2.0 ONSITE GROSS BETA IN AIR

Forty-nine air sampling locations on the Nevada Test Site (NTS) were monitored for gross beta in air during 1996. The sampling units were equipped with glass-fiber filters and had an air flow rate of 140 L/m (5cfm). The filters were typically changed after one week of operation. The glass-fiber filter was analyzed by gamma spectroscopy and, after a five to seven day wait, for radon progeny decay, gross beta, and gross alpha activity. More details on the air sampling activities on the NTS can be found in Chapters 4 and 5 of the U.S. Department of Energy, Nevada Operations Office (DOE/NV), Annual Site Environmental Report - 1996, (ASER) DOE/NV/11718-137.

The 1995 data report describes a number of changes made to the monitoring network in 1995 that resulted in the closing of 21 monitoring locations. In 1996, seven new air monitoring locations were established. A Waste Examination Facility (WEF) is under construction just south of the entrance to the Area 5 Radiological Waste Management Site (RWMS-5). The WEF north and the WEF south air monitoring locations were installed in October 1996 for preoperational monitoring of this facility. At the beginning of 1996, a monitoring station was installed at the Project 57 location. Project 57 was a safety shot experiment conducted on April 24, 1957, in Area 13. Currently this location is being considered for remediation, and air monitoring data is useful for planning remediation activities and evaluating the results of the remedial work. Area 13 is now a part of the Nellis Air Force Range Complex. The Project 57 location is approximately six miles north of the northeast corner of the NTS. In August of 1966, a new air monitoring station was established adjacent to the CABRIOLET test location. This test was a cratering experiment conducted on January 26,1968. This location is on the west boundary of Area 20, approximately halfway between the north and south boundaries of Area 20. Area 52 is approximately 27 miles north of the northwest corner of the NTS. The DOUBLE TRACKS and CLEAN SLATE III air sampling locations were established in Area 52 in December of 1995. The CLEAN SLATE I air sampling location was established in August of 1996. Figure 2.1 shows the locations of the air monitoring stations except for the new Area 52 locations, which are off this map to the north.

Sampling locations, sampling dates, measured concentrations, analytic standard deviations, and analytic detection limits for gross beta in air samples collected in 1996 appear in Attachment 2.1. (All figures, tables, and attachments are located at the end of each chapter.) Descriptive statistics for each station and for all stations combined are given in Table 2.1. The median detection limit for all data combined is 1.53×10^{-15} µCi/mL and only two of the 2,268 results are less than the individual detection limits. None of the 1996 gross beta in air results are negative. In Table 2.1 “Mud Plant” refers to a concrete batch mixing facility. The notation “RWMS TP Building” refers to the Transuranic Pad Building at the Radiological Waste Management Site. NRDS, a historical acronym for activities that occurred in Area 25, is now used to specify the group of administrative buildings in the center of Area 25. Table 2.2 gives descriptive statistics for the NTS operational areas, and Figure 2.2 is a thematic map showing the pattern of area averages of gross beta in air. The ranges for the thematic patterns were chosen to be five quantiles of the data, thus 20 percent of the data is in each range.

Figure 2.3 displays a lognormal probability plot of all the 1996 gross beta in air data, sampling stations, and sampling dates combined, except the three smallest values. This plot shows a very good fit to a lognormal distribution; thus, all statistical hypothesis testing have been done using logarithms of the data values. The data in previous years have also been lognormally distributed. A two way analysis of variance (ANOVA), using the natural logarithm of the gross beta concentrations as the response and sampling station and week of the year as factors,

showed very significant differences between stations and between weeks with no interaction. To simplify this analysis somewhat, the weeks were grouped into months, and the sampling stations were grouped into the NTS operational areas. The sampling stations are nested within the operational areas, and the weeks are nested within months, but this nesting could not be used in the ANOVA test because it results in rank deficient designs. The week was approximated by dividing the day of the year by seven and then rounding. The day of the year is the number of days between the earliest start date (at Well ER 3-1 on December 18, 1995) and the start date of a result. The month was approximated by dividing the day of the year by 30.5 and then rounding. The two way ANOVA using months and operational areas as the factors also showed very significant differences between months and between areas and no interaction. The program used for the two way analyses of variance does not provide for an investigation of patterns in the data that contribute to the significance found in the analysis. To accomplish such investigations, one way analyses of variance were done for each of the factors used in the two way analyses.

Table 2.3 displays the one way ANOVA results for differences between operational areas. The plot of means and confidence intervals has been ordered by increasing values of the mean of the logarithms of each area. The ANOVA table shows a very significant difference between areas. The plot of confidence intervals shows no clustering of mean values; rather there is a gradual increase from the lowest mean to the highest. Tukey's multiple comparison test was used to determine the pattern of means that resulted in the high significance of the ANOVA. This test only showed that the lowest means are significantly different from the highest means, a result which could be anticipated from a visual examination of the confidence intervals. Figure 2.2 gives similar results; however, in this figure, the mean of the gross beta concentrations for each area is used, while Table 2.3 shows the means of the logarithms of the data for each area. Figure 2.4 displays boxplots of the gross beta values (not the logarithms) by operational areas. This figure shows substantial overlap in the ranges of data values between the areas; thus, the statistical significance of the differences between areas may be of no operational significance.

Table 2.4 displays the one way ANOVA for differences in gross beta results between month of sampling. The ANOVA table indicates a very significant difference between month of sampling. The confidence interval portion of the table shows a pattern that is somewhat sinusoidal in shape, with a low point in March or April and a high point in August or September. This pattern suggest an increasing trend in gross beta concentrations during the warm months of the year and a decreasing trend during the cooler months. The thirteenth month in this plot results from the fact that sampling dates started in the middle of December of 1995. Figure 2.4 is a time series plot of all the 1996 gross beta in air results. In this figure, the data values, not their logarithms, are used. The line in this figure is a "locally weighted scatterplot smoother" line. This is a statistical tool for visualizing any trend that may be in the data. This line shows a sinusoidal trend with a low point about the beginning of springtime and a high point about the beginning of autumn. While this figure shows a correlation between higher temperature and rising gross beta concentrations and a decrease for falling temperatures, it does not establish a cause and effect relationship. This type of trend was not seen in the previous five years data; thus, a simple true correlation between temperature and gross beta levels is doubtful.

A sense of the accuracy of the gross beta in air measurements can be obtained from the empirical coefficients of variation which is the analytic standard deviation divided by the corresponding measured concentration. A histogram of these coefficients appears in Figure 2.6 for 1996 gross beta in air. One empirical coefficient is omitted from this histogram, a value of 3.84 that occurred at Area 12 for the measurement beginning April 25, 1996. This value is associated with the smallest measured value and is more of a representation of the measured value than of the analytical error. In most of the data cases the empirical coefficient of variation is 0.1 or less, indicating that the standard deviation tends to be at least an order of magnitude smaller than the measured concentration.

Figure 2.7 is a histogram of all detection limits for the 1996 gross beta in air data. Because of the scale of the ordinate of this figure, the largest values of the detection limit are not seen. There are 15 values above 5 in Figure 2.7 and the maximum is 11.1 µCi/mL × 10^{-15}. The detection limits are not normally distributed, nor are they lognormally distributed; thus, not much statistically can be done with them other than graphical presentations. Figure 2.7 shows that almost all detection limits are less than about 3 × 10^{-15} µCi/mL. The detection limits should be compared to Figure 2.3, the lognormal probability plot of the gross beta concentrations. Such a comparison shows that, in general, the gross beta concentrations are an order of magnitude larger than the detection limits.

HISTORICAL TRENDS

Since 1966, when annual environmental reports began, 70 different locations on the NTS have been used for gross beta in air monitoring. Were a complete analysis of historical trends for all sampling locations included, in addition to the current results, the resulting document would be unwieldy. The five sampling locations used continuously since the beginning of air monitoring in 1966 were selected for analysis of historical trends. Table 2.5 gives the annual averages from these five stations along with the number of active air sampling stations for each year and the annual average for all sampling locations combined for each year. This table does not include the three new sampling locations on the Tonopah Test Range Area 52; thus, for 1996 there are 46 sampling locations in the historical part of this chapter and 49 sampling locations in the annual report part. The Area 52 locations are not geographically a part of the NTS. The five selected stations are:

- Well 5B in Area 5 and located close to the southeast corner of the NTS.
- CP-6 (Building 6 at the Control Point) in Area 6 and located close to the center of the NTS.
- Gate 700 South in Area 10 and located close to the northeast corner of the NTS.
- Area 12 Complex located in the north central part of the NTS.
- Area 27 Cafeteria located in the south central part of the NTS.

The map in Figure 2.1 shows that relatively few air sampling locations have been located on the western side of the NTS. Sampling locations are usually chosen to monitor operational activities on the NTS and most such activities have been located on the eastern side. Figure 2.8 is a time series plot of the annual averages from the five selected stations. This figure also contains a "locally weighted scatterplot smoother" line, which is a statistical tool for displaying trends in data.

The line in Figure 2.8 suggests a trend peaking in 1971, then a steady decrease in annual averages until about 1983 when a level of about 20 × 10^{-15} µCi/mL was reached. Since 1982, the annual averages have remained at or slightly less than the 20 × 10^{-15} µCi/mL level, except for the peak in 1986. Four noticeable peaks of annual average gross beta levels may be seen in Figure 2.8.

- A significant peak occurred in 1971. This is probably attributable to the BANEBERRY event, which was detonated on December 18, 1970, and in which radioactive particles were accidently vented to the atmosphere. This event was located in the southwest section of Area 8 of the NTS.
- A peak occurred in 1977. This is probably attributable to foreign nuclear testing.
- A peak occurred in 1981. This is probably attributable to foreign nuclear testing
- A noticeable increase in annual average gross beta occurred in 1986. This is probably attributable to the accident at Chernoble.

CONCLUSIONS

Since about 1982, gross beta in air levels at the NTS have been uniformly low and essentially at world-wide background, except for a slight increase in 1986 that can be attributed to the Chernoble accident. Almost all values are well above analytical detection limits; thus, the data values are valid measures of environmental exposure levels. Statistically significant differences are found between locations, operational areas, and sample collection dates; however, these differences do not appear to follow any meaningful pattern, and their magnitude is too small to be of any operational significance.

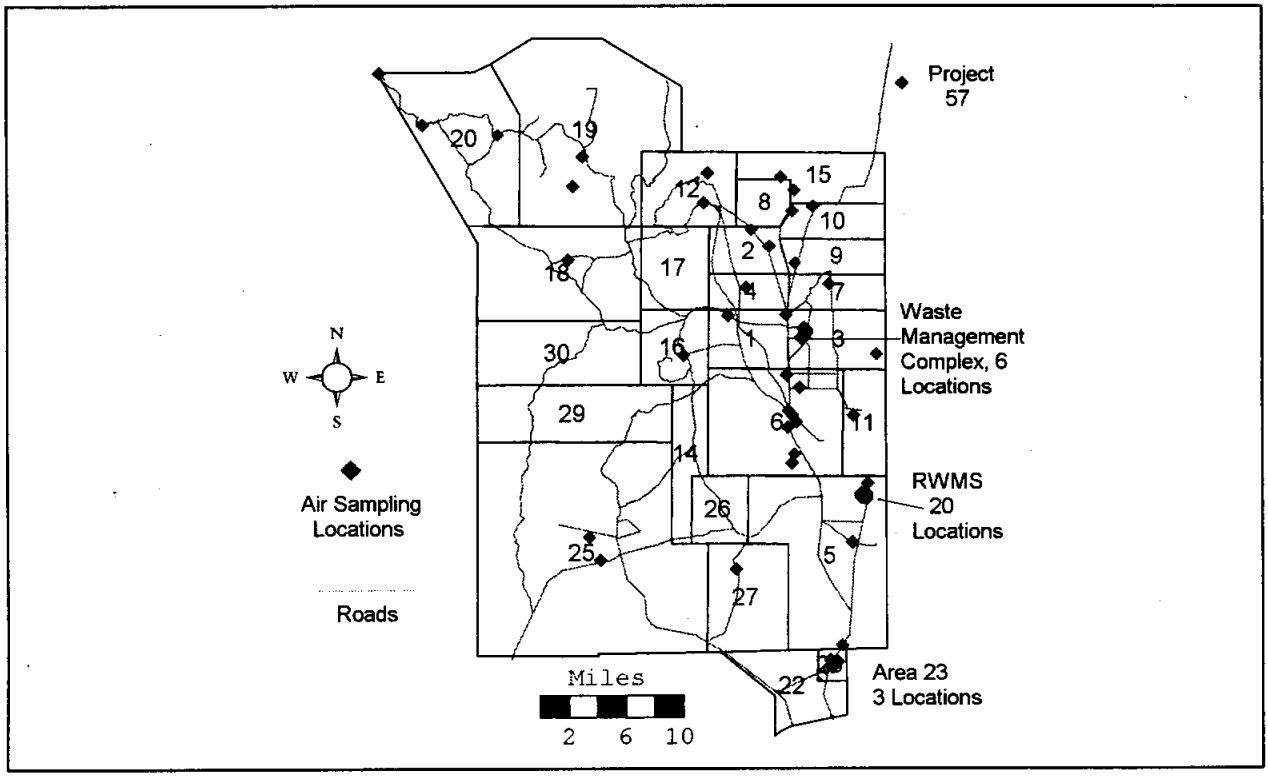

Figure 2.1 Locations of Air Sampling Stations on NTS

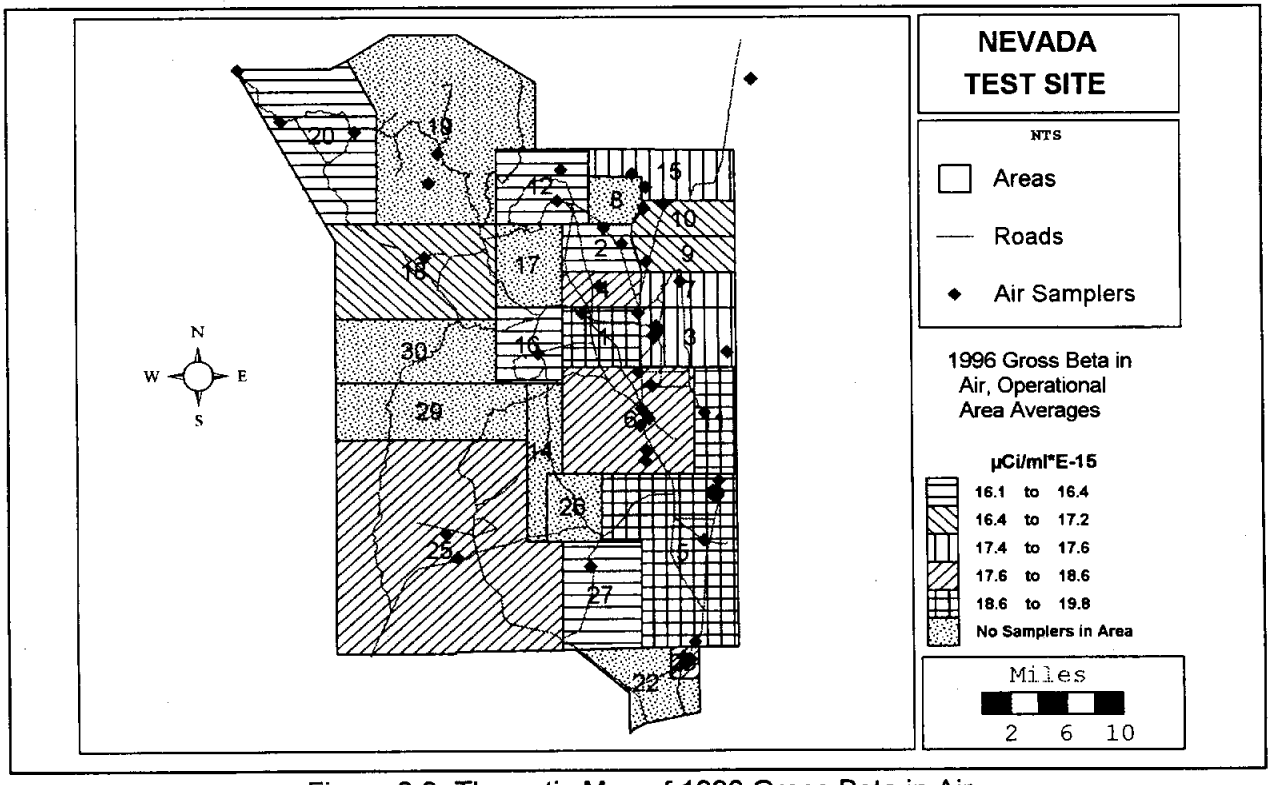

Figure 2.2 Thematic Map of 1996 Gross Beta in Air

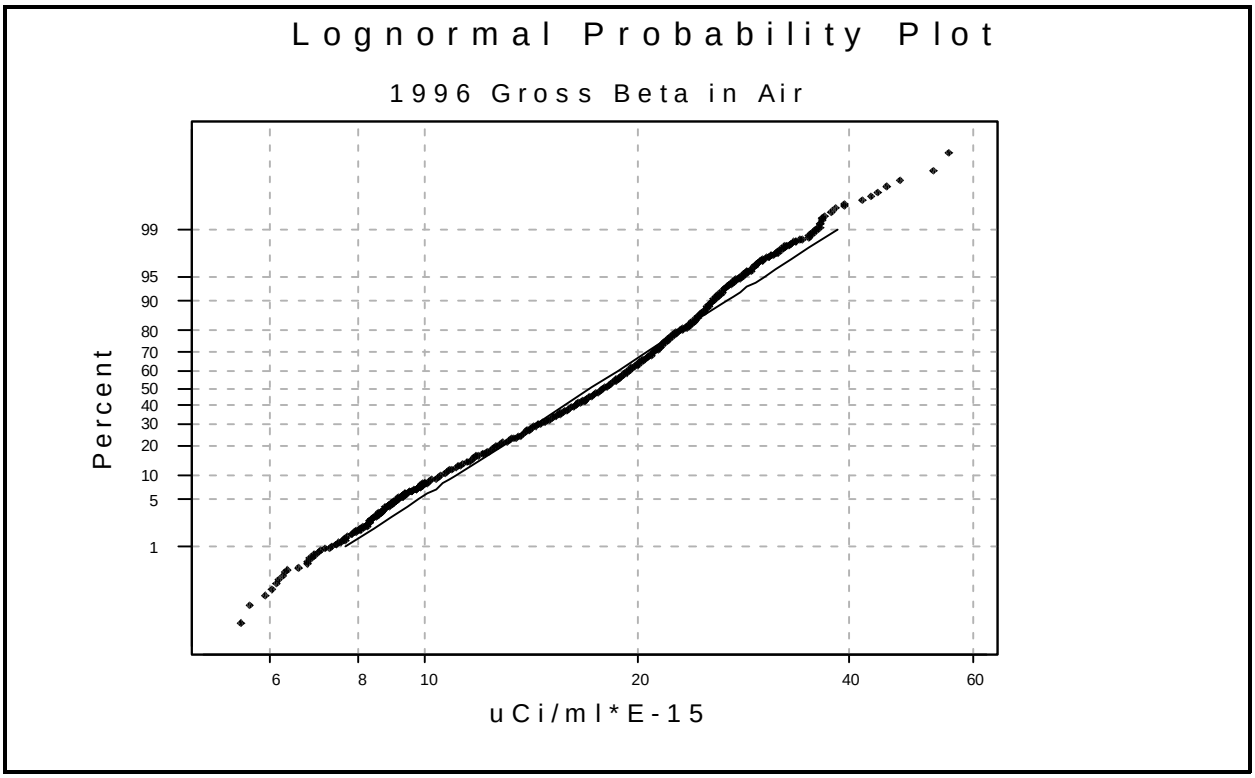

Figure 2.3 Probability Plot for All Stations and Dates Combined

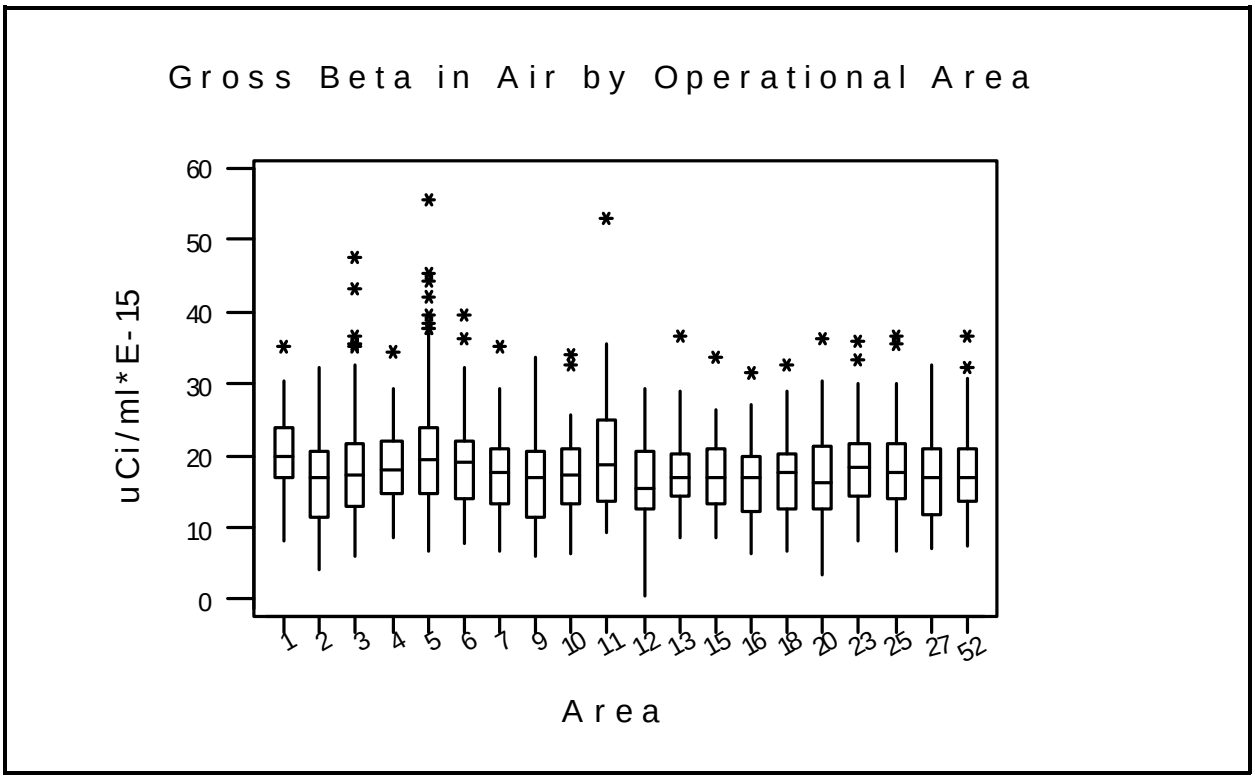

Figure 2.4 Boxplot of Gross Beta in Air by Area

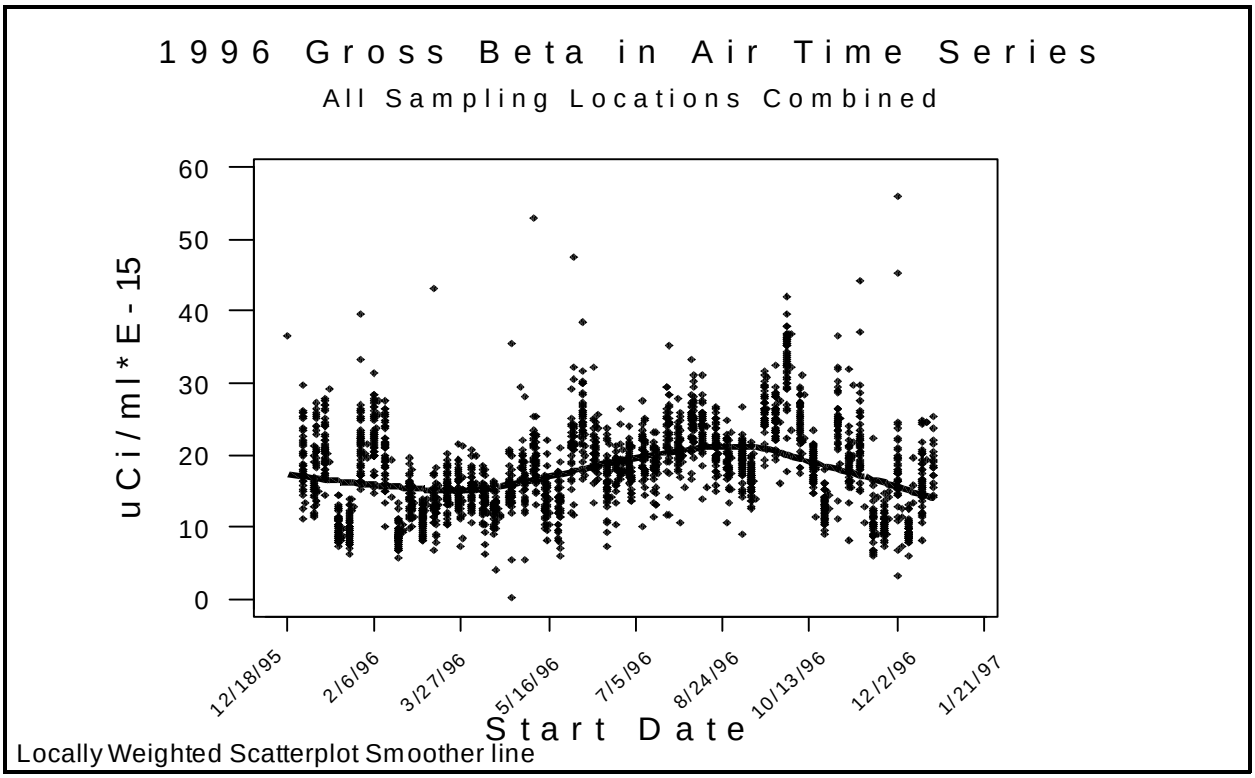

Figure 2.5 Time Series Plot for Gross Beta in Air

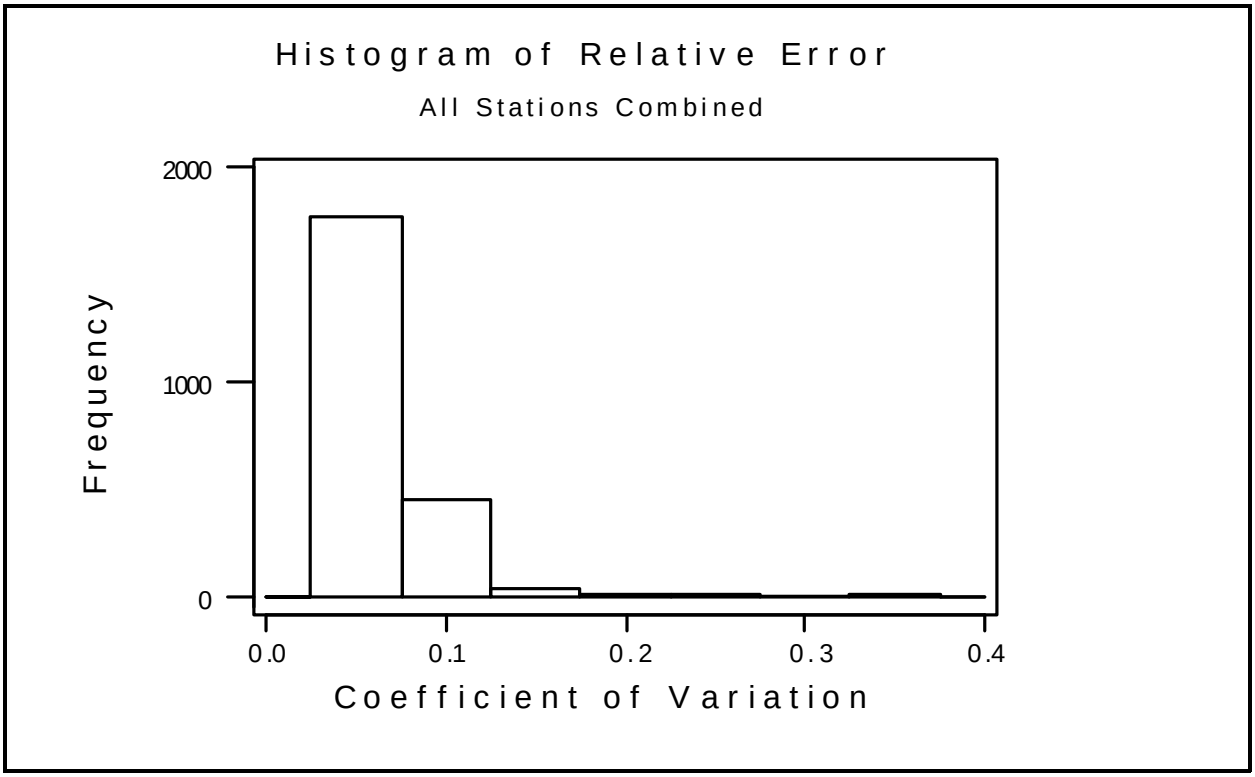

Figure 2.6 Histogram of 1996 Gross Beta in Air Coefficients of Variation

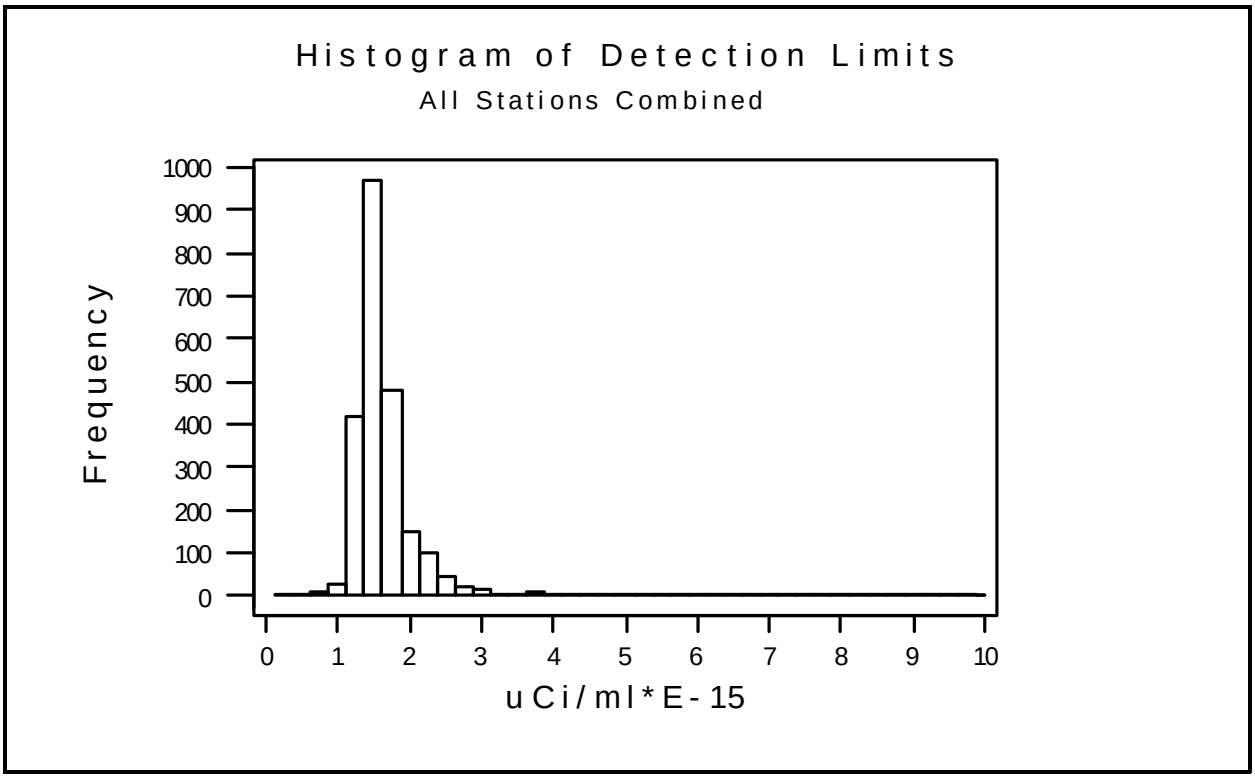

Figure 2.7 Histogram of 1996 Gross Beta in Air Detection Limits

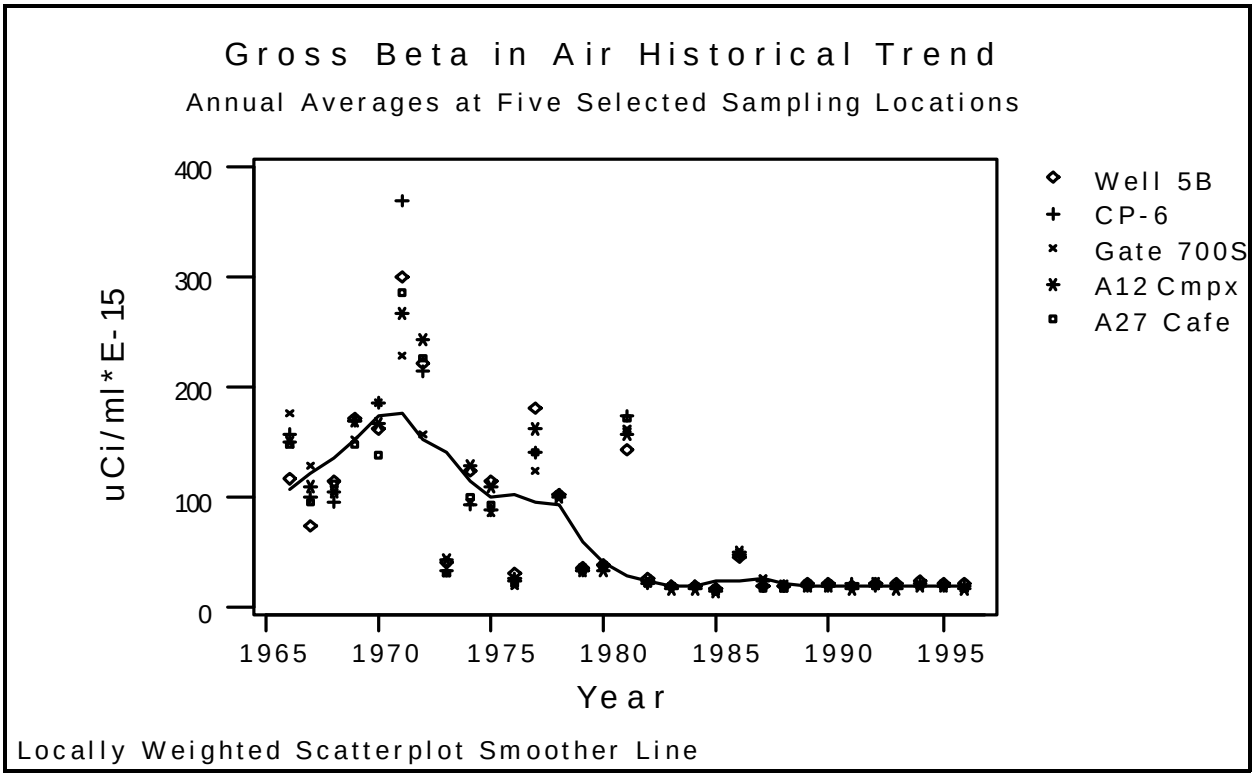

Figure 2.8 Historical Time Series, All Selected Stations Combined

Table 2.1 Descriptive Statistics for Gross Beta in Air by Sampling Location, µCi/mL × 10^{-15}

Station Name	Number of Samples	Mean	Median	Standard Deviation	Minimum	Maximum
BJY	51	19.81	20.00	5.76	8.30	35.10
Area 2, Camp	50	17.79	17.35	5.41	8.47	32.10
2-1 Substation	51	14.96	16.10	6.16	4.10	10.50
U-3ah/at South	50	15.11	15.25	4.28	7.03	26.10
U-3ah/at East	50	17.17	16.75	5.30	7.51	19.90
U-3ah/at North	45	16.96	16.00	5.74	8.05	32.10
U-3ah/at West	50	16.26	16.40	5.05	6.87	26.40
Mud Plant	51	20.87	19.80	7.82	8.53	47.50
Well ER 3-1	49	19.13	20.40	6.98	6.03	36.60
Bunker T-4	50	18.62	18.15	5.63	8.61	34.50
WEF North	3	18.43	18.60	6.55	11.80	24.90
WEF South	4	24.40	24.30	6.75	18.00	31.00
RWMS Pit 5	50	17.52	17.00	5.38	6.78	30.80
RWMS No. 4	51	19.82	19.90	6.09	10.10	36.90
RWMS No. 5	43	20.24	19.70	5.37	11.60	35.60
RWMS No. 6	52	19.22	19.55	5.80	8.07	36.50
RWMS No. 7	39	17.53	17.30	5.58	8.34	35.10
RWMS No. 8	51	19.29	19.90	5.17	10.20	31.50
RWMS No. 9	41	19.62	19.40	6.44	8.79	37.90
DOD Pad	51	20.18	19.10	6.85	9.50	42.00
RWMS No. 3	43	20.16	18.50	5.63	7.63	38.50
RWMS No. 1	52	18.73	18.90	5.27	8.55	31.90
RWMS TP Bldg. North	51	22.25	22.60	9.75	6.92	55.80
RWMS TP Bldg. North	50	19.60	18.20	8.23	8.04	45.40
Well 5B	52	20.69	21.30	5.84	9.39	36.10
Yucca	47	18.84	20.20	5.33	9.73	32.30
CP 6	51	18.69	19.50	6.16	7.82	36.30
Well 3	52	18.06	18.70	6.16	8.24	39.60
UE-7ns	51	17.48	17.60	5.66	6.57	35.30
Area 9, 9-300	53	16.79	17.10	5.86	6.11	33.80
Gate 700 South	50	16.92	17.25	5.48	7.92	32.80
SEDAN Crater	52	17.54	17.25	5.48	6.16	34.20
Gate 293	52	19.84	18.90	7.33	8.25	53.00
Area 12, Camp	51	16.60	15.60	5.70	0.34	29.20
Project 57	51	17.84	17.00	5.40	8.35	36.70
EPA Farm	51	17.50	17.00	5.51	8.36	33.70
3545 Substation	48	16.13	16.90	5.62	6.30	31.70
Well UE-18t	49	17.17	17.50	5.45	6.83	32.50
SCHOONER	48	19.26	19.35	5.99	8.76	36.40
Area 20, Camp	52	14.89	15.05	5.74	3.72	29.50
CABRIOLET	3	14.50	17.50	5.37	8.30	17.70
Bldg. 790 No. 2	53	17.72	18.10	5.65	8.64	36.00

Table 2.1 (Descriptive Statistics for Gross Beta in Air by Sampling Location, µCi/mL × 10^{-15}, cont.)

Station Name	Number of Samples	Mean	Median	Standard Deviation	Minimum	Maximum
H & S Bldg.	53	19.50	19.10	5.63	8.33	33.40
E-MAD North	52	18.01	18.35	5.64	6.89	36.80
NRDS	53	17.66	16.20	6.02	6.83	35.70
Area 27, Camp	47	16.57	16.80	5.62	7.15	32.60
DOUBLE TRACKS	49	16.09	15.60	4.11	7.43	25.70
CLEAN SLATE III	52	18.32	18.10	5.67	9.44	32.30
CLEAN SLATE I	18	21.29	21.90	7.04	10.70	36.70
All Stations Combined	2268	18.23	18.00	6.14	0.34	55.80

Table 2.2 Descriptive Statistics for Gross Beta in Air by Operational Areas, µCi/mL × 10^{-15}

Area Number	Number of Samples	Mean	Median	Standard Deviation	Minimum	Maximum
1	51	19.81	20.00	5.76	8.30	35.10
2	101	16.36	16.80	5.94	4.10	32.10
3	295	17.60	17.30	6.25	6.03	47.50
4	50	18.62	18.15	5.63	8.61	34.50
5	633	19.66	19.40	6.48	6.78	55.80
6	150	18.52	19.30	5.88	7.82	39.60
7	51	17.48	17.60	5.66	6.57	35.30
8	0					
9	53	16.79	17.10	5.86	6.11	33.80
10	102	17.24	17.25	5.46	6.16	34.20
11	52	19.84	18.90	7.33	9.25	53.00
12	51	16.60	15.60	5.70	0.34	29.20
13	51	17.84	17.00	5.40	8.35	36.70
14	0					
15	51	17.49	17.00	5.51	8.36	33.70
16	48	16.13	16.90	5.62	6.30	31.70
17	0					
18	49	17.17	17.50	5.45	6.83	32.50
19	0					
20	103	16.92	16.30	6.20	3.27	36.40
22	0					
23	106	18.61	18.50	5.62	8.33	36.00
25	105	17.83	17.50	5.81	6.83	36.80
26	0					
27	47	16.57	16.80	5.62	7.15	32.60
29	0					
30	0					
52	119	17.85	17.10	5.58	7.43	36.70

Table 2.3 One Way ANOVA on Natural Log of Gross Beta Results for Differences Between Operational Areas, µCi/mL

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic	p-Value
Area	19	11.106	0.585	4.65	0.000
Error	2248	282.749	0.126		
Total	2267	293.854			

Area	N	Mean of Log	Standard Deviation
12	51	-31.833	0.623
2	101	-31.820	0.414
16	48	-31.824	0.378
27	47	-31.789	0.350
20	103	-31.785	0.408
9	53	-31.780	0.362
10	102	-31.748	0.350
18	49	-31.748	0.337
15	51	-31.728	0.326
3	295	-31.733	0.359
7	51	-31.731	0.337
25	105	-31.714	0.345
52	119	-31.704	0.310
13	51	-31.701	0.299
6	150	-31.673	0.336
23	106	-31.663	0.319
4	50	-31.660	0.310
5	633	-31.615	0.337
11	52	-31.609	0.338
1	51	-31.600	0.324

Pooled Standard Deviation = 0.355

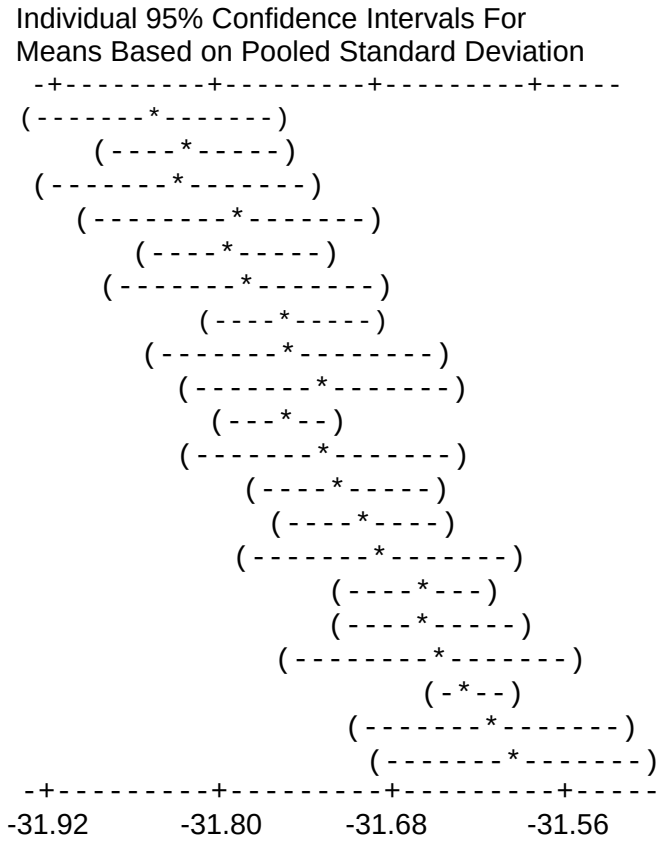

Table 2.4 One Way ANOVA on Natural Log of Gross Beta Results for Differences Between Month of Sample Collection, µCi/mL

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic	p-Value
Month	12	97.6893	8.1408	93.58	0.000
Error	2255	196.1649	0.0870		
Total	2267	293.8541			

Table 2.4 (One Way ANOVA on Natural Log of Gross Beta Results for Differences Between Month of Sample Collection, µCi/mL, cont.)

Month	N	Mean of Log	Standard Deviation
1	82	-31.607	0.246
2	176	-31.868	0.418
3	218	-31.870	0.393
4	173	-31.868	0.210
5	202	-31.850	0.388
6	185	-31.689	0.343
7	211	-31.624	0.189
8	171	-31.477	0.197
9	229	-31.558	0.180
10	183	-31.259	0.183
11	215	-31.605	0.280
12	161	-32.089	0.355
13	62	-31.699	0.229

Pooled Standard Deviation = 0.295

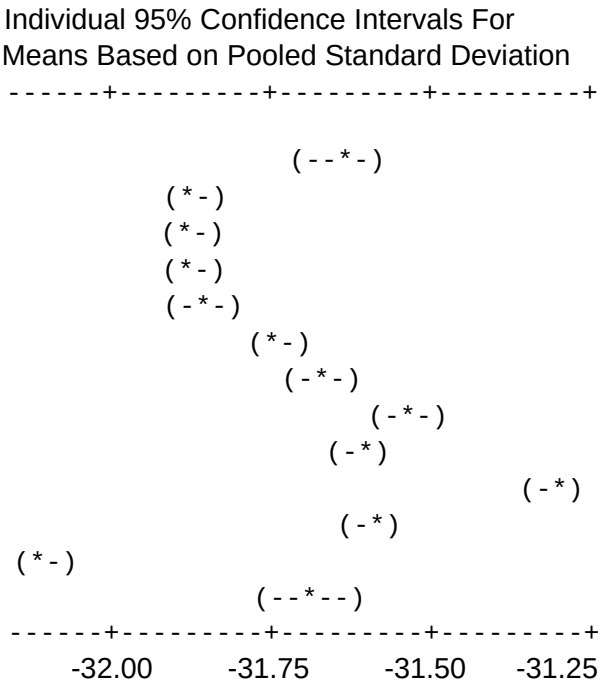

Table 2.5 Gross Beta in Air Historical Annual Averages at Selected Locations and for All Active Sampling Locations Combined, µCi/mL × 10^{-15}

Year	Well 5B Area 5	CP-6 Area 6	Gate 700S Area 10	Area 12 Complex	Area 27 Cafeteria	Number of Stations	Average of All Stations
1966	116.0	157.0	176.0	149.0	147.0	9	135.1
1967	74.7	98.9	128.0	110.0	94.2	14	104.5
1968	115.0	96.2	105.0	104.0	113.0	16	173.2
1969	172.0	170.0	153.0	170.0	148.0	16	171.0
1970	163.0	185.0	186.0	176.0	139.0	17	163.7
1971	300.0	370.0	229.0	266.0	286.0	19	337.7
1972	222.0	215.0	156.0	243.0	226.0	19	304.5
1973	41.0	34.0	31.0	42.0	30.0	19	48.2
1974	123.0	93.0	96.0	129.0	99.0	20	120.7
1975	115.0	87.0	85.0	110.0	93.0	20	97.1
1976	31.0	27.0	19.0	24.0	22.0	20	25.0
1977	181.0	141.0	123.0	162.0	141.0	20	168.9
1978	102.0	102.0	101.0	101.0	102.0	24	97.8
1979	36.0	34.0	35.0	33.0	33.0	30	33.4

Table 2.5 (Gross Beta in Air Historical Annual Averages at Selected Locations and for All Active Sampling Locations Combined, µCi/mL × 10^{-15}, cont.)

Year	Well 5B Area 5	CP-6 Area 6	Gate 700S Area 10	Area 12 Complex	Area 27 Cafeteria	Number of Stations	Average of All Stations
1980	37.0	39.0	37.0	34.0	36.0	40	38.4
1981	142.0	173.0	161.0	157.0	171.0	42	158.0
1982	25.0	22.0	21.0	24.0	22.0	42	23.0
1983	18.0	18.0	18.0	16.0	18.0	42	17.8
1984	19.0	18.0	18.0	17.0	18.0	42	18.7
1985	16.0	16.0	17.0	15.0	15.0	42	17.2
1986	46.0	48.0	50.0	49.0	48.0	42	48.6
1987	18.0	18.0	27.0	24.0	16.0	43	24.7
1988	20.0	19.0	18.0	19.0	17.0	45	19.8
1989	21.0	18.0	19.0	19.0	19.0	52	21.9
1990	20.4	19.1	18.3	18.2	20.3	52	19.0
1991	19.6	20.4	18.2	16.8	19.3	53	19.7
1992	20.5	18.1	18.0	20.9	18.0	53	19.6
1993	20.8	19.3	19.9	17.7	18.2	52	20.0
1994	23.0	22.0	20.0	19.0	20.0	54	20.7
1995	21.0	19.7	19.6	18.4	19.3	57	19.6
1996	20.7	18.7	16.9	16.6	16.6	46	18.2