WATER QUALITY DATA SUMMARY AND LINEAR TREND ANALYSIS OF THE WENATCHEE RIVER BASIN

by
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ABSTRACT

At the request of the Department of Ecology, Central Regional Office, a review and statistical analysis of water quality data from the Wenatchee River Basin was done. Graphical data summaries of selected parameters from both long-term sites on the Wenatchee River are presented. Linear trend analysis revealed a significant increasing trend in percent saturation dissolved oxygen and pH at the Wenatchee River site near Wenatchee (45A070). Also marginal trends ($P < 0.10$) in temperature (increasing) and nitrate/nitrite concentration (decreasing) were detected at this site. A significant upward trend in pH and downward trend in nitrate/nitrite concentration were detected in the data from the Wenatchee River site near Tumwater Campground, upstream from Leavenworth (45A110). Differences in median value between these sites were found in temperature (1.2°C), percent saturation of dissolved oxygen (6%), pH (0.3), nitrate/nitrite concentration (0.057 mg N/L), total suspended solids (1.0 mg/L) and fecal coliform (5/100 mL). The major concern seen from this analysis is the high temperature and high pH values at the site near Wenatchee.

INTRODUCTION

The Ambient Monitoring Section maintains two long-term (core) sampling sites in the Wenatchee River Basin (Table 1); the Wenatchee River at the Highway 2/97 Bridge near Wenatchee (45A070); and the Wenatchee River at the Highway 2 Bridge near the Tumwater Campground (upstream from Leavenworth) (45A110). Samples were also collected in 1976 (wateryear) from

Table 1. Ambient monitoring sites in the Wenatchee River Basin and number of years of collection. Not all parameters were measured in all years.

Site	Storet #	Year
Wenatchee R. @ Wenatchee	45A070	27
Wenatchee R. @ Dryden	45A085	1
Wenatchee R. @ Leavenworth	45A100	1
Wenatchee R. @ Tumwater	45A110	14
Icicle Cr. @ Leavenworth	45B070	1

the Wenatchee River off the downstream Highway 2/97 Bridge at Dryden (45A085); in 1977 from the Wenatchee River off the Icicle Creek Road Bridge in Leavenworth (45A100); and from Icicle Creek off the bridge downstream from the Leavenworth National Fish Hatchery (45B070). Samples are being collected at the Icicle Creek site at the present time.

This report is organized as follows:

1) Site (45A070), the Wenatchee River at Wenatchee:

   a) descriptive statistics of selected parameters, and
   b) results of trend analyses.

2) Site (45A110), the Wenatchee River at Tumwater Campground:

   a) descriptive statistics of selected parameters, and
   b) results of trend analyses.

3) Comparison of water quality variables between these two long-term sites.

4) Data collected from the other sites listed above (presented in Appendix A).

Data Analysis Methods

I chose box-plot type graphs as the most concise means of summarizing data from the two long-term stations. The dotted horizontal line in each box is the median of the data for that month over all years of collection. The lower and upper horizontal lines of the box are the 25th and 75th percentiles of the data, respectively. The ends of the vertical lines (tails) of the plots denote the minimum and maximum values. Where applicable, I have marked the state water quality standard for that parameter on the graph. The range of years in which the data were collected is noted in the upper right corner of the graph. This may not correspond to the number of data in the upper left corner because of discontinuous data collection and the range may not be the same for all parameters from a single site. The "K-W%" in the upper right corner indicates a statistically significant result of the non-parametric Kruskal-Wallis test. This indicates that this parameter varies seasonally.

Linear trends were assessed using the non-parametric Seasonal Kendall test. Plots of parameters which demonstrate a statistically significant trend over time are discussed, but only those trends which were judged to be ecologically and environmentally significant are shown. For example, changes in the analytical detection limit can produce a false trend in the data if many of the measured values are at or below the detection limit.

Differences between the two sites were examined using the non-parametric Seasonal Wilcoxon-Mann-Whitney test. This tests whether the median value of a parameter differs between sites. The difference between medians is shown on the plot as well as confidence level. As above, only significant results are presented graphically.

A probability level of $P<0.05$ was used to determine statistical significance on all tests, however, marginal ($0.10> P>0.05$) results were noted when, in my judgement, it was warranted. All statistical procedures were performed using WQHYDRO software (Aroner, 1992). A good review of all of the statistical tests discussed above, and non-parametric statistics in general, can be found in Gilbert (1987).

Wenatchee River at Wenatchee-Descriptive Statistics

Temperature exceeded Class A water quality standards (18°C) on approximately 25% of the sampling occasions in July and September, and 50% in August (Figure 1). Dissolved oxygen only rarely dropped below 8.0 mg/L (Figure 2) and showed significant seasonal variation, which is expected and normal. Violations of pH standards occurred primarily in August and September (Figure 3). Seasonal variation in pH was present and is probably associated with higher water temperature, lower flows, and relatively high primary productivity in the summer and fall months. Nitrate/nitrite nitrogen concentration also varied seasonally (Figure 4). Ammonia concentration was low, often at or below the detection limit of the analytical technique (Figure 5). Total phosphorus concentration also was often at or below the detection limit (Figure 6). Total suspended solids varied seasonally, as expected (Figure 7). Turbidity varied by season, however, many values were at or below the lab detection limits (Figure 8). Fecal coliform counts varied seasonally, but were generally well below the water quality standard of 100/100 mL (Figure 9). Figure 10 shows flow distribution by month.

Wenatchee River at Wenatchee-Trend Analysis

Temperature showed a weak increasing trend at this site ($P<0.10$) (Figure 11) (Table 2). The calculated slope was 0.03, translating into a temperature change of 0.8°C since 1960. Given the frequency of temperature violations in July-September, this should be monitored closely. Both dissolved oxygen percent saturation (Figure 12) and pH (Figure 13) demonstrated a significant increasing trend over time. Both percent saturation and pH can be driven upward by high primary productivity (algal photosynthesis), so that, although the methodology for calculating percent saturation and the instruments for measuring pH have changed, the upward trends of both these parameters reinforces the argument that these trends are real. Ammonia concentration showed a statistically significant decreasing trend (not shown), however, this trend was probably a result of the lowering of the detection limits for the chemical analysis in the mid-1980's. Ammonia concentration was often at or below the analytical detection limits and this trend should be ignored. A weak ($P<0.10$) decreasing trend was detected in nitrate/nitrite concentration, but the low statistical confidence level and the low magnitude of the trend slope suggest that this trend is not environmentally significant at this time (Figure 14). Total

Table 2. Results of linear trend analyses at the Wenatchee River sites at Wenatchee and above Leavenworth; i=increasing, d=decreasing, ns=not significant, and id=insufficient data to do analysis.

Variable	above Tumwater	@ Wenatchee
Temperature	ns	ns
D.O. % saturation	i	ns
pH	i	i
NH_3	id	id
NO_3+NO_2	ns	d
Total phosphorus	id	id
T. suspended solids	ns	ns
Turbidity	id	id
Fecal coliform	d	ns

phosphorus concentration was often at or below the analytical detection limit. In addition, the detection limit was lowered in the mid-1980's, therefore, the trend indicated by the statistical analysis (not shown) is merely an artifact and should be ignored. Total suspended solids showed no significant trend. The significant decreasing trend (not shown) found in the turbidity data was the result of numerous values at the detection limits and several changes (decreases) in the reported detection limits over the last 30 years. The significant decreasing trend in fecal coliform bacteria is probably real, although the magnitude is not great (Figure 15). Note the $\log_{10}$ scale.

Wenatchee River Above Leavenworth-Descriptive Statistics

More than 50% of the reported temperatures were in violation of Class AA standards (>16°C) in August, and >25% in September (Figure 16). Although dissolved oxygen concentration was generally higher at this site, >50% of the values were in violation in August (<9.5 mg/L) (Figure 17). Seasonal variation was not detected in the pH data and few water quality violations occurred (Figure 18). Nitrate/nitrite concentration was generally low (<0.100 mg/L), and significant seasonal variation was present (Figure 19). Ammonia concentration was usually near the detection limit (Figure 20). Total phosphorus was also very near the analytical detection limit (Figure 21). Total suspended solids concentration was low but displayed significant seasonal variation (Figure 22). Most turbidity values were at the analytical detection limit (Figure 23). Fecal coliform values were low, especially in late winter-early spring, well below the water quality standard (50 /100 mL) (Figure 24). Flow distribution by month is shown in Figure 25.

Wenatchee River at Wenatchee-Trend Analysis

No significant linear trends were detected in temperature, dissolved oxygen percent saturation, total suspended solids, or fecal coliform bacteria. A significant increasing trend was detected in pH (Figure 26), but the magnitude of the change was less than at the Wenatchee site (Figure 13). Significant decreasing trends were detected in ammonia, nitrate/nitrite, and total phosphorus concentrations, and in turbidity. However, due to the low values and to changes in analytical detection limits over time (as discussed above), the trends in ammonia, total phosphorus, and turbidity are artifacts and should be ignored. The decreasing trend in nitrate/nitrate concentration is real (Figure 27).

Comparisons Between the Two Long-term Sites

Statistically significant differences were detected in temperature (Figure 28), percent dissolved oxygen saturation (Figure 29), pH (Figure 30), nitrate/nitrite (Figure 31), total phosphorus (not shown), total suspended solids (Figure 32), turbidity (not shown), and fecal coliform bacteria (Figure 33) (Table 3). However, as discussed above, low values and changing detection limits make the differences in total phosphorus concentration and turbidity meaningless. Although the difference in fecal coliform is low (5/100 mL) the difference is probably real.

Table 3. Results of Wilcoxon-Mann-Whitney rank sum test and difference between Wenatchee River sites at Wenatchee and at Tumwater Campground above Leavenworth in median value. For all significant differences, the Wenatchee site had the higher median value. id=insufficient data.

Variable	Difference
Temperature (°C)	1.2
D.O. % saturation	6%
pH	0.3
NH_3	id
NO_3+NO_2 (mg/L)	0.057
Total phosphorus	id
T. suspended solids (mg/L)	1.0
Turbidity	id
Fecal coliform	5

Water Quality Data From Other Sites

Data were collected at two other sites on the Wenatchee River, at Dryden (1976) and at the Icicle Creek Road Bridge in Leavenworth (1977), and one on Icicle Creek near Leavenworth (1977). I compared median values of all parameters monitored from the Wenatchee River site at Dryden with the site near Wenatchee for the water year 1976 using the Seasonal Wilcoxon-Mann-Whitney rank sum test. Median temperature was 2.1°C higher at the Wenatchee site. No other parameters (dissolved oxygen, pH, ammonia, total phosphorus, turbidity, and fecal coliform bacteria) were different. Likewise, the Icicle Creek site was compared to the Wenatchee River site at the Icicle Creek Road Bridge and, except for temperature (1.2°C higher in the Wenatchee River), no parameters were significantly different.

RECOMMENDATIONS

A significant increasing linear trend was detected at the Wenatchee River at Wenatchee site (45A071) in dissolved oxygen percent saturation and pH. These data were collected from surface samples, so that one question that arises is whether the high temperature and pH conditions observed during July-September extend into the water column. It also may be of interest to monitor temperature, pH, and dissolved oxygen concentration at this site diurnally during July, August, and September with a Hydrolab recording data sonde. Measurements taken at 15-30 minute intervals would allow us to calculate the probability of exceeding a particular water quality standard.

REFERENCES

Aroner, E.R., 1992. WQHYDRO Water quality/hydrology graphics/analysis system.

Gilbert, R.O., 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Co., New York.

FIGURES

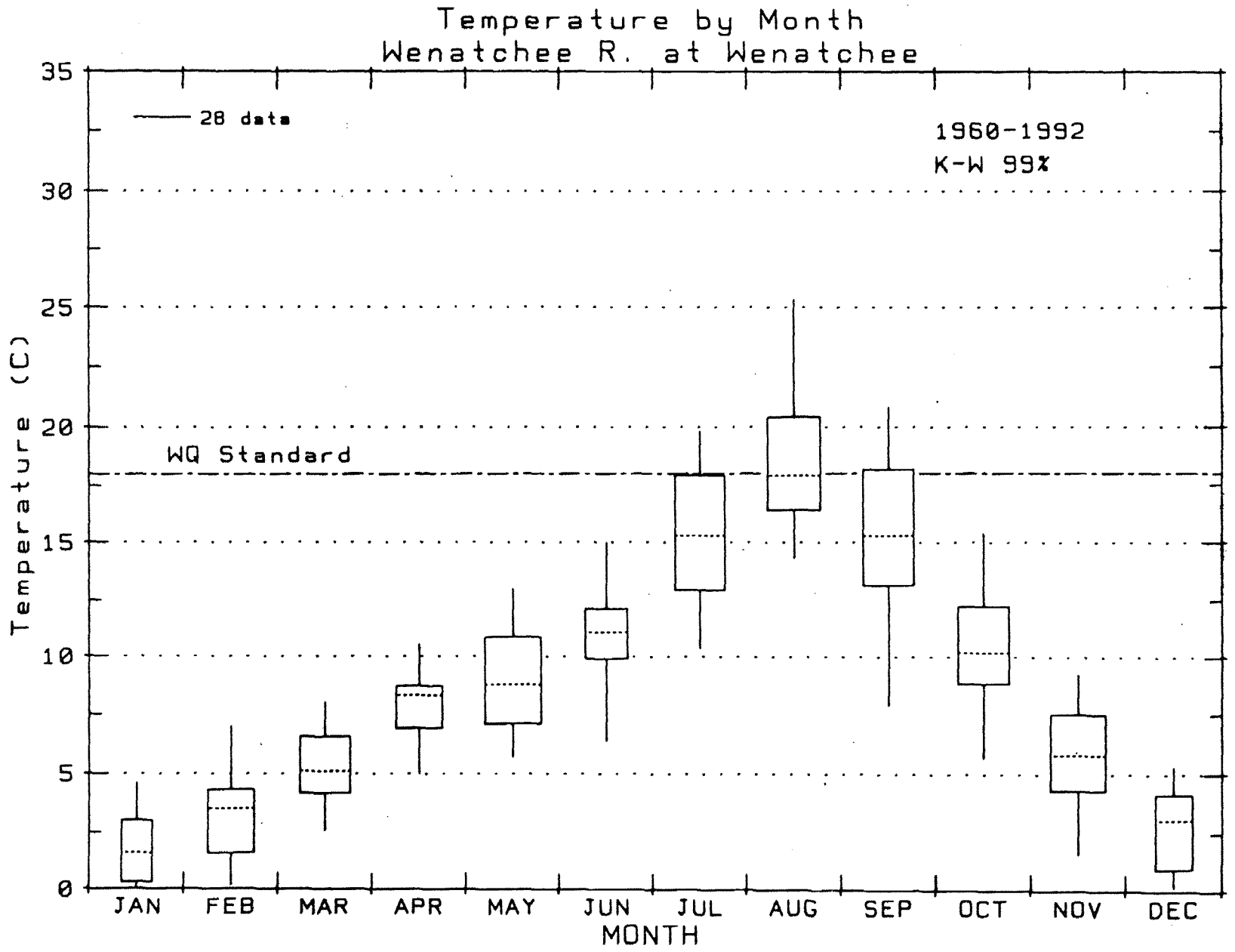

Temperature by Month
Wenatchee R. at Wenatchee
28 data
1960-1992
K-W 99%
WQ Standard
Temperature (C)
35
30
25
20
15
10
5
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 1

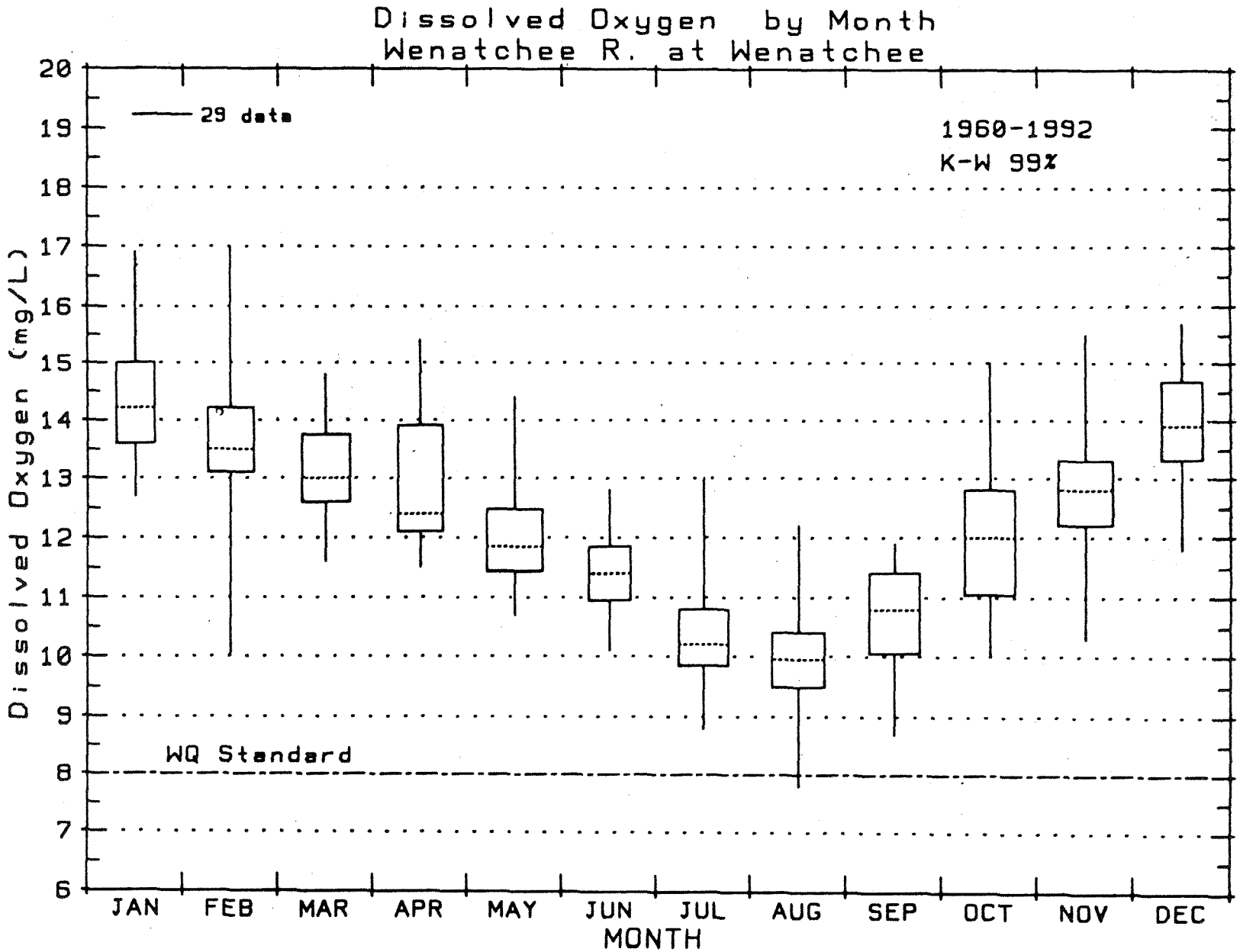

Dissolved Oxygen by Month
Wenatchee R. at Wenatchee
29 data
1960-1992
K-W 99%
WQ Standard
Dissolved Oxygen (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 2

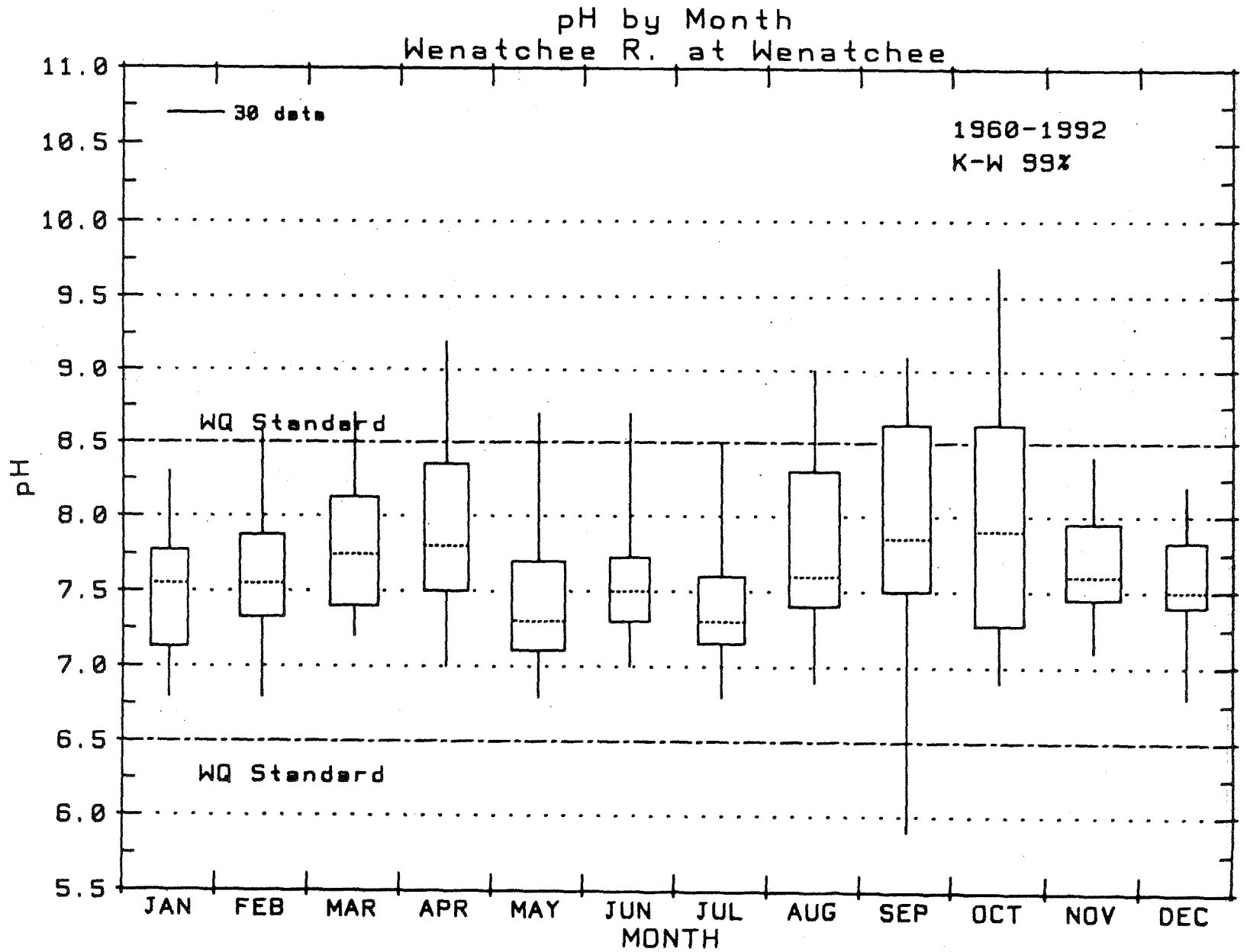

pH by Month
Wenatchee R. at Wenatchee
30 data
1960-1992
K-W 99%
WQ Standard
WQ Standard
pH
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 3

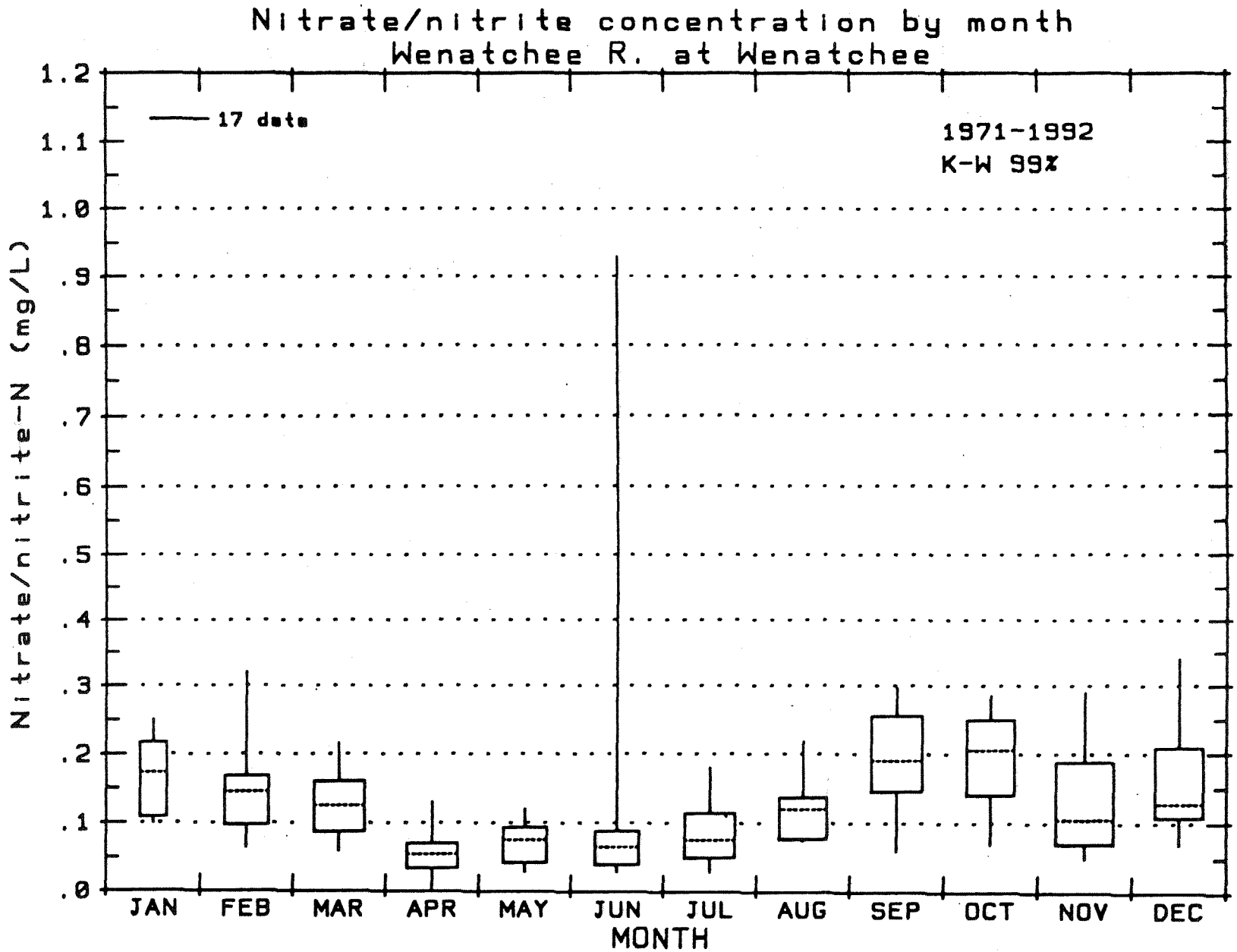

Nitrate/nitrite concentration by month
Wenatchee R. at Wenatchee
17 data
1971-1992
K-W 99%
Nitrate/nitrite-N (mg/L)
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
.0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 4

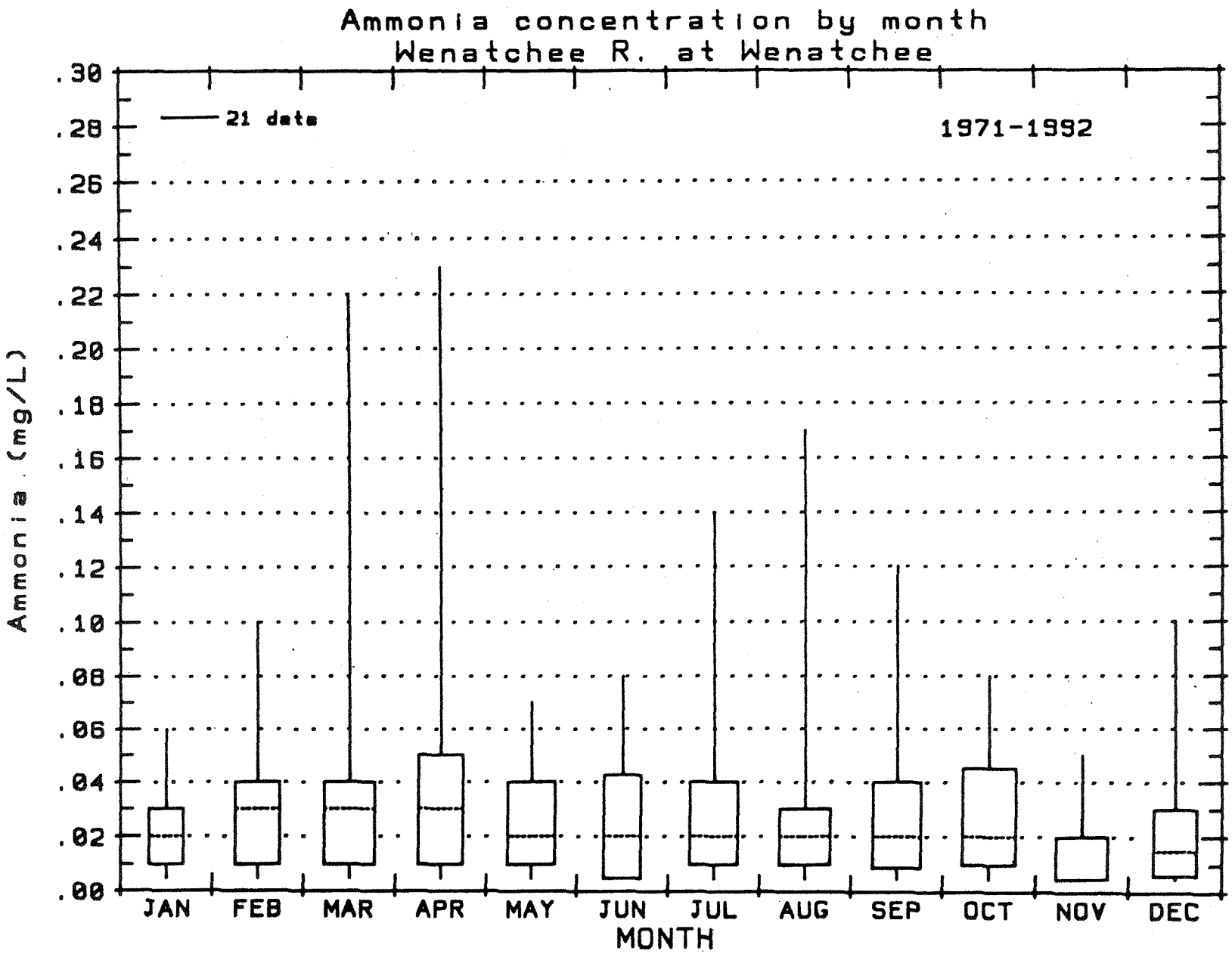

Ammonia concentration by month
Wenatchee R. at Wenatchee
21 data
1971-1992
Ammonia (mg/L)
.30
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
.00
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 5

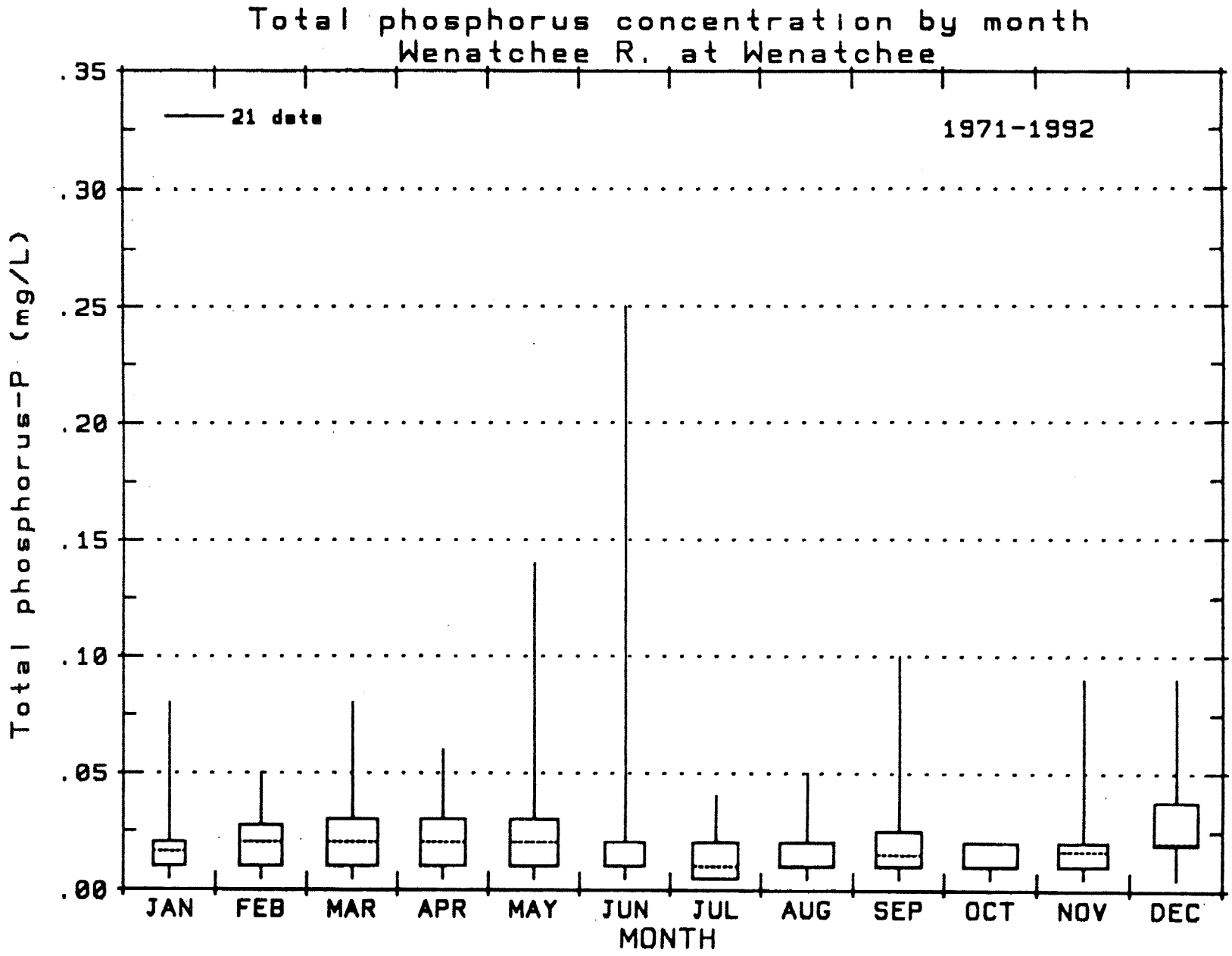

Total phosphorus concentration by month
Wenatchee R. at Wenatchee
21 data
1971-1992
Total phosphorus-P (mg/L)
.35
.30
.25
.20
.15
.10
.05
.00
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 6

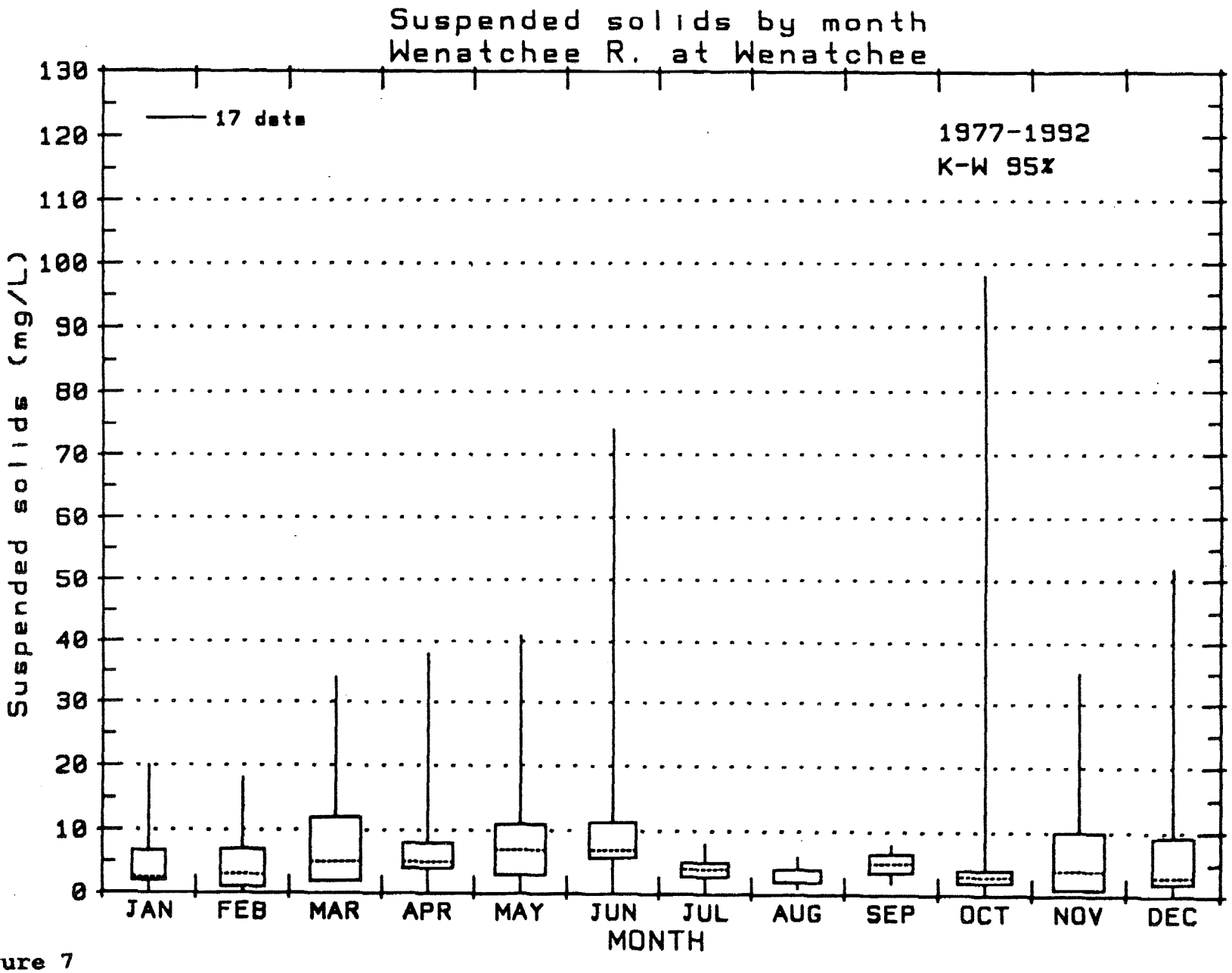

Suspended solids by month
Wenatchee R. at Wenatchee
17 data
1977-1992
K-W 95%
Suspended solids (mg/L)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 7

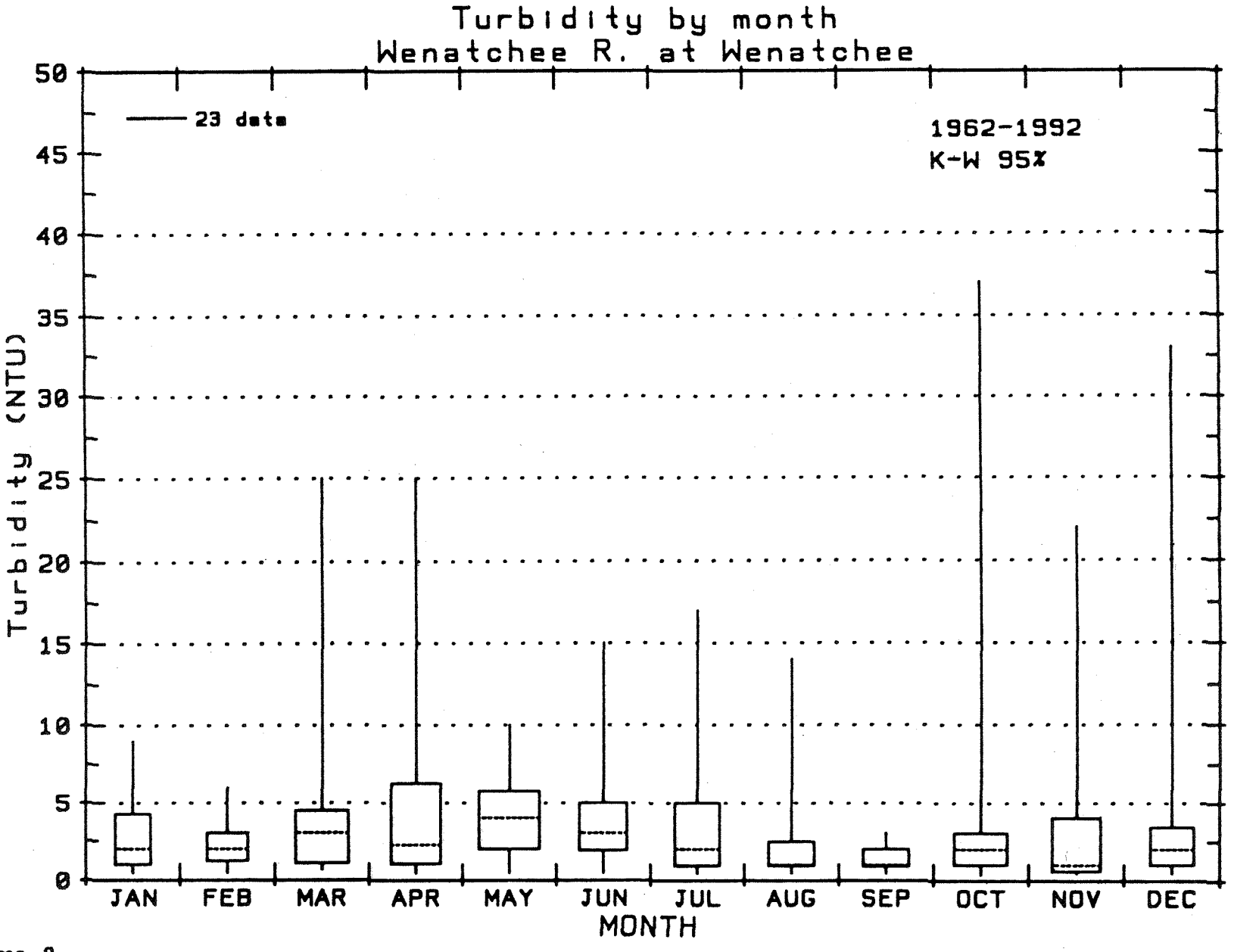

Turbidity by month
Wenatchee R. at Wenatchee
23 data
1962-1992
K-W 95%
Turbidity (NTU)
50
45
40
35
30
25
20
15
10
5
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 8

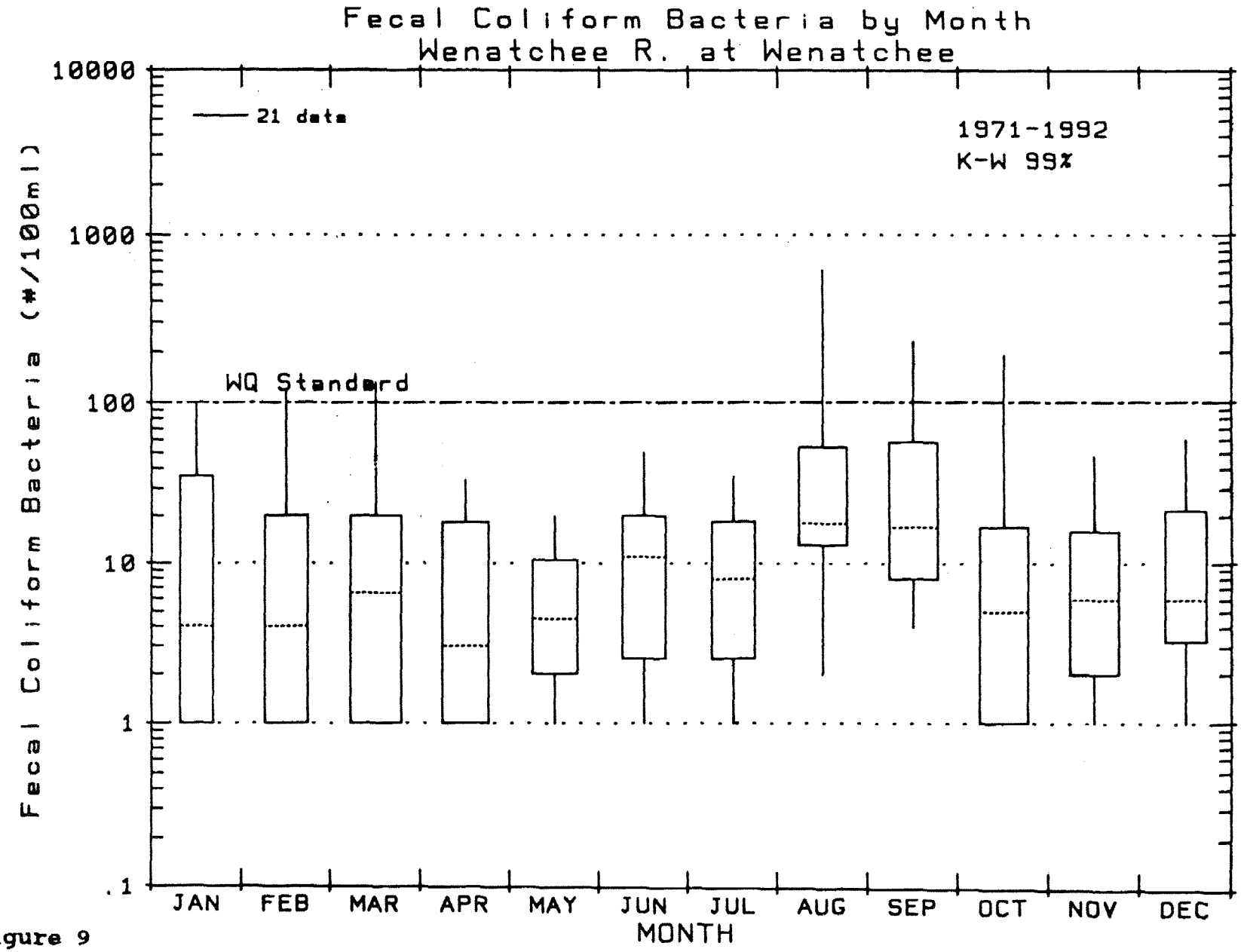

Fecal Coliform Bacteria by Month
Wenatchee R. at Wenatchee
21 data
1971-1992
K-W 99%
WQ Standard
10000
1000
100
10
1
.1
Fecal Coliform Bacteria (#/100ml)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 9

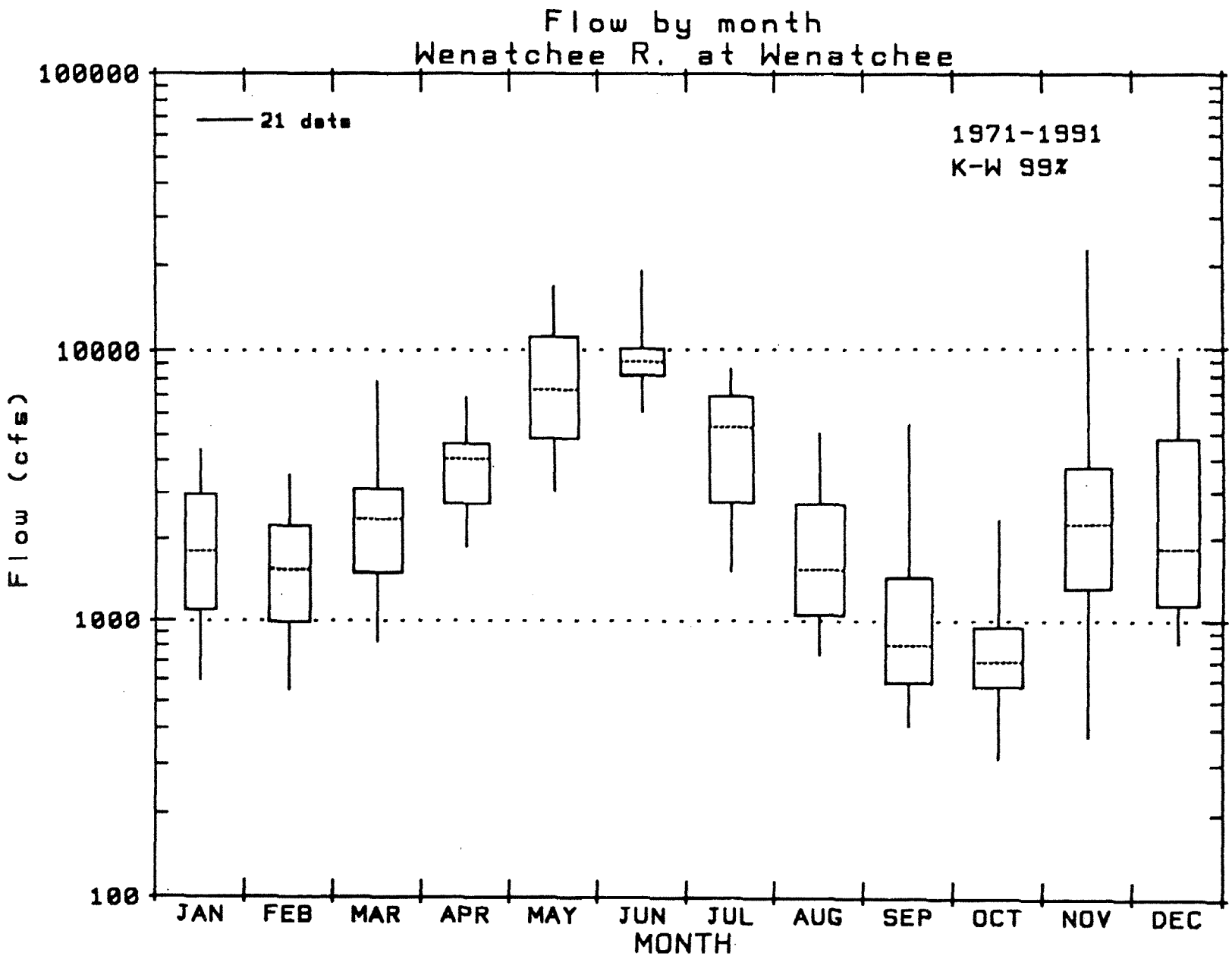

Flow by month
Wenatchee R. at Wenatchee
21 data
1971-1991
K-W 99%
100000
10000
1000
100
Flow (cfs)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 10

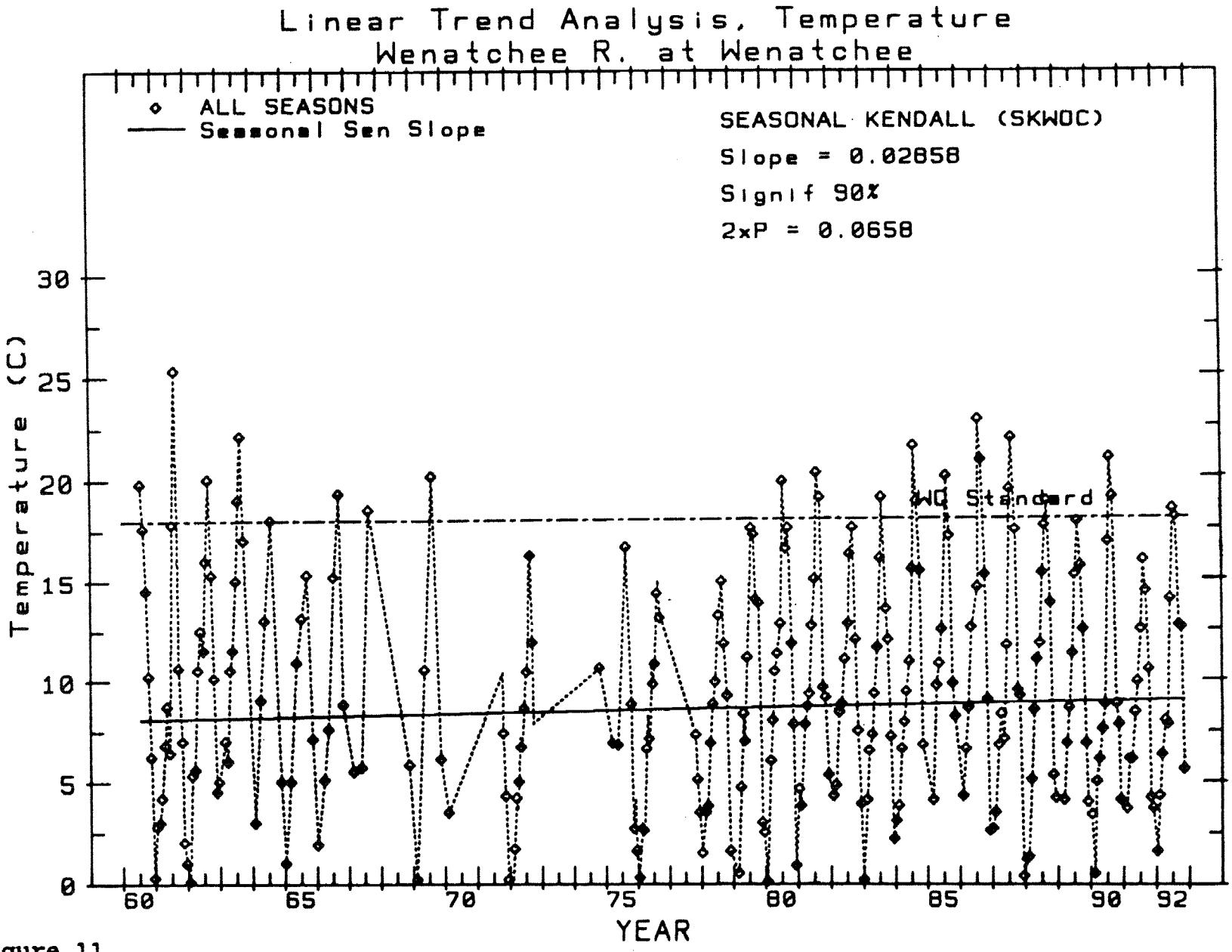

Linear Trend Analysis, Temperature
Wenatchee R. at Wenatchee
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.02858
Signif 90%
2xP = 0.0658
WQ Standard
Temperature (C)
YEAR
0
5
10
15
20
25
30
60
65
70
75
80
85
90
92

Figure 11

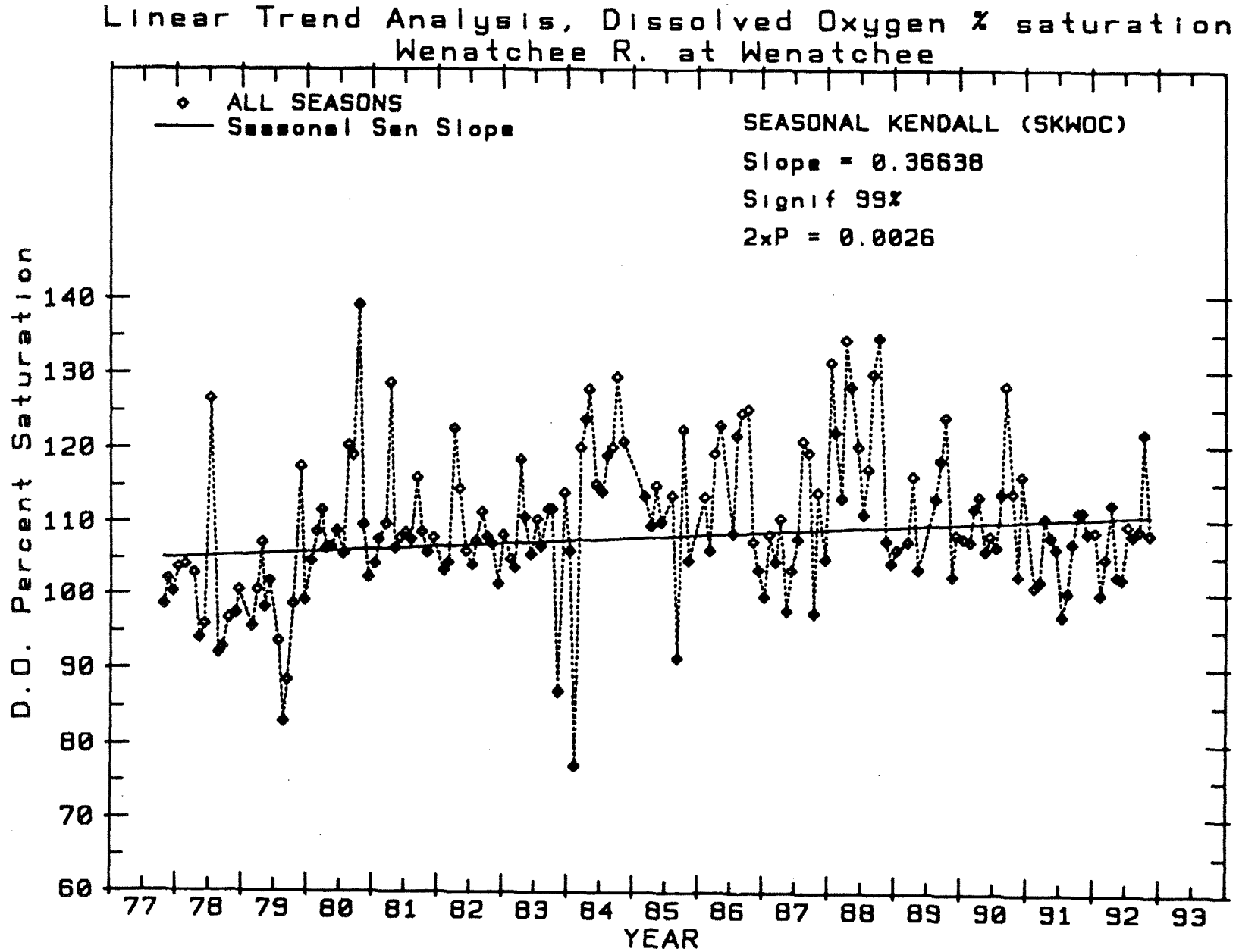

Linear Trend Analysis, Dissolved Oxygen % saturation
Wenatchee R. at Wenatchee
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.36638
Signif 99%
2xP = 0.0026
D.O. Percent Saturation
140
130
120
110
100
90
80
70
60
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
YEAR

Figure 12

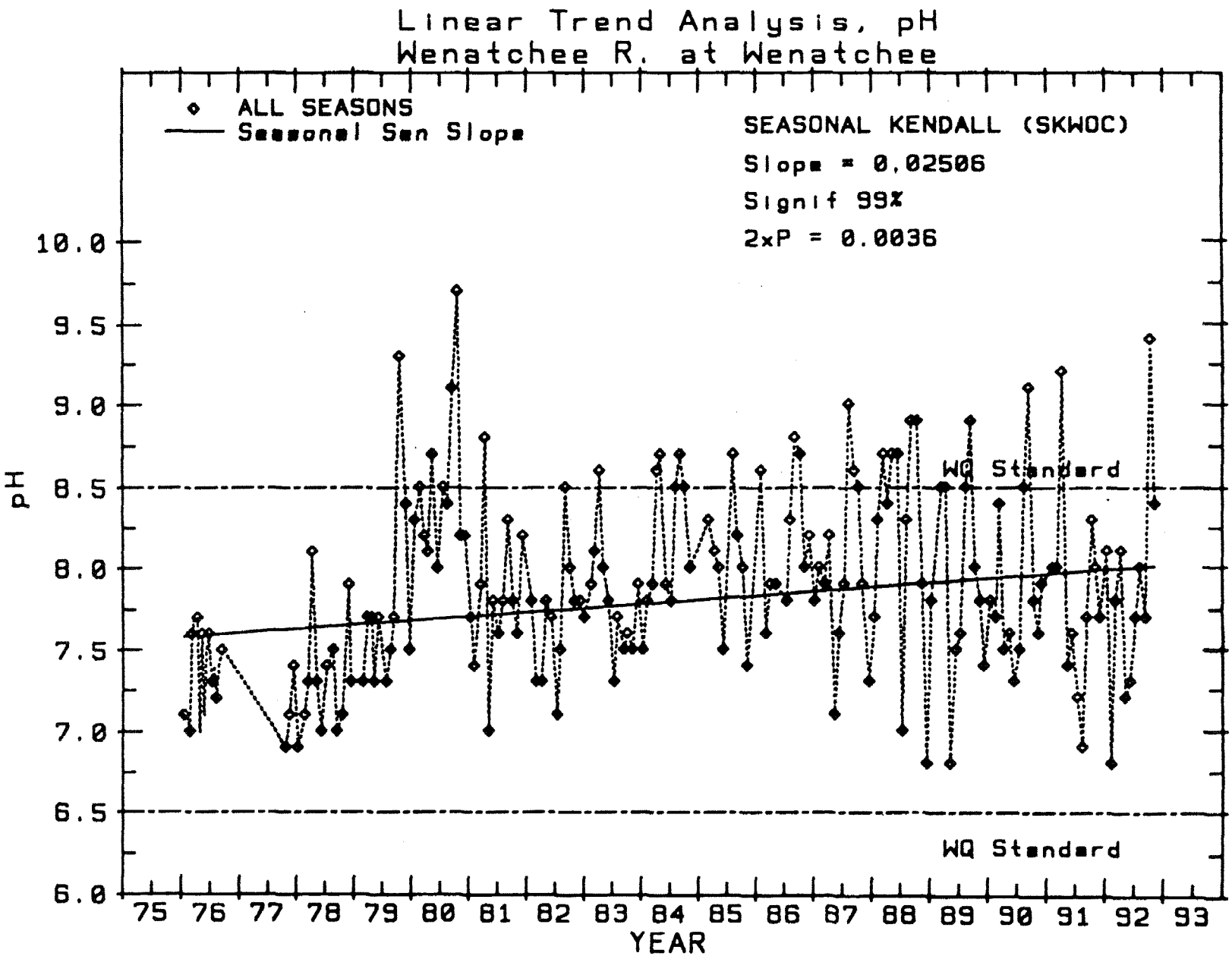

Linear Trend Analysis, pH
Wenatchee R. at Wenatchee
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.02506
Signif 99%
2xP = 0.0036
WQ Standard
WQ Standard
pH
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93
YEAR

Figure 13

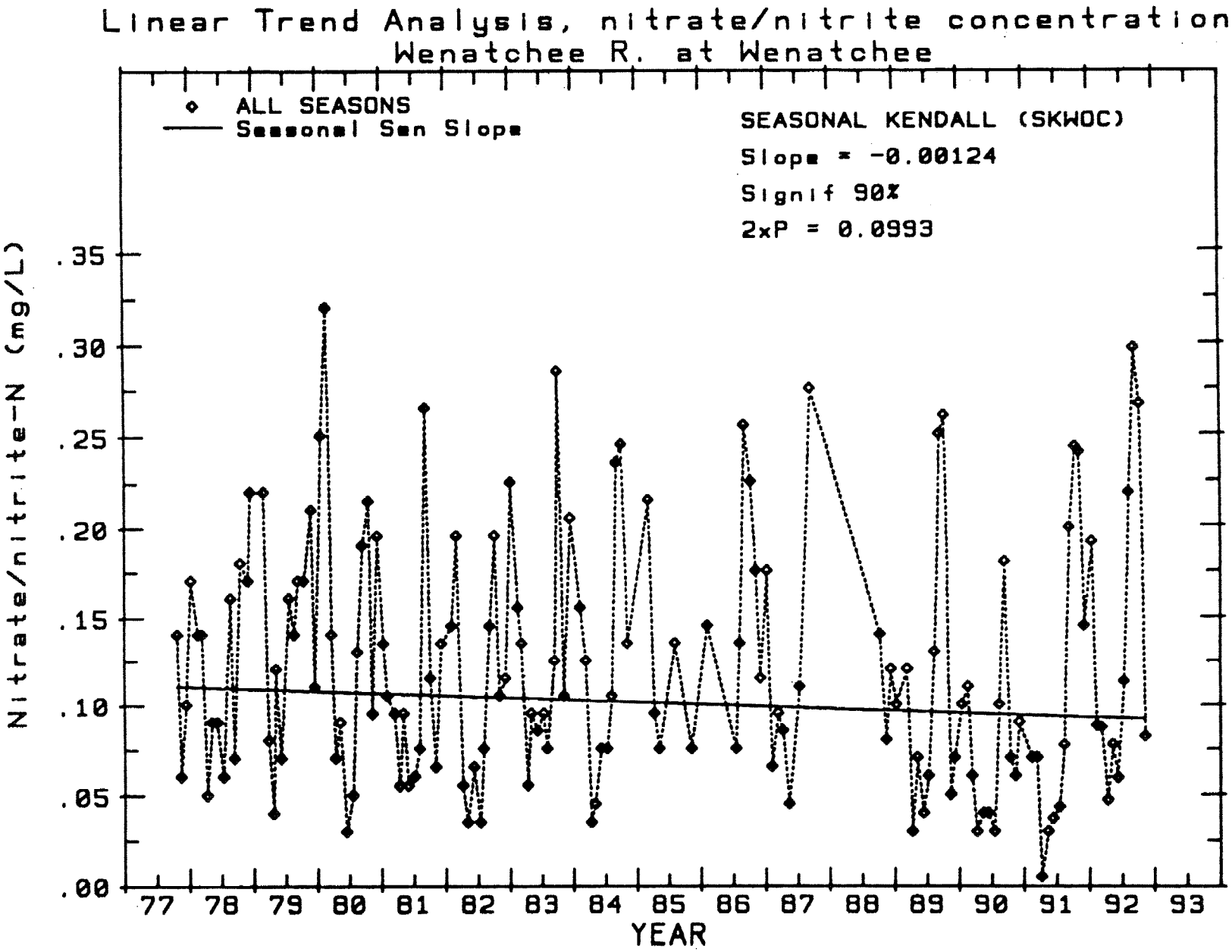

Linear Trend Analysis, nitrate/nitrite concentration
Wenatchee R. at Wenatchee
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = -0.00124
Signif 90%
2xP = 0.0993
Nitrate/nitrite-N (mg/L)
.35
.30
.25
.20
.15
.10
.05
.00
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
YEAR

Figure 14

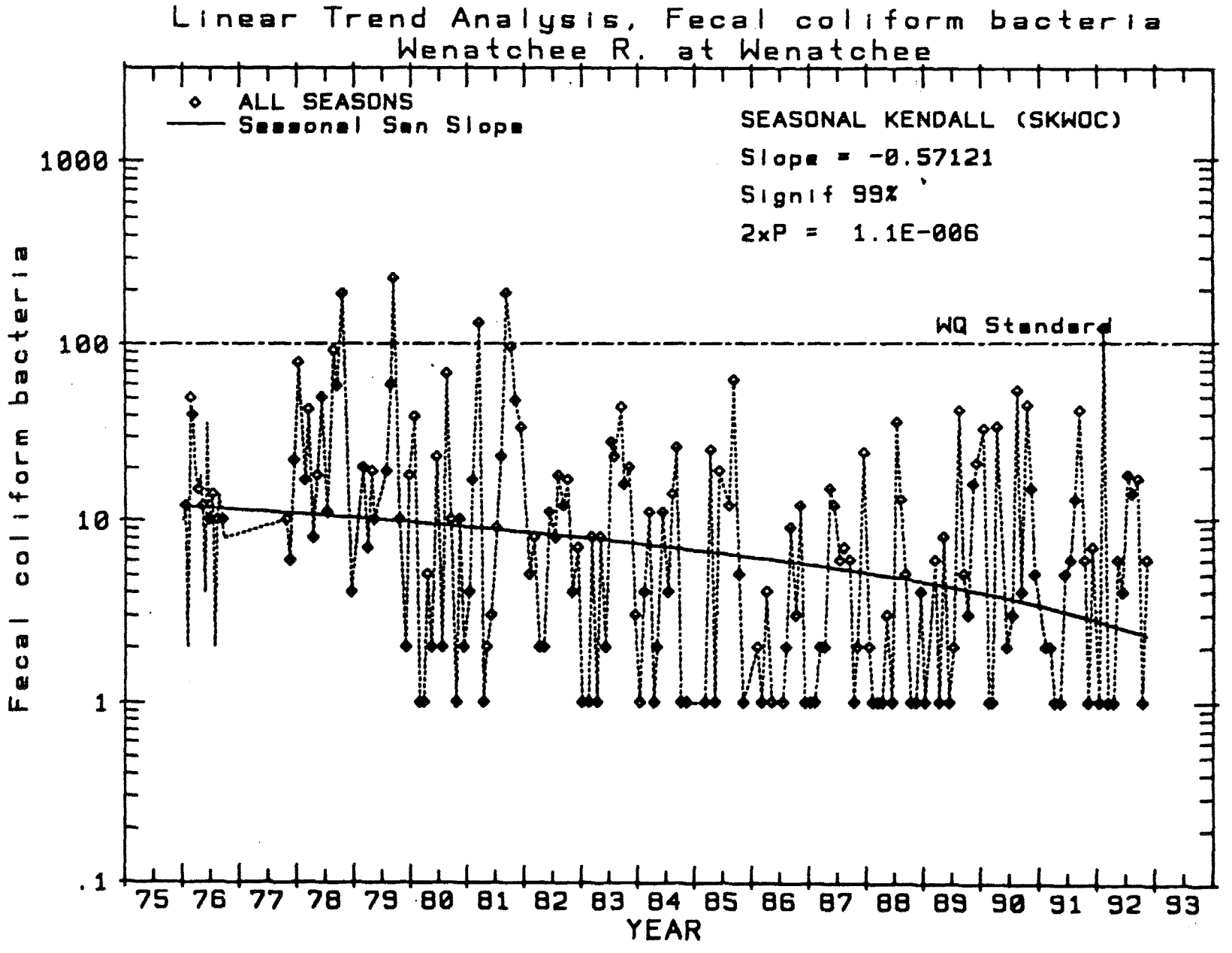
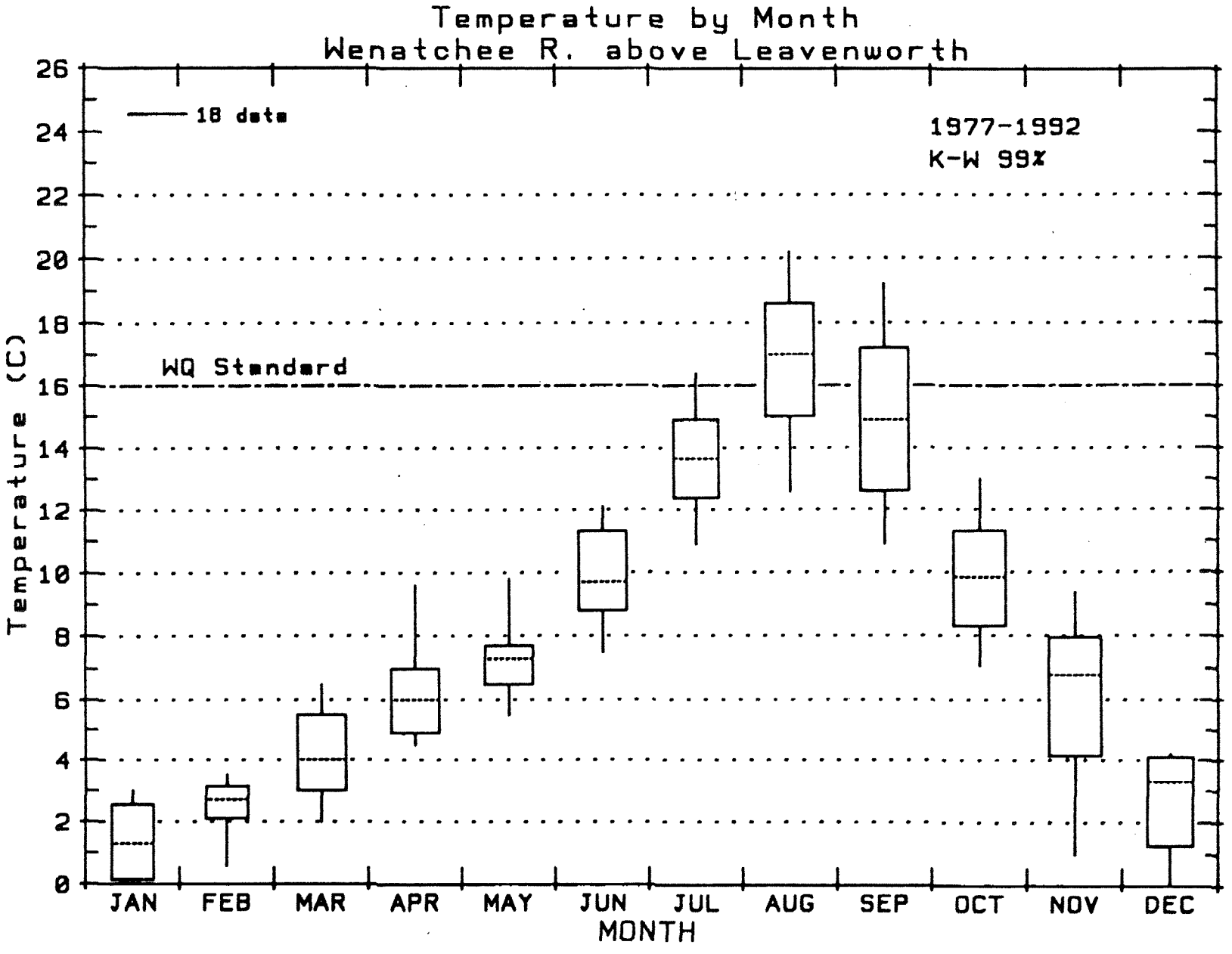

Linear Trend Analysis, Fecal coliform bacteria
Wenatchee R. at Wenatchee
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = -0.57121
Signif 99%
2xP = 1.1E-006
WQ Standard
Fecal coliform bacteria
1000
100
10
1
.1
75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93
YEAR

Figure 15


Temperature by Month
Wenatchee R. above Leavenworth
18 data
1977-1992
K-W 99%
WQ Standard
Temperature (C)
26
24
22
20
18
16
14
12
10
8
6
4
2
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
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OCT
NOV
DEC
MONTH

Figure 16

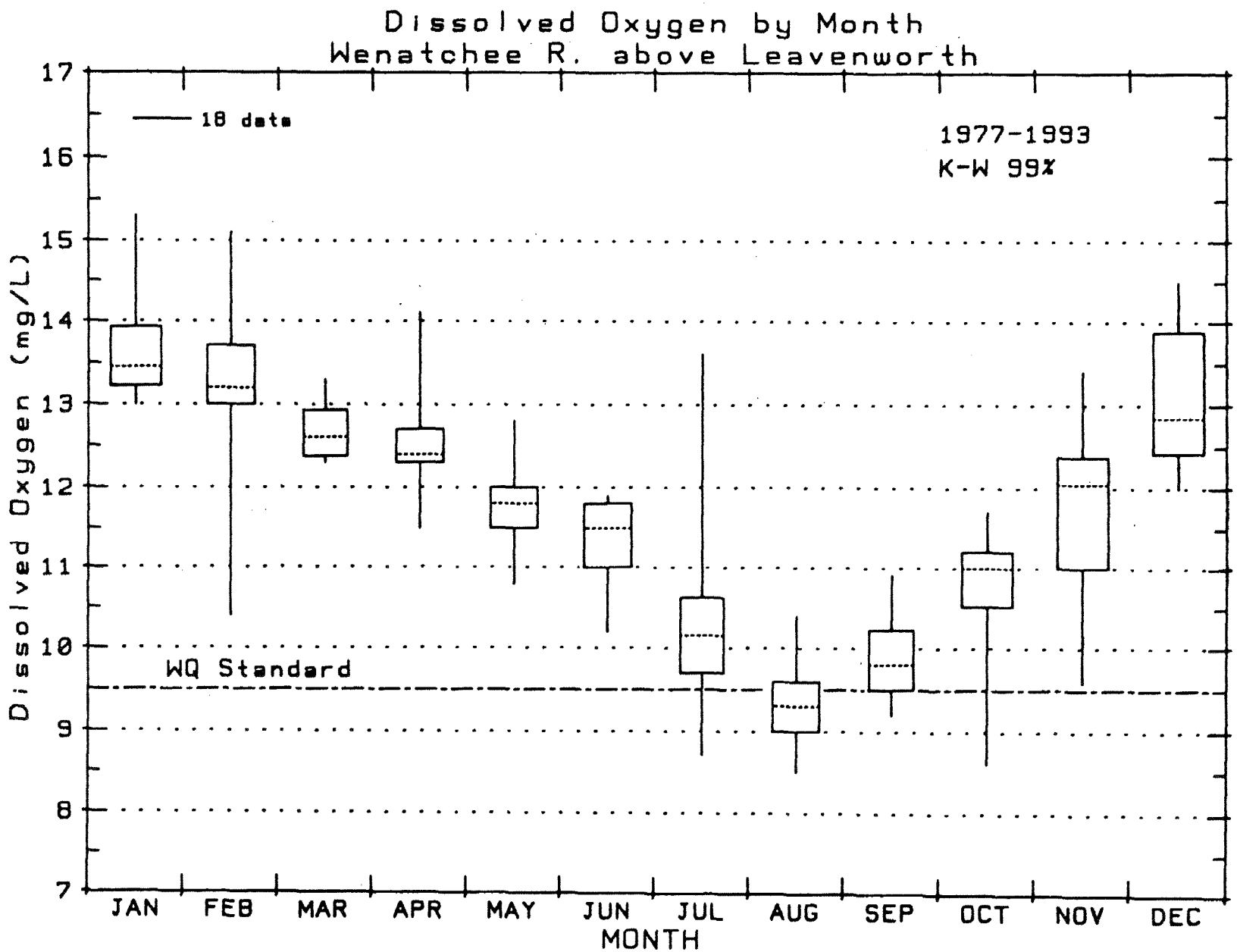
Dissolved Oxygen by Month
Wenatchee R. above Leavenworth
18 data
1977-1993
K-W 99%
WQ Standard
Dissolved Oxygen (mg/L)
17
16
15
14
13
12
11
10
9
8
7
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 17

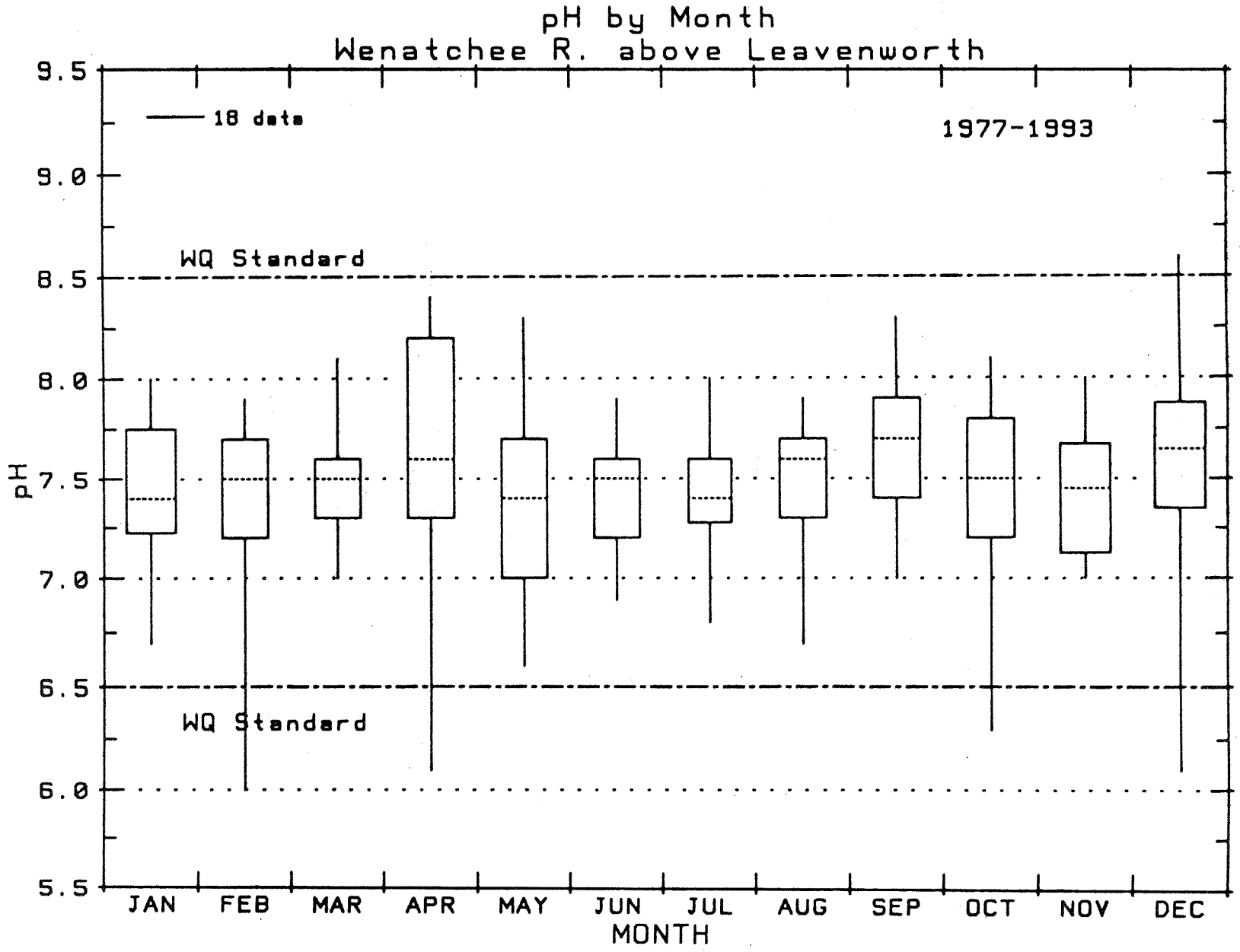
pH by Month
Wenatchee R. above Leavenworth
18 data
1977-1993
WQ Standard
WQ Standard
pH
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 18

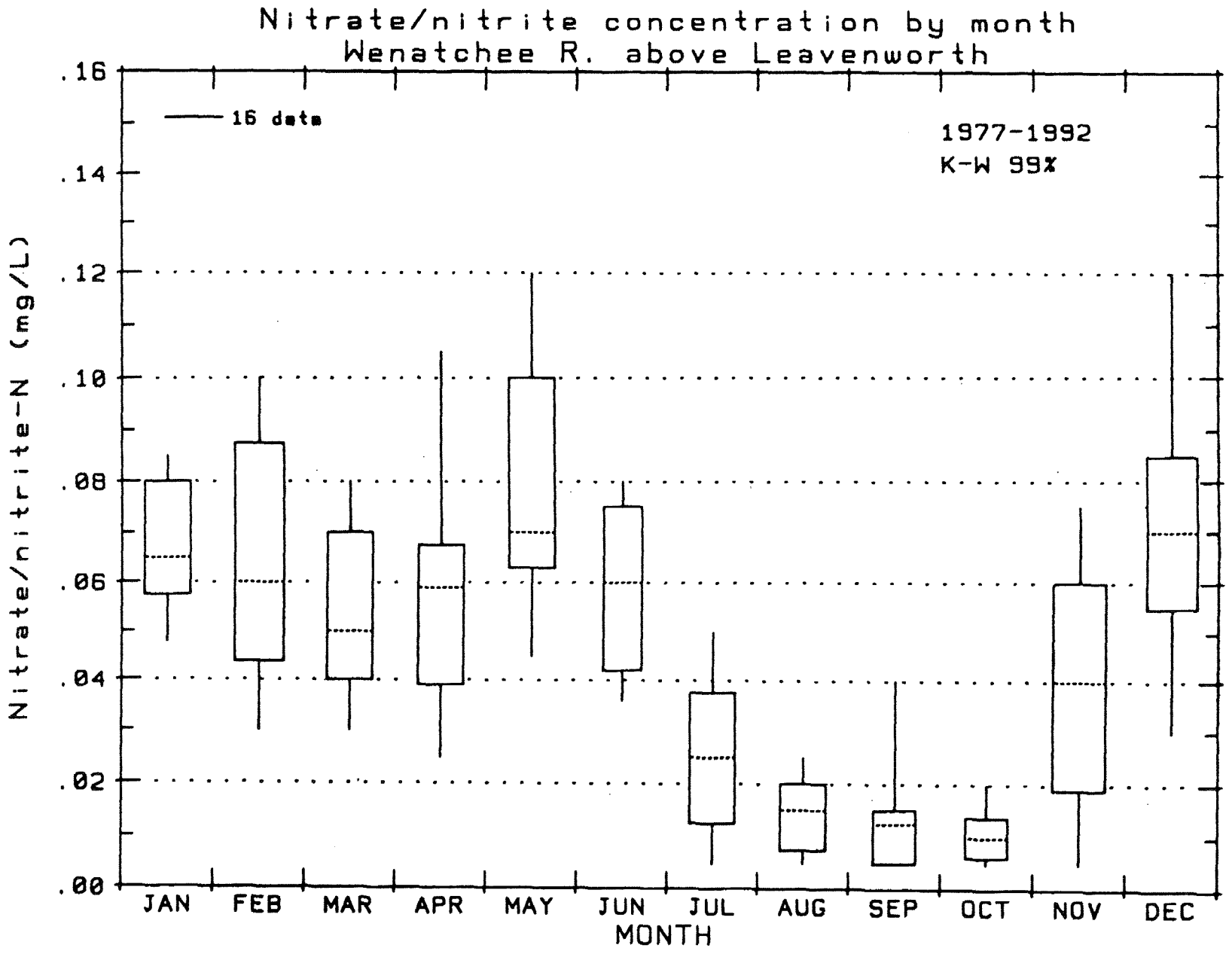
Nitrate/nitrite concentration by month
Wenatchee R. above Leavenworth
15 data
1977-1992
K-W 99%
Nitrate/nitrite-N (mg/L)
.16
.14
.12
.10
.08
.06
.04
.02
.00
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 19

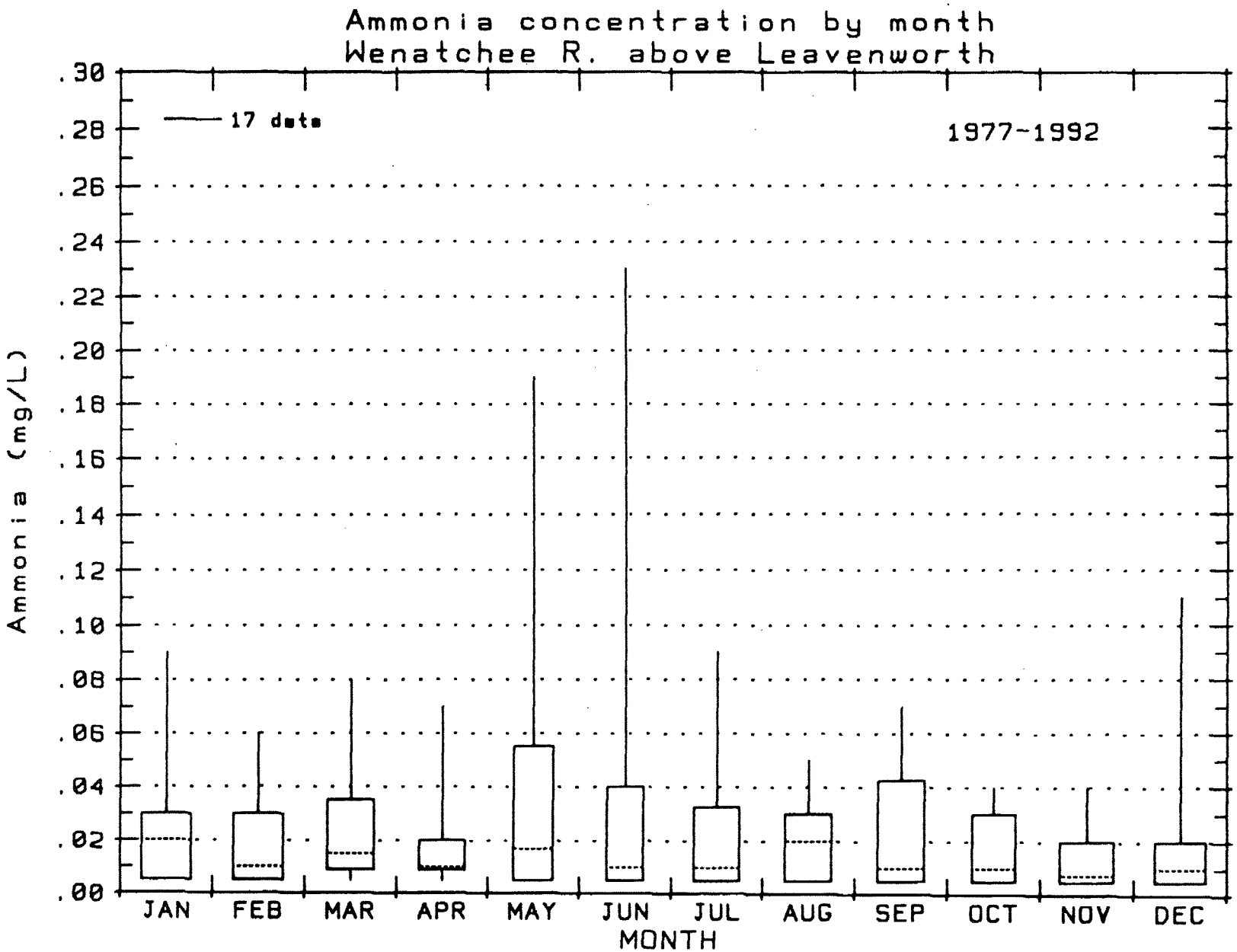
Ammonia concentration by month
Wenatchee R. above Leavenworth
17 data
1977-1992
Ammonia (mg/L)
.30
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
.00
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 20

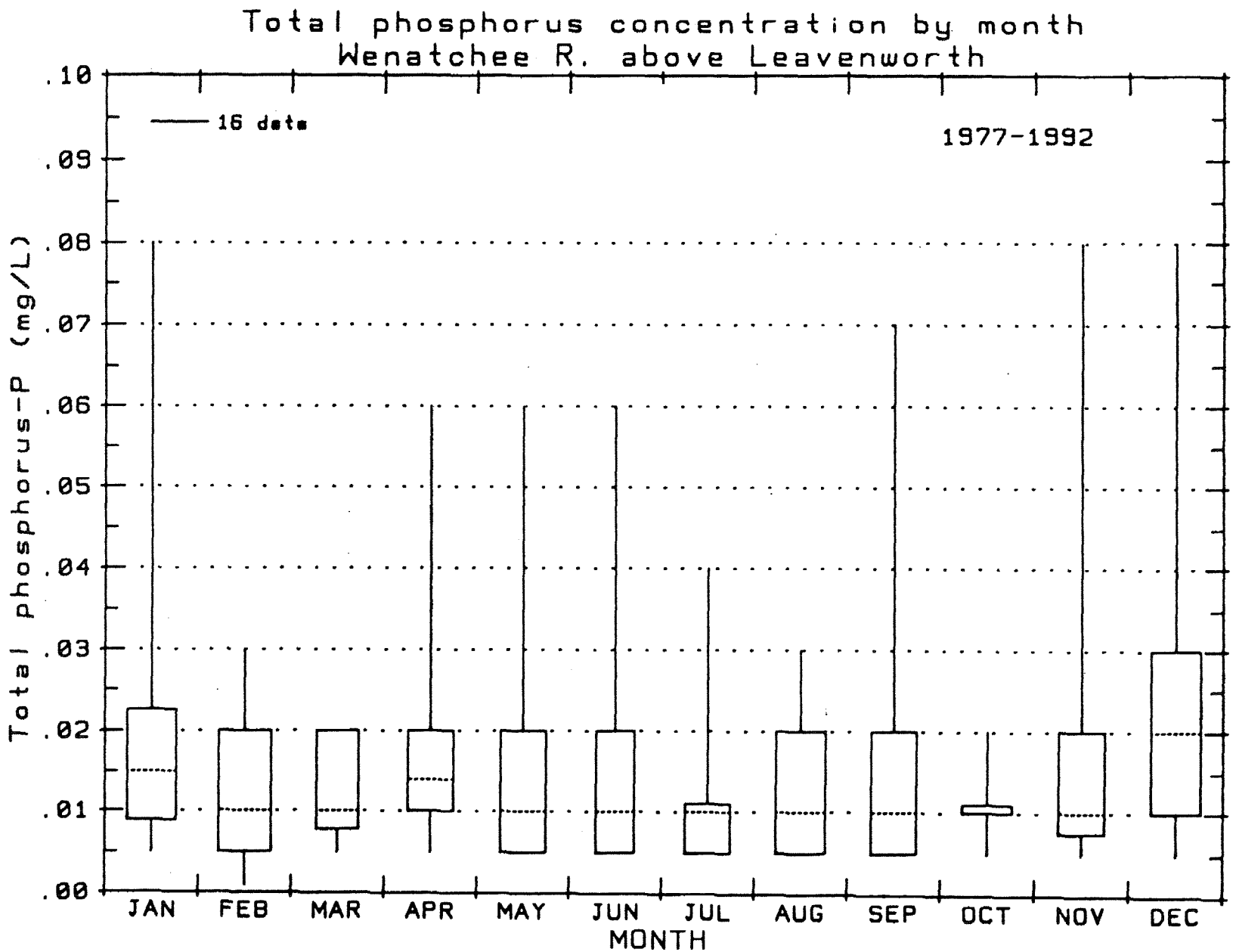
Total phosphorus concentration by month
Wenatchee R. above Leavenworth
16 data
1977-1992
Total phosphorus-P (mg/L)
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
.00
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 21

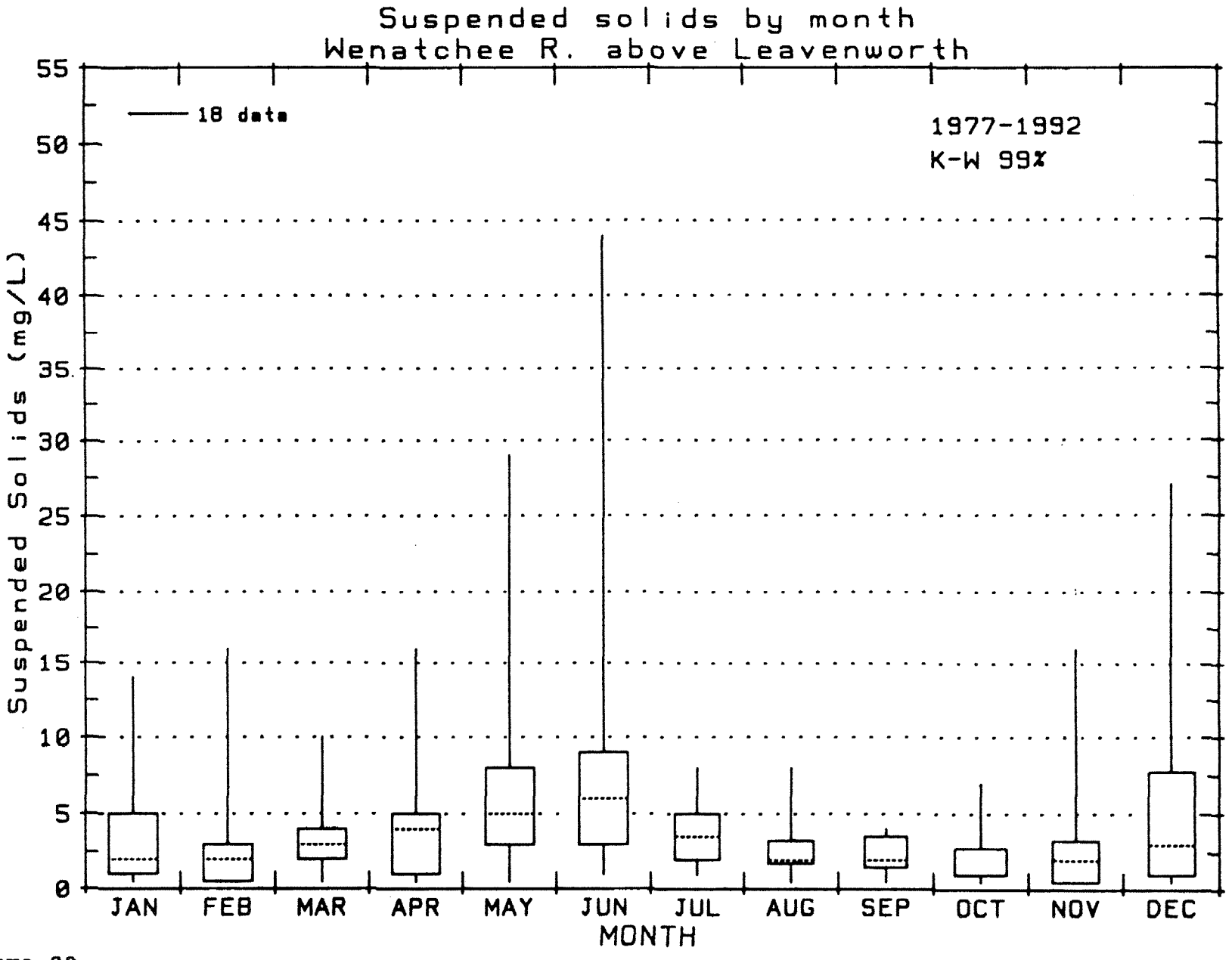
Suspended solids by month
Wenatchee R. above Leavenworth
18 data
1977-1992
K-W 99%
Suspended Solids (mg/L)
55
50
45
40
35
30
25
20
15
10
5
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 22

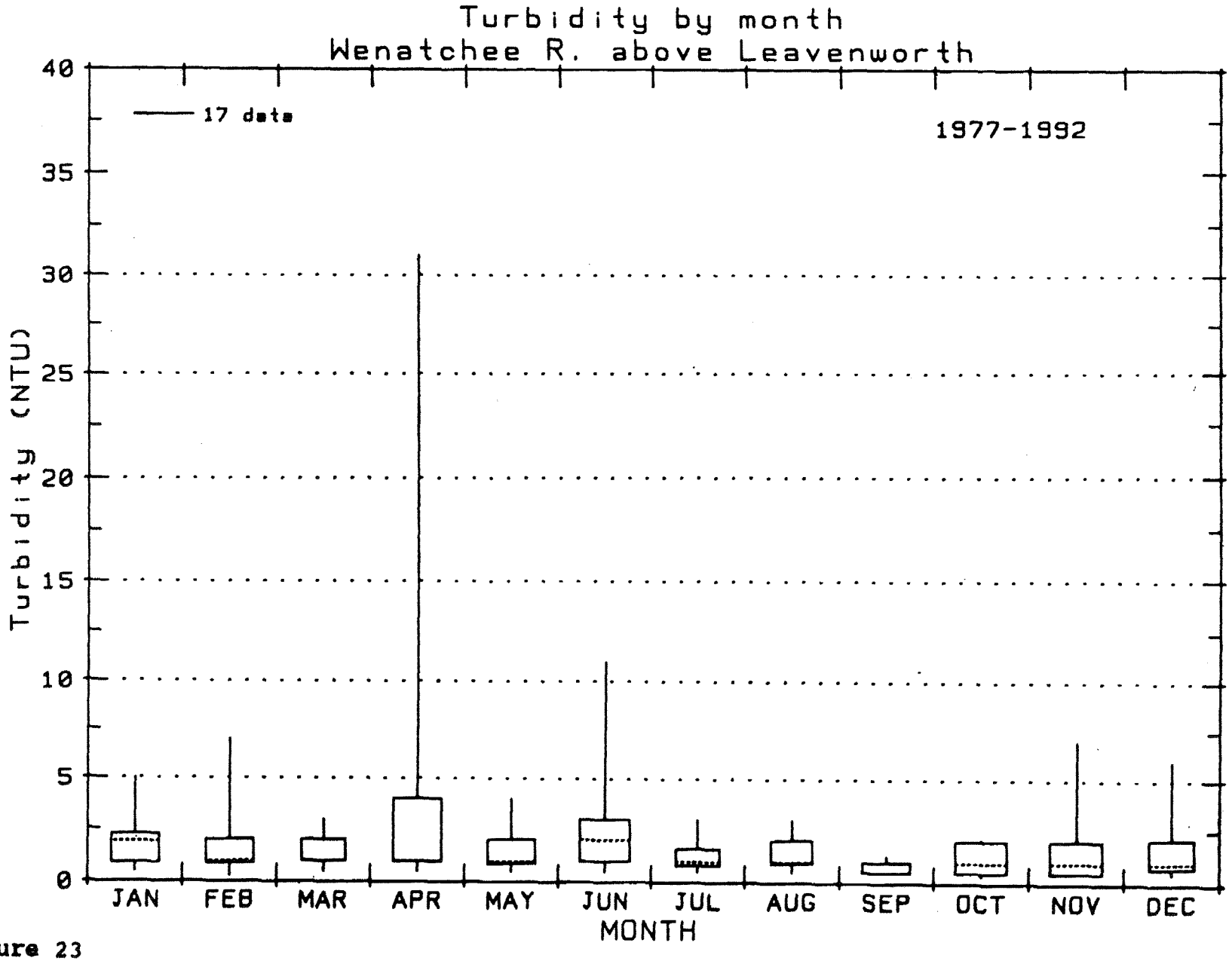
Turbidity by month
Wenatchee R. above Leavenworth
17 data
1977-1992
Turbidity (NTU)
40
35
30
25
20
15
10
5
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 23

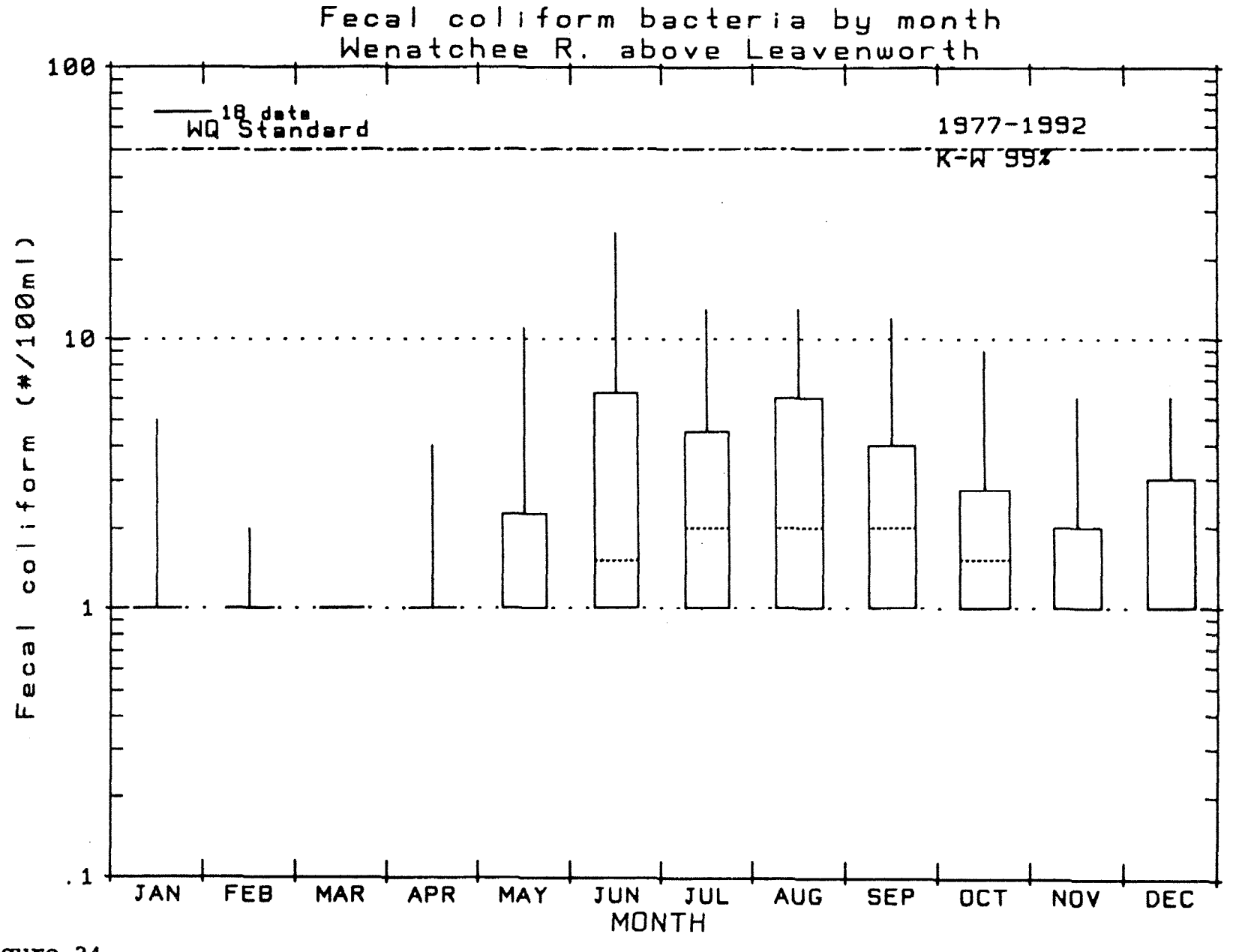
Fecal coliform bacteria by month
Wenatchee R. above Leavenworth
100
10
1
.1
18 data
WQ Standard
1977-1992
K-W 99%
Fecal coliform (#/100ml)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 24

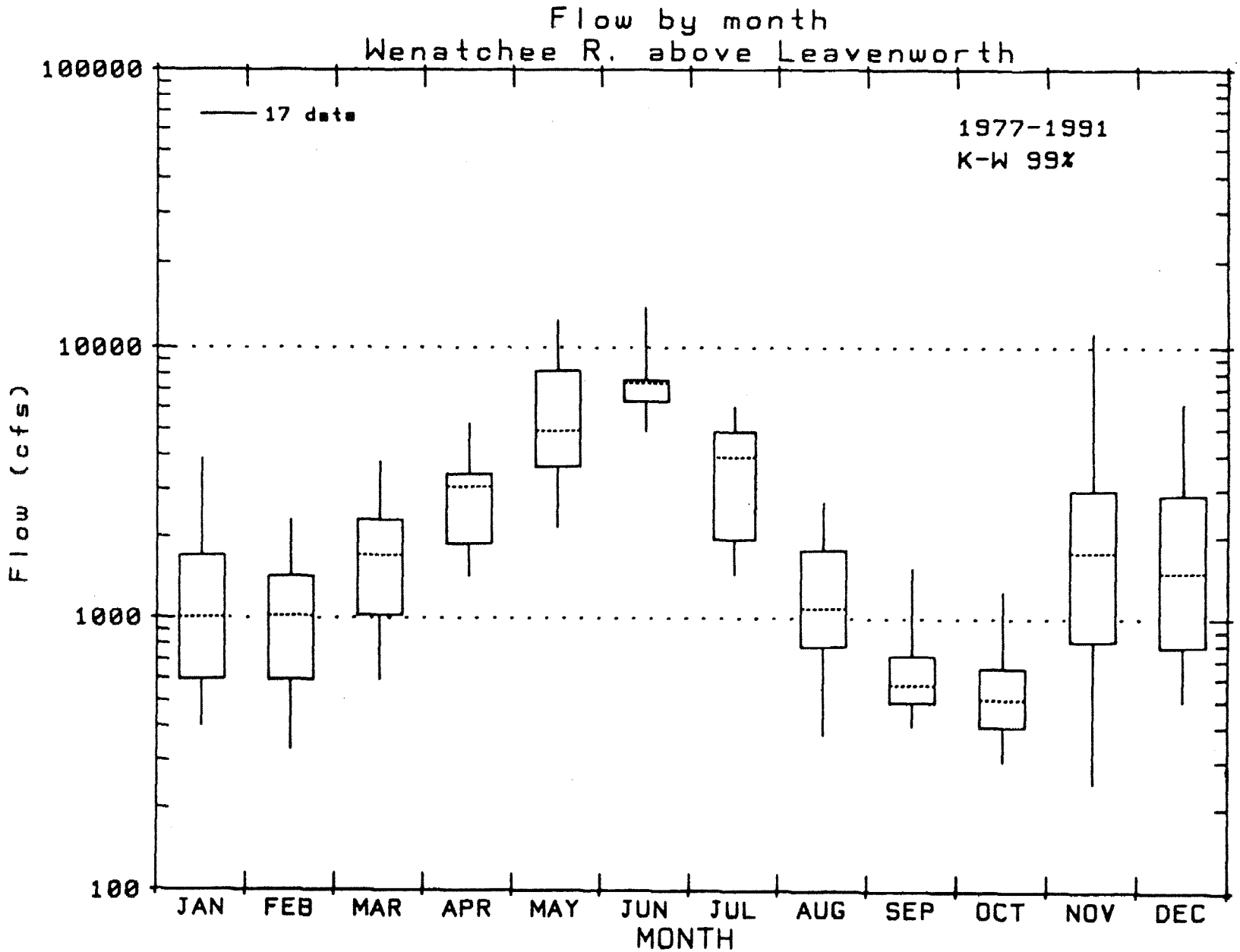
Flow by month
Wenatchee R. above Leavenworth
17 data
1977-1991
K-W 99%
100000
10000
1000
100
Flow (cfs)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 25

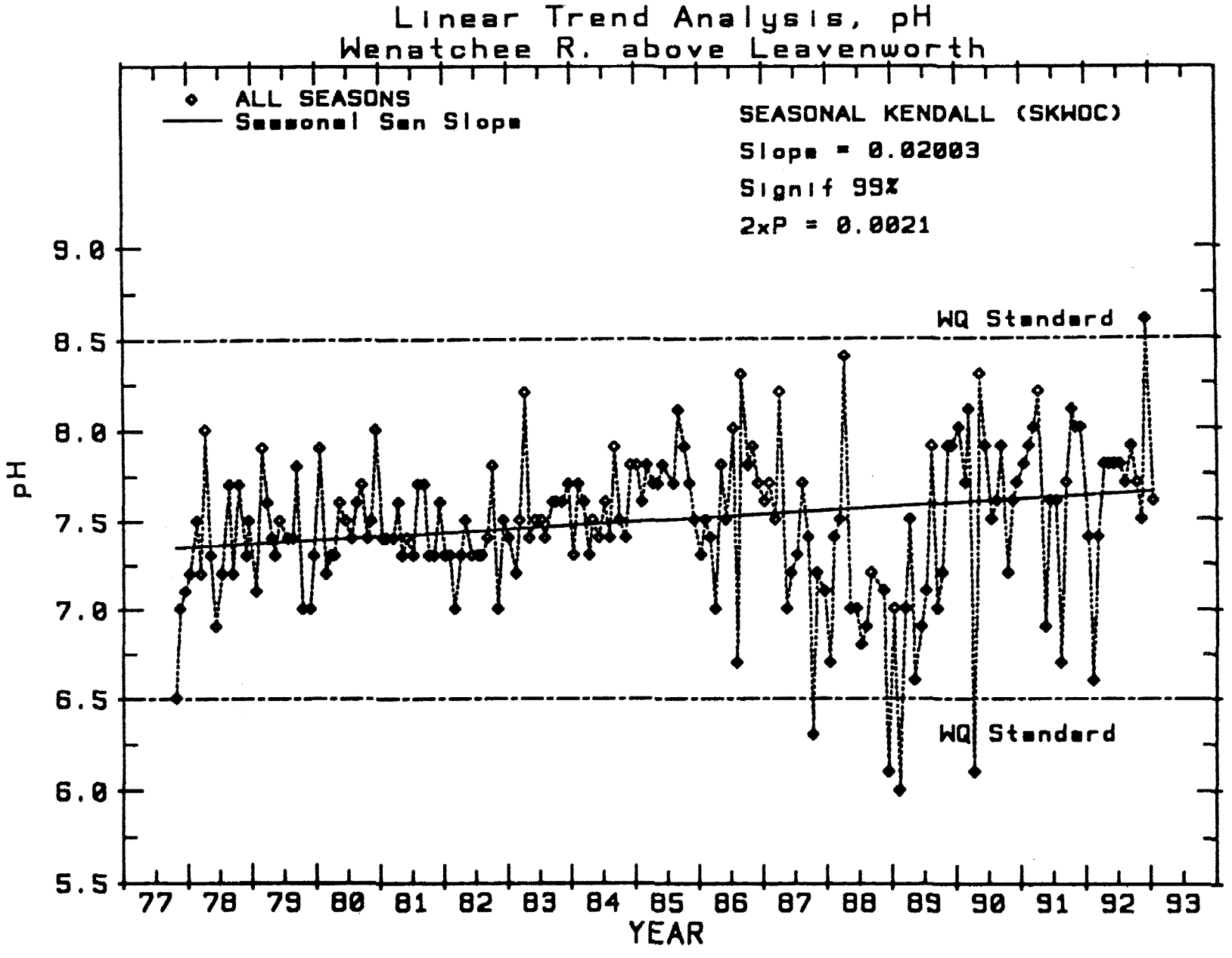
Linear Trend Analysis, pH
Wenatchee R. above Leavenworth
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.02003
Signif 99%
2xP = 0.0021
WQ Standard
WQ Standard
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93
YEAR

Figure 26

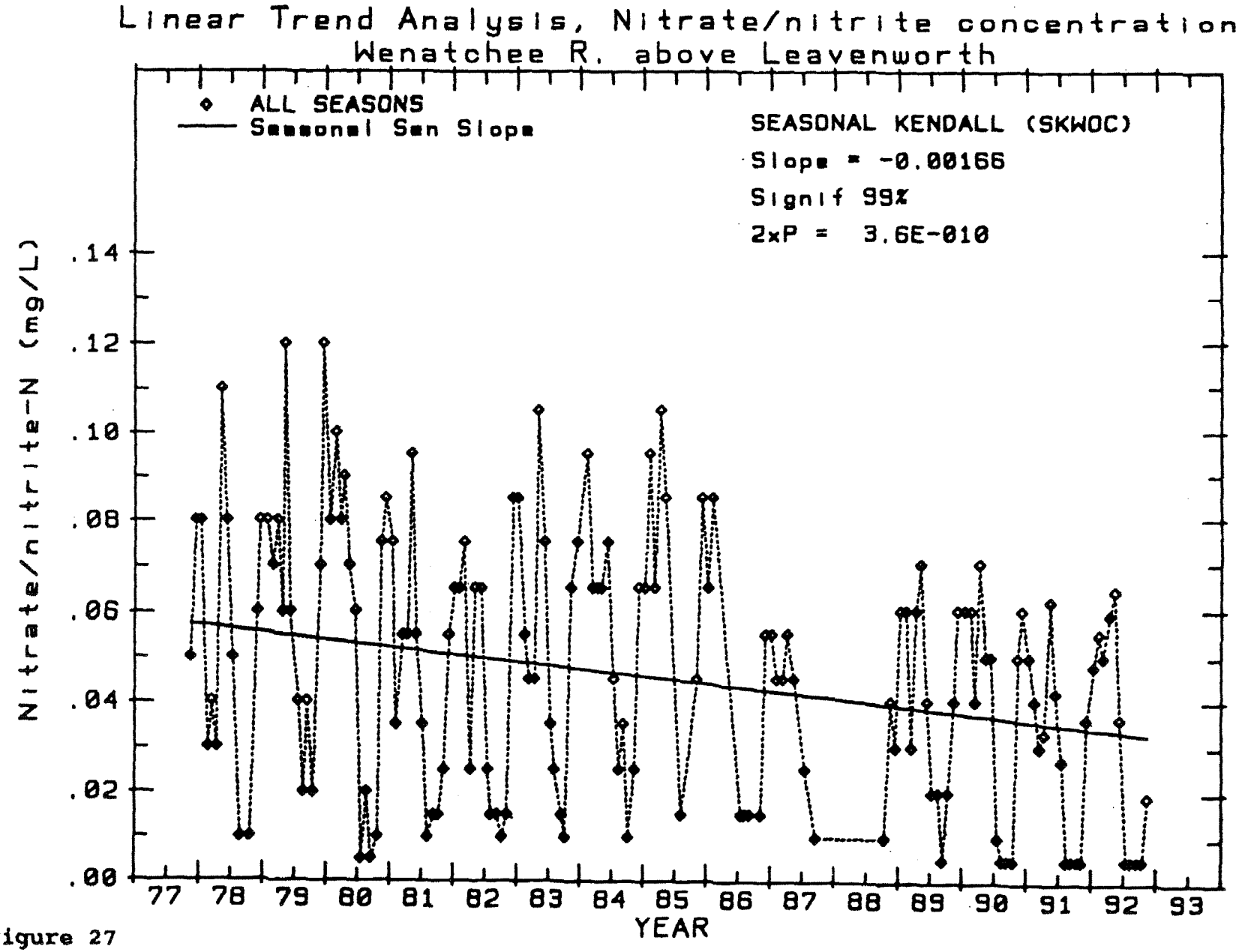
Linear Trend Analysis, Nitrate/nitrite concentration
Wenatchee R. above Leavenworth
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = -0.00166
Signif 99%
2xP = 3.6E-010
Nitrate/nitrite-N (mg/L)
.14
.12
.10
.08
.06
.04
.02
.00
77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93
YEAR

Figure 27

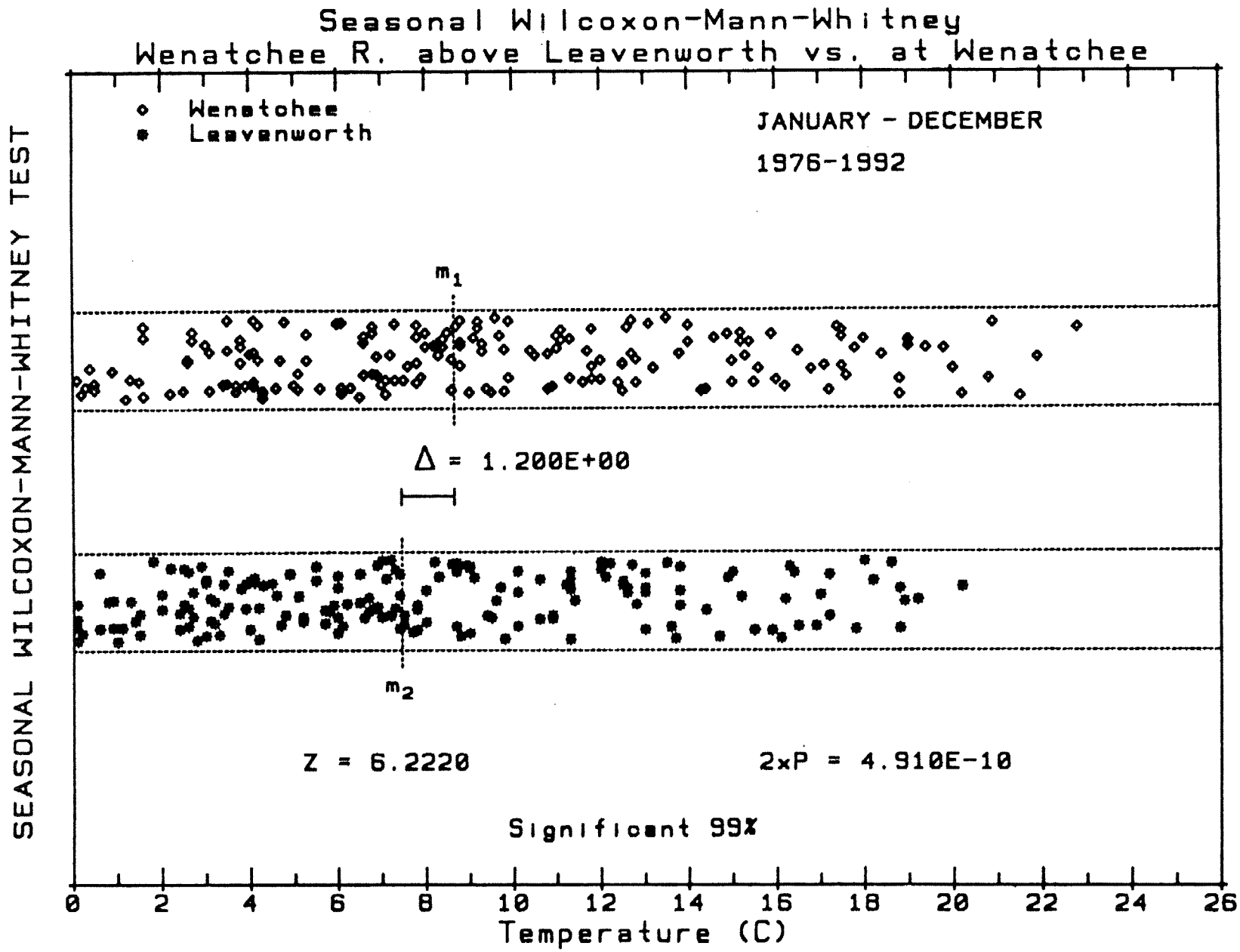
Seasonal Wilcoxon-Mann-Whitney
Wenatchee R. above Leavenworth vs. at Wenatchee
Wenatchee
Leavenworth
JANUARY - DECEMBER
1976-1992
SEASONAL WILCOXON-MANN-WHITNEY TEST
m1
Δ = 1.200E+00
m2
Z = 6.2220
2xP = 4.910E-10
Significant 99%
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Temperature (C)

Figure 28

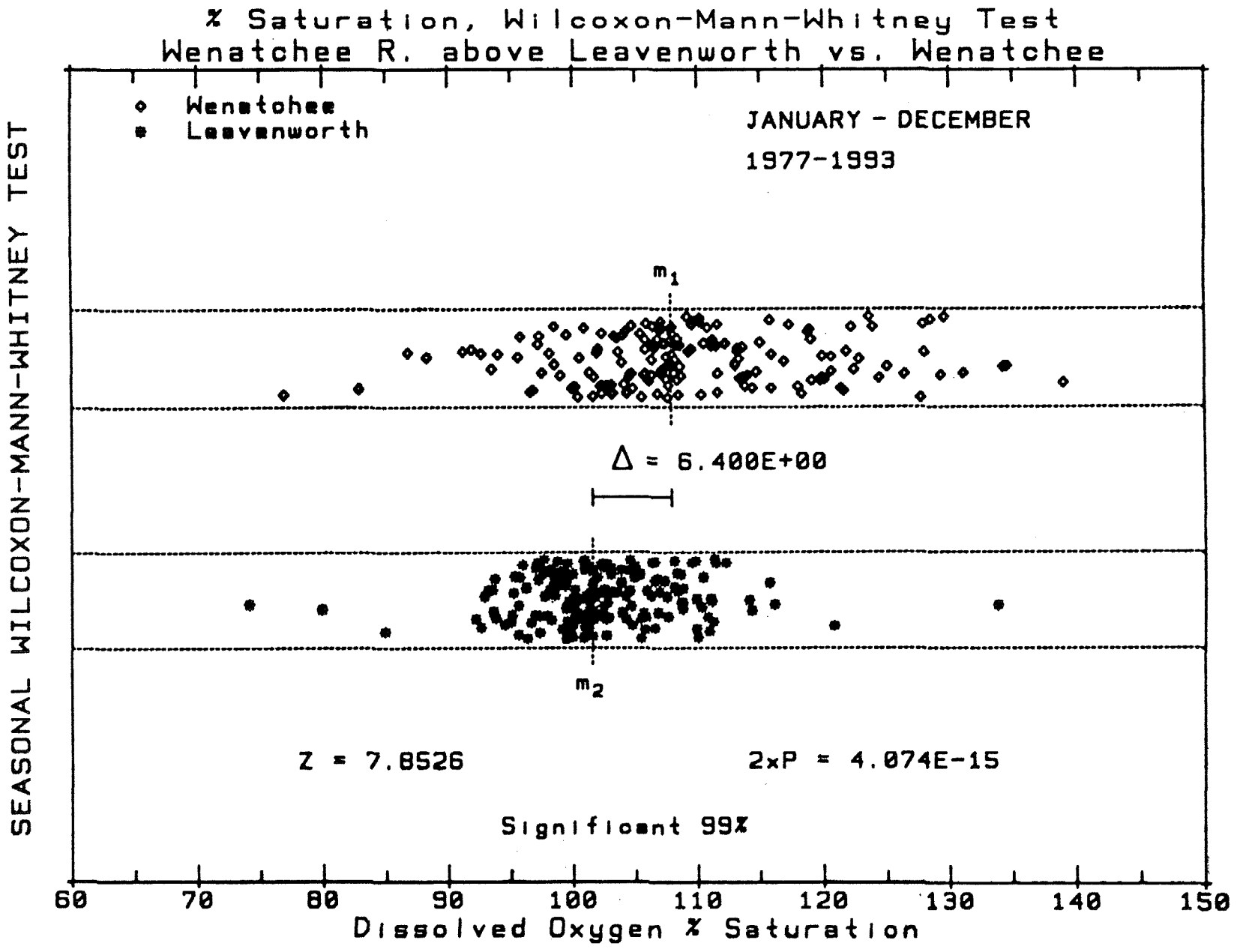
% Saturation, Wilcoxon-Mann-Whitney Test
Wenatchee R. above Leavenworth vs. Wenatchee
Wenatchee
Leavenworth
JANUARY - DECEMBER
1977-1993
SEASONAL WILCOXON-MANN-WHITNEY TEST
m1
Δ = 6.400E+00
m2
Z = 7.8526
2xP = 4.074E-15
Significant 99%
60
70
80
90
100
110
120
130
140
150
Dissolved Oxygen % Saturation

Figure 29

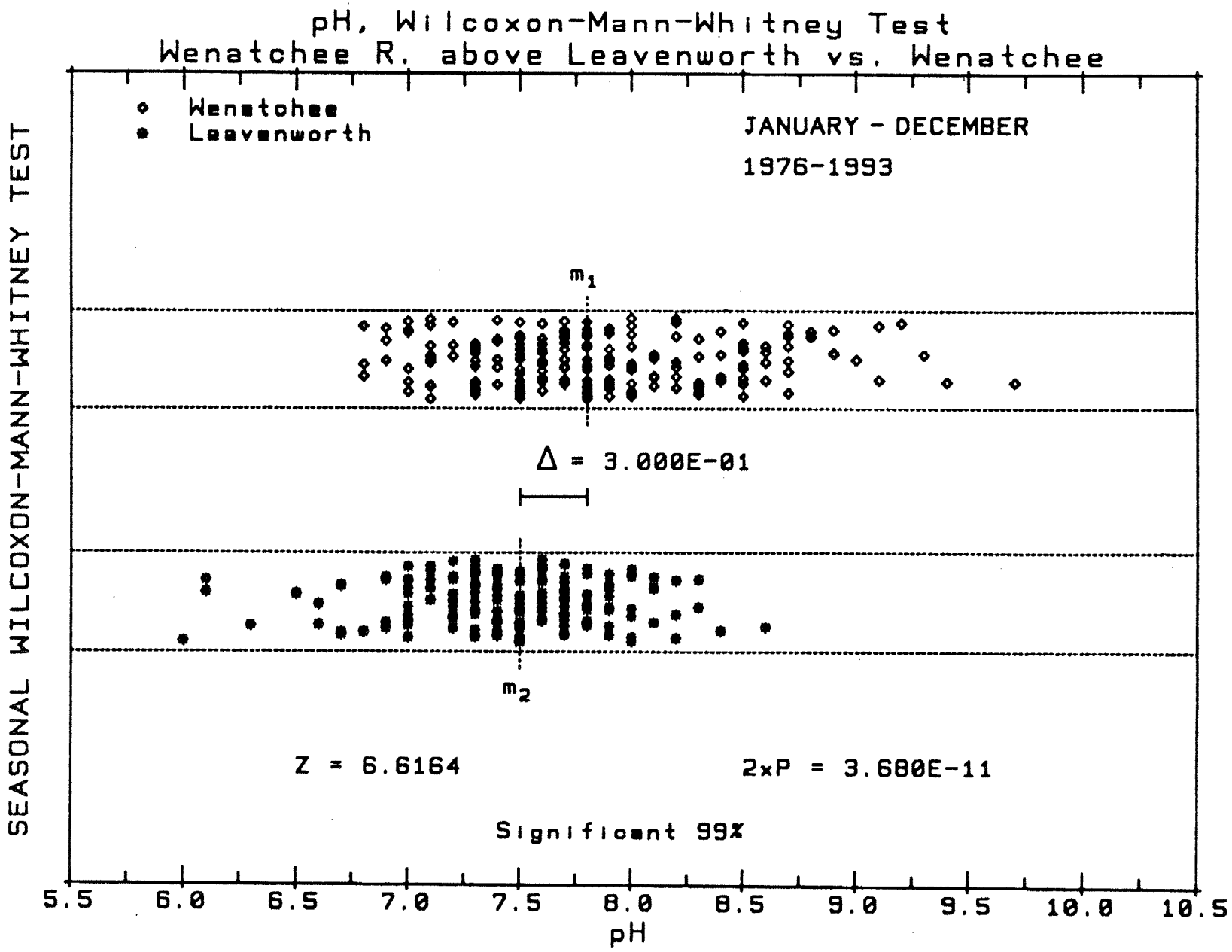
pH, Wilcoxon-Mann-Whitney Test
Wenatchee R. above Leavenworth vs. Wenatchee
Wenatchee
Leavenworth
JANUARY - DECEMBER
1976-1993
SEASONAL WILCOXON-MANN-WHITNEY TEST
m1
Δ = 3.000E-01
m2
Z = 6.6164
2xP = 3.680E-11
Significant 99%
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
pH

Figure 30

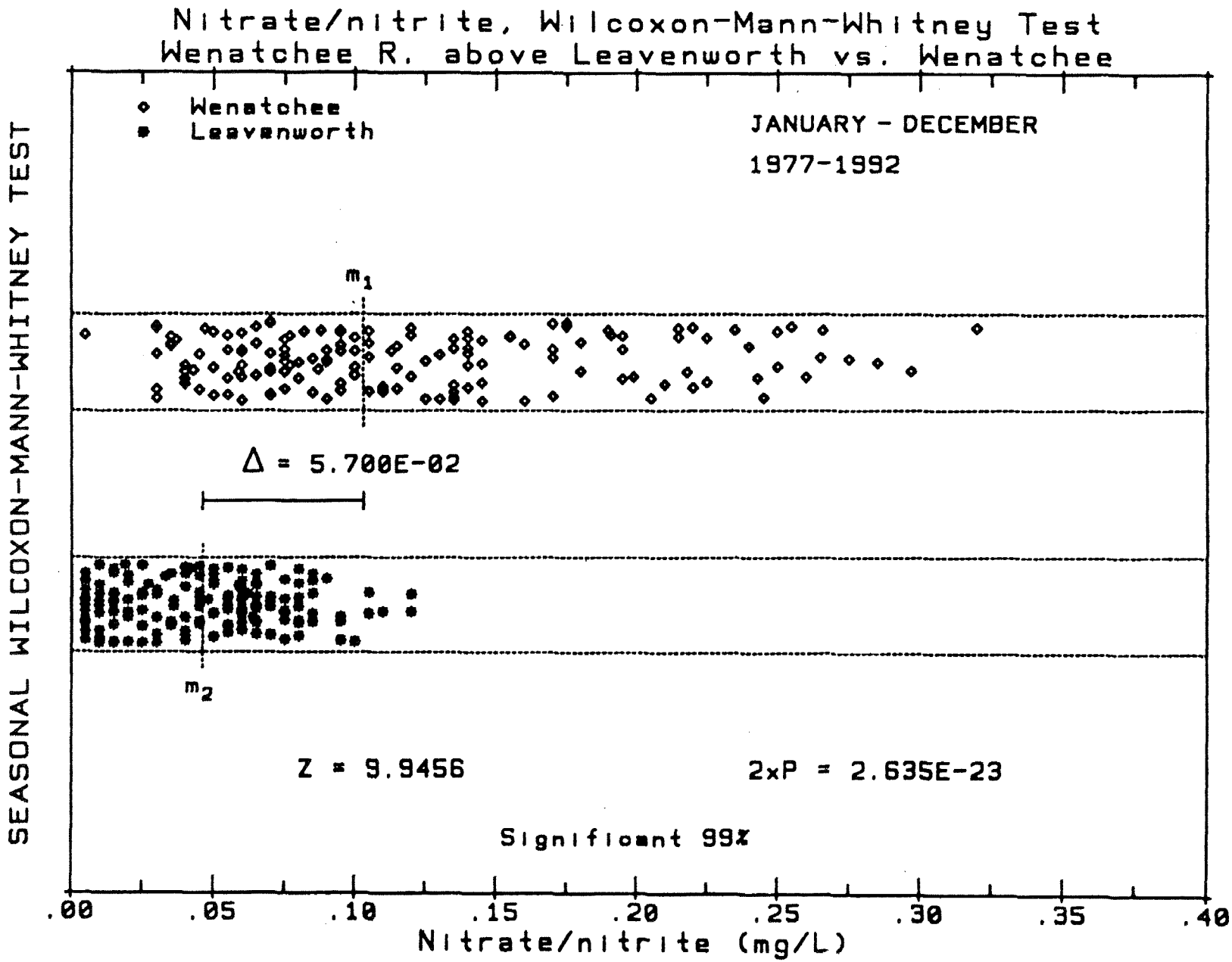
Nitrate/nitrite, Wilcoxon-Mann-Whitney Test
Wenatchee R. above Leavenworth vs. Wenatchee
Wenatchee
Leavenworth
JANUARY - DECEMBER
1977-1992
m1
Δ = 5.700E-02
m2
Z = 9.9456
2xP = 2.635E-23
Significant 99%
SEASONAL WILCOXON-MANN-WHITNEY TEST
.00
.05
.10
.15
.20
.25
.30
.35
.40
Nitrate/nitrite (mg/L)

Figure 31

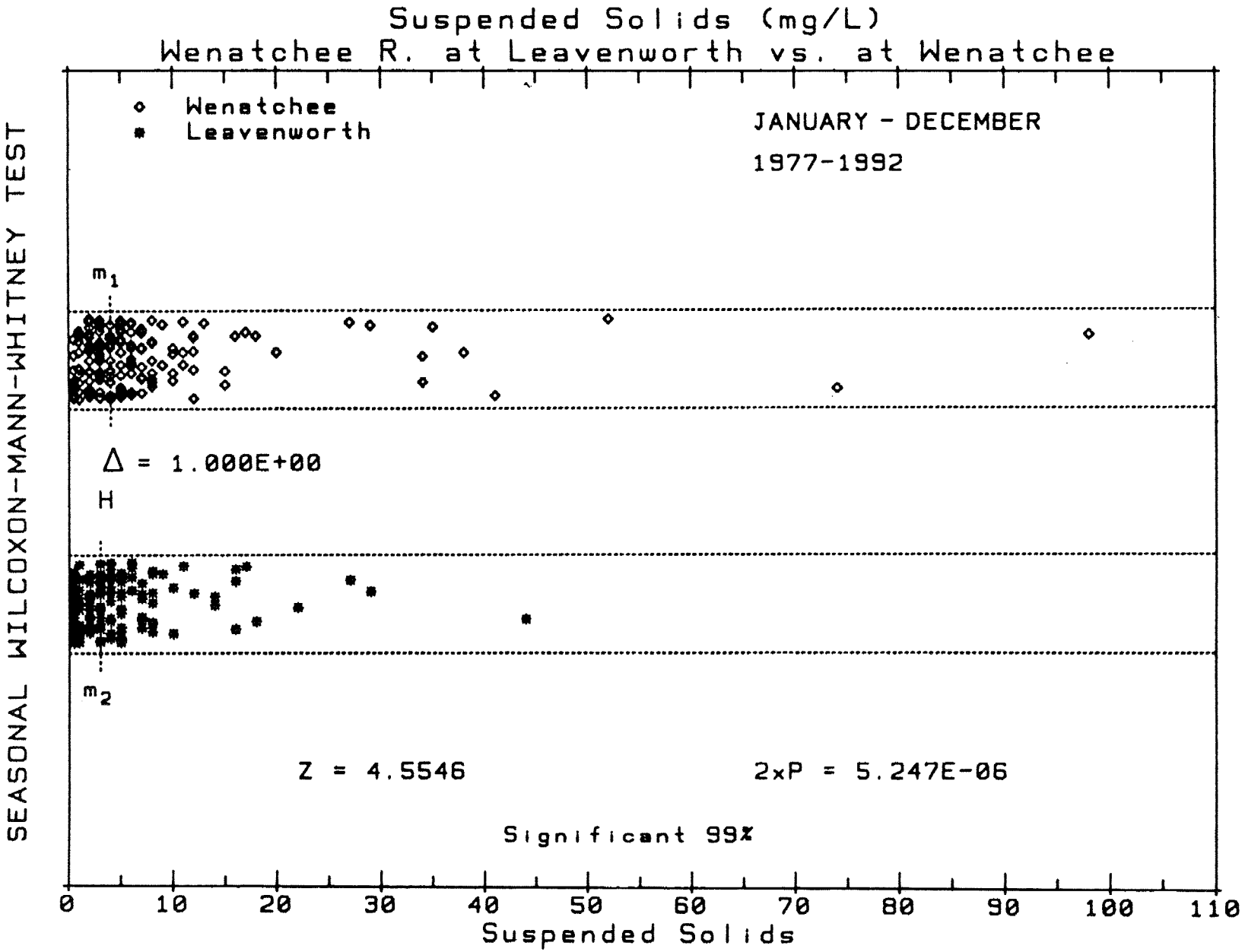
Suspended Solids (mg/L)
Wenatchee R. at Leavenworth vs. at Wenatchee
Wenatchee
Leavenworth
JANUARY - DECEMBER
1977-1992
SEASONAL WILCOXON-MANN-WHITNEY TEST
m1
Δ = 1.000E+00
H
m2
Z = 4.5546
2xP = 5.247E-06
Significant 99%
0
10
20
30
40
50
60
70
80
90
100
110
Suspended Solids

Figure 32

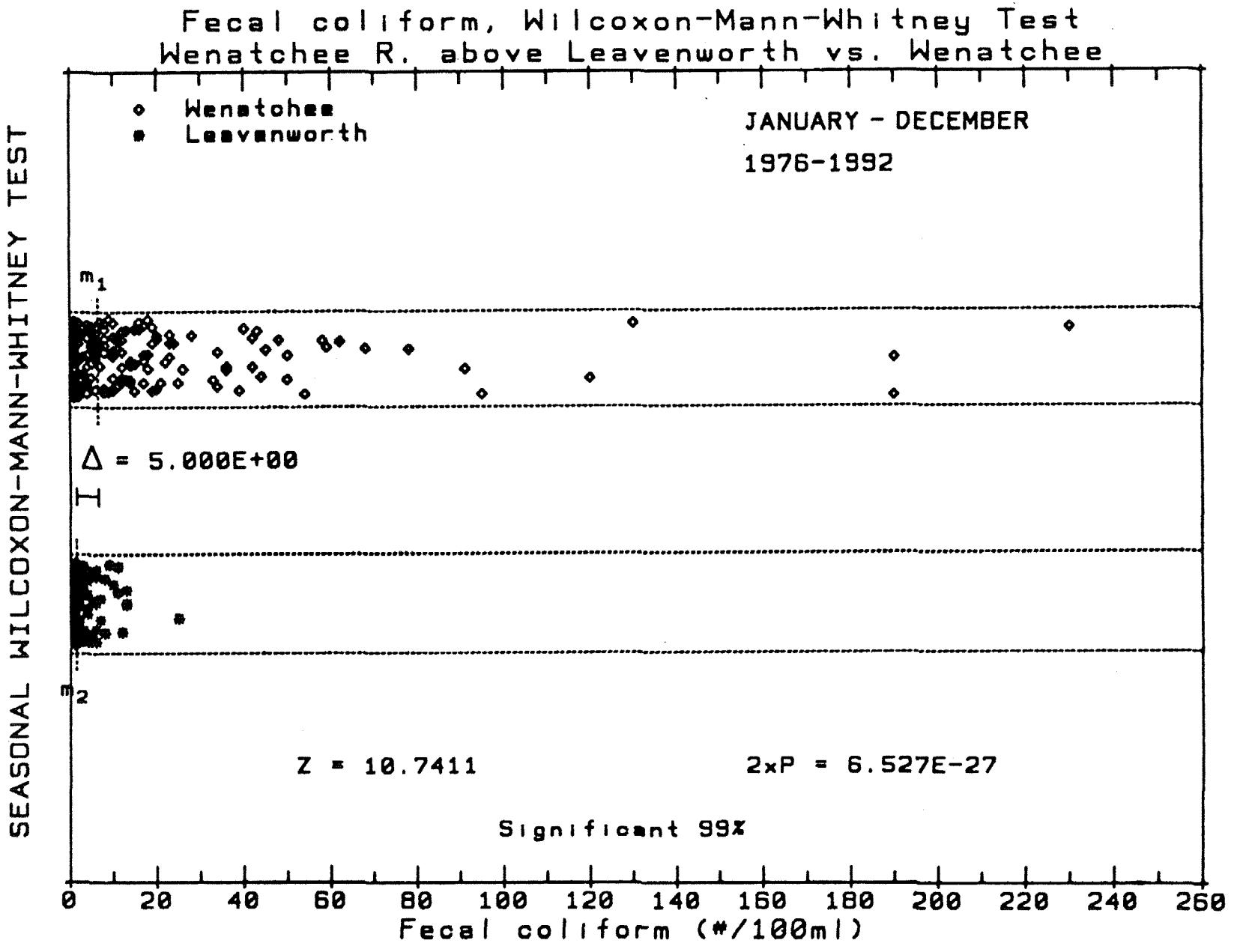
Fecal coliform, Wilcoxon-Mann-Whitney Test
Wenatchee R. above Leavenworth vs. Wenatchee
Wenatchee
Leavenworth
JANUARY - DECEMBER
1976-1992
SEASONAL WILCOXON-MANN-WHITNEY TEST
m1
Δ = 5.000E+00
m2
Z = 10.7411
2xP = 6.527E-27
Significant 99%
0
20
40
60
80
100
120
140
160
180
200
220
240
260
Fecal coliform (#/100ml)

Figure 33

APPENDIX A

WENATCHEE RIVER OFF ICICLE CREEK ROAD AT LEAVENWORTH

24 RM,	TEMP,	COND,	O2,	PCTSAT,	COD,	PH,	TSS,	NH3,	TP,	OP,	HARD,	TURB,	FC,	NO2+NO3	NO2(DIS),	FLOW,	DATE,	TIME,	STANO
0	9	34	11.4	999999	999999	7.7	999999	0.07	0.01	999999	999999	3	999999	999999	999999	2760	751021	900	45A100
0	7.2	36	11.9	999999	999999	7.1	999999	0.06	999999	999999	999999	3	10	999999	999999	1090	751028	905	45A100
0	4.2	34	13	999999	999999	7.4	999999	0.03	999999	999999	999999	2	2	999999	999999	2160	751111	850	45A100
0	3.2	31	13.5	999999	999999	7.3	999999	0.02	999999	999999	999999	1	2	999999	999999	3170	751118	900	45A100
0	4.1	30	13.2	999999	999999	7.3	999999	0.03	0.02	999999	999999	4	4	999999	999999	8060	751209	855	45A100
0	1.6	35	14	999999	999999	7.4	999999	0.06	0.02	999999	999999	3	2	999999	999999	1290	751216	915	45A100
0	0.1	36	14	999999	999999	7.1	999999	0.04	0.01	999999	999999	3	2	999999	999999	1790	760106	905	45A100
0	0.3	37	14.7	999999	999999	7	999999	0.06	0.01	999999	999999	2	2	999999	999999	2650	760120	910	45A100
0	1.5	40	14.2	999999	999999	7.2	999999	0.02	999999	999999	999999	2	2	999999	999999	2280	760203	825	45A100
0	2.5	47	13.5	999999	999999	7.9	999999	0.06	0.01	999999	999999	4	2	999999	999999	1460	760224	905	45A100
0	2.8	45	13.4	999999	999999	7	999999	0.02	0.01	999999	999999	3	2	999999	999999	1030	760309	845	45A100
0	3.7	49	13.3	999999	999999	7.1	999999	0.03	0.01	999999	999999	3	2	999999	999999	1190	760323	840	45A100
0	5.2	46	13.2	999999	999999	7.6	999999	0.02	0.02	999999	999999	8	2	999999	999999	3600	760413	915	45A100
0	7.4	49	11.9	999999	999999	7.4	999999	0.03	0.01	999999	999999	2	2	999999	999999	2720	760427	855	45A100
0	6.7	33	12.9	999999	999999	7.2	999999	0.02	0.04	999999	999999	7	2	999999	999999	13100	760511	920	45A100
0	6.9	34	12.5	999999	999999	7.3	999999	0.02	0.01	999999	999999	5	2	999999	999999	8340	760525	840	45A100
0	9.8	34	11.6	999999	999999	7.3	999999	0.04	0.01	999999	999999	6	16	999999	999999	6660	760608	935	45A100
0	9.1	29	12.2	999999	999999	7.3	999999	0.03	0.01	999999	999999	5	2	999999	999999	11000	760622	855	45A100
0	10.2	27	11.7	999999	999999	7.3	999999	0.06	0.01	999999	999999	5	2	999999	999999	7940	760713	840	45A100
0	11.4	40	11.1	999999	999999	7.2	999999	0.07	0.01	999999	999999	3	2	999999	999999	6660	760727	900	45A100
0	12.2	28	10.9	999999	999999	7.1	999999	0.06	0.01	999999	999999	1	2	999999	999999	4670	760810	915	45A100
0	14	30	10	999999	999999	7.3	999999	0.02	0.01	999999	999999	2	2	999999	999999	2490	760824	825	45A100
0	13.2	36	10.2	999999	999999	7.5	999999	0.04	0.01	999999	999999	1	2	999999	999999	1090	760914	825	45A100
0	13.3	35	10	999999	999999	7.4	999999	0.02	0.01	999999	999999	1	2	999999	999999	1060	760921	830	45A100

ICICLE CREEK AT BRIDGE BELOW LEAVENWORTH NAT'L FISH HATCHERY

24 RM,	TEMP,	COND,	O2,	PCTSAT,	COD,	PH,	TSS,	NH3,	TP,	OP,	HARD,	TURB,	FC,	NO2+NO3	NO2(DIS),	FLOW,	DATE,	TIME,	STANO
0	6.3	42	11.8	999999	999999	7.6	999999	0.06	0.02	999999	999999	2	10	999999	999999	652	751021	915	458070
0	4.3	49	12.5	999999	999999	7	999999	0.05	0.02	999999	999999	4	2	999999	999999	245	751028	930	458070
0	1.8	44	13.9	999999	999999	7.5	999999	0.02	999999	999999	999999	2	2	999999	999999	400	751111	920	458070
0	0.7	43	14.3	999999	999999	7.5	999999	0.03	999999	999999	999999	2	2	999999	999999	540	751118	925	458070
0	3.4	36	13.2	999999	999999	7.6	999999	0.03	0.01	999999	999999	3	2	999999	999999	1850	751209	915	458070
0	0.7	46	14	999999	999999	7.3	999999	0.05	0.01	999999	999999	2	2	999999	999999	769	751216	930	458070
0	0.2	49	14.2	999999	999999	7.3	999999	0.03	0.01	999999	999999	4	2	0.03	999999	500	760106	920	458070
0	0.2	47	14.5	999999	999999	7	999999	0.06	0.01	999999	999999	2	2	999999	999999	756	760120	925	458070
0	1.3	50	14.1	999999	999999	7	999999	0.09	0.01	999999	999999	3	2	999999	999999	476	760203	840	458070
0	2.3	63	13.4	999999	999999	7.6	999999	0.07	0.01	999999	999999	2	2	999999	999999	356	760224	920	458070
0	2.1	60	13.5	999999	999999	7	999999	0.02	0.01	999999	999999	4	2	999999	999999	263	760309	905	458070
0	3.8	68	13.3	999999	999999	7.1	999999	0.03	0.01	999999	999999	3	2	999999	999999	257	760323	905	458070
0	5.1	58	12.8	999999	999999	7.5	999999	0.02	0.01	999999	999999	3	2	999999	999999	652	760413	935	458070
0	6.7	63	11.6	999999	999999	7.4	999999	0.03	0.01	999999	999999	2	2	999999	999999	400	760427	915	458070
0	5.5	36	13.2	999999	999999	7.2	999999	0.02	0.01	999999	999999	3	2	999999	999999	2940	760511	935	458070
0	5.6	39	12.6	999999	999999	7.3	999999	0.02	999999	999999	999999	2	2	999999	999999	1720	760525	855	458070
0	7.4	38	12.1	999999	999999	7.3	999999	0.03	0.01	999999	999999	7	2	999999	999999	1490	760608	950	458070
0	7.5	32	12.5	999999	999999	7.3	999999	0.03	0.01	999999	999999	3	2	999999	999999	2410	760622	915	458070
0	8	32	12.2	999999	999999	7.2	999999	0.05	0.02	999999	999999	4	2	999999	999999	1660	760713	900	458070
0	9.5	30	11.5	999999	999999	7.2	999999	0.06	0.02	0.01	999999	4	2	999999	999999	1260	760727	915	458070
0	11.4	35	11.2	999999	999999	7.3	999999	0.06	0.01	999999	999999	2	2	999999	999999	800	760810	925	458070
0	12.4	37	9.9	999999	999999	7.3	999999	0.02	0.02	999999	999999	1	4	999999	999999	460	760824	850	458070
0	10.7	50	10.4	999999	999999	7.4	999999	0.05	0.01	999999	999999	1	26	999999	999999	188	760914	845	458070
0	12.1	50	10.1	999999	999999	7.4	999999	0.04	0.01	999999	999999	1	2	999999	999999	185	760921	850	458070

WENATCHEE RIVER OFF DOWNSTREAM BRIDGE AT DRYDEN

24	TEMP,	COND,	O2,	PCTSAT,	COD,	PH,	TSS,	NH3,	TP,	OP,	HARD,	TURB,	FC,	NO2+NO3	NO2(DIS),	FLOW,	DATE,	TIME,	STANO
0	8.8	45	11	999999	999999	7.5	999999	0.06	0.02	999999	999999	3	10	999999	999999	2330	751021	835	45A065
0	6.5	50	12.1	999999	999999	6.9	999999	0.05	0.01	999999	999999	4	2	999999	999999	1390	751028	830	45A065
0	4.1	57	13.1	999999	999999	7.6	999999	0.03	0.01	999999	999999	3	2	999999	999999	2510	751111	830	45A065
0	3.4	43	13.5	999999	999999	7.4	999999	0.02	999999	999999	999999	1	2	999999	999999	3540	751118	830	45A065
0	4.3	39	12.9	999999	999999	7.5	999999	0.04	0.04	999999	999999	5	10	999999	999999	8990	751209	835	45A065
0	2	47	13.5	999999	999999	7.3	999999	0.06	0.01	999999	999999	3	2	999999	999999	4370	751216	850	45A065
0	0.3	53	14.1	999999	999999	6.9	999999	0.07	0.01	999999	999999	5	22	999999	999999	1640	760106	835	45A065
0	0.3	56	14.4	999999	999999	7	999999	0.06	0.01	0.01	999999	3	2	999999	999999	3460	760120	845	45A065
0	1.6	40	14	999999	999999	6.9	999999	0.02	999999	999999	999999	2	2	999999	999999	3440	760203	800	45A065
0	3.1	72	13.1	999999	999999	8.1	999999	0.04	0.01	999999	999999	3	10	999999	999999	1960	760224	845	45A065
0	2.9	67	13.5	999999	999999	7.5	999999	0.02	0.01	999999	999999	4	22	999999	999999	1480	760309	815	45A065
0	3.9	66	13.4	999999	999999	7.4	999999	0.05	0.01	999999	999999	2	4	999999	999999	1680	760323	815	45A065
0	6.2	72	12.5	999999	999999	7.7	999999	0.04	0.02	999999	999999	7	999999	999999	999999	4190	760413	835	45A065
0	8.1	72	11	999999	999999	7.6	999999	0.03	0.01	999999	999999	7	2	999999	999999	3010	760427	825	45A065
0	6.8	45	12.5	999999	999999	7.3	999999	0.04	0.03	999999	999999	8	2	999999	999999	14400	760511	840	45A065
0	6.9	44	12.1	999999	999999	7.3	999999	0.02	0.02	999999	999999	6	8	999999	999999	8840	760525	815	45A065
0	10.1	40	11.2	999999	999999	7.4	999999	0.04	0.01	999999	999999	7	8	999999	999999	6900	760608	905	45A065
0	9.2	38	11.9	999999	999999	7.4	999999	0.02	0.01	999999	999999	5	2	999999	999999	11600	760622	820	45A065
0	10.3	33	11.2	999999	999999	7.4	999999	0.04	0.01	999999	999999	8	14	999999	999999	8300	760713	815	45A065
0	11.9	34	10.6	999999	999999	7.3	999999	0.07	0.01	999999	999999	4	2	999999	999999	6840	760727	835	45A065
0	13.2	37	10.6	999999	999999	7.2	999999	0.06	0.03	999999	999999	2	20	999999	999999	4610	760810	845	45A065
0	14.6	42	9.6	999999	999999	7.4	999999	0.06	0.01	999999	999999	2	18	999999	999999	2510	760824	755	45A065
0	12.7	55	10.2	999999	999999	7.5	999999	0.02	0.01	999999	999999	1	14	999999	999999	1140	760914	755	45A065
0	13.3	53	9.8	999999	999999	7.5	999999	0.02	0.01	999999	999999	1	4	999999	999999	1220	760921	755	45A065