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QUALITY ASSURANCE REPORT

Atlanta Central Laboratory

Denver Central Laboratory

By

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QUALITY ASSURANCE REPORT

INTRODUCTION

Standard reference materials taken from the U.S. Geological Survey Standard Reference Water Sample (SRWS) Program (Schroder and others, 1980; Skougstad and Fishman, 1975), and non-Central Laboratory sources are prepared in the Ocala Water Quality Service Unit (QWSU), Ocala, Florida, disguised as routine samples, and distributed to Water Resources Division (WRD) offices. The reference materials are then submitted to the Central Laboratories by the WRD offices on a specified schedule for the determination of major constituents, nutrients, and trace metals. The analytical schedules are chosen to reflect the frequency of analyses for the various constituents. The program is designed so that at least one reference sample should be sent to each laboratory each day for constituents that are determined daily. All constituents in reference materials used to date have been in the dissolved phase; data designated as "total" or "total recoverable" are from samples which have undergone a digestion process, rather than from unfiltered or "whole-water" samples. All samples designated as "total" were analyzed by atomic absorption spectrometry. For the period of this report, analyses were limited to major constituents including specific conductance, nutrients, and trace elements. Samples of precipitation level analyses and selected organic constituents were not shipped to laboratories during the period of this report. These types of analyses will be presented in the next report.

For the period of this report, the following terms are defined:

Major constituents - Alkalinity, boron, calcium, chloride, dissolved solids, fluoride, magnesium, potassium, silica, sodium, sulfate.

Trace Metals - Aluminum; antimony; arsenic; barium; barium, total recoverable; beryllium; cadmium; cadmium, total recoverable; chromium; chromium, total recoverable; cobalt; cobalt, total recoverable; copper, copper, total recoverable; iron; iron, total recoverable; lead; lead, total recoverable; lithium; manganese; manganese, total recoverable; molybdenum; nickel; nickel, total recoverable; selenium; silver; silver, total recoverable; strontium; zinc; zinc, total recoverable.

Nutrients- Ammonia; ammonia plus organic nitrogen; carbon, organic; nitrate plus nitrite-nitrogen; nitrite-nitrogen; phosphorous; phosphorous, ortho.

ICP - Analyses done by inductively coupled plasma spectrometry.

AA - Analyses done by atomic absorption spectrometry.

Once the analysis has passed through the laboratories' quality control and quality assurance routines, the data are permanently stored in WATSTORE. These data reflect the typical quality of results produced by each laboratory and received by each district.

The purpose of this program is to document the quality of data that is generated by the laboratories. The program is not intended to replace the internal quality assurance programs administered by the laboratory chiefs.

Tables 1 and 2 summarize the results of major constituents, specific conductance and trace elements, respectively for the Atlanta and Denver Central Laboratories. Expectation of a normal distribution implies that about 68 percent of the results would be within 1 standard deviation of the most probable value (MPV) and about 95 percent would be within 2 standard deviations. Analyses are considered acceptable if they are within 2 standard deviations of the MPV.

Tables 3 through 6 list each individual value which exceeded the two most probable standard deviation (MPSD) criteria.

Table 7 lists the means and standard deviations for each nutrient mixture submitted to each laboratory.

Table 8 shows the results of a *t* statistic evaluation on the data in table 7.

Figures A1 through A54 and D1 through D54 are control charts of each constituent with time and give a pictorial view of the precision, bias, and possible trends of the data for each laboratory. The ranges given in the legend are approximate and represent the lower, middle, and upper thirds of the range of reference materials available. Starting with this report, data are plotted by log-in dates rather than dates shipped to laboratory as in the past reports. Those samples which take a longer than average time in the laboratory will no longer be plotted until the annual report is published.

Evaluation and statistical criteria

Many of the reference samples were prepared by mixing together two or more SRWSs. The most probable values (MPV) were calculated using a volume-weighted average of the known MPVs. Although a theoretical specific conductance which is calculated by simply averaging the individual specific conductance values may not always be accurate, this approach has been shown to be acceptable for these samples (Peart & Thomas, 1983a). Mixtures that do not behave in a linear fashion have not been used.

Starting with this report the means and standard deviations for all parameters are taken from the results of the interlaboratory, method specific analyses of SRWS No. 24 through 83. For barium, cadmium, cobalt, copper, iron, lead, manganese, molybdenum, and zinc, this report marks the first time method-specific data have been used to evaluate them. Previous reports have included method-specific data for other inorganic constituents. In conformance with WRD Memorandum 81.79, an individual value was considered acceptable if it was less than or equal to 2 standard deviations from the most probable value. The MPSD for each constituent was calculated using a least squares regression analysis of the means and standard deviations obtained from the stated sources. In certain situations, this criterion was impossible to meet. An administrative decision was made to establish a minimum standard deviation for each constituent equal to three-quarters of the value of the reporting level to allow at least one reportable value on each side of the MPV to be accetped. For example, the minimum standard deviation for copper reported to the nearest 10 μg/L is set to 7.5 μg/L and for silver reported to the nearest 1 μg/L is 0.75 μg/L.

Because of an insufficient supply of SRWSs for nutrients (ammonia, ammonia plus organic nitrogen, nitrate plus nitrite, nitrite, orthophosphate, phosphorus, and organic carbon), most of the reference materials used during this period were made from reagent chemicals in the Ocala facility. Methods for preparing these samples are essentially the same as those used in preparing the nutrient samples for the SRWS program; however, stability is uncertain and there are no data from which a list of most probable values can be determined. Therefore, the samples were treated as split samples of unknown concentrations and statistical tests were performed to determine if significant differences existed between the performance of the two laboratories.

As more fully described in WRD Memorandum 81.79 and Friedman, Bradford and Peart, 1983, a binomial distribution was used to evaluate the overall analytical precision for each major and trace constituent. The criteria used gave less than a 1 percent chance that a determination will be considered "unacceptable" solely due to random errors.

Similarly, bias was determined by first examining the number of values which were greater than and less than the MPVs. A binomial probability distribution (at the 50 percent level) was then used such that there was less than a 1 percent chance that a determination would be considered biased solely due to random errors.

To determine a measure of comparability between the two laboratories, the raw data were evaluated using a modification of the Wilcoxon Rank-Sum test (Crawford, Slack, & Hirsch, 1983). Each mixture was ranked separately so that the actual concentration differences between mixtures did not affect the outcome of the test. By using this method, the undesireable effects of outliers are eliminated without eliminating the outliers themselves from the data under consideration.

ANALYTICAL PRECISION

Determination of the following constituents showed statistically significant lack of precision:

Atlanta Central Laboratory - barium(ICP); lead(AA); and lead, total recoverable.

Denver Central Laboratory - copper(ICP); copper, total recoverable; lead, total recoverable; molybdenum(AA); and zinc, total recoverable.

ANALYTICAL BIAS

Determination of the following constituents showed statistically significant bias:

Atlanta Central Laboratory

Positive bias: alkalinity; barium(ICP); calcium(ICP); chloride; cobalt(ICP); dissolved solids; lead(ICP); magnesium(ICP); silica; sodium(ICP); and specific conductance.

Negative bias: aluminum; arsenic; nickel; potassium; and selenium.

Denver Central Laboratory

Positive bias: alkalinity; chloride; copper, total recoverable; fluoride; iron(AA); iron, total recoverable; lead(ICP); lead(AA); magnesium(ICP); silica; sodium(ICP); and zinc, total recoverable.

Negative bias: aluminum; barium(ICP); barium(AA); manganese(ICP);

manganese, total recoverable; and molybdenum(AA).

COMPARABILITY BETWEEN LABORATORIES

The following constituents showed statistically significant differences with respect to the means of the ranked data, indicating lack of comparability between the laboratories: Alkalinity; barium(ICP); barium, total recoverable; beryllium; calcium(ICP); chromium; cobalt(ICP); copper, total recoverabale; dissolved solids; iron(AA); lithium; manganese(ICP); manganese(AA); molybdenum(AA); nickel; nickel, total recoverable; selenium; silver, total recoverable; sodium(AA); sodium(ICP); specific conductance; zinc(AA); and zinc, total recoverable.

Data in table 8 show that both laboratories are performing similarly on all nutrient parameters except ammonia and nitrite plus nitrate-nitrogen, in which the means are similar but the standard deviations are significantly different. The laboratories have had similar means on all nutrients parameters for the past two quarters. They have shown a significantly different standard deviation for ammonia for three of the last four quarters and for nitrite plus nitrate for the last two quarters.

DISCUSSION AND RECOMMENDATIONS

No data for mercury are presented here. We will resume our quality-assurance efforts for mercury following a resolution of the preservation questions discussed in previous reports.

It appears that both laboratories are consistent and in compliance with the Quality of Water Branch policy of reporting "less than the lower limit of detection" rather than zeros for major constituents and trace elements.

There seems to be a problem with one mix used during this reporting period. The same mix for major constituents was used at two different times. In general, data from both laboratories seem to be in agreement for most constituents each time the mix was used. However, the laboratories' data, especially Denver, do not agree with the MPV for one of the two time periods. It appears that there may have been a small error in the dilution of the mix one time or since the levels were very low, the standard deviations were very small and a small laboratory error could explain the problem. It was decided that the data would stay in the report but it would be excluded when testing for lack of precision and bias. Since the laboratories seem to compare very well to each other, the values were left in for the comparability test.

Each of the statistical tests applied to the data as well as the information displayed in the figures (figs. A1-D54) shows a different aspect of the data and may produce results which appear confusing and even contradictory at times. However, a careful evaluation will allow the correct conclusion to be reached. One example is a situation where a constituent shows no lack of precision or bias in either lab, but the Wilcoxon rank-sum test indicates a significant difference between the two labs. One can then look at the figures and may see that one lab has a slight (though not statistically significant) bias in one direction while the other lab has a slight bias in the other direction; or in a much less obvious situation, the figures may look almost identical. One would then conclude that one lab has a general tendency to produce data that is slightly biased with respect to the other, although this bias would not affect data interpretation because neither lab is producing data that can be classified as biased or imprecise.

In a second example, neither lab shows lack of precision, one lab shows bias but the rank-sum test indicates no significant differences and the figures look very similar. The fact that one lab shows significant bias and the other does not is probably due to the fact that it is a borderline situation. There are frequent instances where a constituent misses being classified or is classified as biased by one or two data points. The figures are important in this situation to determine the magnitude of the bias and its resultant effect on data interpretation. If the data are clustered together very close to the zero line, but enough are on one side to indicate a significant bias, this bias would probably not affect data interpretation. It is also important to remember that the standards used here are "most probable values" not a series of "true values", and that they were determined empirically. Consistent or frequently recurring bias of this type may then be interpreted as method or operator related. One must conclude that the two labs are producing comparable data.

SUMMARY AND CONCLUSIONS

Many constituents passed all the statistical tests and can therefore be classified as having acceptable precision, bias and comparability between the labs. Others have shown some statistically significant difference but in a way that would not affect data interpretation (see discussion and examples in the previous section). And others do indeed have notable differences.

Constituents for which no statistically significant difference was found for any test applied during this quarter include: boron; cadmium(ICP); cadmium(AA); cadmium, total recoverable; calcium(AA); chromium, total recoverable; cobalt(AA); cobalt, total recoverable; copper(AA); iron(ICP); magnesium(AA); molybdenum(ICP); silver; strontium; sulfate; zinc. This represents about 30% of all the constituents.

Constituents for which a significant difference was found for at least one test but where the difference(s) is considered to be of minimal importance include: arsenic; barium (AA); barium, total recoverable; beryllium; chromium; cobalt (ICP); copper(ICP); dissolved solids; lithium; manganese(ICP); manganese(AA); manganese, total recoverable; nickel; selenium; silver, total recoverable; and zinc(AA).

Constituents for which both labs show bias in the same direction but where over 95% of the data fall within two standard deviations from the MPV include:

Alkalinity - Both labs show a positive bias and the rank-sum test indicates lack of comparability. Denver had a positive bias in both the 1982 and 1983 annual reports (Peart and Thomas, 1983b, 1984) and Atlanta had a positive bias in 1983. The lack of comparability is likely due to the two outliers in Denver (Nov. and Dec., fig. D1). The bias is small and may be due to slight but consistent overtitration.

Aluminum - Both labs show a negative bias and the rank-sum test indicates data are comparable. Atlanta had a positive bias in both the 1982 and 1983 annual reports (Peart and Thomas, 1983b, 1984. Denver had a negative bias while Atlanta was unbiased in the last quarter of 1983 water year. Since Denver is using the DC plasma method, and Atlanta is using the AA method, the bias may be method related.

Chloride - Both labs show a positive bias and the rank-sum test indicates data are comparable. Atlanta has not previously shown positive bias for this constituent. Denver had a positive bias in the last quarter of WY83 and also for the overall evaluation for WY83 (Peart and Thomas, 1984).

Lead(ICP) - Both labs show a positive bias and the rank-sum test indicates data are comparable.

Magnesium(ICP) - Both labs show a positive bias and the rank-sum test indicates data are comparable. Other than for this quarter, Atlanta has never shown a positive bias for this constituent. Denver has infrequently shown a positive bias for this constituent.

Silica - Both labs show a positive bias and the rank-sum test indicates data are comparable.

Constituents for which a significant difference was found for at least one test but where the influence of the difference(s) on data interpretation is questionable include:

Calcium(ICP) - Atlanta shows a positive bias which it has not had in the last three reports. The rank-sum test indicates significance. However, over 92% of the data from both labs are within two standard deviations from the MPV.

Fluoride - Denver shows a positive bias. No lack of precision is shown in either lab and the rank-sum test did not indicate significance. Atlanta had less than 60% of data within one standard deviation from the MPV.

Iron, total recoverable - Denver shows a positive bias. Both labs had a positive bias for 1983 annual report (Peart and Thomas, 1984).

Nickel, total recoverable - No bias or lack of precision is shown in either lab. The rank-sum test indicates a significant difference in comparability. While Atlanta has 100% of data within one standard deviation from MPV, Denver has only 33.3%.

Potassium - The rank-sum test indicates that the data are comparable but Atlanta shows a negative bias. Atlanta had a negative bias in the 1982 and 1983 annual reports (Peart and Thomas, 1983b, 1984). Denver had a negative bias in 1983 annual but was not biased in 1982 water year. The cluster of October values (figure D42) over two standard deviations from MPV were from the mix discussed earlier, and were disregarded before testing for bias or lack of precision.

Sodium(ICP) - Both labs show a positive bias and the rank-sum test indicates a lack of comparability. Both labs have shown a positive bias in the 1982 and 1983 annual report (Peart and Thomas, 1983b, 1984).

Sodium(AA) - The Rank-sum test indicates lack of comparability. No lack of precision or bias is found. The four values (figure D48) over two standard deviations from the MPV in Denver were from the mix discussed previously and they were disregarded before testing for lack of precision. The corresponding Atlanta values were not over two standard deviations.

Constituents for which significant differences were found for at least one test and that appear to warrant some corrective action include:

Barium(ICP) - Atlanta shows a lack of precision and a positive bias. Denver shows a negative bias and the rank-sum test shows lack of comparability. Atlanta had less than 50% of its data within two standard deviations of the MPV. Better control of precision and bias in Atlanta and of bias in Denver is warranted.

Copper, total recoverable - Denver shows lack of precision and a positive bias. The rank-sum test indicates lack of comparability. While Atlanta had 100% of data within one standard deviation Denver had only 33.3% within two standard deviations. Better control of precision and bias in Denver is warranted.

Iron(AA) - Denver shows a positive bias and the rank-sum test indicates lack of comparability. Denver has shown a positive bias for iron in the last three reports but does not show a bias for iron(ICP).

Lead(AA) - Atlanta shows a lack of precision and Denver shows a positive bias. The rank-sum test does not show a lack of comparability. Better control of precision in Atlanta is warranted.

Lead, total recoverable - Both labs show a lack of precision. Neither lab shows a bias and the rank-sum test does not indicate a lack of comparability.

Molybdenum(AA) - Denver shows a lack of precision and a negative bias. The rank-sum test shows lack of comparability. Denver has 76.2% of data within two standard deviations of the MPV while Atlanta has 83.3%. Both labs need better control of precision.

Specific Conductance - Atlanta shows a positive bias and the rank-sum test indicates lack of comparability. Atlanta has shown a positive bias in two of the last three reports.

Zinc, total recoverable - Denver shows a lack of precision and a positive bias. The rank-sum test indicates a lack of comparability. While Atlanta had 100% of data within two standard deviations of the MPV, Denver had only 66.7%. Better control of bias and precision in Denver is warranted.

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SUPPLEMENTAL DATA

Table 1.--Summary of results for major constituents and specific conductance
[All constituents were in the dissolved phase]

Determination	Atlanta			Denver		
	No. of samples	Percent ≤ 1 standard deviation	Percent ≤ 2 standard deviations	No. of samples	Percent ≤ 1 standard deviation	Percent ≤ 2 standard deviations
Alkalinity	57	93.0	100	64	90.6	96.9
Boron	19	100	100	25	92.0	100
Calcium(ICP)[1]	42	69.0	92.9	52	75.0	92.3
Calcium(AA)[1]	12	66.7	83.3	11	54.5	63.6
Chloride	57	87.7	98.2	64	85.9	100
Dissolved solids	54	94.4	98.1	59	88.1	94.9
Fluoride	57	57.9	93.0	64	70.3	89.1
Magnesium(ICP)[1]	42	95.2	100	52	88.5	96.2
Magnesium(AA)[1]	12	66.7	91.7	11	54.5	81.8
Potassium[1]	54	74.1	98.1	63	61.9	79.4
Silica	57	87.7	100	64	98.4	100
Sodium(ICP)	42	59.5	90.5	52	92.3	100
Sodium(AA)[1]	12	91.7	100	11	63.6	63.6
Specific Conductance[1]	57	75.4	100	64	76.6	98.4
Sulfate	57	93.0	100	64	90.6	100

[1] See Discussion and Recommendations.

Table 2.--Summary of results for trace metals
[All constituents were in the dissolved phase; data designated as "total recoverable" are from samples which have undergone a preliminary digestion]

Determination	Atlanta			Denver		
	No. of samples	Percent $\leq$ 1 standard deviation	Percent $\leq$ 2 standard deviations	No. of samples	Percent $\leq$ 1 standard deviation	Percent $\leq$ 2 standard deviations
Aluminum	27	88.9	96.3	24	100	100
Antimony	3	100	100	3	100	100
Arsenic	49	89.8	100	48	95.8	100
Barium(ICP)	23	13.0	47.8	23	69.6	82.6
Barium(AA)	11	54.5	100	12	50	100
Barium, total recoverable	11	63.6	100	12	83.3	100
Beryllium	23	95.7	100	23	82.6	100
Cadmium(ICP)	23	87.0	100	23	82.6	95.7
Cadmium(AA)	35	80.0	97.1	33	87.9	90.9
Cadmium, total recoverable	11	90.9	100	12	100	100
Chromium	38	73.7	97.4	36	80.6	100
Chromium, total recoverable	11	54.5	100	12	83.3	100

Table 2.--Summary of results for trace metals--Continued

Determination	Atlanta			Denver		
	No. of samples	Percent ≤ 1 standard deviation	Percent ≤ 2 standard deviations	No. of samples	Percent ≤ 1 standard deviation	Percent ≤ 2 standard deviations
Cobalt(ICP)	23	95.7	100	23	95.7	95.7
Cobalt(AA)	11	63.6	81.8	12	100	100
Cobalt, total recoverable	11	63.6	81.8	12	100	100
Copper(ICP)	23	82.6	87.0	23	78.3	78.3
Copper(AA)	35	100	100	33	57.6	87.9
Copper, total recoverable	11	100	100	12	0.0	33.3
Iron(ICP)	23	91.3	100	23	78.3	100
Iron(AA)	35	85.7	100	33	54.5	84.8
Iron, total recoverable	11	36.4	81.8	12	66.7	91.7
Lead(ICP)	23	52.2	100	23	56.5	100
Lead(AA)	35	65.7	82.9	33	72.7	90.9
Lead, total recoverable	11	36.4	63.6	12	8.3	41.7
Lithium	23	91.3	100	23	87.0	100

Table 2.--Summary of results for trace metals--Continued

Determination	Atlanta			Denver		
	No. of samples	Percent ≤ 1 standard deviation	Percent ≤ 2 standard deviations	No. of samples	Percent ≤ 1 standard deviation	Percent ≤ 2 standard deviations
Manganese(ICP)	23	100	100	23	100	100
Manganese(AA)	35	91.4	100	33	93.9	100
Manganese, total recoverable	11	90.9	100	12	100	100
Molybdenum(ICP)	23	56.5	100	23	52.2	100
Molybdenum(AA)	24	54.2	83.3	21	23.8	76.2
Nickel	38	86.8	100	36	88.9	97.2
Nickel, total recoverable	11	100	100	12	33.3	100
Selenium	25	100	100	27	100	100
Silver	14	92.9	100	15	86.7	100
Silver, total recoverable	11	100	100	12	66.7	75.0
Strontium	23	87.0	95.7	23	78.3	100
Zinc(ICP)	23	95.7	100	23	95.7	100
Zinc(AA)	35	85.7	100	33	87.9	93.9
Zinc, total recoverable	11	63.6	100	12	50.0	66.7

Table 3.--Tabulation of data over 2 standard deviations from the most probable value for the Atlanta laboratory: major constituents and specific conductance

[All constituents were in dissolved phase]

Determination/ Percent > 2 standard deviations/ Total Analyses	Concentration range of reference samples (mg/L)	Reported value (mg/L)	Most probable value (mg/L)	Most probable standard deviation (mg/L)	Number of standard deviations
Calcium(ICP)[1]/ 7.1/42	6.9-87	7.1	6.9	0.07	2.53
		7.1	6.9	.07	2.53
		7.8	6.9	.07	11.87
Calcium(AA)[1]/ 16.7/12	6.9-107	7.7	6.9	0.35	2.24
		7.7	6.9	.35	2.24
Chloride/1.8/57	1.3-99	110	98.8	3.45	3.24
Dissolved solids/ 1.9/54	43.8-926	1010	926	33.5	2.51
Fluoride/7.0/57	0.29-1.17	1.2	1.02	0.07	2.40
		1.3	1.07	.07	3.07
		1.3	1.14	.07	2.13
		.6	.76	.07	-2.20
Magnesium(AA)/ 8.3/12	1.79-55	2.1	1.8	0.11	2.72
Potassium[1]/1.9/54	0.95-5.6	1.1	0.9	0.06	2.73
Sodium(ICP)/ 9.5/42	3.15-80	15	12.7	1.11	2.08
		50	55.9	2.27	-2.60
		53	48.5	2.07	2.17
		53	48.5	2.07	2.17

1 See Discussion and Recommendations.

Table 4.--Tabulation of data over 2 standard deviations from the most probable value for the Atlanta laboratory: trace metals

[All constituents were in dissolved phase; data designated as 'total recoverable' are from samples which have undergone a preliminary digestion]

Determination/ Percent > 2 standard deviations/ Total Analyses	Concentration range of reference samples (μg/L)	Reported value (μg/L)	Most probable value (μg/L)	Most probable standard deviation (μg/L)	Number of standard deviations
Aluminum/3.7/27	35-335	130	263	58.5	-2.27
Barium(ICP)/ 52.2/23	18-180	140	120	8.3	2.42
		140	120	8.3	2.42
		43	18	2.7	9.36
		25	18	2.7	2.62
		27	18	2.7	3.37
		25	18	2.7	2.62
		27	18	2.7	3.37
		210	180	11.6	2.59
		210	180	11.6	2.59
		210	180	11.6	2.59
		110	90	6.6	3.02
		49	36	3.7	3.55
Cadmium(AA)/ 2.9/35	2.5-13.3	5	2.8	0.8	2.93
Chromium/2.6/38	4-29	10	28.8	7.2	-2.61
Cobalt(AA)/ 18.2/11	1.2-14.5	10	13.8	1.6	-2.37
		6	9.4	1.6	-2.14
Cobalt, total recoverable/ 18.2/11	5.6-13.8	10	13.8	1.6	-2.37
		6	9.4	1.6	-2.14
Copper(ICP)/ 13/23	15-180	220	180	14.7	2.73
		220	180	14.7	2.73
		210	180	14.7	2.04
Iron, total recoverable/ 18.2/11	352-485	540	357	42.1	4.34
		580	357	42.1	5.29

Table 4.--Tabulation of data over 2 standard deviations from the most probable value for the Atlanta laboratory: trace metals--continued

[All constituents were in dissolved phase; data designated as 'total recoverable' are from samples which have undergone a preliminary digestion]

Determination/ Percent > 2 standard deviations/ Total Analyses	Concentration range of reference samples (μg/L)	Reported value (μg/L)	Most probable value (μg/L)	Most probable standard deviation (μg/L)	Number of standard deviations
Lead(AA)/17.1/35	1.8-22	15	7.9	2.3	3.12
		11	5.9	1.8	2.76
		10	5.9	1.8	2.21
		14	8.3	2.4	2.37
		4	1.8	.9	2.61
		5	1.8	.9	3.77
Lead, total recoverable/ 36.4/11	1.8-9.75	15	7.9	2.3	3.12
		6	1.8	.9	4.93
		5	1.8	.9	3.77
		5	1.8	.9	3.77
Molybdenum(AA)/ 16.7/24	5.5-24.5	31	24.5	3.0	2.18
		31	24.5	3.0	2.18
		20	14.7	2.3	2.28
		17	11.8	2.1	2.45
Strontium/ 4.3/23	60-1196	470	418	21.3	2.44

Table 5.--Tabulation of data over 2 standard deviations from the most probable value for the Denver laboratory: major constituents and specific conductance

[All constituents were in dissolved phase]

Determination/ Percent > 2 standard deviations/ Total Analyses	Concentration range of reference samples (mg/L)	Reported value (mg/L)	Most probable value (mg/L)	Most probable standard deviation (mg/L)	Number of standard deviations
Alkalinity/3.1/64	16.6-174	177	161	6.70	2.33
		181	142	6.70	5.82
Calcium(ICP)[1]/ 7.3/52	6.9-87	7.8	6.9	0.07	11.87
		7.9	6.9	.07	13.20
		7.8	6.9	.07	11.87
		8.0	6.9	.07	14.53
Calcium(AA)[1]/ 36.4/11	6.9-107	8.2	6.9	0.35	3.66
		7.8	6.9	.35	2.53
		7.8	6.9	.35	2.53
		7.7	6.9	.35	2.24
Dissolved solids/ 5.1/59	43.8-926	867	770	29.8	3.26
		431	157	15.1	18.18
		10	43.8	12.4	-2.74
Fluoride/10.9/64	0.26-1.17	1.2	0.76	0.07	5.80
		1.1	.76	.07	4.47
		1.3	1.14	.07	2.13
		1.3	1.14	.07	2.13
		1.4	1.14	.07	3.47
		1.3	1.14	.07	2.13
		1.3	1.14	.07	2.13
Magnesium(ICP)[1]/ 3.8/52	1.79-51.8	2.2	1.8	0.15	2.72
		29	32.0	1.48	-2.03
Magnesium(AA)[1]/ 8.2/11	1.79-55	2.1	1.8	0.11	2.72
		2.1	1.8	.11	2.72

Table 5.--Tabulation of data over 2 standard deviations from the most probable value for the Denver laboratory: major constituents and specific conductance--continued

[All constituents were in dissolved phase]

Determination/ Percent > 2 standard deviations/ Total Analyses	Concentration range of reference samples (mg/L)	Reported value (mg/L)	Most probable value (mg/L)	Most probable standard deviation (mg/L)	Number of standard deviations
Potassium[1]/ 20.6/63	0.95-5.6	1.1	0.9	0.06	2.73
		4.5	.9	.06	62.60
		4.5	.9	.06	62.60
		1.1	.9	.06	2.73
		1.1	.9	.06	2.73
		1.1	.9	.06	2.73
		1.1	.9	.06	2.73
		1.1	.9	.06	2.73
		1.1	.9	.06	2.73
		1.2	.9	.06	4.49
		2.6	3.3	.32	-2.12
		3.7	4.8	.49	-2.22
		3.4	5.1	.52	-3.18
Sodium(AA)[1]/ 36.4/11	3.15-100	4.1	3.1	0.33	2.87
		4.0	3.1	.33	2.57
		4.3	3.1	.33	3.48
		4.9	3.1	.33	5.29
Specific conductance[2]/ 1.6/64	69.3-1306	87	69.3	7.50	2.36

1 See Discussions and Recommendations.
2 Units are mhos/cm at 25 C.

Table 6.--Tabulation of data over 2 standard deviations from the most probable value for the Denver laboratory: trace metals

[All constituents were in dissolved phase; data designated as 'total recoverable' are from samples which have undergone a preliminary digestion]

Determination/ Percent > 2 standard deviations/ Total Analyses	Concentration range of reference samples (µg/L)	Reported value (µg/L)	Most probable value (µg/L)	Most probable standard deviation (µg/L)	Number of standard deviations
Barium(ICP)/ 17.4/23	18-180	140	171	11.1	-2.80
		140	171	11.1	-2.80
		140	171	11.1	-2.80
		140	171	11.1	-2.80
Cadmium(ICP)/ 4.3/23	1.3-7.9	45	7.8	1.6	23.09
Cadmium(AA)/ 9.1/33	2.6-13.3	10	6.6	1.3	2.65
		10	6.6	1.3	2.65
		10	6.6	1.3	2.65
Cobalt(ICP)/ 4.3/23	1.2-14.5	52	2.3	3.3	15.06
Copper(ICP)/ 21.8/23	15-180	220	180	14.7	2.73
		220	180	14.7	2.73
		220	180	14.7	2.73
		220	180	14.7	2.73
		10	54.1	7.5	-5.88
Copper(AA)/ 12.1/33	14.5-197	24	14.5	3.8	2.51
		85	38.4	5.8	8.04
		50	38.4	5.8	2.00
		51	38.4	5.8	2.17
Copper, total recoverable/ 66.7/12	14.5-106	27	14.5	3.8	3.30
		24	14.5	3.8	2.51
		29	14.5	3.8	3.83
		32	14.5	3.8	4.62
		130	106	11.5	2.09
		130	106	11.5	2.09
		130	106	11.5	2.09
		130	98.3	10.8	2.93

Table 6.--Tabulation of data over 2 standard deviations from the most probable value for the Denver laboratory: trace metals--continued

[All constituents were in dissolved phase; data designated as 'total recoverable' are from samples which have undergone a preliminary digestion]

Determination/ Percent > 2 standard deviations/ Total Analyses	Concentration range of reference samples (μg/L)	Reported value (μg/L)	Most probable value (μg/L)	Most probable standard deviation (μg/L)	Number of standard deviations
Iron(AA)/ 15.2/33	16-485	350	262	35.9	2.45
		350	262	35.9	2.45
		380	262	35.9	3.29
		280	213	32.6	2.05
		250	164	29.4	2.92
Iron, total recoverable/ 9.3/12	352-485	590	485	50.6	2.08
Lead(AA)/ 9.1/33	1.8-22	7	1.8	0.9	6.09
		4	1.8	.9	2.61
		4	1.8	.9	2.61
Lead, total recoverable/ 58.3/12	1.8-9.8	4	1.8	0.9	2.61
		4	1.8	.9	2.61
		4	1.8	.9	2.61
		3	9.8	2.7	-2.49
		16	7.9	2.3	3.56
		14	7.9	2.3	2.68
		13	7.9	2.3	2.24
Molybdenum(AA)/ 23.8/21	82.5-465	10	14.7	2.3	-2.03
		9	14.7	2.3	-2.46
		1	5.4	1.7	-2.63
		1	5.4	1.7	-2.63
		1	5.4	1.7	-2.63
Nickel/2.8/36	4.7-14.4	21	11.7	4.3	2.16
Nickel, total recoverable/ 8.3/12	4.7-9.6	63	4.6	4.3	13.57
Silver, total recoverable/ 25/12	0.6-11.2	3	11.2	4.1	-2.02
		3	11.2	4.1	-2.02
		3	11.2	4.1	-2.02

Table 6.--Tabulation of data over 2 standard deviations from the most probable value for the Denver laboratory: trace metals--continued

[All constituents were in dissolved phase; data designated as 'total recoverable' are from samples which have undergone a preliminary digestion]

Determination/ Percent > 2 standard deviations/ Total Analyses	Concentration range of reference samples (µg/L)	Reported value (µg/L)	Most probable value (µg/L)	Most probable standard deviation (µg/L)	Number of standard deviations
Zinc(AA)/ 6.1/33	51-301	280	179	48.1	2.10
		280	179	48.1	2.10
Zinc, total recoverable/ 33.3/12	51-204	280	179	48.1	2.10
		290	179	48.1	2.31
		510	179	48.1	6.88
		280	179	48.1	2.10

Table 7.--Comparison of results for nutrient samples

Constituent	Mix	Atlanta N	Atlanta Mean	Atlanta Standard deviation	Denver N	Denver Mean	Denver Standard deviation
Ammonia	1	5	1.4	0.522	12	1.6	0.049
	3	16	.67	.141	14	.50	.017
	4	10	.66	.333	10	.87	.038
	5	18	1.1	.395	6	1.2	.000
	6	6	1.5	.151	6	1.4	.000
	7	6	3.1	.723	6	3.5	.320
	8	4	.36	.015	16	.37	.023
	9	16	1.4	.070	20	1.3	.047
	10	12	2.3	.946	12	2.8	.311
	13	12	.84	.156	12	.79	.021
	14	12	1.6	.079	20	1.5	.041
Ammonia plus organic nitrogen	1	5	2.9	0.503	12	3.4	0.782
	3	16	1.1	.408	14	1.4	.235
	4	10	1.2	.343	10	1.7	.103
	5	18	2.7	.853	6	3.3	.639
	6	6	2.8	.273	6	2.9	.315
	7	6	4.7	.327	6	5.1	.957
	8	4	1.1	.129	16	1.6	.182
	9	16	2.4	.752	20	2.5	.445
	10	12	3.5	.480	12	3.9	.353
	13	12	1.9	.329	12	2.4	.100
	14	12	2.5	.380	20	2.4	.249
Carbon, organic	3	10	2.8	0.346	10	2.7	0.571
	4	10	6.2	2.05	10	7.2	.487
	6	3	7.2	.802	3	6.8	.808
	7	3	3.8	1.24	3	4.3	.603
	8	2	5.9	.141	4	5.0	.096
	9	3	6.2	.802	2	6.2	.424
	10	2	6.0	.707	3	5.6	.252
Nitrite plus nitrate nitrogen	1	6	3.1	1.20	12	3.4	0.052
	2	4	.10	.000	4	.10	.000
	3	16	1.4	.120	14	1.3	.000
	4	10	.49	.016	10	.48	.028
	5	18	2.1	.452	6	2.1	.000
	6	6	1.9	.041	6	1.7	.052
	7	6	1.2	.256	6	1.2	.000
	8	4	1.3	.000	16	1.2	.050

Table 7.--Comparison of results for nutrient samples--continued

Constituent	Mix	Atlanta N	Atlanta Mean	Atlanta Standard deviation	Denver N	Denver Mean	Denver Standard deviation
Nitrite plus nitrate nitrogen--continued	9	16	1.2	0.062	20	1.1	0.041
	10	12	1.9	.051	12	1.8	.049
	11	4	3.3	2.15	2	4.1	.141
	12	4	3.8	.550	3	4.0	.000
	13	12	3.6	.411	12	3.2	.039
	14	12	1.7	.067	20	1.6	.032
Nitrite-nitrogen	3	13	0.61	0.031	12	0.61	0.005
	4	10	.16	.009	10	.17	.000
	5	18	.33	.247	3	.32	.000
	10	3	.48	.012	3	.53	.010
Phosphorus	1	5	1.6	0.084	12	1.4	0.185
	2	4	.08	.005	4	.10	.037
	3	16	1.9	.102	14	1.7	.085
	4	10	.55	.033	10	.56	.007
	5	18	2.2	.183	6	2.2	.383
	6	3	1.5	.115	3	1.3	.115
	7	3	.27	.012	3	2.5	.000
	8	2	.68	.028	12	.69	.021
	9	16	1.3	.323	20	1.3	.000
	10	12	1.6	1.80	12	4.0	.530
	11	4	.86	.026	2	.88	.021
	12	4	.61	.015	3	.76	.206
	13	12	1.9	.116	12	1.7	.131
	14	12	.57	.656	20	1.2	.099
Phosphorus, ortho	3	16	1.7	0.082	14	1.3	0.138
	4	10	.36	.020	10	.35	.013
	5	18	1.6	.184	6	1.6	.000
	10	6	2.9	.680	6	3.7	.204

Table 8.--Results of statistical evaluation for nutrients

Constituent	Comparison of means	Comparison of standard deviations
Ammonia	A	B
Ammonia plus organic N	A	A
Carbon, organic	A	A
Nitrite plus nitrate N	A	B
Nitrite N	A	A
Phosphorus	A	A
Phosphorus, ortho	A	A

A = No significant difference

B = Significant difference

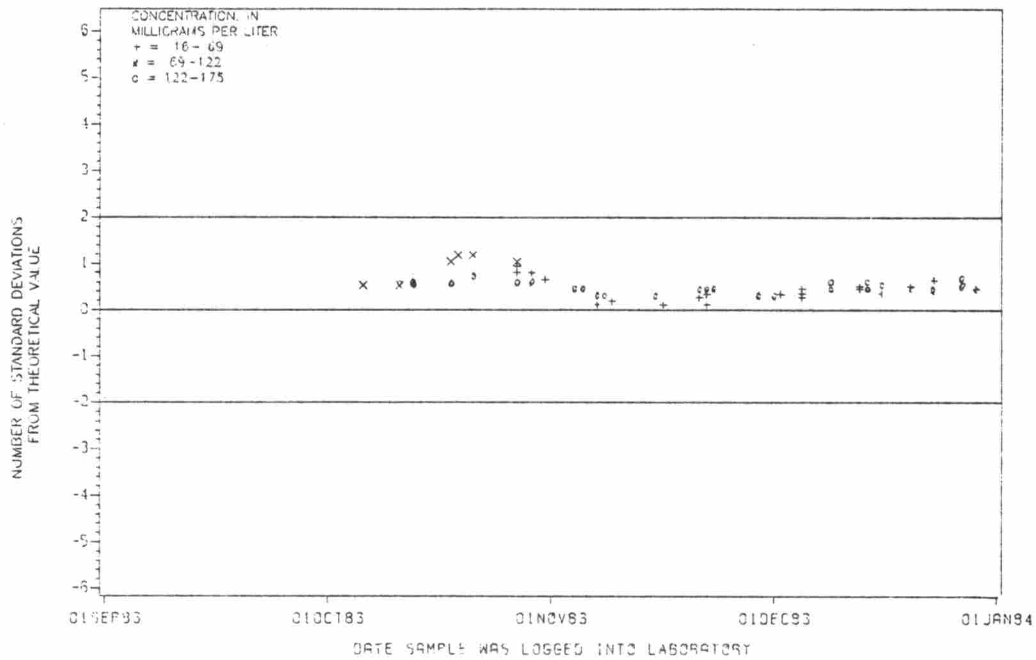

Figure A1.--Alkalinity data from the Atlanta laboratory.

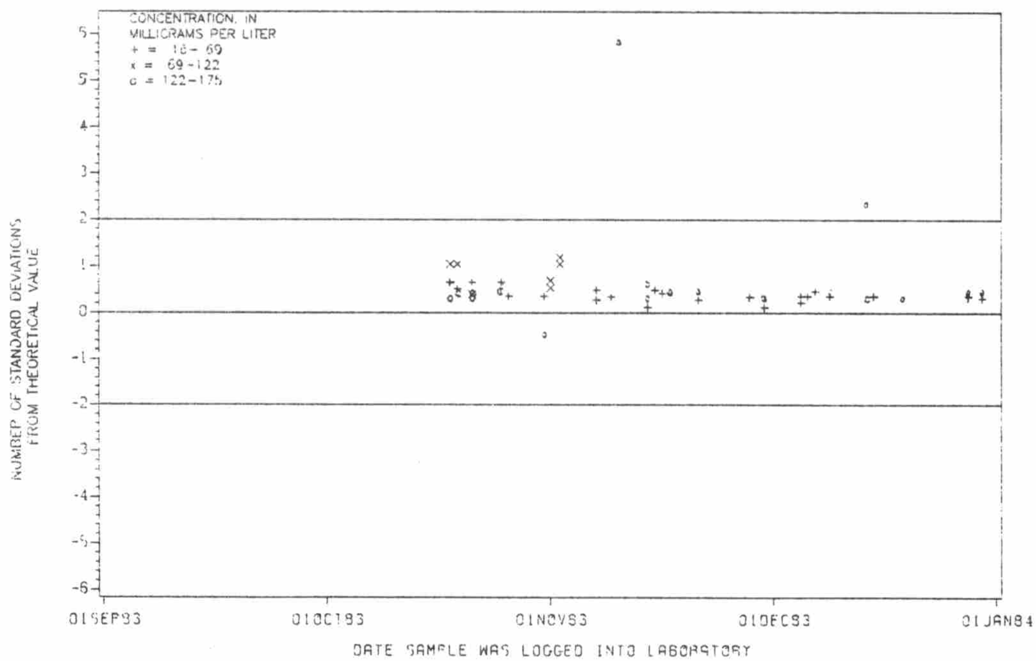

Figure D1.--Alkalinity data from the Denver laboratory

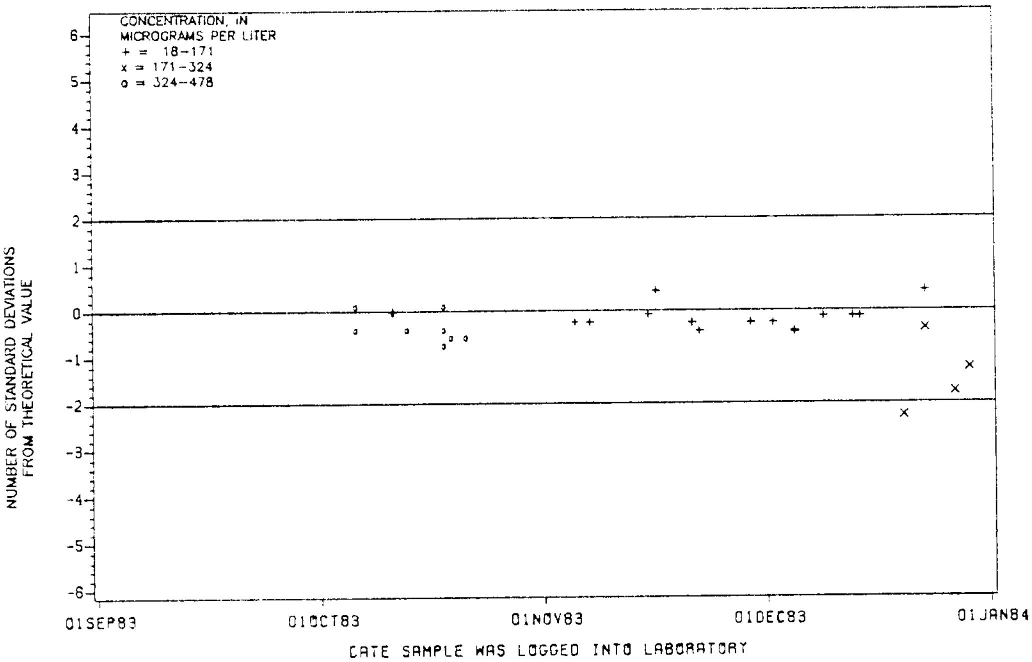

Figure A2.--Aluminum data from the Atlanta laboratory.

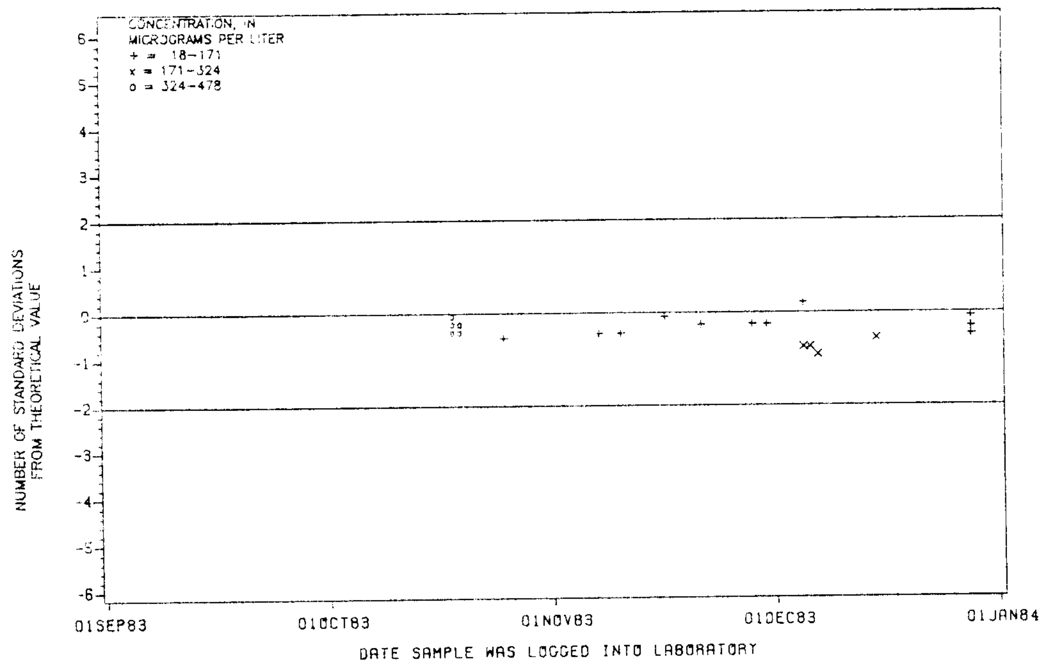

Figure D2.--Aluminum data from the Denver laboratory.

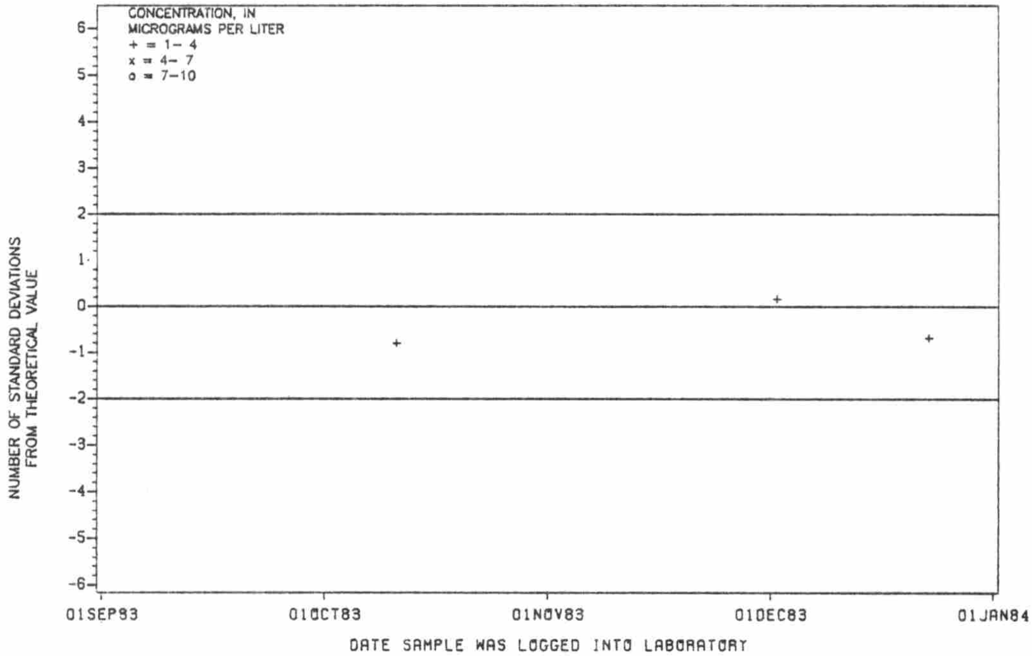

Figure A3.--Antimony data from the Atlanta laboratory.

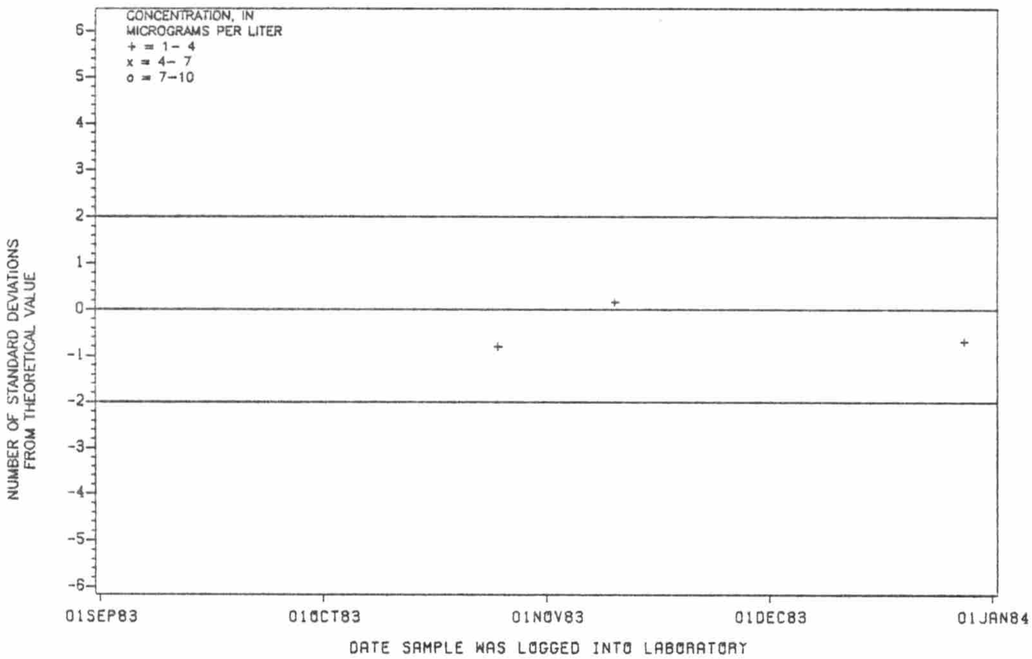

Figure D3.--Antimony data from the Denver laboratory.

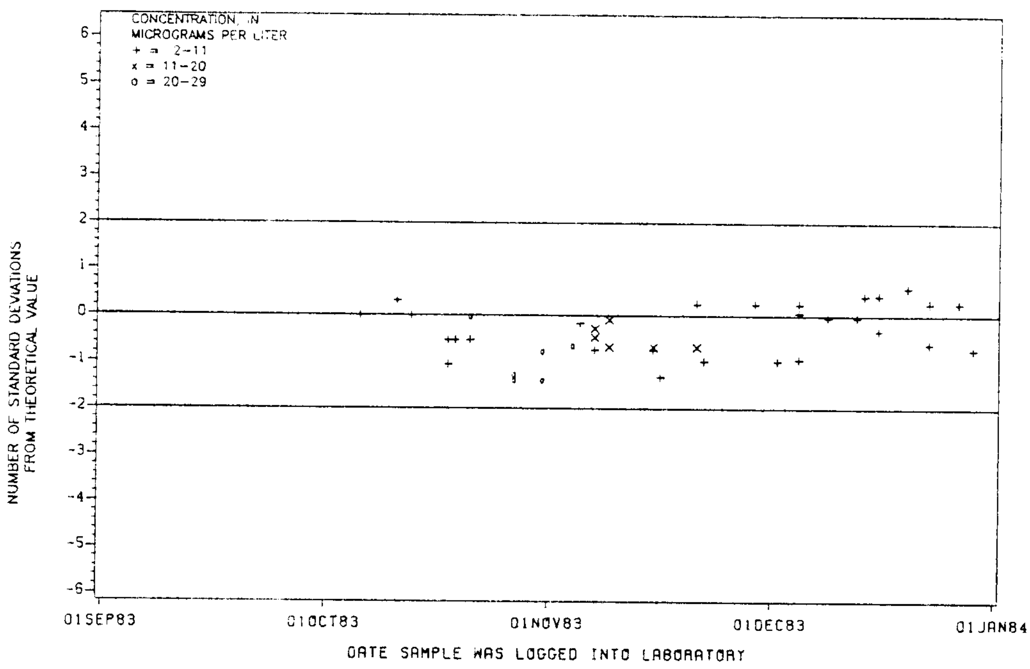

Figure A4.--Arsenic data from the Atlanta laboratory.

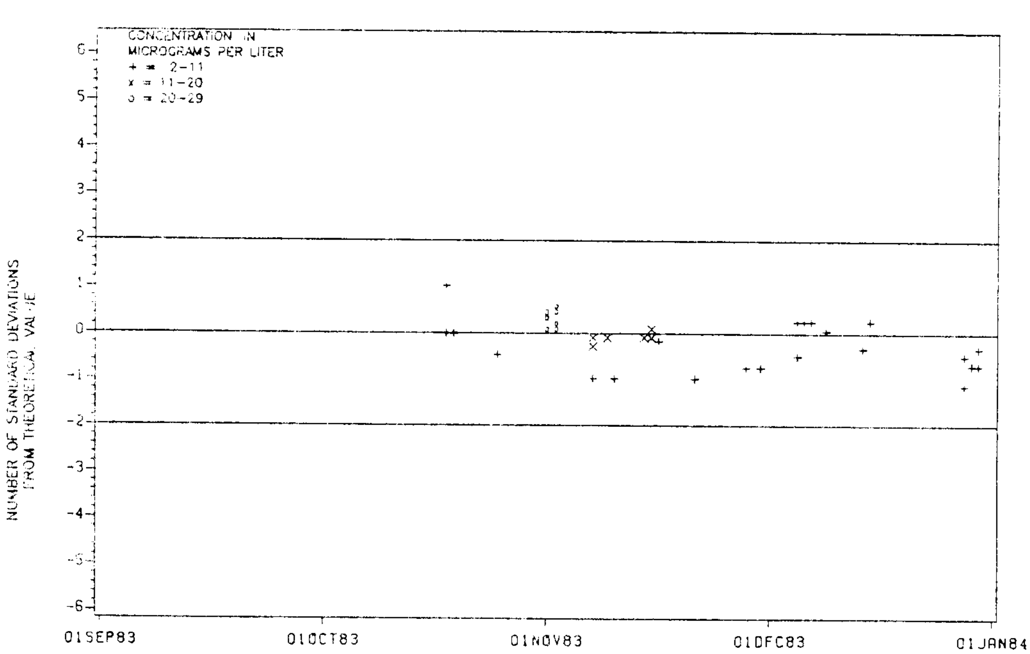

Figure D4.--Arsenic data from the Denver laboratory.

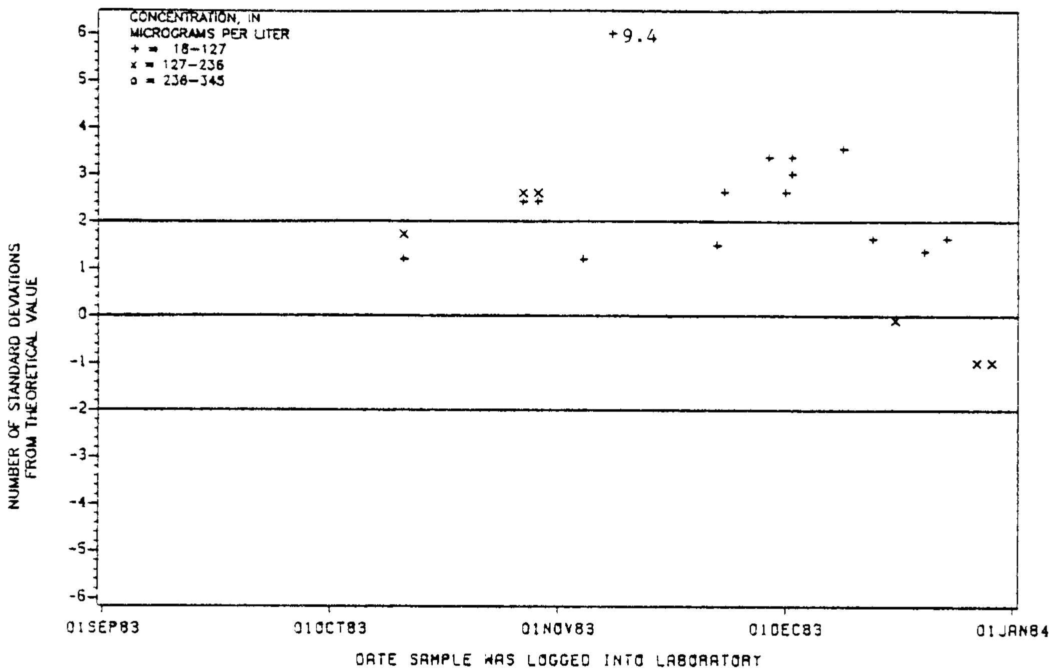

Figure A5.--Barium(ICP) data from the Atlanta laboratory.

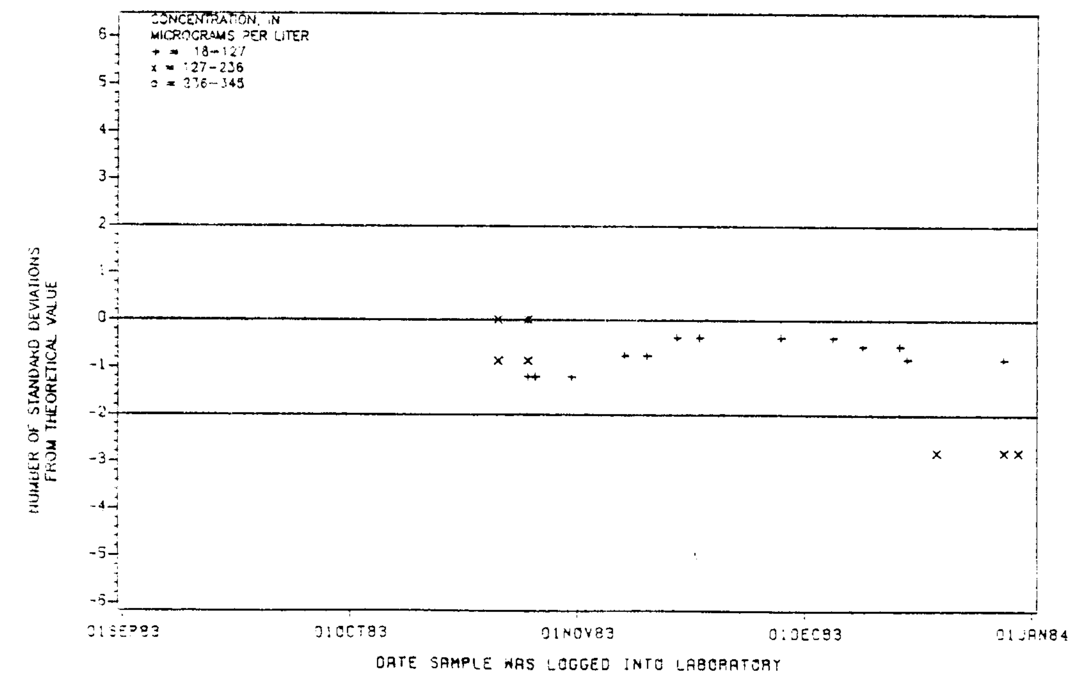

Figure D5.--Barium(ICP) data from the Denver laboratory.

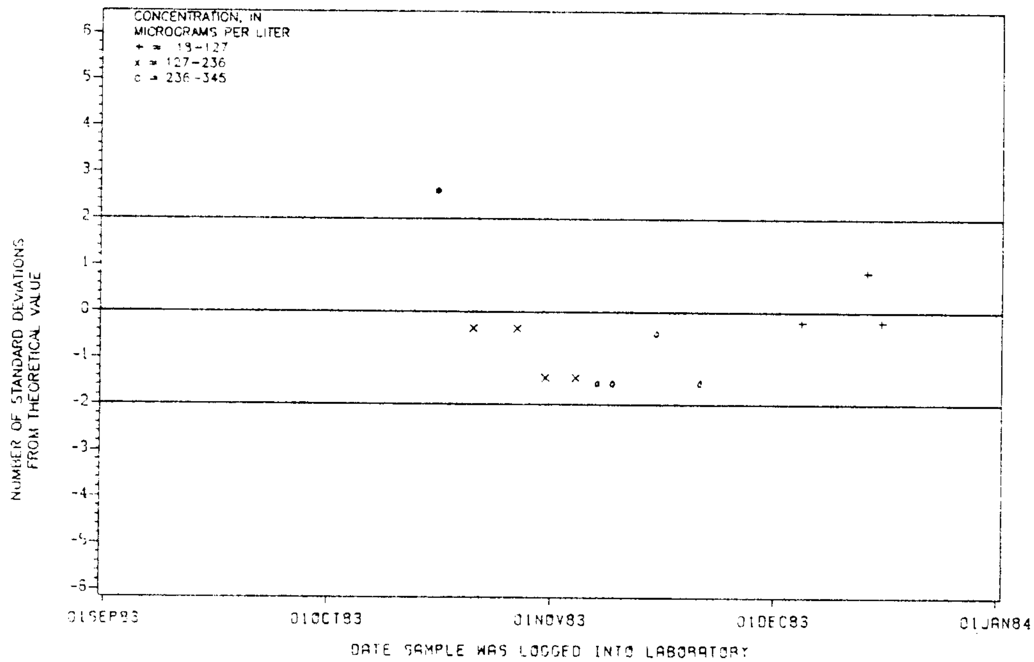

Figure A6.--Barium(AA) data from the Atlanta laboratory.

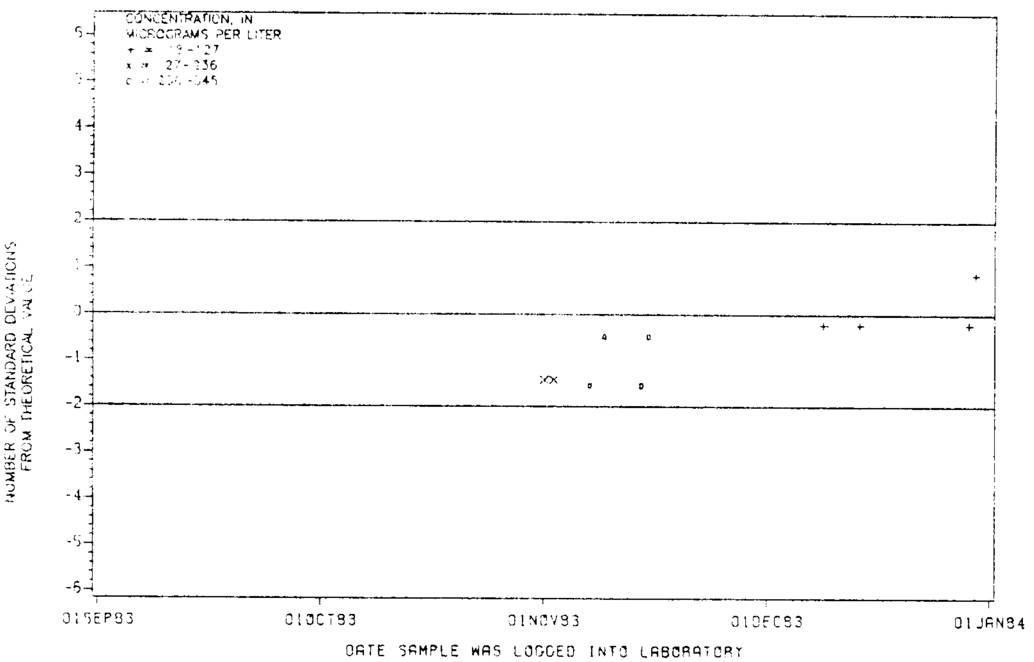

Figure D6.--Barium(AA) data from the Denver laboratory.

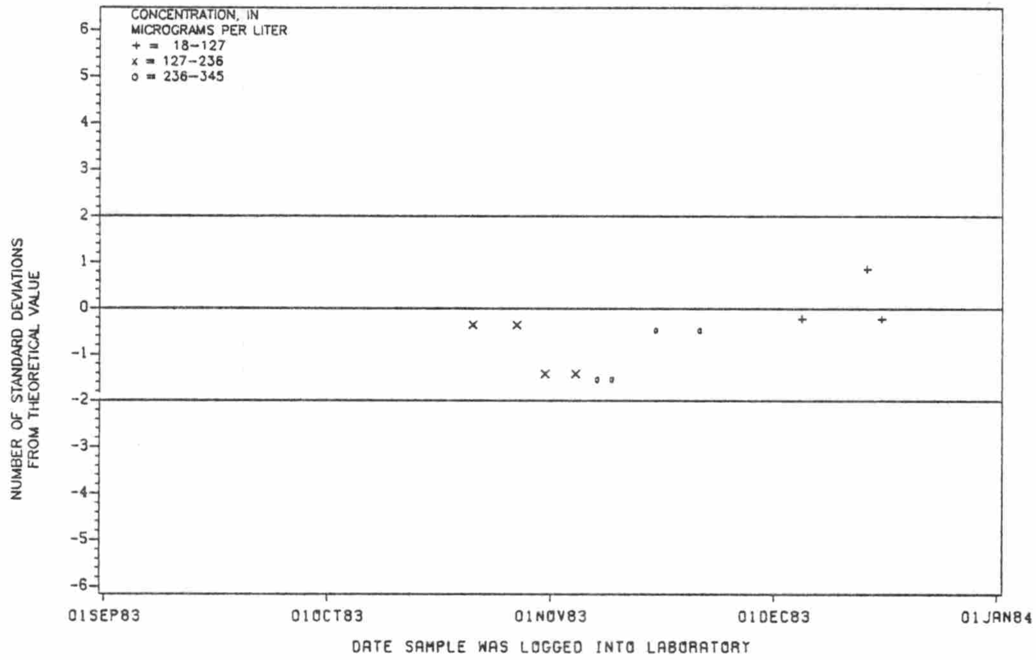

Figure A7.--Barium, total recoverable data from the Atlanta laboratory.

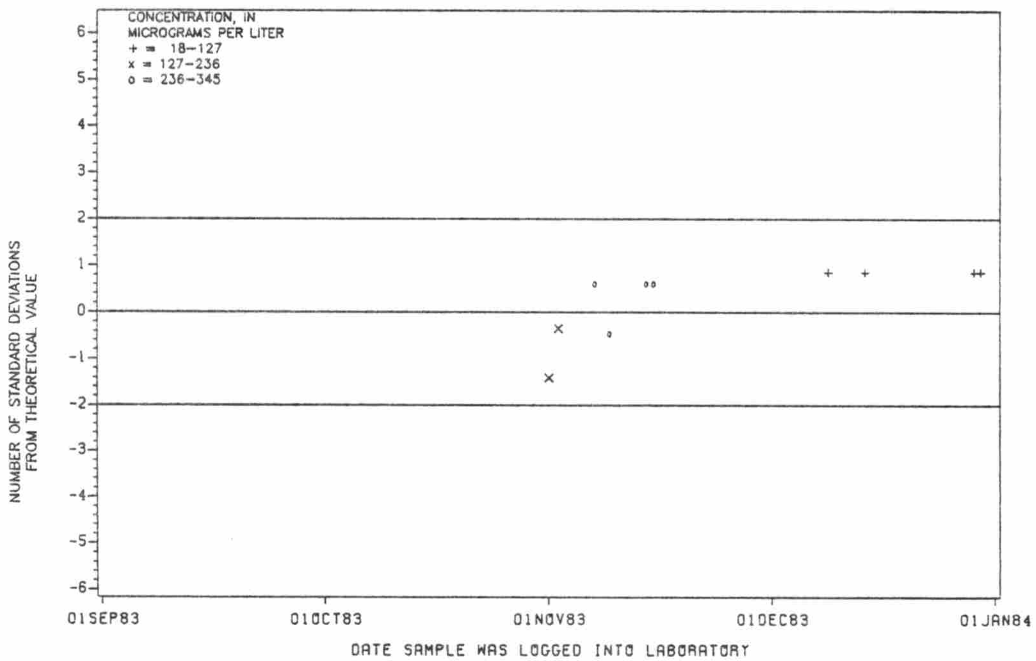

Figure D7.--Barium, total recoverable data from the Denver laboratory.

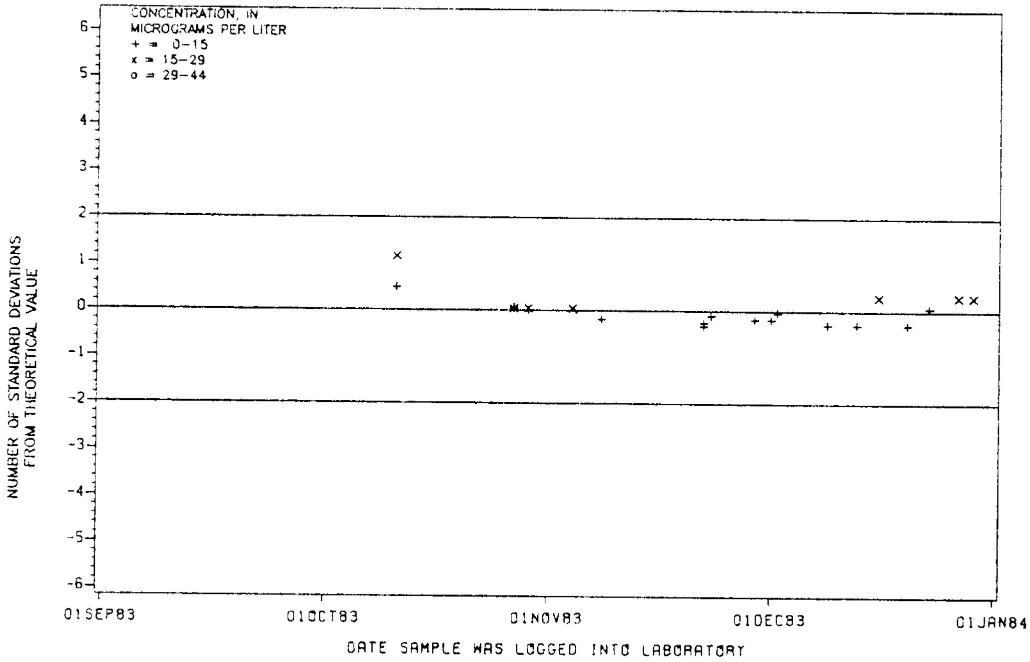

Figure A8.--Beryllium data from the Atlanta laboratory.

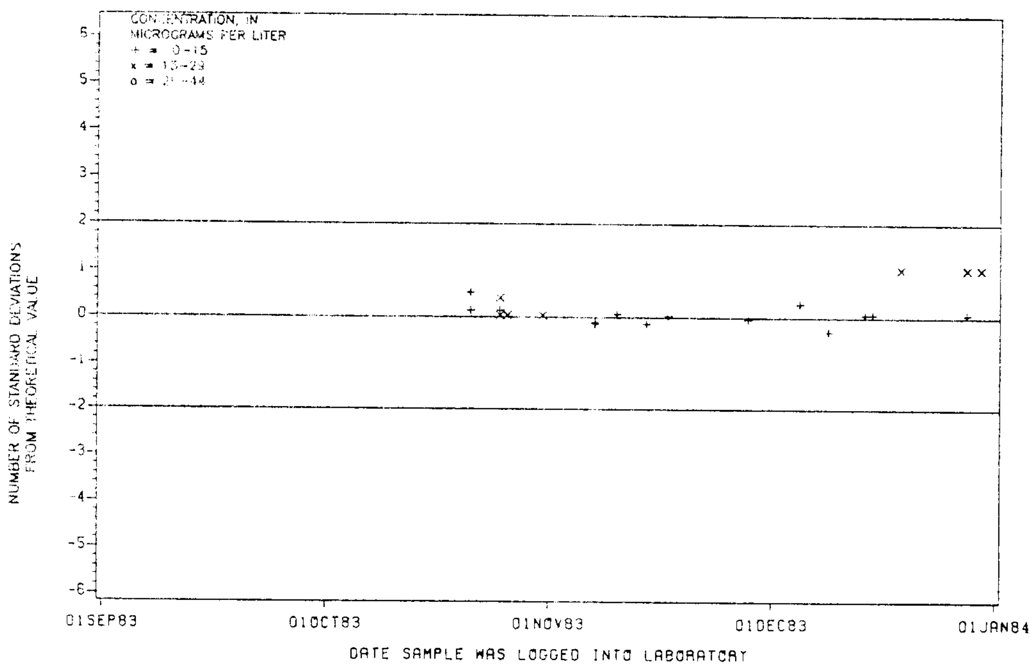

Figure D8.--Beryllium data from the Denver laboratory.

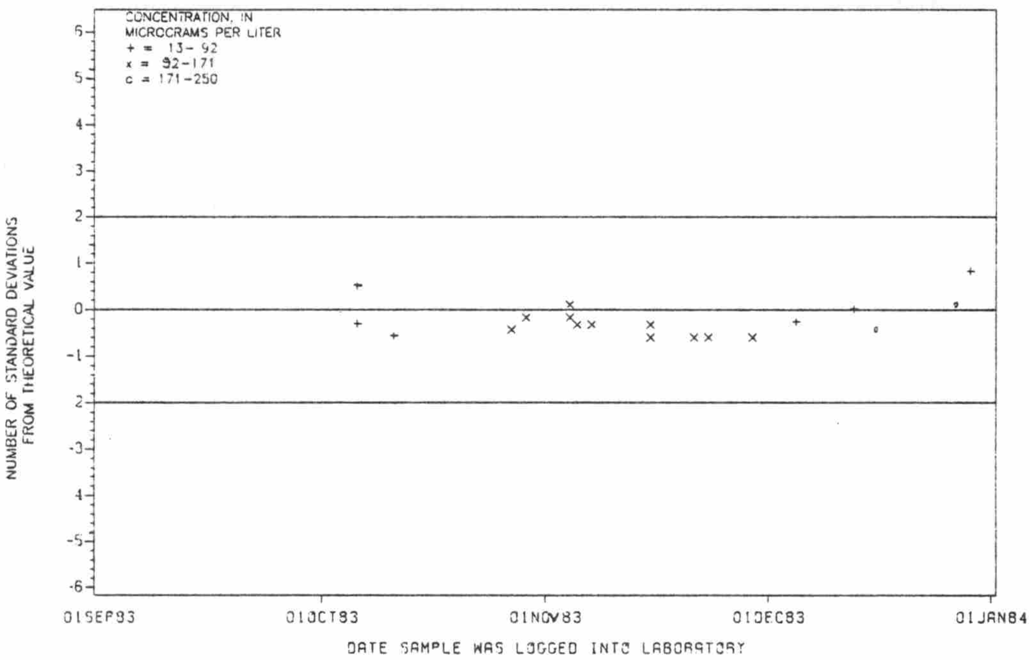

Figure A9.--Boron data from the Atlanta laboratory.

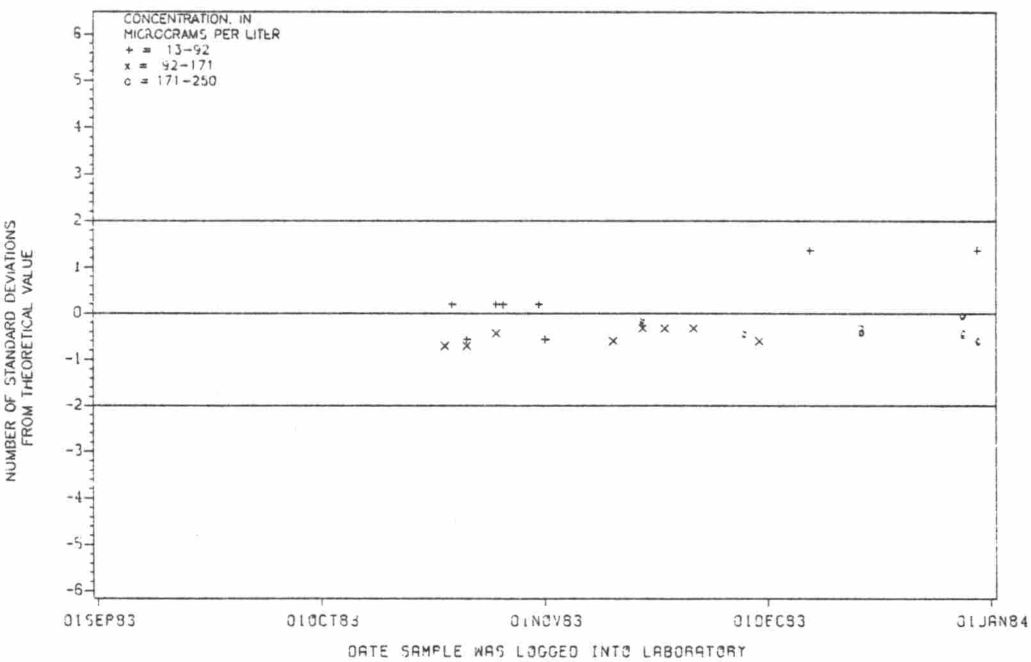

Figure D9.--Boron data from the Denver laboratory.

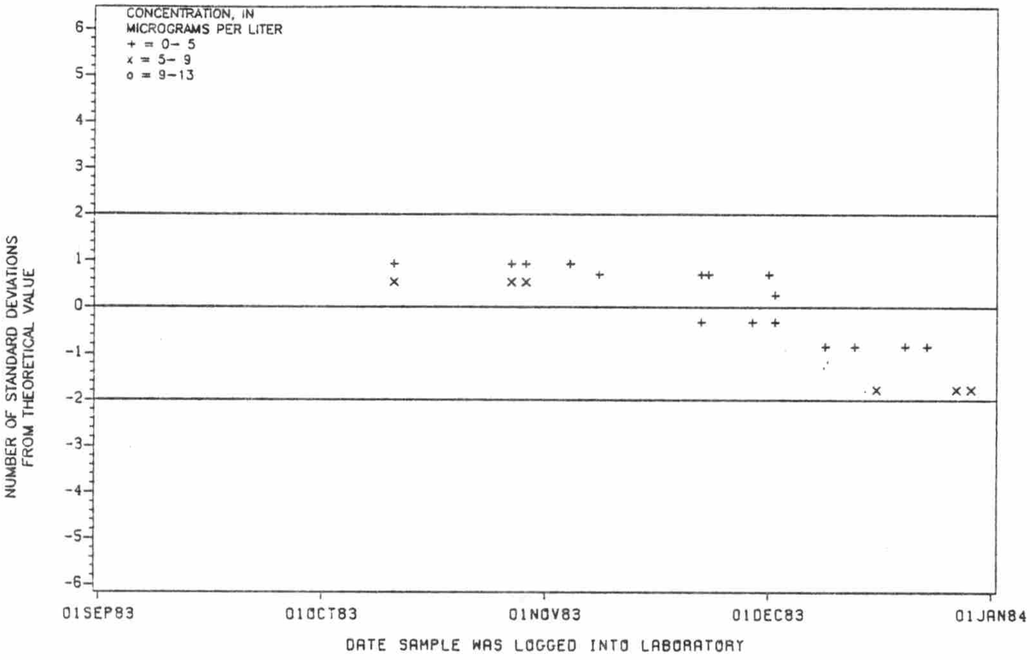

Figure A10.--Cadmium(ICP) data from the Atlanta laboratory.

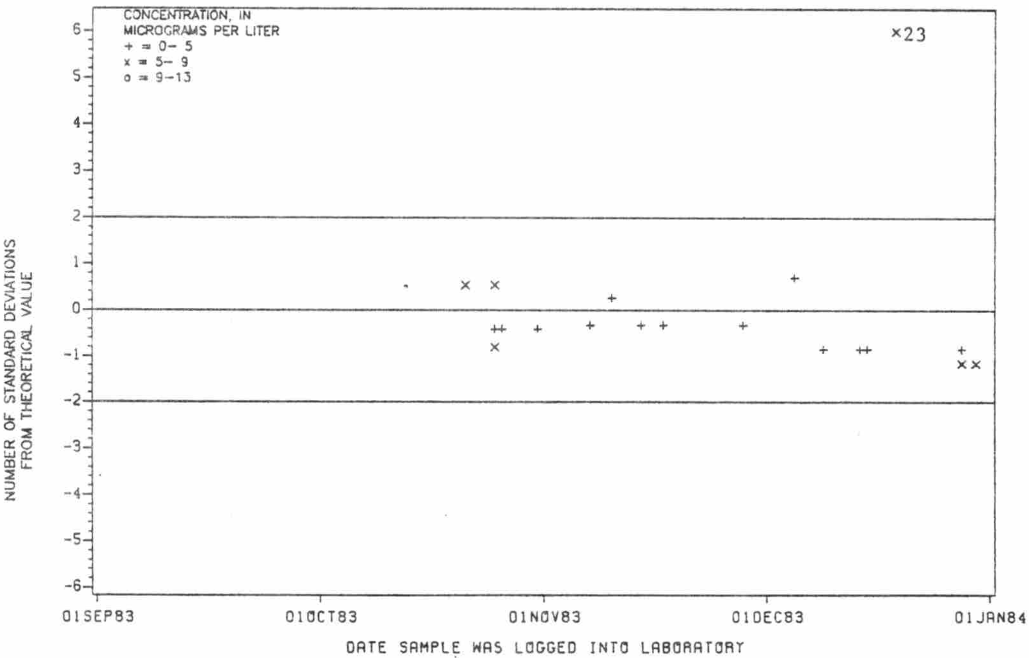

Figure D10.--Cadmium(ICP) data from the Denver laboratory.

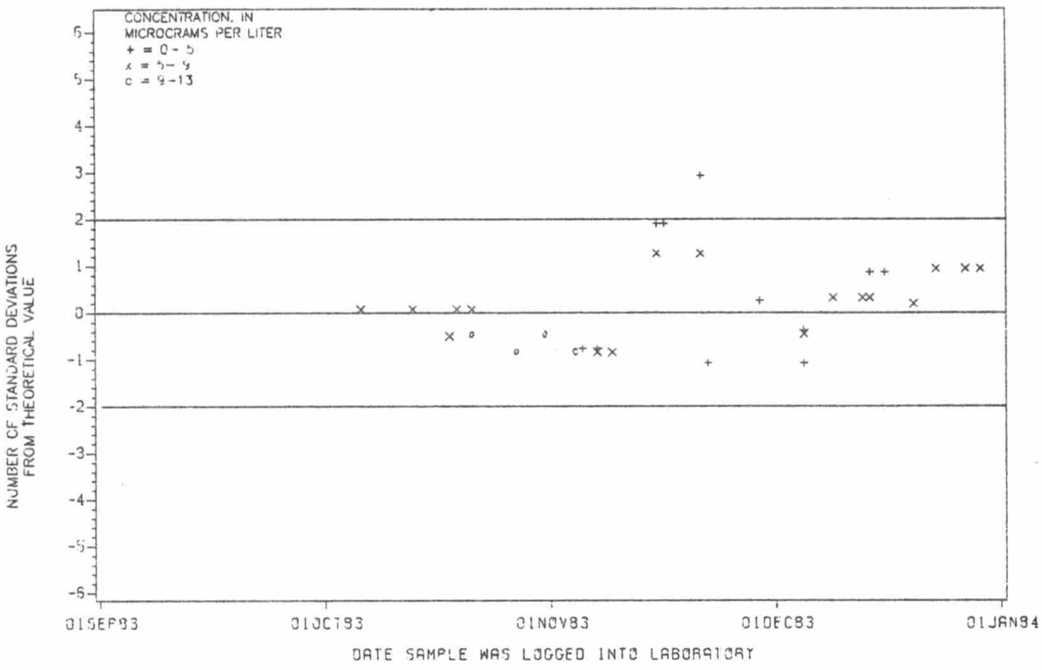

Figure A11.--Cadmium(AA) data from the Atlanta laboratory.

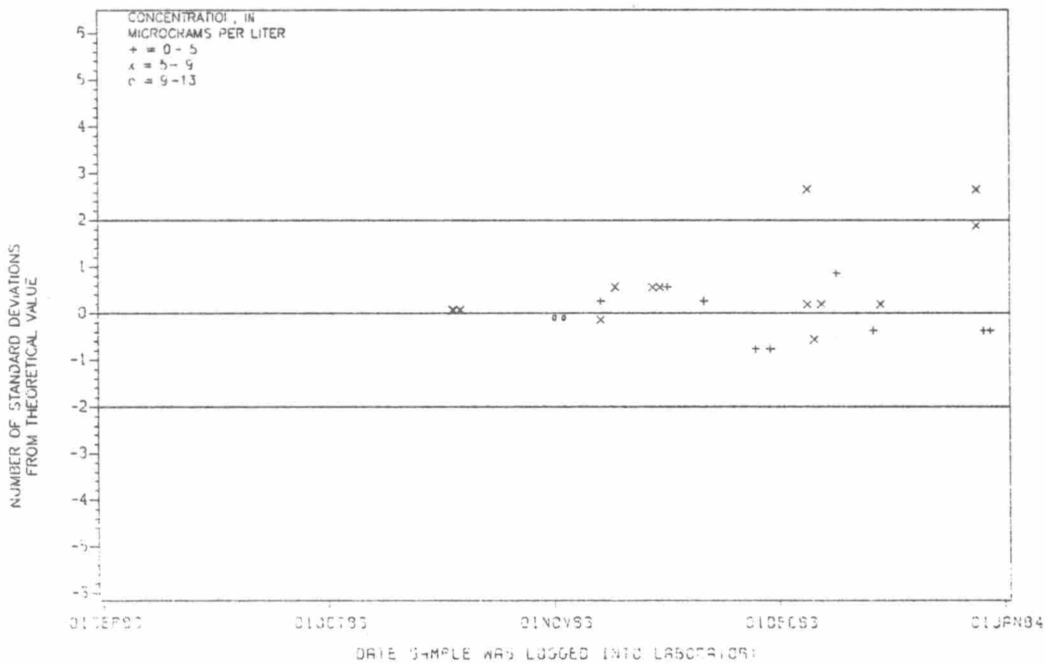

Figure D11.--Cadmium(AA) data from the Denver laboratory.

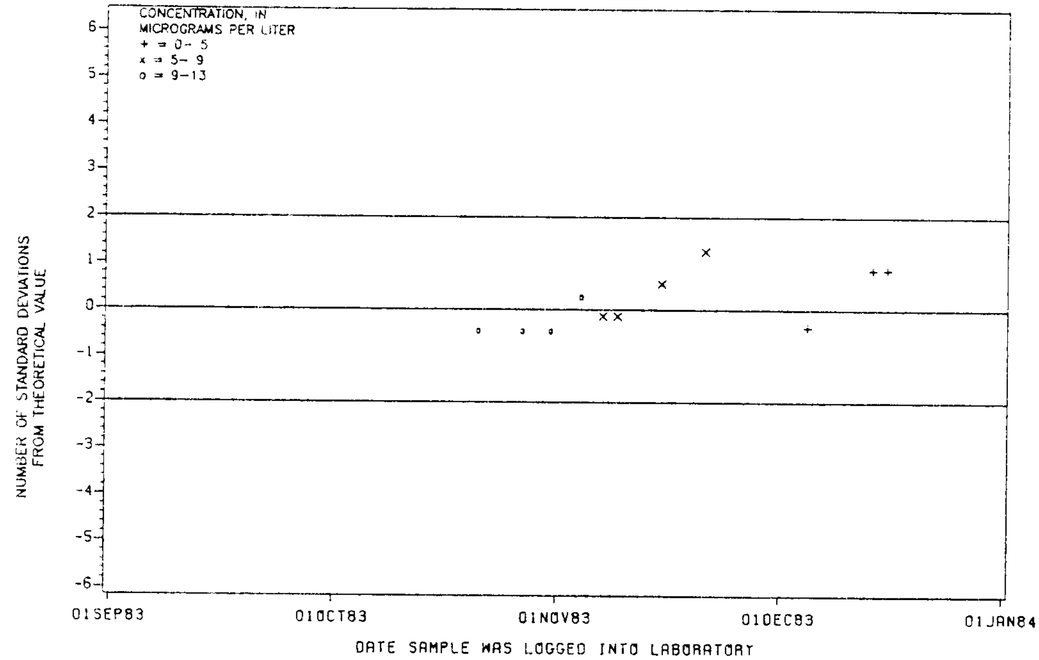

Figure A12.--Cadmium, total recoverable data from the Atlanta laboratory.

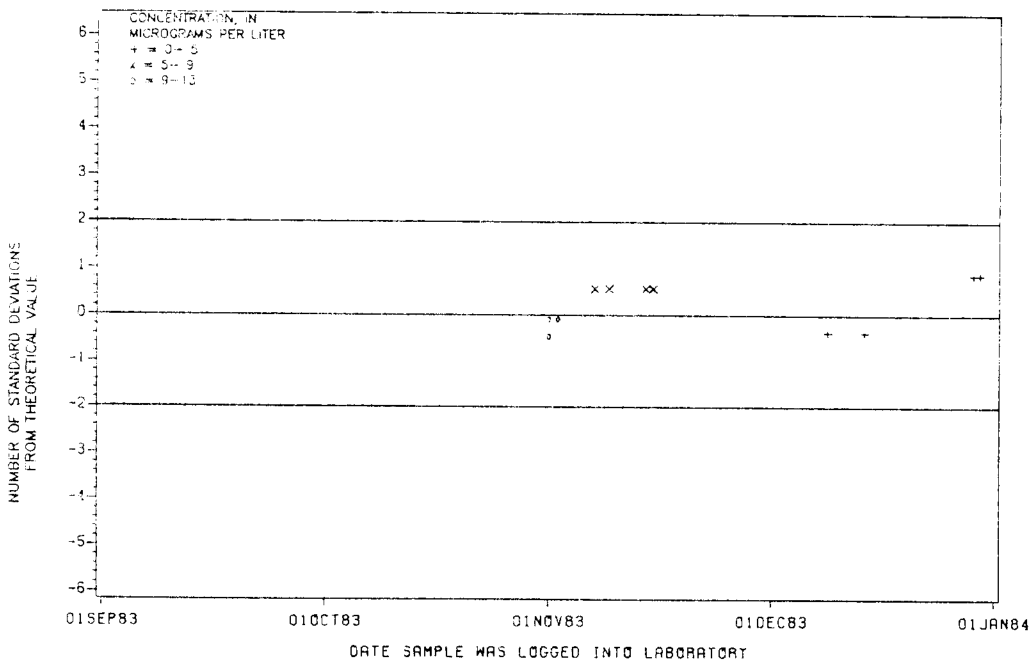

Figure D12.--Cadmium, total recoverable data from the Denver laboratory.

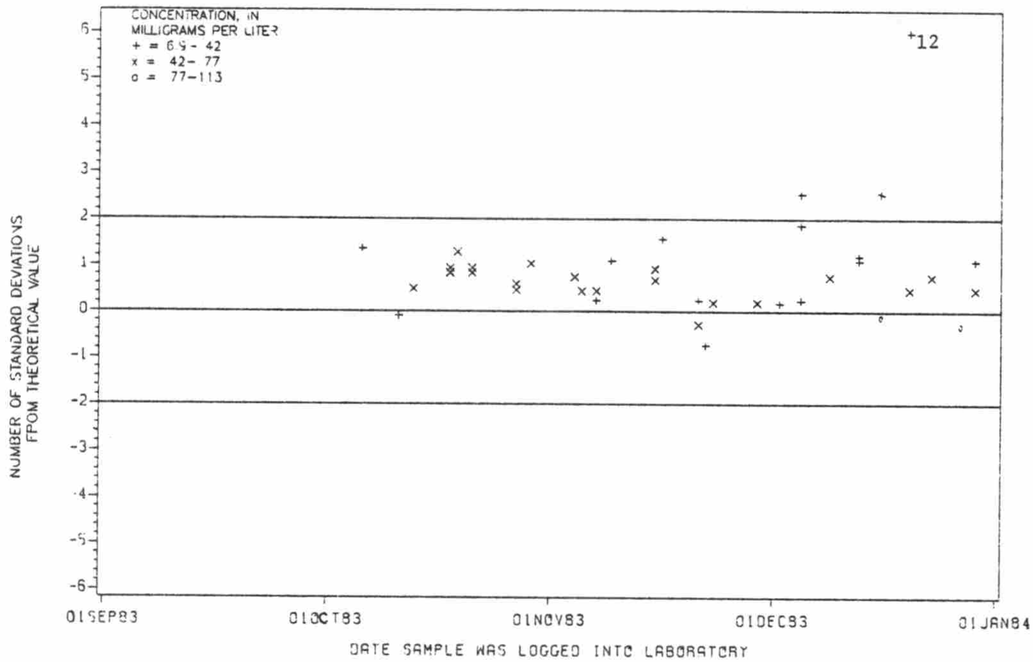

Figure A13.--Calcium(ICP) data from the Atlanta laboratory.

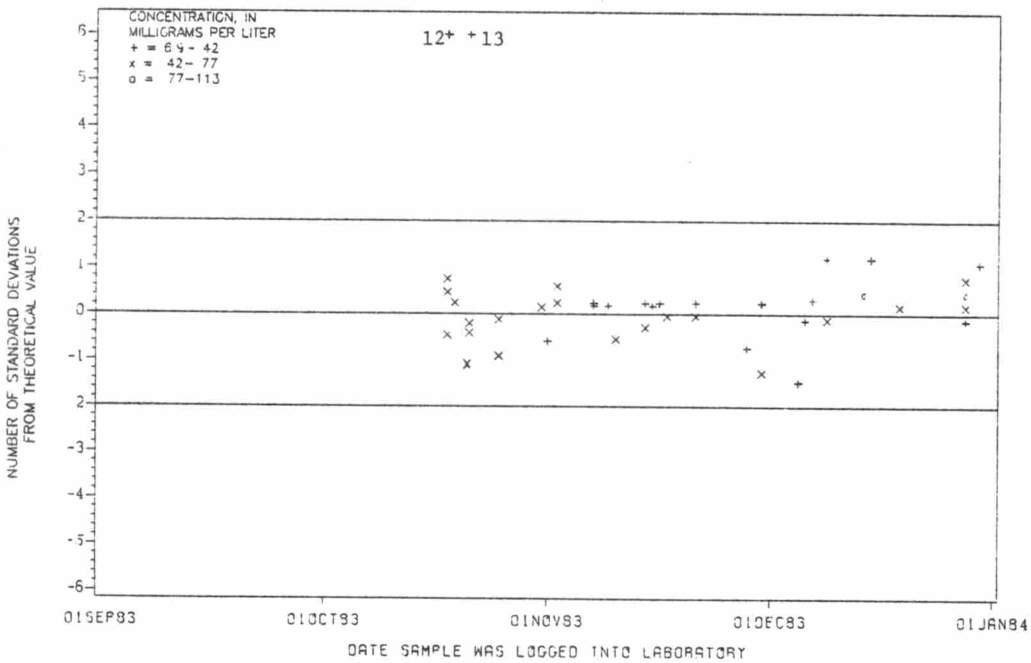

Figure D13.--Calcium(ICP) data from the Denver laboratory.

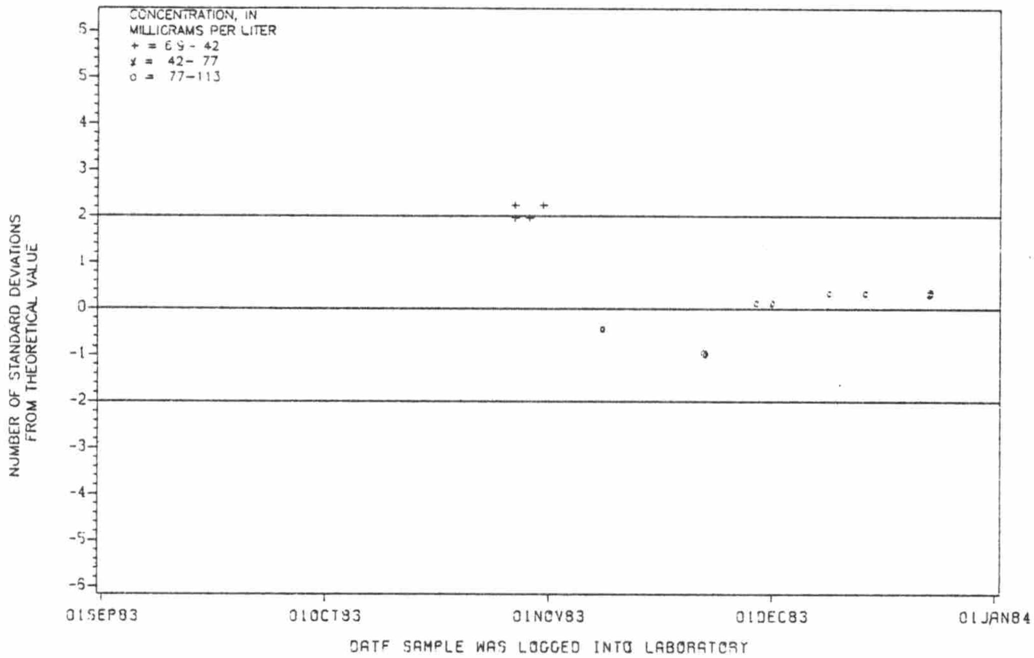

Figure A14.--Calcium(AA) data from the Atlanta laboratory.

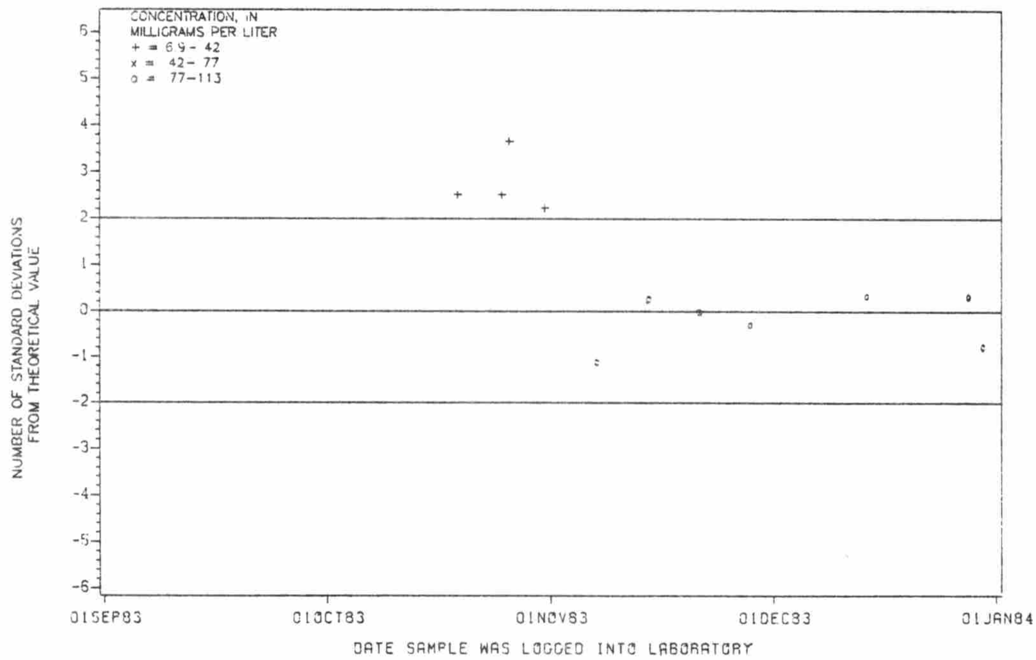

Figure D14.--Calcium(AA) data from the Denver laboratory.

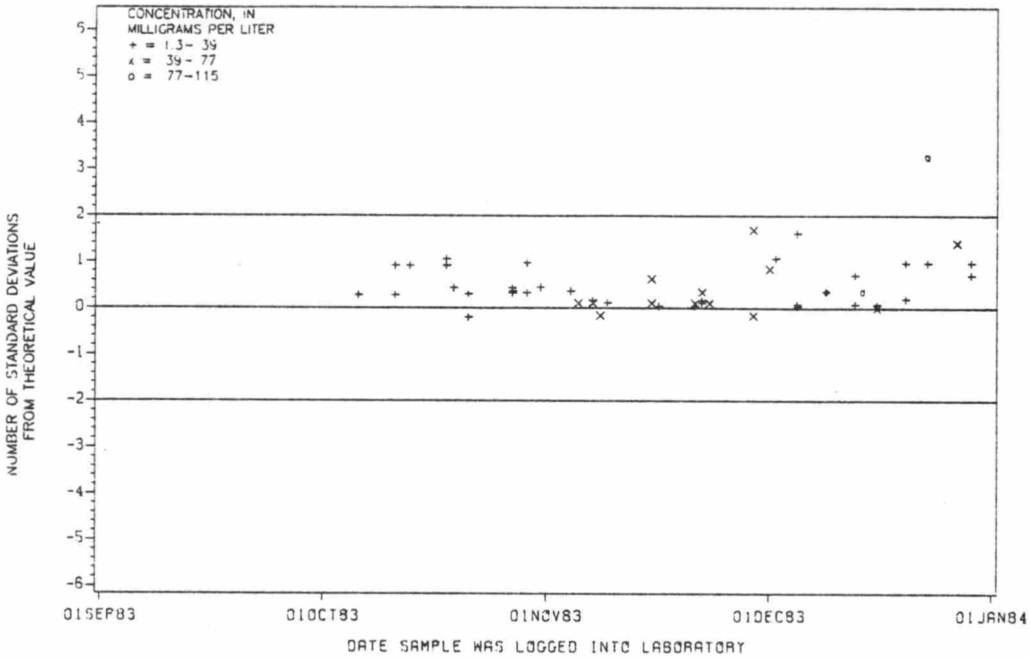

Figure A15.--Chloride data from the Atlanta laboratory.

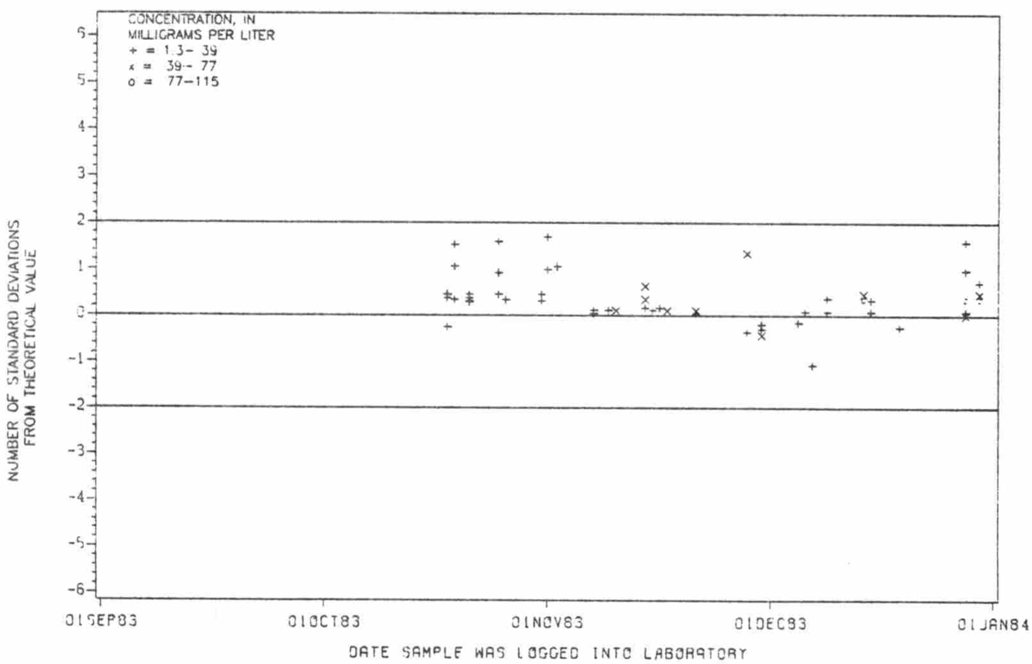

Figure D15.--Chloride data from the Denver laboratory.

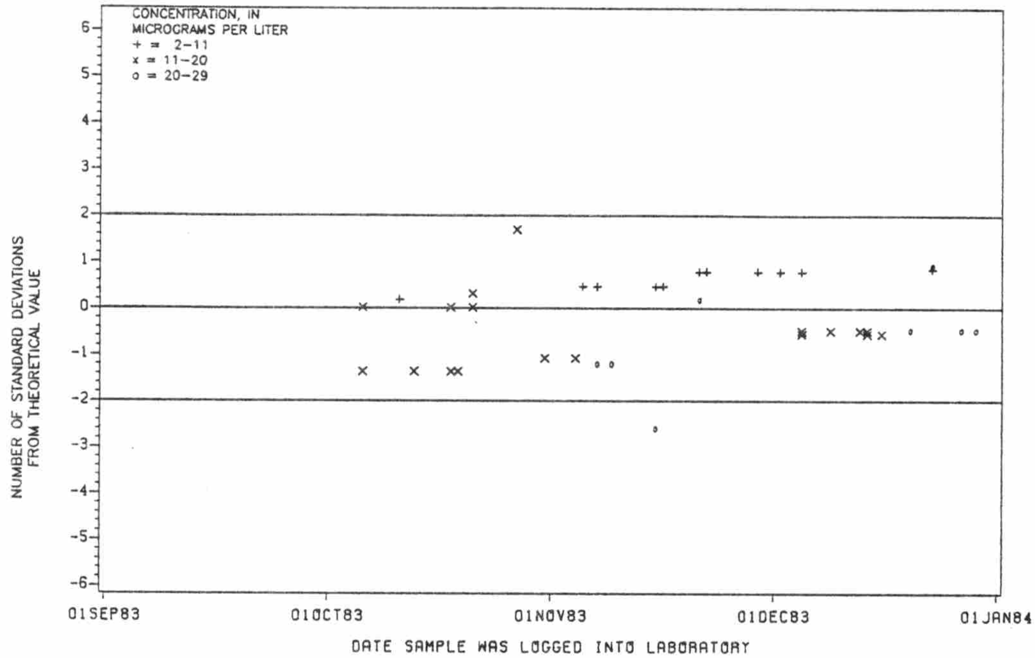

Figure A16.--Chromium data from the Atlanta laboratory.

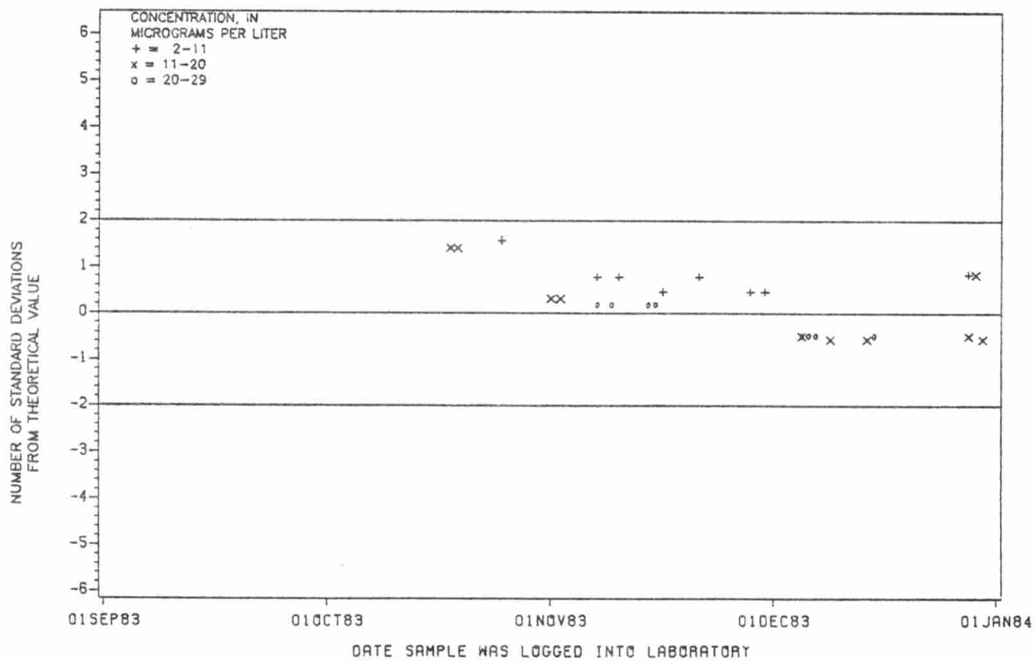

Figure D16.--Chromium data from the Denver laboratory.

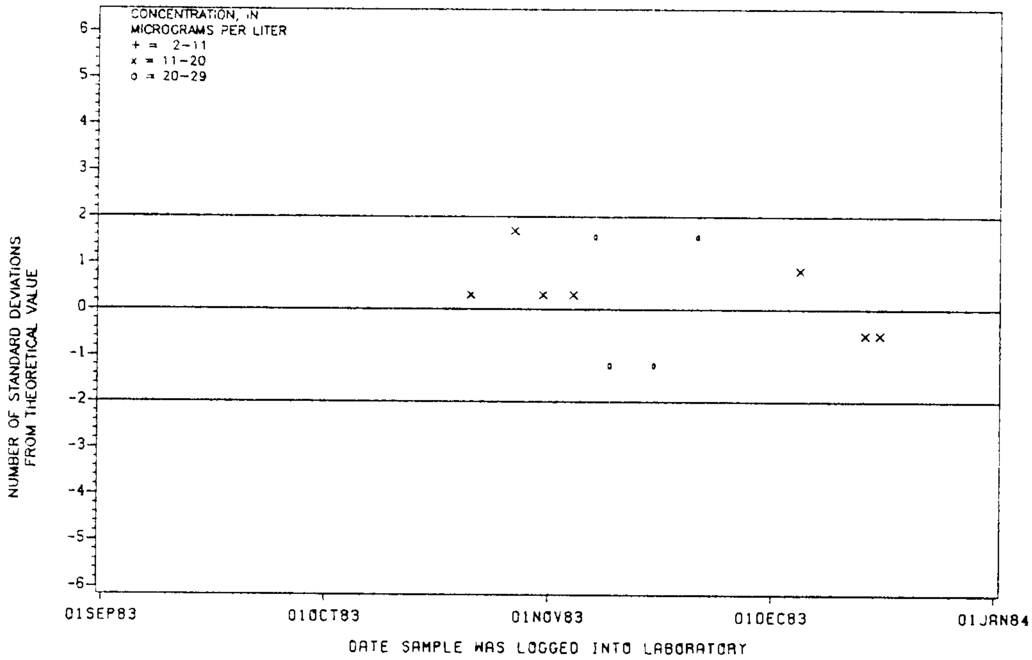

Figure A17.--Chromium, total recoverable data from the Atlanta laboratory.

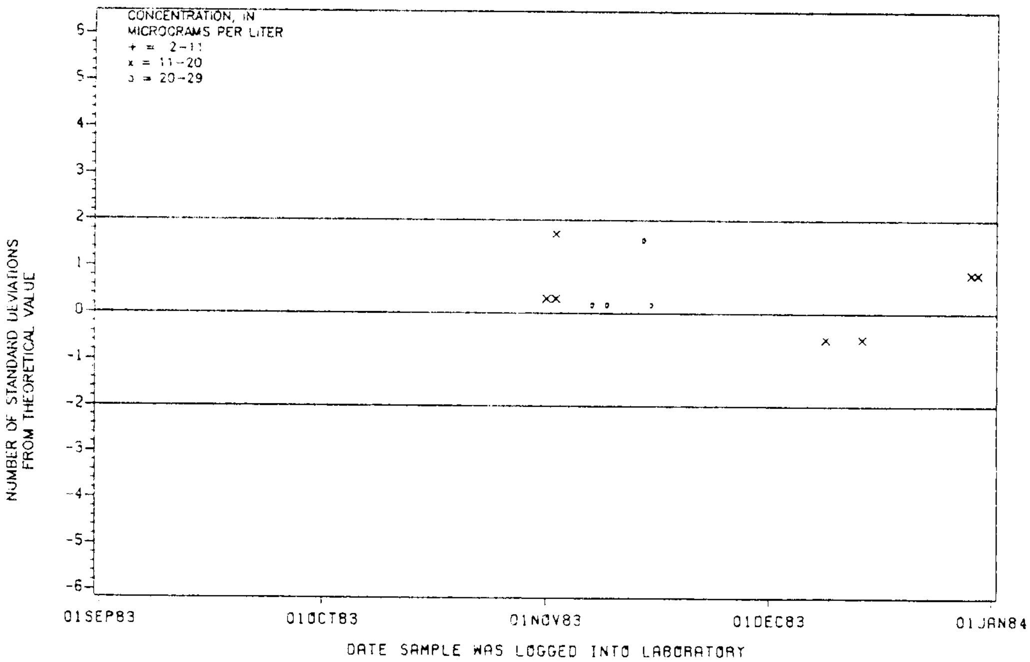

Figure D17.--Chromium, total recoverable data from the Denver laboratory.

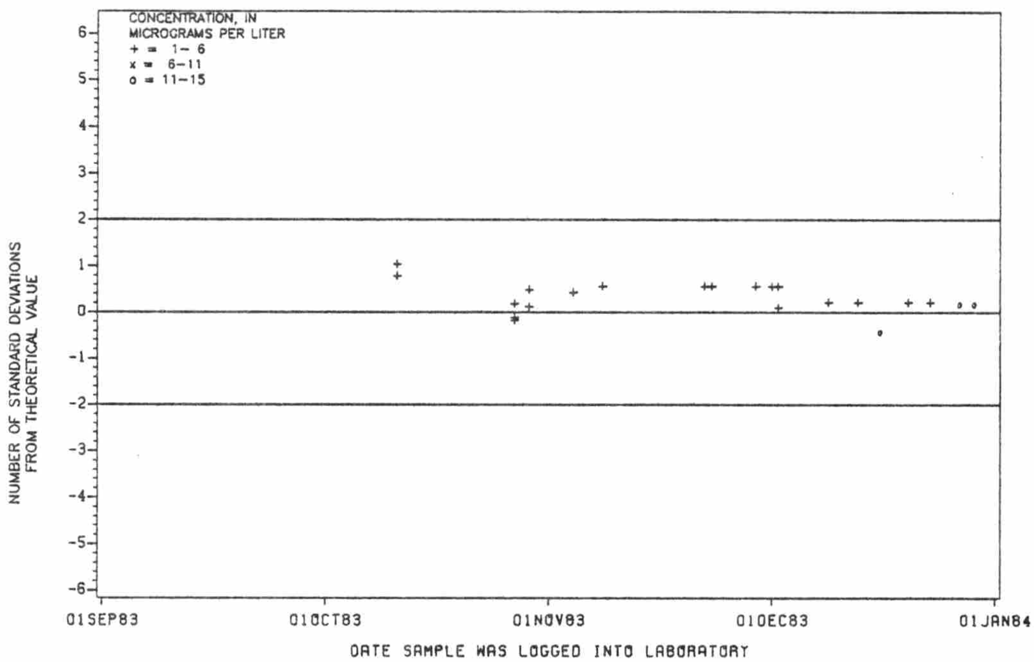

Figure A18.--Cobalt(ICP) data from the Atlanta laboratory.

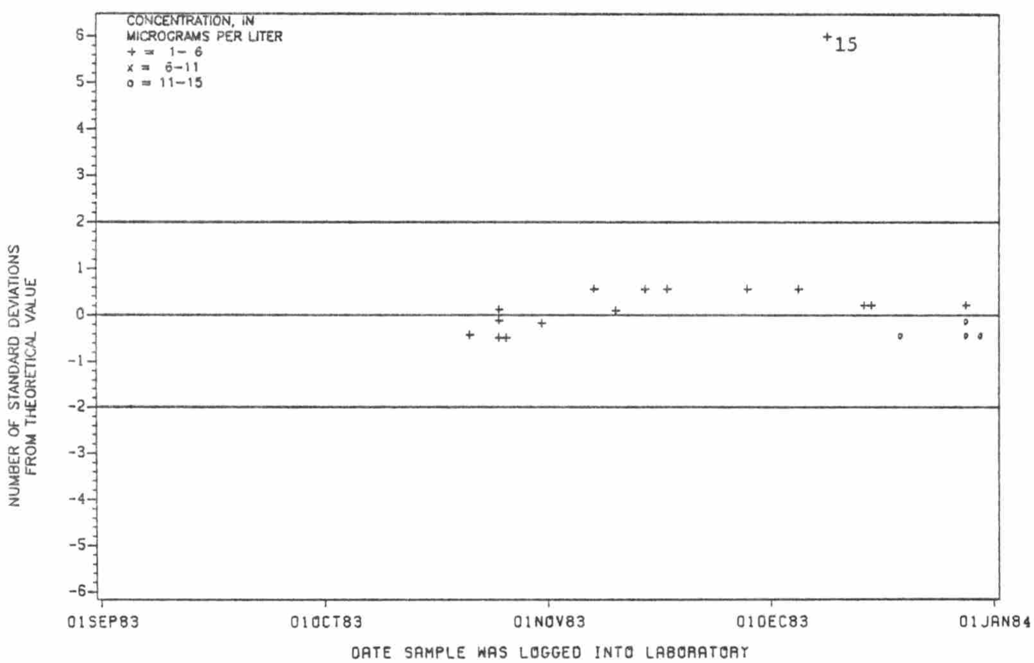

Figure D18.--Cobalt(ICP) data from the Denver laboratory.

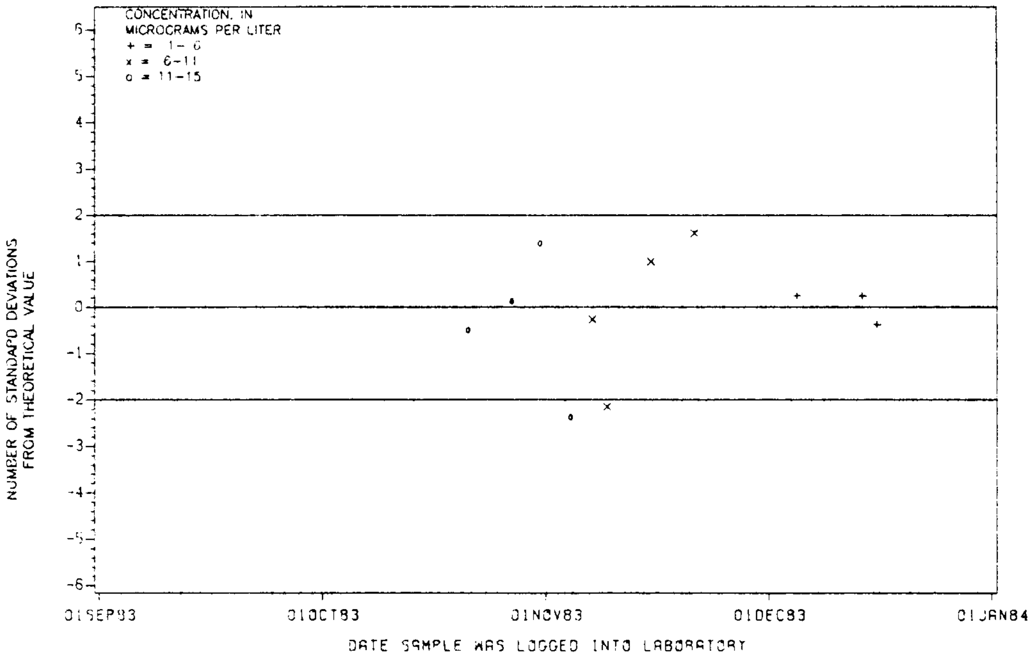

Figure A19.--Cobalt(AA) data from the Atlanta laboratory.

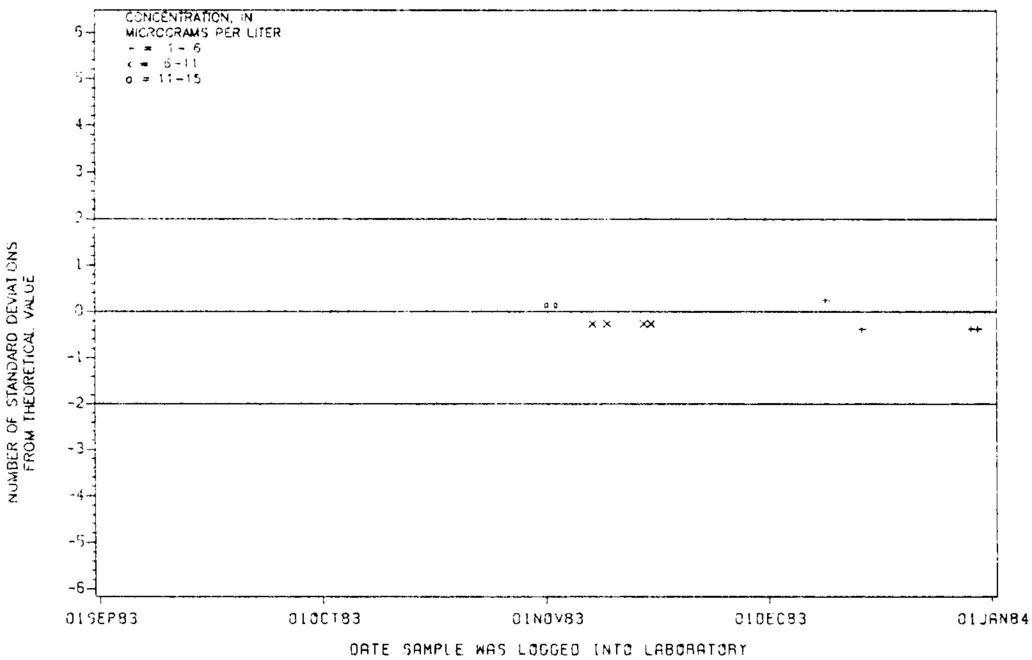

Figure D19.--Cobalt(AA) data from the Denver laboratory.

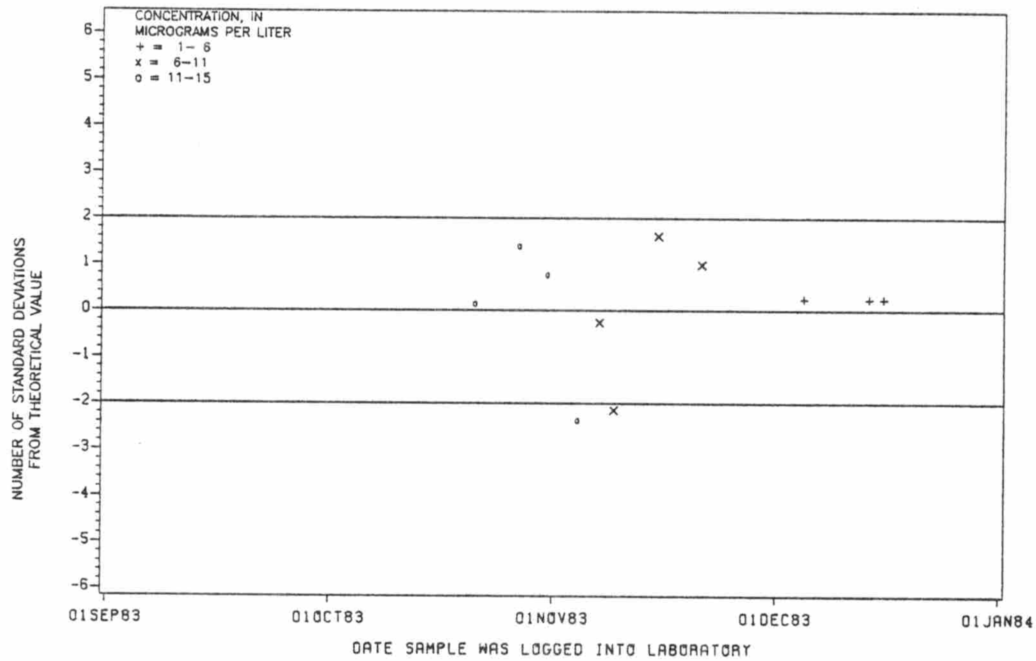

Figure A20.--Cobalt, total recoverable data from the Atlanta laboratory.

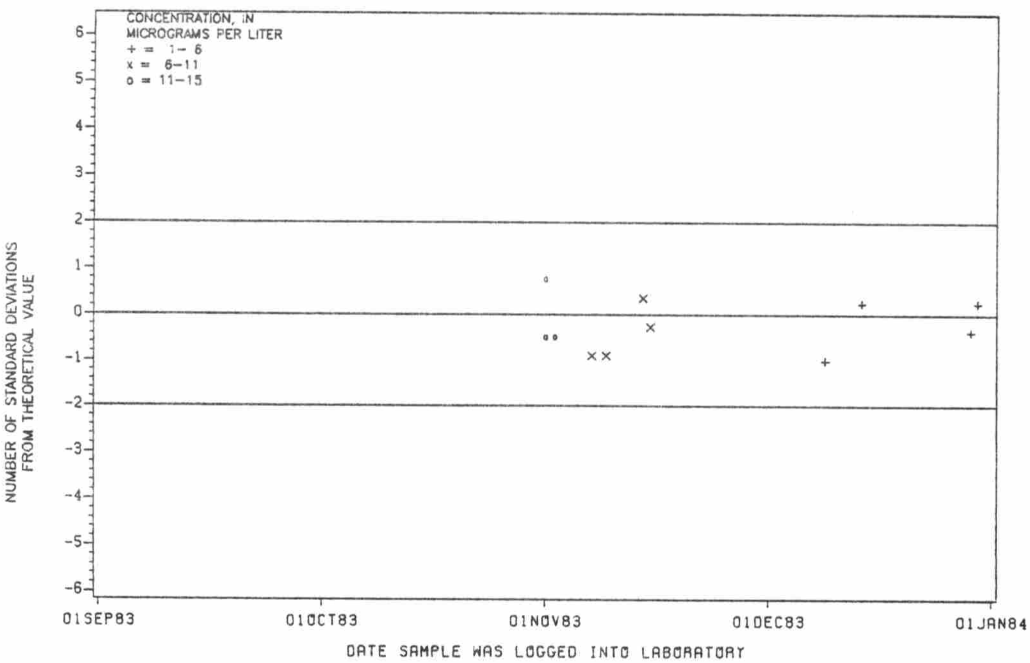

Figure D20.--Cobalt, total recoverable data from the Denver laboratory.

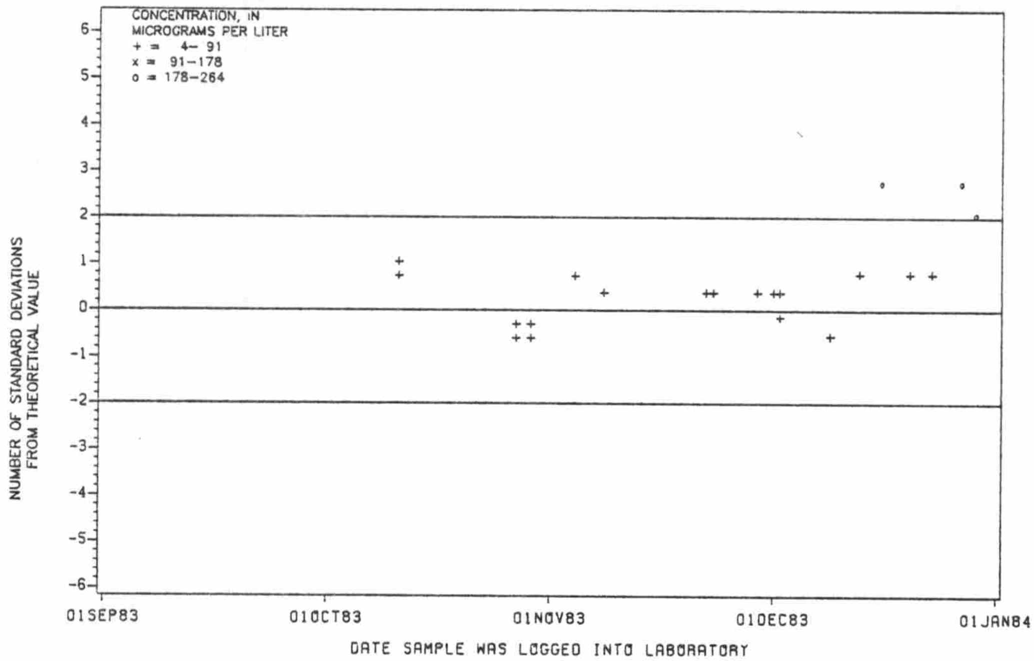

Figure A21.--Copper(ICP) data from the Atlanta laboratory.

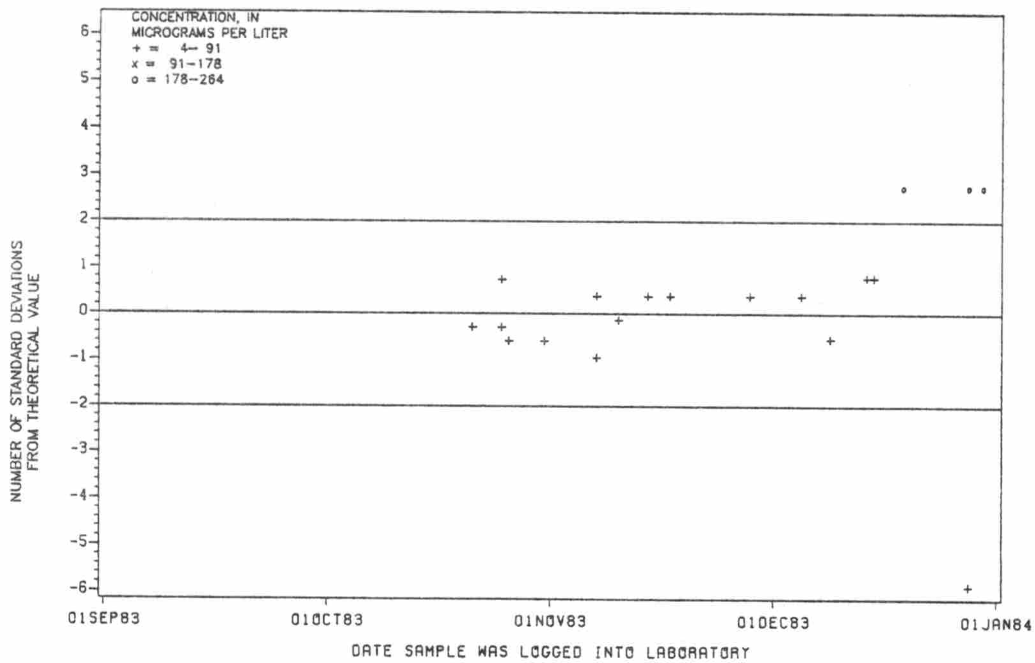

Figure D21.--Copper(ICP) data from the Denver laboratory.

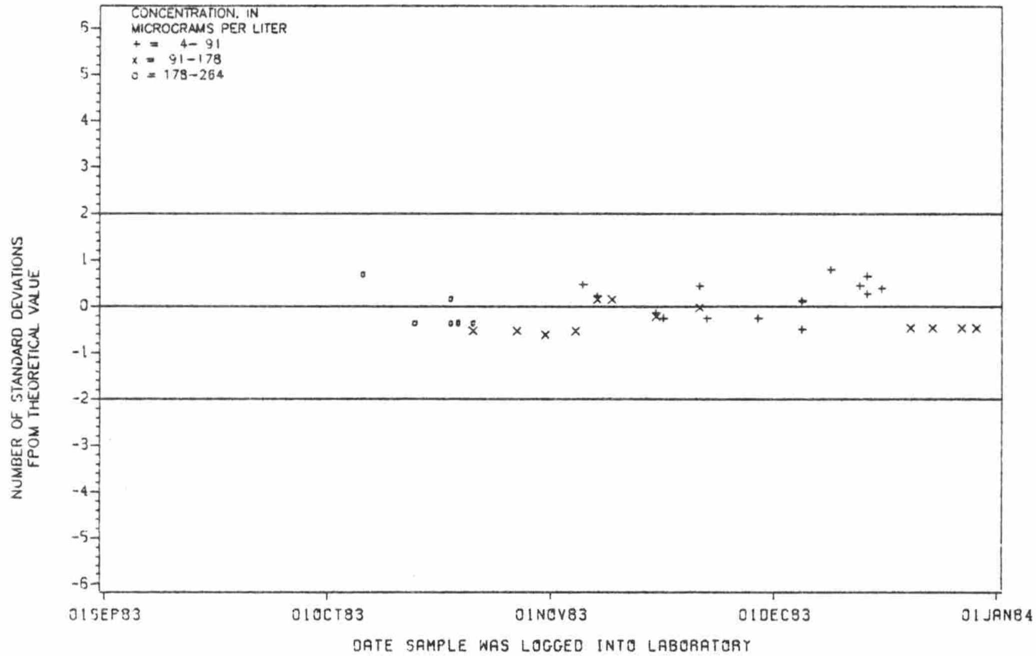

Figure A22.--Copper(AA) data from the Atlanta laboratory.

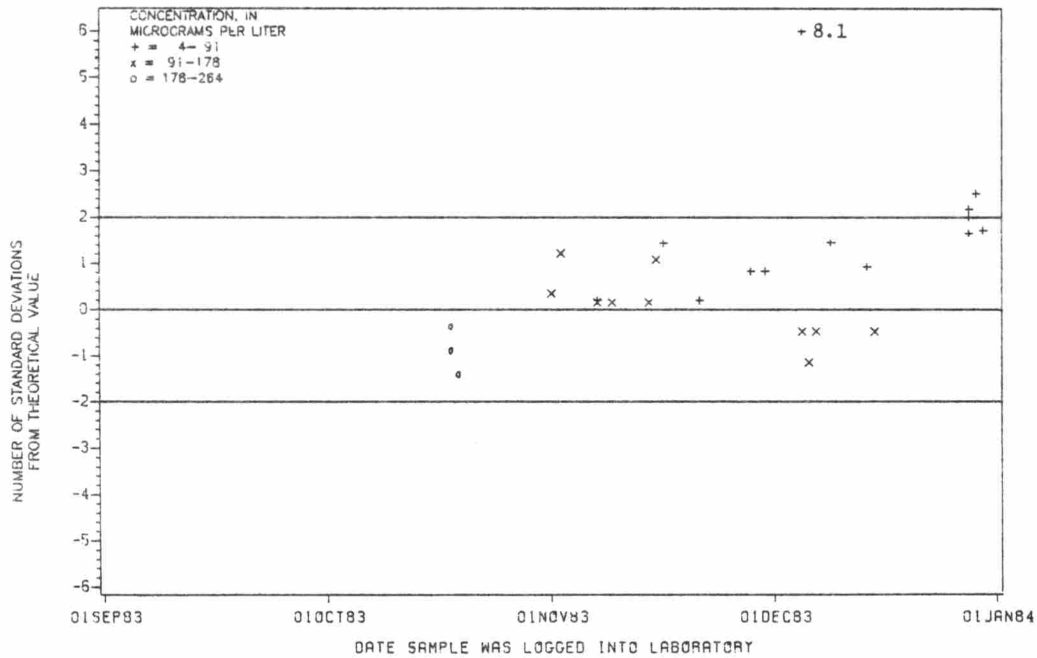

Figure D22.--Copper(AA) data from the Denver laboratory.

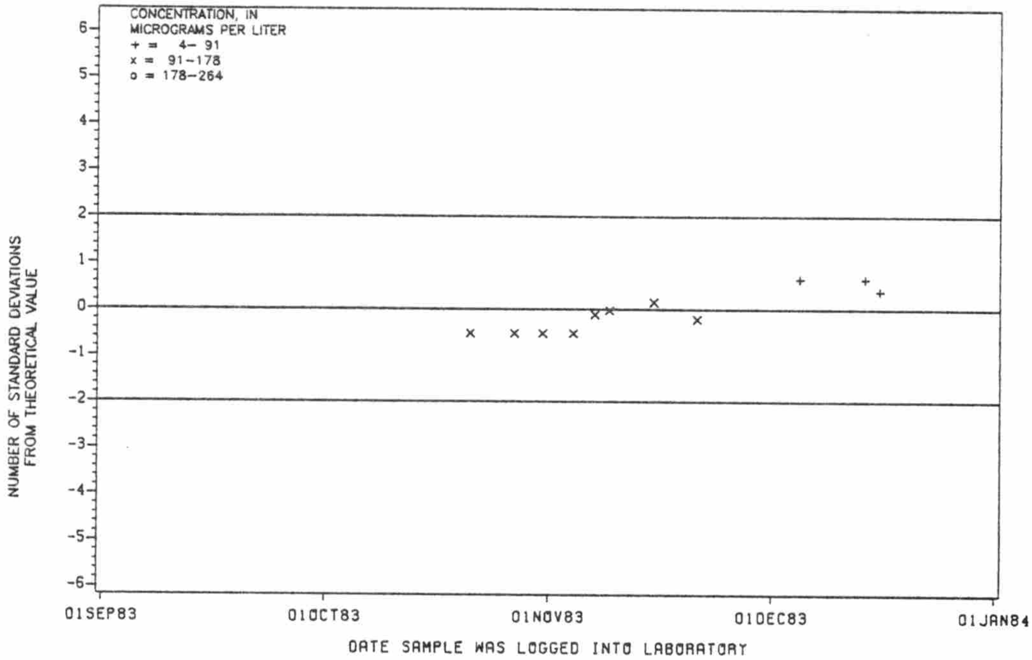

Figure A23.--Copper, total recoverable data from the Atlanta laboratory.

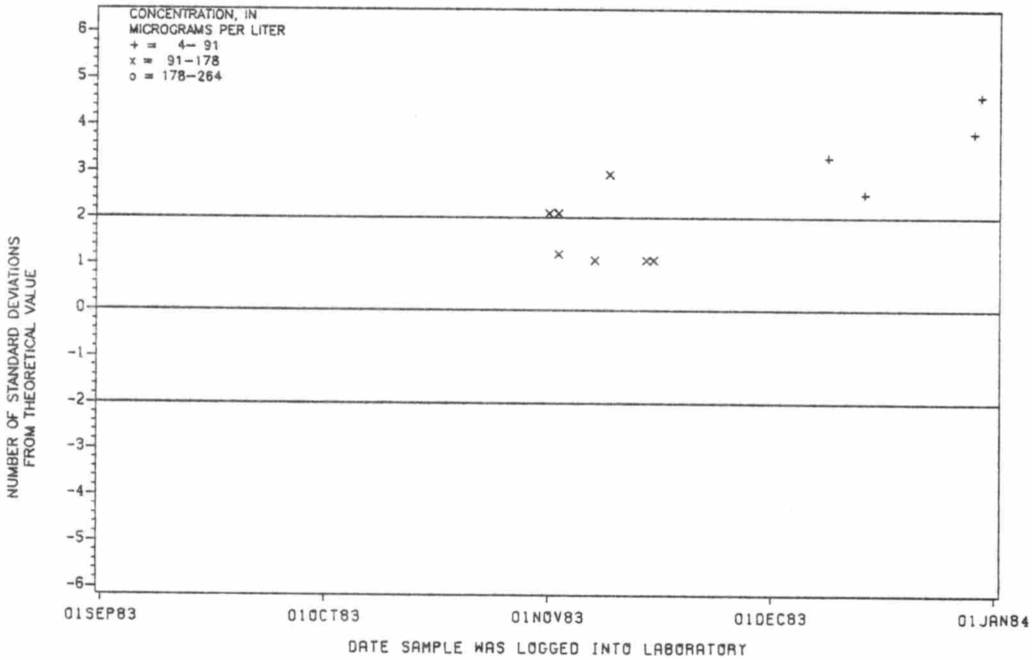

Figure D23.--Copper, total recoverable data from the Denver laboratory.

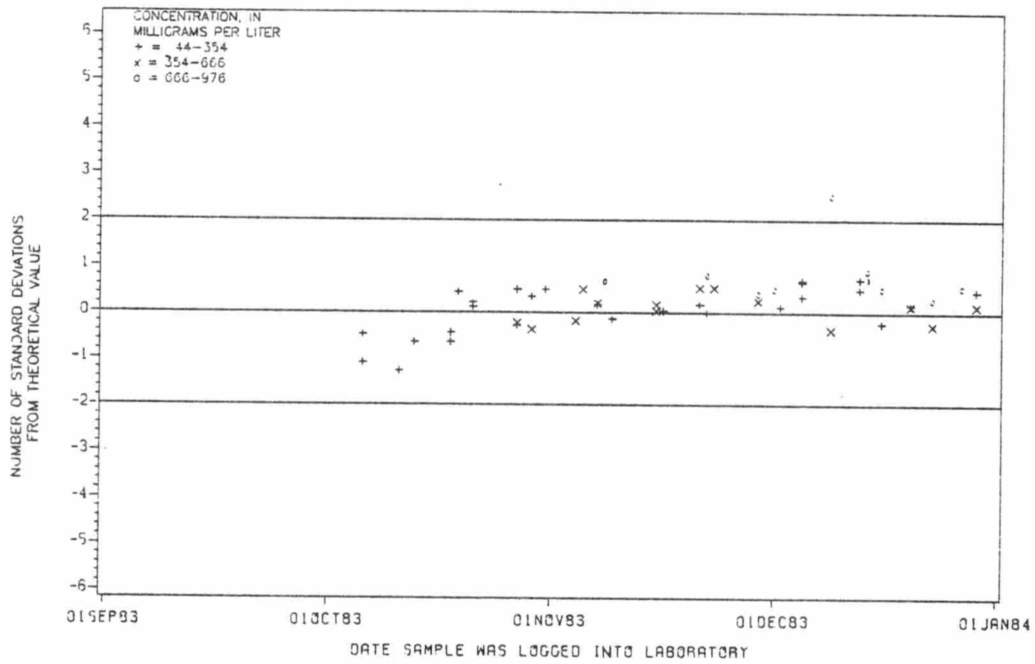

Figure A24.--Dissolved Solids, data from the Atlanta laboratory.

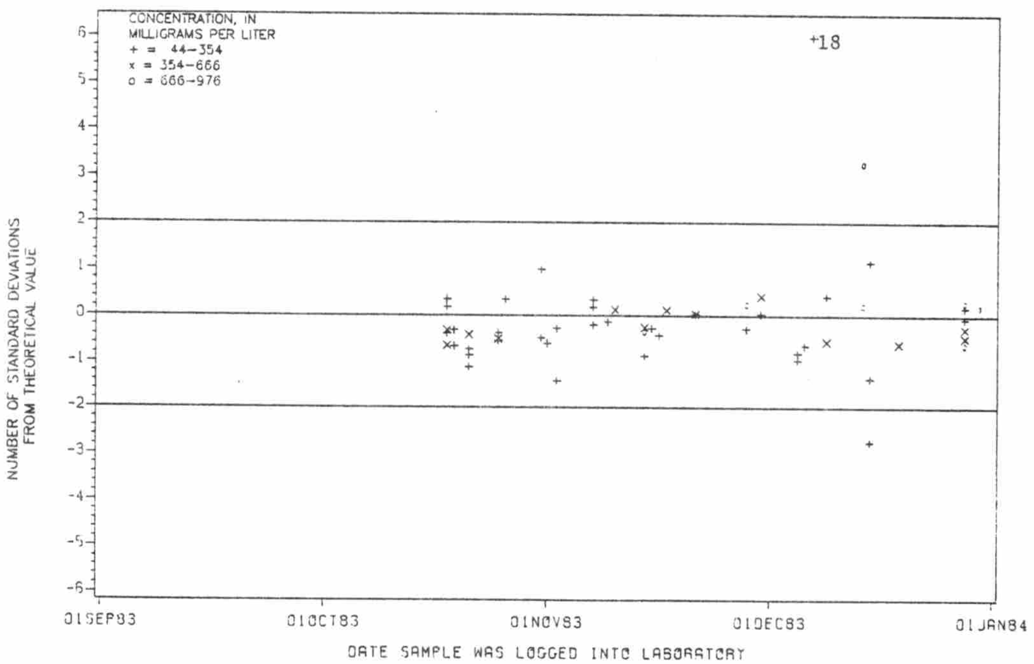

Figure D24.--Dissolved Solids, data from the Denver laboratory.

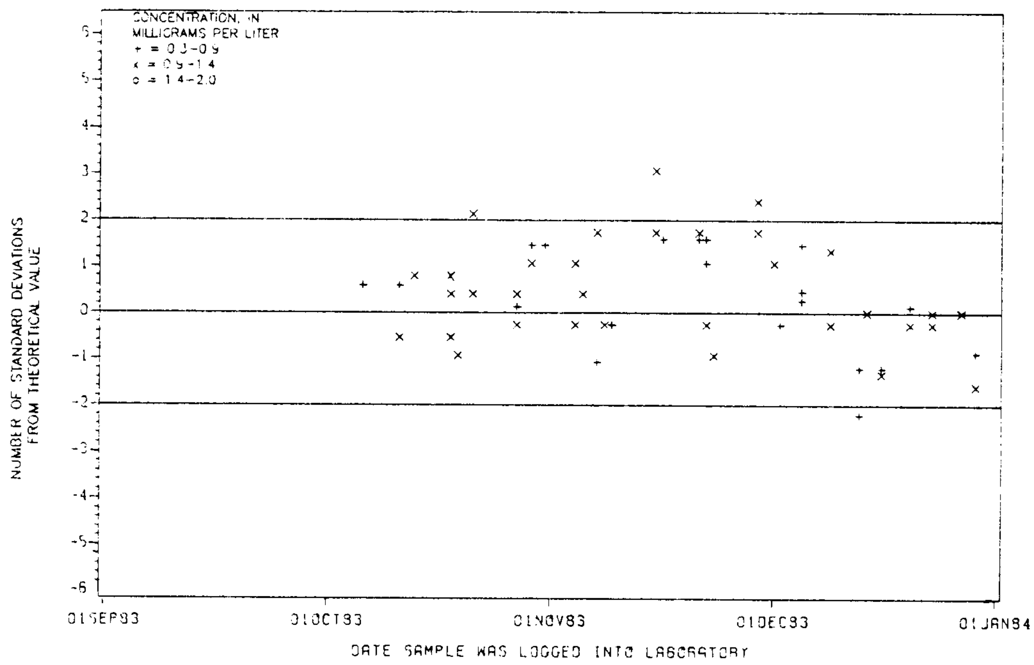

Figure A25.--Fluoride data from the Atlanta laboratory.

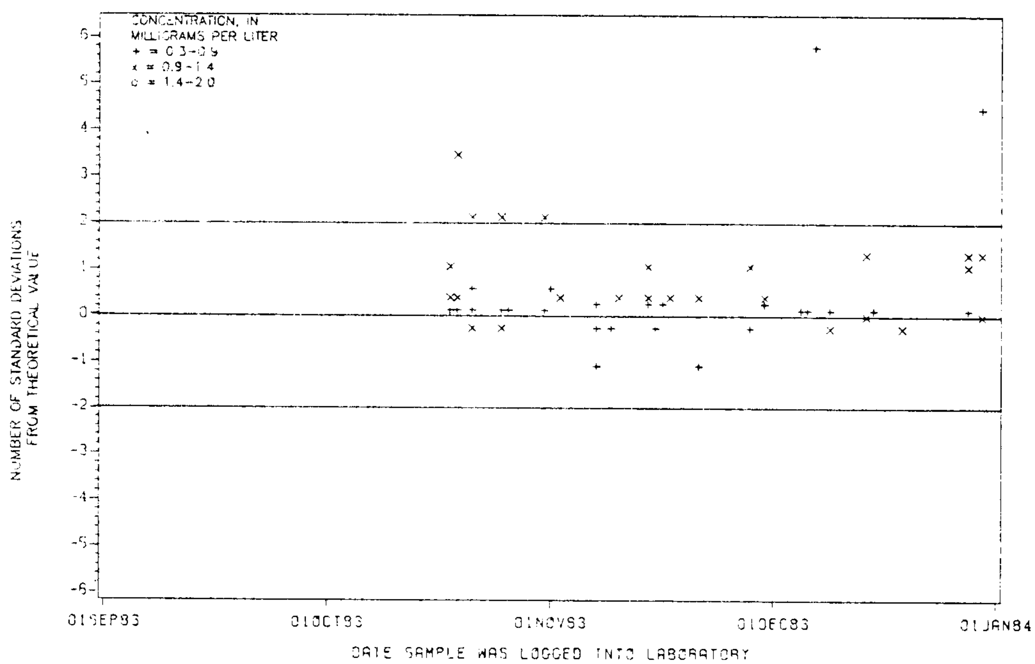

Figure D25.--Fluoride data from the Denver laboratory.

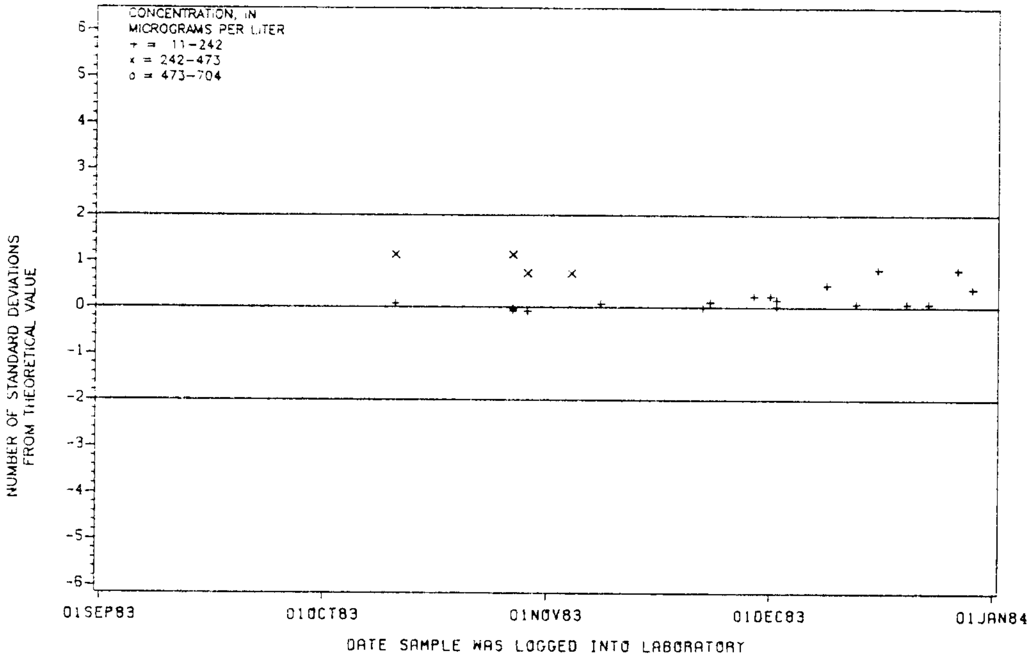

Figure A26.--Iron(ICP) data from the Atlanta laboratory.

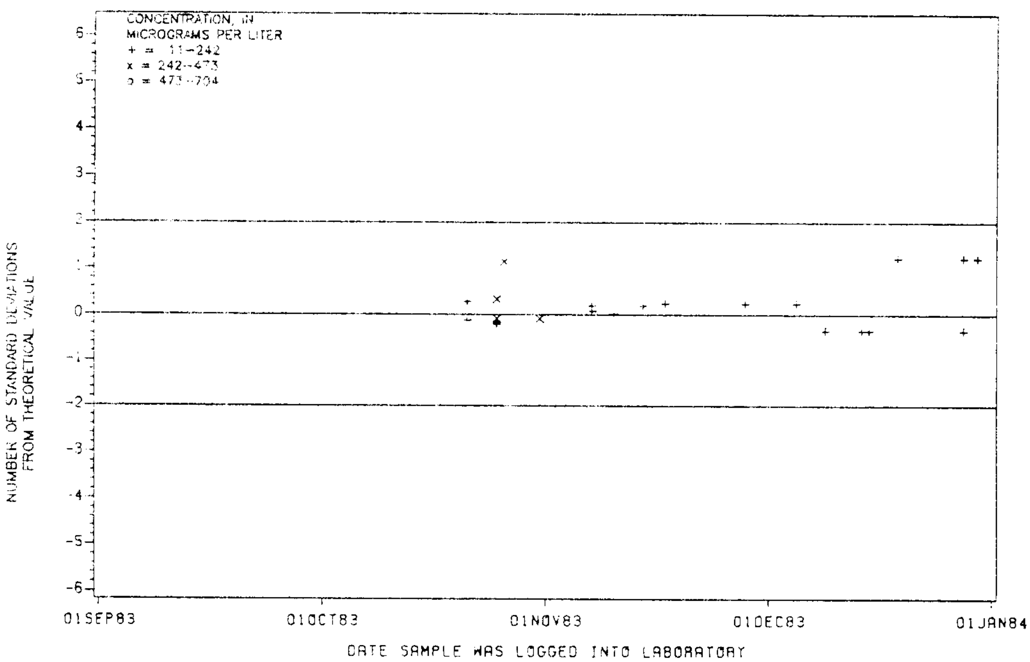

Figure D26.--Iron(ICP) data from the Denver laboratory.

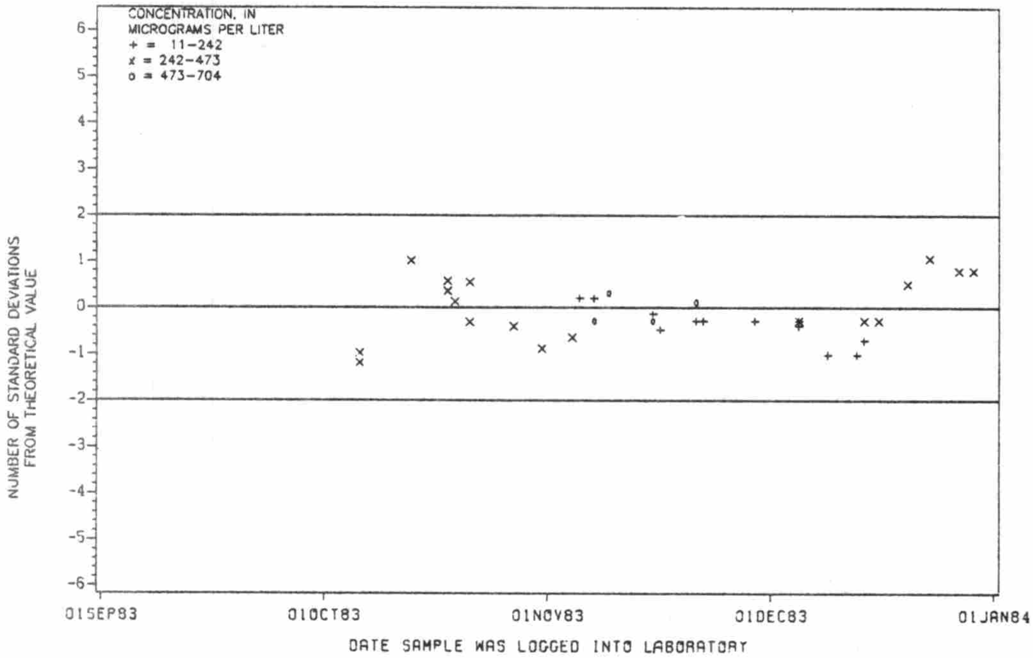

Figure A27.--Iron(AA) data from the Atlanta laboratory.

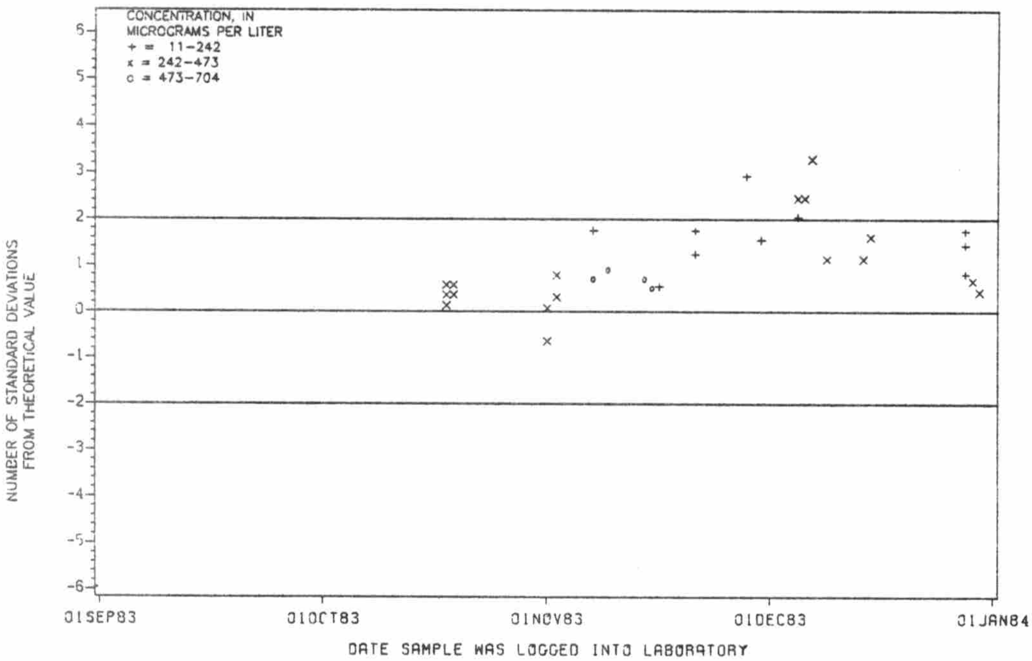

Figure D27.--Iron(AA) data from the Denver laboratory.

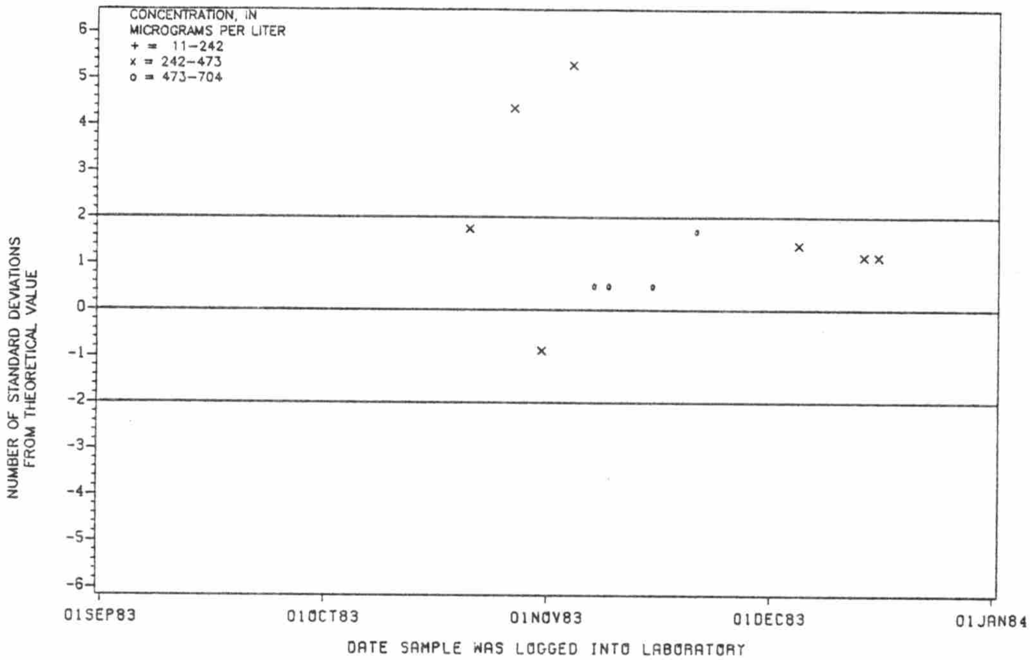

Figure A28.--Iron, total recoverable data from the Atlanta laboratory.

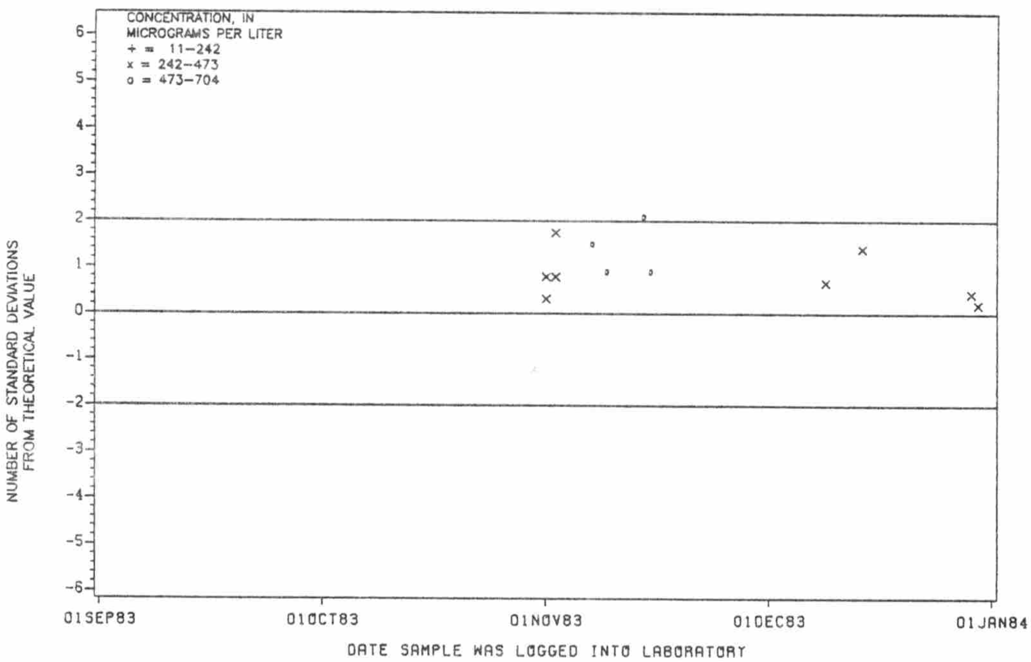

Figure D28.--Iron, total recoverable data from the Denver laboratory.

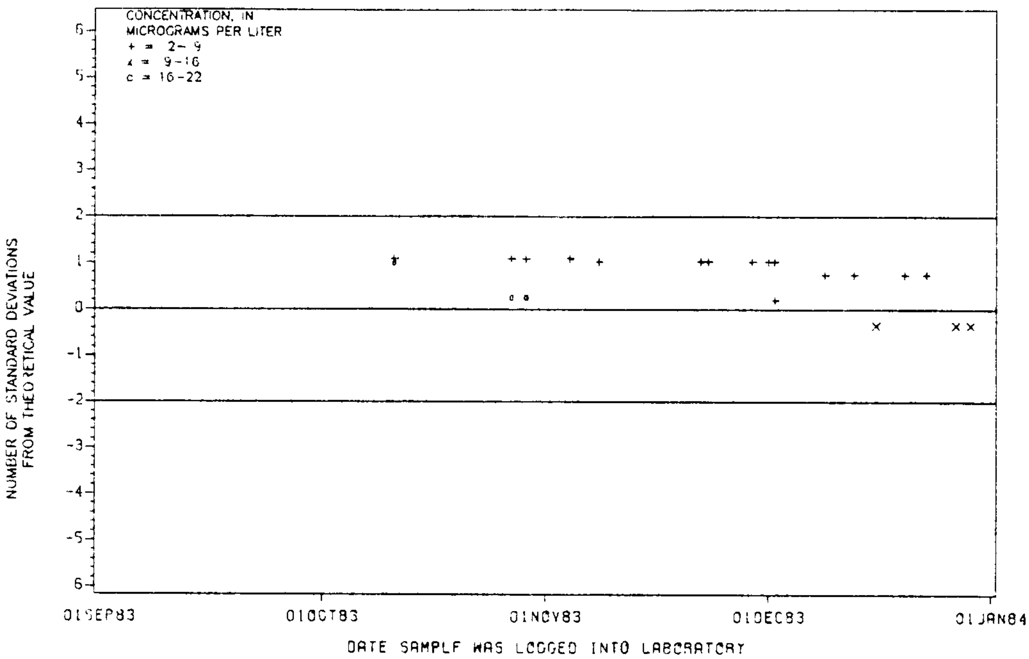

Figure A29.--Lead(ICP) data from the Atlanta laboratory

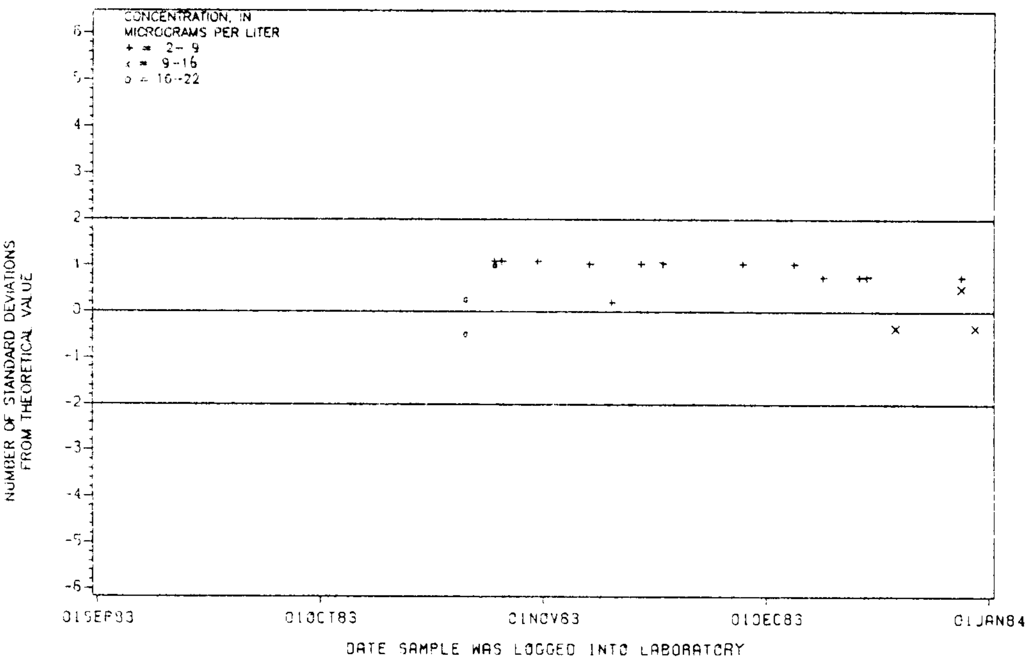

Figure D29.--Lead(ICP) data from the Denver laboratory.

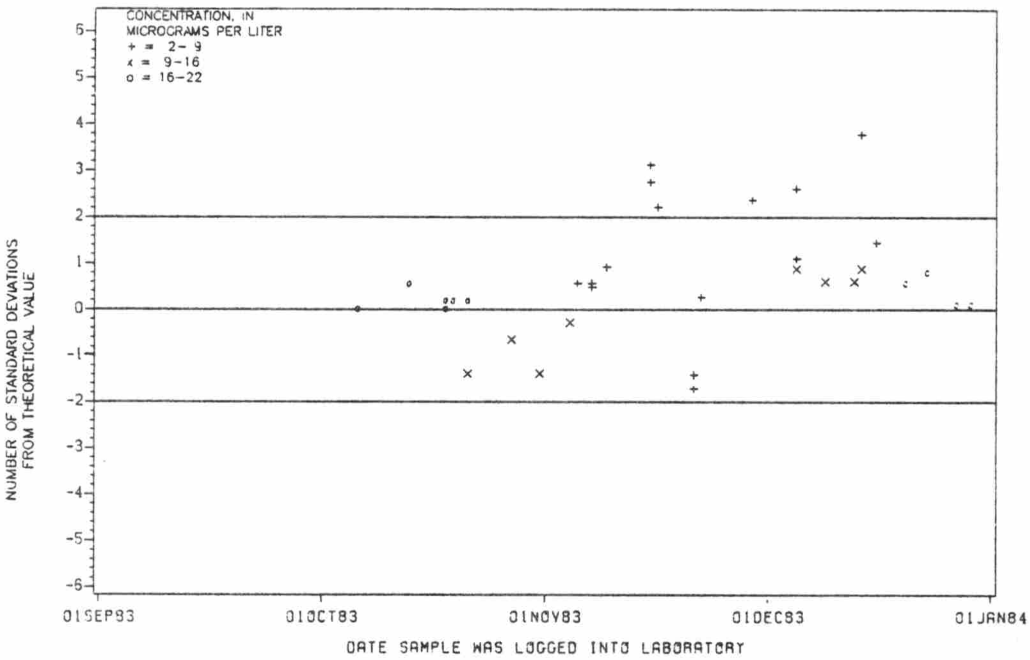

Figure A30.--Lead(AA) data from the Atlanta laboratory.

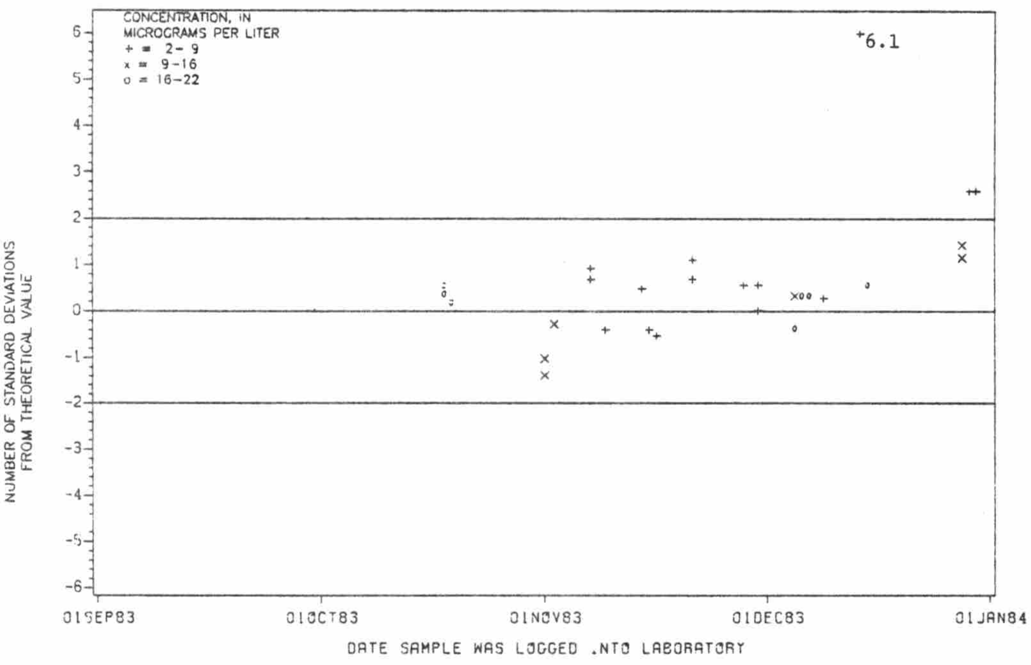

Figure D30.--Lead(AA) data from the Denver laboratory.

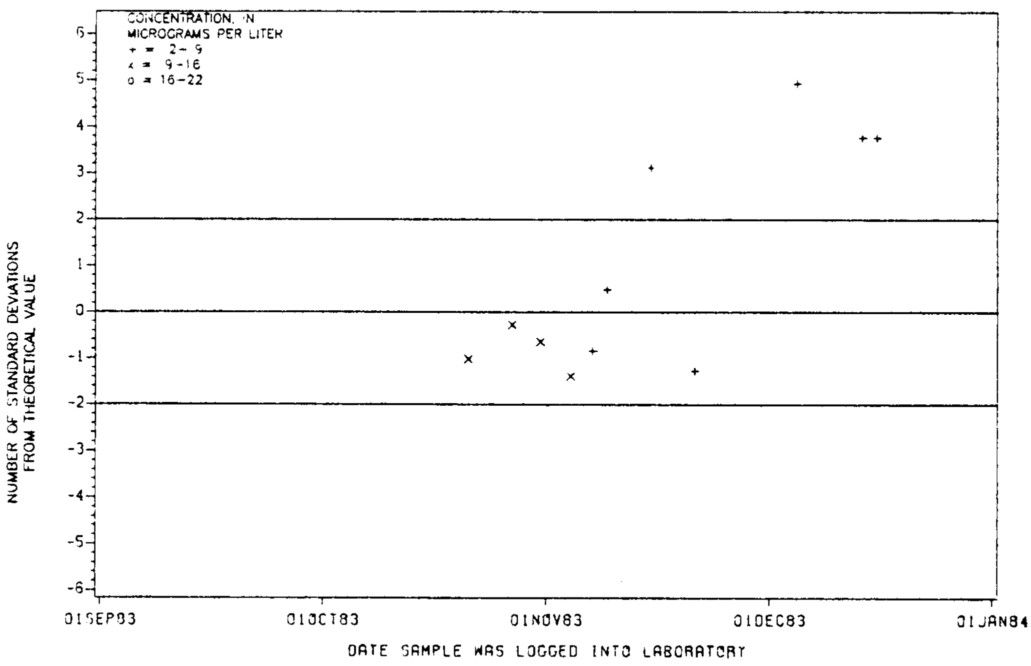

Figure A31.--Lead, total recoverable data from the Atlanta laboratory.

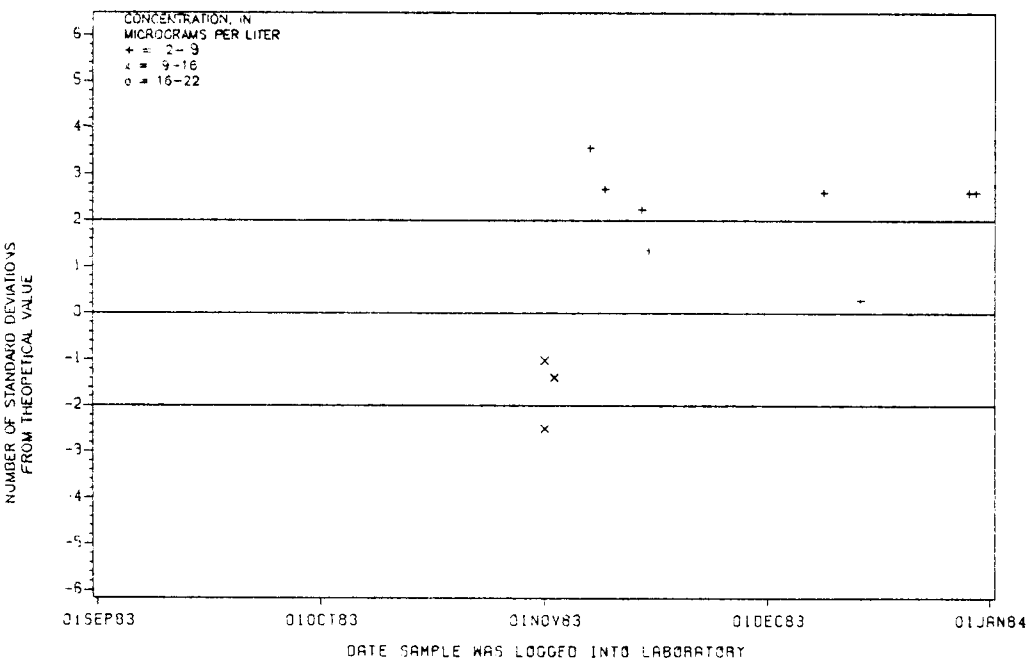

Figure D31.--Lead, total recoverable data from the Denver laboratory.

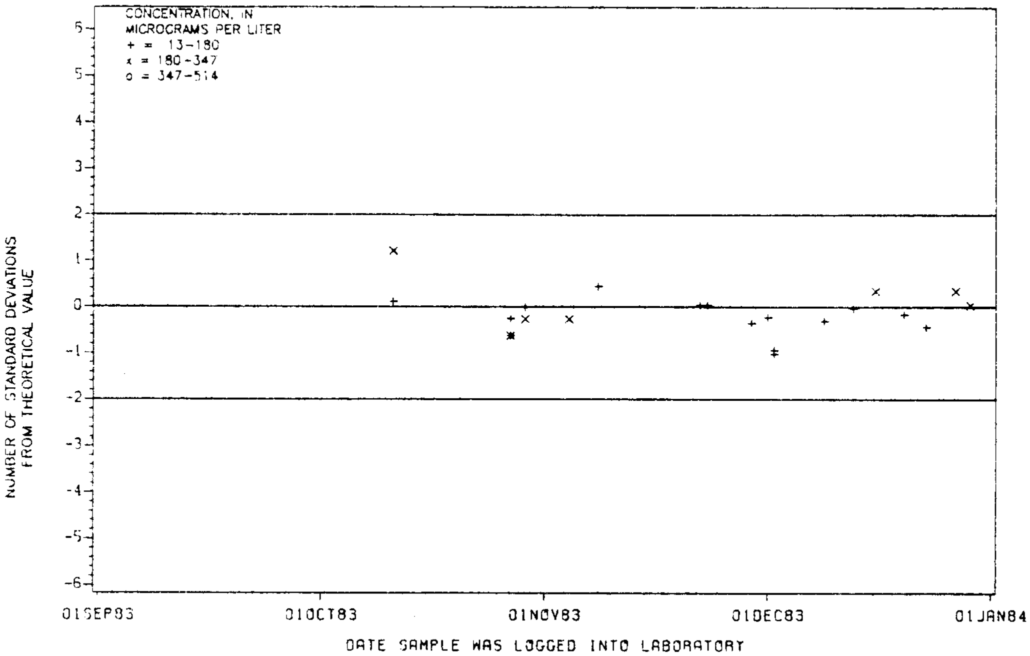

Figure A32.--Lithium data from the Atlanta laboratory.

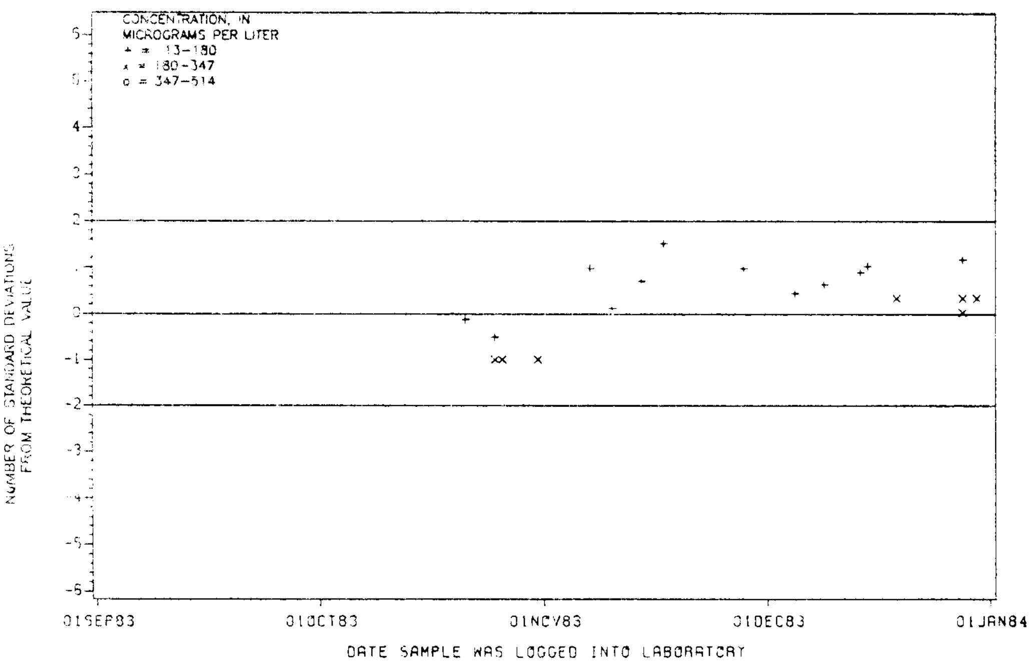

Figure D32.--Lithium data from the Denver laboratory.

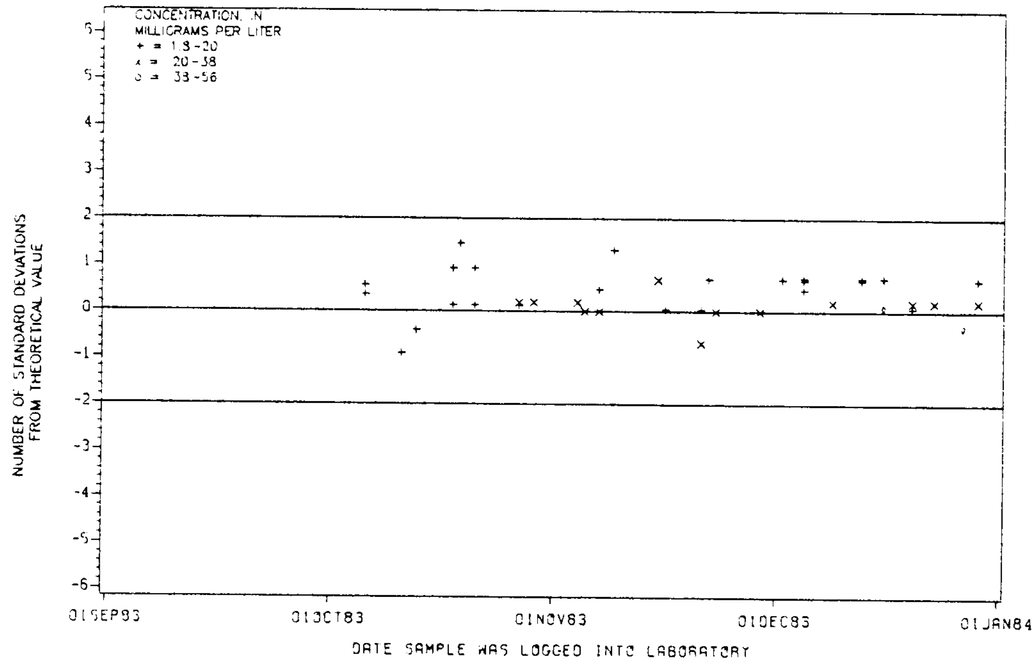

Figure A33.--Magnesium(ICP) data from the Atlanta laboratory.

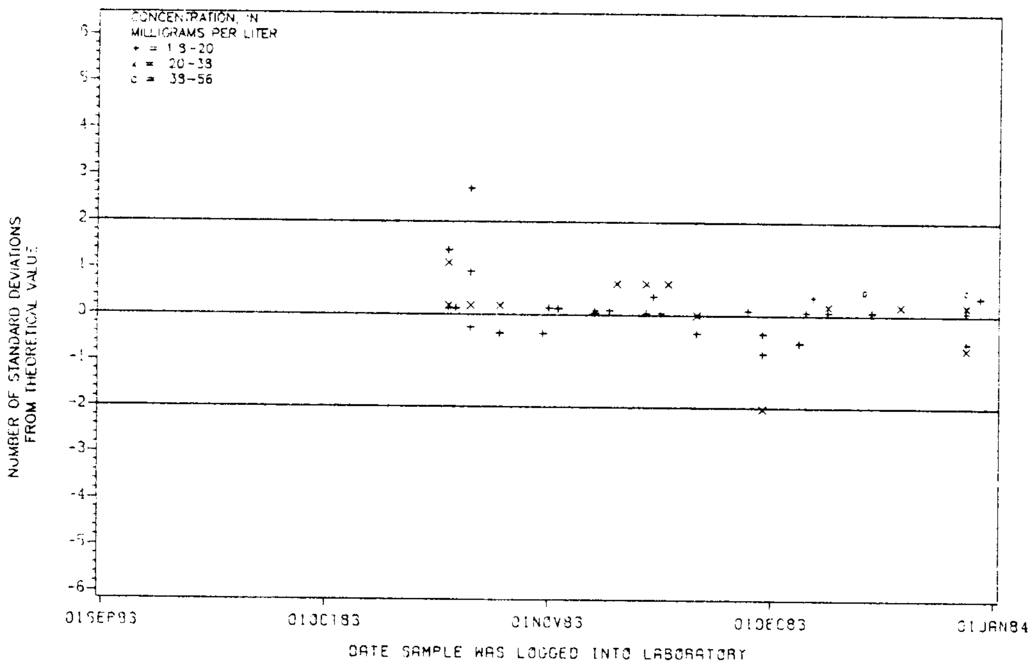

Figure D33.--Magnesium(ICP) data from the Denver laboratory.

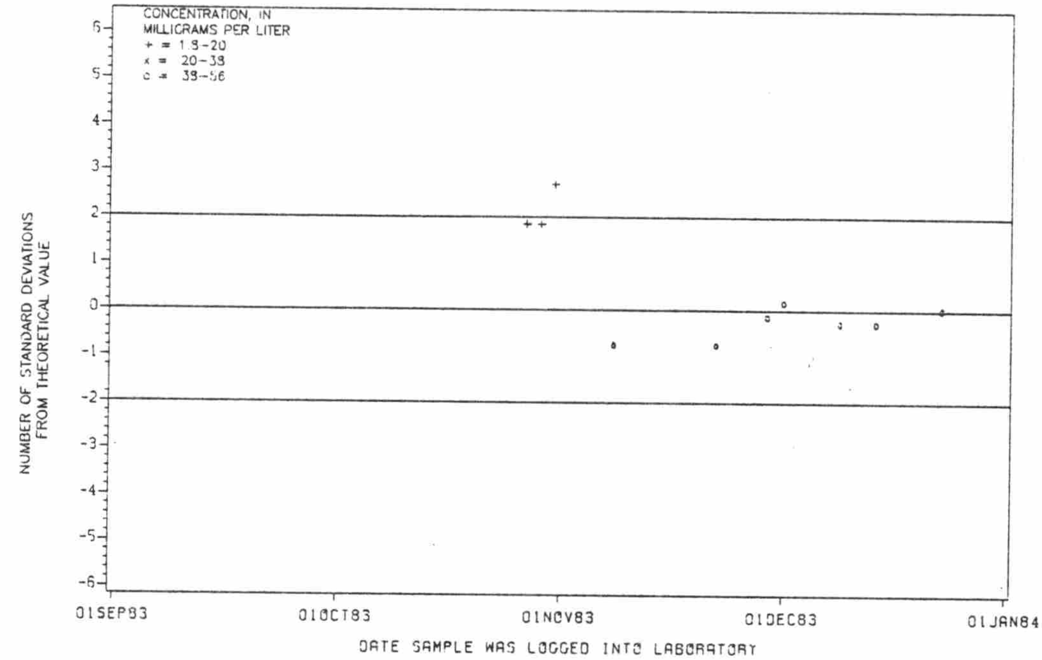

Figure A34.--Magnesium(AA) data from the Atlanta laboratory.

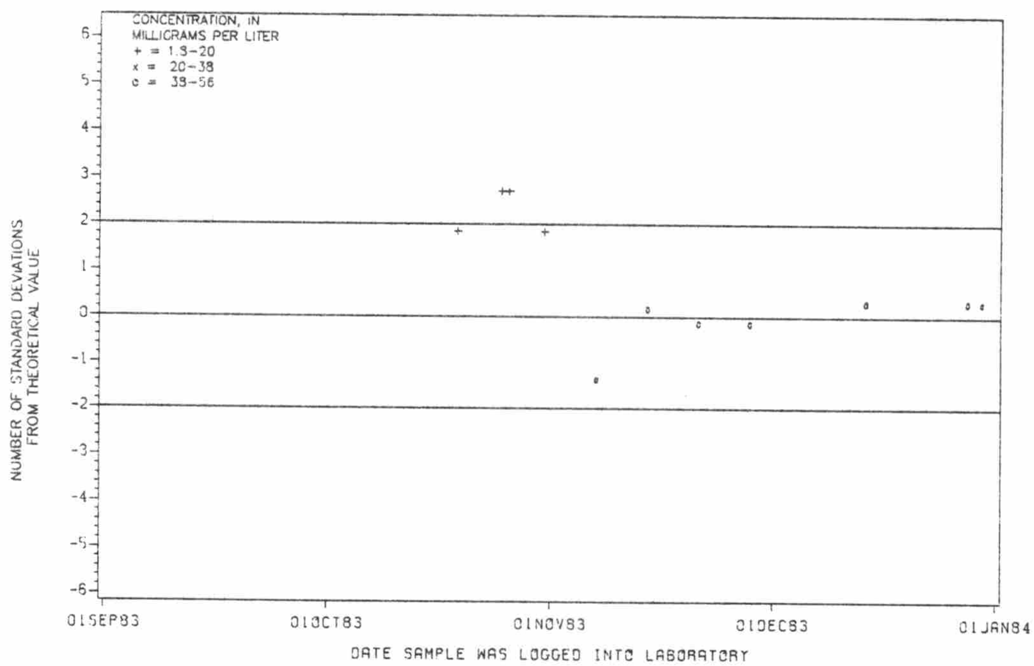

Figure D34.--Magnesium(AA) data from the Denver laboratory.

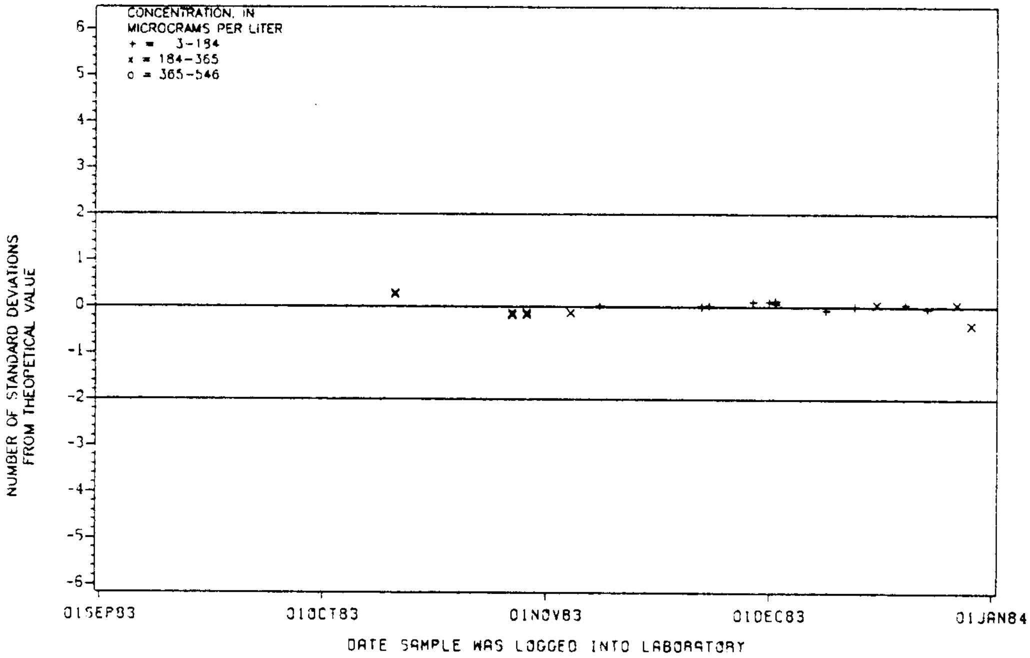

Figure A35.--Manganese(ICP) data from the Atlanta laboratory.

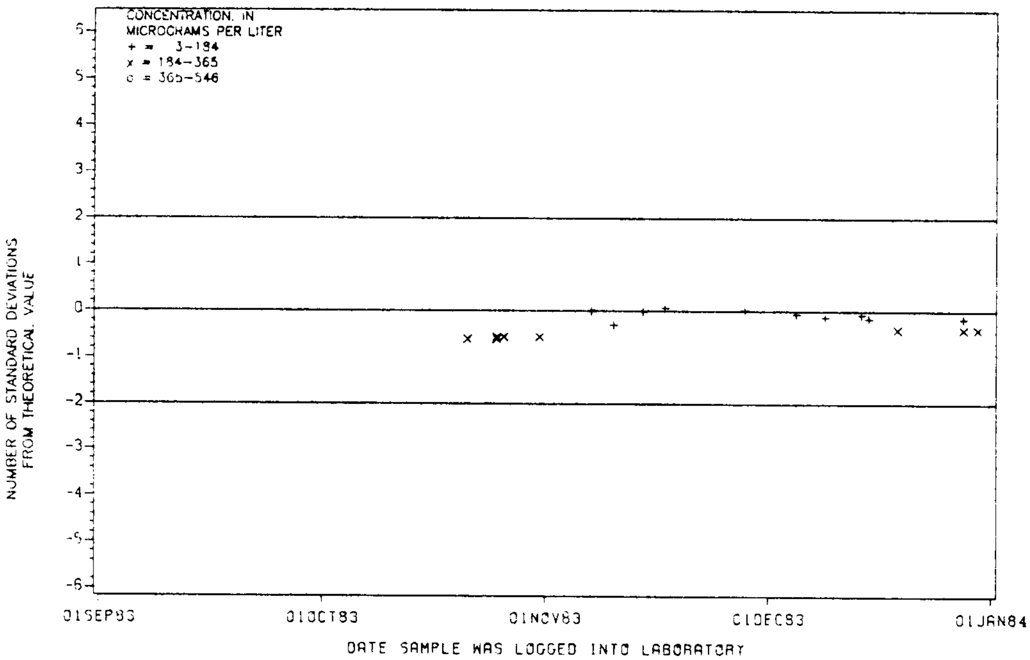

Figure D35.--Manganese(ICP) data from the Denver laboratory.

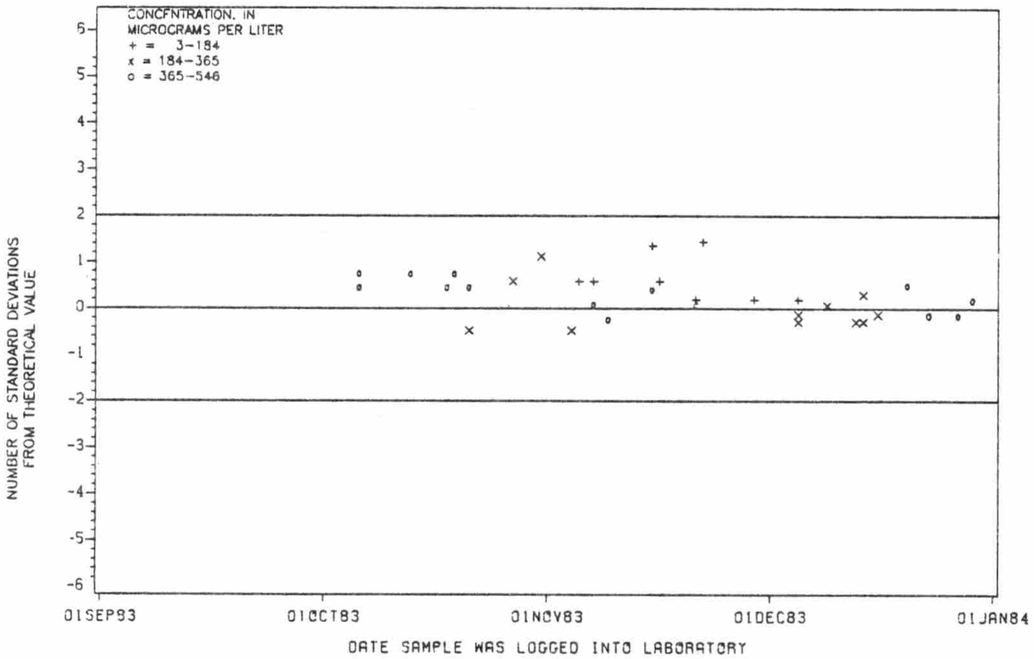

Figure A36.--Manganese(AA) data from the Atlanta laboratory.

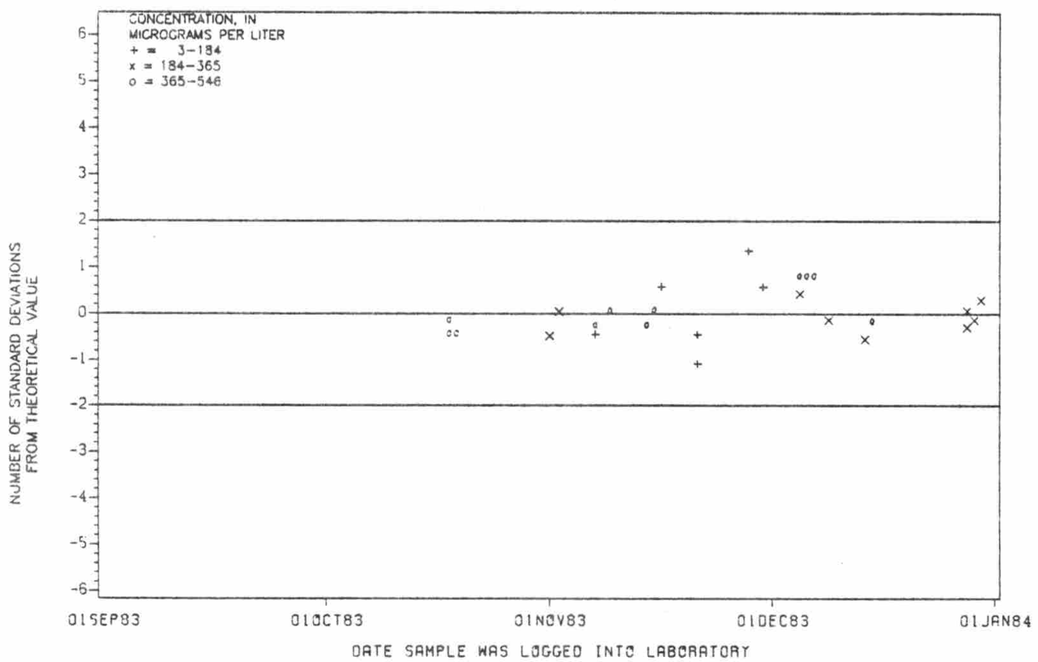

Figure D36.--Manganese(AA) data from the Denver laboratory.

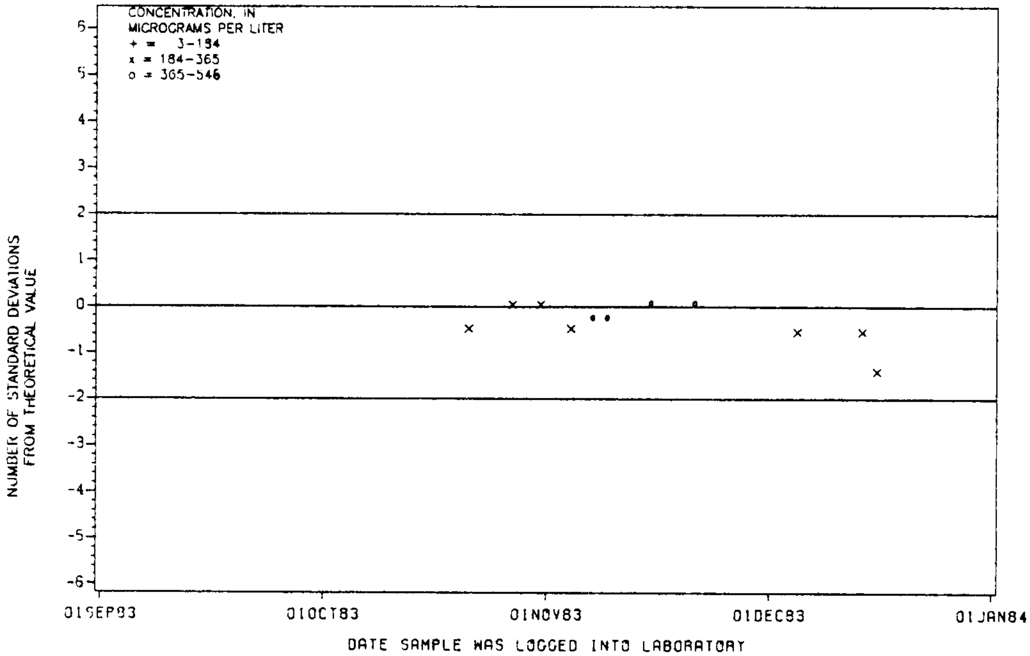

Figure A37.--Manganese, total recoverable data from the Atlanta laboratory.

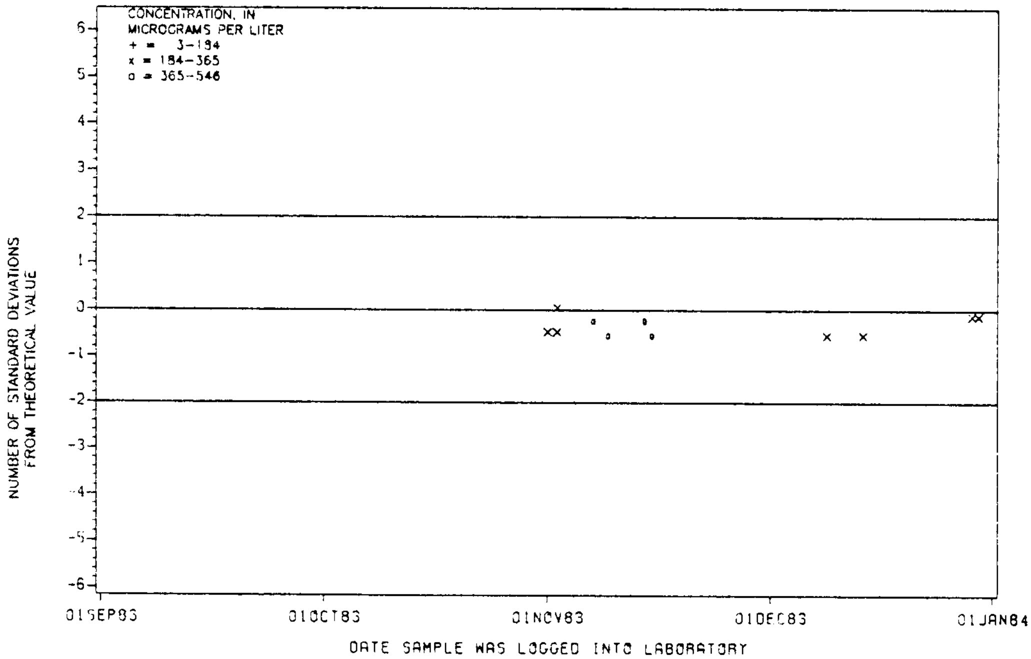

Figure D37.--Manganese, total recoverable data from the Denver laboratory.

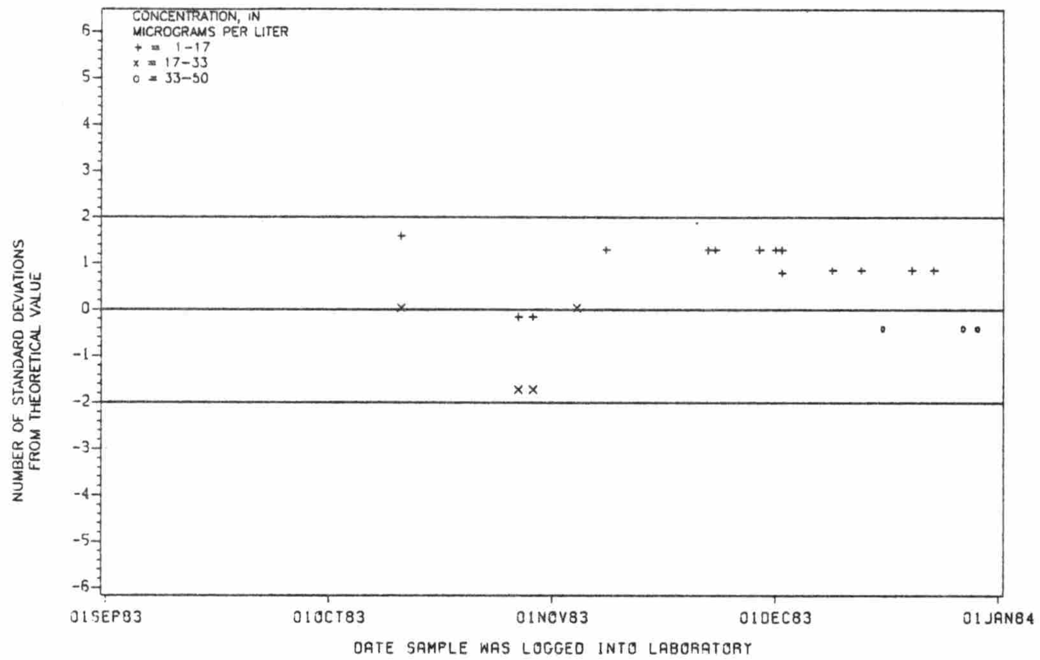

Figure A38.--Molybdenum(ICP) data from the Atlanta laboratory.

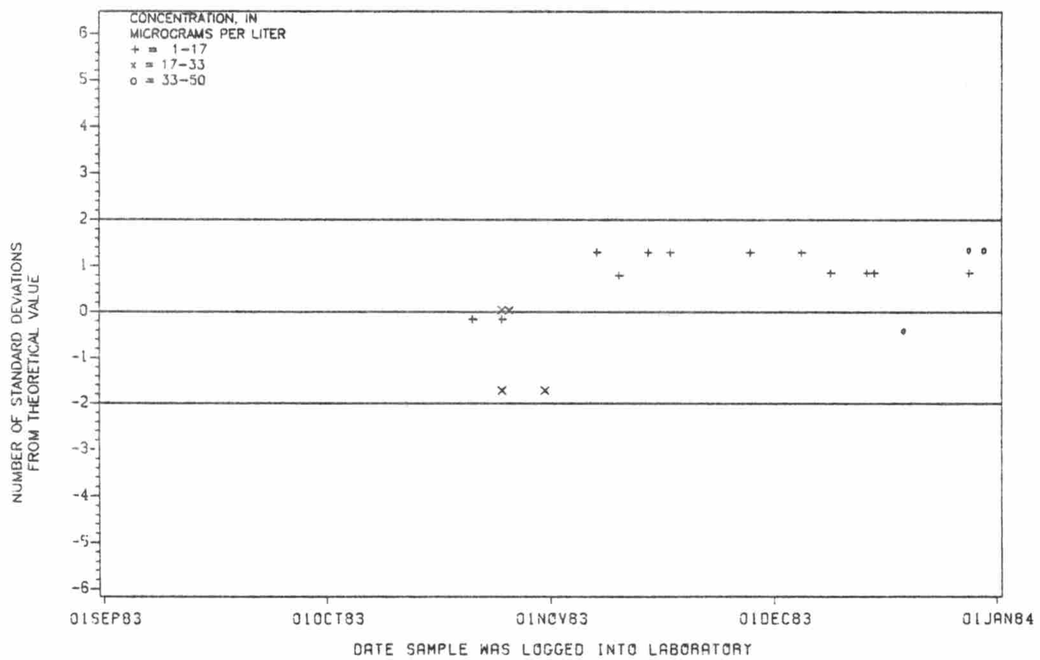

Figure D38.--Molybdenum(ICP) data from the Denver laboratory.

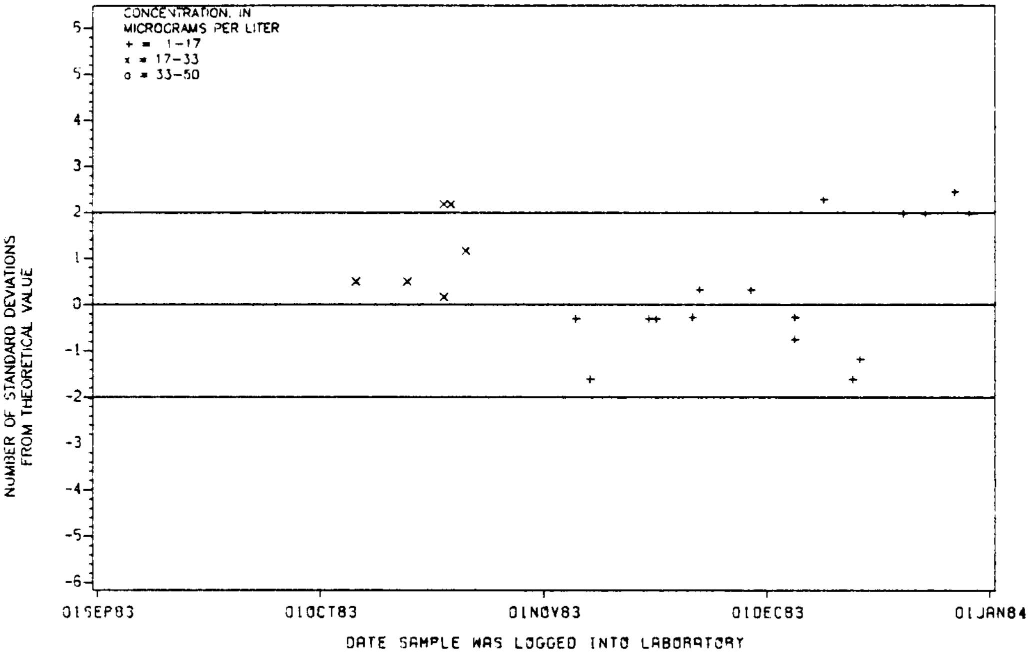

Figure A39.--Molybdenum(AA) data from the Atlanta laboratory.

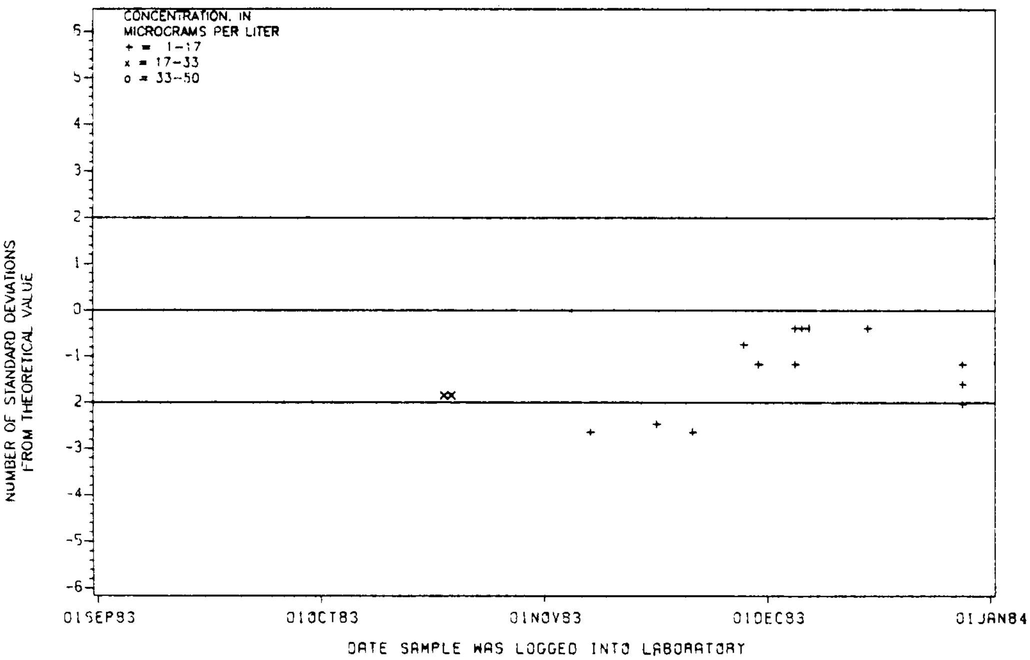

Figure D39.--Molybdenum(AA) data from the Denver laboratory.

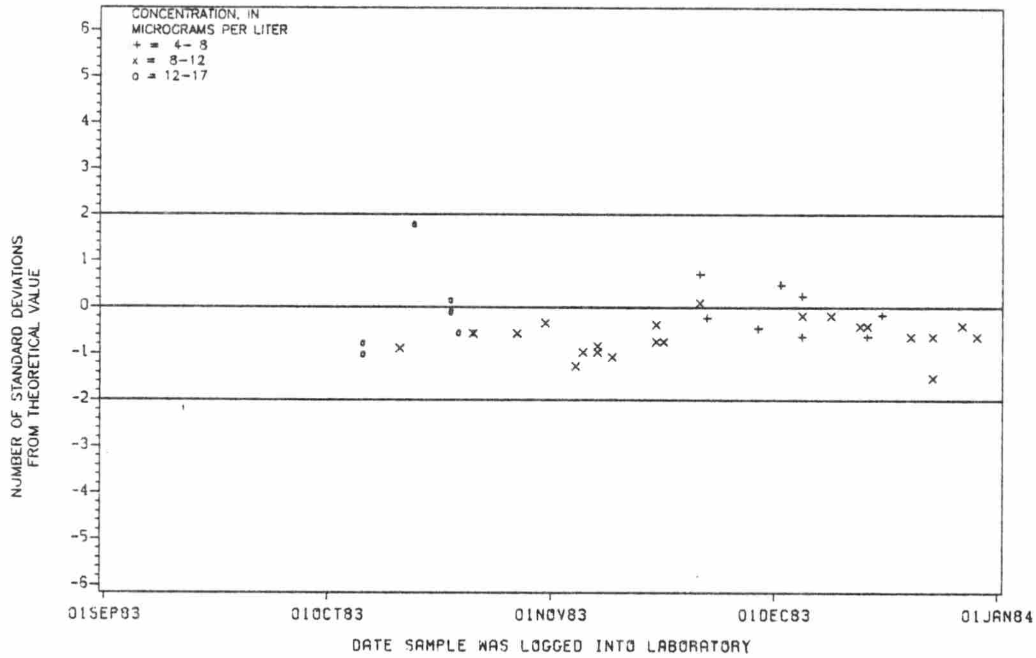

Figure A40.--Nickel data from the Atlanta laboratory.

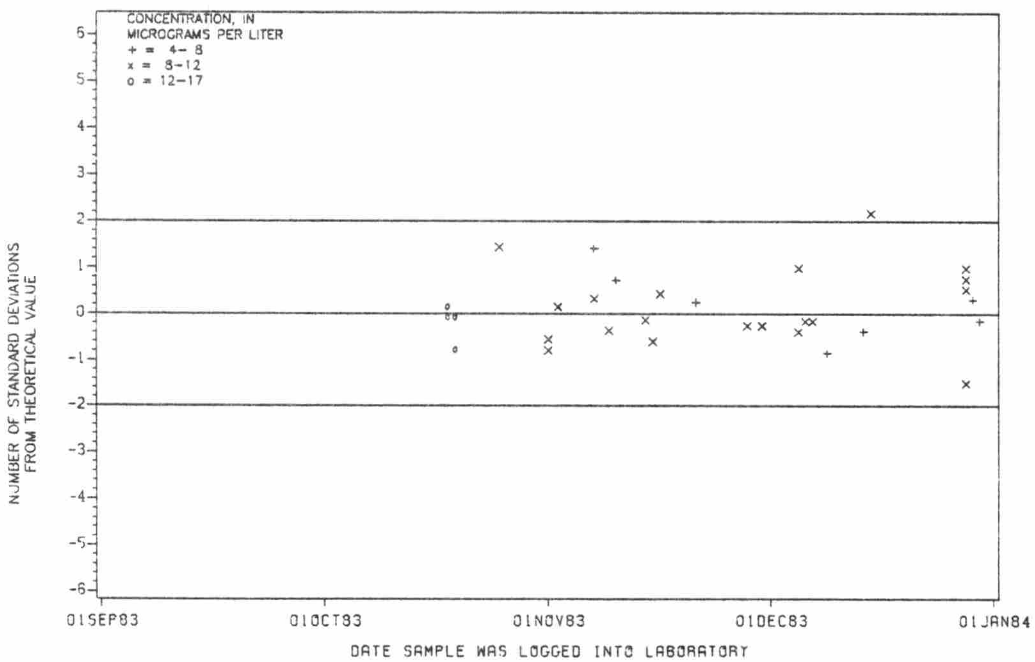

Figure D40.--Nickel data from the Denver laboratory.

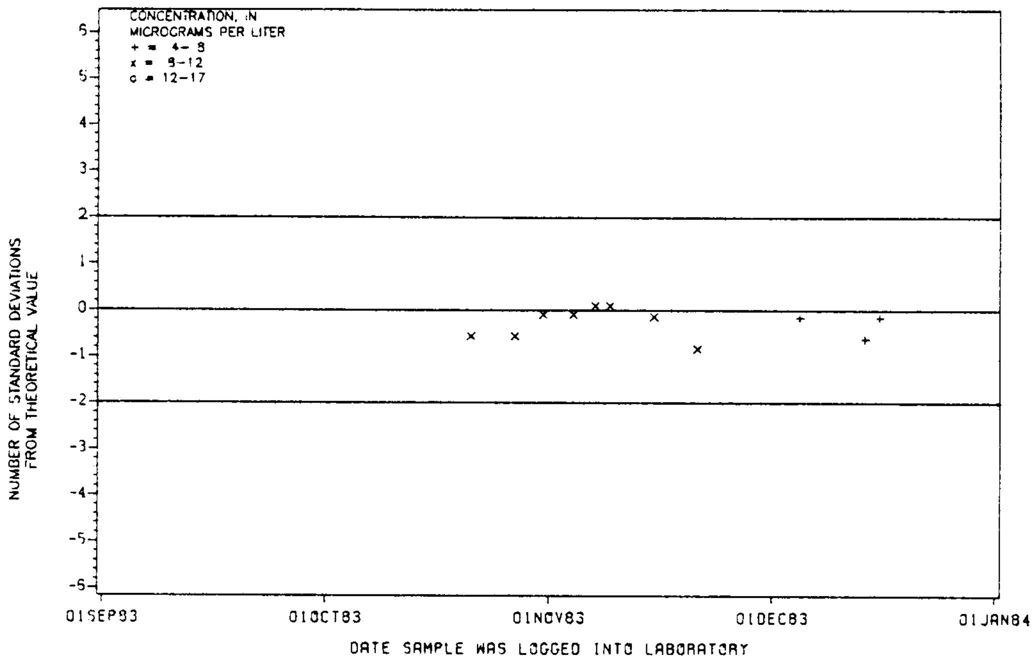

Figure A41.--Nickel, total recoverable data from the Atlanta laboratory.

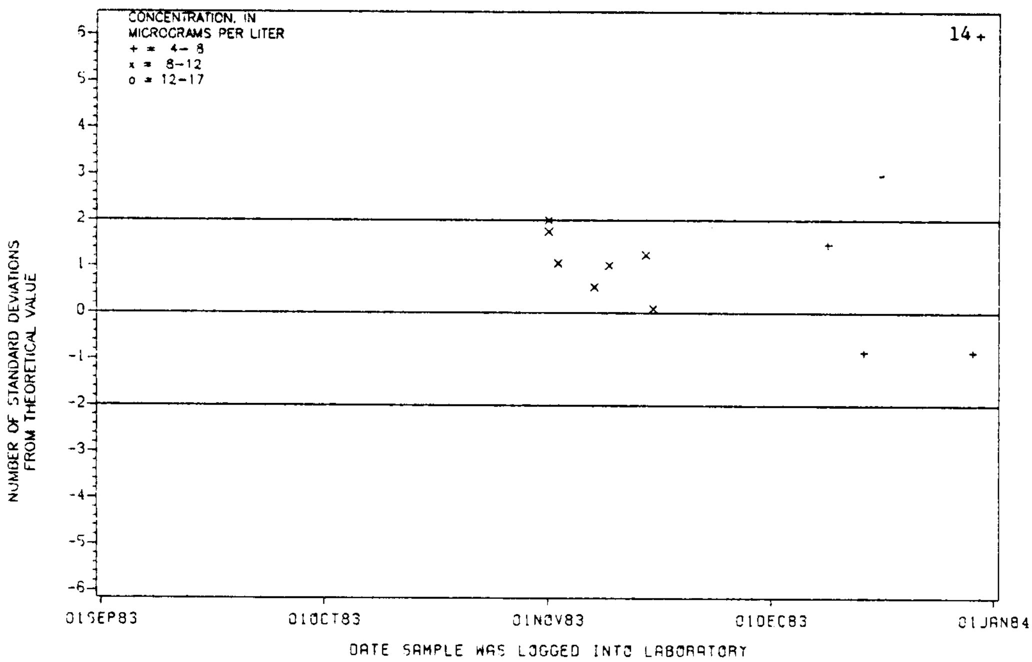

Figure D41.--Nickel, total recoverable data from the Denver laboratory.

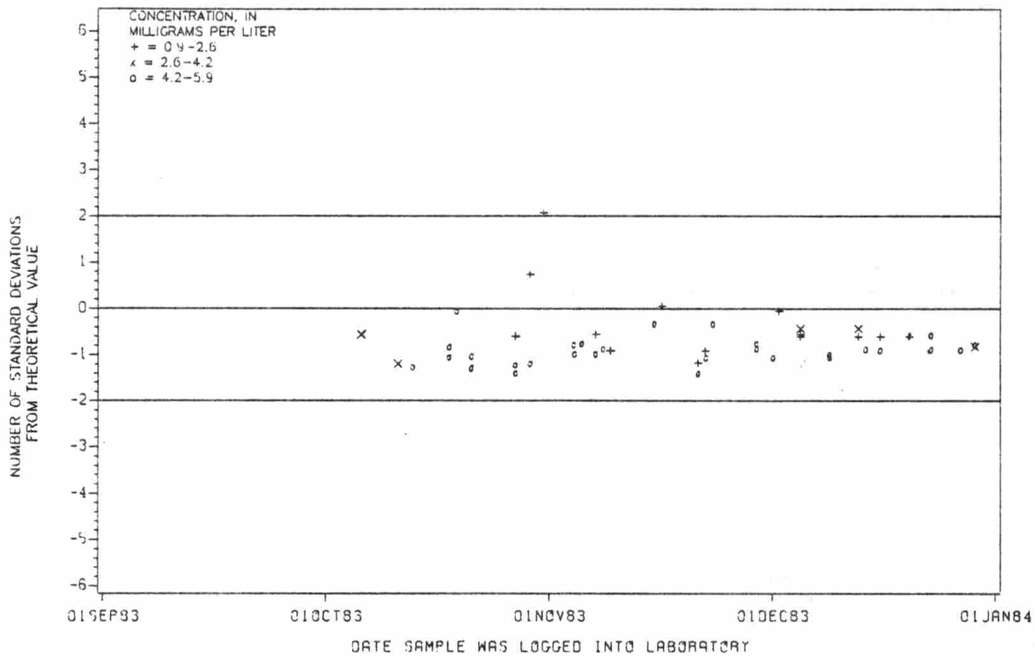

Figure A42.--Potassium data from the Atlanta laboratory.

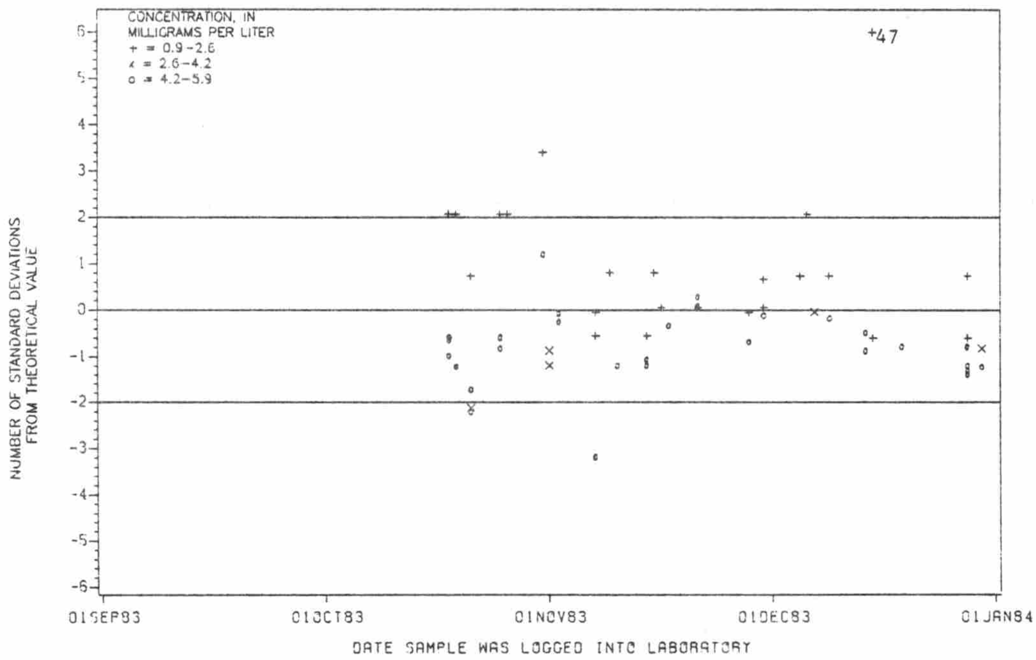

Figure D42.--Potassium data from the Denver laboratory.

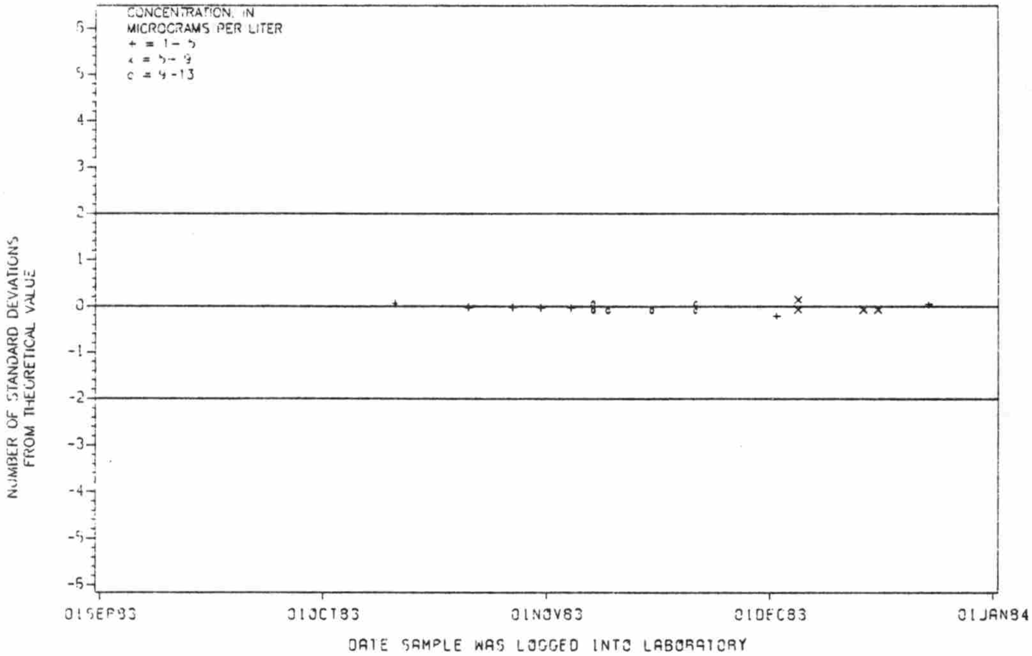

Figure A43.--Selenium data from the Atlanta laboratory.

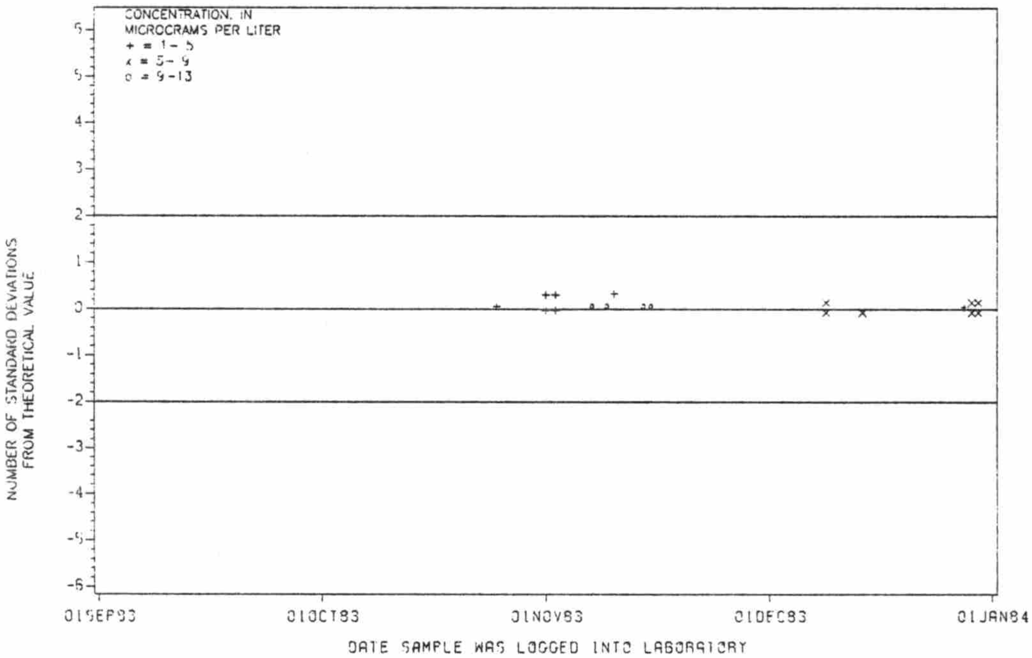

Figure D43.--Selenium data from the Denver laboratory.

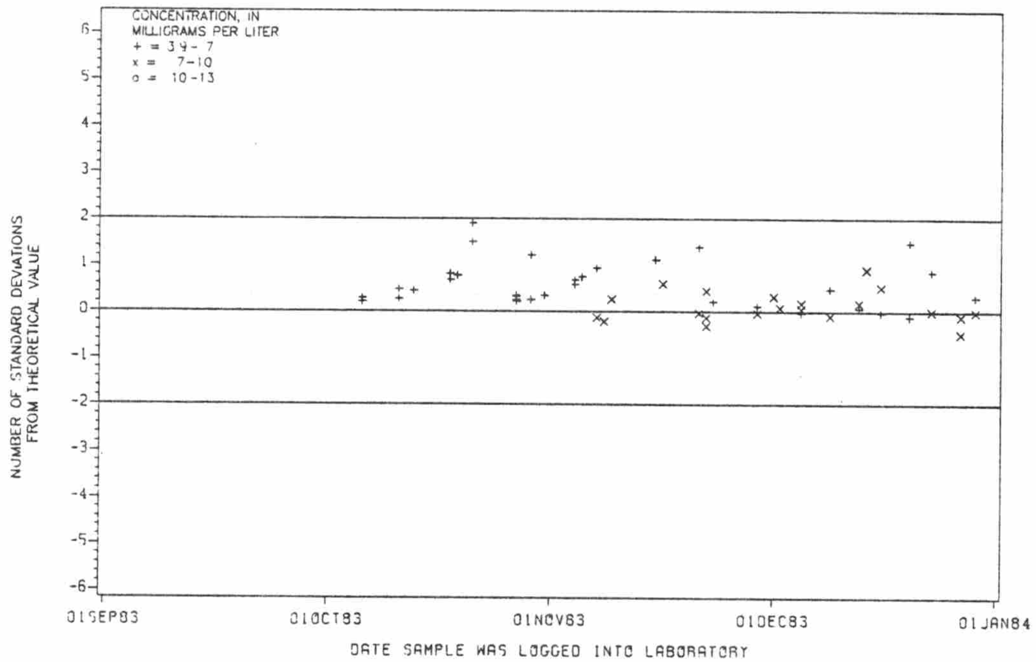

Figure A44.--Silica data from the Atlanta laboratory.

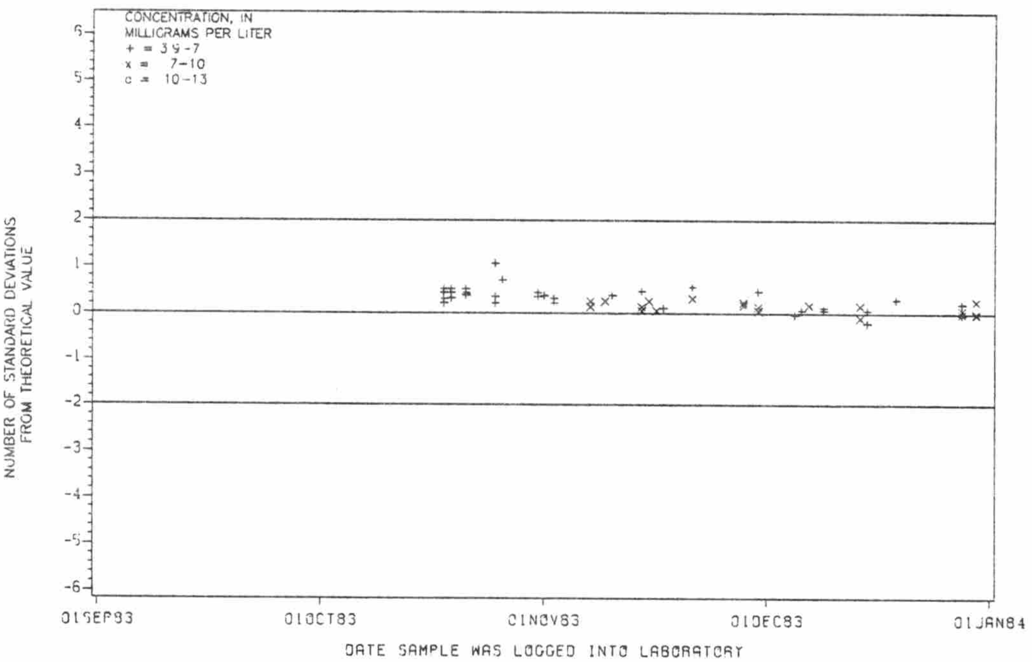

Figure D44.--Silica data from the Denver laboratory.

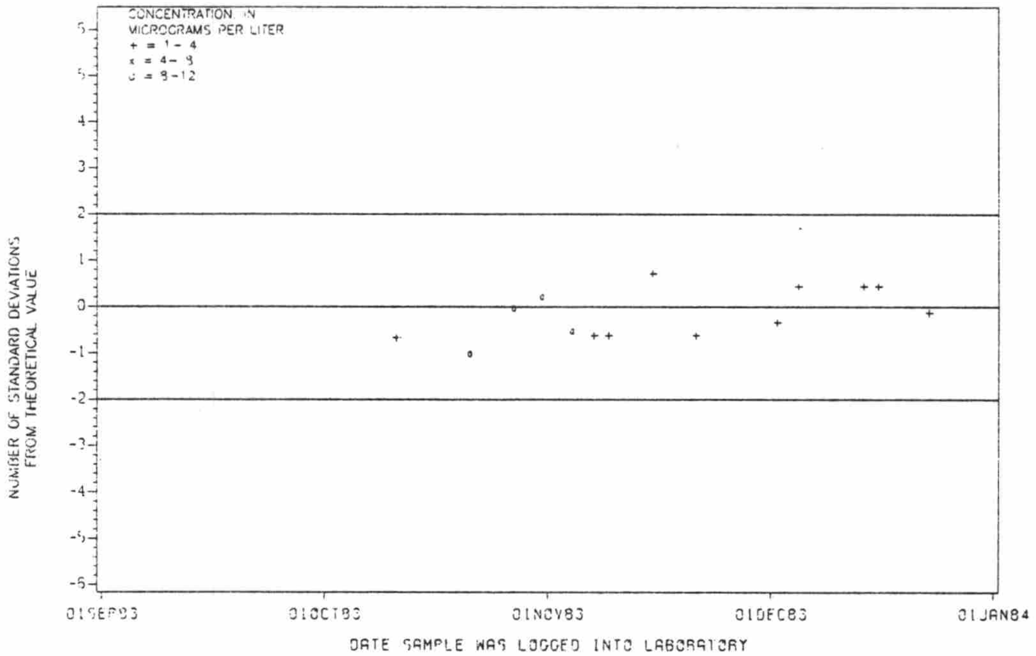

Figure A45.--Silver data from the Atlanta laboratory.

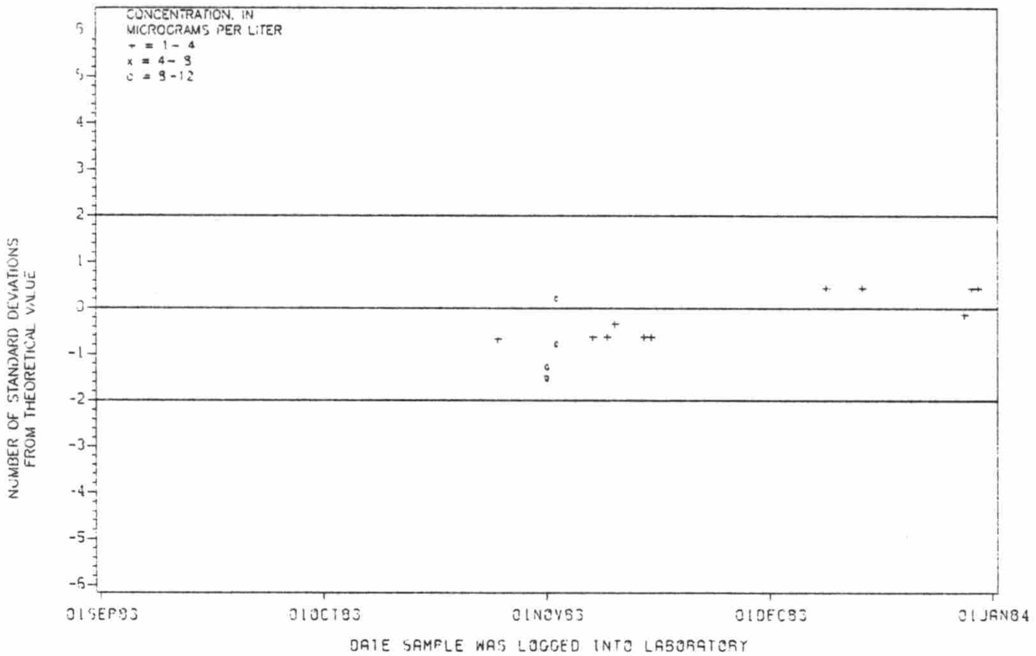

Figure D45.--Silver data from the Denver laboratory.

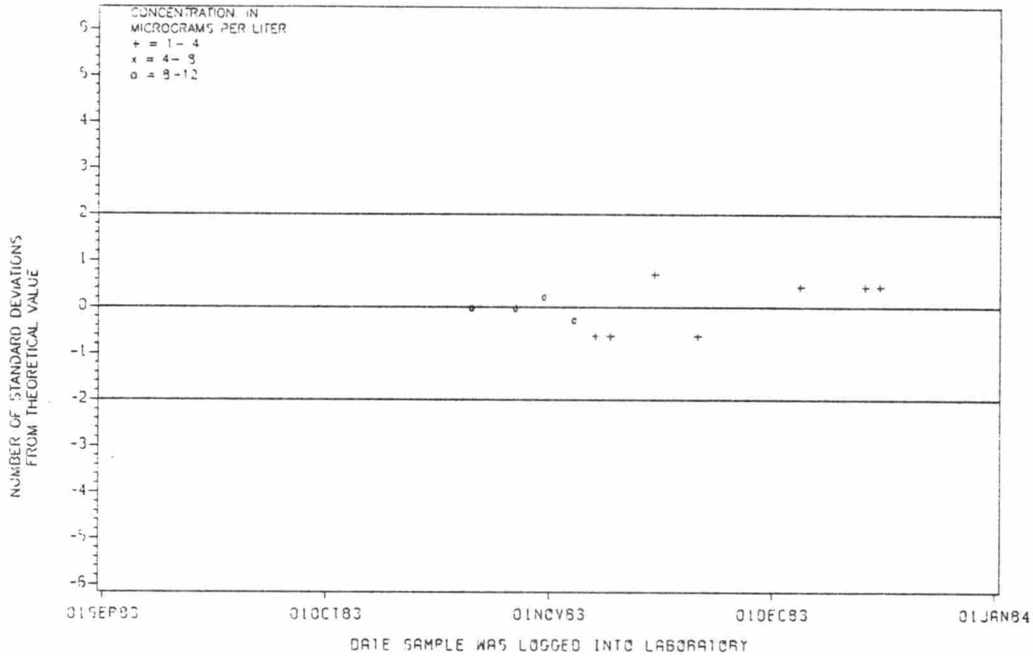

Figure A46.--Silver, total recoverable data from the Atlanta laboratory.

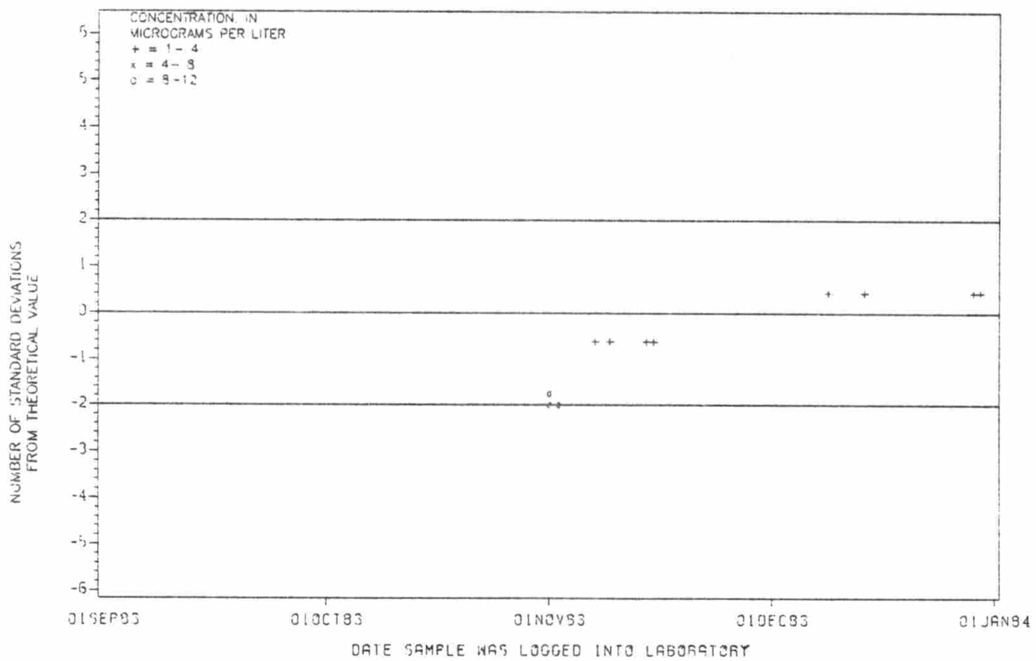

Figure D46.--Silver, total recoverable data from the Denver laboratory.

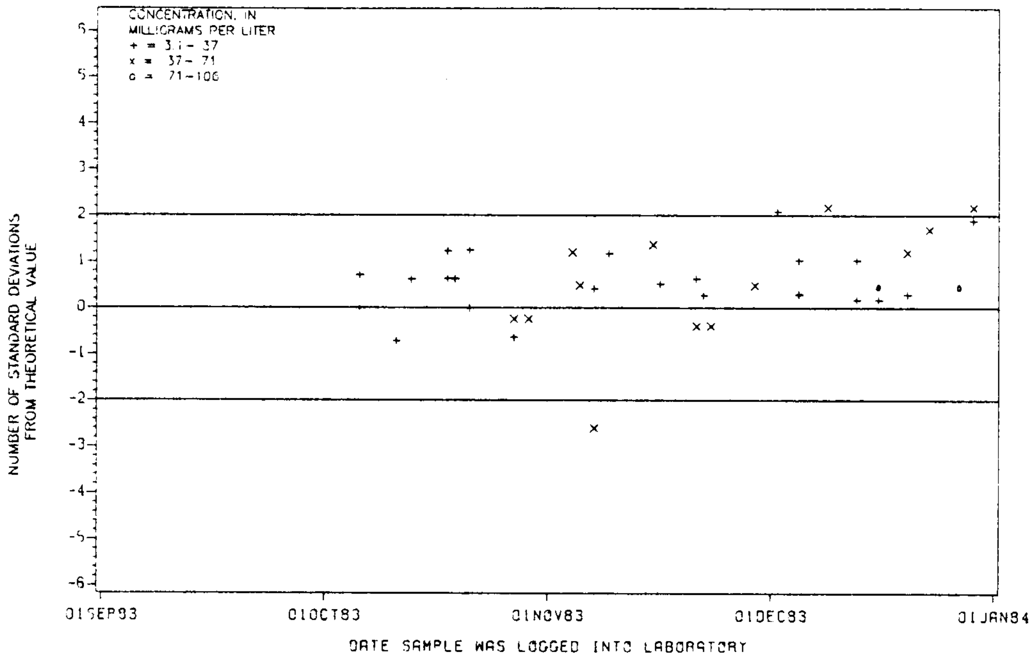

Figure A47.--Sodium(ICP) data from the Atlanta laboratory.

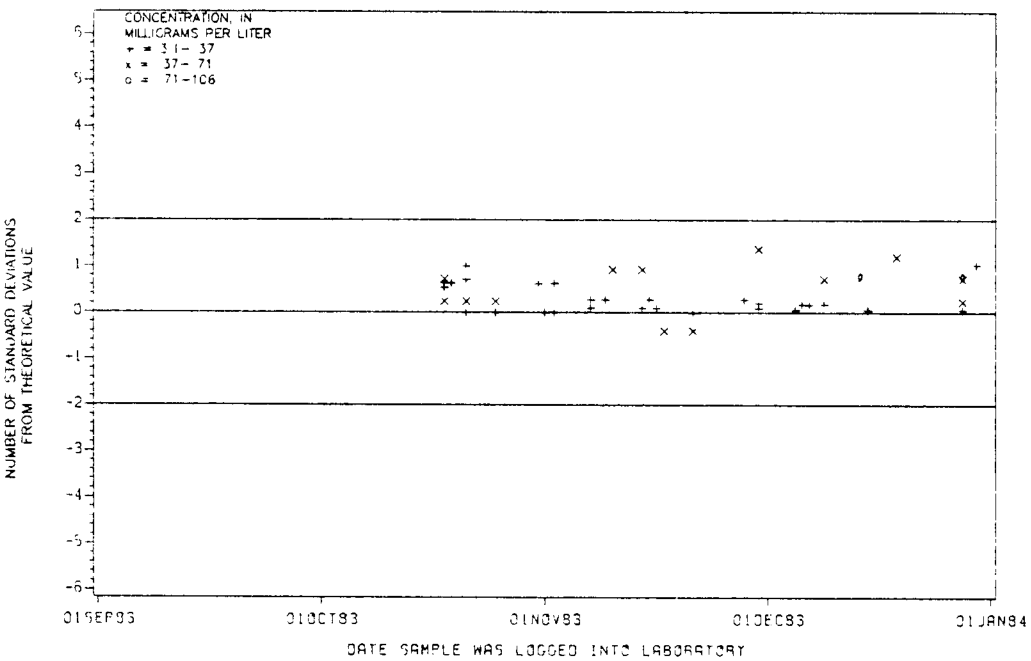

Figure D47.--Sodium(ICP) data from the Denver laboratory.

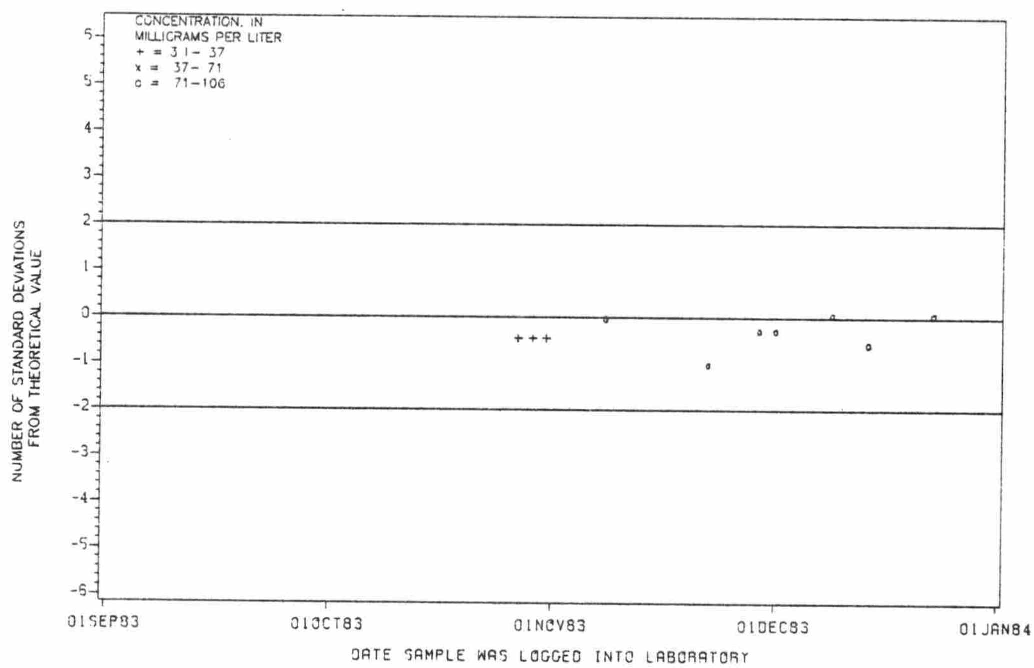

Figure A48.--Sodium(AA) data from the Atlanta laboratory.

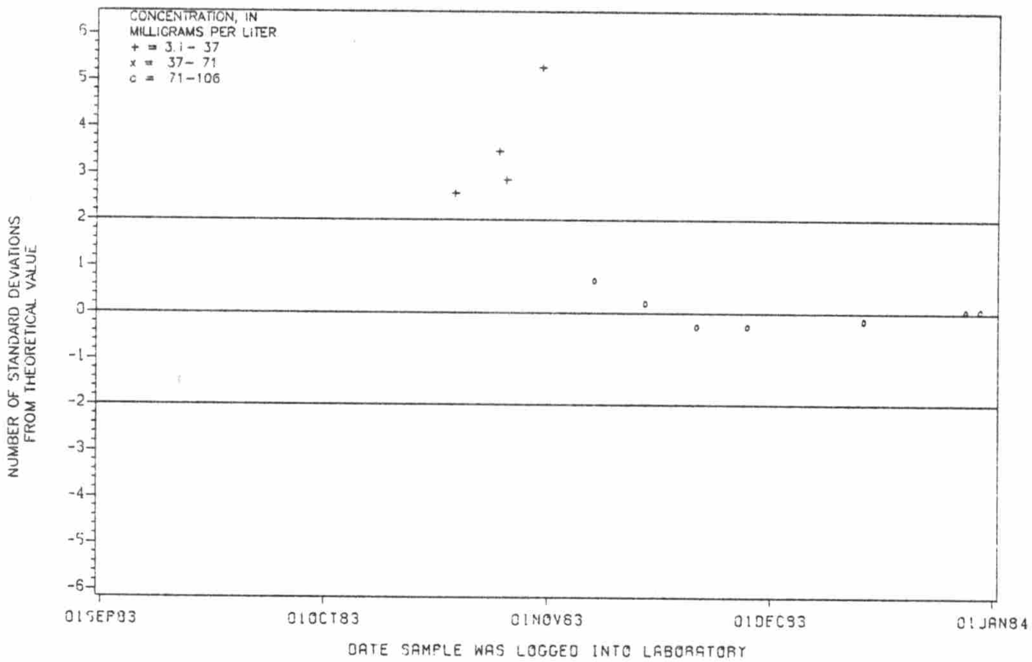

Figure D48.--Sodium(AA) data from the Denver laboratory.

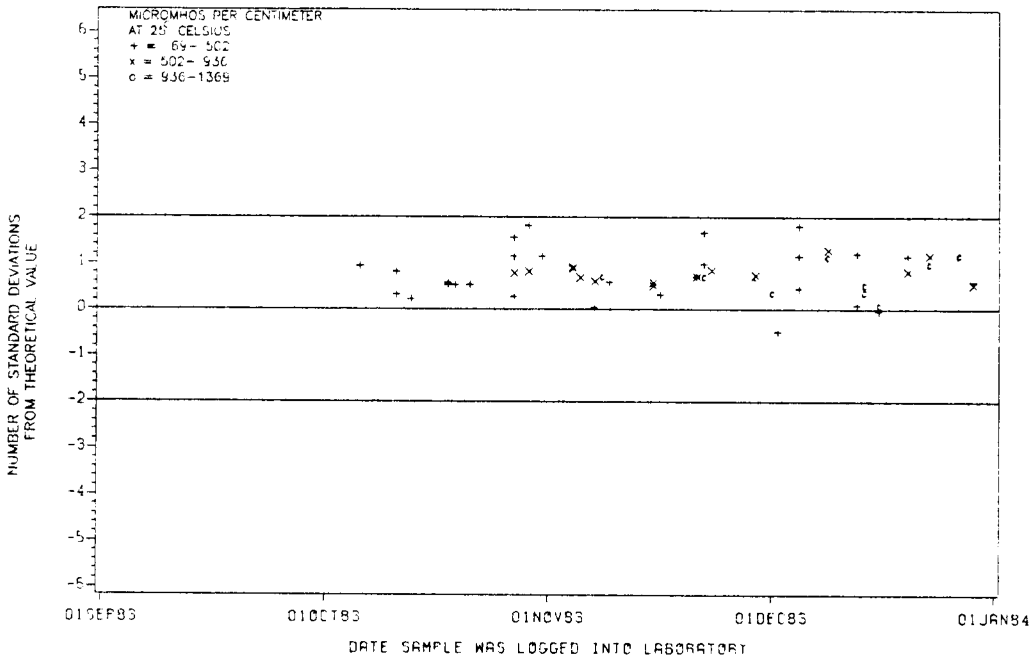

Figure A49.--Specific conductance, data from the Atlanta laboratory.

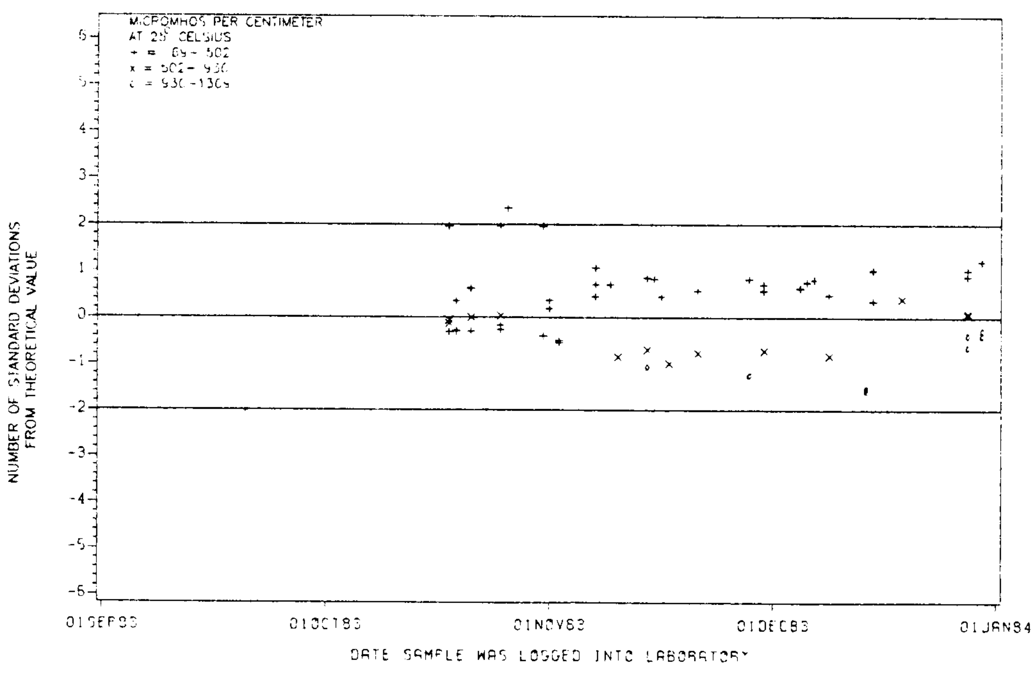

Figure D49.--Specific conductance, data from the Denver laboratory.

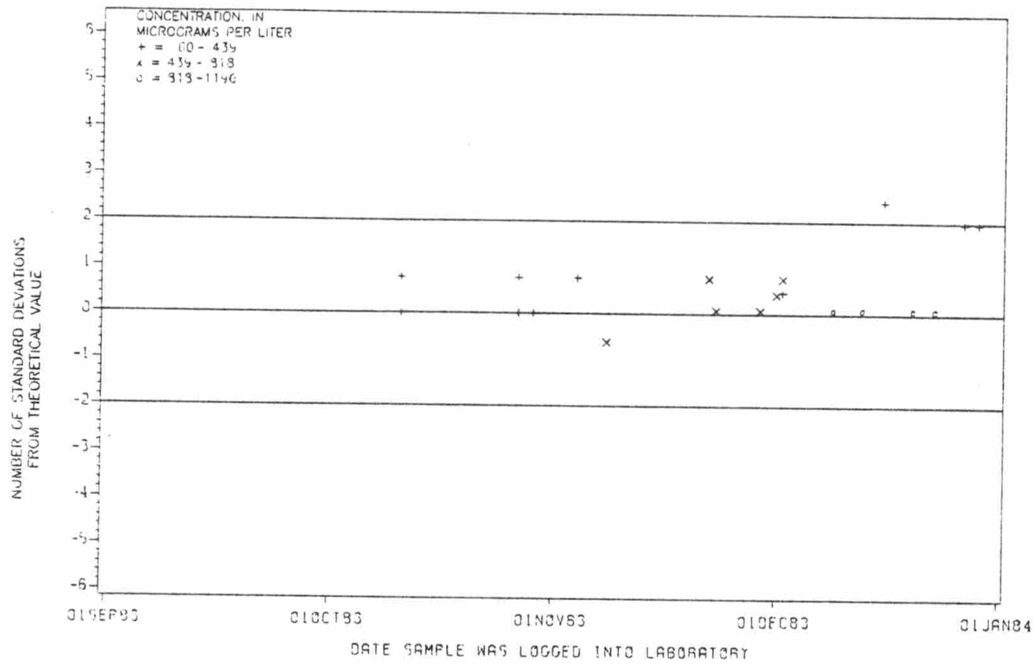

Figure A50.--Strontium data from the Atlanta laboratory.

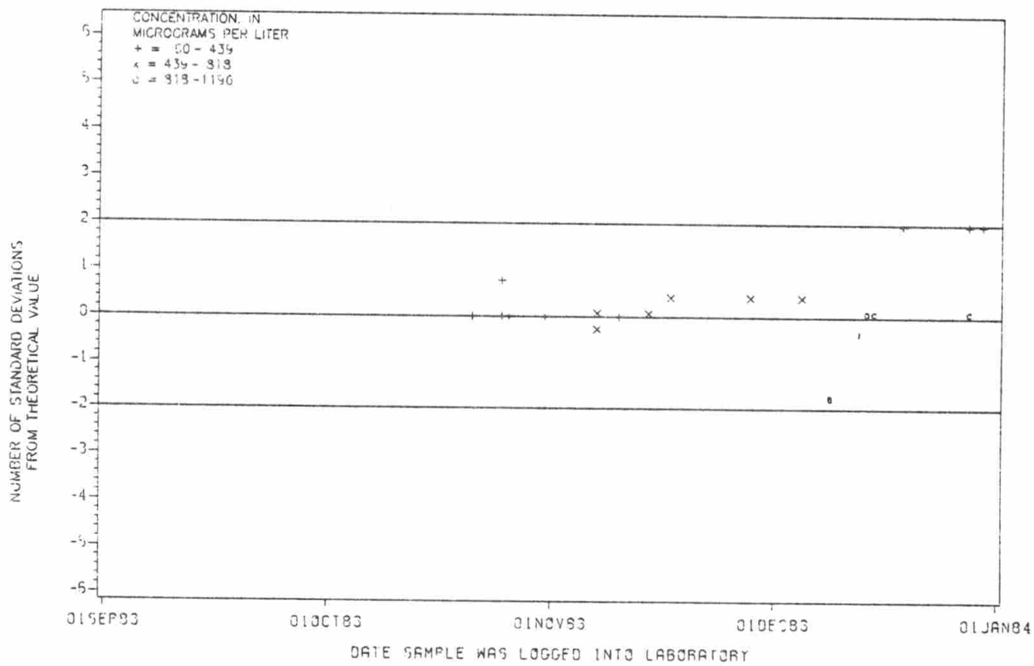

Figure D50.--Strontium data from the Denver laboratory.

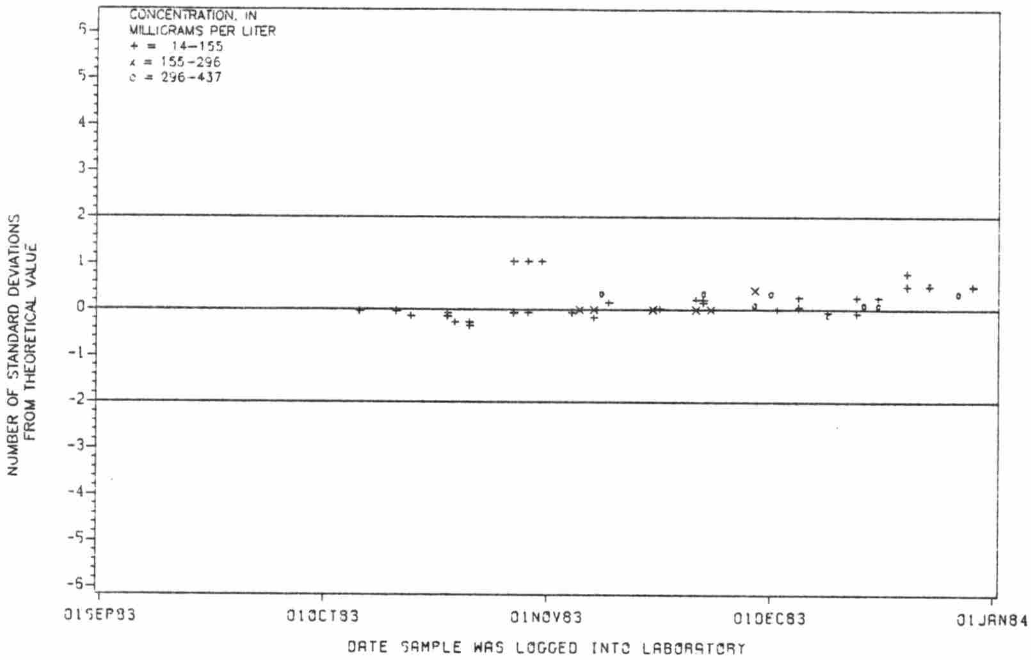

Figure A51.--Sulfate data from the Atlanta laboratory.

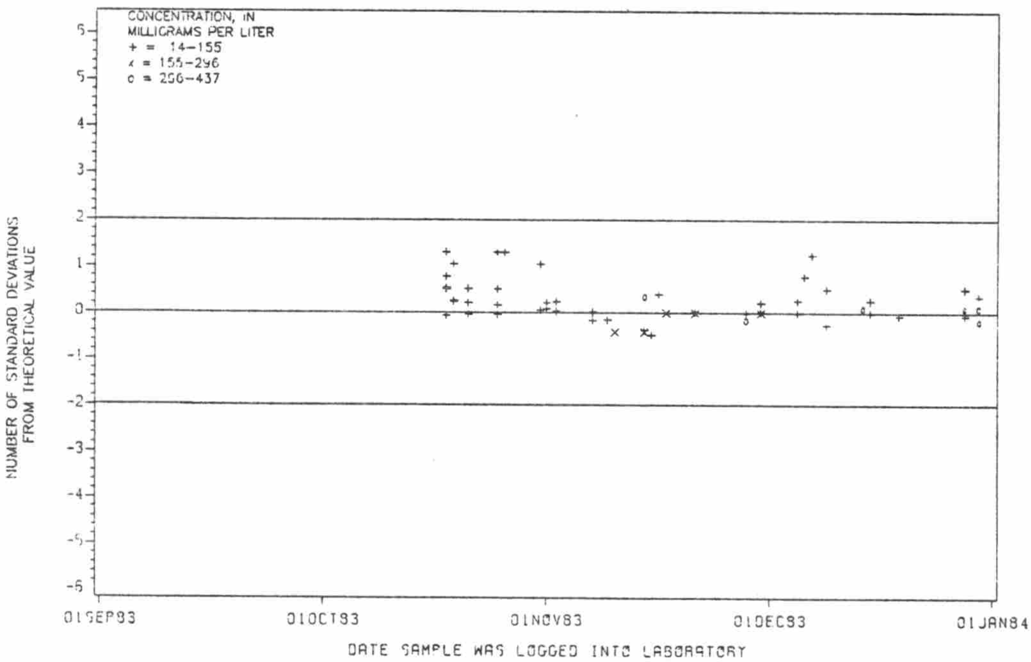

Figure D51.--Sulfate data from the Denver laboratory.

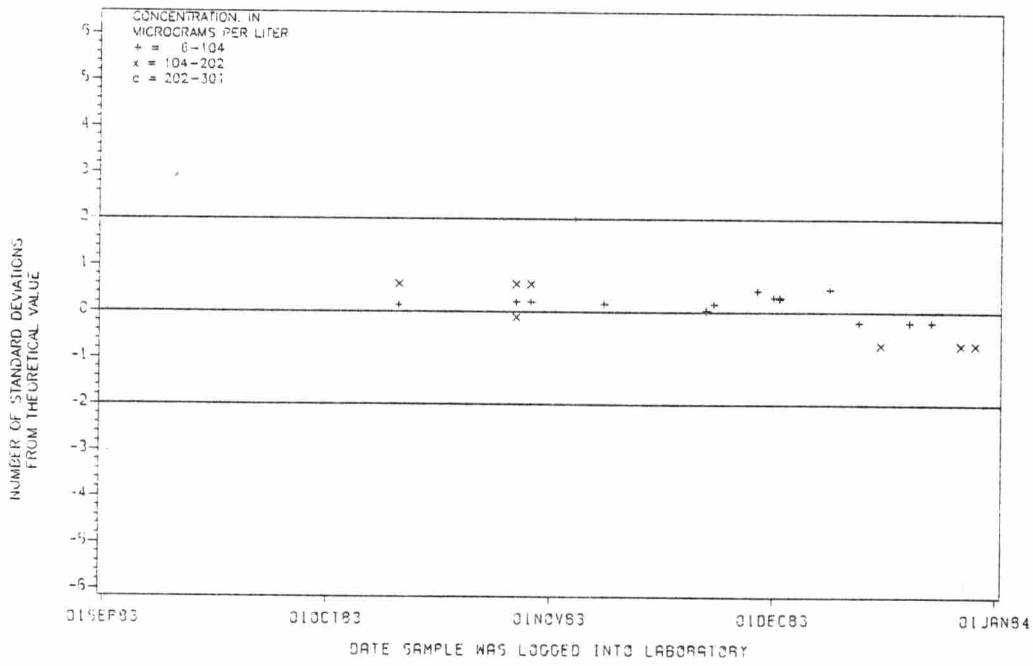

Figure A52.--Zinc(ICP) data from the Atlanta laboratory.

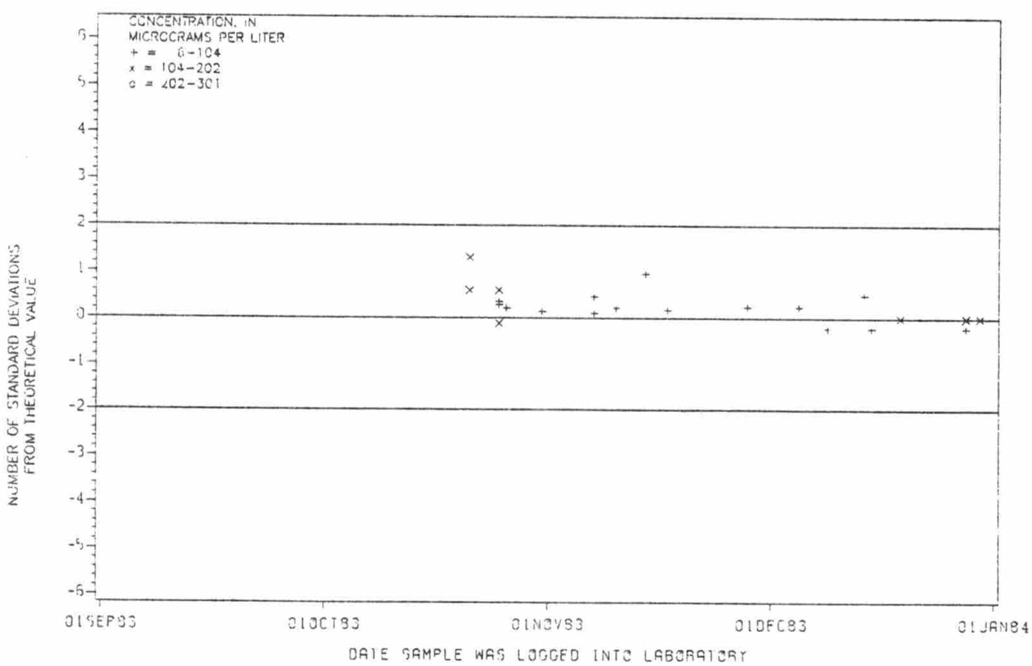

Figure D52.--Zinc(ICP) data from the Denver laboratory.

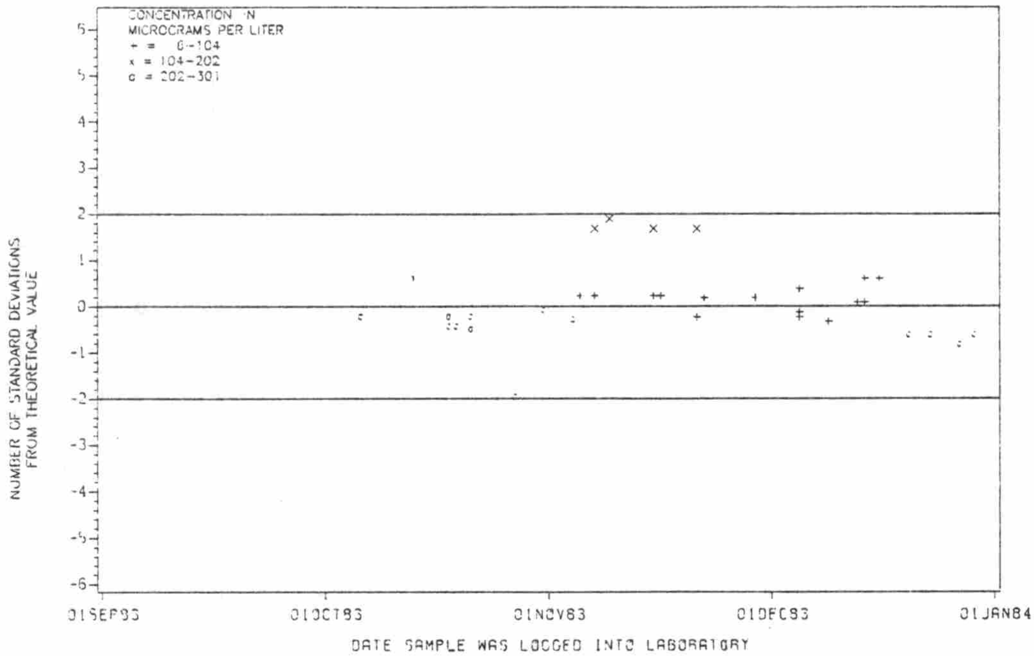

Figure A53.--Zinc(AA) data from the Atlanta laboratory.

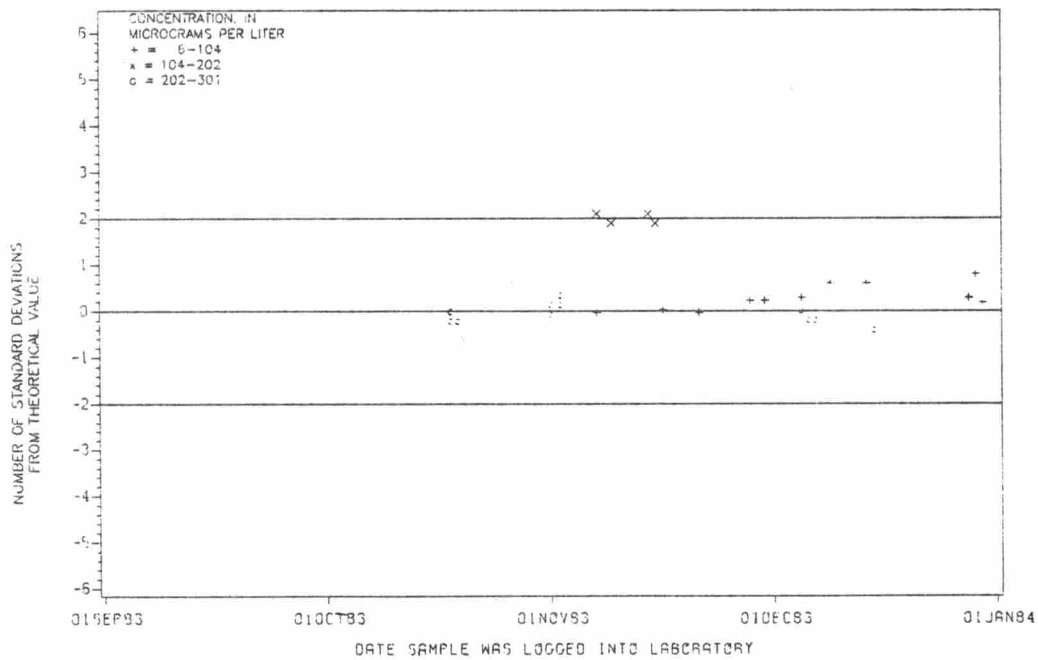

Figure D53.--Zinc(AA) data from the Denver laboratory.

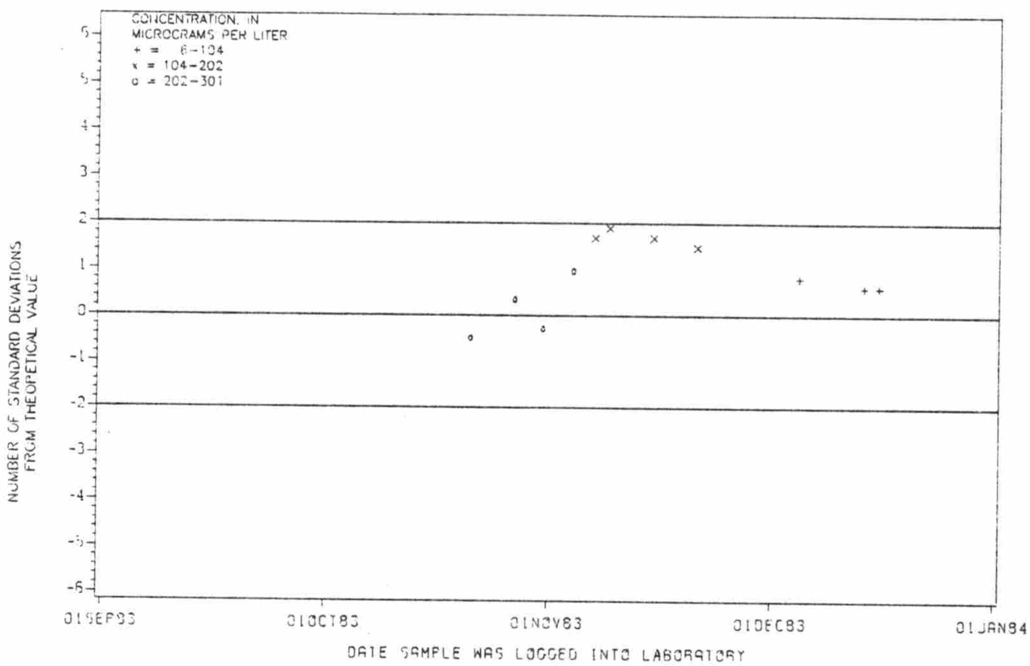

Figure A54.--Zinc, total recoverable data from the Atlanta laboratory.

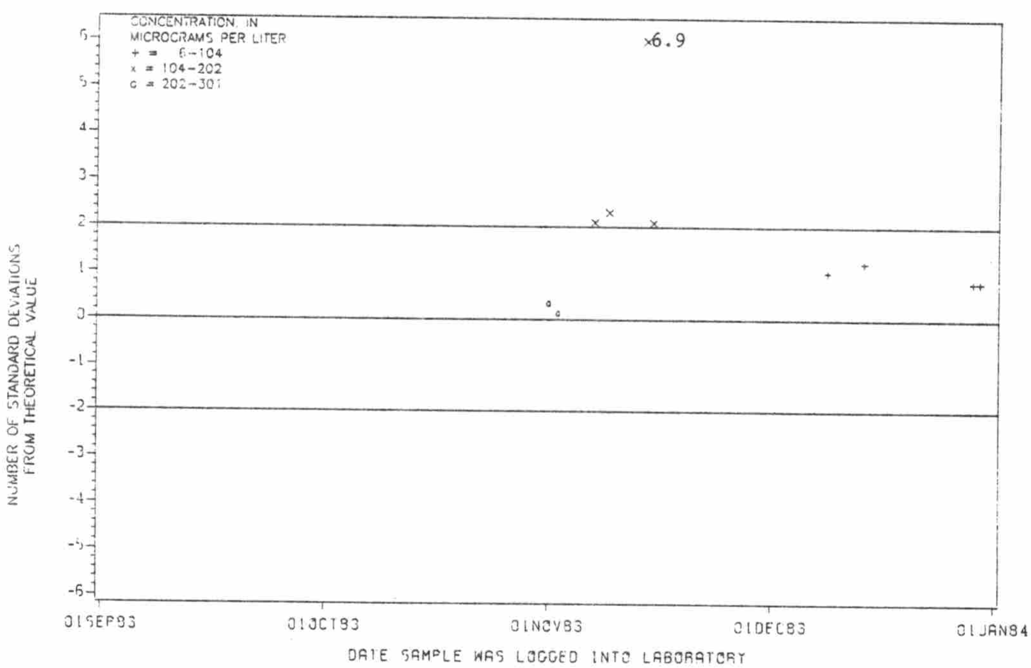

Figure D54.--Zinc total recoverable data from the Denver laboratory.