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## 9.0 Soil Monitoring

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Radiological monitoring of soil is conducted at a variety of locations: 1) onsite near Hanford Site facilities, waste sites, contamination areas and operations, 2) onsite away from facilities and operations, 3) and offsite at perimeter and distant locations and in nearby communities. Contaminant concentration data are used for the following:

- Determine the effectiveness of effluent monitoring and radioactive material controls
- Assess the adequacy of containment at waste disposal sites, waste site remediation and contamination areas
- Detect and monitor unusual conditions in which there was a potential release or spread of radioactive material
- Provide information on long-term radionuclide contamination trends in soil at undisturbed sample locations.

Data obtained from onsite soil samples is used as a qualitative indicator and subordinate data of ambient air sampling results per the Washington State Department of Health (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 for calendar years 2016 (DOE/RL-2013-53, Rev. 2) and 2017 (DOE/RL-2013-53, Rev. 3).

### 9.1 Monitoring Results

According to the latest version of the [Hanford Site Environmental Monitoring Plan](#) (DOE/RL-91-50), soil monitoring provides information about long-term contamination trends and baseline environmental radionuclide activities at undisturbed sample locations both on and off the Hanford Site.

### 9.2 Sampling Results

Soil samples are collected near facilities, waste sites, contamination areas and operations on the Hanford Site to detect potential migration and deposition of radioactive materials 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 2016 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 are collected every 3 to 5 years and were last collected in 2015.

**Table 9-1. Soil Sample Locations.**

Number of Samples Analyzed	Operational Area (discrete samples analyzed)								
	ETF	Trench 94	100-N	200-West <sup>a</sup>	200-East <sup>a</sup>	300 <sup>a</sup>	400	600 <sup>a</sup>	ERDF
73	3	3	3	27	11	8	1	16	1

<sup>a</sup> Number of samples includes one or more duplicate samples.

Individual soil samples are 2.2 lb (1.0 kg), which consist of five plugs of soil. Each sample is approximately 1 in. (2.5 cm) deep and 4 in. (10 cm) in diameter. Soil samples were 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.

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 with concentrations of radionuclides measured in samples collected offsite at various locations in Grant, Yakima, Walla Walla, Adams, Benton, and Franklin counties in 2015 (Section 9.3). 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 (e.g., 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 hrs/yr 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<sup>a</sup>.**

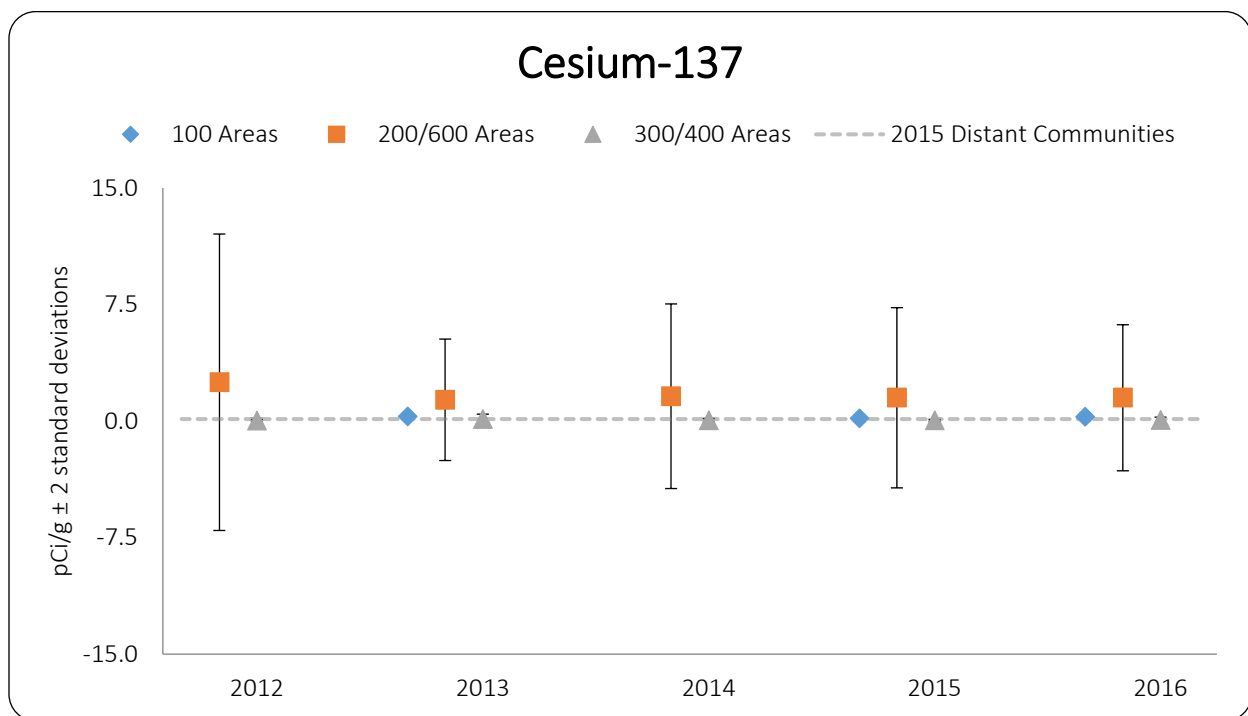
Category	Cobalt-60	Strontium-90	Cesium-137	Uranium-234	Uranium-235	Uranium-238	Plutonium-239/-240
Accessible soil concentration limits <sup>b</sup>	7.1	2,800	30	630	170	370	190

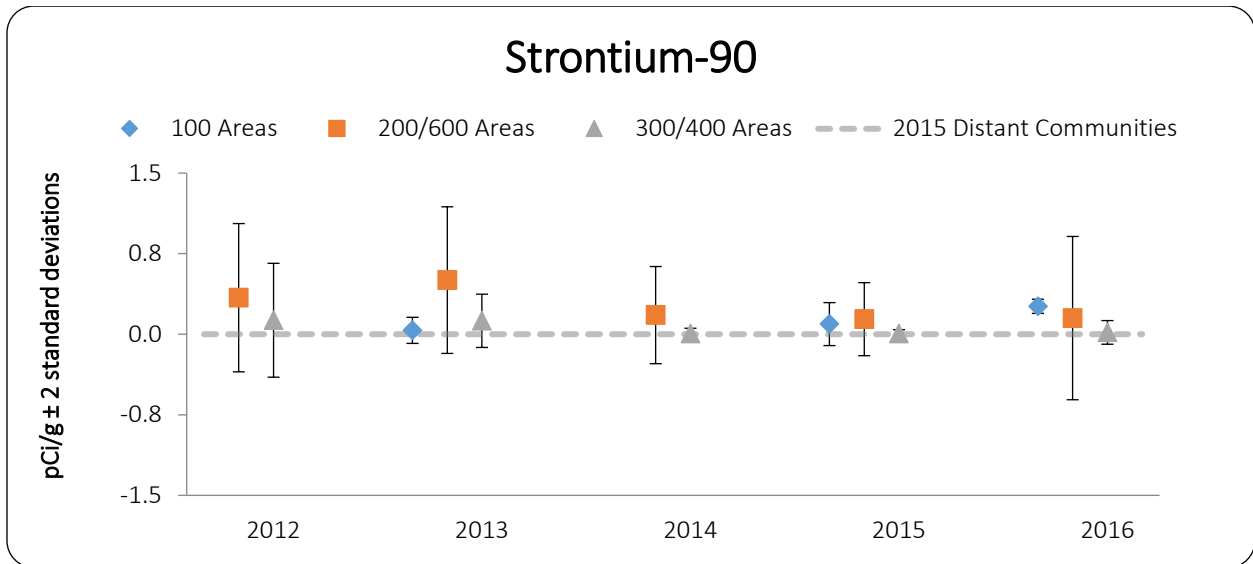
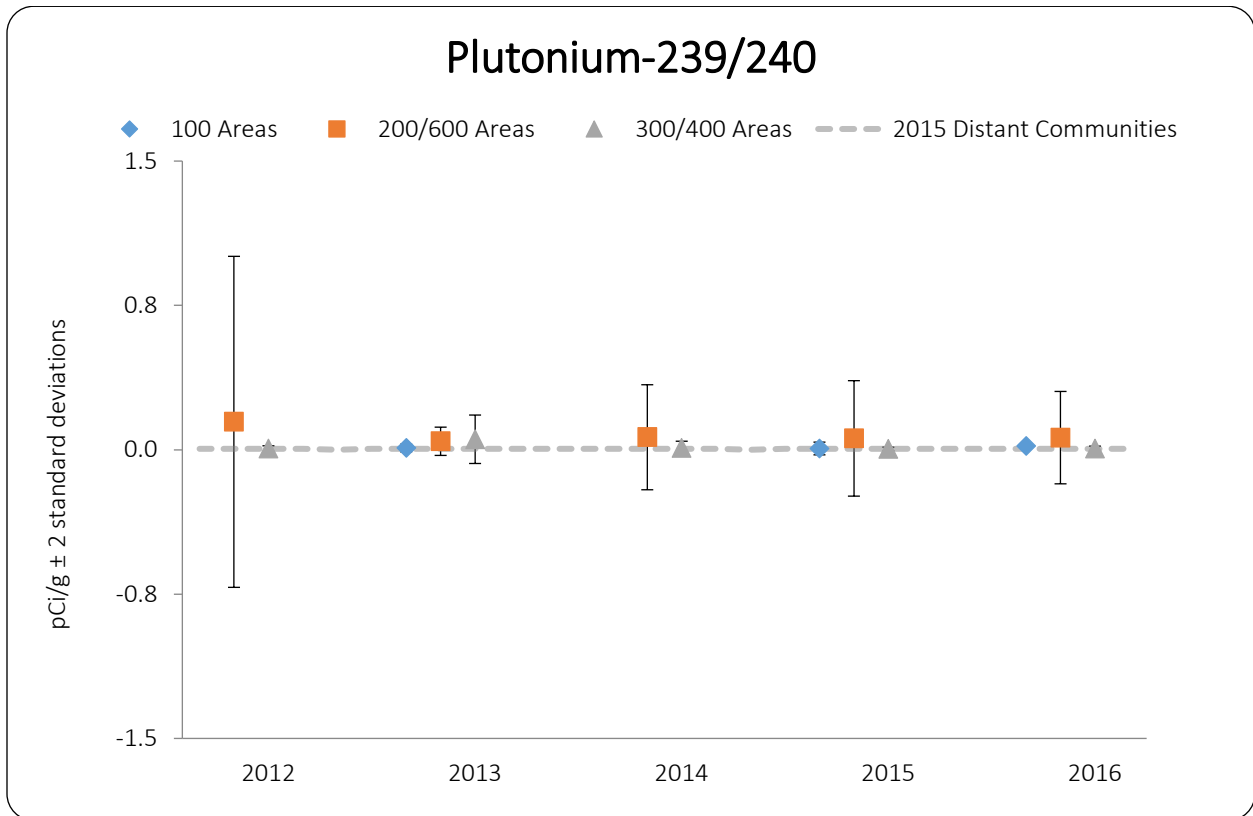
<sup>a</sup> pCi/g dry weight. To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

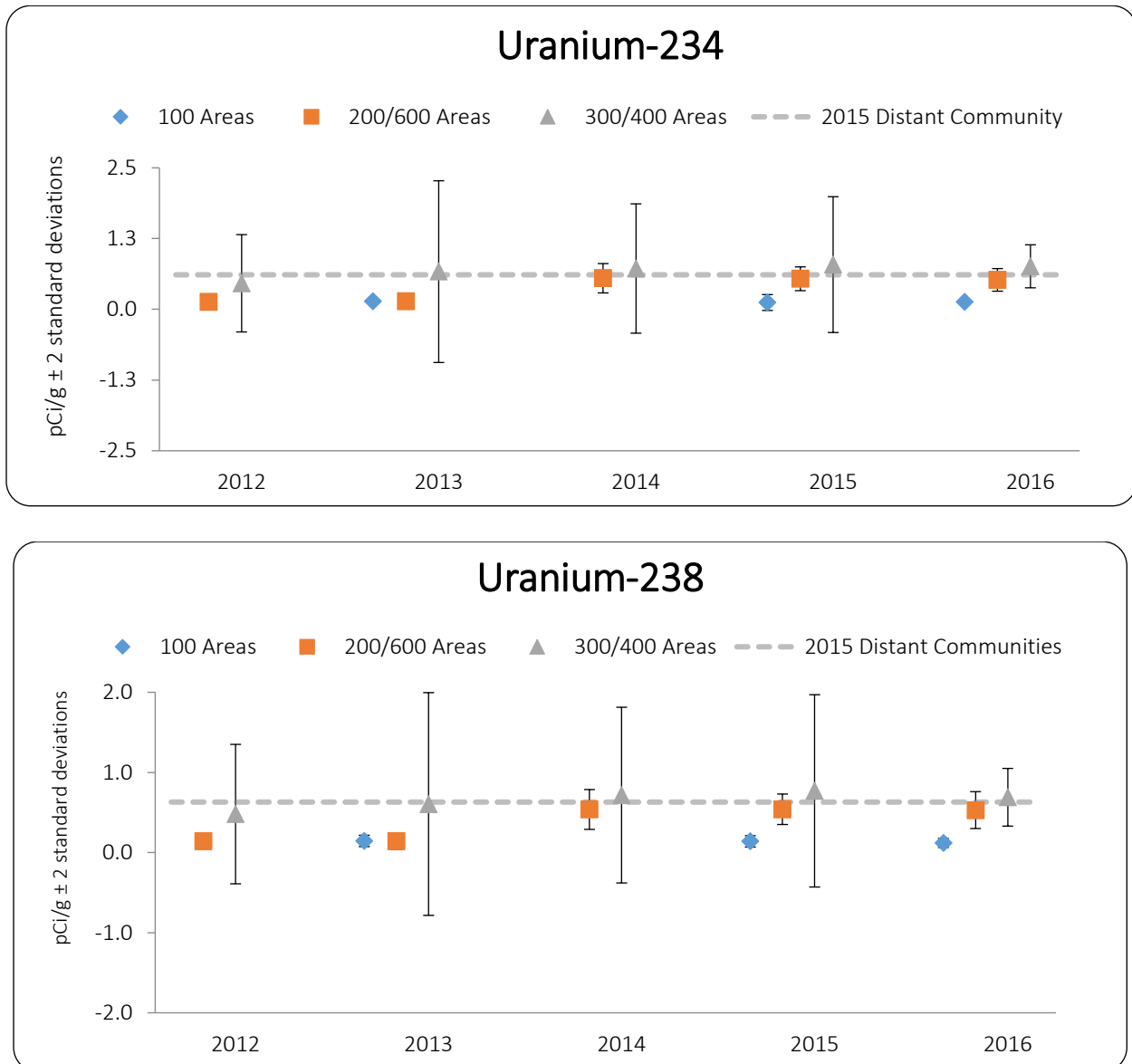
<sup>b</sup> Hanford Site soil that is not behind security fences; refer to WHC-SD-EN-TI-070.

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 2016 were higher than the concentrations in samples collected farther away. As expected, data also showed that concentrations of certain radionuclides in 2016 were similar or 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 2016 soil samples. Concentrations of these radionuclides were similar or slightly elevated near and within facility boundaries when compared to concentrations measured offsite at distant communities. Figure 9-1 shows the average concentrations of selected radionuclides in soil samples collected during 2016 and the preceding 4 years. Some individual levels demonstrate a high degree of variability, although overall trends are stable.







**Figure 9.1. Hanford Site Soil Samples Average Concentrations of Selected Radionuclides, 2011–2016 (As a result of figure scale, some uncertainties [error bars] are concealed by the point symbol).**

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 2016, as well as sampling location maps, are available upon request.

Results for soil samples collected in 2016 at locations in the 100, 200-East, 200-West, 300, and 600 Areas 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 and recent remediation activities. 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.

To comply with WDOH Notice of Construction requirements, special soil deposition sampling was collected during 2016 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 the Environmental Restoration Disposal Facility from a predominantly downwind sampling location. The 2016 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.

Soil monitoring provides information on long-term contamination trends and baseline environmental radionuclide activities at undisturbed sampling locations both on and off the Hanford Site (DOE/RL-91-50). Soil samples collected on and around the Hanford Site for more than 50 years have been added to a large database documenting onsite and offsite levels of manmade radionuclides in soil at specific locations. This database contains baseline data against which analysis results from unplanned contaminant releases from the Hanford Site can be compared. Soil at sitewide (onsite away from facilities and operations) and offsite locations was last routinely monitored for radiation in 2015.

Table 9-3. Concentrations of Selected Radionuclides in Hanford Site Soil Samples<sup>a</sup>. (2 Pages)

Isotope	Hanford Area	2016				2011 to 2015			
		Number of Samples	Detects	Average <sup>b</sup> (pCi/gm)	Maximum <sup>c</sup> (pCi/gm)	Number of Samples	Detects	Average <sup>b</sup> (pCi/gm)	Maximum <sup>c</sup> (pCi/gm)
<b>Cobalt-60</b>	100	3	0	1.7E-02 ± 4.0E-02	4.5E-02 ± 2.0E-02 <sup>(4)</sup>	3	3	4.4E-02 ± 4.4E-02	6.7E-02 ± 1.3E-02
	200-East	16	0	1.5E-03 ± 2.2E-02	1.8E-02 ± 4.6E-02 <sup>(4)</sup>	52	0	2.4E-04 ± 1.8E-02	2.9E-02 ± 2.8E-02 <sup>d</sup>
	200-West	28	0	-1.2E-04 ± 2.1E-02	2.0E-02 ± 2.6E-02 <sup>(4)</sup>	85	0	-1.3E-03 ± 2.1E-02	2.7E-02 ± 3.4E-02 <sup>d</sup>
	300	8	0	4.4E-04 ± 1.7E-02	1.4E-02 ± 1.9E-02 <sup>(4)</sup>	52	0	3.9E-04 ± 1.2E-02	1.7E-02 ± 1.9E-02 <sup>d</sup>
	400	1	0	1.5E-02 <sup>e</sup>	1.5E-02 ± 1.5E-02 <sup>(4)</sup>	5	0	3.7E-03 ± 2.1E-02	2.3E-02 ± 1.9E-02 <sup>d</sup>
	600	16	0	-6.6E-04 ± 3.2E-02	2.8E-02 ± 4.1E-02 <sup>(4)</sup>	54	0	-1.4E-03 ± 2.9E-02	3.8E-02 ± 5.1E-02 <sup>d</sup>
<b>Cesium-137</b>	100	3	3	2.7E-01 ± 3.0E-01	4.8E-01 ± 6.7E-02	3	3	2.0E-01 ± 3.6E-01	4.5E-01 ± 5.8E-02
	200-East	16	16	2.8E+00 ± 7.4E+00	1.1E+01 ± 5.4E-01	52	52	3.2E+00 ± 9.8E+00	2.0E+01 ± 2.7E+00
	200-West	28	27	1.4E+00 ± 3.3E+00	6.2E+00 ± 3.3E-01	85	82	1.1E+00 ± 1.9E+00	4.0E+00 ± 5.3E-01
	300	8	5	7.1E-02 ± 1.8E-01	2.9E-01 ± 3.1E-02	52	33	4.8E-02 ± 1.3E-01	4.1E-01 ± 6.9E-02
	400	1	1	5.3E-02 <sup>e</sup>	5.3E-02 ± 1.5E-02	5	5	5.4E-02 ± 7.5E-02	1.3E-01 ± 2.1E-02
	600	16	16	5.1E-01 ± 9.2E-01	1.8E+00 ± 1.8E-01	54	53	4.7E-01 ± 9.8E-01	2.5E+00 ± 3.3E-01
<b>Plutonium-238</b>	100	3	0	3.5E-02 ± 3.7E-02	5.0E-02 ± 5.8E-02 <sup>(4)</sup>	3	0	-3.4E-04 ± 7.0E-03	2.2E-03 ± 2.2E-03 <sup>d</sup>
	200-East	16	5	4.4E-04 ± 1.1E-03	1.2E-03 ± 6.1E-04	52	14	-5.4E-04 ± 2.3E-02	5.1E-02 ± 2.2E-02
	200-West	28	18	1.8E-03 ± 4.1E-03	9.9E-03 ± 3.3E-03	85	26	4.9E-03 ± 3.8E-02	1.4E-01 ± 2.3E-02
	300	8	4	7.5E-04 ± 9.9E-04	1.4E-03 ± 7.2E-04	52	3	8.5E-04 ± 1.7E-02	3.2E-02 ± 4.2E-02 <sup>d</sup>
	400	1	1	4.7E-04 <sup>e</sup>	4.7E-04 ± 3.8E-04	5	0	-7.2E-03 ± 4.3E-02	8.0E-03 ± 2.8E-03 <sup>d</sup>
	600	15	5	7.7E-04 ± 2.3E-03	3.6E-03 ± 8.3E-04	54	13	1.1E-03 ± 1.1E-02	1.9E-02 ± 1.3E-02
<b>Plutonium-239/-240</b>	100	3	0	1.9E-02 ± 1.2E-02	2.6E-02 ± 4.1E-02 <sup>(4)</sup>	3	2	1.3E-02 ± 1.5E-02	2.0E-02 ± 1.4E-02
	200-East	16	13	1.2E-02 ± 2.2E-02	4.1E-02 ± 4.2E-03	52	38	8.4E-02 ± 9.5E-01	3.5E+00 ± 7.7E-01
	200-West	28	27	1.1E-01 ± 3.2E-01	6.9E-01 ± 1.0E-01	85	74	1.0E-01 ± 5.2E-01	2.1E+00 ± 5.4E-01
	300	8	6	5.4E-03 ± 1.3E-02	2.1E-02 ± 3.2E-03	52	16	8.4E-03 ± 3.3E-02	9.9E-02 ± 3.1E-02
	400	1	1	2.1E-03 <sup>e</sup>	2.1E-03 ± 7.9E-04	5	2	8.0E-03 ± 2.0E-02	2.8E-02 ± 1.6E-02
	600	16	16	3.7E-02 ± 1.2E-01	2.3E-01 ± 1.8E-02	54	34	5.4E-02 ± 3.0E-01	8.5E-01 ± 1.0E-01
<b>Strontium-90</b>	100	3	0	2.6E-01 ± 6.6E-02	2.8E-01 ± 3.5E-01 <sup>(4)</sup>	3	1	4.9E-01 ± 4.1E-01	7.3E-01 ± 5.5E-01
	200-East	16	9	3.9E-01 ± 1.3E+00	2.2E+00 ± 4.1E-01	52	30	3.1E-01 ± 6.9E-01	1.4E+00 ± 3.4E-01
	200-West	28	11	7.9E-02 ± 2.5E-01	4.2E-01 ± 9.6E-02	84	52	3.3E-01 ± 7.6E-01	1.9E+00 ± 4.7E-01

Table 9-3. Concentrations of Selected Radionuclides in Hanford Site Soil Samples<sup>a</sup>. (2 Pages)

Isotope	Hanford Area	2016		Maximum <sup>c</sup> (pCi/gm)	2011 to 2015		Maximum <sup>c</sup> (pCi/gm)		
		Number of Samples	Detects		Average <sup>b</sup> (pCi/gm)	Number of Samples		Detects	Average <sup>b</sup> (pCi/gm)
	300	8	1	2.3E-02 ± 1.0E-01	1.4E-01 ± 4.8E-02	52	1	7.4E-02 ± 4.4E-01	8.9E-01 ± 5.3E-01 <sup>d</sup>
	400	1	0	-2.2E-02 <sup>e</sup>	-2.2E-02 ± 2.0E-02 <sup>(4)</sup>	5	0	-1.2E-04 ± 7.8E-01	6.5E-01 ± 4.6E-01 <sup>d</sup>
	600	16	2	3.7E-02 ± 1.1E-01	2.0E-01 ± 5.4E-02	54	25	2.0E-01 ± 6.1E-01	1.2E+00 ± 4.6E-01
Uranium -234	100	3	3	1.3E-01 ± 7.5E-03	1.3E-01 ± 7.7E-02	3	3	1.6E-01 ± 5.7E-02	1.9E-01 ± 6.2E-02
	200-East	16	16	5.2E-01 ± 1.5E-01	6.5E-01 ± 1.1E-01	52	51	3.4E-01 ± 4.9E-01	1.1E+00 ± 1.9E-01
	200-West	28	28	4.9E-01 ± 1.8E-01	6.0E-01 ± 1.0E-01	85	80	3.0E-01 ± 3.9E-01	7.5E-01 ± 1.2E-01
	300	8	8	7.5E-01 ± 4.2E-01	1.1E+00 ± 1.7E-01	52	52	6.6E-01 ± 1.3E+00	2.5E+00 ± 6.5E-01
	400	1	1	5.8E-01 <sup>e</sup>	5.8E-01 ± 1.1E-01	5	5	3.7E-01 ± 4.6E-01	7.4E-01 ± 2.1E-01
	600	16	16	5.7E-01 ± 2.2E-01	9.0E-01 ± 1.4E-01	54	53	3.2E-01 ± 4.0E-01	7.5E-01 ± 1.1E-01
	100	3	0	6.8E-03 ± 2.3E-02	2.3E-02 ± 3.8E-02 <sup>(4)</sup>	3	1	1.2E-02 ± 5.4E-03	1.5E-02 ± 1.2E-02
Uranium -235	200-East	15	12	5.6E-02 ± 5.7E-02	1.1E-01 ± 4.3E-02	52	35	3.3E-02 ± 6.5E-02	1.1E-01 ± 5.1E-02
	200-West	28	23	5.4E-02 ± 4.7E-02	1.1E-01 ± 5.0E-02	78	50	2.8E-02 ± 4.5E-02	9.7E-02 ± 4.1E-02
	300	8	8	9.7E-02 ± 6.4E-02	1.4E-01 ± 5.4E-02	52	44	4.6E-02 ± 9.4E-02	1.9E-01 ± 5.7E-02
	400	1	1	7.7E-02 <sup>e</sup>	7.7E-02 ± 4.0E-02	5	4	2.8E-02 ± 3.5E-02	5.8E-02 ± 2.7E-02
	600	16	13	6.2E-02 ± 5.5E-02	1.1E-01 ± 5.0E-02	44	27	3.4E-02 ± 5.4E-02	9.9E-02 ± 4.3E-02
	100	3	3	1.2E-01 ± 5.7E-02	1.5E-01 ± 9.5E-02	3	3	1.4E-01 ± 4.2E-02	1.7E-01 ± 5.5E-02
Uranium -238	200-East	16	16	5.2E-01 ± 1.2E-01	6.1E-01 ± 1.1E-01	52	51	3.3E-01 ± 4.7E-01	1.1E+00 ± 1.9E-01
	200-West	28	28	5.0E-01 ± 2.0E-01	6.3E-01 ± 9.8E-02	85	80	3.0E-01 ± 3.7E-01	6.6E-01 ± 1.0E-01
	300	8	8	7.0E-01 ± 3.4E-01	1.1E+00 ± 1.6E-01	52	51	6.5E-01 ± 1.2E+00	2.5E+00 ± 6.8E-01
	400	1	1	4.4E-01 <sup>e</sup>	4.4E-01 ± 9.3E-02	5	5	3.9E-01 ± 6.0E-01	9.3E-01 ± 2.5E-01
	600	16	16	6.0E-01 ± 2.9E-01	9.7E-01 ± 1.4E-01	54	53	3.4E-01 ± 4.1E-01	8.0E-01 ± 1.2E-01

<sup>a</sup> pCi/g dry weight.<sup>b</sup> Average ± two standard deviations.<sup>c</sup> Maximum ± analytical uncertainty.<sup>d</sup> Maximum value reported is a non-detect.<sup>e</sup> Standard deviation cannot be calculated for one sample.



Table 9-4. Radionuclide Concentrations in Other Contractor Project Soil Samples<sup>a</sup>.

Project/ Facility	Locatio n <sup>b</sup>	Date	Cobalt-60	Strontium-90	Cesium-137	Uranium-234	Uranium-238	Plutonium-239/- 240
Trench 94	D458	6/20/201 6	-1.6E-02±3.2E- 02	7.70E-02±3.50E- 02	2.10E-01±5.80E- 02	6.00E-01±1.00E- 01	5.80E-01±1.10E- 01	1.90E-03±1.60E- 03
	D460	6/20/201 6	9.9E-03±2.00E- 02	1.10E-02±2.70E- 02	2.00E-01±5.30E- 02	4.40E-01±8.70E- 02	4.90E-01±9.10E- 02	2.00E-03±1.00E- 03
	D461	6/20/201 6	1.20E-02±2.9E- 02	3.0E-01±7.5E-02	6.5E+00±5.8E-01	6.50E-01±1.10E- 01	6.10E-01±1.10E- 01	5.70E-03±1.5E- 03
Effluent Treatment Facility	D457	6/20/201 6	4.10E-03±2.60E- 02	2.20E+00±4.10E- 01	1.10E+01±5.40E- 01	6.00E-01±1.00E- 01	5.80E-01±9.9E- 02	2.90E-04±1.20E- 03
	D458	6/20/201 6	-1.6E-02±3.2E- 02	7.70E-02±3.50E- 02	2.10E-01±5.80E- 02	6.00E-01±1.00E- 01	5.80E-01±1.10E- 01	1.90E-03±1.60E- 03
	D459	6/20/201 6	-2.10E-02±2.70E- 02	2.10E-01±5.60E- 02	1.10E+00±1.30E- 01	6.40E-01±1.10E- 01	5.70E-01±8.70E- 02	7.70E-03±1.60E- 03
ERDF	D146	4/27/201 6	-6.60E-03±1.30E- 02	-2.00E-01±1.60E- 01	8.10E-03±1.10E- 02	1.10E-01±9.00E- 02	1.00E-01±9.00E- 02	1.40E-02±3.10E- 02
100N	D156	8/2/2016	-1.8E-03±1.20E- 02	2.80E-01±3.50E- 01	1.40E-01±3.00E- 02	1.20E-01±7.50E- 02	1.20E-01±7.50E- 02	2.00E-02±4.40E- 02
	D158	8/2/2016	4.50E-02±2.00E- 02	2.80E-01±3.10E- 01	4.90E-01±4.30E- 02	1.30E-01±8.60E- 02	1.50E-01±9.50E- 02	2.60E-02±4.10E- 02
	D183	8/2/2016	8.00E-03±1.50E- 02	2.10E-01±2.80E- 01	4.80E-01±6.70E- 02	1.30E-01±7.70E- 02	8.20E-02±5.90E- 02	1.20E-02±2.60E- 02
Accessible soil concentration <sup>c</sup>			7.1	2,800	30	630	370	190

<sup>a</sup> pCi/g dry weight: 1 pCi = 0.037 Bq. Dry weight ± total analytical uncertainty.  
<sup>b</sup> Sampling location code.  
<sup>c</sup> 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.

There were 17 instances of radiological contamination in soil discovered during 2016 site investigations. Of the 17, five were posted as contamination areas, the other 12 were cleaned up and disposed of onsite in licensed burial grounds. None of the soil samples were submitted for radioisotopic analysis. The number of soil investigation contamination incidents in 2016 were generally within historical values. Table 9-5 summarizes the number and general locations of soil contamination incidents investigated during 2016, and provides the number of contamination incidents investigated from 2000 through 2016.

**Table 9-5. Soil Contamination Incidents Investigated.**

Location	2016 Incidents	Year	Incidents
100 Area	2	2000	25
<b>200-East Area</b>		2001	20
Tank farms	1	2002	22
Burial grounds	2	2003	30
Cribs, ponds, and ditches	6	2004	19
Fence lines	0	2005	20
Roads and railroads	0	2006	25
Unplanned release sites	0	2007	17
Underground pipelines	0	2008	16
LERF/ETF	1	2009	28
Miscellaneous	0	2010	22
<b>200-West Area</b>		2011	10
Tank farms	1	2012	10
Burial grounds	1	2013	21
Cribs, ponds, and ditches	0	2014	22
Fence lines	0	2015	20
Roads and railroads	0	2016	17
Unplanned release sites	0		
Underground pipelines	0		
Miscellaneous	0		
Cross-site transfer line	1		
200-BC cribs and trenches	0		
200-North Area	0		
300 Area	0		
400 Area	0		
600 Area	2		
Total	17		