**COMPARISON OF NEAR-FIELD AND FAR-FIELD AIR
MONITORING OF PLUTONIUM-CONTAMINATED SOILS
FROM THE TONOPAH TEST RANGE, NEVADA**

prepared by

John L. Bowen and David S. Shafer

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EXECUTIVE SUMMARY

Operation Roller Coaster, a series of nuclear material dispersal experiments, resulted in three areas (Clean Slates 1, 2, and 3) of widespread surface soil plutonium (Pu) contamination on the Tonopah Test Range (TTR). TTR is located 225 km (140 miles) northwest of Las Vegas, Nevada, within the Nellis Air Force Range. In support of remediation of these sites by the U.S. Department of Energy, National Nuclear Security Administration, Nevada Operations Office, the Desert Research Institute (DRI) conducted background air monitoring prior to excavation of any contaminated soils from the Clean Slate sites. The State of Nevada, Division of Environmental Protection, has raised concerns that dispersal of airborne Pu particles from the Clean Slate sites could result in undetected deposition farther downwind than the DRI background air-monitoring site for the Clean Slate sites. To begin addressing this issue, two *existing* sets of air monitoring data that characterized the airborne particles with aerodynamic diameters less than 10 μm (PM_{10}) at different distances from the Clean Slate sites but during the same period of time were compared.

The two sets consisted of 1) the results of air monitoring conducted by DRI between February 1996 and January 1997 to establish background conditions for airborne mass concentration and Pu contamination in the PM_{10} particle size range in the vicinity of the Clean Slate test locations and 2) the results of particulate sampling conducted by Sandia National Laboratories (SNL) between February 1996 and February 1997 to collect airborne samples of airborne PM_{10} mass and Pu and americium (Am) contamination for National Emission Standards for Hazardous Air Pollutants (NESHAPs) compliance. The DRI samples were collected on Teflon membrane filters by portable low volume (5 l/min) samplers; the SNL samples were collected on quartz fiber filters by high-volume PM_{10} samplers (1.13 m^3/min). The DRI sampling site was 3 km northwest of Clean Slate 3; the SNL sampling site was 8 km west-northwest of Clean Slate 3 and approximately 2.7 times the distance from Clean Slate 3 as the DRI sampling site. Data on total mass concentration of PM_{10} particles ($\mu\text{g}/\text{m}^3$), total radionuclide activity for Pu isotopes, and radionuclide activity concentration were compared with the DRI data representing the “near-field” set and the SNL data the “far-field” set.

The PM_{10} mass concentration for samples collected by SNL and by DRI averaged 6.2 $\mu\text{g}/\text{m}^3$ and 6.9 $\mu\text{g}/\text{m}^3$, respectively. Application of a Wilcoxon Rank-Sum test showed no statistical difference between the two sets of mass concentrations, which implies a relatively uniform aerosol loading in the area to the north of the Clean Slate sites. The similarity of the mass concentrations and their low values indicate that there were no major sources of airborne PM_{10} near either site, although simultaneous measurements upwind and downwind of the Clean Slate sites would have been necessary to definitively determine emissions that might have come from the Clean Slate sites. From the available data there is no indication that airborne PM_{10} particles are being transported farther to the SNL site. However, the data are statistically insufficient to conclude whether there is significant difference in transport of Pu particles in the PM_{10} size range in large part because of the small number of samples where the total activity or the activity concentration exceeded the Minimum Detection Activity (MDA). Only 20.8 percent of the SNL samples and only one of the four DRI composite samples for ^{238}Pu and $^{239+240}\text{Pu}$ exceeded the MDA. Comparisons of total radionuclide activity and activity concentration could only be conducted by substituting the MDA for samples for which levels were below detection. While the low values of total activity and activity concentration suggest that the inhalation hazard of Pu from the Clean Slate sites is low, the data are insufficient to conclude whether there is a difference in transport of respirable Pu particles to the near-field versus the far-field sites from the Clean Slate sites.

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ACRONYMS

Am	americium
BN	Bechtel Nevada
DCG	Derived Concentration Guide
DRI	Desert Research Institute
EDE	effective dose equivalent
MDA	Minimum Detection Activity
MEI	Maximally Exposed Individual
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NNSA/NV	National Nuclear Security Administration/Nevada Operations Office
Pu	plutonium
SNL	Sandia National Laboratories
TTR	Tonopah Test Range

1.0 INTRODUCTION

Operation Roller Coaster was a series of nuclear material dispersal experiments, including three (Clean Slate 1, 2, and 3) that resulted in widespread areas of surface soil plutonium (Pu) contamination on the Tonopah Test Range (TTR) in Nevada. The Clean Slates 1, 2, and 3 experiments resulted in the dispersal of Pu from nuclear devices over the area surrounding the three ground zeros as well as downwind. The TTR is located 225 km (140 miles) northwest of Las Vegas, Nevada, within the boundaries of the Nellis Air Force Range (Figure 1). U.S. Department of Energy's National Nuclear Security Administration (NNSA) operations at TTR are conducted by Sandia National Laboratories-New Mexico (SNL), although environmental restoration of the Clean Slate sites is being conducted by the NNSA Nevada Operations Office (NV).

As part of the Soils Project of the NNSA/NV Environmental Restoration Project, large-scale surface excavation of surface soils has already been conducted at Clean Slate 1. To support the remediation of the Clean Slate sites, Desert Research Institute (DRI) collected samples of airborne particles prior to soil excavation to establish background dispersal of Pu from the sites for comparison with air monitoring data collected after excavation. The focus of background sampling was on particles with aerodynamic diameters less than 10 μm (PM_{10}), the particle size range of greatest health concern to site workers or potential off-site receptors from respiration. For ambient background measurements for the Clean Slate sites, portable PM_{10} samplers were deployed 3 km to the west-northwest of Clean Slate 3 (Bowen, 1996a,b,c, 1997a). The locations of the sampling sites are displayed in Figure 2, as are the Clean Slate sites.

The State of Nevada, Division of Environmental Protection, has raised concerns to NNSA/NV that dispersal of Pu particles from the Clean Slate sites may result in deposition of Pu particles farther downwind where samplers deployed by DRI would not have detected them. To begin addressing this issue, NNSA/NV sought to make a comparison of *existing* air monitoring data that were collected at a greater distance ("far-field") from the Clean Slate sites than data collected by DRI as part of background monitoring ("near-field"). The data set selected for comparison was air-monitoring data collected by SNL as part of National Emission Standards for Hazardous Air Pollutants (NESHAPs) requirements for TTR (SNL, 1997). SNL was required under its NESHAPs permit for TTR to measure emissions of radionuclides from "diffuse" sources, namely the three Clean Slate sites. The period of SNL data collection virtually coincides with the one year of continuous background monitoring by DRI between February 1996 and January 1997 prior to excavation work on any of the Clean Slate sites (Bowen, 1997b).

Between February 1996 and February 1997, as part of a NESHAPs study to measure the dose of a Maximally Exposed Individual (MEI) at TTR, SNL conducted one year of continuous air monitoring near the Clean Slate sites (Culp *et al.*, 1998). The MEI location near the airfield at TTR is about 8 km west-northwest of Clean Slate 3, and approximately 2.7 times the distance from Clean Slate 3 as the background sampling site used by DRI. Data on PM_{10} particle mass concentration ($\mu\text{g}/\text{m}^3$), total activity for ^{238}Pu and $^{239+240}\text{Pu}$ (pCi), and radionuclide concentration (pCi/g) for the Pu isotopes from these two data sets have been herein compared to evaluate whether there is evidence of farther afield transport (namely to the SNL MEI site) of Pu from the Clean Slate sites that is in addition to that detected at the near-field site.

On an annual basis, TTR has a dichotomy in prevailing wind directions. From late fall to the spring, winds are mostly from the northwest, being influenced by the Pacific air flow patterns

Figure 1. U.S. Department of Energy, National Nuclear Security Administration sites and facilities in Nevada where environmental restoration is occurring, including the Tonopah Test Range.

over the Sierra Nevada Mountains. From summer through early fall, the winds generally shift to a southeasterly direction from air masses moving out of the Gulf of Mexico and Gulf of California (Culp et al., 1998). The winds measured by DRI at the Clean Slate background site also showed this dichotomy in the prevailing directions for February 1996 through January 1997. As shown in Table 1, most of the directions were in the southerly sector from southeasterly to southwesterly or in the northerly sector from northwesterly to northeasterly. During the 12 months including the 11-month overlap period between sampling by DRI and SNL, the winds were southerly 45 percent of the time and northerly 37 percent of the time. The wind was calm 8 percent of the time and had directions other than southerly or northerly 10 percent of the time. As

Figure 2. SNL and DRI sampling sites at the Tonopah Test Range.

Table 1. Wind frequency in percent at the Clean Slate background site, Feb 1996 - Jan 1997.

Month	Day			Night			Total		
	Northerly	Southerly	Calm	Northerly	Southerly	Calm	Northerly	Southerly	Calm
Feb 1996	34	49	7	34	46	13	34	47	11
Mar 1996	46	41	4	42	44	7	44	43	6
Apr 1996	59	26	6	57	31	6	58	29	6
May 1996	60	31	2	58	25	8	59	28	5
Jun 1996	22	65	4	30	49	8	25	58	6
Jul 1996	16	70	4	26	53	9	21	62	6
Aug 1996	25	61	6	20	42	14	23	52	10
Sep 1996	34	49	5	28	43	8	31	46	7
Oct 1996	50	39	5	35	47	10	41	44	8
Nov 1996	45	40	8	39	43	11	42	42	10
Dec 1996	31	54	6	26	48	16	28	50	13
Jan 1997	43	47	8	39	38	15	41	41	12
12 months	38	48	5	36	43	11	37	45	8
Overlap Period	39	48	5	36	42	10	37	45	8

noted above, summer months had higher incidences of southerly winds. In addition, southerly winds were more prevalent than northerly during both the daytime and nighttime, although more so during the daytime during the summer.

The comparison of the Clean Slate background monitoring results with the SNL NESHAPs monitoring results should not in any way be construed as a re-evaluation of the SNL data for meeting its NESHAPs requirements. That is, the SNL data were not specifically collected for this air monitoring results comparison. Lastly, as a point of reference, the ambient background air monitoring conducted by DRI and the NESHAPs data were collected prior to Corrective Action at any of the Clean Slate sites. Excavation of contaminated surface soils for remediation of Clean Slate 1 was done from April to August 1997.

2.0 PARTICLE COLLECTION AND ANALYSES

The SNL samples were collected on quartz filters with a high-volume PM₁₀ sampler. The sampler was operated at a flow rate of approximately 1.13 m³/min (40 ft³/min) in accordance with the design of the size-selective inlet used to obtain PM₁₀. Individual air samples were exposed for 48 hours and then composited as 14-day samples. The filters were weighed before and after sampling to obtain the net mass loading on the filters. For each two-week period, seven filters were composited and analyzed for ²⁴¹Am, ²³⁸Pu, and ²³⁹⁺²⁴⁰Pu by alpha spectroscopy. The concentrations of ambient PM₁₀ were calculated for each composite period from the net mass collected, the flow rate, and the exposure time. Each individual sample represented a volume of about 3,100 m³ and each composite about 22,000 m³. Approximately 0.1 g of material would have been collected during a two-week period if the mass concentration in the ambient air had been 5 µg/m³.

The DRI samples were collected on Teflon filters by battery-operated, low-volume samplers that operated at 5 l/min flow rates for 24-hour periods. Two 24-hour samples were collected each week: one on Monday and the other on Friday. An additional collocated sample was collected each Monday. Each filter was weighed at DRI's Reno laboratory before and after sampling to obtain its net mass loading. The concentration of ambient PM₁₀ for each sample period was calculated from the net mass collected, the flow rate, and the exposure time. The concentration on those days with two collocated samples was the average of the two samples. All exposed filters, including the collocated samples, were submitted to Bechtel Nevada (BN) Analytical Services Laboratory in Mercury, Nevada, for analysis of ²³⁸Pu and ²³⁹⁺²⁴⁰Pu by alpha spectroscopy. BN combined the material on the filters into four sets, each covering a three-month period, and then analyzed the four composite sets. BN provided activity data in µCi per composite sample for ²³⁸Pu and ²³⁹⁺²⁴⁰Pu with Minimum Detection Activities (MDAs) for each sample. The samples were not analyzed for ²⁴¹Am. Each sample represented a sample volume of about 7.2 m³. Approximately 36 µg of material would have been collected on a filter if the ambient concentration had been 5 µg/m³. The quarterly composite samples, which consisted of about 40 filters, would have contained about 1.4 mg of material.

SNL analyzed a total of 26 composite samples that were collected between the end of February 1996 and end of February 1997. DRI collected samples on 101 days of a possible 107 days between the end of January 1996 and the end of January 1997. A total of 144 valid filter samples, including the collocated samples, was collected, all of which were composited for radioactivity analysis. Samples were invalidated because of sampler failures that resulted in no sample collection and filter handling problems that resulted in damaged filters. For the

overlapping period of sampling from the end of February 1996 to the end of January 1997, SNL collected 24 composites, while DRI collected samples on 94 of a possible 99 sample days. Corresponding to the DRI three-month composites, there were five, six and a half, six and a half, and six SNL composites for the first, second, third, and fourth periods, respectively.

3.0 SAMPLE COMPARISONS

3.1 Mass Concentration Comparisons

The DRI mass concentrations for PM₁₀ particles for each SNL sample period were identified and averaged for comparison to the SNL mass concentrations for those periods as shown in Table 2. The average concentrations were 6.2 µg/m³ for the SNL samples and 6.9 µg/m³ for the DRI samples. The variation of the two sample sets was similar with the SNL samples having a standard deviation of ±3.8 µg/m³ and a range of 0.4 µg/m³ to 14.9 µg/m³ and the DRI samples having a standard deviation of ±4.1 µg/m³ and a range of 1.8 µg/m³ to 15.2 µg/m³. The DRI mass concentrations were higher than their corresponding SNL concentrations for 14 samples, while SNL concentrations were higher for 10 samples. All of the DRI mass concentrations are included in the Appendix as well as the uncertainties of the mass concentration measurements. The uncertainties have been calculated using the method of Watson et al. (1989) in which variances of the collocated and blank filter measurements and of the collected volume are propagated to the measurements of the mass concentrations. The uncertainties have been determined for the three-month periods that corresponded to the original reporting periods, since the mass data were adjusted for the blank filter masses during those periods. The variances of the collocated mass differences and the blanks controlled the uncertainty for samples that were exposed for 24 hours so that the uncertainties for each three-month period were the same. For samples that were exposed for other than 24 hours, uncertainties changed in inverse proportion to the fraction of the day sampled. The uncertainties for the 24-hour samples were 3.4 µg/m³ for January to April 1996, 2.7 µg/m³ for May to July 1996, 3.3 µg/m³ for August to October 1996, and 1.3 µg/m³ for November 1996 to February 1997.

Although the two sample sets were collected during the same time period, they were not collected with the same type of instruments at the same frequency or at the same locations and were not truly paired samples. To compare the concentrations of the two sets of measurements, a nonparametric statistical test that allows the testing for the difference between the medians of two independent samples, the Wilcoxon Rank-Sum Test, was used (Computing Resource Center, 1992). This test did not require that the underlying distributions for the two sets of samples were normal but generated a statistic, the Wilcoxon Rank-Sum Statistic, that had an approximately normal distribution (Weinberg et al., 1981). The composite SNL data and the average DRI mass concentrations were combined into one set of data and ranked in ascending order with each concentration given a number rank. Equal concentrations were given equal to the average of the ranks for those concentrations. The Wilcoxon Rank-Sum Statistics for each sample were calculated as the sum of the ranks for each sample: 560.5 for the 24 SNL samples and 615.5 for the 24 DRI samples. The expected value for each statistic was found from

$$E(T_{SNL\ or\ DRI}) = \frac{m_{SNL\ or\ DRI} (N + 1)}{m_{SNL\ or\ DRI}}$$

Table 2. Comparison of PM₁₀ mass concentrations.

SNL NESHAPs Sampling			DRI Clean Slate Background Sampling		
Composite		Composite PM ₁₀ Concentration (µg/m ³)	Sample Dates		Average PM ₁₀ Concentration (µg/m ³)
Start	End		First	Last	
02/20/1996	03/04/1996	5.3	02/23/1996	03/04/1996	2.3
03/05/1996	03/18/1996	3.0	03/08/1996	03/18/1996	3.8
03/19/1996	04/01/1996	6.1	03/22/1996	04/01/1996	7.1
04/02/1996	04/15/1996	5.0	04/05/1996	04/15/1996	9.5
04/16/1996	04/29/1996	6.9	04/19/1996	04/29/1996	8.1
04/30/1996	05/13/1996	6.3	05/03/1996	05/13/1996	7.3
05/14/1996	05/27/1996	7.3	05/17/1996	05/27/1996	11.9
05/28/1996	06/10/1996	10.1	05/31/1996	06/10/1996	14.6
06/11/1996	06/24/1996	10.3	06/14/1996	06/24/1996	12.8
06/25/1996	07/06/1996	6.7	06/28/1996	07/08/1996	9.5
07/09/1996	07/22/1996	8.0	07/12/1996	07/22/1996	5.8
07/23/1996	08/09/1996	12.9	07/26/1996	08/05/1996	15.2
08/10/1996	08/23/1996	14.9	08/12/1996	08/23/1996	11.4
08/24/1996	09/06/1996	11.0	08/26/1996	09/06/1996	9.1
09/07/1996	09/20/1996	6.5	09/09/1996	09/20/1996	6.4
09/21/1996	10/06/1996	7.1	09/23/1996	10/04/1996	5.6
10/07/1996	10/20/1996	7.0	10/11/1996	01/00/00	5.2
10/21/1996	11/01/1996	4.5	10/21/1996	11/01/1996	4.4
11/02/1996	11/17/1996	3.0	11/04/1996	11/15/1996	1.8
11/18/1996	12/07/1996	1.9	11/18/1996	12/02/1996	1.8
12/08/1996	12/21/1996	1.4	12/09/1996	12/20/1996	4.5
12/22/1996	01/06/1997	1.0	12/23/1996	01/06/1997	3.6
01/07/1997	01/20/1997	1.6	01/10/1997	01/20/1997	1.9
01/21/1997	02/03/1997	0.4	01/24/1997	01/31/1997	2.6
Average		6.2	Average		6.9
Standard Deviation		3.8	Standard Deviation		4.1
Maximum		14.9	Maximum		15.2
Minimum		0.4	Minimum		1.8
Number		24	Number		24
Wilcoxon Rank-Sum Test					
			SNL		DRI
Wilcoxon Rank-Sum Statistic			560.5		615.5
Expected Sum of Ranks			588		
Variance			2352		
Z-Statistic			-0.567		0.567
Probability of incorrectly rejecting null hypothesis			0.571		

where $E(T_{\text{SNL or DRI}})$ was the expected value for the ranks of either SNL or DRI concentrations, $m_{\text{SNL or DRI}}$ was the number of concentrations in the particular set of concentrations, and N was the total number of concentrations. The variance for either set of concentrations was given by

$$\text{Var}(T_{\text{SNL or DRI}}) = \frac{m_{\text{SNL}}m_{\text{DRI}}(N+1)}{12}$$

where $\text{Var}(T_{\text{SNL or DRI}})$ was the variance of the ranks for either SNL or DRI concentrations and m_{SNL} and m_{DRI} were the number of concentrations for the two sets. For the data in question, the expected value for the sum of the ranks was 588 and the variance was 2,352.

The medians of the two distributions were compared with a statistical test that first assumed that there was no difference between the actual sums of ranks and the expected sum of ranks, i.e., the null hypothesis. The probability of incorrectly rejecting this null hypothesis gave a measure of the statistical significance of possible differences between the medians of the distributions of the concentrations. Since the distribution of the Wilcoxon Rank-Sum Statistics was approximately normal, the following Z statistic was generated for comparison with a normal distribution:

$$Z_{\text{SNL or DRI}} = \frac{T_{\text{SNL or DRI}} - E(T_{\text{SNL or DRI}})}{\sqrt{\text{Var}(T_{\text{SNL or DRI}})}}$$

The Z statistics were -0.567 for the SNL ranks and 0.567 for the DRI ranks. For a two-sided test of a normal distribution, these Z statistics showed that the medians were not statistically different at any level smaller than the 57.1 percent level. It can be concluded from this test that the calculated median mass loadings of PM_{10} particles at the two sites were not different.

3.2 Radiation Measurement Comparisons

Data listed in SNL's NESHAPs report and supplied to DRI by SNL show that the amount of radioactivity on most of the composite samples was at or below the MDAs of the measurement technique. Table 3 gives the number of SNL samples for the overlapping period with the DRI samples that had activities greater than, equal to, and less than the MDA.

Radiation measurements of the DRI samples showed activities that were below MDAs for three of the four composites. Only one sample had a $^{239+240}\text{Pu}$ activity that was above detection limits.

Table 3. SNL samples compared to minimum detection activity.

Sample Activity Relative to Minimum Detection Activity	Number of Samples		
	^{241}Am	^{238}Pu	$^{239+240}\text{Pu}$
Sample Activity > MDA	5	1	2
Sample Activity = MDA	4	1	6
Sample Activity < MDA	15	22	16

With most of the measurements below detection limits, the activities of the two sets of samples cannot be definitively compared. The activities could only be compared by replacing those activities that were below detection limits with their MDAs.

To compare maximum possible sample activities, the SNL activities were combined into four groups with each corresponding to one of the DRI composite periods. The activities of the combined SNL samples were computed as total activity in pCi/g and activity concentrations in pCi/m³ with the MDAs used for those samples having activities below the MDA. The SNL and DRI activities for the three-month periods are given in Table 4. The one DRI sample that was above detection limits is noted in the table. The number of SNL samples at or above detection limits is also noted for each three-month period.

The total activities on the SNL samples were higher than those on the DRI samples, likely the result of collecting a much higher amount of mass with the higher volume air samplers and longer exposure times used for the NESHAPs monitoring. However, the activity concentration, in pCi/g, was greater for the one DRI composite sample above the MDA. The SNL samples for the February-April 1996 and May-July 1996 periods, most of which were at or above the MDAs for ²⁴¹Am and ²³⁹⁺²⁴⁰Pu, had activity concentrations that were a few tenths of a pCi/g, while the DRI activity was 77 pCi/g for ²³⁹⁺²⁴⁰Pu for the February-April 1996 composite. DRI samples for the August-October 1996 period had lower MDAs and thus lower possible maximum activities than during the two previous periods but still had MDAs that were five times the maximum possible SNL MDAs. The SNL samples for November 1996–January 1997 had higher MDAs than in previous months but still had maximum possible activities that were half those of the maximum possible DRI activities. However, the limited number of samples exceeding the MDA limits the significance of these seasonal differences.

4.0 CONCLUSIONS

The PM₁₀ mass concentrations for samples collected by SNL at a site near the TTR airport and by DRI at the Clean Slate background site averaged 6.2 µg/m³ and 6.9 µg/m³, respectively, for the comparison period. Application of a Wilcoxon Rank-Sum Test showed that there was no statistical difference between the medians of the mass concentrations of the two sample sets, which implies a relatively uniform aerosol loading in the area to the north of the Clean Slate sites. The similar mass concentrations and their low values imply that there were no major sources of airborne PM₁₀ near either sampling site, although simultaneous measurements upwind and downwind of the Clean Slate sites would have been necessary to definitively determine emissions that might have come from the Clean Slate sites. More specifically, there is no indication from the available data that airborne PM₁₀ particles are being transported farther to the SNL NESHAPs monitoring location from the Clean Slate sites than to the near-field, DRI monitoring site.

However, the available data are insufficient to conclude whether there are significant differences in the transport of airborne plutonium particles in the respirable size range between the near-field (DRI) and the far-field (SNL) monitoring sites. In large part, this is a consequence of the small number of samples where the total activity or the activity concentration exceeded the MDA of the measurements. Only 10 of 48 SNL samples (20.8 percent) had activities for ²³⁸Pu and ²³⁹⁺²⁴⁰Pu that were equal to or greater than the MDA. Similarly, only one of the four composite samples collected by DRI had a ²³⁹⁺²⁴⁰Pu activity that exceeded the MDA. The low

Table 4. Maximum activities for three-month composite samples.

Organization	Composite				Maximum Activity/Composite, pCi			Maximum Activity/Composite, pCi/m ³			Maximum Activity/Composite, pCi/g		
	Start	End	Volume m ³	Mass mg	²⁴¹ Am	²³⁸ Pu	²³⁹⁺²⁴⁰ Pu	²⁴¹ Am	²³⁸ Pu	²³⁹⁺²⁴⁰ Pu	²⁴¹ Am	²³⁸ Pu	²³⁹⁺²⁴⁰ Pu
SNL ^a	02/20/1996	04/29/1996	105612.3	554.9	0.09	0.05	0.05	8.52E-07	4.73E-07	4.73E-07	0.16	0.09	0.09
	04/30/1996	08/09/1996	146416.8	1301.1	0.13	0.29	0.09	8.88E-07	1.98E-06	6.15E-07	0.10	0.22	0.07
	08/10/1996	11/01/1996	118821.4	1023.6	0.75	1.01	1.02	6.31E-06	8.50E-06	8.58E-06	0.73	0.99	1.00
	11/02/1996	02/03/1997	190186.8	291.4	3.10	1.18	1.91	1.63E-05	6.20E-06	1.00E-05	10.64	4.05	6.55
DRI ^b	01/26/1996	04/29/1996	278.45	1.45	-	0.05	0.11 ^b	-	1.62E-04	4.02E-04 ^b	-	31.0	77.2 ^b
	05/03/1996	07/29/1996	249.55	2.69	-	0.05	0.05	-	1.92E-04	1.92E-04	-	17.8	17.8
	08/02/1996	10/28/1996	252.43	2.18	-	0.01	0.01	-	4.75E-05	4.75E-05	-	5.5	5.5
	11/01/1996	01/31/1997	244.23	0.83	-	0.01	0.01	-	4.09E-05	4.09E-05	-	12.0	12.0

^aSNL samples at or above detection limits in summation of composites:

Sample 1: 4 for ²⁴¹Am, 0 for ²³⁸Pu, 5 for ²³⁹⁺²⁴⁰Pu from a total of 5 samples

Sample 2: 2 for ²⁴¹Am, 1 for ²³⁸Pu, 3 for ²³⁹⁺²⁴⁰Pu from a total of 7 samples

Sample 3: 1 for ²⁴¹Am, 0 for ²³⁸Pu, and 0 for ²³⁹⁺²⁴⁰Pu from a total of 6 samples

Sample 4: 2 for ²⁴¹Am, 1 for ²³⁸Pu, 0 for ²³⁹⁺²⁴⁰Pu from a total of 6 samples

^bAnalysis above detection limits

values of total activity and activity concentration from both sites suggest the inhalation hazard from plutonium is low. Compared to the Derived Concentration Guide (DCG) for exposure to the general public of 3×10^{-15} $\mu\text{Ci/ml}$ (an effective dose equivalent {EDE} of 10 mrem/yr), the highest measured concentration from the DRI sampling (the February to April 1996 sample) was 13.3 percent of the DCG (Bowen, 1997a). Similarly, SNL calculated average net activity concentrations from ^{241}Am , ^{238}Pu , and $^{239+240}\text{Pu}$ for an EDE of 0.024 mrem/yr, or 0.24 percent of the DCG of 10 mrem/yr (Sandia National Laboratories, 1997). Nevertheless, the data sets are statistically insufficient to conclude whether there are differences in transport of radionuclides from the Clean Slate sites to the near-field versus the far-field site.

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APPENDIX

Ambient Concentrations of Airborne PM₁₀ at Clean Slate Background Site
26 January 1996 to 31 January 1997

Table A-1. Ambient Concentrations of Airborne PM₁₀ at Clean Slate Background Site, TTR, 26 January 1996 to 29 April 1996^a.

Filter ID	Sampling Date	Sampling Period		Sample day Concentration ^b µg/m ³	Collocated Filter Concentration µg/m ³	Comments
		HHMM	to HHMM			
CSTT001	1/26/1996	0000	1914	-	-	Weighing error
CSTT003	1/29/1996	0000	2400	3.1	4.2	
CSTT004 ^c		0000	2400		2.0	
CSTT005	2/2/1996	0000	2400	1.5	-	
CSTT007	2/5/1996	0000	1944	3.8	3.9	Short sample/ Pump stopped after 19.75 hours
CSTT008 ^c		0000	2400		3.6	
CSTT009	2/9/1996	0000	2400	4.2	-	
CSTT011	2/12/1996	0000	2400	2.6	4.0	
CSTT012 ^c		0000	2400		1.1	
CSTT013	2/16/1996	0000	2400	6.4	-	
CSTT015	2/19/1996	0000	2400	6.5	7.4	
CSTT016 ^c		0000	2400		5.7	
CSTT017	2/23/1996	0000	2353	3.2	-	
CSTT019	2/26/1996	0000	2400	-	-	Weighting error
CSTT020 ^c		0000	2400		-	Weighting error
CSTT021	3/1/1996	0000	0645	2.5	-	Short sample/ Pump stopped after 6.75 hours
CSTT023	3/4/1996	0000	2400	3.5	5.6	Estimated Time, No Elapsed Time Indicator
CSTT024 ^c		0000	2400		1.4	
CSTT025	3/8/1996	0000	2400	2.4	-	
CSTT027	3/11/1996	0000	2400	3.8	4.2	Estimated Time, No Elapsed Time Indicator
CSTT028 ^c		0000	2400		3.3	
CSTT029	3/15/1996	0000	2400	4.3	-	
CSTT031	3/18/1996	0000	2400	4.6	4.2	
CSTT032 ^c		0000	2400		5.0	
CSTT033	3/22/1996	0000	2400	8.1	-	

Table A-1. Ambient Concentrations of Airborne PM₁₀ at Clean Slate Background Site, TTR, 26 January 1996 to 29 April 1996^a (continued).

Filter ID	Sampling Date	Sampling Period		Sample day Concentration ^b µg/m ³	Collocated Filter Concentration µg/m ³	Comments	
		HHMM to HHMM					
CSTT035	3/25/1996	0000	2400	2.9	2.6		
CSTT036 ^c		0000	2400		3.2		
CSTT039	3/29/1996	0000	2400	10.8	-		
CSTT037	4/1/1996	0000	2400	6.5	3.8		
CSTT038 ^c		0000	0647		9.3	Short sample/ Pump stopped after 6.75 hours	
CSTT041	4/5/1996	0000	2400	4.7	-		
CSTT043	4/8/1996	0000	2115	7.7	6.3	Short sample/ Pump stopped after 21.25 hours	
CSTT044 ^c		0000	1838		9.1	Short sample/ Pump stopped after 18.5 hours	
CSTT045	4/12/1996	0000	1708	25.4		Short sample/ Pump stopped after 17 hours	
CSTT047	4/15/1996	0000	2400	-	-	Weighing error	
CSTT048 ^c		0000	0000		-	Pump did not start	
CSTT049	4/19/1996	0000	2400	9.3			
CSTT051	4/22/1996	0000	2400	12.2	12.6		
CSTT053 ^c		0000	2400		11.8		
DTTT209	4/26/1996	0000	2400	4.9			
DTTT211	4/29/1996	0000	2400	5.9	8.3		
DTTT212 ^c		0000	2113		3.5	Short sample/ Pump stopped after 21.25 hours	
		Average					6.0
		Std. Dev.					4.9
		Maximum					25.4
		Minimum					1.5
		Number					25

^a For period, uncertainty for sample is 3.4 x (1440/minutes of exposure) µg/m³^b Sample day concentration from either single sample or from average of collocated concentrations^c Collocated sample

Table A-2. Ambient Concentrations of Airborne PM₁₀ at Clean Slate Background Site, TTR, 3 May 1996 to 29 July 1996^a.

Filter ID	Sampling Date	Sampling Period		Sample day Concentration ^b μg/m ³	Collocated Filter Concentration μg/m ³	Comments
		HHMM to HHMM				
CSTT058	5/3/1996	0000	2400	6.8	-	
CSTT060	5/6/1996	0000	2400	2.9	2.4	
CSTT061 ^c		0000	2400		3.4	
CSTT062	5/10/1996	0000	2400	9.2	-	
CSTT064	5/13/1996	0000	2400	10.4	9.3	
CSTT065 ^c		0000	2400		11.4	
CSTT066	5/17/1996	0000	1208	17.3	-	Short sample/ Pump stopped after 12 hours
CSTT068	5/20/1996	0000	2400	12.0	13.1	
CSTT069 ^c		0000	2400		11.0	
CSTT070	5/24/1996	0000	2400	12.9	-	
CSTT072	5/27/1996	0000	2400	8.1	-	Weighing error
CSTT073 ^c		0000	2400		8.1	
CSTT074	5/31/1996	0000	2400	18.5	-	
CSTT076	6/3/1996	0000	2400	8.8	9.5	
CSTT077 ^c		0000	2400		8.1	
CSTT078	6/7/1996	0000	1128	30.9	-	Short sample/ Pump stopped after 11.5 hours
CSTT080	6/10/1996	0000	2400	8.6	9.2	
CSTT081 ^c		0000	2400		8.1	
CSTT082	6/14/1996	0000	2400	13.7	-	
CSTT084	6/17/1996	0000	2400	9.1	8.9	
CSTT085 ^c		0000	2400		9.3	
CSTT086	6/21/1996	0000	2400	12.8	-	
CSTT088	6/24/1996	0000	2400	15.6	14.9	
CSTT089 ^c		0000	2400		16.3	
CSTT090	6/28/1996	0000	2400	6.1	-	

Table A-2. Ambient Concentrations of Airborne PM₁₀ at Clean Slate Background Site, TTR, 3 May 1996 to 29 July 1996^a (continued).

Filter ID	Sampling Date	Sampling Period		Sample day Concentration ^b µg/m ³	Collocated Filter Concentration µg/m ³	Comments	
		HHMM to HHMM					
CSTT092	7/1/1996	0000	2400	10.5	9.5		
CSTT093 ^c		0000	2400		11.6		
CSTT094	7/5/1996	0000	2400	7.7	-		
CSTT096	7/8/1996	0000	2400	13.6	13.6		
CSTT097 ^c		0000	2400		13.5		
CSTT098	7/12/1996	0000	2400	5.0	-		
CSTT101	7/15/1996	0000	0000	-	-	Pump did not start	
CSTT102 ^c		0000	0004		-	Pump did not start	
CSTT103	7/19/1996	0000	0013	-	-	Pump did not start	
CSTT105	7/22/1996	0000	1636	6.7	6.2	Short sample/ Pump stopped after 16 hours	
CSTT106 ^c		0000	2400		7.1		
CSTT107	7/26/1996	0000	2400	39.8	-		
CSTT109	7/29/1996	0000	2400	12.7	9.2		
CSTT110 ^c		0000	2400		16.3		
		Average					12.5
		Std. Dev.					8.1
		Maximum					39.8
		Minimum					2.7
		Number					24

^a For period, uncertainty for sample is 2.7 x (1440/minutes of exposure) µg/m³

^b Sample day concentration from either single sample or from average of collocated concentrations

^c Collocated sample

Table A-3. Ambient Concentrations of Airborne PM₁₀ at Clean Slate Background Site, TTR, 2 August 1996 to 28 October 1996^a.

Filter ID	Sampling Date	Sampling Period		Sample day Concentration ^b μg/m ³	Collocated Filter Concentration μg/m ³	Comments
		HHMM	to HHMM			
CSTT111	8/2/1996	0000	2400	9.1	-	
CSTT113	8/5/1996	0000	2400	7.6	8.1	
CSTT114 ^c		0000	0722		7.0	Short sample/ Pump stopped after 7 hours
CSTT115	8/9/1996	0000	2400	6.7	-	
CSTT117	8/12/1996	0000	2400	12.8	12.6	
CSTT118 ^c		0000	2400		13.0	
CSTT119	8/16/1996	0000	2400	12.3	-	
CSTT121	8/19/1996	0000	2400	13.5	13.4	
CSTT122 ^c		0000	2400		13.5	
CSTT123	8/23/1996	0000	2400	7.1	-	
CSTT125	8/26/1996	0000	1208	6.3	7.0	Short sample/ Pump stopped after 12 hours
CSTT126 ^c		0000	2400		5.6	
CSTT127	8/30/1996	0000	2400	9.0	-	
CSTT129	9/2/1996	0000	0553	15.4	17.2	Short sample/ Pump stopped after 5 hours
CSTT130 ^c		0000	2400		13.5	
CSTT131	9/6/1996	0000	2400	5.8	-	
CSTT133	9/9/1996	0000	2400	5.8	6.0	
CSTT134 ^c		0000	2400		5.5	
CSTT135	9/13/1996	0000	0554	5.3	-	Short sample/ Pump stopped after 5 hours
CSTT137	9/16/1996	0000	2400	5.7	6.6	
CSTT138 ^c		0000	2400		4.8	
CSTT139	9/20/1996	0000	2400	8.0	-	
CSTT141	9/23/1996	0000	2400	7.4	4.4	
CSTT142 ^c		0000	2400		10.5	
CSTT143	9/27/1996	0000	2400	1.7	-	

Table A-3. Ambient Concentrations of Airborne PM₁₀ at Clean Slate Background Site, TTR, 2 August 1996 to 28 October 1996^a (continued).

Filter ID	Sampling Date	Sampling Period		Sample day Concentration ^b µg/m ³	Collocated Filter Concentration µg/m ³	Comments	
		HHMM	to HHMM				
CSTT145	9/30/1996	0000	0558	5.2	7.5	Short sample/ Pump stopped after 6 hours	
CSTT146 ^c		0000	2400		3.0		
CSTT147	10/4/1996	0000	2400	7.8	-		
CSTT149	10/7/1996	0000	2400	5.5	5.6		
CSTT151 ^c		0000	2400		5.3		
CSTT152	10/11/1996	0000	2400	8.5	-		
CSTT154	10/14/1996	0000	2400	4.2	6.9		
CSTT155 ^c		0000	2400		1.6		
CSTT156	10/18/1996	0000	1231	0.8	-	Short sample/ Pump stopped after 12 hours	
CSTT158	10/21/1996	0000	2400	1.7	1.3		
CSTT159 ^c		0000	2400		2.1		
CSTT160	10/25/1996	0000	2400	11.5	-		
CSTT162	10/28/1996	0000	2400	2.1	2.7		
CSTT163 ^c		0000	2400		1.5		
		Average					7.2
		Std. Dev.					3.7
		Maximum					15.4
		Minimum					0.8
		Number					26

^a For period, uncertainty for sample is 3.3 x (1440/minutes of exposure) µg/m³

^b Sample day concentration from either single sample or from average of collocated concentrations

^c Collocated sample

Table A-4. Ambient Concentrations of Airborne PM₁₀ at Clean Slate Background Site, TTR, 1 November 1996 to 7 February 1997^a.

Filter ID	Sampling Date	Sampling Period		Sample day Concentration ^b μg/m ³	Collocated Filter Concentration μg/m ³	Comments
		HHMM to HHMM				
CSTT164	11/1/1996	0000	2400	2.4	-	
CSTT166	11/4/1996	0000	2400	2.8	2.0	
CSTT167 ^c		0000	1725		3.6	Short sample/ Pump stopped after 17 hours
CSTT168	11/8/1996	0000	0300	3.3	-	Short sample/ Pump stopped after 3 hours
CSTT170	11/11/1996	0000	1030	1.5	1.3	Short sample/ Pump stopped after 10.5 hours
CSTT171 ^c		0000	2400		1.7	
CSTT173	11/15/1996	0000	2400	0.8	-	Filter damaged, part of filter torn by holder.
CSTT174	11/18/1996	0000	2400	3.3	3.9	
CSTT175 ^c		0000	2400		2.6	
CSTT177	11/22/1996	0000	2400	0.3	-	
CSTT178	11/25/1996	0000	0629	1.5	1.0	Short sample/ Pump stopped after 6.5 hours
CSTT179 ^c		0000	2400		2.0	
CSTT181	11/29/1996	0000	0850	2.3	-	Short sample/ Pump stopped after 9 hours
CSTT182	12/2/1996	0000	2400	2.1	1.8	
CSTT183 ^c		0000	2400		2.4	
CSTT184	12/6/1996	0000	0000	-	-	Pump did not start
CSTT186	12/9/1996	0000	2400	3.1	3.1	
CSTT187 ^c		0000	2400		3.1	
CSTT188	12/13/1996	0000	2400	8.1	-	
CSTT190	12/16/1996	0000	0000	4.5	-	Pump did not start
CSTT191 ^c		0000	2400		4.5	Ran for 2.21 days, 12/16-18
CSTT192	12/20/1996	0000	2400	3.2	-	Ran 12/20 0000-2400; 12/27 0000-1115
CSTT194	12/23/1996	0000	0016	4.2	-	Pump did not start
CSTT195 ^c		0000	2400		4.2	Ran for 2.25 days, 12/23-25
CSTT196	12/27/1996	1130	2400	7.8	-	Late start
CSTT198	12/30/1996	0000	2400	2.1	2.2	
CSTT199 ^c		0000	2400		2.0	

Table A-4. Ambient Concentrations of Airborne PM₁₀ at Clean Slate Background Site, TTR, 1 November 1996 to 7 February 1997^a (continued).

Filter ID	Sampling Date	Sampling Period		Sample day Concentration ^b µg/m ³	Collocated Filter Concentration µg/m ³	Comments
		HHMM to HHMM				
CSTT201	1/3/1997	0000	2400	0.6	-	
CSTT203	1/6/1997	0000	0000	4.6	-	Pump did not start
CSTT204 ^c		0000	2400		4.6	
CSTT205	1/10/1997	0000	2400	0.3	-	
CSTT207	1/13/1997	0000	2400	4.2	4.2	
CSTT208 ^c		0000	0205		-	Short sample/ Pump stopped after 2 hours
CSTT209	1/17/1997	0000	0700	1.9	-	Short sample/ Pump stopped after 7 hours
CSTT211	1/20/1997	0000	2400	2.0	1.9	
CSTT212 ^c		0000	0110		-	Short sample/ Pump stopped after 1 hour
CSTT213	1/24/1997	0000	2400	1.9	-	
CSTT215	1/27/1997	0000	0410	2.2	-	Short sample/ Pump stopped after 4 hours
CSTT216 ^c		0000	2400		2.2	
CSTT218	1/31/1997	0000	2400	3.5	-	
CSTT220	2/3/1997	0000	0034	2.8	-	Short sample/ Pump stopped after 0.5 hour
CSTT219 ^c		0000	2400		2.8	
CSTT221	2/7/1997	0000	2400	2.5	-	Ran 2/7 0000-2400, 2/14 0000-2400
CSTT223	2/7/1997	0000	0004	4.1	-	Pump did not start
CSTT224 ^c		0000	2400		4.1	Ran 2/7 0000-2400, 2/14 0000-2400
		Average		2.9		
		Std. Dev.		1.9		
		Maximum		8.1		
		Minimum		0.3		
		Number		26		

^a For period, uncertainty for sample is 1.3 x (1440/minutes of exposure) µg/m³^b Sample day concentration from either single sample or from average of collocated concentrations^c Collocated sample