4.0 ONSITE TRITIUM IN AIR

Sixteen samplers for airborne tritiated water vapor were placed at locations on the Nevada Test Site (NTS). Attachment 4.1 displays the sampling locations, dates that sampling began and ended, observed concentrations in picocuries per milliliter (10^{-6} pCi/mL = pCi/m^3 = 10^{-12} µCi/mL), analytic standard deviation, and detection limits for the 385 analyses performed in 1996. (All tables, figures, and attachments are located at the end of this chapter in that order.) Samples were usually collected over two-week periods. The analytic standard deviations are in the same units of measurement as the concentration. The simple descriptive statistics for all the data combined and the detection limits (DL) are:

Number of data values	=	385 - including 20 missing values
Arithmetic mean	=	3.70 x 10^{-6} pCi/mL
Median	=	2.26 x 10^{-6} pCi/mL
Standard deviation	=	5.76 x 10^{-6} pCi/mL
Minimum value	=	-2.67 x 10^{-6} pCi/mL
Maximum value	=	64.70 x 10^{-6} pCi/mL
DL Mean ± s	=	1.70 ± 1.02 x 10^{-6} pCi/mL

Note that the standard deviation given above with the DL is the sample standard deviation of the DL values. The first quartile of the data is 0.74 x 10^{-6} pCi/mL and the third quartile is 4.55 x 10^{-6} pCi/mL. Half the data values are between these statistics. Forty-one percent of the data values are below the individual detection limits. Most of the above DL results are from the Radioactive waste Management Site (RWMS) stations, the U.S. Environmental Protection Agency (EPA) Farm, the SEDAN Crater, and E-Tunnel stations. These statistics are almost identical to those reported in the 1994 and 1995 annual reports.

Figure 4.1 shows the locations of the tritium in air sampling stations as black squares on a map of the NTS. The unnamed stations are currently inactive. In this figure, the major roads are indicated by the wavy dotted lines. The nine RWMS stations are indicated by the larger square in Area 5. These stations are numbered counter-clockwise from the lower right corner with three stations to a side. In October of 1996, the four stations in the middle of each side of the RWMS were shut down, leaving only the stations on the corners of the RWMS. The reason for this reduction in the RWMS monitoring effort was to reduce cost, since no statistical differences among the several stations had been observed for several years. (The stations that were shut down are RWMS Nos. 3, 5, 7 and 9.) The Health and Safety Building (H&S Building) in Area 23 is also called Building 650. The term "Mud Plant" refers to a concrete mixing batch plant.

Note that there is no tritium in air sampling in most of the test site areas. Sampling locations are chosen where tritium may be detected. The RWMS is storage for tritiated waste. Area 23 has laboratories that analyze samples for tritium. The EPA Farm is close to the SEDAN crater, which is a known source of low levels of tritium. Area 12 Camp is close to several tunnel portals which have, in past years, discharged some tritiated water. BJY is a location within Yucca Valley, where many underground tests were conducted. Location U-3ah/at north was added in June of 1996; it is located at a waste management site entrance.

Figures 4.2 through 4.17 are time series plots of the data in Attachment 4.1. There is one figure for each sampling location. The data values are represented by an "o", the solid line shows the detection limit, and the dotted lines give the approximate upper and lower 95 percent confidence intervals for the data (calculated as the data value plus or minus twice the analytical standard deviation). The abscissa gives the time that sampling started. Note that the values for the ordinate range from 0 to 100 for two of the sampling stations, 0 to 30 for five sampling stations, and the remaining plots have a range of 0 to 10. Figure 4.18 shows all the data combined in one plot; this plot does not contain any confidence intervals or detection limits. The highest value in all plots is 64.7 x 10^{-12} µCi/mL at RWMS No. 5 for the collection date beginning March 25, 1996. This value is considered an outlier since it obviously is not consistent with the pattern established by the remaining data points; however, no errors in sampling and analysis were found for this datum. These plots seem to show occasional values that are higher than most values. The high values seem to occur in the late summer and occur at some of the RWMS stations, the SEDAN Crater, and the E-Tunnel pond. These are locations with known inventories of tritium. This pattern has consistently occurred for many years. Research work has been proposed to determine if the late summer increases are due to plant transpiration of groundwater contaminated with tritium. Near surface soil samples also have tritium at a level about an order of magnitude less than the plants and could contribute to tritium in air by evaporation. The spatial distribution of tritium in soil around plants is unknown. During the early summer, there is adequate surface water for the vegetation, but by late summer the surface soil dries out and plants then seek moisture deeper in the soil. Examination of the time series figures shows that the stations seem to fall into two groups: (1) those stations with all values close to zero and most values below the corresponding detection limit; and (2) those locations with known contamination, the RWMS stations, the EPA Farm, the SEDAN Crater, and the E Tunnel Containment Pond.

DATA ANALYSIS

The exploratory statistical analysis of these data for statistical distribution characteristics, illustrated in Figures 4.19 and 4.20, indicates that the data are lognormally distributed and a logarithmic transformation will cause those few high values seen in Figure 4.19 to appear less remarkable. Figure 4.19 shows a curvature increasing towards the right, which suggests that the logarithm of the data should be used. The correlation test indicates that these data are not distributed normally, which is the expected result because of the clearly defined curvature of the data shown in the figure. The same procedure was repeated using the natural logarithms of the data and the resulting plot is shown in Figure 4.20. This figure now shows the data approximately falling on a straight line, except for the two lower values that are very close to zero. Since statistical tests are dependent on the data distribution, the natural logarithms of the data values were used for all of the following statistical testing. Note that there are 34 fewer data values in Figure 4.19 than in Figure 4.20; this is because the logarithmic transformation changes all negative values to missing values.

The correlation coefficient test for goodness of fit does not indicate a fit to a normal distribution for the logarithms of the data in Figure 4.20. However, if the two lowest data points are deleted, the data does approximately fit a lognormal distribution. Since the low deleted data values are well below the detection limit, they cannot be assumed to be from the same distribution as the data above the detection limit. They are positive values that are very close to zero. Thus, the conclusion of these tests is that this data set has a lognormal data distribution, except for a few values at the extreme low end of the range of values. The lognormal distribution was also found to be appropriate in last years' annual report. There are 16 sampling stations in this years' report; there were 21 in last years’ report.

The distinctly high values, indicated graphically for some of the RWMS sampling locations, are not remarkable when working with logarithms of the data and thus do not seem to be high outliers. However, the highest value, discussed above from RWMS No. 5, was deleted from the data before any of the following statistics were done. Simple descriptive statistics can be used to summarize the data for each sampling station. Table 4.1 gives these statistics. The reason the overall mean in this table is not the same as the mean given on the first page of this chapter is that for Table 4.1 the highest value from RWMS No. 5 was deleted. The first and third quartiles of the data are defined so that one quarter of the data have values lower than the first quartile, and one quarter of the data have values higher than the third quartile. Note that the medians are smaller than the means, and the medians are closer to the first quartile than to the third quartile. This is typical of lognormally distributed data. A comparison of Table 4.1 with the corresponding table in the 1995 Annual Site Environmental Report shows that concentrations were about the same for these two years.

An examination of Figures 4.2 to 4.18 indicates no reason to suspect any time trends within the tritium data other than that described above, that is, the trend possibly due to tritium transpiration and evaporation in the late summer. No formal statistical test for trend was performed. The significance of this possible trend awaits the testing of the transpiration and evaporation hypothesis. The final statistical test on these data was a one-way analysis of variance (ANOVA) to test for differences between location. The data were logarithmically transformed, using natural logarithms, before this test. Also, the negative values were removed by the transformation to logarithms. The output of this procedure is given in Tables 4.2 and 4.3. In Table 4.2, the "p" value gives the probability associated with the F-statistic and is the probability that there are no significant differences among the station means. Since the "p" value is essentially zero, the statistical conclusion is that there are statistically significant differences between the station medians. Note that the mean values and confidence intervals are of the natural logarithms of the data, thus an exponential transformation gives an estimate of the data median and the confidence interval of the median.

The medians in the ANOVA in Table 4.3, do not equal the corresponding medians in Table 4.1 for two reasons. First, the medians in Table 4.1 were derived from all the data while the medians reported in the ANOVA are computed from only the data values above zero. This truncation of the data is necessary because logarithms of negative numbers are imaginary numbers and cannot be used in the ANOVA. Second, the medians are estimated in Table 4.3 from the mean of the logarithms of the data. Statistically, if the data is lognormally distributed, the anti-logarithm of the mean of the logarithms of the data is an estimator of the median of the data. The ANOVA table shows strong evidence of differences between group medians, and the plot of confidence intervals suggests how the medians are grouped.

The ANOVA "groupings" denotes the median data values that are statistically similar; any geographical meaning to these groupings is secondary and interpretive. Tukey's multiple comparison procedure was used to simultaneously compare all medians for equality. This process identified two groupings in Table 4.3. The high grouping in Table 4.3 contains those locations known to be near sources of tritium: the RWMS locations, the SEDAN Crater, the EPA Farm, and the E Tunnel Pond. The remaining stations make up the low grouping.

HISTORICAL TRENDS

Annual averages are available for 12 of the tritium in air stations starting with 1982. Table 4.4 gives the data, and Figures 4.21 and 4.22 are plots of some of the data in this table. The laboratories, which were left out of the combined annual averages, are the Health and Safety Building, which is also known as Building 650, and Building 790. The high data values for these buildings from 1982 through 1987 are not indicative of environmental conditions, but rather reflect analytical activities of the laboratories. In Building 650, during those earlier years, many distillations of tritium and plutonium in water were performed. Building 790 was used as a soils laboratory. After 1987, the number of waste shipments into the RWMS significantly decreased, and this is evident in the magnitude of the tritium concentrations measured at these locations. In recent years, the laboratories show tritium levels that are not significantly different from the other sampling locations in Table 4.4. However, for consistency with earlier data, we continue to exclude the laboratories from the overall average. The somewhat high average for the RWMS in 1987 is due to the obviously high annual average for RWMS No. 4 in that year. No reason is known for this reading and it is possibly in error. The two negative values reported in 1988 are probably in error and these two values were not used to compute the two annual averages reported in Table 4.4.

Figure 4.21 is a plot of the RWMS annual averages. It shows an obvious decrease in concentrations over the years with a rapid decline in the earlier years of the plot and a gradual decline in more recent years. The shape of this curve is typical of the exponential decay curve. The break in the pattern of exponential decreases is obvious for 1987; this was discussed in the previous paragraph. The rapid decrease in concentrations in the early 1980's is probably due to a decrease in all radiological activity over the entire NTS due to a decrease in testing and better confinement of the underground tests that were performed.

Figure 4.22 shows the annual tritium in air concentrations averaged over the entire NTS for the past 15 years, excluding the data from the laboratory buildings for the reasons discussed above, and including the RWMS stations. The discussion of the pattern above for Figure 4.21 also describes the pattern in Figure 4.22. Thus, the pattern seen at the RWMS is not distinct from the pattern seen for the entire NTS. However, the levels at the RWMS have generally been higher than the average of the other stations since 1989. The slight increase seen in Figure 4.22 for 1987, could show a contribution through world-wide fallout from the Chernoble accident which occurred in mid 1986.

CONCLUSIONS

The typical tritium in air pattern seen in the environmental sampling locations is that almost all concentrations are below the individual detection limits. Concentrations substantially higher than detection limits are observed only at the RWMS locations, the EPA Farm, the SEDAN Crater, and the E Tunnel Containment Pond. Tritium was used as a biological tracer at the EPA Farm and the SEDAN Crater is an open crater produced by a nuclear device. The E Tunnel pond received drainage water from the tunnel when it was used for device testing; the tunnel is now closed but water continues to drain from it. The RWMS locations show a distinct pattern of near detection limit tritium concentrations in the cool months of the year, then increased levels during the late summer months. It has been hypothesized that this pattern is due to plant transpiration and soil evaporation of tritiated water from the deeper levels of soil within the RWMS after water in surface soils is depleted by summer heat.

Several general conclusions can be drawn from the historical annual average tritium in air data for the 15 stations of the NTS used for Table 4.4. All stations show the same general trend; thus that trend should be representative of the entire site. In the early 1980's, concentrations decreased rapidly; this decrease corresponds to a time of decreasing test activity. Current concentrations are typically very low and are within the statistical confidence interval of the detection limit. These levels are substantially below levels of regulatory concern and thus are not a consideration for workers at the NTS.

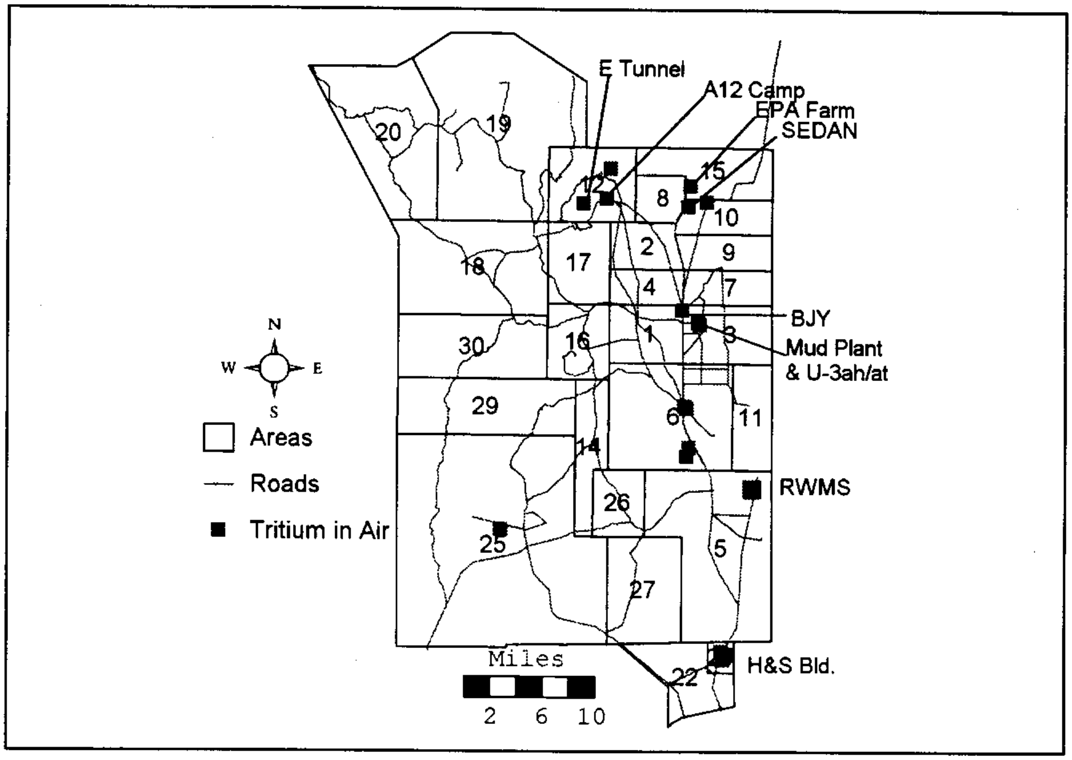

Figure 4.1 Tritium in Air Sampling Stations

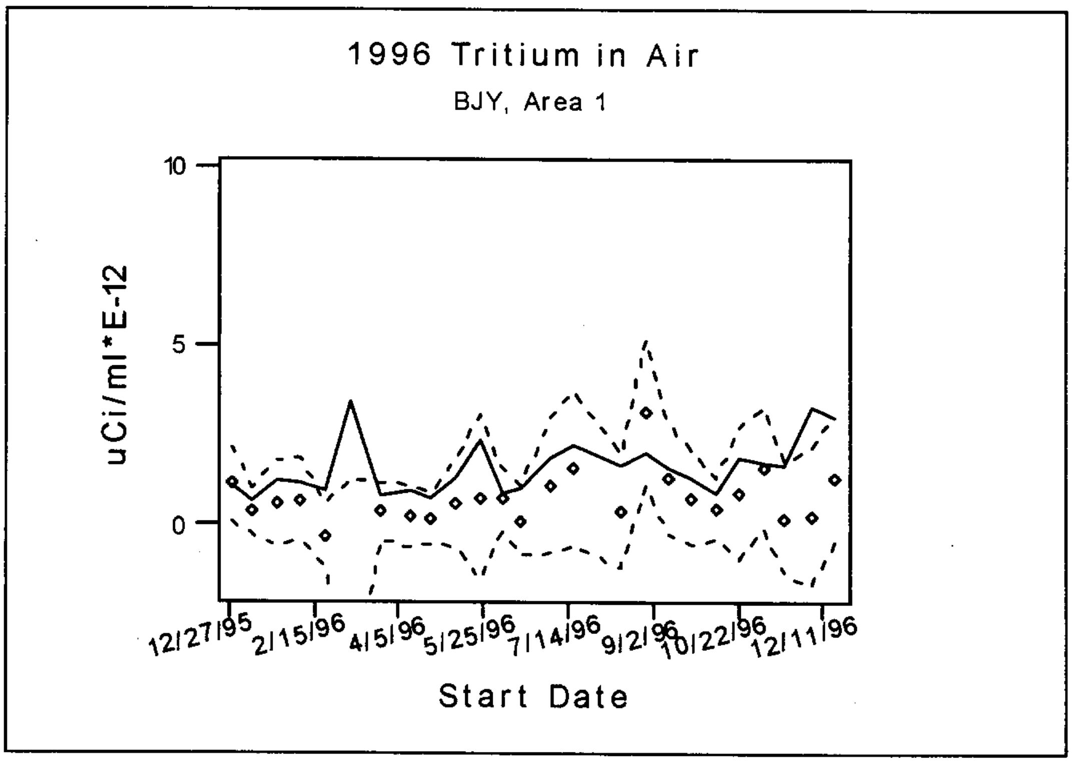

Figure 4.2 Time Series Plot for BJY

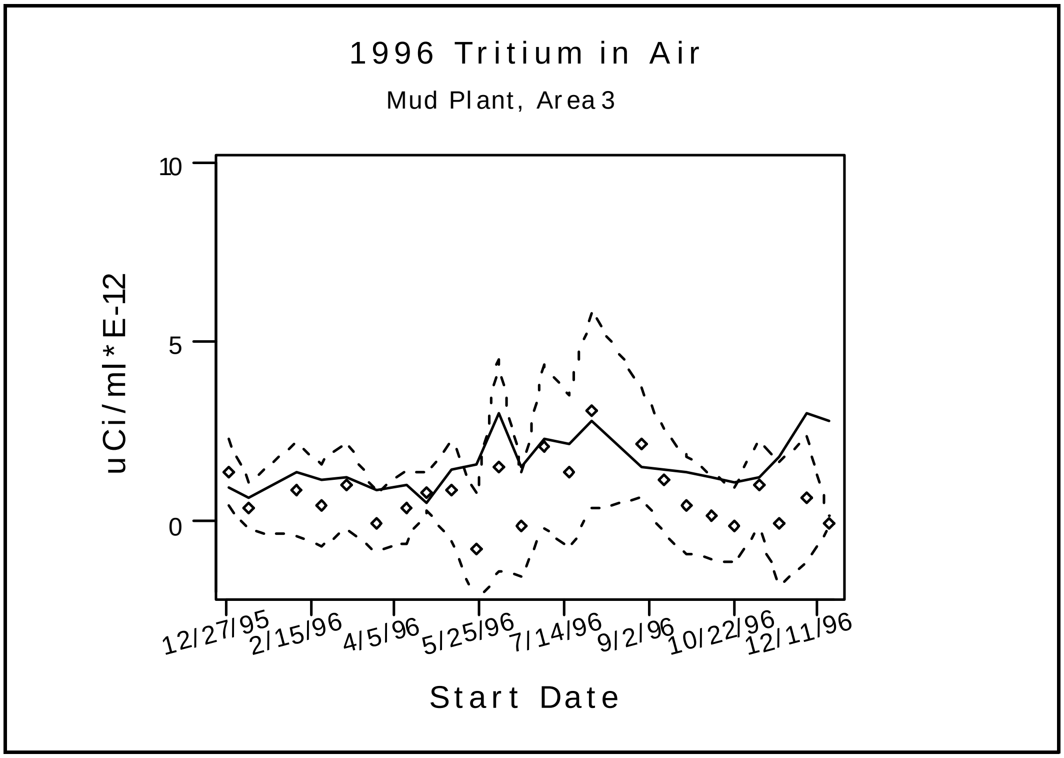

Figure 4.3 Time Series Plot for Area 3 Mud Plant

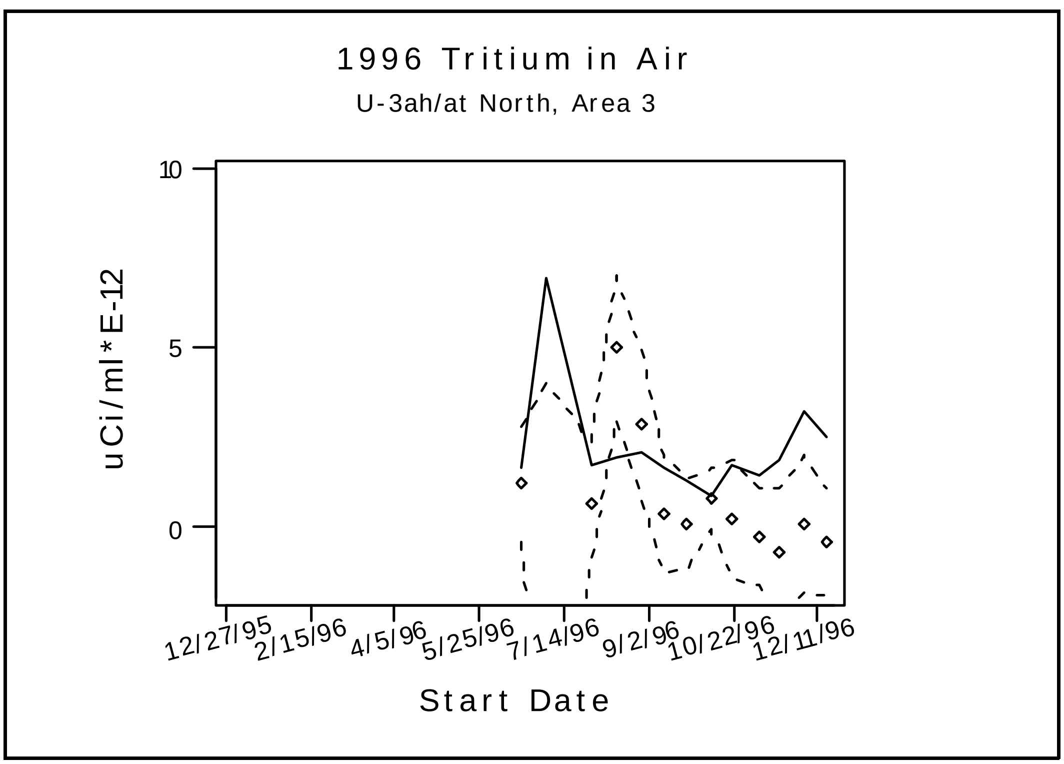

Figure 4.4 Time Series Plot for U-3ah/at North

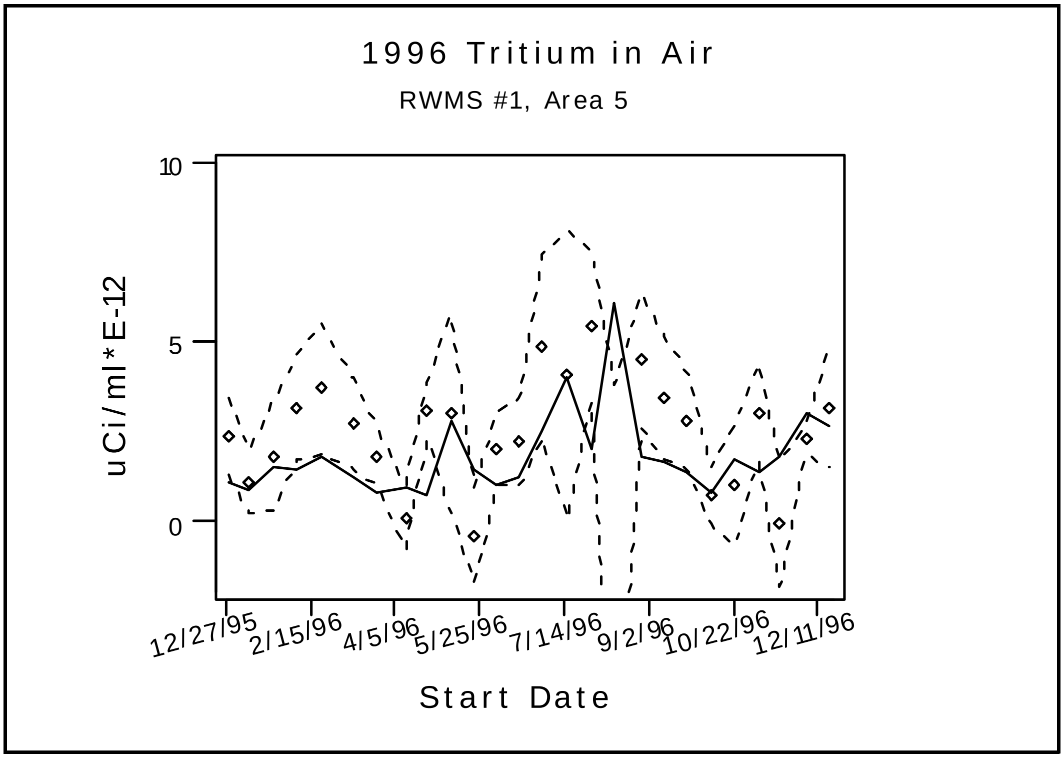

Figure 4.5 Time Series Plot for RWMS No. 1

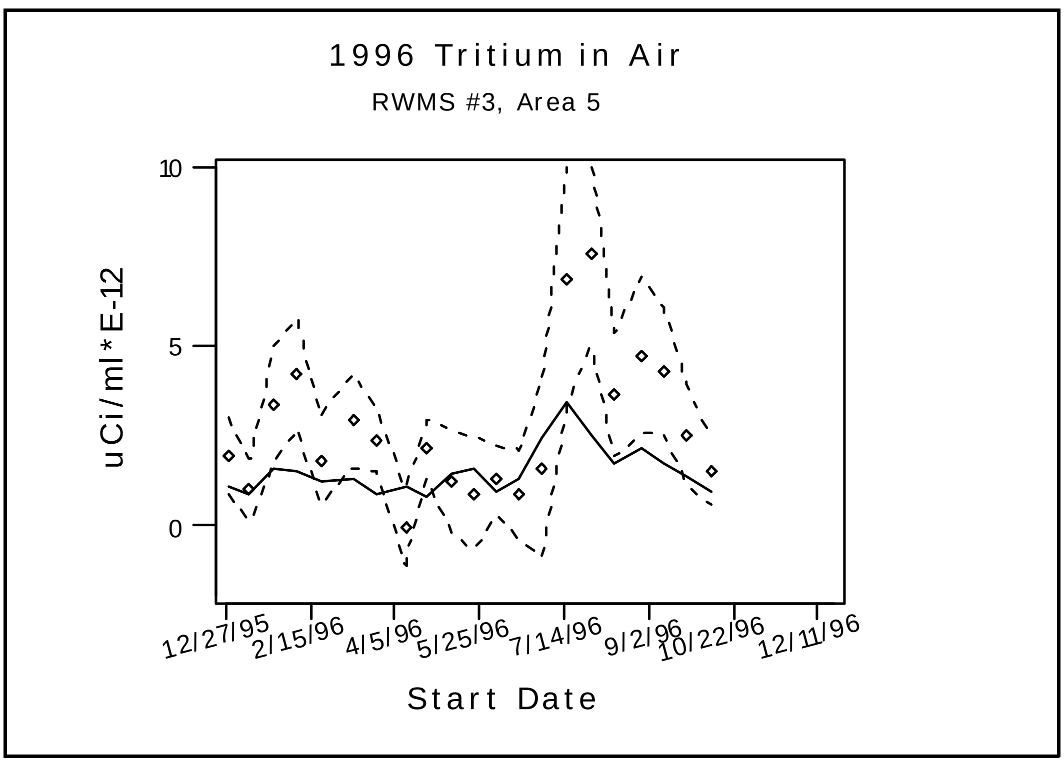

Figure 4.6 Time Series Plot for RWMS No. 3

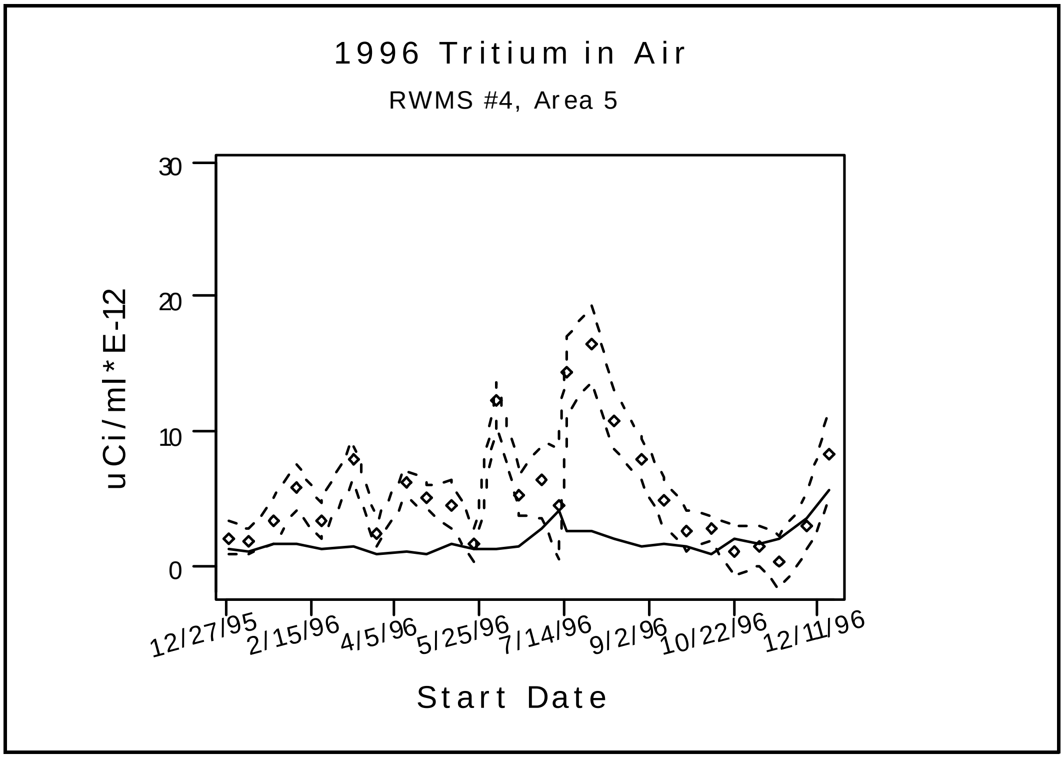

Figure 4.7 Time Series Plot for RWMS No. 4

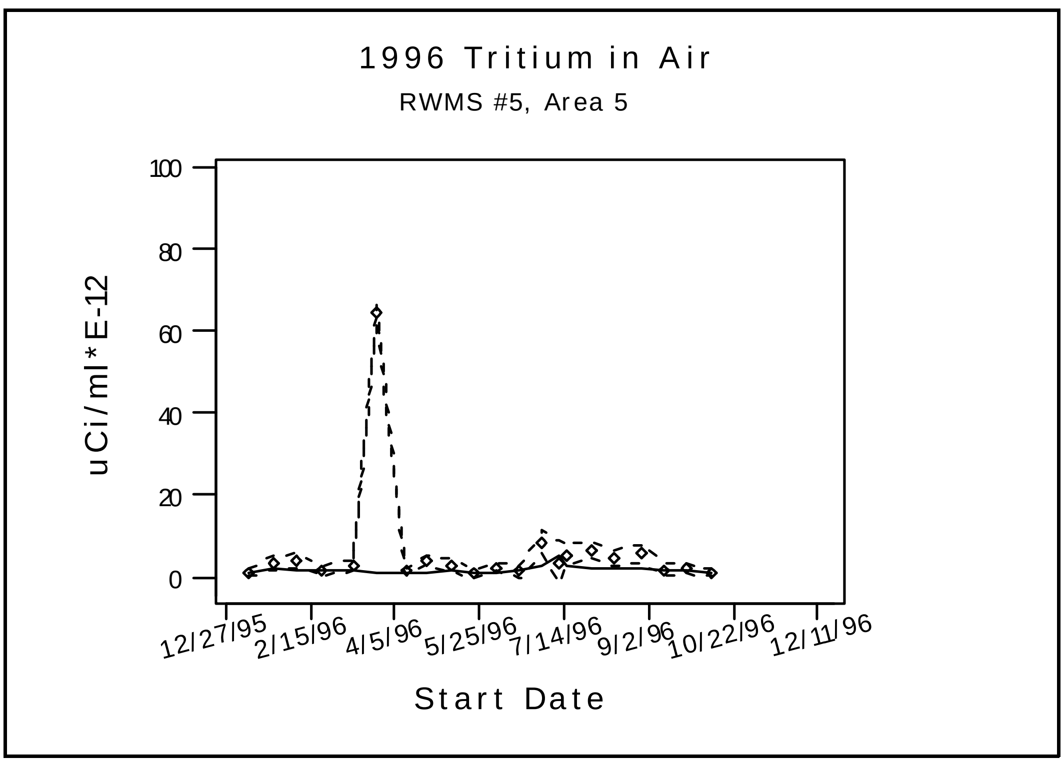

Figure 4.8 Time Series Plot for RWMS No. 5

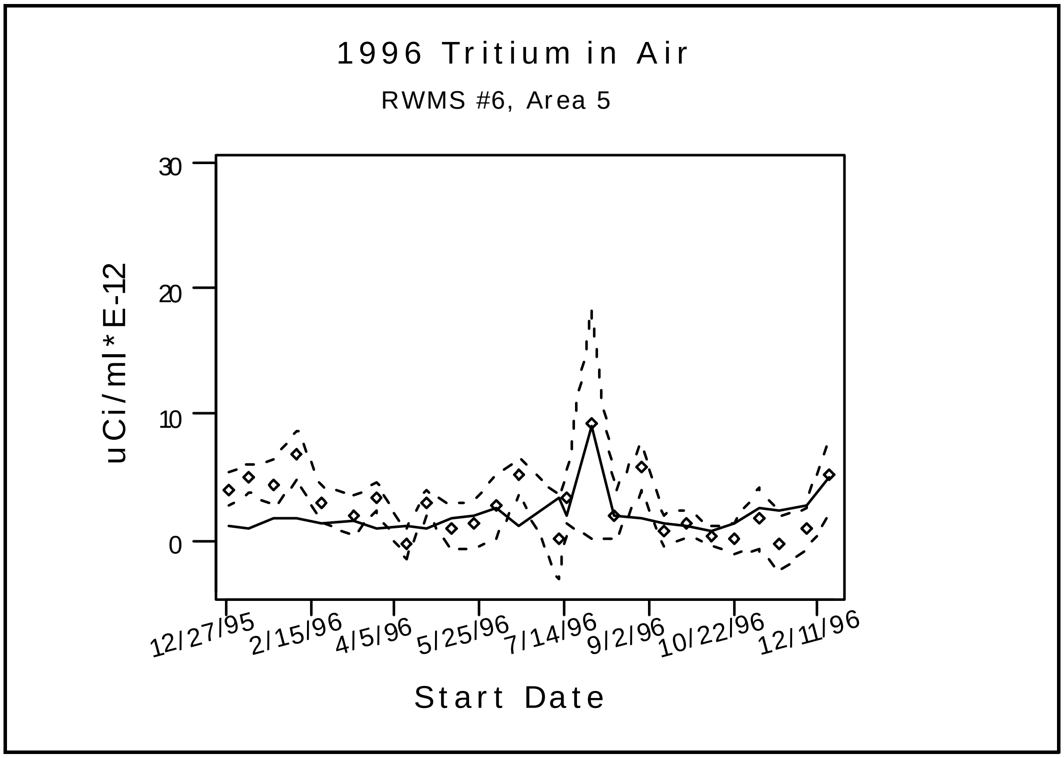

Figure 4.9 Time Series Plot for RWMS No. 6

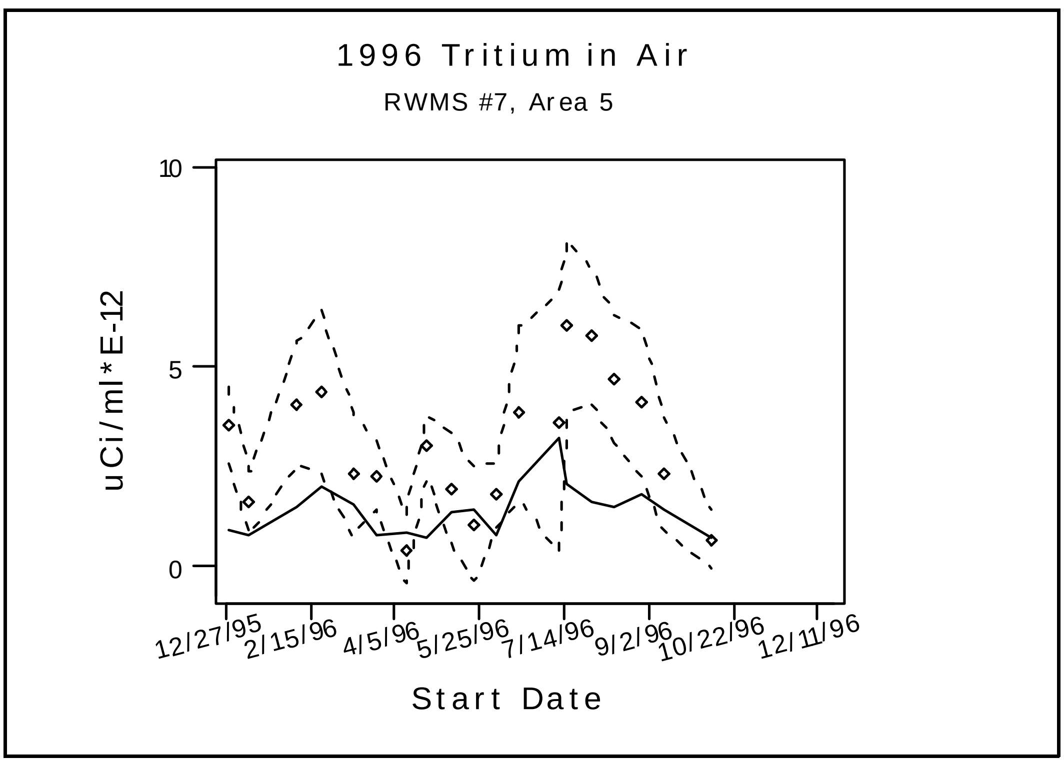

Figure 4.10 Time Series Plot for RWMS No. 7

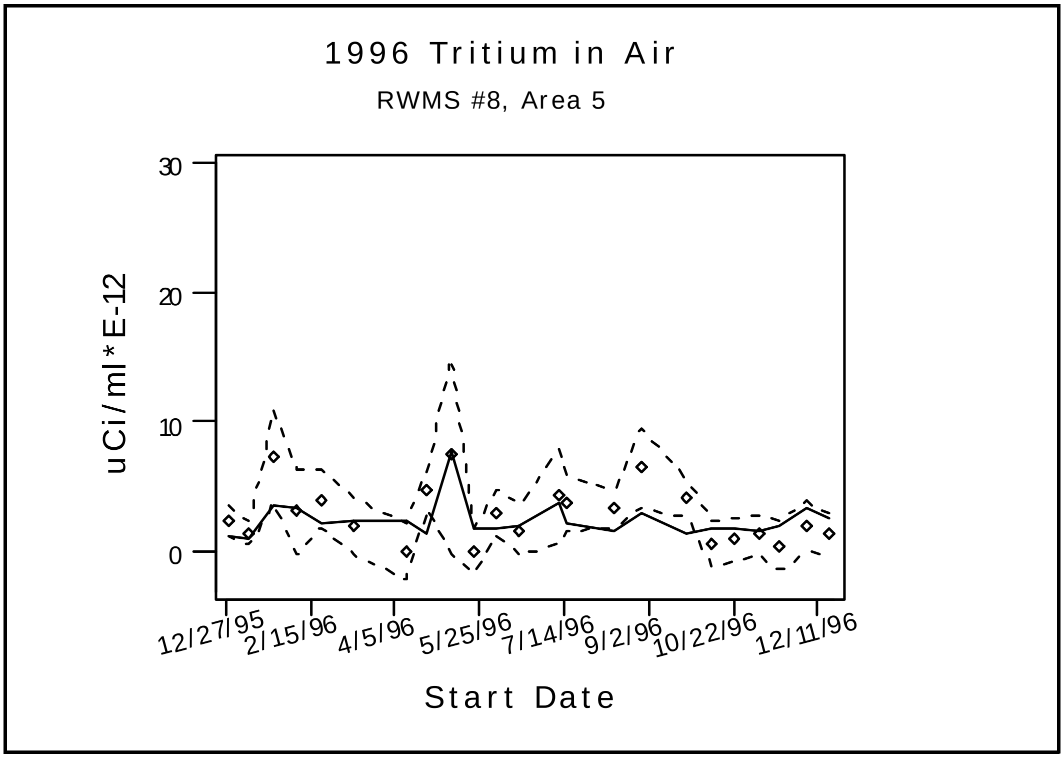

Figure 4.11 Time Series Plot for RWMS No. 8

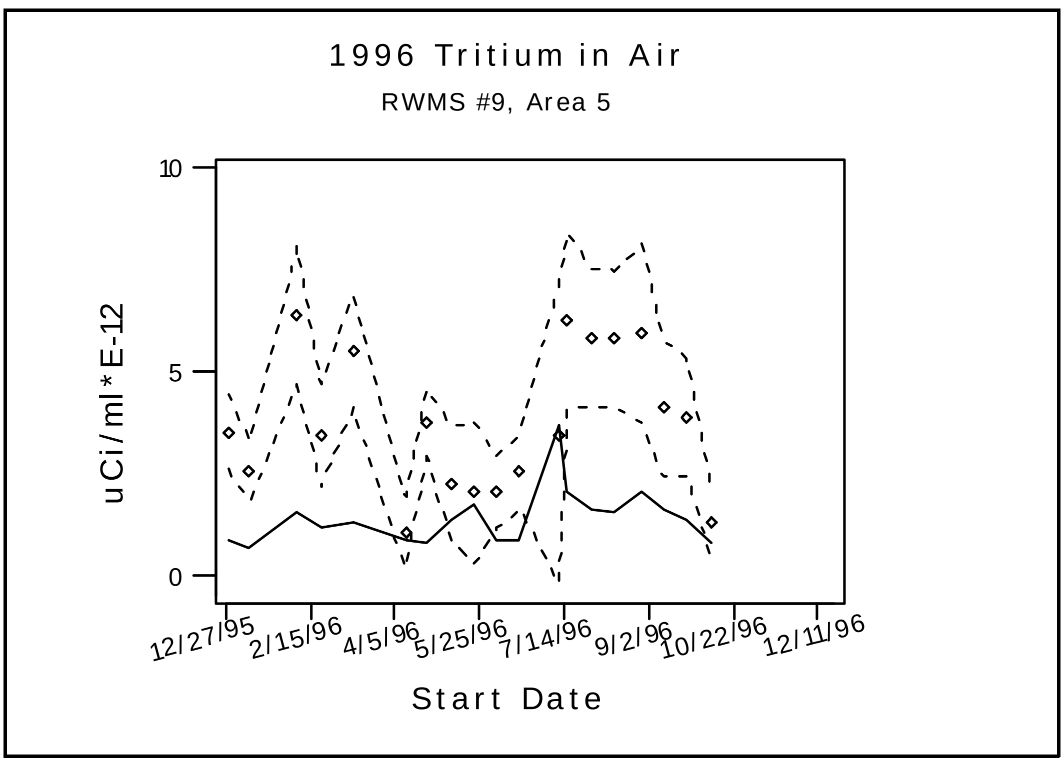

Figure 4.12 Time Series Plot for RWMS No. 9

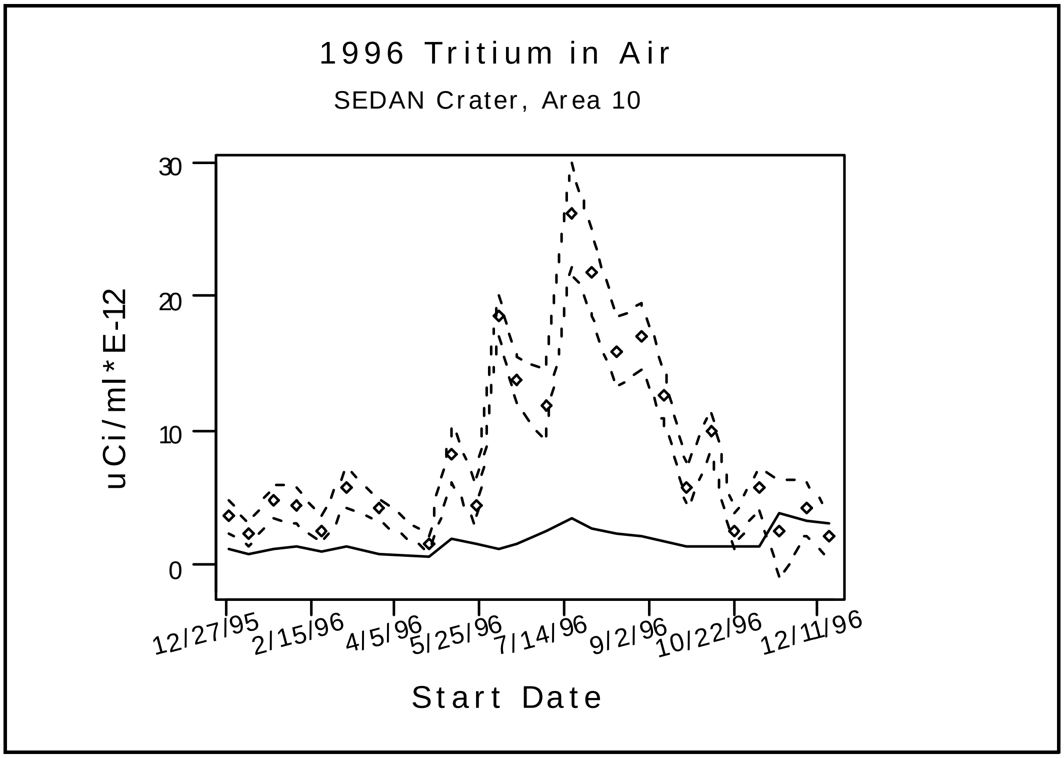

Figure 4.13 Time Series Plot for SEDAN Crater

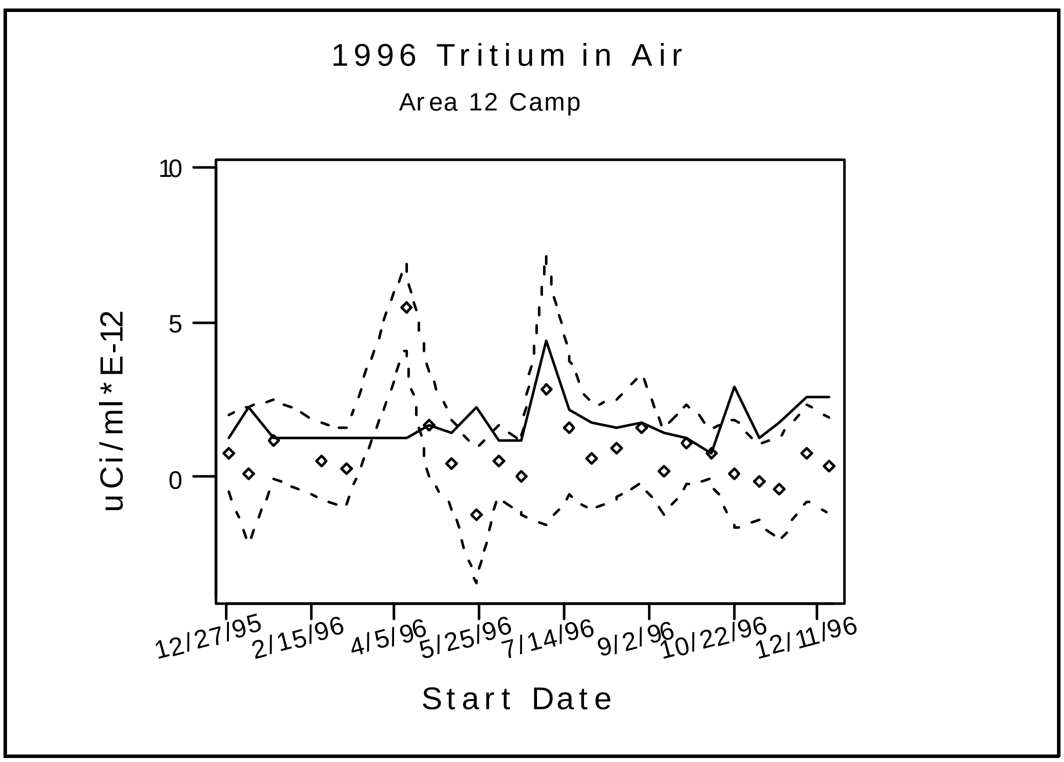

Figure 4.14 Time Series Plot for Area 12 Camp

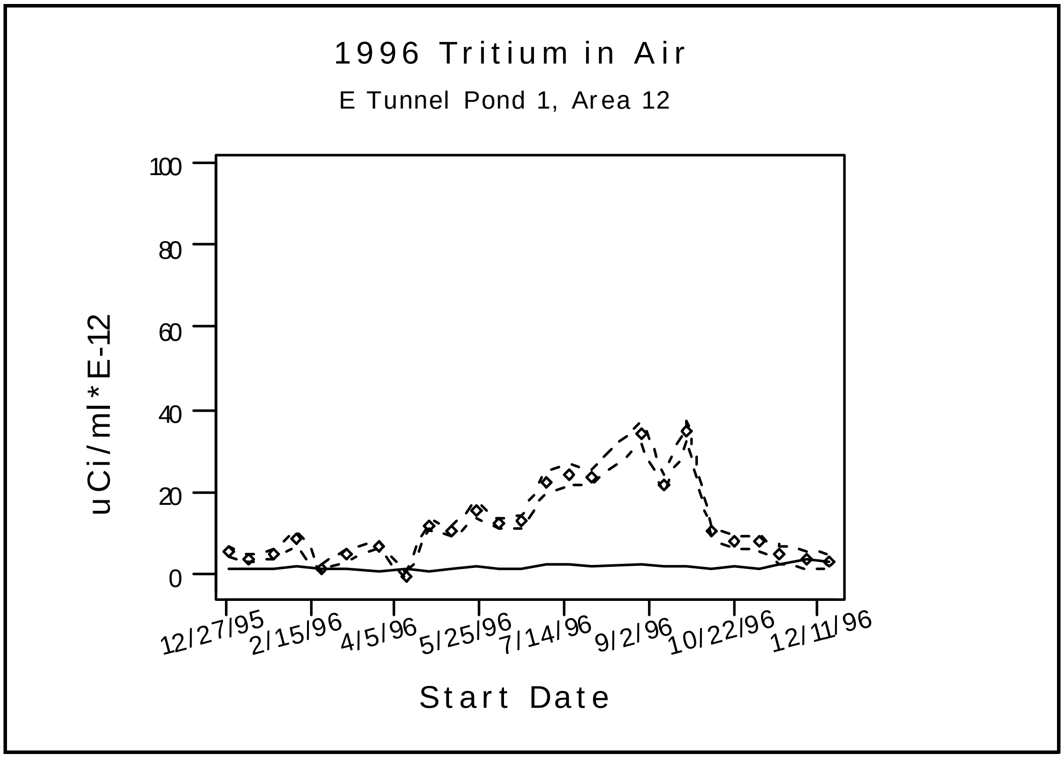

Figure 4.15 Time Series Plot for E Tunnel Pond No. 1

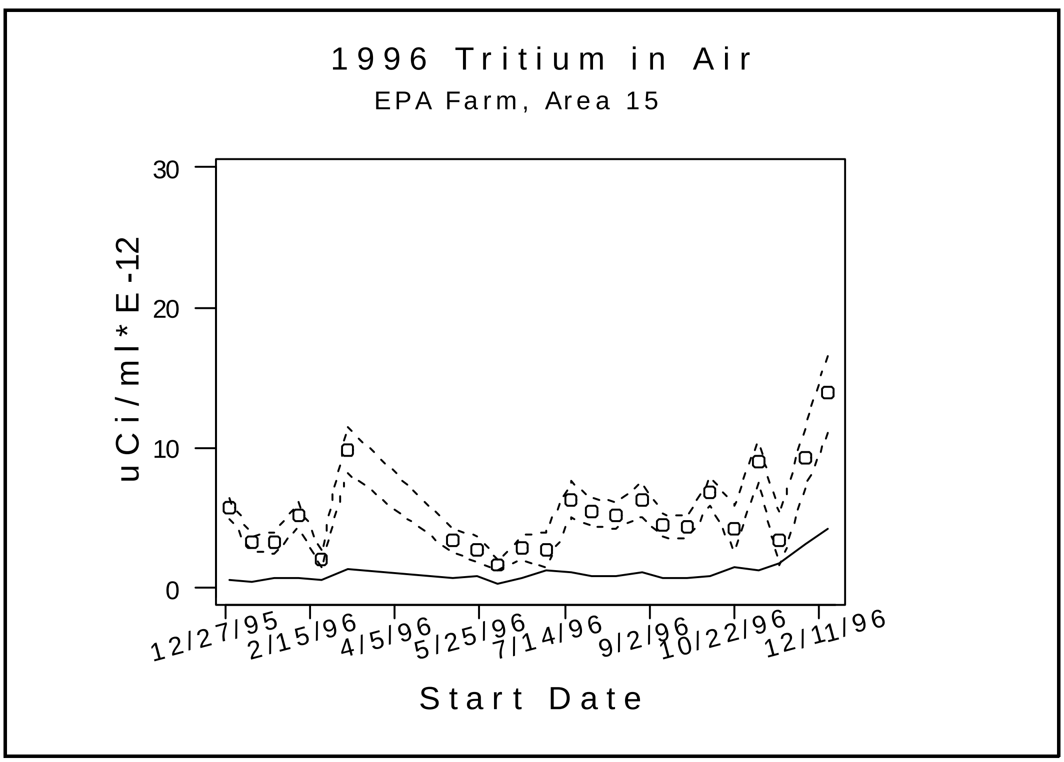

Figure 4.16 Time Series Plot for EPA Farm

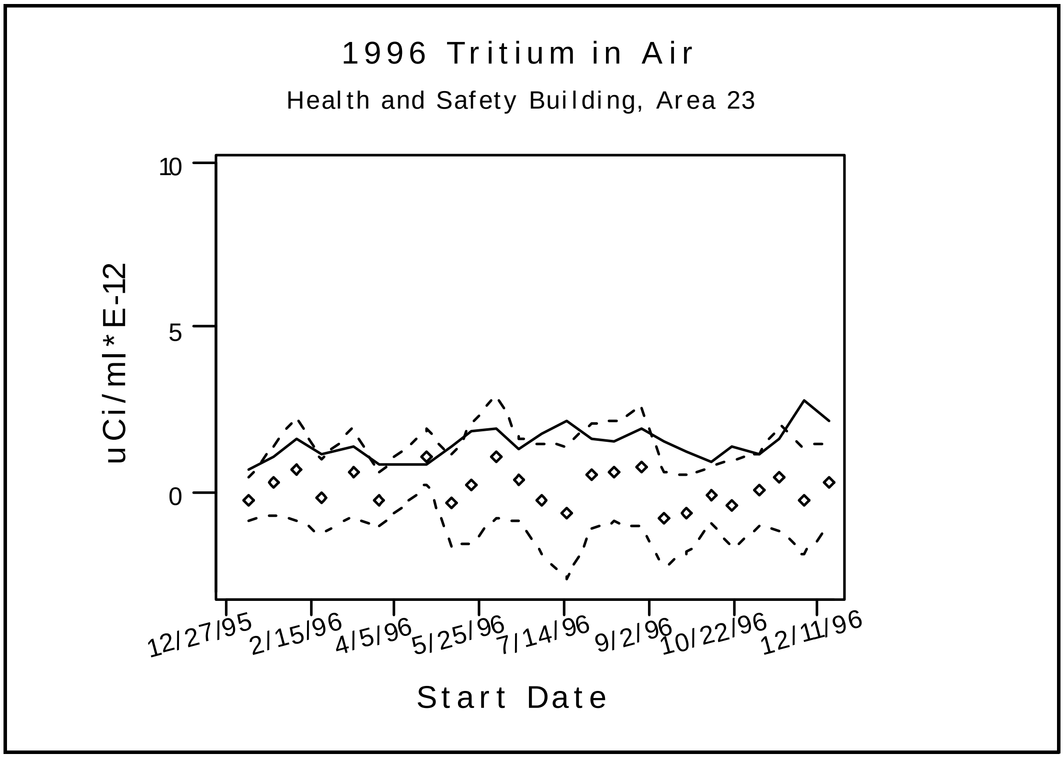

Figure 4.17 Time Series Plot for H&S Building

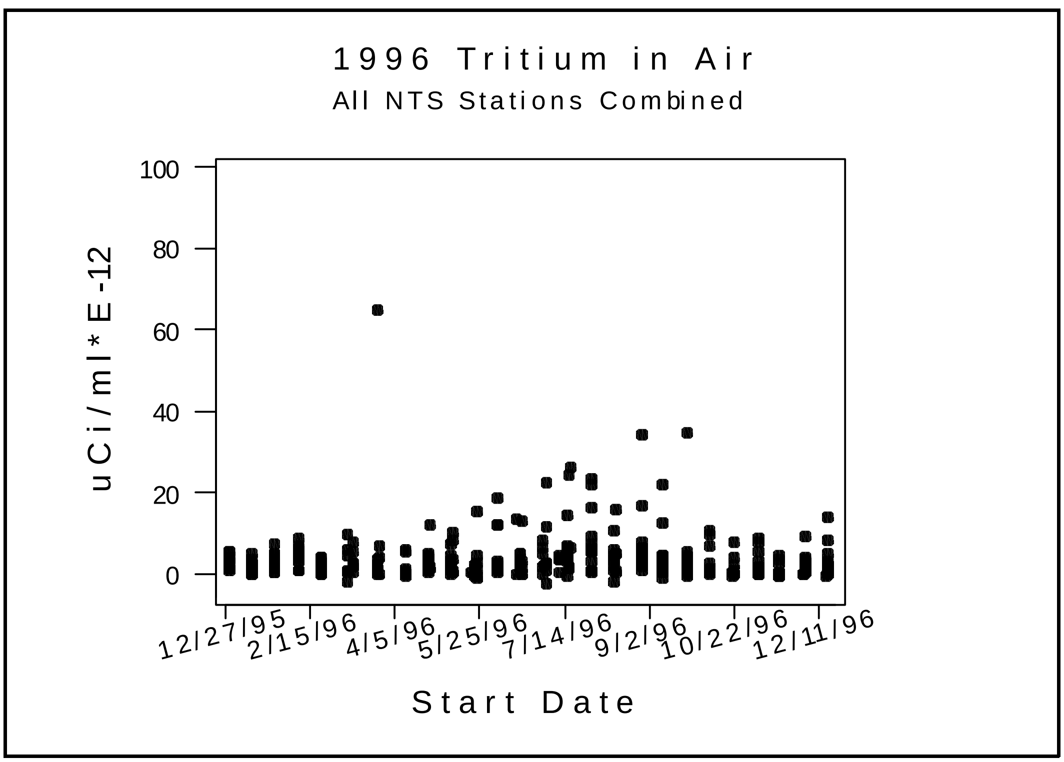

Figure 4.18 Times Series Plot for All NTS Stations Combined

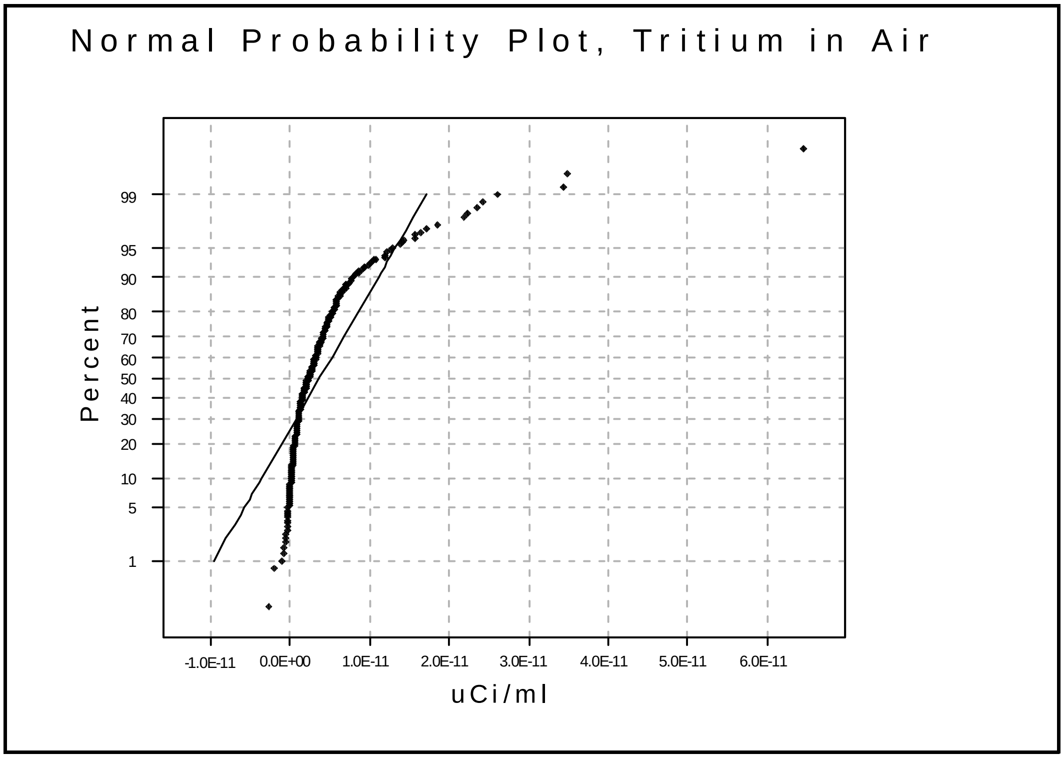

Figure 4.19 Normal Probability Plot, All NTS Stations Combined

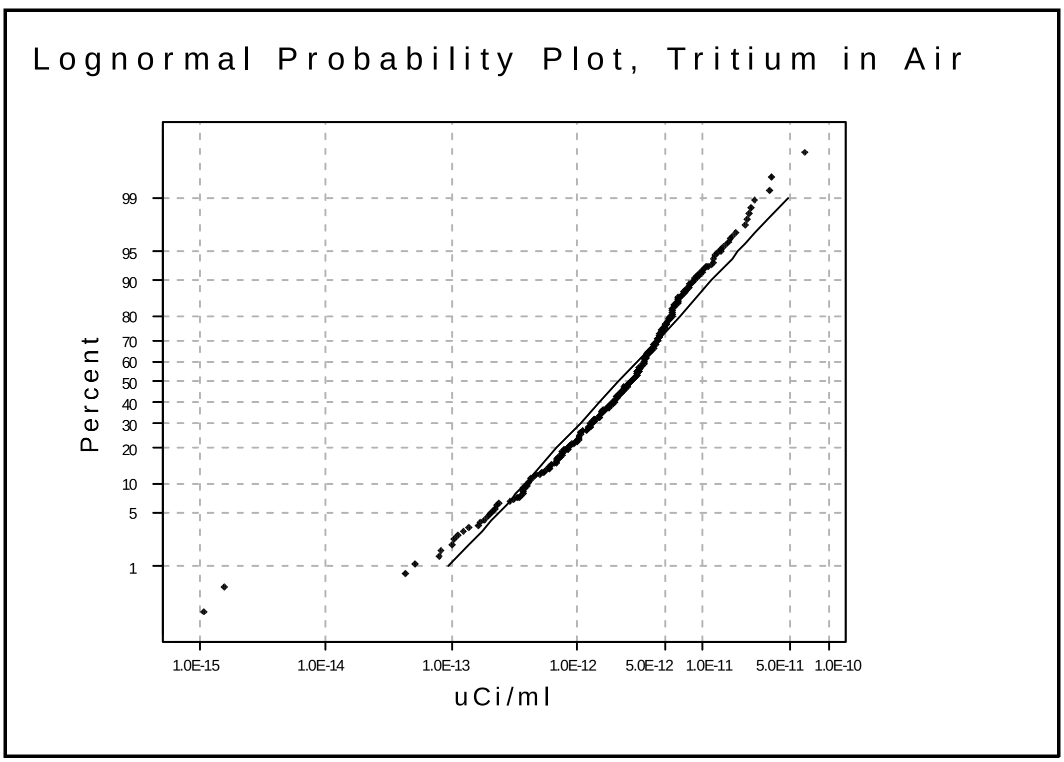

Figure 4.20 Lognormal Probability Plot, All NTS Stations Combined

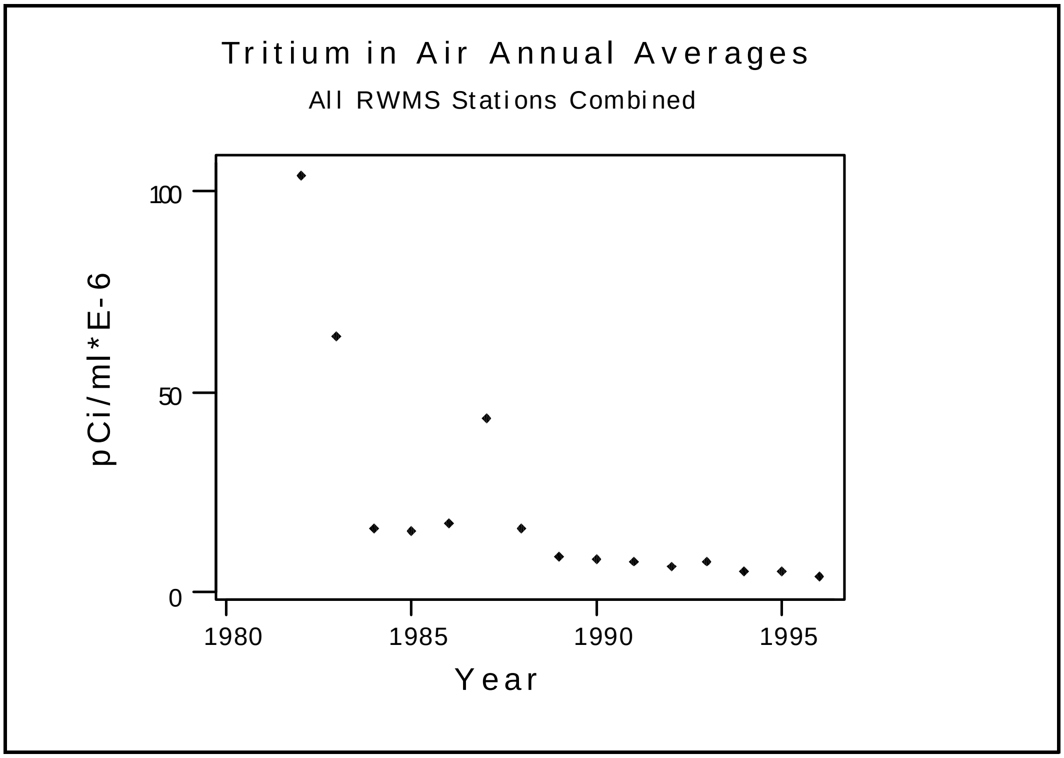

Figure 4.21 Historical Time Series Plot for RWMS

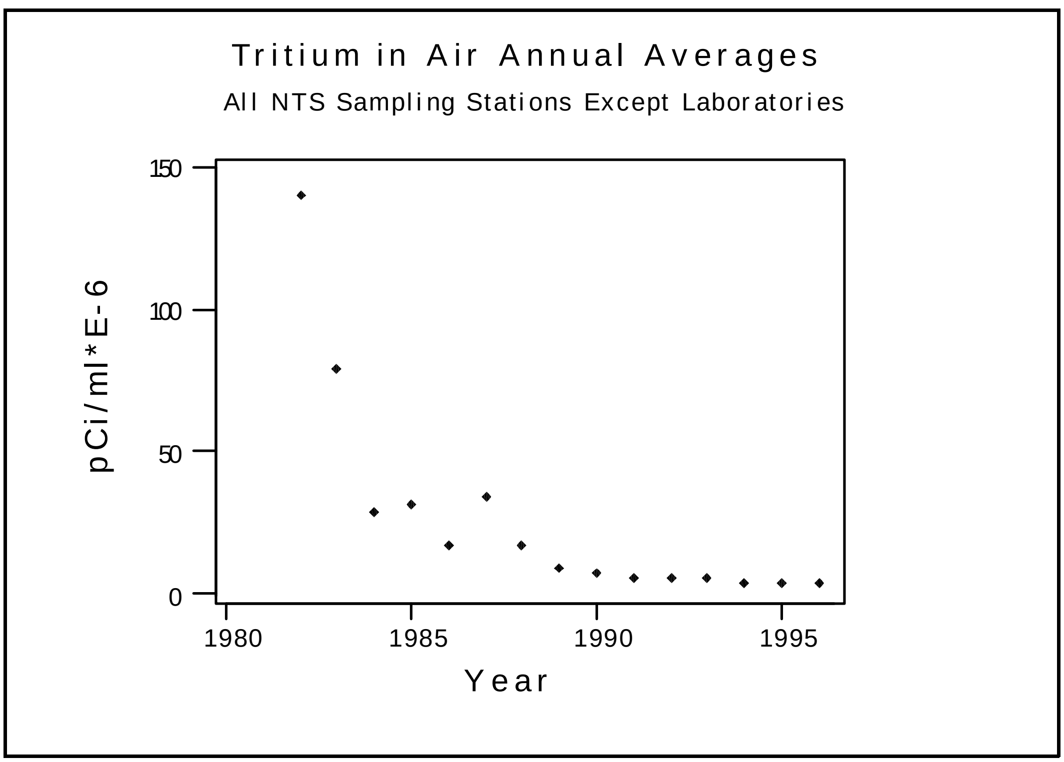

Figure 4.22 Historic Time Series Plot for NTS

Table 4.1 1996 Descriptive Statistics by Sampling Station

		10^{-6} pCi/mL				
		Standard		1st	3rd	
Station	Number	Mean	Deviation	Median	Quartile	Quartile
H & S Building 650	24	0.10	0.53	0.14	-0.28	0.55
RWMS No. 1	26	2.3	1.7	2.5	1.1	3.2
RWMS No. 3	21	2.7	2.0	2.1	1.2	3.9
RWMS No. 4	27	5.4	4.1	4.6	2.4	7.8
RWMS No. 5	20	3.2	2.1	2.6	1.3	4.5
RWMS No. 6	26	2.8	2.4	2.4	0.88	4.6
RWMS No. 7	19	3.0	1.6	3.0	1.8	4.1
RWMS No. 8	23	2.8	2.2	2.4	1.2	4.1
RWMS No. 9	19	3.8	1.7	3.5	2.3	5.8
BJY	25	0.63	0.89	0.59	0.20	1.1
Area 12, Camp	24	0.84	1.3	0.58	0.13	1.2
EPA Farm	23	5.3	2.9	4.5	3.3	6.4
SEDAN Crater	25	8.5	6.9	5.7	3.1	13.2
Mud Plant	24	0.76	0.88	0.71	0.0	1.3
E Tunnel Pond No. 1	25	11.9	9.8	8.6	4.7	18.7
U-3ah/at North	13	0.54	1.8	0.22	-0.36	0.98
All Locations Combined	364	3.5	4.8	2.3	0.74	4.5

Table 4.2 ANOVA on the Natural Log of Tritium in Air Concentrations by Sampling Location

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic	p Value
Location	15	262.547	17.503	17.6	0.000
Error	314	312.286	0.995		
Total	329	574.834			

Table 4.3 Comparison of Station Medians for Significant Differences

Station	N	Ln of Median	Standard Deviation	Individual 95 Confidence Intervals for Ln Median Based on Pooled Standard Deviation
H & S Building	13	-28.529	0.842	(---*----)
Area 12, Camp	21	-28.314	1.728	(---*---)
U-3ah/at N	9	-28.291	1.525	(----*-----)
BJY	23	-28.198	0.877	(--*--)
Mud Plant	18	-27.795	0.778	(--*---)
RWMS No. 8	22	-27.111	1.749	(--*---)
RWMS No. 6	24	-26.915	1.069	(---*--)
RWMS No. 1	23	-26.844	0.841	(--*---)
RWMS No. 3	20	-26.796	0.657	(---*--)
RWMS No. 7	19	-26.714	0.709	(--*---)
RWMS No. 5	20	-26.689	0.715	(---*--)
RWMS No. 9	19	-26.425	0.533	(---*---)
RWMS No. 4	27	-26.264	0.919	(--*--)
EPA Farm	23	-26.091	0.524	(---*--)
SEDAN Crater	25	-25.810	0.821	(--*--)
E Tunnel	24	-25.417	0.831	(--*---)

Pooled Standard Deviation = 0.997

Axis: -28.8, -27.6, -26.4, -25.2

Table 4.4 Historical Annual Station Averages, Tritium in Air (10^{-6} pCi/mL)

Station	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
RWMS No. 1	400.	74.	37.	78.	46.	25.	12.	9.4	4.8	6.1	4.2	4.3	4.2	3.2	2.3
RWMS No. 2	58.	46.	12.	10.	19.	24.	12.	7.3	5.7	4.8	6.7	4.4	4.3	3.1	-
RWMS No. 3	21.	23.	7.7	3.6	8.6	25.	16.	11.	5.8	4.0	4.2	3.8	4.5	4.1	2.7
RWMS No. 4	85.	36.	17.	4.5	11.	220.	38.	9.5	8.5	5.1	6.5	10.	13.6	15.1	5.4
RWMS No. 5	130.	170.	26.	15.	30.	25.	6.7	8.8	7.9	5.0	4.0	6.8	3.6	3.0	3.2
RWMS No. 6	160.	35.	7.9	3.9	7.2	13.	-180.	5.5	7.5	5.4	4.0	7.7	2.9	8.6	2.8
RWMS No. 7	30.	67.	6.5	4.7	11.	13.	8.7	5.1	12.	14.	12.	21.	2.9	3.4	3.0
RWMS No. 8	24.	73.	4.1	4.9	5.3	11.	9.4	10.	9.1	8.9	5.0	6.2	2.2	3.4	2.8
RWMS No. 9	24.	54.	29.	8.9	12.	27.	22.	12.	11.	14.	12.	6.6	5.8	4.8	3.8
Average of RWMS	104.	64.	16.	15.	17.	43.	16.	8.7	8.1	7.5	6.5	7.9	4.9	5.4	3.6
BJY	150.	21.	25.	34.	37.	17.	-120.	15.	2.4	1.8	1.4	1.7	1.0	0.86	0.63
Gate 700 South	-	420.	5.8	7.1	9.8	45.	42.	3.2	1.8	1.5	0.63	0.72	0.57	0.64	-
Area 12, Camp	420.	28.	19.	260.	21.	21.	11.	5.9	2.0	1.3	0.54	0.42	0.42	0.25	0.84
EPA Farm	140.	96.	220.	29.	32.	30.	35.	26.	10.	6.3	10.	8.6	9.6	5.1	5.3
H & S Building	6000.	2700.	560.	8000.	390	66.	7.5	5.7	15.	0.90	0.53	0.34	0.30	0.29	0.11
East Boundary	-	17.	5.3	3.0	2.9	4.6	2.6	2.3	7.2	0.78	0.36	0.13	0.44	-	-
Building 790 No. 2	6300.	100.	120.	27.	3.9	6.6	0.8	2.4	2.5	0.54	0.76	0.78	0.75	0.31	-
E-MAD North	150.	29.	18.	2.9	3.8	6.7	3.8	3.0	5.5	4.5	7.6	0.17	0.25	0.11	-
All Stations Combined, Except Laboratories (Included RWMS)	140.	79.	29.	31.	17.	34.	17.	8.9	6.8	5.6	5.3	5.5	3.9	4.0	3.2