An Examination of the Nutrient and Heavy Metals Budget in the Spokane River Between Post Falls and Hangman Creek

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INTRODUCTION

High concentrations of heavy metals and the nutrients, nitrogen and phosphorus, are major water quality problems in the Spokane River and its tributaries (Figure 1). Heavy metals, for which the principal source is the metals processing industries on the South Fork of the Coeur d'Alene River, are in quantity sufficiently high in the Spokane River to exceed the 24-hour average criterion given by the U.S. Environmental Protection Agency (1980). Nutrient loads, resulting from urbanization, domestic waste discharges, agriculture and silviculture, have created water quality conditions favorable to high algal productivity. (Soltero et al (1980). Soltero et al (1979), Soltero et al (1978), Soltero et al (1976), Soltero et al (1974), and Soltero et al (1973).

The State of Washington's Department of Ecology (DOE) has been supporting the study of water quality conditions in the Spokane River from just upstream of its confluence with Hangman Creek to Long Lake Dam since 1973. The purpose of the DOE studies has been primarily, to characterize the trophic state of Long Lake. More recently, the prospect of increased development on the Spokane River between Lake Coeur d'Alene and Hangman Creek has raised questions regarding the nature of the heavy metals and nutrient inventories in this segment of the river. The questions which have been raised must be addressed, not only to protect downstream water uses, but also to maintain the quality of the Spokane-Rathdrum Aquifer, with which the river can have either a positive or negative exchange rate.

In an attempt to determine the sources or sinks for nutrients and heavy metals in this segment of the Spokane River, the EPA Region 10, in a cooperative program with the DOE, conducted a series of four two-to-three-day intensive surveys. This report describes some of the results of these surveys.

DATA COLLECTION

Experimental Design

Since the concentration of many of the heavy metals and nutrients in the Spokane River are strongly influenced by river flow (Yake (1979)), the intent of the sampling program was to characterize water quality conditions during the following four hydrologic regimes:

1) spring run-off = rising limb of hydrograph
2) spring run-off = falling limb of hydrograph
3) summer low flow
4) fall/winter "first flush".

Operational constraints dictated that the surveys be done during the periods shown in Table 1. The relationship between the actual survey dates and the hydrograph of the Spokane River at Spokane is shown in Figure 2. Survey I (August 13-16, 1979) corresponded to summer low-flow, Survey II (April 1-3, 1980) was conducted about three weeks before optimum conditions characterizing the rising limb of the spring run-off hydrograph, Survey III (June 10-12, 1980) was conducted during the falling limb of the spring run-off hydrograph, and Survey IV (February 10-12, 1981) was about four weeks after the winter "first-flush".

Since the main purpose of the surveys was to determine the heavy metals and nutrient inventories of the river segment, sampling locations were located as closely together in space and time as resources permitted. The locations at which we obtained water samples from the Spokane River are shown in Figure 3. Our original intention was to obtain samples every three hours for at least a two-day period. We were able to do this during Survey I, but manpower limitations during the other surveys made it possible to collect samples at approximately equal intervals, four times daily during daylight hours, only.

Major point sources in the river segment were sampled on a daily basis, with at least one 24-hour composite taken from each source during the survey. There is considerable interchange between the Spokane River and the groundwater in this segment and we obtained daily grab samples from the City of Spokane's water supply well near Upriver Dam, in an attempt to characterize the contributions from the groundwater. The locations of these sampling sites are shown in Figure 3.

The water budget of the Spokane River in this river segment is complex because of the interchange between river and aquifer. The water budget is an important element in the mass budget. Since there are active U.S. Geological Survey (USGS) gaging stations only at the upstream and downstream boundaries of the segment, we established temporary gaging stations at two locations in the middle of the segment. The location of the USGS and EPA Region 10 gaging stations are shown in Figure 3.

Methods

Water samples collected from the river and point sources shown in Figure 3 were stored in polyurethane containers, packed in ice and shipped via air freight to Seattle. The EPA Region 10 Laboratory, the DOE Tumwater Environmental Laboratory, and a contract laboratory, Kramer, Chin, and Mayo, performed the chemical analyses as shown in Table 2.

Measurements of temperature and dissolved oxygen were made on-site with standard field equipment (Table 2).

Gaging measurements at the two EPA stations were done using a Gurley-type current meter suspended from a bridge crane. Vertical velocity profiles were taken at intervals of 10 feet, or less, from one side of the river to the other.

RESULTS

All of the receiving water data from the four surveys have been stored in EPA's STORET data system. Sample station codes are given in Table 3, and STORET codes for parameters measured during the study are given in Table 2.

Hydrology

Daily averaged flows from the USGS gaging stations near Post Falls (River Mile 100.7), near Otis Orchards (River Mile 93.9), and at Spokane (River Mile 72.9) and flows measured by EPA at Trent Road Bridge (River Mile 85.3) and Greene St. Bridge (River Mile 78.0) for the period of each survey are given in Table 4.

Receiving Water Quality

Average, maximum and minimum values of temperature, dissolved oxygen, nitrite & nitrate-nitrogem, total phosphorus, total cadmium, total copper, total iron, total lead, total mercury, and total zinc during each survey are shown in Figures 4 through 39.

Point Sources

Estimates of the average loadings of nitrite + nitrate-nitrogen, total phosphorus, total cadmium, total copper, total iron, total lead, total mercury, and total zinc from point sources in this segment of the Spokane River are shown in Tables 5 through 8.

ANALYSIS

The data were analyzed using three different methods of analysis.

1. A simple mass inventory was done for important nutrients and metals to characterize sources and sinks.

2. A steady-state mathematical model, based upon conservation of mass principles was used to simulate water quality conditions during summer low flow (Survey I).

3. The two-sample t-statistic, for samples with unequal variance, was used to compare concentrations at sample stations upstream from major groundwater and cultural influences with measurements collected at stations which might be influenced by these two factors.

Mass Inventory

The mass inventory was done for the following constituents:

nitrite + nitrate-nitrogen
total phosphorus
total cadmium
total copper
total iron
total lead
total mercury
total zinc

This inventory is an estimate of the mass entering the system at the Idaho - Washington border, the contribution from the four point sources, the contributions from the groundwater, and the estimate of the mass leaving the system at the Spokane gage, just upstream from the confluence of the Spokane River and Hangman Creek. The inventories were computed in the following way:

1. Spokane River @ Otis Orchards - The daily-averaged stream flow at USGS gaging stations 12419500, averaged over each survey period, was used with the average of water quality measurements made during the survey at the Stateline Bridge (EPA STORET station No. 03A019) to compute loadings.

2. Point Sources - Daily-average flow from gages operated by the specific discharger were used with water quality measurements made from a 24-hour composite sample to. Generally, there was no more than one such sample taken from each point source during a survey.

3. Groundwater - The difference in the average flows computed for the Spokane River @ Otis Orchards (see #1 above) and the average flows computed for the Spokane River @ Spokane (see #4 below) was used with the average of water quality measurements obtained from samples collected from the City of Spokane's water supply facility at Upriver Dam (EPA STORET stations no. 03Z009, 03Z010, and 03Z012).

4. Spokane River @ Spokane - The daily-averaged stream flow at USGS gaging station 12422500 averaged over each survey was used with the average of water quality measurements made during each survey at the same location (EPA STORET station no. 03A010)

The results for the four surveys are given in Tables 9 through 12, The estimated standard deviations of the loadings at the Spokane gage for each of the surveys is given in Table 13. The estimated standard deviations of loadings for the i^{th} constituent were computed from:

$$\sigma_Z^2 (i) = (5.39)^2 \left(\sigma_C^2 (i) \; \mu_Q^2 + \sigma_Q^2 \; \mu_C (i)\right)$$

where

5.39 = the factor to convert the product of flow (cfs) and concentration (mg/l to loading (lbs/day),

μ_Q = the mean flow,

μ_C (i) = the mean concentration of the i^{th} constituent, mg/l,

σ_Q = the standard deviation of the flow, cfs,

σ_C (i) = the standard deviation of the concentration of the i^{th} constituent, mg/l.

Means and standard deviations of concentrations were determined from water quality measurements made at the Spokane gage, as described in #4, above. The mean and standard deviation for the flow were computed from gage height data, obtained from the Spokane gage at approximately the same time as a water quality sample was collected.

Steady - State Mathematical Model

A steady-state mathematical model (Yearsley (1975)) was used to simulate the following parameters.

1. Temperature
2. Dissolved oxygen
3. NO_2 + NO_3 - nitrogen
4. Total phosphorus
5. Total copper
6. Total zinc

Data requirements for these water quality simulations included the following:

1. Hydrologic data
2. Meteorologic data
3. River geometry
4. Source quality and quantity
5. Background/initial river quality
6. Transformation rates for non-conservative constituents.

During Survey I (August 13-16, 1979). The quality and quantity of known sources are shown in Table 14. The data, except for carbonaceous biological oxygen demand and ammonia-nitrogen, were obtained from the measurements made during Survey I. Carbonaceous BOD and ammonia-nitrogen were not measured in the point sources during Survey I, so the average value of these parameters, determined from the other three surveys, was used instead. Groundwater quality was determined from measurements obtained from the City of Spokane's water supply, as described previously. Groundwater quantity (Table 15) was inferred from the gaging measurements by the U.S. Geological Survey at Otis Orchards and the Spokane gage and by EPA Region 10 at the Trent Road Bridge and the Greene St. Bridge. Flow Values between these points were obtained by linear extrapolation, rather than by using the results of the USGS groundwater model, as URS (1981) did. The USGS in Spokane provided flow data for the gages at Spokane and near Otis Orchards, Washington, while the USGS in Sandpoint, Idaho provided flow data from the gage near Post Falls, Idaho. These data were used in conjunction with the flow measurements made by EPA Region 10 at the Trent Road Bridge (R.M. 85.4) and Greene St. Bridge (R.M. 78.0) to estimate the groundwater flow (Table 15).

In order to simulate water temperatures, it is necessary to define the heat budget at the air-water interface (Wunderlich (1968)), WRE (1968), Yearsley (1969, 1975), (Roesner et al (1977)). Minimum data requirements for the mathematical model used in this study are air temperature, dew point, wind speed, and cloud cover. Average values of these parameters during the period August 13-16, 1979, were computed from measurements made every three hours at the Spokane International Airport and reported by the National Oceanic and Atmospheric Administration. These average values, given in Table 16, were used to compute the average equilibrium temperature and rate of heat transfer for the Spokane River, during the period of the survey. The results are given in Table 16.

Selected gaging data, from measurements made by the USGS in Spokane at the stations near Otis Orchards, below Greene Street, and at Spokane, provided the basis for relating velocity and depth to flow according to the relationship.

$$U = A_1 Q^{B_1}$$

$$D = A_2 Q^{B_2}$$

Where

U = the river velocity, feet per second,

D = the river depth, feet,

Q = the river flow, cubic feet per second

A_1, A_2, B_1, B_2 = emperical coefficients determined by least squares from gaging data.

The resulting coefficients, and the segment of the river for which it is assumed that the coefficients remain constant are given in Table 17.

The results of measurements made during Survey I at four point sources (Table 6) and at the City of Spokane's water supply system at Upriver Dam were used to characterize the quality and quantity of the contributions from known sources. For those constituents which were not measured during Survey I, average values from the three other surveys were used as estimates or in the case of the groundwater, typical measurements from nearby observation wells, collected for other studies, were assumed to be reasonable estimates. Measurements included in this category, for all sources, were BOD and ammonia-nitrogen, and for the groundwater, temperature and dissolved oxygen. Average values of the constituents, calcuated from data collected near Port Falls (R.M. 100.7), were used to characterize the initial, or background, water quality for the simulation. The results are given in Table 14.

Non-conservative constituents simulated in this analysis were temperature, dissolved oxygen, BOD, ammonia-nitrogen, and nitrite + nitrate-nitrogen. The transformation rate for temperature was determined from the energy budget, as described previously. The reaeration rate for the dissolved oxygen was computed from the formulation developed by Churchill et al (1962). The BOD rate constant was assumed to be constant throughout the river segment and similar in magnitude to rate constants for BOD in the Spokane River upstream from Post Falls (Yearsley (1980)). The nitrification rate, or rate of conversion of ammonia-nitrogen to nitrite + nitrate-nitrogen, was estimated from the range of values given by Zison et al (1978). All transformation rates are given in Table 18.

The results of the simulations for temperature, dissolved oxygen, nitrite + nitrate-nitrogen, total phosphorus, total copper, and total zinc are compared with the field measurements from Survey I in Figures 40 through 46

Two-Sample t-Test

The two-sample t-test, when the population variances are not assumed to be equal, is based upon the statistic (See Engelman et al (1979)):

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}}$$

where,

X = the sample mean,
S = the standard deviation,
N = the sample size

Population 1 included all receiving water measurements from the Sullivan Road Bridge (EPA STORET station 03A016) upstream to Post Falls (EPA STORET station 03A021). Population 2 included all those measurements made downstream from the Sullivan Road Bridge. The rationale for choosing this division point was based upon the *a priori* knowledge that, major point source and groundwater influences occur downstream from the Sullivan Road Bridge. The null hypothesis for the test is then, despite the influence of groundwater and point source discharges downstream, the mean values of the concentration of those constituants measured during each of the surveys are the same downstream from the Sullivan Road Bridge as it is upstream. The t-statistics and levels of significance for a two-sided test are given for the various constituents during each survey in Table 20.

DISCUSSION

The interpretation of results from geophysical experiments is always frustrated by the way in which the data fails to satisfy our simple models. The Spokane River, in the segment which have studied here, is no exception. There are, however, some salient features which merit discussion.

Mass Inventory

First of all, it is plain from the mass inventory (Table 10 through 13) that the groundwater is a major source for nitrate-nitrogen. The inventory also shows that upstream sources provide major contributions to the heavy metals loading. This is not surprising, given what we know about metals processing on the South Fork of the Coeur d'Alene River. It is important to note, though, that the inventory shows that the Spokane Industrial Park and the groundwater are important sources of copper.

One of the major purposes of the study, of course, was to determine the magnitude of unknown sources and sinks. The rather large standard deviations of loadings at the Spokane gage make it difficult to infer how much of the difference between systems gains and loss can be attributed to unknown sources.

In the case of phosphorus, the data support the argument that there is more material entering the system than there is leaving during low flow (Table 9) and that the converse is true during high flow (Table 11). During those surveys for which the flow was near the annual average discharge of 6870 cfs at the Spokane gage the amount of material entering was within the accuracy of the estimate, very nearly the same as that leaving (Tables 10 and 12).

The mass inventories for the metals, with some exceptions, support the hypothesis that there is deposition at low flow, scouring at high flow, and no net gain or loss during average flows. The data for total zinc support this hypothesis for the low flow condition (Table 10) and for the average conditions (Tables 11 and 12), but not for the high flow condition (Table 13). The total iron data support the hypothesis during the average conditions and high flow but not the low flow.

A possible explanation for the failure of the total iron data to support the hypothesis during low flow is that the groundwater constitutes an important source of iron when the river flow is low. The uncertainty associated with the estimates for the groundwater loadings are substantial and, therefore, particularly important at low flow. The total copper data are in agreement with the conceptual model inferred from the phosphorus data, though the anomalously high loading of total copper attributed to groundwater during the low flow (Table 10) is suspect. Other data from nearby wells suggests that the groundwater loading should be an order of magnitude less than the estimate given in Table 10. The lower value, however, would not change the conclusion regarding the net gain, or loss of material. Total cadmium and mercury concentrations are too near the detection limit of the measurement technique to provide useful measures. Total lead does not support the hypothesis, but it well may be that there are non-point sources for lead within the segment we studied, that we have not included in the mass inventory. Nitrate-nitrogen has been excluded from these arguments, because it is influenced so greatly by the groundwater. The uncertainty of the nitrate loadings from the groundwater, due to our lack of precise knowledge of the location and magnitude of groundwater return, make it very difficult to defend conclusions about small differences between large numbers.

Mathematical Modeling

The results of the simulation reaffirm the conclusion reached in the previous section (Mass Inventory) that the groundwater has a major impact upon the levels of nitrite + nitrate-nitrogen. Furthermore, the modeling results provide some insights into the impact that the groundwater has upon temperature at low flow. This impact is demonstrated in Figure 46 where the simulation results obtained above are compared to simulations obtained when the temperature of the groundwater is assumed to be equal to the equilibrium temperature (Table 16) . For the conservative constituents, total phosphorus, total copper, and total zinc, the descrepancies between simulated and observed are a reflection of the imprecision of our knowledge of groundwater quality and quantity, as well as our inability to describe potentially important material sinks.

The mean and standard deviation of the difference between simulated and average observed values are given in Table 19.

Two-Sample t-test

The results of the two-sample t-test, where the means of all observation at, and below the Trent Road Bridge are compared with the observations upstream, are given in Table 20. Table 20 contains the t-statistic determined from Equation (2) and the level of significance, p, which is the probability of rejecting the null hypothesis when it is, in fact, true. The level of significance given is for a two-tailed test.

The most striking result, of course, is that upstream nitrite + nitrate-nitrogen is, for all surveys, significantly different from downstream nitrite + nitrate-nitrogen. This is not surprising, in view of the results of the previous analyses. The consistent sign of the t-statistic, as well as its magnitude, provide a posteriori support for the conclusion that nitrite + nitrate-nitrogen is significantly higher at the locations affected by the groundwater and point sources than are those locations which are upstream from such influences. The t-statistic also suggest, a posteriori, that there is a total copper and somewhat less convincingly, a total lead increase in the segment of the river downstream from Trent Road Bridge. Another experiment of this type would have to be performed to establish this in a rigorous fashion.

With regard to the question of whether or not there is a loss of total phosphorus in this segment, the t-statistic supports, a posteriori, the argument proposed earlier, that there is loss of total phosphorus during low flow, a gain during high flow and no significant difference during average flow. Here again a rigorous application of the two-sample t-test would require that the experiment be done again and a one-tailed test performed

CONCLUSIONS

With respect to most of the constituents measured during the four surveys, the uncertainties associated with the estimates of average loadings make it difficult to satisfy the initial objectives of the studies. Those objectives were the identification of all sources and sinks for nutrients and metals in the segment of the Spokane River between Post Falls, Idaho and the confluence of the Spokane River and Hangman Creek. However, the data do provide support for the conclusion that there is deposition of phosphorus during low flow, removal of the deposited phosphorus during high flow, and a condition of equilibrium in which there is neither net deposition nor net removal during average flow. The mass inventories for the other constituents we analyzed provide additional, but not entirely consistent, support for this conclusion. Furthermore, the strength of this support is diluted by the fact that in some cases the standard deviation of the loading at the Spokane gage are larger than the estimated difference between material entering the system and that leaving the system.

The mass inventories do show the importance of the groundwater contribution to the nitrite + nitrate-nitrogen load of the Spokane River. However, there is little to be gained in discussing the magnitude of the differences between the amount of nitrate + nitrate-nitrogen entering and leaving the system due to the nature of the loading uncertainty.

(The mass inventories suggest that the groundwater and the Spokane Industrial Park are significant sources of copper.)

The results of the mathematical modeling show that the groundwater lowers the average river temperature as much as 4.6° C during the summer low flow, but lowers the average dissolved oxygen less than 0.2° mg/l. The minimal impact upon dissolved oxygen is due to the fact that the groundwater also lowers the river temperature. This, in turn, raises the saturation level for dissolved oxygen compared to that which would obtain if the river were near the equilibrium temperature thereby increasing the rate at which oxygen is transferred across the air-water interface.

A posteriori arguments, using the two-sample t-statistic provide qualitative support for the conclusions described above. In addition, the t-test suggests that the concentration of total lead in the Spokane River increases between Post Falls and the confluence with Hangman Creek. A rigorous demonstration of these conclusions, using the t-test, requires that a new experiment be performed using a one-tailed test.

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TABLE-1

DATES DURING WHICH EPA REGION 10 CONDUCTED
INTENSIVE WATER QUALITY SURVEYS ON THE SPOKANE RIVER

SURVEY	DATES
I	August 14-16, 1979
II	April 1-3, 1980
III	June 10-12, 1980
IV	February 10-12, 1981

TABLE 2

STORET PARAMETERS NUMBERS AND MEASUREMENTS METHODS USED DURING FOUR INTENSIVE SURVEYS ON THE SPOKANE RIVER. METHODS USED BY THE CONTRACT LABORATORY, KRAMER, CHINS, AND MAYO ARE LABELLED (KCM)

Parameter	STORET Parameter No.	Method	Reference*
		Mercury Thermometer	SM
Water Temperature	10	Thermistor	SM
Dissolved Oxygen	300	Modified Winkler	SM
		Auto Analyzer II	EPA
$NH_3 + NH_4$ - Nitrogen	610	Distillation - Nessler (KCM)	EPA
NO_2 - Nitrogen	615	Diazatization (KCM)	SM
NO_3 - Nitrogen	620	Brucine (KCM)	SM
		Block Digestion-Auto Analyzer II	EPA
Total Kjeldahl Nitrogen	625	Digestion-Distillation-Nestler (KCM)	EPA
$NO_2 + NO_3$ - Nitrogen	630	Auto Analyzer II	EPA
		Persulfate Digestion Ascorbic Acid (KCM)	SM
Total Phosphorus	665	Ammonia Persulfate Digestion	EPA
Dissolved Phosphorus	666	Ammonia Persulfate Digestion	EPA
		Persulfate Digestion/Ascorbic Acid (KCM)	SM
Dissolved Orthophosphorus	671	Auto Analyzer II	EPA
Total Organic Carbon	680	Dow-Beckman Analyzer No. 915	EPA
Dissolved Cadmium	1025	Atomic Absorption - Flameless	EPA
Total Cadmium	1027	" " "	"
Dissolved Copper	1040	" " "	"
Total Copper	1042	" " "	"
Total Iron	1045	" " "	"
Dissolved Iron	1046	" " "	"
Dissolved Lead	1049	" " "	"
Total Lead	1051	" " "	"
Dissolved Zinc	1090	" " "	"
Total Zinc	1092	" " "	"
Dissolved Mercury	71890	" " "	"
Total Mercury	71891	" " "	"

* SM - American Public Health Association, 1975. Standard Methods for the Examination of Water and Wastewater, 14th Edition. APHA, Washington, D.C.

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TABLE 3

STORET CODES FOR RECEIVING WATER AND POINT SOURCE SAMPLING STATION LOCATIONS DURING FOUR INTENSIVE SURVEYS OF THE SPOKANE RIVER (THE STORET IDENTIFICATION NUMBER FOR ALL OF THESE SAMPLING STATIONS IS 10EPAINT)

NAME	RIVER MILE	STORET CODE
Inland Empire Paper Co.	--	03#001
Kaiser Aluminum Co.	--	03#002
Spokane Industrial Park	--	03#003
Millwood Sewage Treatment Plant	--	03#004
Spokane Water Works (Pump #5)	--	03Z009
City of Spokane Waterworks Well #2	--	03Z010
Spokane Waterworks	--	03Z012
Spokane River at Spokane	73.4	03A010
Spokane River above Washington Street Bridge	74.5	03A011
Spokane River at Mission Street Bridge	76.8	03A012
Spokane River below Spokane City Dam	79.5	03A013
Spokane River at Argonne Street Bridge	82.6	03A014
Spokane River at Trent Road Bridge	85.3	03A015
Spokane River at Sullivan Road Bridge	87.8	03A016
Spokane River at Barker Road Bridge	90.4	03A017
Spokane River at Harvard Road Bridge	92.7	03A018
Spokane River at State Line Bridge	96.5	03A019
Spokane River below Post Falls	100.7	03A021

TABLE 4

DAILY-AVERAGED FLOWS REPORTED BY THE USGS AND SPOT MEASUREMENTS MADE BY EPA REGION 10 AT VARIOUS LOCATIONS IN THE SPOKANE RIVER DURING FOUR INTENSIVE SURVEYS

Date	Flow in the Spokane River (cfs)				
	below Post Falls (USGS)	At Otis Orchards (USGS)	at Trent Rd* (EPA)	at Greene St* (EPA)	at Spokane (USGS)
8/14/79	622	625	673(1730-1900)	-------	1010
8/15/79	622	611	654(1020-1120) 666(1545-1640)	849(0745-0920) 862(1325-1450)	969
8/16/79	628	625	701(0750-0850)	929(0920-1040)	987
4/01/80		4550	4214(0830-1000) 5160(1420-1545)	4985(1030-1210)	4760
4/02/80		4850	5114(1110-1310)	5300(0815-1010) 5280(1445-1600)	5090
4/03/80		4810			5050
6/10/80		8120	-------	-------	8360
6/11/80		8150	-------	-------	8400
6/12/80		7770	-------	-------	8060
2/10/81		6300	-------	6620(0815-0915)	6550
2/11/81		6220	-------	6648(1000-1115)	6510
2/12/81		5900	-------	-------	6310

* Times at which spot measurements were made are in parentheses.

TABLE 5

ESTIMATES OF POINT SOURCE LOADINGS FOR VARIOUS WATER QUALITY CONSTITUENTS IN THE SPOKANE RIVER DURING SURVEY I (AUGUST 14-16, 1979)

	Spokane Industrial Park			Kaiser Aluminum Co.			Inland Empire Paper Co.			Millwood STP		
	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)	Flow (cfs)	Conc.[1] (mg/l)	Load (lbs/day)	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)
NO2+NO3-N	0.93	5.20	26.1	38.4	0.01	2.1	3.4	0.26	4.8	0.05	14.0	3.8
Total P	0.93	2.50	12.5	38.4	<0.01	-	3.4	<0.01	-	0.05	4.9	1.3
Total Cd	0.93	0.004	0.01	38.4	0.0001	0.01	3.4	<0.01	-	0.05	<0.001	-
Total Cu	0.93	3.50	17.5	38.4	0.004	1.5	3.4	0.005	0.092	0.05	0.012	0.003
Total Fe	0.93	-	-	38.4	0.01	-	3.4	0.25	4.6	0.05	0.50	0.1
Total Pb	0.93	0.073	0.37	38.4	< .01	-	3.4	<0.001	-	0.05	0.006	0.001
Total Hg[2]	0.93	1.0	0.005	38.4	1.0	0.001	3.4	0.2	0.004	0.05	0.4	0.001
Total Zn	0.93	-	-	38.4	<0.01	-	3.4	0.030	0.6	0.05	0.170	0.1

[1]Estimated net change in concentration computed as the difference between the effluent(24-hour composite) and influent(quality of the Spokane River at R.M. 86.1).

[2]Total Hg is reported in ug/l

TABLE 6

ESTIMATES OF POINT SOURCE LOADINGS
FOR VARIOUS WATER QUALITY CONSTITUENTS
IN THE SPOKANE RIVER DURING SURVEY II
(APRIL 1-3, 1980)

	Spokane Industrial Park			Kaiser Aluminum Co.			Inland Empire Paper Co.			Millwood STP		
	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)	Flow (cfs)	Conc.[1] (mg/l)	Load (lbs/day)	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)
NO2+NO3-N	0.95	1.40	7.2	41.2	0.04	8.9	3.33	<0.05	-		NOT IN OPERATION	
Total P	0.95	1.60	8.2	41.2	0.06	13.3	3.33	0.43	7.7			
Total Cd	0.95	<0.01	-	41.2	<0.01	-	3.33	<0.01	-			
Total Cu	0.95	2.20	11.3	41.2	<0.01	-	3.33	0.01	0.2			
Total Fe	0.95	0.15	0.8	41.2	-	-	3.33	0.11	2.0			
Total Pb	0.95	0.20	1.0	41.2	0.05	-	3.33	<0.05	-			
Total Hg[2]	0.95	0.33	1.69	41.2	<0.01	-	3.33	0.20	-			
Total Zn	0.95	0.14	0.72	41.2	-	-	3.33	0.02	-			

[1]Estimated net change in concentration computed as the difference between the effluent(24-hour composite) and influent(quality of the Spokane River at R.M. 86.1).

[2]Total Hg is reported in ug/l

TABLE 7

ESTIMATES OF POINT SOURCE LOADINGS
FOR VARIOUS WATER QUALITY CONTITUENTS
IN THE SPOKANE RIVER DURING SURVEY III
JUNE 10-12, 1980

	Spokane Industrial Park			Kaiser Aluminum Co.			Inland Empire Paper Co.			Millwood STP		
	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)	Flow (cfs)	Conc.[1] (mg/l)	Load (lbs/day)	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)
NO2+NO3-N	1.07	4.10	23.6	42.3	0.04	9.1	3.39	0.1	-	0.031	3.4	0.6
Total P	1.07	2.90	16.7	42.3	0.03	6.8	3.39	0.80	14.6	0.031	16.0	2.7
Total Cd	1.07	<0.01	-	42.3	<0.01	-	3.39	<0.01	-	0.031	<0.01	-
Total Cu	1.07	3.10	17.9	42.3	<0.01	-	3.39	0.03	0.55	0.031	0.55	-
Total Fe	1.07	0.98	5.65	42.3	0.01	0.2	3.39	0.25	4.57	0.031	10.5	1.75
Total Pb	1.07	0.17	0.98	42.3	0.05	-	3.39	0.05	-	0.031	0.1	0.017
Total Hg[2]	1.07	-	-	42.3	-	-	3.39	-	-	0.031	-	-
Total Zn	1.07	0.20	1.15	42.3	-	-	3.39	0.02	0.37	0.031	1.2	0.2

[1]Estimated net change in concentration computed as the difference between the effluent(24-hour composite) and influent(quality of the Spokane River at R.M. 86.1).

[2]Total Hg is reported in ug/l

TABLE 8

ESTIMATES OF POINT SOURCE LOADINGS FOR VARIOUS WATER QUALITY CONSTITUENTS IN THE SPOKANE RIVER DURING SURVEY IV FEBRUARY 10-12, 1981

	Spokane Industrial Park			Kaiser Aluminum Co.			Inland Empire Paper Co.			Millwood STP		
	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)	Flow (cfs)	Conc.[1] (mg/l)	Load (lbs/day)	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)	Flow (cfs)	Conc. (mg/l)	Load (lbs/day)
NO2+NO3-N	1.21	2.0	13.0	40.8	0.05	11.0	3.72	<0.1	-	0.06	10.0	3.23
Total P	1.21	3.7	24.1	40.8	0.07	15.4	3.72	0.75	15.0	0.06	2.8	0.91
Total Cd	1.21	<0.01	-	40.8	<0.01	-	3.72	<0.01	-	0.06	<0.01	-
Total Cu	1.21	2.7	17.6	40.8	0.008	1.76	3.72	0.08	1.60	0.06	0.04	0.013
Total Fe	1.21	0.46	3.00	40.8	0.01	-	3.72	0.13	2.61	0.06	0.32	0.10
Total Pb	1.21	1.00	6.52	40.8	<0.01	-	3.72	<0.07	-	0.06	<0.07	-
Total Hg[2]	1.21	0.72	0.0047	40.8	0.08	0.02	3.72	0.24	0.0048	0.06	0.6	0.0002
Total Zn	1.21	0.82	5.35	40.8	<0.01	-	3.72	<0.01	-	0.06	0.12	0.04

[1]Estimated net change in concentration computed as the difference between the effluent(24-hour composite) and influent(quality of the Spokane River at R.M. 86.1).

[2]Total Hg is reported in ug/l.

TABLE 9

MASS INVENTORY FOR CERTAIN NUTRIENTS AND HEAVY METALS IN THE SPOKANE RIVER DURING THE PERIOD AUGUST 14-16, 1979

	System Gains							System Losses	
	Spokane @Otis Orchards (lbs/day)	Inland Empire Paper Co. (lbs/day)	Millwood STP (lbs/day)	Kaiser Aluminum (lbs/day)	Spokane Industrial Park (lbs/day)	Ground-water (lbs/day)	Total (lbs/day)	Spokane River Spokane (lbs/day)	Gains Less Losses (lbs/day)
NO2+NO3-N	33	5	4	2	26	2374	2444	2766	-322
Total P	110	-	1	-	13	6	130	69	61
Total Cd	1.1	-	-	-	-	0.2	1.3	1.6	-0.3
Total Cu	5.0	0.1	-	1.5	17.5	158.0	182.1	17.3	164.8
Total Fe	177	5	-	-	-	99	281	372	-89
Total Pb	24.0	-	-	-	0.4	9.9	34.3	43.0	-8.7
Total Hg	1.0	-	-	-	-	0.4	1.4	0.8	0.6
Total Zn	256	1	-	-	-		257	185	72

TABLE 10

MASS INVENTORY FOR CERTAIN NUTRIENTS AND HEAVY METALS
IN THE SPOKANE RIVER DURING THE PERIOD
APRIL 1-3, 1980

	System Gains							System Losses	
	Spokane @Otis Orchards (lbs/day)	Inland Empire Paper Co. (lbs/day)	Millwood STP (lbs/day)	Kaiser Aluminum (lbs/day)	Spokane Industrial Park (lbs/day)	Ground-water (lbs/day)	Total (lbs/day)	Spokane River Spokane (lbs/day)	Gains Less Losses (lbs/day)
NO2+NO3-N	935	-	-	9	7	2060	3011	3657	-646
Total P	753	8	-	13	8	15	797	791	6
Total Cd	31.9	-	-	-	-	-	31.9	31.4	0.5
otal Cu	103.8	0.2	-	-	11.3	19.1	134.4	139.7	-5.3
Total Fe	1454	2	-	-	1	73	1530	1515	15
Total Pb	174.2	-	-	-	1.0	22.1	197.3	218.3	-21.0
Total Hg	8.1	-	-	-	1.7	0.7	10.5	12.6	-2.1
Total Zn	4749	-	-	-	1	162	4912	5117	-205

TABLE 11

MASS INVENTORY FOR CERTAIN NUTRIENTS AND HEAVY METALS
IN THE SPOKANE RIVER DURING THE PERIOD JUNE 10-12, 1980

	System Gains							System Losses	
	Spokane @Otis Orchards (lbs/day)	Inland Empire Paper Co. (lbs/day)	Millwood STP (lbs/day)	Kaiser Aluminum (lbs/day)	Spokane Industrial Park (lbs/day)	Ground-water (lbs/day)	Total (lbs/day)	Spokane River Spokane (lbs/day)	Gains Less Losses (lbs/day)
NO2+NO3-N	907	-	33	9	24	1457	2430	2096	334
Total P	1166	15	9	7	17	112	1326	2898	-1572
Total Cd	4.0	-	-	-	-	-	4.0	38.7	-34.7
Total Cu	185.3	0.6	-	-	17.9	4.5	208.3	654.2	-445.9
Total Fe	3611	5	2	-	6	-	3624	4050	-426
Total Pb	178.8	-	-	-	1.0	8.4	188.2	245.2	-57.0
Total Hg	18.0	-	-	-	-	1.0	19.0	28.0	-9.0
Total Zn	7213	-	-	-	1	3	7217	7059	158

TABLE 12

MASS INVENTORY FOR CERTAIN NUTRIENTS AND HEAVY METALS
IN THE SPOKANE RIVER DURING THE PERIOD FEBRUARY 10-12, 1981

	System Gains							System Losses	
	Spokane @Otis Orchards (lbs/day)	Inland Empire Paper Co. (lbs/day)	Millwood STP (lbs/day)	Kaiser Aluminum (lbs/day)	Spokane Industrial Park (lbs/day)	Ground-water (lbs/day)	Total (lbs/day)	Spokane River Spokane (lbs/day)	Gains Less Losses (lbs/day)
NO2+NO3-N	2720	-	3	11	13	2648	5395	5012	383
Total P	589	15	1	15	24	-	644	609	35
Total Cd	34.6	-	-	-	-	-	34.6	37.0	-2.4
Total Cu	91.9	1.6	-	1.8	17.6	11.6	124.5	100.2	24.3
Total Fe	7906	3	-	-	3	34	7946	6960	986
Total Pb	481.9	-	-	-	6.5	5.5	493.9	474.2	19.7
Total Hg	5.5	-	-	-	-	-	5.5	5.9	-0.4
Total Zn	6728	-	-	-	5	7	6740	6960	-220

TABLE 13

STANDARD DEVIATIONS ASSOCIATED WITH THE MEAN LOADINGS OF CERTAIN NUTRIENTS AND METALS AT THE SPOKANE GAGE DURING FOUR INTENSIVE SURVEYS OF THE SPOKANE RIVER

Parameter	Standard Deviation, Survey I (lbs/day)	Survey II (lbs/day)	Survey III (lbs/day)	Survey IV (lbs/day)
NO2+NO3-N	527	865	781	896
Total P	32	561	1420	172
Total Cd	0.84	3.7	4.7	2.8
Total Cu	0.10	57.7	377.	38.5
Total Fe	167	322	1310	769
Total Pb	34.6	106.	181.	72.1
Total Hg	0.73	6.0	6.0	0.53
Total Zu	70	440	680	506

TABLE 14

POINT SOURCE QUALITY AND QUANTITY USED TO SIMULATE WATER QUALITY CONDITIONS IN THE SPOKANE RIVER DURING SURVEY I (AUGUST 14-16, 1979)

Source	Flow (cfs)	DO (mg/l)	BOD_5 (mg/l)	NH3-N Nitrogen (mg/l)	NO2+NO3-N Nitrogen (mg/l)	PO4-P Phosphorus (mg/l)	Temperature (oC)	Copper (ug/l)	Zinc (ug/l)
Spokane River Below Post Falls	624.	7.7	0.5	0.014	0.010	0.013	21.9	8	10
Spokane Industrial Park	0.94	7.8	24.5	2.4	5.2	2.5	18.0	3500	180
Kaiser[1] Aluminum Co.	38.4	8.3	5.2	5.0	0.32	0.02	22.5	9	55
Inland Empire Paper Co.	3.4	2.7	267.	0.8	0.26	0.01	24.1	5	20
Millwood STP	0.05	2.6	734.	0.08	14.0	4.9	18.1	65	210

[1]Kaiser Aluminum diverts an equivalent volume of water from the Spokane River at R.M. 86.1. This diversion is made with the water quality predicted by the model at that location.

TABLE 15

GROUNDWATER QUALITY AND QUANTITY USED TO SIMULATE WATER QUALITY CONDITIONS IN THE SPOKANE RIVER DURING SURVEY I (AUGUST 14-16, 1979)

River Segment (River Mile)	Flow (cfs)	DO	BOD_5	NH_3-Nitrogen	$NO_2 + NO_3$-Nitrogen	PO_4-Phosphorus	Temperature	Copper	Zinc
102.2 - 87.0	50.0	6.0	0.0	0.01	1.4	0.01	9.5	8	10
87.0 - 84.0	68.7	6.0	0.0	0.01	1.4	0.01	9.5	8	10
84.0 - 79.8	96.1	6.0	0.0	0.01	1.4	0.01	9.	8	10
79.8 - 78.0	41.2	6.0	0.0	0.01	1.4	0.01	9.7	8	10
78.0 - 74.0	109.0	6.0	0.0	0.01	1.4	0.01	9.7	8	10

..BLE 16

AVERAGE AIR TEMPERATURE, DEW POINT, WIND SPEED AND SKY COVER USED TO SIMULATE ENERGY BUDGET FOR THE SPOKANE RIVER DURING SURVEY I (AUGUST 14-16, 1979) AND COMPUTED VALUE OF EQUILIBRIUM TEMPERATURE AND THERMAT TRANSFER RATE

Parameter	Units	Value
Air Temperature	(° C)	19.1
Dew Point	(° C)	10.9
Wind Speed	(Meters/sec)	4.12
Sky Cover	(Tenths)	7.1
Equilibrium Temeperature	(° C)	20.3
Thermal Transfer Rate	(Meters/sec)	6.35×10^{-6}

TABLE 17

COEFFICIENTS RELATING DEPTH, D, AND VELOCITY, U, TO FLOW, Q

Segment	$D = A_1 Q^{B_1}$		$U = A_2 Q^{B_2}$	
River Mile	A_1	B_1	A_2	B_2
102.2 - 87.0	0.36393	0.33610	2.6057×10^{-2}	0.54811
87.0 - 84.0	0.36393	0.33610	2.6057×10^{-2}	0.54811
84.0 - 79.8	0.36393	0.33610	2.6057×10^{-2}	0.54811
79.8 - 78.0	7.21596	3.1041×10^{-2}	2.9779×10^{-2}	0.79956
78.0 - 74.0	7.21576	3.1041×10^{-2}	2.9779×10^{-2}	0.79956

TABLE 18

CONSTITUENT TRANSFORMATION RATES, AT 20°C, FOR DISSOLVED OXYGEN, CARBONACEOUS BOD, AND AMMONIA-NITROGEN USED TO SIMULATE WATER QUALITY CONDITIONS DURING SURVEY I (AUGUST 14-16, 1979)

Segment River Mile	Reaeration Rate (days^{-1})	Deoxygenation Rate (days^{-1})	Nitrification Rate (days^{-1})
102.2 - 87.0	1.50	0.10	0.20
87.0 - 84.0	1.49	0.10	0.20
84.0 - 79.8	1.49	0.10	0.20
79.8 - 78.0	0.20	0.10	0.20
78.0 - 74.0	0.21	0.10	0.20

TABLE 19

MEAN DIFFERENCE AND STANDARD DEVIATION OF DIFFERENCE BETWEEN SIMULATED AND MEAN OBSERVED VALUES OF CERTAIN WATER QUALITY CONSTITUENTS DURING SURVEY I (AUGUST 14-16, 1979)

Constituent	Mean Difference	Standard Deviation of Difference	Units
Temperature	-0.74	1.04	°C
DO	0.44	0.39	mg/l
Nitrite + Nitrate-Nitrogen	-0.022	0.089	mg/l
Total Phosphorus	-0.006	0.005	mg/l
Total Copper	-2.05	1.98	µg/l
Total Zinc	-7.28	9.39	µg/l

TABLE 20

TWO-SAMPLE T-TEST STATISTICS AND
LEVEL OF SIGNIFIGANCE FOR SPOKANE RIVER

	SURVEY I		SURVEY II		SURVEY III		SURVEY IV	
	t	P	t	P	t	P	t	P
$NO_2 + NO_3$-N	47.05	0.000	15.14	0.000	3.72	0.000	11.95	0.000
Total P	-14.00	0.000	1.03	0.307	3.65	0.001	-0.48	0.632
Total C_D	-3.56	0.001	-1.60	0.118	-1.67	0.100	-0.77	0.443
Total C_U	8.41	0.000	3.20	0.002	4.57	0.000	2.83	0.006
Total F_E	4.44	0.000	-1.51	0.134	3.34	0.002	-3.84	0.000
Total P_B	1.53	0.128	2.44	0.018	2.45	0.017	-1.78	0.079
Total H_G	-3.99	0.000	2.28	0.027	6.88	0.000	0.34	0.735
Total Z_N	-14.44	0.000	1.98	0.051	-2.92	0.005	-0.12	0.901
Temperature	-32.14	0.000	3.35	0.001	-2.45	0.020	--	--

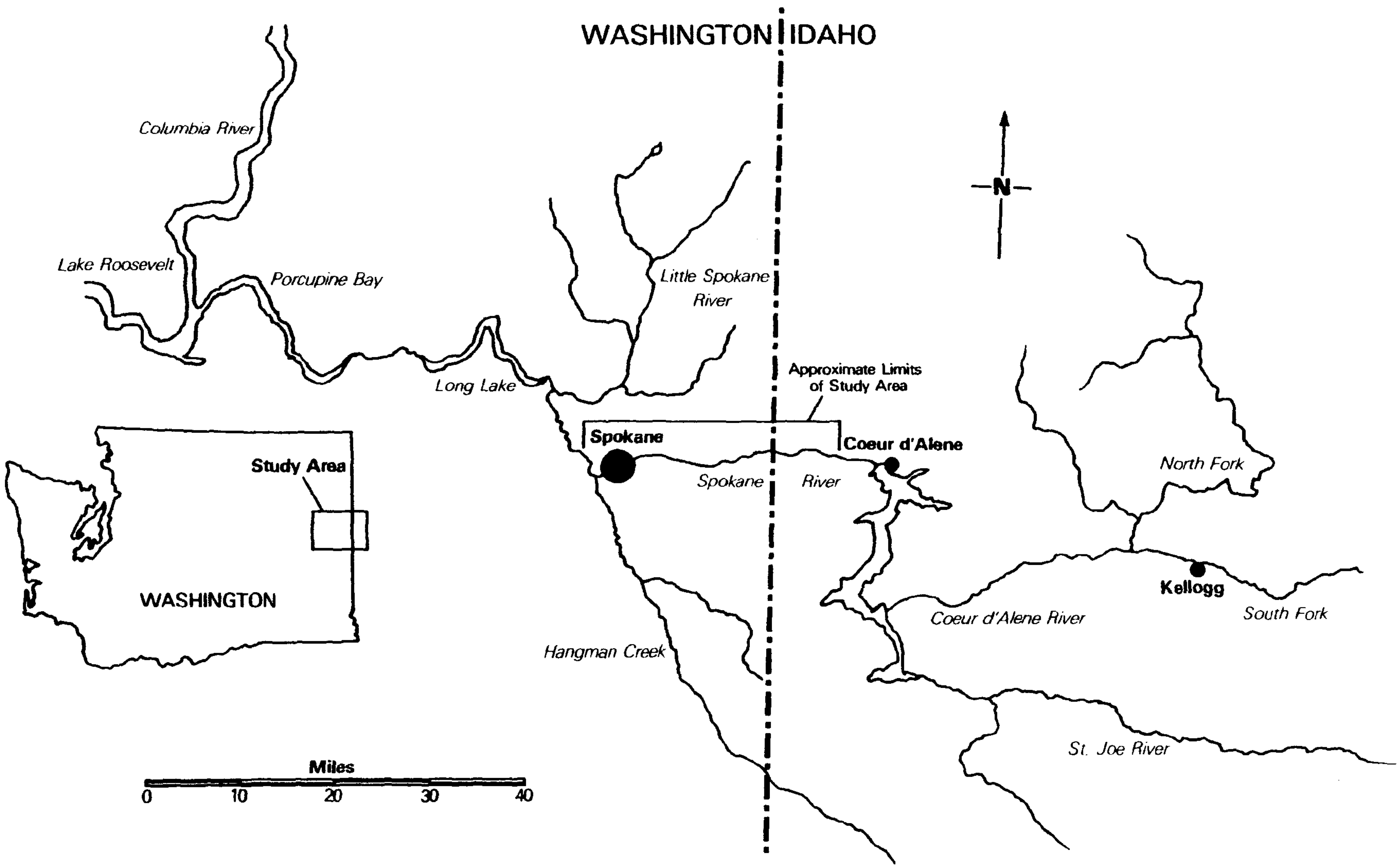
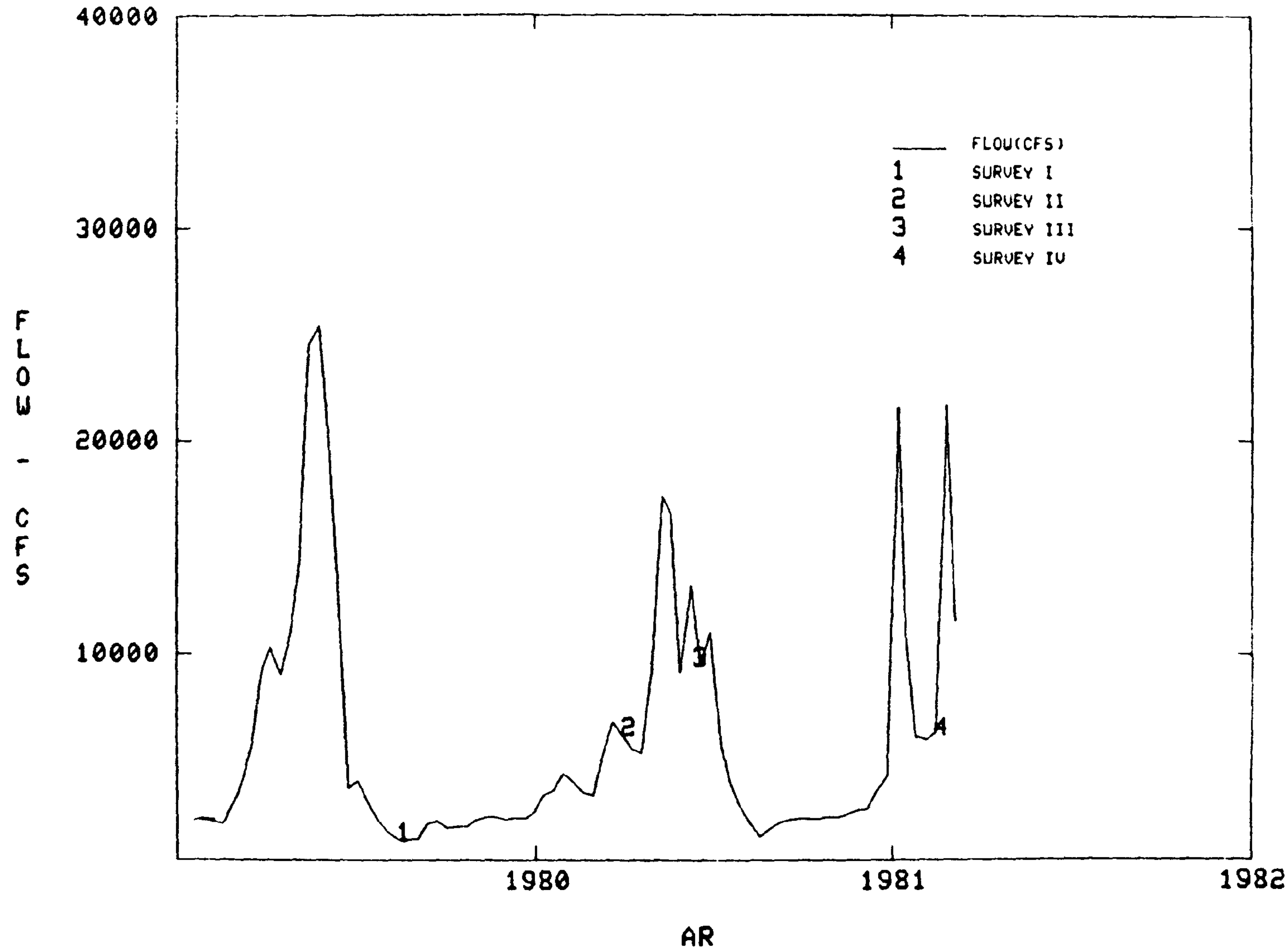


Figure 1. **Spokane River Basin**

FIGURE 2 . TEN-DAY AVERAGE FLOW IN THE SPOKANE RIVER AT THE SPOKANE GAGE DURING 1979-1981. EPA/DOE SURVEY DATES NOTED.



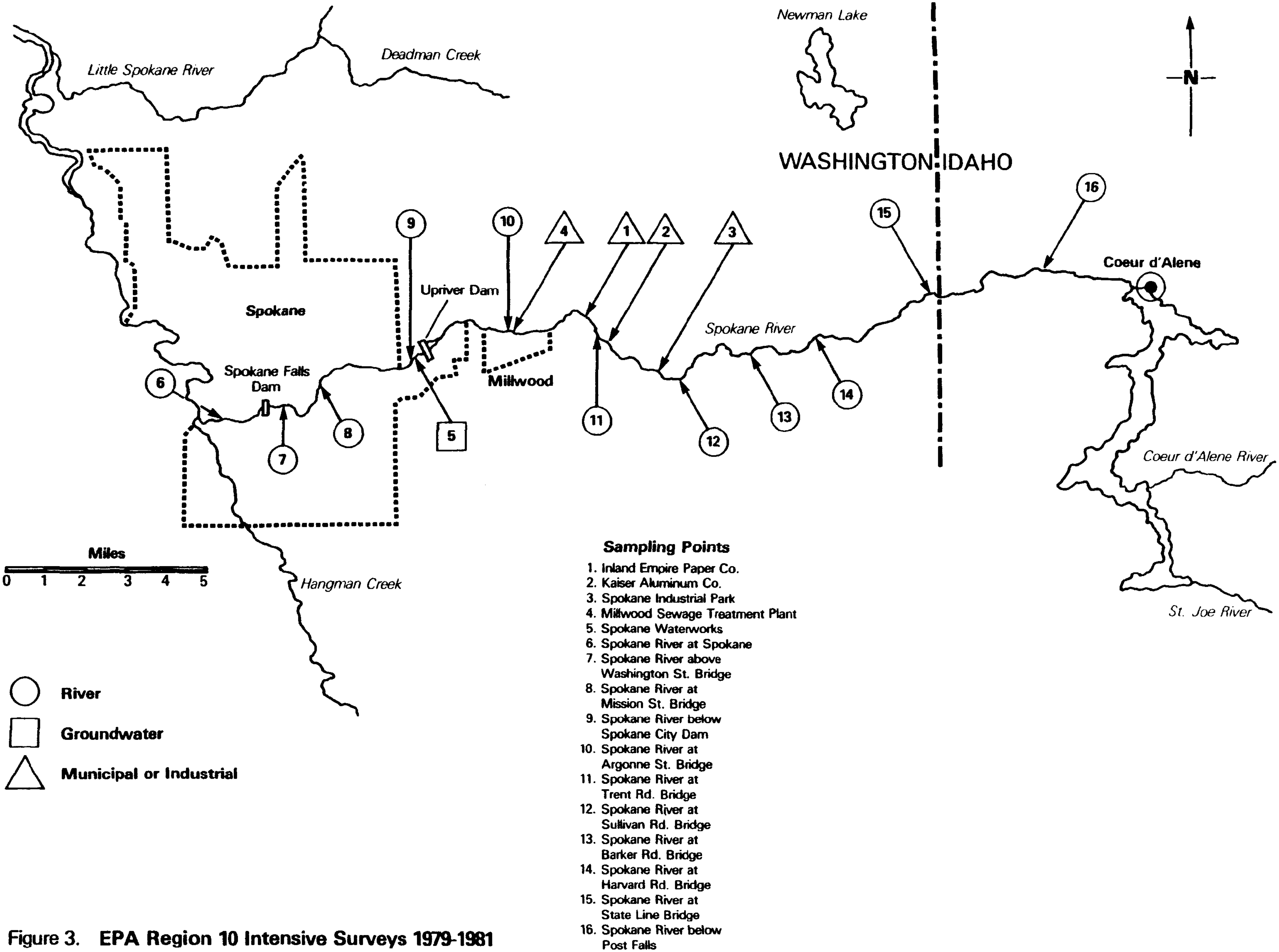


Figure 3. **EPA Region 10 Intensive Surveys 1979-1981**

FIGURE 4 . AVERAGE, MAXIMUM AND MINIMUM TOTAL CADMIUM IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY I.

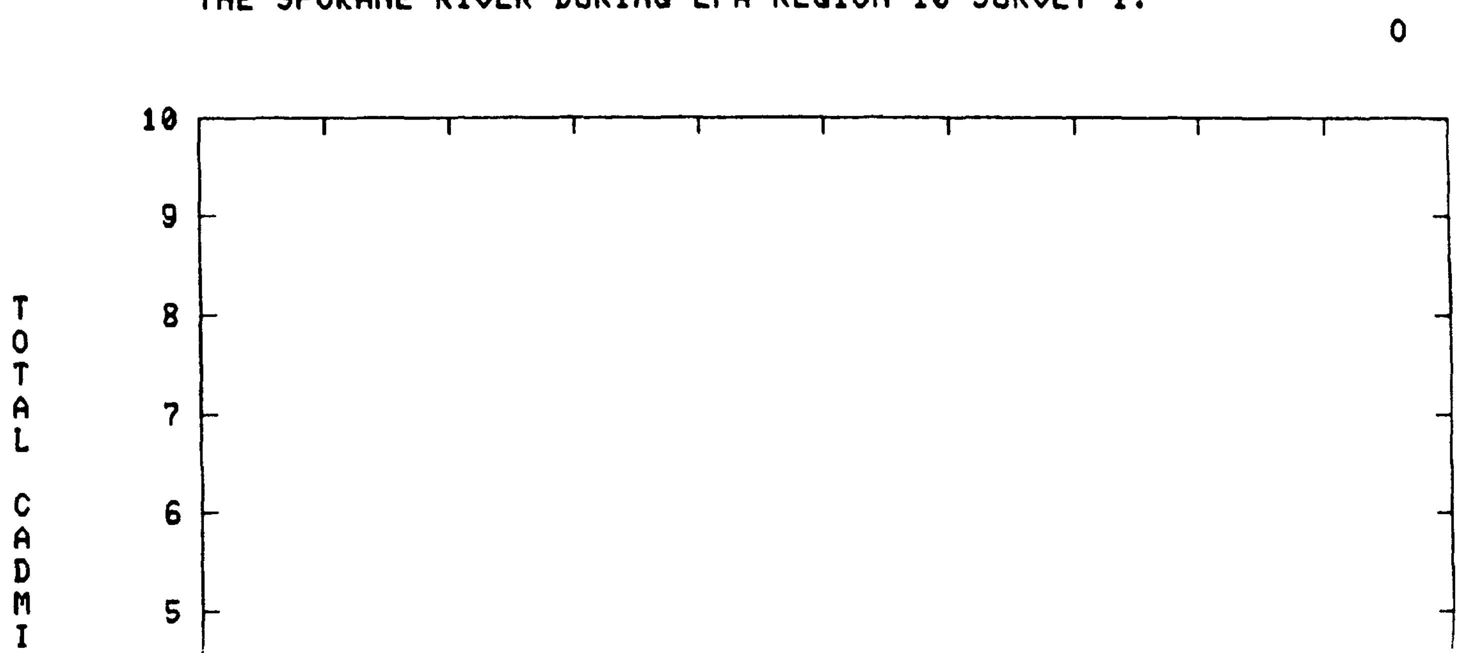


FIGURE 4 . AVERAGE, MAXIMUM AND MINIMUM TOTAL CADMIUM IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY I.

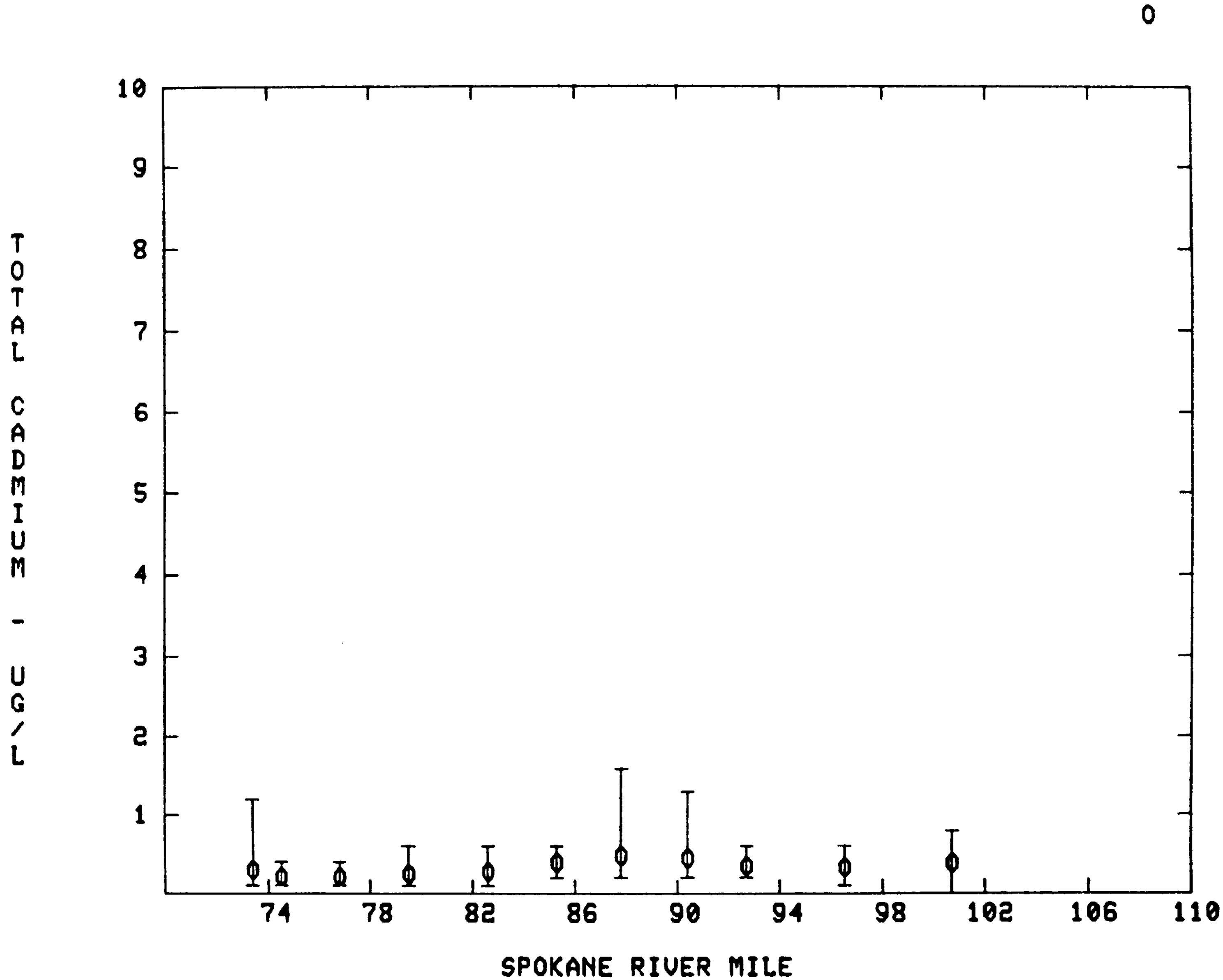


FIGURE 5 . AVERAGE, MAXIMUM AND MINIMUM TOTAL CADMIUM IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY II.

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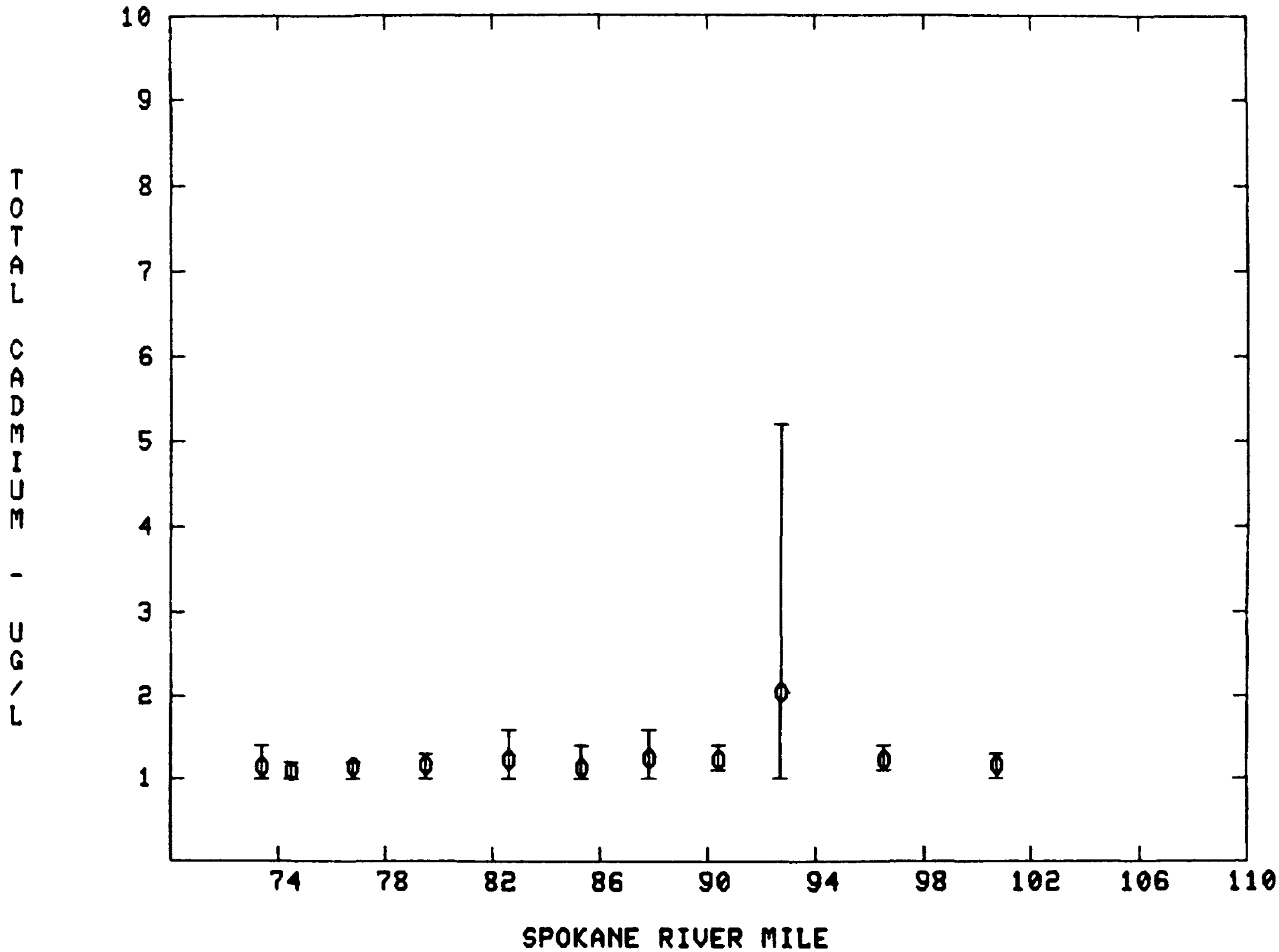


FIGURE 6. AVERAGE, MAXIMUM AND MINIMUM TOTAL CADMIUM IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY III.

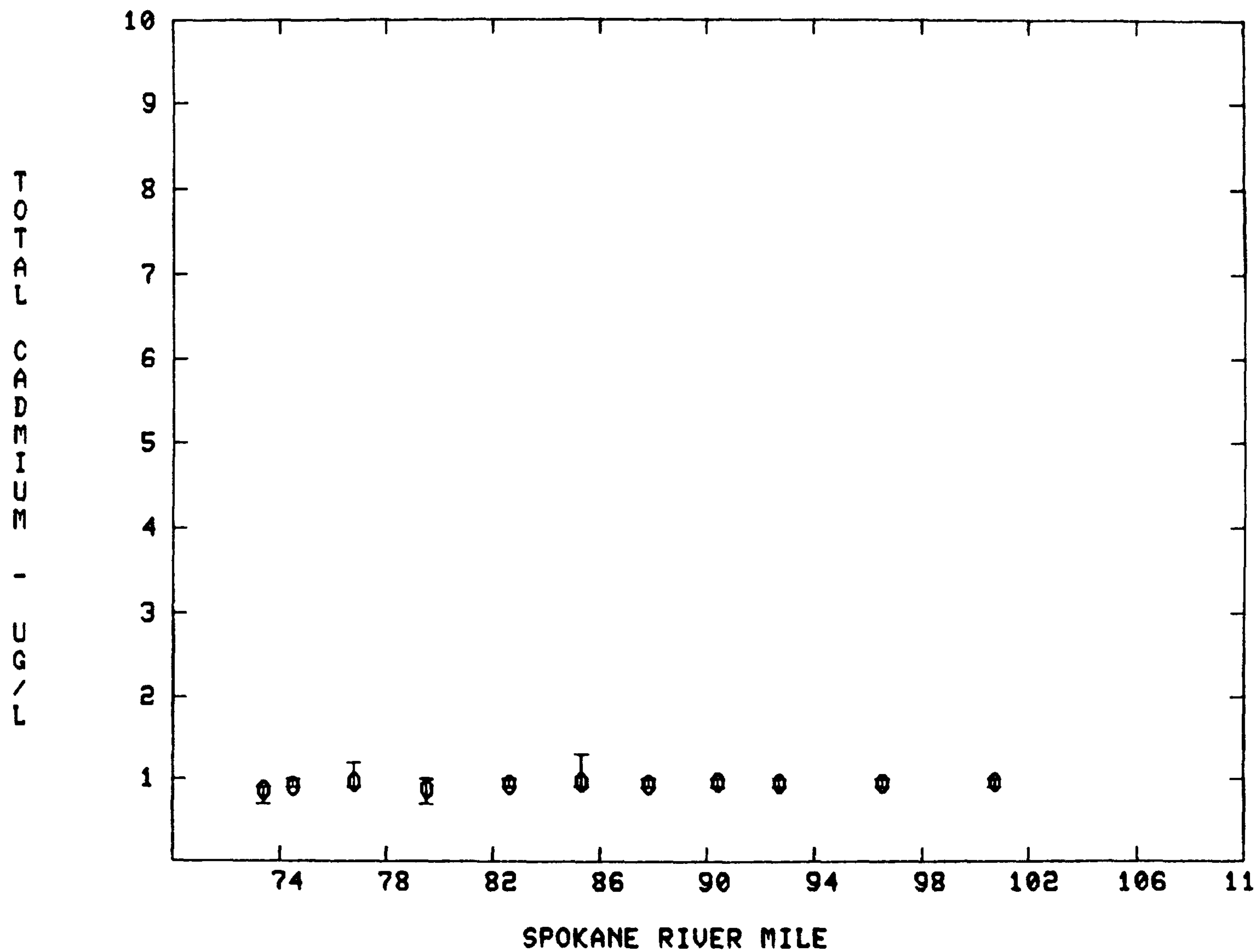


FIGURE 7. AVERAGE, MAXIMUM AND MINIMUM TOTAL CADMIUM IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY IV.

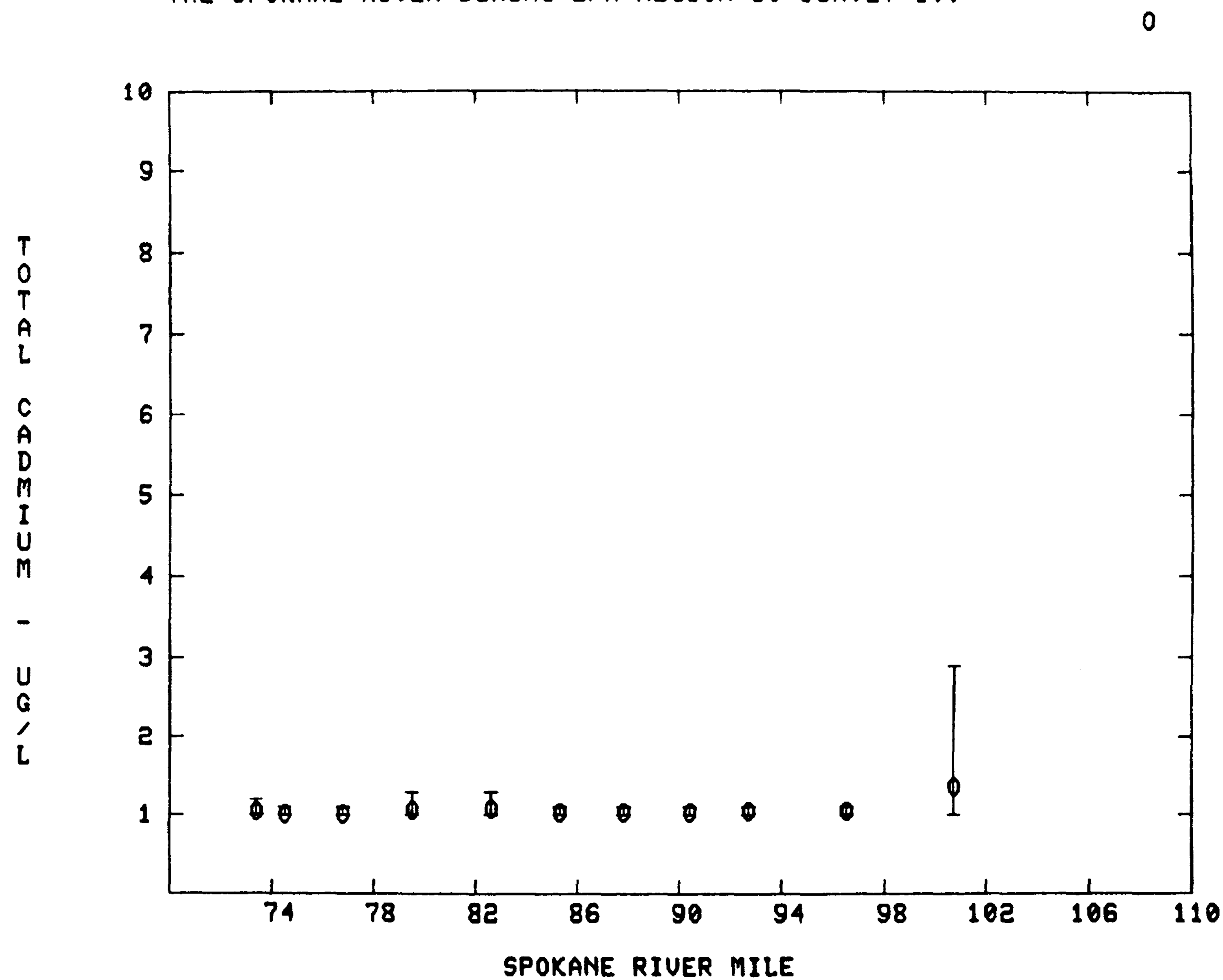


FIGURE 8. AVERAGE, MAXIMUM AND MINIMUM TOTAL COPPER IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY I.

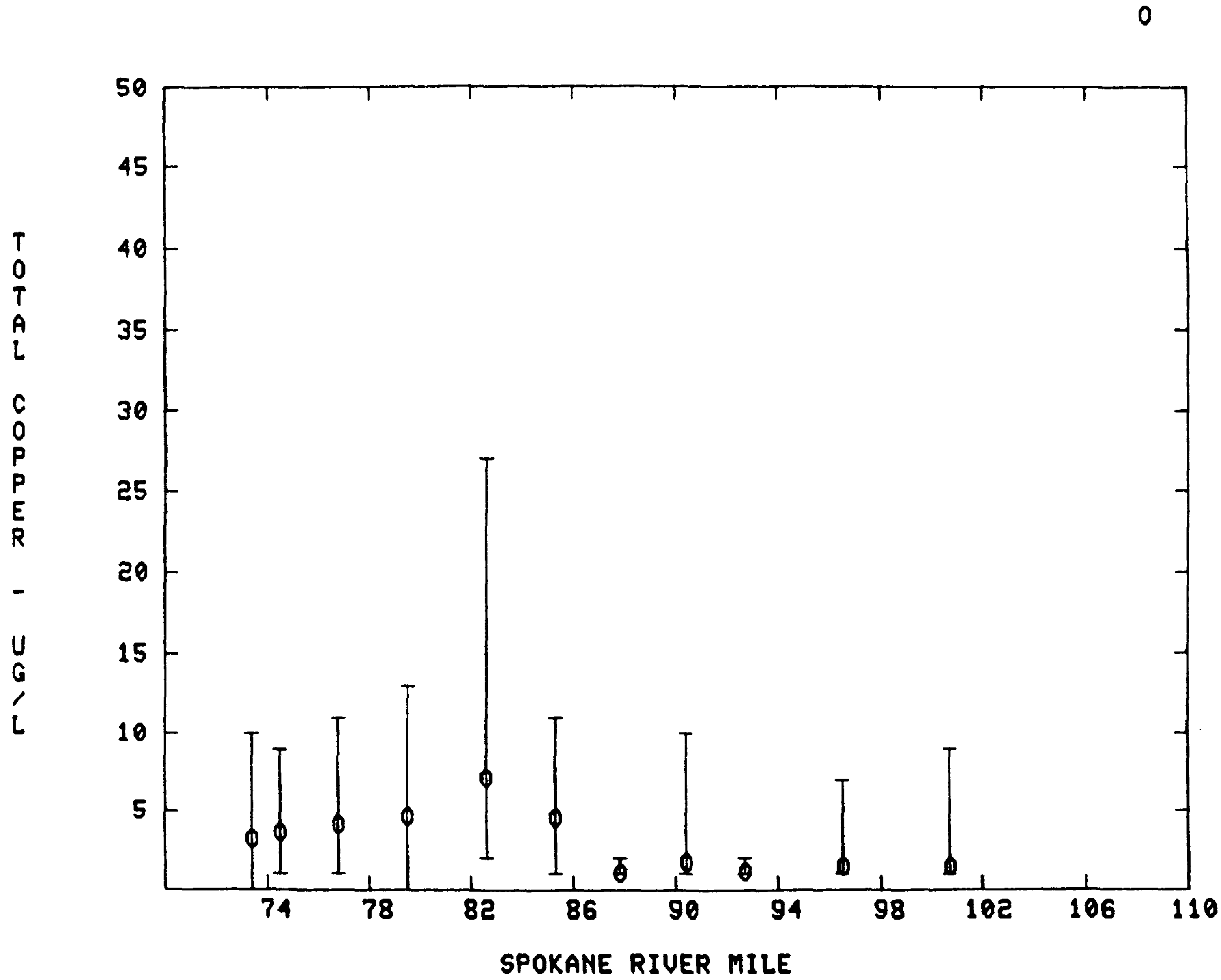


FIGURE 9. AVERAGE, MAXIMUM AND MINIMUM TOTAL COPPER IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY II.

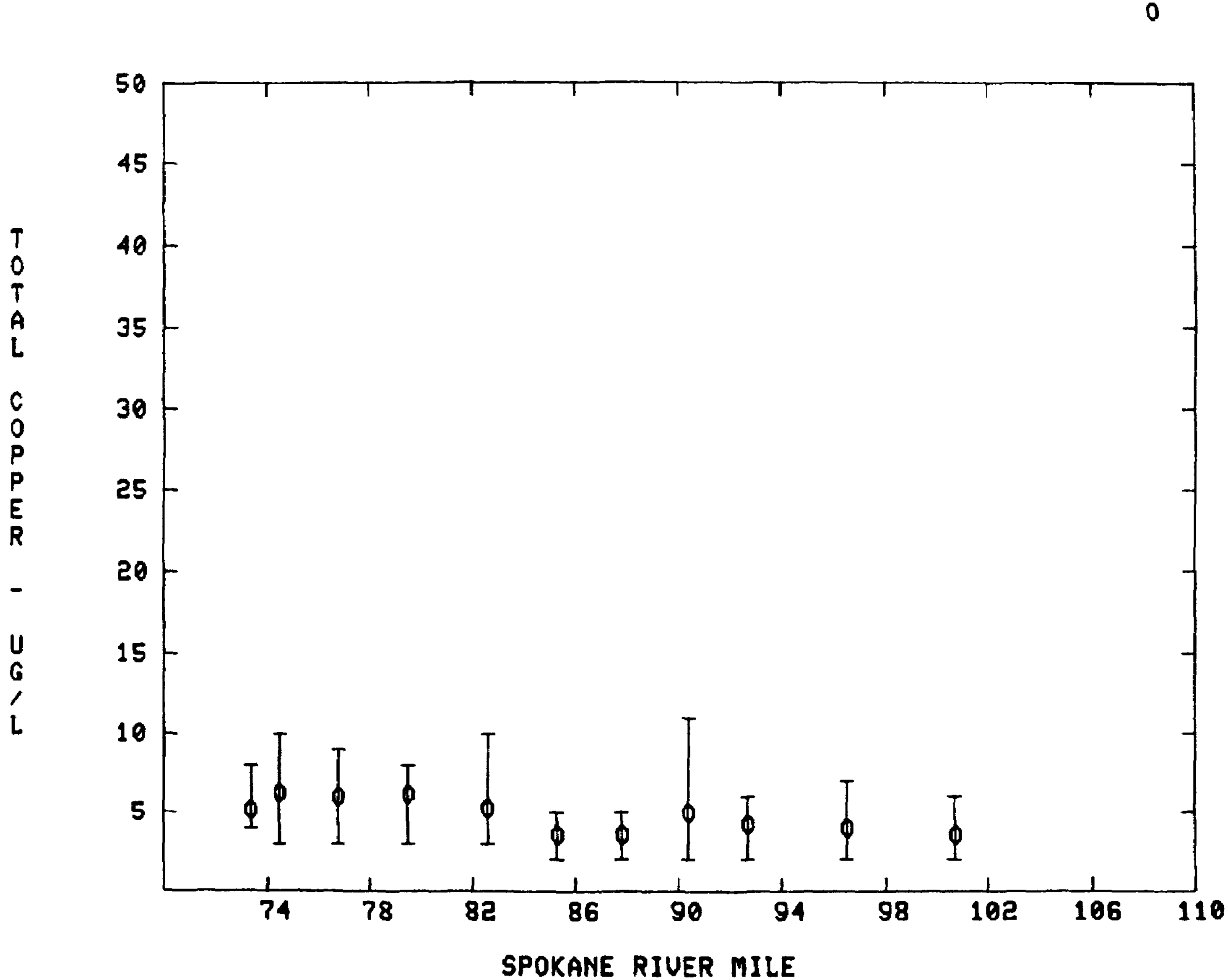


FIGURE 10. AVERAGE, MAXIMUM AND MINIMUM TOTAL COPPER IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY III.

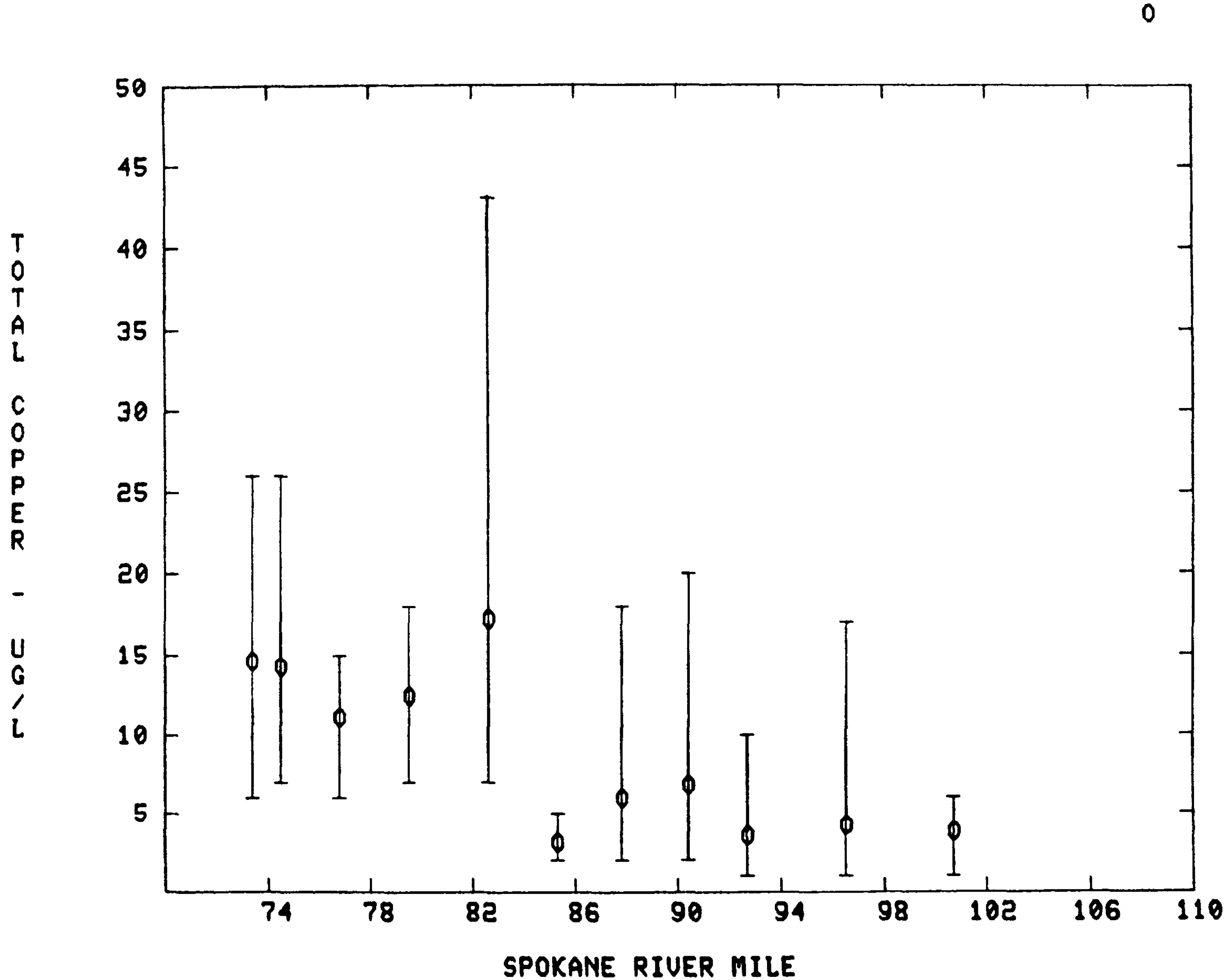


FIGURE 11. AVERAGE, MAXIMUM AND MINIMUM TOTAL COPPER IN THE SPOKANE RIVER DURINGE EPA REGION 10 SURVEY IV.

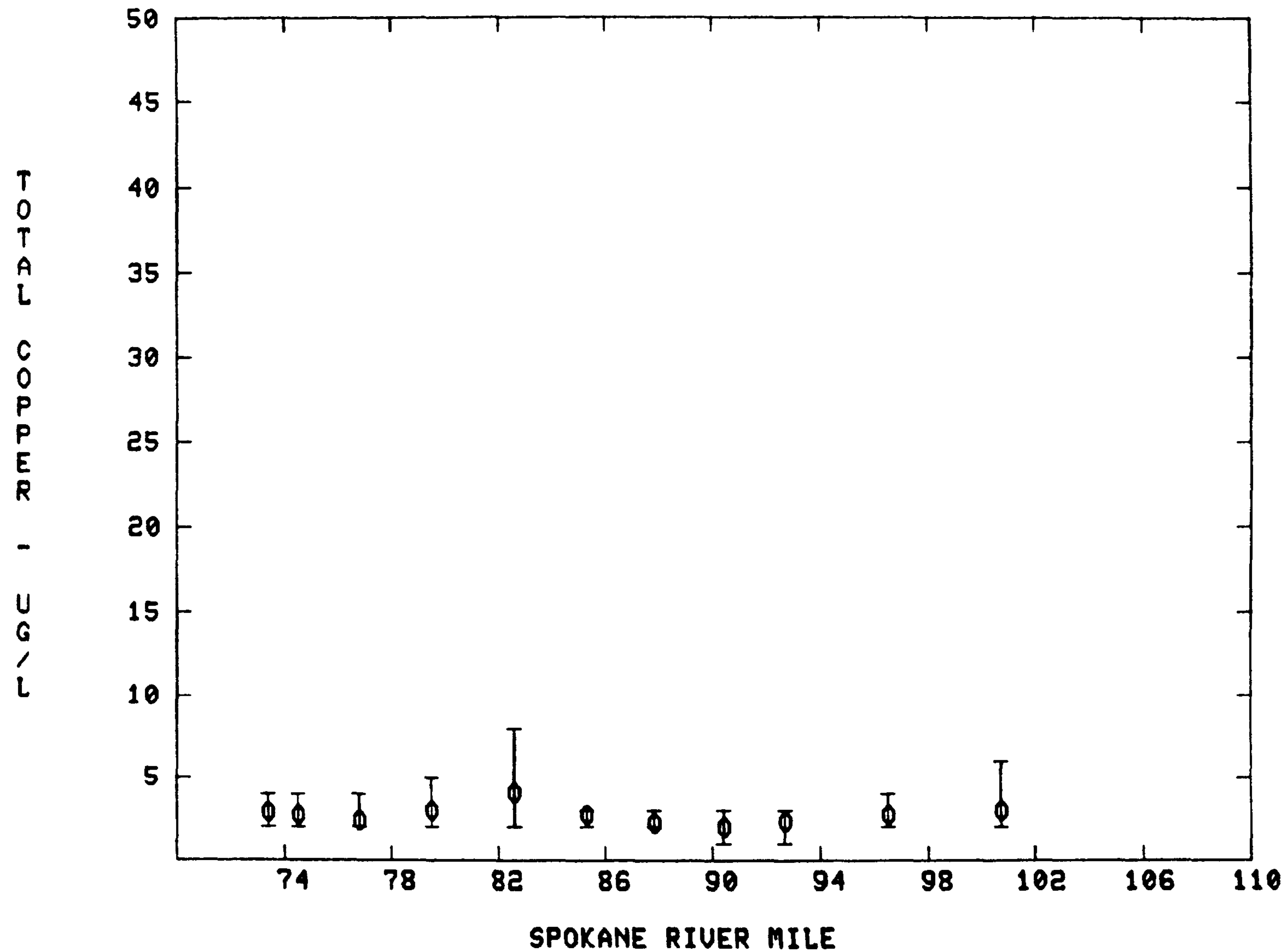


FIGURE 12. AVERAGE, MAXIMUM AND MINIMUM TOTAL IRON IN THE SPOKANE RIVER DURINGE EPA REGION 10 SURVEY I.

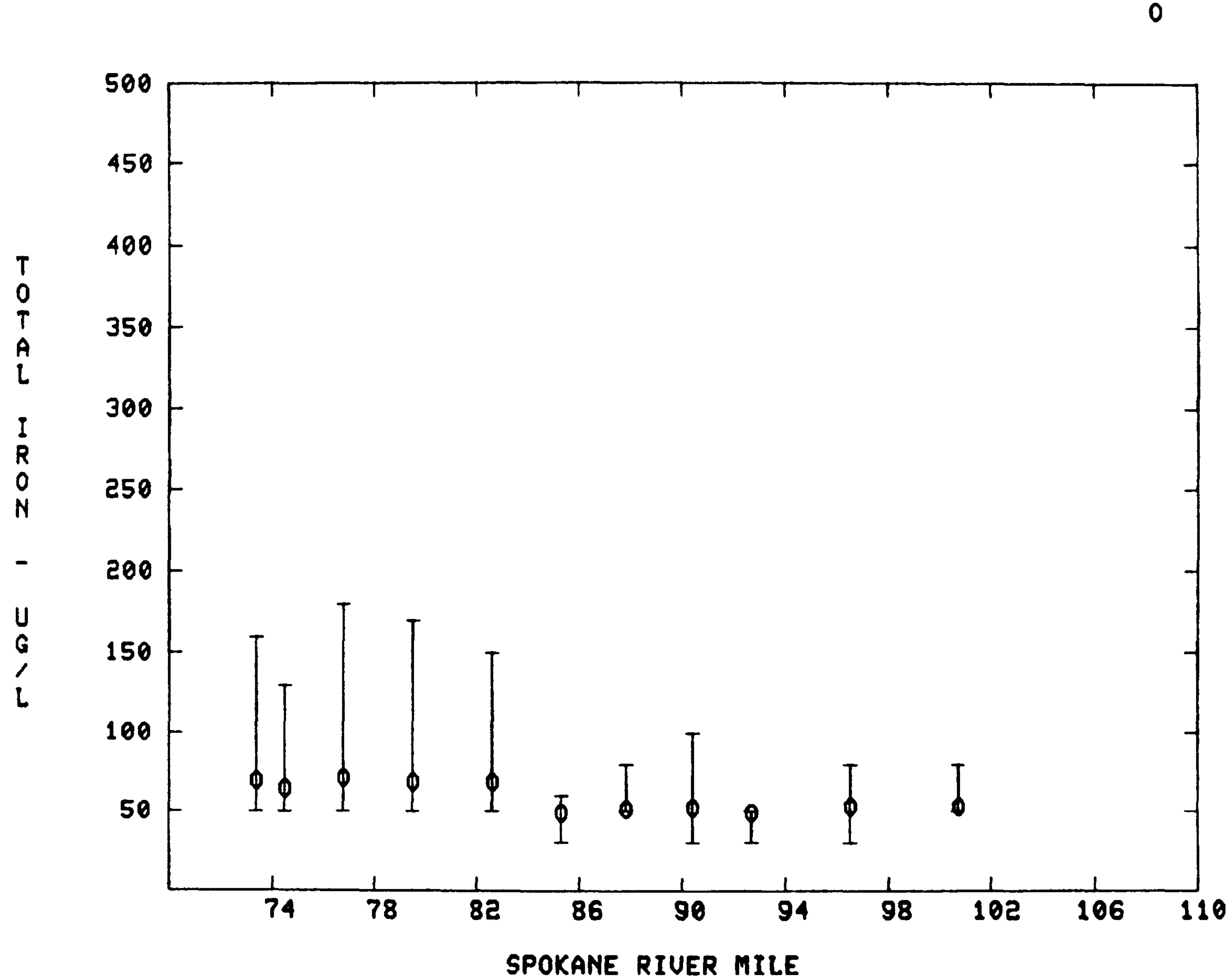


FIGURE 13. AVERAGE, MAXIMUM AND MINIMUM TOTAL IRON IN THE SPOKANE RIVER DURINGE EPA REGION 10 SURVEY II.

O

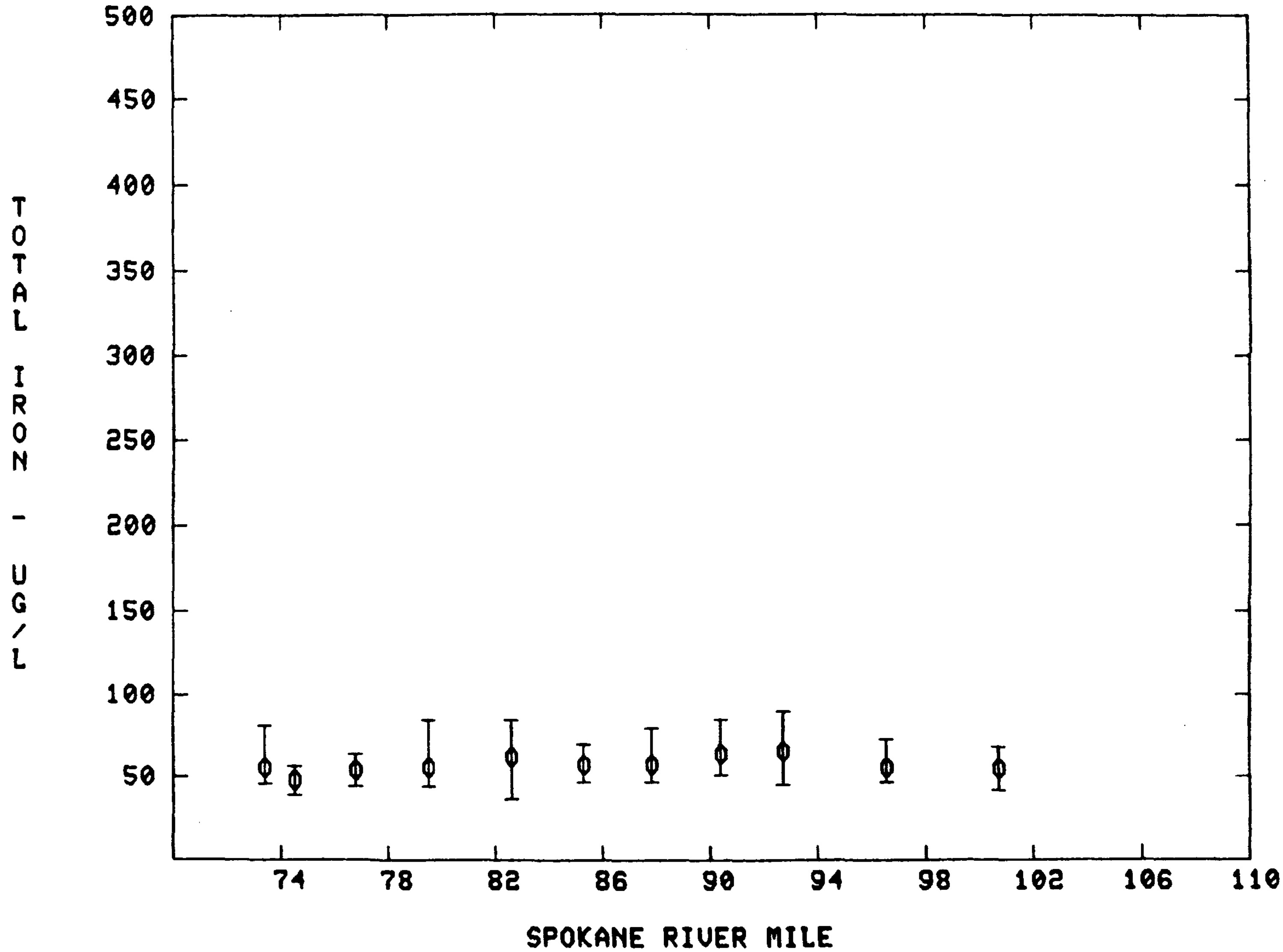


FIGURE 14. AVERAGE, MAXIMUM AND MINIMUM TOTAL IRON IN THE SPOKANE RIVER DURINGE EPA REGION 10 SURVEY III.

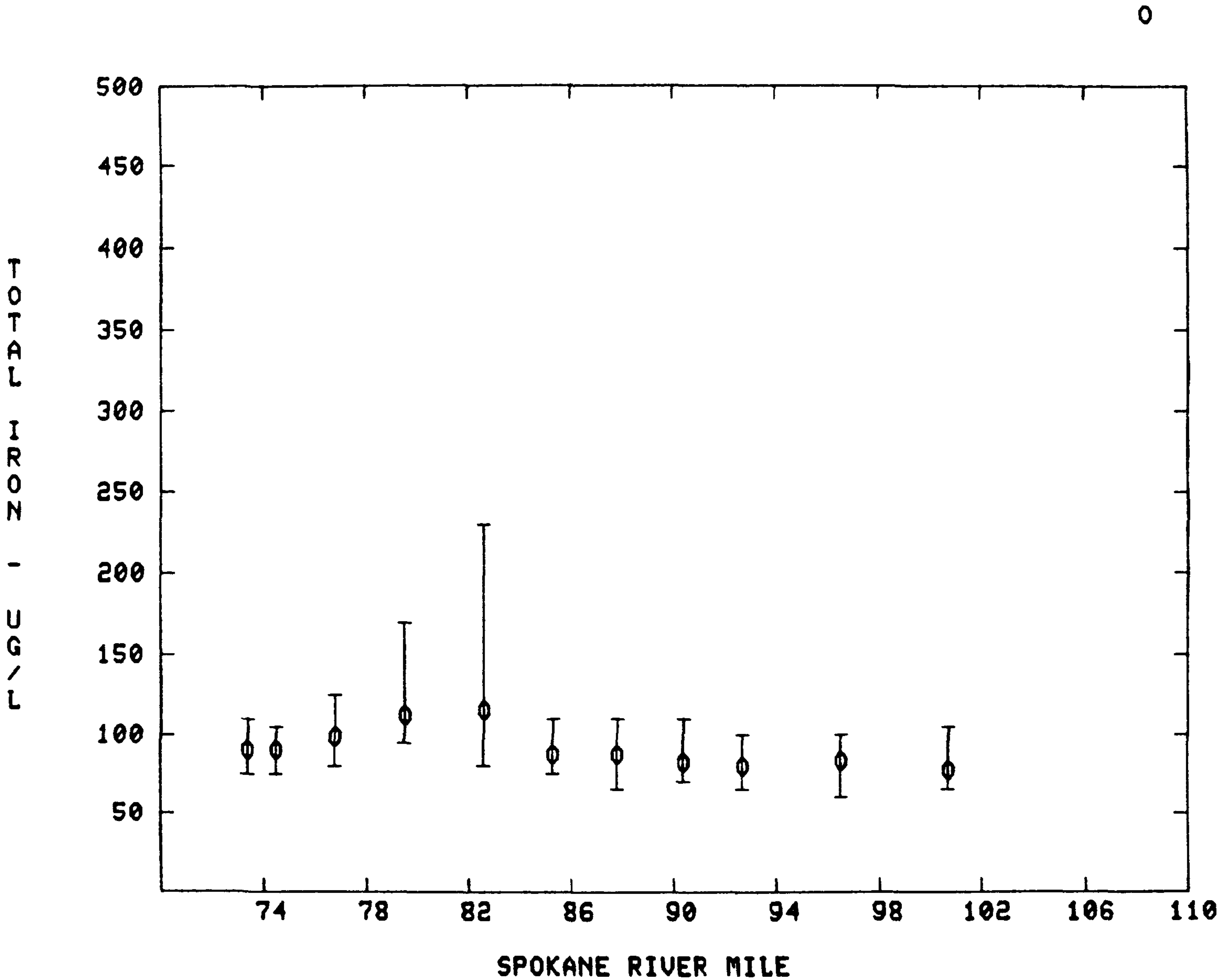


FIGURE 15. AVERAGE, MAXIMUM AND MINIMUM TOTAL IRON IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY IV.

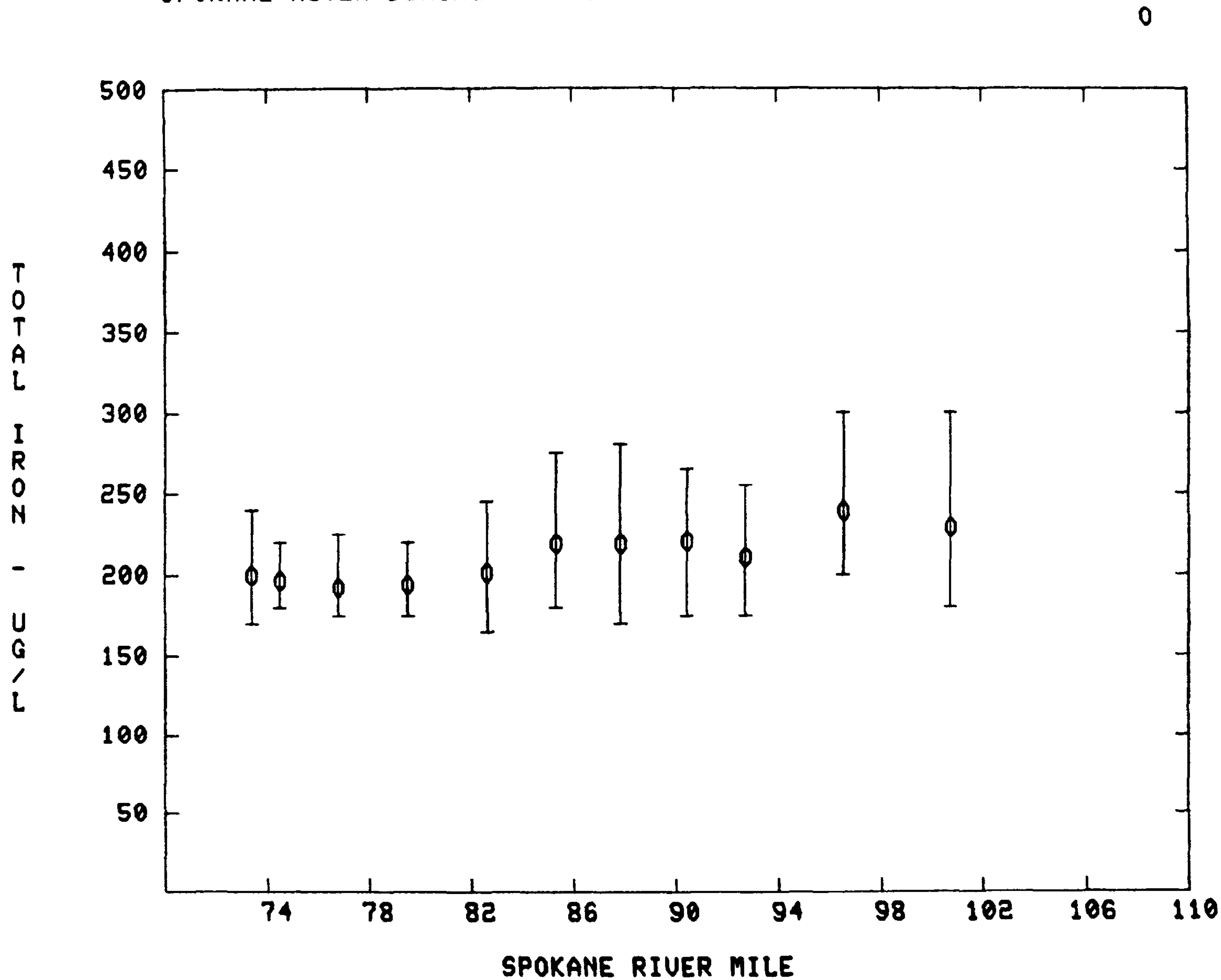


FIGURE 16. AVERAGE, MAXIMUM AND MINIMUM TOTAL LEAD IN THE SPOKANE RIVER DURINGE EPA REGION 10 SURVEY I.

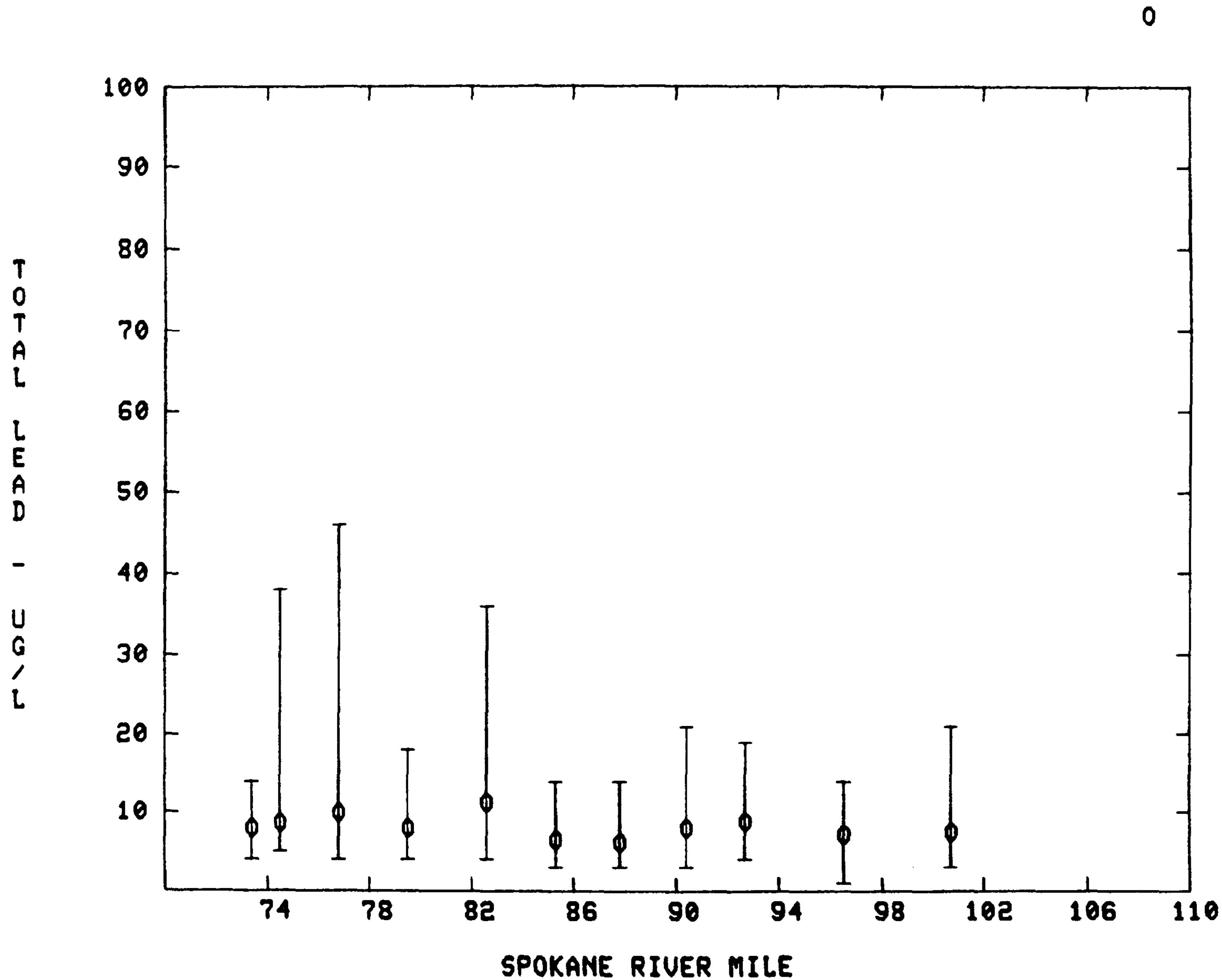


FIGURE 17. AVERAGE, MAXIMUM AND MINIMUM TOTAL LEAD IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY II.

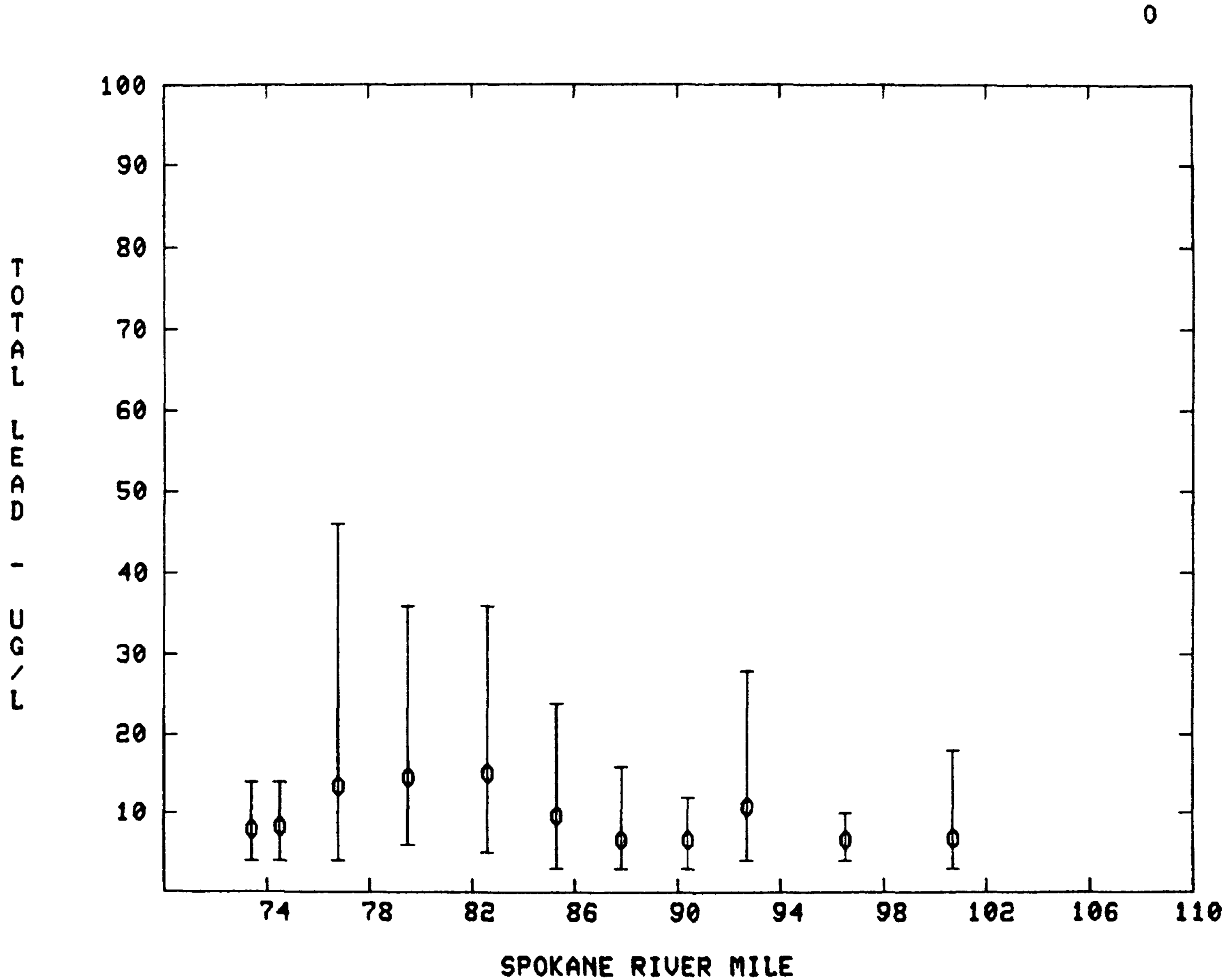


FIGURE 18. AVERAGE, MAXIMUM AND MINIMUM TOTAL LEAD IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY III.

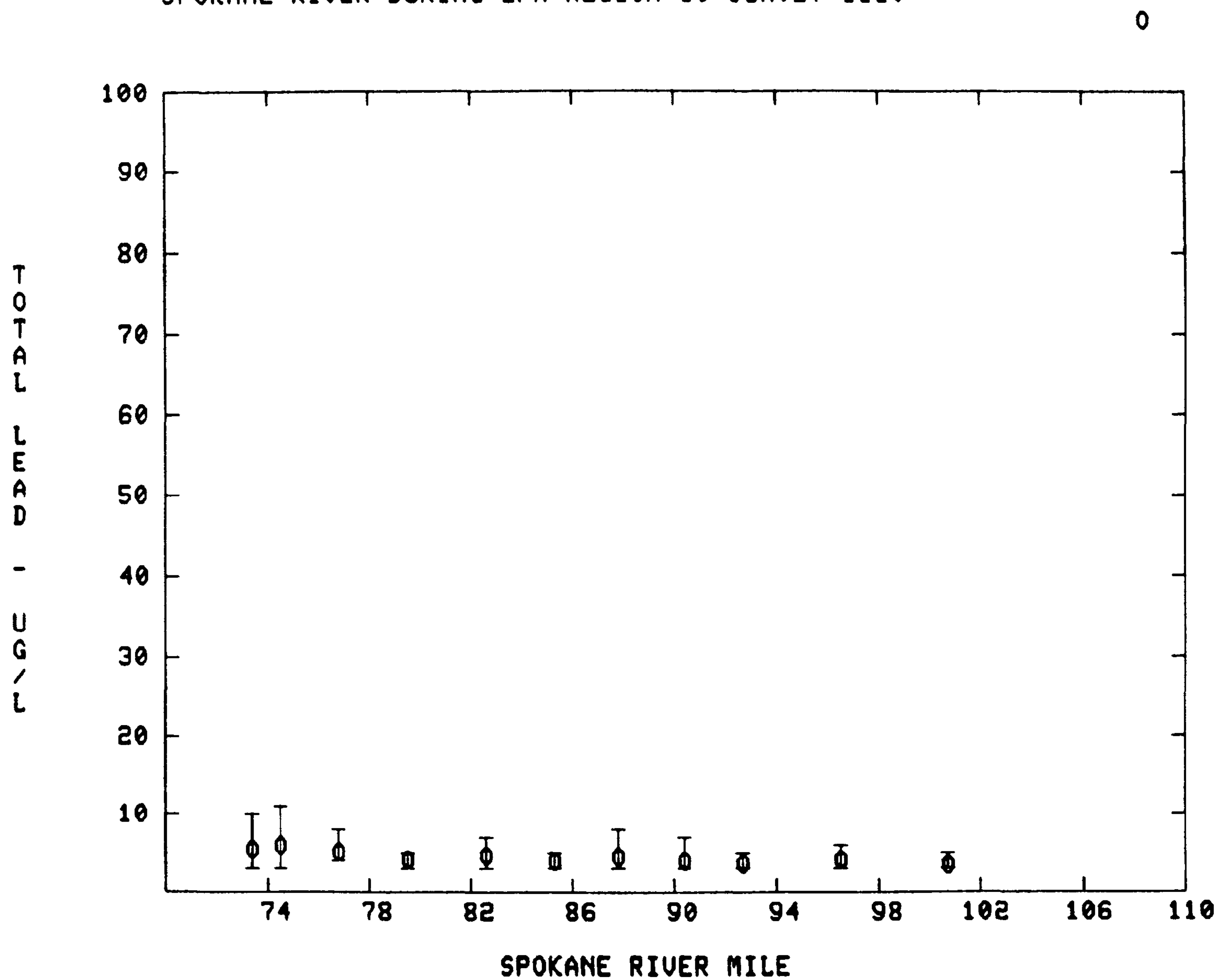


FIGURE 19. AVERAGE, MAXIMUM AND MINIMUM TOTAL LEAD IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY IV.

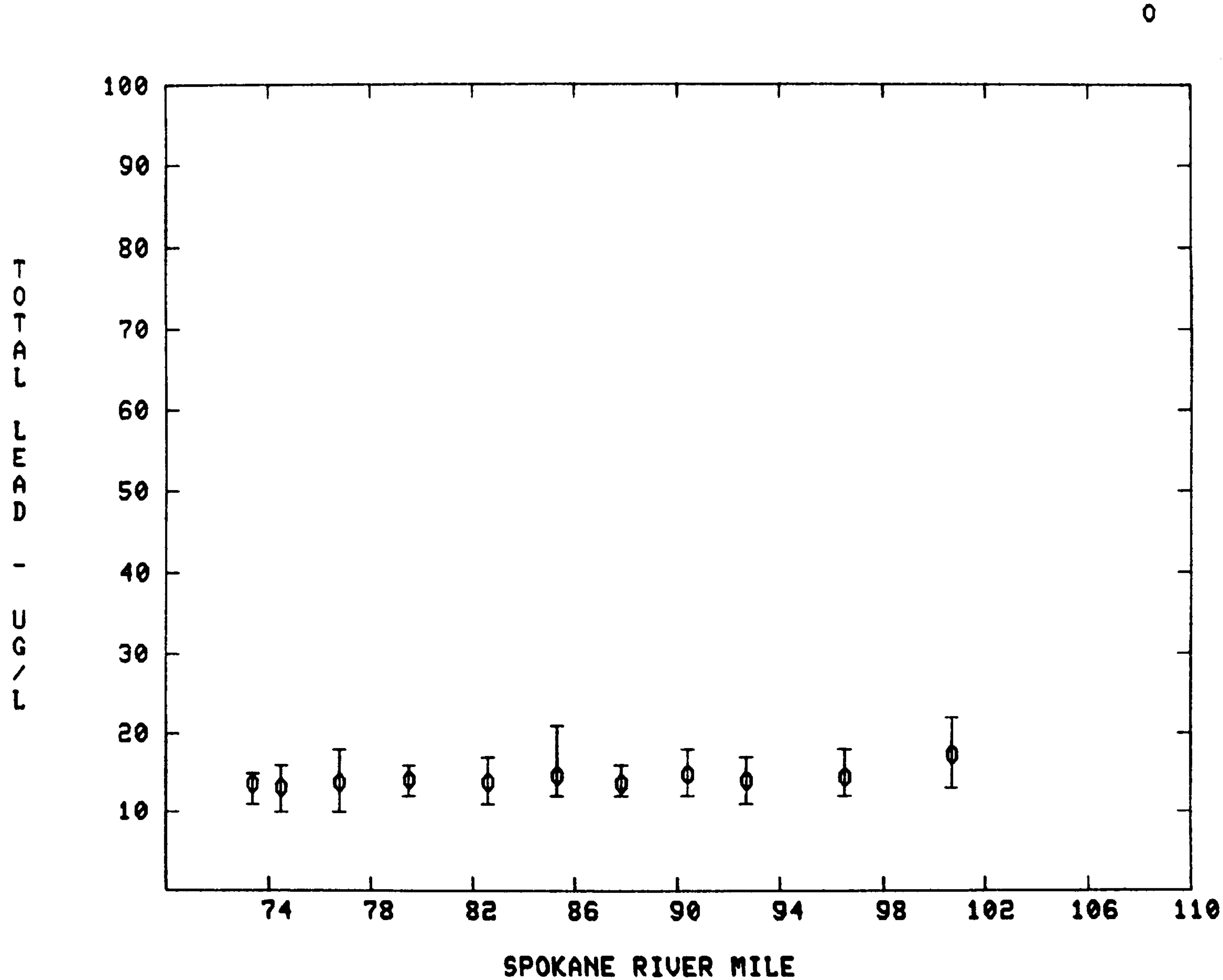


FIGURE 20. AVERAGE, MAXIMUM AND MINIMUM TOTAL MERCURY IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY I.

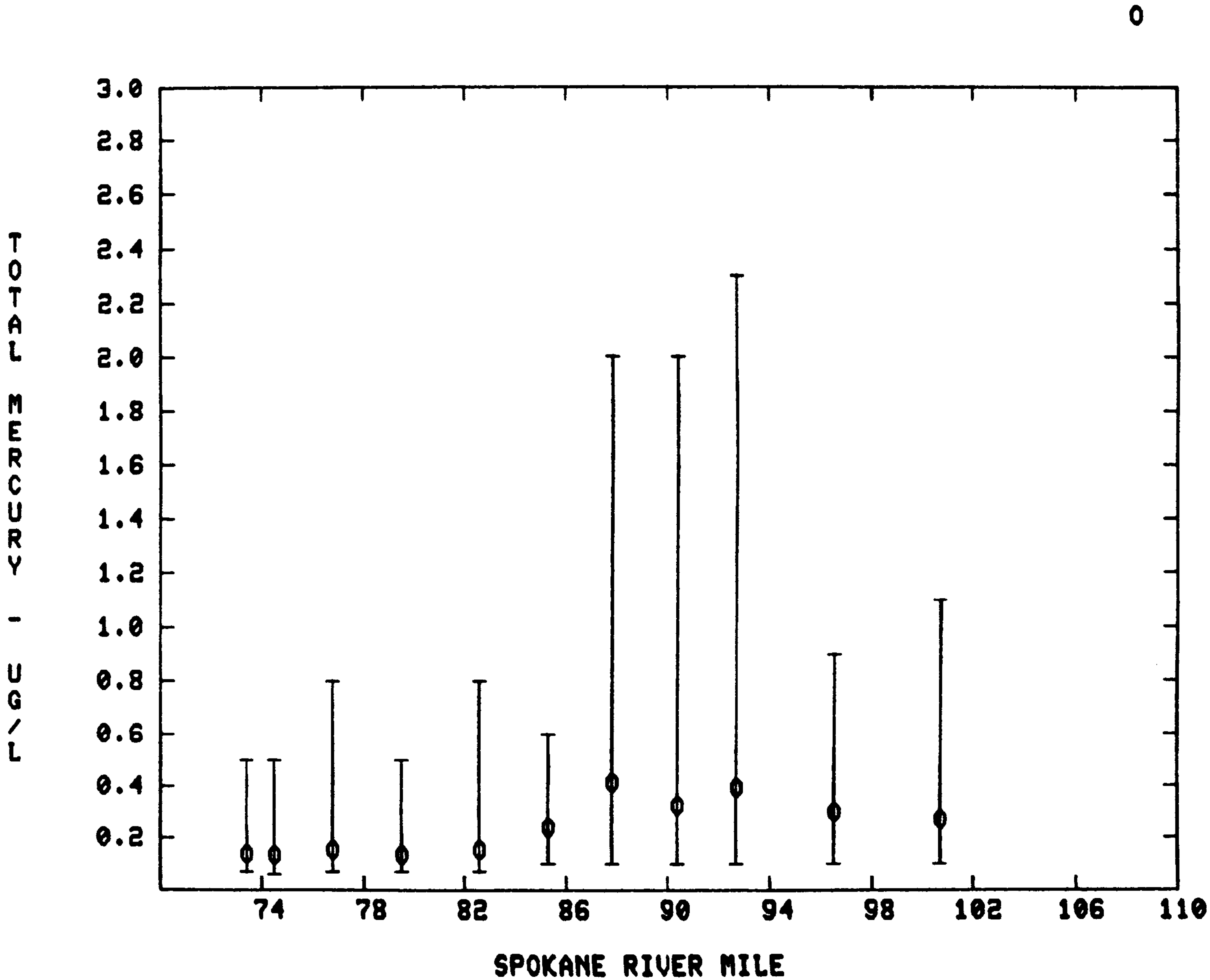


FIGURE 21. AVERAGE, MAXIMUM AND MINIMUM TOTAL MERCURY IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY II.

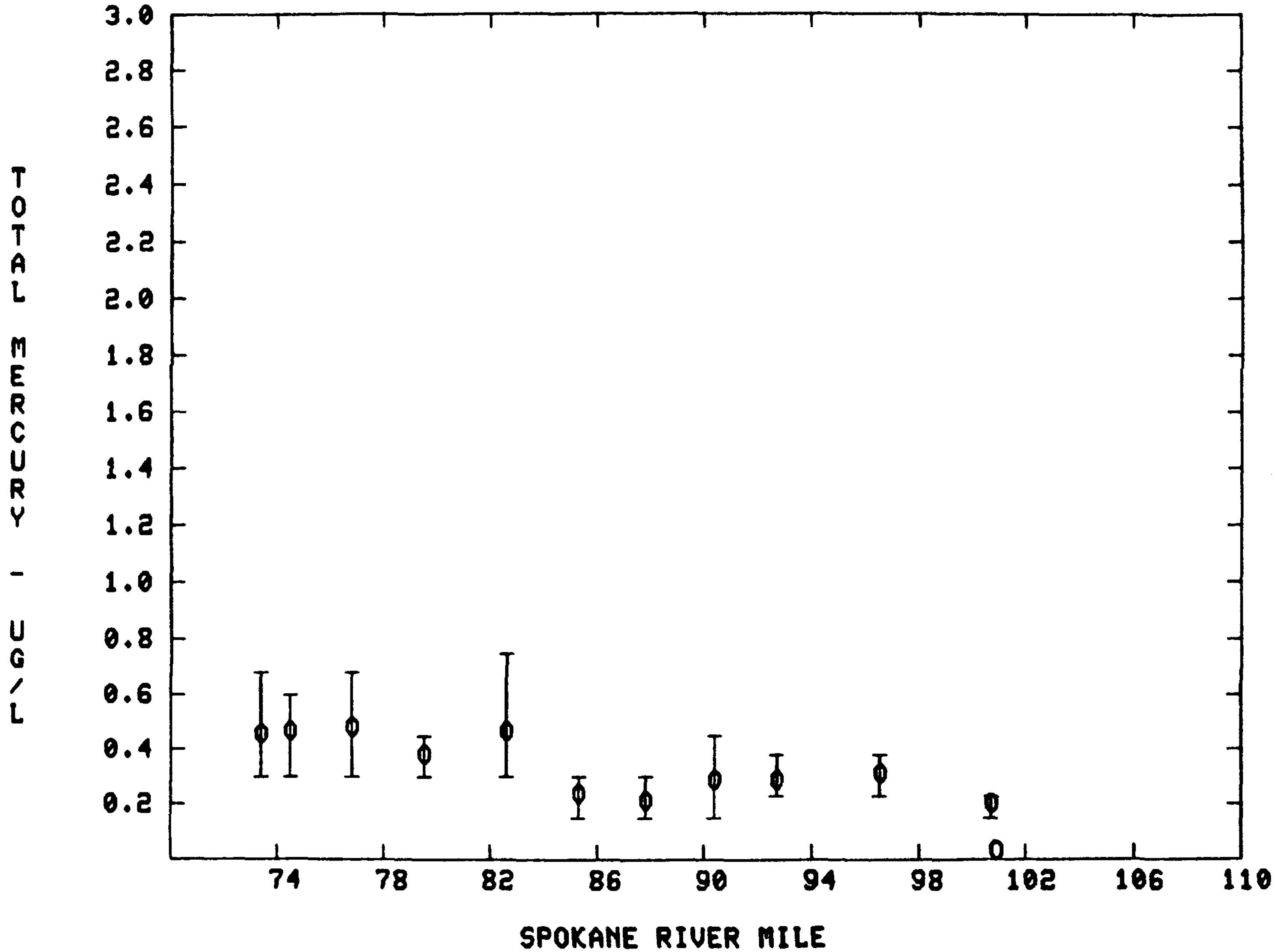


FIGURE 22. AVERAGE, MAXIMUM AND MINIMUM TOTAL MERCURY IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY III.

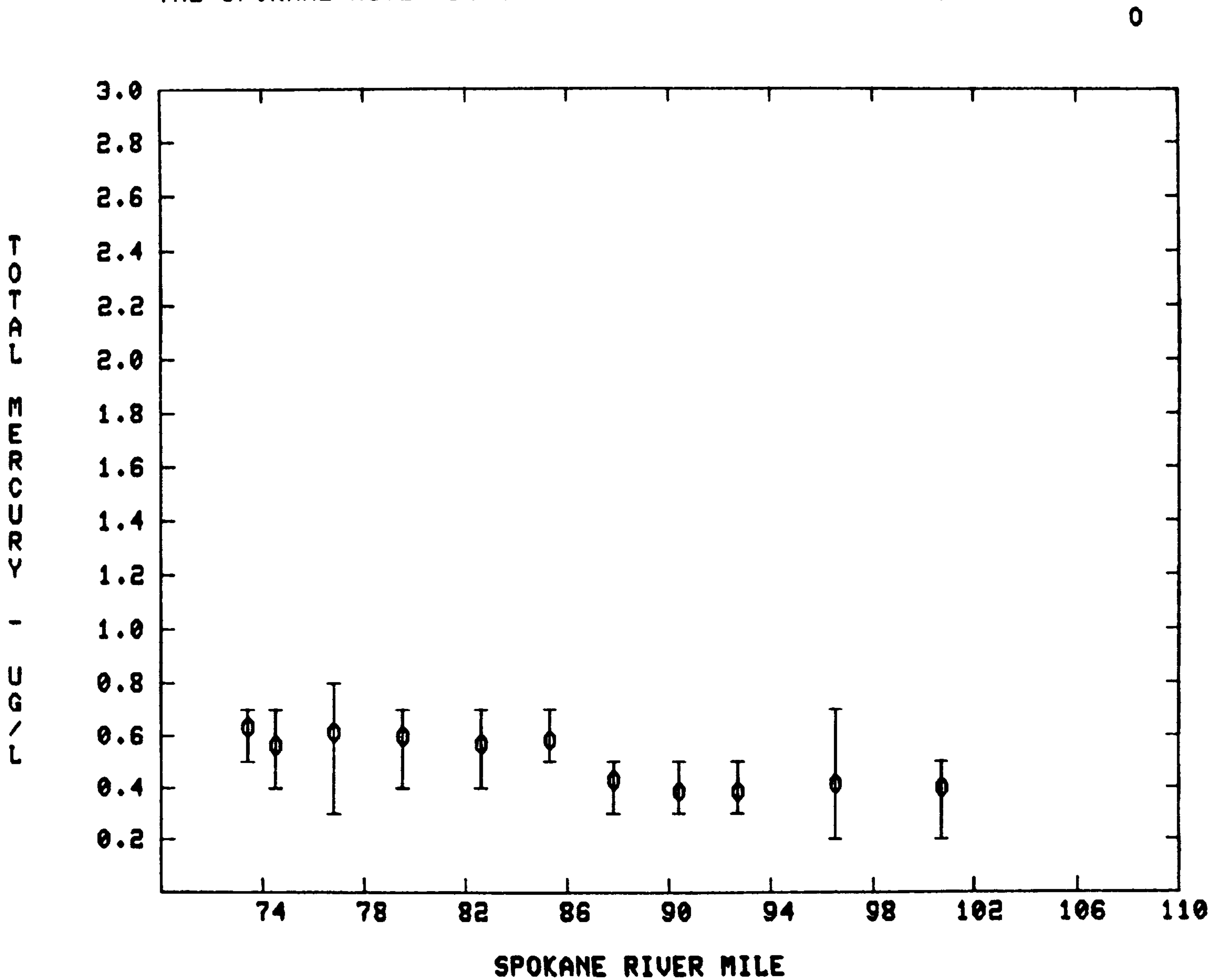


FIGURE 23. AVERAGE, MAXIMUM AND MINIMUM TOTAL MERCURY IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY IV.

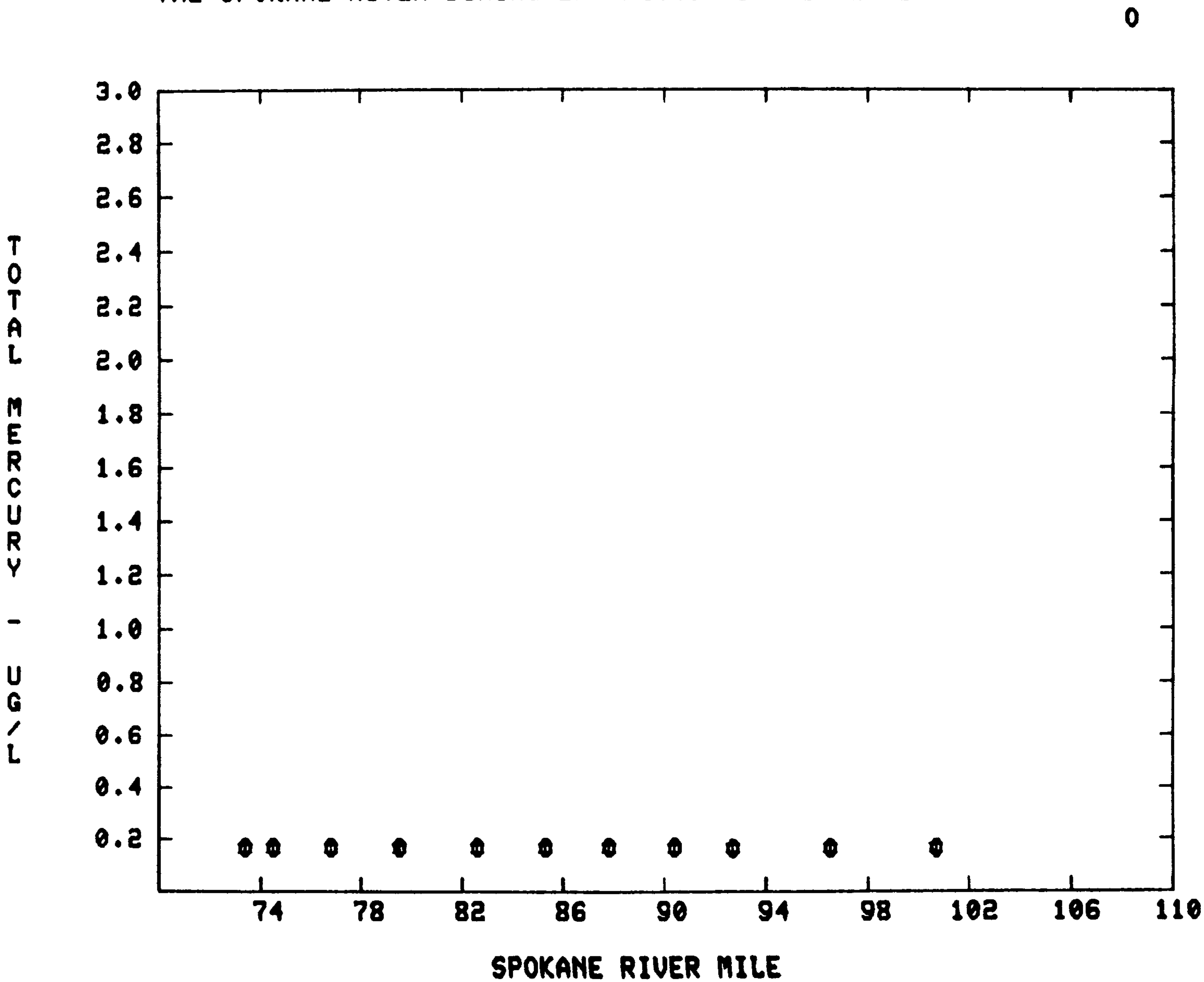


FIGURE 24. AVERAGE, MAXIMUM AND MINIMUM TOTAL ZINC IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY I.

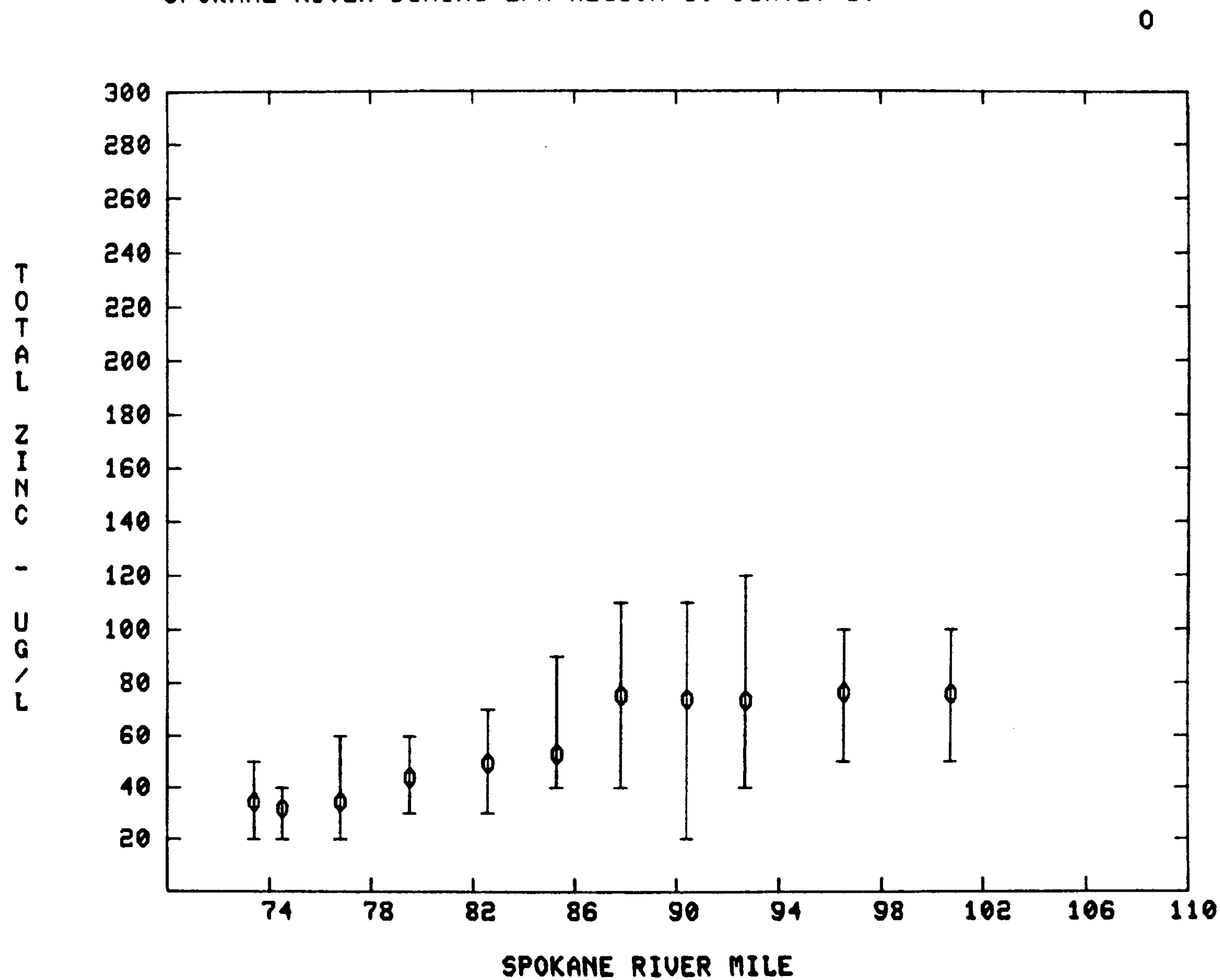


FIGURE 25. AVERAGE, MAXIMUM AND MINIMUM TOTAL ZINC IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY II.

O

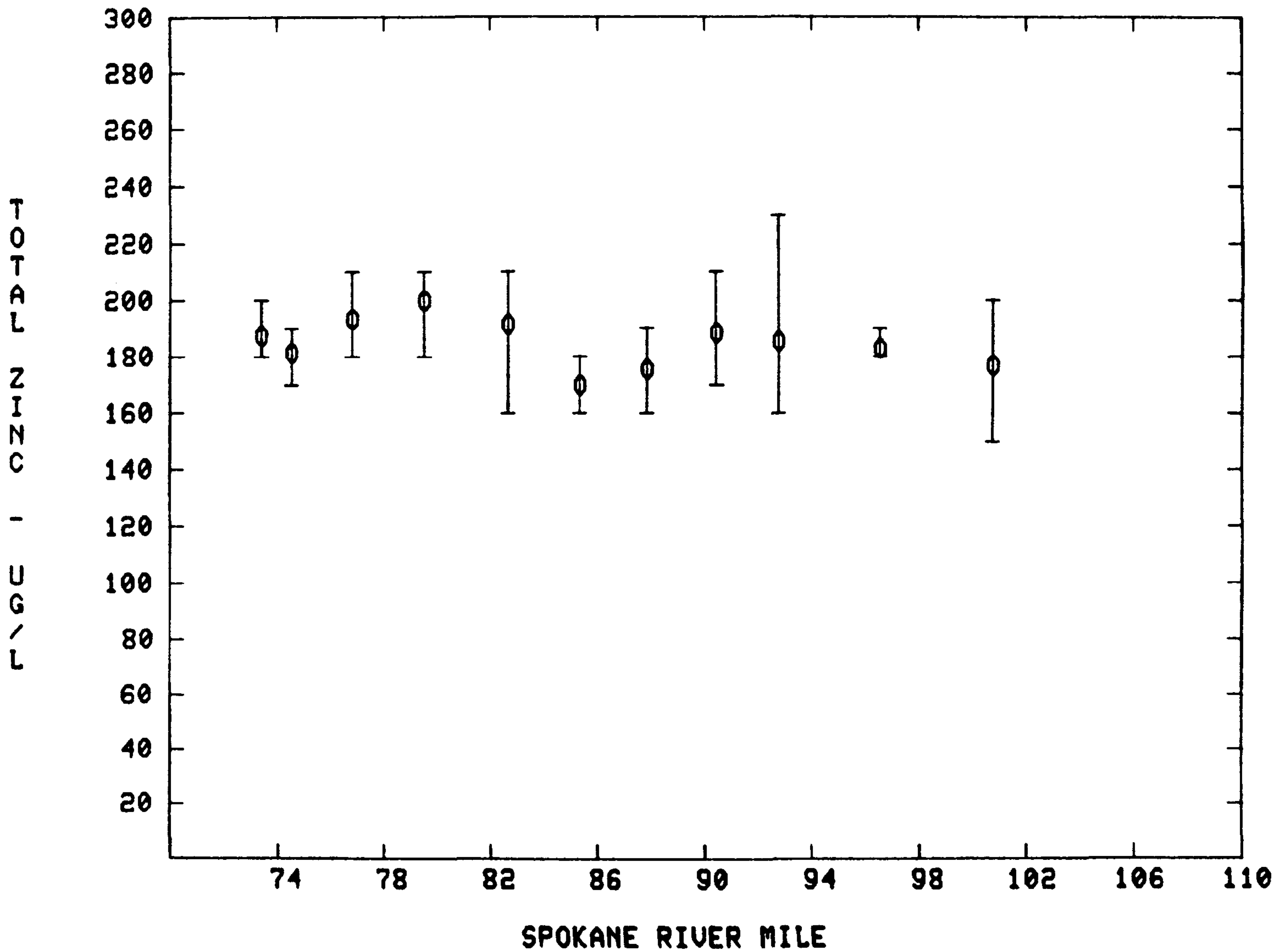


FIGURE 26. AVERAGE, MAXIMUM AND MINIMUM TOTAL ZINC IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY III.

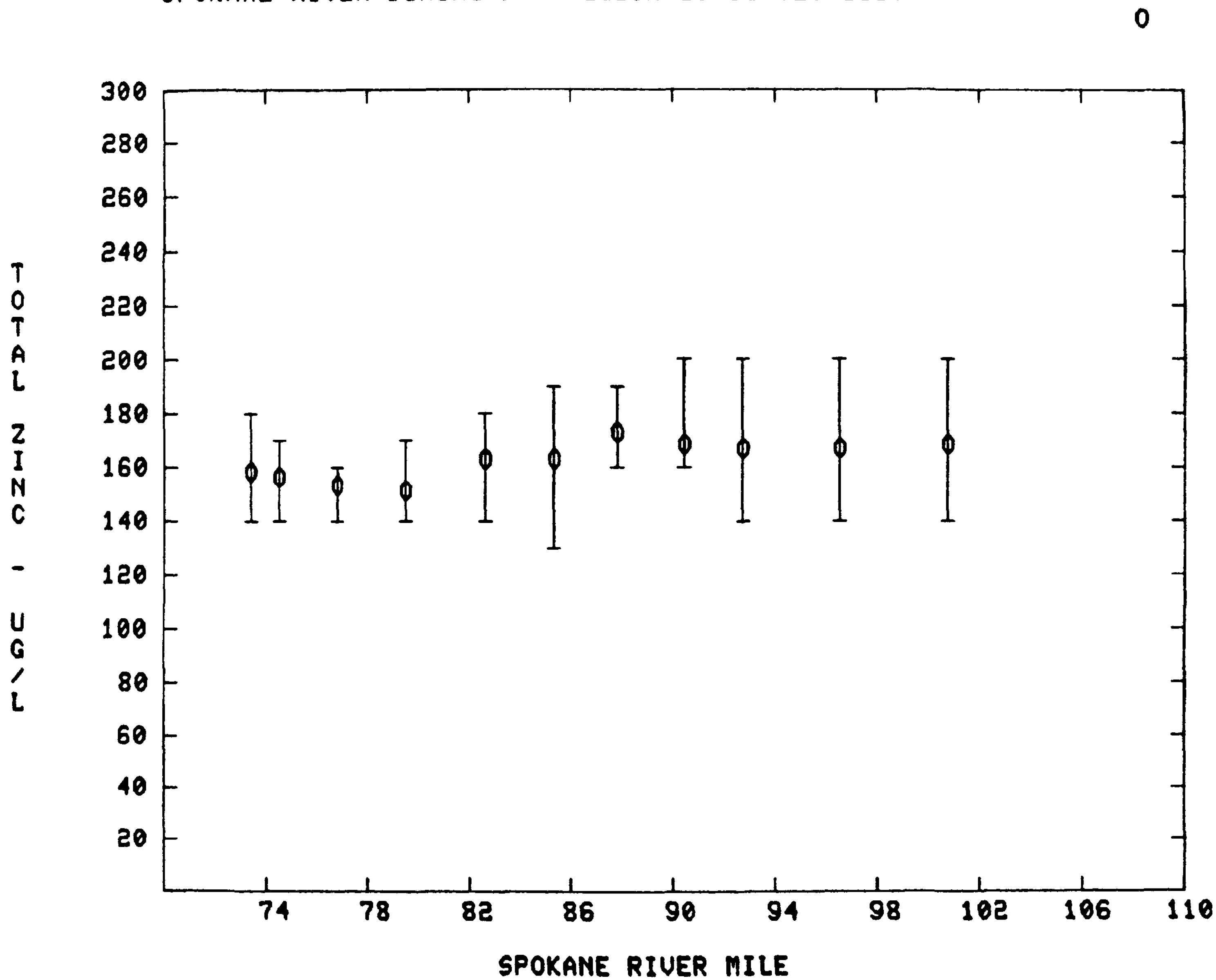


FIGURE 27. AVERAGE, MAXIMUM AND MINIMUM ZINC IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY IV.

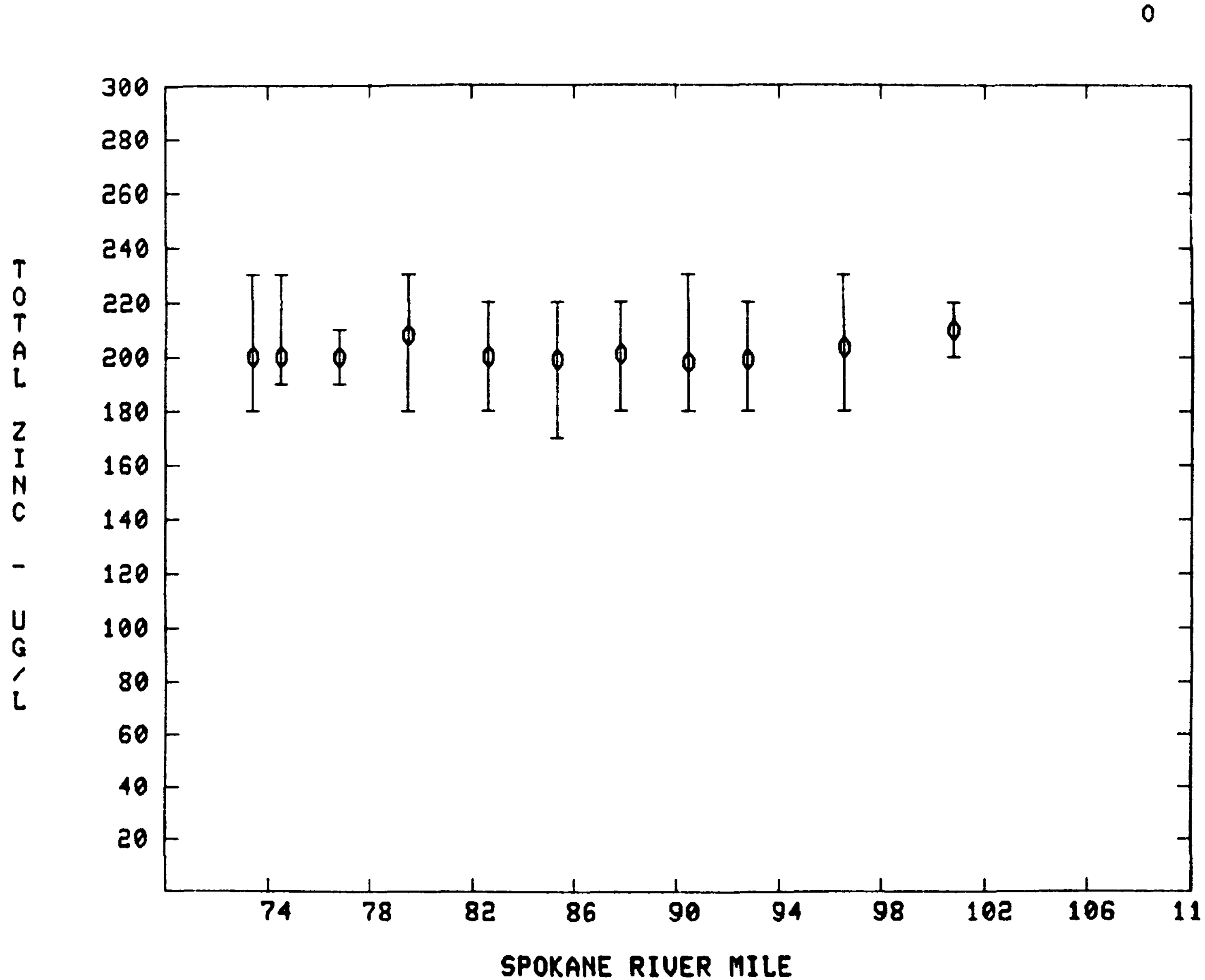


FIGURE 28. AVERAGE, MAXIMUM AND MINIMUM NITRITE+NITRATE-NITROGEN IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY I.

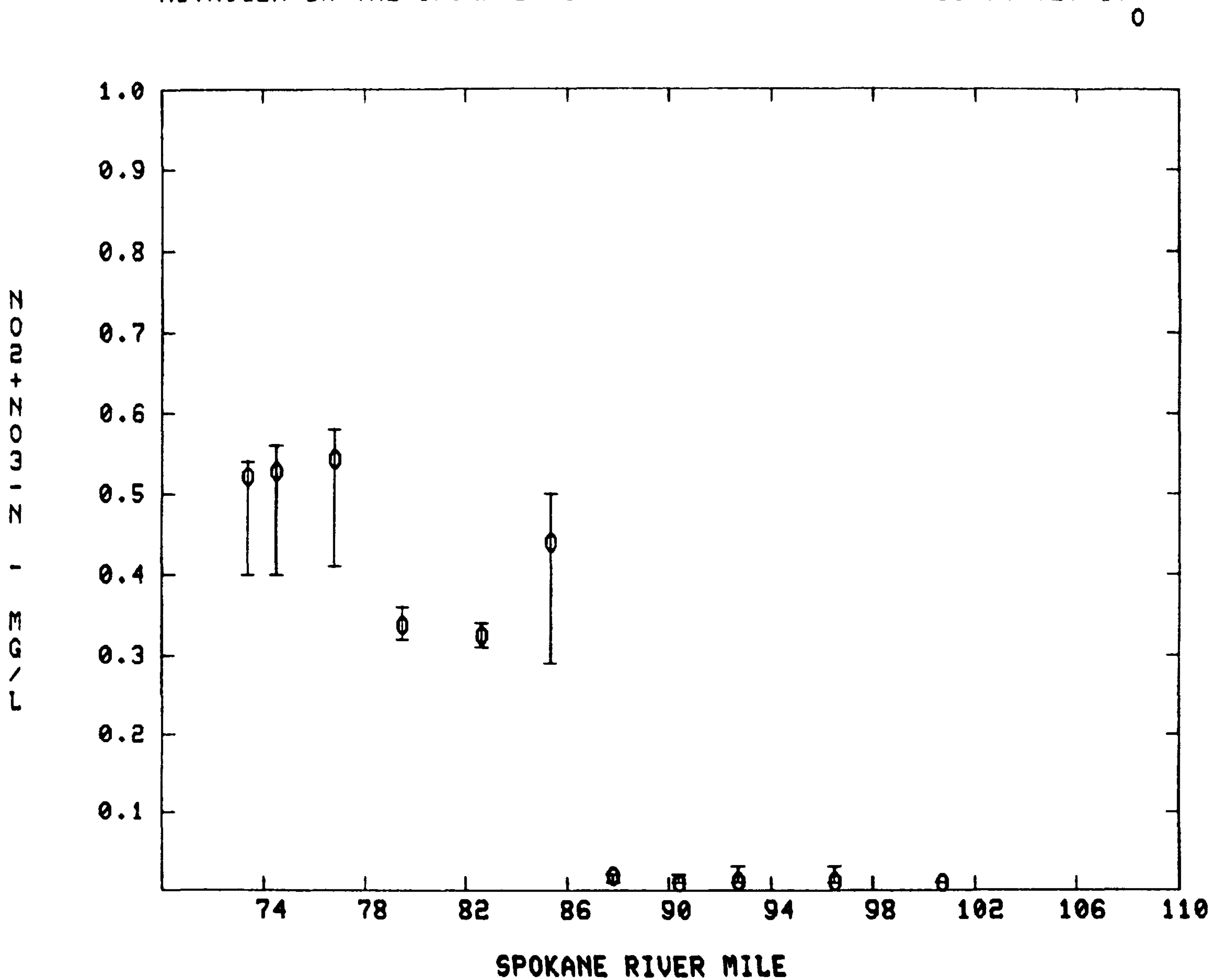


FIGURE 29. AVERAGE, MAXIMUM AND MINIMUM NITRITE+NITRATE-NITROGEN IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY II.

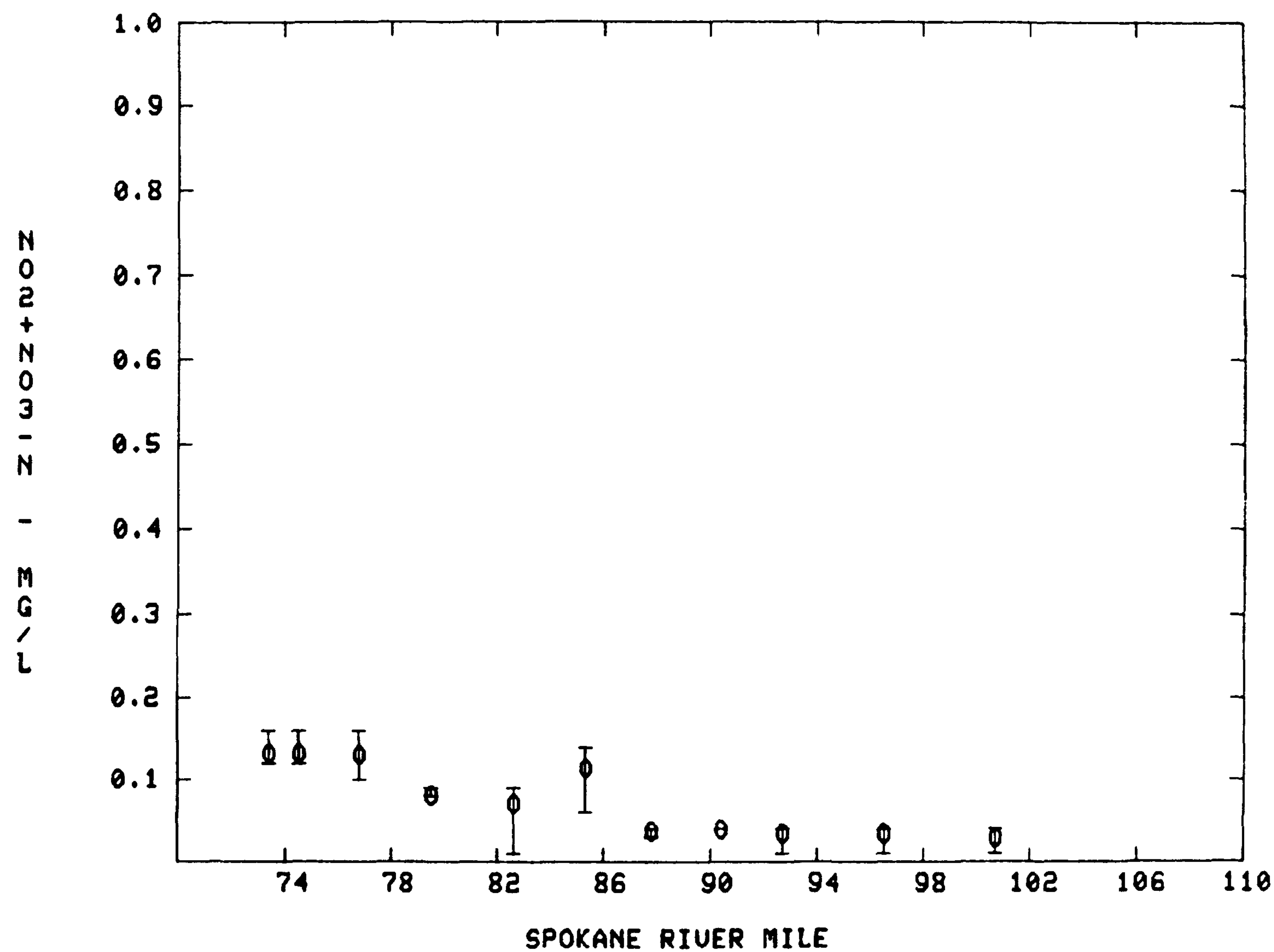


FIGURE 30. AVERAGE, MAXIMUM AND MINIMUM NITRITE+NITRATE-NITROGEN IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY III.

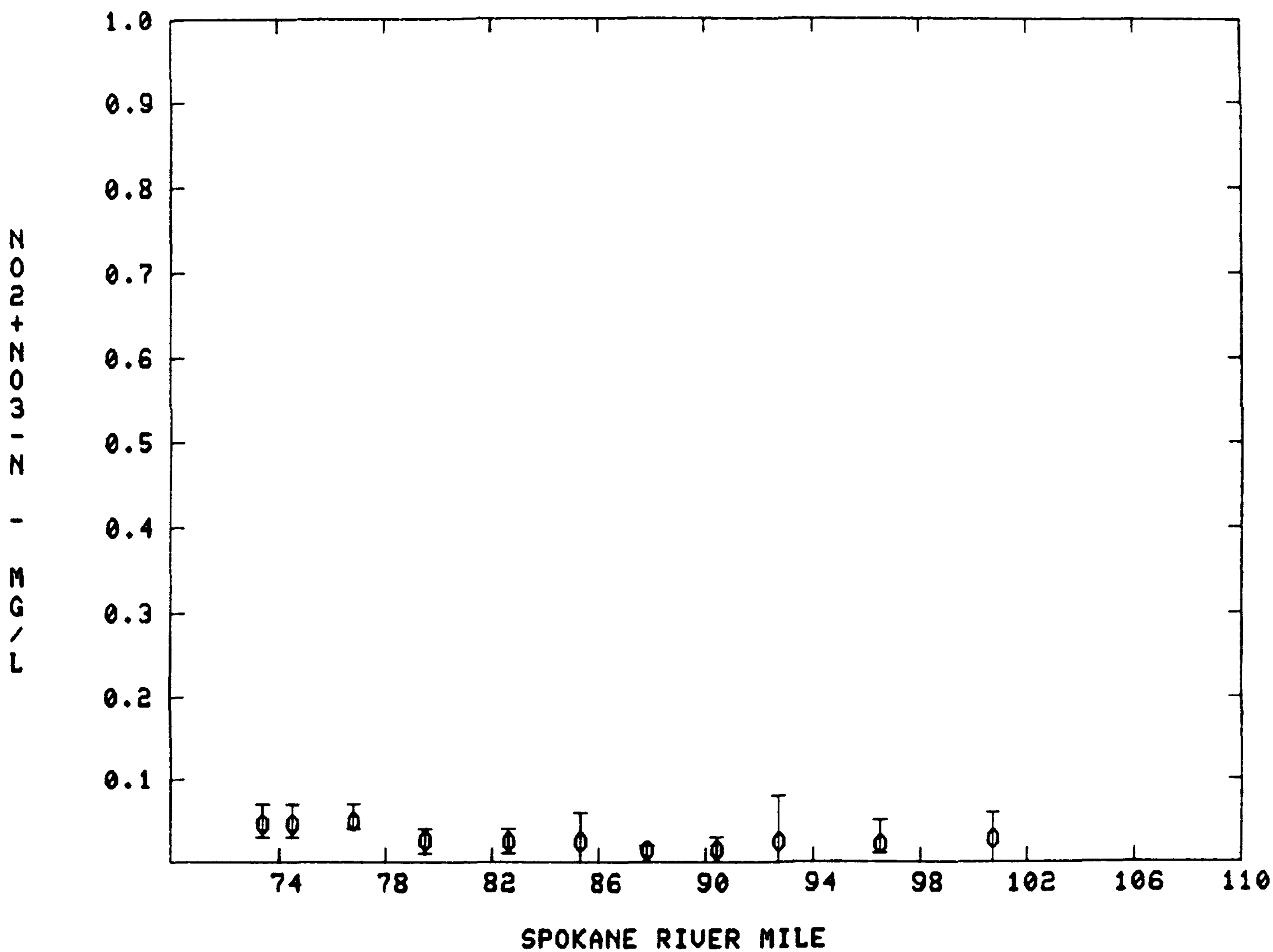


FIGURE 31. AVERAGE, MAXIMUM AND MINIMUM NITRITE+NITRATE-NITROGEN IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY IV.

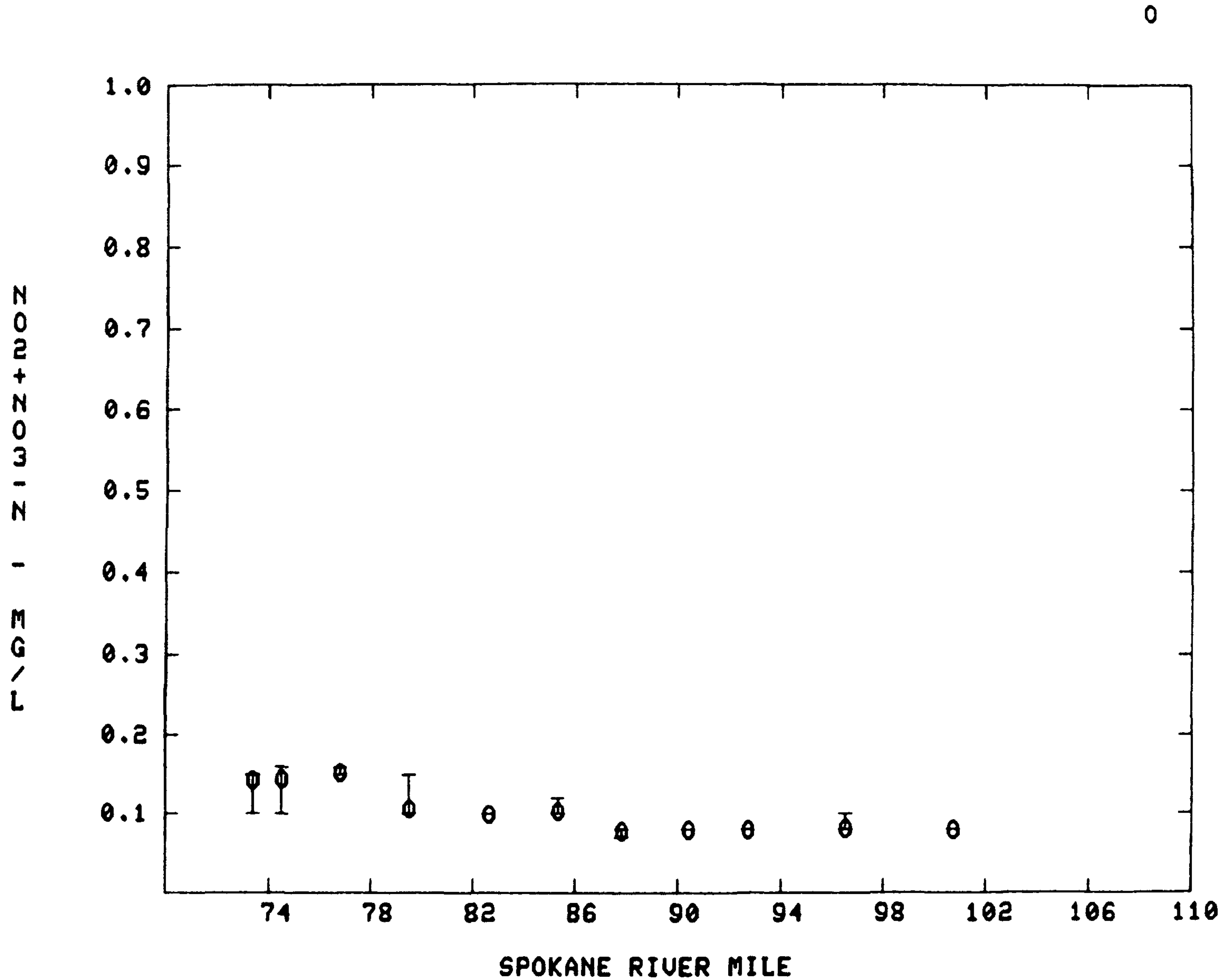


FIGURE 32. AVERAGE, MAXIMUM AND MINIMUM TOTAL PHOSPHORUS IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY I.

O

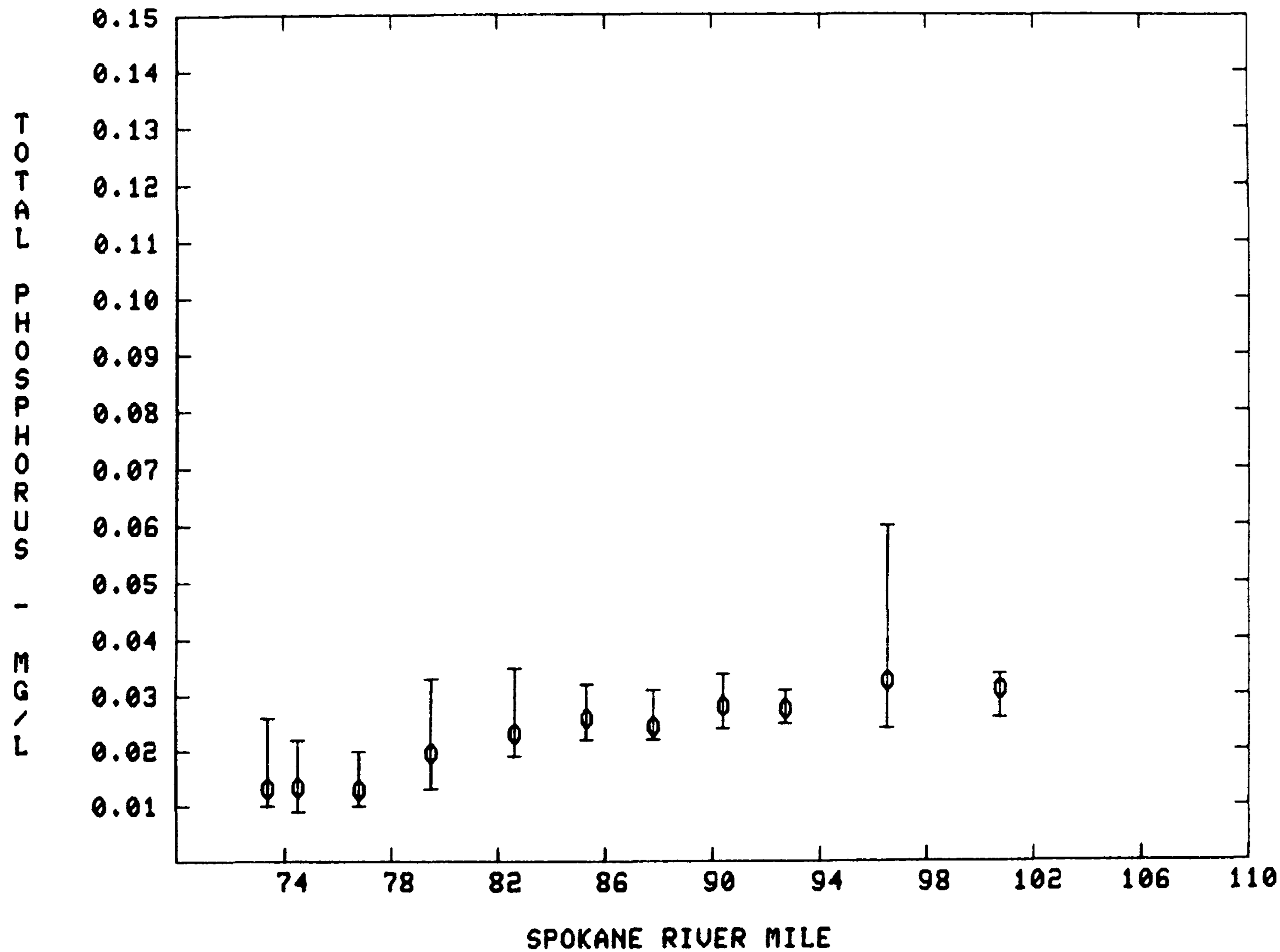


FIGURE 33. AVERAGE, MAXIMUM AND MINIMUM TOTAL PHOSPHORUS IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY II.

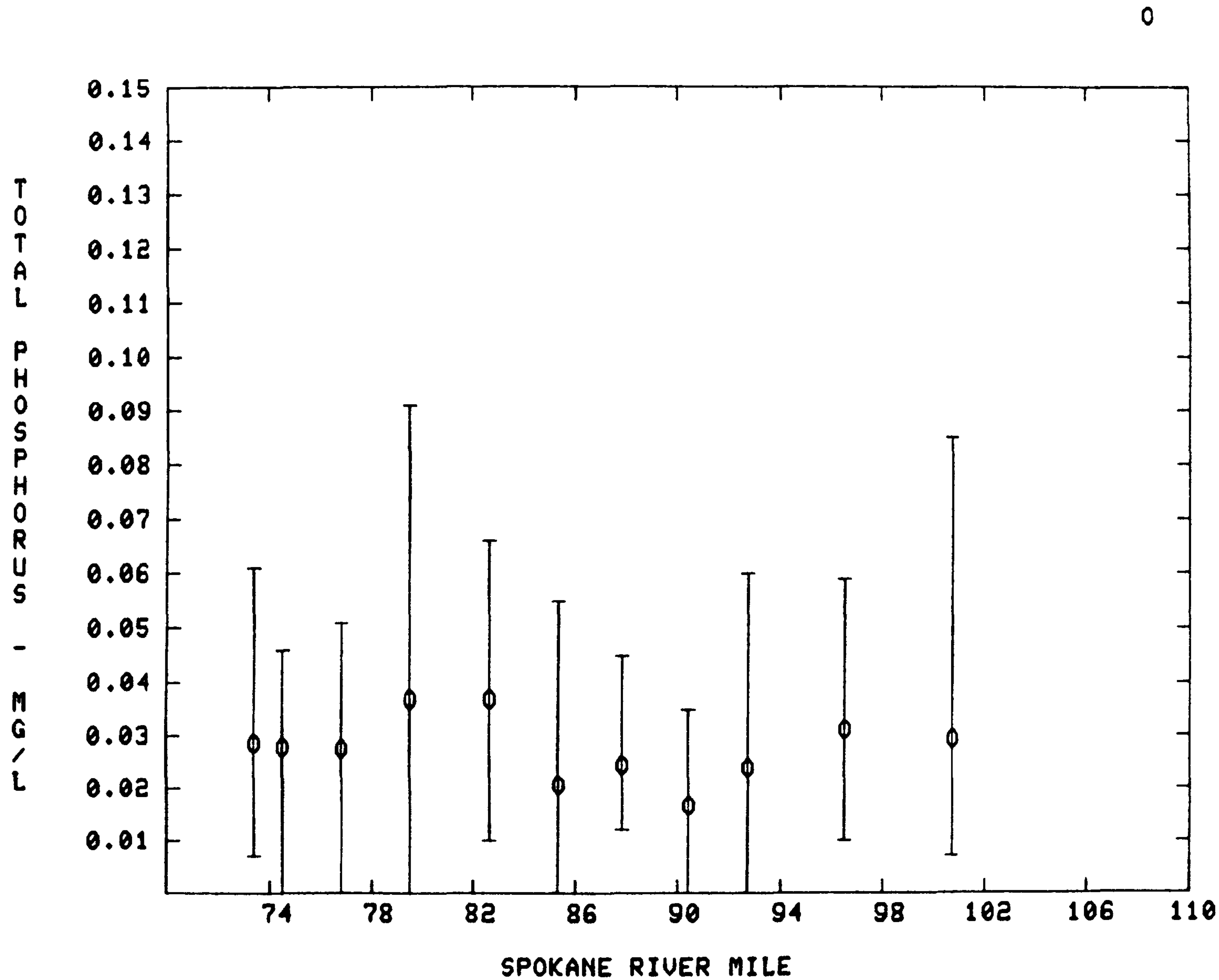


FIGURE 34. AVERAGE, MAXIMUM AND MINIMUM TOTAL PHOSPHORUS IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY III.

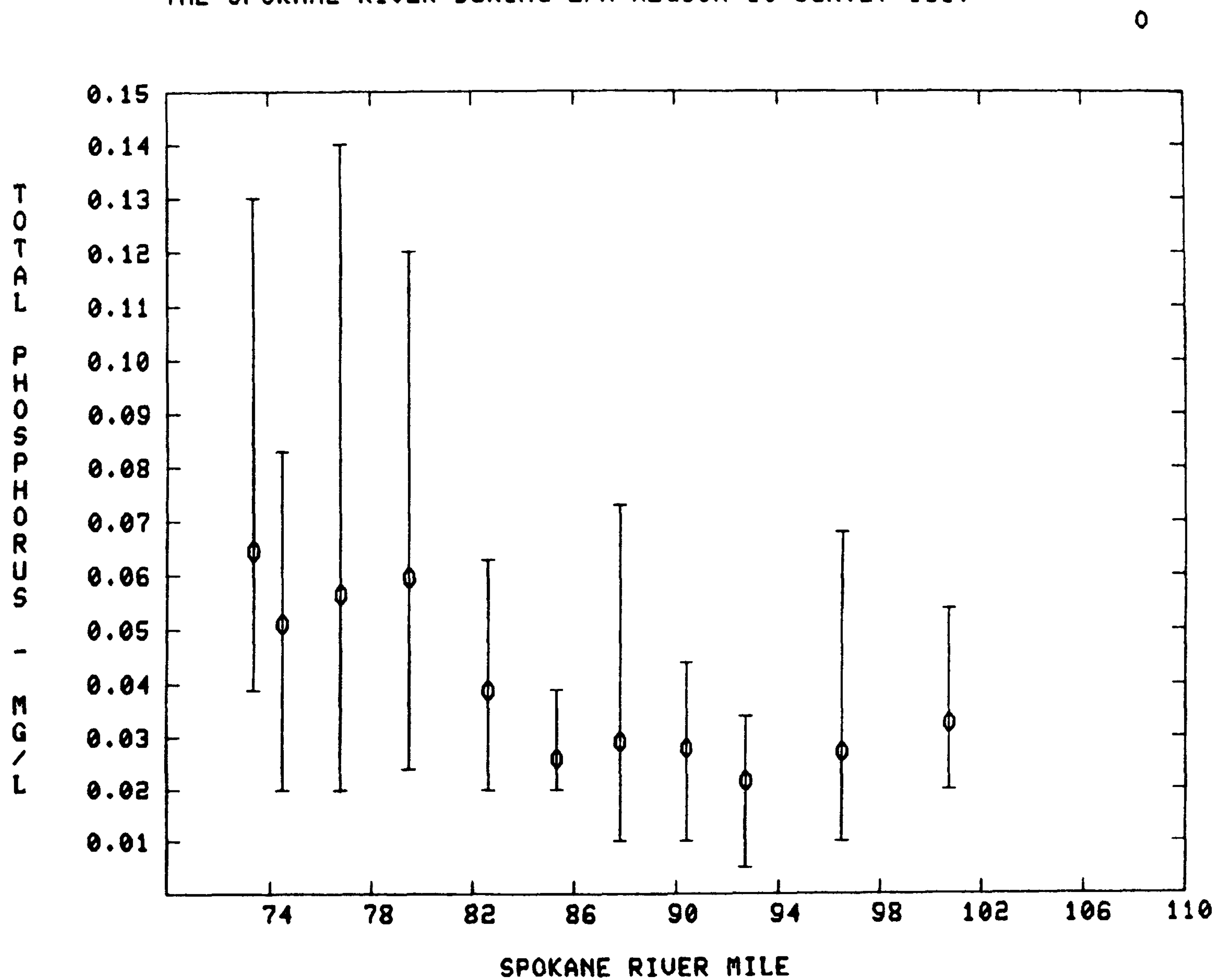


FIGURE 35. AVERAGE, MAXIMUM AND MINIMUM TOTAL PHOSPHORUS IN THE SPOKANE RIVER DURING EPA REGION 10 SURVEY IV.

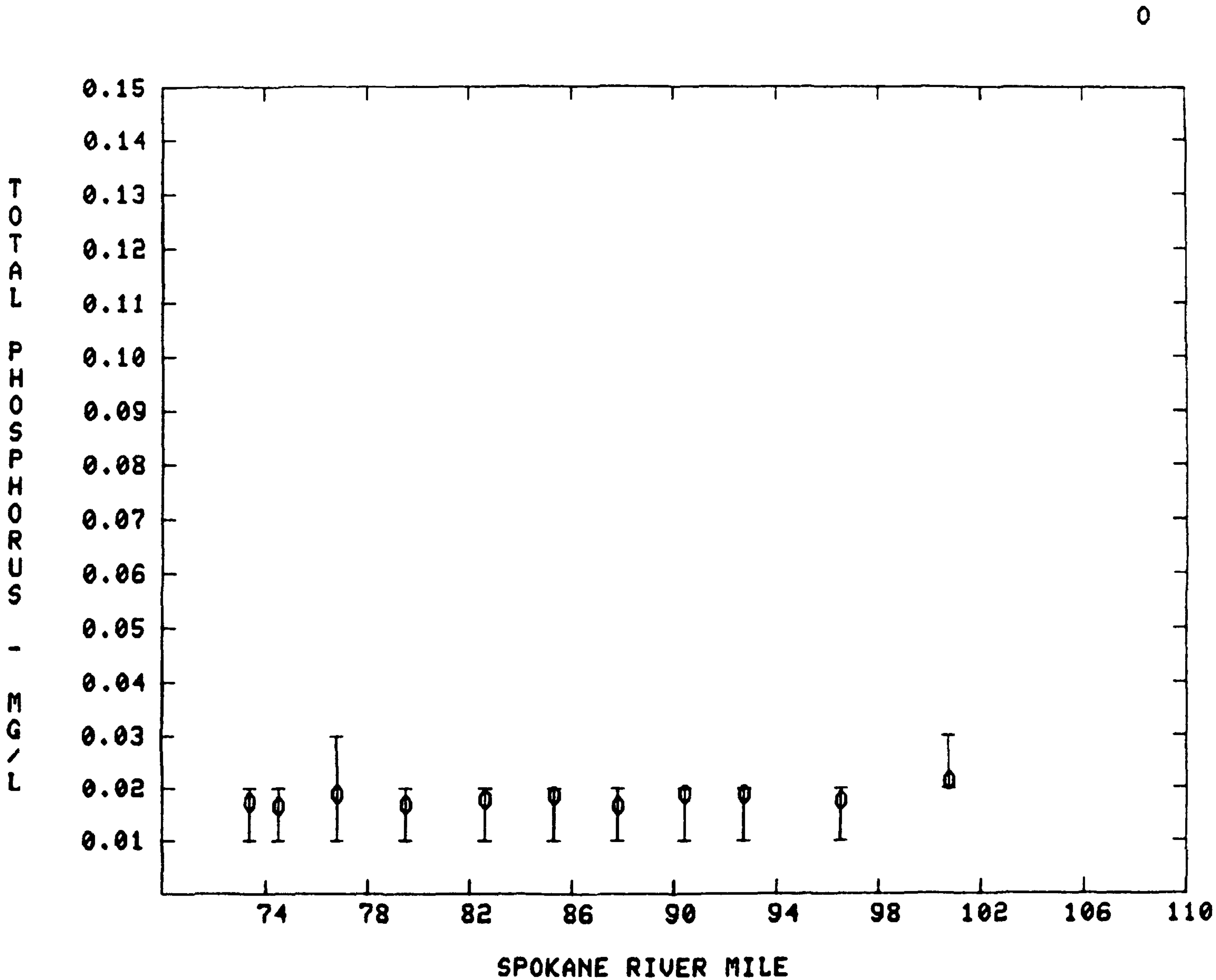


FIGURE 36. AVERAGE, MAXIMUM AND MINIMUM TEMPERATURE IN THE SPOKANE RIVER DURING EPA REGION 10 INTENSIVE SURVEY I.

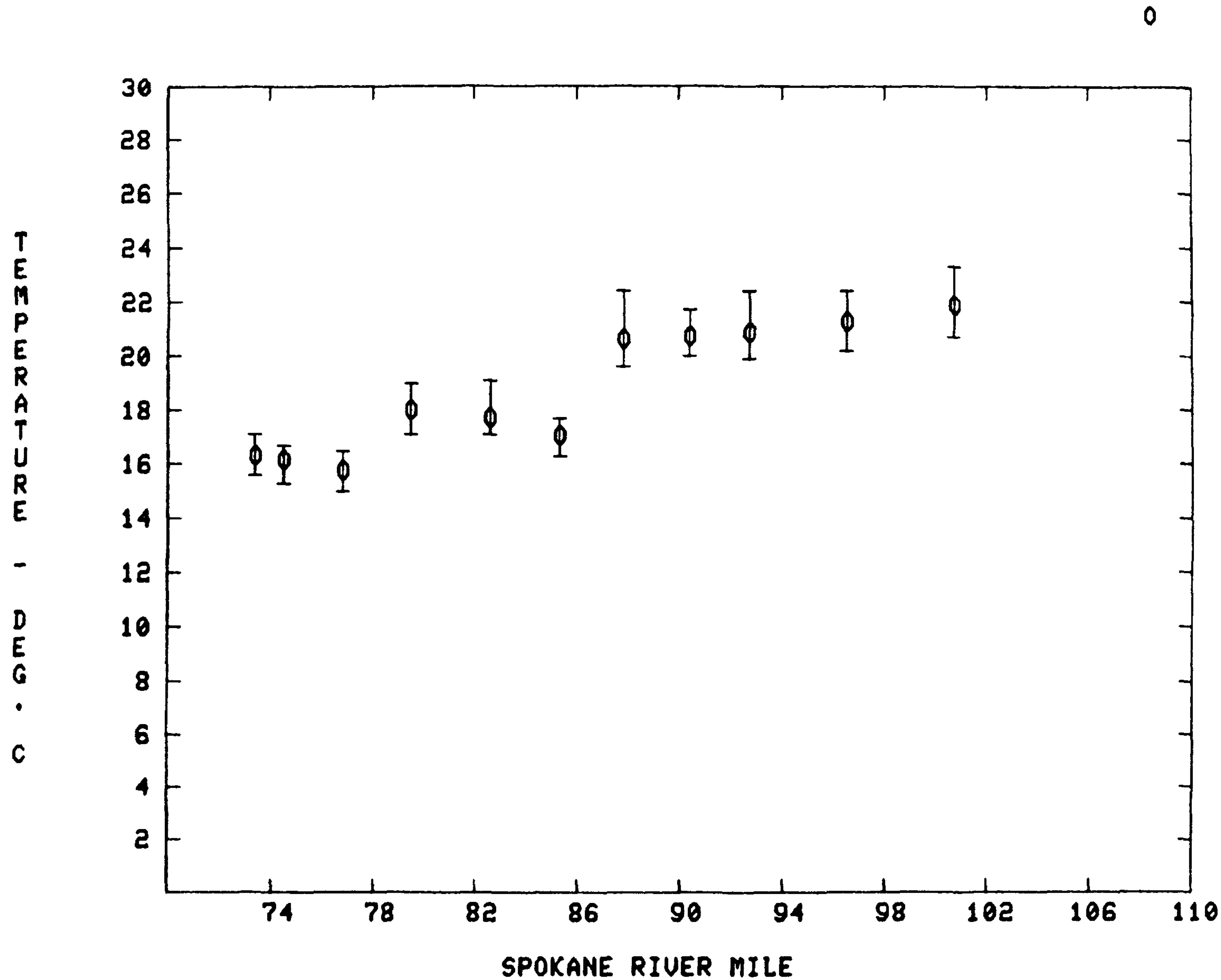


FIGURE 37. AVERAGE, MAXIMUM AND MINIMUM TEMPERATURE IN THE SPOKANE RIVER DURING EPA REGION 10 INTENSIVE SURVEY II.

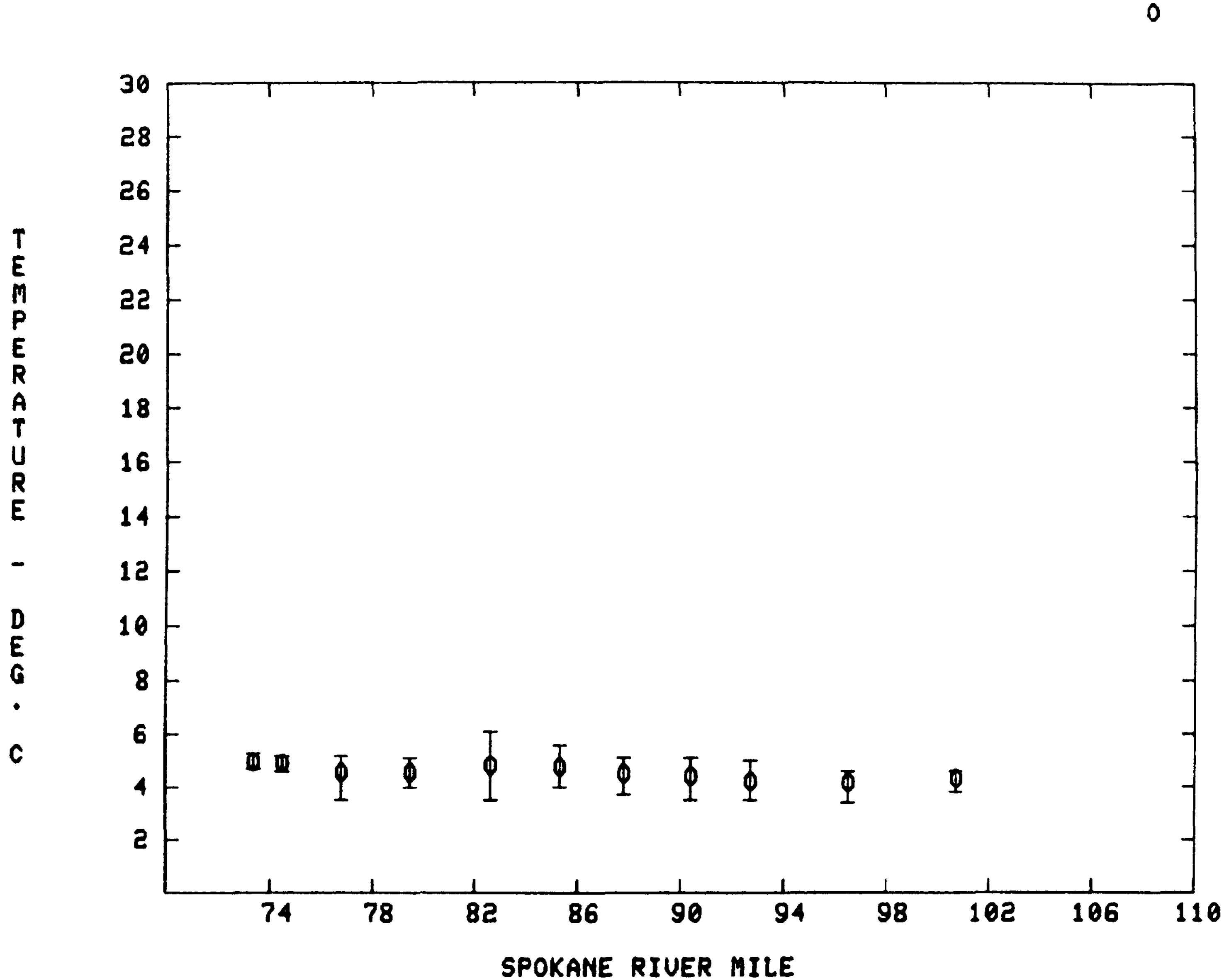


FIGURE 38. AVERAGE, MAXIMUM AND MINIMUM TEMPERATURE IN THE SPOKANE RIVER DURING EPA REGION 10 INTENSIVE SURVEY III.

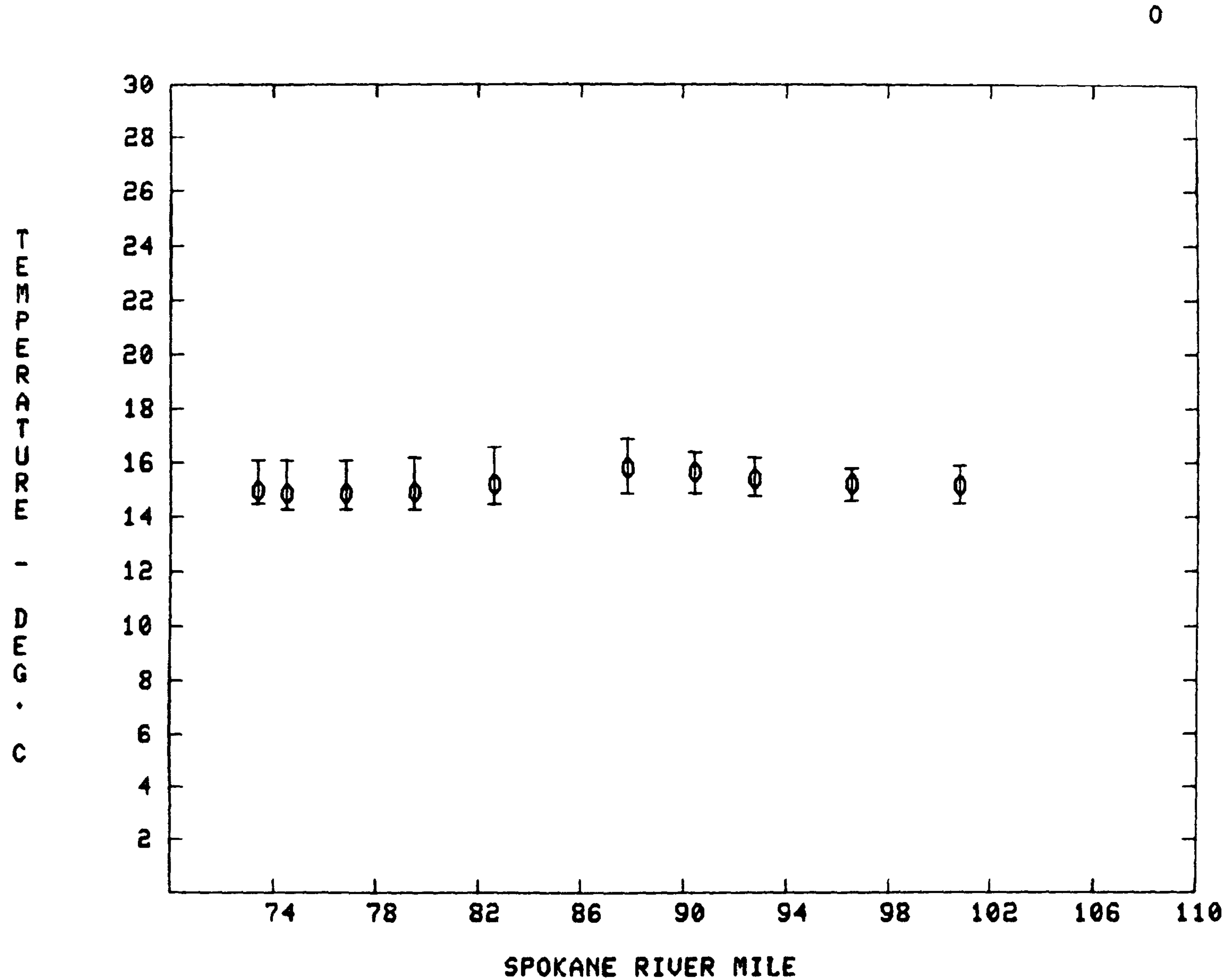


FIGURE 39. AVERAGE, MAXIMUM AND MINIMUM DISSOLVED OXYGEN IN THE SPOKANE RIVER DURING EPA REGION 10 INTENSIVE SURVEY I.

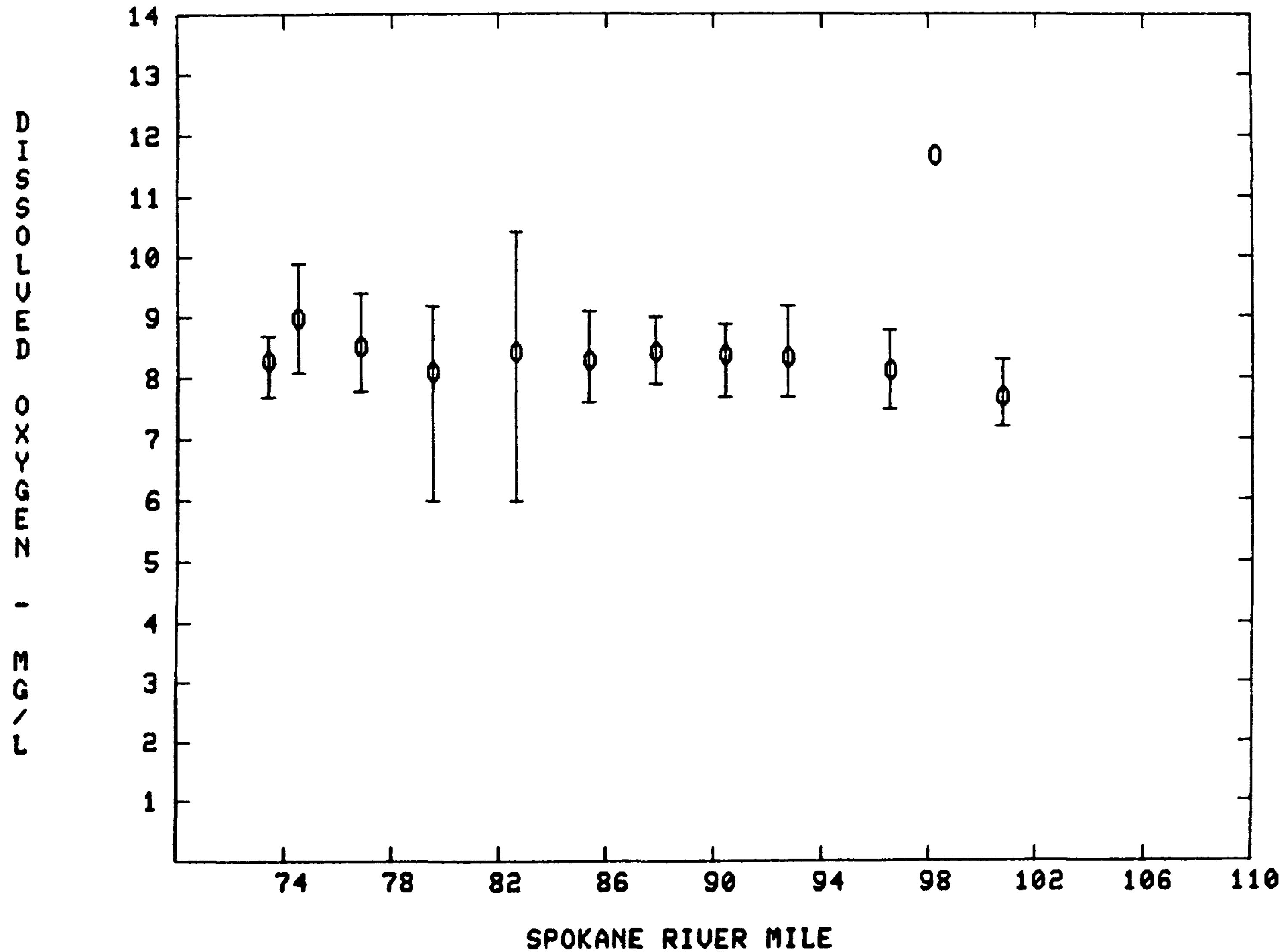


FIGURE 40. SIMULATED AND OBSERVED DISSOLVED OXYGEN IN THE SPOKANE RIVER DURING SURVEY I.

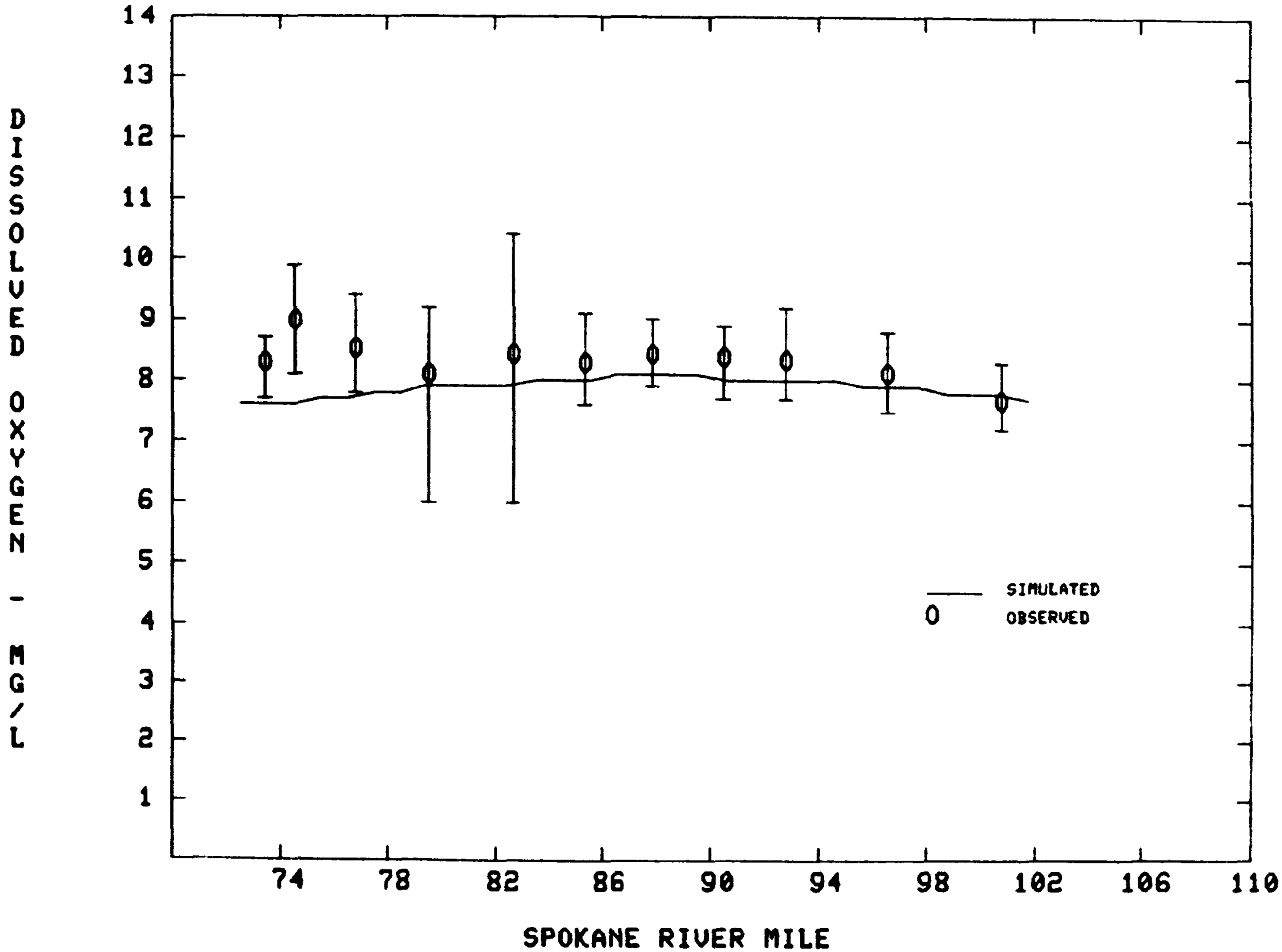


FIGURE 41. SIMULATED AND OBSERVED TEMPERATURE IN THE SPOKANE RIVER DURING SURVEY I.

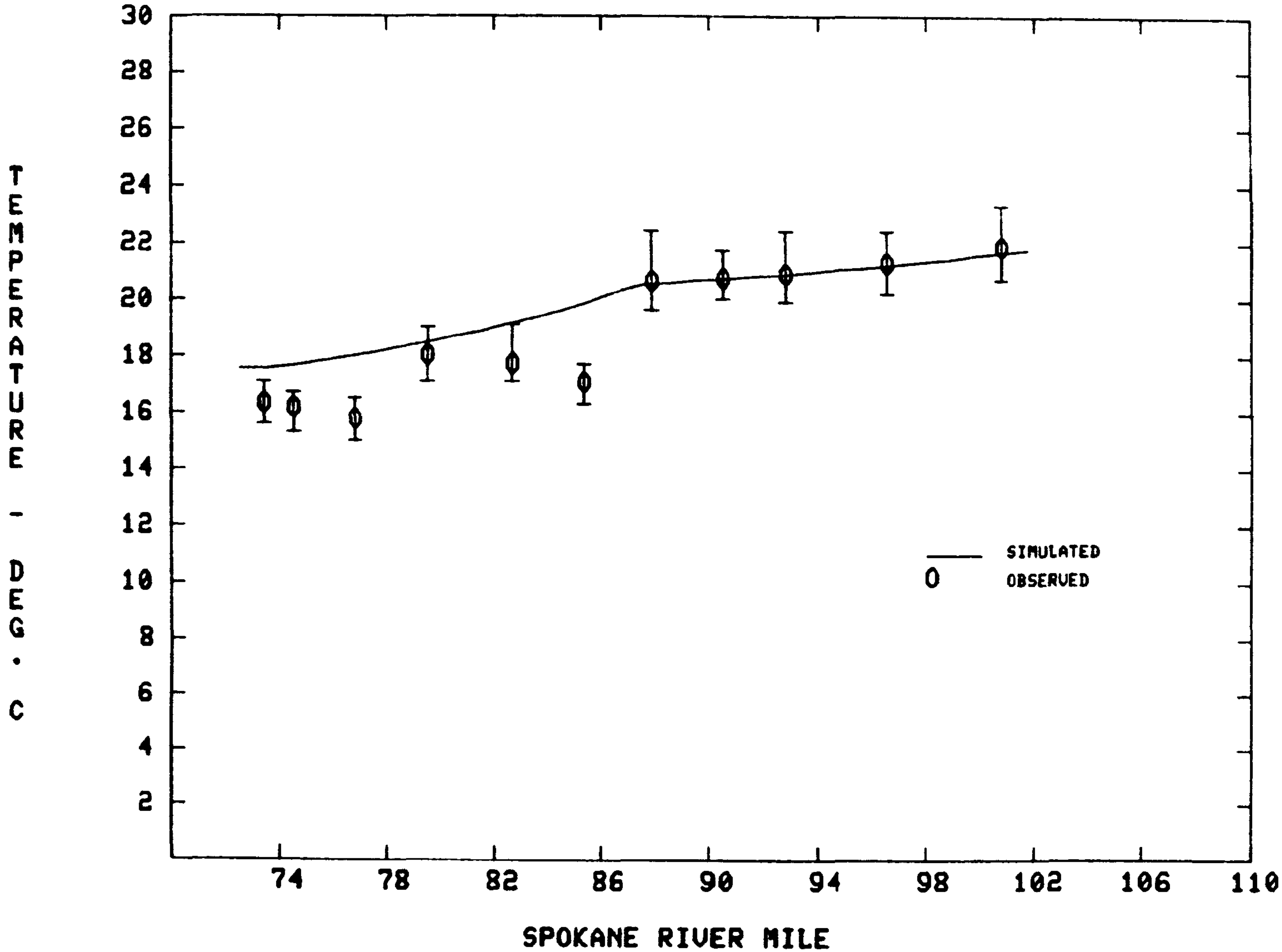


FIGURE 42. SIMULATED AND OBSERVED TOTAL PHOSPHORUS IN THE SPOKANE RIVER DURING SURVEY I.

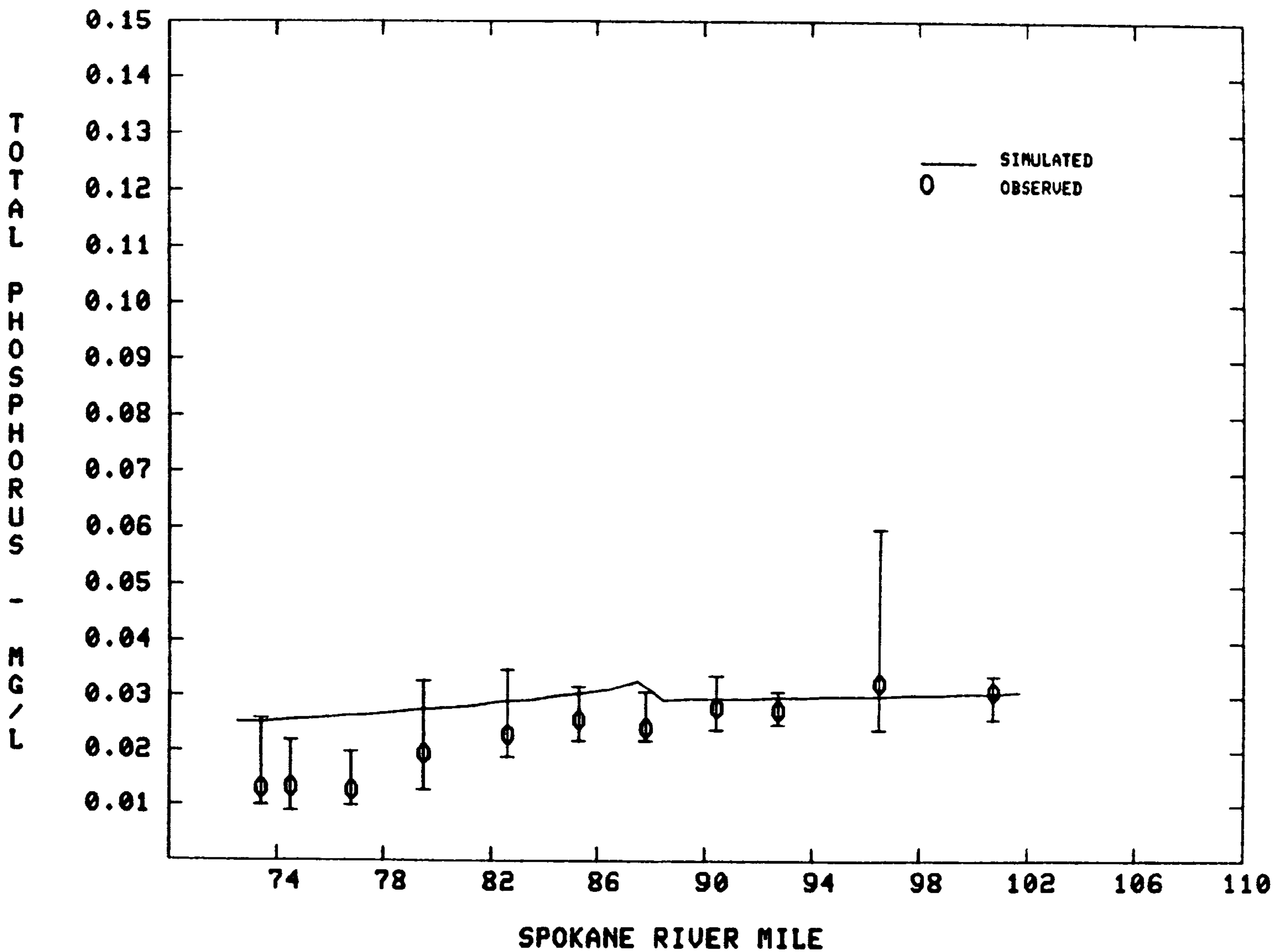


FIGURE 43. SIMULATED AND OBSERVED TEMPERATURE IN THE SPOKANE RIVER SHOWING THE EFFECT OF GROUNDWATER TEMPERATURE.

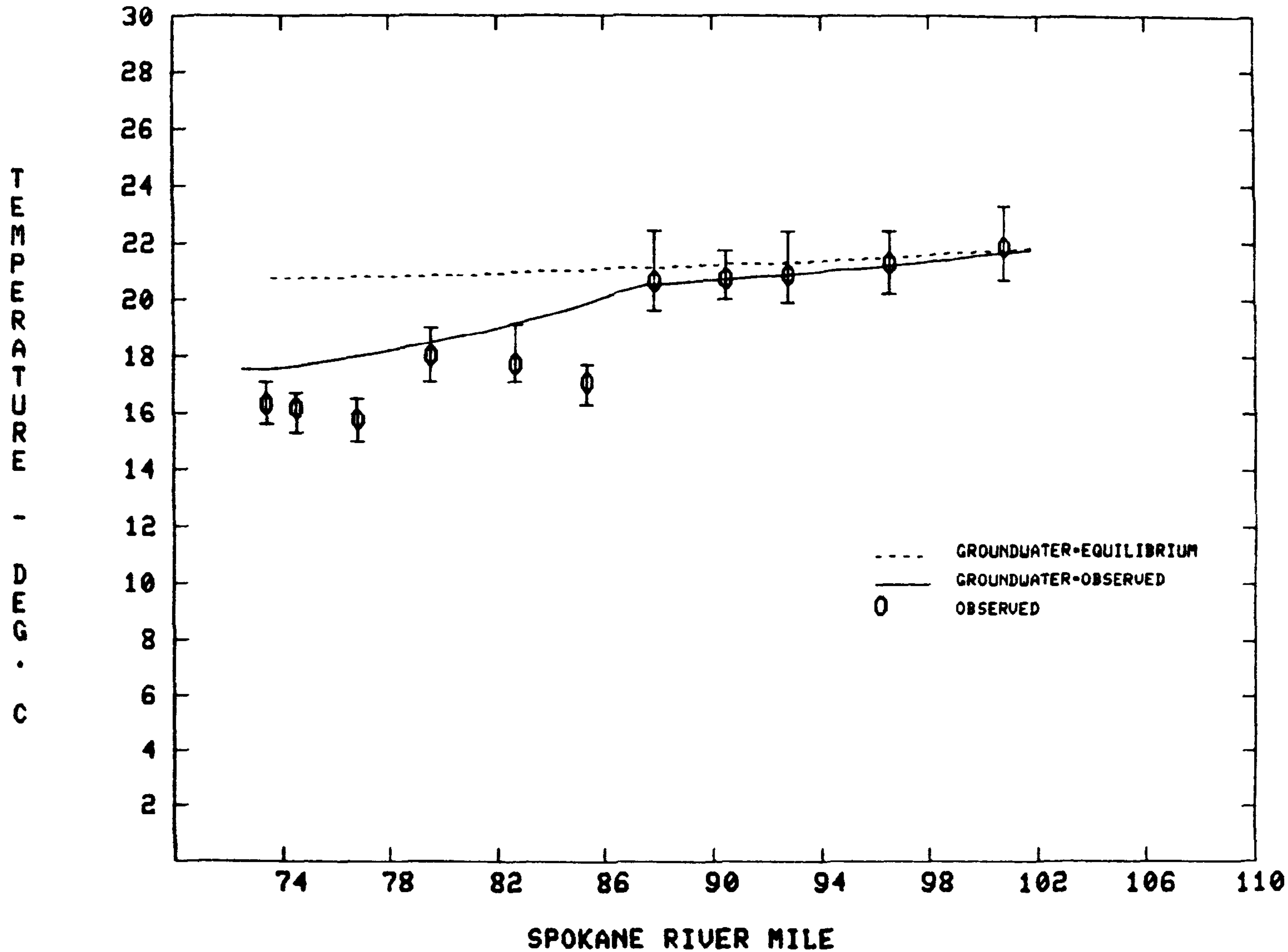


FIGURE 44. SIMULATED AND OBSERVED NITRITE+NITRATE-NITROGEN IN THE SPOKANE RIVER DURING SURVEY I.

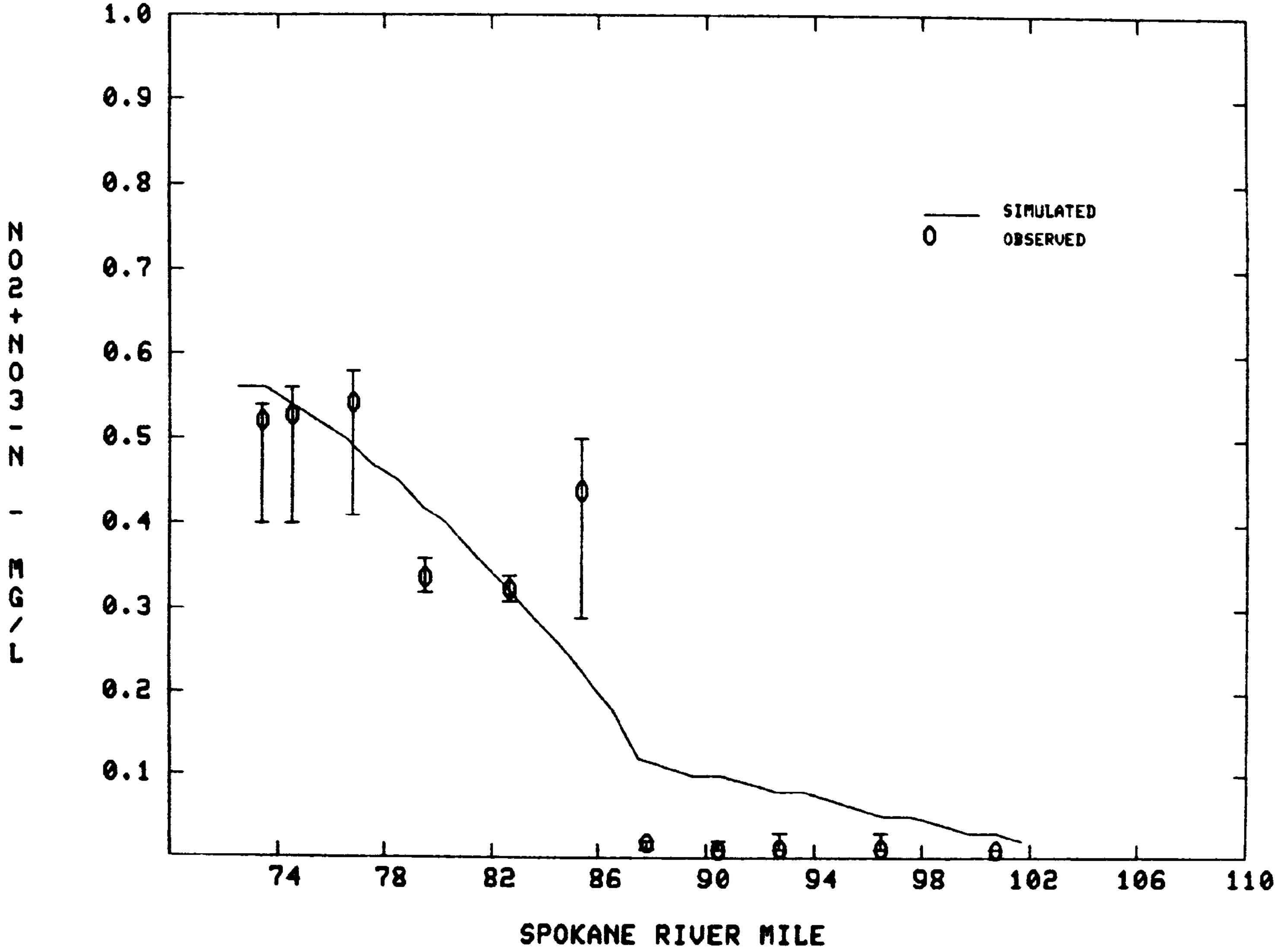


FIGURE 45 . SIMULATED AND OBSERVED TOTAL ZINC IN THE SPOKANE RIVER DURING SURVEY I.

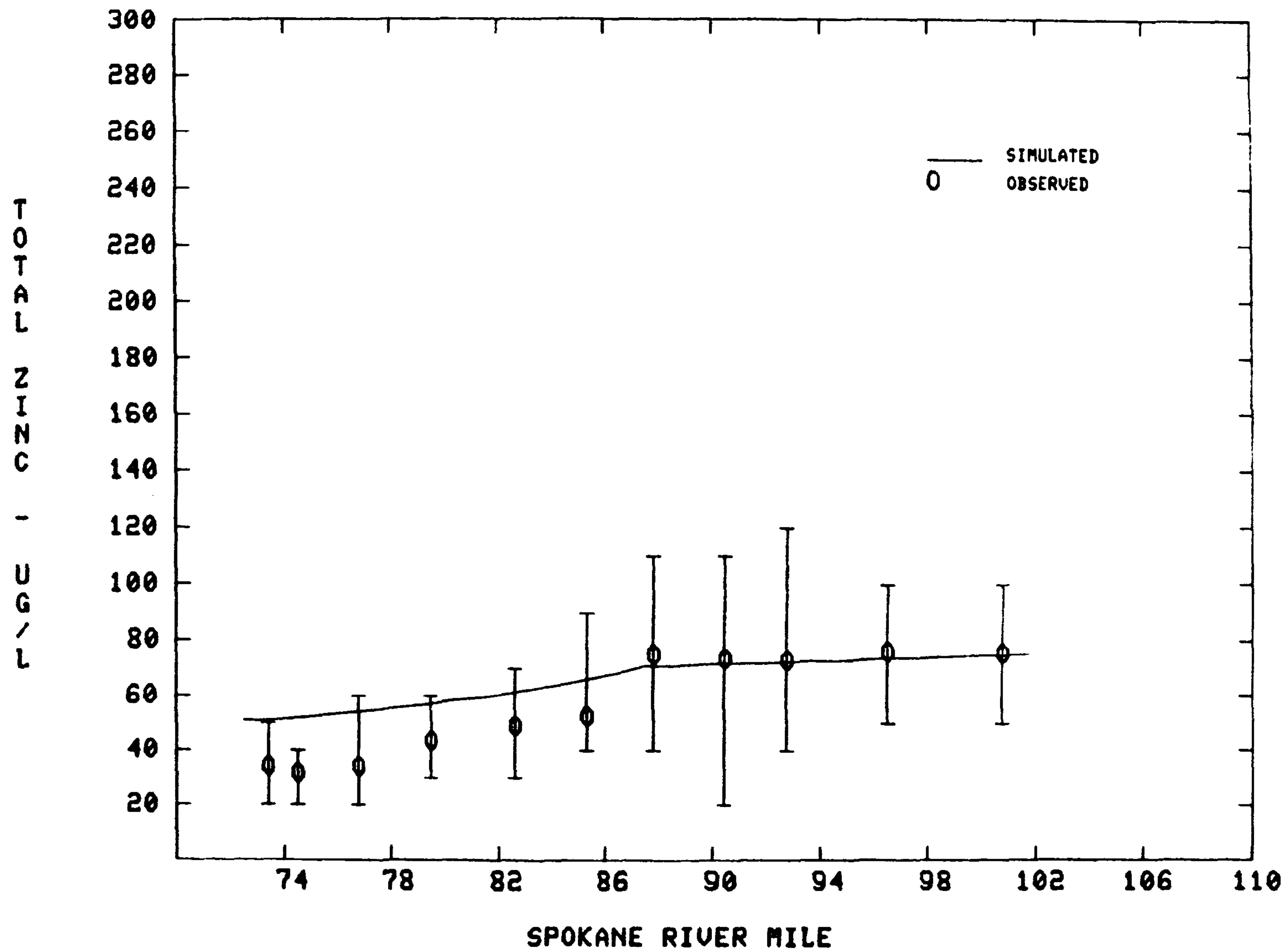
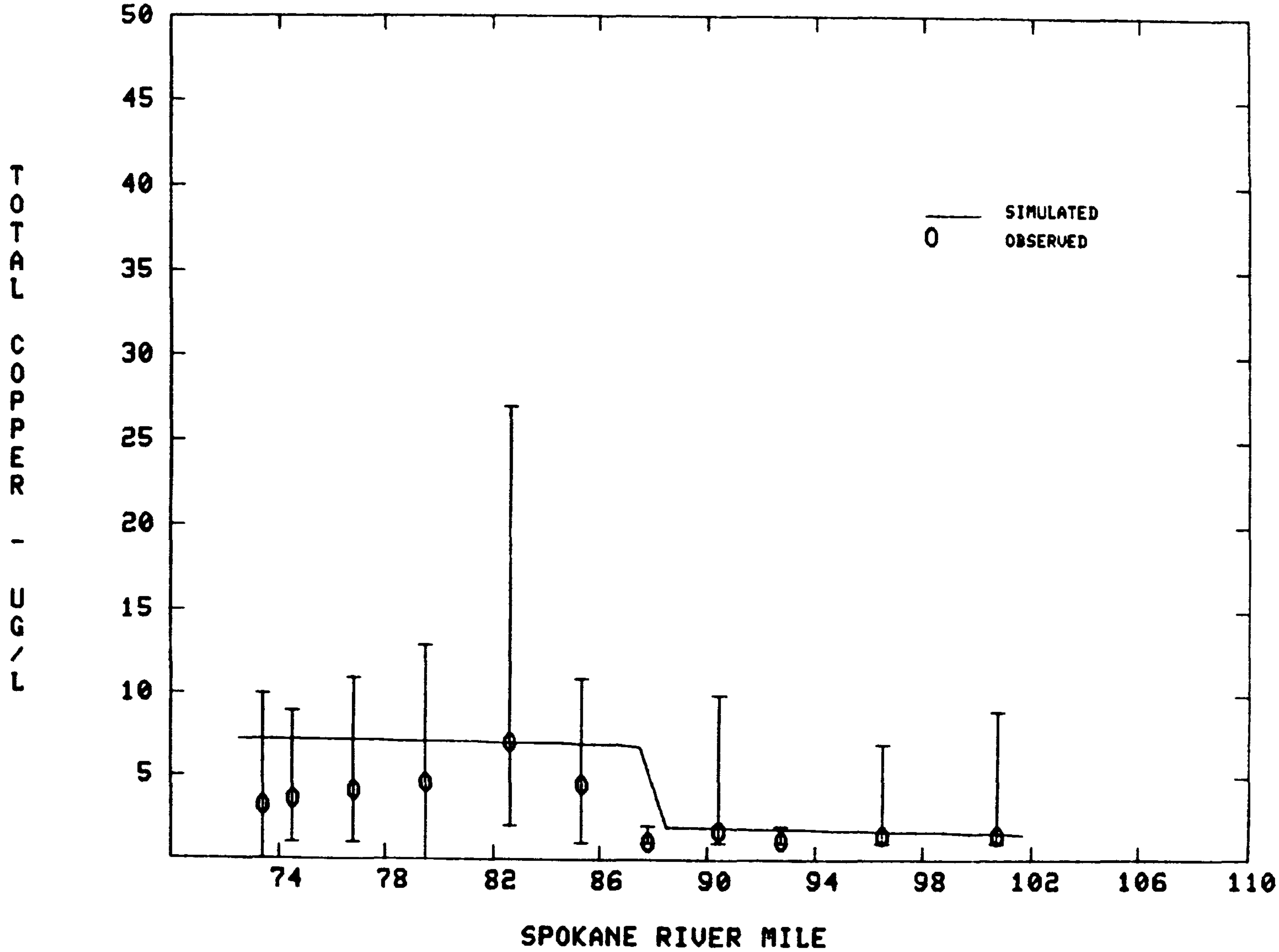


FIGURE 46. SIMULATED AND OBSERVED TOTAL COPPER IN THE SPOKANE RIVER DURING SURVEY I.



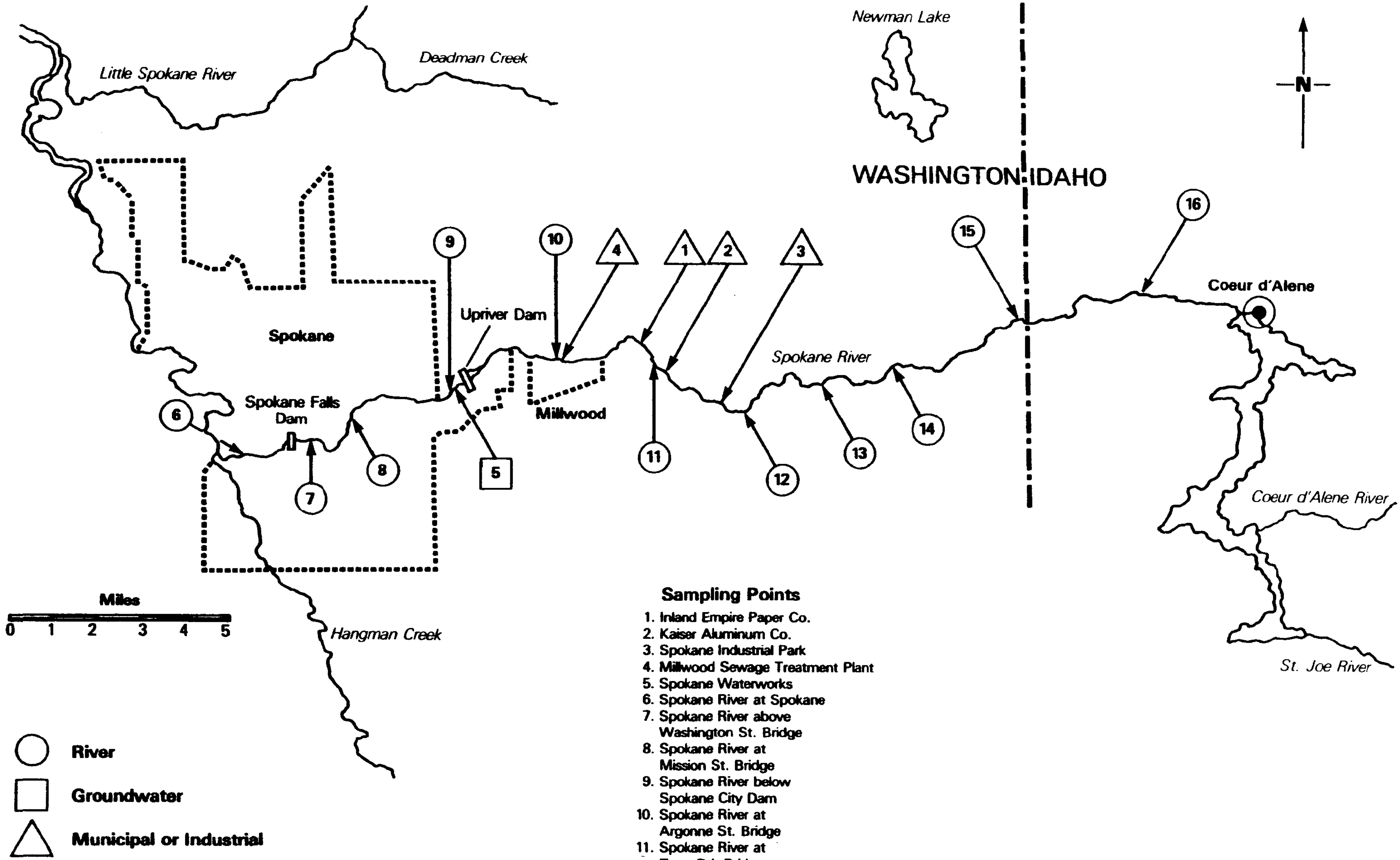
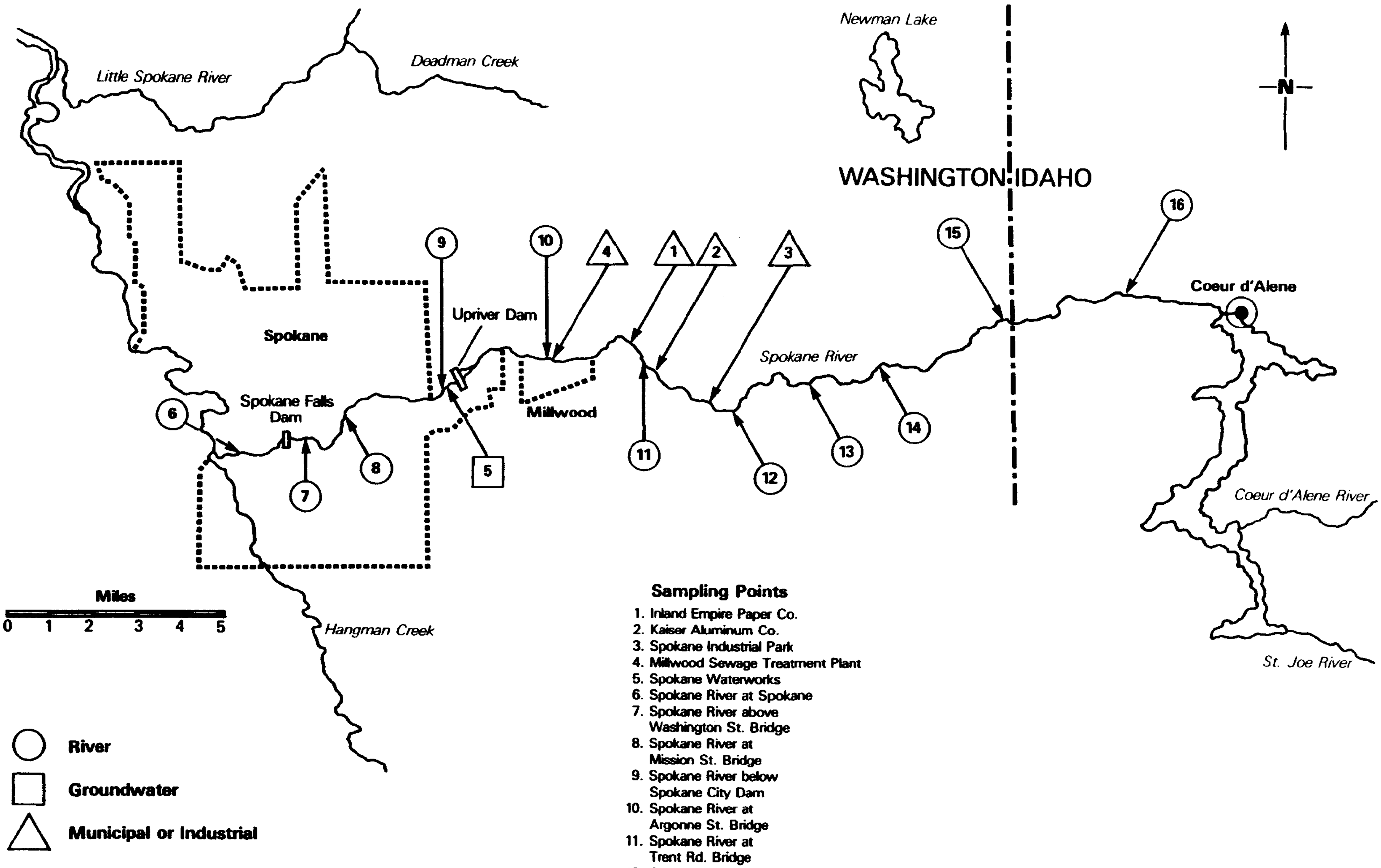


Figure 3. EPA Region 10 Intensive Surveys 1979-1981

Sampling Points

1. Inland Empire Paper Co.
2. Kaiser Aluminum Co.
3. Spokane Industrial Park
4. Millwood Sewage Treatment Plant
5. Spokane Waterworks
6. Spokane River at Spokane
7. Spokane River above Washington St. Bridge
8. Spokane River at Mission St. Bridge
9. Spokane River below Spokane City Dam
10. Spokane River at Argonne St. Bridge
11. Spokane River at Trent Rd. Bridge
12. Spokane River at Sullivan Rd. Bridge
13. Spokane River at Barker Rd. Bridge
14. Spokane River at Harvard Rd. Bridge
15. Spokane River at State Line Bridge
16. Spokane River below Post Falls



Sampling Points

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