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# 2021
# SITE ENVIRONMENTAL REPORT
## Idaho National Laboratory

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**Prepared by**

Battelle Energy Alliance
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*Anderson's Larkspur*

# To Our Readers

The Idaho National Laboratory (INL) Site Environmental Report for Calendar Year 2021 is an overview of environmental activities conducted on and in the vicinity of the INL Site from January 1 through December 31, 2021. This report includes:

- Effluent monitoring and environmental surveillance of air, water, soil, vegetation, biota, and agricultural products for radioactivity. The results are compared with historical data, background measurements, and/or applicable standards and requirements in order to verify that the INL Site does not adversely impact the environment or the health of humans or biota.
- A summary of environmental management systems in place to protect air, water, land, and other natural and cultural resources potentially impacted by INL Site operations.
- Ecological and other scientific research conducted on the INL Site that may be of interest to the reader.
- The report addresses three general levels of reader interest:
- The first level is a brief summary with a take-home conclusion. This is presented in the chapter highlights text box at the beginning of each chapter. There are no tables, figures, or graphs in the highlights. This section is intended to highlight general findings for an audience with a limited scientific background.
- The second level is a more in-depth discussion with figures, summary tables, and summary graphs accompanying the text. The chapters of the annual report represent this level, which requires some familiarity with scientific data and graphs. A person with some scientific background can read and understand this report after reading the section entitled, 'Helpful Information.'
- The third level includes links to supplemental and technical reports and websites that support the annual report. This level is directed toward scientists who would like to see original data and more in-depth discussions of the methods used and results.

The links to these reports may be found in the Publications tab of the webpage at https://idahoeser.inl.gov/publications.html.

The Environmental Surveillance, Education, and Research Program (ESER) is responsible for contributing to and producing the INL Annual Site Environmental Report. Environmental monitoring within the INL Site boundaries is primarily the responsibility of the INL and Idaho Cleanup Project (ICP) Core contractors. The ESER Program focuses on surveillance off the INL Site. On October 1, 2021, the ESER Program was transitioned from Veolia Nuclear Solutions - Federal Services to BEA, who manages the INL. Sampling activities were conducted by Veolia Nuclear Solutions Federal Services during the first through third quarters of 2021; therefore, the data will be represented by the ESER contractor. The sampling activities conducted during the fourth quarter of 2021 were performed under BEA, and therefore, that data will be represented by the INL contractor.

Other major contributors to the annual INL Site Environmental Report include the INL contractor (BEA); ICP Core contractor (Fluor Idaho, LLC); U.S. Department of Energy–Idaho Operations Office (DOE-ID); NOAA; and USGS. Links to their websites and the Environmental Surveillance, Education, and Research Program website are:

- INL (https://www.inl.gov/)
- ICP Core (https://fluor-idaho.com/default.aspx#about)
- DOE-ID Office (https://www.id.energy.gov/)

- Field Research Division of National Oceanic and Atmospheric Administration's Air Resources Laboratory (https://www.noaa.inl.gov)
- U.S. Geological Survey (https://www.usgs.gov/centers/idaho-water-science-center)
- Environmental Surveillance, Education, and Research Program (https://idahoeser.inl.gov/).

*Elk grazing on ridgeline*

# Executive Summary

## Introduction

In operation since 1949, the Idaho National Laboratory (INL) Site is a U.S. Department of Energy (DOE) reservation located in the southeastern Idaho desert, approximately 25 miles west of Idaho Falls (Figure ES-1). At 890 square miles (569,135 acres), the INL Site is roughly 85% the size of Rhode Island. It was established in 1949 as the National Reactor Testing Station, and for many years it was the site of the largest concentration of nuclear reactors in the world. Fifty-two nuclear reactors were built, including the Experimental Breeder Reactor-I, which in 1951 produced the first usable amounts of electricity generated by nuclear power. Researchers pioneered many of the world's first nuclear reactor prototypes and advanced safety systems at the INL Site. During the 1970s, the laboratory's mission broadened into other areas, such as biotechnology, energy and materials research, and conservation and renewable energy.


*Figure ES-1. Regional location of the INL Site.*

Today, INL is a science-based, applied engineering national laboratory dedicated to supporting DOE's nuclear and energy research, science, and national defense missions.

INL's mission is to discover, demonstrate, and secure innovative nuclear energy solutions and other clean energy options and critical infrastructure with a vision to change the world's energy future and secure the nation's critical infrastructure.

In order to clear the way for the facilities required for the new nuclear energy research mission, the Idaho Cleanup Project (ICP) Core has been charged with the environmental cleanup of the legacy wastes generated from World War II-era conventional weapons testing, government-owned reactors, and spent fuel reprocessing. The overarching aim of the project is to reduce risks to workers and production facilities, the public, and the environment and to protect the Snake River Plain Aquifer.

## Purpose of the INL Site Environmental Report

The INL Site's operations, as well as the ongoing cleanup mission, necessarily involve a commitment to environmental stewardship and full compliance with environmental protection laws. As part of this commitment, the INL Site Environmental Report is prepared annually to inform the public, regulators, stakeholders, and other interested parties of the INL Site's environmental performance during the year. This report is published for DOE-ID in compliance with DOE O 231.1B, "Environment, Safety and Health Reporting." Its purpose is to:

- Present the INL Site, mission, and programs
- Report compliance status with applicable federal, state, and local regulations
- Describe the INL Site environmental programs and activities
- Summarize results of environmental monitoring
- Discuss potential radiation doses to the public residing in the vicinity of the INL Site
- Report on ecological monitoring and research conducted by contractors and affiliated agencies and by independent researchers through the Idaho National Environmental Research Park
- Describe quality assurance methods used to ensure confidence in monitoring data
- Provide supplemental technical data and reports that support the INL Site Environmental Report (https://idahoeser.inl.gov/publications.html).

## Major INL Site Programs and Facilities

There are two primary programs at the INL Site: INL and the ICP Core. The prime contractors at the INL Site in 2021 were: Battelle Energy Alliance (BEA), the management and operations contractor for INL, and Fluor Idaho, which managed ongoing cleanup operations under the ICP Core and operated the Advanced Mixed Waste Treatment Project (AMWTP).

The INL Site consists of several primary facilities situated on an expanse of otherwise undeveloped terrain. Buildings and structures at the INL Site are clustered within these facilities, which are typically less than a few square miles in size and separated from each other by miles of undeveloped land. In addition, DOE-ID owns or leases laboratories and administrative offices in the city of Idaho Falls, some 25 miles east of the INL Site border. About 30% of employees work in administrative, scientific support, and non-nuclear laboratory programs at offices in Idaho Falls.

The major facilities at the INL Site are the Advanced Test Reactor (ATR) Complex; Central Facilities Area (CFA); Critical Infrastructure Test Range Complex (CITRC); Idaho Nuclear Technology and Engineering Center (INTEC); Materials and Fuels Complex (MFC); Naval Reactors Facility (NRF); Radioactive Waste Management Complex (RWMC); and Test Area North (TAN), which includes the Specific Manufacturing Capability (SMC). The Research and Education Campus (REC) is located in Idaho Falls. The locations of major facilities are shown in Figure ES-2, and their missions are outlined in Table ES-1.

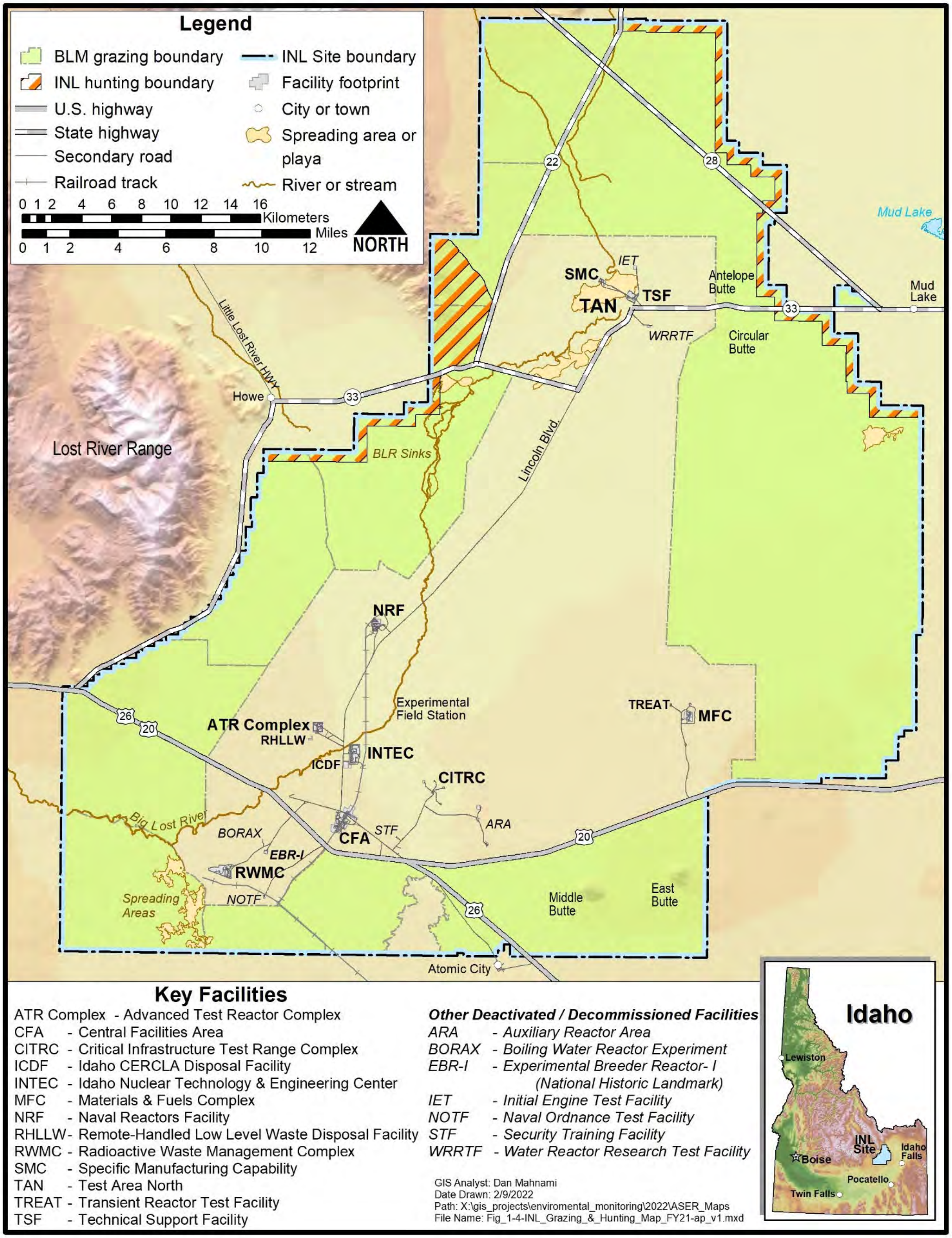


***Figure ES-2. INL Site facilities.***

**Table ES-1. Major INL Site areas and missions.**

| MAJOR INL SITE AREA[a] | OPERATED BY | MISSION |
|---|---|---|
| Advanced Test Reactor Complex | INL | Research and development of nuclear reactor technologies. Home of the ATR, a DOE Nuclear Science User Facility and the world's most advanced nuclear test reactor. The ATR provides unique irradiation capabilities for nuclear technology research and development. |
| Central Facilities Area | INL | INL support for the operation of other INL Site facilities and management responsibility for the balance of the INL outside of the facility boundaries. |
| Critical Infrastructure Test Range Complex | INL | Supports National and Homeland Security missions of the laboratory, including program and project testing (i.e., critical infrastructure resilience and nonproliferation testing and demonstration). |
| Idaho Nuclear Technology and Engineering Center | ICP Core | Dry and wet storage of spent nuclear fuel; management of high-level waste calcine and sodium-bearing liquid waste; and operation of the Idaho Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Disposal Facility including a landfill, evaporation ponds, and a staging and treatment facility. |
| Materials and Fuels Complex | INL | Research and development of nuclear fuels. Pyro-processing, which uses electricity to separate waste products in the recycling of nuclear fuel, is also researched here. Nuclear batteries for use on the nation's space missions are made at MFC. |
| Radioactive Waste Management Complex | ICP Core | Environmental remediation and waste treatment, storage, and disposal for wastes generated at the INL Site and other DOE sites. The AMWTP characterizes, treats, and packages transuranic waste for shipment out of Idaho to permanent disposal facilities. Location of the Integrated Waste Treatment Unit (IWTU), a first-of-a-kind, 53,000-square-foot facility, that will treat 900,000 gallons of liquid radioactive and hazardous waste that has been stored in underground storage tanks. |
| Research and Education Campus | INL | Located in Idaho Falls, Idaho, REC is home to DOE's Radiological and Environmental Sciences Laboratory (RESL), INL administration, the INL Research Center (IRC), the Center for Advanced Energy Studies (CAES), and other energy and security research programs. Research is conducted at IRC in robotics, genetics, biology, chemistry, metallurgy, computational science, and hydropower. CAES is a research and education partnership between Boise State University, INL, Idaho State University, and University of Idaho to conduct energy research and address the looming nuclear energy work-force shortage. |
| Test Area North/Specific Manufacturing Capability | INL | Several historic nuclear research and development projects were conducted at TAN. Major cleanup and demolition of the facility was completed in 2008, and the current mission is the manufacture of tank armor for the U.S. Army's battle tanks at the SMC for the U.S. Department of Defense (DoD). |

a. NRF is also located on the INL Site. It is operated for Naval Reactors by Fluor Marine Propulsion, LLC. The Naval Nuclear Propulsion Program is exempt from DOE requirements and is therefore not addressed in this report.

## Environmental Protection Programs

Directives, orders, guides, and manuals are DOE's primary means of establishing policies, requirements, responsibilities, and procedures for DOE offices and contractors. Among these are a series of orders directing each DOE site to implement sound stewardship practices that are protective of the public and the environment. These orders require the implementation of an environmental management system (EMS), a Site Sustainability Plan, a radioactive waste management program, and programs addressing radiation protection of the public and the environment. BEA and Fluor Idaho have each established and implemented an EMS, as well as contributing to the INL Site Sustainability Plan, as required by DOE and executive orders. Each EMS integrates environmental protection, environmental compliance, pollution prevention, and waste minimization into work planning and execution throughout all work areas. The INL Site

Sustainability Plan contains strategies and activities that will lead to continual greenhouse gas reductions, as well as energy, water, and transportation fuels efficiency at the INL Site. Plan requirements are integrated into each INL Site contractor's Integrated Safety Management System (ISMS) and EMS.

## Environmental Restoration

Environmental restoration at the INL Site is conducted under the Federal Facility Agreement and Consent Order (FFA/CO) among DOE, the state of Idaho, and the U.S. Environmental Protection Agency (EPA). The FFA/CO governs the INL Site's environmental remediation activities. It specifies actions that must be completed to safely clean-up sites at the INL Site in compliance with the CERCLA, as well as the corrective action requirements of the Resource Conservation and Recovery Act (RCRA). The INL Site is divided into ten Waste Area Groups (WAGs) as a result of the FFA/CO, and each WAG is divided into smaller cleanup areas called operable units. Since the FFA/CO was signed in 1991, the INL Site has cleaned up sites containing asbestos, acids and bases, radionuclides, unexploded ordnance and explosive residues, polychlorinated biphenyls, heavy metals, and other hazardous materials.

Comprehensive remedial investigation/feasibility studies have been conducted at all WAGs and closeout activities have been completed at six WAGs. In 2021, all institutional controls and operational and maintenance requirements were maintained, and active remediation continued on WAGs 1, 3, 7, and 10.

## Radiation Dose to the Public and Biota from INL Site Releases

Humans, plants, and animals potentially receive radiation doses from various INL Site operations. DOE sets dose limits for the public and biota to ensure that exposure to radiation from site operations are not a health concern. Potential radiological doses to the public from INL Site operations were calculated to determine compliance with pertinent regulations and limits (Table ES-2). The calculated dose to the maximally exposed individual in 2021 from the air pathway was 0.067 mrem (0.67 µSv), well below the 10-mrem standard established by the Clean Air Act. The maximally exposed individual is a hypothetical member of the public who could receive the maximum possible dose from INL Site releases as determined by the air dispersion model. This person is assumed to live at a location east of INL's east entrance and south of Highway 20. For comparison, the dose from natural background radiation was estimated in 2021 to be 387 mrem (3,870 µSv) to an individual living on the Snake River Plain.

The maximum potential population dose to the approximately 353,435 people residing within an 80 km (50 mi) radius of any INL Site facility was calculated as 0.028 person-rem (0.00028 person-Sv), below that expected from exposure to background radiation (136,779 person-rem or 1,368 person-Sv). The 50 mi population dose calculated for 2021 is lower than that calculated for 2020 (0.054 person-rem or 0.00054 person-Sv).

The maximum potential individual dose from consuming waterfowl contaminated at the INL Site, based on the highest concentrations of radionuclides measured in edible tissue of samples collected near the ATR Complex ponds, was estimated to be 0.002 mrem (0.02 µSv). In 2021, none of the game samples collected (e.g., eight elk and two mule deer) had a detectable concentration of cesium-137 ($^{137}Cs$) or other human-made radionuclides. When the dose estimated for the air pathway was summed with the dose from consuming contaminated waterfowl, assuming that the waterfowl is eaten by the same hypothetical individual, the representative person off the INL Site could potentially receive a total dose of 0.069 mrem (0.69 µSv) in 2021. This is 0.069% of the DOE health-based dose limit of 100 mrem/yr (1 mSv/yr) from all pathways for the INL Site.

***Table ES-2. Contribution to estimated annual dose from INL Site facilities by pathway (2021).***

| PATHWAY | ANNUAL DOSE TO MAXIMALLY EXPOSED INDIVIDUAL (mrem) | ANNUAL DOSE TO MAXIMALLY EXPOSED INDIVIDUAL (µSv) | PERCENT OF DOE 100 MREM/YR LIMIT[a] | ESTIMATED POPULATION DOSE (PERSON-mrem) | ESTIMATED POPULATION DOSE (PERSON-Sv) | POPULATION WITHIN 80 KM | ESTIMATED BACKGROUND RADIATION POPULATION DOSE (PERSON-rem)[b] |
|---|---|---|---|---|---|---|---|
| Air | 0.067 | 0.67 | 0.067 | 0.028 | 0.00028 | 353,435 | 136,779 |
| Waterfowl | 0.002 | 0.02 | 0.002 | NA[c] | NA | NA | NA |
| Big game animals | 0.000 | 0.00 | NA | NA | NA | NA | NA |
| **Total pathways** | **0.069** | **0.69** | **0.069** | **0.028** | **0.00028** | **NA** | **NA** |

a. The DOE public dose limit from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose is 100 mrem/yr (1 mSv/yr) total effective dose equivalent. It does not include dose from background radiation.

b. The individual background dose was estimated to be 387 mrem or 0.387 rem in 2021, as shown previously in Table 7-8. The background population dose is calculated by multiplying the individual background dose by the population within 80 km (50 mi) of the INL Site.

c. NA = Not applicable.

Tritium has been previously detected in two U.S. Geological Survey (USGS) monitoring wells located on the INL Site along the southern boundary. A hypothetical individual ingesting the maximum concentration of tritium (4,280 pCi/L) via drinking water from these wells would receive a dose of approximately 0.2 mrem (0.002 mSv) in one year. This is an unrealistic pathway to humans because there are no drinking water wells located along the southern boundary of the INL Site. The maximum contaminant level established by EPA for tritium (20,000 pCi/L) corresponds to a dose of approximately 4 mrem (0.04 mSv [40 µSv/yr]).

A dose to a maximally exposed individual located in Idaho Falls near the DOE RESL and the IRC, within the REC, was calculated for compliance with the Clean Air Act. For 2021, the dose was conservatively estimated to be 0.062 mrem (0.62 µSv), which is less than 0.1% of the 10-mrem/yr federal standard.

Doses were also evaluated for nonhuman biota at the INL Site using a graded approach. Based on the conservative screening calculations, there is no evidence that INL Site-related radioactivity in soil or water is harming populations of plants or animals.

## Environmental Compliance

One measure of the achievement of the environmental programs at the INL Site is compliance with applicable environmental regulations, which have been established to protect human health and the environment. INL Site compliance with major federal regulations is presented in Table ES-3.

*Table ES-3. Major federal regulations established for protection of human health and the environment.*

| REGULATOR/ REGULATION | REGULATORY PROGRAM DESCRIPTION | COMPLIANCE STATUS | REPORT SECTIONS |
|---|---|---|---|
| EPA/40 CFR 61 | The Clean Air Act is the basis for national air pollution control. Emissions of radioactive hazardous air pollutants are regulated by EPA, via the National Emission Standards for Hazardous Air Pollutant (40 CFR 61, Subpart H). | The INL Site is in compliance, as reported in *National Emission Standards for Hazardous Air Pollutants – Calendar Year 2021*. | 2.2.1<br>4.2<br>4.3<br>8.2.1 |
| DOE/Order 458.1, Change 3 | The order establishes requirements to protect the public and the environment against undue risk from radiation associated with radiological activities conducted under the control of DOE pursuant to the Atomic Energy Act of 1954, as amended. The Order requires preparation of an Environmental Radiation Protection Plan that outlines the means by which facilities monitor their impacts on the public and the environment. | The INL Site maintains and implements several plans and programs for monitoring the management of facilities, wastes, effluents, and emissions to determine if operations present risk to the public, workers, or the environment. Environmental monitoring plans are well documented, and the results are published in the annual INL Site Environmental Report. The INL Site maintains compliance with DOE O 458.1. | Chapter 4<br>Chapter 5<br>Chapter 6<br>Chapter 7<br>Chapter 8 |
| EPA/40 CFR 300 | The CERCLA provides the regulatory framework for remediation of releases of hazardous substances and remediation (including decontamination and decommissioning) of inactive hazardous waste disposal sites. | Nuclear research and other operations at the INL Site left behind contaminants that pose a potential risk to human health and the environment. DOE-ID entered into a tri-party agreement in 1991, the FFA/CO, the EPA, and the state of Idaho. INL Site remediation is conducted by the ICP Core, which operates in compliance with the governing regulatory framework. | 2.1 |
| EPA/40 CFR 109-140 | The Clean Water Act establishes goals to control pollutants discharged to U.S. surface waters. | The INL Site complies with two Clean Water Act permits as applicable or needed – the National Pollution Discharge Elimination System permits and Storm Water Discharge Permits for construction activity. | 2.3.1 |
| EPA/40 CFR 141-143 | The Safe Drinking Water Act establishes primary standards for public water supplies to ensure it is safe for consumption. | The INL Site routinely sampled and analyzed 10 drinking water systems in 2021 as required by the state of Idaho and the EPA. The Site maintains compliance with the Safe Drinking Water Act. | 2.3.2<br>6.7 |
| EPA/40 CFR 239-282 | The Resource Conservation and Recovery Act established regulatory standards for generation, transportation, storage, treatment, and disposal of hazardous waste. | The Idaho Department of Environmental Quality (DEQ) conducted a Resource Conservation and Recovery Act inspections of the INL Site in June 2021. There were no violations cited. The INL Site operates in compliance with the governing EPA and State hazardous waste regulations. | 2.1.2 |

## Environmental Monitoring of Air

Airborne releases of radionuclides from INL Site operations are reported annually in a document prepared in accordance with the Code of Federal Regulations (CFR), Title 40, “Protection of the Environment,” Part 61, “National Emission Standards for Hazardous Air Pollutants,” Subpart H, “National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities.” An estimated total of 1,076 curies ($3.98 \times 10^{13}$ Bq) of radioactivity, primarily in the form of short-lived noble gas isotopes, were released as airborne effluents in 2021. These airborne releases of radionuclides are reported to comply with regulatory requirements and are considered in the design and conduct of INL Site environmental surveillance activities.

The INL Site environmental surveillance programs, conducted by the INL, ICP Core, and ESER contractors, emphasize measurement of airborne radionuclides, because air transport is considered the major potential pathway from INL Site releases to human receptors. During 2021, the INL contractor monitored ambient air at 16 locations on the INL Site and at six locations off the INL Site. The ICP Core contractor focused on ambient air monitoring of waste management facilities, namely INTEC and RWMC. The ESER contractor monitored ambient air at three locations on the INL Site, at seven locations bounding the INL Site, and at six locations distant from the INL Site.

Air particulate samples were collected weekly by the ESER and INL contractors and biweekly by the ICP Core contractor. These samples were initially analyzed for gross alpha and gross beta activity. The particulate samples were then combined into monthly (ICP Core contractor), or quarterly (ESER and INL contractors) composite samples and were analyzed for gamma-emitting radionuclides, such as $^{137}$Cs. Particulate filters were also composited quarterly by the INL, ICP Core, and ESER contractors and analyzed for specific alpha- and beta-emitting radionuclides, specifically strontium-90 ($^{90}$Sr), plutonium-238 ($^{238}$Pu), plutonium-239/240 ($^{239/240}$Pu), and americium-241 ($^{241}$Am). Charcoal cartridges were also collected weekly by the ESER and INL contractors and analyzed for radioiodine.

All radionuclide concentrations in ambient air samples were below DOE radiation protection standards for air. In addition, gross alpha and gross beta concentrations were analyzed statistically, and there were no differences between samples collected on the INL Site, at the INL Site boundary, and off the INL Site. Trends in the data appear to be seasonal in nature and do not demonstrate any INL Site influence. This indicates that INL Site airborne effluents were not measurable in environmental air samples.

The INL contractor collected atmospheric moisture samples at two stations on and two stations off the INL Site in 2021. The ESER contractor collected atmospheric moisture at one location on and three locations off the INL Site. Precipitation was collected at the same four locations. The INL and ESER samples were all analyzed for tritium. The results were within measurements made historically and below DOE Derived Concentration Standards (DCS). Tritium measured in these samples is most likely the result of natural production in the atmosphere and remnants of nuclear weapons testing and not the result of INL Site effluent releases.

## Environmental Monitoring of Groundwater, Drinking, and Surface Water

The INL and ICP Core contractors monitor liquid effluents (wastewater), drinking water, groundwater, and storm water runoff at the INL Site, primarily for nonradioactive constituents, to comply with applicable laws and regulations, DOE orders, and other requirements. Wastewater is typically discharged from INL Site facilities to infiltration ponds or to evaporation ponds. Wastewater discharges occur at percolation ponds southwest of INTEC, a cold waste pond at the ATR Complex, and an industrial waste pond at MFC. DOE-ID complies with the state of Idaho groundwater quality, wastewater, and reuse rules for these effluents through reuse permits, which provide for monitoring of the wastewater and, in some instances, groundwater in the area. During 2021, liquid effluent and groundwater monitoring were conducted in support of reuse permit requirements. An annual site performance report for each permitted reuse facility was prepared and submitted to the DEQ. No permit limits were exceeded.

Additional liquid effluent monitoring was performed at the ATR Complex Cold Waste Pond, INTEC, and MFC Industrial Waste Pond to comply with environmental protection objectives of DOE orders. Most results were within historical measurements. All radioactive parameters were below health-based contaminant levels.

Drinking water parameters are regulated by the state of Idaho under authority of the Safe Drinking Water Act. The INL and ICP Core contractors monitored 10 drinking water systems at the INL Site in 2021. (The NRF contractor monitors an additional drinking water system, the results of which are reported separately by NRF.) Results were below limits for all relevant drinking water standards.

Surface water flows off the Subsurface Disposal Area (SDA) following periods of heavy precipitation or rapid snowmelt. During these times, water may be pumped out of the SDA retention basin into a drainage canal, potentially carrying radionuclides originating from radioactive waste or contaminated surface soil off the SDA. Surface water is collected when it is available. Americium-241, and $^{239/240}$Pu were detected in 2021 samples collected from the SDA Lift Station. The detected concentrations are well below standards established by DOE for radiation protection of the public and the environment.

## Environmental Monitoring of the Eastern Snake River Plain Aquifer

The eastern Snake River Plain Aquifer is perhaps the single-most important aquifer in Idaho. Composed of layered basalt lava flows and some sediment, it covers an area of approximately 27,972 $km^2$ (10,800 square miles). The highly productive aquifer has been declared a sole source aquifer by the EPA due to the nearly complete reliance on the aquifer for drinking water supplies in the area.

The USGS began to monitor the groundwater below the INL Site in 1949. Currently, the USGS performs groundwater monitoring, analyses, and studies of the eastern Snake River Plain Aquifer under and adjacent to the INL Site. These activities utilize an extensive network of strategically placed monitoring wells on and around the INL Site. In 2021, the USGS continued to monitor localized areas of chemical and radiochemical contamination beneath the INL Site produced by past waste disposal practices—in particular, the direct injection of wastewater into the aquifer at INTEC. Results for monitoring wells sampled within the plumes show nearly all wells had decreasing trends of tritium and $^{90}$Sr concentrations over time.

Volatile organic compounds (VOCs) are present in water from the eastern Snake River Plain Aquifer because of historical waste disposal practices at the INL Site. Several purgeable VOCs were detected by USGS in 29 groundwater monitoring wells and one perched well sampled at the INL Site in 2021. Most concentrations of the 61 analyzed compounds were either below the laboratory reporting levels or their respective primary contaminant standards. Trend test results for tetrachloromethane concentrations in water from the RWMC production well show a decreasing trend in that well since 2005. The more recent decreasing trend indicates that remediation efforts designed to reduce VOC movement to the aquifer are having a positive effect. Concentrations of tetrachloromethane from USGS-87 and USGS-120, south of RWMC, have had an increasing trend since 1987, but concentrations have decreased through time at USGS-88. Trichloroethylene was detected above the maximum contaminant level (MCL) in one well sampled by the USGS at TAN, which was expected as there is a known groundwater plume at this location.

Groundwater surveillance monitoring continued for the CERCLA WAGs on the INL Site in 2021. At TAN (WAG 1), groundwater monitoring continues to monitor the progress of remediation of the plume of trichloroethylene in addition to $^{90}$Sr, $^{137}$Cs, tritium, and uranium-234 ($^{234}$U). Remedial action consists of three components: in situ bioremediation; pump and treat; and monitored natural attenuation. Strontium-90 and $^{137}$Cs were present in wells in the source area at levels higher than those prior to starting in situ bioremediation. The elevated concentrations of these radionuclides are due to in situ bioremediation activities. The radionuclide concentrations will continue to be evaluated to determine if they will meet remedial action objectives by 2095.

Groundwater samples were collected from seven aquifer wells in the vicinity of ATR Complex (WAG 2) during 2021 and were analyzed for $^{90}$Sr, cobalt-60 ($^{60}$Co), tritium, and chromium. Chromium and tritium were the only analytes detected; however, neither of the concentrations were above their respective drinking water MCL established by the EPA.

Groundwater samples were collected from 17 aquifer monitoring wells at and near INTEC (WAG 3) during 2021 and analyzed for a suite of radionuclides and inorganic constituents. Strontium-90, technetium-99 ($^{99}$Tc), and nitrate exceeded their respective drinking water MCLs in one or more aquifer monitoring wells at or near INTEC, with $^{90}$Sr exceeding its MCL by the greatest margin in a well south (downgradient) of the former INTEC injection well. All other well locations showed $^{90}$Sr levels similar or slightly lower than those reported in previous samples.

Monitoring of groundwater at CFA (WAG 4) consists of CFA landfill monitoring as well as monitoring of a nitrate plume south of the CFA. Wells at the landfill were monitored in 2021 for metals (filtered), VOCs, and anions (e.g., nitrate, chloride, fluoride, sulfate). Iron and pH for CFA landfill monitoring exceeded a secondary MCL. Nitrate continued to exceed the EPA MCL in one well in the plume south of the CFA in 2021, and overall, the data show a downward trend since 2006.

Groundwater samples were collected from monitoring wells near the RWMC (WAG 7) in April/May 2021 and analyzed for radionuclides, inorganic constituents, and VOCs. No analytes were detected above the MCLs in samples collected from the aquifer in April/May 2021.

Wells at MFC (as part of WAG 9, and the MFC Industrial Waste Pond Reuse Permit) were sampled for radionuclides, metals, and other water quality parameters in the spring and fall of 2021. Overall, the results were not above the Primary Constituent Standard (PCS)/Secondary Constituent Standard (SCS) and show no evidence of impacts from MFC activities.

Wells along the southern INL Site boundary (as part of WAG 10) are sampled every two years. Groundwater samples were collected in 2021 and were analyzed for chloride, nitrate/nitrite as nitrogen, gross alpha, and gross beta. None of the analytes exceeded EPA MCLs or secondary maximum contaminant levels (SMCLs).

Groundwater is monitored at the Remote-Handled Low Level Waste Facility (RHLLW) for gross alpha, gross beta, carbon-14 ($^{14}C$), iodine-129 ($^{129}I$), $^{99}Tc$, and tritium. Samples were collected from three monitoring wells in April 2021. The results were not above the PCS/SCS and show no discernable impacts to the aquifer from RHLLW operations.

Drinking water and surface water samples were sampled downgradient of the INL Site and analyzed for gross alpha and beta activity and tritium. Tritium was detected in some samples at levels within historical measurements and below the EPA maximum contaminant level for tritium. Gross alpha and beta results were within historical measurements and the gross beta activity was well below the EPA's screening level. The data appear to show no discernible impacts from activities at the INL Site.

## Monitoring of Agricultural Products, Wildlife, Soil, and Direct Radiation Measurements

To help assess the impact of contaminants released to the environment by operations at the INL Site, agricultural products (e.g., milk, lettuce, alfalfa, grain, potatoes) and wildlife were sampled and analyzed for radionuclides in 2021. The agricultural products were collected on, around, and distant from the INL Site by the ESER contractor.

Some human-made radionuclides were detected in agricultural products. However, measurements were consistent with those made historically.

No human-made radionuclides were detected in big game animal samples collected in 2021. Cobalt-60, and $^{90}Sr$ were detected in tissues of waterfowl collected near the ATR Complex ponds indicating that they accessed the contaminated ponds.

Cobalt-60, zinc-65 ($^{65}Zn$), $^{90}Sr$, $^{137}Cs$, $^{238}Pu$ and $^{239/240}Pu$ were detected in some composited bat samples, indicating that bats may have visited radioactive wastewater ponds, such as those at the ATR Complex.

Direct radiation measurements made at offsite, boundary, and onsite locations were consistent with historical and/or natural background levels.

## Natural and Cultural Resources Conservation and Monitoring

Conservation planning, land stewardship, and natural resource monitoring and research are routinely used to provide information and direction about protecting or restoring the ecological resources of the INL Site. These efforts also ensure compliance to various environmental laws and regulations so that the INL Site mission and goals can be achieved.

Conservation plans are developed for the protection of species and ecosystems to maintain healthy populations and restore, protect, or enhance natural ecosystems. These plans are initiated when a concern is identified that may impact the INL mission or to protect valuable ecosystems unique to the INL Site. Conservation plans define the concern, develop methods to monitor species and its habitat, and identify best management practices that can be implemented to minimize impacts to species and ecosystems. Conservation plans that have been implemented on the INL Site consist of:

- A Candidate Conservation Agreement (CCA) for the Greater Sage-Grouse (*Centrocercus urophasianus*) was approved and signed by DOE-ID and the U.S. Fish and Wildlife Service in 2014. This conservation agreement provides for the protection of the greater sage-grouse and its habitat on the INL Site. This voluntary agreement developed conservation measures and objectives to avoid or minimize threats to sage-grouse and established a sage-grouse Conservation Area (SGCA). The CCA also established a population trigger based on the 2011 male sage-grouse lek attendance on 27 active leks and a habitat trigger based on sagebrush-dominated habitats within the SGCA at the beginning of 2013.
- The INL Site Bat Protection Plan was finalized in 2018 and identifies threats to bats, provides monitoring and surveying directions, and identifies conservation measures that can be used to conserve bats and their habitat on the INL Site.
- The Sagebrush Steppe Ecosystem Reserve (SSER) was established in 1999 on the INL Site, due to the recognition of the value and uniqueness of this undisturbed sagebrush ecosystem. The primary mission of this area is to conserve native ecosystem components, cultural resources, and Native American Tribal values. The SSER also provides opportunities for scientific investigation of the resources present on the Reserve.
- A Migratory Bird Conservation Plan and a Power Management Avian Protection Plan and Bird Management Policy are in place to protect migratory bird species that inhabit the INL Site for breeding, nesting, or foraging purposes. These plans identify conservation measures that provide protection to birds. A Bird/Wildlife Conservation Working Group has also been established that enables staff members to discuss bird or wildlife issues at their respective facilities, and to identify solutions that can be used to minimize impacts to nesting birds and ensure compliance with requirements of the Migratory Bird Treaty Act.

The INL Site strives to be good stewards of the land by addressing both natural and human caused impacts (e.g., wildland fires, weed invasions). Land stewardship efforts consider climate change and address impacts already being experienced as a result of the changing climate. These efforts include:

- Wildland Fire Protection Planning, Management, and Recovery documents address how to plan for, respond to, and mitigate impacts from wildland fire. Wildland fire is considered a primary threat to the sagebrush steppe ecosystem and those species that rely on this system. Wildland fires have become more frequent than historically experienced. To combat this, a balanced fire management approach has been adopted to ensure the protection of improved laboratory assets in a manner that minimizes effects on natural, cultural, and biological resources.
- Restoration and revegetation are key elements in the preservation of the sagebrush steppe ecosystem at the INL Site. These activities are utilized when native species have been removed by either a project or by wildland fire. Revegetation using native species is also used to stabilize soils and to aid in the prevention of invasive or noxious weed infestations. The INL Site also carries out a compensatory sagebrush mitigation strategy for projects that remove sagebrush habitat. This strategy outlines an approach for projects to provide funds for sagebrush to be restored in designated priority restoration areas where they can provide the greatest habitat benefit for sage-grouse and other wildlife species that depend on sagebrush for survival.
- Rangelands store most of their carbon long-term in the soil in the form of organic carbon through deep-rooted native perennial grasses and shrubs. Keeping INL Site rangeland soils intact is an important action for preserving natural carbon storage. Below-ground carbon stores are lost when annual invasive grasses, like cheatgrass, displace deep-rooted perennial plants. Preventative management and targeted restoration are being used to combat this threat.
- Noxious weeds are spreading at an alarming rate across the western U.S., including the state of Idaho. State and federal regulations require noxious weed control on all lands, including federal reservations such as the INL Site. The INL Site has developed a noxious weed management program to remain in compliance with state and federal laws and have been implementing methods to meet management objectives.

Natural resource monitoring and research at the INL Site are used to support both conservation planning and land stewardship by providing current data on species or areas of concern. Much of the annual monitoring that occurs on the INL Site has been conducted for 30+ years with long-term vegetation data being collected for more than 70 years. Monitoring of sage-grouse, breeding birds, and raptors occurs on an annual basis, while long-term vegetation data is collected once every five-years. More recently, a geographic information system (GIS) has been used for inventory and monitoring of ecological resources on the INL Site. All monitoring data are used to determine current species status and provides valuable information regarding the health of vegetation communities on the INL Site and how they are responding after disturbance. Data are also used to support National Environmental Policy Act (NEPA) analysis. Research is a valuable resource to aid in achieving environmental goals on the INL Site. In 1975, the INL Site was designated a National Environmental Research Park which facilitates various university-led research projects, such as documenting ants and associated arthropods, tracking rattlesnake movements, and addressing ecohydrology in sagebrush steppe.

The INL Cultural Resource Management Office (CRMO) coordinates cultural resource-related activities at the INL Site and implements the INL Cultural Resource Management Plan (DOE-ID 2016) with oversight by DOE-ID's Cultural Resource Coordinator. Cultural resource identification and evaluation studies in fiscal year (FY) 2021 included: (1) archaeological field surveys; (2) monitoring, and site updates related to INL Site project activities; and (3) meaningful collaboration with members of the Shoshone-Bannock Tribes and public stakeholders.

## USGS Research

The USGS INL Project Office drills and maintains research wells that provide information about subsurface water, rock and sediment, and contaminant movement in the eastern Snake River Plain Aquifer at and near the INL Site. In 2021, the USGS published four research reports and two software releases.

## Quality Assurance

Quality assurance and quality control programs are maintained by contractors conducting environmental monitoring and by laboratories performing environmental analyses to help provide confidence in the data and ensure data completeness. Programs involved in environmental monitoring developed quality assurance programs and documentation, which follow requirements and criteria established by DOE. Environmental monitoring programs implemented quality assurance program elements through quality assurance project plans developed for each contractor.

Adherence to procedures and quality assurance project plans was maintained during 2021. Data reported in this document were obtained from several commercial, university, government, and government contractor laboratories. To ensure quality results, these laboratories participated in a number of laboratory quality check programs. Quality issues that arose with laboratories used by the INL, ICP Core, and ESER contractors during 2021 were addressed with the laboratories and have been or are being resolved.

# Helpful Information

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## What is Radiation?

Much of the Annual Site Environmental Report deals with radioactivity levels measured in environmental media, such as air, water, soil, and plants. The following information is intended for individuals with little or no familiarity with radiological data or radiation dose. It presents terminology and concepts used in the Annual Site Environmental Report to aid the reader.

Matter is composed of atoms. Some atoms are energetically unstable and change to become more stable. During this transformation, unstable or radioactive atoms give off energy called 'radiation' in the form of particles or electromagnetic waves. Generally, we refer to the various radioactive atoms as radionuclides. The radiation released by radionuclides has enough energy to eject electrons from other atoms it encounters. The resulting charged atoms or molecules are called ions, and the energetic radiation that produced the ions is called ionizing radiation. Ionizing radiation is referred to simply as 'radiation' throughout this report. The most common types of radiation are alpha particles, beta particles, X-rays, and gamma-rays. X-rays and gamma-rays, just like visible light and radio waves, are packets of electromagnetic radiation. Collectively, packets of electromagnetic radiation are called photons. One may, for instance, speak of X-ray photons or gamma-ray photons.

***Alpha Particles.*** An alpha particle is a helium nucleus without orbital electrons. It is composed of two protons and two neutrons and has a positive charge of two. Because alpha particles are relatively heavy and have a double charge, they cause intense tracks of ionization but have little penetrating ability, as observed in Figure HI-1. Alpha particles can be stopped by thin layers of materials, such as a sheet of paper or a piece of aluminum foil. Examples of alpha-emitting radionuclides include radioactive atoms of radon, uranium, plutonium, and americium.

***Beta Particles.*** Beta particles are electrons that are ejected from unstable atoms during the transformation or decay process. Beta particles penetrate more than alpha particles but are less penetrating than X-rays or gamma-rays of equivalent energies. A piece of wood or a thin block of plastic can stop beta particles, as can be seen in Figure HI-1. The ability of beta particles to penetrate matter increases with energy. Examples of beta-emitting radionuclides include tritium ($^{3}H$) and radioactive strontium.

***X-Rays and Gamma-Rays.*** X-rays and gamma-rays are photons with very short wave-lengths compared to other electromagnetic waves, such as visible light, heat rays, and radio waves. Gamma-rays and X-rays have identical properties, behavior, and effects, but differ only in their origin. Gamma-rays originate from an atomic nucleus, and X-rays originate from interactions with the electrons orbiting around atoms. All photons travel at the speed of light. Their energies, however, vary over a large range. The penetration of X-ray or gamma-ray photons depend on the energy of the photons, as well as the thickness, density, and composition of the shielding material. Concrete is a common material used to shield people from gamma-rays and X-rays, as shown in Figure HI-1.

Examples of gamma-emitting radionuclides include radioactive atoms of iodine and cesium. X-rays may be produced by medical X-ray machines in a doctor's office.

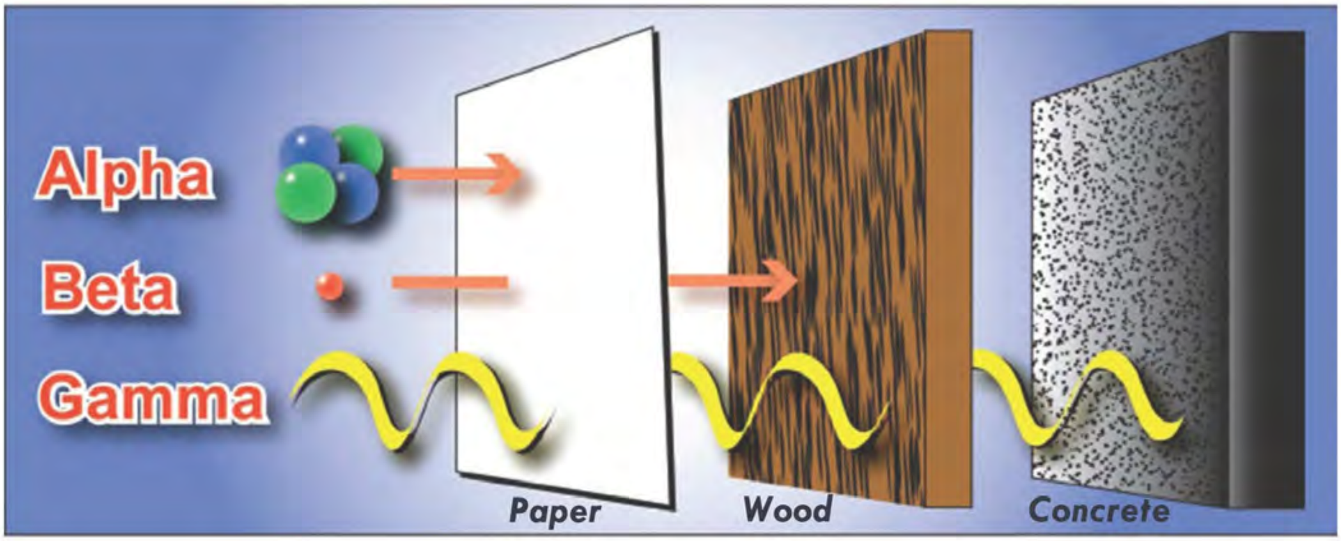



***Figure HI-1. Comparison of penetrating ability of alpha, beta, and gamma radiation.***

## How are Radionuclides Designated?

Radionuclides are frequently expressed with a one or two letter abbreviation for the element and a superscript to the left of the symbol that identifies the atomic weight of the isotope. The atomic weight is the number of protons and neutrons in the nucleus of the atom. Most radionuclide symbols used in this report are shown in Table HI-1. This table also shows the half-life of each radionuclide. Half-life refers to the time in which one-half of the atoms of a radioactive sample transforms or decays in the quest to achieve a more energetically stable nucleus. Most radionuclides do not decay directly to a stable element, but rather undergo a series of decays until a stable element is reached. This series of decays is called a decay chain.

## How are Radioactivity and Radionuclides Detected?

Environmental samples of air, water, soil, and plants are collected in the field and then prepared and analyzed for radioactivity in a laboratory. A prepared sample is placed in a radiation counting system with a detector that converts the ionization produced by the radiation into electrical signals or pulses. The number of electrical pulses recorded over a unit of time is called a count rate. The count rate is proportional to the amount of radioactivity in the sample.

Air and water samples are often analyzed to determine the total amount of alpha-emitting and beta-emitting radioactivity present. This is referred to as a gross measurement because the radiation from all alpha-emitting and beta-emitting radionuclides in the sample is quantified. Such sample analyses measure both human-generated and naturally occurring radioactive material. Gross alpha and beta analyses are generally considered screening measurements since specific radionuclides are not identified. The amount of gross alpha-emitting and beta-emitting radioactivity in air samples is frequently measured to screen for the potential presence of man-made radionuclides. If the results are higher than normal, sources other than background radionuclides may be suspected, and other laboratory techniques may be used to identify the specific radionuclides in the sample. Gross alpha and beta activity also can be examined over time and between locations to detect trends.

The low penetration ability of alpha-emitting particles makes detection by any instrument difficult. Identifying specific alpha-emitting radionuclides typically involves chemical separations in the laboratory to purify the sample prior to analysis with an alpha detection instrument. Radiochemical analysis is very time-consuming and expensive.

Beta particles are easily detected by several types of instruments, including the common Geiger-Mueller counter. However, detection of specific beta-emitting radionuclides, such as $^{3}H$ and $^{90}Sr$, requires chemical separation first.

*Table HI-1. Radionuclides and their half-lives.*

| SYMBOL | RADIONUCLIDE | HALF-LIFE[a,b] | SYMBOL | RADIONUCLIDE | HALF-LIFE[a,b] |
|---|---|---|---|---|---|
| $^{241}Am$ | Americium-241 | 432.2 yr | $^{54}Mn$ | Manganese-54 | 312.12 d |
| $^{243}Am$ | Americium-243 | 7,370 yr | $^{59}Ni$ | Nickel-59 | 1.01 x $10^5$ yr |
| $^{125}Sb$ | Antimony-125 | 2.75856 yr | $^{63}Ni$ | Nickel-63 | 100.1 yr |
| $^{41}Ar$ | Argon-41 | 109.61 min | $^{238}Pu$ | Plutonium-238 | 87.7 yr |
| $^{137m}Ba$ | Barium-137m | 2.552 min | $^{239}Pu$ | Plutonium-239 | 2.411 x $10^4$ yr |
| $^{140}Ba$ | Barium-140 | 12.752 d | $^{240}Pu$ | Plutonium-240 | 6,564 yr |
| $^{7}Be$ | Beryllium-7 | 53.22 d | $^{241}Pu$ | Plutonium-241 | 14.35 yr |
| $^{14}C$ | Carbon-14 | 5,700 yr | $^{242}Pu$ | Plutonium-242 | 3.75 x $10^5$ yr |
| $^{141}Ce$ | Cerium-141 | 32.508 d | $^{40}K$ | Potassium-40 | 1.251 x $10^9$ yr |
| $^{144}Ce$ | Cerium-144 | 284.91 d | $^{226}Ra$ | Radium-226 | 1,600 yr |
| $^{134}Cs$ | Cesium-134 | 2.0648 yr | $^{228}Ra$ | Radium-228 | 5.75 yr |
| $^{137}Cs$ | Cesium-137 | 30.1671 yr | $^{220}Rn$ | Radon-220 | 55.6 s |
| $^{51}Cr$ | Chromium-51 | 27.7025 d | $^{222}Rn$ | Radon-222 | 3.8235 d |
| $^{60}Co$ | Cobalt-60 | 5.2713 yr | $^{103}Ru$ | Ruthenium-103 | 39.26 d |
| $^{152}Eu$ | Europium-152 | 13.537 yr | $^{106}Ru$ | Ruthenium-106 | 373.59 d |
| $^{154}Eu$ | Europium-154 | 8.593 yr | $^{90}Sr$ | Strontium-90 | 28.79 yr |
| $^{3}H$ | Tritium | 12.32 yr | $^{99}Tc$ | Technetium-99 | 2.111 x $10^5$ yr |
| $^{129}I$ | Iodine-129 | 1.57 x $10^7$ yr | $^{232}Th$ | Thorium-232 | 1.405 x $10^{10}$ yr |
| $^{131}I$ | Iodine-131 | 8.0207 d | $^{233}U$ | Uranium-233 | 1.592 x $10^5$ yr |
| $^{55}Fe$ | Iron-55 | 2.737 yr | $^{234}U$ | Uranium-234 | 2.455 x $10^5$ yr |
| $^{59}Fe$ | Iron-59 | 44.495 d | $^{235}U$ | Uranium-235 | 7.04 x $10^8$ yr |
| $^{85}Kr$ | Krypton-85 | 10.756 yr | $^{238}U$ | Uranium-238 | 4.468 x $10^9$ yr |
| $^{87}Kr$ | Krypton-87 | 76.3 min | $^{90}Y$ | Yttrium-90 | 64.1 hr |
| $^{88}Kr$ | Krypton-88 | 2.84 hr | $^{65}Zn$ | Zinc-65 | 244.06 d |
| $^{212}Pb$ | Lead-212 | 10.64 hr | $^{95}Zr$ | Zirconium-95 | 64.032 d |

a. From ICRP Publication 107 (ICRP 2008).

b. d = days; hr = hours; min = minutes; s = seconds; yr = years.

The high-energy photons from gamma-emitting radionuclides are relatively easy to detect. Because the photons from each gamma-emitting radionuclide have a characteristic energy, gamma emitters can be simply identified in the laboratory with only minimal sample preparation prior to analysis. Gamma-emitting radionuclides, such as $^{137}$Cs, can even be measured in soil by field detectors called in-situ detectors.

Gamma radiation originating from naturally occurring radionuclides in soil and rocks on the earth's surface is a primary contributor to the background external radiation exposure measured in air. Cosmic radiation from outer space is another contributor to the external radiation background. External radiation is easily measured with devices known as environmental dosimeters.

## How are Results Reported?

***Scientific Notation.*** Concentrations of radionuclides detected in the environment are typically quite small. Scientific notation is used to express numbers that are very small or very large. A very small number may be expressed with a negative exponent, for example, 1.3 x $10^{-6}$ (or 1.3E-06). To convert this number to its decimal form, the decimal point is moved left by the number of places equal to the exponent (in this case, six). The number 1.3 x $10^{-6}$ may also be expressed as 0.0000013. When considering large numbers with a positive exponent, such as 1.0 x $10^{6}$, the decimal point is moved to the right by the number of places equal to the exponent. In this case, 1.0 x $10^{6}$ represents one million and may also be written as 1,000,000.

***Unit Prefixes.*** Units for very small and very large numbers are often expressed with a prefix. One common example is the prefix kilo (abbreviated k), which means 1,000 of a given unit. One kilometer, therefore, equals 1,000 meters. Table HI-2 defines the values of commonly used prefixes.

***Table HI-2. Multiples of units.***

| MULTIPLE | DECIMAL EQUIVALENT | PREFIX | SYMBOL |
|---|---|---|---|
| $10^{6}$ | 1,000,000 | mega- | M |
| $10^{3}$ | 1,000 | kilo- | k |
| $10^{2}$ | 100 | hecto- | h |
| 10 | 10 | deka- | da |
| $10^{-1}$ | 0.1 | deci- | d |
| $10^{-2}$ | 0.01 | centi- | c |
| $10^{-3}$ | 0.001 | milli- | m |
| $10^{-6}$ | 0.000001 | micro- | µ |
| $10^{-9}$ | 0.000000001 | nano- | n |
| $10^{-12}$ | 0.000000000001 | pico- | p |
| $10^{-15}$ | 0.000000000000001 | femto- | f |
| $10^{-18}$ | 0.000000000000000001 | atto- | a |

***Units of Radioactivity.*** The basic unit of radioactivity used in this report is the curie (abbreviated Ci) which is based on the disintegration rate occurring in 1 gram of the radionuclide radium-226 ($^{226}$Ra) that is 37 billion (3.7 x $10^{10}$) disintegrations per second (becquerels). For any other radionuclide, 1 Ci is the amount of the radionuclide that produces this same decay rate.

***Units of Exposure and Dose (Table HI-3).*** Exposure, or the amount of ionization produced by gamma or X-ray radiation in air, is measured in terms of the roentgen (R). Dose is a general term to express how much radiation energy is deposited in something. The energy deposited can be expressed in terms of absorbed, equivalent, and/or effective dose.

The term rad, which is short for radiation absorbed dose, is a measure of the energy absorbed in an organ or tissue. The equivalent dose, which considers the effect of different types of radiation on tissues and is therefore the potential for biological effects, is expressed as the R equivalent man or 'rem.' Radiation exposures to the human body, whether from external or internal sources, can involve all or a portion of the body. To enable radiation protection specialists to express partial-body exposures (and the accompanying doses) to portions of the body in terms of an equal dose to the whole body, the concept of 'effective dose' was developed.

***Table HI-3. Names and symbols for units of radioactivity and radiological dose used in this report.***

| SYMBOL | NAME |
|---|---|
| Bq | Becquerel |
| Ci | Curie (37,000,000,000 Bq) |
| mCi | Millicurie ($1 \times 10^{-3}$ Ci) |
| μCi | Microcurie ($1 \times 10^{-6}$ Ci) |
| mrad | Millirad ($1 \times 10^{-3}$ rad) |
| mrem | Millirem ($1 \times 10^{-3}$ rem) |
| R | Roentgen |
| mR | Milliroentgen ($1 \times 10^{-3}$ R) |
| μR | Microroentgen ($1 \times 10^{-6}$ R) |
| Sv | Sievert (100 rem) |
| mSv | Millisievert (100 mrem) |
| μSv | Microsievert (0.1 mrem) |

The Système International (SI) is the official system of measurement used internationally to express units of radioactivity and radiation dose. The basic SI unit of radioactivity is the Becquerel (Bq), which is equivalent to one nuclear disintegration per second. The number of curies must be multiplied by $3.7 \times 10^{10}$ to obtain the equivalent number of becquerels. The concept of dose may also be expressed using the SI units, Gray (Gy) for absorbed dose (1 Gy = 100 rad) and sievert (Sv) for effective dose (1 Sv = 100 rem).

***Concentrations of Radioactivity in Environmental Sample Media.*** Table HI-4 shows the units used to identify the concentration of radioactivity in various sample media.

There is always uncertainty associated with the measurement of radioactivity in environmental samples. This is mainly because radioactive decay events are inherently random. Thus, when a radioactive sample is counted again and again for the same length of time, the results will differ slightly, but most of the results will be close to the true value of the activity of the radioactive material in the sample. Statistical methods are used to estimate the true value of a single measurement and the associated uncertainty of the measurement. The uncertainty of a measurement is reported by following the result with an uncertainty value that is preceded by the plus or minus symbol, ± (e.g., 10 ± 2 pCi/L). The uncertainty is often referred to as sigma (or σ). For concentrations of greater than or equal to three times the uncertainty, there is 95% probability that the radionuclide was detected in a sample. For example, if a radionuclide is reported for a sample at a concentration of 10 ± 2 pCi/L, that radionuclide is considered to be detected in that sample because 10 is greater than 3 × 2 or 6. On the other hand, if the reported concentration of a radionuclide (e.g., 10 ± 6 pCi/L) is smaller than three times its associated uncertainty, then the sample probably does not contain that radionuclide (i.e., 10 is less than 3 × 6 or 18). Such low concentrations are considered to be undetected by the method and/or instrumentation used.

*Table HI-4. Units of radioactivity.*

| MEDIA | UNIT |
|---|---|
| Air | Microcuries per milliliter (µCi/mL) |
| Liquid, such as water and milk | Picocuries per liter (pCi/L) |
| Soil and agricultural products | Picocuries per gram (pCi/kg) dry weight |
| Annual human radiation exposure, measured by environmental dosimeters | Milliroentgens (mR) or millirem (mrem), after being multiplied by an appropriate dose equivalent conversion factor |

***Mean, Median, Maximum, and Minimum Values.*** Descriptive statistics are often used to express the patterns and distribution of a group of results. The most common descriptive statistics used in this report are the mean, median, minimum, and maximum values. Mean and median values measure the central tendency of the data. The mean is calculated by adding up all the values in a set of data and then dividing that sum by the number of values in the data set. The median is the middle value in a group of measurements. When the data are arranged from largest (maximum) to smallest (minimum), the result in the exact center of an odd number of results is the median. If there is an even number of results, the median is the average of the two central values. The maximum and minimum results represent the range of the measurements.

Statistical analysis of many of the air data reported in this annual report indicate that the median is a more appropriate representation of the central tendency of those results. For this reason, some of the figures present the median value of a data group. For example, Figure HI-2 is a box plot showing the minimum, maximum, and median of a set of air measurements.

## How are Data Represented Graphically?

Charts and graphs often are used to compare data and to visualize patterns, such as trends over time. Four kinds of graphics are used in this report to represent data: pie charts, column graphs, line plots, and contour lines.

A ***pie chart*** is used in this report to illustrate fractions of a whole. For example, Figure HI-3 shows the approximate contribution to dose that a typical person might receive while living in southeast Idaho. The percentages are derived from the table in the lower left-hand corner of the figure. The medical, consumer, and occupational/industrial portions are from the National Council on Radiation Protection and Measurements Report No. 160 (NCRP 2009). The contribution from background (e.g., natural radiation, mostly radon) is estimated in Table 7-7 of this report.

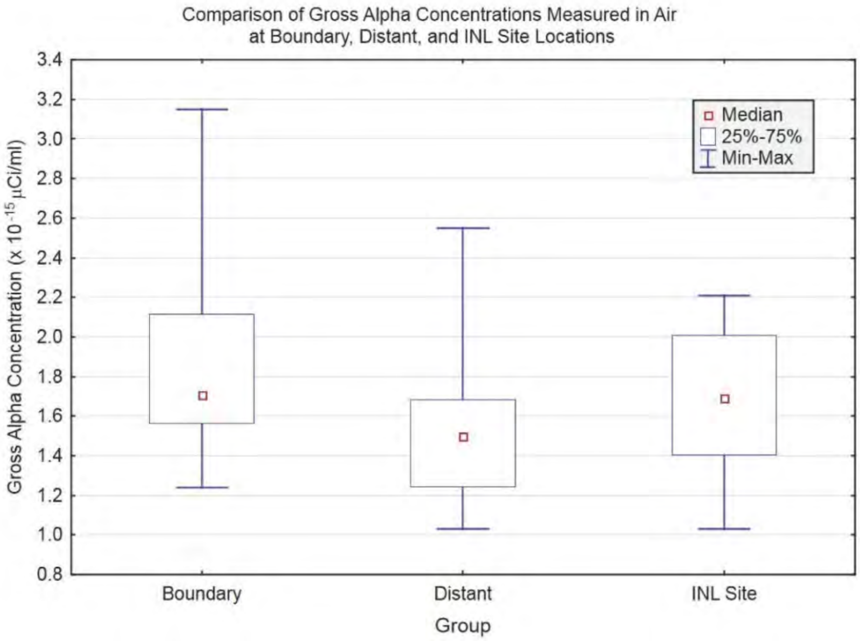
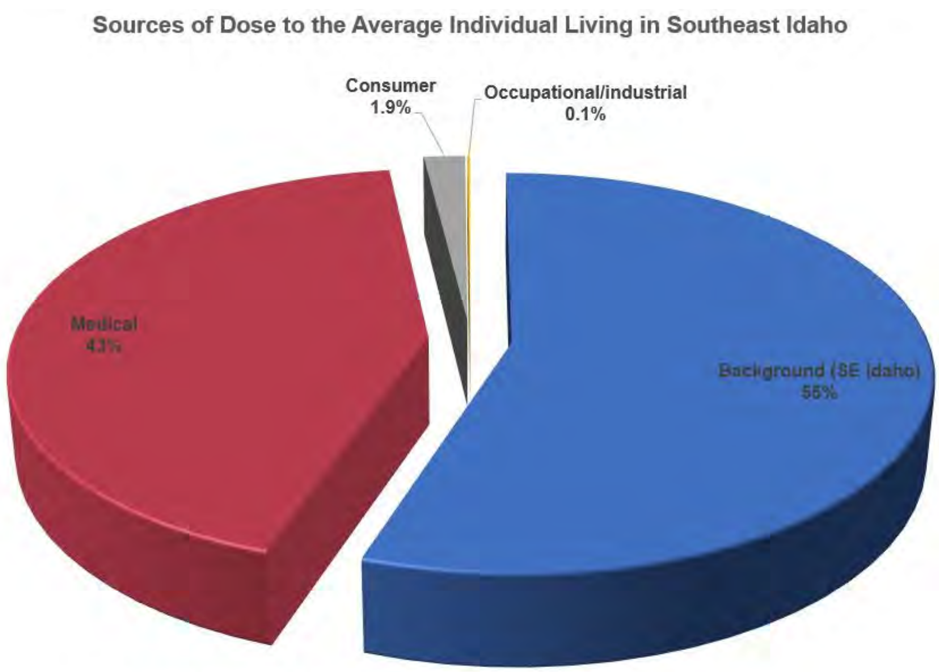



***Figure HI-2. A graphical representation of minimum, median, and maximum results with a box plot.*** *The 25th and 75th percentiles are the values such that 75% of the measurements in the data set are greater than the 25th percentile, and 75% of the measurements are less than the 75th percentile.*




| | Effective dose (mrem) | % of Total |
|---|---|---|
| Background | 387 | 55% |
| Medical | 300 | 43% |
| Consumer | 13 | 1.9% |
| Occupational/industrial | 0.8 | 0.1% |
| Total | 701 | 100% |

***Figure HI-3. Data presented using a pie chart.***

A ***column or bar chart*** can show data changes over a period of time or illustrate comparisons among items. Figure HI-4 illustrates the maximum dose (mrem) calculated for the maximally exposed individual from 2012 through 2021. The maximally exposed individual is a hypothetical member of the public who is exposed to radionuclides from airborne releases through various environmental pathways and the media through which the radionuclides are transported (i.e., air, water, and food). The chart shows the general trend of the dose over time.

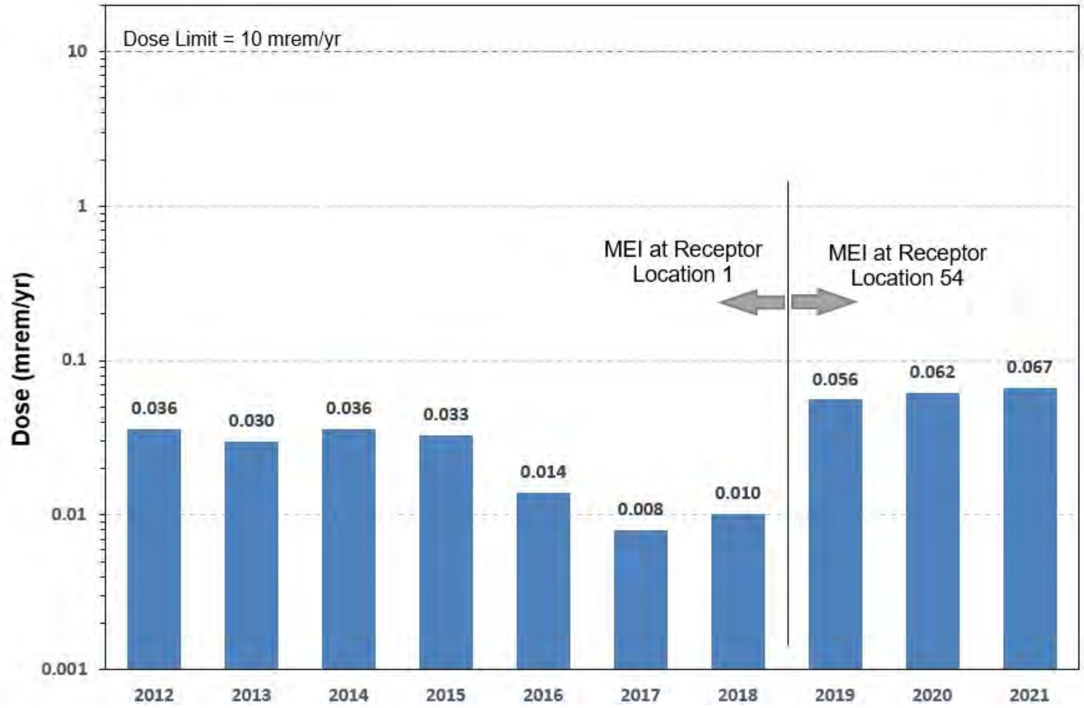



***Figure HI-4. Data plotted using a column chart.***

A ***plot*** can be useful to visualize differences in results over time. Figure HI-5 shows the $^{90}$Sr measurements in three wells collected by USGS for 21 years (2001-2021). The results are plotted by year.

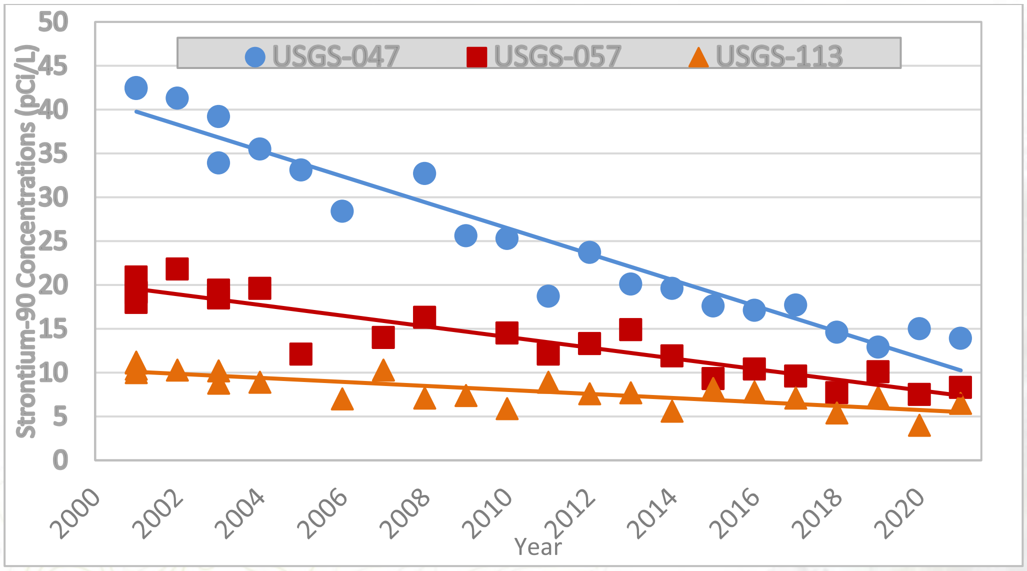



***Figure HI-5. Data plotted using a linear plot.***

***Contour lines*** are sometimes drawn on a map to discern patterns over a geographical area. For example, Figure HI-6 shows the distribution of $^{90}Sr$ in groundwater around INTEC. Each contour line, or isopleth, represents a specific concentration of the radionuclide in groundwater. It was estimated from measurements of samples collected from wells around INTEC. Each contour line separates areas that have concentrations above the contour line value from those that have concentrations below that value. The figure shows the highest concentration gradient near INTEC and the lowest farther away. It reflects the movement of the radionuclide in groundwater from INTEC where it was injected into the aquifer in the past.

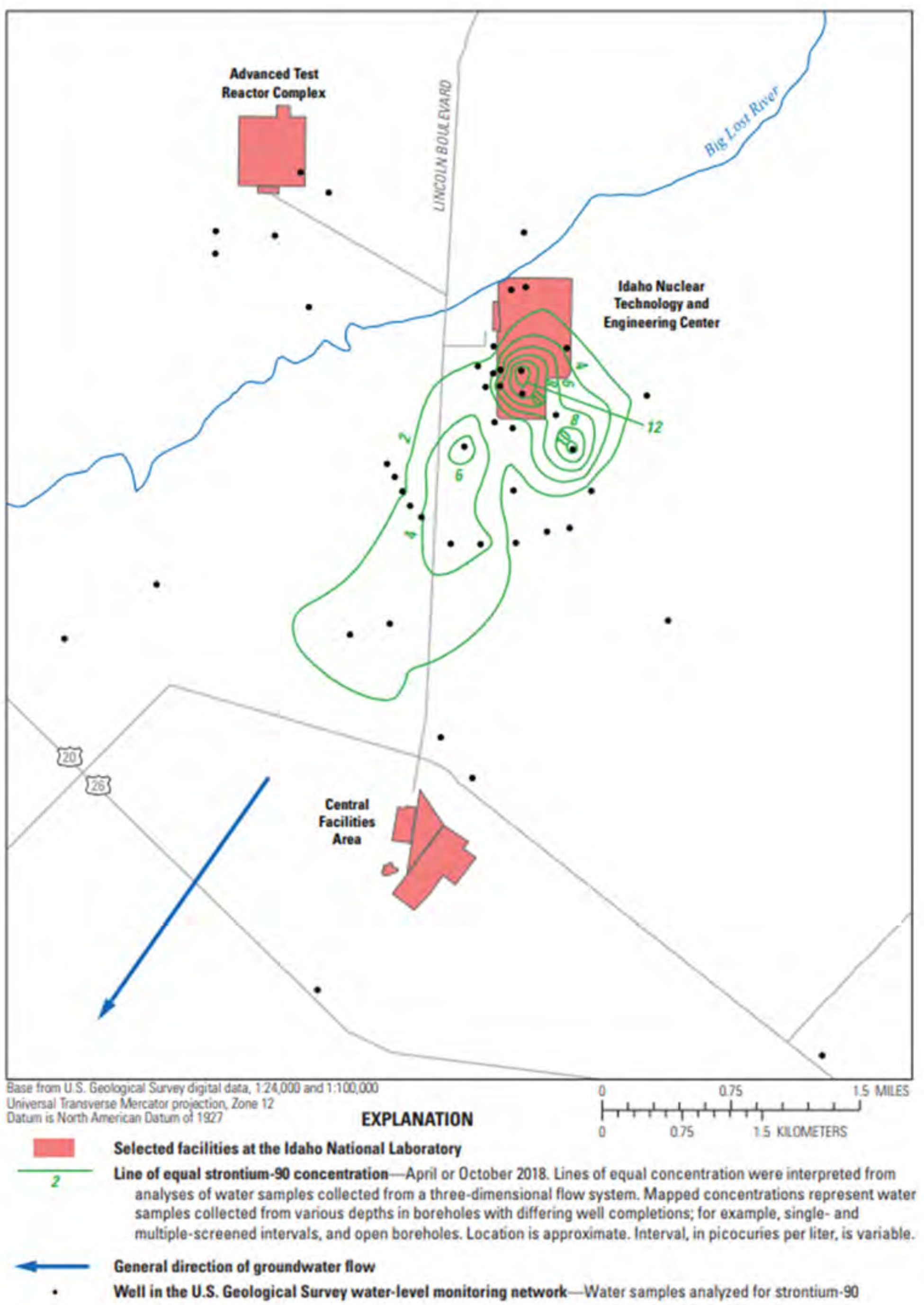



***Figure HI-6. Data plotted using contour lines.*** *Each contour line drawn on this map connects points of equal* $^{90}Sr$ *concentration in water samples collected at the same depth from wells on the INL Site.*

## How Are Results Interpreted?

To better understand data, results are compared in one or more ways, including:

- Comparison of results collected at different locations. For example, measurements made at INL Site locations are compared with those made at locations near the boundary of the INL Site and distant from the INL Site to find differences that may indicate an impact (Figure HI-2).
- Trends over time or space. Data collected during the year can be compared with data collected at the same location or locations during previous years to see if concentrations are increasing, decreasing, or remaining the same with time. See, for example, Figure HI-4, which shows a general decrease in dose from 2012 to 2018 followed by a slight increase from 2019 to 2021. Figure HI-6 illustrates a clear spatial pattern of radionuclide concentrations in groundwater decreasing with distance from the source.
- Comparison with background measurements. Humans are now, and always have been, continuously exposed to ionizing radiation from natural background sources. Background sources include natural radiation and radioactivity, as well as radionuclides from human activities. These sources are discussed in the following section.

## What Is Background Radiation?

- Radioactivity from natural and fallout sources is detectable as background in all environmental media. Natural sources of radiation include: (1) radiation of extraterrestrial origin (called cosmic rays); (2) radionuclides produced in the atmosphere by cosmic ray interaction with matter (called cosmogenic radionuclides); and (3) radionuclides present at the time of the formation of the earth (called primordial radionuclides). Radiation that has resulted from the activities of modern man is primarily fallout from past atmospheric testing of nuclear weapons. One of the challenges to environmental monitoring on and around the INL Site is to distinguish between what may have been released from the INL Site and what is already present in background from natural and fallout sources. These sources are discussed in more detail below.
- ***Natural Sources.*** Natural radiation and radioactivity in the environment, which is natural background, represent a major source of human radiation exposure (NCRP 1987, 2009). For this reason, natural radiation frequently is used as a standard of comparison for exposure to various human-generated sources of ionizing radiation. An individual living in southeast Idaho was estimated, in 2021, to receive an average dose of about 387 mrem/yr (3.8 mSv/yr) from natural background sources of radiation on earth, as observed in Figure HI-7. These sources include cosmic radiation and naturally occurring radionuclides.

Cosmic radiation is radiation that constantly bathes the earth from extraterrestrial sources. The atmosphere around the earth absorbs some of the cosmic radiation, so doses are lowest at sea level and increase sharply with altitude. Cosmic radiation is estimated, using data in NCRP (2009), to produce a dose of about 57 mrem/yr (0.57 mSv/yr) to a typical individual living in southeast Idaho (Figure HI-7). Cosmic radiation also produces cosmogenic radionuclides, which are found naturally in all environmental media and are discussed in more detail below.

Naturally occurring radionuclides are of two general kinds: cosmogenic and primordial. Cosmogenic radionuclides are produced by the interaction of cosmic radiation within the atmosphere or in the earth. Cosmic rays have high enough energies to blast apart atoms in the earth's atmosphere. The result is the continuous production of radionuclides, such as $^{3}H$, beryllium-7 ($^{7}Be$), sodium-22 ($^{22}Na$), and $^{14}C$. Cosmogenic radionuclides, particularly $^{3}H$ and $^{14}C$, have been measured in humans, animals, plants, soil, polar ice, surface rocks, sediments, the ocean floor, and the atmosphere. Concentrations are generally higher at mid-latitudes than at low- or high-latitudes. Cosmogenic radionuclides contribute only about 1 mrem/yr to the total average dose, mostly from $^{14}C$, that might be received by an adult living in the U.S. (NCRP 2009). Tritium and $^{7}Be$ are routinely detected in environmental samples collected by environmental monitoring programs on and around the INL Site, as observed in Table HI-5, but contribute little to the dose that might be received from natural background sources.

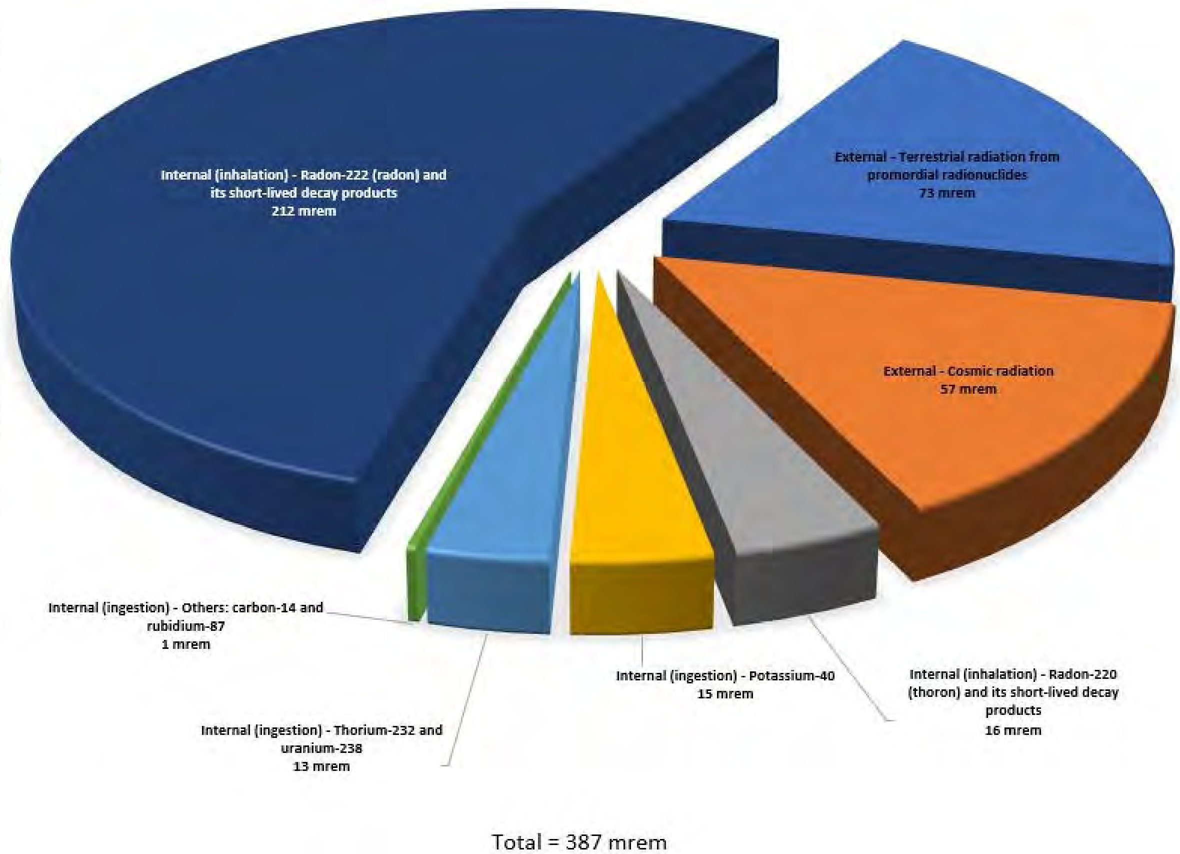



***Figure HI-7. Calculated doses (mrem per year) from natural background sources for an average individual living in southeast Idaho (2021).***

***Table HI-5. Naturally occurring radionuclides that have been detected in environmental media collected on and around the INL Site.***

| RADIONUCLIDE | HALF-LIFE | HOW PRODUCED? | DETECTED OR MEASURED IN: |
|---|---|---|---|
| Beryllium-7 ($^{7}$Be) | 53.22 da | Cosmic rays | Rain, air |
| Tritium ($^{3}$H) | 12.32 yr | Cosmic rays | Water, rain, air moisture |
| Potassium-40 ($^{40}$K) | $1.2516 \times 10^{9}$ yr | Primordial | Water, air, soil, plants, animals |
| Thorium-232 ($^{232}$Th) | $1.405 \times 10^{10}$ yr | Primordial | Soil |
| Uranium-238 ($^{238}$U) | $4.468 \times 10^{9}$ yr | Primordial | Water, air, soil |
| Uranium-234($^{234}$U) | $2.455 \times 10^{5}$ yr | $^{238}$U progeny | Water, air, soil |
| Radium-226 ($^{226}$Ra) | 1,600 yr | $^{238}$U progeny | Water |

Primordial radionuclides are those that were present when the earth was formed. The primordial radionuclides detected today are billions of years old. The radiation dose to a person from primordial radionuclides comes from internally deposited radioactivity, inhaled radioactivity, and external radioactivity in soils and building materials. Three of the primordial radionuclides—potassium-40 ($^{40}$K), uranium-238 ($^{238}$U), and thorium-232 ($^{232}$Th)—are responsible for most of the dose received by people from natural background radioactivity. They have been detected in environmental samples collected on and around the INL Site (Table HI-5). The external dose to an adult living in southeast Idaho from terrestrial natural background radiation exposure (73 mrem/yr or 0.73 mSv/yr) has been estimated using concentrations of $^{40}$K, $^{238}$U, and $^{232}$Th measured in soil samples collected from areas surrounding the INL Site from 1976 through 1993. This number varies slightly from year to year based on the amount of snow cover. Uranium-238 and $^{232}$Th are also estimated to contribute 13 mrem/yr (0.13 mSv/yr) to an average adult through ingestion (NCRP 2009).

Potassium-40 is abundant and measured in living and nonliving matter. It is found in human tissue and is a significant source of internal dose to the human body (approximately 15 mrem/yr [0.15 mSv/yr] according to NCRP [2009]). Rubidium-87 ($^{87}$Rb), another primordial radionuclide, contributes a small amount (< 1 mrem/yr) to the internal dose received by people but is not typically measured in INL Site samples.

Uranium-238 and $^{232}$Th each initiate a decay chain of radionuclides. A radioactive decay chain starts with one type of radioactive atom called the parent that decays and changes into another type of radioactive atom called a progeny radionuclide. This system repeats, involving several different radionuclides. The parent radionuclide of the uranium decay chain is $^{238}$U. The most familiar element in the uranium series is radon, specifically radon-222 ($^{222}$Rn). This is a gas that can accumulate in buildings. Radon and its progeny are responsible for most of the inhalation dose (e.g., an average of 200 mrem/yr [2.0 mSv/yr] nationwide) produced by naturally occurring radionuclides, as shown in Figure HI-7.

The parent radionuclide of the thorium series is $^{232}$Th. Another isotope of radon ($^{220}$Rn), called thoron, occurs in the thorium decay chain of radioactive atoms. Uranium-238, $^{232}$Th, and their progeny are often detected in environmental samples (Table HI-5).

***Global Fallout.*** The U.S., the Union of Soviet Socialist Republics, and China tested nuclear weapons in the Earth's atmosphere in the 1950s and 1960s. This testing resulted in the release of radionuclides into the upper atmosphere, and such a release is referred to as fallout from weapons testing. Concerns over worldwide fallout rates eventually led to the Partial Test Ban Treaty in 1963, which limited signatories to underground testing. Not all countries stopped atmospheric testing with the treaty. France continued atmospheric testing until 1974 and China until 1980. Additional fallout, but to a substantially smaller extent, was produced by the Chernobyl and Fukushima nuclear accidents in 1986 and 2011, respectively.

Most of the radionuclides associated with nuclear weapons testing and the Chernobyl and Fukushima accidents have decayed and are no longer detected in environmental samples. Radionuclides that are currently detected in the environment and typically associated with global fallout include $^{90}$Sr and $^{137}$Cs. Strontium-90, a beta-emitter with a 29-year half-life, is important because it is chemically similar to calcium and tends to accumulate in bone tissues. Cesium-137, which has a 30-year half-life, is chemically similar to potassium and accumulates rather uniformly in muscle tissue throughout the body.

The deposition of these radionuclides on the earth's surface varies by latitude, with most occurring in the northern hemisphere at approximately 40°. Variation within latitudinal belts is a function primarily of precipitation, topography, and wind patterns. The dose produced by global fallout from nuclear weapons testing has decreased steadily since 1970. The annual dose rate from fallout was estimated in 1987 to be less than 1 mrem (0.01 mSv) (NCRP 1987). It has been nearly 34 years since that estimate, so the current dose is assumed to be even lower.

## What are the Risks of Exposure to Low Levels of Radiation?

Radiation protection standards for the public have been established by state and federal agencies based mainly on recommendations of the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements. The International Commission on Radiological Protection is an association of scientists from many countries, including the U.S. The National Council on Radiation Protection and Measurements is a nonprofit corporation chartered by Congress. Through radiation protection standards, exposure of members of the general public to radiation is controlled so that risks are small enough to be considered insignificant compared to the risks undertaken during other activities deemed normal and acceptable in modern life.

A large amount of data exists concerning the effects of acute delivery (all at once) of high doses of radiation, especially in the range of 50 to 400 rem (0.5 to 4.0 Sv). Most of this information was gathered from the Japanese atomic bombing survivors and patients who were treated with substantial doses of X-rays. Conversely, information is limited, and therefore, it is difficult to estimate risks associated with low level exposure. Risk can be defined in general as the probability (chance) of injury, illness, or death resulting from some activity. Low-dose effects are those that might be caused by doses of less than 20 rem (0.2 Sv), whether delivered acutely or spread out over a period as long as a year (Taylor 1996). Most of the radiation exposures that humans receive are very close to background levels. Moreover, many sources emit radiation that is well below natural background levels. This makes it extremely difficult to isolate its effects. For this reason, government agencies make the conservative (cautious) assumption that any increase in radiation exposure is accompanied by an increased risk of health effects. Cancer is considered by most scientists to be the primary health effect from long-term exposure to low levels of radiation while each radionuclide represents a somewhat different health risk. A 2011 report by the U.S. Environmental Protection Agency (EPA) estimated a $5.8 \times 10^{-2}$ $Gy^{-1}$ cancer mortality risk coefficient for uniform whole-body exposure throughout life at a constant dose rate. Given a 1 gray (100 rad) ionizing radiation lifetime exposure this corresponds to 580 deaths, above normal cancer mortality rates, within an exposure group of 10,000 people. For low-linear energy transfer radiation (i.e., beta and gamma radiation) the dose equivalent in Sv (100 rem) is numerically equal to the absorbed dose in Gy (100 rad). Therefore, if each person in a group of 10,000 people is exposed to 1 rem (0.01 Sv) of ionizing radiation in small doses over a lifetime, we would expect around six people to die of cancer than would otherwise. For perspective, most people living on the eastern Snake River Plain receive over 381 mrem (3.8 mSv) every year from natural background sources of radiation.

DOE limits the dose to a member of the public from all sources and pathways to 100 mrem (1 mSv) and the dose from the air pathway only to 10 mrem (0.1 mSv) (DOE O 458.1). The doses estimated to maximally exposed individuals from INL Site releases are typically well below 1 mrem per year.

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*Northwest Indian Paintbrush and Bombus*

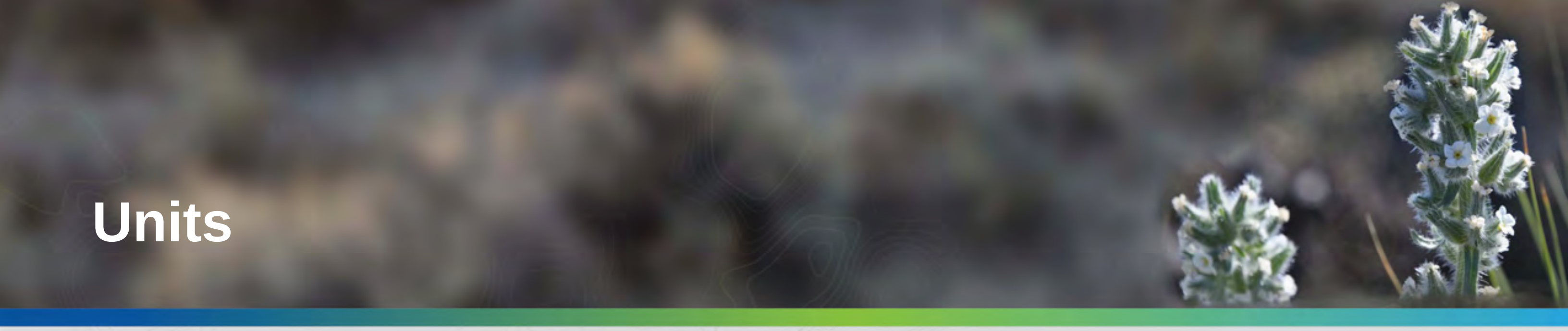
# Acronyms

| | |
|---|---|
| AFV | alternative fuel vehicle |
| ANL | Argonne National Laboratory |
| ARP | Accelerated Retrieval Project |
| ATR | Advanced Test Reactor |
| BBS | breeding bird survey |
| BCG | Biota Concentration Guide |
| BEA | Battelle Energy Alliance, LLC |
| BLM | Bureau of Land Management |
| BMP | best management practices |
| BRR | Biological Resource Review |
| C&D | construction and demolition |
| CA | corrective action |
| CAA | Clean Air Act |
| CAES | Center for Advanced Energy Studies |
| CAP | criteria air pollutant |
| CAP88-PC | Clean Air Act Assessment Package-1988 computer model, PC |
| CARP | Climate Adaptation and Resilience Plan |
| CCA | Candidate Conservation Agreement |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFA | Central Facilities Area |
| CFR | Code of Federal Regulations |
| CITRC | Critical Infrastructure Test Range Complex |
| CTF | Contained Test Facility |
| CWA | Clean Water Act |
| CWP | Cold Waste Pond |
| CY | calendar year |
| D&D | decontamination and decommissioning |
| DCS | Derived Concentration Standard |
| DEQ | Department of Environmental Quality (state of Idaho) |
| DEQ-IOP | Department of Environmental Quality – INL Oversight Program |
| DOE | U.S. Department of Energy |
| DOE-ID | U.S. Department of Energy, Idaho Operations Office |
| DOSEMM | dose multi-media |
| DQO | data quality objective |
| EA | Environmental Assessment |
| EAL | Environmental Assessments Laboratory |
| EBR-I | Experimental Breeder Reactor-I |
| ECP | Environmental Compliance Permits |
| EFS | Experimental Field Station |
| EMS | Environmental Management System |
| EO | Executive Order |
| EPA | U.S. Environmental Protection Agency |
| EPCRA | Emergency Planning and Community Right-to-Know Act |
| EPEAT | Electronic Product Environmental Assessment Tool |
| EPI | emergency plan implementing procedures |
| EROB | Engineering Research Office Building |
| ESA | Endangered Species Act |
| ESER | Environmental Surveillance, Education, and Research |
| ESPC | Energy Savings Performance Contract |
| ESRP | Eastern Snake River Plain |
| EV | electric vehicle |
| FCF | Fuel Conditioning Facility |
| FFA/CO | Federal Facility Agreement and Consent Order |

| | |
|---|---|
| FIFRA | Federal Insecticide, Fungicide, and Rodenticide Act |
| FWS | U.S. Fish and Wildlife Service |
| FY | fiscal year |
| GPRS | Global Positioning Radiometric Scanner |
| HAA5 | haloacetic acids |
| HEU | highly enriched uranium |
| HFC | hydrofluorocarbons |
| HLW | high level waste |
| HYSPLIT | Hybrid Single-particle Lagrangian Integrated Trajectory |
| IC | institutional control |
| ICDF | Idaho CERCLA Disposal Facility |
| ICP | Idaho Cleanup Project |
| ICPP | Idaho Chemical Processing Plant |
| IDAPA | Idaho Administrative Procedures Act |
| IDFG | Idaho Department of Fish and Game |
| INEEL | Idaho National Engineering and Environmental Laboratory |
| INL | Idaho National Laboratory |
| INTEC | Idaho Nuclear Technology and Engineering Center (formerly Idaho Chemical Processing Plant) |
| IRC | INL Research Center |
| ISA | Idaho Settlement Agreement |
| ISB | in situ bioremediation |
| ISO | International Organization for Standardization |
| IUPAC | International Union of Pure and Applied Chemistry |
| IWCS | Industrial Wastewater Collection System |
| IWD | Industrial Waste Ditch |
| IWTU | Integrated Waste Treatment Unit |
| LAN | local area network |
| LCS | laboratory control spike |
| LCSD | laboratory control spike duplicate |
| LED | light emitting diode |
| LLW | low-level waste |
| LTV | long-term vegetation |
| Ma | million years |
| MAPEP | Mixed Analyte Performance Evaluation Program |
| MCL | maximum contaminant level |
| MEI | maximally exposed individual |
| MFC | Materials and Fuels Complex |
| MLLW | mixed low-level waste |
| MLMS | multilevel monitoring system |
| MS | matrix spike |
| MSD | matrix spike duplicate |
| MVMS | Mountain View Middle School |
| N&HS | National and Homeland Security |
| NA | not applicable |
| NAREL | National Analytical Radiation Environmental Laboratory |
| NCRP | National Council on Radiation Protection and Measurements |
| NFPA | National Fire Protection Association |
| ND | not detected |
| NEPA | National Environmental Policy Act |
| NERP | National Environmental Research Park |
| NESHAP | National Emission Standards for Hazardous Air Pollutants |
| NM | not measured |
| NOAA | National Oceanic and Atmospheric Administration |
| NON/CO | Notice of Noncompliance/Consent Order |
| NS | no sample |
| O&M | Operations & Maintenance |
| OSLD | optically stimulated luminescence dosimeter |
| PCB | polychlorinated biphenyls |
| PCS | primary constituent standard |
| PE | performance evaluation |

| | |
|---|---|
| PFAF | perfluoroalkyl substance |
| PFOA | perfluorooctanic acid |
| PFOS | perfluorooctane sulfonate |
| PI | principal investigator |
| PL | primary line |
| PR | principal researcher |
| PUE | power usage effectiveness |
| QA | Quality Assurance |
| QC | Quality Control |
| QSM | Quality System Manual |
| RCRA | Resource Conservation and Recovery Act |
| REC | Research and Education Campus |
| RESL | Radiological and Environmental Sciences Laboratory |
| RHLLW | Remote Handled Low-level Waste Disposal Facility |
| RI/FS | Remedial Investigation/Feasibility Study |
| ROD | Record of Decision |
| RRTR-NTR | Radiological Response Training Range – Northern Test Range |
| RWMC | Radioactive Waste Management Complex |
| SDA | Subsurface Disposal Area |
| SGCA | Sage-grouse Conservation Area |
| SMC | Specific Manufacturing Capability |
| SMCL | secondary maximum contaminant level |
| SNF | spent nuclear fuel |
| SOC | synthetic organic compound |
| SSER | Sagebrush Steppe Ecosystem Reserve |
| STP | Sewage Treatment Plant |
| TAN | Test Area North |
| TCE | trichloroethylene |
| TLD | thermoluminescent dosimeter |
| TREAT | Transient Reactor Experiment and Test Facility |
| TRU | transuranic |
| TSCA | Toxic Substances Control Act |
| TTHM | total trihalomethane |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| UTL | Upper Tolerance Limit |
| UTV | utility task vehicle |
| VOC | volatile organic compound |
| WAG | waste area group |
| WFMC | Wildland Fire Management Committee |
| WIPP | Waste Isolation Pilot Plant |
| WMF | Waste Management Facility |
| WNS | white-nose syndrome |
| YOY | year over year |

*Scarab beetle*



# Units

| | |
|---|---|
| Bq | becquerel |
| C | Celsius |
| cfm | cubic feet per minute |
| CFU | colony forming unit |
| Ci | curie |
| cm | centimeter |
| cps | counts per second |
| d | day |
| F | Fahrenheit |
| ft | feet |
| g | gram |
| gal | gallon |
| Gy | gray |
| ha | hectare |
| keV | kilo-electron-volts |
| kg | kilograms ($10^{3}$) gram |
| km | kilometer ($10^{3}$) meter |
| L | liter |
| lb | pound |
| m | meter |
| µCi | microcurie ($10^{-6}$) curies |
| µg | microgram ($10^{-6}$) grams |
| µR | microroentgen ($10^{-6}$) roentgen |
| µS | microsiemen ($10^{-6}$) siemen |
| µSv | microsievert ($10^{-6}$) sievert |
| Ma | million years |
| mCi | millicurie ($10^{-3}$) curies |
| MeV | mega electron volt |
| mg | milligram ($10^{-3}$) grams |
| MG | million gallons |
| mGy | milligray ($10^{-3}$) gray |
| Ml | million liters |
| mi | mile |
| min | minute |
| mL | milliliter ($10^{-3}$) liter |
| mR | milliroentgen ($10^{-3}$) roentgen |
| mrad | milliard ($10^{-3}$) rad |
| mSv | millisievert ($10^{-3}$) sievert |
| oz | ounce |
| pCi | picocurie ($10^{-12}$ curies) |
| R | roentgen |
| rad | radiation absorbed dose |
| rem | roentgen equivalent man |
| Sv | sievert |
| yd | yard |
| yr | year |

*Gray-crowned Rosy Finch*