3.2 Near-Facility Environmental Monitoring

C. J. Perkins, B. M. Markes, S. M. McKinney, and R. M. Mitchell

Near-facility environmental monitoring is defined as routine monitoring near facilities that have the potential to discharge, or have discharged, stored, or disposed of radioactive or hazardous contaminants. Monitoring locations are associated with nuclear facilities such as the Plutonium Finishing Plant, Canister Storage Building, and the 100-K Fuel Storage Basins; inactive nuclear facilities such as N Reactor and the Plutonium-Uranium Extraction Plant; and active and inactive waste storage or disposal facilities such as burial grounds, cribs, ditches, ponds, underground waste storage tanks, and trenches.

Much of the monitoring program consists of collecting and analyzing environmental samples and conducting radiological surveys in areas near facilities. The program also is designed to evaluate and report analytical data, determine the effectiveness of facility effluent monitoring and controls, measure the adequacy of containment at waste disposal sites, and detect and monitor unusual conditions. The program implements applicable portions of DOE Orders 435.1, 5400.1, 5400.5, and 5484.1; 10 CFR 835 and 40 CFR 61; and WAC 246-247.

Near Hanford Site facilities, several types of environmental media are sampled, and various radiological and non-radiological measurements are taken. These sample types and measurements include air, spring water, surface contamination, soil, vegetation, and external radiation. Samples are collected from known or expected effluent pathways. These pathways are generally downwind of potential or actual airborne releases and downgradient of liquid discharges.

Active and inactive waste disposal sites and the terrain surrounding them are surveyed to detect and characterize radioactive surface contamination. Routine radiological survey locations include former waste disposal cribs and trenches, retention basin perimeters, ditch banks, solid waste disposal sites (e.g., burial grounds), unplanned release sites, tank farm perimeters, stabilized waste disposal sites, roads, and firebreaks in and around the site operational areas.

Sampling and analysis information and analytical results for 2001 are summarized in the following sections. Additional data may be found in *Hanford Site Near-Facility Environmental Monitoring Data Report for Calendar Year 2001* (PNNL-13910, APP. 2). Near-facility monitoring in 2001 is summarized in Table 3.2.1, which indicates the type, quantity, and general location of samples collected.

3.2.1 Air Monitoring

In 2001, routine monitoring for radioactivity in air near Hanford Site facilities used a network of continuously operating samplers at 76 locations (Table 3.2.2) (sampling locations illustrated in PNNL-13910, APP. 2). Air samplers were located primarily at or within ~500 meters (~1,500 feet) of sites and/or facilities having the potential for, or history of, environmental releases and were predominantly located in the prevailing downwind direction. To avoid duplication of sampling, air data for the 300 and 400 Areas, some onsite remediation projects, and some offsite distant locations were obtained from Pacific Northwest National Laboratory.

Samples were collected according to a schedule established before the 2001 monitoring year. Airborne particles were sampled at each sampling location by drawing air through a glass-fiber filter. The filters were collected biweekly, field surveyed for gross radioactivity, held for at least 7 days, and then analyzed for gross alpha and beta activity. The 7-day holding period was necessary to allow for the decay of naturally occurring, short-lived radionuclides that would otherwise obscure detection of longer-lived radionuclides associated with emissions from nuclear facilities. The gross radioactivity measurements were used to indicate changes in trends in the near-facility environment.

Table 3.2.1. Near-Facility Routine Environmental Monitoring Samples and Locations, 2001

Sample Type	Number of Sample Locations	Operational Area								
		100-B/C	100-D/DR	100-K	100-F	100-H	100-N	ERDF[a]	200/600	300/400
Air	76	3	3	8	6	6	5	3	41[b]	1
Water	10	0	0	0	0	0	10	0	0	0
Soil	92	1	0	0	2	2	11	1	57	18
Vegetation	75	0	0	0	0	0	9	0	49	17
External radiation	133	5	0	15[c]	5	3	14	3	67[d]	21

(a) Environmental Restoration Disposal Facility in the 200-West Area.
(b) Includes 1 station at the Wye Barricade, 19 in the 200-East Area, and 21 in the 200-West Area.
(c) Includes 11 locations in the 100-KE/KW Areas and 4 at the Cold Vacuum Drying Facility.
(d) Includes 66 locations in the 200 Areas and 1 location at the 212-R facility in the 200-North Area.

For most specific radionuclide analyses, the amount of radioactive material collected on a single filter during a 2-week period was too small to be measured accurately. To increase the accuracy of the analysis, the samples were combined into either quarterly or semiannual composite samples for each location.

Figure 3.2.1 shows the average concentrations of selected radionuclides in the 100 and 200/600 Areas compared to DOE derived concentration guides and air concentrations measured in distant communities. The DOE derived concentration guides (DOE Order 5400.5) are reference values that are used as indexes of performance. The data indicate a large degree of variability. Air samples collected from areas located at or directly adjacent to Hanford Site facilities had higher concentrations than did those samples collected farther away. In general, analytical results for most radionuclides were at or near Hanford Site background levels, which is much less than DOE derived concentration guides but greater than those measured off the site. The data also show that concentrations of certain radionuclides were higher within different operational areas. Table 3.2.3 shows the annual average and maximum concentrations of radionuclides in near-facility air samples during 2001. A complete listing of the 2001 near-facility ambient air monitoring results can be found in PNNL-13910, APP. 2. Results for selected Pacific Northwest National Laboratory air samples are also reported in PNNL-13910, APP. 2, as well as in Section 4.1.

The 2001 analytical results for the remedial action projects at the 100-B/C, 100-H, and 100-F Areas generally indicated that for most radionuclides, concentrations were greater than levels measured off the site, though well within historical ranges.

At the 100-B/C Area, ambient air monitoring was re-established in February 2001 at three locations. These locations were the same ones used in 1999 when cleanup activities were temporarily halted. The radionuclides uranium-234 and -238 were consistently detected. Strontium-90 and uranium-235 were detected occasionally in 2001.

Remedial action activities for fiscal year 2001 were completed at the 100-H site, and air monitoring ended in March 2001. Uranium-234 and plutonium-239/240 were detected in two of the four composite samples analyzed in 2001.

At the 100-F remedial action site, ambient air monitoring continued at four locations in 2001. Uranium-234 and -238 were detected consistently; strontium-90, uranium-235, and plutonium-239/240 were detected occasionally.

In 2001, two samplers operated at each of the 105-DR and 105-F interim safe storage projects. The quarterly analytical results from these air samples were generally similar to the results seen over the past 3 years.

Air monitoring at the 105-H and 105-D interim safe storage projects began in November 2000 and, at the request of project management, the air sampler at 105-D was operated only while actual decontamination and decommissioning work was being done (i.e., one work shift on weekdays). For this location, sample volumes were significantly lower than for all other near-facility air samplers. The overall effect of reduced sample volumes was radionuclide concentrations that appeared to be higher than those measured at the other site samplers. Air sample concentrations are mathematically calculated by dividing the concentration (picocuries) measured in the laboratory by the sample volume (cubic meters of air that passed through the filter). Environmental air sample concentrations are typically very low (at or near background levels) and when divided by a

Table 3.2.2. Near-Facility Air Sampling Locations and Analyses, 2001

Site	Number of Samplers	EDP Code[a]	Analyses	
			Biweekly	Composite
100-B/C remedial action project	3	N464, N465, N466	Gross alpha, gross beta	GEA,[b] Sr-90, Pu-iso,[c] U-iso[d]
105-D interim safe storage project	1	N523	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-DR interim safe storage project	2	N492, N493	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-F interim safe storage project	2	N494, N495	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-F remedial action project	4	N519, N520, N521, N522	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-H interim safe storage project	2	N524, N525	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
100-H remedial action project	4	N507, N508, N509, N510	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
100-K spent nuclear fuels	8	N401, N402, N403, N404, N476, N477, N478, N479	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso, Pu-241, Am-241
100-NR-1 remedial action and 100-N surveillance, maintenance/transition projects	5	N102, N103, N105, N106, N526	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
200-East Area	17	N019, N158, N498, N499, N957, N967, N968, N969, N970, N972, N973, N976, N977, N978, N984, N985, N999	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
Canister Storage Building, 200-East Area	2	N480, N481	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso, Pu-241, Am-241
200-West Area	21	N155, N161, N165, N168, N200, N304, N433, N441, N442, N449, N456, N457, N956, N963, N964, N965, N966, N974, N975, N987, N994	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
300 Area	1	N130	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
Environmental Restoration Disposal Facility	3	N482, N517, N518	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
600 Area	1	N981	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso

(a) EDP Code = Sampler location code. See PNNL-13910, APP. 2.
(b) GEA = Gamma energy analysis.
(c) Isotopic plutonium-238 and -239/240.
(d) Isotopic uranium-234, -235, and -238.

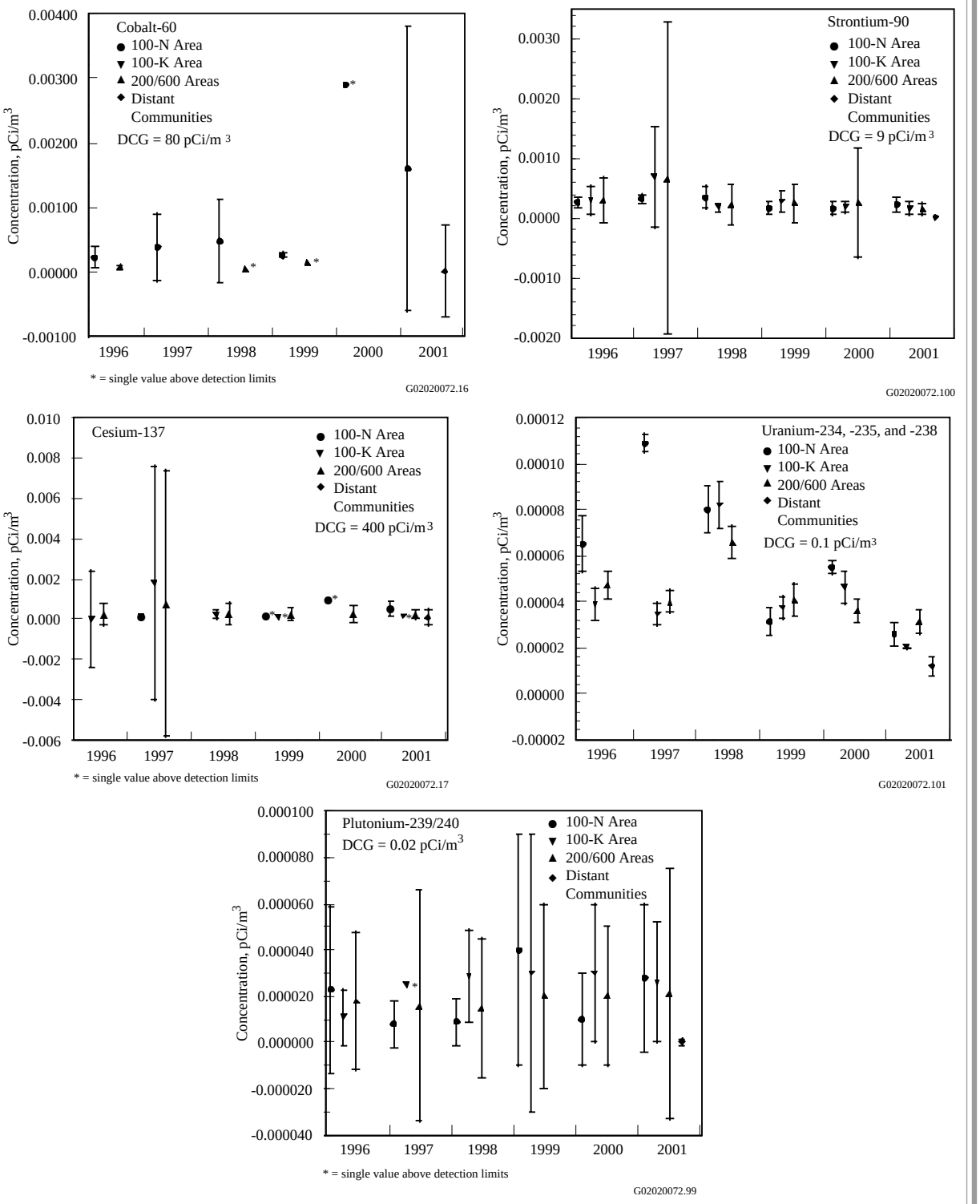


Figure 3.2.1. Average Concentrations of Selected Radionuclides in Near-Facility Air Samples Compared to Those in Distant Communities, 1996 through 2001. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol. Error bars are ±2 standard deviations except for uranium values which are ±2 standard error of the mean.

Table 3.2.3. Annual Average and Maximum Concentrations (aCi/m³)[a] of Radionuclides in Near-Facility Air Samples, 2001

Cobalt-60

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	-17 ± 150	52 ± 76	N466
100-F RA	-3.8 ± 69	31 ± 92	N519
100-H RA	45 ± 150	180 ± 190	N508
105-DR/F/D/H ISS[f]	30 ± 180	210 ± 120	N524
100-K	4.5 ± 73	65 ± 74	N479
100-N[g]	1,600 ± 2,200	2,900 ± 830	N105
200-East	9.3 ± 71	100 ± 88	N985
200-West	1.1 ± 80	120 ± 99	N165
300 Area	6.2 ± 45	22 ± 65	N130
ERDF[h]	290 ± 10	300 ± 140	N482
Distant community[i]	20 ± 700	450 ± 120	
DCG[j]		80,000,000	

Strontium-90

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	140 ± 100	140 ± 100	N466
100-F RA	190 ± 88	250 ± 130	N519
100-H RA	25 ± 80	280 ± 230	N507
105-DR/F/D/H ISS[f]	460 ± 880	1,900 ± 950	N523
100-K	170 ± 110	270 ± 130	N479
100-N[g]	230 ± 120	290 ± 140	N102
200-East	160 ± 98	300 ± 130	N480
200-West	160 ± 110	270 ± 120	N161
300 Area	32 ± 150	85 ± 84	N130
ERDF[h]	220 ± 110	280 ± 120	N517
Distant community[i]	-29 ± 63	14 ± 56	
DCG[j]		9,000,000	

Cesium-137

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	18 ± 120	57 ± 110	N464
100-F RA	5.3 ± 45	46 ± 76	N519
100-H RA	-41 ± 300	87 ± 190	N509
105-DR/F/D/H ISS[f]	37 ± 190	350 ± 780	N523
100-K	48 ± 100	160 ± 150	N476
100-N[g]	520 ± 360	740 ± 270	N105
200-East	230 ± 110	340 ± 190	N984
200-West	260 ± 280	570 ± 240	N155
300 Area	-5.5 ± 78	22 ± 61	N130
ERDF[h]	150 ± 36	160 ± 130	N482
Distant community[i]	100 ± 420	400 ± 510	
DCG[j]		400,000,000	

Uranium-234

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	12 ± 4.6	15 ± 8.9	N465
100-F RA	16 ± 11	26 ± 13	N522
100-H RA	8.7 ± 12	14 ± 11	N508
105-DR/F/D/H ISS[f]	20 ± 12	35 ± 20	N493
100-K	10 ± 9.8	26 ± 12	N403
100-N[g]	13 ± 6.2	19 ± 9.9	N106
200-East	13 ± 11	27 ± 12	N969
200-West	15 ± 10	25 ± 13	N956
300 Area	12 ± 1.9	13 ± 7.6	N130
ERDF[h]	18 ± 5.2	23 ± 11	N517
Distant community[i]	13 ± 13	27 ± 11	
DCG[j]		90,000	

Uranium-235

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	7.4 ± 2.2	8.5 ± 6.5	N465
100-F RA	4.6 ± 0.19	4.7 ± 4.2	N520
100-H RA	6.6 ± 13	12 ± 13	N509
105-DR/F/D/H ISS[f]	9.1 ± 4.0	13 ± 9.6	N492
100-K	1.9 ± 2.7	4.3 ± 5.3	N478
100-N[g]	5.2 ± 2.4	6.4 ± 5.3	N102
200-East	5.8 ± 2.4	7.8 ± 5.3	N984
200-West	4.8 ± 2.6	9.0 ± 7.3	N168
300 Area	2.6 ± 2.7	3.5 ± 4.3	N130
ERDF[h]	3.1 ± 4.9	6.3 ± 5.6	N482
Distant community[i]	0.30 ± 0.40	0.67 ± 2.9	
DCG[j]		100,000	

Uranium-238

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	12 ± 4.4	14 ± 8.5	N466
100-F RA	12 ± 13	26 ± 12	N522
100-H RA	1.9 ± 3.8	9.6 ± 9.3	N508
105-DR/F/D/H ISS[f]	18 ± 17	43 ± 21	N493
100-K	10 ± 10	26 ± 12	N403
100-N[g]	7.9 ± 3.2	11 ± 6.8	N103
200-East	12 ± 8.2	21 ± 11	N984
200-West	13 ± 9.6	25 ± 12	N457
300 Area	11 ± 9.0	16 ± 8.6	N130
ERDF[h]	13 ± 9.6	20 ± 10	N517
Distant community[i]	14 ± 11	24 ± 10	
DCG[j]		100,000	

Table 3.2.3. (contd)

Plutonium-238

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	80. ± 10	13 ± 11	N464
100-F RA	3.3 ± 12	16 ± 14	N520
100-H RA	-0.59 ± 12	30 ± 27	N507
105-DR/F/D/H ISS[f]	17 ± 22	28 ± 21	N493
100-K	-0.094 ± 19	14 ± 21	N401
100-N[g]	2.7 ± 15	18 ± 16	N105
200-East	2.4 ± 11	19 ± 23	N480
200-West	2.7 ± 11	16 ± 11	N457
300 Area	2.6 ± 1.6	3.1 ± 8.7	N130
ERDF[h]	2.7 ± 11	9.3 ± 11	N518
Distant community[i]	-0.53 ± 0.69	0.15 ± 1.8	
DCG[j]		30,000	

Plutonium-239/240

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	1.8 ± 2.0	3.0 ± 4.5	N464
100-F RA	9.9 ± 2.8	11 ± 6.8	N521
100-H RA	18 ± 160	42 ± 23	N507
105-DR/F/D/H ISS[f]	35 ± 76	130 ± 62	N523
100-K	26 ± 26	48 ± 24	N403
100-N[g]	28 ± 32	50 ± 18	N105
200-East	8.5 ± 9.0	19 ± 9.4	N968
200-West	27 ± 82	180 ± 61	N449
300 Area	0.055 ± 2.1	0.79 ± 0.82	N130
ERDF[h]	81 ± 320	430 ± 130	N482
Distant community[i]	0.19 ± 1.6	1.6 ± 2.1	
DCG[j]		20,000	

Plutonium-241

Site	Average[b]	Maximum[c]	EDP Code[d]
100-K	-30 ± 690	530 ± 190	N478
200-East	-340 ± 650	-49 ± 50	N480
Distant community[i]		Not reported	
DCG[j]		1,000,000	

Americium-241

Site	Average[b]	Maximum[c]	EDP Code[d]
100-K	5.5 ± 11	15 ± 10	N476
200-East	3.2 ± 2.9	4.7 ± 9.0	N480
Distant community[i]		Not reported	
DCG[j]		20,000	

(a) To convert to international metric system units, multiply aCi/m^3 by 0.000000037 to obtain Bq/m^3.
(b) ±2 standard deviations.
(c) ± total analytical uncertainty.
(d) See PNNL-13910, APP. 2.
(e) RA = Remedial Action project.
(f) ISS = Interim Safe Storage project.
(g) Includes 100-NR-1 remedial action project and 100-N surveillance and maintenance/transition project.
(h) ERDF = Environmental Restoration Disposal Facility.
(i) See Section 4.1.
(j) DOE Derived Concentration Guide.

small sample volume, the resulting concentration will appear to be higher than the calculated concentration obtained from an air sample with a higher (normal) sample volume.

The airborne contaminant levels in the 100-K Area were similar to those measured over the previous years. Facility emissions in the 100-K Area decreased substantially in 1996 and subsequent radionuclide concentrations in the ambient air samples have been near detection limits. Strontium-90 and uranium-234 and -238 were detected consistently. Occasionally, plutonium-239/240 and americium-241 were detected also.

Analytical results for ambient air samples from the 100-NR-1 remedial action and 100-N surveillance and maintenance/transition projects in 2001 were similar to those measured in previous years. A fifth air sampling location was added in August 2001 at the 100-NR-1 project to monitor ambient air near remedial action activities at the 116-N-3 treatment, storage, and disposal unit. Strontium-90, uranium-234 and -238, and plutonium-239/240 were detected consistently. Occasionally detected were cobalt-60, cesium-137, uranium-238, and plutonium-238. Cobalt-60 was detected at only one of the five 100-N Area air sampling locations in 2001. The concentrations of cobalt-60 at

this location were considerably higher than at any other near-facility air sampling location at Hanford in 2001. The sampling location was near the retired 1325-N Liquid Waste Disposal Facility (116-N-3 treatment, storage, and disposal facility), which was being excavated to remove contaminated soil throughout 2001.

In 2001, radionuclide levels measured in the 200-East Area were generally similar to those measured over the previous years. Strontium-90, uranium-234 and -238, and plutonium-239/240 were detected consistently. Occasionally, cesium-137 and uranium-235 were detected.

Radionuclide levels measured in the 200-West Area were similar to results for previous years. Uranium-234 and -238 and plutonium-239/240 were detected consistently. Strontium-90, cesium-137, and uranium-235 were occasionally detected.

The air sampling network at the Environmental Restoration Disposal Facility (200-West Area) used two existing Hanford Site samplers for upwind monitoring (one near-facility sampler, "N-963;" one Pacific Northwest National Laboratory sampler, station #13 "200 W SE" [see Section 4.1]) and three air samplers at the facility that provided downwind coverage. The 2001 analytical results indicated that strontium-90, uranium-234, -235, and -238, and plutonium-239/240 levels were slightly higher than 2000 levels. Consistently detected were uranium-234 and -238 and plutonium-239/240. Cobalt-60, cesium-137, and strontium-90 were occasionally detected.

The remedial action, interim safe storage, and surveillance and maintenance/transition projects discussed above are described in more detail in Section 2.3.10.

3.2.2 Spring Water Monitoring

In the past, radioactive effluent streams were sent to the 1301-N and 1325-N Liquid Waste Disposal Facilities in the 100-N Area. After moving through the soil column to the water table, this waste migrated with the groundwater and contributed to the release of radionuclides to the Columbia River. Radionuclides from these facilities enter the Columbia River along the riverbank region sometimes called N Springs. Groundwater springs and/or shoreline seepage wells at the N Springs are sampled annually to verify that the reported radionuclide releases to the Columbia River are conservative (i.e., not underreported). The amount of radionuclides entering the Columbia River at these springs (i.e., release) is calculated based on analyses of monthly samples collected from monitoring well 199-N-46 located near the shoreline. Analytical results and discussion of these releases may be found in Section 3.1 and in HNF-EP-0527-11. A groundwater pump-and-treat system designed to reduce the discharge of strontium-90 to the Columbia River in the 100-N Area was put into operation in 1995 and continued to operate in 2001. Additional discussion about this system and its effects may be found in Section 6.2.

In October 2001, samples were collected from ten 100-N Area shoreline wells. The samples were collected using a bailer carefully lowered into the water column of each well to avoid sediment suspension, and a 4-liter (1-gallon) sample was obtained. Analyses of these samples detected tritium, strontium-90, and gamma-emitting radionuclides.

In 2001, the levels of strontium-90 detected in samples from riverbank springs were highest in N Springs wells Y302 and Y303, which are nearest well 199-N-46. None of the concentrations exceeded the DOE derived concentration guide value. Tritium and gamma-emitting radionuclide concentrations were below analytical detection limits in 2001. Tritium and strontium-90 data from 2001 riverbank springs sampling are summarized in Table 3.2.4.

3.2.3 Radiological Surveys of Surface Contamination

Radiological surveys are used to monitor and detect contamination on the Hanford Site. The main types of contaminated areas are underground radioactive materials areas, contamination areas, soil contamination areas, and high contamination areas.

Underground radioactive materials areas are areas that have contamination contained below the soil surface. These areas are typically stabilized cribs, burial grounds, covered ponds, trenches, and ditches. Barriers over the contamination sources are used to inhibit radionuclide transport to the surface environs. These areas are surveyed at least annually to document the current radiological status.

Contamination/soil contamination areas may or may not be associated with an underground structure containing radioactive material. A breach in the surface

Table 3.2.4. Radionuclide Concentrations (pCi/L) in 100-N Area Riverbank Springs, 2001

Radionuclide	Facility Effluent Monitoring Well 199-N-46[a]	Shoreline Springs Maximum[b]	Shoreline Springs Average[c]	DCG[d]
Tritium	5,000 ± 500	Not detected		2,000,000
Strontium-90	9,700 ± 2,200	45 ± 7	13 ± 10	1,000

(a) To convert to international metric system units, multiply pCi/L by 0.037 to obtain Bq/L.
(b) ± total analytical uncertainty.
(c) ±2 standard deviations.
(d) DCG = DOE derived concentration guide (DOE Order 5400.5).

barrier of a contaminated underground area may result in the growth of contaminated vegetation. Insects or animals may burrow into the soil and bring contamination to the surface. Vent pipes or risers from an underground structure may be a source of speck contamination (particles with a diameter less than 0.6 centimeter [0.25 inch]). Areas of contamination not related to subsurface structures can include sites contaminated with fallout from effluent stacks and sites that are the result of unplanned releases (e.g., contaminated tumbleweeds, animal feces). All contaminated areas may be susceptible to contamination migration and are surveyed at least annually to document the current radiological status (locations of contaminated areas are illustrated in PNNL-13910, APP. 2).

At the end of 2001, the Hanford Site had ~3,638 hectares (~8,990 acres) of posted outdoor contamination areas (all types) and 668 hectares (1,650 acres) of posted underground radioactive materials areas not including active facilities. It was estimated that the external dose rate at 80% of the outdoor contaminated areas was less than 1 mrem/h (0.01 mSv/h), though direct dose rate readings from isolated radioactive specks could have been higher. Table 3.2.5 lists the contaminated areas and underground radioactive materials areas. Vehicles equipped with radiation detection devices and a global positioning system were again used in 2001 to more accurately measure the extent of the contamination. Area measurements are entered into the Hanford Geographical Information System, a computer database maintained by Bechtel Hanford, Inc.

The number and size of contaminated areas vary from year to year for several reasons: stabilization of areas of known contamination, discovery of new areas of contamination, and/or ongoing improvement of the geographical measurements of contaminated areas. Table 3.2.6 summarizes the effects of these efforts during 2001.

Stabilization activities in 2001 resulted in the re-classification of ~14 hectares (~34 acres) from contamination/soil contamination areas to underground radioactive materials areas in the 100 and 200 Areas.

Though small areas of contamination were newly identified in 2001, no individual large areas were found. During 2001, ~18 hectares (~44 acres) across the site were either newly discovered contamination/soil contamination areas or had their boundaries re-defined.

3.2.4 Soil and Vegetation Monitoring

Soil and vegetation 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. Samples were collected to evaluate long-term trends in environmental accumulation of radioactivity and to detect potential migration and deposition of facility effluents. Special samples also were collected where potential physical or biological pathway problems were identified. Contaminant movement can occur as the result of resuspension from radioactively contaminated surface areas, absorption of radionuclides by the roots of vegetation growing on or near underground and surface-water disposal units, or animal activities at the waste site. The sampling methods and locations used are discussed in detail in DFSNW-OEM-001. Radiological analyses of soil and vegetation samples included strontium-90, isotopic uranium, isotopic plutonium, and gamma-emitting radionuclides.

The number and location of soil and vegetation samples collected in 2001 are summarized in Table 3.2.1. A comprehensive presentation of the analytical data can be found in PNNL-13910, APP. 2. Only those radionuclide concentrations above analytical detection limits are discussed in this section.

Each 1-kilogram (2.2-pound) soil sample represented a composite of five plugs of soil, each 2.5 centimeters (1 inch) deep and 10 centimeters (4 inches) in diameter collected from each site. Each vegetation sample (~500 grams [~16.1 ounces]) consists of new-growth

leaf cuttings taken from the available species of interest at a sample location. Often, the vegetation sample consisted of a composite of several like members of the sampling site plant community to avoid decimation of any individual plant through overharvesting.

In the spring through early summer of each year, soil and vegetation samples are collected on the Hanford Site and submitted for radioanalyses. The analyses include those for radionuclides expected to be found in the areas sampled (i.e., gamma-emitting radionuclides, strontium isotopes, uranium isotopes, and/or plutonium isotopes). The results are then compared to levels found at various offsite sampling locations in Yakima, Benton, and Franklin Counties (see Section 4.6). Comparison of the levels can be used to determine the difference between contributions from site operations and remedial action sites and contributions from natural sources and worldwide fallout.

Soil sampling results also are compared to the "accessible soil" concentrations (WHC-SD-EN-TI-070) developed specifically for use at the Hanford Site (see PNNL-13910, APP. 2 for complete listing). These radioactive concentration values were established to assure 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 ingestion of food crops, including animal products. The accessible soil concentration values are based on a radiation dose estimate scenario where an individual would have to spend 100 hours per year in direct contact with the contaminated soil. The conservatism inherent in pathway modeling assures that the required degrees of protection are in place (WHC-SD-EN-TI-070). These concentrations apply specifically to the Hanford Site with respect to onsite disposal operations, stabilization, cleanup, and decontamination and decommissioning operations.

Some degree of variability is always associated with the collection and analysis of environmental samples. Therefore, minor variations in concentrations from year to year are expected. In general, radionuclide concentrations in soil and vegetation samples collected from, or adjacent to, waste disposal facilities were higher than the concentrations in samples collected farther away and were significantly higher than concentrations measured offsite. The data also show, as expected, that concentrations of certain radionuclides were higher within different operational areas when compared to concentrations measured in distant communities. Generally, the predominant radionuclides were activation and fission products in the 100-N Area, fission products in the 200 Areas, and uranium in the 300/400 Areas.

Table 3.2.5. Outdoor Contamination Status, 2001

Area	Contamination Areas,[a] ha	(acres)	Underground Radioactive Materials Areas,[b] ha	(acres)
100-B/C	0	(0)	39	(96)
100-D/DR	0	(0)	39	(96)
100-F	0	(0)	34	(84)
100-H	0	(0)	14	(35)
100-K	9	(22)	62	(153)
100-N	29	(72)	12	(30)
200-East[c]	67	(166)	143	(353)
200-West[c]	36	(89)	225	(556)
300	19	(47)	45	(111)
400	0	(0)	0	(0)
600[d]	3,478	(8,594)	55	(136)
Totals	3,638	(8,990)	668	(1,650)

(a) Includes areas posted as contamination/soil contamination or as radiologically controlled and areas that had both underground radioactive material and contamination/soil contamination.
(b) Includes areas with only underground contamination. Does not include areas that had contamination/soil contamination as well as underground radioactive material.
(c) Includes tank farms.
(d) Includes BC controlled area and waste disposal facilities outside the 200-East Area boundary that received waste from 200-East Area facilities (e.g., 216-A-25, 216-B-3) and waste disposal facilities outside the 200-West Area boundary that received waste from 200-West Area facilities (e.g., 216-S-19, 216-U-11). The first cell of the Environmental Restoration Disposal Facility was added during 1997.

Table 3.2.6. Zone Status Change of Posted Contamination Areas, 2001[a]

Areas	Zone Changes[b]	Area, ha	(acres)
100	CA to URM	8	(19.8)
100	None to CA	3	(7.4)
200-East	CA to URM	4.5	(11.1)
200-West	CA to URM	1.4	(3.5)
200-West	None to CA	6	(14.8)
300	None to CA	8	(19.7)
400	None to report	0	(0)
600	None to CA	1	(2.5)

(a) Changes from stabilization activities, newly discovered sites, or re-surveyed using a global positioning system.
(b) CA = Contamination/soil contamination area.
URM = Underground radioactive materials area.

3.2.4.1 Radiological Results for Soil Samples

In Hanford soil samples, cobalt-60, strontium-90, cesium-137, plutonium-239/240, and uranium were detected consistently. The concentrations of these radionuclides were elevated near and within facility boundaries when compared to historical concentrations measured off the site. Figure 3.2.2 shows average soil values for 2001 and the preceding 5 years. The levels demonstrate a high degree of variability.

Generally, the surface soil samples collected near the 1301-N Liquid Waste Disposal Facility exhibited somewhat higher radionuclide concentrations than those collected at the other soil sampling locations in the 100-N Area. Average radionuclide concentrations detected in the surface soil samples near the facility from 1996 through 2001 are presented in Table 3.2.7. Results were at or near historical levels measured on the Hanford Site, and the concentrations for most radionuclides were lower than the 2000 levels.

Average radionuclide concentrations detected in all of the surface soil samples collected in the 100-N Area from 1996 through 2001 are presented in Table 3.2.8. The average values for 100-N Area soil were also down in 2001 for most radionuclides. The 2001 maximum, average, offsite average concentrations, and accessible soil concentrations are compared in Table 3.2.9.

Soil samples were collected from 57 of 111 sampling locations in the 200/600 Areas in 2001. Analytical results from soil samples taken from the 200/600 Areas showed generally level trends for the average values for all of the radionuclides measured in 2001. Sampling location D146, located at the southern end of the Environmental Restoration Disposal Facility in the 200-West Area, is now sampled on an annual basis. The 2001 maximum, average, offsite average, and accessible soil concentrations are compared in Table 3.2.10. Complete listings of radionuclide concentrations and sampling location maps are provided in PNNL-13910, APP. 2.

Soil samples were collected from 18 sampling locations in the 300/400 Areas in 2001: 17 from the 300 Area and 1 from the 400 Area. The 2001 maximum, average, offsite average concentrations, and accessible soil concentrations are compared in Table 3.2.11. Complete listings of radionuclide concentrations and sampling location maps are provided in PNNL-13910, APP. 2. For the samples collected in 2001, average values remained elevated for uranium isotopes but were much lower than the concentrations reported in 2000. Uranium concentrations were expected to be higher in the 300 Area samples than at other site locations because uranium was used during past fuel fabrication operations in the 300 Area.

In 2001, one soil sample was collected at the remedial action project in the 100-B/C Area, and two each at the remedial action projects in the 100-F and 100-H Areas. Four samples were collected from the 100-NR-1 remedial action project site. A single sample was collected from the Environmental Restoration Disposal Facility (200-West Area) to determine the effectiveness of contamination controls. Sample results from each of these locations were comparable to those seen at other locations at Hanford. The samples collected from these locations provide baseline data to be compared with future samples. Table 3.2.12 provides a summary of the analytical data for selected radionuclides. All of the 2001 data are provided in PNNL-13910, APP. 2.

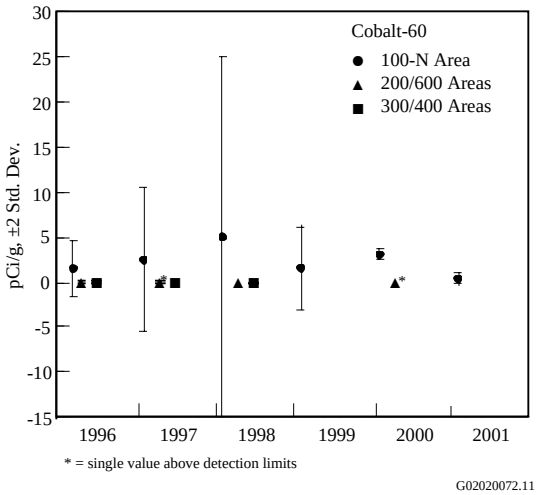
3.2.4.2 Radiological Results for Vegetation Samples

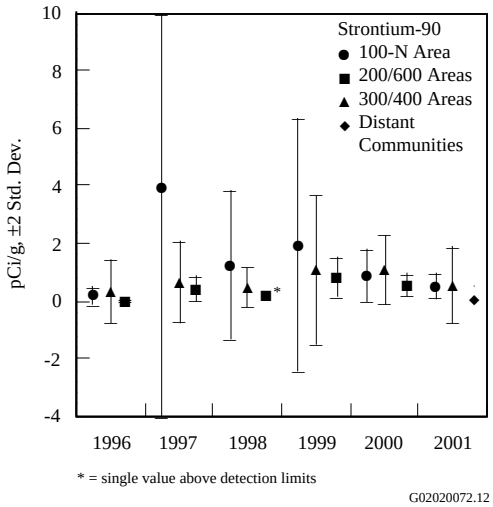
In Hanford vegetation samples, cobalt-60, strontium-90, cesium-137, plutonium-239/240, and uranium were detected consistently. Concentrations of these radionuclides in vegetation were elevated near and within facility boundaries compared to concentrations measured off the site. Figure 3.2.3 shows average vegetation values for 2001 and the preceding 5 years. The results demonstrate a high degree of variability.

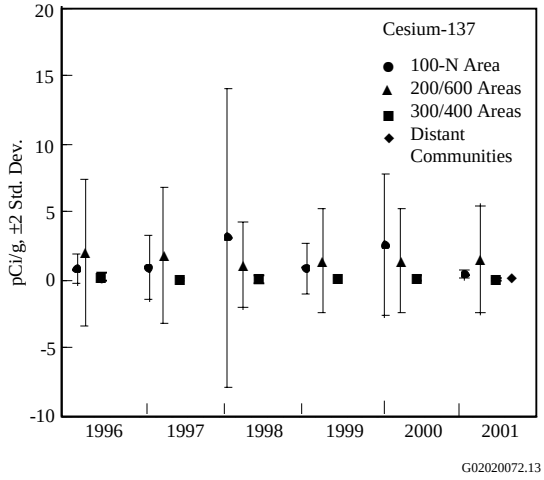
Average radionuclide concentrations detected in the vegetation samples near the retired 1301-N Liquid Waste Disposal Facility (also known as the 116-N-3 treatment, storage, and disposal unit) from 1996 through 2001 are presented in Table 3.2.13. In 2001, concentrations in these samples were well within the range of historical levels.

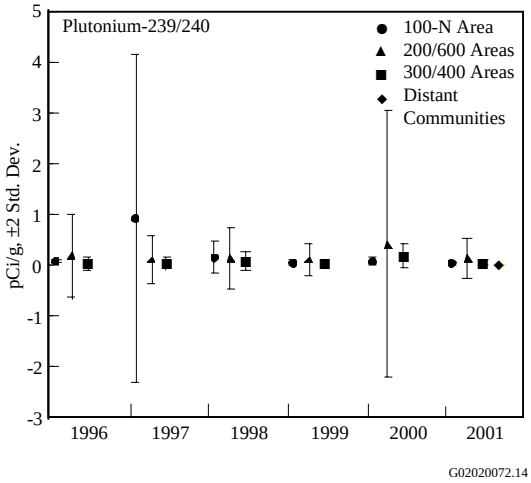
Average radionuclide concentrations detected in all of the vegetation samples collected in the 100-N Area from 1996 through 2001 are presented in Table 3.2.14. These concentrations were also within the range of historical values. The levels of cesium-137 and strontium-90 at the 100-N Area were higher than levels found in the 200 and 300/400 Areas.

Vegetation samples collected along the 100-N Area shoreline (N Springs) contain radionuclides that were not completely retained in the soil columns beneath the retired 1301-N and 1325-N Liquid Waste Disposal Facilities. Radionuclides concentrations were similar in 2000 and 2001, with the exception of a single positive result for cobalt-60 in 2001. Table 3.2.15 shows the average radionuclide concentrations detected in the vegetation samples collected along N Springs from 1996 to 2001.









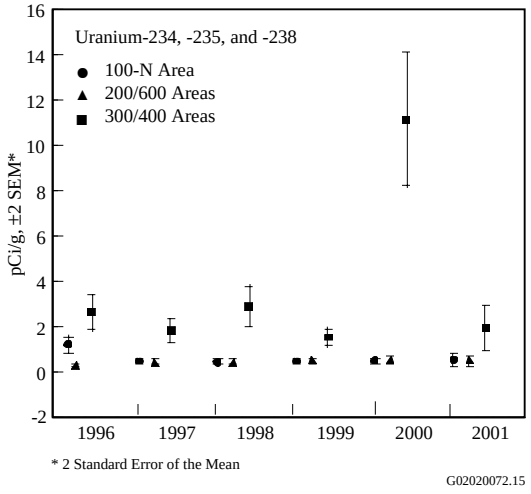


Figure 3.2.2. Average Concentrations of Selected Radionuclides in Near-Facility Soil Samples Compared to Those in Distant Communities, 1996 through 2001. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol. Error bars are ±2 standard deviations except for uranium values which are ±2 standard error of the mean.

Table 3.2.7. Average Radionuclide Concentrations (pCi/g[a] dry wt.)[b] Detected in Surface Soil Samples near the 1301-N Liquid Waste Disposal Facility, 1996 through 2001

Year	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
1996	2.5 ± 7.8	0.23 ± 0.11	0.98 ± 1.0	0.57 ± 0.24	0.059 ± 0.049	0.56 ± 0.38	0.066 ± 0.019
1997	4.3 ± 9.0	5.8 ± 19.0	1.5 ± 2.6	0.22 ± 0.11	0.020 ± 0.007	0.22 ± 0.01	1.2 ± 3.4
1998	8.5 ± 24	1.6 ± 2.8	5.2 ± 13	0.22 ± 0.19	0.039 ± 0.013	0.16 ± 0.07	0.19 ± 0.34
1999	2.6 ± 5.0	2.9 ± 4.8	1.3 ± 1.9	0.21 ± 0.086	0.014 ± 0.006	0.19 ± 0.07	0.094 ± 0.048
2000	1.6 ± 0.68	1.0 ± 0.82	2.7 ± 5.6	0.20 ± 0.066	0.016 ± 0.000004	0.22 ± 0.09	0.07 ± 0.07
2001	0.46 ± 0.76	0.48 ± 0.42	0.39 ± 0.4	0.25 ± 0.08	0.024 ± 0.01	0.26 ± 0.05	0.04 ± 0.04

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ±2 standard deviations.

Table 3.2.8. Average Radionuclide Concentrations (pCi/g[a] dry wt.)[b] Detected in all 100-N Area Surface Soil Samples, 1996 through 2001

Year	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
1996	1.5 ± 3.0	0.20 ± 0.22	0.077 ± 1.1	0.567 ± 0.082	0.038 ± 0.021	0.566 ± 0.125	0.07 ± 0.016
1997	2.5 ± 8.0	3.9 ± 16	0.89 ± 2.4	0.21 ± 0.04	0.020 ± 0.002	0.207 ± 0.036	0.91 ± 3.2
1998	4.9 ± 20	1.2 ± 2.6	3.1 ± 11	0.214 ± 0.063	0.033 ± 0.008	0.166 ± 0.026	0.15 ± 0.3
1999	1.6 ± 4.6	2.0 ± 4.4	0.84 ± 1.8	0.22 ± 0.04	0.016 ± 0.004	0.20 ± 0.03	0.029 ± 0.05
2000	3.1 ± 0.6	0.84 ± 0.9	2.5 ± 5.2	0.22 ± 0.09	0.018 ± 0.007	0.22 ± 0.03	0.058 ± 0.074
2001	0.4 ± 0.68	0.48 ± 0.42	0.39 ± 0.36	0.24 ± 0.09	0.024 ± 0.01	0.25 ± 0.07	0.031 ± 0.04

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ±2 standard deviations.

Table 3.2.9. Concentrations of Selected Radionuclides (pCi/g[a] dry wt.) in all 100-N Area Surface Soil Samples, 2001

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[b]	1.0 ± 0.08	0.7 ± 0.3	0.6 ± 0.08	0.32 ± 0.08	0.03 ± 0.02	0.3 ± 0.08	0.06 ± 0.03
Average[c]	0.4 ± 0.76	0.48 ± 0.42	0.39 ± 0.36	0.240 ± 0.09	0.024 ± 0.01	0.25 ± 0.07	0.031 ± 0.04
Distant community[c,d]	NR[e]	0.052 ± 0.11	0.15 ± 0.32	NR	NR	0.13 ± 0.11	0.0055 ± 0.012
Accessible soil concentration (WHC-SD-EN-TI-070)[f]	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) ± total analytical uncertainty.
(c) ±2 standard deviations.
(d) See Section 4.6.
(e) NR = Not reported.
(f) Hanford soils that are not behind security fences.

Table 3.2.10. Concentrations of Selected Radionuclides (pCi/g[a] dry wt.) in 200/600 Areas Surface Soil Samples, 2001

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[b]	ND[c]	3.8 ± 0.8	11.0 ± 1.6	0.47 ± 0.1	0.048 ± 0.022	0.43 ± 0.01	0.98 ± 0.21
Average[d]	ND	0.55 ± 1.3	1.5 ± 4.0	0.22 ± 0.11	0.02 ± 0.02	0.22 ± 0.11	0.13 ± 0.4
Distant community[d,e]	NR[f]	0.052 ± 0.11	0.15 ± 0.32	NR	NR	0.13 ± 0.11	0.0055 ± 0.012
Accessible soil concentration limits (WHC-SD-EN-TI-070)[g]	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) ± total analytical uncertainty.
(c) ND = Not detected.
(d) ±2 standard deviations.
(e) See Section 4.6.
(f) NR = Not reported.
(g) Hanford soils that are not behind security fences.

Table 3.2.11. Concentrations of Selected Radionuclides (pCi/g[a] dry wt.) in 300/400 Areas Surface Soil Samples, 2001

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[b]	ND[c]	ND	0.15 ± 0.03	5.7 ± 1.1	0.31 ± 0.084	5.9 ± 1.1	0.08 ± 0.03
Average[d]	ND	ND	0.05 ± 0.08	0.94 ± 3.0	0.06 ± 0.17	0.95 ± 3.2	0.041 ± 0.06
Distant community[d,e]	NR[f]	0.052 ± 0.11	0.15 ± 0.32	NR	NR	0.13 ± 0.11	0.0055 ± 0.012
Accessible soil concentration limits (WHC-SD-EN-TI-070)[g]	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) ± total analytical uncertainty.
(c) ND = Not detected.
(d) ±2 standard deviations.
(e) See Section 4.6.
(f) NR = Not reported.
(g) Hanford soils that are not behind security fences.

The 2001 analytical results for vegetation samples collected at the 100-N Area are compared to offsite averages in Table 3.2.16. A complete list of radionuclide concentrations and sampling location maps are provided in PNNL-13910, APP. 2. In 2001, analytical results from vegetation samples collected from the 100-N Area were slightly elevated compared to those observed in 2000. The radionuclide levels measured in 100-N Area vegetation were greater than those measured off the Hanford Site.

Vegetation samples from 49 of 115 sampling locations were collected in the 200/600 Areas in 2001. The 2001 maximum and average concentrations for selected radionuclides are compared to the offsite average in Table 3.2.17. A complete list of radionuclide concentrations and sampling location maps is provided in PNNL-13910, APP. 2. Analytical results from vegetation samples taken in 2001 from the 200/600 Areas were comparable to those observed in previous years. Radionuclide levels for strontium-90, cesium-137, and plutonium-239/240 were greater than those measured off the Hanford Site.

Seventeen vegetation samples were collected from the 300/400 Areas in 2001. The 2001 maximum, average, offsite average, and accessible soil limits for 300/400 Areas samples are listed in Table 3.2.18. Complete listings of radionuclide concentrations and sampling location maps are provided in PNNL-13910, APP. 2.

Table 3.2.12. Radionuclide Concentrations (pCi/g[a] dry wt. ± total analytical uncertainty) in Environmental Restoration Contractor Projects' Soil Samples, 2001

Site	Sample Location[b]	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
ERDF[c]	D146	ND[d]	ND	0.21 ± 0.034	0.22 ± 0.057	0.027 ± 0.016	0.28 ± 0.07	0.018 ± 0.012
100-B/C	D150	ND	ND	0.22 ± 0.035	0.21 ± 0.059	0.014 ± 0.012	0.23 ± 0.062	0.015 ± 0.012
100-H	D151	ND	ND	0.38 ± 0.072	0.12 ± 0.037	ND	0.15 ± 0.044	ND
100-H	D152	ND	ND	0.55 ± 0.11	0.14 ± 0.043	0.017 ± 0.013	0.16 ± 0.048	ND
100-F	D154	ND	ND	0.21 ± 0.036	0.24 ± 0.062	ND	0.18 ± 0.05	0.013 ± 0.011
100-F	D155	ND	0.39 ± 0.2	0.077 ± 0.018	0.17 ± 0.048	0.016 ± 0.012	0.19 ± 0.051	0.019 ± 0.013
100-N	D156	0.021 ± 0.019	ND	0.032 ± 0.013	0.28 ± 0.07	0.016 ± 0.013	0.31 ± 0.074	ND
100-N	D157	0.68 ± 0.055	ND	0.41 ± 0.066	0.17 ± 0.048	0.01 ± 0.009	0.14 ± 0.042	ND
100-N	D158	0.033 ± 0.007	0.34 ± 0.2	0.038 ± 0.01	0.17 ± 0.048	0.016 ± 0.013	0.19 ± 0.051	ND
100-N	D159	0.017 ± 0.008	ND	0.049 ± 0.013	0.2 ± 0.054	ND	0.23 ± 0.06	ND
Distant community[e,f]		NR[g]	0.052 ± 0.11	0.15 ± 0.32	NR	NR	0.13 ± 0.11	0.0055 ± 0.012
Accessible soil concentration[h]		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) Sampling location code. See PNNL-13910, APP. 2.
(c) ERDF = Environmental Restoration Disposal Facility.
(d) ND = Not detected.
(e) ±2 standard error of the mean.
(f) See Section 4.6.
(g) NR = Not reported.
(h) Hanford soils that are not behind security fences.

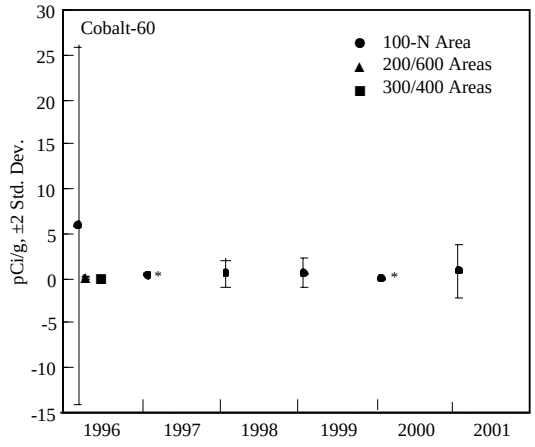
The levels of most radionuclides measured in the 300 Area were greater than those measured off the Hanford Site, and uranium levels were higher than levels measured in either the 100 and 200 Areas. The higher uranium levels were expected because uranium was released during past fuel fabrication operations in the 300 Area. In the 400 Area, the levels recorded for most radionuclides were higher than those measured off the site in previous years.

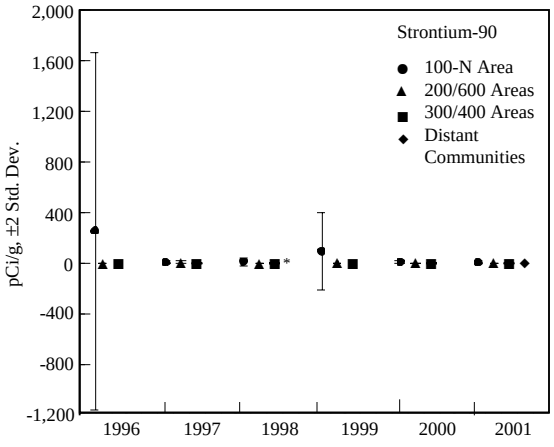
3.2.5 External Radiation

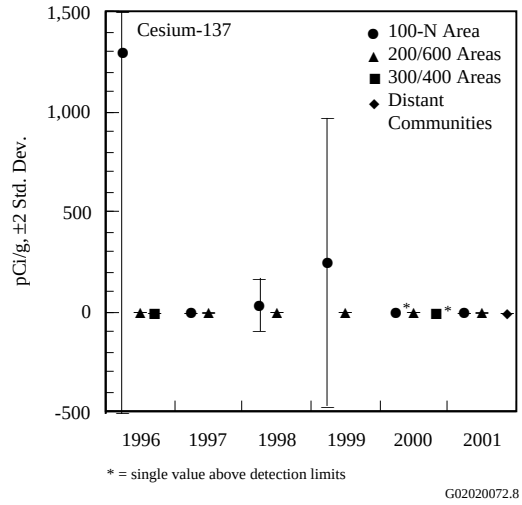
External radiation fields were monitored near facilities and waste handling, storage, and disposal sites to measure and assess the impact of operations. Thermoluminescent dosimeters were used at numerous fixed locations to gather dose rate information over longer periods of time. Thermoluminescent dosimeter results were used individually or averaged to determine dose rates in a given area for a particular sampling period. A summary of the 2000 and 2001 thermoluminescent dosimeter results can be found in Table 3.2.19. Individual thermoluminescent dosimeter results and locations are provided in PNNL-13910, APP. 2. Specific information regarding external radiation sampling methods and locations can be found in DFSNW-OEM-001. Dose rate information for Hanford perimeter locations can be found in Section 4.6.

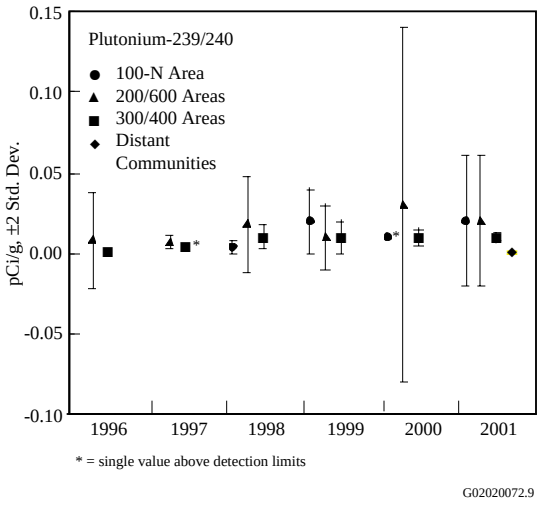
Environmental thermoluminescent dosimeters measure dose rates from all types of external radiation sources. These sources include cosmic radiation, naturally occurring radioactivity in air and soil, and fallout from past nuclear weapons testing, as well as any contribution from Hanford Site activities. These outside radiation sources may cause an estimated 20% deviation in thermoluminescent dosimeter results.

Near-facility monitoring uses the Harshaw thermoluminescent dosimeter system, which includes the Harshaw 8807 dosimeter and the Harshaw 8800 reader. The packaging, which uses an O-ring seal, protects the dosimeter from light, heat, moisture, and dirt. The thermoluminescent dosimeters were placed 1 meter (3.28 feet) above the ground near facilities, active and









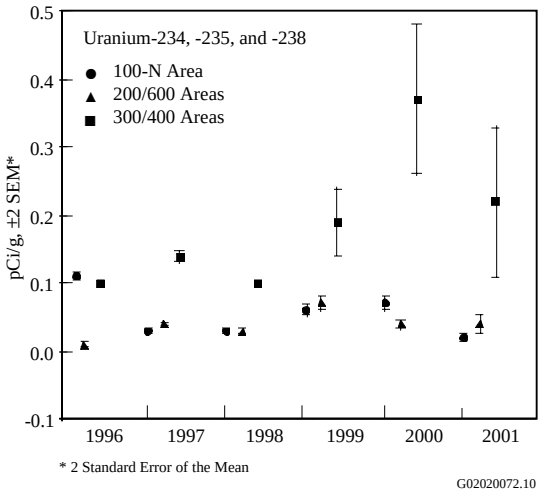


Figure 3.2.3. Average Concentrations of Selected Radionuclides in Near-Facility Vegetation Samples Compared to Those in Distant Communities, 1996 through 2001. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol. Error bars are ±2 standard deviations except for uranium values which are ±2 standard error of the mean.

Table 3.2.13. Average Radionuclide Concentrations (pCi/g[a] dry wt.)[b] Detected in Vegetation Samples Collected near the 1301-N Liquid Waste Disposal Facility, 1996 through 2001

Year	^{60}Co	^{90}Sr	^{137}Cs	$^{239/240}$Pu
1996	7.9 ± 22	750 ± 2,200	2,750 ± 9,200	-0.013 ± 0.38[c]
1997	0.42[d]	0.49[d]	0.14 ± 0.08	ND[e]
1998	0.54 ± 0.93	13.6 ± 38.0	50.1 ± 140	0.0071[d]
1999	0.99 ± 1.7	205 ± 340	505 ± 720	0.017 ± 0.009
2000	ND	0.09 ± 0.019	0.2[d]	ND
2001	0.17 ± 0.17	3.4 ± 9.2	0.26 ± 0.24	ND

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ±2 standard deviations.
(c) Negative value indicates results at or below background levels of radioactivity.
(d) Single value above detection limit.
(e) ND = Not detected.

Table 3.2.14. Average Radionuclide Concentrations (pCi/g[a] dry wt.)[b] Detected in all 100-N Area Vegetation Samples, 1996 through 2001

Year	^{60}Co	^{90}Sr	^{137}Cs	$^{239/240}$Pu
1996	6.0 ± 20	250 ± 1,400	1,300 ± 7,000	-0.0051 ± 0.013[c]
1997	0.42 ± 0.05	3.6 ± 14	0.16 ± 0.19	ND[d]
1998	0.62 ± 1.5	12 ± 32	38 ± 130	0.0042 ± 0.004
1999	0.61 ± 1.6	91 ± 300	250 ± 720	0.022 ± 0.02
2000	0.05 ± 0.03	5.7 ± 19	0.2[e]	0.009[e]
2001	0.89 ± 3.0	3.5 ± 9.0	0.38 ± 0.44	0.024 ± 0.04

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ±2 standard error of the mean.
(c) Negative value indicates results at or below background levels of radioactivity.
(d) ND = Not detected.
(e) Single value above detection limit.

inactive surface-water disposal sites, and remedial action projects. The dosimeters were exchanged and analyzed each calendar quarter. The Radiological Calibrations Facility in the 318 Building (300 Area) calibrates the response of the chips; results are reported in terms of external dose.

In 2001, there were 133 thermoluminescent dosimeter locations collecting external radiation information. At six locations, the dosimeter results showed a decrease in external radiation from 2000 levels. At one location (212-R in the 200-North Area), there was a 20% increase in the amount of radiation detected. At the remaining locations, there were no changes in the amount of external radiation detected.

At the former 116-B-11 and 116-C-1 Liquid Waste Disposal Facilities (located in the 100-B/C Area), five thermoluminescent dosimeter sites monitored dose rates in 2001. In the 100-F Area, five thermoluminescent dosimeter monitoring sites were used. In the 100-H Area, three thermoluminescent dosimeter monitoring sites were used. Remedial action activities by the environmental restoration contractor were completed in 2001, and the dosimeters were removed in September 2001. Dose rates measured in 2001 at each location were comparable to those measured in 2000.

Cleanup activities at the 100-K Fuel Storage Basins and adjacent retired reactor buildings in the 100-K Area continue to be monitored. Dose rates in this area in 2001

Table 3.2.15. Average Radionuclide Concentrations (pCi/g[a] dry wt.)[b] Detected in N Springs Vegetation Samples, 1996 through 2001

Year	^{60}Co	^{90}Sr	^{137}Cs	$^{239/240}$Pu
1996	0.01 ± 0.01	2.4 ± 6.0	0.15[c]	-0.0015 ± 0.002[d]
1997	ND[e]	6.2 ± 17.0	0.18 ± 0.24	ND
1998	0.068[c]	21.0 ± 26.0	ND	0.0028[c]
1999	ND	0.98 ± 1.1	0.42 ± 0.70	ND
2000	ND	9.4 ± 22.0	ND	0.009[c]
2001	0.57[c]	4.7 ± 9.2	ND	0.008[c]

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ±2 standard deviations.
(c) Single value above detection limit.
(d) Negative value indicates results at or below background levels of radioactivity.
(e) ND = Not detected.

Table 3.2.16. Concentrations of Selected Radionuclides (pCi/g[a] dry wt.) in 100-N Area Vegetation Samples, 2001

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[b]	3.8 ± 0.3	11.0 ± 1.6	0.71 ± 0.16	0.016 ± 0.09	0.006[c]	0.013 ± 0.007	0.055 ± 0.018
Average[d]	0.89 ± 3.0	3.5 ± 9.0	0.38 ± 0.44	0.01 ± 0.01		0.01 ± 0.01	0.024 ± 0.04
Distant community[d,e]	NR[f]	0.066 ± 0.059	0.0022 ± 0.034	NR	NR	ND[g]	0.00078 ± 0.0016

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ± total analytical uncertainty.
(c) Single value above detection limit.
(d) ±2 standard deviations.
(e) See Section 4.6.
(f) NR = Not reported.
(g) ND = Not detected.

Table 3.2.17. Concentrations of Selected Radionuclides (pCi/g[a] dry wt.) in 200/600 Areas Vegetation Samples, 2001

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[b]	ND[c]	4.8 ± 0.7	0.8 ± 0.3	0.05 ± 0.02	0.01 ± 0.006	0.05 ± 0.02	0.1 ± 0.03
Average[d]	ND	1.0 ± 3.0	0.17 ± 0.30	0.019 ± 0.02	0.006 ± 0.003	0.018 ± 0.02	0.021 ± 0.04
Distant community[d,e]	NR[f]	0.066 ± 0.059	0.0022 ± 0.034	NR	NR	ND	0.00078 ± 0.0016

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ± total analytical uncertainty.
(c) ND = Not detected.
(d) ±2 standard deviations.
(e) See Section 4.6.
(f) NR = Not reported.

Table 3.2.18. Concentrations of Selected Radionuclides (pCi/g[a] dry wt.) in 300/400 Areas Vegetation Samples, 2001

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[b]	ND[c]	0.81 ± 0.16	ND	0.54 ± 0.11	0.033 ± 0.013	0.57 ± 0.11	0.0074 ± 0.0054
Average[d]	ND	0.26 ± 0.38	ND	0.10 ± 0.32	0.012 ± 0.02	0.01 ± 0.34	0.006 ± 0.003
Distant community[d,e]	NR[f]	0.066 ± 0.059	0.0022 ± 0.034	NR	NR	ND	0.00078 ± 0.0016

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ± total analytical uncertainty.
(c) ND = Not detected.
(d) ±2 standard deviations.
(e) See Section 4.6.
(f) NR = Not reported.

Table 3.2.19. Thermoluminescent Dosimeter Results (mrem/yr)[a] for Waste Handling Facilities, 2000 and 2001, based on 24 hours/day

	No. of	2000		2001		
Area	Locations, 2001	Maximum	Mean	Maximum	Mean	% Change[b]
100-B/C	5	87	84	94	88	5
100-F	5	88	85	87	83	-2
100-H	3	90	88	95	71	-19
100-K	11	390	120	419	125	4
100-N	14	4,700	1,100	991	319	-71
200/600	66	300	106	317	114	7
212-R	1	2,500	2,000	2,800	1,809	-10
300 TEDF[c]	6	85	83	90	85	2
300	8	180	100	172	106	6
400	7	81	80	84	82	3
CVDF[d]	4	81	75	81	78	4
ERDF[e]	3	93	89	111	93	4

(a) To convert to international metric system units, multiply mrem/yr by 0.01 to obtain mSv/yr.
(b) Numbers indicate a decrease (-) or increase from the 2000 mean.
(c) TEDF = 300 Area Treated Effluent Disposal Facility.
(d) CVDF = Cold Vacuum Drying Facility.
(e) ERDF = Environmental Restoration Disposal Facility.

slightly increased by 4% relative to 2000 values, due primarily to natural fluctuation. For the same reason, the four thermoluminescent dosimeter monitoring sites around the Cold Vacuum Drying Facility also showed an annual dose rate increase of 4% in 2001.

The 2001 results for the 100-N Area indicate that direct radiation levels are highest near facilities that contained or received liquid effluent from N Reactor. These facilities primarily include the retired 1301-N and 1325-N Liquid Waste Disposal Facilities. The results for these two facilities were noticeably higher than those for other 100-N Area thermoluminescent dosimeter locations, but were significantly lower than dose levels measured at these locations in 2000. This reduction was directly attributable to the removal of source material from the facilities by the environmental restoration contractor. Overall, the average dose rate measured in the 100-N Area in 2001 was ~71% lower than that measured in 2000. Annual average thermoluminescent dosimeter results for the entire 100-N Area from 1987 through 2001 are presented in Figure 3.2.4.

Dose rates were measured at the N Springs shoreline to determine potential external radiation doses to the public as well as to onsite workers. Because of the cleanup at the liquid waste disposal facilities, the "skyshine" effect (i.e., radiation reflected by the atmosphere back to the earth's surface) at the N Springs shoreline continued to slowly decrease in 2001 (see Figure 3.2.5 for annual average since 1987).

The highest dose rates in the 200 Areas were measured near waste handling facilities. The location within

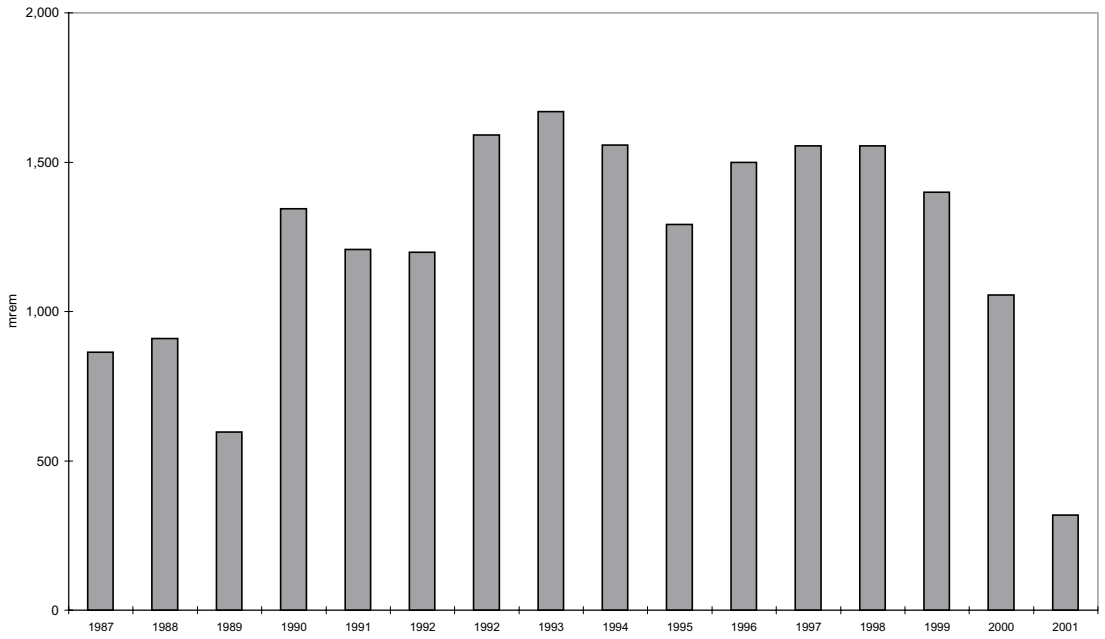


Figure 3.2.4. Annual Average Thermoluminescent Dosimeter Results in the 100-N Area, 1987 through 2001

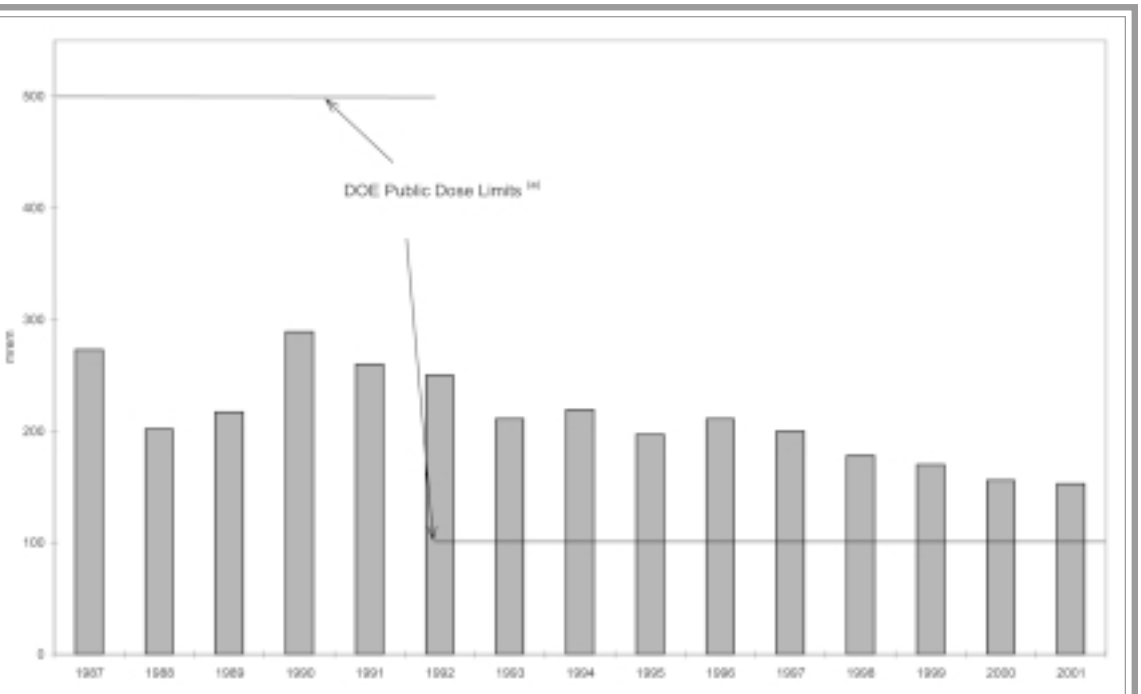


Figure 3.2.5. Average Annual Dose Rates at N Springs, 1987 through 2001. (a) DOE limits were reduced from 500 mrem/yr in 1992. The lower value was selected in recognition of the International Commission on Radiation Protection recommendation to limit the long-term average effective dose equivalence to 100 mrem (1 mSv)/yr or less (DOE Order 5400.5).

the 200 Areas exhibiting the highest dose rate was at the AZ tank farm in the 200-East Area. The average annual dose rate measured in 2001 in the 200 Areas was slightly higher than the average 2000 measurement. The annual average thermoluminescent dosimeter results from 1987 through 2001 are presented in Figure 3.2.6.

This is the sixth year that thermoluminescent dosimeters have been placed at the Environmental Restoration Disposal Facility to evaluate dose rates during ongoing activities. Dose rates measured in 2001 were comparable to the 2000 results.

The highest dose rates in the 300 Area in 2001 were measured near the retired 316-3 process trench. The average dose rates measured in 2001 in the 300 Area, at the 300 Area Treated Effluent Disposal Facility, and in the 400 Area were similar to those measured in 2000. The annual average thermoluminescent dosimeter results for the 300 and 400 Areas from 1991 through 2001 are presented in Figure 3.2.7.

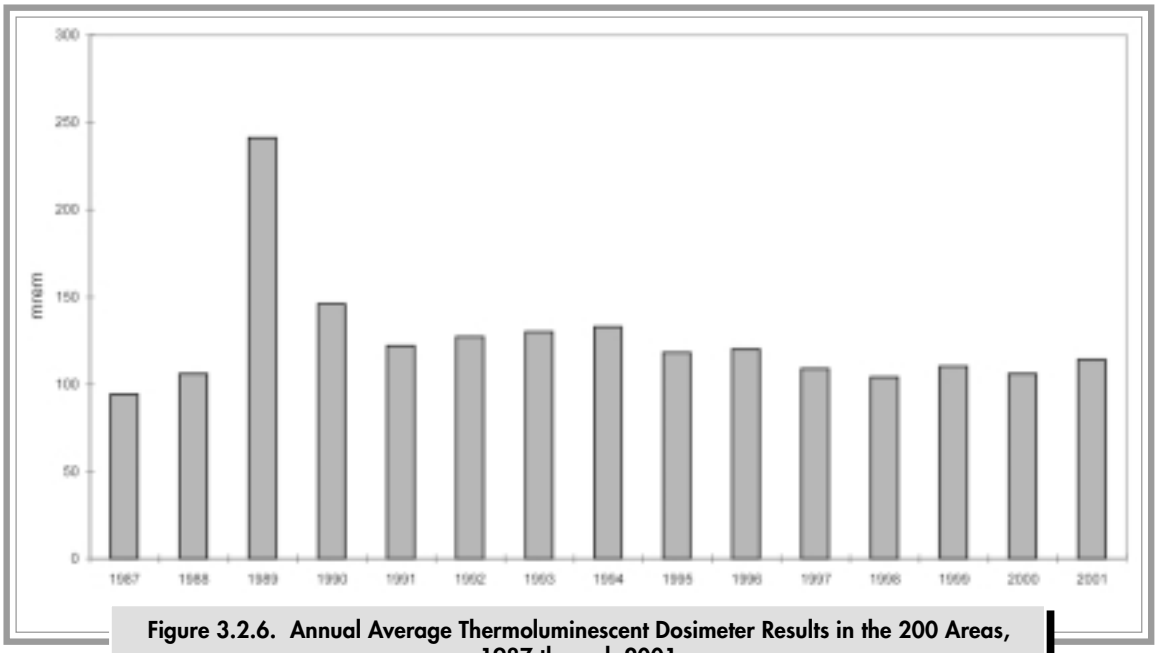


Figure 3.2.6. Annual Average Thermoluminescent Dosimeter Results in the 200 Areas, 1987 through 2001

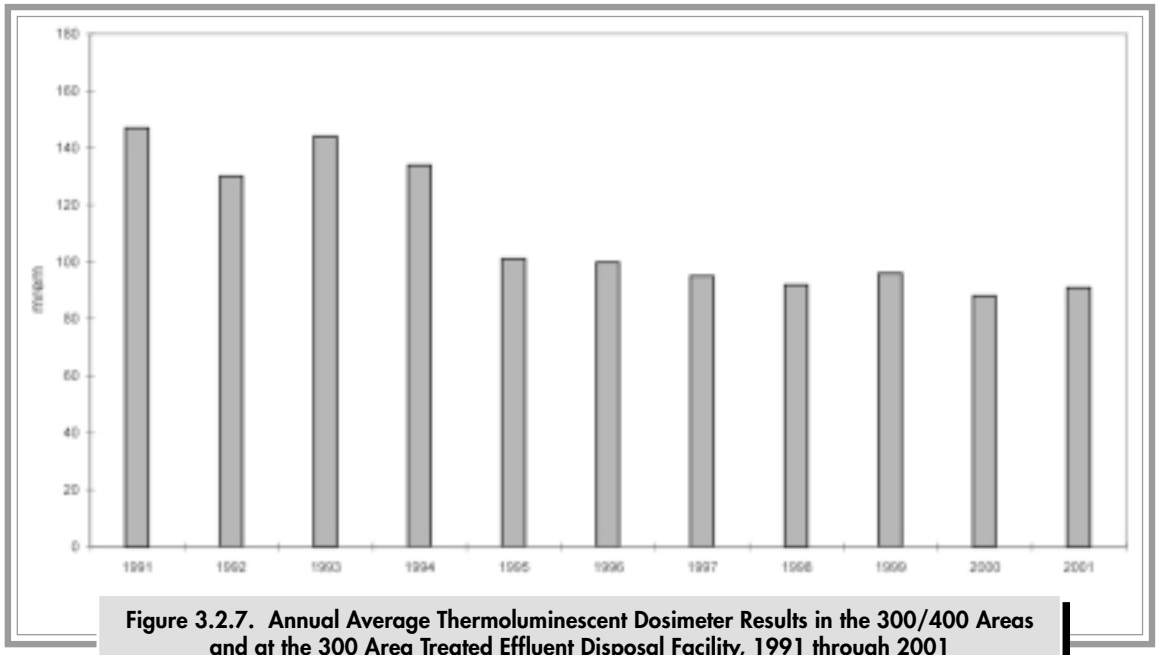


Figure 3.2.7. Annual Average Thermoluminescent Dosimeter Results in the 300/400 Areas and at the 300 Area Treated Effluent Disposal Facility, 1991 through 2001

One thermoluminescent dosimeter monitoring site is located in the 200 North Area at the (contaminated) 212-R Railroad Car Disposition Area. This location was established in 2000 to monitor expected high radiation levels in the immediate vicinity. The annual average dose rate at 212-R in 2001 showed an increase of 20% compared to 2000. Dose rates measured at this location exceed the DOE annual external dose limit to the members of the public; however, no member of the public, or Hanford worker, would conceivably spend an entire year at this location.

3.2.6 Investigative Sampling

Investigative sampling was conducted in the operations areas to monitor the presence or movement of radioactive and/or hazardous materials around areas of known or suspected contamination or to verify radiological conditions at specific project sites. Investigative sampling took place near facilities such as storage and disposal sites for at least one of the following reasons:

- to follow up radiological surface surveys that had indicated radioactive contamination was present
- to conduct preoperational surveys to characterize the radiological/chemical conditions at a site before facility construction, operation, or ultimate remediation
- to determine if biotic intrusion (e.g., animal burrows or deep-rooted vegetation) had created a potential for contaminants to spread
- to determine the integrity of waste containment systems.

Generally, the predominant radionuclides discovered during these efforts were cesium-137, strontium-90, and plutonium-239/240 in the 100 and 200 Areas and uranium-234, -235, and -238 in the 300 Area. Hazardous chemicals generally have not been identified above background levels in preoperational environmental monitoring samples.

Investigative samples collected in 2001 included mammals (mice, bats, rabbit), animal feces (mouse, coyote, bird), soils, and vegetation (tumbleweeds, rabbitbrush, grass). Methods for collecting investigative samples are described in DFSNW-OEM-001. Field monitoring was conducted to detect beta/gamma and alpha radioactivity in samples before they were submitted for analysis. Field monitoring results are expressed as disintegrations per minute per 100 square centimeters. Beta/gamma radiation field surveys were conducted with a Geiger-Müeller detector, while alpha radiation field surveys were performed with a portable alpha meter. Laboratory analyses results and field readings are provided in Section 7.0, PNNL-13910, APP. 2.

In 2001, five investigative samples were analyzed for radionuclides at the 222-S laboratory in the 200-West Area. Of the samples analyzed, all showed measurable levels of activity. Another 63 contaminated investigative environmental samples were reported and disposed of without isotopic analyses (though field instrument survey readings were recorded) during cleanup operations. See Table 3.2.20 for a summary of historical investigative sample collections.

In 2001, there were 20 instances of radiological contamination in investigative soil samples. Of the 20, 11 were identified as speck or soil speck contamination. None of the investigative soil samples were submitted for radioisotopic analysis. Eighteen of the 20 locations were cleaned up, and the contaminated soil was disposed of in low-level burial grounds. At the remaining sites, the contamination levels did not exceed limitations of the posting and the soil was left in place.

The number of investigative soil contamination incidents, range of radiation dose levels, and radionuclide concentrations in 2001 were generally within historical values (WHC-MR-0418). Areas of special soil sampling that were found outside radiological control areas and that had dose rate levels greater than radiological control limits were cleaned up or posted as surface contamination areas.

Table 3.2.20. Investigative Sample Collections[a]

	Sample Type		
Year	Soil	Vegetation	Wildlife[b]
1994	94	39	27
1995	73	39	25
1996	37	21	41
1997	51	46	30
1998	41	51	55
1999	42	85	16
2000	25	66	12
2001	20	31	10

(a) Annual number of samples collected.
(b) May include wildlife-related materials (e.g., feces, nests, etc.)

In 2001, there were 31 instances of radiological contamination in investigative vegetation samples. Of the 31 instances, 27 were identified as tumbleweeds or tumbleweed fragments, one as grass, and three as rabbitbrush. None of these samples were analyzed for radionuclide activities. There were eight tumbleweed samples with elevated field readings. Of these, five were from the 218-E-12B burial ground in the 200-East Area, two were found on the SX-SY tank farm in the 200-East Area, and one was suspected to have originated from an inactive transfer line between the B tank farm and the 244-B evaporator in the 200-East Area. Investigative vegetation samples not sent to the laboratory for analysis were disposed of in low-level burial grounds.

Tumbleweed and rabbitbrush are deep-rooted species and become radiologically contaminated by the uptake of below ground contaminants through their root systems. Herbicide application is intended to halt vegetation growth before this uptake occurs. During 2001, application techniques were improved, and administrative procedures were implemented to improve vegetation management. The reduced number of incidents (31) in 2001 appears to reflect these improvements. Nevertheless, contaminated vegetation continued to be identified by radiological surveys. However, as "old" contaminated vegetation from past years is identified and cleaned up, subsequent years should show the results of program improvements.

Investigative wildlife samples were collected directly from or near facilities to monitor and track the effectiveness of measures designed to deter animal intrusion. Samples were collected either as part of an integrated pest management program designed to limit the access of animals to radioactive materials, or as a result of finding radiologically contaminated wildlife-related material (e.g., feces, nests) during radiation surveys.

Radiological surveys were performed after the collection of wildlife to determine whether an animal was radioactively contaminated. If a live animal was found to be free of contamination, it was taken to an area of suitable habitat, still in a controlled area, and released. If an animal was contaminated, a decision was made based on the level of contamination, location, and frequency of occurrence either to collect the animal as a sample or to dispose of the animal in a low-level burial ground.

In 2001, ten wildlife and wildlife-related samples were collected, five of which were submitted for laboratory analysis. The number of samples submitted for analysis depended on opportunity (i.e., resulting from the pest control activities), the technical merits of having isotopic analyses results, and the analytical budget, rather than prescheduled sampling at established sampling points.

The maximum radionuclide concentrations in investigative wildlife samples in 2001 were in mouse feces collected near the 241-TX-155 diversion box in the 200-West Area. Contaminants included strontium-89/90, cesium-137, europium-154, europium-155, plutonium-238, and plutonium-239/240. The numbers of animals found to be radioactively contaminated in 2001 were the lowest since 1994, and the range of radionuclide activities were within historical levels (WHC-MR-0418).

In May 2001, contaminated feces were found around the 241-AY/AZ construction trailers in the 200-East Area. Examination of the fecal pellets did not provide a conclusive determination of whether they were weathered mouse feces or fragments of bird feces. The area has a history of contaminated mouse feces. However, a bird feeder at the site also attracted large numbers of birds. The feeder was immediately removed.

The feces were collected and submitted for analysis. Contaminants included cobalt-60, strontium-89/90, cesium-137, europium-154, europium-155, plutonium-238, and plutonium-239/240. A sampling effort for avian feces was established in the area, the sampling stations were monitored for 3 months, and no further contamination was noted.

There were five cases of contaminated wildlife or related samples found during cleanup operations that were not submitted to a laboratory for analysis. These samples included ant mounds and mouse feces.

Special characterization projects conducted or completed in 2001 to ascertain the radiological, and in some cases, potential hazardous chemical status of site-specific operations included the project listed below:

- A preoperational monitoring plan (RPP-6877) was developed in support of the Waste Vitrification initiative. As part of this plan, a survey is being conducted on the proposed location for the Remote-Handled Immobilized Low-Activity Waste Disposal Facility in the 200-East Area. Tasks completed in 2001 included radiological and ground penetrating radar surveys and surface and subsurface soil sampling at three locations near the ash disposal pile. Following the completion of all the tasks outlined in the monitoring plan, the obtained data will be published in a final report. The report is scheduled for publication in 2004.