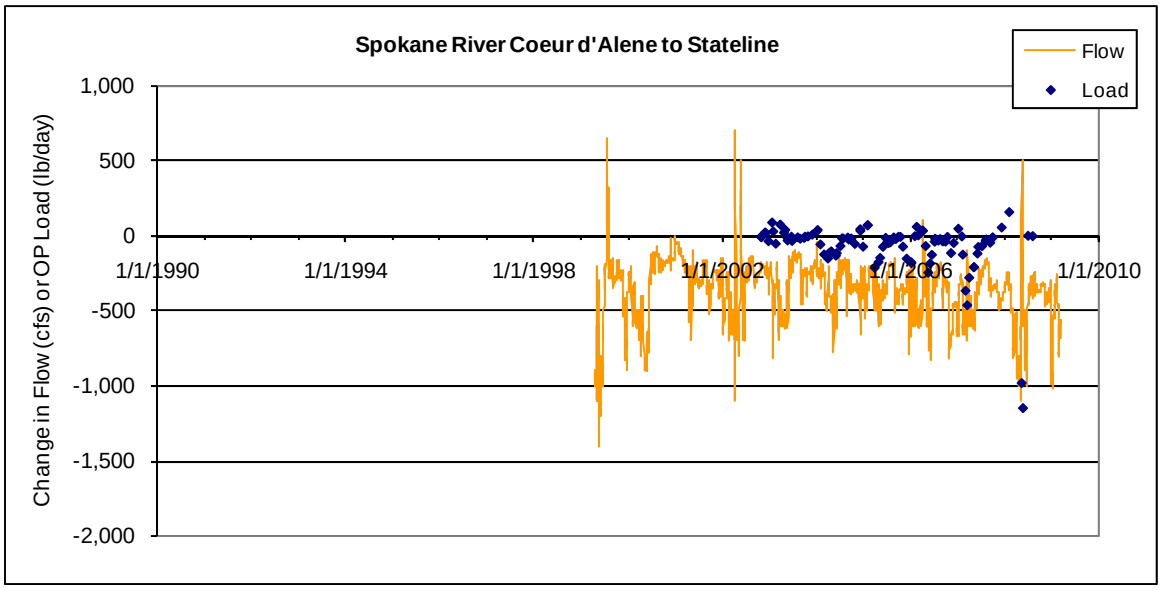

Figure 1.7. Change in Flows and Loads Coeur d'Alene to Stateline

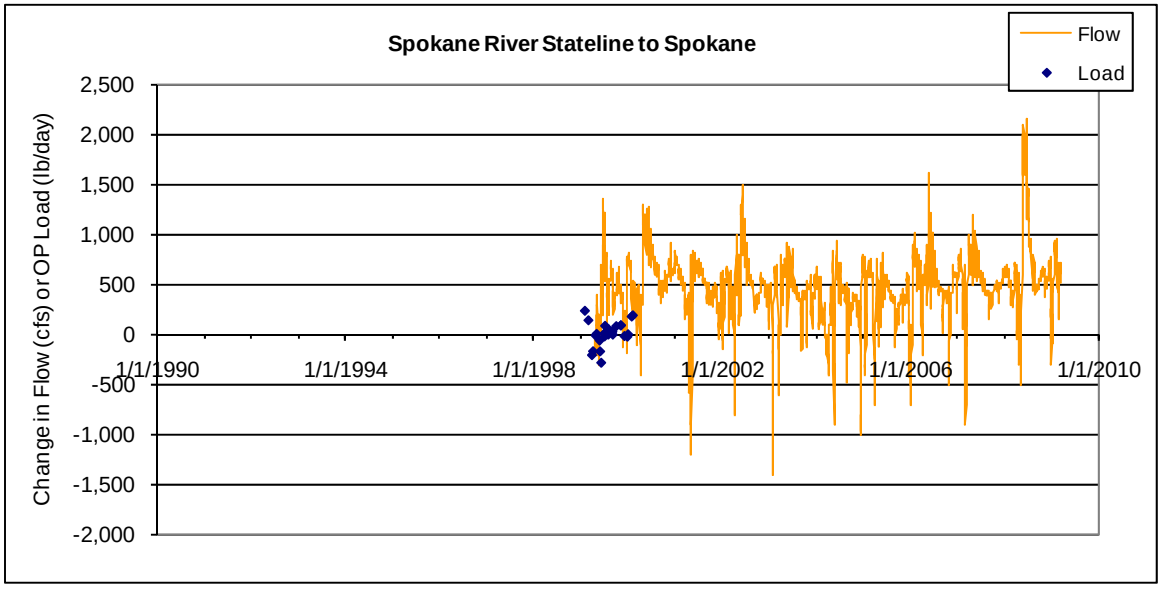

Figure 1.8. Change in Flows and Loads Stateline to Spokane

For the six locations both orthophosphorus and total phosphorus were reported with the samples. The trends are generally similar. Orthophosphorus trends are less, as the ratio of orthophosphorus to total phosphorus varies widely from 0 to 100 percent with an average of about 50 percent. The average ratios by location are:

- 55% OP:TP Spokane River at Lake Coeur d'Alene
- 54% OP:TP Spokane River at Stateline
- 53% OP:TP Spokane River at Spokane
- 48% OP:TP Spokane River at Long Lake headwaters
- 44% OP:TP Hangman Creek at Spokane River
- 50% OP:TP Little Spokane River at Spokane River

2. "DNA" STRIP CHARTS

Objective

The DNA strip charts provide a simple representation of the temporal continuity of the dataset. The Supplemental Phase 1 DNA charts are for all the monitoring locations in the database.

Linkage to TMDL

The DNA charts show the available data for the TMDL model year 2001.

Results

Plots of when orthophosphorus was sampled as recorded in the database are shown in Figure 2.1. The data dates are shown by sample location code, on the y-axis, as assigned in the study database. There are some gaps in the sample location codes (the codes are not continuous) and these are shown as blanks in Figure 2.1. Orthophosphorus has been sampled at 162 locations. An average of 54 and a median of 11 samples have been collected per location for these 162 locations. For 78 locations, or about half of the total locations, ten or fewer samples have been collected. There are 23 locations with more than 100 samples and of those 12 locations with more than 200 samples. The general location of these 12 locations are provided in Table 2.1.

Figure 2.1 shows that other than the stations with long records, there were not many other locations sampled.

Table 2.1. Locations of 12 Largest Datasets

Station Location Code	General Location		Station Location Code	General Location
1141	Spokane River Stateline		2052	Lake Coeur d'Alene, Coeur d'Alene River branch
1282	Hangman Creek		2060	Saint Joe River
1491	Hangman Creek		2062	Saint Maries River
1492	Little Spokane River		2070	Hayden Lake area
2005	Coeur d'Alene River		2081	Spokane River Idaho
2046	South Fork Coeur d'Alene River		2093	below Long Lake Dam

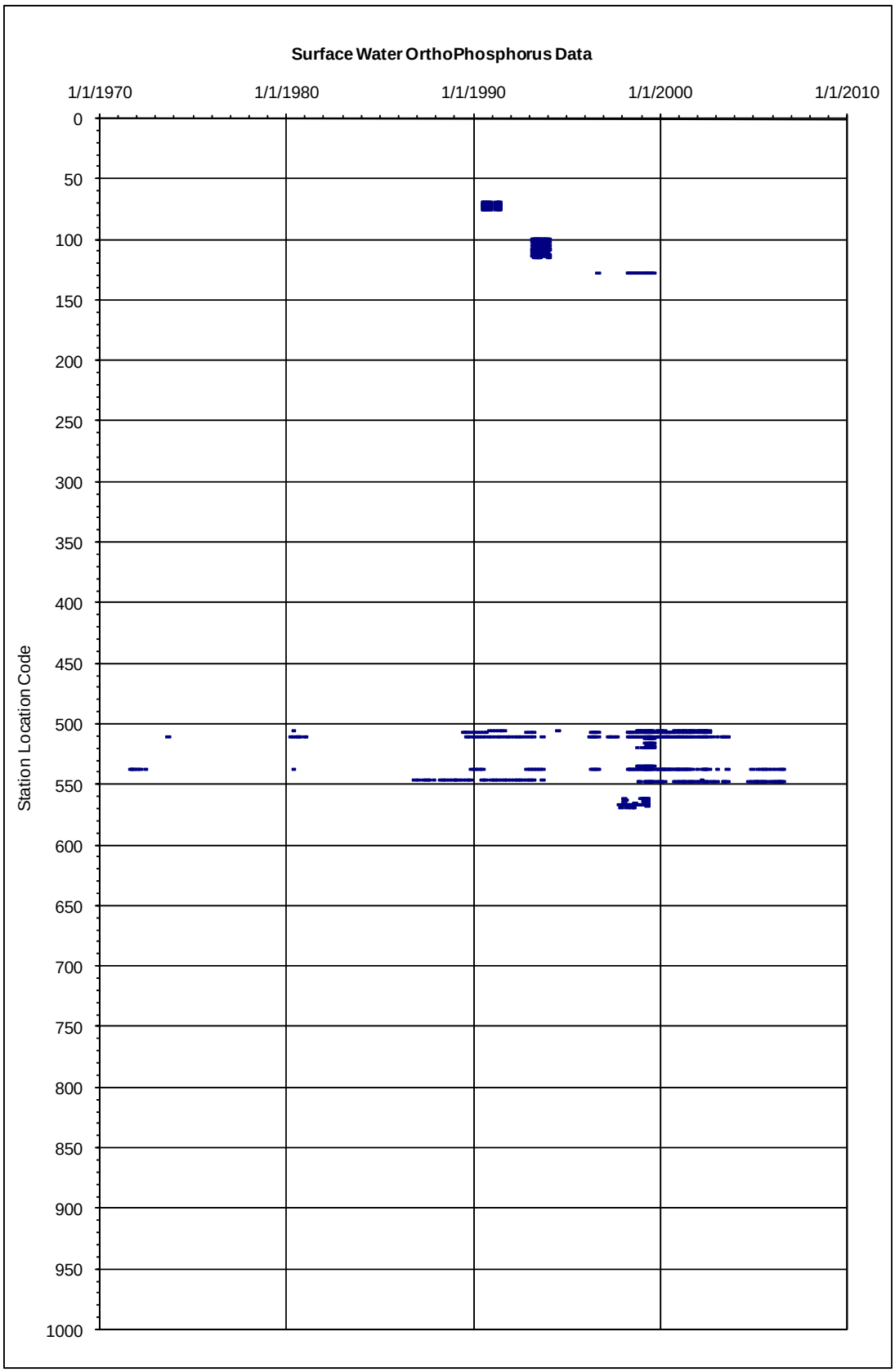

Figure 2.1a. Surface Water Orthophosphorus Sampling Dates

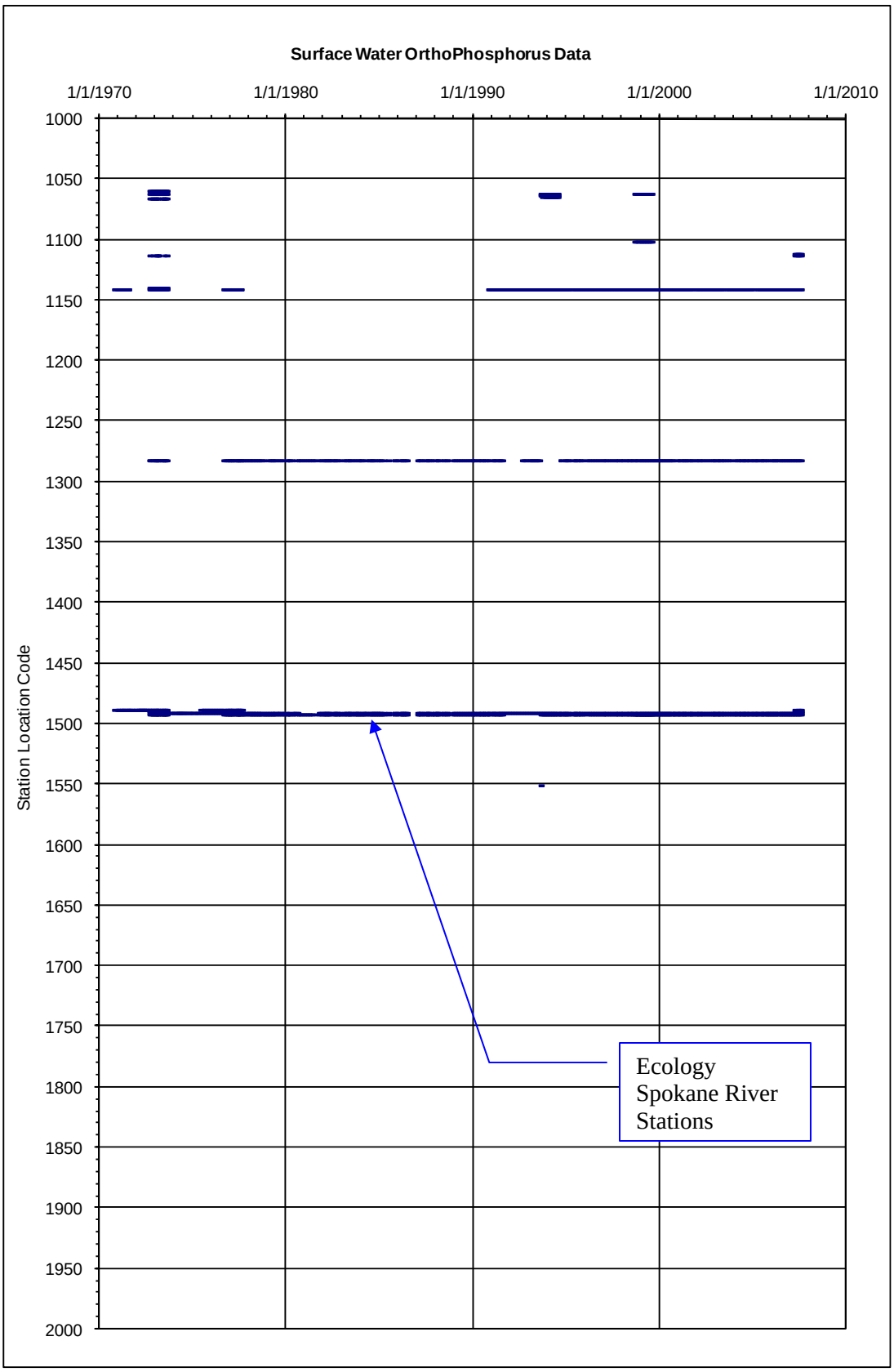

Figure 2.1b. Surface Water Orthophosphorus Sampling Dates

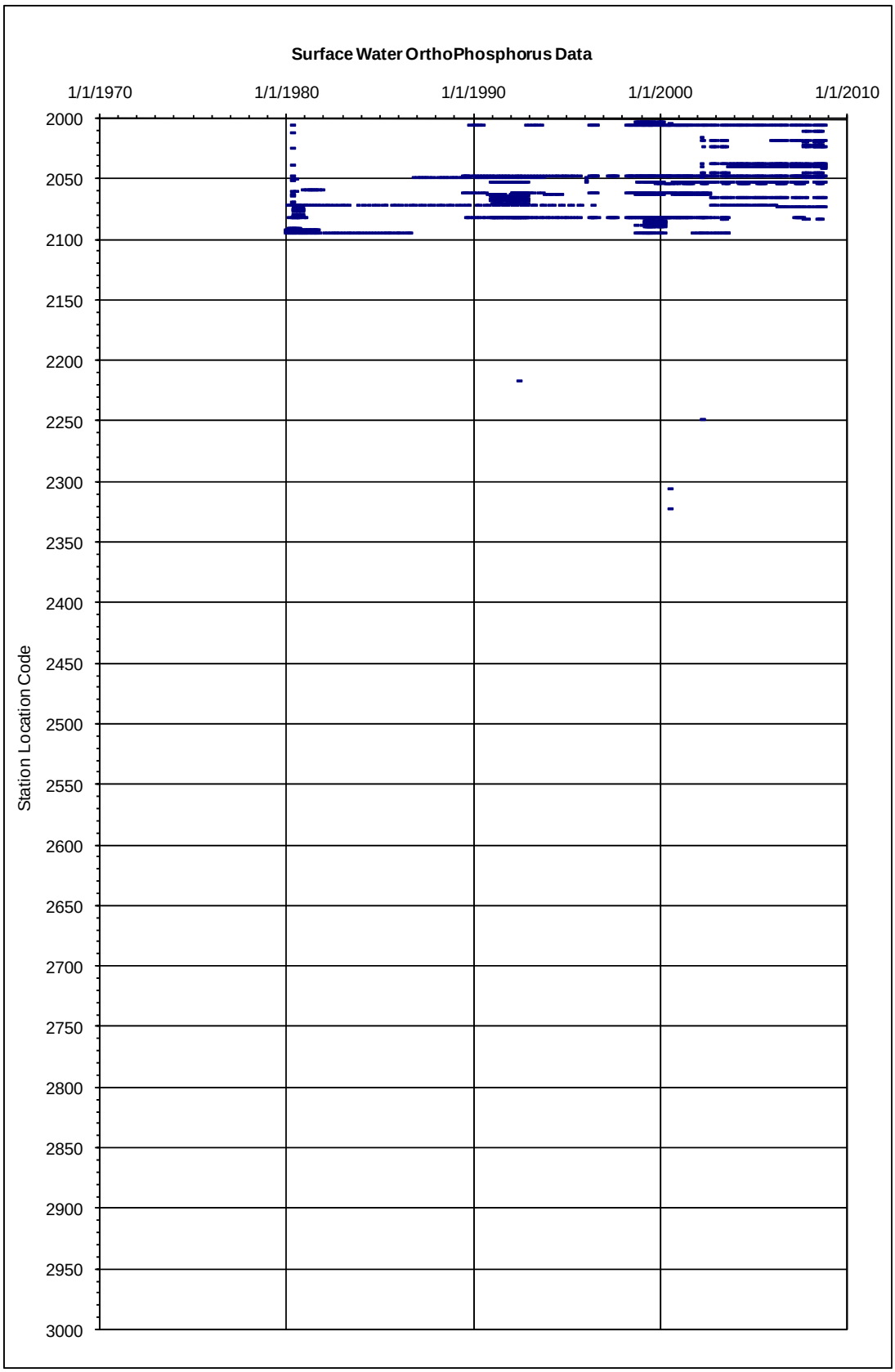

Figure 2.1c. Surface Water Orthophosphorus Sampling Dates

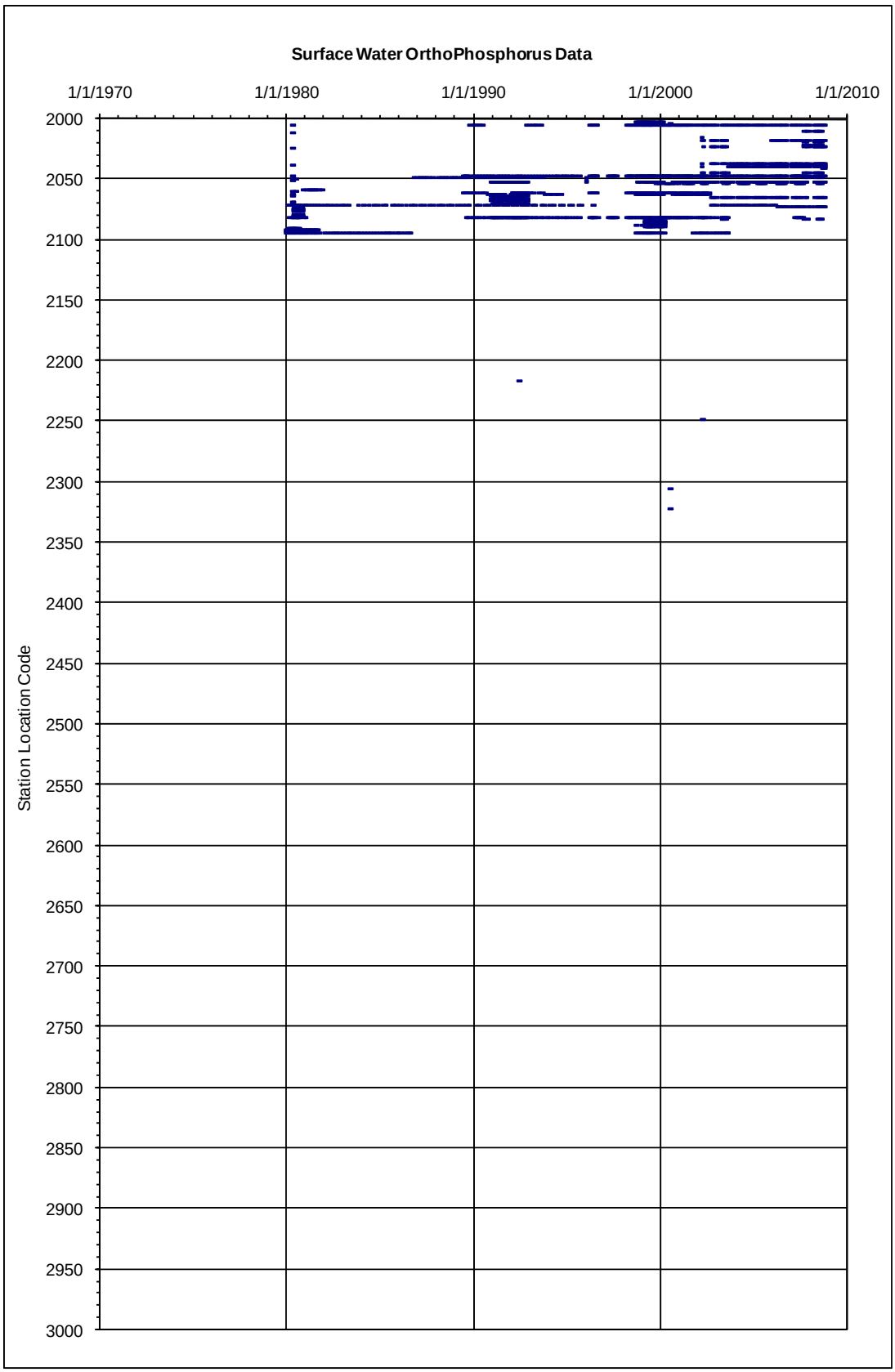

Figure 2.1d. Surface Water Orthophosphorus Sampling Dates

In Figure 2.1, the sample dates are shown by sample location code as assigned in the database. There are some sample location codes without data. These gaps in the graphs were removed by reassigning the codes only for Figure 2.2 to show all the dates on one figure.

The 23 locations with more 100 samples are shown in Figure 2.3. Additionally shown is the location name in the database as provided in the original dataset. The same data are shown in Figure 2.4 with the date scales modified to start at 1990 to focus on the more recent data.

The 96 locations with data from 2001 for total phosphorus are shown in Figure 2.5 for times with orthophosphorus data.

The sample dates are shown in Figure 2.6 for the six selected locations Spokane River at Coeur d'Alene, Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.

There are fewer locations with orthophosphorus results than total phosphorus. Orthophosphorus generally appears to be more frequently reported with total phosphorus for long-term monitoring sites that may have a more thorough and designed monitoring plan, potentially with multiple objectives. Orthophosphorus was frequently not reported when total phosphorus was for the locations with only a few samples. Orthophosphorus appears to be less frequently analyzed and reported for these short-term sampling projects.

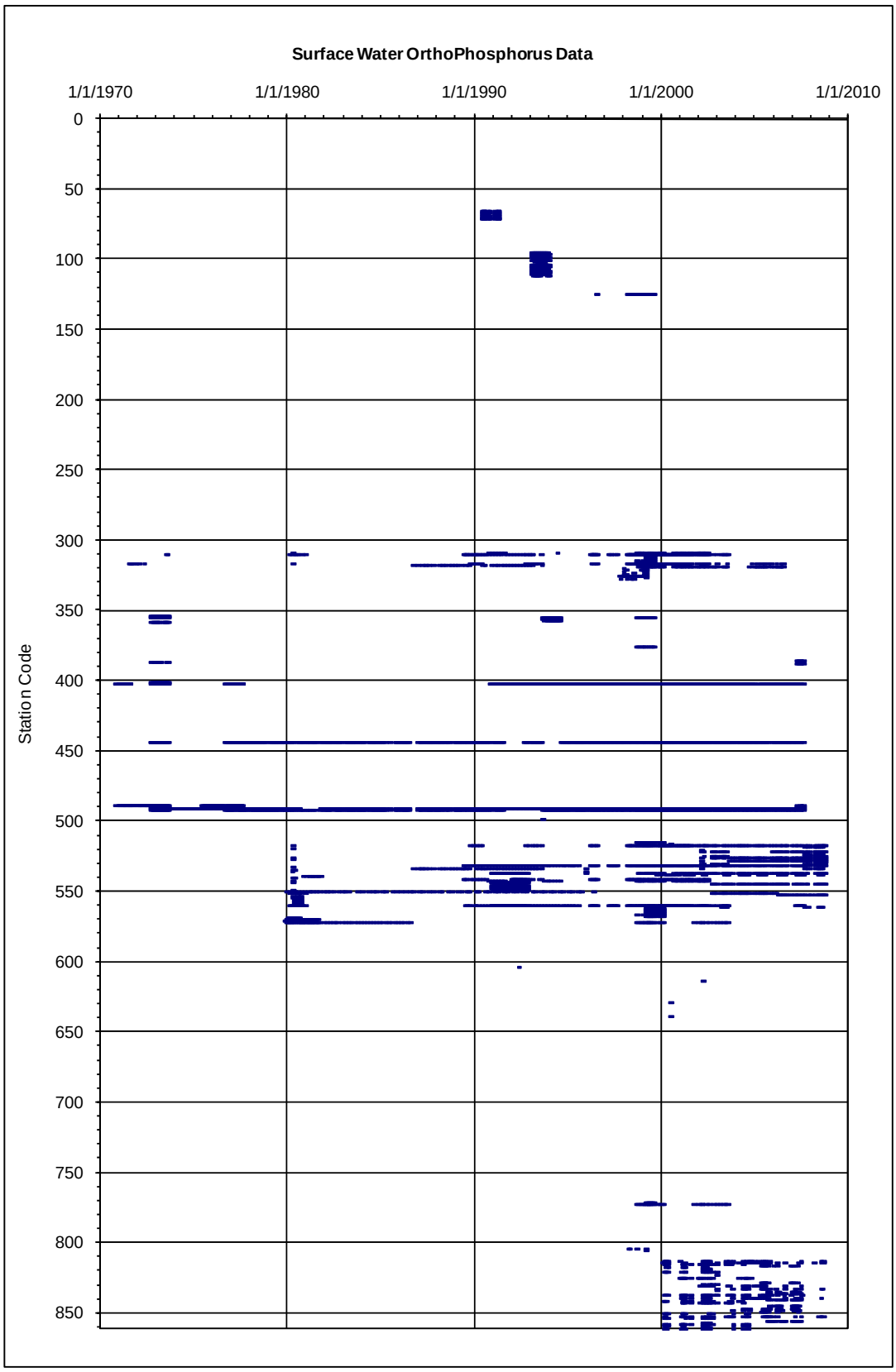

Figure 2.2. Surface Water Orthophosphorus Sampling Dates
Note: Station codes are unique for this figure.

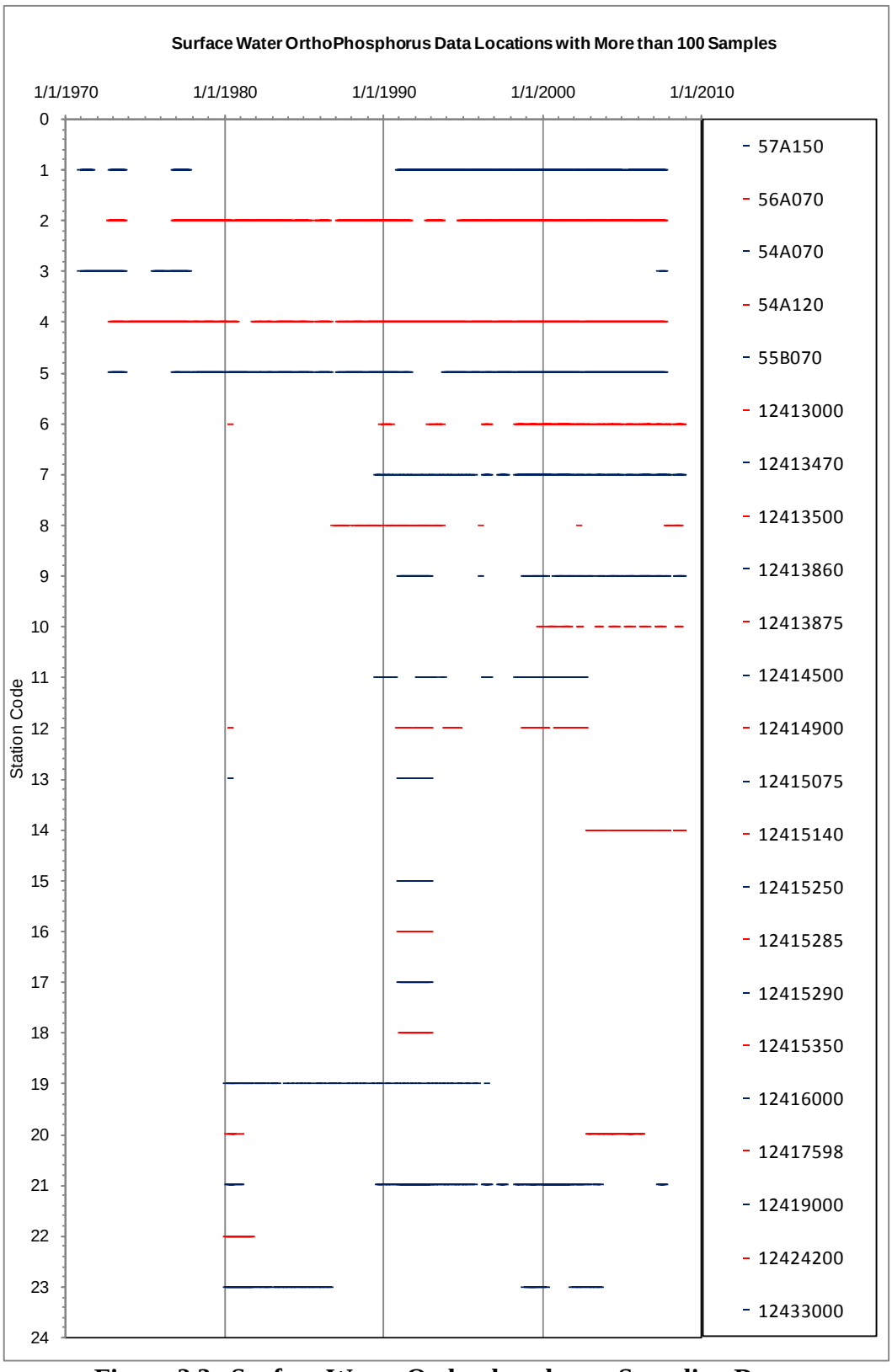

Figure 2.3. Surface Water Orthophosphorus Sampling Dates for Locations with more than 100 Samples
Note: Station codes are unique for this figure.

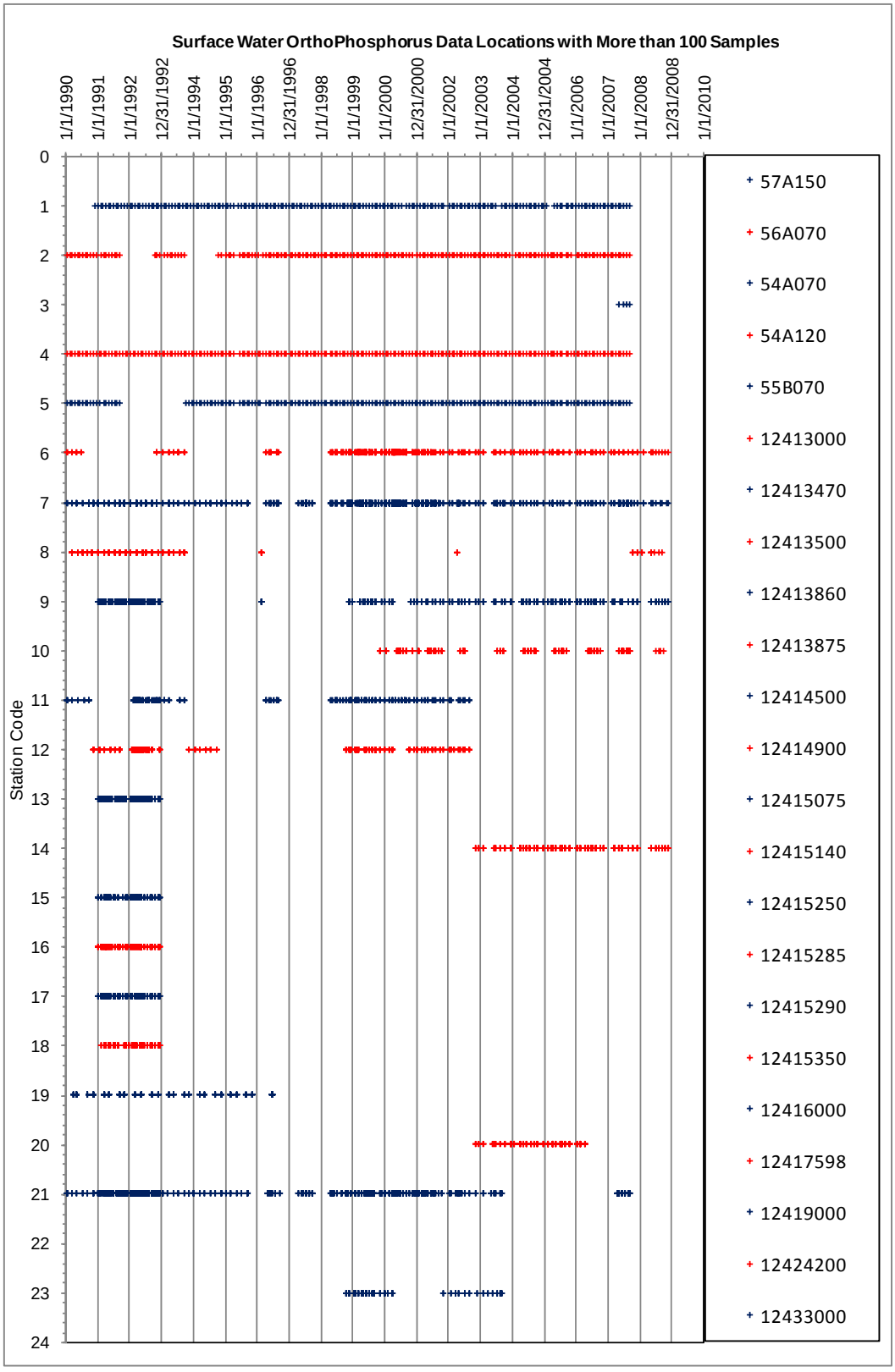

Figure 2.4. Surface Water Orthophosphorus Sampling Dates for Locations with more than 100 Samples starting at 1990

Note: Station codes are unique for this figure.

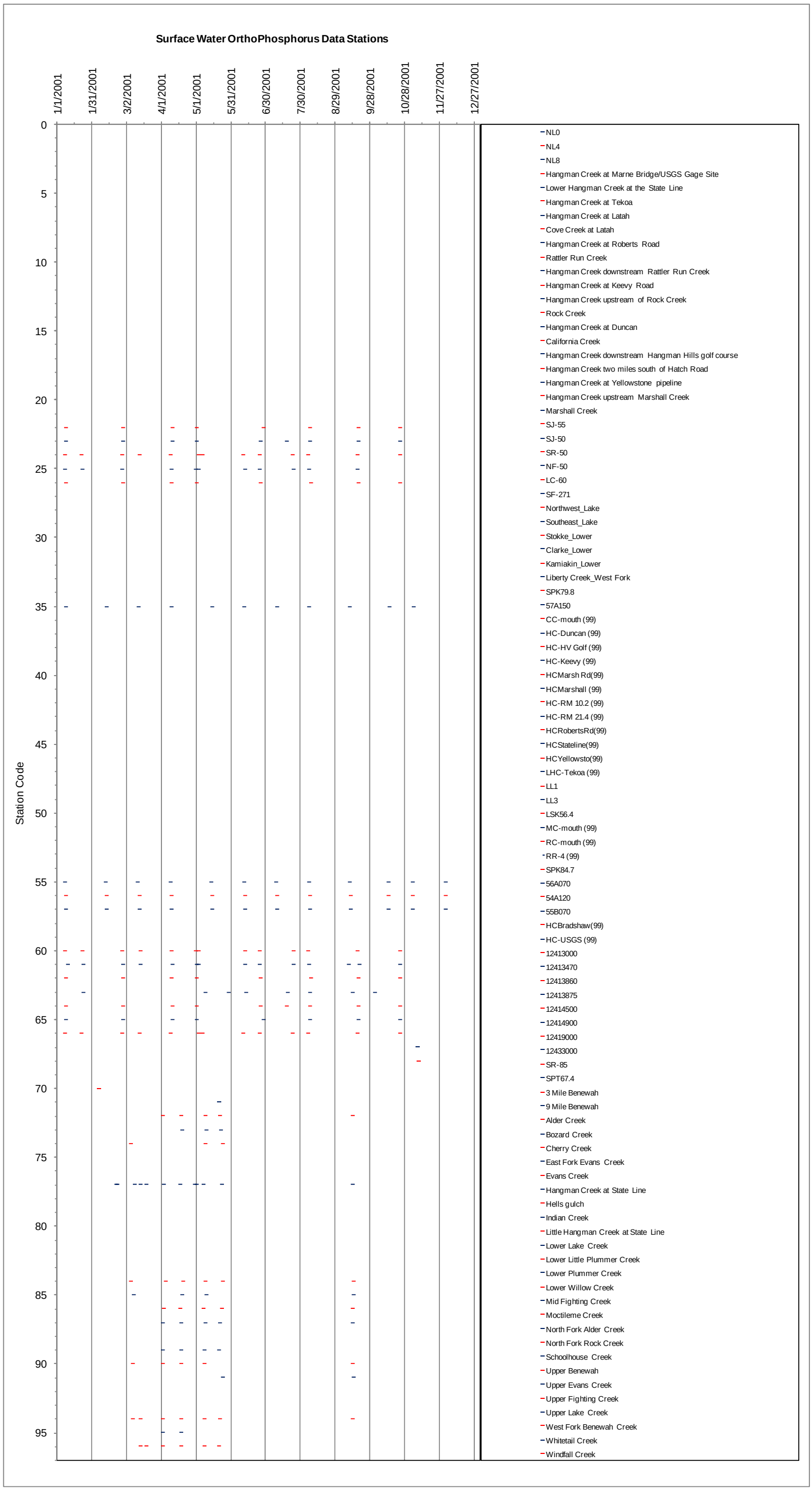

Figure 2.5. Surface Water Orthophosphorus Sampling 2001
Note: Station codes are unique for this figure.

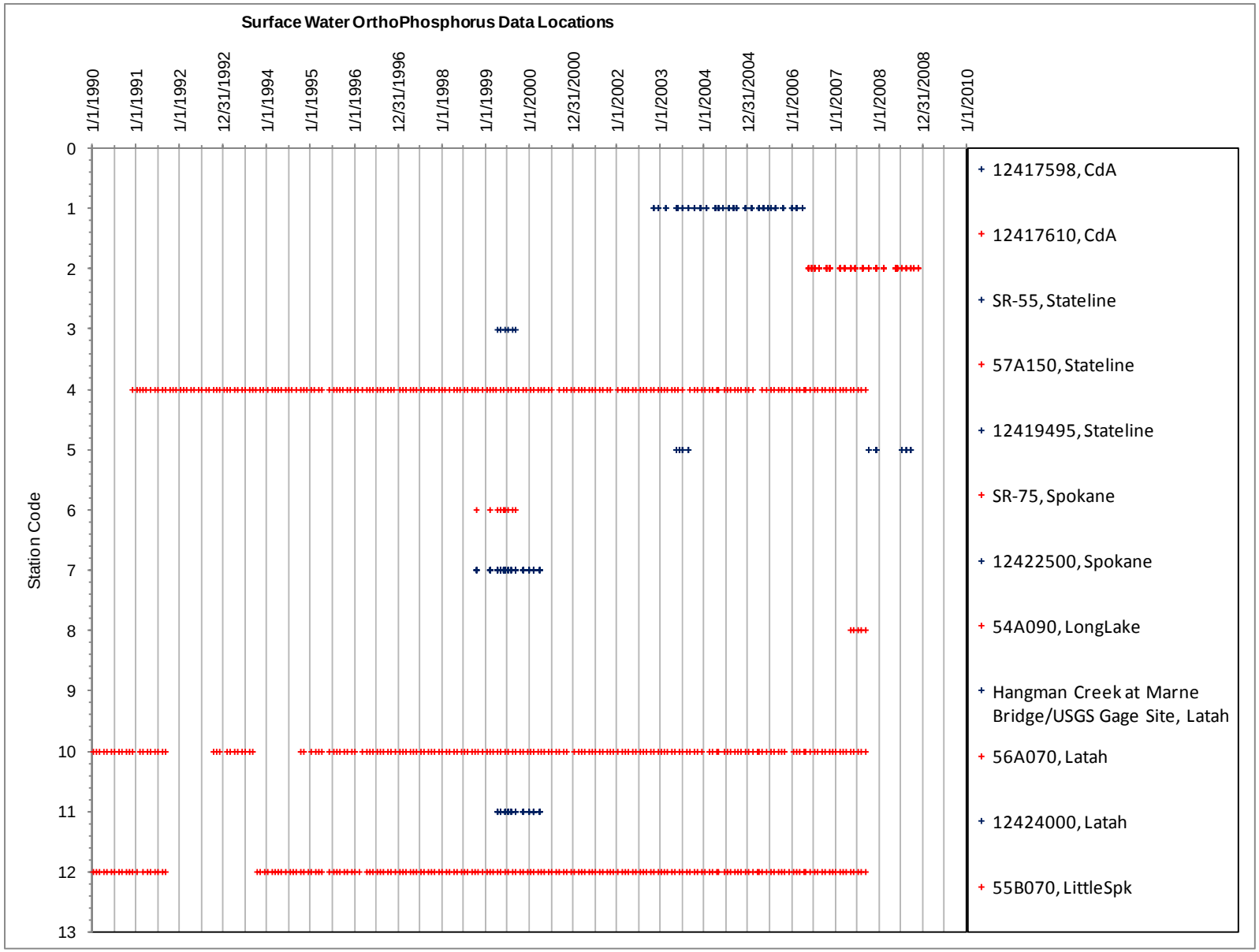

Figure 2.6. Surface Water Orthophosphorus Sampling Dates for Selected Locations starting at 1990
Note: Station codes are unique for this figure.

3. AVERAGE MONTHLY PHOSPHORUS LOADINGS

Objective

The average monthly phosphorus loadings provide a simple portrayal of orthophosphorus loads by month. The Supplemental Phase 1 locations selected for bar graphs of surface water loads are at Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.

Linkage to TMDL

The average monthly loads provide a means of comparison to TMDL loads to the Spokane River for the fraction of orthophosphorus to total phosphorus.

Results

Plots of the average monthly orthophosphorus load are shown in Figures 3.1 through 3.6. (These figures have the y-axis scale set to the maximum value at the monitoring location to best show the data range and trends. Figures with the y-axis set the same for all graphs for comparison between monitoring locations are shown in Figures 3.1Scale through 3.6Scale in Appendix A.) Monthly data for the period of record were averaged. Three plots are shown of the average monthly orthophosphorus load: 1) of the monthly load; 2) the monthly load along with the number of samples averaged and the numbers of years with samples for the month both on the second y-axis on the right side of the graph; and 3) the monthly load along with the current and targeted load in the Spokane River TMDL. The current and targeted TMDL loads are from Table 4 and Appendix C of the Spokane River TMDL (Ecology, 2008).

The loads are usually greater during the first half of the year (January through June) than the second half of the year (July through December). The highest loads generally occur in May in the Spokane River, except at Long Lake headwaters where May has one of the lowest loads and November has the highest. As shown in Figure 3.2, the Stateline load is based on data from about 20 years whereas the Long Lake load is only based on data from about 2 years as shown in Figure 3.4. For Hangman Creek the loads are highest in January, February, and March. For the Little Spokane River, loads are highest in March.

Average monthly orthophosphorus loads by month and year are shown in Figures 3.7 through 3.10 for the years 2000 through 2007. The loads for each of the six stations are compared side-by-side. The Spokane River at Stateline and Hangman Creek generally has some of the highest orthophosphorus loads, although the Spokane River at Coeur d'Alene and the Little Spokane River had some high loads during the later years.

The average monthly loads for orthophosphorus and total phosphorus generally have similar trends with the orthophosphorus loads being less. Orthophosphorus has a higher monthly average in March for the Spokane River at Lake Coeur d'Alene while the monthly average in March for total phosphorus was similar to the annual average. Orthophosphorus for Spokane River at Long Lake headwaters exhibits a different trend than total phosphorus with orthophosphorus loads similar throughout the year, slightly higher in August through December, while total phosphorus loads are highest in January and then decrease.

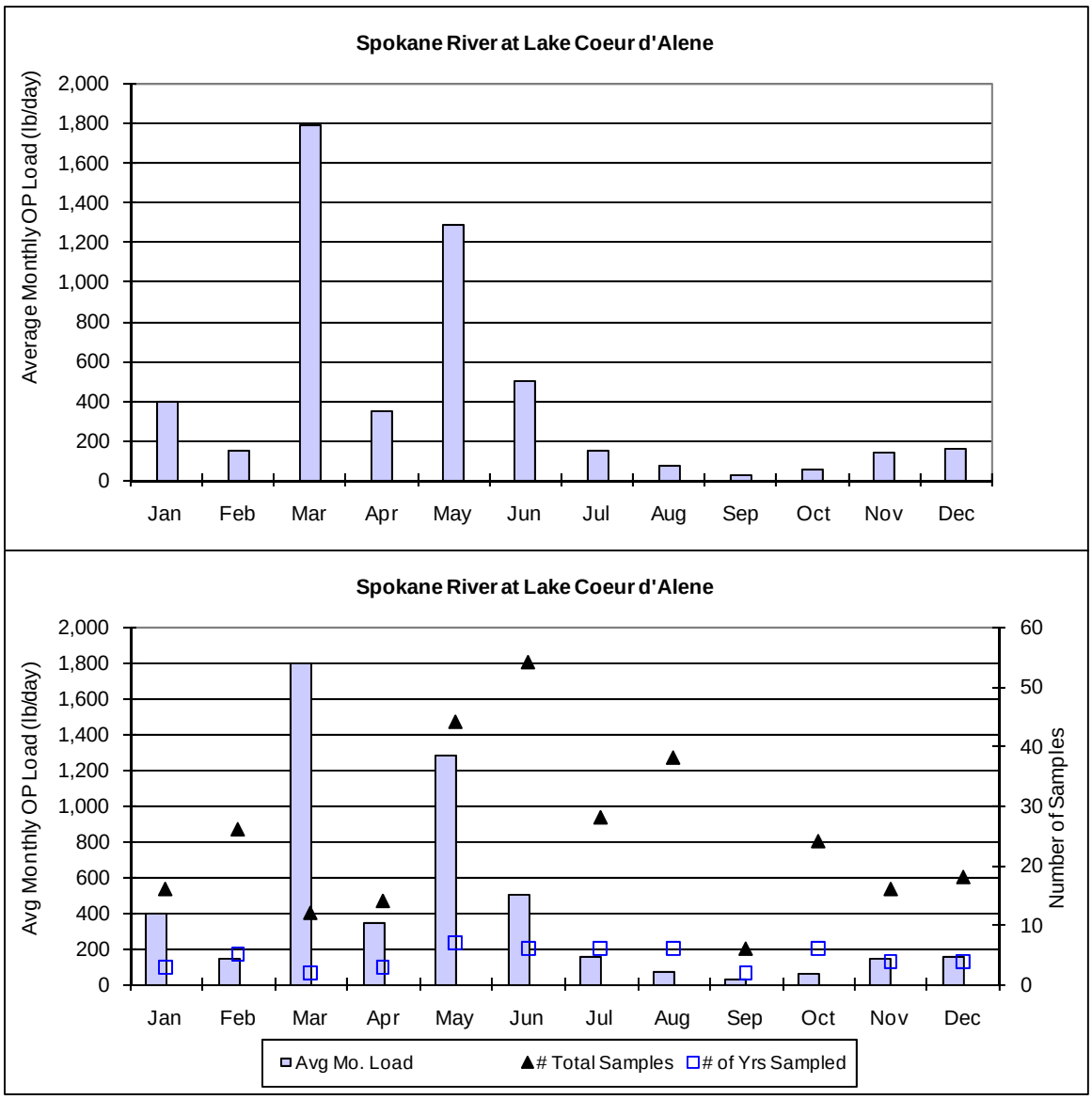

Figure 3.1. Average Monthly Orthophosphorus Load for Spokane River at Lake Coeur d'Alene

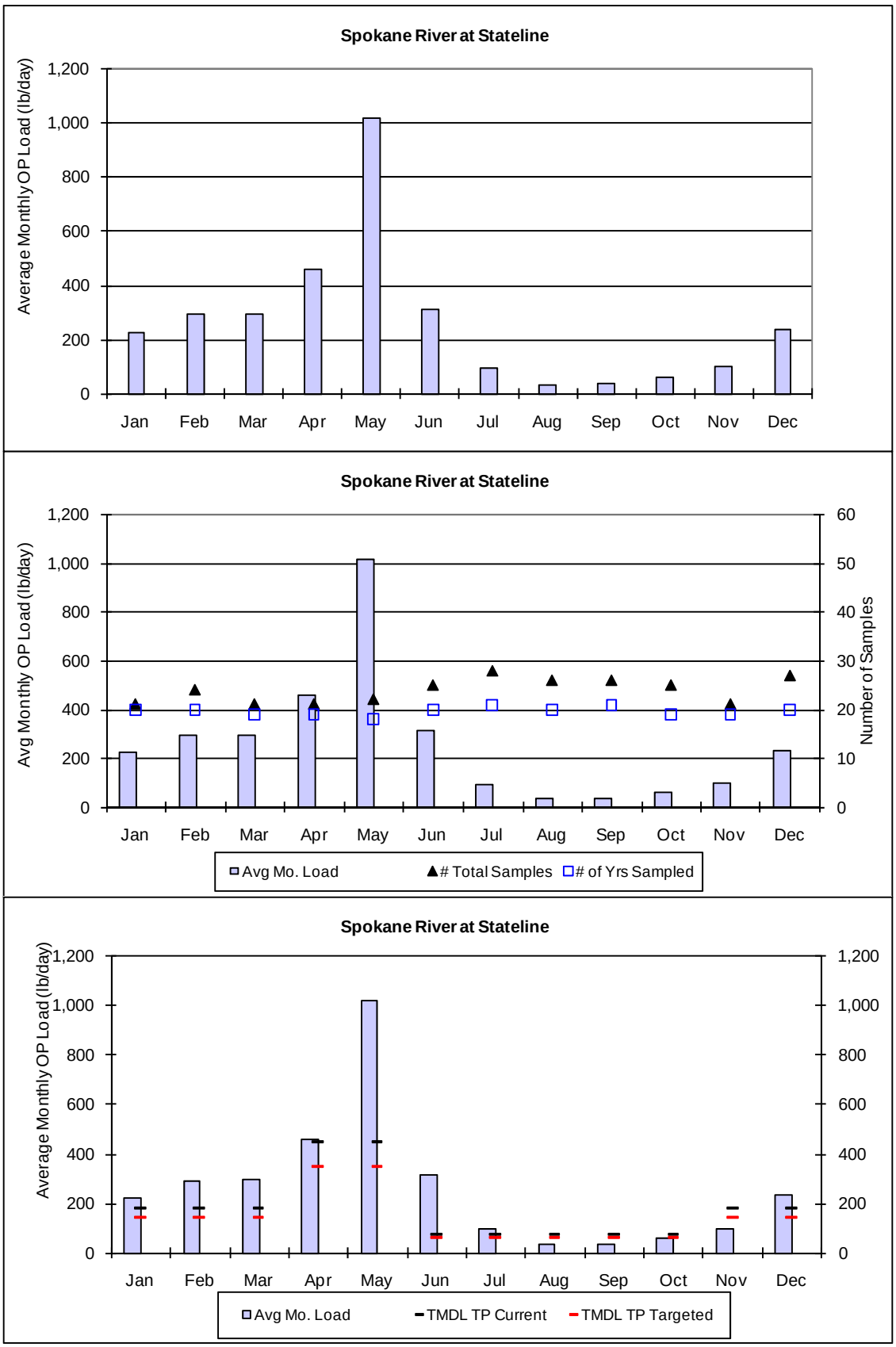

Figure 3.2. Average Monthly Orthophosphorus Load for Spokane River at Stateline

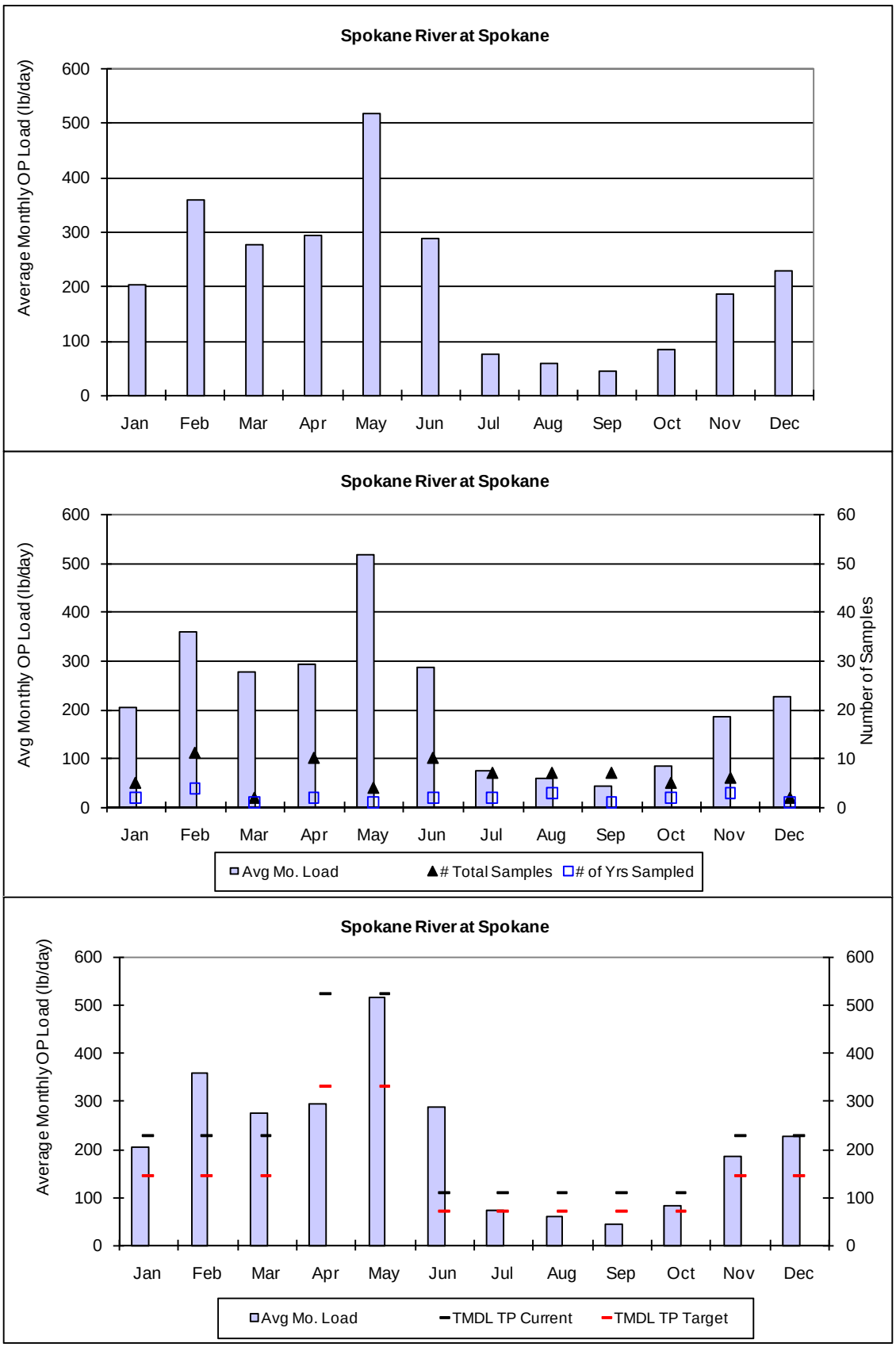

Figure 3.3. Average Monthly Orthophosphorus Load for Spokane River at Spokane

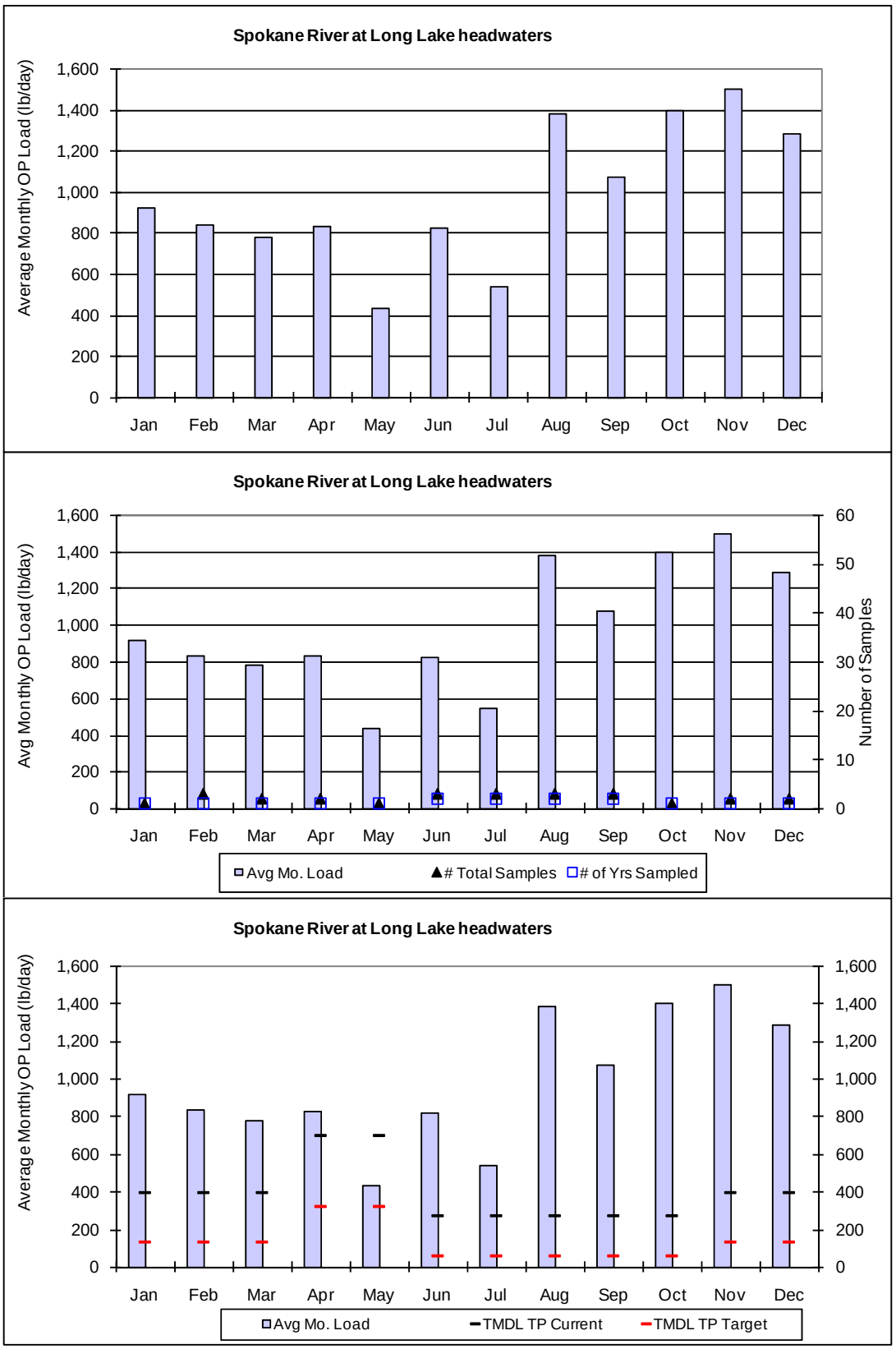

Figure 3.4. Average. Monthly Orthophosphorus Load for Spokane River at Long Lake headwaters

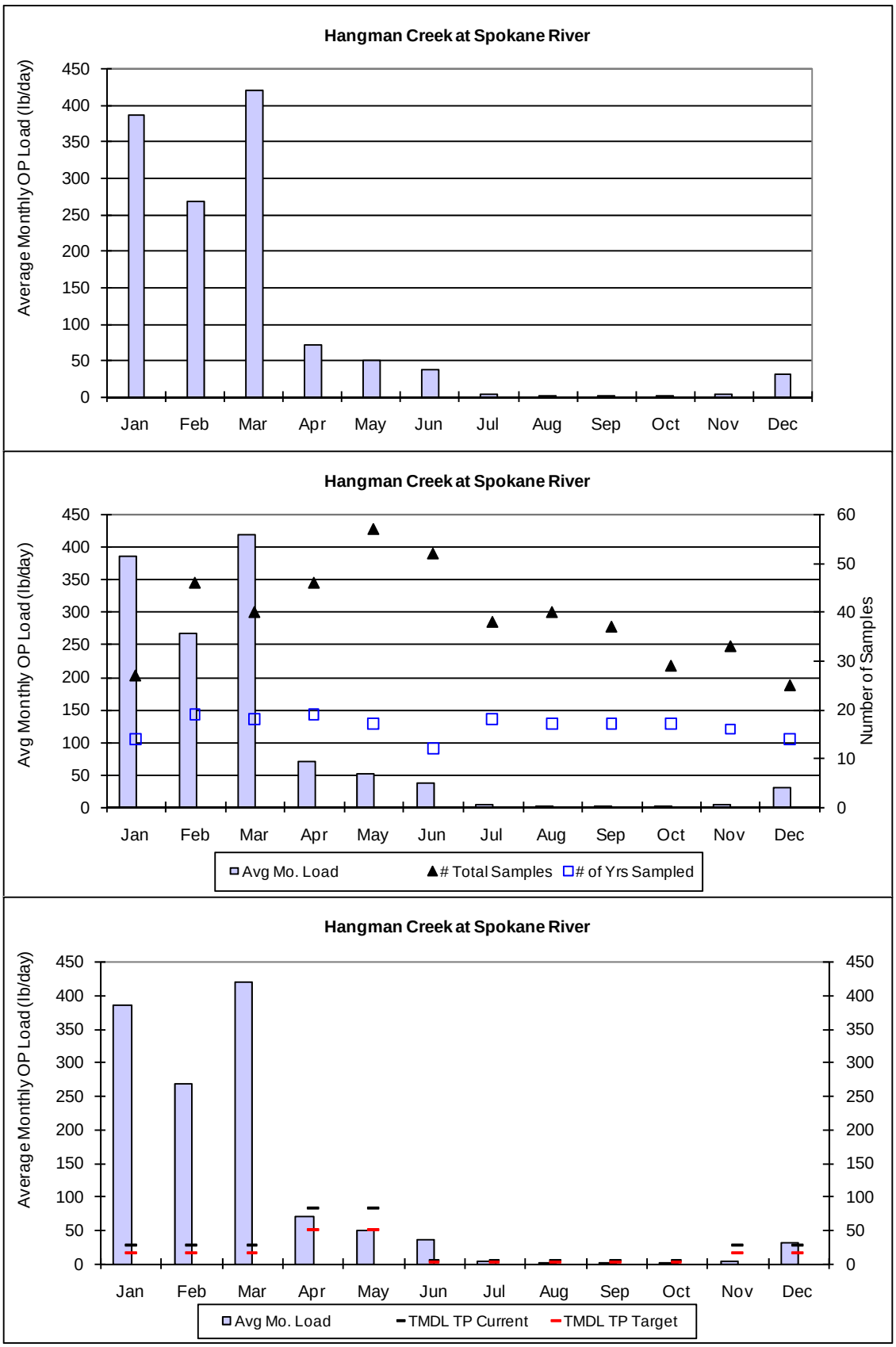

Figure 3.5. Average Monthly Orthophosphorus Load for Hangman Creek at Spokane River

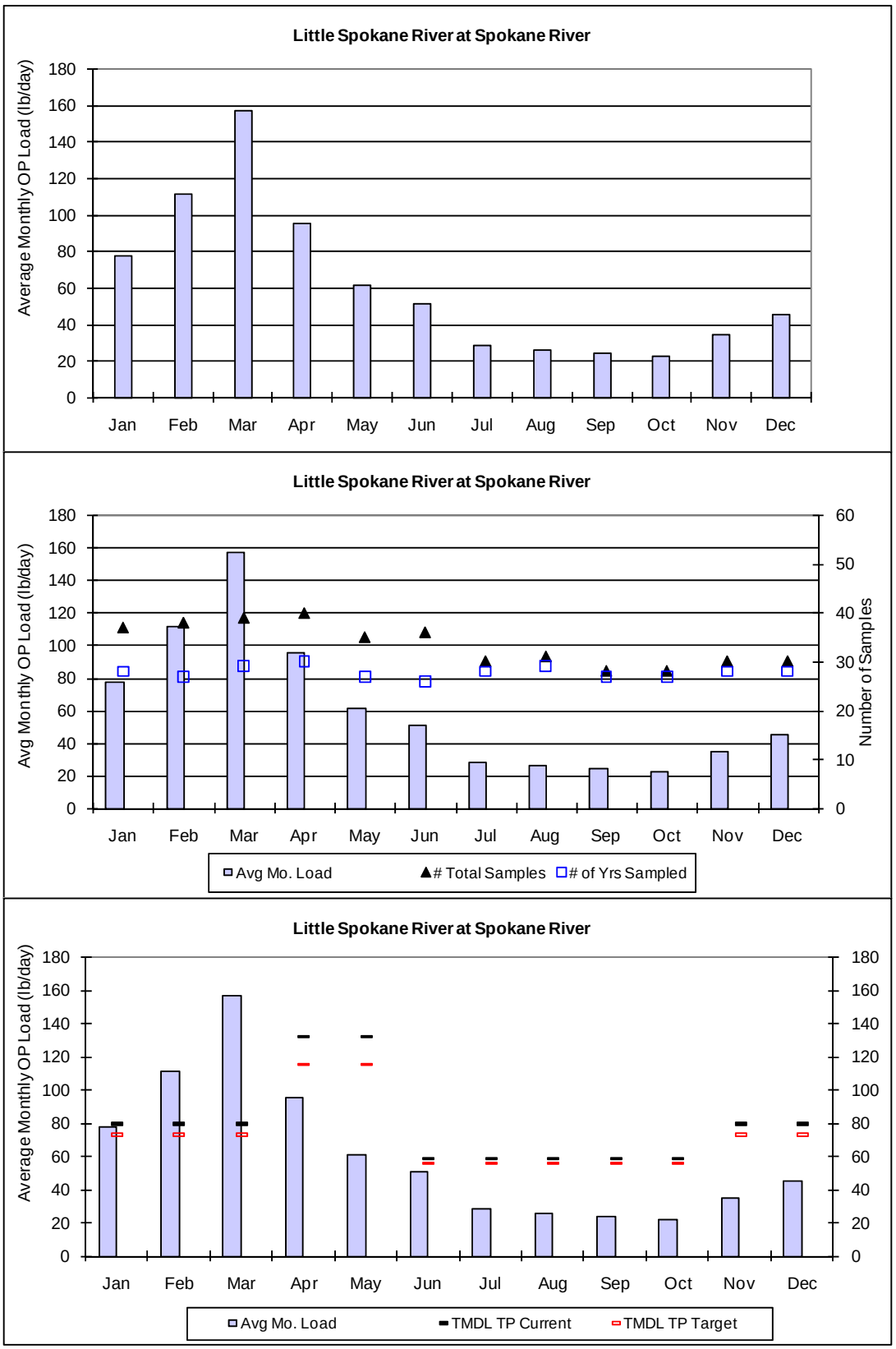

Figure 3.6. Average Monthly Orthophosphorus Load for Little Spokane River at Spokane River

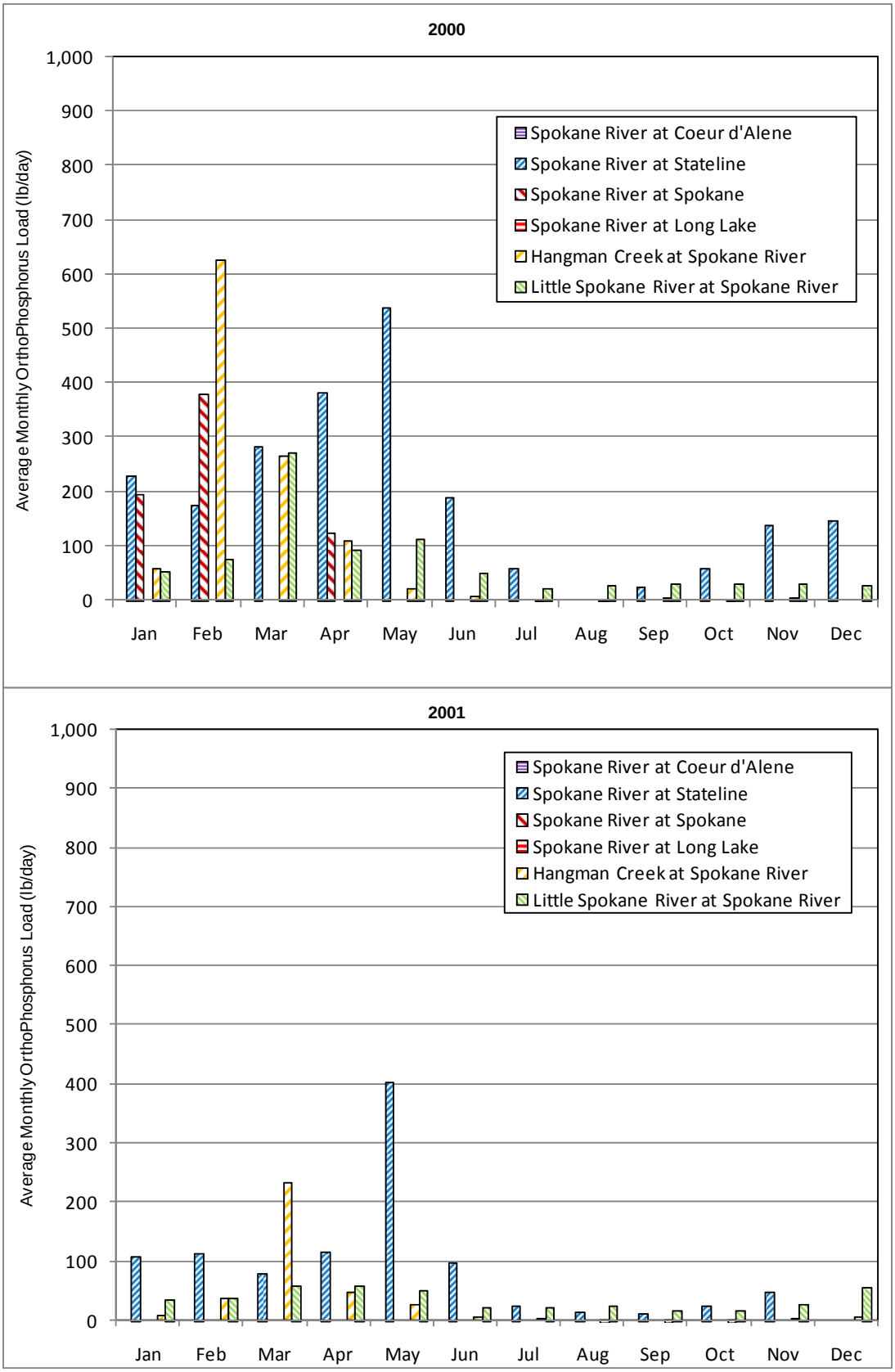

Figure 3.7. Average Monthly Orthophosphorus Load by Year, 2000 and 2001

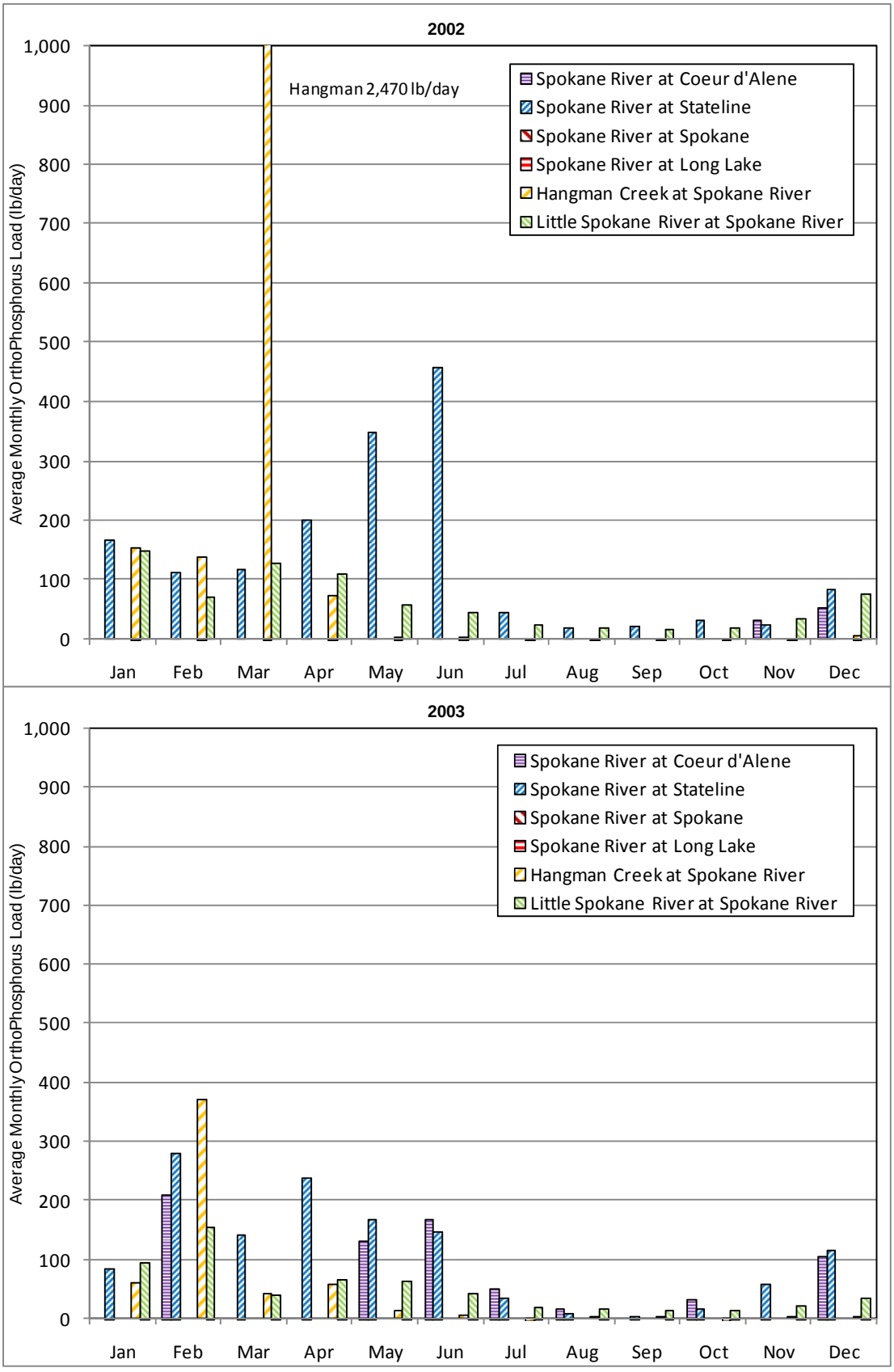

Figure 3.8. Average Monthly Orthophosphorus Load by Year, 2002 and 2003

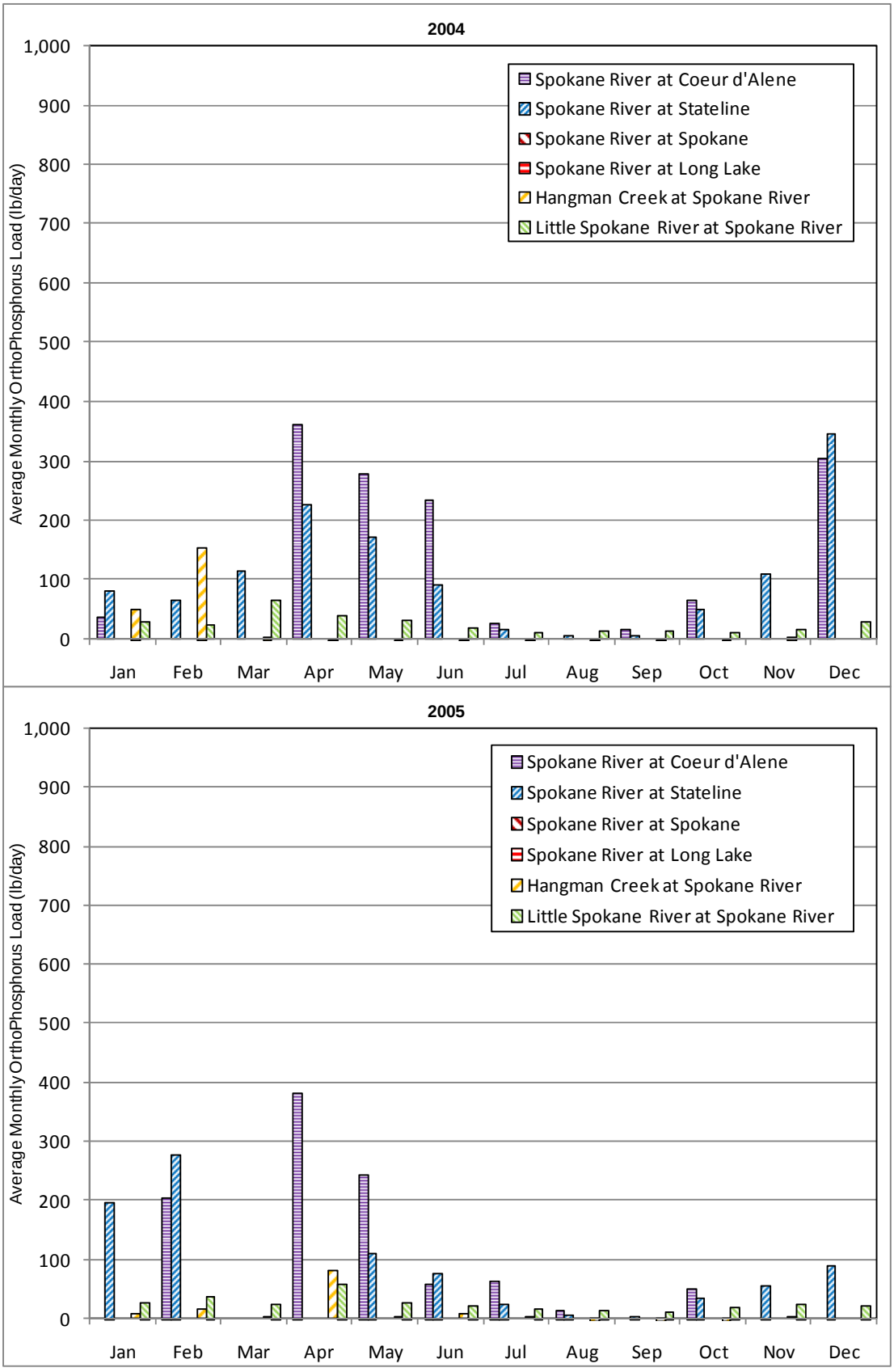

Figure 3.9. Average Monthly Orthophosphorus Load by Year, 2004 and 2005

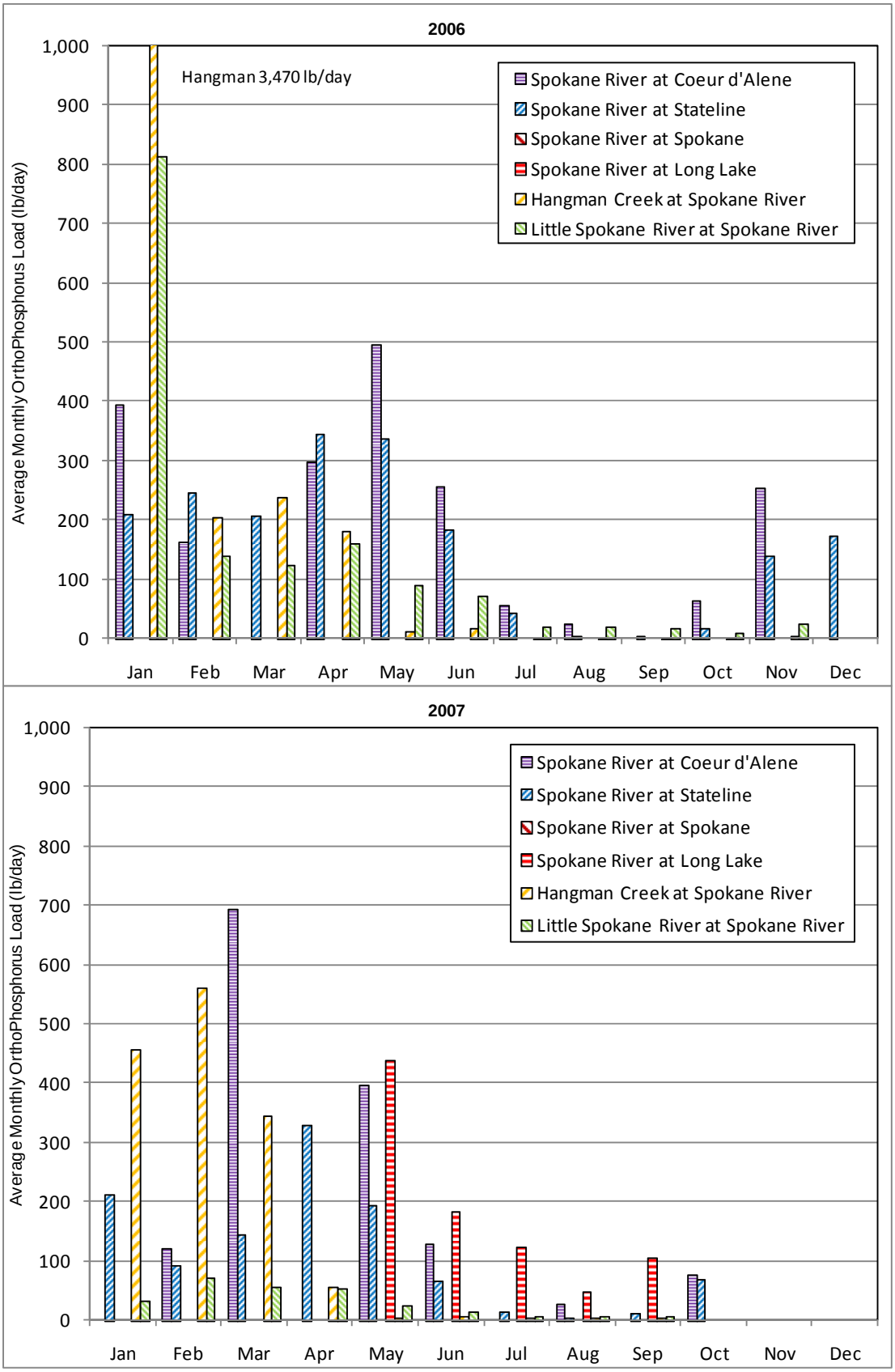

Figure 3.10. Average Monthly Orthophosphorus Load by Year, 2006 and 2007

4. KEY FLOW CHARACTERISTIC AVERAGE MONTHLY PHOSPHORUS LOADINGS

Objective

The monthly phosphorus loadings by flow characteristic provide further disaggregating of averaging by selecting only key flow periods. The Supplemental Phase 1 locations selected for bar graphs of surface water in 2001 are at Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.

Linkage to TMDL

The TMDL is based on 2001 flows. Average monthly phosphorus loadings for 2001 provide a comparison of the fraction of orthophosphorus to total phosphorus. (The label TMDL TP Current in the figures refers to the 2001 loads.)

Results

Plots of the monthly orthophosphorus load are shown in Figures 4.1 through 4.3. Only three of the six locations are shown because the other three locations do not have data for 2001. Two plots are shown of the average monthly orthophosphorus load: 1) of the monthly load; and 2) the monthly load along with the number of samples averaged (usually one) on the second y-axis on the right side of the graph. The results for 2001 are similar to the results of averaging the dataset.

The 2001 trends for orthophosphorus loads are similar to the total phosphorus trends. The 2001 orthophosphorus loads are about 50 percent less than the total phosphorus loads.

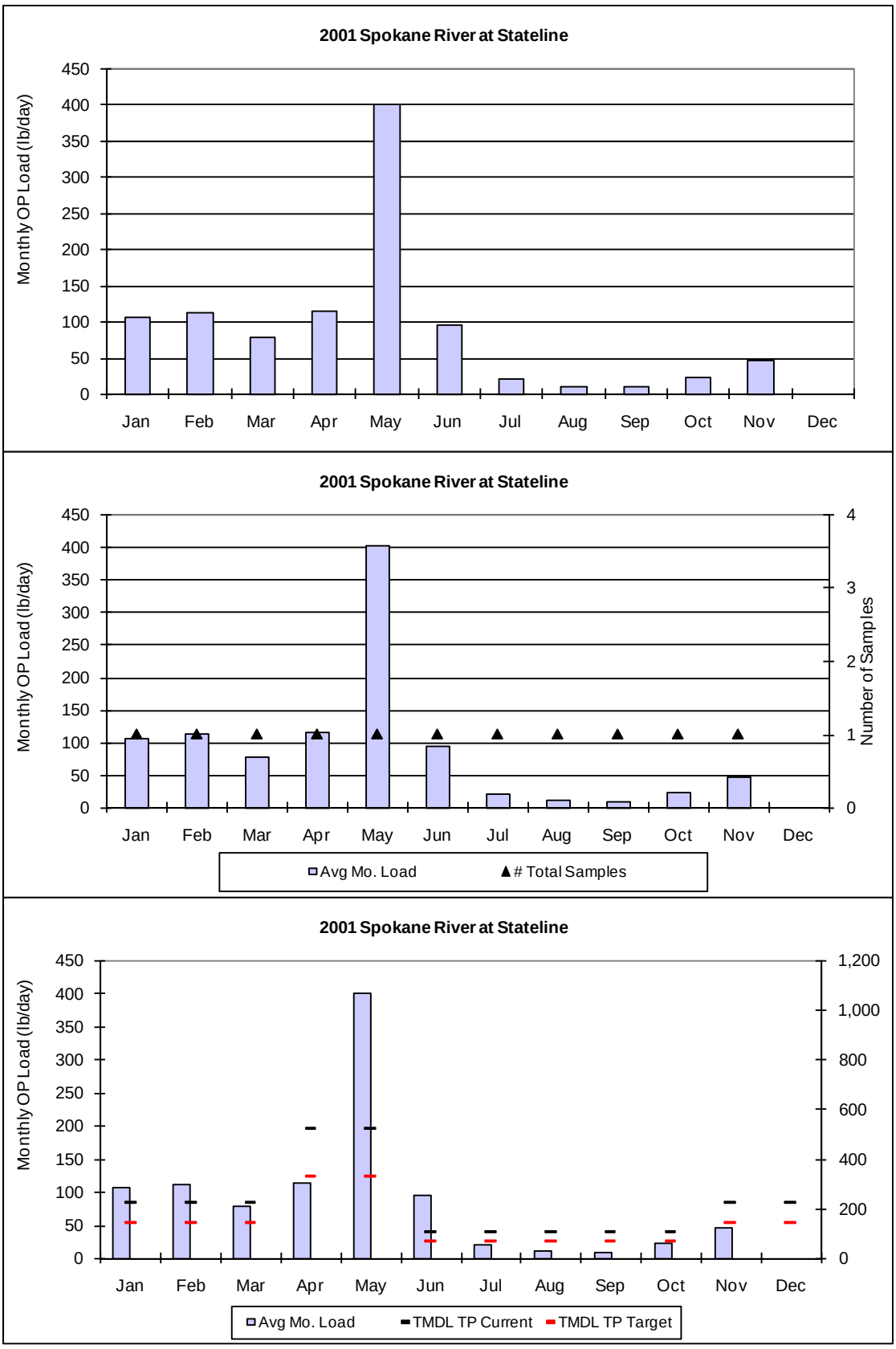

Figure 4.1. 2001 Monthly Orthophosphorus Load Spokane River at Stateline

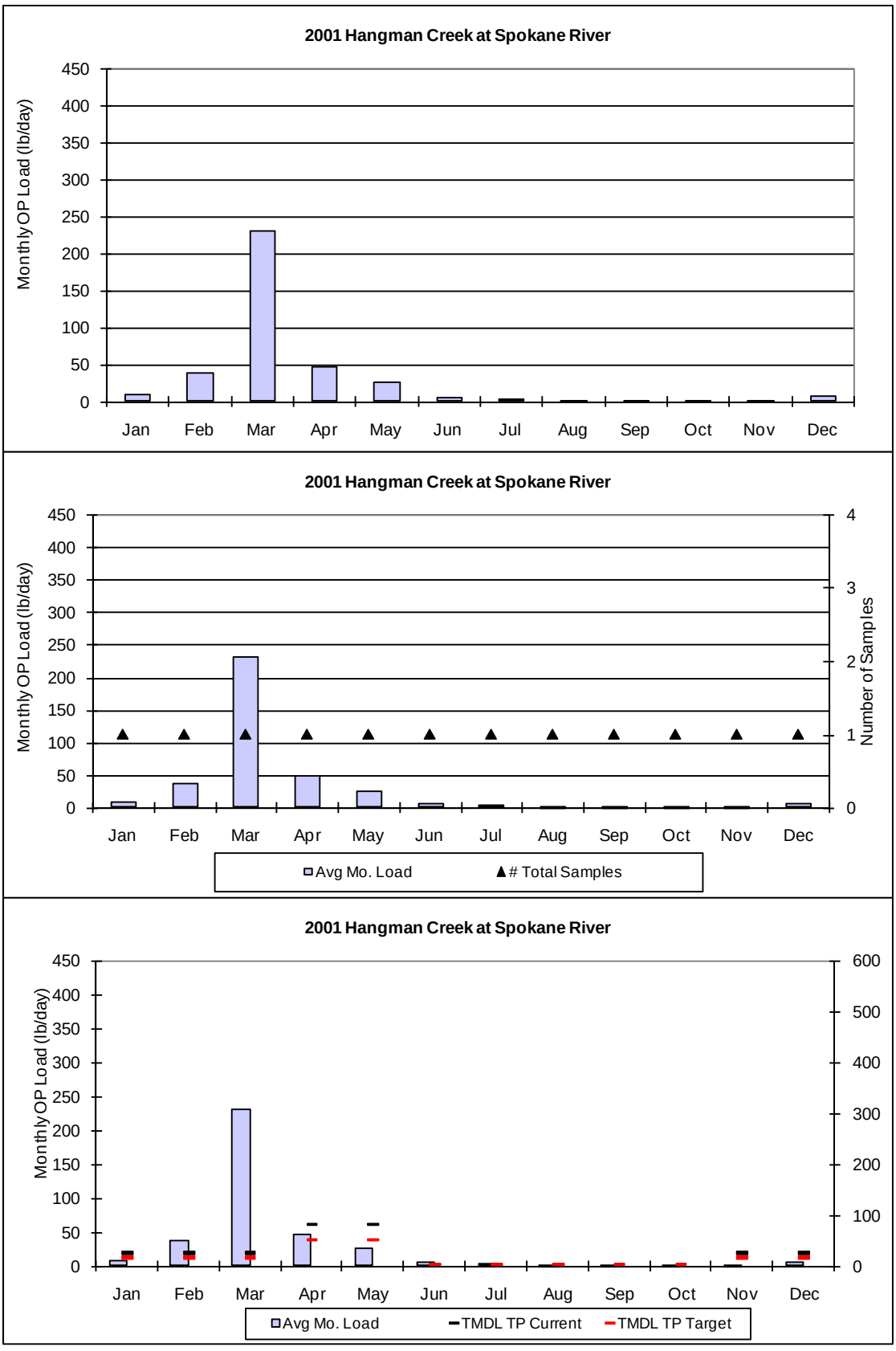

Figure 4.2. 2001 Monthly Orthophosphorus Load Hangman Creek at Spokane River

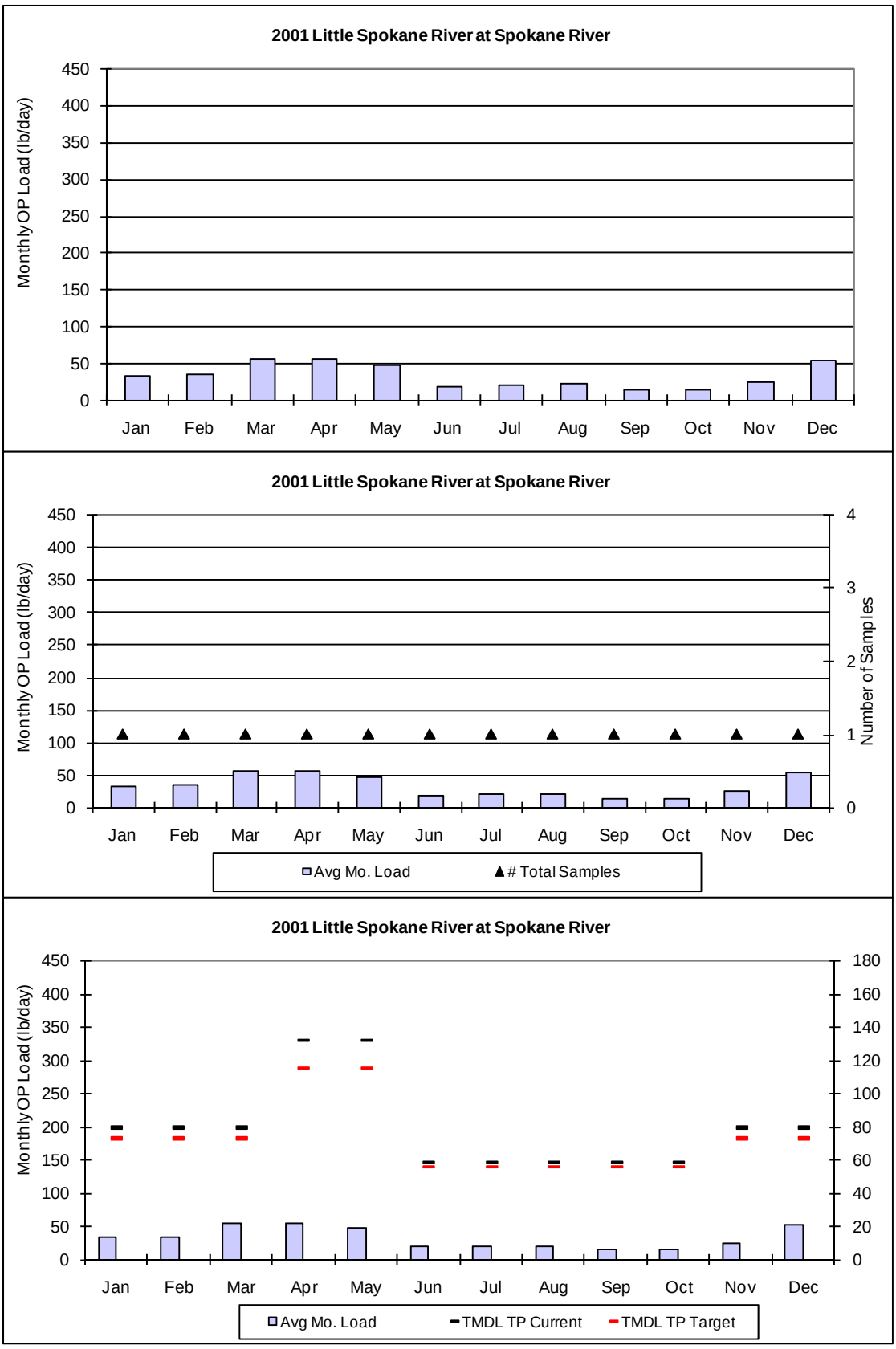

Figure 4.3. 2001 Monthly Orthophosphorus Load Little Spokane River at Spokane River

4.5. KEY FLOW CHARACTERISTIC AVERAGE MONTHLY PHOSPHORUS LOADINGS

Objective

The monthly phosphorus loadings by flow characteristic provide further disaggregating of averages by selecting only key flow periods. The Supplemental Phase 1 locations selected for bar graphs of loads are at Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.

Results

Since only three of the six locations had data for loads in 2001, loads were plotted for four flow conditions as shown in Figures 4.4 through 4.9. Each of these figures has a top graph and a bottom graph. Both graphs have arithmetic vertical scales. However, the vertical scale on the bottom graph is reduced to provide more detail regarding relative magnitudes and trends for the smaller loads. The average monthly loads are shown for comparison. The four flow conditions are flows below the seven-day minimum, flows less than 90 percent exceed, flows more than 10 percent exceed, and flows within 10 percent of 50 percent exceed. These flow values are from the USGS water data report for Spokane River at Spokane, Hangman Creek at Spokane, and Little Spokane River at Dartford and are shown in Tables 4.1, 4.2 and 4.3, respectively. The database was searched for when samples were collected at these flows. The loads were then graphed as shown in Figures 4.4 through 4.9. These flow ranges may have occurred at other times but orthophosphorus was not sampled then.

For the Spokane River, when high flow events occurred, the resulting orthophosphorus loads were generally greater than the average by 50 percent or more. Low flow events generally resulted in loads less than the average, except for a high load at Long Lake headwaters. For Hangman Creek, high flows results in high loads, 2 to 4 times the average. The Little Spokane River appears to be less variable in loads over the range of flows, with most of the high flow loads being similar to the average load.

As with total phosphorus loads, orthophosphorus loads are typically high during high flows, generally late spring for the Spokane River, and earlier for the Hangman Creek and Little Spokane River tributaries.

Table 4.1. USGS Flow Statistics Spokane River

12422500 SPOKANE RIVER AT SPOKANE, WA—Continued

SUMMARY STATISTICS

	Calendar Year 2006		Water Year 2007		Water Years 1891 - 2007	
Annual total	2,574,017		2,156,009			
Annual mean	7,052		5,907		6,682	
Highest annual mean					12,310	1974
Lowest annual mean					2,508	1977
Highest daily mean	20,600	Apr 19	23,000	Mar 29	49,000	May 31, 1894
Lowest daily mean	601	Sep 4	539	Sep 7	466	Aug 11, 1973
Annual seven-day minimum	610	Sep 3	545	Sep 4	502	Aug 21, 1994
Annual runoff (ac-ft)	5,106,000		4,276,000		4,841,000	
10 percent exceeds	16,400		13,800		17,000	
50 percent exceeds	6,400		5,220		3,720	
90 percent exceeds	837		700		1,500	

Flows in cubic feet per second (cfs)

Table 4.2. USGS Flow Statistics Hangman Creek

12424000 HANGMAN CREEK AT SPOKANE, WA—Continued

SUMMARY STATISTICS

	Calendar Year 2007		Water Year 2008		Water Years 1948 - 2008	
Annual total	65,495.7		100,181			
Annual mean	179		274		230	
Highest annual mean					629	1997
Lowest annual mean					27.3	1977
Highest daily mean	2,950	Jan 4	2,920	Mar 12	18,000	Jan 1, 1997
Lowest daily mean	4.9	Aug 13	10	Aug 19	0.81	Sep 5, 1992
Annual seven-day minimum	6.2	Aug 9	11	Oct 11	0.92	Sep 14, 1992
Annual runoff (ac-ft)	129,900		198,700		166,300	
Annual runoff (cfsm)	0.260		0.397		0.333	
Annual runoff (inches)	3.54		5.41		4.53	
10 percent exceeds	593		851		580	
50 percent exceeds	35		77		43	
90 percent exceeds	9.4		13		8.7	

Flows in cubic feet per second (cfs)

Table 4.3. USGS Flow Statistics Little Spokane

12431000 LITTLE SPOKANE RIVER AT DARTFORD, WA—Continued

SUMMARY STATISTICS

	Calendar Year 2007		Water Year 2008		Water Years 1929 - 2008	
Annual total	85,868		113,020			
Annual mean	235		309		300	
Highest annual mean					626	1997
Lowest annual mean					128	1931
Highest daily mean	748	Mar 26	1,330	Apr 15	3,710	Mar 21, 1997
Lowest daily mean	88	Aug 18	111	Aug 18	63	Jul 24, 1930
Annual seven-day minimum	89	Aug 12	113	Aug 13	65	Aug 13, 1931
Annual runoff (ac-ft)	170,300		224,200		217,100	
Annual runoff (cfsm)	0.354		0.464		0.451	
Annual runoff (inches)	4.80		6.32		6.12	
10 percent exceeds	476		716		608	
50 percent exceeds	185		201		201	
90 percent exceeds	96		128		119	

Flows in cubic feet per second (cfs)

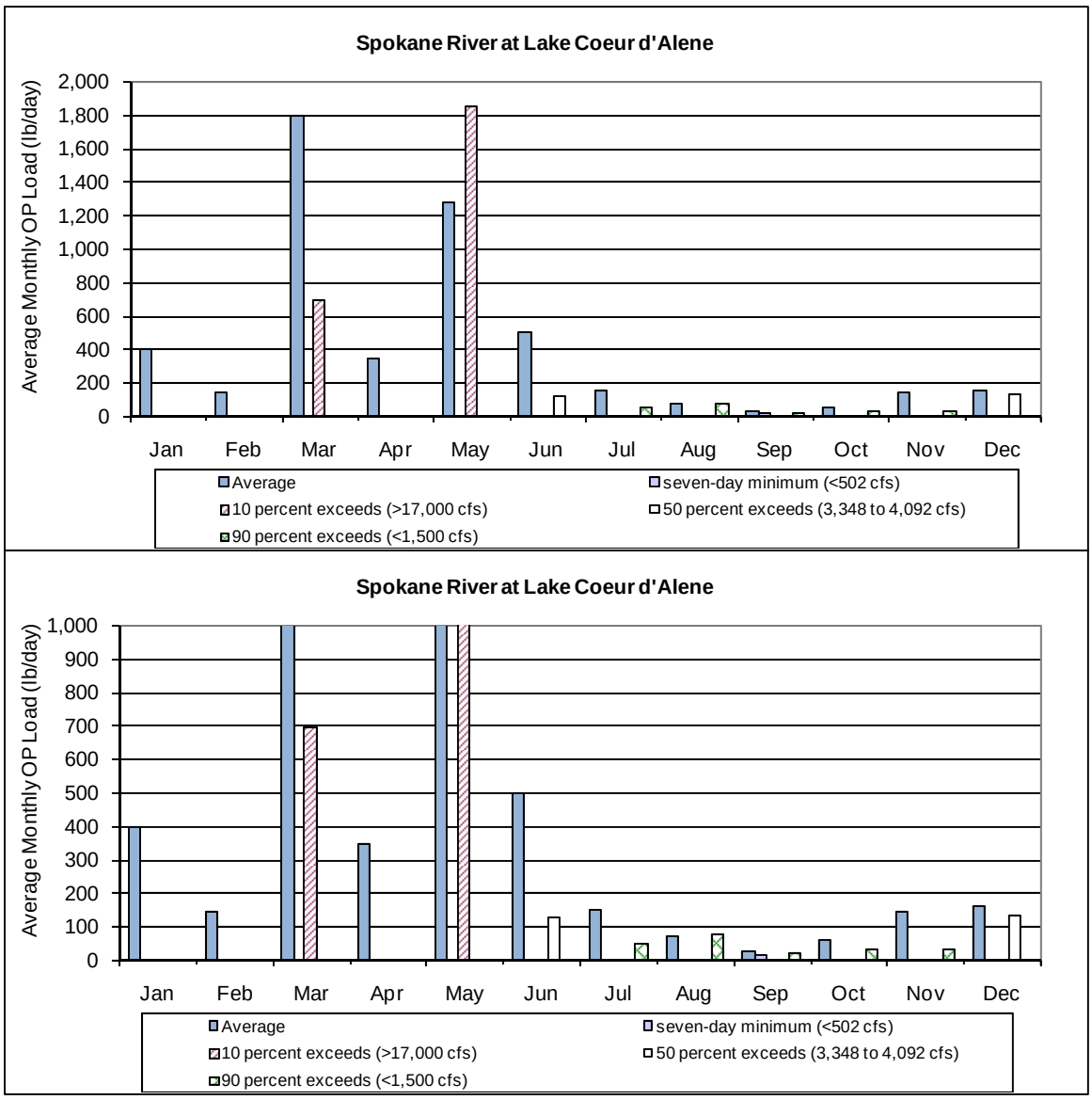

Figure 4.4. Loads by Flow for Spokane River at Lake Coeur d'Alene

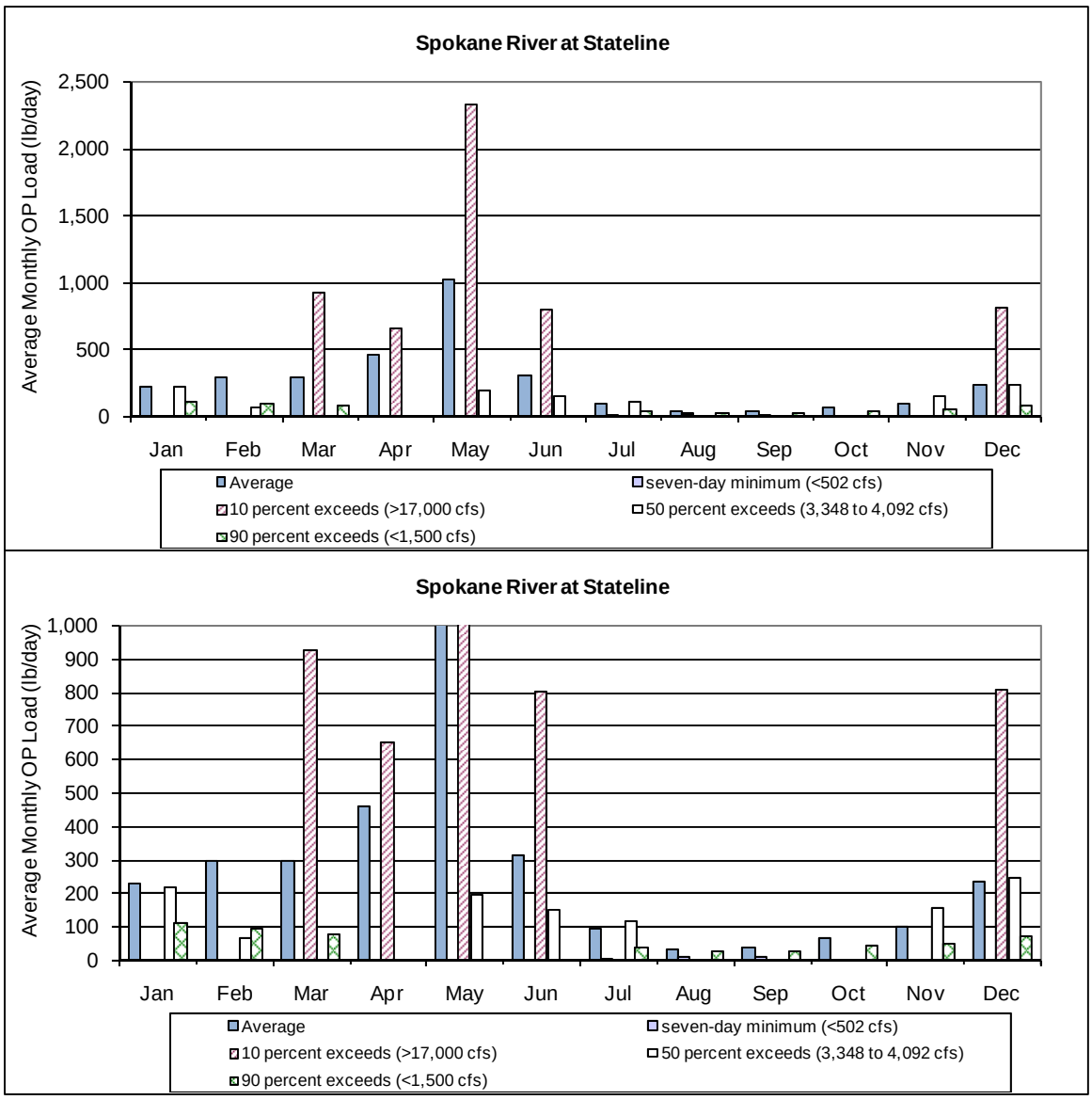

Figure 4.5. Loads by Flow for Spokane River at Stateline

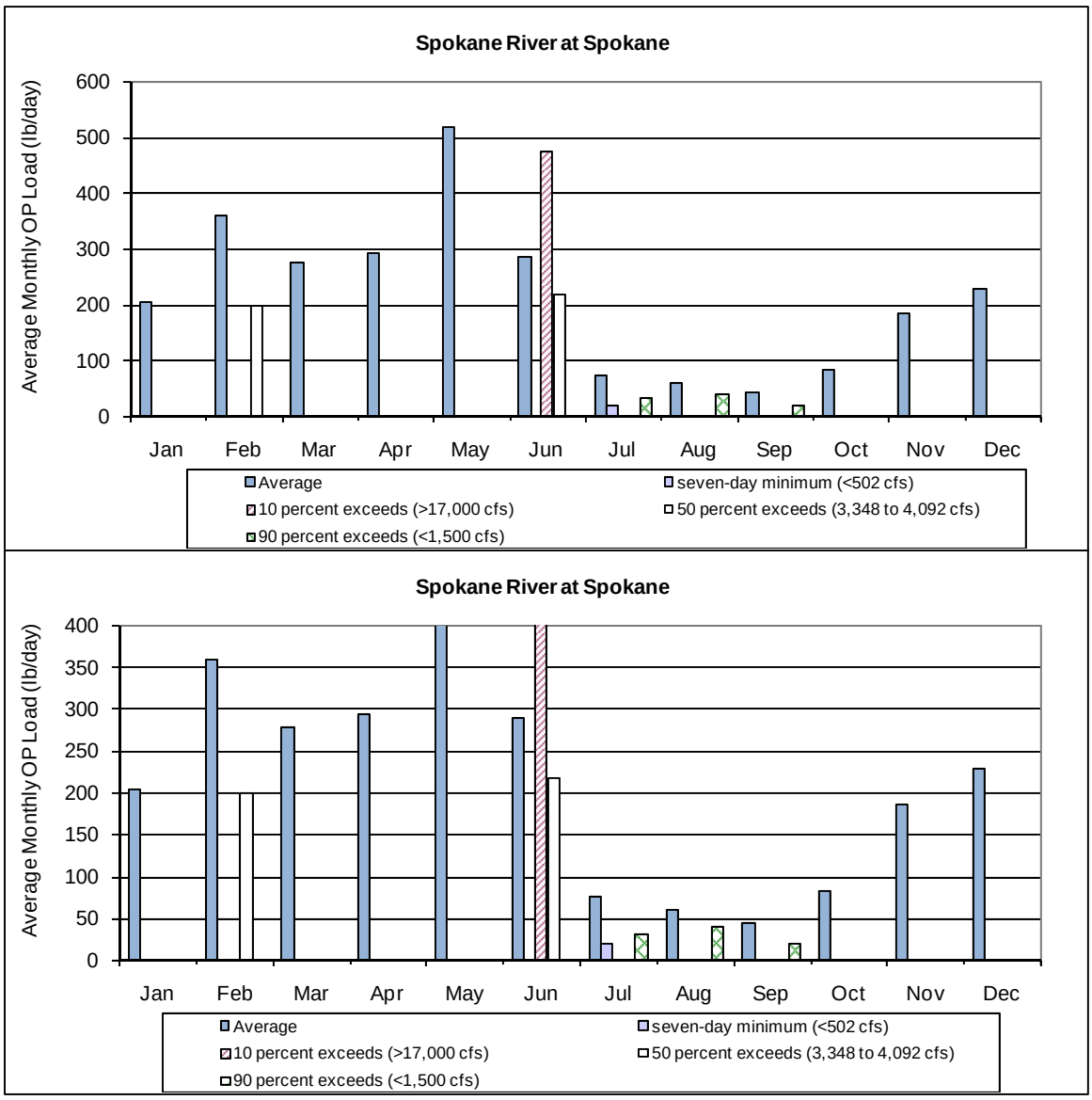

Figure 4.6. Loads by Flow for Spokane River at Spokane

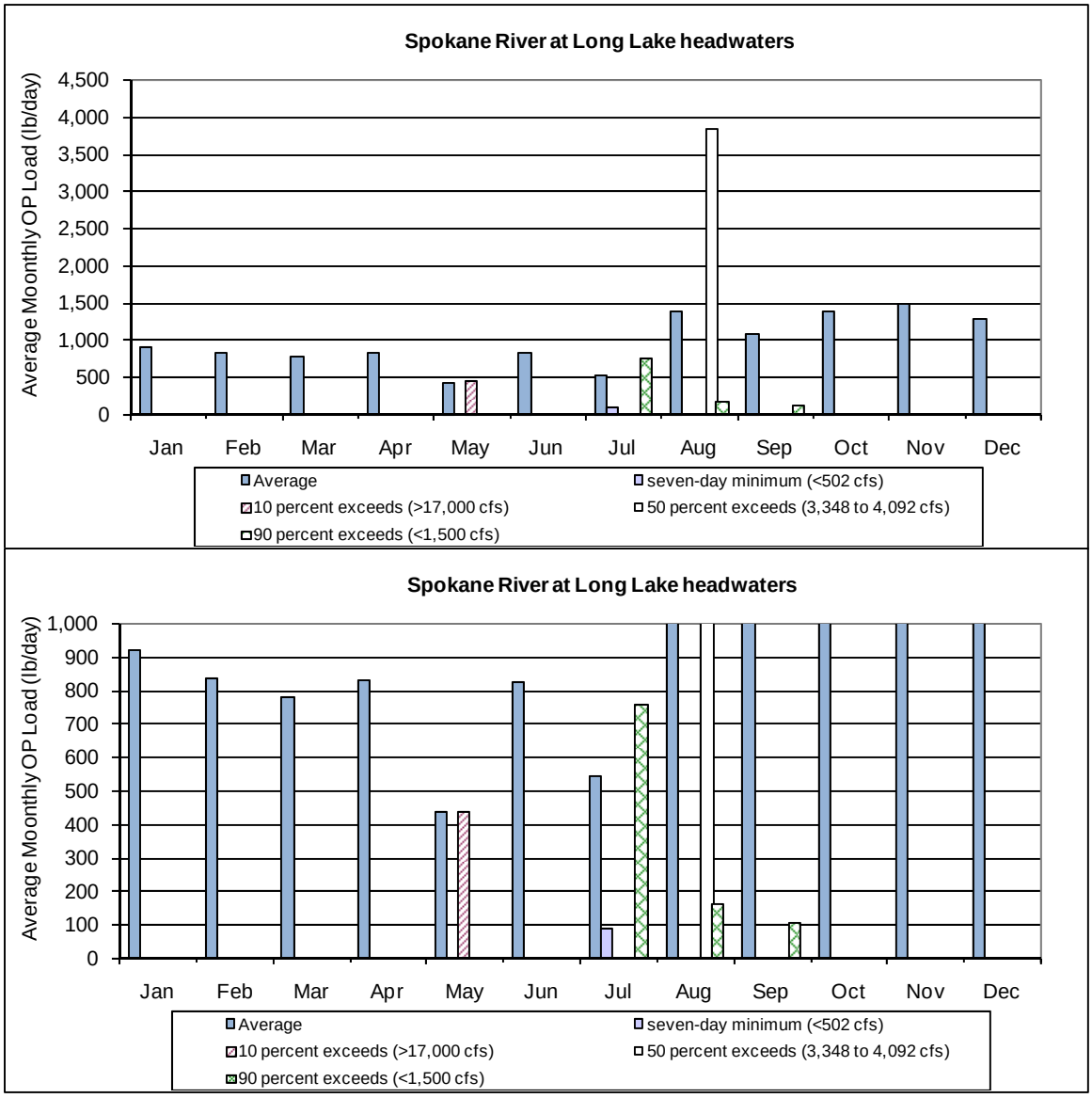

Figure 4.7. Loads by Flow for Spokane River at Long Lake headwaters (Nine Mile)

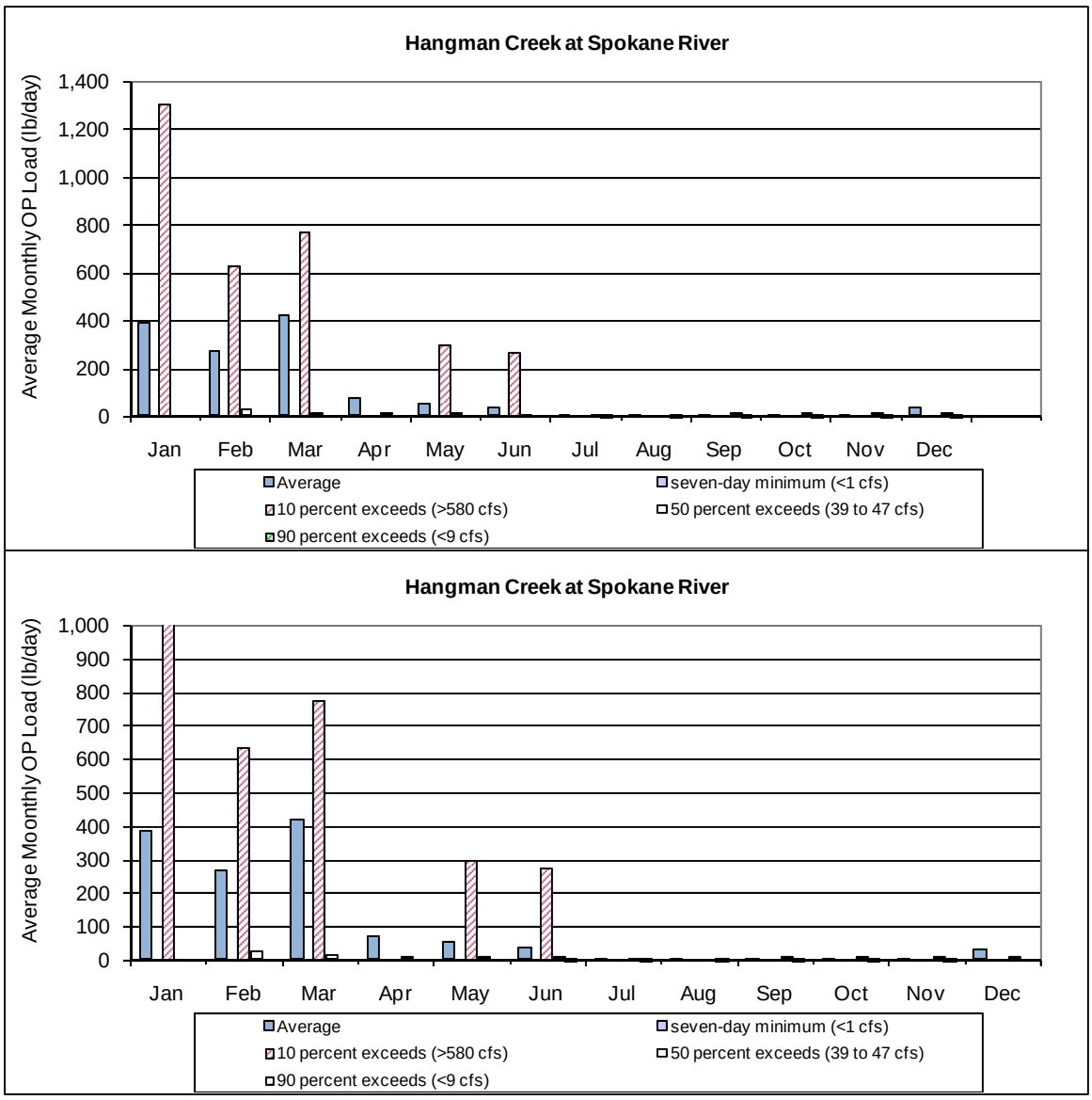

Figure 4.8. Loads by Flow for Hangman Creek at Spokane River

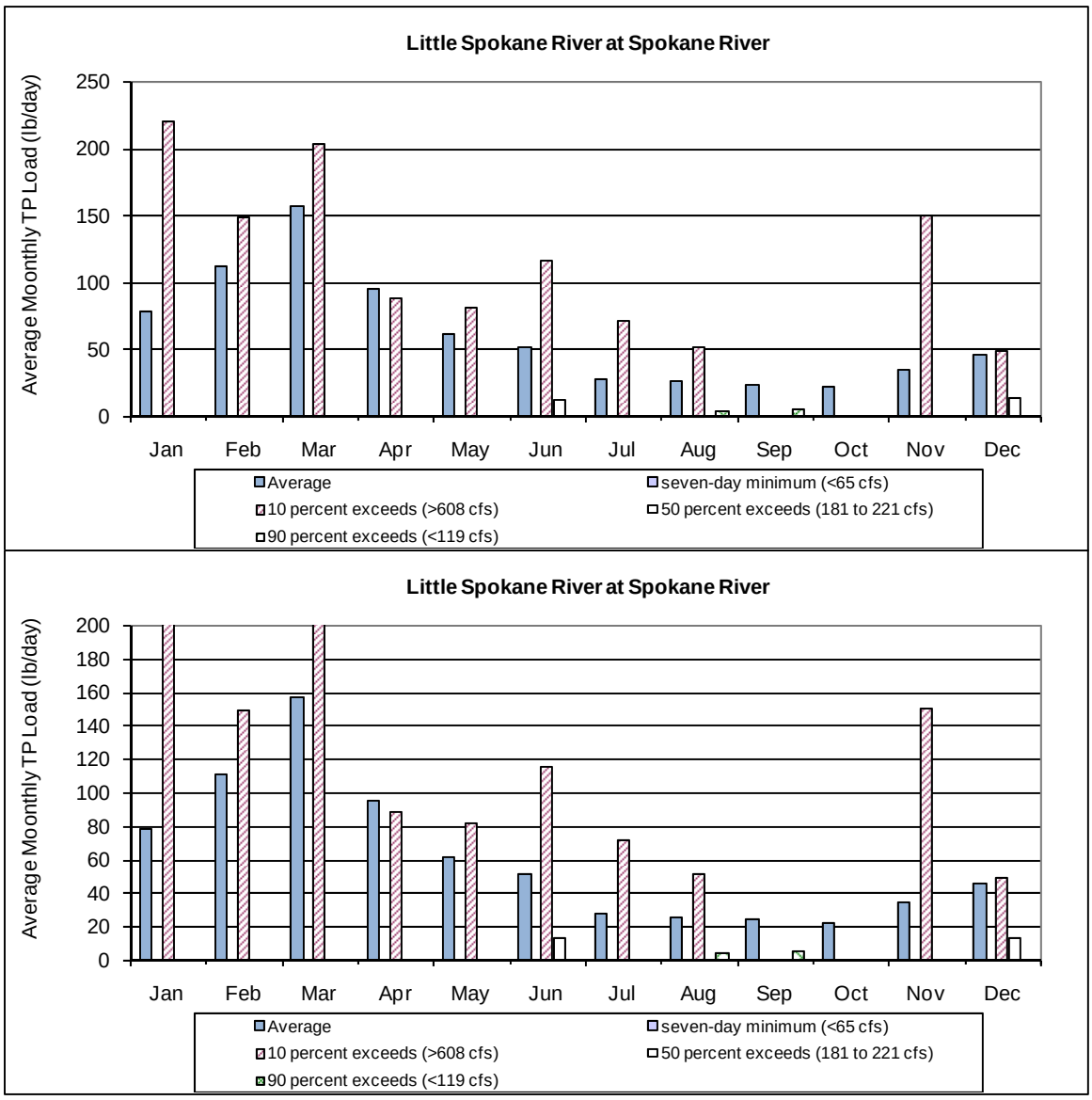

Figure 4.9. Loads by Flow for Little Spokane River at Spokane River

5. AVERAGE SEASONAL PHOSPHORUS CONCENTRATIONS AND LOADINGS

Objective

The seasonally averaged loads provide a simple portrayal of orthophosphorus loads by season. The Supplemental Phase 1 locations selected for 2001 graphs of loads are at Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.

Linkage to TMDL

Graphs presented in this report section provide loads for the same seasons and 2001 low flow year as in the 2001 TMDL. Summer is defined as April through October (seven months) and winter is November through March (five months). This definition is used in the Spokane River TMDL. The seasons were modified in the 2010 TMDL and defined summer as March through October (eight months) and winter as November through February (four months) (Ecology, 2010). The seasons were not updated in this analysis to maintain consistency with the previous total phosphorus report (HDR, 2009a) and comparison.

Results

Plots of the 2001 orthophosphorus loads divided between summer and winter seasons are shown in Figures 5.1 through 5.3. Only three of the six locations are shown because the other three locations do not have data for 2001. The pie chart labels include the season, load (lb/day), and percentage of the total. For the Spokane River and Little Spokane River the loads are about evenly split between summer and winter, slightly higher in the summer. For Hangman Creek, typically the load is greater during the winter season although that was not the case in 2001.

Using the same summer and winter seasons, the percentage of load of the upstream location to the downstream location is shown in Figures 5.4 and 5.5. The Spokane River at Spokane location was not used because the short record with a few data points skews the results. Thus, the locations Stateline and Long Lake headwaters were used along with Hangman Creek. The Little Spokane River at Spokane River location was not used because a downstream location is not part of this Supplemental Phase 1 analysis. The loads are separated by groundwater and surface water as shown in Figures 5.6 through 5.8.

The proportion of summer to winter loads is similar for orthophosphorus and total phosphorus, although for orthophosphorus the summer percentage is generally slightly greater than summer percentage for total phosphorus. For orthophosphorus, both the summer and winter loads decrease from Coeur d'Alene to Stateline. The winter percentages by reach are similar for orthophosphorus and total phosphorus. The summer percentages indicate the majority of orthophosphorus loads from the Stateline to Long Lake reach whereas for total phosphorus loads the upstream of Stateline reach was the greatest. About 15 percent of the Stateline to Long Lake load is from groundwater.

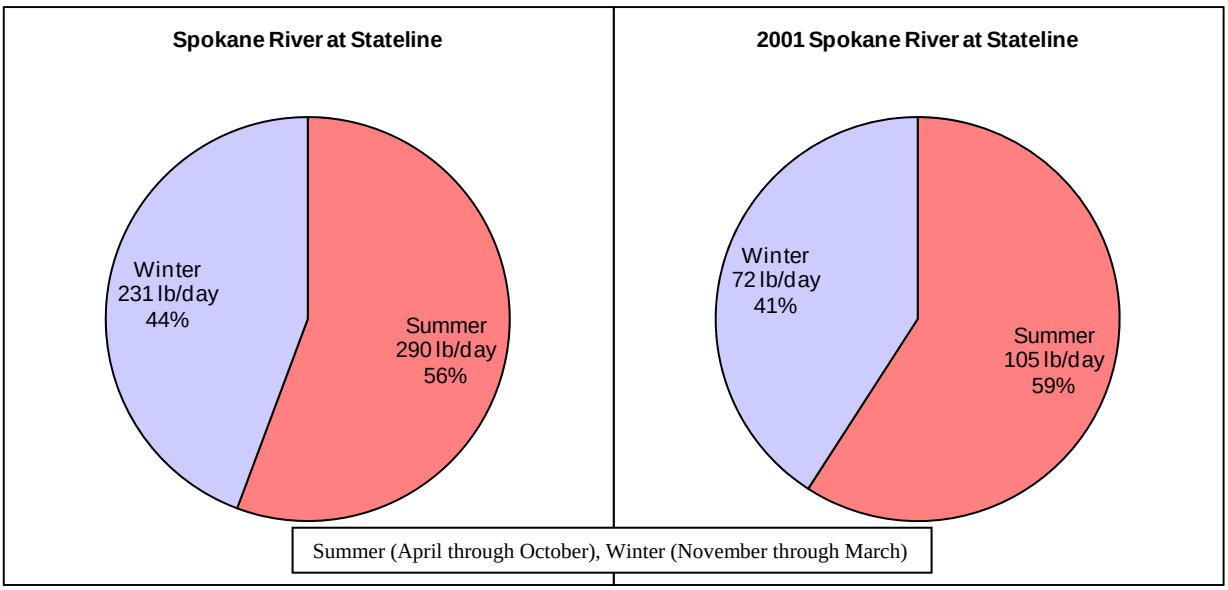

Figure 5.1. Loads by Season for Spokane River at Stateline

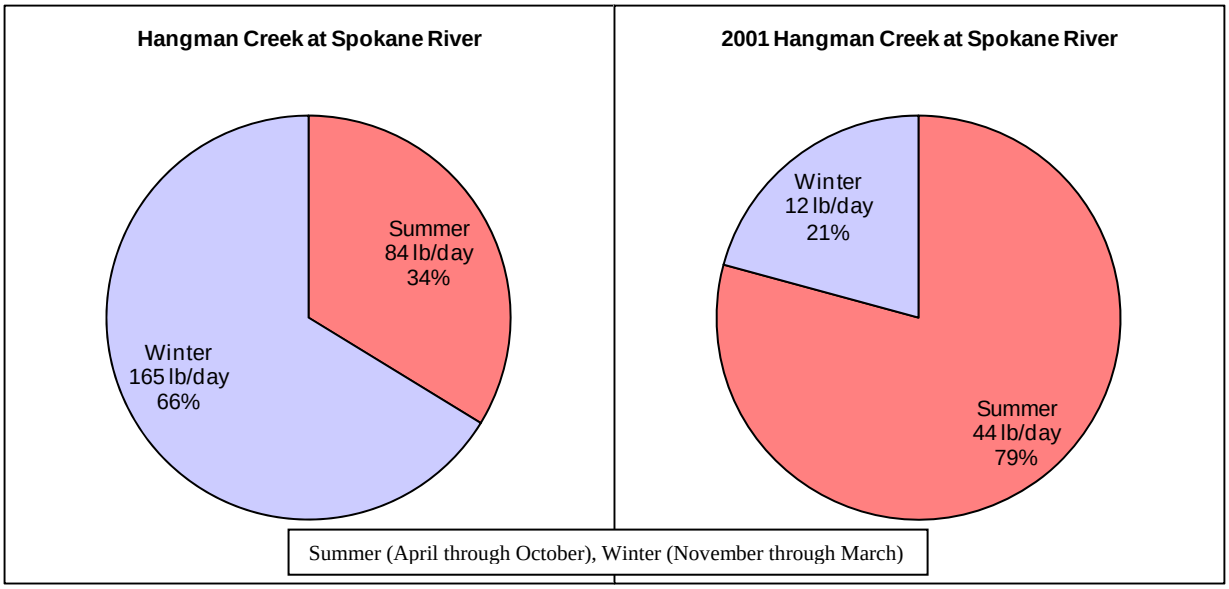

Figure 5.2. Loads by Season for Hangman Creek at Spokane River

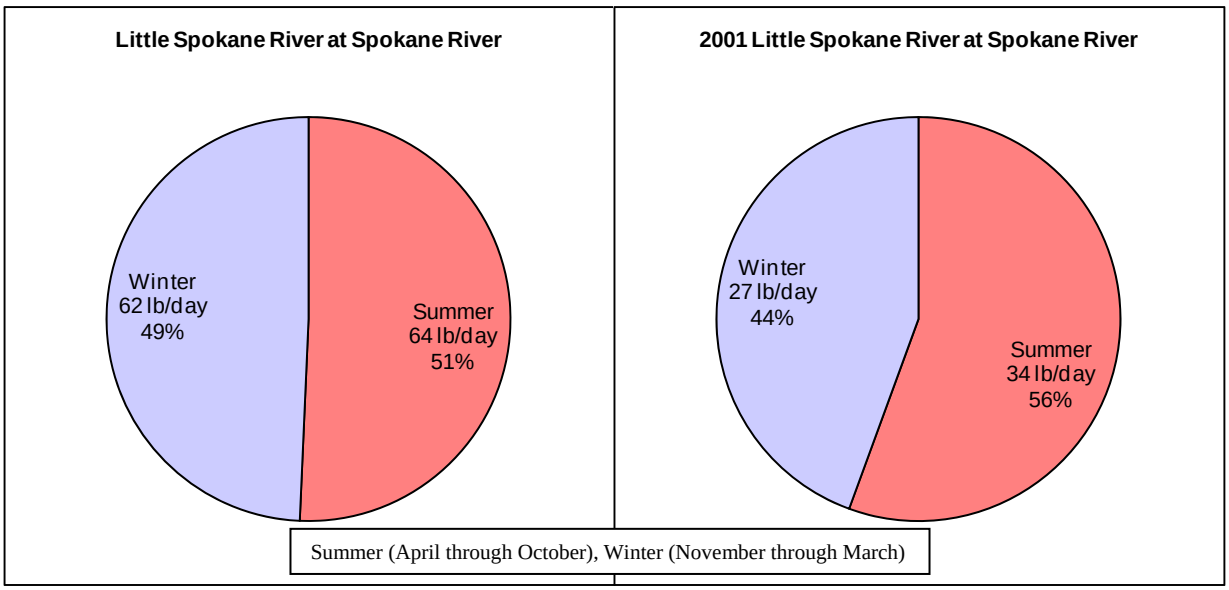

Figure 5.3. Loads by Season for Little Spokane River at Spokane River

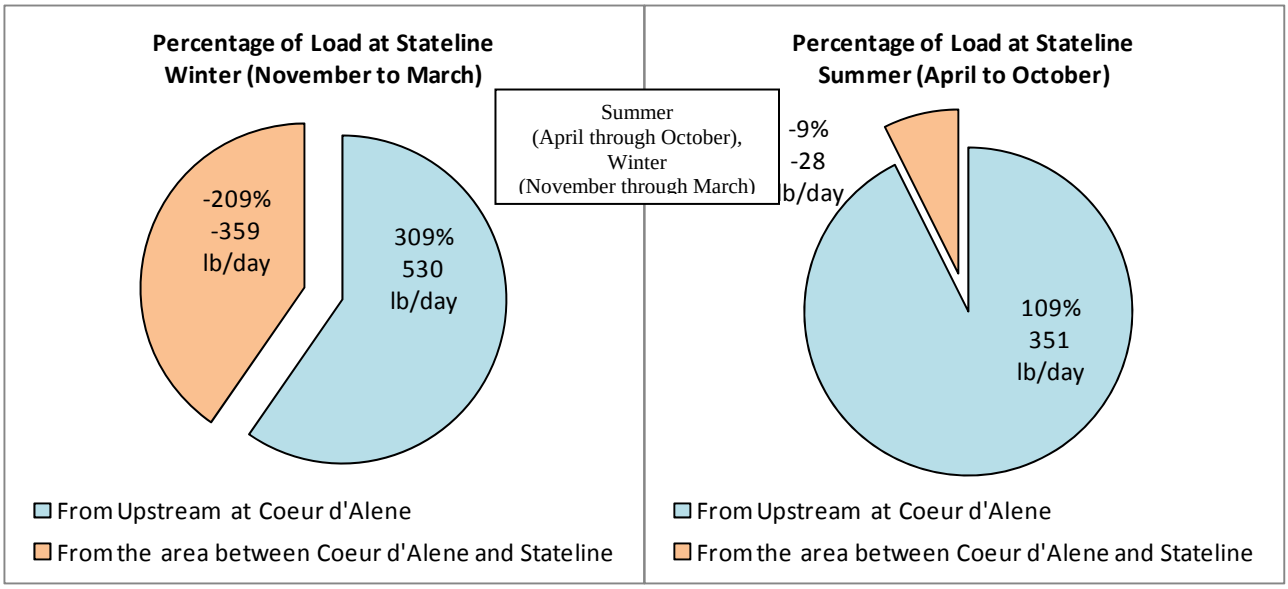

Figure 5.4. Percentage of Loading by Season at Stateline

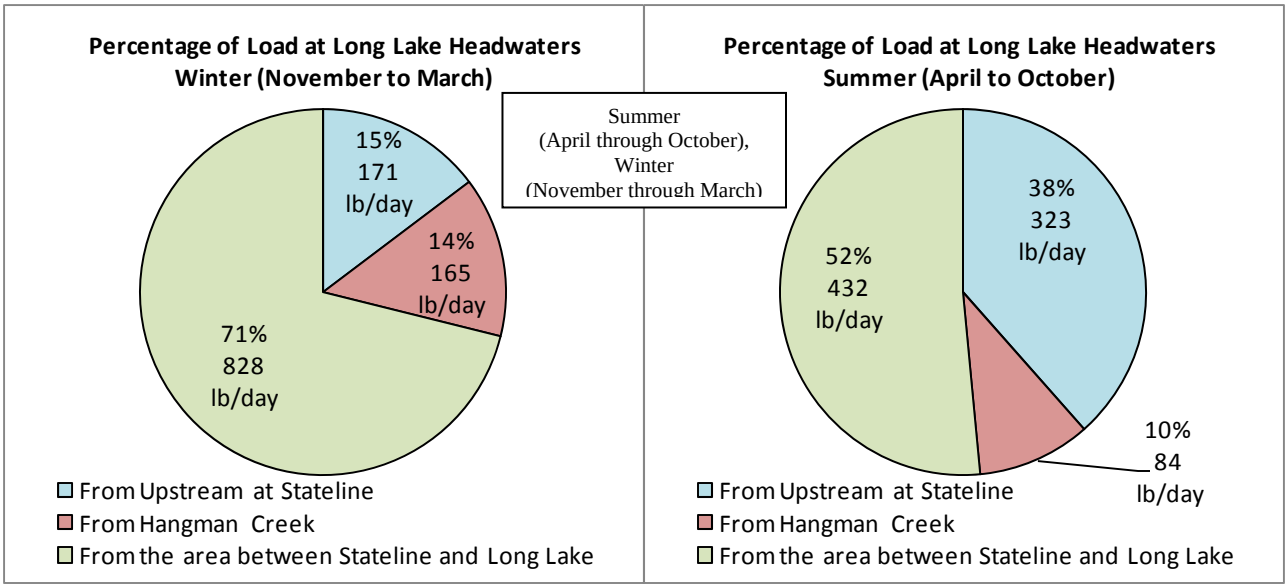

Figure 5.5. Percentage of Loading by Season at Long Lake Headwaters

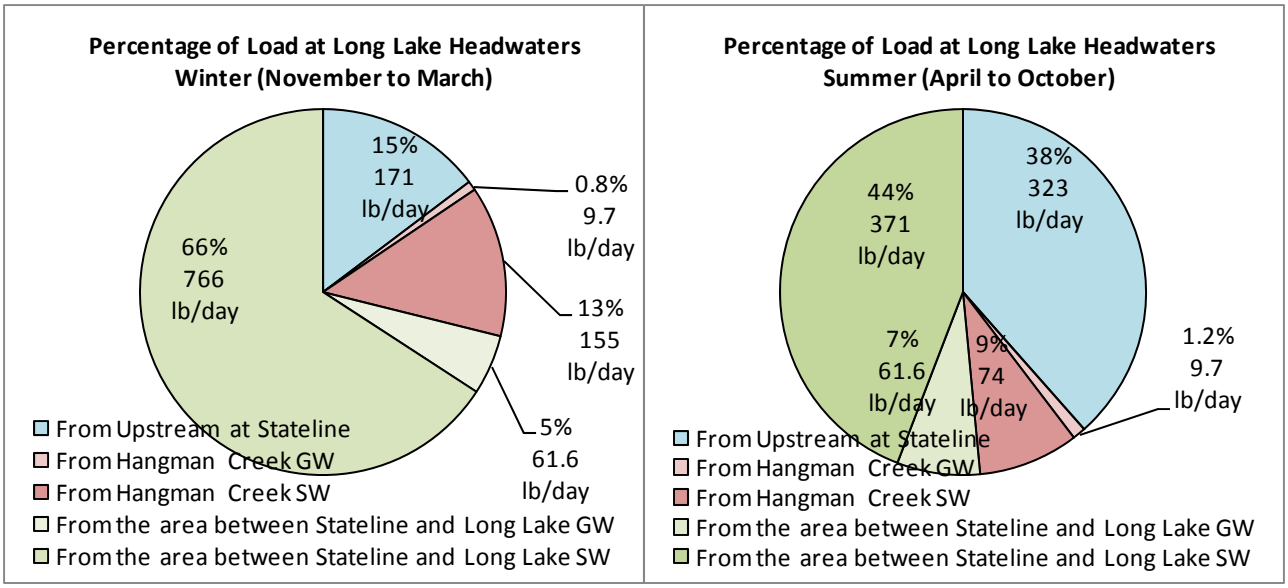

Figure 5.6. Percentage of Loading by Season at Long Lake Headwaters separated by Groundwater and Surface Water

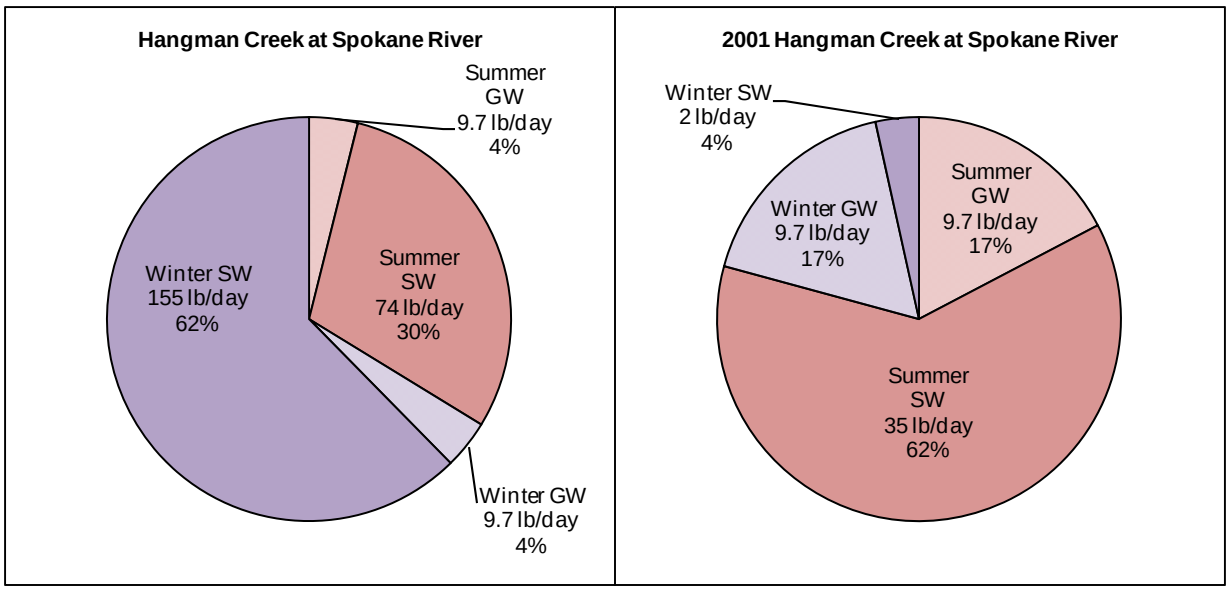

Figure 5.7. Loads by Season for Hangman Creek at Spokane River separated by Groundwater and Surface Water

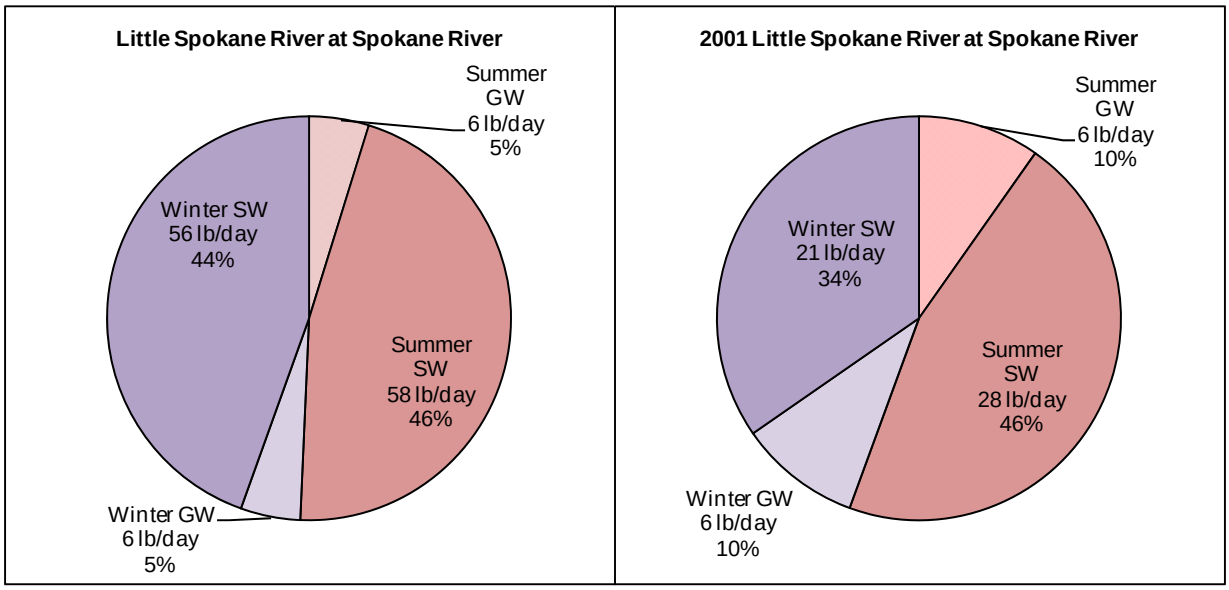

Figure 5.8. Loads by Season for Little Spokane River at Spokane River separated by Groundwater and Surface Water

6. LAND USE TO PHOSPHORUS CONCENTRATIONS CORRELATION

Objective

Examine linking land use to phosphorus loads to provide a connection between non-point sources and the TMDL loads. Phosphorus loads may be associated with land uses and the potential best management practices are typically specific to the land use.

Linkage to TMDL

Provide a comparison of classification of land uses in the TMDL and load allocations for non-point sources.

Results

This analysis is included in a separate document.

Appendix A – Alternative Figure Scales for Analysis 3

3. AVERAGE MONTHLY PHOSPHORUS LOADINGS

Figures with the y-axis set the same for all graphs for comparison between monitoring locations are shown in Figures 3.1Scale through 3.6Scale. These are the same figures as Figures 3.1 through 3.6 only with the vertical axis set differently. With the scales set the same, it is visually easier to compare the flows, concentrations, and loads in the figures from the different locations in the watershed.

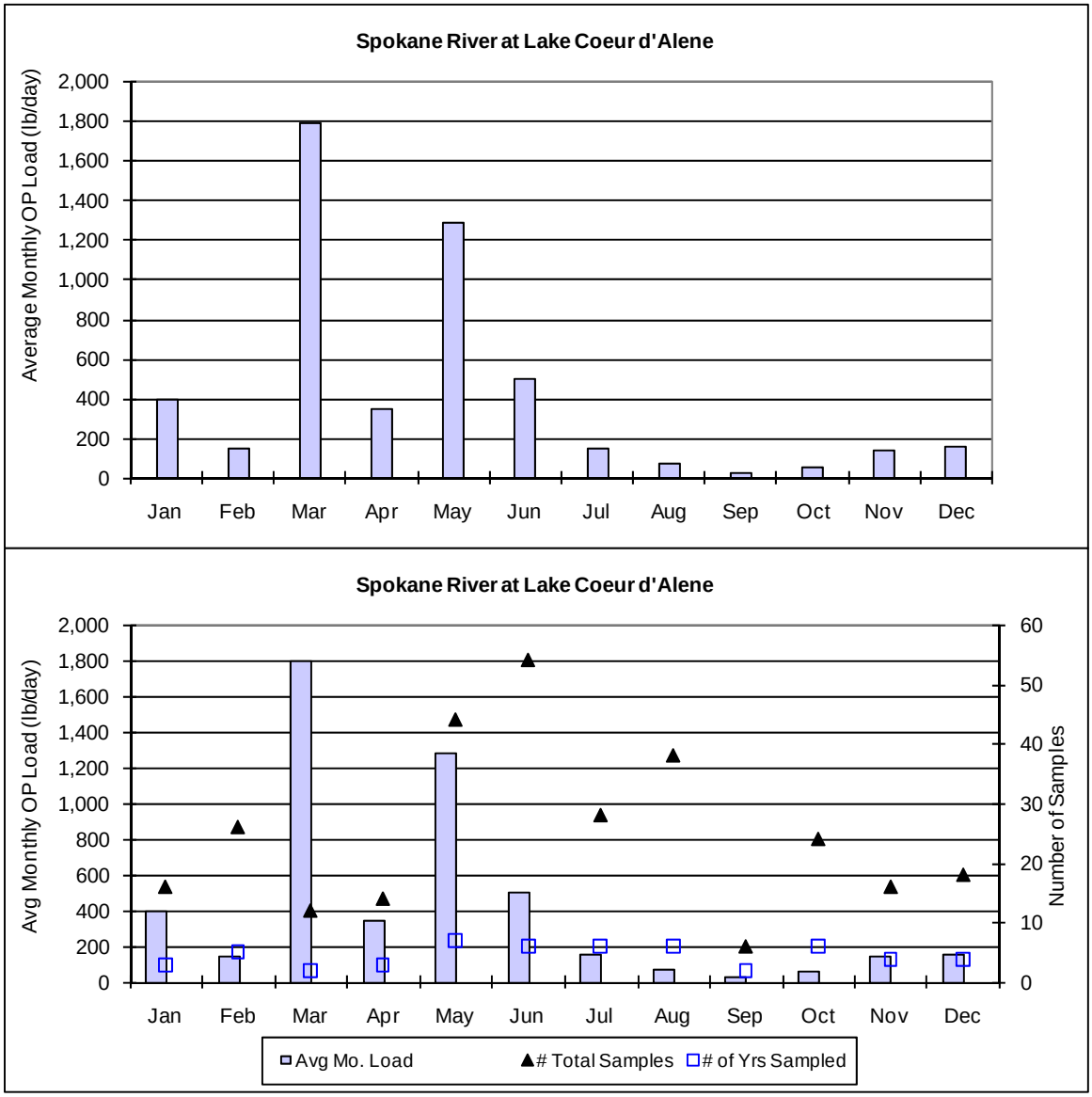

Figure 3.1Scale. Average Monthly Orthophosphorus Load for Spokane River at Lake Coeur d'Alene

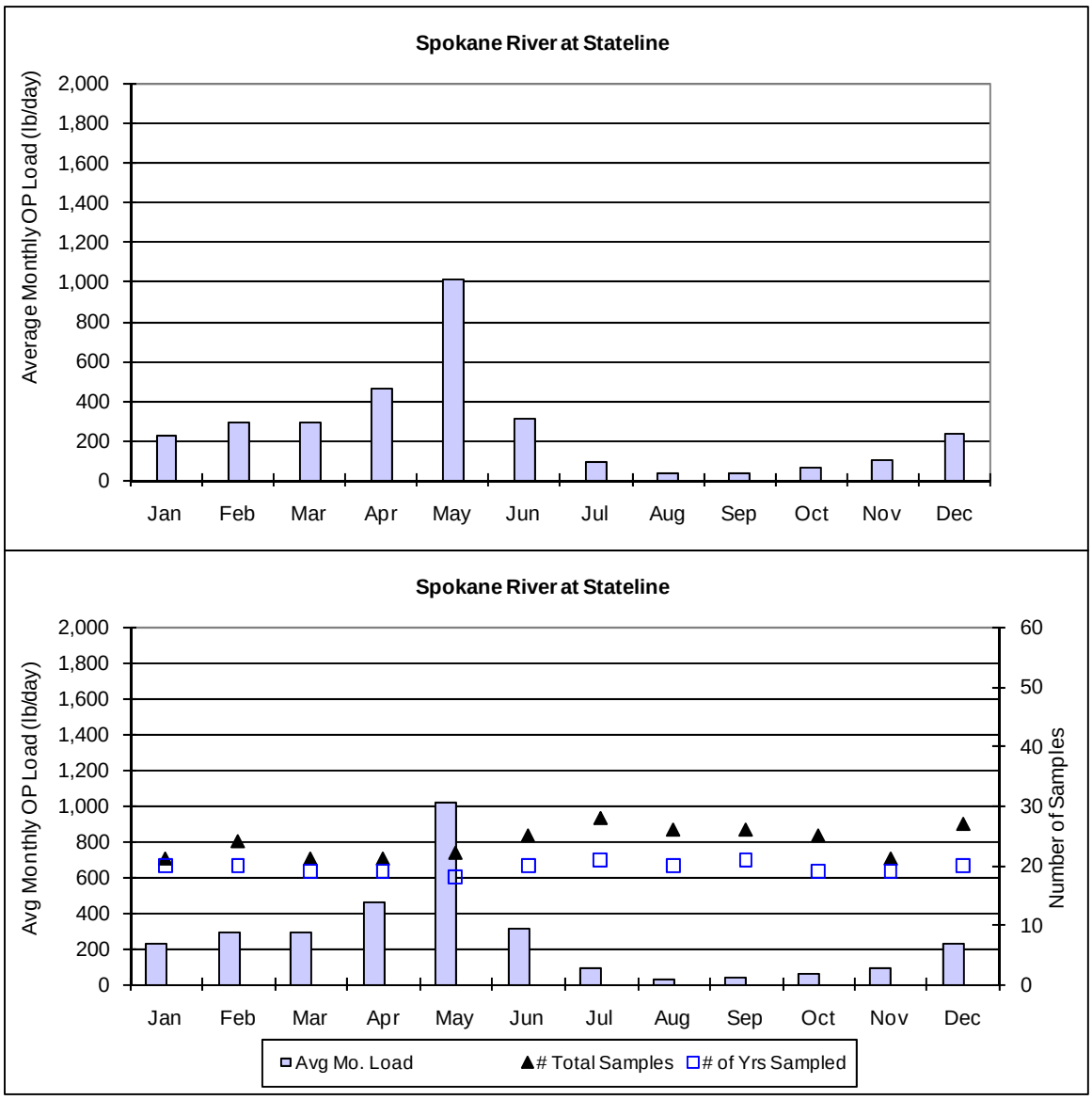

Figure 3.2Scale. Average Monthly Orthophosphorus Load for Spokane River at Stateline

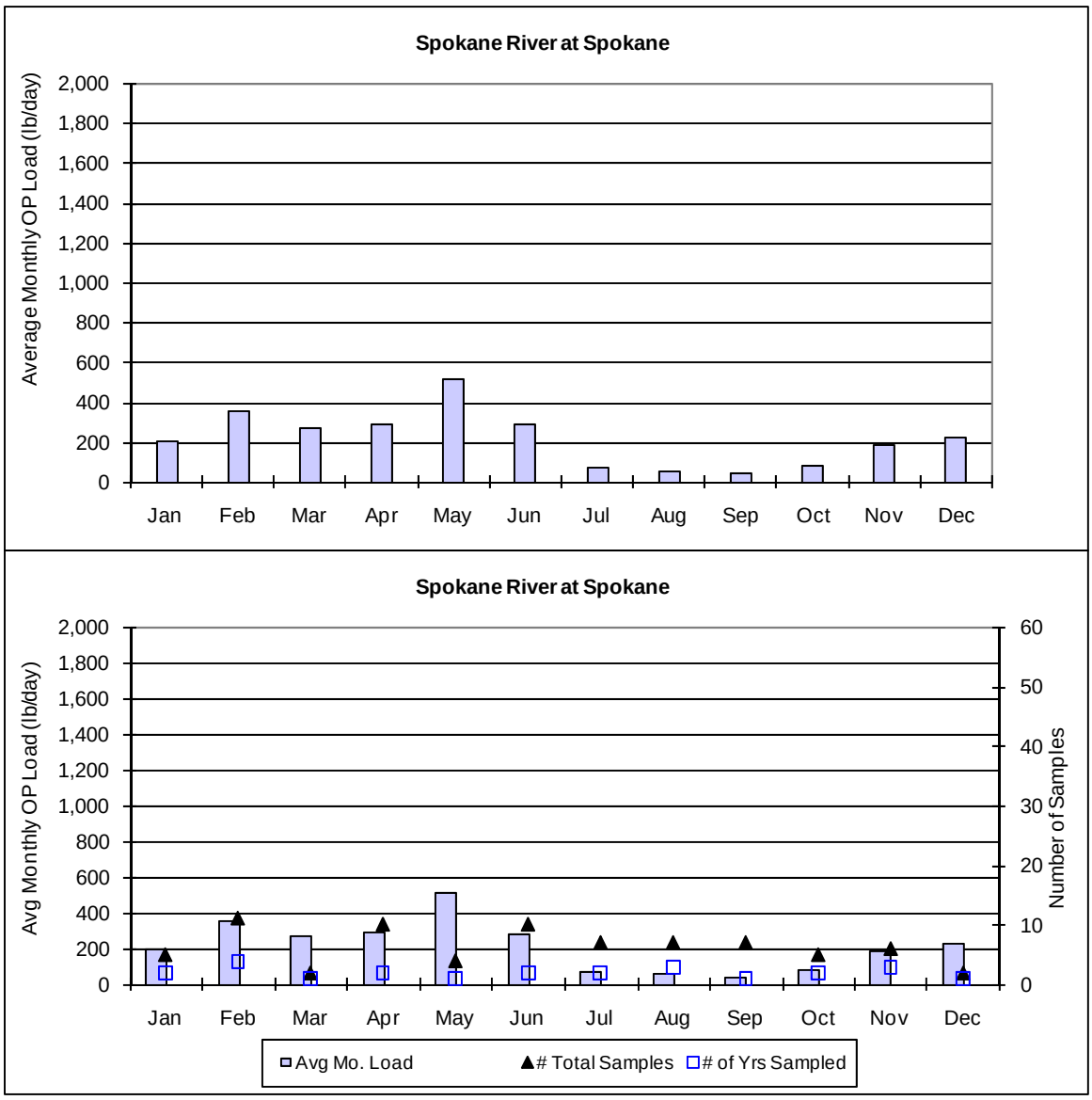

Figure 3.3Scale. Average Monthly Orthophosphorus Load for Spokane River at Spokane

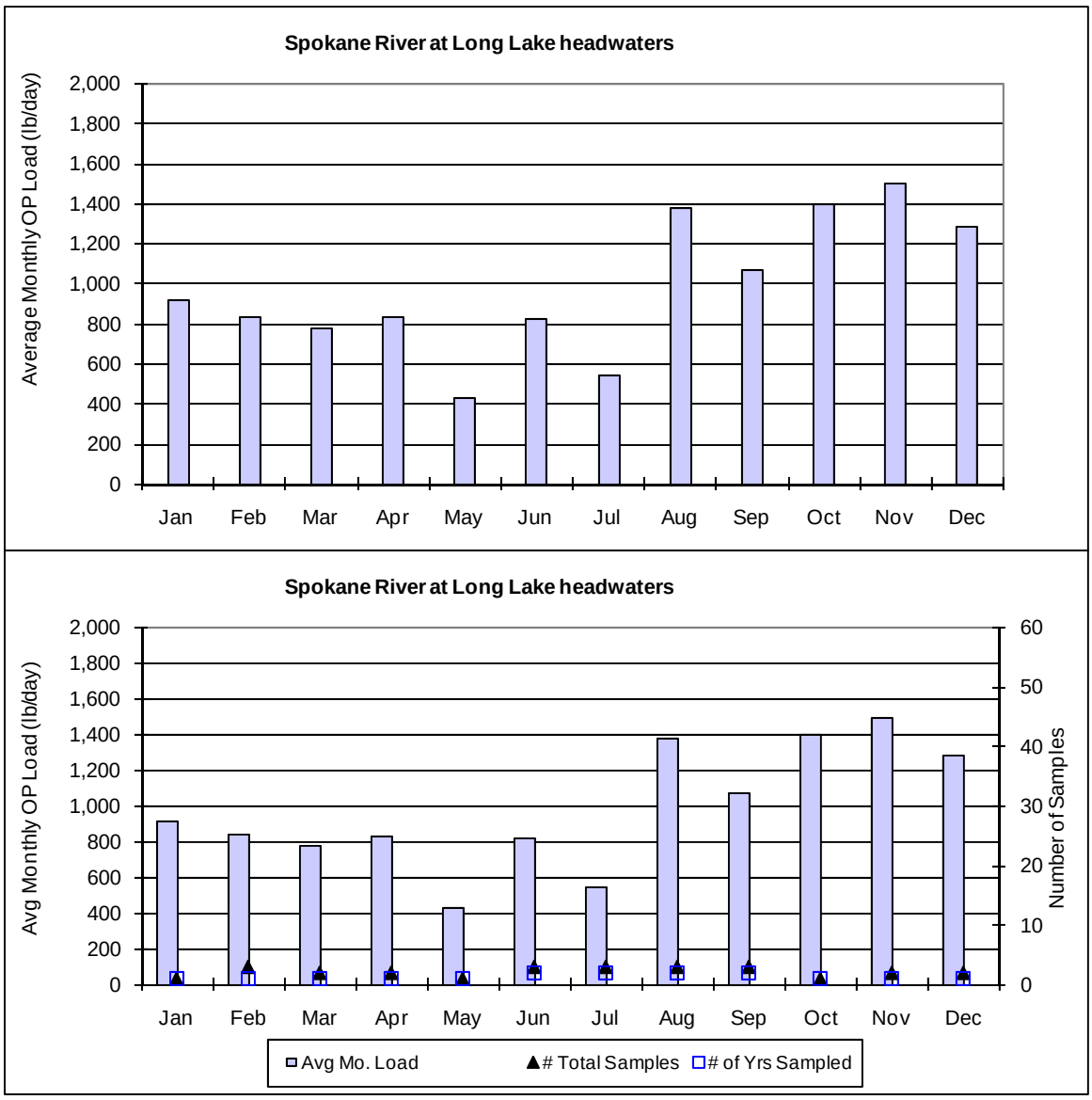

Figure 3.4Scale. Average Monthly Orthophosphorus Load for Spokane River at Long Lake headwaters

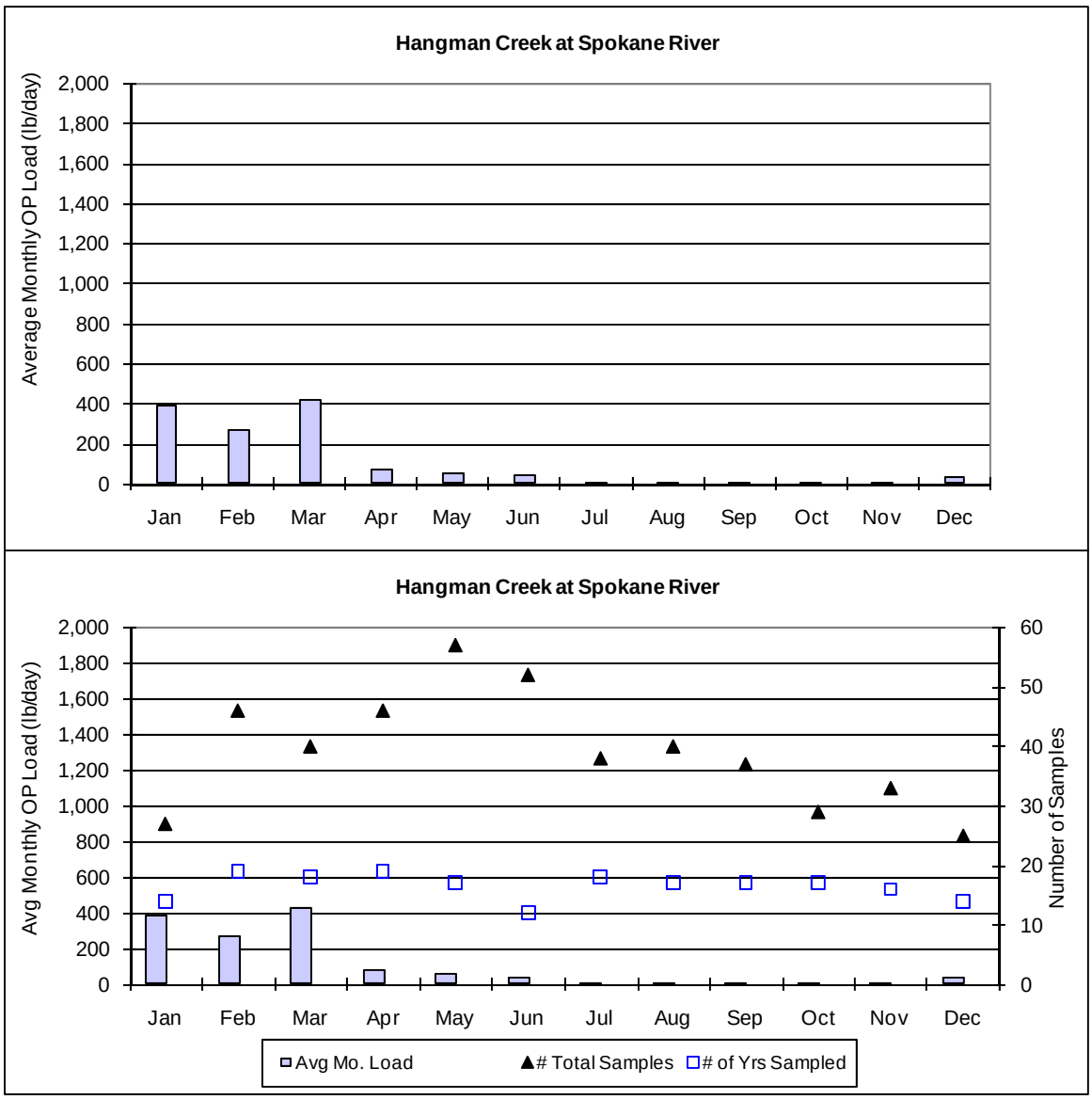

Figure 3.5Scale. Average Monthly Orthophosphorus Load for Hangman Creek at Spokane River

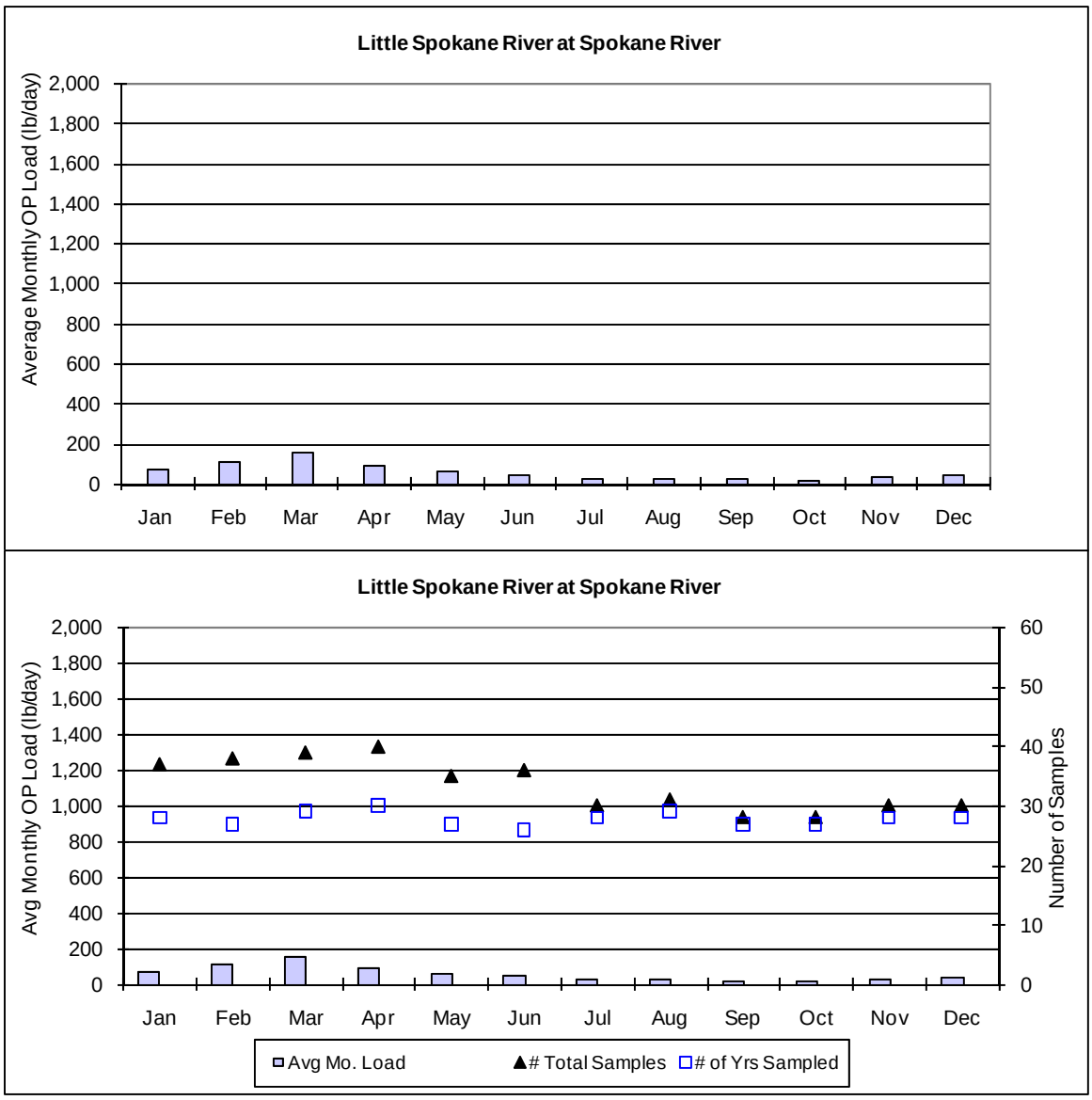

Figure 3.6Scale. Average Monthly Orthophosphorus Load for Little Spokane River at Spokane River