

Appendix C

Supplemental Air Information

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Acronyms

BCG	Biota Concentration Guide
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
IEMP	Integrated Environmental Monitoring Plan
NESHAP	National Emissions Standards for Hazardous Air Pollutants
OU5 ROD	<i>Operable Unit 5 Record of Decision</i>
TLD	thermoluminescent dosimeter

Measurement Abbreviations

1/d ²	inverse square of the distance
cfs	cubic feet per second
cm	centimeters
m ³	cubic meters
°C	degrees Celsius
°F	degrees Fahrenheit
mph	miles per hour
mrem	millirem
mSv	milliSievert
pCi	picocuries
pCi/L	picocuries per liter
µg/g	micrograms per gram
yr	year

Appendix C presents additional air monitoring data and analysis in support of Section 5 of this 2008 *Site Environmental Report*. This appendix consists of five attachments:

- Attachment C.1 provides the results of the radiological air particulate monitoring program, including an assessment of 2008 results with respect to historical data and concentration versus time plots of the total uranium and total particulate.
- Attachment C.2 provides the results of the radon monitoring program, including an assessment of radon data relative to continuous radon monitors. This discussion focuses on the U.S. Department of Energy (DOE) standards contained in DOE Order 5400.5, proposed 10 CFR 834, and an evaluation of trends observed in the 2008 data.
- Attachment C.3 provides information on the direct radiation monitoring program, including an assessment of 2008 results with respect to historical data.
- Attachment C.4 provides a summary of the meteorological data measured at the Butler County Airport during 2008, and historical wind speed and directional data collect at the Fernald Preserve.
- Attachment C.5 provides the results of supplemental dose assessments that are part of the standards and requirements contained in DOE Order 5400.5. The methods and data sources used for the population and biota dose assessments are explained. In addition, an evaluation of trends observed in the dose assessments over the past 9 years is also provided.

References

10 CFR 834. U.S. Environmental Protection Agency, "Radiation Protection of the Public and Environment," *Code of Federal Regulations*, July 1, 2008.

40 CFR 61. U.S. Environmental Protection Agency, "National Emission Standards for Hazardous Air Pollutants," *Code of Federal Regulations*, July 1, 2008.

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Attachment C.1: Radiological Air Particulate

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C.1.0 Radiological Air Particulate

In 2008, the Fernald Preserve operated six air monitoring stations (Figure C.1–1) as part of the Integrated Environmental Monitoring Plan (IEMP) Radiological Air Particulate Monitoring Program (Attachment D of the *Comprehensive Legacy Management and Institutional Controls Plan* [DOE 2008]). Data from five boundary monitoring stations and one background monitoring station are used to demonstrate compliance with 40 CFR 61 “National Emissions Standards for Hazardous Air Pollutants” (NESHAP), Subpart H.

Table C.1–1 provides an operational summary for the air monitoring stations in 2008. Most instruments operated nearly 100 percent of the time, with the worst performance being 87.3 percent at AMS-24. Although the stations are shut down for about 5 minutes when the filters are changed, this does not accumulate a sufficient amount of time to account for downtime in the calculation. Therefore, some monitors show nearly 100 percent operational time. Periodic electrical outages and equipment malfunctions created short periods of downtime that result in operation times of less than 99 percent.

Table C1–1. Operational Summary for Air Particulate Monitoring Stations

Location	Number of Samples	Sample Start Date	Last Sample Collection Date	Operating Time (hours)	Percent of Operation
Boundary					
AMS-2	12	03-Jan-08	05-Jan-09	8,696	98.5
AMS-3	12	03-Jan-08	05-Jan-09	8,342	94.5
AMS-6	12	03-Jan-08	05-Jan-09	8,615	97.5
AMS-8A	12	03-Jan-08	05-Jan-09	8,758	99.2
AMS-24	12	03-Jan-08	05-Jan-09	7,712	87.3
Background					
AMS-12	12	03-Jan-08	05-Jan-09	8,810	99.8

C.1.1 Particulate Monitoring Results

Air filters were exchanged in each instrument every month and analyzed for total uranium and total particulate. Tables C.1–2 (uranium) and C.1–3 (particulate) summarize minimum, maximum and average values for 2008 and 2007 at each location. Relative to the 2007 results, 2008 results were slightly lower for uranium and slightly higher for particulate mass. Additionally, there are no July results for uranium, as the laboratory inadvertently discarded the samples after particulate mass was measured.

Figures C.1–2 through C.1–7 summarize the total uranium and total particulate for each location. Most uranium values reported for August and September samples were slightly below the method detection limit. However, reported values are used, rather than one-half the method detection limit, to ensure conservative (i.e., higher) values are used in all calculations. In general, uranium and particulate exceed the background measurement (AMS-12) most frequently at the eastern boundary monitors (AMS-3 and AMS-8A), as the prevailing winds blow from southwest to northeast across the site.

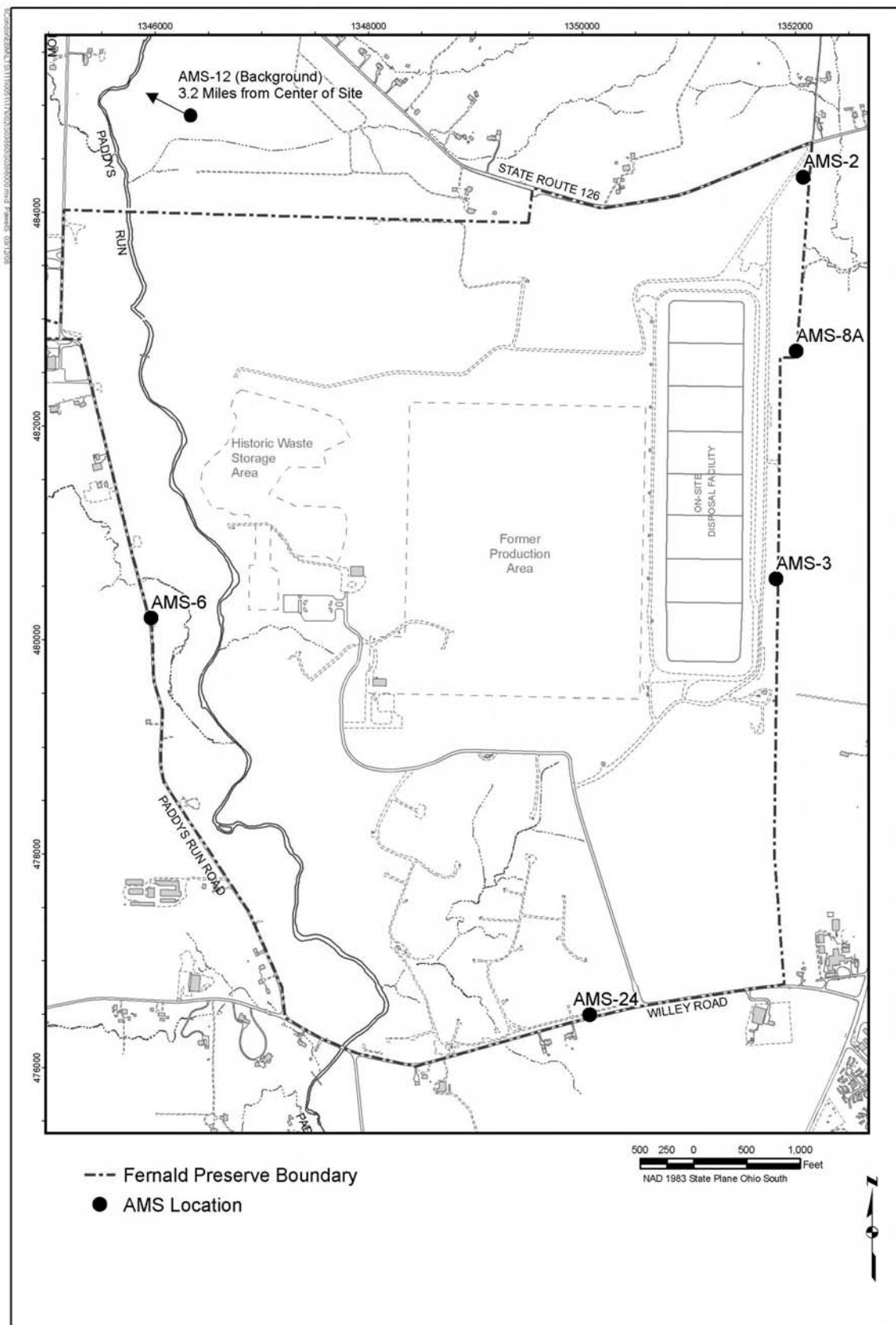


Figure C.1-1. IEMP Air Monitoring Locations

Table C.1-2. Total Uranium Concentration in Air Particulate^a

Location	2008 Results pCi/m ³ x 1E-06				2007 Results pCi/m ³ x 1E-06			
	Number of Samples ^b	Minimum	Maximum	Average	Number of Samples	Minimum	Maximum	Average
Boundary								
AMS-2	11	7.2 ± 0.37	18 ± 0.98	12 ± 0.24	12	11 ± 0.41	24 ± 0.42	15 ± 0.14
AMS-3	11	5.1 ± 0.21	19 ± 0.73	13 ± 0.37	12	6.0 ± 0.92	41 ± 1.31	18 ± 0.20
AMS-6	11	7.9 ± 1.07	15 ± 0.95	11 ± 0.29	12	9.2 ± 1.38	20 ± 0.75	16 ± 0.20
AMS-8A	11	7.2 ± 1.00	77 ± 2.46	19 ± 0.35	12	10 ± 0.41	54 ± 2.45	18 ± 0.28
AMS-24	11	6.6 ± 0.83	13 ± 0.75	9.6 ± 0.22	12	7.7 ± 0.33	26 ± 1.51	14 ± 0.17
Background								
AMS-12	11	8.1 ± 0.92	13 ± 1.79	11 ± 0.27	12	7.3 ± 1.08	18 ± 0.76	13 ± 0.17

^aMonthly samples (total U activity calculated assuming natural isotopic distribution)

^bSamples for July 2008 were inadvertently discarded by the laboratory after particulate mass was measured.

± = analytical uncertainty

Table C.1-3. Total Particulate Concentrations in Air^a

Location	2008 Results ug/m ³				2007 Results ug/m ³			
	Number of Samples	Minimum	Maximum	Average	Number of Samples	Minimum	Maximum	Average
Boundary								
AMS-2	12	11	45	28	12	1.2	39	21
AMS-3	12	13	59	27	12	1.7	46	25
AMS-6	12	5.8	60	28	12	1.5	42	26
AMS-8A	12	12	65	29	12	1.3	46	23
AMS-24	12	4.0	44	18	12	1.2	32	19
Background								
AMS-12	12	17	44	26	12	1.0	36	23

^aMonthly samples

An increase in particulate for the June time interval (samples collected in early July) corresponds to dry and dusty conditions in the early summer of 2008. The maximum particulate and uranium values observed at AMS-8A correspond to construction activities on the north access road (repairs and new gravel placement). In particular, the placement of new gravel appears to have generated higher dust levels (relative to other locations) that were captured at AMS-8A. Uranium associated with this dust is tied to the background uranium concentration in carbonate rock (generally less than 3 micrograms per gram [$\mu\text{g/g}$]), which is the source rock for the gravel. The uranium concentration in the June particulate from AMS-8A is 1.8 $\mu\text{g/g}$, which is about twice that observed for June samples from the other monitors. Although the uranium value for AMS-8A is elevated relative to other monitor locations, it is less than 4.5 $\mu\text{g/g}$, which is the 95 percent confidence limit for background uranium in soil (DOE 2001d).

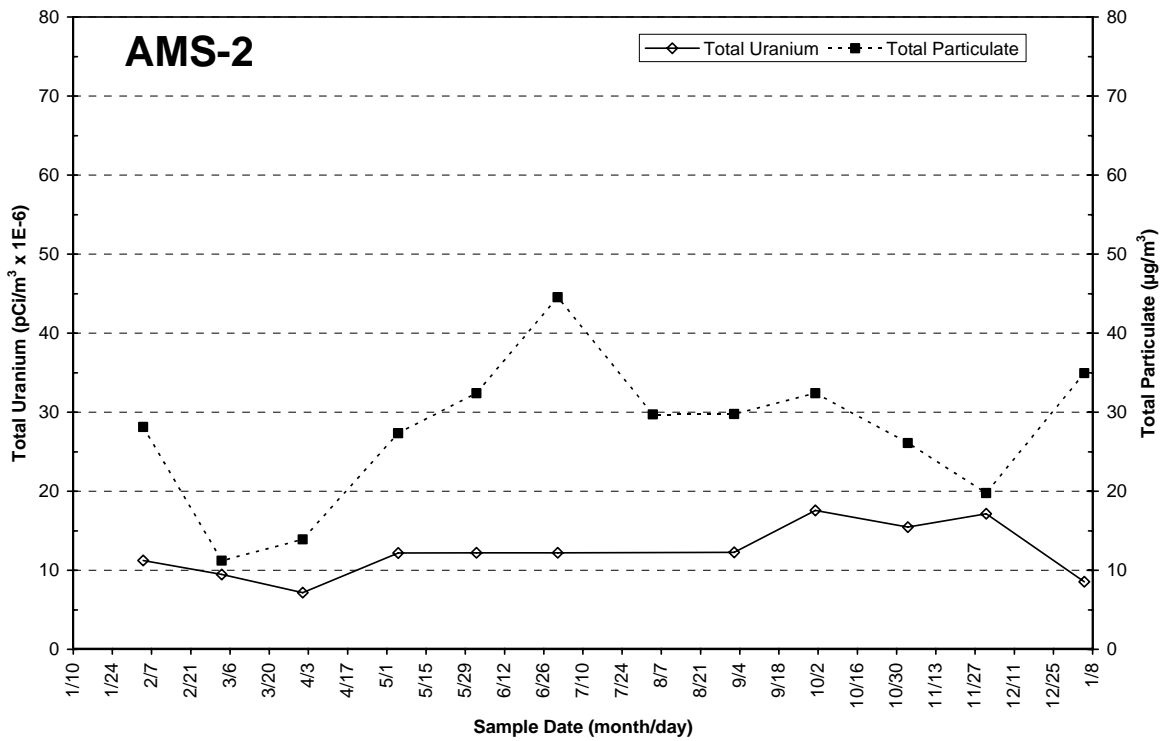


Figure C.1-2. 2008 Uranium and Particulate Air Concentrations at AMS-2

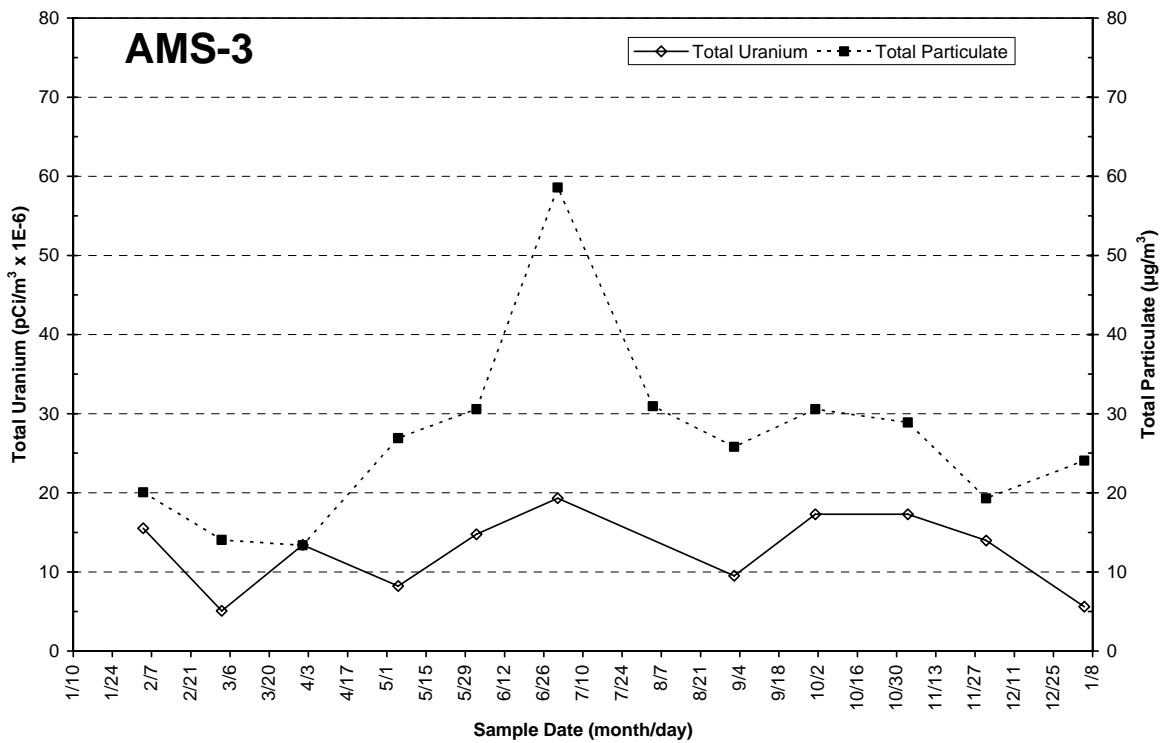


Figure C.1-3. 2008 Uranium and Particulate Air Concentrations at AMS-3

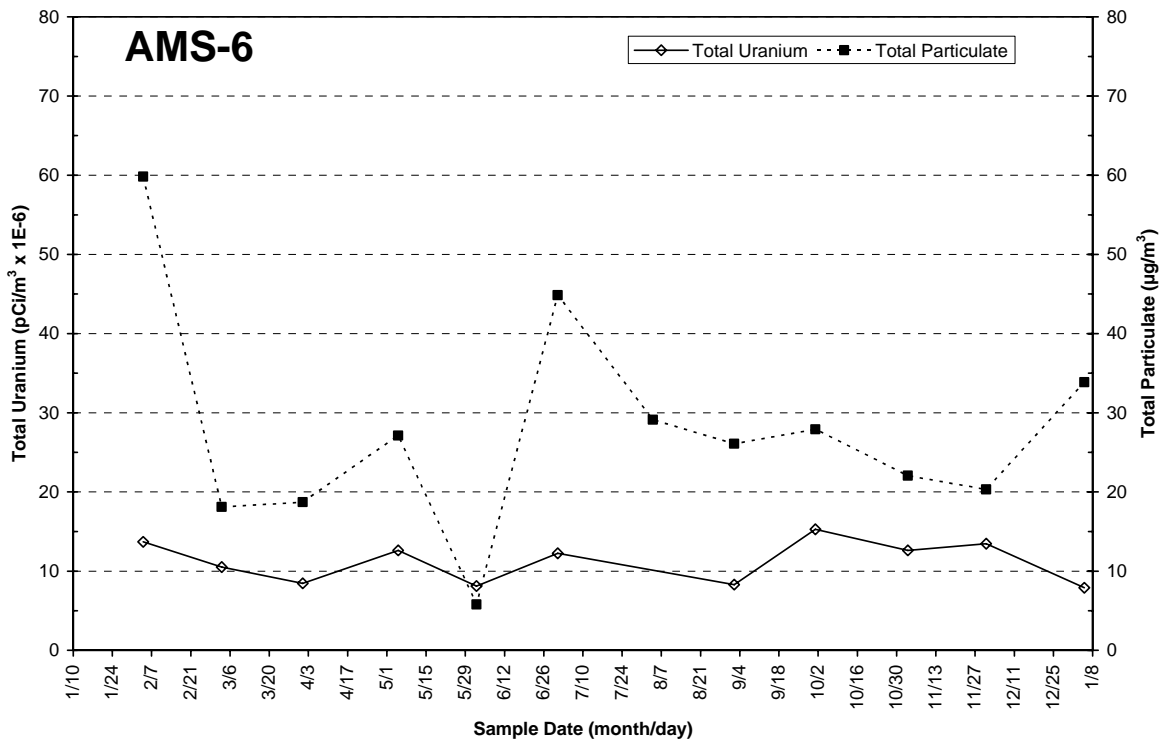


Figure C.1-4. 2008 Uranium and Particulate Air Concentrations at AMS-6

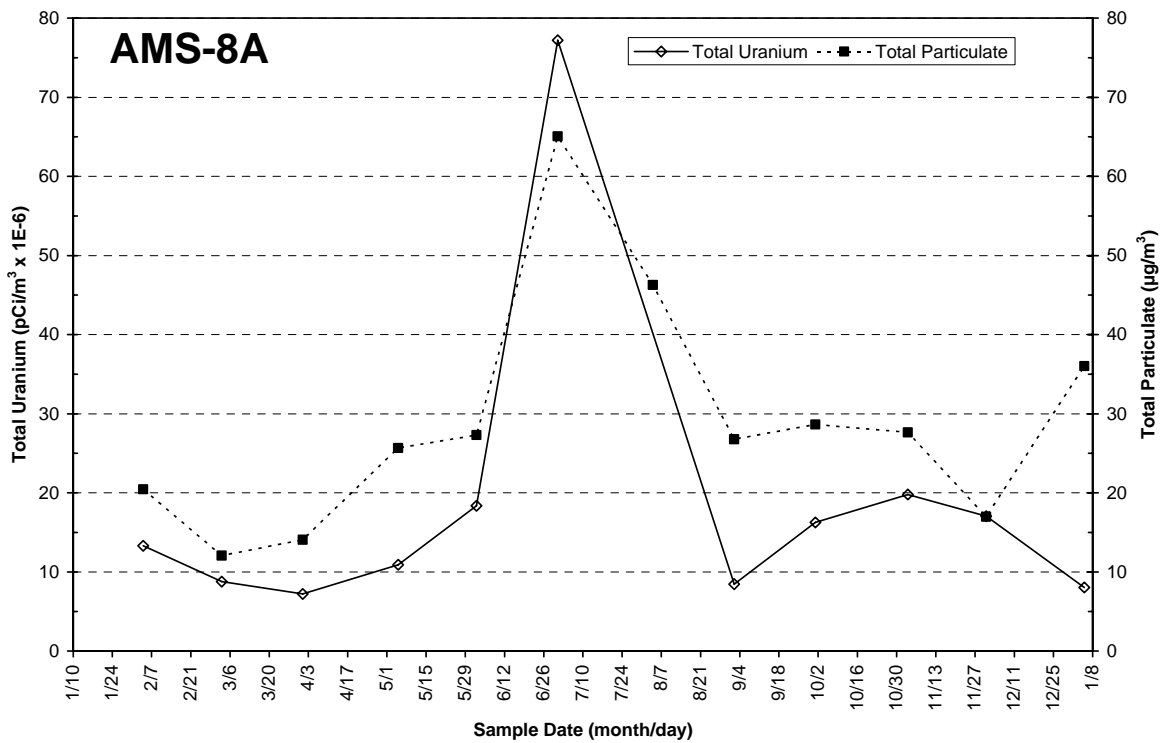


Figure C.1-5. 2008 Uranium and Particulate Air Concentrations at AMS-8A

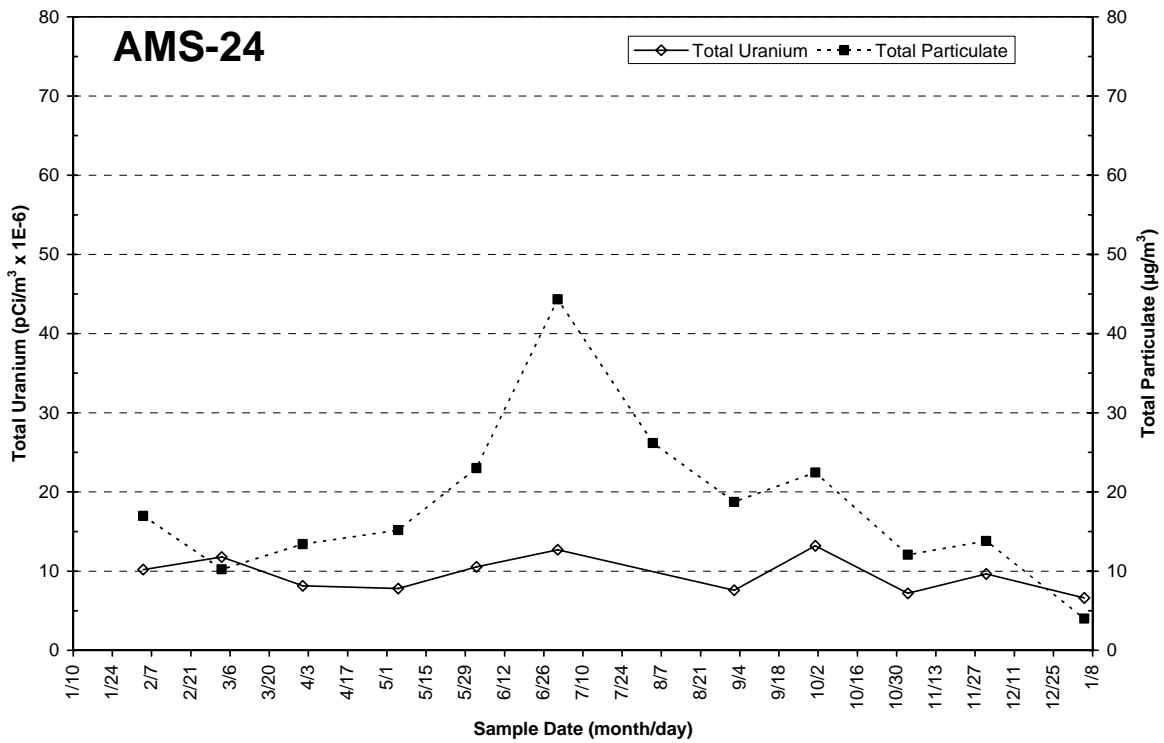


Figure C.1-6. 2008 Uranium and Particulate Air Concentrations at AMS-24

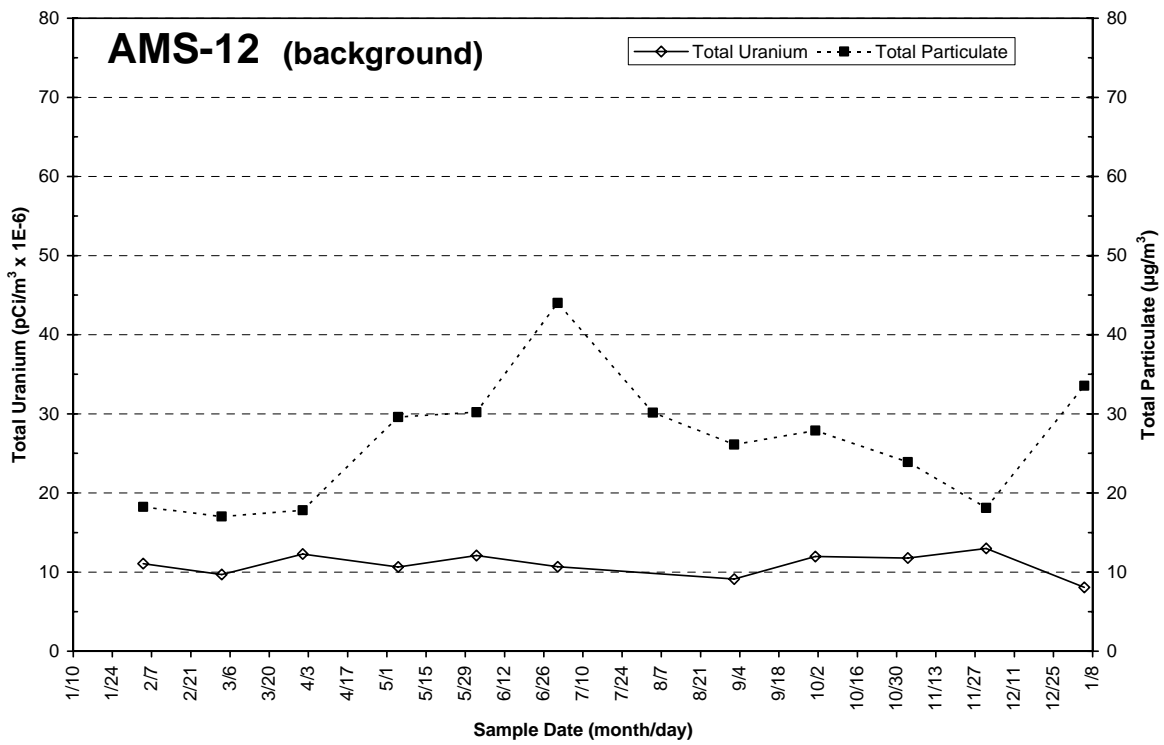


Figure C.1-7. 2008 Uranium and Particulate Air Concentrations at AMS-12

Figure C.1–8 shows that the mean and 95 percent confidence interval for monthly uranium and particulate data collected at the boundary monitors are not significantly different than the mean at the background location. This conclusion is consistent with the results of the soil certification process, which show that the uranium concentration in the site soil is below the final remediation levels established in the *Final Record of Decision for Remedial Actions at Operable Unit 5* (OU5 ROD) (DOE 1996). The large confidence interval for uranium samples at AMS-8A is due to the elevated uranium measurement for the June sample, as discussed previously and shown on Figure C.1–5.

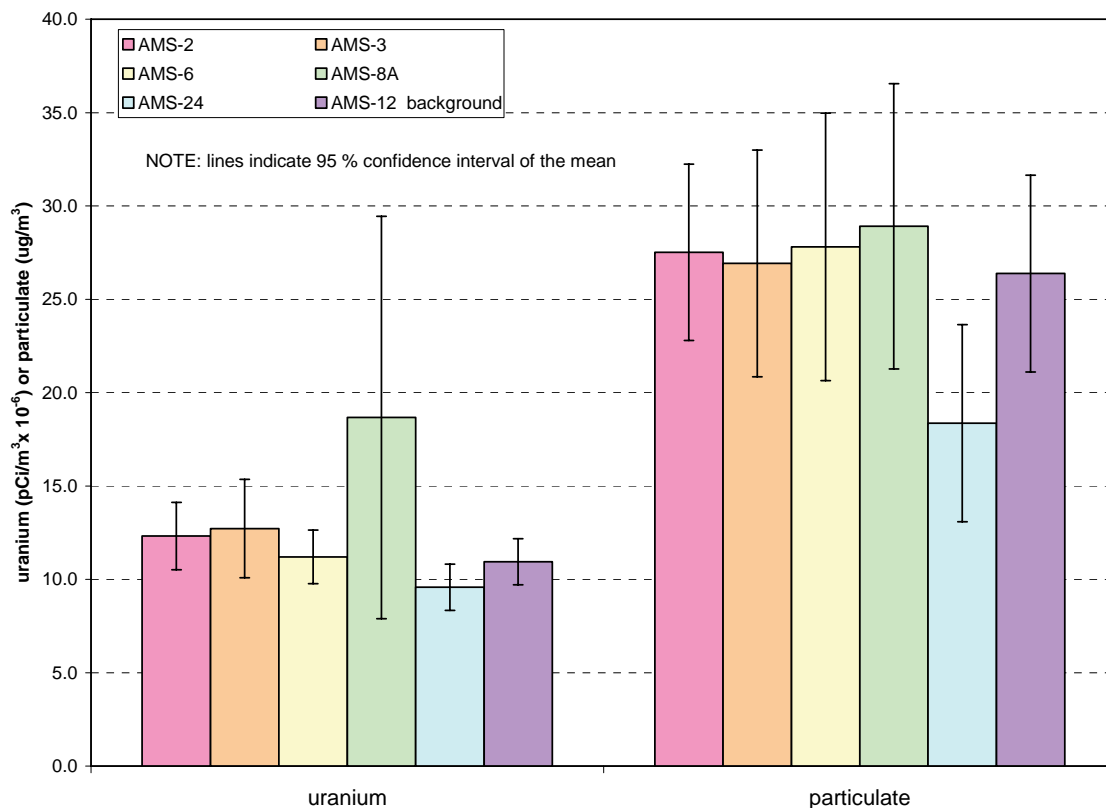


Figure C.1–8. 2008 Comparison of Means for Air Data

C.1.2 Evaluation of Isotopic Data from Airborne Emissions

Quarterly composites of the monthly samples were analyzed for the isotopes of uranium (234, 235, and 238), thorium (228, 230, and 232) and radium (226) to evaluate compliance with NESHAP requirements (Appendix D). Average values and uncertainties (Table C.1–4) indicate the isotope activities in the particulate collected at the site boundary are similar to those collected at the background location. As noted in Section C.1.1, samples for July were lost by the laboratory after particulate mass was measured, so the third-quarter results are based on a 2-month composite (August and September).

A plot of the mean and 95 percent confidence interval (Figure C.1–9) for the quarterly results indicates there is not a significant difference between the boundary and background monitors. However, the large confidence interval for some results reflects a large standard deviation at some locations, and this reflects the analytical challenges of analyzing samples with low activity,

rather than true variation at the location. When the analytical measurement uncertainty and confidence interval are taken into consideration, the locations have essentially the same result, which indicates the remediation of soil achieved the OU 5 final remediation levels established for the radionuclide contaminants.

On an elemental basis, the boundary data (represented by the sum of all monitors for each element) show the total activity to be distributed as 20 percent uranium, 24 percent thorium, and 56 percent radium (Table C.1–4). The 2008 background activities (AMS-12) are distributed as 14 percent uranium, 22 percent thorium, and 64 percent radium. Slight differences in the boundary and background distribution are expected, as soil remediation activities restored isotopic values in the soil to concentrations below the final remediation levels established in the OU5 ROD, which are slightly different than background values.

Table C.1–4. 2008 Average Radionuclide Concentrations in Air Particulate^{a,b}

Location	Concentration (pCi/m ³)							Total Activity
	U-234	U-235 ^c	U-238	Th-228	Th-230	Th-232	Ra-226	
Boundary								
AMS-2	5.60E-06	0.00E+00	5.30E-06	6.90E-06	4.90E-06	1.90E-06	3.50E-05	5.96E-05
±	6.70E-07	NA	6.60E-07	8.90E-07	6.10E-07	4.40E-07	4.00E-06	4.27E-06
AMS-3	5.50E-06	0.00E+00	6.60E-06	1.00E-05	4.70E-06	3.10E-06	3.60E-05	6.59E-05
±	7.10E-07	NA	7.40E-07	1.00E-06	6.40E-07	5.20E-07	5.80E-06	6.03E-06
AMS-6	5.20E-06	0.00E+00	5.40E-06	7.20E-06	4.40E-06	2.80E-06	3.90E-05	6.40E-05
±	7.00E-07	NA	6.80E-07	8.90E-07	5.80E-07	5.40E-07	4.10E-06	4.38E-06
AMS-8A	7.60E-06	5.90E-07	8.30E-06	7.20E-06	5.70E-06	3.00E-06	4.80E-05	8.04E-05
±	7.30E-07	2.10E-07	7.50E-07	9.10E-07	6.50E-07	5.10E-07	4.40E-06	4.69E-06
AMS-24	4.40E-06	0.00E+00	4.60E-06	4.90E-06	4.60E-06	2.30E-06	1.20E-05	3.28E-05
±	5.50E-07	NA	5.30E-07	8.00E-07	5.80E-07	4.30E-07	2.50E-06	2.83E-06
Sum for Boundary Monitors								
	2.83E-05	5.90E-07	3.02E-05	3.62E-05	2.43E-05	1.31E-05	1.70E-04	3.03E-04
±	1.51E-06	2.10E-07	5.30E-07	2.01E-06	1.37E-06	1.10E-06	9.59E-06	1.01E-05
Background								
AMS-12	5.40E-06	0.00E+00	4.50E-06	7.90E-06	4.90E-06	3.10E-06	4.60E-05	7.18E-05
±	6.30E-07	NA	5.70E-07	9.60E-07	6.50E-07	5.20E-07	4.10E-06	4.38E-06
Isotope Percent								
	U-234	U-235	U-238	Th-228	Th-230	Th-232	Ra-226	Total
boundary ^d	9.35	0.19	9.98	11.96	8.03	4.33	56.2	100
background	7.52	0.00	6.27	11.00	6.82	4.32	64.1	100

^aA concentration of 0.00 indicates the filter results were below the detection limit or equal to or less than the blank results.

^bAverage obtained by summing the activity of four quarterly composite samples and dividing by total annual air volume through the monitor.

^cNA = not applicable

^dRepresents the sum of all boundary monitors.

± = 2 sigma error propagated from reported quarterly errors.

Data in Table C.1–4 are also used for the NESHAP calculations presented in Appendix D. The NESHAP calculations evaluate the dose contribution in excess of background for radium, thorium and uranium isotopes. A summary of the elemental distribution of dose at each boundary monitor is provided on Figure C.1–10. Note that the quarterly composite samples were not analyzed for radium-224, radium-228, and thorium-231 isotopes, but they are assumed to be in secular equilibrium with their parent isotopes for the NESHAP analysis. The receptor dose at AMS-2, AMS-6, and AMS-24 is entirely due to uranium, as uranium isotopes are the only nuclides above background at these locations. At AMS-3, the majority of the dose is attributed to thorium, whereas radium contributes a significant dose at AMS-8A. However, the maximum total dose from all isotopes is 0.017 millirem per year (mrem/yr) above background at AMS-8A, which is well below the allowed NESHAP limit of 10 mrem/yr above background (see Appendix D).

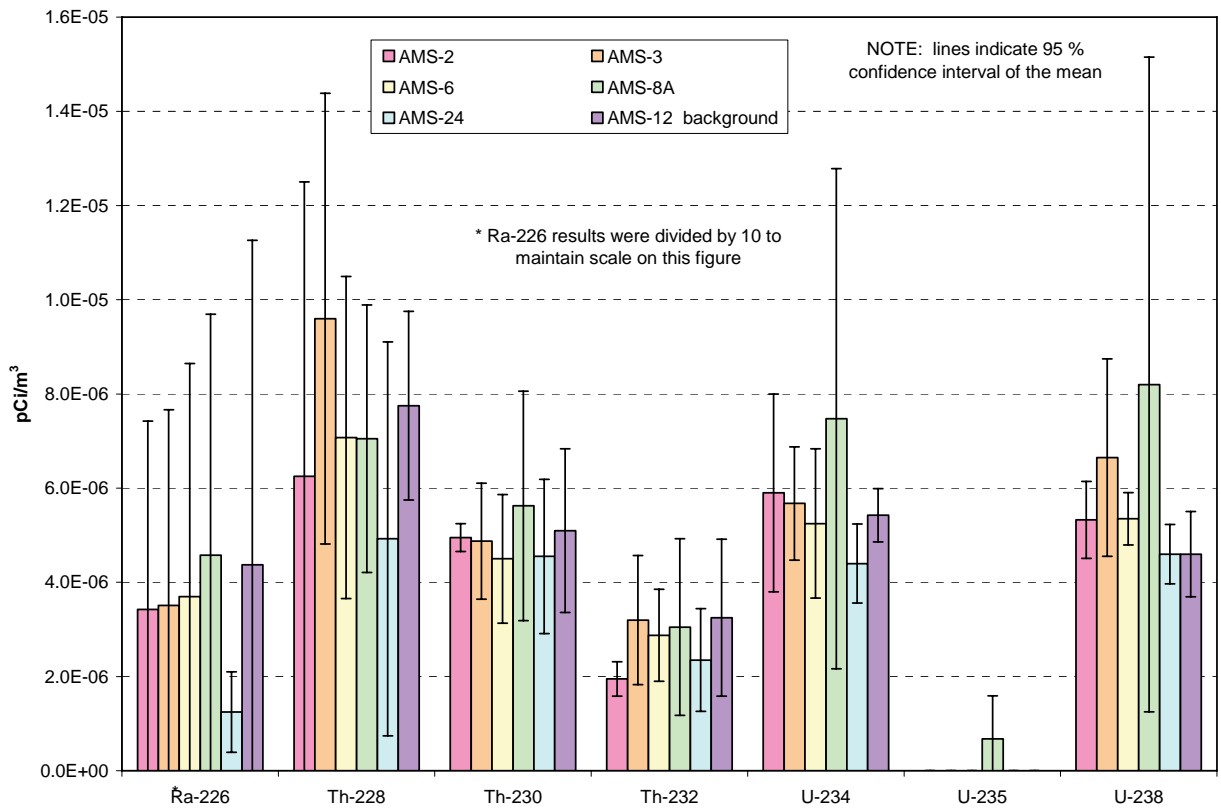


Figure C.1-9. 2008 Comparison of Means for NESHAP Data

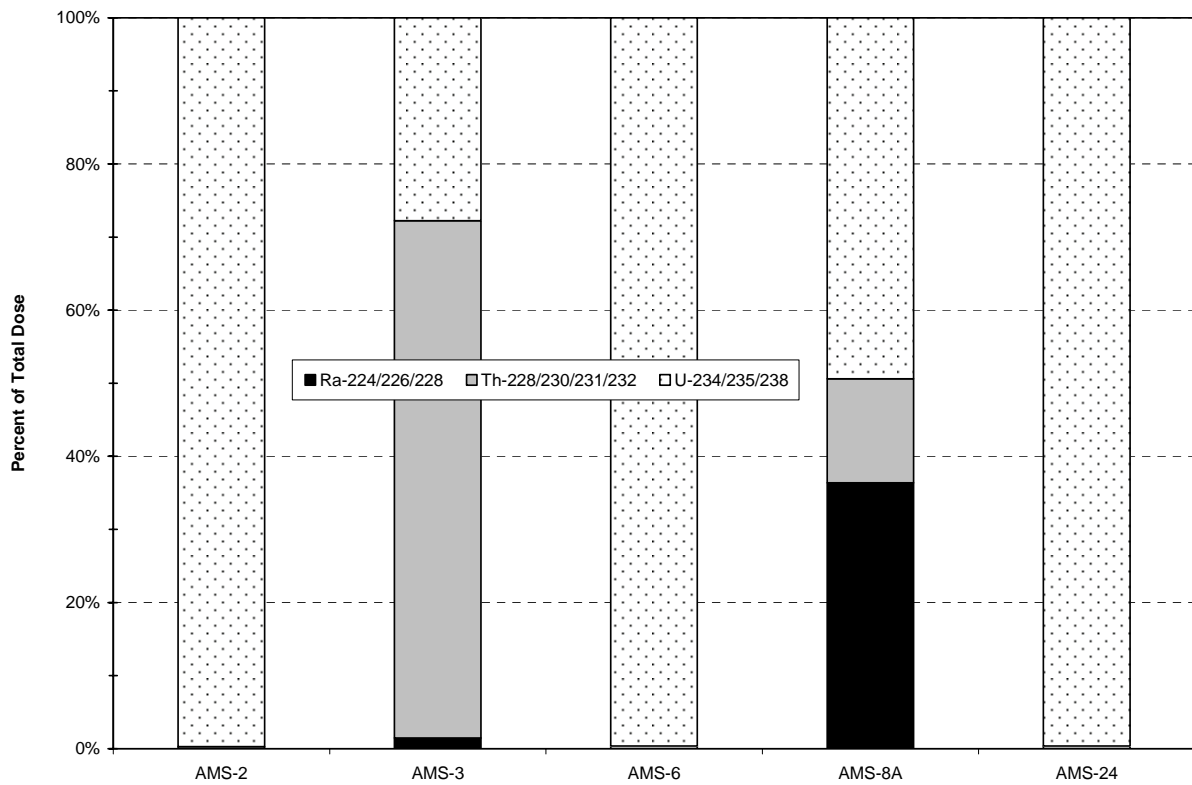


Figure C.1-10 2008 Isotopic Dose Contributions at AMS Locations

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Attachment C.2: Radon

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C.2.0 Radon

The Fernald Preserve radon monitoring program was reduced to five boundary monitors and one background monitor in January 2007 (Figure C.2–1), as radon emissions associated with the silos treatment facilities ceased in 2006 and there is no longer a significant surface source for radon on the site.

Radon data collected in 2008 at the six monitors are compared to the radon concentration standards contained in DOE Order 5400.5 (DOE 1993) and proposed Title 10 *Code of Federal Regulations* Part 834 (10 CFR 834) as follows:

- In DOE Order 5400.5, the annual average limit over the site is 30 picocuries per liter (pCi/L) above background, and 100 pCi/L above background at any point over the facility. As expected, the limits were not exceeded in 2008 because significant surface sources for radon no longer exist at the Fernald Preserve.
- The proposed 10 CFR 834 annual average limit at and beyond the facility boundary is 0.5 pCi/L above background; there were no exceedances in 2008.

Continuous monitors used at the Fernald Preserve boundary track daily changes in the radon levels and determine compliance with the noted standards. The monitor instruments report hourly radon values to the nearest 0.1 pCi/L, and measurement uncertainty is not given on the data log. In 2008, the radon monitors at the site boundary operated greater than 95 percent of the time. The downtime was associated with downloading instrument data, interruptions due to extremely cold temperatures, power interruptions, or an increase in routine maintenance.

Table C.2–1 provides a summary of the minimum, maximum, and average radon concentrations for 2008 and 2007. There are no significant differences between the 2007 and 2008 data sets.

Figure C.2–2 shows the net annual average radon concentration (boundary average minus background average) recorded at each location. All locations show background corrected radon values that are below the 10 CFR 834 proposed limit of 0.5 pCi/L above background.

Figures C.2–3 through C.2–7 summarize the monthly average reading for each boundary monitor, which is derived from hourly readings. An overall trend observed on the charts is an increase in measurable radon from late summer into fall, which is attributed to warm and dry conditions that promote soil fractures and release of radon gas. This trend is common in data from previous years, but the extension of the trend well into the fall of 2008 reflects the low rainfall in September, October, and November of 2008 (see Table C.4–1 in Attachment C.4). The charts show monthly values that fall between the 0.1 pCi/L measurement resolution due to calculations within the spreadsheet that are not truncated to one significant figure.

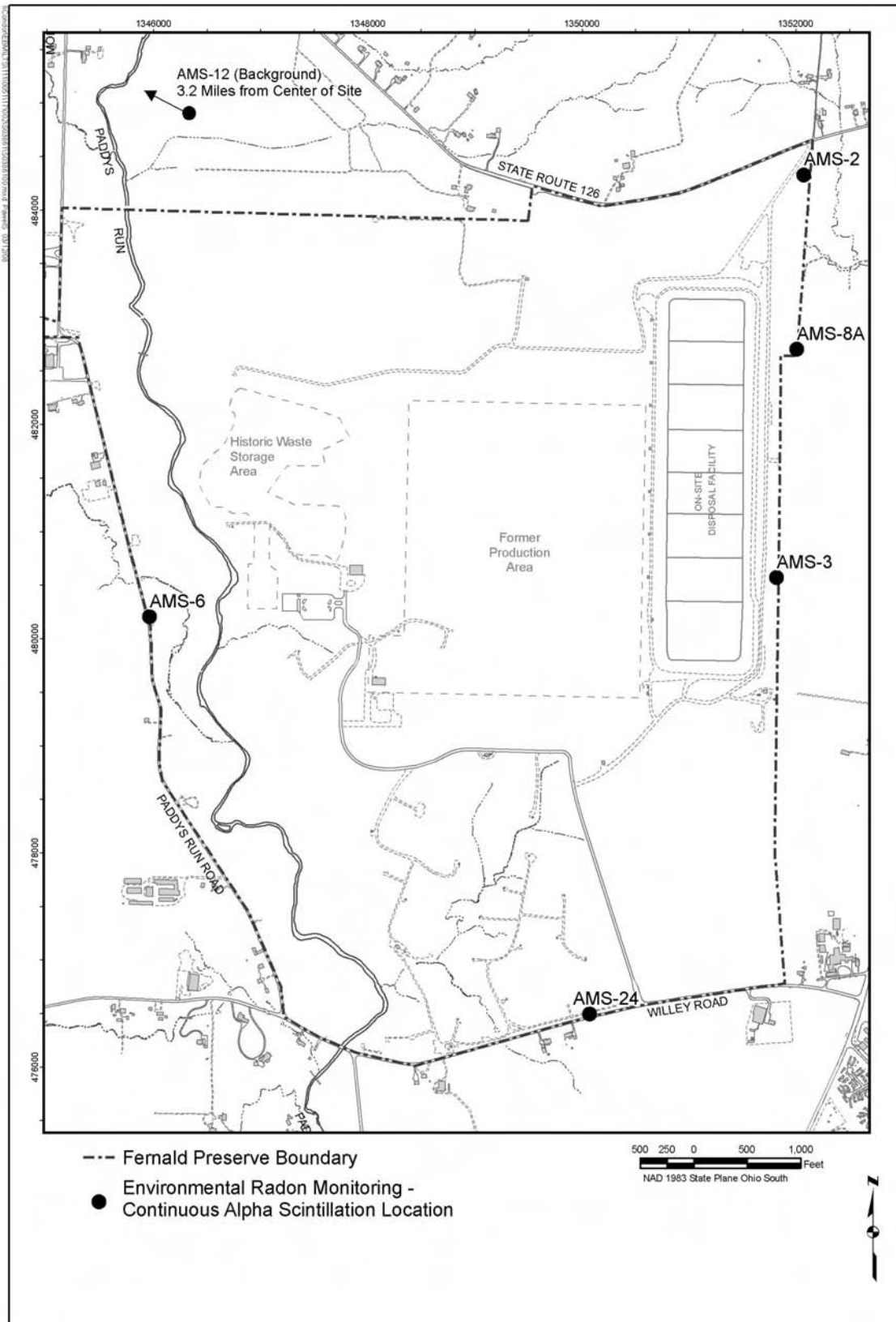


Figure C.2-1. Radon Monitoring Locations

Table C.2-1. Continuous Radon Monitors^a

Location	2008 Results (pCi/L)			2007 Results (pCi/L)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Boundary						
AMS-2	0.2	0.8	0.4	0.2	0.7	0.3
AMS-3	0.2	0.9	0.5	0.2	0.8	0.5
AMS-6	0.2	0.9	0.5	0.2	0.7	0.3
AMS-8A	0.1	0.7	0.4	0.2	0.7	0.3
AMS-24	0.1	0.9	0.5	0.3	0.8	0.4
Background						
AMS-12	0.1	0.5	0.3	0.2	0.5	0.3

^aMonthly averages used to calculate annual minimum, maximum, and average

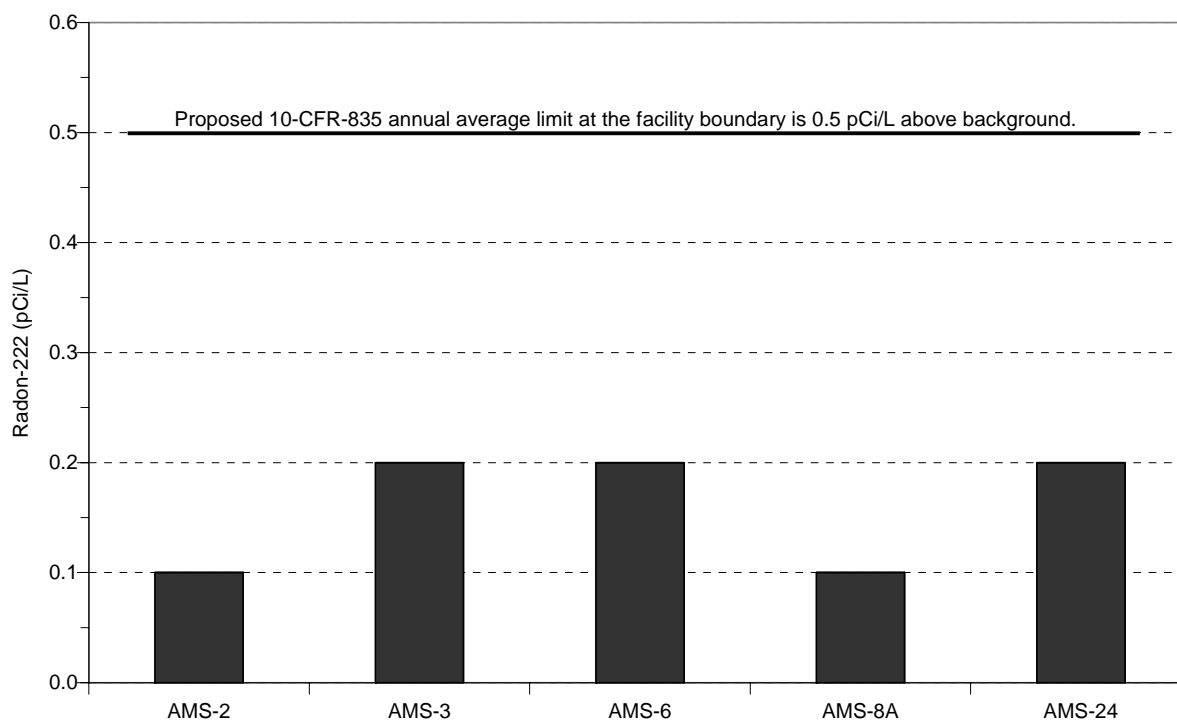


Figure C.2-2 2008 Net Annual Average Concentration for Each Facility Boundary Monitor

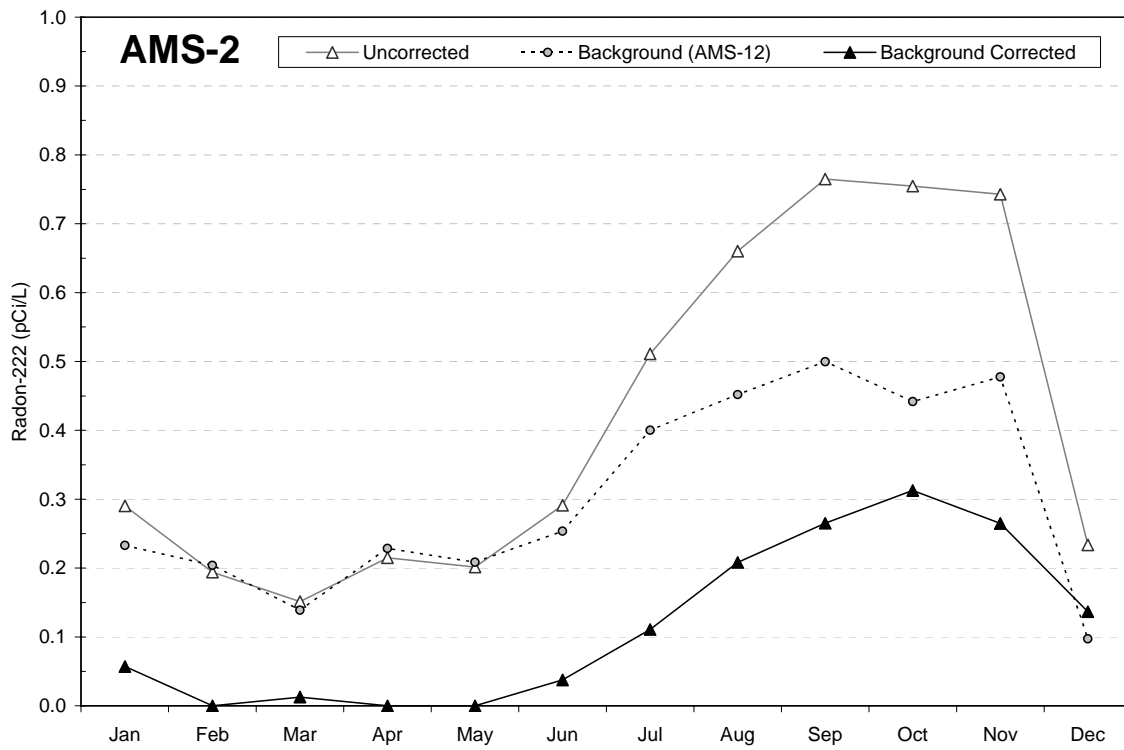


Figure C.2-3 2008 Monthly Average Concentration at AMS-2 Boundary

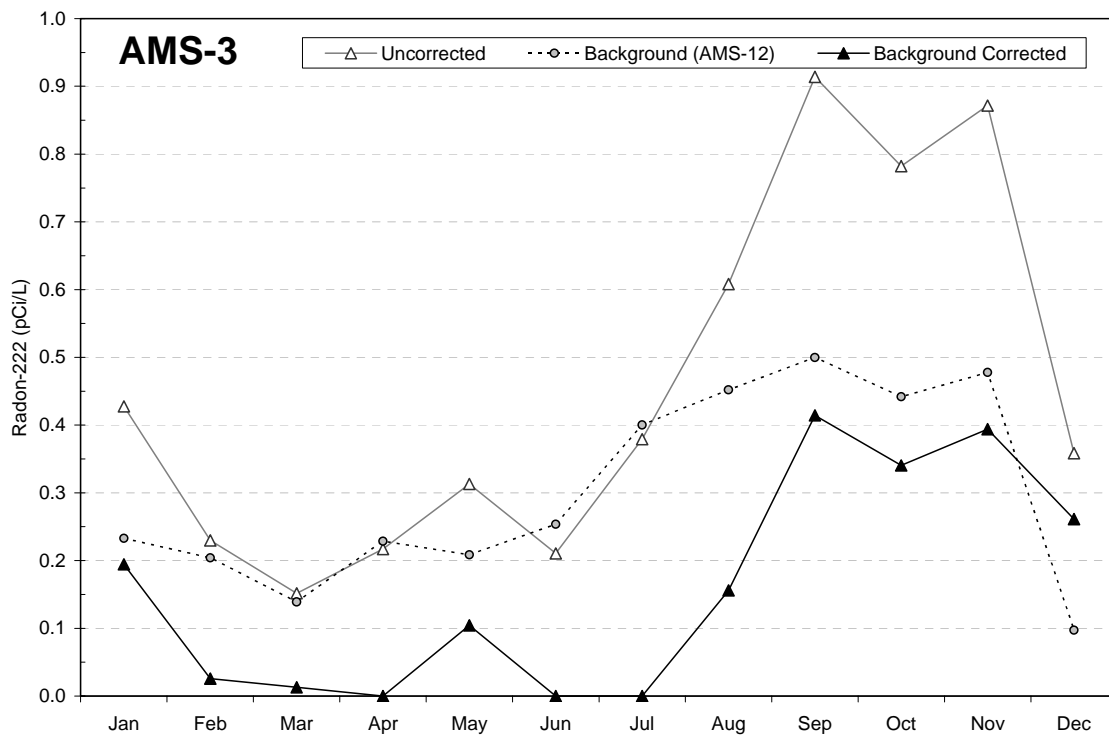


Figure C.2-4 2008 Monthly Average Concentration at AMS-3 Boundary

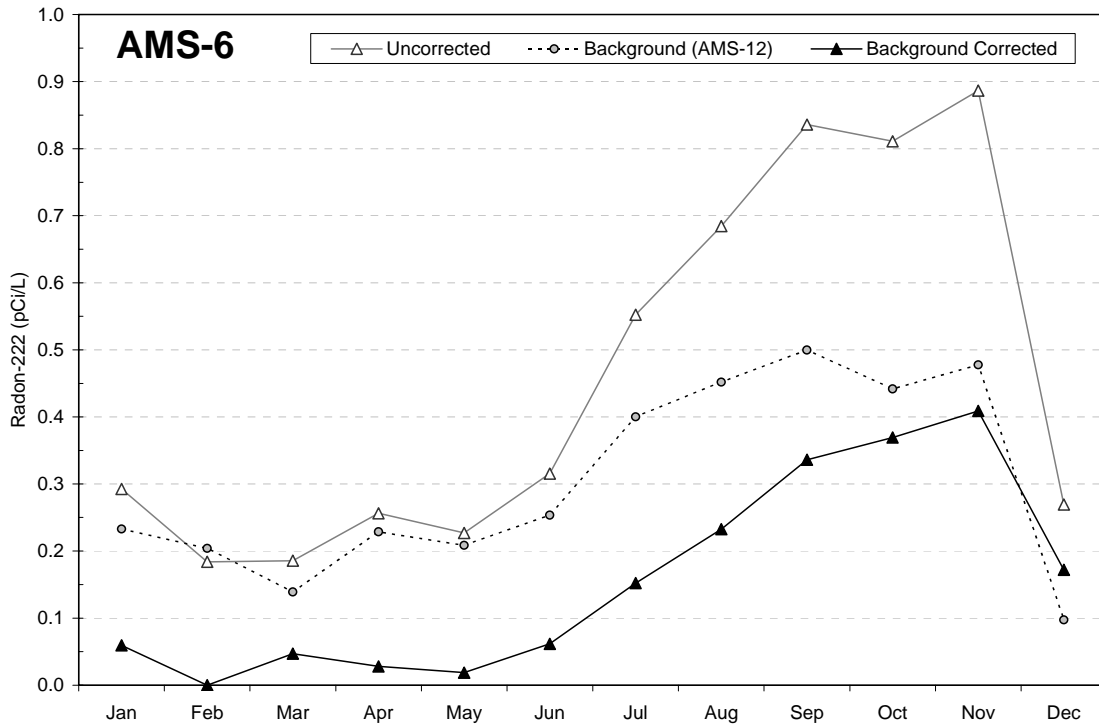


Figure C.2-5 2008 Monthly Average Concentration at AMS-6 Boundary

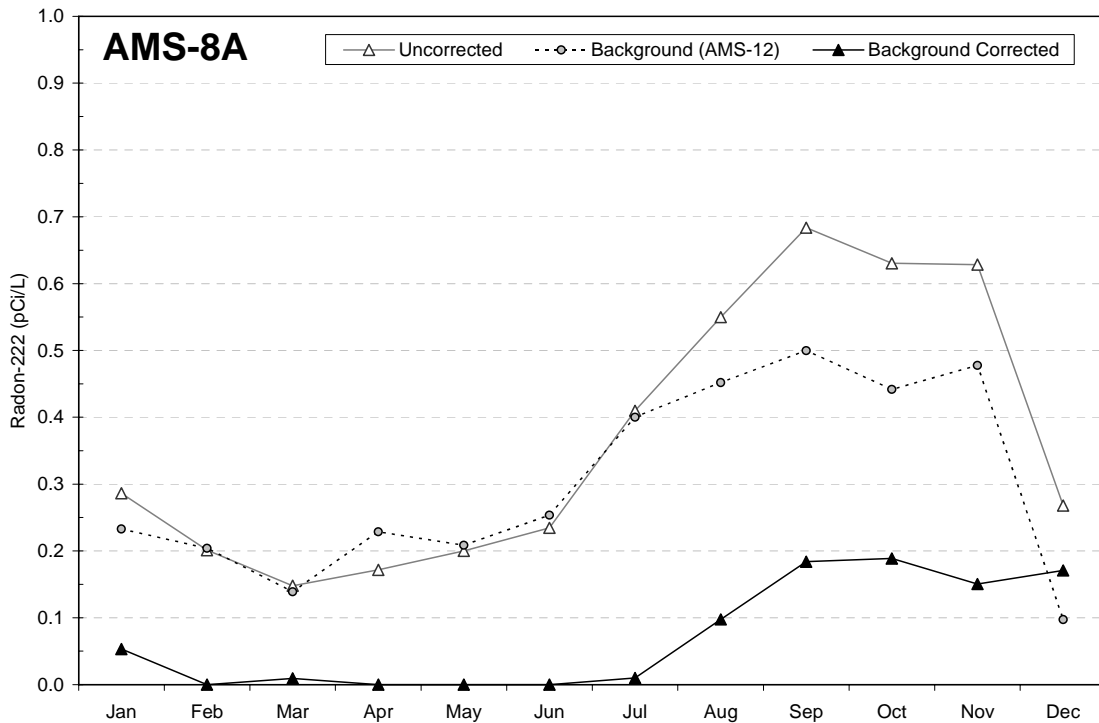


Figure C.2-6 2008 Monthly Average Concentration at AMS-8A Boundary

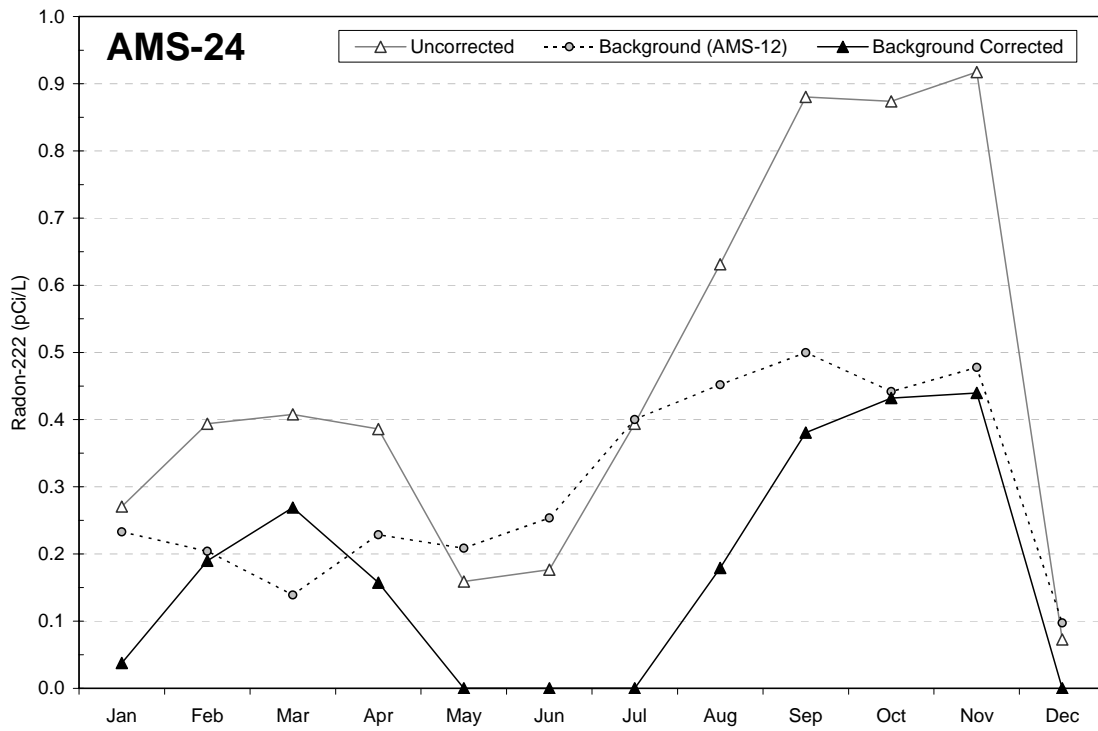


Figure C.2-7 2008 Monthly Average Concentration at AMS-24 Boundary

Attachment C.3: Direct Radiation

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C.3.0 Direct Radiation

Direct radiation measurements were collected at six monitoring locations using thermoluminescent dosimeters (TLDs). Five of the TLDs are located along the Fernald Preserve boundary (2, 3, 6, 8A, and 35) and one is placed at the background station (27) northwest of the site (Figure C.3–1). Three TLDs are deployed at each location to track and evaluate direct radiation, and each TLD is collected and measured on a quarterly basis (approximately every 91 days). The three measurements are averaged to obtain a quarterly result for each location. Quarterly results and errors are plotted on Figure 5–6 in Section 5.

Table C.3–1 provides a summary of the annual dose for 2008 and 2007, and the results indicate no significant difference between the 2007 and 2008 data. Annual dose is calculated by summing the quarterly results at each location. Quantification of the direct radiation dose delivered to an individual at the Fernald Preserve boundary (Appendix D) indicates there is no significant dose associated with direct radiation.

Results presented in Appendix D are in line with Figure C.3–2, which shows that the 95 percent confidence interval of the mean for the quarterly values overlaps for boundary and background (location 27) monitors. Moreover, the Fernald Preserve no longer has open waste disposal areas to serve as surface sources for direct radiation. Given the lack of sources and statistically similar boundary and background values in 2007 and 2008, it is reasonable to expect future readings to be at or near background levels.

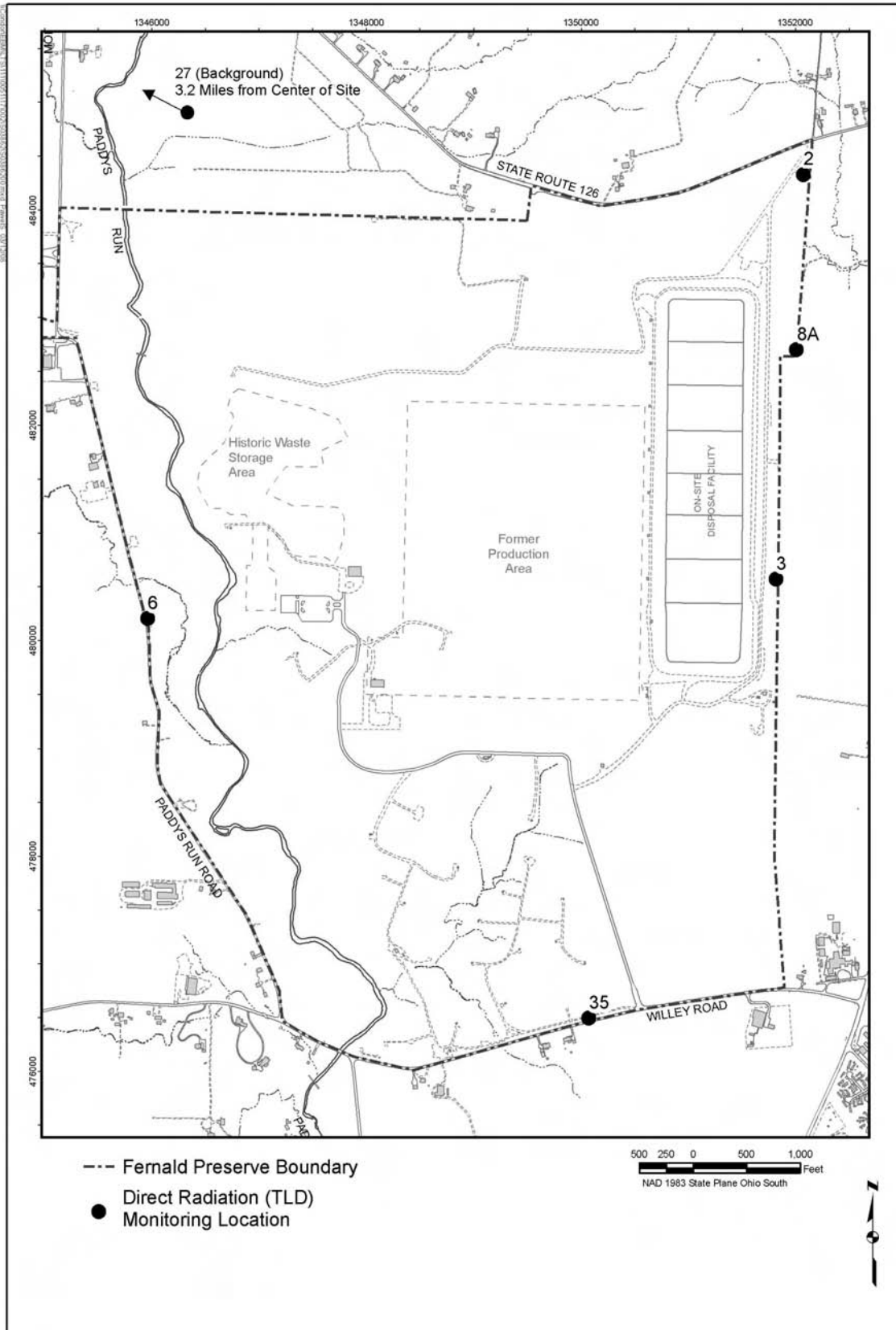


Figure C.3-1. Direct Radiation (TLD) Monitoring Locations

Table C.3-1. Dose based on Direct Radiation (TLD) Measurements

Location	Direct Radiation (mrem) ^a	
	2008	2007
Boundary		
2	52	52
3	52	49
6	51	49
8A	54	53
35	48	47
Minimum	48	47
Maximum	54	53
Background		
27	48	48

^a Annual dose is derived by summing the average quarterly result for each location.

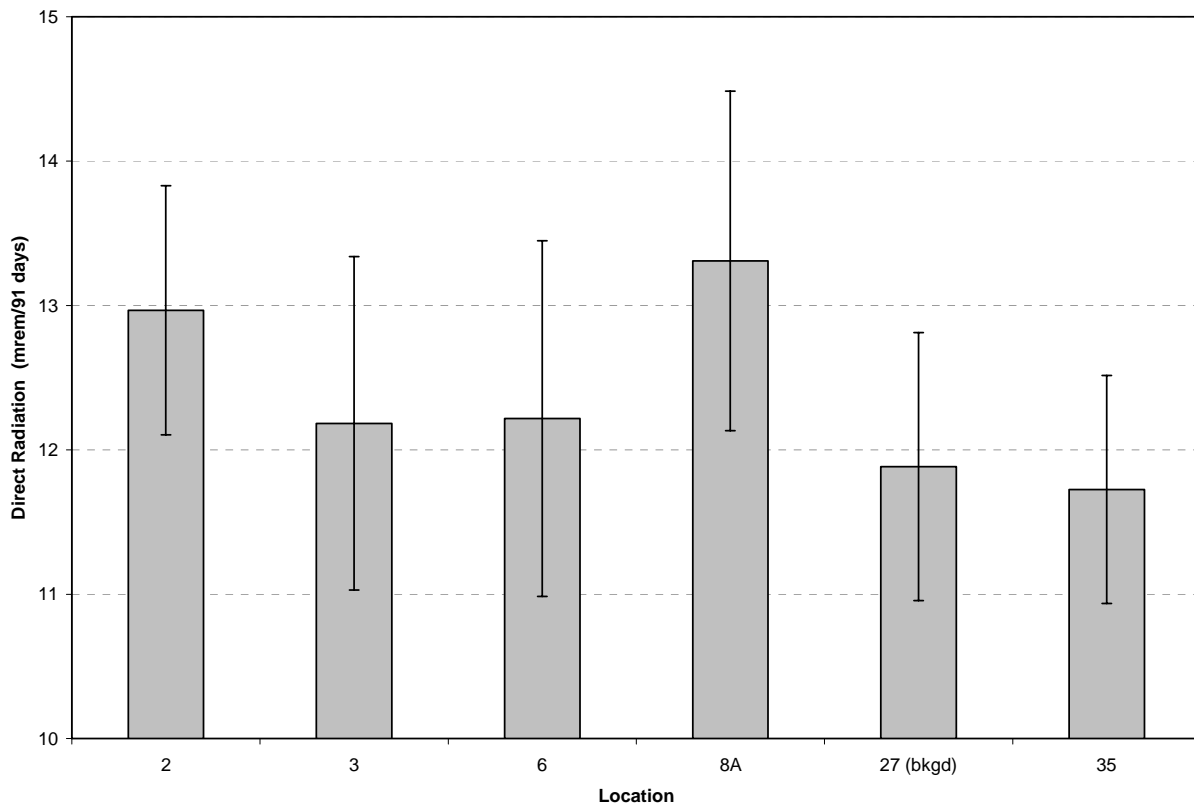


Figure C.3-2. 2008 Mean and 95 Percent Confidence Interval for Quarterly Measurements

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Attachment C.4: Meteorological Data

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C.4.0 Meteorological Data

Meteorological data were collected at the Fernald site's meteorological station through May 16, 2006, when the station was shut down. As meteorological data have not been collected at the Fernald Preserve since May 2006, two sources were used to obtain the data used in the 2007 and 2008 dose assessments. Temperature and precipitation data were obtained from the Butler County Airport. Wind velocity and direction data were obtained by averaging the wind data collected at the former site meteorological station over the period 2002 through 2006, as these parameters are sensitive to vegetative cover and topography and play a key role in predicting how pollutants are distributed in the surrounding environment.

Wind speed data from the 10-meter and 60-meter heights (Table C.4-1) are summarized as monthly maximum and minimum, with the largest range occurring in March (42 and 0.3 miles per hour [mph] at the 10-meter height; 52 and 0.4 mph at 60-meter height). Ambient air temperature at the 10-meter level includes monthly average, maximum, and minimum. As expected for the northern hemisphere, the yearly maximum temperatures occur from May through August, with minimums observed in January and February. Historical precipitation information indicates that April and May are the wettest months; however, March and May were the wettest months of 2008.

Table C.4-2 indicates the prevailing winds are from the southwest quadrant (WSW, SW, and SSW) about 39 percent of the time at the 10-meter height and about 35 percent of the time for the 60-meter height. Winds out of the north and east quadrants are the least frequent. Average wind speed varies from 3 to 7 mph at the 10-meter height and 5 to 10 mph at the 60-meter height.

Although meteorological data on wind speed and direction were not collected in 2008, it is assumed that the Fernald 2002 to 2006 values for wind speeds and directions are representative of present conditions at the Fernald Preserve, and the information in Table C.4-2 was used for the dose assessment presented in Attachment C.5.

Table C.4-1. Meteorological Data

	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10-Meter Wind Velocity^a													
Maximum (hourly average)	mph	32	37	42	36	34	27	37	31	28	30	33	31
	kph	51	59	67	57	54	44	59	49	44	48	52	49
Minimum (hourly average)	mph	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2
	kph	0.5	0.4	0.5	0.5	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4
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60-Meter Wind Velocity^a													
Maximum (hourly average)	mph	44	49	52	47	41	35	48	35	42	40	45	42
	kph	70	78	82	75	66	55	77	57	67	65	72	68
Minimum (hourly average)	mph	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.2	0.2	0.4	0.2
	kph	0.6	0.4	0.7	0.7	0.6	0.6	0.6	0.4	0.4	0.4	0.7	0.4
<hr/>													
Ambient Air Temperature^b													
Average	°F	30	32	40	54	60	73	75	73	68	54	40	33
	°C	-1	0	5	12	15	23	24	23	20	12	5	1
Maximum	°F	64	61	58	71	74	81	81	80	80	70	57	64
	°C	18	16	14	22	23	27	27	27	27	21	14	18
Minimum	°F	11	12	16	41	52	63	68	66	61	39	22	11
	°C	-12	-11	-9	5	11	17	20	19	16	4	-6	-12
<hr/>													
Precipitation^b													
Total	in	1.8	4.2	9.3	2.3	5.8	4.8	2.6	4.3	0.8	1.5	1.8	4.6
	cm	4.6	10.6	23.7	5.8	14.6	12.3	6.5	11.0	2.1	3.8	4.6	11.6
Daily Maximum	in	0.8	1.3	3.3	0.6	1.4	1.7	0.9	2.7	0.3	0.9	0.7	1.4
	cm	2.0	3.2	8.4	1.6	3.6	4.4	2.2	6.8	0.7	2.2	1.9	3.6

^aWind-velocity data were not collected at the Fernald Preserve in 2007 or 2008. Values represent 5-yr average for site data collected from 2002 through mid-2006.

^b2008 Data obtained from the airport in Butler County, Ohio.

Table C.4-2. Average Wind Speed and Percent of Time from Direction at 10 and 60 Meters Above Ground Level^a

Direction	Average 10-meter Wind Speed		Percent of Time from Direction ^b	Average 60-meter Wind Speed		Percent of Time from Direction ^b
	(mph)	(kph)		(mph)	(kph)	
N	6	10	1.5	9	14	1.5
NNE	7	11	2.7	10	16	3.7
NE	6	9	5.4	8	13	8.0
ENE	5	8	6.7	7	11	8.3
E	4	6	4.0	6	10	4.3
ESE	3	5	2.9	5	9	2.7
SE	3	5	3.3	6	9	3.2
SSE	3	6	4.1	7	11	3.8
S	5	7	6.8	9	14	7.4
SSW	6	10	13.0	10	16	13.1
SW	5	8	14.8	9	15	11.9
WSW	4	6	11.1	10	15	9.6
W	4	7	9.3	10	15	7.9
WNW	5	8	6.9	10	15	5.9
NW	6	9	5.4	10	15	5.5
NNW	7	12	2.4	10	16	3.2

^a Wind-velocity data were not collected at the Fernald Preserve in 2007 or 2008. Values represent 5-yr average for site data collected from 2002 through mid-2006.

^b Percent of time wind is blowing from the indicated direction.

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Attachment C.5: Supplemental Dose Assessments

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C.5.0 Supplemental Dose Assessments

This attachment contains a detailed discussion of the supplemental dose assessments performed for calendar year 2008, and compares the 2008 results to those from 2000 through 2007. The population and biota dose assessments comprise the supplemental dose assessment, which provides required information for compliance with DOE Order 5400.5 (DOE 1993).

A population dose assessment provides an aggregate measure of the impact of airborne emissions and direct radiation from sources at the Fernald Preserve to the population in the area. However, with the completion of soil remediation and capping of the final OSDF cells in 2006, the only remaining source for airborne emissions and direct radiation is the soil. As the soil has been certified to contain contaminant levels below the Operable Unit 5 final remediation levels, there is no remaining source to deliver a statistically significant dose to the public. The population dose assessment presented below supports this conclusion.

The groundwater remediation program continues to discharge large volumes of water to the Great Miami River, and the biota dose assessment provides information on the Fernald Preserve's compliance with dose limits to aquatic organisms in the Great Miami River.

C.5.1 Population Dose Assessment

Computation of a population dose is a requirement of DOE Order 5400.5, which defines population dose as the collective effective dose equivalent. Collective effective dose is the dose spread across the population within a 50-mile radius of the site. For 2008, the effective dose equivalent was 0.058 person-rem/yr. This includes 0.039 person-rem/yr from site airborne emissions (excluding radon) and 0.019 person-rem/yr from the direct radiation component (Table C.5-1). There was no estimated biota dose to the population from consumption of produce, as the produce monitoring program was completed in 2003.

Table C.5-1. Estimated Population Doses (person-rem)

	2000	2001^a	2002^a	2003	2004^a	2005^a	2006^a	2007^a	2008^a
Air Inhalation	3.29	3.35	3.47	3.84	3.87	1.2	0.485	0.010	0.039
Direct radiation	0.108	0.159	0.23	0.155	0.47	0.35	0.030	0.015	0.019
Biota ^b	0.48	NA	NA	0.002	NA	NA	NA	NA	NA
Total	3.88	3.51	3.70	4.00	4.34	1.55	0.515	0.025	0.058

^aNA = not applicable.

^bProduce for biota dose was sampled every three years, and program was completed in 2003.

The air inhalation dose component was estimated by using census information for the population within 50 miles of the site, as distributed between four equally sized quadrants (NE, SE, SW, and NW). In 2008, monitoring was performed at only five of the 16 boundary locations per U.S. Environmental Protection Agency (EPA) approval (DOE 2006a and 2006b), and the data are not uniformly distributed between four equal quadrants. Therefore, the net concentration above background for each of the five locations was summed and averaged to obtain an estimate of the net concentration at the 11 stations that lacked 2008 data. A dose was estimated for each population quadrant based on the net air concentration at each boundary monitor, the population

at varying distances from the site, and the dose conversion factors. The following conservative assumptions are used in the calculations:

- Inhalation rate of 1.2 cubic meters (m³) per hour for 8,760 hours per year (ICRP 1975).
- Population distribution in area (DOE 1997).
- Wind rose data (refer to Appendix D, Figure D-2 of this report).
- Average net concentrations are applied out to a distance of three miles from the site boundary (the nearest site background monitor). For populations beyond three miles, the average net concentration is diluted as the inverse square of the distance ($1/d^2$) from the boundary to account for dispersion of the site-generated particulate (e.g., between 3 and 4 miles from the boundary, the dose calculation uses the average net concentration divided by nine).
- Inhalation dose conversion factors (DOE 1988).

The direct radiation dose component was estimated by using the population distribution within 50 miles of the site, as distributed between 16 equally sized compass sectors (N, NNE, NE, ENE, etc). In 2008, monitoring was performed at only five of the 16 boundary locations per EPA approval (DOE 2006a and 2006b) and the TLD data are not uniformly distributed between four equal quadrants. Therefore, an estimate of the direct radiation at the unmonitored 11 locations is needed to evaluate the direct radiation dose. The 95 percent confidence interval of the mean for quarterly measurements at the boundary and background locations overlap (Attachment C.3). This implies that direct radiation at the site boundary is not significantly different from background, and the background value was used at the 11 locations that had no data. A dose was estimated for each population sector based on the direct radiation level that exceeded background at the site boundary and the distance between the location of the population and the major source of past radiation at the Fernald Preserve (e.g., silos project area). The following conservative assumptions were used in the calculations:

- Population lives 8,760 hours per year in area (DOE 1997).
- The number of people per household is estimated by total population per sector per mile divided by number of households per sector per mile.
- The net direct radiation levels are calculated from boundary TLD results minus the background result, with no correction for analytical uncertainty.

The collective effective population dose was similar in 2007 and 2008, with slightly higher inhalation and direct radiation in 2008. As discussed in Attachment C.3, the direct radiation dose has been at or near background for the past several years. The very low direct radiation net dose (net dose = monitor value – background value) reported for the past several years is a result of using analytical measurements without considering (1) the error on the measurement and (2) the statistical similarity of background and boundary values. If measurement error and statistical variability were evaluated for all TLD measurements, all boundary readings would be indistinguishable from background, and the direct radiation net dose would be zero.

Air inhalation is the only realistic component of the collective population dose, because particulate emissions from the Fernald Preserve may contain radionuclides that slightly exceed the background values. However, the total collective population doses attributed to remedial actions at the Fernald Preserve over the years 2000 through 2008 (Table C.5–1) are very low relative to background dose values. The background radiation dose, from the sun and naturally occurring radionuclides in food products and the earth, is estimated to be 300,000 person-rem for the population within 50 miles of the Fernald Preserve. A review of the 2008 estimated dose in Table C.5–1 shows it is almost 10 million times less than background dose, which implies it is an insignificant dose in terms of compliance with NESHAP requirements (Appendix D).

C.5.2 Biota Dose Assessment

DOE Order 5400.5 requires that populations of aquatic biota be protected at a dose limit of 1 rad/day. The DOE has issued a technical standard entitled, “A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota” (DOE 2002), and supporting software (RAD-BCG) for use in the evaluation and reporting of biota dose limits. A biota dose assessment divides the radionuclide concentrations in surface water and/or sediment samples to pre-established biota concentration guides (BCGs) for specific radionuclides and sums the fractions for each radionuclide. If the resulting sum of fractions is less than 1.0, compliance with the biota dose limit is assured. BCGs have been established for radionuclides that are relatively common constituents in past radionuclide releases to the environment from DOE facilities. For the isotopes at the Fernald Preserve, the radium isotopes have the lowest BCG values, hence they account for most of the weight in the sum of fractions presented here.

For 2000 through 2005, the Fernald site determined compliance with the biota dose limit to aquatic biota using the RAD-BCG code and the diluted (i.e., mixed) concentration for each applicable radionuclide discharged to the Great Miami River at the Parshall Flume. Although the Parshall Flume was the only discharge point evaluated through 2005, two discharge points (Paddys Run and the Parshall Flume) are delivering mass to the Great Miami River. Beginning in 2006, both discharge points were evaluated to calculate the dose to aquatic biota in the Great Miami River.

In 2003, OEPA published a fact sheet that provided the harmonic mean flow of 0.19 cfs for Paddys Run (OEPA 2003), allowing this discharge point to be evaluated in addition to the Parshall Flume. Therefore, the biota assessments for 2003 through 2008 were performed using the mass delivered from both discharge points to determine the annual average mixing concentration in the Great Miami River. Note that these assessments only evaluate the contaminant contribution from the Fernald Preserve, and contaminant concentrations in the Great Miami River may be higher due to other sources that discharge similar pollutants.

The maximum measured concentration for each radionuclide at the Parshall Flume (PF-4001) and Paddys Run (SWP-03) monitoring locations was multiplied by the annual volume of water discharged to the Great Miami River at the Parshall Flume and Paddys Run to obtain an estimate of the maximum mass of each radionuclide delivered to the river at each discharge point (e.g., $\text{pCi/L} \times \text{L} = \text{total pCi}$). For each radionuclide, the mass discharged at the Parshall Flume was added to the mass discharged at Paddys Run to obtain the annual total mass delivered to the river. The annual total mass delivered to the river was divided by the annual total volume of mixed water (Parshall Flume + Paddys Run + Great Miami River) to obtain the annual

radionuclide concentrations used in the RAD-BCG model for the biota dose assessment (as noted above, this concentration represents discharge from a single source, the Fernald Preserve).

Table C.5–2 contains a summary of the output from the RAD-BCG computer model for 2000 through 2008, showing results for one discharge point (Parshall Flume 2000 through 2005) and two discharge points (Parshall Flume and Paddys Run 2003 through 2008). Results for 2008 show that the sum-of-fractions (0.010) is well below the compliance threshold value of 1.0.

Table C.5–2. Estimated Sum-of-the-Fractions^a for Biota Dose

	2000 ^b	2001 ^b	2002 ^b	2003	2004	2005	2006 ^b	2007 ^b	2008 ^b
A	0.035	0.038	0.023	0.035	0.059	0.017	NA	NA	NA
B	NA	NA	NA	0.035	0.059	0.005	0.062	0.009	0.010

Note: A = 2000 through 2005 calculated using one discharge point (Parshall Flume)
 B = 2003 through 2008 calculated using two discharge points (Paddys Run and Parshall Flume)

^aSum-of-the-fractions calculated with the RAD-BCG code.

^bNA = not applicable.

Recalculated results for 2003 and 2004, for two discharge points, are identical to the initial results calculated for one discharge point. This indicates that the mass delivered from Paddys Run is insignificant relative to the mass delivered at the Parshall Flume. When the contaminant concentration is similar at the two discharge points, the contaminant mass delivered to the Great Miami River from Paddys Run will be much less than the mass delivered to the river at the Parshall Flume because of the large difference in discharge volume. Based on the harmonic mean flow for Paddys Run (0.19 cubic feet per second [cfs]; OEPA 2003), the annual volume of water discharged to the Great Miami River is 1.70E+08 L, compared to 9.25E+09 L for the 2008 Parshall Flume data.

The 2005 sum-of-fractions result for Scenario A (one discharge point) is greater than Scenario B (two discharge points). This anomaly is due to an incorrect calculation of the mass of radium discharged to the Great Miami River for Scenario A. In 2005, the maximum radium concentration recorded for water discharged to Paddys Run was multiplied by the annual volume discharged at the Parshall Flume. As the maximum radium concentration at Paddys Run was much higher than than radium values recorded at the Parshall Flume, changing the radium concentration to maximum observed at the Parshall Flume (lower than the maximum value for Paddys Run) lowers the mass of radium delivered to the Great Miami River and decreases the sum-of-fractions for Scenario B to the proper value.