9.0 Soil Monitoring

JW Wilde

Radiological monitoring of soil is conducted at a variety of locations: on site near Hanford Site facilities and operations, on site away from facilities and operations, and off site at perimeter and distant locations and in nearby communities. Contaminant concentration data are used for the following:

- Determine the effectiveness of effluent monitoring and controls within facilities
- Assess the adequacy of containment at waste disposal sites
- Detect and monitor unusual conditions
- Provide information on long-term radionuclide contamination trends in soil at undisturbed locations.

Data obtained from onsite soil samples is used as a qualitative indicator and verification of ambient air sampling results per the WDOH Radioactive Emissions License for the Hanford Site (FF-01).

Soil samples have been collected on and around the Hanford Site for more than 50 years. Consequently, a large amount of data exist that document onsite and offsite levels of manmade radionuclides in Hanford Site soils. These data provide a baseline to which unplanned releases are compared. The Hanford Site Environmental Surveillance Master Sampling Schedule is available online at http://www.hanford.gov/page.cfm/environmentalsurveillance.

9.1 Monitoring Results

Soil monitoring provides information about long-term contamination trends and baseline environmental radionuclide activities at undisturbed locations both on and off the Hanford Site according to the Hanford Site Environmental Monitoring Plan (DOE/RL-91-50, Rev. 6A).

9.2 Sampling Results

Soil samples are collected near facilities and operations on the Hanford Site to detect potential migration and deposition of facility emissions and evaluate long-term trends in the environmental accumulation of radioactive materials. Soil contamination can occur as the result of direct deposition from facility emissions, resuspension and movement of contaminants from radiologically contaminated surface areas, uptake of contaminants into plants whose roots contact groundwater or below ground waste, or translocation of buried waste by intruding animals.

Soil samples were collected on or adjacent to waste disposal sites and from locations downwind and near or within the boundaries of operating facilities and remedial action sites. The number and locations of soil samples collected in 2014 are summarized in Table 9.1. Only radionuclides with concentrations consistently above analytical detection limits are discussed in this section. Soil samples from offsite locations were last collected in 2008 (PNNL-18427, *Hanford Site Environmental Surveillance Data Report for Calendar Year 2008*).

Table 9.1. Soil Sample Locations

Number of Samples Analyzed	Operational Area (discrete samples analyzed)							
	ETF	200-West[a]	200-East[a]	300[a]	400	600[a]	ERDF	Composites [a, b]
50	3	9	8	8	1	6	1	14

[a] Number of samples includes one or more replicate samples.
[b] 41 individual soil samples from the 200 and 600 Areas were combined into 14 composite samples using a multi-incremental approach.

Individual soil samples are 2.2 pounds (1.0 kilogram), which represent a parent sample consisting of five plugs of soil; each sample is approximately 1.0 inch (2.5 centimeters) deep and 4 inches (10 centimeters) in diameter. Soil samples are sieved in the field to remove potential sample intrusions such as rocks and plant debris, and then dried in the laboratory prior to analysis to remove residual moisture. Some soil samples were analyzed as single parent samples (discrete codes), while others were composited using the following approach.

A multi-incremental sampling technique is used when collecting samples from a large given area (i.e., a decision unit). Individual samples are processed using a gridded pattern approach and combined with other samples from the decision unit to create a composite sample that represents the decision unit as a whole. This compositing limits the variability of selected environmental contaminant concentrations in a given area and reduces the amount of sampling error due to heterogeneity, while allowing for a reproducible mean concentration for the decision unit.

Soil samples were analyzed for radionuclides expected to occur in the areas sampled (i.e., gamma-emitting radionuclides, strontium-90, uranium isotopes, and/or plutonium isotopes). The analytical results from Hanford Site soil samples were compared to concentrations of radionuclides measured in samples collected off site at various sampling locations in Grant, Yakima, Walla Walla, Adams, Benton, and Franklin counties in 2008. These comparisons were used to differentiate concentrations of Hanford Site-produced contaminants from levels resulting from natural sources and worldwide fallout.

Onsite soil sampling results can be compared to the accessible soil concentrations (WHC-SD-EN-TI-070, *Soil Concentration Limits for Accessible and Inaccessible Areas*) developed specifically for use at the Hanford Site. These concentration values for radionuclides were established to ensure that effective dose equivalents to the public do not exceed the established limits for any reasonable scenario, such as direct exposure, inadvertent ingestion, inhalation, and consumption of foods, including animal products. The accessible soil concentration values are based on a radiation-dose estimate scenario (WHC-SD-EN-TI-070) in which an individual would have to spend 100 hours per year in direct contact with the contaminated soil. The conservatism inherent in pathway modeling ensures the required degrees of protection are in place. These concentrations apply specifically to the Hanford Site with respect to onsite waste disposal operations, cleanup, and decontamination and decommissioning activities. A partial list of these values is provided in Table 9.2.

Table 9.2. Accessible Soil Concentration Limits for Selected Radionuclides
pCi/g [a] dry weight

	Cobalt-60	Strontium-90	Cesium-137	Uranium-234	Uranium-235	Uranium-238	Plutonium-239/240
Accessible soil [b] concentration limits (WHC-SD-EN-TI-070)	7.1	2,800	30	630	170	370	190

[a] To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
[b] Hanford Site soil that is not behind security fences.
WHC-SD-EN-TI-070, *Soil Concentration Limits for Accessible and Inaccessible Areas*

Some degree of variability is always associated with collecting and analyzing environmental samples; therefore, variations in sample concentrations from year to year are expected. In general, radionuclide concentrations in soil samples collected from or adjacent to waste disposal facilities in 2014 were higher than the concentrations in samples collected farther away. The data also showed, as expected, that concentrations of certain radionuclides in 2014 were higher in different operational areas when compared to concentrations measured in distant communities in previous years. Historically, the predominant radionuclides detected were activation and fission products in the 100 Areas, fission products in the 200 and 600 Areas, and uranium in the 300 and 400 Areas.

Cesium-137, strontium-90, plutonium-239/240, and uranium were detected consistently in the 2014 soil samples. Concentrations of these radionuclides were elevated near and within facility boundaries when compared to historical concentrations measured offsite at distant communities. Figure 9.1 shows the average concentrations of selected radionuclides in soil samples collected during 2014 and the preceding 4 years. Some individual levels demonstrate a high degree of variability, although overall trends are stable.

Table 9.3 provides a summary of selected analytical results for near-facility soil samples collected and analyzed. The average and maximum results were reported for the major operational areas, along with comparative data for the preceding 5 years. Complete lists of radionuclide concentrations for all soil samples collected during 2014, as well as sampling location maps, are available upon request.

Results for soil samples collected in 2014 at locations in the 200-East Area, 200-West Area, 300 Area, and 600 Area were comparable to previous years. Soil samples collected in the 300 Area showed concentrations of uranium-234 and uranium-238 that were comparable to historical data, but remained higher than those measured in the 200 Area. The higher uranium levels in the 300 Area were expected because of uranium releases to the environment during past fuel-fabrication operations. Plutonium-239/240 was detected in a number of soil samples in the 200, 300, and 600 Areas. Strontium-90 was detected in the 200 and 600 Areas and were within historical concentration ranges. Cesium-137 was detected consistently at levels comparable to historical levels over the past 5 years.

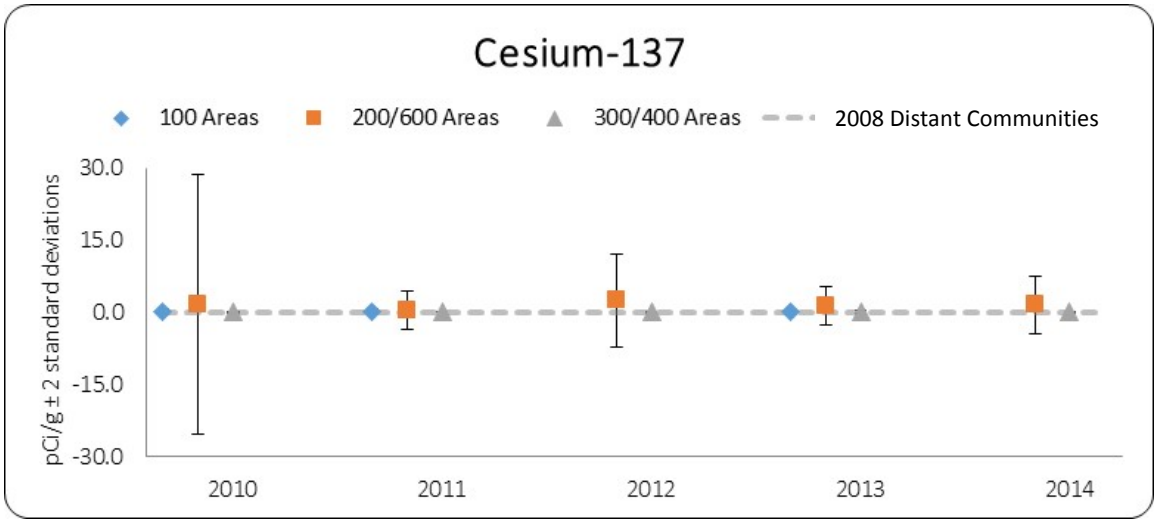
There were no soil samples collected in the 100 Areas during 2014.

To comply with WDOH Notice of Construction requirements, special soil deposition sampling was implemented during 2014 around the 200 Effluent Treatment Facility and Trench 94 of the 218-E-12B waste site in the 200-East Area. Sample results from both sites showed cesium-137 concentrations comparable to values from other sample areas. Table 9.4 provides a summary of selected analytical results for samples from these sites.

A soil sample is collected annually at ERDF from a predominantly downwind sampling location. The 2014 soil sample showed slightly elevated concentrations of uranium, however, detections were comparable to levels observed in previous years at other near-facility sampling locations on the Hanford Site.

Figure 9.1. Hanford Site Soil Samples Average Concentrations of Selected Radionuclides (2010 through 2014)

As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.



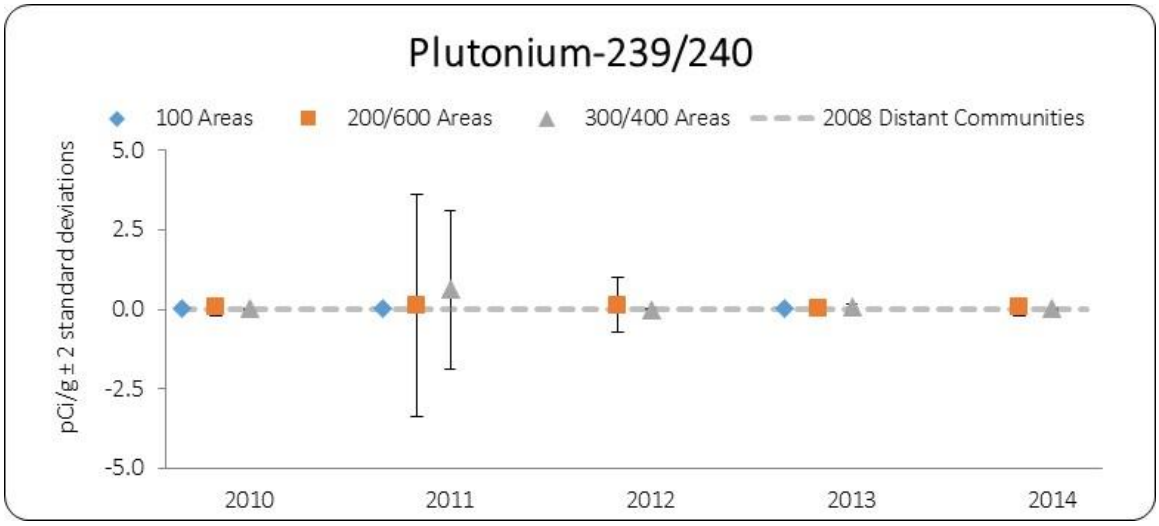
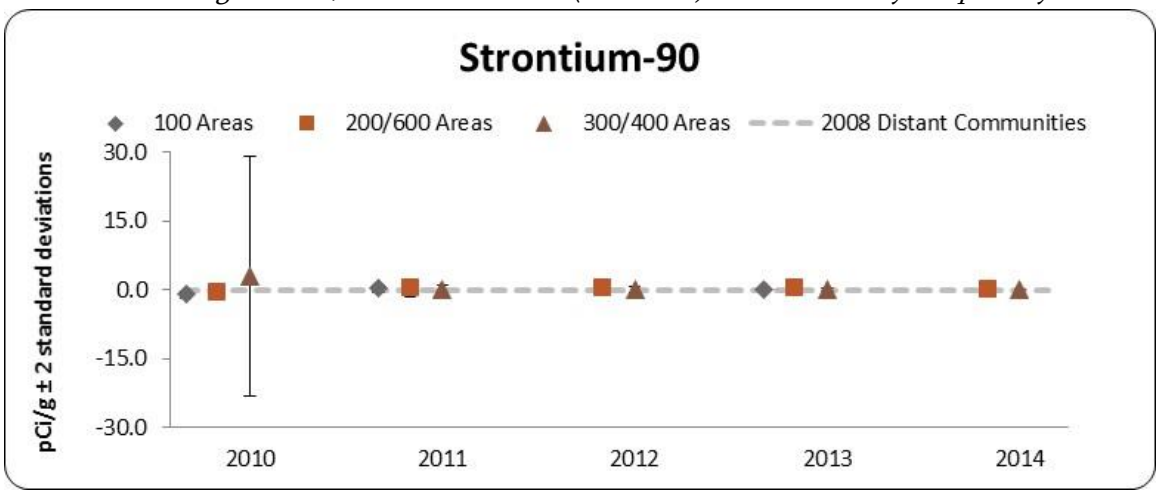
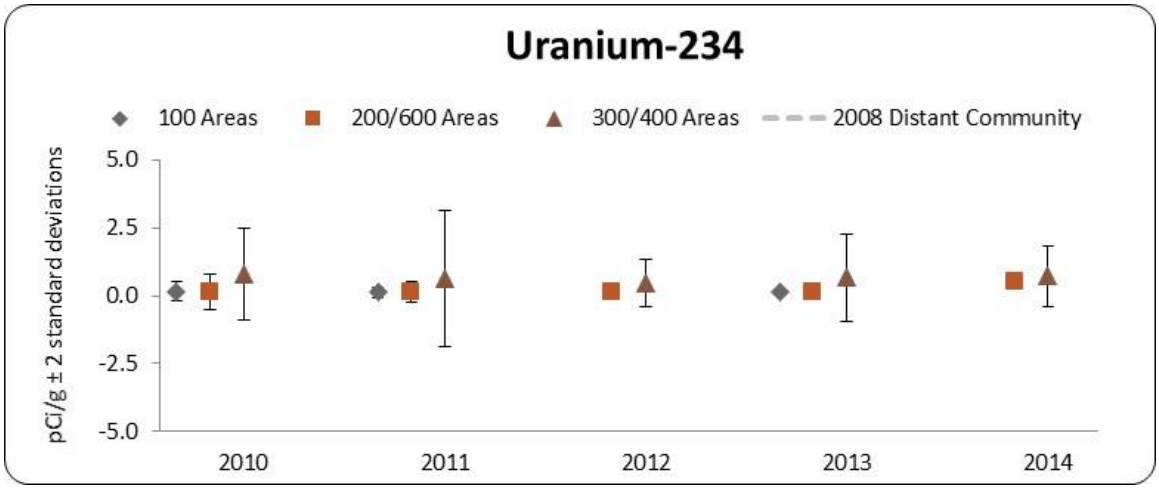


Figure 9.1. Hanford Site Soil Samples Average Concentrations of Selected Radionuclides (Cont.)
(2010 through 2014)
As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.





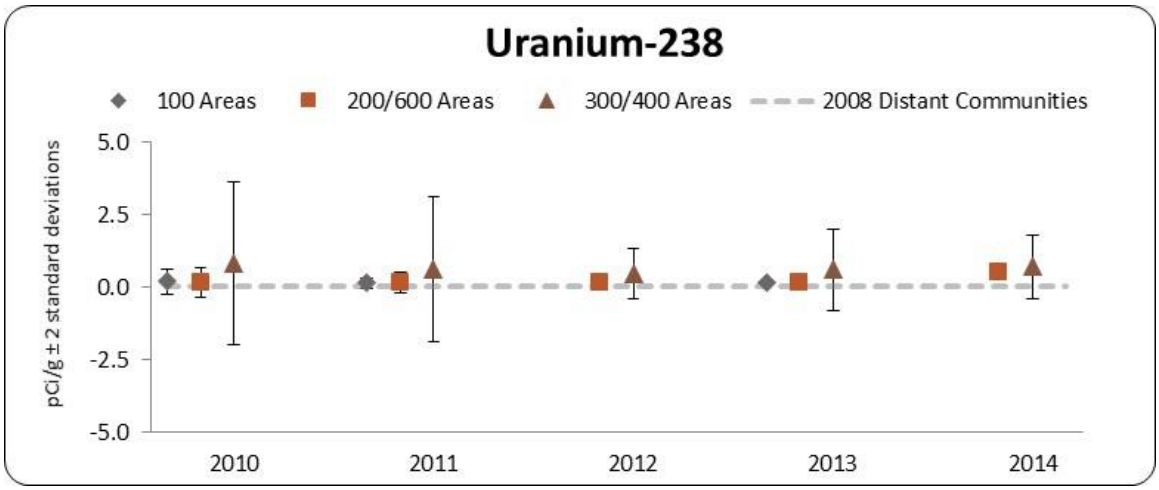


Table 9.3. Concentrations of Selected Radionuclides in Hanford Site Soil Samples
(pCi/g dry weight)
(2014 compared to previous years)

Isotope	Hanford Area	2014 Number of Samples	2014 Number of Detects	2014 Average [a,)] (pCi/gm)	2014 Maximum[b] (pCi/gm)	2009 to 2013 Number of Samples	2009 to 2013 Number of Detects	2009 to 2013 Average [a] (pCi/gm)	2009 to 2013 Maximum [b] (pCi/gm)
Cobalt 60	100	0	0	N/A-	N/A	41	4	6.5E-03 ± 4.0E-02	9.8E-02 ± 1.9E-02
	200-East	8	0	2.9E-03 ± 2.6E-02	2.9E-02 ± 2.8E-02(c)	59	0	-1.2E-03 ± 9.8E-03	9.1E-03 ± 1.1E-02c
	200-West	11	0	-3.2E-03 ± 1.7E-02	1.5E-02 ± 1.4E-02(c)	102	0	-4.1E-04 ± 9.1E-03	1.3E-02 ± 1.3E-02c
	300	8	0	4.0E-03 ± 2.3E-02	1.7E-02 ± 1.9E-02(c)	64	0	-5.2E-04 ± 7.5E-03	9.7E-03 ± 8.5E-03c
	400	1	0	2.3E-02(d)	2.3E-02 ± 1.9E-02(c)	5	0	-5.7E-04 ± 1.0E-02	5.2E-03 ± 8.6E-03c
	600	6	0	-6.6E-03 ± 1.8E-02	8.3E-03 ± 1.1E-02(c)	64	0	9.8E-05 ± 9.9E-03	1.4E-02 ± 1.3E-02c
Cesium 137	100	0	0	N/A	N/A	41	40	2.0E-01 ± 3.7E-01	7.9E-01 ± 1.4E-01
	200-East	8	8	3.4E+00 ± 9.1E+00	1.4E+01 ± 1.2E+00	59	59	2.5E+00 ± 7.9E+00	2.0E+01 ± 2.7E+00
	200-West	11	10	8.5E-01 ± 1.5E+00	2.8E+00 ± 2.5E-01	102	101	1.2E+00 ± 2.7E+00	6.5E+00 ± 8.6E-01
	300	8	5	5.8E-02 ± 9.7E-02	1.6E-01 ± 5.1E-02	64	46	5.4E-02 ± 1.2E-01	4.1E-01 ± 6.9E-02
	400	1	1	4.0E-02(d)	4.0E-02 ± 2.2E-02	5	5	5.5E-02 ± 7.5E-02	1.3E-01 ± 2.1E-02
	600	6	6	3.9E-01 ± 5.3E-01	7.9E-01 ± 7.1E-02	64	63	8.0E-01 ± 6.6E+00	2.7E+01 ± 3.6E+00
Plutonium 238	100	0	0	N/A	N/A	41	1	1.9E-03 ± 3.3E-02	4.8E-02 ± 2.9E-02
	200-East	8	0	2.7E-03 ± 5.8E-03	8.0E-03 ± 2.9E-03	59	2	5.2E-04 ± 3.4E-02	5.1E-02 ± 4.1E-02(c)
	200-West	11	2	3.8E-03 ± 9.7E-03	1.5E-02 ± 5.4E-03	102	8	5.5E-03 ± 3.5E-02	8.0E-02 ± 4.7E-02
	300	8	0	3.7E-03 ± 2.1E-03	5.3E-03 ± 2.5E-03	64	1	-2.3E-04 ± 2.2E-02	3.2E-02 ± 4.2E-02(c)
	400	1	0	8.0E-03(d)	8.0E-03 ± 2.8E-03	5	0	-6.5E-03 ± 4.3E-02	1.0E-02 ± 1.3E-02(c)
	600	6	0	6.6E-04 ± 4.0E-03	3.0E-03 ± 6.0E-03(c)	64	3	7.4E-03 ± 9.3E-02	3.7E-01 ± 1.1E-01
Plutonium 239/240	100	0	0	N/A	N/A	41	13	1.2E-02 ± 1.6E-02	2.9E-02 ± 2.3E-02(c)
	200-East	8	6	1.3E-02 ± 1.7E-02	2.9E-02 ± 7.0E-03	59	27	7.5E-02 ± 9.0E-01	3.5E+00 ± 7.7E-01
	200-West	11	10	1.3E-01 ± 3.6E-01	6.8E-01 ± 6.4E-02	102	80	1.3E-01 ± 6.1E-01	2.1E+00 ± 5.4E-01
	300	8	3	9.5E-03 ± 3.5E-02	5.4E-02 ± 7.9E-03	64	16	1.1E-02 ± 3.4E-02	9.9E-02 ± 3.1E-02
	400	1	0	2.0E-03(d)	2.0E-03 ± 2.0E-03(c)	5	1	7.3E-03 ± 2.1E-02	2.8E-02 ± 1.6E-02
	600	6	4	1.4E-02 ± 2.9E-02	4.2E-02 ± 9.3E-03	64	31	1.2E-01 ± 1.2E+00	4.9E+00 ± 1.3E+00
Strontium 90	100	0	0	N/A	N/A	41	1	-4.1E-01 ± 1.0E+00	7.3E-01 ± 5.5E-01
	200-East	8	6	2.9E-01 ± 6.3E-01	1.0E+00 ± 2.0E-01	59	16	1.9E-01 ± 4.6E+00	1.7E+01 ± 2.2E+00
	200-West	10	7	1.4E-01 ± 2.9E-01	5.2E-01 ± 1.1E-01	102	26	1.9E-02 ± 2.7E+00	1.1E+01 ± 1.4E+00
	300	8	0	9.7E-03 ± 4.5E-02	4.5E-02 ± 3.1E-02(c)	64	4	6.7E-01 ± 1.4E+01	5.5E+01 ± 7.1E+00
	400	1	0	-2.1E-02(d)	-2.1E-02 ± 2.4E-02(c)	5	0	-2.5E-01 ± 1.3E+00	6.5E-01 ± 4.6E-01(c)
	600	6	3	5.9E-02 ± 9.0E-02	1.4E-01 ± 4.0E-02	64	12	-1.5E-01 ± 1.1E+00	1.2E+00 ± 4.6E-01

Table 9.3. Concentrations of Selected Radionuclides in Hanford Site Soil Samples
(pCi/g dry weight)
(2014 compared to previous years)

		2014				2009 to 2013			
Isotope	Hanford Area	Number of Samples	Number of Detects	Average [a,)] (pCi/gm)	Maximum[b] (pCi/gm)	Number of Samples	Number of Detects	Average [a] (pCi/gm)	Maximum [b] (pCi/gm)
Uranium 234	100	0	0	N/A	N/A	41	41	1.5E-01 ± 1.2E-01	3.4E-01 ± 1.1E-01
	200-East	8	8	5.9E-01 ± 3.8E-01	1.1E+00 ± 1.9E-01	59	58	1.4E-01 ± 8.5E-02	2.5E-01 ± 8.0E-02
	200-West	11	11	5.3E-01 ± 1.7E-01	7.5E-01 ± 1.2E-01	102	97	1.6E-01 ± 1.2E-01	4.3E-01 ± 1.2E-01
	300	8	8	5.1E-02 ± 7.5E-02	1.4E-01 ± 4.6E-02	64	49	4.6E-02 ± 1.0E-01	2.7E-01 ± 8.6E-02
	400	1	1	4.1E-01[(d)]	4.1E-01 ± 8.3E-02	5	5	2.7E-01 ± 4.8E-01	7.4E-01 ± 2.1E-01
	600	6	6	5.2E-01 ± 1.4E-01	6.0E-01 ± 9.6E-02	64	63	1.6E-01 ± 1.5E-01	6.4E-01 ± 1.8E-01
Uranium 235	100	0	0	N/A	N/A	41	20	1.2E-02 ± 1.5E-02	3.4E-02 ± 1.9E-02
	200-East	8	7	3.7E-02 ± 1.9E-02	4.8E-02 ± 3.6E-02	59	30	1.1E-02 ± 1.4E-02	3.0E-02 ± 1.8E-02
	200-West	11	8	3.5E-02 ± 3.3E-02	7.3E-02 ± 4.2E-02	95	55	1.5E-02 ± 2.1E-02	5.1E-02 ± 2.7E-02
	300	8	8	5.1E-02 ± 7.5E-02	1.4E-01 ± 4.6E-02	64	49	4.6E-02 ± 1.0E-01	2.7E-01 ± 8.6E-02
	400	1	1	2.7E-02[(d)]	2.7E-02 ± 2.1E-02	5	4	2.2E-02 ± 3.6E-02	5.8E-02 ± 2.7E-02
	600	6	2	3.1E-02 ± 2.3E-02	4.6E-02 ± 2.9E-02	54	26	1.3E-02 ± 1.7E-02	6.1E-02 ± 2.7E-02
Uranium 238	100	0	0	N/A	N/A	41	41	1.5E-01 ± 1.2E-01	4.2E-01 ± 1.2E-01
	200-East	8	8	5.8E-01 ± 4.2E-01	1.1E+00 ± 1.9E-01	59	58	1.5E-01 ± 7.9E-02	2.4E-01 ± 7.7E-02
	200-West	11	11	5.3E-01 ± 1.2E-01	6.6E-01 ± 1.0E-01	102	97	1.6E-01 ± 1.3E-01	4.5E-01 ± 1.3E-01
	300	8	3	9.5E-03 ± 3.5E-02	5.4E-02 ± 7.9E-03	64	16	1.1E-02 ± 3.4E-02	9.9E-02 ± 3.1E-02
	400	1	0	2.0E-03[(d)]	2.0E-03 ± 2.0E-03[(c)]	5	1	7.3E-03 ± 2.1E-02	2.8E-02 ± 1.6E-02
	600	6	4	1.4E-02 ± 2.9E-02	4.2E-02 ± 9.3E-03	64	31	1.2E-01 ± 1.2E+00	4.9E+00 ± 1.3E+00

[a] Average ± two standard deviations
[b] Maximum ± analytical uncertainty
[c] Maximum value reported is a non-detect.
[d] Standard deviation cannot be calculated for one sample.

Table 9.4. Radionuclide Concentrations in Other Contractor Project Soil Samples
pCi/g[(a)] dry weight[(b)]

Project/Facility	Location[(c)]	Date	Cobalt-60	Strontium-90	Cesium-137	Uranium-234	Uranium-238	Plutonium-239/240
Trench 94	D457	11/19/2014	2.90E-03±1.30E-02	1.40E-00±2.60E-01	7.80E-00±6.30E-01	5.50E-01±9.20E-02	5.30E-01±9.00E-02	3.60E-03±3.20E-03
	D458	11/19/2014	1.30E-03±1.20E-02	1.40E-01±4.10E-02	7.80E-00±6.30E-01	5.30E-01±9.00E-02	4.90E-01±8.50E-02	3.90E-03±7.00E-03
	D459	11/19/2014	-5.10E-03±1.10E-02	1.90E-02±2.90E-02	1.90E-01±2.60E-02	6.10E-01±9.60E-02	6.10E-01±9.50E-02	3.00E-03±3.10E-03
Effluent Treatment Facility	D458	11/19/2014	1.30E-03±1.20E-02	1.40E-01±4.10E-02	7.80E-00±6.30E-01	5.30E-01±9.00E-02	4.90E-01±8.50E-02	3.90E-03±7.00E-03
	D460	11/19/2014	-3.60E-03±1.20E-02	3.40E-02±2.90E-02	8.80E-02±1.70E-02	4.50E-01±9.20E-02	4.40E-01±8.40E-02	1.70E-05±1.70E-04
	D461	11/19/2014	3.80E-03±1.40E-02	5.00E-01±1.10E-01	3.70E-00±3.00E-01	6.00E-01±9.60E-02	5.70E-01±9.20E-02	5.60E-03±3.20E-03
ERDF	D146	4/2/2014	3.90E-03±1.50E-02	N/A	1.2E-02±1.40E-02	5.00E-01±1.60E-01	5.1E-01±1.70E-01	-2.3E-03±1.40E-02
Accessible soil concentration[(d)]			**7.1**	**2,800**	**30**	**630**	**370**	**190**

[a] 1 pCi = 0.037 Bq.
[b]± total analytical uncertainty.
[c] Sampling location code.
[d] Hanford soils that are not behind security fences.

9.3 Radiological Contamination Investigations

Investigations for radioactive contamination in soil were conducted in and near operational areas to monitor the presence or movement of radioactive materials around areas of known or suspected contamination or to verify radiological conditions at specific project sites. All samples collected during investigations were field surveyed for alpha- and beta-gamma radiation. Generally, the predominant radionuclides in samples from the 100 Area and 200 Areas were strontium-90, cesium-137, and plutonium-239/240. Uranium-234, uranium-235, and uranium-238 were routinely found in 300 Area samples.

There were 22 instances of radiological contamination in soil discovered during 2014 site investigations. Of the 22, 9 were cleaned up and disposed of on site in licensed burial grounds, and the other 13 were posted as contamination areas. None of the soil samples were submitted for radioisotopic analysis. The number of soil investigation contamination incidents in 2014 were generally within historical values. Table 9.5 summarizes the number and general locations of soil contamination incidents investigated during 2014, and provides the number of contamination incidents investigated from 2000 through 2014.

Table 9.5. Soil Contamination Incidents Investigated

Location	2014 Incidents
100 Area	0
200-East Area	
Tank farms	3
Burial grounds	1
Cribs, ponds, and ditches	0
Fence lines	1
Roads and railroads	0
Unplanned release sites	7
Underground pipelines	0
LERF/ETF	1
Miscellaneous	1
200-West Area	
Tank farms	4
Burial grounds	0
Cribs, ponds, and ditches	1
Fence lines	0
Roads and railroads	0
Unplanned release sites	1
Underground pipelines	0
Miscellaneous	1
Cross-site transfer line	0
200-BC cribs and trenches	0
200-North Area	0
300 Area	0
400 Area	0
600 Area	1
Total	**22**

Year	Incidents
2000	25
2001	20
2002	22
2003	30
2004	19
2005	20
2006	25
2007	17
2008	16
2009	28
2010	22
2011	10
2012	10
2013	21
2014	**22**

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