Appendix C

Supplemental Air Information

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Contents

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Abbreviations

AMS	air monitoring station
BCG	Biota Concentration Guide
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FRL	final remediation level
IEMP	*Integrated Environmental Monitoring Plan*
LM	DOE Office of Legacy Management
NESHAP	National Emissions Standards for Hazardous Air Pollutants
OEPA	Ohio Environmental Protection Agency
OU5 ROD	*Operable Unit 5 Record of Decision*
OSL	optically stimulated luminescence
TLD	thermoluminescent dosimeter

Measurement Abbreviations

$1/d^2$	inverse square of the distance
cfs	cubic feet per second
cm	centimeters
in	inch
kph	kilometers per hour
m^3	cubic meters
mph	miles per hour
mrem	millirem
pCi/m^3	picocuries per cubic meter
pCi/L	picocuries per liter
rad	radiation absorbed dose
rem	roentgen equivalent man
$\mu g/m^3$	micrograms per cubic meter
yr	year

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Appendix C presents additional air monitoring data and analysis in support of Section 5 of this *Fernald Preserve 2009 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 2009 results with respect to historical data and plots of concentration versus time for total uranium and total particulate.
- Attachment C.2 provides information on the direct radiation monitoring program, including an assessment of 2009 results with respect to historical data.
- Attachment C.3 provides a summary of the meteorological data measured at the Butler County Airport during 2009, and historical wind speed and directional data collected at the Fernald Preserve.
- Attachment C.4 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

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

DOE (U.S. Department of Energy), 1988. *Internal Dose-Rate Conversion Factors for Calculation of Dose to the Public*, DOE/EH-0071, Washington, D.C., July.

DOE (U.S. Department of Energy), 1996. *Final Record of Decision for Remedial Actions at Operable Unit 5*, 7478 U-007-501.4, prepared by S.M. Stoller Corporation for DOE, Fernald Area Office, Cincinnati, Ohio, January.

DOE (U.S. Department of Energy), 1997. *1996 Site Environmental Report*, DE-A24-92OR21972, Fluor Fernald, DOE, Fernald Area Office, Cincinnati, Ohio, June.

DOE (U.S. Department of Energy), 2002. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, Final Technical Standard, Project No. ENVR-0011, Washington, D.C.

DOE (U.S. Department of Energy), 2006a. Approval for removing Phase 1 – TLD, Radon and Particulate Monitors (AMS-04, AMS-05, AMS-07, AMS-23, AMS-25 and AMS-28), received at weekly conference call on 11 April 2006.

DOE (U.S. Department of Energy), 2006b. Phase II Site Boundary Air Monitor Reductions approval letter, received from EPA on November 29, 2006.

DOE (U.S. Department of Energy), 2009. *Comprehensive Legacy Management and Institutional Controls Plan*, LMS/FER/S03496, Revision 3, prepared by S.M. Stoller Corporation for DOE, Fernald Area Office, Cincinnati, Ohio, May.

DOE Order 5400.5. U.S. Department of Energy. *Radiation Protection of the Public and the Environment,* Change 2, Washington, D.C., January 1993.

ICRP (International Commission on Radiological Protection), 1975. Reference Manual: *Anatomical, Physiological, and Metabolic Characteristics*, ICRP Publication 23.

OEPA (Ohio Environmental Protection Agency), 2003. *NPDES Permit Fact Sheet*, Public Notice# 03-04-019, April 7, 2003.

Attachment C.1: Radiological Air Particulate

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C1.0 Radiological Air Particulate

In 2009, the Fernald Preserve operated six air monitoring stations (AMS) (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 2009]). 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 AMS in 2009. Most instruments operated nearly 100 percent of the time; the worst performance was 88.2 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	05-Jan-09	04-Jan-10	8723	99.9
AMS-3	12	05-Jan-09	04-Jan-10	8265	94.6
AMS-6	12	05-Jan-09	04-Jan-10	8421	96.4
AMS-8A	10[a]	05-Jan-09	04-Jan-10	8564	98.0
AMS-24	12	05-Jan-09	04-Jan-10	7701	88.2
Background					
AMS-12	12	05-Jan-09	04-Jan-10	8729	99.9

[a]Samples for June and July were damaged due to birds nesting in the monitor box.

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 2009 and 2008 at each location. Relative to the 2008 results, 2009 results were slightly lower for uranium and particulate mass. Additionally, AMS-8A results for uranium and particulate are not reported for June and July due to birds nesting in the monitor box. Discussion between the U.S. Department of Energy Office of Legacy Management (LM) and Ohio Environmental Protection Agency (OEPA) resulted in a consensus that the presence of birds' nests resulted in unreliable data for these months.

Figures C.1−2 through C.1−7 summarize the total uranium and total particulate for each location. Uranium values below the method detection limit are reported and used at the detection limit value, rather than one-half the method detection limit, to ensure that conservative (i.e., higher) values are used in all calculations.

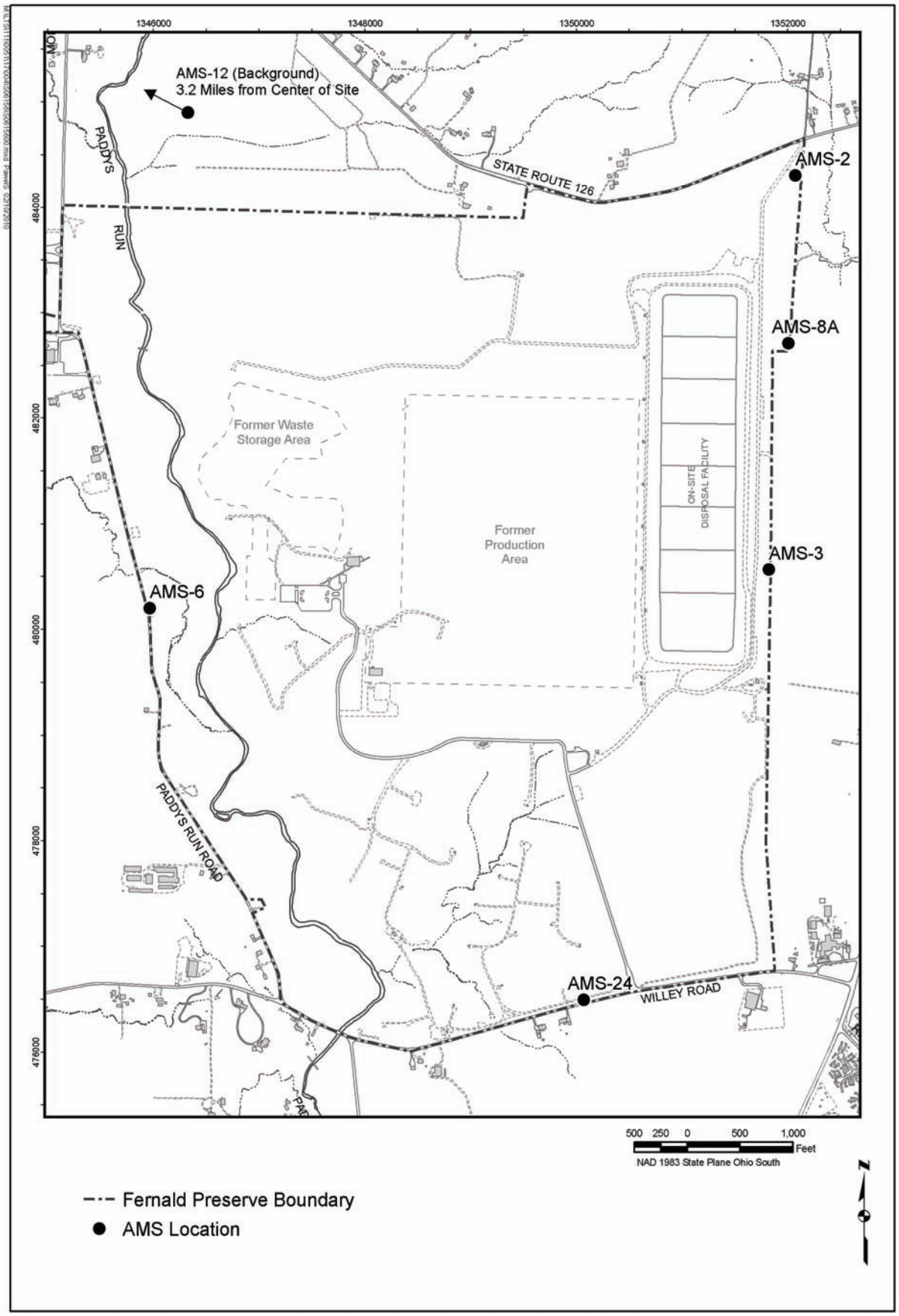

Figure C.1–1. IEMP Air Monitoring Locations

Table C.1−2. Total Uranium Activity in Air Particulate[a]

Location	2009 Results pCi/m^3 x 1E-06 Number of Samples	Minimum	Maximum	Average	2008 Results pCi/m^3 x 1E-06 Number of Samples[b]	Minimum	Maximum	Average
Boundary								
AMS-2	12	7.9 ± 0.53	13 ± 0.80	9.9 ± 0.18	11	7.2 ± 0.37	18 ± 0.98	12 ± 0.24
AMS-3	12	7.6 ± 0.53	14 ± 0.88	10 ± 0.19	11	5.1 ± 0.21	19 ± 0.73	13 ± 0.37
AMS-6	12	7.4 ± 0.52	14 ± 1.0	11 ± 0.22	11	7.9 ± 1.1	15 ± 0.95	11 ± 0.29
AMS-8A	10[c]	8.2 ± 0.49	20 ± 1.3	11 ± 0.26	11	7.2 ± 1.0	77 ± 2.5	19 ± 0.35
AMS-24	12	4.2 ± 0.28	9.5 ± 0.59	7.0 ± 0.14	11	6.6 ± 0.83	13 ± 0.75	9.6 ± 0.22
Background								
AMS-12	12	7.8 ± 0.47	12 ± 0.70	9.2 ± 0.18	11	8.1 ± 0.92	13 ± 1.79	11 ± 0.27

Note: ± = analytical uncertainty

[a]Monthly samples (total uranium activity calculated assuming natural isotopic distribution).

[b]Samples for July 2008 were inadvertently discarded by the laboratory after particulate mass was measured.

[c]Samples for June and July were damaged due to birds nesting in the monitor box.

Table C.1−3. Total Particulate Concentrations in Air[a]

Location	2009 Results µg/m^3 Number of Samples	Minimum	Maximum	Average	2008 Results µg/m^3 Number of Samples[b]	Minimum	Maximum	Average
Boundary								
AMS-2	12	14	45	25	11	11	45	28
AMS-3	12	15	42	24	11	13	59	27
AMS-6	12	15	45	25	11	5.8	60	28
AMS-8A	10[c]	13	47	23	11	12	65	29
AMS-24	12	7.6	37	17	11	4.0	44	18
Background								
AMS-12	12	15	42	24	11	17	44	26

[a]Monthly samples

[b]Samples for July 2008 were inadvertently discarded by the laboratory after particulate mass was measured.

[c]Samples for June and July were damaged due to birds nesting in the monitor box.

An increase in particulate for the September time interval (Figures C.1−2 through C.1−7) corresponds to dry and dusty conditions in the early fall of 2009. The maximum particulate and uranium values are observed at AMS-8A and correspond to samples in September and October, respectively.

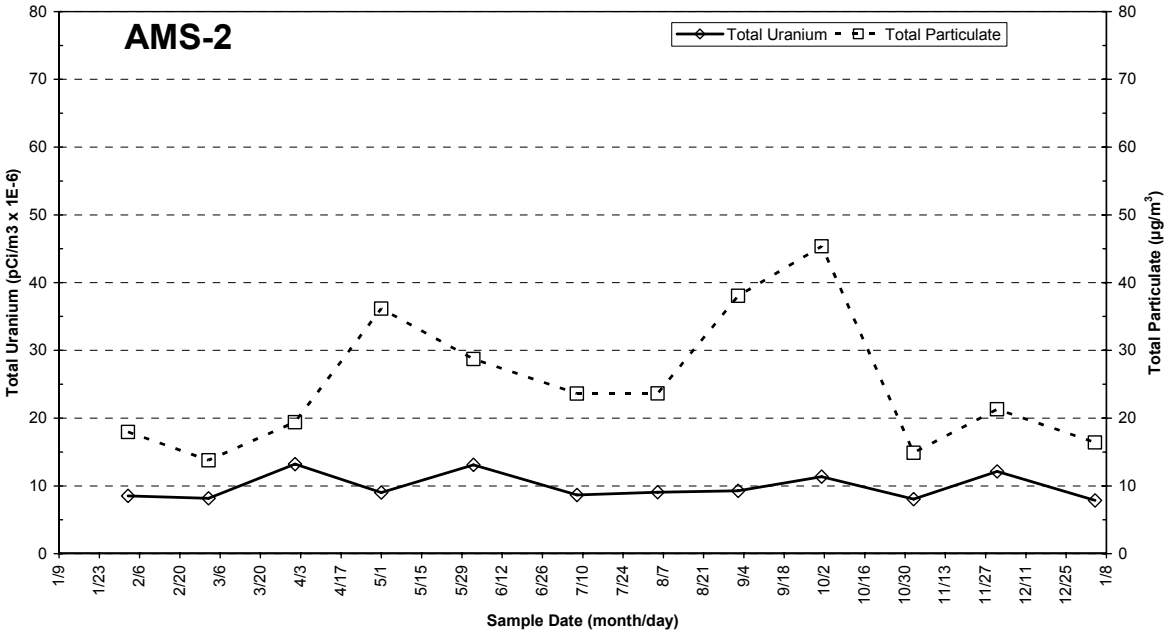

Figure C.1−2. 2009 Total Uranium Activity and Particulate Air Concentrations at AMS-2

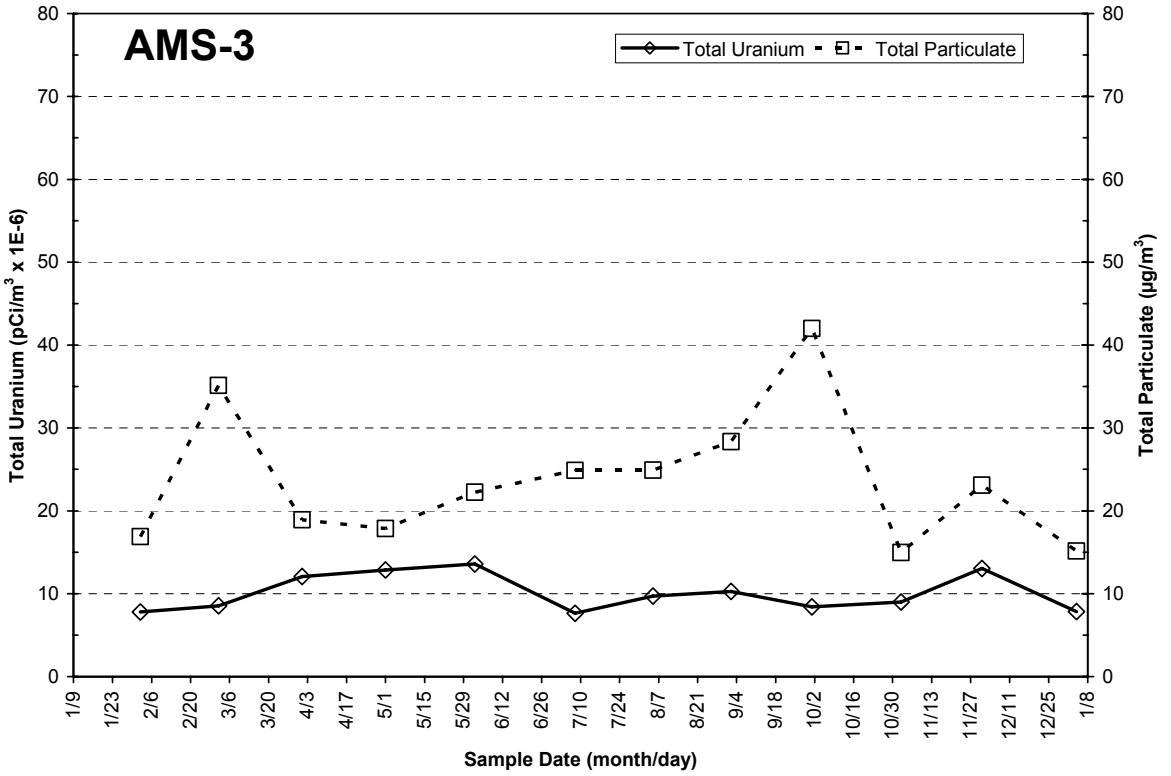

Figure C.1−3. 2009 Total Uranium Activity and Particulate Air Concentrations at AMS-3

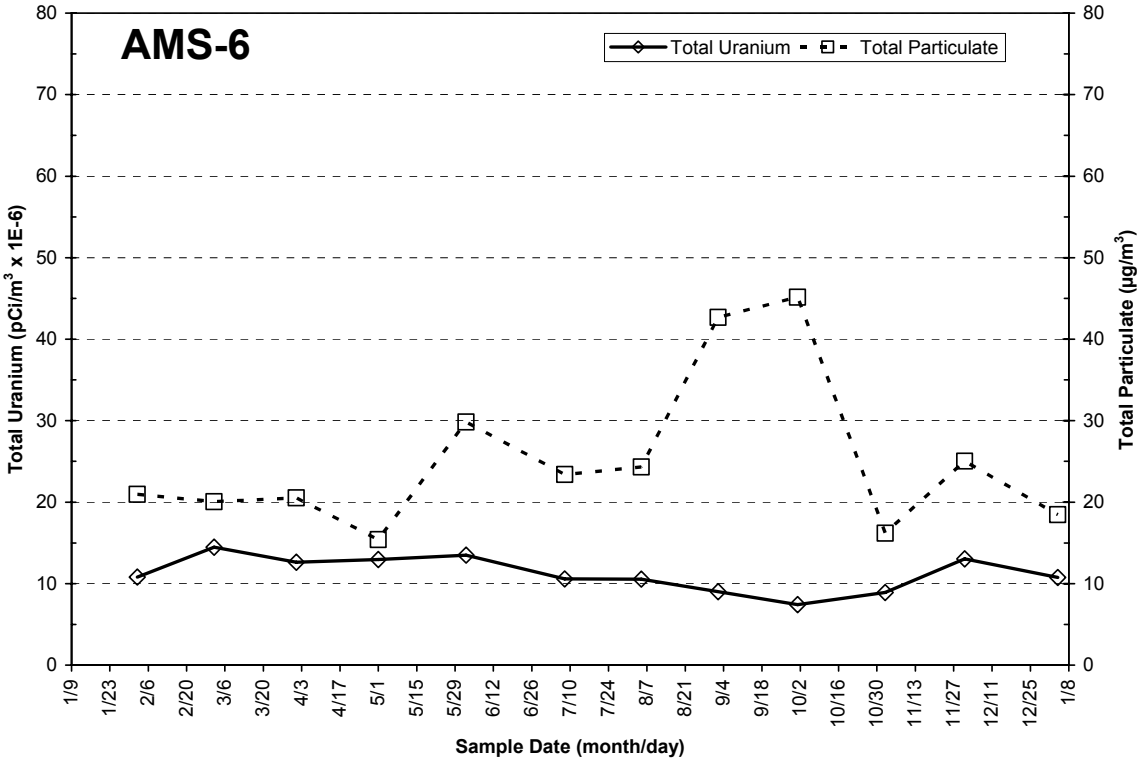

Figure C.1−4. 2009 Total Uranium Activity and Particulate Air Concentrations at AMS-6

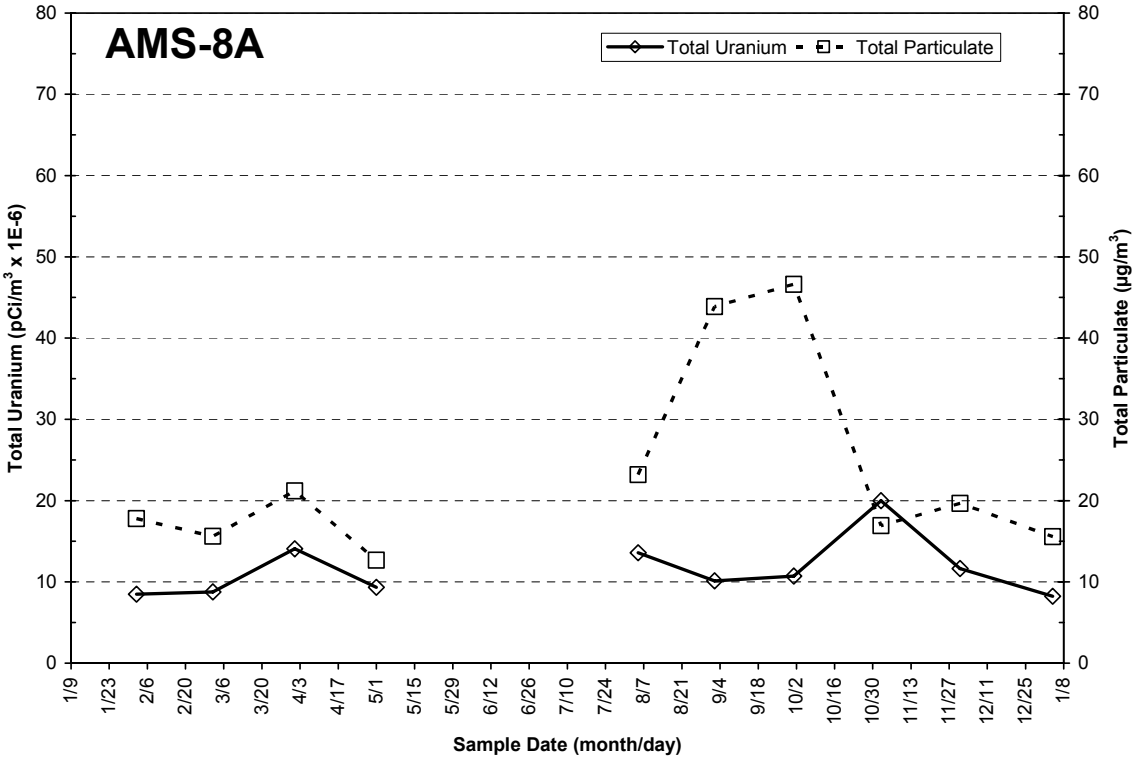

Figure C.1−5. 2009 Total Uranium Activity and Particulate Air Concentrations at AMS-8A

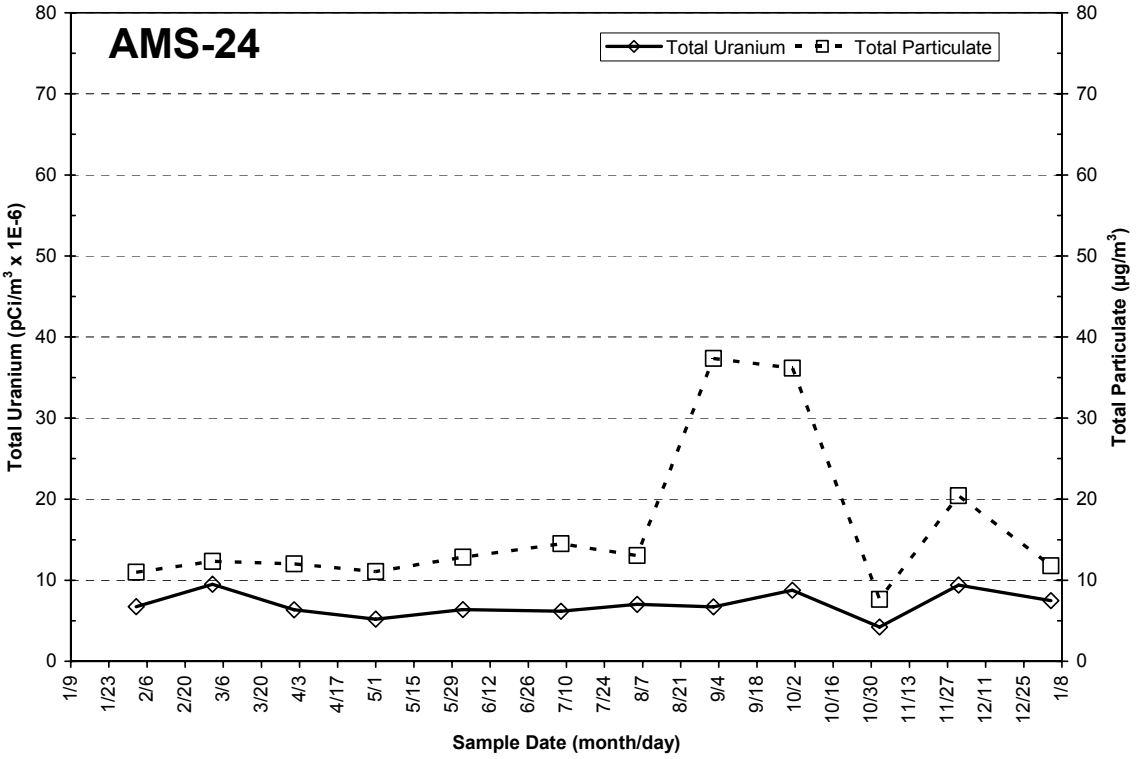

Figure C.1−6. 2009 Total Uranium Activity and Particulate Air Concentrations at AMS-24

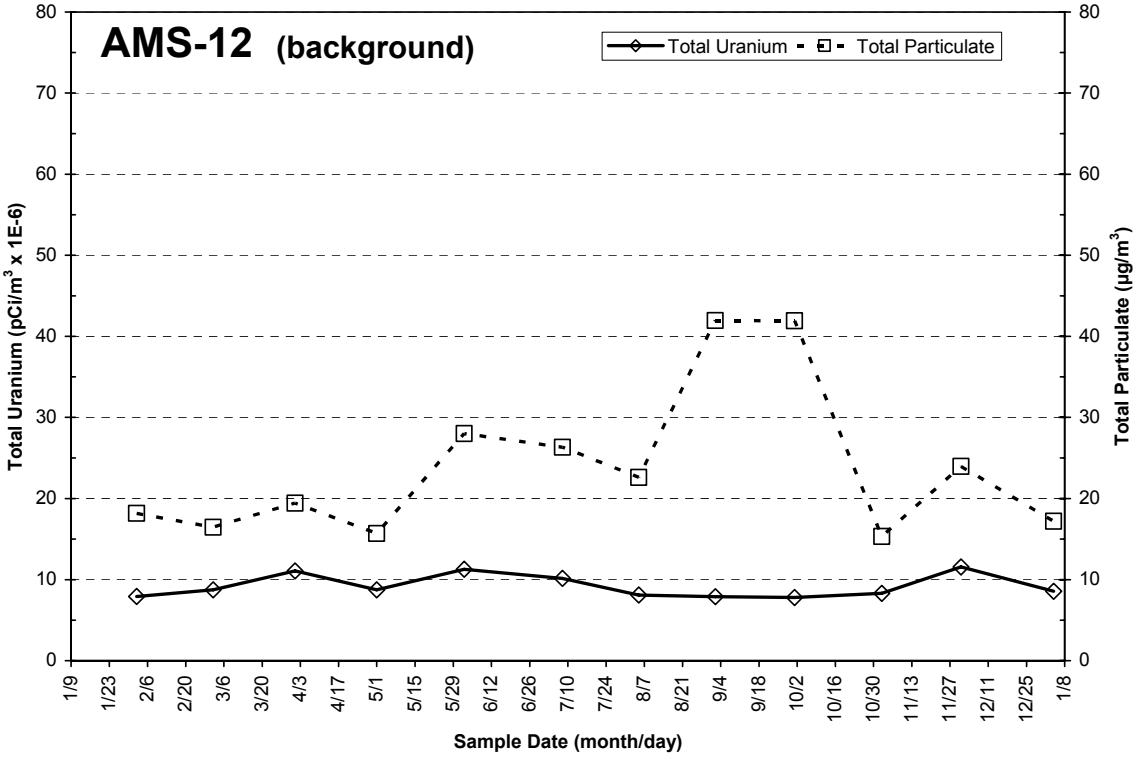

Figure C.1−7. 2009 Total Uranium Activity and Particulate Air Concentrations at AMS-12

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 from the mean at the background location, with the exception of uranium for AMS-24, which is less than background. 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 (FRLs) established in the *Final Record of Decision for Remedial Actions at Operable Unit 5* (OU5 ROD) (DOE 1996).

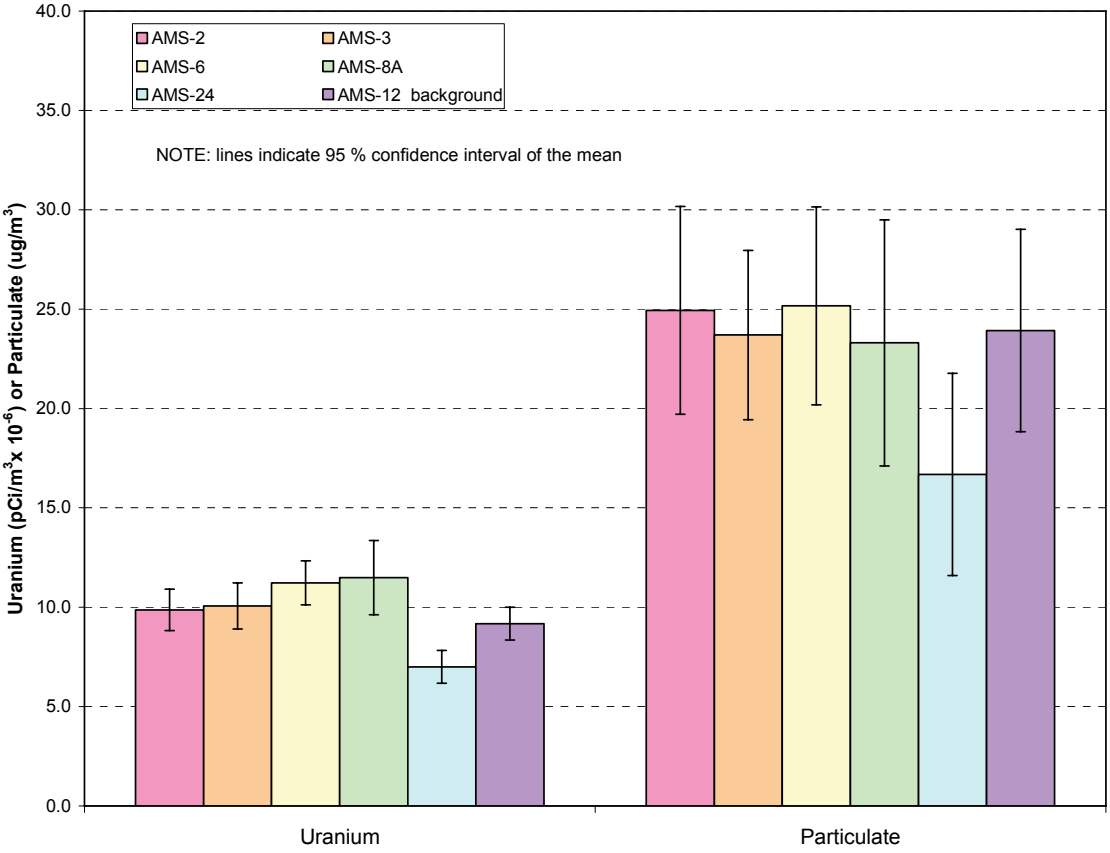

Figure C.1−8. 2009 Comparison of Means for Air Data

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 that 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 from AMS-8A for June and July were not used because of nesting birds, so the second-quarter result is based on the filter from a single month (i.e., May).

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, and these results are in line with the soil certification results that demonstrate remediation of soil achieved the OU5 FRLs 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 17 percent uranium, 21 percent thorium, and 62 percent radium (Table C.1−4). The 2009 background activities (AMS-12) are distributed as 16 percent uranium, 27 percent thorium, and 57 percent radium. Slight differences in the boundary and background distribution are expected, as soil remediation activities reduced isotopic values in the soil to concentrations below the FRLs established in the OU5 ROD, which are slightly different from background values.

Table C.1−4. 2009 Average Radionuclide Activity in Air Particulate[a,b]

		Activity (pCi/m^3)							
Location		U-234	U-235[c]	U-238	Th-228	Th-230	Th-232	Ra-226	Total
Boundary									
AMS-2		4.35E-06	0.00E+00	4.31E-06	4.68E-06	3.67E-06	2.56E-06	3.72E-05	5.68E-05
	±	7.16E-07	NA	7.28E-07	8.81E-07	7.91E-07	5.28E-07	1.18E-05	1.19E-05
AMS-3		4.17E-06	0.00E+00	3.65E-06	3.02E-06	1.42E-06	2.22E-06	2.53E-05	3.98E-05
	±	7.38E-07	NA	6.65E-07	7.96E-07	5.59E-07	5.17E-07	1.19E-05	1.20E-05
AMS-6		5.10E-06	0.00E+00	4.92E-06	5.28E-06	4.00E-06	2.87E-06	3.71E-05	5.93E-05
	±	7.79E-07	NA	7.74E-07	8.78E-07	8.50E-07	5.59E-07	1.12E-05	1.14E-05
AMS-8A		4.16E-06	0.00E+00	4.49E-06	5.46E-06	2.56E-06	1.92E-06	1.12E-05	2.98E-05
	±	7.30E-07	NA	7.37E-07	8.20E-07	6.84E-07	4.31E-07	7.35E-06	7.51E-06
AMS-24		1.04E-06	0.00E+00	3.04E-06	2.04E-06	3.28E-06	1.87E-06	3.22E-05	4.34E-05
	±	2.79E-07	NA	6.80E-07	6.55E-07	7.71E-07	5.18E-07	9.29E-06	9.38E-06
Sum for Boundary Monitors									
		1.88E-05	0.00E+00	2.04E-05	2.05E-05	1.49E-05	1.14E-05	1.43E-04	2.29E-04
	±	1.51E-06	NA	1.61E-06	1.81E-06	1.65E-06	1.15E-06	2.34E-05	2.36E-05
Background									
AMS-12		4.04E-06	0.00E+00	3.24E-06	6.27E-06	3.89E-06	2.87E-06	2.67E-05	4.70E-05
	±	6.90E-07	NA	5.95E-07	9.35E-07	7.76E-07	5.57E-07	9.56E-06	9.70E-06

Isotope Percent	U-234	U-235	U-238	Th-228	Th-230	Th-232	Ra-226	Total
Boundary[d]	8.21	0.00	8.91	8.94	6.52	4.99	62.4	100
Background	8.61	0.00	6.89	13.3	8.29	6.11	56.8	100

Note: ± = 2 sigma error propagated from reported quarterly errors.

[a]An activity of 0.00 indicates the filter results were below the detection limit or equal to or less than the blank results.

[b]Average obtained by summing the activity of four quarterly composite samples and dividing by total annual air volume through the monitor.

[c]NA = not applicable

[d]Represents the sum of all boundary monitors.

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. 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-3 and AMS-8A is entirely due to uranium, as uranium isotopes are the only nuclides above background at these locations. At AMS-24, the entire dose is due to radium, as this is the only nuclide above background. For AMS-2 and AMS-6, the majority of the dose is attributed to radium. The maximum total dose from all isotopes is 0.034 millirem per year (mrem/yr) above background at AMS-6, which is well below the allowed NESHAP limit of 10 mrem/yr above background (see Appendix D).

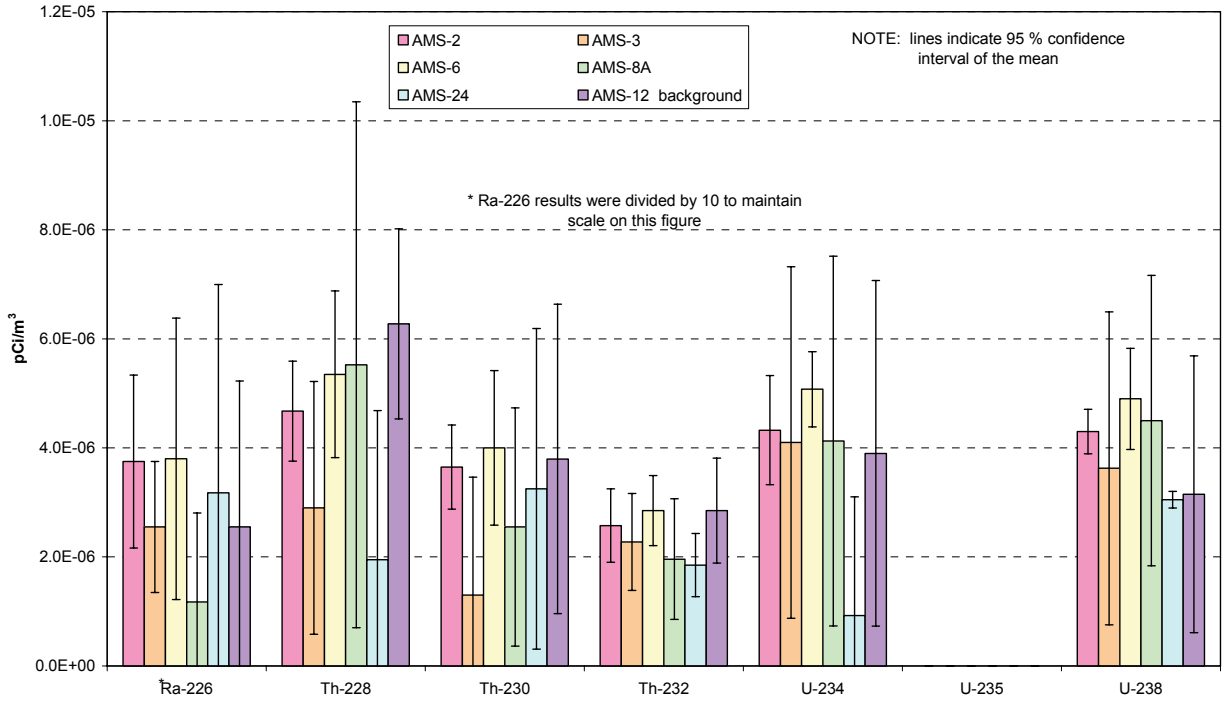

Figure C.1−9. 2009 Comparison of Means for NESHAP Data

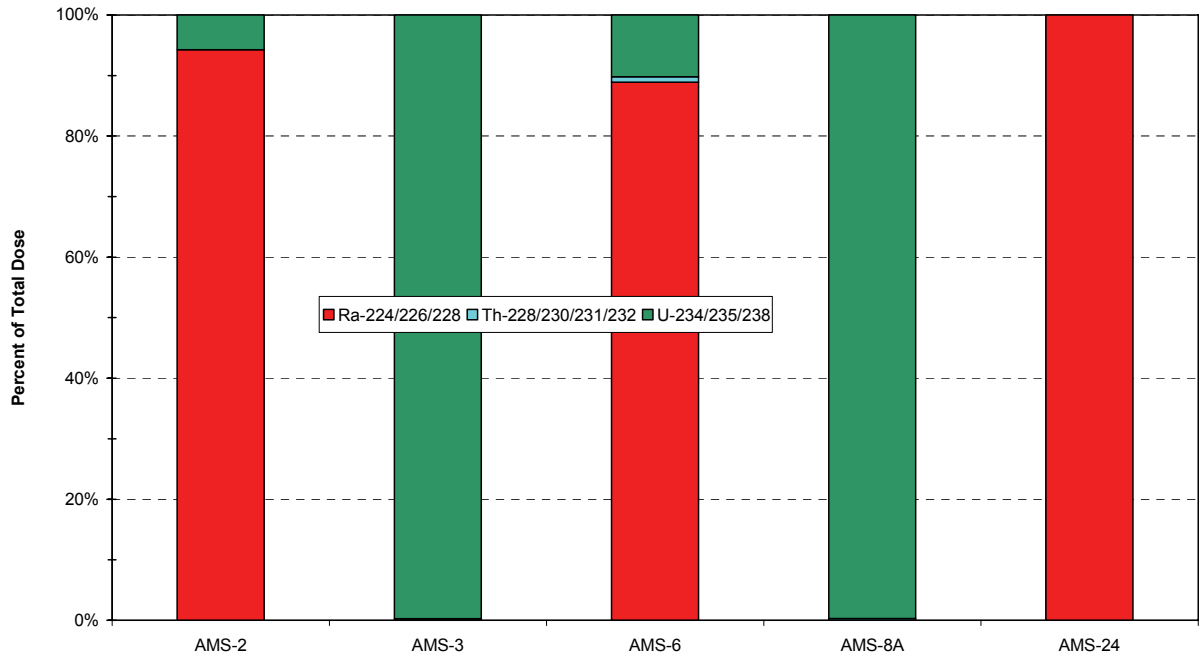

Figure C.1−10 2009 Isotopic Dose Contributions at AMS Locations

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Attachment C.2: Direct Radiation

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C.2.0 Direct Radiation

Direct radiation measurements were collected using optically stimulated luminescence (OSL) dosimeters at one background, five boundary, and four trail locations, as well as a single location at the Visitors Center (Figure C.2−1). Three OSL dosimeters are deployed at each location to track and evaluate direct radiation, and each OSL dosimeters is collected and measured quarterly (approximately every 91 days). The three measurements are averaged to obtain a quarterly result for each location. Quarterly results are plotted on Figure 5–6 in Section 5.

Table C.2−1 provides a summary of the annual dose for 2009 and 2008. The OSL dosimeters have a different energy response relative to thermoluminescent dosimeters (TLDs), which accounts for the difference in absolute values between the dosimeters. However, the relative difference between background and monitor locations is similar for the different dosimeters, and this difference is what determines the receptor dose. 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. These results are in agreement with Figure C.2−2, which shows that the 95 percent confidence interval of the mean values for the on-site dosimeters and background dosimeter overlap. Note that OSL-54 is inside the Visitors Center, and direct radiation is lowest there due to the shielding effects of the building. Given the remediation of the Fernald Preserve to soil FRLs, and statistically similar boundary and background values in 2009, it is reasonable to expect future readings to be at or near background levels.

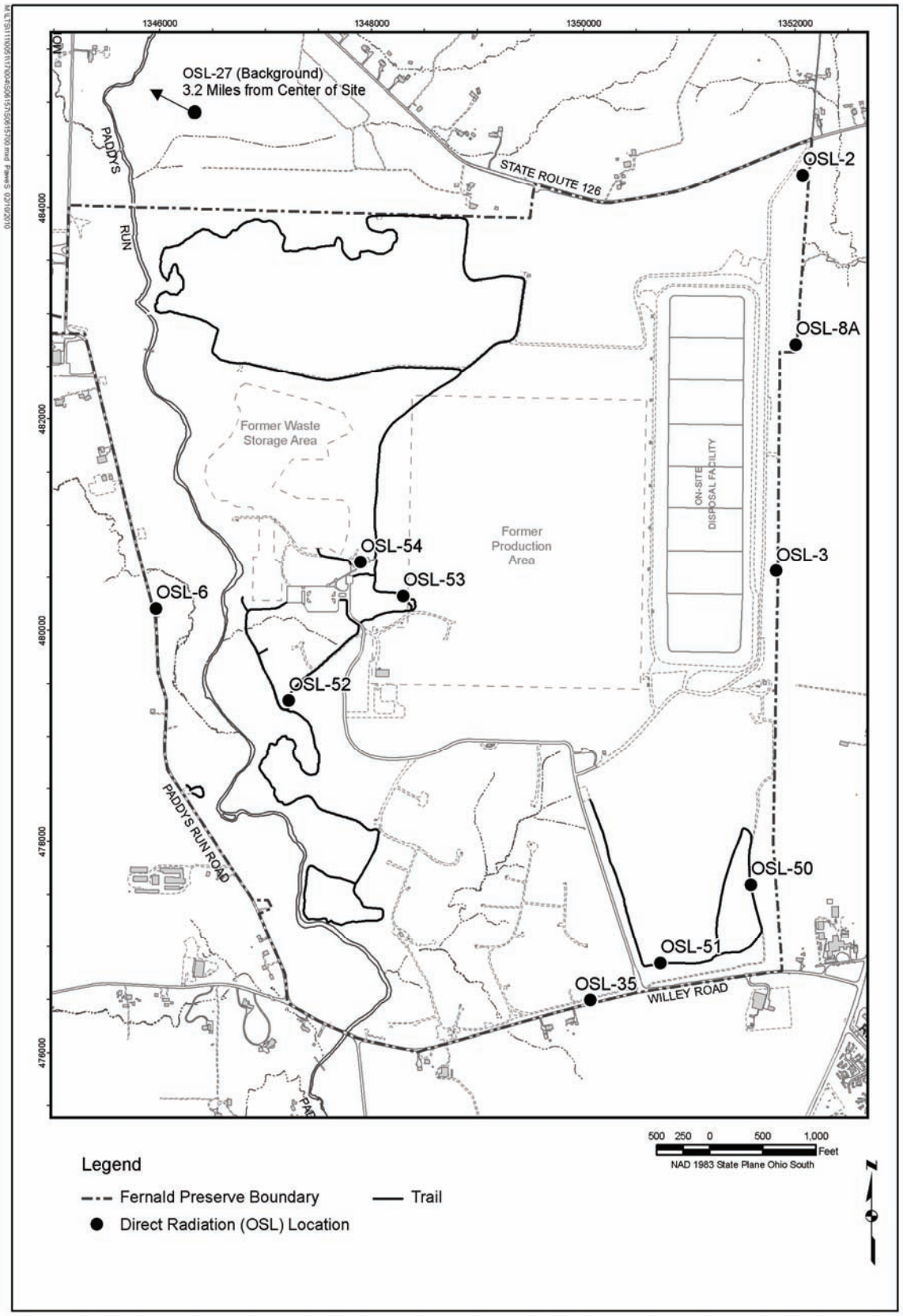

Figure C.2−1. Direct Radiation (OSL) Monitoring Locations

Table C.2−1. Dose Based on Direct Radiation (OSL/TLD) Measurements

	Direct Radiation (mrem)[a]	
Location	2009[b]	2008[c,d]
On-site		
2	26	52
3	24	52
6	26	51
8A	29	54
35	20	48
50[e]	26	NA
51[e]	29	NA
52[e]	20	NA
53[e]	21	NA
54[f]	8.0	NA
Minimum	**8.0**	**48**
Maximum	**29**	**54**
Background		
27	20	48

[a]Annual dose is derived by summing the average quarterly result for each location.
[b]2009 direct radiation measurements were performed with OSL dosimeters.
[c]2008 direct radiation measurements were performed with TLDs.
[d]NA=not applicable
[e]2009 was the first year for this location (trail).
[f]2009 was the first year for this location (Visitor Center).

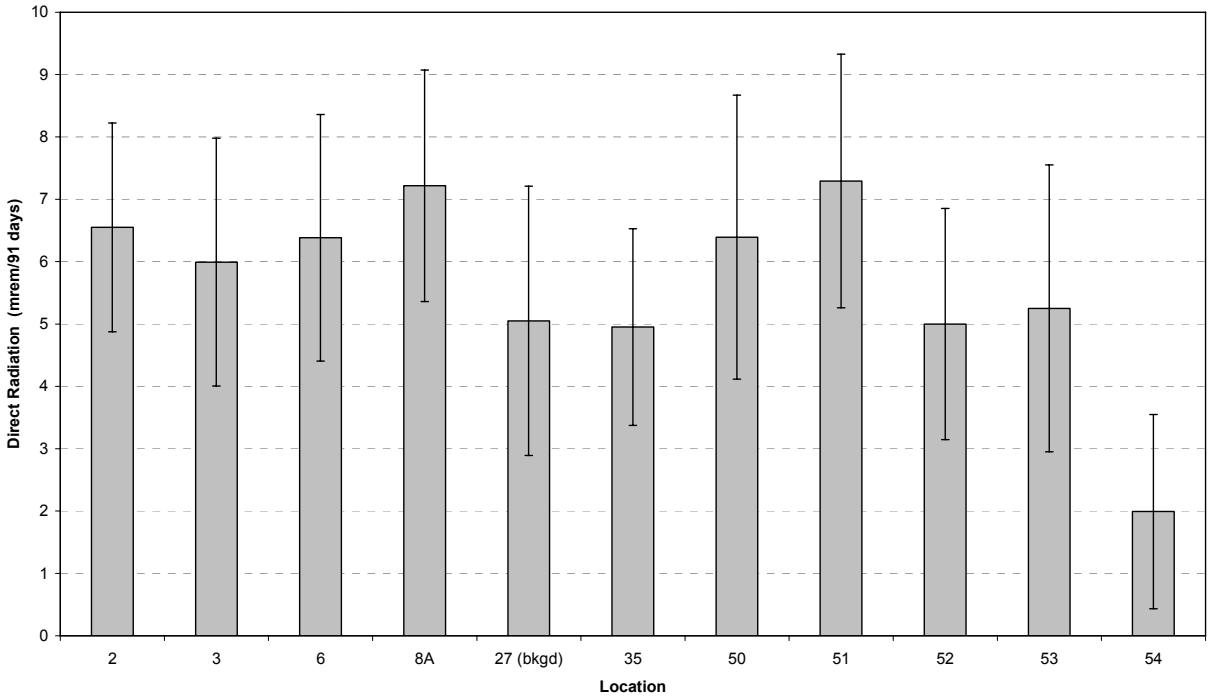

Figure C.2−2. 2009 Mean and 95 Percent Confidence Interval for Quarterly Dosimeter Measurements

Attachment C.3: Meteorological Data

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C.3.0 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 through 2009 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 vegetation 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.3−1) are summarized as monthly maximum and minimum; the largest range occurs 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, and minimums are observed in January and February. Historical precipitation information indicates that May and June are the wettest months; however, July and October were the wettest months of 2009.

Table C.3−2 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 2009, it is assumed that the Fernald 2002 to 2006 values for wind speeds and directions are representative of present conditions at the Fernald Preserve. The information in Table C.3−2 was used for the dose assessment presented in Attachment C.4.

Table C.3−1. Meteorological Data

	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10-Meter Wind Velocity[a]													
Maximum	mph	32	37	42	36	34	27	37	31	28	30	33	31
(hourly average)	kph	51	59	67	57	54	44	59	49	44	48	52	49
Minimum	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
(hourly average)	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
60-Meter Wind Velocity[a]													
Maximum	mph	44	49	52	47	41	35	48	35	42	40	45	42
(hourly average)	kph	70	78	82	75	66	55	77	57	67	65	72	68
Minimum	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
(hourly average)	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
Ambient Air Temperature[b]													
Average	°F	25	34	46	53	63	72	70	72	66	52	46	33
	°C	-4	1	8	12	17	22	21	22	19	11	8	1
Maximum	°F	46	56	63	74	76	81	77	80	76	71	57	50
	°C	8	13	17	23	24	27	25	27	24	22	14	10
Minimum	°F	7	8	18	38	50	61	64	61	51	39	32	21
	°C	-14	-13	-8	3	10	16	18	16	11	4	0	-6
Precipitation[b]													
Total	in	1.9	1.2	1.2	3.8	3.9	3.9	4.6	2.9	4.4	5.4	0.9	3.2
	cm	4.9	3.1	3.0	9.6	10.0	9.9	11.7	7.4	11.3	13.8	2.2	8.0
Daily Maximum	in	0.5	0.9	0.5	0.7	1.2	1.4	1.5	1.6	2.2	1.2	0.4	0.7
	cm	1.3	2.3	1.3	1.8	3.1	3.7	3.8	3.9	5.5	2.9	1.0	1.9

[a]Wind-velocity data were not collected at the Fernald Preserve in 2007, 2008, or 2009. Values represent 5-yr average for site data collected from 2002 through mid-2006.

[b]2009 Data obtained from the airport in Butler County, Ohio.

Table C.3−2. Average Wind Speed and Percent of Time from Direction at 10 and 60 Meters Above Ground Level[a]

Direction	Average 10-meter Wind Speed (mph)	(kph)	Percent of Time from Direction[b]	Average 60-meter Wind Speed (mph)	(kph)	Percent of Time from Direction[b]
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, 2008, or 2009. 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.4: Supplemental Dose Assessments

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C.4.0 Supplemental Dose Assessments

This attachment contains a detailed discussion of the supplemental dose assessments performed for calendar year 2009, and compares the 2009 results to those from 2000 through 2008. The supplemental dose assessment comprises the population and biota dose assessments, which provide required information for compliance with DOE Order 5400.5.

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, removal of the silo and waste pit material, 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 OU5 FRLs, there is no significant remaining source to deliver a dose to the public in excess of the dose that corresponds to an incremental lifetime cancer risk of 1 in 10,000, which is acceptable for EPA superfund sites. 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. Groundwater is not considered as part of the population dose because contaminated groundwater is not consumed by the public.

C.4.1 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 2009, the effective dose equivalent was 0.042 person-rem/yr. This includes 0.014 person-rem/yr from site airborne emissions (excluding radon) and 0.028 person-rem/yr from the direct radiation component (Table C.4−1). There was no estimated biota dose to the population from consumption of produce, as the produce monitoring program was completed in 2003.

Table C.4−1. Estimated Population Doses (person-rem)

	2000	2001[a]	2002[a]	2003[b]	2004[a]	2005[a]	2006[a]	2007[a]	2008[a]	2009[a]
Air Inhalation	3.29	3.35	3.47	3.84	3.87	1.2	0.485	0.010	0.039	0.014
Direct radiation	0.108	0.159	0.23	0.155	0.47	0.35	0.030	0.015	0.019	0.028
Biota[b]	0.48	NA	NA	0.002	NA	NA	NA	NA	NA	NA
Total	**3.88**	**3.51**	**3.70**	**4.00**	**4.34**	**1.55**	**0.515**	**0.025**	**0.058**	**0.042**

[a]NA = not applicable.
[b]Produce 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 16 equally spaced compass directions (N, NNE, NE, ENE, etc.). In 2009, monitoring was reduced to 5 locations per U.S. Environmental Protection Agency (EPA) approval (DOE 2006a and 2006b), but the data from the 5 locations are not uniformly distributed between 16 equally spaced compass

directions. Therefore, the net concentration above background for each of the 5 locations was summed and averaged to obtain an estimate of the net concentration at the 11 quadrants that lacked 2009 data. A dose was estimated for each population quadrant using the net concentration at 5 locations and the average at the 11 quadrants that lacked data, 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 (m^3) per hour for 8,760 hours per year (ICRP 1975).
- Population distribution in the 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 3 miles from the site boundary (the nearest site background monitor). For populations beyond 3 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 9).
- 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 spaced compass sectors (N, NNE, NE, ENE, etc.). In 2009, monitoring was performed at the 5 boundary locations approved by EPA (DOE 2006a and 2006b), resulting in direct radiation dose data that are not uniformily distributed between the 16 sectors. Therefore, an estimate of the direct radiation at the unmonitored 11 compass sectors is used to evaluate the direct radiation dose.

The 95 percent confidence interval of the mean for quarterly measurements at the on-site and background locations overlap (Attachment C.2). This implies that direct radiation at the site boundary is not significantly different from background; therefore, the background value was applied to the 11 compass sectors that had no collected 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 site boundary. The following conservative assumptions were used in the calculations:

- Population lives 8,760 hours per year in area (DOE Order 5400.5).
- 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 on-site OSL dosimeter results minus the background result, with no correction for analytical uncertainty.

The collective effective population dose was similar in 2008 and 2009, with slightly lower inhalation and slightly higher direct radiation in 2009. As discussed in Attachment C.2, the direct radiation dose has been at or near background for the past several years.

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 2009 (Table C.4−1) are very low relative to background dose values from the sun and food products. 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 2009 estimated dose in Table C.4−1 shows dose attributable to the Fernald Preserve is almost 7 million times less than background dose, which implies it is an insignificant dose in terms of compliance with NESHAP requirements (Appendix D).

C.4.2 Biota Dose Assessment

DOE Order 5400.5 requires that populations of aquatic biota be protected at a dose limit of 1 rad/day. 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 by 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 isototpes 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 RAD-BCG 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 cubic feet per second (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 2009 were performed using the mass delivered from both discharge points to determine the annual average mixing concentration in the Great Miami River. 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 (see Section 4.0 and Appendix B) 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 activity of each radionuclide delivered to the river at each discharge point (e.g., pCi/L × L = total pCi). For each radionuclide, the activity discharged at the Parshall Flume was added to the activity discharged at Paddys Run to obtain the annual total activity delivered to the river. The annual total activity 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 activities used in RAD-BCG for the biota dose assessment (as noted above, this activity represents discharge from a single source, the Fernald Preserve).

Table C.4−2 contains a summary of the output from RAD-BCG for 2000 through 2009. Results for 2009 show that the sum-of-fractions result (0.005) is well below the compliance threshold value of 1.0.

Table C.4−2. Estimated Sum-of-Fractions[a] for Biota Dose

Scenario[b]	2000[c]	2001[c]	2002[c]	2003	2004	2005	2006[c]	2007[c]	2008[c]	2009[c]
A	0.035	0.038	0.023	0.035	0.059	0.017	NA	NA	NA	NA
B	NA	NA	NA	0.035	0.059	0.005	0.062	0.009	0.010	0.005

[a]Sum-of-the-fractions calculated with the RAD-BCG code.

[b]A = One discharge point (Parshall Flume); B = Two discharge points (Paddys Run and Parshall Flume)

[c]NA = 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 cfs; OEPA 2003), the annual volume of water discharged to the Great Miami River is 1.70×10^8 L, compared to 9.94×10^9 L for the 2009 Parshall Flume data.

The 2005 sum-of-fractions result for Scenario A (one discharge point) is greater than that for 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 result for Scenario B to the proper value.