Publication No. 79-e32

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

WATER QUALITY TREND ANALYSIS
THE SPOKANE RIVER BASIN

July 1979

Water Body Nos. WA-54-1020, WA-55-1010
WA-56-1010 and WA-57-1010
Publication No. PR-6
printed on recycled paper

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Water Quality Trend Analysis
Spokane River Basin

by
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Olympia, Washington 98504-7710

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PREFACE

The Spokane River drainage system is, in a sense, unique. Because concern about water quality in the drainage has been intense at the local, state, and federal levels, numerous investigations have focused on various aspects of the drainage. All ecosystems are complex; however, this scrutiny has generated a general appreciation for the physical, chemical, and biological complexities of the Spokane drainage.

This report uses a recently developed trend detection technique to evaluate ambient water quality in the Spokane River drainage. The collection, analysis, and publication of water quality data in Washington State has long been a cooperative function of the Department of Ecology (and its predecessor, the Washington State Pollution Control Commission) and the United States Geological Survey. The analysis of these data provides an additional tool for understanding the Spokane River, its tributaries and impoundments. It is hoped that this analytical tool will provide insights which will be useful to all persons concerned with the waters of Washington State.

As is the case with any tool, the trend detection technique is designed to perform certain functions. The reader is admonished to note carefully the limitations of the technique and to refrain from extrapolation.

There remain aspects of this ecosystem which are not fully defined and the Department of Ecology is actively considering additional investigations which should further clarify the interrelations between man's activities and water quality problems in the Spokane River. While this report provides a synoptic view of water quality in the Spokane River, ensuing investigations will aid in defining the specific cause and effect relationships responsible for the complex phenomena (i.e., *Anabaena* blooms and hypolimnetic oxygen depletion in Long Lake) which impare the full use and enjoyment of the Spokane River system.

ABSTRACT

Routine water quality monitoring data from six (6) stations in the Spokane River Basin are analyzed using a trend detection technique which employs data deseasonalization and non-parametric statistical analysis. Nine parameters are tested: total and ortho-phosphate; total and dissolved zinc; nitrate; specific conductivity; temperature; dissolved oxygen; and flow.

Monthly means for each of these parameters are tabulated for their respective periods of record. Total zinc and phosphate loadings to the system are calculated and tabulated.

Trend analysis reveals decreasing zinc concentrations over the past five years in the Spokane River. Phosphate concentration trends in the lower Spokane River are also detected; however, analyses of loading data and concentration/flow relationships indicate these trends are primarily flow-related artifacts.

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INTRODUCTION

Water quality monitoring is a necessary function of pollution control agencies at the local, state, and federal levels. Historically, monitoring functions have fallen into two major categories: intensive monitoring and long-term ambient monitoring.

An intensive monitoring strategy is developed to serve the needs of a specific study. Time frames may range from several days to several years, but the frequency of sampling, station location, and parametric coverage are functions of the intent of the survey.

Long-term ambient monitoring serves somewhat different purposes. Ambient monitoring provides an historical data base. These data are roughly equivalent to census data. These "water quality census data" can be used by institutions at all levels of society to evaluate water quality in a reach of stream, a county, a state, or throughout the nation. In a sense, these data serve as a foundation for the legal and regulatory functions which have been established to maintain and improve water quality. One of the implicit functions of long-term ambient monitoring is the detection of water quality trends, which can in turn be used to assess the effects of regulatory, societal, and natural changes on water quality.

To this end, the Washington State Department of Ecology (DOE) contracted with Dennis P. Lettenmaier of the University of Washington to develop a technique for detecting and assessing water quality trends in ambient monitoring data.

Lettenmaier reviewed the state's monitoring network design and suggested several changes. Prior to 1977, the DOE sampling strategy focused on stations in one-third of the state, sampling these stations twice monthly. This resulted in recurring two-year data gaps in data records at many stations. In the interest of increasing trend detectability in these data records, Lettenmaier recommended establishing a network which would be sampled no less frequently than once a month and would remain intact year after year. At the beginning of water year 1978, the DOE heeded this advice and began operation of a "permanent" station network.

In addition, Lettenmaier developed an approach to trend detection which deseasonalizes data and allows the analyst to test for trends using nonparametric statistics. The results of this work were published by Lettenmaier (1977). Other publications which support and develop this approach are Lettenmaier (1975), Lettenmaier and Burges (1976), and Lettenmaier (1978).

In late 1977, the contract was completed and a computer-aided trend detection technique was made available to the DOE. This paper summarizes the department's initial use of this technique to analyze ambient monitoring data.

Trend Detection Technique

Water quality data are retrieved from the national STORET (STOrage and RETrieval) system on data processing cards. Cards from each station are then placed in chronologically ordered decks. If data are reported on a monthly basis, excess cards are culled and blank cards inserted for months when no data were collected, so that the deck contains one card for each month of data recorded.

Figure 1 outlines the trend analysis technique. For the purpose of this work, each parameter at each station is analyzed separately in two passes. The first pass gives the analyst indications of possible trends, the second pass allows the analyst to test possible trends for significance. Each step of the passes is facilitated by a subroutine which performs the necessary calculations and executes graphic plots. Each of the passes is outlined below. Full explanation is available in Lettenmaier (1977).

Pass I - Detection of Possible Trends

1. Data deseasonalization: The year is subdivided in seasons (e.g., months). Seasonal and annual means are calculated. The seasonal mean is then subtracted from each data point. This difference is then added to the annual mean to generate a "deseasonalized data point". This removes repetitious seasonal cycles from the data record to aid in long-term trend detection. Seasonal means are printed out.

2. Quantile-Quantile Plot: The deseasonalized data are plotted in a way which allows the analyst to determine if these data are normally and/or symmetrically distributed. If the data are asymmetrically distributed, two possibilities remain:

    a. Data Transformation: Data may be transformed using either logarithmic or power transformations prior to deseasonalization.

    b. Outlying data points can be identified, and if there is reason to believe that these outliers could not have come from the primary population, they may be removed prior to deseasonalization.

After symmetry is achieved, the analyst may proceed.

3. Deseasonalized Time Series Plot: Deseasonalized data are plotted against time of collection. Possible trends may be spotted using this and the following plot.

4. Cumulative Sum Plot: After being given an "intervension point", m, this subroutine plots the function:

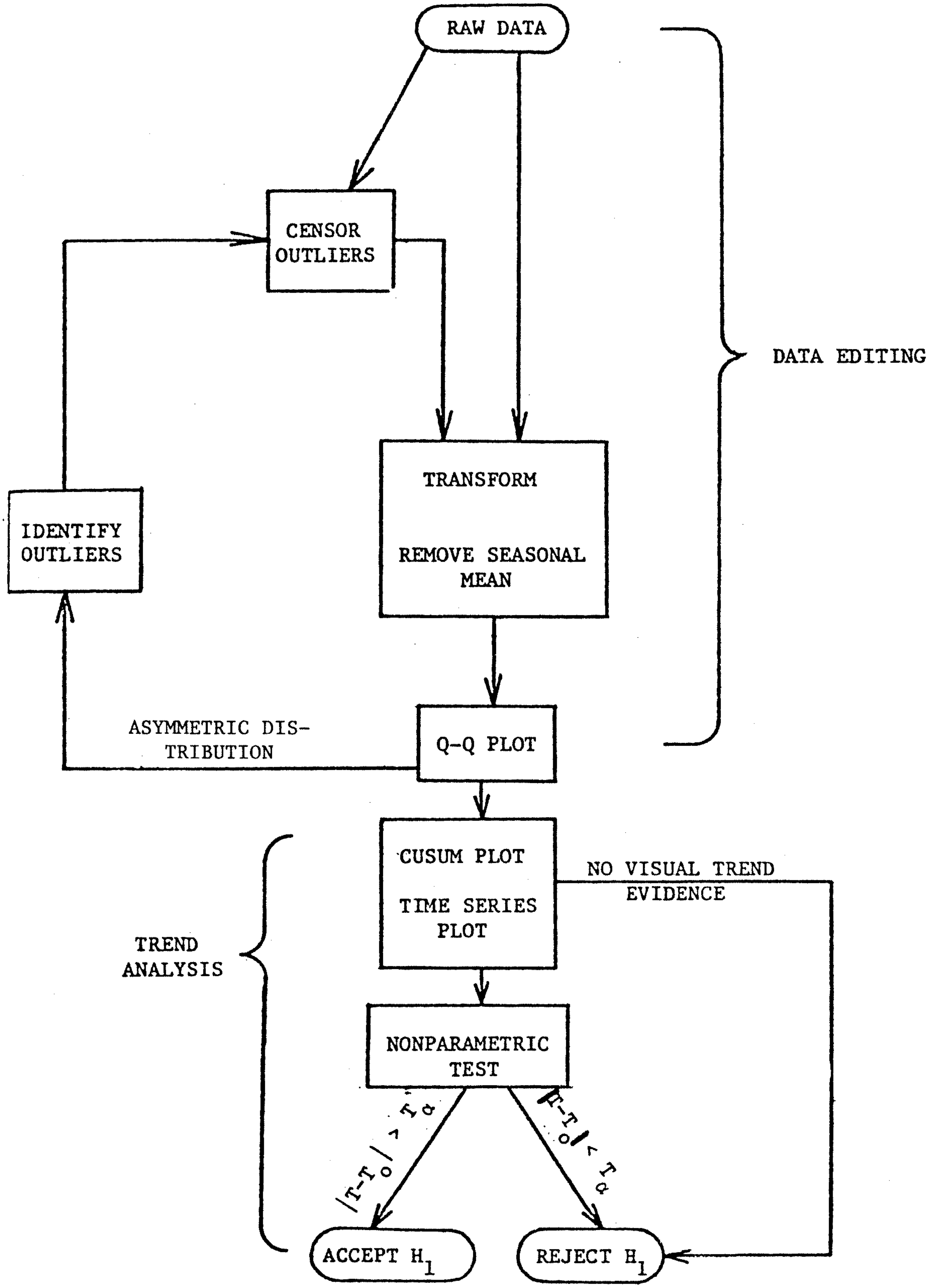

Figure 1 Procedure for Data Analysis (after Lettenmaier, 1977)

$$\text{CUSUM}j = \sum_{i=1}^{j} x_i - j/m \sum_{i=1}^{m} x_i$$

where j = the number of data points in the entire data record.

i = the sequence number of data points progressing from 1 to j.

x_i = the value of deseasonized data point i.

m = the intervention point, a value between 1 and j where the analyst believes a trend may begin.

If a step trend is present, the plot is a sloped, linear line. If a linear trend is present, the plot will trace a quadratic curve.

If, based on the first pass, there appear to be trends in the data record, the analyst will proceed to the second pass.

Pass II - Statistical Analysis of Possible Trends

1. Data is transformed and edited as necessary. It is then deseasonalized as above.

2. Statistical Analysis of Possible Trends: The analyst may test for either step (abrupt) changes or linear (gradual) changes in data. If a step trend is suspected, "before" and "after" time periods are defined and the subroutine generates the Mann-Whitney test statistic.

   If a linear trend is suspected, the time period is defined. The subroutine then calculates Spearman's Rho test statistic.

   Because there is a degree of autocorrelation in most water quality records, the calculation of test statistics allows for the inclusion of a daily lag one correlation coefficient which is modelled as a lag one Markov process. Subroutines are available for calculating actual lag one correlation coefficients; however, because the data necessary for these calculations were not available, the daily lag one correlation of 0.85 was assumed.

3. Estimation of Trend Magnitudes: Mean values are calculated for the "before" and "after" periods of step trends. Linear trends are estimated using least-squares methodology. In both cases, standard deviations are also

calculated. Trend lines may be plotted on the time series plot. It should be stressed that these estimations of trend magnitude do not allow for calculation of confidence limits and serve only to give an approximate indication of trend magnitude.

After test statistics are generated, they are tested for significance. There was no subroutine for this procedure in the original program; however, a program was written by Dan Kruger and the author which allows the analyst to quickly determine significance. Lag one correlation coefficients for the effective sample period are again taken into account. Significance at the 80%, 90%, 95%, 98%, and 99% levels can be determined.

Lettenmaier (1977) stresses that this technique should be used only for relatively long time periods (several years) and that this technique, in and of itself, is not capable of establishing or verifying cause-and-effect relationships.

The Spokane River Drainage System - Background

The Coeur d'Alene-Spokane Drainage System is located in northern Idaho and eastern Washington (Figure 2). The Coeur d'Alene and St. Joe Rivers drain the westernmost Rocky Mountains in northern Idaho and flow into Lake Coeur d'Alene. The Spokane River is an interstate stream which originates at the outlet of Lake Coeur d'Alene, flows westward into eastern Washington, through the city of Spokane, to its confluence with the Columbia River (Lake Roosevelt) 115 river miles from its source. Two major tributaries feed the Spokane River. Hangman (Latah) Creek drains a dryland agricultural area to the south of Spokane. This stream joins the Spokane River approximately 1 mile below the Spokane city center. Approximately 3 miles below this confluence the Spokane Sewage Treatment Plant (35 MGD) discharges to the Spokane River. The second major tributary, the Little Spokane River, drains an area north of Spokane and enters the Spokane River at the head of Long Lake. Long Lake is impounded for approximately 22 miles behind Long Lake Dam.

The surface waters of the Spokane River drainage system exchange water with a major aquifer originating near Lake Pend Oreille in northern Idaho. Fed by runoff from the highlands surrounding the Spokane-Rathdrum Prairie, this groundwater flows south and west into Washington where it parallels the flow of the Spokane River. Surface water/groundwater interchanges are complex and time-dependent, but are being closely studied by the USGS (Drost and Seitz, 1978, and Vaccaro, 1979) and the designated 208 planning agencies in Idaho and Washington. A portion of this aquifer ultimately flows directly to the Spokane River, while the remainder flows north below Spokane to feed the Little Spokane River. Nitrate concentrations in the aquifer range from 1 to 2 mg/l. Because most of the flow is intercepted by the Spokane River drainage system, the aquifer is responsible for much of the nitrate loading to Long Lake.

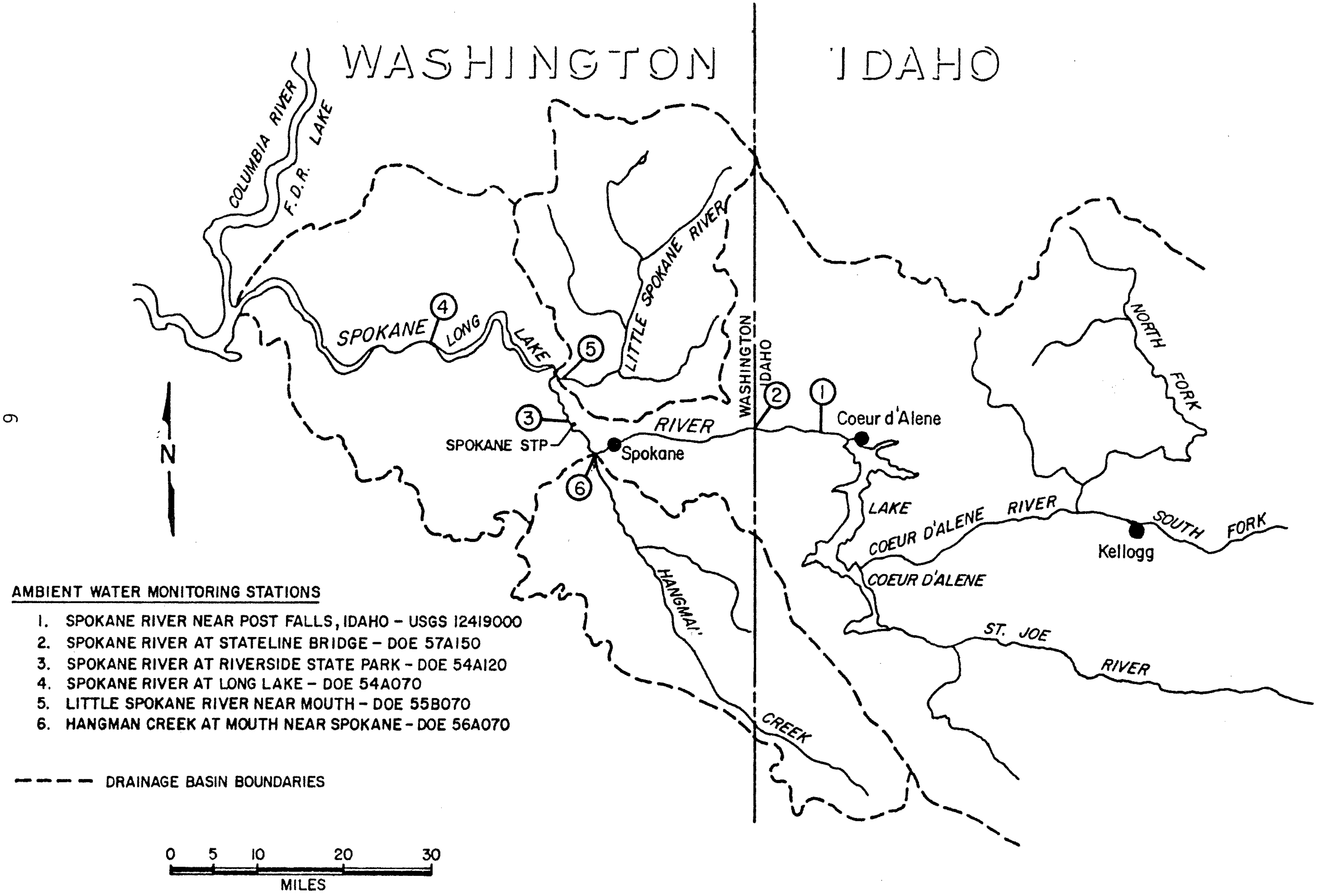

Figure 2. SPOKANE RIVER DRAINAGE SYSTEM

A series of water quality problems and associated controversies have plagued the system. These water quality problems fall into two major categories:

1. Trace Metals:

   The Kellogg mining district, located along the South Fork of the Coeur d'Alene River in northern Idaho, contains major mineral deposits. The largest silver mine and the first and third largest lead producing mines in the United States are located here. Mining and milling activities have discharged quantities of metals (primarily zinc, but also lead, copper, chromium, and other trace metals) to the drainage system since ore production began in 1885. In addition to metals contributed by mine drainage water and tailings leachate; metals are discharged by a large lead smelter located near Kellogg, Idaho, and an electrolyte zinc plant which reduce ore and ore concentrates to refined metals ready for market. During the early 1970's, 83 percent of the zinc entering the Spokane drainage basin was contributed by mining and milling operations in the Kellogg mining district (Schmidt, *et al.*, 1973). In 1968 mining interests began constructing settling ponds throughout the South Fork of the Coeur d'Alene drainage to impound mining wastewaters prior to discharge. In 1973 lime neutralization and clarification of tailings pond decant at the Bunker Hill complex further reduced trace metal loading to the system. Nonetheless, significant quantities of trace metals continue to leach into the South Fork. Zinc influx from the Bunker Hill tailings pond alone was estimated at 3950 lbs/day in October of 1976 (Rouse, 1977).

   In addition to on-going operations, there are large quantities of relatively metallic "jig tailings" deposited in the bottomlands of the South Fork valley as well as substantial deposits of contaminated tailings deposited in the Coeur d'Alene River delta of Lake Coeur d'Alene (Maxfield, *et al.*, 1974). These deposits could **attenuate** downstream concentrations of zinc and other trace metals for years, even if wastewater discharge in the Kellogg mining district were immediately eliminated.

   A great deal of research has been conducted on the sources and effects of trace metals in the drainage system, and has been published in works by Ellis (1970), Mink, *et al.*, (1971), Savage and Rabe (1973), Funk, *et al.*, (1973, 1975), Maxfield *et al.*, (1974), Sheppard and Funk (1975), Yake (1977), and others.

   The possible links between trace metal concentrations and algal blooms, particularly in Long Lake, will be addressed in the following section.

2. Algal Blooms, Excess Nutrient Loadings, and Low Dissolved Oxygen Concentrations:

As the Spokane River flows through the urbanized Spokane area, its nutrient load is increased by numerous sources. The upper Spokane River is somewhat enriched by comparatively small municipal and industrial discharges. Spokane's combined sanitary and storm sewer system contributes nutrient loadings when storm runoff overloads the sanitary system and results in the discharge of domestic sewage from storm water outfalls. Hangman Creek, which drains the productive agricultural area south of Spokane, adds various forms of both nitrogen and phosphorus. Influent aquifer waters contribute large nitrate loads directly to both the Spokane River and the Little Spokane River. The primary phosphate source has been, however, the Spokane Sewage Treatment Plant. With a flow of approximately 35 MGD, this plant discharged approximately 1150 lbs. of phosphate-P/day until tertiary phosphate removal came online in early 1978.

This river water, enriched with nutrients, flows to Long Lake, which is impounded for about 22 miles behind Long Lake Dam. Long Lake has a long history of substantial algal blooms and low dissolved oxygen concentrations which recur annually during the late summer and early fall in both the hypolimnion and waters discharged from the power penstocks of Long Lake Dam. These problems were first studied in 1966 (Cunningham and Pine, 1969). The relationship between treatment plant effluents, excessive nutrient loading, Long Lake eutrophy, and oxygen depletion were explored extensively during the 1970's (Condit, 1972; Soltero, *et al.*, 1973, 1974, 1975, 1976, and 1978).

Based on accumulating research, the city of Spokane was required to proceed with design and construction of an upgraded treatment plant which would provide both secondary treatment and 85 percent phosphorus removal. Construction of the new plant was begun in 1975. On October 6 to 9, 1975, the plant flow bypassed the primary facilities to allow necessary construction. One year later (September and October, 1976) a toxic bloom of *Anabaena flos-aquae* (a blue-green algae) occurred in Long Lake. A similar, however less toxic, bloom occurred the following year in July and August of 1977. Property and resort owners in the Long Lake area filed suit against the DOE, the City of Spokane, and the engineering contractor seeking to establish a cause-and-effect relationship between the bypass and the blooms.[1]

In August 1977, flow was routed through the new plant for the first time. Initially the plant experienced difficulties in achieving consistent phosphate removal efficiency. However, by May 1978 removal of greater than 90 percent of influent phosphorus was being achieved consistently.

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[1] On July 20, 1979 the Superior Court of Spokane County found "that the blooms of 1976, 1977 and 1978 were not caused by the October, 1975, bypass."

The cause-and-effect relationships between nutrient discharges to the Spokane River, algal blooms, and deoxygenation in Long Lake is complex. Discussion of these relationships is beyond the scope of this publication. However, research into possible trace metal (particularly zinc) inhibition of the growth of Spokane River algae is outlined briefly to provide a setting for the later analysis of zinc trends.

In concert with research being conducted on the upper Spokane River, a paper was published in 1974 which reported the growth inhibition of the test algae *Selenastrum capricornatum* at zinc concentrations similar to those found in the Spokane River (Bartlett, *et al.*, 1974). Subsequent algal assays reported growth inhibition by trace metals in general, and zinc in particular (Green, *et al.*, 1975; Miller, *et al.*, 1975; Soltero, *et al.*, 1975, 1976, and 1978). Growth inhibition of *S. capricornatum* has been reported for zinc concentrations in excess of 30 to 100 μg/l which is well within the range of zinc concentrations found in the Spokane River. A large percentage of samples tested for trace metal inhibition (Soltero, *et al.*, 1975, 1976, and 1978) indicated that algal growth was being inhibited by trace metals in Spokane River and Long Lake waters.

METHODS

Water quality data for nine parameters at six stations in the Spokane River drainage system were retrieved from STORET on computer cards. These stations were selected on the basis of period of record, completeness of data record, and station location. These stations are identified in Table 1.

Table 1. Ambient Water Quality Stations Selected for Trend Analysis

Station Name	DOE I.D. Number	USGS I.D. Number	Type of Station	River Mile Primary Stream	River Mile Secondary Stream
Spokane River near Post Falls, Idaho	--	12419000	NASQUAN	100.7	
Spokane River at Stateline Bridge	57A150	12419495	NASQUAN	93.9	
Spokane River at Riverside State Park	54A120	12424200	NWQSS	66.1	
Spokane River at Long Lake	54A070	12433000	NASQUAN	33.88	
Little Spokane River near Mouth	55B070	12431900	DOE/USGS	56.3	0.5
Hangman Creek near Mouth	56A070	12424000	DOE/USGS	72.4	0.8

It should be noted that the Long Lake Station is located immediately downstream from Long Lake Dam.

The nine parameters retrieved for analyses were flow, temperature, dissolved oxygen, specific conductivity, nitrate-N, total phosphate-P, orthophosphate-P, dissolved zinc, and total zinc. The lengths of data records available for each of these parameters at each of the stations are compiled in Table 2. Generally a minimum sequential string of 30 data points is required to detect trends using the analytical technique employed here. If the data record is broken, determination of its adequacy is somewhat more subjective. Based on Table 2 and a total of 54 station-parameter combinations, 21 data records had sufficient data for trend analysis; 17 records were marginal; and 16 records had insufficient data.

Sufficient and marginal data records were analyzed for possible trends in accordance with Lettenmaier (1977) as outlined previously. A maximum of two (2) data points per record were censored to achieve symmetrical data distribution. Most data records remained intact.

The analytical technique employed here is devised to detect only long-term trends; and, as Lettenmaier (1977) notes, "Testing of... shorter sequences, for instance, years one and two of a ten year sequence, should be avoided." During the course of analysis, however, it became apparent that the deseasonalized time series for many data records appeared to exhibit step changes during the 10/76 to 10/77 period. This was a period of severe drought and low flow in the drainage, and such step changes were not analyzed for significance due to the limitations of data frequency and the analytical method. They were, however, noted and compiled in Table 3. Although no statistical significance is implied for these apparent trends, they do provide an indication of which water quality parameters may be flow dependent in this drainage.

A word of caution is necessary before proceeding with the results of trend analysis. Despite the fact that the detection of trends is a rather complex and involved process, it is mathematically definable and explicable in terms of strict logic. Explaining detected trends (i.e., establishing cause-and-effect relationships) is necessarily a more subjective process. This is particularly true in cases, such as the present one, in which generalized historical data are analyzed. Apparent water quality trends may be generated by natural causes (low flow or high flow conditions, changes in climate, meteorological conditions, etc.); changes in land uses or changes in land use practices (forestry or agricultural practices); inception or elimination of point discharges; improved waste water treatment; interaction of the drainage system's physical, chemical, and biological properties; and the techniques employed in collecting, storing, and analyzing water samples. Any, several, or all of these factors may impinge on a given data record. Although cause/effect relationships may be inferred from detected trends, the trend detection process, in and of itself, does not establish or "prove" these relationships.

Table 2
Data Records Available for Trend Analysis

Station Name	Flow	Temperature	Diss. O_2	Conductivity	Nitrate	Ortho Phosphate	Total Phosphate	Diss. Zinc	Total Zinc
Spokane R. at Post Falls	08/73-03/74 I.D.	03/73-05/78 S	03/73-05/78 S	08/73-05/78 S	N.D. I.D.	N.D. I.D.	08/73-04/78 S	N.D. I.D.	08/73-05/78 S
Spokane R. at Stateline Bridge	07/59-09/77 Int. S	07/59-09/77 Int. S	07/59-09/77 Int. S	07/59-09/77 Int. S	07/59-09/73 Int. S	10/72-05/78 Int. M	12/70-09/77 Int. M	10/76-09/77 I.D.	N.D. I.D.
Spokane R. at Riverside St. Park	10/76-08/77 I.D.	07/59-09/77 Int. S	10/72-04/78 S	02/72-05/78 S	10/72-05/78 Int. I.D.	10/72-03/78 S	10/72-05/78 S	10/77-04/78 I.D.	12/73-03/78 Int. M
Spokane R. at Long Lake	10/71-09/77 Int. M	10/62-05/78 S	09/62-05/78 S	10/59-05/78 S	10/72-09/77 Int. M	11/70-05/78 S	11/70-09/77 Int. S	11/61-04/78 Int. M	10/73-04/78 Int. M
Hangman Creek near Mouth	10/72-09/77 Int. M	10/72-05/78 Int. M	I.D. I.D.	10/72-06/78 Int. M	10/72-05/78 Int. I.D.	10/72-06/78 Int. M	10/72-06/78 Int. M	N.D. I.D.	N.D. I.D.
Little Spokane R. near Mouth	11/70-06/78 Int. M	11/70-06/78 Int. M	I.D. I.D.	11/70-06/78 Int. M	11/70-05/78 Int. I.D.	12/70-04/78 Int. M	11/70-05/78 Int. M	10/76-11/77 I.D.	N.D. I.D.

N.D. - No data
Int. - Intermittant Data
I.D. - Insufficient data for trend analysis
M - Data record marginal for trend analysis
S - Sufficient data for trend analysis

Table 3
APPARENT DROUGHT RELATED TRENDS
10/76 - 10/77

Station	Flow	Temperature	Cond.	D.O.	NO_3	$O-PO_4-P$	$T-PO_4-P$	Diss. Zn	T-Zn
Post Falls	I.D.	UP	UP	--	I.D.	I.D.	--	I.D.	--
Stateline Bridge	DOWN	--	(UP)	--	I.D.	I.D.	--	I.D.	I.D.
Riverside State Park	I.D.	UP	(UP)	DOWN	I.D.	(UP)	(UP)	I.D.	--
Long Lake	DOWN	(UP)	--	--	UP	(UP)	(UP)	--	--
Hangman Creek	DOWN	--	(UP)	I.D.	I.D.	--	--	I.D.	I.D.
Little Spokane	DOWN	UP	--	I.D.	I.D.	(DOWN)	--	I.D.	I.D.

UP - Parameter values higher during drought period
(UP) - Parameter values marginally higher during drought period
DOWN - Parameter values lower during drought period
(DOWN) - Parameter values marginally lower during drought period
-- - No apparent change in values during drought period
I.D. - Insufficient data for determination

RESULTS AND DISCUSSION

Results are discussed in seven subsections: Phosphates (ortho and total); Zinc (dissolved and total); Nitrate; Specific Conductivity; Temperature; Dissolved Oxygen; and Flow. Long-term trends were detected in phosphate, zinc, and nitrate data. Monthly means for the periods of record have been compiled in the appendices (Tables A1 to A7) and are illustrated graphically in their respective subsections.

Phosphates:

Annual variations in total phosphate concentrations are illustrated in Figure 3. All Spokane River stations display double peak curves with high concentrations occurring from February to April and during the low flow conditions from July to November. Low flow concentration peaks are indicative of relatively steady upstream phosphate loading. As flows decrease, dilution decreases and concentrations increase. This low flow peak is most notable at the Riverside State Park station immediately below the Spokane Sewage Treatment Plant. The high flow peak generally occurs early in the spring as precipitation, snowpack melt and flows begin to increase dramatically. This peak is probably associated primarily with rural and urban runoff and because flows and concentrations are simultaneously high, this period is responsible for much of the phosphate loading to the system. This early spring peak appears to be a "first flush" phenomena as phosphate concentrations begin to fall before the highest flows (in late spring) are recorded. The low flow peaks are critical because they occur during the prime algal growth period (August to October).

Orthophosphate concentrations display the low flow peak at Spokane River stations; however, the high flow peak is muted, and in the case of the Long Lake station, does not occur at all. This indicates that much of the runoff contribution of phosphate may pass through the system in complex polyphosphate and particulate forms.

Hangman Creek has total phosphate concentrations two to ten times those of other stations in the system. Because Hangman Creek's flow is comparitively low, its phosphate loading to the system is relatively low (about 7 percent on an annual basis). Hangman Creek's total phosphate concentrations are high from February to August. They are also much higher than orthophosphate concentrations. Hangman Creek carries large sediment loads and is turbid until late in the summer. This suggests that much of this phosphate in Hangman Creek may be associated with suspended sediments. It is probable that much of the phosphate load is linked to the agricultural character of the drainage, a low flow/ drainage area ratio and the 'flashy' characteristics of the creek's flow.

The Little Spokane River is the hydraulic opposite of Hangman Creek. It maintains a relatively steady flow throughout the year. Much of the Little Spokane's flow is recruited from the Spokane aquifer. This flow has been estimated at 310 cfs and varies little

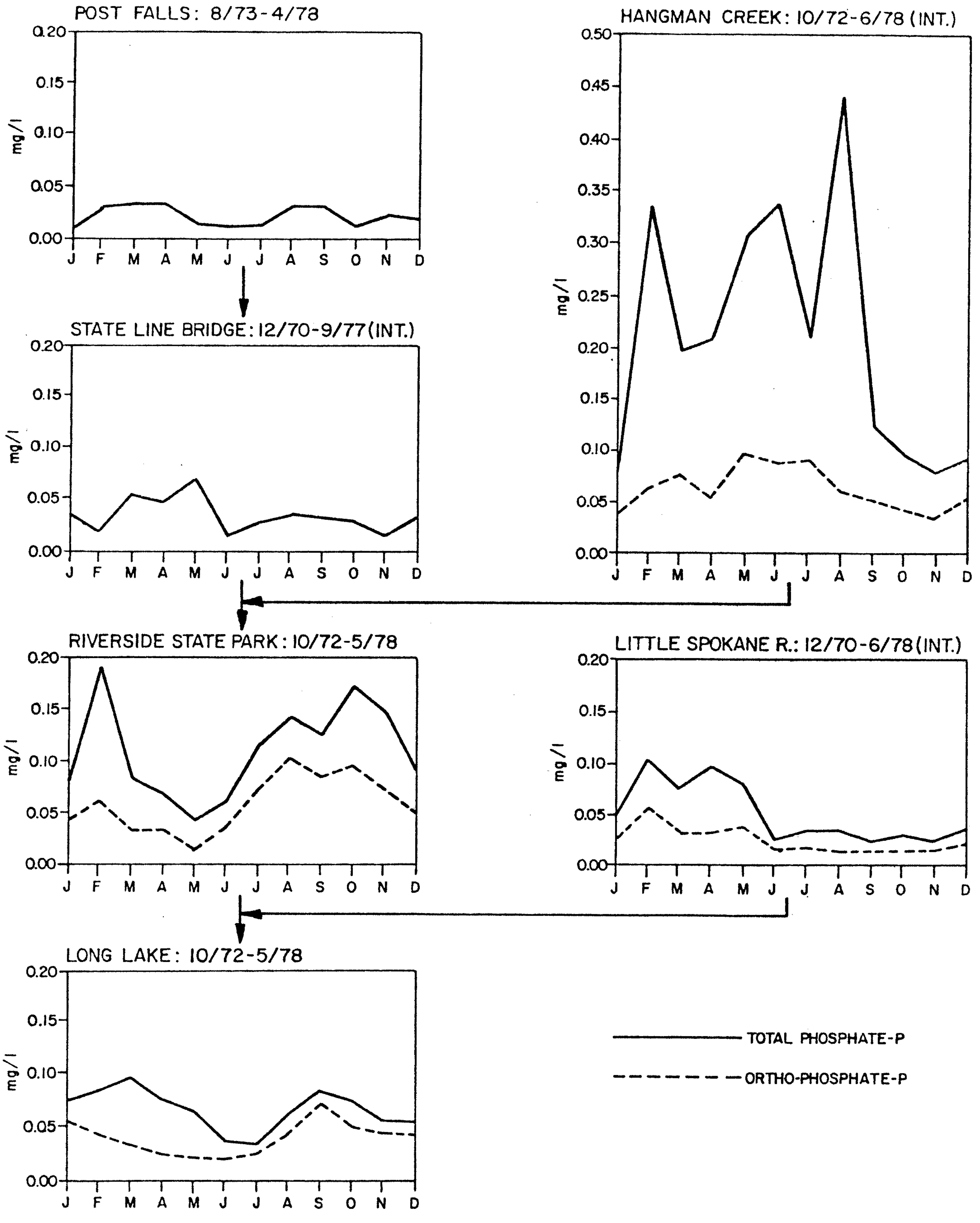


Figure 3. MEAN MONTHLY PHOSPHATE CONCENTRATIONS-SPOKANE DRAINAGE SYSTEM.

throughout the year (Drost and Seitz, 1978). Annual variations in phosphate concentrations display this stable character. Steady summer flows and low phosphate concentrations in the aquifer are reflected in low phosphate concentrations in the Little Spokane. A February-to-May phosphate peak is probably, in part, due to overland runoff during the high precipitation period.

Total phosphate loadings (pounds of total phosphate-P/day) were calculated to illustrate the relative contribution of various sources (see Table 4). Loadings were calculated using individual total phosphate-P concentrations for the period of record and flows from 10/72 to 5/78. Mean monthly loadings were calculated, then combined to yield annual loadings and loadings for the prime algal growth period (July, August, September, and October) and are given in Table 4.

Table 4 - Total Phosphate Loadings - Spokane Drainage System*

	Annual Average		July, Aug., Sept., Oct. Avgs.	
Source	lbs-P/day	% of Total Load	lbs-P/day	% of Total Load
Spokane R. at Stateline	975	28.1%	291	18.7%
Other Sources	(930)	26.8%	(25)	1.6%
Hangman Creek	267	7.7%	25	1.6%
Spokane Sewage Treatment Plant*	(1,150)	33.1%	(1,150)	73.9%
Little Spokane R.	150	4.3%	66	4.2%
Total	3,472	100%	1,557	100%

*Prior to Advanced Secondary Treatment - Phosphate Removal at the Spokane Treatment Plant.
( ) - Estimated Loadings, see text.

The loading attributed to the Spokane Treatment Plant is based on DOE records and previous studies (Soltero, *et al.*, 1974, 1975, and 1976). Combined sewer overflow, minor point sources and overland runoff are included under 'other sources'. Contribution by other sources was obtained by subtracting the combined loadings of the Spokane River at Stateline, Hangman Creek, and the Spokane Treatment Plant from the calculated loadings at the Spokane River at Riverside State Park.

Using these loading data and discharge loading from Long Lake, it is calculated that an annual average of 240 lbs-P/day is retained by the Long Lake impoundment.

Several long-term phosphate concentration trends were detected in records examined. These trends are summarized in Table 5. It is

Table 5

Phosphate Trends

Type of Trend	Time Period	Direction/Magnitude of Trend	Significance of Trend
Post Falls			
Total-Phosphate-P			
Period of Record:	8/73-5/78		
Linear	8/73-9/75	Down, .04 mgP/l (.05 → .01)	95%
Riverside State Park			
Total-Phosphate-P			
Period of Record:	10/72-5/78		
Linear	10/72-4/76	Down, 0.10 mgP/l (0.16 → 0.06)	99%
Linear	2/75-2/78	Up, 0.15 mgP/l (0.04 → 0.19)	99%
Riverside State Park			
Ortho-Phosphate-P			
Period of Record:	10/72-5/78		
Step	10/72-1/75	.066, Down/0.023 mgP/l	95%
		↓	
	2/75-8/76	.043	
Step	2/75-8/76	.043, Up/0.033 mgP/l	99%
		↓	
	9/77-5/78	.077	
Long Lake			
Ortho-Phosphate-P			
Period of Record:	11/70-9/77		
Step	11/70-3/74	.046, Down, 0.013 mgP/l	95%
		↓	
	4/74-9/76	.033	
Step	4/74-9/76	.033, Up, 0.023 mgP/l	99%
		↓	
	10/76-9/77	.056	
Hangman Creek			
Ortho-Phosphate-P			
Period of Record:	10/72-9/73, 10/76-6/78		
Step	10/72-9/73	.040, Up, 0.023 mgP/l	98%
		↓	
	10/76-6/78	.063	
Little Spokane			
Ortho-Phosphate-P			
Period of Record:	11/70-9/71, 10/72-9/73, 10/76-6/78		
Linear	10/70-6/78	0.035 → 0.020, Down, 0.015 mg/l	95%

stressed that the trend magnitudes in this table are estimates and, as noted earlier, are not defined by confidence limits.

The Post Falls station exhibited a decrease in total phosphate concentrations from 1973 to 1975. Concentrations remained relatively constant from 1975 to 1977 (see Figure 4). Riverside State Park (see Figure 5) and Long Lake stations revealed similar decreasing trends in the 1972-1976 period, followed by increasing trends in the 1975 to 1978 period. It should be noted that both the phosphate concentrations and magnitude of trends are much lower at the Post Falls station than at lower Spokane River stations. Therefore, conditions which are responsible for decreasing concentrations at the Post Falls station have little relative impact on lower Spokane River phosphate concentrations and trends.

It is possible that the 1973 to 1975 decrease at Post Falls reflects the effects of municipal sewage collection treatment in the Coeur d'Alene River Valley which proceeded rapidly during this time period. The USEPA (1975) noted that "Total phosphorus concentrations [in the Coeur d'Alene River Subbasin] have been reduced throughout the year over the six year period from 1968 through 1974." They attribute this reduction to a "reduction in phosphorus discharged from Bunker Hill Company and collection and treatment of municipal discharges in the South Fork Coeur d'Alene River area."

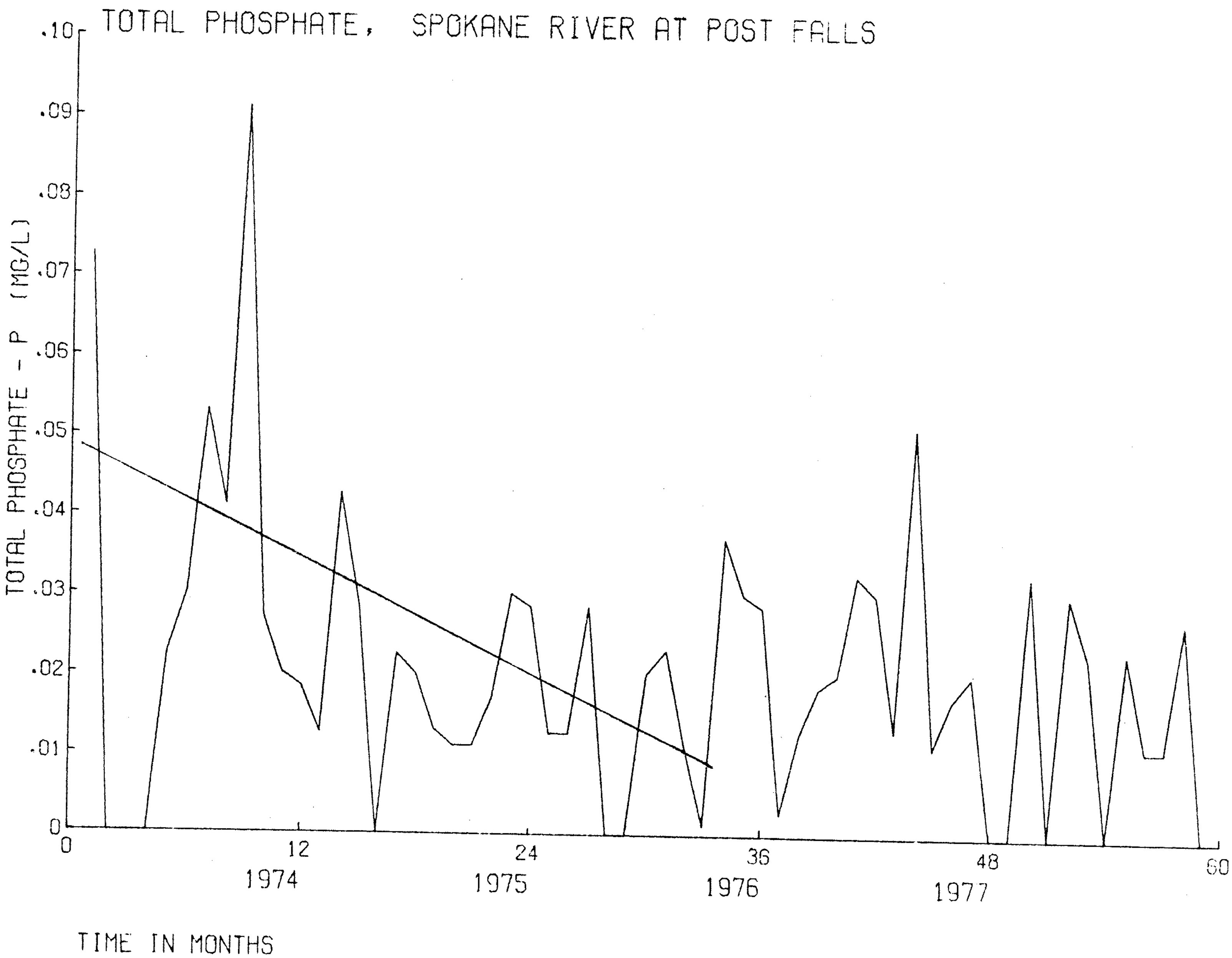
The phosphate concentration trends at the lower Spokane River stations appear to be primarily flow-related. Based on loadings, Soltero (1979) found no indication of similar trends in the lower Spokane River. To clarify this point, total phosphate loadings at the Riverside State Park station were calculated based on total phosphate concentrations and flow on the day of collection. Figure 6 is the deseasonalized time series for these loading data. Analysis of these loading data reveals no long-term trends (i.e., no significant long-term increases or decreases). Mean annual loadings were calculated and are compared to Soltero's (1979) data in Table 6.

Table 6 Annual Total Phosphate Loading
Spokane River Below Spokane Treatment Plant

Year	Spokane River at Riverside State Park, Present Study. lbs. T-PO_4-P/day	Spokane River at Seven Mile, Soltero (1979) lbs. T-PO_4-P/day*
1972	-----	2,154
1973	2,360	1,938
1974	3,602	2,082
1975	2,399	1,507
1976	2,847	-----
1977	1,963	1,292

*June through November data only.

Figure 4



TOTAL PHOSPHATE, SPOKANE RIVER AT POST FALLS

Figure 5

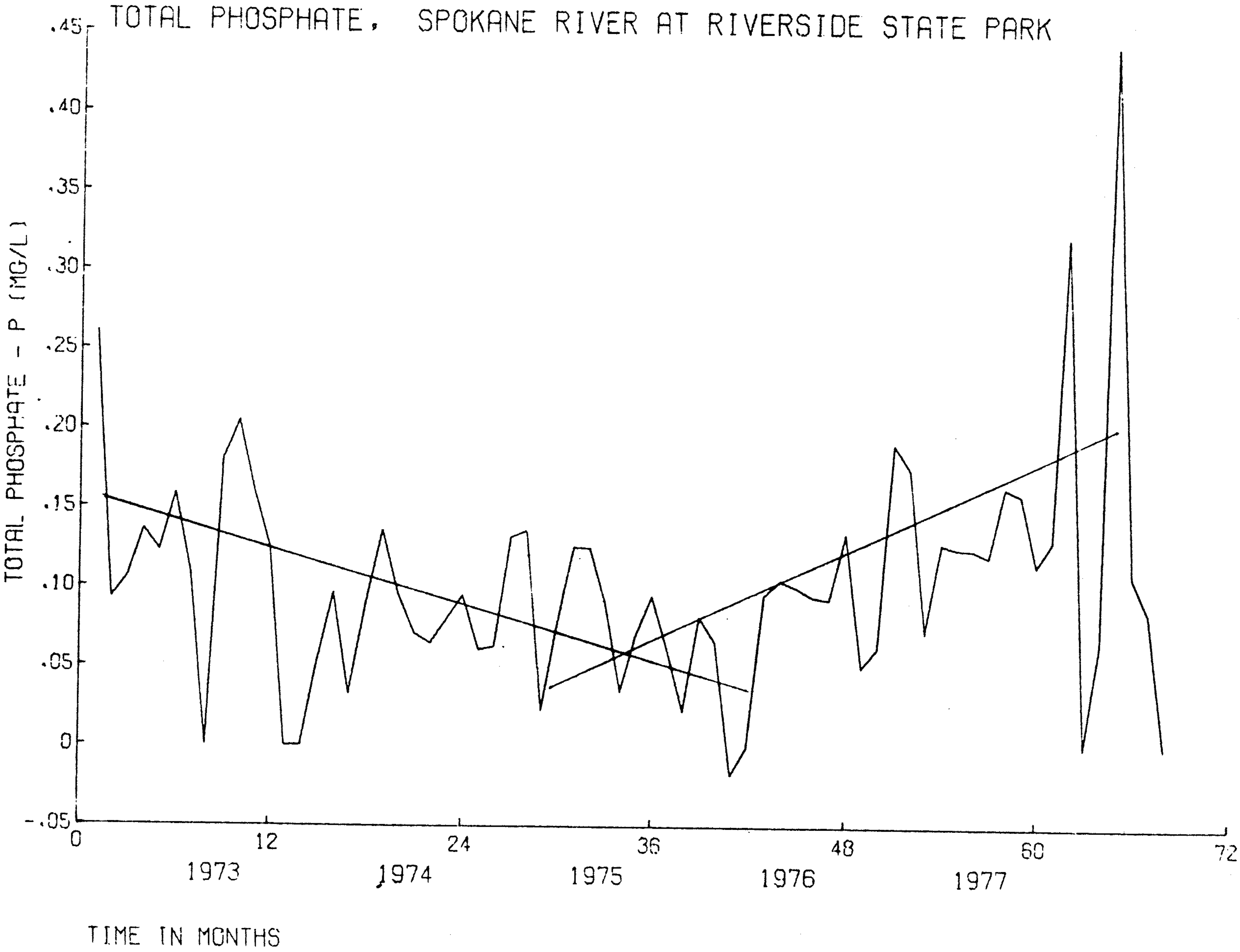
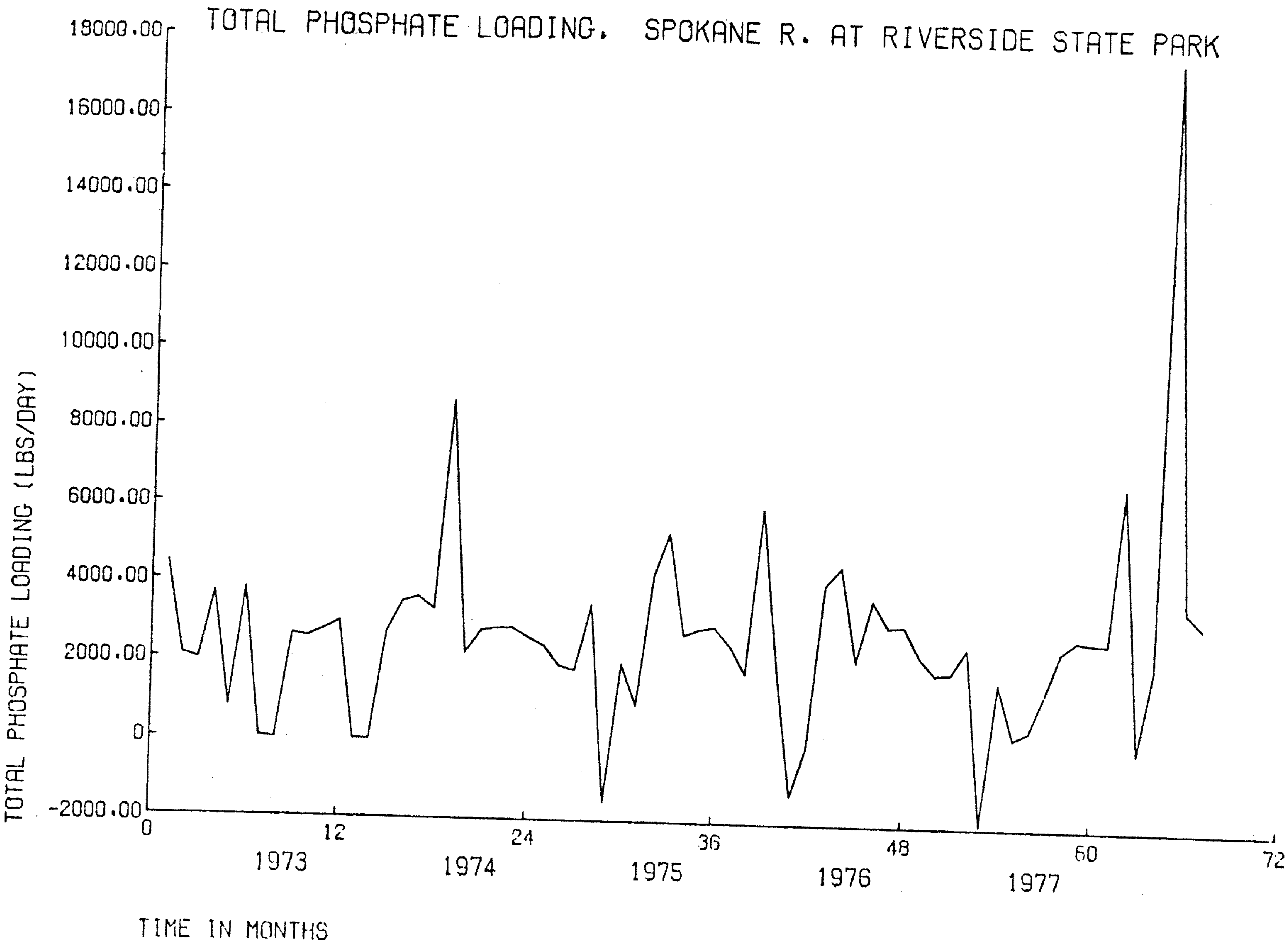

TOTAL PHOSPHATE, SPOKANE RIVER AT RIVERSIDE STATE PARK
TOTAL PHOSPHATE - P (MG/L)
.45
.40
.35
.30
.25
.20
.15
.10
.05
0
-.05
0
12
24
36
48
60
72
1973
1974
1975
1976
1977
TIME IN MONTHS

Figure 6



TOTAL PHOSPHATE LOADING, SPOKANE R. AT RIVERSIDE STATE PARK

Soltero's data reflect lower loadings due to the restricted (June to November) sampling period; however, the relative loadings track each other well.

The discrepancy between concentration and loading trends suggests that observed concentration trends are, at least partially, artifacts of a subtle flow/phosphate concentration relationship. Figure 7 illustrates the mean annual Spokane River flows from 1972 to 1977. The relative phosphate concentrations detected during trend analysis are noted at the top of the figure. Two low flow years (1973 and 1977) are associated with high phosphate concentrations in the river. The high flow years are associated with low phosphate concentrations. It appears, therefore, that there is a generally inverse relationship between phosphate concentrations and flows in the Spokane River.

This relationship is clearly displayed in Figure 8. Flow/total phosphate-P concentration data were plotted and regression lines fitted, using least squares, for four standard mathematical curves. The best fit (correlation coefficient = .72) line was:

Equation 1. $y = 6.288(x)^{-.504}$

where y = total phosphate-P concentration (mg/l)
x = river flow (cfs)

This regression line is represented by the solid curve in Figure 8. If phosphate loading were entirely independent of flow, the relationship between concentration and flow would be parabolic. For the period of record, the average total phosphate load at Riverside State Park was 2593 lbs T-PO_4-P/day. Using this average, the Equation 2 would represent this inverse relationship:

Equation 2. $5.39(x)(y) = 2593$

where y = total phosphate-P concentration (mg/l)
x = river flow (cfs)
5.39 = conversion factor

Rearranging, Equation 2 becomes:

Equation 3. $y = 481(x)^{-1}$

This relationship is represented by the dashed curve in Figure 8. The similarity of the curves is striking, and the strong inverse relationship between flows and total phosphate concentrations in the lower Spokane River is clear. The actual (regression) relationship is not perfectly inverse. Concentrations at lower flows are somewhat lower; concentrations at higher flows somewhat higher than would be the case if loading were completely independent of flow. As noted earlier, high early spring flows appear to contribute additional phosphates from agricultural and urban runoff and are probably, at least partially, responsible for this variance.

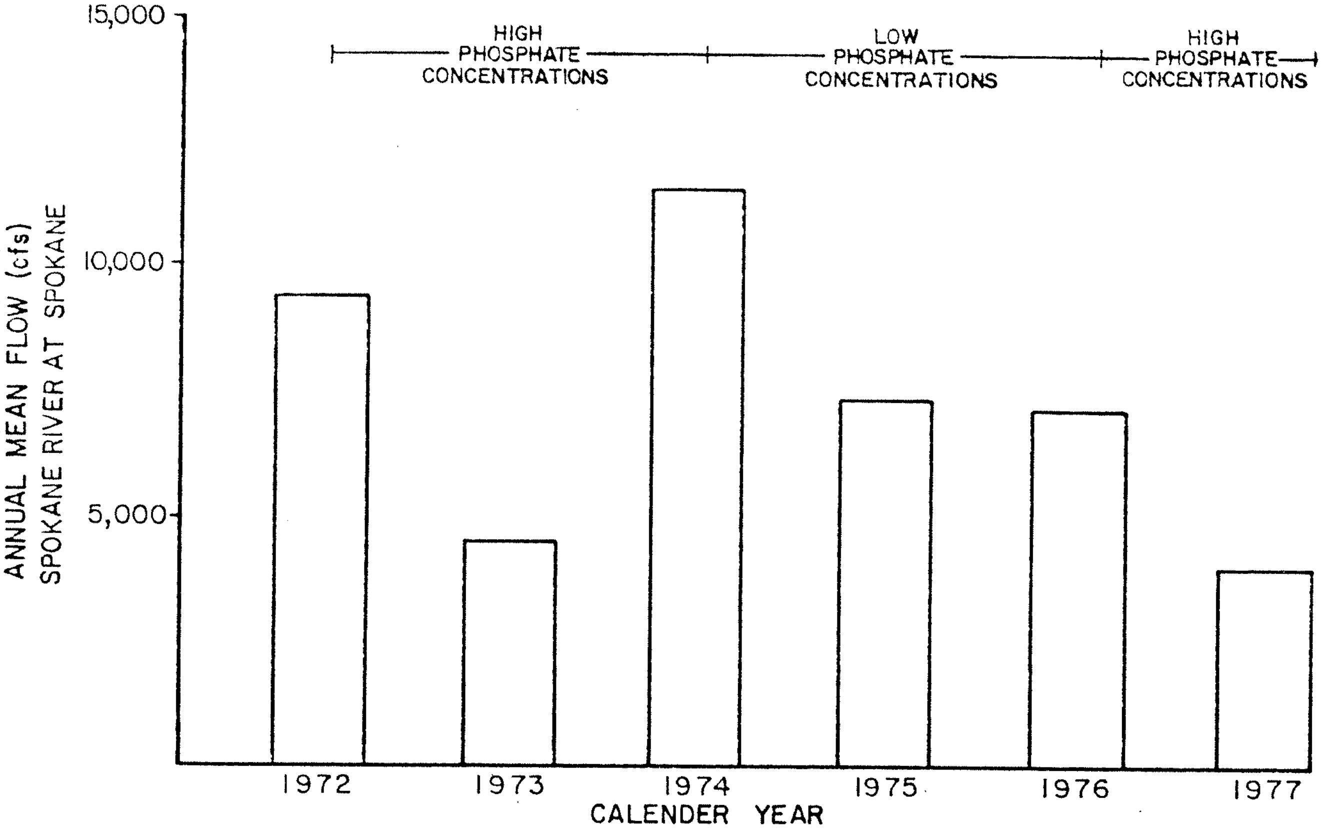


FIGURE 7. RELATIONSHIP BETWEEN LONG-TERM PHOSPHATE TRENDS AND FLOWS IN THE SPOKANE RIVER

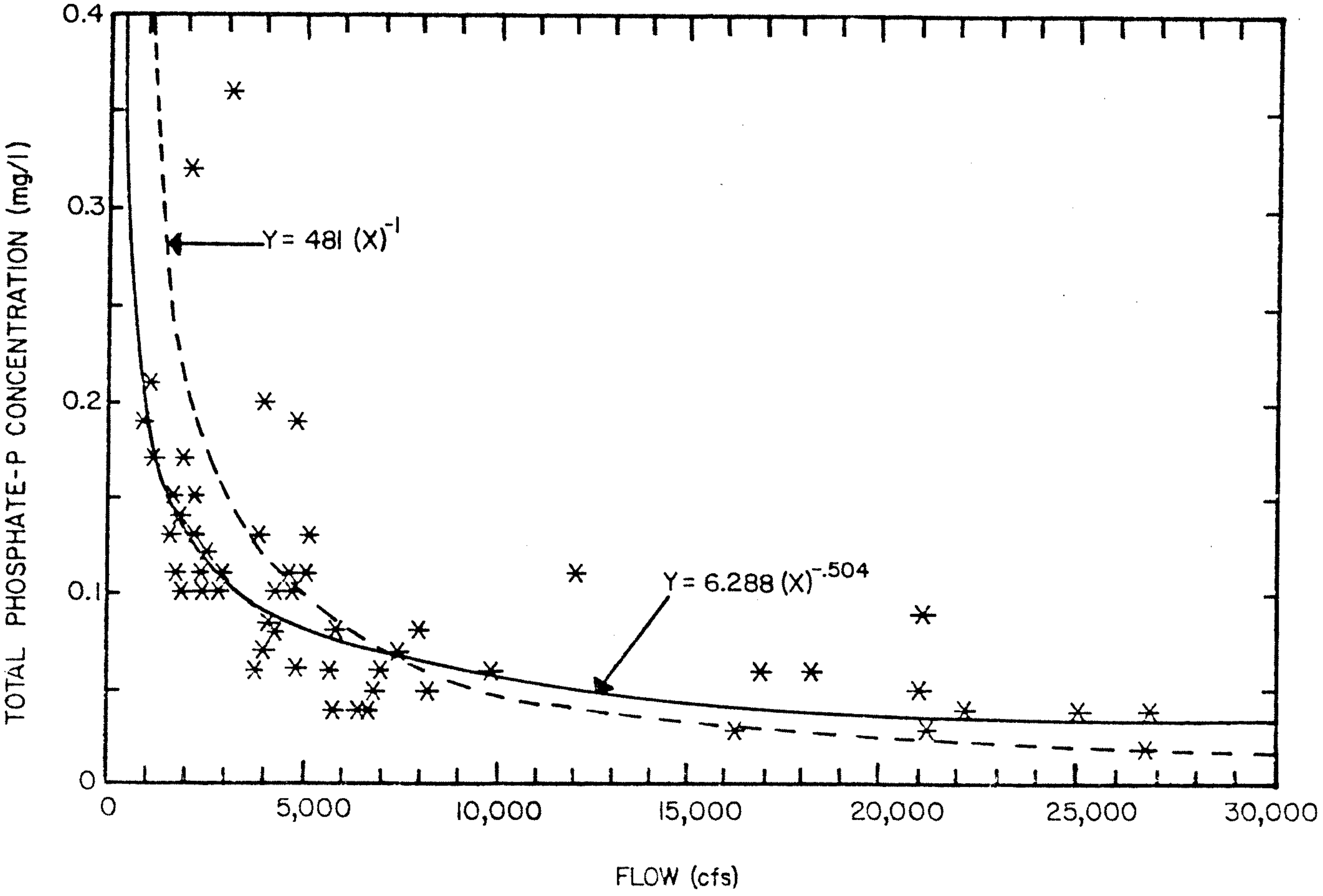


FIGURE 8. TOTAL PHOSPHATE-P VS. FLOW: SPOKANE RIVER AT RIVERSIDE STATE PARK

Based on the absence of trends in the analyses of loading data (Figure 6) and the data displayed in Figures 7 and 8, it appears that the phosphate concentration trends detected at the lower Spokane River stations are, in fact, largely responses to high and low flow conditions.

Observed phosphate trends shed little light on the *Anabaena* blooms of 1976 and 1977. Concentrations of both total and orthophosphate were near their low ebbs during the more toxic bloom in 1976. Concentrations of phosphates were higher both before and after the blooms. Phosphate data at neither downstream station indicate a response to the October 1975 sewage bypass.

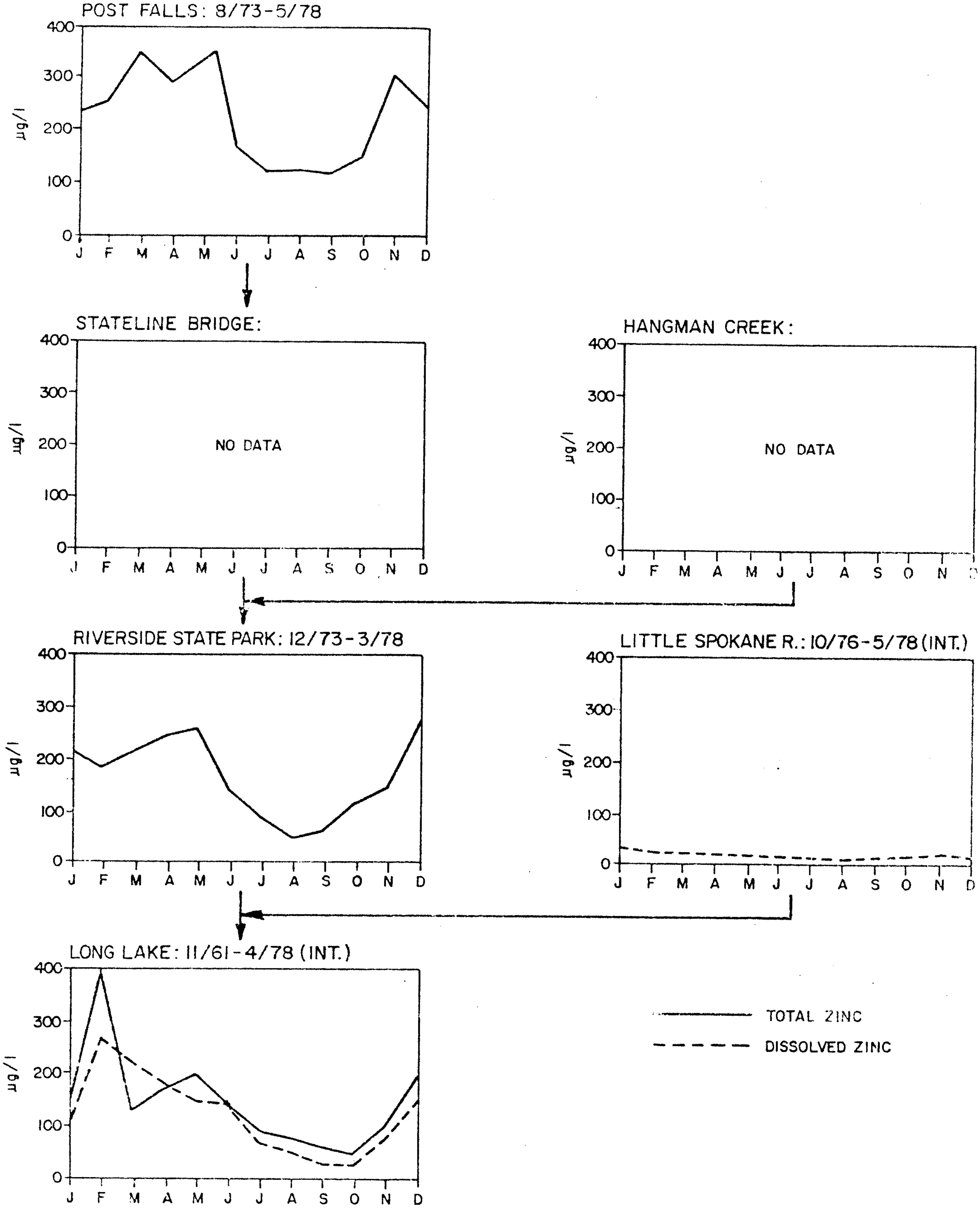
The Hangman Creek and Little Spokane phosphate data trends again appear to be best explicable in terms of low flow effects. Both data records are intermittant and marginal in terms of trend analysis. Low flows and high orthophosphate concentrations late in the Hangman Creek record appear to be responsible for the apparent trend.

The effect of drought on phosphate concentrations in the Little Spokane River is reversed. Because the Spokane aquifer provides the Little Spokane with a constant supply of low phosphate waters, drought minimizes phosphate input from overland runoff and appears to actually decrease in-stream orthophosphate levels.

Zinc:

Mean monthly zinc concentrations are illustrated in Figure 9. Data were available for only four of the six stations examined. Dissolved zinc is defined by the sampling technique as the fraction of sampled zinc which passes a 0.45 micron filter. As noted in the introduction, the major sources of zinc to the drainage systems are mining and refining activities in the Kellogg mining district in northern Idaho.

In general, zinc concentrations in the Spokane River appear to peak in conjunction with flows (see Figure 16). This has been noted previously (USEPA, 1975). These authors found that although zinc concentrations in the Coeur d'Alene River drop to a seasonal low of about 500 μg/l during high flow periods, zinc loading to Lake Coeur d'Alene peaks during the spring. This peak is attributed to accelerated leaching from tailings in the valley of the South Fork of the Coeur d'Alene River. Zinc concentrations at the north end of Lake Coeur d'Alene and in the Spokane River respond by peaking during maximum flow periods. This response can be attributed to two related factors: 1) high flows in the Coeur d'Alene River short-circuit Lake Coeur d'Alene, and pass to the lake outlet with minimal mixing; and, 2) the extent to which Lake Coeur d'Alene can serve as a zinc sink is a function of detention time. High river flows minimize detention time and thus the extent to which zinc can be lost to lake sediments.



POST FALLS: 8/73-5/78

STATELINE BRIDGE:

HANGMAN CREEK:

RIVERSIDE STATE PARK: 12/73-3/78

LITTLE SPOKANE R.: 10/76-5/78 (INT.)

LONG LAKE: 11/61-4/78 (INT.)

Figure 9. MEAN MONTHLY ZINC CONCENTRATIONS-SPOKANE DRAINAGE SYSTEM.

The annual pattern in zinc concentrations has an important implication. Zinc concentrations seasonally fall to the lower ranges of algal growth inhibition (30 to 100 μg/l) reported by Bartlett, *et al.*, (1974), Green, *et al.*, (1975), and Miller, *et al.*, (1975). This occurs during the prime algal growth season while nutrient concentrations are peaking.

Zinc loadings were calculated using mean monthly total-Zn concentrations for the period of record (Table A-3) and mean monthly flows from 10/70 to 10/78 (Table A-1). These mean monthly loadings were then combined to yield annual loadings. The results are summarized in Table 7.

Table 7. Annual Total Zinc Mass Balance - Spokane Drainage System

	Zinc Loadings lbs. Zn/day	Sources lbs. Zn/day	Sinks lbs. Zn/day
Spokane River at Post Falls	9,625	+9,625	--
Spokane River - Post Falls to Riverside State Park	--	--	(-1,389)
Spokane River at Riverside State Park	8,236	--	--
Little Spokane River	--	+ 48	--
Long Lake Influent	8,284	--	--
Long Lake	--	--	(- 607)
Long Lake Effluent	7,677	--	--

Thus the upper Spokane River serves as a sink for approximately 14 percent of influent zinc, while Long Lake removes about 7 percent of the remainder.

Significant decreasing zinc concentration trends were detected at two of the three Spokane River stations with adequate data records. These decreases occurred during a period from about 1972 to end of data records in early 1978 (Table 8). The Riverside State Park station showed decreasing values, but the trend was not significant at the 80 percent confidence level. Interestingly, estimated trend magnitudes all indicate drops to about 50 percent of historical concentrations. The total zinc record at the Post Falls station provides the most complete data record. The deseasonalized time series and estimated linear trend line are illustrated in Figure 10.

It is probable that decreasing zinc concentrations in the Spokane River can be largely attributed to pollution abatement efforts in the Kellogg mining district. The beginning of the downward trend coincides well with installation of lime neutralization and decant clarification treatment systems at Bunker Hill Company in 1973. The generally linear, rather than step, character of the trends is probably due to several factors including continued zinc leaching from old tailings deposits, the presence of Coeur d'Alene River

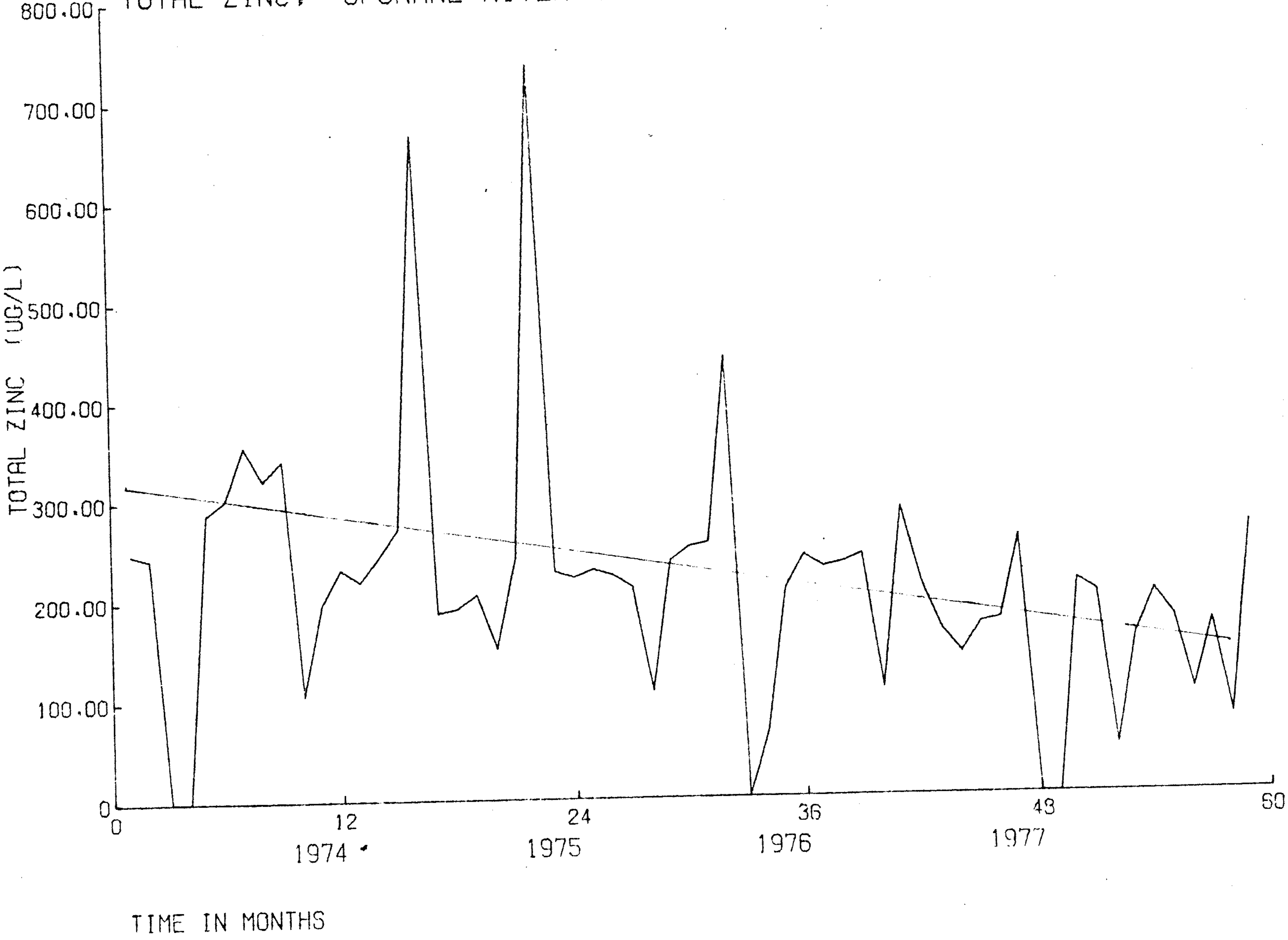
Table 8

Zinc Trends

Type of Trend	Time Period	Direction/Magnitude of Trend	Significance of Trend
Post Falls Total Zinc			
Period of Record:	8/73-5/78		
Linear	8/73-5/78	Down/159 ug/l (320 → 160)	99%
Long Lake Total Zinc			
Period of Record:	12/70-4/78 (Intermittant)		
Step	12/70-1/75	155, Down, 42 ug/l ↓	90%
	2/75-4/78	110	
Long Lake Dissolved Zinc			
Period of Record:	11/61-4/78 (Intermittant)		
Linear	2/72-4/78	Down, 94 ug/l (160 → 70)	90%

Figure 10

TOTAL ZINC, SPOKANE RIVER AT POST FALLS



delta sediments high in zinc content, concentration equalization in Lake Coeur d'Alene, and leakage from tailings ponds; most notably the central impoundment area at Bunker Hill Company (Rouse, 1977). Zinc concentrations in the Spokane River are still well above those in most U.S. waters.

Nitrate:

Annual variations in nitrate concentrations are illustrated in Figure 11. Nitrate concentrations at the Stateline Bridge station are comparitively low and stable on an annual basis. Lower Spokane River stations show low nitrate concentrations during high flow (April through June) with higher concentrations throughout the rest of the year. Nitrate loading to Long Lake is high from December through July (10,000 to 25,000 lbs. nitrate-N/day) but drops from August through November (6,000 to 9,000 lbs. nitrate-N/day). This indicates that there are seasonal nitrate sources in the Spokane River basin. These sources are probably runoff dependent. However, a substantial portion of that nitrate loading occurs throughout the year. Groundwater recruitment from the Spokane aquifer is responsible for a major portion of the nitrate in the lower Spokane River system. Nitrate-N concentrations in aquifer waters reaching the surface drainage range from about 1.8 to 2.0 mg/l (Esvelt, 1978). Estimates of annual average groundwater flow to the Spokane and Little Spokane Rivers range from about 700 cfs (Vaccaro, 1979) to about 1100 cfs (Drost and Seitz, 1978). Conservatively, groundwater flow would be responsible for contributing about 6800 lbs. NO_3-N/day to the drainage system.

The influence of the aquifer on nitrate concentrations in the Little Spokane River is marked, with high nitrate concentrations throughout the year and peak concentrations at low flow periods when essentially all flow in the Little Spokane is contributed by groundwater.

Hangman Creek displays high nitrate concentrations from February through September. Substantial portions of this nitrate is probably related to the agricultural character of the basin.

Data were inadequate at most stations to permit long-term trend analyses or detection. The only exception was the Stateline Bridge station. The deseasonalized time series and estimated trend lines for this station are shown in Figure 12. The trends are identified in Table 9. These apparent trends are substantial and largely inexplicable. One possible explanation may involve changes in sample preservation and analytical techinques. USGS records do not detail procedures in the early 1960's; however, nutrient analyses were automated in 1970, resulting in decreased sample storage time. In 1971, samples were shipped and stored on ice for the first time. The apparent drop in nitrate concentrations coincides with these changes. Oxidation of ammonia and organic nitrogen to nitrate may have been decreased or eliminated by these changes, resulting in

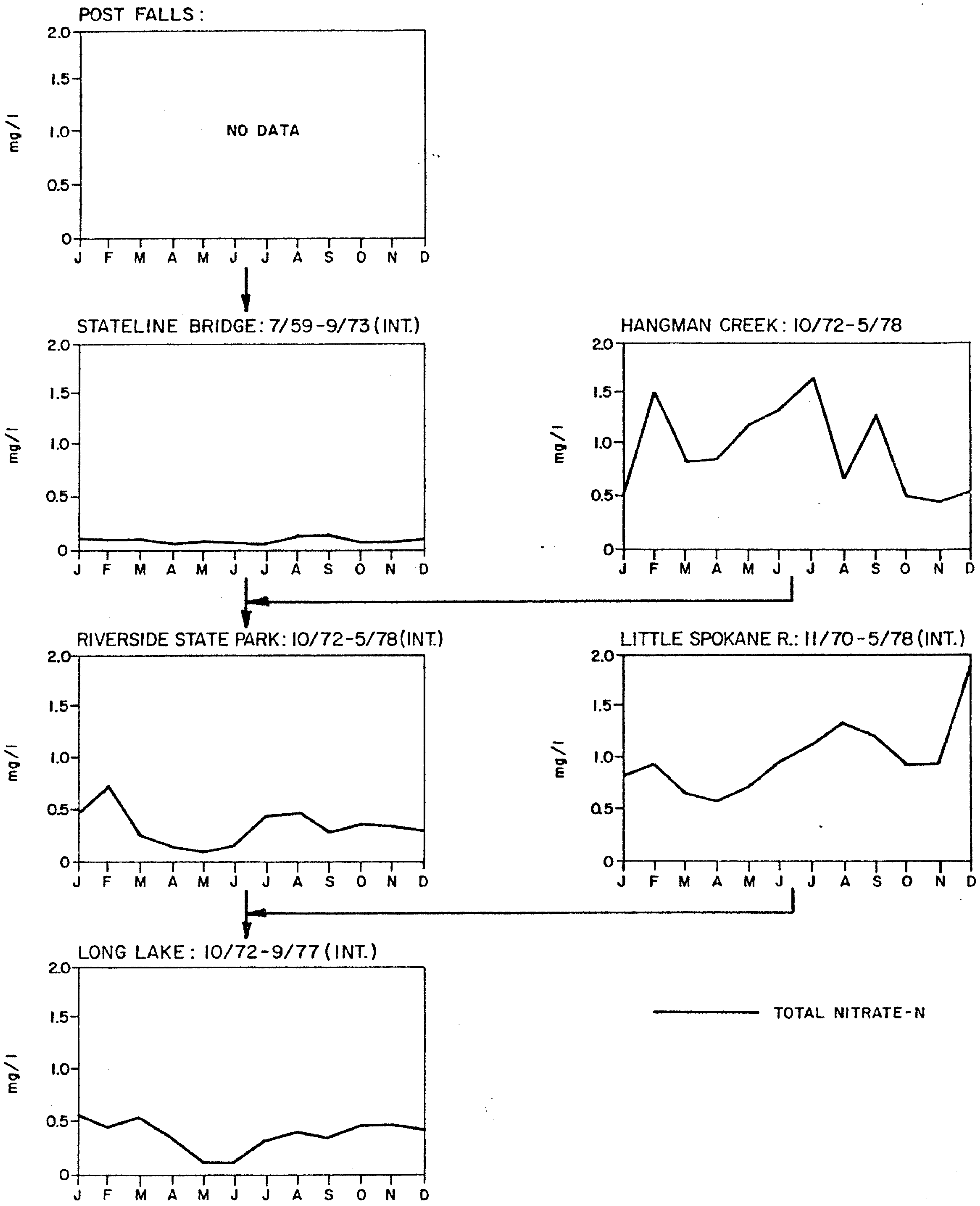
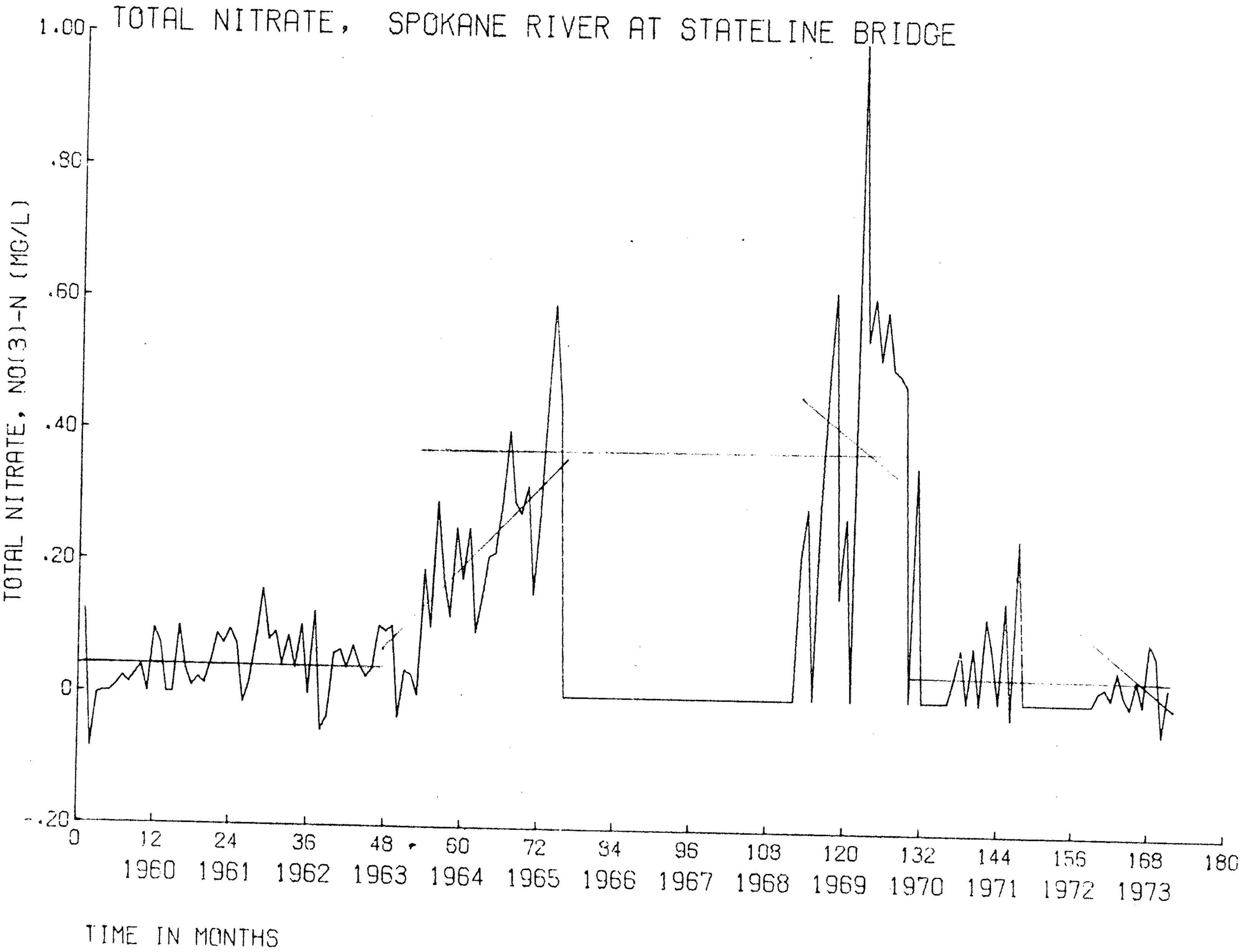


Figure 11 MEAN MONTHLY NITRATE CONCENTRATIONS - SPOKANE DRAINAGE SYSTEM.

Figure 12



TOTAL NITRATE, SPOKANE RIVER AT STATELINE BRIDGE

Table 9

Nitrate Trends

Type of Trend	Time Period	Direction/Magnitude of Trend	Significance of Trend
Stateline Bridge Nitrate-N Period of Record: 7/59-9/65, 11/68-9/71, 10/72-9/73			
Step	7/59-10/63	0.041, Up, 0.26 $\mathrm{mgNO_3}$-N/l ↓ 0.301	99%
Linear	8/63- 9/65	Up, 0.43 $\mathrm{mgNO_3}$-N/l(0.074 → 0.497)	99%
Step	11/63- 3/70 4/70- 9/73	0.301, Down, 0.26 $\mathrm{mgNO_3}$-N/l ↓ 0.041	99%
Linear	11/68- 9/73	Down, 0.43 $\mathrm{mgNO_3}$-N/l(0.497 → 0.017)	99%

lower (and more accurate) nitrate values. This does not, however, explain the apparent increase in values in the 1963 to 1966 period.

Specific Conductivity, Temperature, Dissolved Oxygen and Flow

Annual variations in conductivity, temperature, dissolved oxygen, and flow are presented in Figures 13, 14, 15, and 16. These curves serve to further define flow and water quality in these stream sections. The effect of Lake Coeur d'Alene in moderating conductivity and temperature fluctuations is apparent. Lower Spokane River stations show increased temperature variations and elevated conductivities. In addition, the low dissolved oxygen problems at the Long Lake station are apparent in the late summer and early fall.

Groundwater inflow moderates temperatures and elevates conductivity in the Little Spokane River.

Hangman Creek displays wide fluctuations in temperature, conductivity, and flows.

No long-term trends were detected in records available for these parameters.

CONCLUSIONS

Based on the data reviewed and analyzed, the following conclusions can be made. These conclusions are listed in order of importance and confidence.

1. Trend analysis reveals that zinc concentrations in the Spokane River appear to have decreased by approximately 50 percent between 1973 and 1978. Improved collection and treatment of wastewaters by mining and refining interests in the Kellogg Mining District are probably, at least partially, responsible for this trend.

2. Maximum nutrient concentrations in the Lower Spokane River (and Long Lake) occur under low flow conditions in the late summer. Nutrient loadings peak from January to June. Nutrient concentration maxima and low zinc concentrations occur simultaneously during the period of highest algal growth potential (August to October).

3. Trend analysis of phosphate concentrations in the lower Spokane River reveal a decreasing trend from 1972 to about 1975, followed by an increasing trend from about 1975 to late 1977. Analysis of phosphate loading at Riverside State Park reveals no long-term trends. This, in addition to the strong inverse relationship between phosphate concentrations and flows, appears to confirm that these concentration trends were, in large part, generated by changes in river flow over the periods of record analyzed.

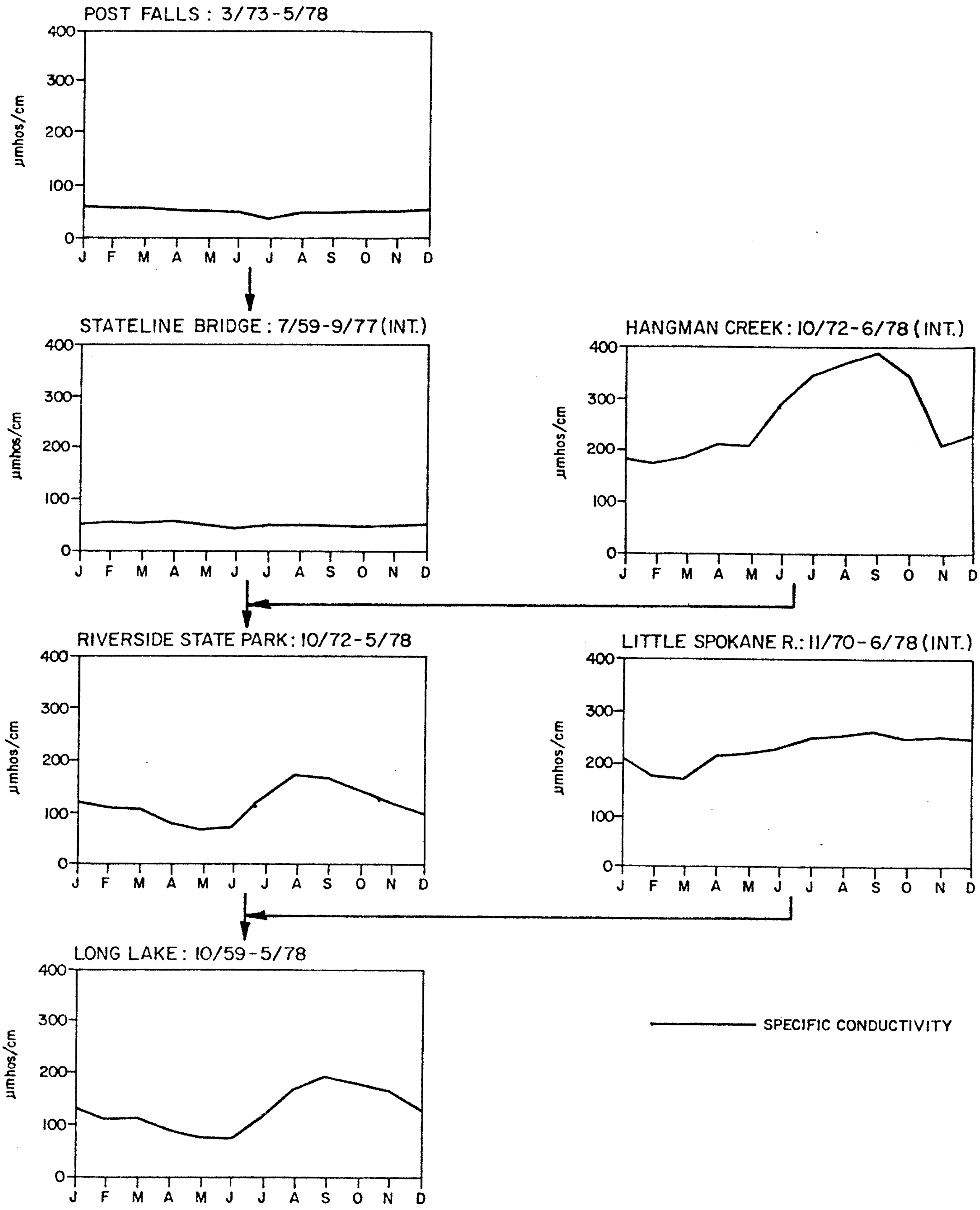


Figure 15 MEAN MONTHLY CONDUCTIVITY - SPOKANE DRAINAGE SYSTEM.

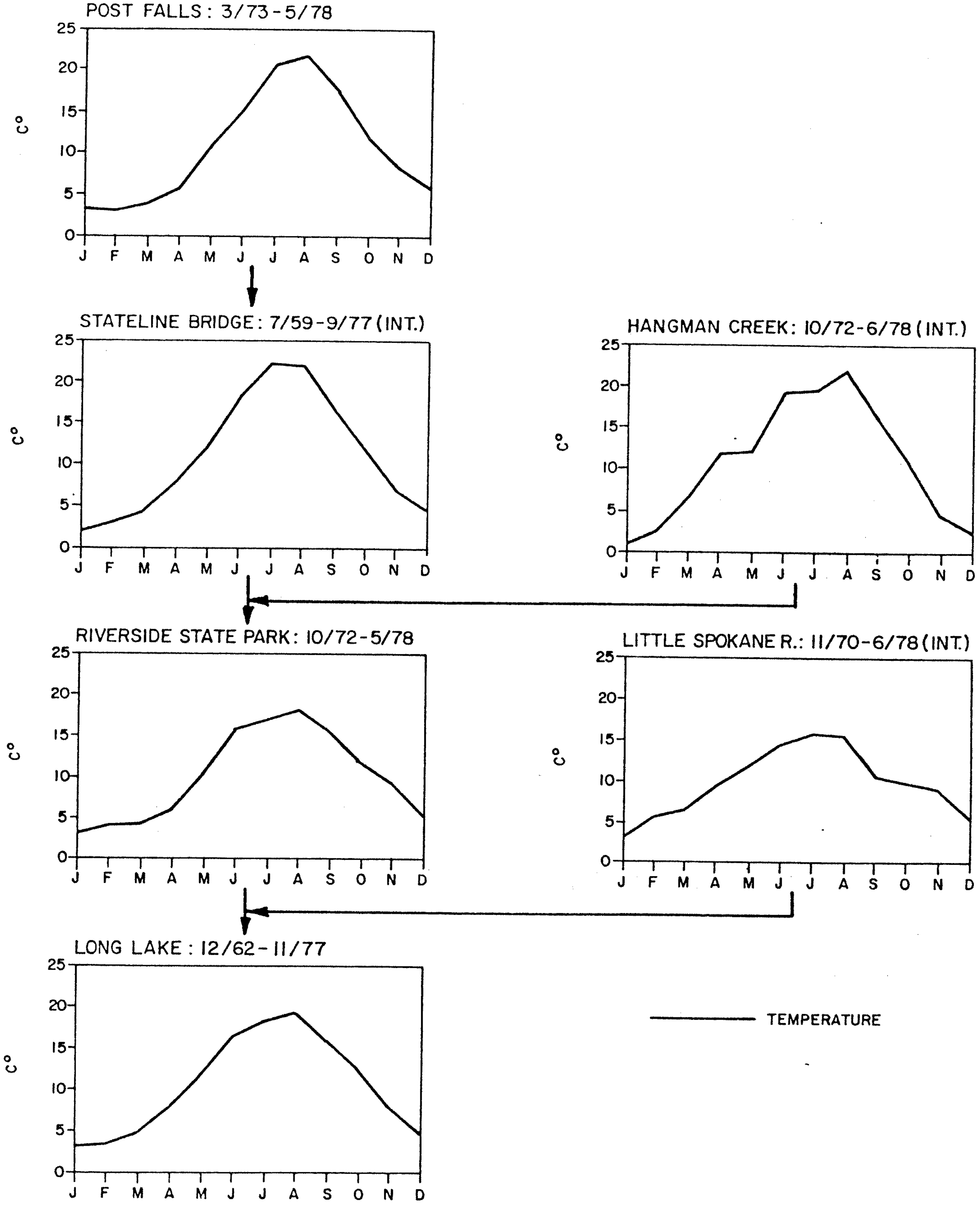


Figure 14 MEAN MONTHLY TEMPERATURES -SPOKANE DRAINAGE SYSTEM.

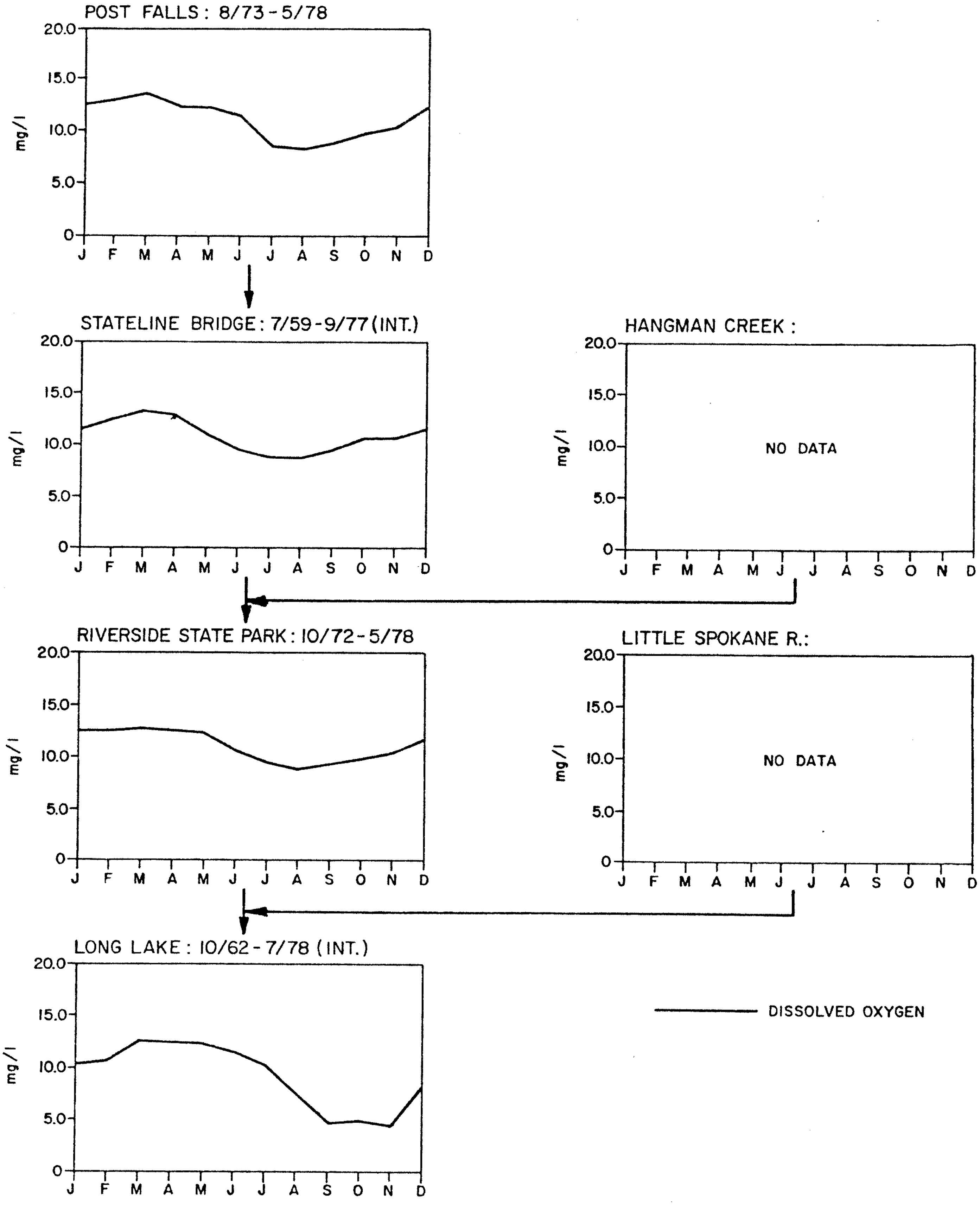


Figure 15. MEAN MONTHLY DISSOLVED OXYGEN CONCENTRATIONS-SPOKANE DRAINAGE SYSTEM.

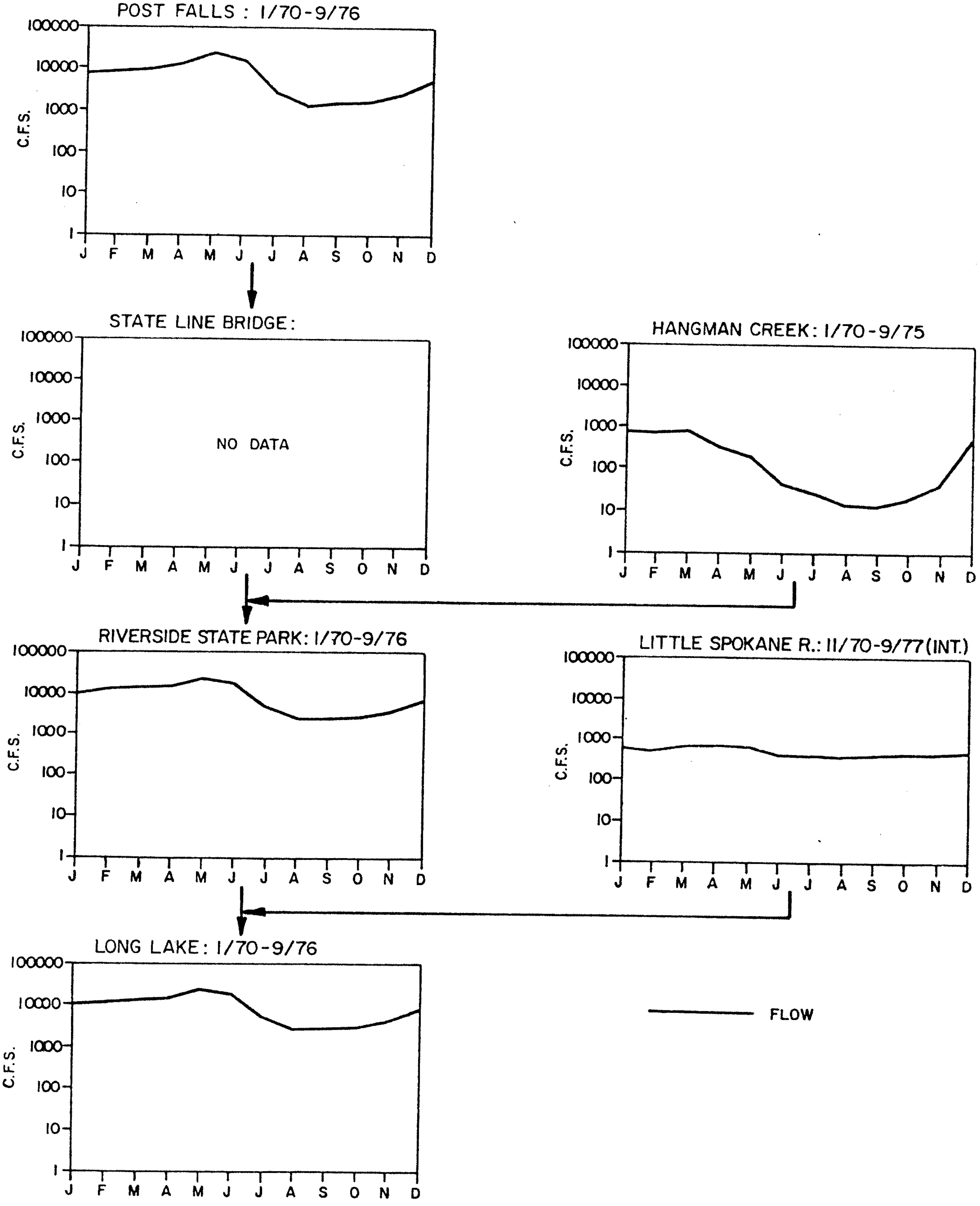


Figure 16 MEAN MONTHLY FLOWS - SPOKANE DRAINAGE SYSTEM.

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APPENDIX

TABLE A-1

MEAN MONTHLY FLOWS - 1/70 to 9/77

Post Falls & Otis Orchards[1] Month	Flow (cfs)	Stateline Bridge Flow (cfs)	Riverside State Park[1,2] Flow (cfs)	Long Lake[1] Flow (cfs)	Hangman Creek[1] Flow (cfs)	Little Spokane River[3] Flow (cfs)
Jan.	6,732	--	7,797	8,915	616	580
Feb.	7,054	--	8,287	9,204	597	529
Mar.	8,699	--	9,880	11,120	737	629
Apr.	11,778	--	12,804	13,192	333	639
May	18,840	--	19,849	19,902	159	630
June	13,628	--	14,823	15,323	83	440
July	2,663	--	3,481	4,208	22	392
Aug.	1,156	--	1,700	2,332	23	358
Sept.	1,514	--	1,939	2,551	15	384
Oct.	2,231	--	2,262	2,922	21	434
Nov.	2,390	--	2,836	3,587	42	442
Dec.	4,592	--	5,178	6,032	283	440

[1] From "Water Quality Records, Washington State." United States Geological Survey, 1970-1977.

[2] Spokane River at Spokane flows, plus Hangman Creek flows, 1970-1977.

[3] Department of Ecology data, 11/70-6/78, Intermittant Data Base.

TABLE A-2

MEAN MONTHLY PHOSPHATE CONCENTRATIONS

	Post Falls		Stateline Bridge		Riverside State Pk.		Long Lake		Hangman Creek		Little Spokane River	
	8/73 - 4/78		12/70 - 9/77 Int.*		10/72 - 5/78		11/70 - 5/78		10/72 - 6/78 Int.*		12/70 - 6/78 Int.*	
Month	O-PO$_4$-P (mg/1)	T-PO$_4$-P (mg/1)	O-PO$_4$-P (mg/1)	T-PO$_4$-P (mg/1)	O-PO$_4$-P (mg/1)	T-PO$_4$-P (mg/1)	O-PO$_4$-P (mg/1)	T-PO$_4$-P (mg/1)	O-PO$_4$-P (mg/1)	T-PO$_4$-P (mg/1)	O-PO$_4$-P (mg/1)	T-PO$_4$-P (mg/1)
Jan.	--	.015	--	.035	.047	.087	.057	.077	.037	.067	.028	.050
Feb.	--	.032	--	.020	.062	.190	.041	.085	.060	.332	.059	.107
Mar.	--	.034	--	.055	.033	.084	.034	.099	.072	.194	.032	.076
Apr.	--	.034	--	.047	.033	.070	.024	.076	.051	.209	.032	.098
May	--	.018	--	.070	.015	.047	.024	.065	.095	.304	.038	.080
June	--	.015	--	.013	.039	.062	.020	.039	.086	.334	.016	.027
July	--	.017	--	.029	.074	.118	.027	.037	.089	.209	.019	.033
Aug.	--	.032	--	.037	.104	.142	.043	.063	.060	.439	.015	.036
Sept.	--	.032	--	.033	.086	.128	.072	.085	.050	.122	.016	.026
Oct.	--	.017	--	.030	.099	.172	.050	.076	.041	.096	.014	.030
Nov.	--	.025	--	.017	.073	.150	.046	.057	.033	.079	.016	.027
Dec.	--	.022	--	.030	.051	.091	.044	.054	.050	.090	.021	.035

Int.* = Intermittant Data Base

TABLE A-3

MEAN MONTHLY ZINC CONCENTRATIONS

Month	Post Falls 8/73 - 5/78 Diss.-Zn (μg/l)	Post Falls 8/73 - 5/78 Total-Zn (μg/l)	Stateline Bridge Diss.-Zn (μg/l)	Stateline Bridge Total-Zn (μg/l)	Riverside State Pk. 12/73 - 3/78 Int.* Diss.-Zn (μg/l)	Riverside State Pk. 12/73 - 3/78 Int.* Total-Zn (μg/l)	Long Lake 11/61 - 4/78 Int.* Diss.-Zn (μg/l)	Long Lake 11/61 - 4/78 Int.* Total-Zn (μg/l)	Hangman Creek Diss.-Zn (μg/l)	Hangman Creek Total-Zn (μg/l)	Little Spokane River 10/76 - 5/78 Int.* Diss.-Zn (μg/l)	Little Spokane River 10/76 - 5/78 Int.* Total-Zn (μg/l)
Jan.	--	230	--	--	--	215	104	138	--	--	30	--
Feb.	--	256	--	--	--	135	267	400	--	--	20	--
Mar.	--	350	--	--	--	216	220	126	--	--	20	--
Apr.	--	290	--	--	--	245	180	173	--	--	20	--
May	--	346	--	--	--	260	145	200	--	--	15	--
June	--	163	--	--	--	140	143	140	--	--	15	--
July	--	120	--	--	--	90	66	90	--	--	10	--
Aug.	--	122	--	--	--	50	50	80	--	--	10	--
Sept.	--	118	--	--	--	63	25	--	--	--	15	--
Oct.	--	150	--	--	--	120	23	48	--	--	17	--
Nov.	--	305	--	--	--	150	75	100	--	--	20	--
Dec.	--	254	--	--	--	270	152	195	--	--	15	--

Int.* = Intermittant Data Base

TABLE A-4

MEAN MONTHLY NITRATE CONCENTRATIONS

Month	Post Falls NO_3-N (mg/l)	Stateline Bridge 7/59 - 9/73 Int.* NO_3-N (mg/l)	Riverside State Park 10/72 - 5/78 Int.* NO_3-N (mg/l)	Long Lake 10/72 - 9/77 Int.* NO_3-N (mg/l)	Hangman Creek 10/72 - 5/78 Int.* NO_3-N (mg/l)	Little Spokane River 11/70 - 5/78 Int.* NO_3-N (mg/l)
Jan.	--	.084	.490	.533	.509	.833
Feb.	--	.087	.710	.453	1.529	.935
Mar.	--	.101	.230	.537	.810	.670
Apr.	--	.065	.135	.327	.850	.592
May	--	.070	.095	.105	1.200	.703
June	--	.049	.160	.100	1.349	.997
July	--	.063	.420	.302	1.649	1.117
Aug.	--	.119	.460	.400	.690	1.329
Sept.	--	.128	.290	.327	1.300	1.207
Oct.	--	.069	.365	.467	.500	.923
Nov.	--	.070	.345	.477	.460	.947
Dec.	--	.090	.300	.423	.540	1.843

Int.* = Intermittant Data Base

TABLE A-5

MEAN MONTHLY DISSOLVED OXYGEN CONCENTRATION

Month	Post Falls 8/73 - 5/78 Diss. Oxygen (mg/l)	Stateline Bridge 7/59 - 9/73 Int.* Diss. Oxygen (mg/l)	Riverside State Park 10/72 - 5/78 Int.* Diss. Oxygen (mg/l)	Long Lake 10/72 - 9/77 Int.* Diss. Oxygen (mg/l)	Hangman Creek I.D. Diss. Oxygen (mg/l)	Little Spokane River I.D. Diss. Oxygen (mg/l)
Jan.	12.7	11.7	12.6	10.4	--	--
Feb.	13.0	12.4	12.4	10.6	--	--
Mar.	13.7	13.2	12.7	12.8	--	--
Apr.	12.2	12.9	12.6	12.6	--	--
May	12.1	11.0	12.2	12.6	--	--
June	11.3	9.7	10.5	11.5	--	--
July	8.5	8.8	9.3	10.2	--	--
Aug.	8.2	8.7	8.8	7.2	--	--
Sept.	8.9	9.3	9.2	5.8	--	--
Oct.	9.8	10.7	9.7	6.0	--	--
Nov.	10.4	10.7	10.3	5.7	--	--
Dec.	12.1	11.4	11.8	8.1	--	--

Int.* = Intermittant Data Base
I.D. = Insufficient Data

TABLE A-6

MEAN MONTHLY SPECIFIC CONDUCTIVITY

Month	Post Falls 8/73 - 5/78 Spec. Cond. (μmhos/cm)	Stateline Bridge 7/59 - 9/77 Int.* Spec. Cond. (μmhos/cm)	Riverside State Park 2/72 - 5/72 Spec. Cond. (μmhos/cm)	Long Lake 10/59 - 5/78 Spec. Cond. (μmhos/cm)	Hangman Creek 10/72 - 6/78 Int.* Spec. Cond. (μmhos/cm)	Little Spokane River 11/70 - 6/78 Int.* Spec. Cond. (μmhos/cm)
Jan.	60.4	58.1	120	131	183	216
Feb.	59.4	59.6	107	111	177	178
Mar.	60.2	58.7	108	114	187	175
Apr.	57.4	60.8	81	93.9	215	219
May	54.2	54.1	71	78.5	211	221
June	49.3	47.1	77	77.1	295	229
July	39.3	52.8	135	112	345	247
Aug.	52.4	53.4	178	167	373	257
Sept.	50.7	54.3	161	195	393	263
Oct.	55.0	53.1	145	180	345	253
Nov.	55.2	54.7	121	170	213	257
Dec.	57.4	57.5	103	133	228	257

Int.* = Intermittant Data Base

TABLE A-7

MEAN MONTHLY TEMPERATURES

Month	Post Falls 3/73 - 5/78 Temperature (°C)	Stateline Bridge 7/59 - 9/77 Int.* Temperature (°C)	Riverside State Park 10/72 - 5/78 Temperature (°C)	Long Lake 10/62 - 11/77 Temperature (°C)	Hangman Creek 10/72 - 6/78 Int.* Temperature (°C)	Little Spokane River 11/70 - 6/78 Int.* Temperature (°C)
Jan.	3.2	2.1	3.2	3.2	1.3	3.6
Feb.	3.1	3.1	3.9	3.6	2.7	5.7
Mar.	3.9	4.3	4.3	4.9	6.8	6.5
Apr.	6.1	7.7	6.2	7.7	12.1	9.9
May	11.2	12.3	10.3	11.6	12.2	11.9
June	15.1	18.1	16.1	16.4	19.4	14.8
July	20.7	22.3	17.2	18.7	19.6	16.2
Aug.	21.5	22.1	18.4	19.7	22.1	15.5
Sept.	17.9	16.5	15.6	16.1	16.2	10.6
Oct.	12.0	11.7	11.9	12.7	11.0	10.0
Nov.	8.5	7.1	9.4	8.0	4.6	9.0
Dec.	6.2	4.9	5.4	4.7	2.6	5.3

Int.* = Intermittant Data Base