Chapter 7: Environmental Monitoring Programs - Agricultural Products, Wildlife, Soil and Direct Radiation

CHAPTER 7

Radionuclides released by Idaho National Laboratory (INL) Site operations and activities have the potential to be assimilated by agricultural products and game animals, which can then be consumed by humans. These media are thus sampled and analyzed for human-made radionuclides because of the potential transfer of radionuclides to people through food chains. Strontium-90 was detected in seven of 13 milk samples at concentrations that are consistent with past measurements and is likely due to the presence of fallout radionuclides in the environment. The results were well below the Derived Concentration Standard established for strontium-90 in drinking water by the U.S. Department of Energy for the protection of human health. Human-made radionuclides were not detected in any of the other agricultural products (e.g., lettuce, grain, potatoes, alfalfa) collected in 2021.

No human-made radionuclides were detected in road-killed animal samples collected in 2021. Two human-made radionuclides (e.g., cobalt-60, strontium-90) were detected in some tissue samples of waterfowl collected on ponds in the vicinity of the Advanced Test Reactor Complex at the INL Site. The source of these radionuclides was most likely the radioactive wastewater evaporation pond, which can be accessed by waterfowl, but not the public.

Bat carcasses have been collected on the INL Site since the summer of 2015. Five human-made radionuclides (e.g., cobalt-60, zinc-65, strontium-90, cesium-137, plutonium-239/240) were detected in 2021 in some of the bats sampled. While cesium-137 and strontium-90 may be of fallout origin, the presence of cobalt-60, zinc-65, and plutonium isotopes may indicate that the bats have visited radioactive effluents ponds on the INL Site.

Soil samples were not collected on or off the INL Site in 2021.

Direct radiation measurements made at boundary and distant locations were consistent with background levels. The average annual dose equivalent from external exposure was estimated from dosimeter measurements to be 121 mrem off the INL Site. The total background dose from natural sources to an average individual living in southeast Idaho was estimated to be approximately 387 mrem per year.

Radiation measurements taken in the vicinity of waste storage and soil contamination areas near INL Site facilities were consistent with previous measurements. Direct radiation measurements using a radiometric scanner system at the Radioactive Waste Management Complex and the Comprehensive Environmental Response, Compensation, and Liability Act Disposal Facility were near background levels.

7. ENVIRONMENTAL MONITORING PROGRAMS: AGRICULTURAL PRODUCTS, WILDLIFE, SOIL AND DIRECT RADIATION

This chapter summarizes results of environmental monitoring of agricultural products, wildlife, soil, and direct radiation on and around the Idaho National Laboratory (INL) Site during 2021. Details of these programs may be found in the *Idaho National Laboratory Site Environmental Monitoring Plan* (DOE-ID 2014a). The INL, Idaho Cleanup Project (ICP) Core, and Environmental Surveillance, Education, and Research Program (ESER) contractors monitor soil, vegetation, biota, and direct radiation on and off the INL Site to comply with applicable U.S. Department of Energy (DOE) orders and other requirements. The focus of the monitoring being conducted by INL and ICP Core contractors is on the INL Site, particularly on and around facilities, as shown in Table 7-1. The ESER contractor's primary responsibility is to monitor the presence of contaminants in media off the INL Site, which may originate from INL Site releases, as can be seen in Table 7-1.

In December 2020, DOE initiated transition of the ESER Program from DOE management to the INL contract managed by Battelle Energy Alliance, LLC (BEA). A team composed of DOE, BEA, and the ESER Program contractor, Veolia Nuclear Solutions – Federal Services (VNSFS), successfully transitioned the Program on September 30, 2021; it is now called Environmental Monitoring & Natural Resource Services. The ESER Program environmental surveillance scope has been integrated into the INL environmental surveillance program. Sampling activities conducted prior to September 30, 2021, were performed by VNSFS and the results are presented in this chapter under the ESER contractor. Sampling activities conducted after September 30, 2021, were performed under BEA and are presented in this chapter under the INL contractor.

Table 7-1. Environmental monitoring of agricultural products, biota, soil, and direct radiation on and around the INL Site.

	MEDIA				
AREA/FACILITY[a]	AGRICULTURAL PRODUCTS	BIOTA	ECOLOGICAL	SOIL	DIRECT RADIATION
ENVIRONMENTAL SURVEILLANCE, EDUCATION, AND RESEARCH PROGRAM CONTRACTOR					
INL Site/Regional	•	•	•	•	•
IDAHO NATIONAL LABORATORY CONTRACTOR					
INL Site				•	•
Regional					•
IDAHO CLEANUP PROJECT CORE CONTRACTOR					
ICDF[b]					•
RWMC[c]					•

a. INL Site = Idaho National Laboratory Site facility areas and areas between facilities.
b. ICDF = Idaho Comprehensive Environmental Response, Compensation, and Liability Act Disposal Facility.
c. RWMC = Radioactive Waste Management Complex.

7.1 Agricultural Products and Biota Sampling

Agricultural products and game animals are sampled by the ESER contractor because of the potential transfer of radionuclides to people through food chains, as was shown previously in Figure 4-1. Figure 7-1 shows the locations where agricultural products were collected in 2021.

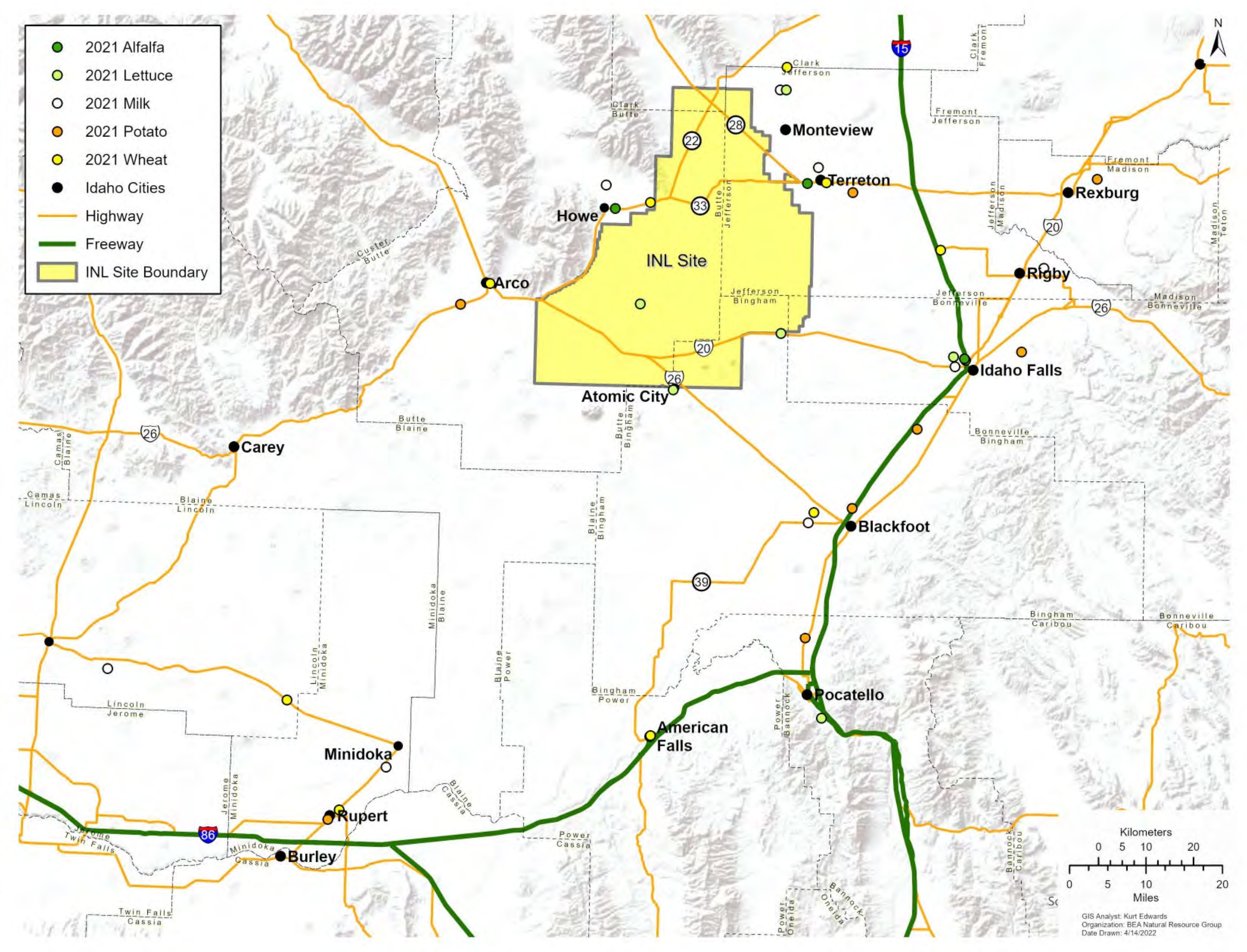


Figure 7-1. Locations of agricultural product samples collected (2021).

7.2 Sampling Design for Agricultural Products

Agricultural products could become contaminated by radionuclides released from INL Site facilities, which are transported offsite by wind and deposited in soil and on plant surfaces. This is important, since approximately 45% of the land surrounding the INL Site is used for agriculture (DOE-ID 1995). In addition, many residents maintain home gardens that could be impacted by INL Site releases. Animals could also eat contaminated crops and soil and in turn transfer radionuclides to humans through consumption of meat and milk.

Agricultural product sampling began in the vicinity of the INL Site in the 1960s with milk and wheat as part of the routine environmental surveillance program. Currently, the program focuses on milk, leafy green vegetables, alfalfa, potatoes, and grains.

As specified in the *DOE Handbook Environmental Radiological Effluent Monitoring and Environmental Surveillance* (DOE 2015), representative samples of the pathway-significant agricultural products grown within 16 km (10 miles) of the site should be collected and analyzed for radionuclides potentially present from site operations. These samples should be collected in at least two locations: (1) the place of expected maximum radionuclide concentrations, and (2) a 'background' location unlikely to be affected by radionuclides released from the INL Site.

Sample design was primarily guided by wind direction and frequencies and farming practices. Air dispersion modeling, using CALPUFF and INL Site meteorological data measured from 2006 through 2008, was performed to develop data quality objectives for radiological air surveillance for the INL Site using the methodology documented in Rood and Sondrup (2014). The same methodology was used to discern deposition patterns. The dispersion and deposition patterns resulting from these sources reflect wind patterns typical of the INL Site. Prevailing winds at most INL Site locations are from the southwest during daytime hours. During evening hours, the winds will sometimes shift direction and blow from the north or northeast but at a lower velocity. Model results show the location of maximum offsite deposition is located between the southwest INL Site boundary and Big Southern Butte. Because there are no agricultural activities in this region, sampling is focused on other agricultural areas west and northeast of the INL Site. In addition, the sampling design considers locations of interest to the public, as well as those of historical interest, which is why some samples are collected at extended distances from the INL Site.

7.2.1 Methods

Fresh produce and milk are purchased from local farmers when available. In addition, lettuce is grown by the ESER program in areas that have no commercial or private producers.

7.2.2 Milk Results

Milk is sampled to monitor the pathway from potentially contaminated, regionally grown feed to cows, then to milk, which is then ingested by humans. During 2021, the ESER contractor collected 191 milk samples (including duplicates and controls) at various locations off the INL Site (Figure 7-1) and from commercially available milk from outside the state of Idaho (the control). The number and location of the dairies can vary from year to year as farmers enter and leave the business. Milk samples were collected weekly from dairies in Idaho Falls and Terreton, as well as monthly at other locations around the INL Site. The Blackfoot dairy is unique because milk is collected from goats. Goat's milk is of particular interest because it may contain higher concentrations of radioiodine than that found in cow's milk due to the ability of the goat to transfer iodine from forage to milk more efficiently than cows (IAEA 2010).

All milk samples were analyzed for gamma-emitting radionuclides, including iodine-131 (^{131}I) and cesium-137 (^{137}Cs). During the second and fourth quarters, samples were analyzed for strontium-90 (^{90}Sr) and tritium, except for Blackfoot. Milk from the Blackfoot location was not analyzed in November 2021 because the family-run goat dairy at that location did not have enough samples for ^{90}Sr analysis. The Idaho Falls location was not sampled for ^{90}Sr and tritium in November due to the cows being moved to a new location in Terreton. Due to already having a location in Terreton, a Rigby dairy was sampled in November for ^{90}Sr and tritium instead and will replace the Idaho Falls sampling location.

Iodine is an essential nutrient and is readily assimilated by cows or goats that eat plants containing the element. Iodine-131 is of particular interest because it is produced by nuclear reactors or weapons, is readily detected, and, along with cesium-134 and ^{137}Cs, can dominate the ingestion dose regionally after a severe nuclear event, such as the Chernobyl accident (Kirchner 1994) or the 2011 accident at Fukushima in Japan. The ingestion of milk pathway is the main route of internal ^{131}I exposure for people. Iodine-131 has a short half-life (eight days) and therefore does not persist in the environment. Past releases from experimental reactors at the INL Site and fallout from atmospheric nuclear weapons tests and Chernobyl are no longer present. Most of the ^{131}I released in 2021 was from the Materials and Fuels Complex (approximately 0.09 Ci). None was detected in air samples collected at or beyond the INL Site boundary (see Chapter 4). Iodine-131 was also not detected in any milk sample collected during 2021.

Cesium-137 is chemically analogous to potassium in the environment and behaves similarly by accumulating in many types of tissue, most notably in muscle tissue. It has a half-life of about 30 years and tends to persist in soil. If in soluble form, it can readily enter the food chain through plants. It is widely distributed throughout the world from historic nuclear weapons detonations, which occurred between 1945 and 1980, and has been detected in all environmental media at the INL Site. Regional sources include releases from INL Site facilities and resuspension of previously contaminated soil particles. Cesium-137 was not detected in any milk sample collected in 2021.

Strontium-90 is an important radionuclide because it behaves like calcium and can deposit in bones. Strontium-90, like ^{137}Cs, is produced in high yields either from nuclear reactors or from detonations of nuclear weapons. It has a half-life of about 29 years and can persist in the environment. Strontium tends to form compounds that are more soluble than ^{137}Cs and is therefore comparatively mobile in ecosystems. Strontium-90 was detected in seven of the 15 milk samples analyzed. Detectable concentrations ranged from 0.25 ± 0.08 pCi/L at Minidoka to 1.53 ± 0.10 pCi/L at Blackfoot as observed in Table 7-2. These levels were consistent with levels reported by the U.S. Environmental Protection Agency (EPA) as resulting from worldwide fallout deposited on soil and taken up by cows through the ingestion of grass. Results from EPA Region 10, which includes Idaho, for a limited data set of seven samples collected from 2007 through 2016, ranged from 0 to 0.54 pCi/L (EPA 2017). The maximum concentration detected in the past 10 years was 2.37 ± 0.29 pCi/L, measured at Fort Hall in November 2013.

DOE has established Derived Concentration Standards (DCSs) (DOE 2011) for radionuclides in air and water. A DCS is the concentration of a radionuclide in air or water that would result in a dose of 100 mrem from ingestion, inhalation, or immersion in a gaseous cloud for one year. There are no established DCSs for foodstuffs such as milk. For reference purposes, the DCS for ^{90}Sr in water is 1,100 pCi/L. Therefore, the maximum observed value in milk samples (1.53 ± 0.10 pCi/L) is approximately 0.14% of the DCS for drinking water.

Tritium, with a half-life of about 12 years, is an important radionuclide because it is a radioactive form of hydrogen, which combines with oxygen to form tritiated water. The environmental behavior of tritiated water is like that of water, and can be present in surface water, precipitation, and atmospheric moisture. Tritium is formed by natural processes, as well as by reactor operation and nuclear weapons testing. Tritium enters the food chain through surface water that people and animals drink, as well as from plants that contain water. Tritium was not detected in any of the milk samples analyzed during 2021, as observed in Table 7-2. Concentrations varied from -51 ± 22 pCi/L in a sample from Terreton in November 2020 to 44 ± 33 pCi/L in a sample from Idaho Falls in May 2021. These concentrations are similar to those of previous years and are consistent with those found in atmospheric moisture and precipitation samples. The DCS for tritium in water is 1,900,000 pCi/L.

7.2.3 Lettuce

Lettuce was sampled because radionuclides in air can be deposited on soil and plants, which can then be ingested by people, as shown in Figure 4-1. Uptake of radionuclides by plants may occur through root uptake from soil and/or absorption of deposited material on leaves. For most radionuclides, uptake by foliage is the dominant process for contamination of plants (Amaral et al. 1994). For this reason, green, leafy vegetables, like lettuce, have higher concentration ratios of radionuclides to soil than other kinds of plants. The ESER contractor collects lettuce samples every year from areas on and adjacent to the INL Site, as observed in Figure 7-1. The number and locations of gardens have changed from year to year depending on whether vegetables were available. Home gardens have generally been replaced with portable lettuce planters, as shown in Figure 7-2, because the availability of lettuce from home gardens was unreliable at some key locations.

Table 7-2. Strontium and tritium concentrations[a] in milk samples collected off the INL Site in 2021.

STRONTIUM-90 (pCi/L)		
LOCATION	**MAY 2021**	**NOVEMBER 2021**
Blackfoot	1.53 ± 0.10	NS[b]
Dietrich	-0.50[c] ± 0.12	0.35 ± 0.06
Howe	-0.06 ± 0.06	0.25 ± 0.18
Idaho Falls[d]	0.78 ± 0.11	NS
Minidoka	0.14 ± 0.05	0.25 ± 0.08
Monteview	0.51 ± 0.06	-0.43 ± 0.17
Rigby[d]	NS	0.43 ± 0.10
Terreton	0.16 ± 0.06	0.51 ± 0.08
AVERAGE	**0.37**	**0.23**
Control (Colorado)	-0.63 ± 0.08	0.24 ± 0.11
TRITIUM (pCi/L)		
LOCATION	**MAY 2021**	**NOVEMBER 2021**
Blackfoot	63 ± 32	NS[b]
Dietrich	19 ± 31	-48 ± 22
Howe	17 ± 31	-24 ± 22
Idaho Falls[d]	44 ± 33	NS
Minidoka	5.8 ± 31	6.1 ± 23
Monteview	-29 ± 23	-10 ± 22
Rigby[d]	NS	-3.7 ± 23
Terreton	12 ± 31	-51 ± 22
AVERAGE	**19**	**-22**
Control (Colorado)	8.2 ± 23	-40 ± 24

a. Results ± 1σ. Results greater than 3σ uncertainty are considered statistically detected.
b. NS = no sample. The Blackfoot sample is collected from a small goat farm. There was insufficient sample collected in 2021 for radiochemical analysis.
c. A negative result indicates that the measurement was less than the laboratory background measurement.
d. The Idaho Falls location moved its cows. A new dairy was sampled in Rigby to replace the one in Idaho Falls.

Figure 7-2. Portable lettuce planter.

In addition, the planters can be placed, and the lettuce collected at areas previously unavailable to the public, such as on the INL Site and near air samplers. The planters can allow radionuclides deposited from air to accumulate on the soil and plant surfaces throughout the growth cycle. The planters are placed in the spring, filled with soil and potting mix, sown with lettuce seed, and self-watered through a reservoir.

Five lettuce samples were collected from portable planters at Atomic City, the Experimental Field Station, the Federal Aviation Administration Tower, Howe, and Monteview. In 2021, soil from the vicinity of the sampling locations was used in the planters. This soil was amended with potting soil as a gardener in the region would typically do when they grow their lettuce. In addition to the portable samplers, a sample was obtained from farms in Idaho Falls and Pocatello and a control sample was purchased at the grocery store from an out-of-state location (Oregon).

The samples were analyzed for ^{90}Sr and gamma-emitting radionuclides. Strontium-90 was not detected in the lettuce samples collected during 2021. Strontium-90 is present in the environment as a residual of fallout from above-ground nuclear weapons testing, which occurred between 1945 and 1980. No other human-made radionuclides were detected in any of the lettuce samples. Although ^{137}Cs from nuclear weapons testing fallout is measurable in soils, the ability of vegetation, such as lettuce, to incorporate cesium from soil in plant tissue is much lower than for strontium (Fuhrmann et al. 2003; Ng, Colsher, and Thompson 1982; Schulz 1965). In addition, the availability of ^{137}Cs to plants depends highly on soil properties, such as clay content or alkalinity, which can act to bind the radionuclide (Schulz 1965). Soils in southeast Idaho tend to be moderately to highly alkaline.

7.2.4 Grain

Grain (including wheat and barley) is sampled because it is a staple crop in the region. In 2021, the ESER contractor collected grain samples at 10 locations from areas surrounding the INL Site (Figure 7-1), and an additional duplicate sample was collected from Roberts. A control sample was purchased from outside the state of Idaho. The locations were selected because they are typically farmed for grain and are encompassed by the air surveillance network. Exact locations may change as growers rotate their crops. No human-made radionuclides were found in any samples. Agricultural products such as fruits and grains are naturally lower in radionuclides than green, leafy vegetables (Pinder et al. 1990).

7.2.5 Potatoes

Potatoes are collected because they are one of the main crops grown in the region and are of special interest to the public. Because potatoes are not exposed to airborne contaminants, they are not typically considered a key part of the ingestion pathway. Potatoes were collected by the INL contractor at eight locations in the vicinity of the INL Site (Figure 7-1) and obtained from one location outside eastern Idaho. None of the potato samples (including duplicates) collected during 2021 contained a detectable concentration of any human-made radionuclides. Potatoes, like grain, are generally less efficient at removing radioactive elements from soil than leafy vegetables such as lettuce.

7.2.6 Alfalfa

In addition to analyzing milk, the ESER contractor began collecting data in 2010 on alfalfa consumed by milk cows. A sample of alfalfa was collected in June 2021 from locations in the Mud Lake area, Howe, and Idaho Falls. Mud Lake is an agricultural area with a high potential for offsite contamination via the air pathway are shown in Figure 8-6. (Note: The highest offsite air concentration used for estimating human doses was located southeast of the INL Site's east entrance; however, there is limited agriculture near that location.) The samples were analyzed for gamma-emitting radionuclides and ^{90}Sr. No human-made radionuclides were detected in the alfalfa samples collected during 2021.

7.2.7 Big Game Animals

Muscle, liver, and thyroid samples were collected from ten big game animals. The muscle and liver samples were analyzed for ^{137}Cs because it is an analog of potassium and is readily incorporated into muscle and organ tissues. Thyroids are analyzed for ^{131}I because it selectively concentrates in the thyroid gland when assimilated by many animal species, and is thus an excellent bio-indicator of atmospheric releases.

Iodine-131 was not detected in the thyroid samples. No ^{137}Cs or other human-made, gamma-emitting radionuclides were found in any of the muscle samples.

7.2.8 Waterfowl

Waterfowl are collected each year at ponds on the INL Site and at a location off the INL Site. Two waterfowl collected from wastewater ponds located at the Advanced Test Reactor (ATR) Complex plus three control waterfowl collected from Burton and Swan Valley were analyzed for gamma-emitting radionuclides, ^{90}Sr, and actinides americium-241 (^{241}Am), plutonium-238 (^{238}Pu), and plutonium-239/240 ($^{239/240}$Pu). These radionuclides were selected because they have historically been measured in liquid effluents from some INL Site facilities. Each sample was divided into the following three sub-samples: (1) edible tissue (e.g., muscle, gizzard, heart, liver), (2) external portion (e.g., feathers, feet, head), and (3) all remaining tissue.

Two human-made radionuclides were detected in edible, exterior, and remainder subsamples from the ducks collected at the ATR Complex ponds. These were cobalt-60 (^{60}Co), and ^{90}Sr. A Northern Shoveler collected from the sewage lagoons at ATR Complex had one of these radionuclides in edible tissue identified in Table 7-3. Three Mallards were collected as control ducks. Strontium-90 was detected in the edible tissue for all three of the control ducks.

Because more human-made radionuclides were found in ducks from the ATR Complex than other locations and at higher levels, it is assumed that the evaporation pond associated with this facility is the source of these radionuclides. The ducks were not taken directly from the two-celled Hypalon™-lined radioactive wastewater evaporation pond, but rather from an adjacent sewage lagoon. However, it is likely the ducks also spent time at the evaporation pond. Concentrations of the detected radionuclides in the waterfowl collected at the ATR Complex were for the most part lower than those collected in 2020. The ^{90}Sr detected in the control ducks is most likely from fallout from past weapons testing. The hypothetical dose to a hunter who eats a contaminated duck from the ATR Complex ponds is presented in Chapter 8, Section 8.3.1.

Table 7-3. Radionuclide concentrations detected in waterfowl collected in 2021.

RADIONUCLIDES DETECTED IN WATERFOWL TISSUE (pCi/kg)				
LOCATION	SPECIES	PORTION	RADIONUCLIDE	CONCENTRATION
ATR Complex Ponds	Northern Shoveler	Exterior	^{60}Co	49 ± 6
			^{90}Sr	196 ± 9
		Remainder	^{60}Co	7 ± 2
			^{90}Sr	112 ± 7
	Northern Shoveler	Edible	^{90}Sr	49 ± 5
		Exterior	^{60}Co	71 ± 7
			^{90}Sr	177 ± 6
		Remainder	^{90}Sr	99 ± 6
Controls	Mallard	Edible	^{90}Sr	24 ± 5
		Exterior	^{90}Sr	21 ± 4
	Mallard	Edible	^{90}Sr	73 ± 4
		Exterior	^{90}Sr	22 ± 4
		Remainder	^{90}Sr	11 ± 3
	Mallard	Edible	^{90}Sr	30 ± 3
		Exterior	^{90}Sr	30 ± 4
		Remainder	^{90}Sr	16 ± 4

7.2.9 Bats

Bat carcasses have been collected on the INL Site since the summer of 2015. Bats are typically desiccated when received and generally weigh about a few grams each. The samples collected in 2021 were analyzed for gamma-emitting radionuclides, for specific alpha-emitting radionuclides (plutonium isotopes and ^{241}Am), and for ^{90}Sr (a beta-emitting radionuclide).

The bat carcasses were divided and composited by the following areas in 2021: Test Area North, Naval Reactors Facility, Materials and Fuels Complex, Central Facilities Area/Experimental Breeder Reactor-I, and ATR Complex/Idaho Nuclear Technology and Engineering Center (INTEC).

The bat analysis results are summarized in Table 7-4. The following radionuclides were detected in at least one sample during 2021: ^{137}Cs, ^{60}Co, ^{238}Pu, $^{239/240}Pu$, ^{90}Sr, and zinc-65. Cesium-137 is fairly ubiquitous in the environment because of fallout from historical nuclear weapons tests. Strontium-90 is another fallout radionuclide. Cobalt-60 and zinc-65, which are fission products, may indicate that the bats visited radioactive effluent ponds on the INL Site, such as at the ATR Complex ponds. Plutonium-238 and $^{239/240}Pu$, which is present in radioactive waste as well as in the environment from past weapons testing, was detected in one sample collected in 2021. The potential doses received by bats are discussed in Chapter 8, Section 8.8.2.

Table 7-4. Radionuclide concentrations measured in bats collected in 2021.

BAT TISSUE CONCENTRATIONS (pCi/kg DRY WEIGHT)			
RADIONUCLIDE	MINIMUM[a]	MAXIMUM[b]	NUMBER OF DETECTIONS[c]
^{241}Am	ND[d]	ND	0
^{137}Cs	642 ± 132	2,310 ± 112	2
^{60}Co	12,000 ± 166	16,000 ± 271	2
^{238}Pu	ND	30 ± 5	1
^{239}Pu	ND	12 ± 4	1
^{90}Sr	93 ± 10	29,300 ± 190	5
^{65}Zn	1,730 ± 171	6,420 ± 339	2

a. Minimum detected concentration.
b. Maximum detected concentration.
c. Out of 5 composites analyzed.
d. ND = not detected.

7.3 Soil Sampling

In the early 1970s, the DOE Radiological and Environmental Sciences Laboratory (RESL) established a routine program for collecting surface and subsurface soils (0–5 and 5–10 cm deep) on and around the INL Site. At that time, RESL established extensive onsite soil sampling grids outside INL Site facilities. Offsite locations were also established by RESL during this process to serve as background sites. RESL analyzed all samples (onsite and offsite) for gamma-emitting radionuclides with a subset onsite analyzed for ^{90}Sr, ^{241}Am, and isotopes of plutonium. In addition, all soil from the surface component (0–5 cm) of the offsite samples was analyzed for ^{90}Sr and alpha emitting-radionuclides (^{241}Am and isotopes of plutonium).

Between 1970 and 1978, RESL extensively sampled the onsite grids outside INL Site facilities and then reduced the onsite sampling frequency to a seven-year rotation that ended in 1990 with sampling at the Test Reactor Area (now known as the Advanced Test Reactor Complex). Surface soils were sampled at distant and boundary locations off the INL Site annually from 1970 to 1975, and the collection interval for offsite soils was extended to every two years starting in 1978.

The INL contractor currently completes soil sampling on a five-year rotation at the INL Site to evaluate long-term accumulation trends and to estimate environmental radionuclide inventories. Sampling occurred in 2017 and is next scheduled for 2022. Data from previous years of soil sampling and analysis on the INL Site show slowly declining concentrations of short-lived radionuclides of human origin (e.g., ^{137}Cs), with no evidence of detectable concentrations depositing onto surface soil from ongoing INL Site releases, as discussed in INL (2016).

The ESER contractor collects soil samples in offsite locations first established by RESL every two years (in even-numbered years). Results to date indicate that the source of detected radionuclides in soil is not from INL Site operations and is most likely derived from world-wide fallout activity (DOE-ID 2014a).

7.3.1 Soil Sampling Design

The basis for the current INL contractor soil sampling design is defined in the *Data Quality Objectives Supporting the Environmental Soil Monitoring Program for the INL Site* (INL 2016), which is discussed in the 2017 Annual Site Environmental Report. Soil was not sampled by the INL contractor in 2021.

7.3.2 Offsite Soil Sampling Results

Offsite soil was not sampled by the ESER contractor in 2021.

7.3.3 Onsite Soil Sampling Results

Onsite soils were not collected in 2021.

7.4 Direct Radiation

7.4.1 Sampling Design

Thermoluminescent dosimeters (TLDs) were historically used to measure cumulative exposures in air (in milliRoentgen or mR) to ambient ionizing radiation. The TLD packets contain four lithium fluoride chips and were placed approximately 1 m (about 3 ft) above the ground at specified locations. Beginning with the May 2010 distribution of dosimeters, the INL contractor began collocating optically stimulated luminescent dosimeters (OSLDs) with TLDs. The primary advantage of the OSLD technology over the traditional TLD is that the nondestructive reading of the OSLD allows for dose verification (i.e., the dosimeter can be read multiple times without destruction of the accumulated signal inside the aluminum oxide chips). TLDs, on the other hand, are heated, and once the energy is released, they cannot be reread. The last set of INL contractor TLD results were from November 2012. The ESER contractor began the use of OSLDs in November 2011 in addition to the TLDs.

ESER TLDs were analyzed by the ICP Core contractor through 2015, after which the task was no longer performed. In 2017, the Idaho State University Environmental Assessment Laboratory (EAL) assumed responsibility for the ESER TLD monitoring effort with the transfer of the TLD analytical equipment to the Idaho State University radiological science laboratory. The EAL spent 2017 bringing the TLD reader into service, including acquiring and installing software to operate the reader. The reader was calibrated using known exposures of TLDs irradiated by the DOE RESL. In 2021, the ESER contractor TLDs were prepared and read by EAL.

Dosimeter locations are shown in Figure 7-3. The sampling periods for 2021 were from November 2020–April 2021 and May 2021–October 2021.

Dosimeters on the INL Site are placed at facility perimeters, concentrated in areas likely to detect the highest gamma radiation readings. Other dosimeters on the INL Site are located near radioactive materials storage areas and along roads.

7.4.2 Methods

TLDs are deployed in the field in May and then replaced in November. The dosimeters are sent to the EAL for analysis.

OSLDs are also placed in the field for six months at the same locations as the TLDs. The ESER OSLDs are sent to the EAL for analysis. The INL OSLDs are returned to the manufacturer for analysis. Transit control dosimeters are shipped with the field dosimeters to measure any dose received during shipment.

Background radiation levels are highly variable; therefore, historical information establishes localized regional trends to identify variances. It is anticipated that five percent of the measurements will exceed the background dose. If a single measurement is greater than the background dose, it does not necessarily qualify that there is an unusually high amount of radiation in the area. When a measurement exceeds the background dose, the measurement is compared to other values in the area and to historical data to determine if the results may require further action as described in Data Quality Objectives Supporting the Environmental Direct Radiation Monitoring Program for the Idaho National Laboratory (INL 2019). The method for computing the background value as the upper tolerance limit (UTL) is described in EPA (2009) and EPA (2013). The ProUCL software (EPA 2013) has been used to compute UTLs, given all available data in the area since 2009.

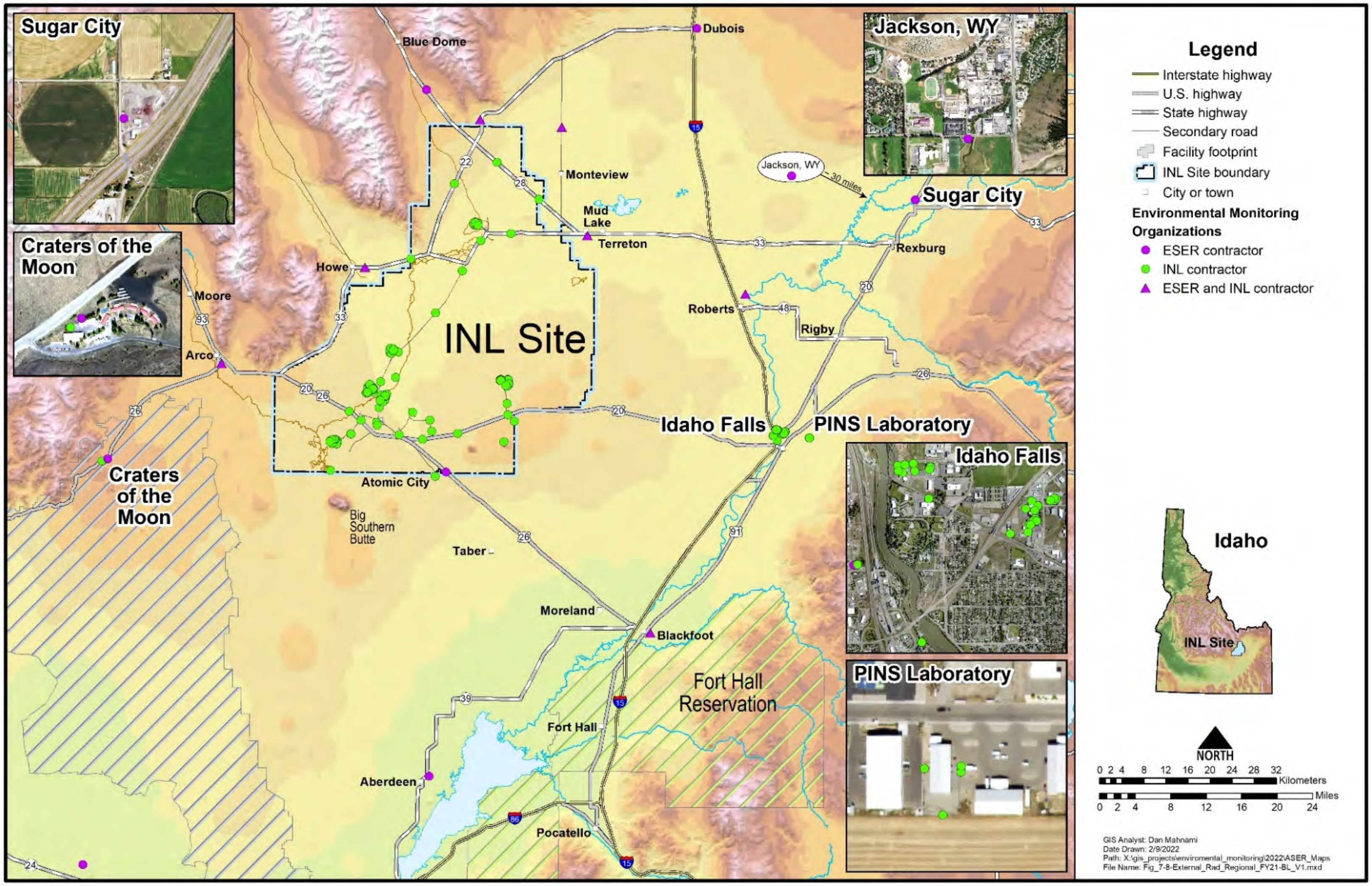


Figure 7-3. Regional direct radiation monitoring locations (2021).

7.4.3 Results

The ESER and INL contractor OSLD data measured at common locations around the INL Site in 2021 are shown in Table 7-5. Using OSLD data collected by both the ESER and INL contractors, the mean annual ambient dose was estimated at 121 mrem (1,210 µSv) for boundary and 122 mrem (1,220 µSv) for distant locations. The mean annual ambient dose for all locations combined is 122 mrem (1,220 µSv).

The 2021 direct radiation results collected by the INL contractor at sitewide and regional locations are provided in Appendix C. Results are reported in gross units of ambient dose equivalent (mrem), rounded to the nearest mrem. The 2021 reported values for field locations were primarily below the historic six-month UTL. Table 7-6 shows locations that exceeded the specific six-month UTL, which was calculated using results measured from 2009 through 2018 (INL 2019). As discussed in Section 7.3.2, a result greater than the background level UTL does not necessarily mean that radiation levels have increased since it is anticipated that 5% of the measurements will exceed the background dose. Rather it indicates that the measurement should be compared to other values in the area and to historical data to provide context and determine if the results may require further action. The facility dosimeters that exceeded the background level UTL in 2021 are located at Argonne National Laboratory (ANL) (see Figure C-6), INTEC (listed as Idaho Chemical Processing Plant (ICPP), (see Figure C-4) and the Radioactive Waste Management Complex (RWMC), (see Figure C-9). The ANL O-8 exceedance appears to be a one-time occurrence. The ANL O-21 results appears to be following a trend since 2020. The ICPP results presented in Table 7-7 appear to follow a pattern of elevated measurements observed at those locations. The locations have consistently shown higher results when compared to other locations at INTEC. The RWMC O-11A dosimeter result was only slightly above the UTL. The dosimeter result for RWMC O-13A is the highest seen for that area. The UTL exceedances for locations near ANL, INTEC, and RWMC are most likely due to operations in those areas. All 2021 environmental dosimetry results were provided to the Radiation Control Department for their consideration.

Neutron dose monitoring is conducted around buildings in Idaho Falls where sources may emit or generate neutron radiation. These buildings include the IF-675 Portable Isotopic Neutron Spectroscopy Laboratory, the IF-670 Bonneville County Technology Center, and the IF-638 Physics Laboratory. Additional neutron dosimeters are placed at the INL Research Center along the south perimeter fence and at the background location Idaho Falls O-10. All neutron dosimeters collected in 2021 were reported as 'M' which denotes the dose equivalents are below the minimum measurable quantity of 10 mrem. The background level for neutron dose is zero and the current dosimeters have a detection limit of 10 mrem. Any neutron dose measured is considered present due to sources inside the building. The INL contractor follows the recommendations of the manufacturer to prevent environmental damage to the neutron dosimetry by wrapping each in aluminum foil. To keep the foil intact, the dosimeter is inserted into an ultraviolet protective cloth pouch when deployed.

Table 7-5. Annual environmental radiation doses using OSLDs at all offsite locations (2017–2021).

LOCATION	2017		2018		2019		2020		2021	
	ESER[a] (mrem)	INL[b] (mrem)	ESER (mrem)	INL (mrem)	ESER[c] (mrem)	INL (mrem)	ESER (mrem)	INL (mrem)	ESER (mrem)	INL (mrem)
DISTANT										
Aberdeen	120	NA	123	NA	134	NA	125	NA	134	NA
Blackfoot	112	NA	NA	NA	NA	NA	NA	NA	NA	NA
Blackfoot (Mountain View[f])	102	110	110	125	116	113	115	121	109	115
Craters of the Moon	116	125	118	132	122	116	118	133	118	132
Dubois	98	NA	103	NA	110	NA	102	NA	106	NA
Idaho Falls	110	119	118	126	134	114	115	134	127	121
IF-IDA	NA	106	NA	119	NA	106	NA	112	NA	106
Jackson	[e]	NA	109	NA	113	NA	108	NA	113	NA
Minidoka	102	NA	109	NA	118	NA	111	NA	113	NA
Rexburg/Sugar City[g]	141	NA	151	NA	156	NA	144	NA	149	NA
Roberts[h]	119	124	130	145	134	133	129	138	134	128
MEAN	**113**	**117**	**119**	**129**	**126**	**116**	**119**	**128**	**122**	**120**
BOUNDARY										
Arco	111	122	122	134	127	118	122	127	128	128
Atomic City	117	122	122	132	135	112	124	125	130	130
Birch Creek Hydro[i]	93	94	110	119	114	110	105	113	113	108
Blue Dome	94	NA	106	NA	111	NA	99	NA	109	NA
Howe	109	115	119	129	121	119	117	117	120	111

Table 7-5. continued.

LOCATION	2017		2018		2019		2020		2021	
	ESER[a] (mrem)	INL[b] (mrem)	ESER (mrem)	INL (mrem)	ESER[c] (mrem)	INL (mrem)	ESER (mrem)	INL (mrem)	ESER (mrem)	INL (mrem)
Monteview	110	133	119	130	127	119	125	134	125	118
Mud Lake	117	131	132	143	131	130	133	139	128	129
MEAN	**107**	**120**	**119**	**131**	**124**	**120**	**118**	**126**	**122**	**121**

a. ESER = Environmental Surveillance, Education, and Research Program.

b. INL = Idaho National Laboratory.

c. The 2018 ESER OSLD results are approximately 10 mrem/yr higher than in previous years. This is due to the application of a revised standard control dose.

d. NA = Not applicable. Neither contractor samples at this location.

e. The Jackson location was not operating from May 2015 through January 2017 because a new location was identified and constructed during this period.

f. ESER has two locations at Blackfoot – one at Mountain View Middle School (MVMS) and one at Groveland, which is called "Blackfoot" by ESER. The INL has one OSLD station at MVMS, which is called "Blackfoot." For the sake of consistency in this report, the MVMS site is called "Mountain View" for both ESER and the INL. The Blackfoot (Groveland) station was inadvertently removed by the Idaho Transportation personnel in early 2018 and is no longer used by ESER.

g. The ESER dosimeter was moved from Rexburg to Sugar City in July 2013. The INL contractor ended surveillance at Rexburg/Sugar City in May 2015.

h. INL contractor calls this location RobNOAA.

i. INL contractor calls this location Reno Ranch.

Table 7-6. Dosimetry locations above the six-month background upper tolerance limit (2021).

LOCATION	MAY 2021 SAMPLE RESULT (mrem)	NOV. 2021 SAMPLE RESULT (mrem)	BACKGROUND LEVEL UTL[a] (mrem)
ANL O-8	108.8	*	86.3
ANL O-21	101.1	103.7	86.3
ICPP O-20	316.9	325.7	197.1
ICPP O-27	224.9	203.6	197.1
ICPP O-28	214.3	209.3	197.1
ICPP O-30	225.1	233.8	197.1
RWMC O-11A	*	89.5	86.7
RWMC O-13A	*	223.3	86.7

a. The UTL is the value such that 95 percent of all the doses in the area are less than that value with 95 percent confidence. That is, only 5 percent of the doses should exceed the UTL.

* Sample did not exceed the UTL for the collection period.

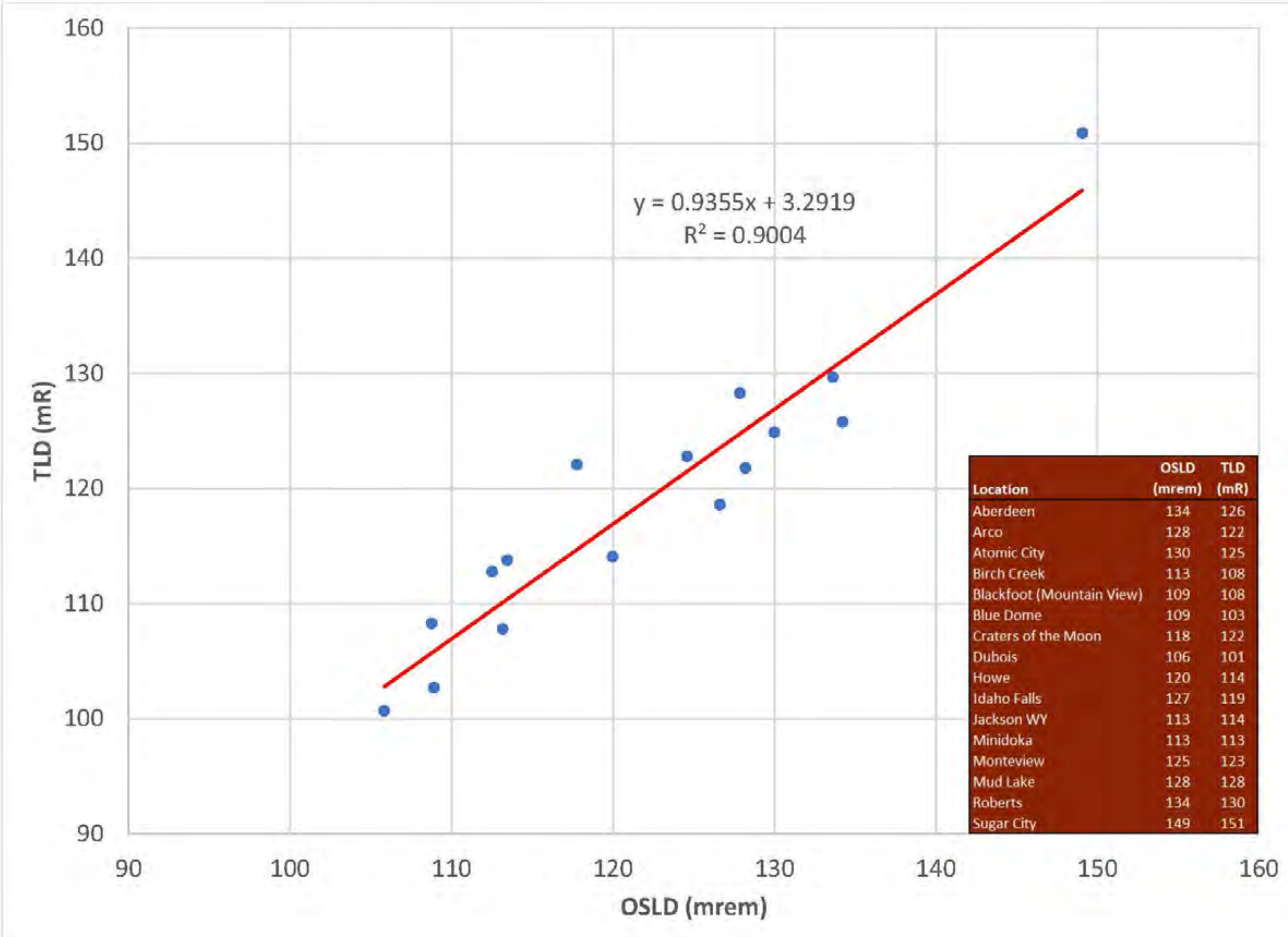
The 2021 ESER TLD data are shown in Figure 7-4. The TLD results demonstrate a strong linear relationship ($r^2 = 0.90$) with the 2021 ESER OSLD results, indicating a good correlation as observed in Figure 7-4. The two dosimetry systems do not measure the same radiological quantity. The TLD system is calibrated to measure the quantity and exposure expressed in units of Roentgen. The OSLD system is calibrated to measure the quantity, ambient dose equivalent (H*[10]), expressed in units of rem. However, they appear to respond in a similar fashion to penetrating radiation fields in the field.

Table 7-7 summarizes the calculated effective dose a hypothetical individual would receive on the Snake River Plain from various natural background radiation sources (e.g., cosmic and terrestrial). This table includes the latest recommendations of the National Council of Radiation Protection and Measurements (NCRP) in Ionizing Radiation Exposure of the Population of the United States (NCRP 2009).

The terrestrial natural background radiation exposure estimate is based on concentrations of naturally occurring radionuclides found in soil samples collected from 1976–1993, as summarized by Jessmore, Lopez, and Haney (1994). Concentrations of naturally occurring radionuclides in soil do not change significantly over this relatively short period. Data indicate the average concentrations of uranium-238 (^{238}U), thorium-232 (^{232}Th), and potassium-40 (^{40}K) were 1.5, 1.3, and 19 pCi/g, respectively. The calculated external dose equivalents received by a member of the public from ^{238}U plus decay products, ^{232}Th plus decay products, and ^{40}K based on the above-average area soil concentrations were 21, 28, and 27 mrem/yr, respectively, for a total of 76 mrem/yr (Mitchell et al. 1997). Because snow cover can reduce the effective dose that Idaho residents receive from soil, a correction factor must be made each year to the estimated 76 mrem/yr. In 2021, this resulted in a reduction in the effective dose from soil to a value of 73 mrem.

The cosmic component varies primarily with increasing altitude. Using Figure 3.4 in NCRP Report No. 160 (NCRP 2009), it was estimated that the annual cosmic radiation dose near the INL Site is approximately 57 mrem. Cosmic radiation may vary slightly because of solar cycle fluctuations and other factors.

Based on this information, the sum of the terrestrial and cosmic components of external radiation dose to a person residing on the Snake River Plain in 2021 was estimated to be 130 mrem/yr. This is similar to the 121 mrem/yr measured at offsite locations using OSLD data. Measured values are typically within normal variability of the calculated background doses. Therefore, it is unlikely that INL Site operations contributed to background radiation levels at distant locations in 2021.



Location	OSLD (mrem)	TLD (mR)
Aberdeen	134	126
Arco	128	122
Atomic City	130	125
Birch Creek	113	108
Blackfoot (Mountain View)	109	108
Blue Dome	109	103
Craters of the Moon	118	122
Dubois	106	101
Howe	120	114
Idaho Falls	127	119
Jackson WY	113	114
Minidoka	113	113
Monteview	125	123
Mud Lake	128	128
Roberts	134	130
Sugar City	149	151

Figure 7-4. Comparison of TLD versus OSLD results measured by ESER in 2021.

Table 7-7. Calculated effective dose from natural background sources (2021).

SOURCE OF RADIATION DOSE	TOTAL AVERAGE ANNUAL DOSE	
	CALCULATED (mrem)	MEASURED[a] (mrem)
EXTERNAL IRRADIATION		
Terrestrial	73[b]	NA[c]
Cosmic	57[d]	NA
Subtotal	130	121
INTERNAL IRRADIATION (PRIMARILY INGESTION)[e]		
Potassium-40	15	NM[f]
Thorium-232 and uranium-238	13	NM
Others (carbon-14 and rubidium-87)	1	NM
INTERNAL IRRADIATION (PRIMARILY INHALATION)[d]		
Radon-222 (radon) and its short-lived decay products	212	NM
Radon-220 (thoron) and its short-lived decay products	16	NM
TOTAL	**387**	**NM**

a. Calculated from the average annual external exposure at all offsite locations measured using OSLDs (see Table 7-5).
b. Estimated using concentrations of naturally occurring radionuclide concentrations in soils in the Snake River Plain.
c. NA indicates terrestrial and cosmic radiation parameters were not measured individually but were measured collectively using dosimeters.
d. Estimated from Figure 3.4 of NCRP Report No. 160.
e. Values reported for average American adult in Table 3.14 of NCRP Report No. 160.
f. NM = not measured.

The component of background dose that varies the most is inhaled radionuclides. According to the NCRP, the major contributor of effective dose received by a member of the public from ^{238}U plus decay products is short-lived decay products of radon (NCRP 2009). The amount of radon in buildings and groundwater depends, in part, upon the natural radionuclide content of soil and rock in the area. The amount of radon also varies among buildings of a given geographic area depending upon the materials each contains, the amount of ventilation and air movement, and other factors. The United States average of 212 mrem/yr was used in Table 7-7 for this component of the total background dose. The NCRP also reports that the average dose received from thoron, a decay product of ^{232}Th, is 16 mrem.

People also receive an internal dose from ingestion of ^{40}K and other naturally occurring radionuclides in environmental media. The average ingestion dose to an adult living in the United States was reported in NCRP Report No. 160 to be 29 mrem/yr (NCRP 2009).

With all these contributions, the total background dose to an average individual living in southeast Idaho was estimated to be approximately 387 mrem/yr identified in Table 7-7. This value was used to calculate background radiation dose to the population living within 50 mi of INL Site facilities shown in Table 8-6.

7.5 Waste Management Surveillance Sampling

For compliance with DOE O 435.1, "Radioactive Waste Management" (2011), vegetation and soil are sampled at the Radioactive Waste Management Complex (RWMC), and direct surface radiation is measured at RWMC and the Idaho Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Disposal Facility (ICDF).

7.5.1 Vegetation Sampling at the Radioactive Waste Management Complex

At RWMC, vegetation was historically collected from four major areas identified in Figure 7-5, and a control location approximately seven miles south of the Subsurface Disposal Area (SDA) at the base of Big Southern Butte. Russian thistle was collected in even-numbered years. Crested wheatgrass and rabbitbrush were collected in odd-numbered years. In 2018, the ICP Core decided, using guidance from DOE-HDBK-1216-2015 (DOE 2015), to discontinue further biota sampling activities. This decision was based on an evaluation of biota sample data trends, which concluded that vegetation is not considered a major mode of radionuclide transport through the environment surrounding the SDA at RWMC.

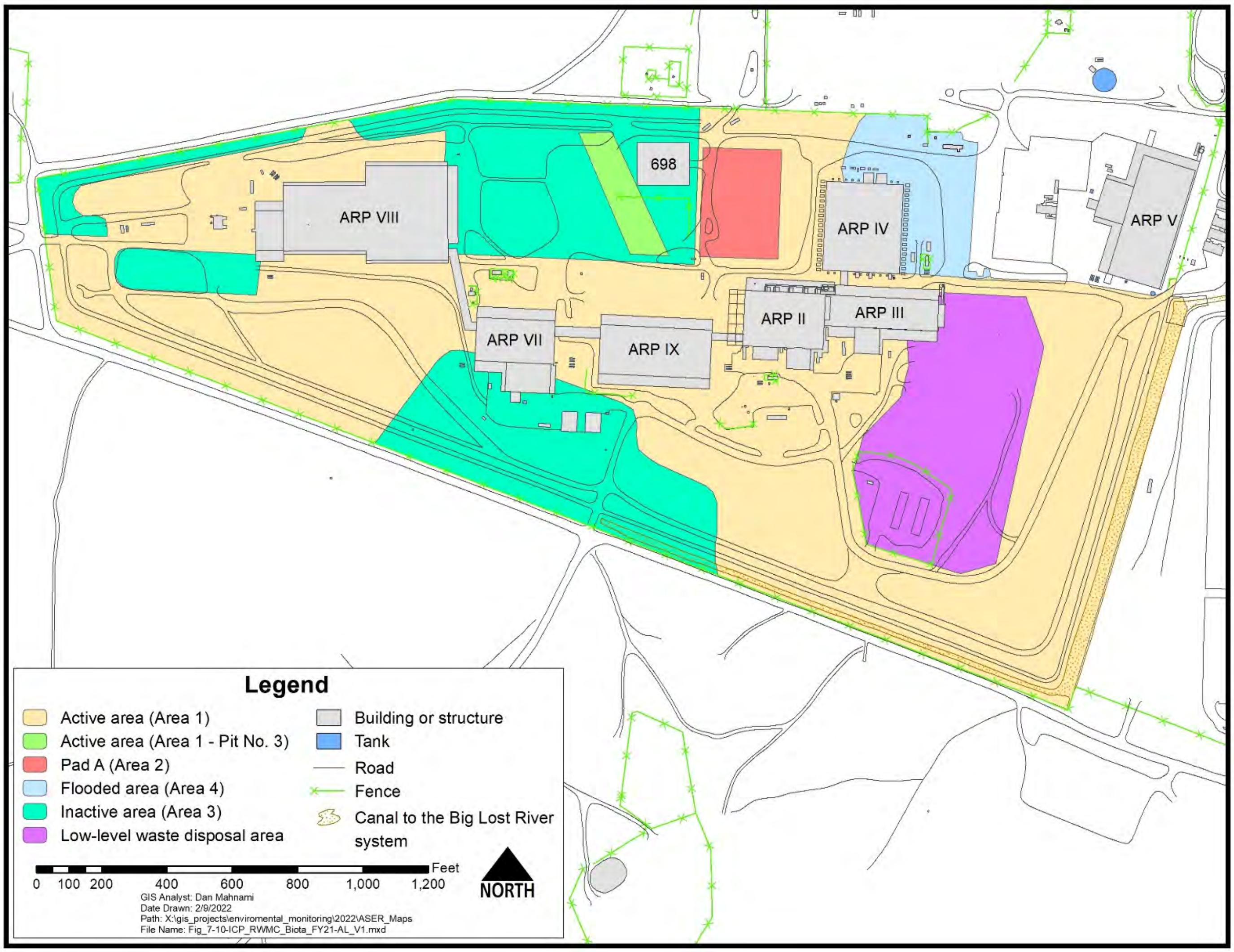


Figure 7-5. Historical vegetation sampling areas at the RWMC.

7.5.2 Soil Sampling at the Radioactive Waste Management Complex

Waste management surveillance soil sampling has been conducted triennially at the SDA at RWMC since 1994. The last triennial soil sampling event was conducted in 2015. In 2017, the results of soil sampling from 1994–2015 were reviewed for each constituent of interest and compared to their respective environmental concentration guide; these guidelines were established in 1986 in *Development of Criteria for the Release of Idaho National Engineering Laboratory Sites Following Decontamination and Decommissioning* (EGG-2400 1986). All results were well below their respective environmental concentration guide.

The footprint at RWMC has changed drastically since this soil sampling began. The area where soil sampling has been performed at the SDA at RWMC is now a heavily disturbed area. Structures cover a majority of the area and fill has been brought in where subsidence has occurred. Gravel has been applied for road base. The DOE Handbook, *Environmental Radiological Effluent Monitoring and Environmental Surveillance* (DOE 2015) states, "Except where the purpose of soil sampling dictates otherwise, every effort should be made to avoid tilled or disturbed areas and locations near buildings when selecting soil sampling locations."

In 2017, a decision was made to discontinue soil monitoring based on several factors: (1) the limited availability of undisturbed soils; and (2) sufficient historical data being collected previously to satisfy the characterization objectives; and (3) the conclusion that planned activities in the SDA do not have the potential to change surface soil contaminant concentrations prior to installation of the surface cover over the entire SDA under the CERCLA program.

7.5.3 Surface Radiation Survey at the Radioactive Waste Management Complex and the Idaho CERCLA Disposal Facility

Surface radiation surveys are performed to characterize gamma radiation levels near the ground surface at waste management facilities. Comparing the data from these surveys year to year helps to determine whether radiological trends exist in specific areas. This type of survey is conducted at the SDA at RWMC and at the ICDF to complement air sampling. The SDA contains legacy waste, of which some is in the process of being removed for repackaging and shipment to an off-Site disposal facility. The ICDF consists of a landfill and evaporation ponds, which serve as the consolidation points for CERCLA-generated waste within the INL Site boundaries.

A vehicle-mounted Global Positioning Radiometric Scanner (GPRS) system (Radiation Solutions, Inc., Model RS-701) was used to conduct this year's soil surface radiation (gross gamma) surveys to detect trends in measured levels of surface radiation. The RS-701 system consists of two sodium iodide (NaI) scintillator gamma detectors, housed in two separate metal cabinets, and a Trimble global positioning system receiver, mounted on a rack attached to the front bumper of a four-wheel drive vehicle. The detectors are approximately 24 in. above ground. The detectors and the global positioning system receiver are connected to a system controller and to a laptop computer located inside the cabin of the field vehicle. The GPRS system software displays the gross gamma counts and spectral second-by-second data from the detectors, along with the corresponding latitude and longitude of the system in real-time on the laptop screen. The laptop computer also stores the data files collected for each radiometric survey. During radiometric surveys, the field vehicle is driven 5 mph (7 ft/second), and the GPRS system collects latitude, longitude, and gamma counts per second from both detectors. Data files generated during the radiological surveys are saved and transferred to the ICP Core spatial analysis laboratory for mapping after the surveys are completed. The maps indicate areas where survey counts were at or near background levels and areas where survey counts are above background levels. No radiological trends were identified in 2021 in comparison to previous years.

Figure 7-6 shows a map of the area that was surveyed at RWMC in 2021. Some areas that had been surveyed in previous years could not be accessed due to construction activities and subsidence restrictions. Although readings vary slightly from year to year, the 2021 results are comparable to measurements in previous years. Most of the active low-level waste pit was covered during 2009, and, as a result of the reduced shine, elevated measurements from the buried waste in pits and trenches are more visible. Average background values near or around areas that were radiometrically scanned were generally at or below 4,000 counts per second. Most of the 2021 RWMC gross gamma radiation measurements were at or near background levels. The 2021 maximum gross gamma radiation measurement on the SDA was 27,874 counts per second, as compared to the maximum 2020 measurement of 34,716 counts per second. In previous years, maximum readings were measured in a small area at the western end of the soil vault row (SVR)-7, but measurements were lower for this location in 2021. The maximum readings in 2021 were observed directly west of Accelerated Retrieval Project VIII (WMF-1621). This is likely attributed to waste operations and waste transport vehicles located on the concrete pad during the time of the survey.

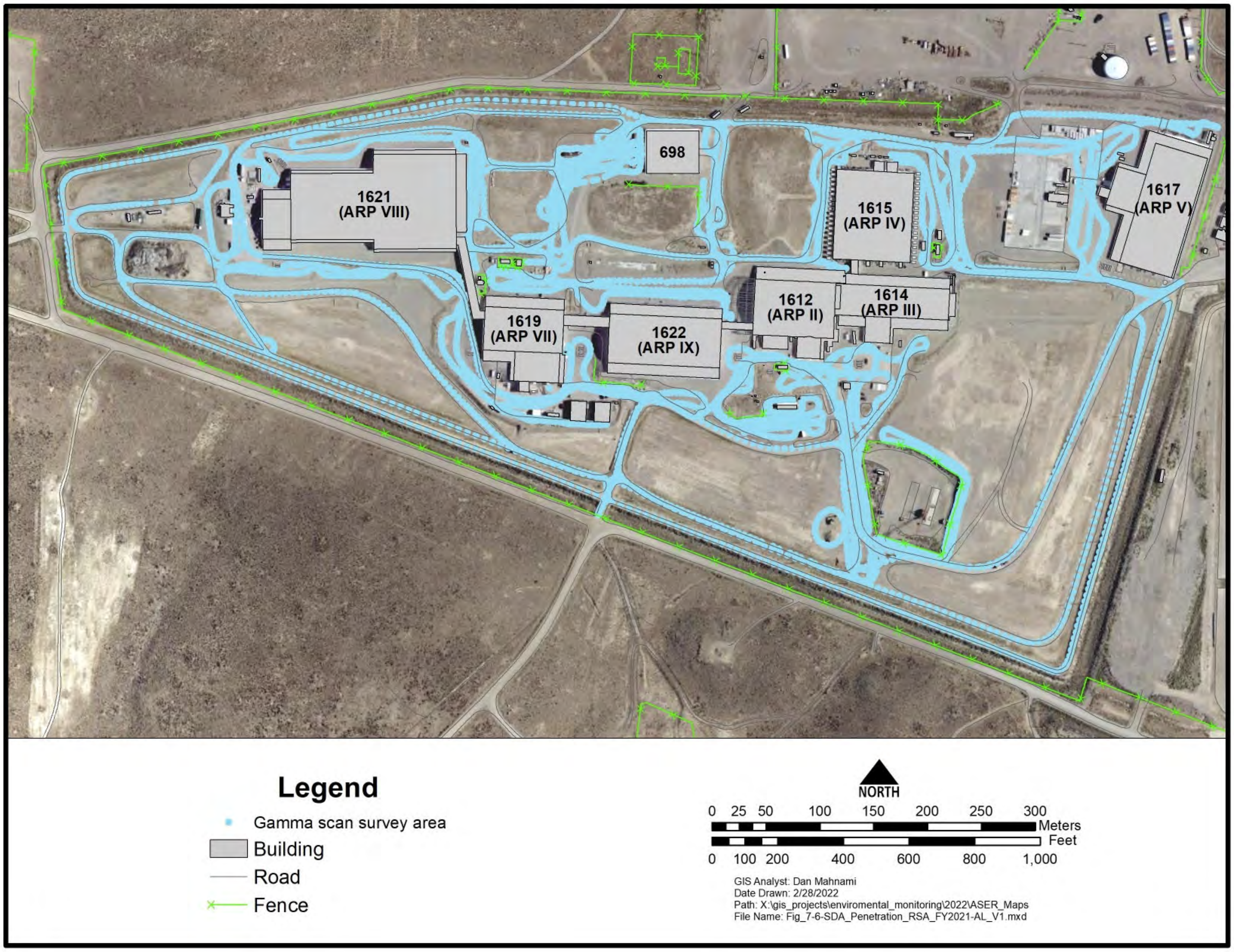


Figure 7-6. SDA surface radiation survey area (2021).

The area that was surveyed at the ICDF is shown in Figure 7-7. The readings at the ICDF vary from year to year. These variations are related to the disposal and burial of new CERCLA remediation wastes in accordance with the ICDF waste placement plan (EDF-ER-286 2017). In 2021, the readings were either at background levels or slightly above background levels (approximately 3,000 counts per second), which is expected until the facility is closed and capped.

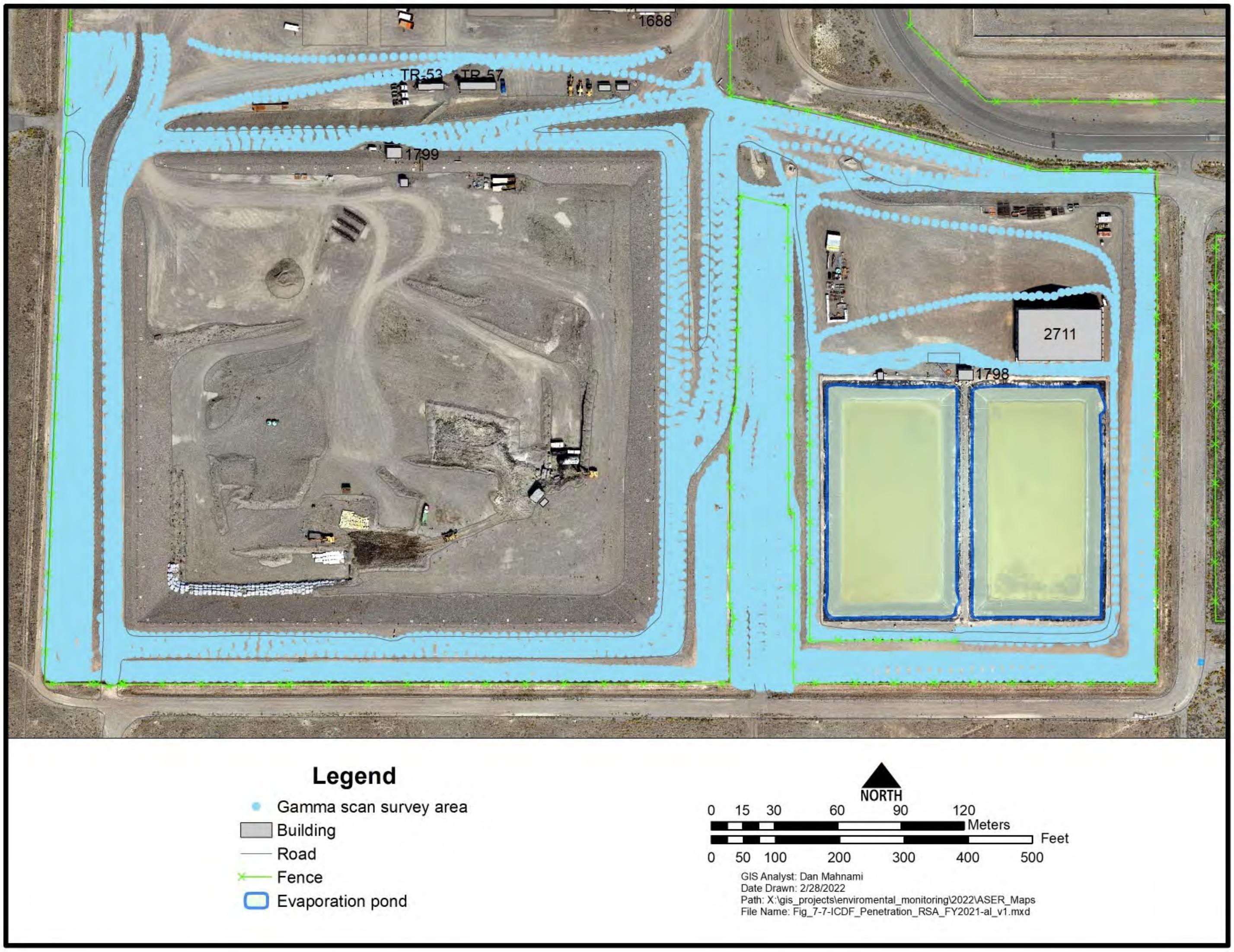


Figure 7-7. ICDF surface radiation survey area (2021).

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