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Technical Basis for Environmental Monitoring and Surveillance at the Idaho National Laboratory Site

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ACRONYMS

ALARA	as low as reasonably achievable
AMWTP	Advanced Mixed Waste Treatment Project
ANL–W	Argonne National Laboratory–West
ASER	annual site environmental report
ARP	Accelerated Retrieval Project
ATR	Advanced Test Reactor
BEA	Battelle Energy Alliance, LLC
BLM	U.S. Bureau of Land Management
BLR	Big Lost River
CAES	Center for Advanced Energy Studies
CEM	continuous emission monitoring
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
CITRC	Critical Infrastructure Test Range Complex
COC	Contaminants of Concern
CWI	CH2M-WG Idaho, LLC
CWP	Cold Waste Pond
D&D	decontamination and decommissioning
DCG	derived concentration guide
DCS	derived concentration standard
DEQ	Idaho Department of Environmental Quality
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy, Idaho Operations Office
EBR-I	Experimental Breeder Reactor I
EDE	effective dose equivalent
EPA	Environmental Protection Agency
ESER	Environmental Surveillance, Education, and Research (Program)
ESRP	Eastern Snake River Plain
ESRPA	Eastern Snake River Plain Aquifer
ETR	Engineering Test Reactor
FCF	Fuel Conditioning Facility
gpd	gallons per day
gpm	gallons per minute

GSS	Gonzales-Stoller Surveillance, LLC
HDPE	high density polyethylene
HFEF	Hot Fuel Examination Facility
HSS	DOE Office of Health, Safety, and Security
ICDF	Idaho CERCLA Disposal Facility
ICP	Idaho Cleanup Project
IDAPA	Idaho Administrative Procedures Act
IDFG	Idaho Department of Fish and Game
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
IOP	INL Oversight Program
IRC	INL Research Center
IWRP	Industrial Wastewater Reuse Permit
ITG	Idaho Treatment Group, LLC
IWA	Industrial Wastewater Discharge Permit
IWP	Industrial Waste Pond
IWTU	Integrated Waste Treatment Unit
LI	Laboratory Instruction
LOFT	Loss of Fluid Test Facility
LLMW	low-level mixed waste
MDA	minimum detectable activity
MDC	minimum detectable concentration
MEI	maximally exposed individual
MFC	Materials and Fuels Complex
M&O	management and operating
MTR	Materials Test Reactor
NERP	National Environmental Research Park
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
NOx	nitrogen oxides
NRAD	Neutron Radiography Reactor
NRC	Nuclear Regulatory Commission
NRTS	National Reactor Testing Station
NRF	Naval Reactors Facility
PBF	Power Burst Facility

PER	Power Excursion Reactor
POTW	publicly-owned treatment works
RCRA	Resource Conservation and Recovery Act
REC	Research and Education Campus
RESL	Radiological and Environmental Sciences Laboratory
R&D	research and development
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
STF	Sewage Treatment Facility
SMC	Specific Manufacturing Capability
SO_2	sulfur dioxide
SPERT	Special Excursion Reactor Test
SRPA	Snake River Plain Aquifer
SWS	Service Waste System
TAN	Test Area North
TED	total effective dose
TDS	total dissolved solids
TKN	Total Kjeldahl nitrogen
USGS	United States Geological Survey
VOCs	volatile organic compounds
WMF	Waste Management Facility

TERMS AND DEFINITIONS

acute—A high **dose** of **ionizing** radiation received in a short time.

administrative controls—Limits on or changes in work schedules or operations that reduce **exposure** to a hazard.

ambient air—The surrounding **atmosphere**, usually the outside air.

analyte—A substance measured in the laboratory.

aquifer—An underground **source** of water.

area source—A collection of individually small emission sources within a single geographic area that produces similar air pollutants. Area sources are classified together by air quality control agencies to facilitate estimating emissions from their activities because they are usually too small or too numerous to be inventoried individually.

atmosphere—The layer of air surrounding the earth.

atomic nucleus—The very dense region consisting of **protons** and **neutrons** at the center of an atom.

background level—An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

biota—The plants and animals of a region.

biotic intrusion—The penetration into buried radioactive waste by plants, via roots, or by burrowing mammals.

Carcinogen—A substance that causes cancer or is believed to cause cancer.

chronic—A low **dose** of ionizing radiation received either continuously or intermittently over a prolonged period of time.

COC (chain-of-custody)—A method for documenting the history and possession of a sample from the time of collection, through analysis and data reporting, to its final disposition.

cold waste pond—A **permitted** pond located near the southeast corner of the ATR Complex.

composite sample—A sample of an environmental medium containing a certain number of sample portions collected over a period of time, possibly from different locations. The constituent samples may or may not be collected at equal time intervals over a predefined period of time, such as 24 hours.

concentration—The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

conceptual model—A diagram that defines entities, objects, or conditions of a system and the relationships between them.

contamination—Unwanted radioactive and/or hazardous material that is dispersed on or in equipment, structures, objects, air, soil, or water.

continuous emissions monitoring—A system that constantly collects and records data from permitted sources, such as stacks, that are used as a means to comply with air emission standards such as state-permitted emission standards.

demographics—The current statistical characteristics of a population.

deposition—The process of particles collecting or depositing themselves on solid surfaces, decreasing the concentration of the particles in the air.

detection limit—The lowest concentration of a substance that can reliably be distinguished from a zero concentration.

dispersion—The environmental transport of contaminants through air or water. In air, contaminants in an airborne release are transported downwind and are affected by turbulent eddies in the atmosphere, which diffuse the effluent material as the entire plume is being transported downwind. With respect to groundwater, it is the phenomenon by which dissolved material tends to spread out from the path it would follow simply due to the motion of the groundwater in which it is dissolved. It causes dilution of the dissolved material. It occurs because of physical mixing during fluid movement between the solid grains in the rock (fluid in the center of the pore moves faster than fluid at the boundary of the pore) and the crossing of flow paths as the fluid flows around the solid grains in the rock and because of molecular diffusion.

DOE (Department of Energy)—The federal agency that promotes scientific and technical innovation to support the national, economic, and energy security of the United States.

dose—Short for **radiation dose,** the amount of energy from ionizing radiation that is actually absorbed by the body.

dosimeter—A portable detection device for measuring exposure to ionizing radiation.

DQO (Data Quality Objective)—A process developed by **EPA** for facilities to use when describing their environmental monitoring matrices, sampling methods, locations, frequencies, and measured parameters, as well as methods and procedures for data collection, analysis, maintenance, reporting, and archiving. The DQO process also addresses data that monitor quality assurance and quality control.

ecosystem—A system formed by the interaction of a community of organisms with their environment.

effective dose equivalent—A value used to express the health risk from radiation exposure to tissue in terms of an equivalent whole-body exposure. It is a “normalized” value that allows the risk from radiation exposure received by a specific organ or part of the body to be compared with the risk due to whole-body exposure. The EDE equals the sum of the doses to different organs of the body multiplied by their respective weighting factors. It includes the sum of the EDE due to radiation from sources external to the body and the committed effective dose equivalent due to the internal deposition of radionuclides. EDE is typically expressed in rems and is calculated for air emissions at the INL to demonstrate compliance with the 10 mrem standard set by 40 CRF 61, Subpart H, “National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities.”

effluent—Any treated or untreated air emission or liquid discharge, including storm-water runoff.

electron—(Symbol: e^-) A subatomic particle with a negative elementary electric charge.

emissions—Any gaseous or particulate matter discharged to the **atmosphere**.

engineering controls—Designing equipment, tools, and workplaces to reduce workers’ exposures to factors that cause harm.

entrainment—To carry (suspended particles, for example) along in a current.

environmental surveillance—The collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media from DOE sites and their environs and the measurement of external radiation for purposes of demonstrating compliance with applicable standards, assessing radiation exposure to members of the public, and assessing effects, if any, on the environment.

evaporation—The process by which a liquid (generally water) converts to a gas.

evaporation pond—An artificial pond designed to evaporate water by sunlight and exposure to ambient temperatures.

exposure—Generally, contact of an organism with a harmful agent. In this document, humans exposed to ionizing radiation, either by direct radiation or contamination.

exposure pathway—The route a substance takes from its source (where it began) to its end point (where it ends), and how people may come into contact with (or be exposed to) it.

exposure routes—Means by which people may be exposed to hazardous environmental agents. Some basic routes are inhalation, ingestion, injection, dermal contact, and direct exposure.

fallout—Radioactive material, made airborne as a result of aboveground nuclear weapons testing, that has been deposited on the Earth's surface.

gross alpha/beta—Analytic radiation screening method. No radionuclide-specific information is obtained.

HPGe—High purity germanium, a type of semiconductor that is used to detect, identify, and quantify gamma-emitting radionuclides.

ingestion—The act of swallowing something through eating, drinking, or mouthing objects.

inhalation—The act of breathing in air or other substances, including agents of exposure.

immersion—A potential **exposure pathway**; possible in scenarios with contaminated water.

injection—The insertion of a material, usually a liquid, into another material.

injection well—A vertical pipe in the ground into which water, other liquids, or gases are pumped or allowed to flow.

INL—The portion of the INL Site that Battelle Energy Alliance manages and operates.

INL Site—The area within the boundaries of the 890-square-mile (2,300 km^2) complex located between the town of Arco to the west and the cities of Idaho Falls and Blackfoot to the east.

in situ—For this document: In place, direct measurements of environmental gamma-emitting radionuclides using tripod-mounted high purity germanium (HPGe) detectors.

ionizing radiation—Radiation with sufficient energy to remove **electrons** from atoms or molecules; units, generally reported in **rems** or **sieverts.**

irrigation—The process of inundating with water.

leaching—The loss of water-soluble contaminants from solid buried waste through contact with water.

MEI (maximally exposed individual)—A hypothetical individual whose location and habits tend to maximize his/her radiation dose, resulting in a dose higher than that received by other individuals in the general population. The MEI is used to demonstrate that air emissions at INL are in compliance with the 10 mrem standard set by 40 CRF 61, Subpart H, "National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities."

media—Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

molecular sieve—Material containing tiny pores of a precise and uniform size that is used as an adsorbent for gases and liquids.

monitoring—The collection and analysis of samples or measurements of effluents and emissions for the purpose of characterizing and quantifying contaminants and demonstrating compliance with applicable standards or **permits**.

neutron—(Symbol n or n0) A subatomic particle found in the **atomic nucleus** with no net electric charge and a mass slightly larger than that of a proton.

non-radiological contaminants—A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

pathway analysis—An evaluation of the potential ways a release could impact human health and the environment. A pathway analysis generally includes a look at potential soil contamination impacts, air pollution impacts, ecological impacts, including endangered species assessment, and water pollution impacts.

percolation—The process of a liquid slowly passing through a material such as sediment.

percolation pond—A pond (usually man-made) designed to allow water to percolate slowly into the ground.

permit—An authorization issued by a federal, state, or local regulatory agency. Permits grant permission to operate, to discharge, to construct, and may include emission/effluent limits and other requirements, such as the use of pollution control devices, monitoring, record keeping and reporting.

planchet—A small shallow metal container in which a radioactive substance is deposited for measurement of its activity.

plume—A body of contaminated **groundwater** or polluted air flowing from a specific source.

point source—Any confined and discrete conveyance (e.g., pipe, ditch, well, or stack) of a discharge.

proton—(Symbol p or p+) A subatomic particle found in the **atomic nucleus** with a positive electric charge of 1 elementary charge. One or more protons are present in the nucleus of each atom. The number of protons in each atom is its atomic number.

QA (quality assurance)—In environmental monitoring, any action to ensure the reliability of monitoring and measurement data. Aspects of QA include procedures, inter-laboratory comparison studies, evaluations, and documentation.

QC (quality control)—In environmental monitoring, the routine application of procedures to obtain the required standards of performance in monitoring and measurement processes. QC procedures include calibration of instruments, control charts, and analysis of replicate and duplicate samples.

radiation—Excess energy released in the form of charged particles or electromagnetic waves. Some atoms possess excess energy, causing them to be physically unstable until radiation is released, moving the atom toward a more stable state.

radiation dose—The amount of energy from radiation that is actually absorbed by the body.

radioactivity—The spontaneous transition of an unstable **atomic nucleus** from a higher energy to a lower energy state. This transition is accompanied by the release of a charged particle or electromagnetic waves from the atom. Also known as “activity.”

radionuclide—A radioactive element characterized by the number of **protons** and **neutrons** in the nucleus. There are several hundred known radionuclides, both artificially produced and naturally occurring.

radiological contaminants—The presence of radioactive substances where their presence is unintended.

receptors—Humans, animals or plants that receive a dose or exposure.

release—Spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of a hazardous substance, pollutant, or contaminant into the environment. The National Contingency Plan also defines the term to include a threat of release.

Research and Education Complex—The portion of INL off-Site of the 890-square-mile (2,300 km2) complex located between Arco, Blackfoot, and Idaho Falls. It occupies 30 facilities, including laboratories.

re-suspension—The process by which radioactive particles become airborne after being deposited on the ground, potentially becoming a secondary source of contamination long after a release has stopped.

roentgen—(Symbol R) A unit of exposure to ionizing radiation. It is the amount of gamma or x-rays required to produce ions carrying one electrostatic unit of electrical charge in one cubic centimeter of dry air under standard conditions. It is named after the German scientist Wilhelm Roentgen, who discovered x-rays.

roentgen equivalent man—(Symbol rem) A unit by which human radiation dose is assessed (*see also* **Sv**). The rem is a risk-based value used to estimate the potential health effects to an exposed individual or population. 100 rem = 1 sievert.

source—The point at which something derives or is released.

source term—The types, quantities, and chemical forms of the radionuclides that encompass the source of potential exposure to radioactivity.

submersion—A type of exposure in which an entity is dunked in water or other fluid.

surveillance—Sampling for contaminants in air, water, sediment, soil, food stuffs, plants, and animals, either by directly measuring or by collecting and analyzing samples.

sievert—(Symbol s) A unit for assessing the risk of human radiation dose, used internationally and, with increasing frequency, in the United States. 1 s = 100 rem.

target analytes—The set of substances coming from INL that are monitored because they could present a risk to human health and the environment.

transport pathway—A means by which contaminants move from a **source** to receptors such as air or water.

uptake—The taking in or absorption of a substance by a living organism or bodily organ.

warm waste pond—A remediated three-celled percolation pond that received liquid waste other than sewage from ATR between about 1952 and 1992.

watershed—The region or area drained by a river, stream, etc.; drainage area.

wind rose—A diagram that shows the frequency of wind from different directions at a specific location.

Technical Basis for Environmental Monitoring and Surveillance at the Idaho National Laboratory

1. INTRODUCTION

1.1 Purpose and Scope

The Idaho National Laboratory Site (INL Site), with an area of 2305 km^2 (890 mi^2), is located west of Idaho Falls, Idaho. During World War II, the U.S. Navy and U.S. Army used a large portion of the area that is now the INL Site as a gunnery and bombing range. In 1949, the U.S. Atomic Energy Commission established the National Reactor Testing Station on the Site. Its purpose was to conduct nuclear energy research and related activities. The National Reactor Testing Station was renamed three times: as Idaho National Engineering Laboratory in 1974, as Idaho National Engineering and Environmental Laboratory in 1997, and as INL in 2005.

The term Idaho National Laboratory (INL) is synonymous with the portion of the INL Site that Battelle Energy Alliance manages and operates. INL's current mission is to ensure the nation's energy security with safe, competitive, and sustainable energy systems and unique national and homeland security capabilities. The vision for INL is to be the preeminent nuclear-energy laboratory, with synergistic, world-class, multi-program capabilities and partnerships. Two of INL's site-strategic objectives are to develop public trust and confidence in Site operations and nuclear programs and to demonstrate sound environmental stewardship.

Environmental monitoring has been performed at the INL Site—by the U.S. Department of Energy, Idaho Operations Office (DOE-ID) and its predecessors, the Atomic Energy Commission and Energy Research and Development Administration, as well as by other federal agencies, various contractors, and state agencies—since its inception in 1949. The organization of environmental monitoring programs has remained fairly consistent throughout much of the history of the INL Site. The Atomic Energy Commission's Health Services Laboratory, later named the DOE-ID's Radiological and Environmental Sciences Laboratory, was responsible for conducting most environmental surveillance tasks from the early 1950s to 1993 both on and off the INL Site. Beginning in 1993, contractors operating the various facilities were responsible for monitoring activities performed within the facility boundaries, including effluent monitoring.

At the request of DOE-ID for the purposes of continuous improvement, the U.S. Department of Energy (DOE) Office of Independent Oversight, within the Office of Health, Safety, and Security (HSS), performed an assessment of the environmental monitoring and surveillance at the INL Site during March and April 2010 (HSS 2010). The independent assessment focused on determining whether the current INL Site environmental monitoring program components are adequate to evaluate all significant potential impacts from laboratory and cleanup operations on the surrounding environment and the public; potential pathways of contaminant emission; and on identifying strengths, lessons-learned, and opportunities for improvement in the INL Site environmental monitoring and surveillance program.

Consistent with the DOE-ID requested scope, the environmental monitoring assessment did not assess compliance with environmental laws and regulations, permit requirements, or certain federal compliance-driven environmental monitoring activities, such as air-effluent (stack) monitoring, dose calculation (National Emission Standards for Hazardous Air Pollutants), and drinking water and groundwater monitoring.

The 2010 HSS assessment states in the Executive Summary, "Overall, environmental monitoring and surveillance activities at the INL Site are comprehensive and meet the basic objectives of applicable DOE requirements." However, they also identified four main areas for enhancement:

1. The current programmatic design does not provide a complete definition of the technical basis for all environmental monitoring and surveillance activities being conducted at the INL Site
2. Some aspects of the program were not sufficiently coordinated and communicated among contractors
3. Some information in published environmental reports was not fully accurate and clear
4. Implementation of certain quality-assurance protocols and media-specific monitoring and surveillance actions were not fully effective.

The Technical Basis for Environmental Monitoring and Surveillance at the Idaho National Laboratory was prepared to address the areas for enhancement identified by the HSS assessment, emphasizing the scientific basis for the radiological environmental surveillance activities. Environmental surveillance monitoring is driven by DOE orders and is performed to identify key contaminants released into the environment, evaluate different pathways through which contaminants move in the environment, and determine the potential effects of these contaminants on the environment. The monitoring performed at the INL Site to demonstrate compliance with permits and other regulatory requirements is summarized in the Idaho National Laboratory Site Environmental Monitoring Plan (DOE-ID 2012a).

1.2 Approach

According to DOE guidance (DOE 1991), the initial step used to plan an environmental monitoring program is to develop a site conceptual-exposure-pathway model which provides the framework upon which critical pathways from site releases through the environment to human and biotic receptors can be identified. An essential preparative step to developing the conceptual model is to define the region being evaluated, including location and composition of sources, environmental characteristics of the potentially impacted area, and potential receptors. The conceptual model should represent the interaction of INL Site facility releases with area features, natural forces, and ecological characteristics that creates a pathway by which a contaminant could travel from a source to a receptor. The relevant pathways at the INL Site are illustrated graphically in the conceptual model presented in Figure 1-1. This figure was constructed based on over 50 years of study of the INL Site and the movement of contaminants through the environment. The major components of the model are 1) sources, 2) transport media, 3) transport pathways, 4) exposure routes, 5) human receptors, and 6) dose. The major transport media through which radionuclides can be transported to humans are 1) air, 2) groundwater, 3) waterfowl, 4) terrestrial game animals, 5) agricultural products, and 6) surface water. The routes by which humans can receive doses are: 1) inhalation, 2) ingestion, and 3) external exposure.

The INL Site has historic releases to groundwater and to surface soil. The groundwater beneath the INL Site is contaminated primarily from historic Advanced Test Reactor (ATR) and Idaho Nuclear Technology and Engineering Center (INTEC) liquid effluent directly injected into the aquifer and from infiltration of effluents released into unlined ponds for approximately 50 years. Therefore, the groundwater pathway to down gradient wells and springs begins primarily with the contaminated groundwater beneath the INL Site. That is, the eastern Snake River Plain aquifer is the transport medium.

The surface soil at and around the Radioactive Waste Management Complex (RWMC) was contaminated primarily by flooding of buried Rocky Flats waste in 1962 and 1969 and subsequent wind transport in the northeast direction (Markham, Puphal, and Filer 1978). The area was subsequently engineered with a diversion dam and spreading areas to divert water during flooding events. In addition, contaminated portions of the burial site were covered with topsoil. Radionuclides (primarily transuranics) detected in the surface soils outside the RWMC were determined to be below EPA guidance for health protection of the general population, except for a few locations adjacent to the RWMC perimeter that are not accessible to the public. Some low, but measureable, concentrations of plutonium isotopes and americium-241 still exist outside the RWMC perimeter fence (Jessmore, Lopez, and Haney 1994).

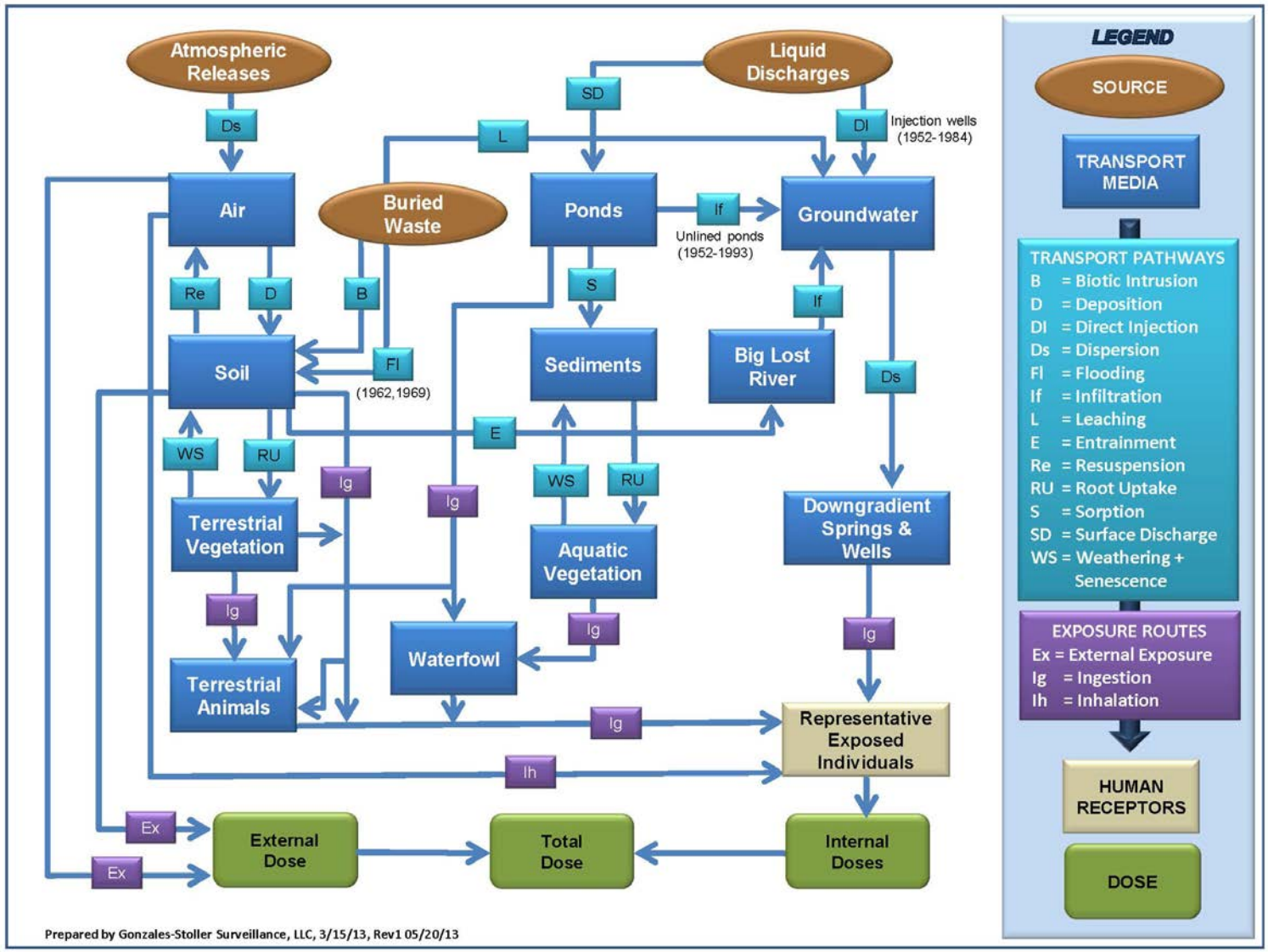

Figure 1-1. Environmental transport pathways and exposure routes contributing to potential doses to humans from INL Site releases.

The pathways shown in Figure 1-1 are not equal in importance (i.e., do not necessarily result in similar doses to a human receptor) or of equal concern to members of the public. Some pathways are included because they may be a concern to stakeholders even though they do not necessarily result in significant doses to human receptors. For example, the Big Lost River is distinctive because it flows through the site, enters the ground at the Big Lost River Sinks, and reemerges via groundwater in down gradient springs along the Snake River. While it is unlikely to contribute to dose, it is nonetheless included in the conceptual model because it is a special pathway of concern to members of the public and stakeholders.

The biotic receptors (plants and animals in their natural environments that may uptake or be exposed to radionuclides) shown in Figure 1-1 are not only a source of dose to humans who eat them, but also receive doses through ingestion of, inhalation of, and exposure to radionuclides in the environment. Based on historical INL Site data and the findings of the DOE's Biota Dose Assessment Committee in development of DOE Standard "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (DOE 2002), biota (plants and animals in their natural environments) access radionuclides and could receive doses primarily through contaminated soils and contaminated wastewater ponds and associated sediments. The air release pathway is not a major source of exposure because biota inhalation and immersion in air was estimated to be minor in comparison (DOE 2002). Historical studies have shown that biota can access buried waste but the level of transport to the surface was insignificant (<0.05%) (Arthur and Markham 1983). Also historical studies on direct exposure to small mammals residing on waste disposal could provide significant exposures (Arthur et al 1986; Halford and Markham 1978). However, cleanup of waste facilities over the years have reduced the significance of this impact to plant and animal populations residing on these areas (DOE-ID 2012b). The screening doses to terrestrial and aquatic biota are reported in the annual Site Environmental Report (e.g., DOE-ID 2012b) and have never exceeded the DOE Biota Concentration Guides since they were first evaluated in 2002.

Although the environmental monitoring and surveillance programs on the INL Site take different approaches on some aspects and may assess different isotopes and pathways, together they provide a comprehensive program which seeks to characterize the sources, transport pathways, and exposure routes shown in Figure 1-1. Together they provide DOE with an assessment of the release, movement, distribution, and impacts of INL Site operations on the worker, public and environment. As stated in the Health, Safety and Security Assessment (HSS 2010), "The environmental monitoring and surveillance activities on the INL Site are comprehensive and effectively support the overall statements in the Annual Site Environmental Report, and the independent assessment did not identify any program vulnerabilities that would affect the ability of the INL Site to detect significant site impacts." The purpose of this document is to develop a technical basis for all aspects of the INL Site surveillance and monitoring programs and to identify enhancements or redundancies to improve the monitoring and surveillance programs.

This document discusses the basis for the environmental monitoring and surveillance programs for the INL Site. The document includes a brief discussion of the preliminary environmental monitoring being performed at INL facilities in Idaho Falls to determine if a detailed evaluation of monitoring requirements is necessary. Chapter 2 presents a brief description of the INL Site. Chapter 3 discusses radiological emissions, and Chapter 4 discusses the exposure routes and environmental pathways, as presented in Figure 1-1.

Chapters 5–14 provide the technical basis for the environmental surveillance monitoring programs. These chapters discuss the monitoring design criteria and the rationale for the monitoring locations, sampling methods, and target analytes. These chapters include a discussion of media-specific recommendations from the HSS assessment.

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2. INL SITE DESCRIPTION

This chapter provides general information on the environmental characteristics of the Site. These comprise the physical nature of the area, including local geography, hydrology, and meteorology, as well as ecological features, including resident plant and animal communities (Section 2.1). The regional demographics of humans potentially impacted by INL Site operations are also presented (Section 2.2).

2.1 Environmental Setting

The following sections provide a brief description of the environmental characteristics associated with the INL Site area. For a more extensive discussion of each of these subjects, see the Annual Site Environmental Report (DOE-ID 2012a), available on the Environmental Surveillance, Education, and Research Program (ESER) website at http://www.gsseser.com/, and the annual Idaho National Laboratory Site Environmental Monitoring Plan (DOE-ID 2012b). The ESER website also provides detailed information on the ecology of the INL Site and provides links to other organizations that study the environment at the INL Site, including National Oceanic and Atmospheric Administration (NOAA) (http://www.noaa.inel.gov/) and the USGS (http://id.water.usgs.gov/).

The INL Site is located in southeastern Idaho and covers approximately 2305 km^2 (890 mi^2) of land (Figure 2-1). Federal lands surround much of the INL Site, including Bureau of Land Management lands and Craters of the Moon National Monument to the southwest, Challis National Forest to the west, and Targhee National Forest to the north (Figure 2-6). Mud Lake Wildlife Management Area, Camas National Wildlife Refuge, and Market Lake Wildlife Management Area are within 80 km (50 mi) of the INL Site. About 60% of the INL Site is open to livestock grazing and hunting is permitted in a limited area on the northwestern portion of the Site.

The INL Site was designated as a National Environmental Research Park (NERP) in 1975 and, as such, all land within the INL Site is protected as an outdoor laboratory where the effects of energy development, industrial activities on the environment, and the complex ecological relationships of this cool desert ecosystem can be studied.

The Site occupies a large, relatively undisturbed expanse of sagebrush-steppe habitat. Approximately 94 percent of the land on the INL Site is open and undeveloped. The INL Site has an average elevation of 1,500 m (4,900 ft) above sea level and is bordered, on the north and west, by mountain ranges and, on the south, by volcanic buttes and open plain. Lands immediately adjacent to the INL Site are open sagebrush steppe, foothills, or agricultural fields. Agriculture is concentrated in areas northeast of the INL Site.

The climate of the high desert environment of the INL Site is characterized by sparse precipitation (less than 22.8 cm/yr [9 in./yr]), warm summers (average daily temperature of 15.7°C [60.3°F]), and cold winters (average daily temperature of –5.2°C [22.6°F]) (DOE-ID 1989). The altitude, intermountain setting, and latitude of the INL Site combine to produce a semiarid climate. Prevailing weather patterns are from the southwest, moving up the Snake River Plain.

Air masses, which gather moisture over the Pacific Ocean, traverse several hundred miles of mountainous terrain before reaching southeastern Idaho. Frequently, the result is dry air and little cloud cover. Solar heating can be intense, with extreme day-to-night temperature fluctuations.

Basalt flows cover most of the plain, producing rolling topography. Vegetation is visually dominated by big sagebrush (*Artemisia tridentata*). Beneath these shrubs are grasses and flowering plants adapted to the harsh climate. A total of 409 plant species have been recorded on the INL Site (Anderson et al. 1996).

Vertebrate animals include small burrowing mammals, snakes, birds, and several game species. Published species records include six fish, one amphibian, nine reptile, 164 bird, and 39 mammal species (Reynolds et al. 1986).

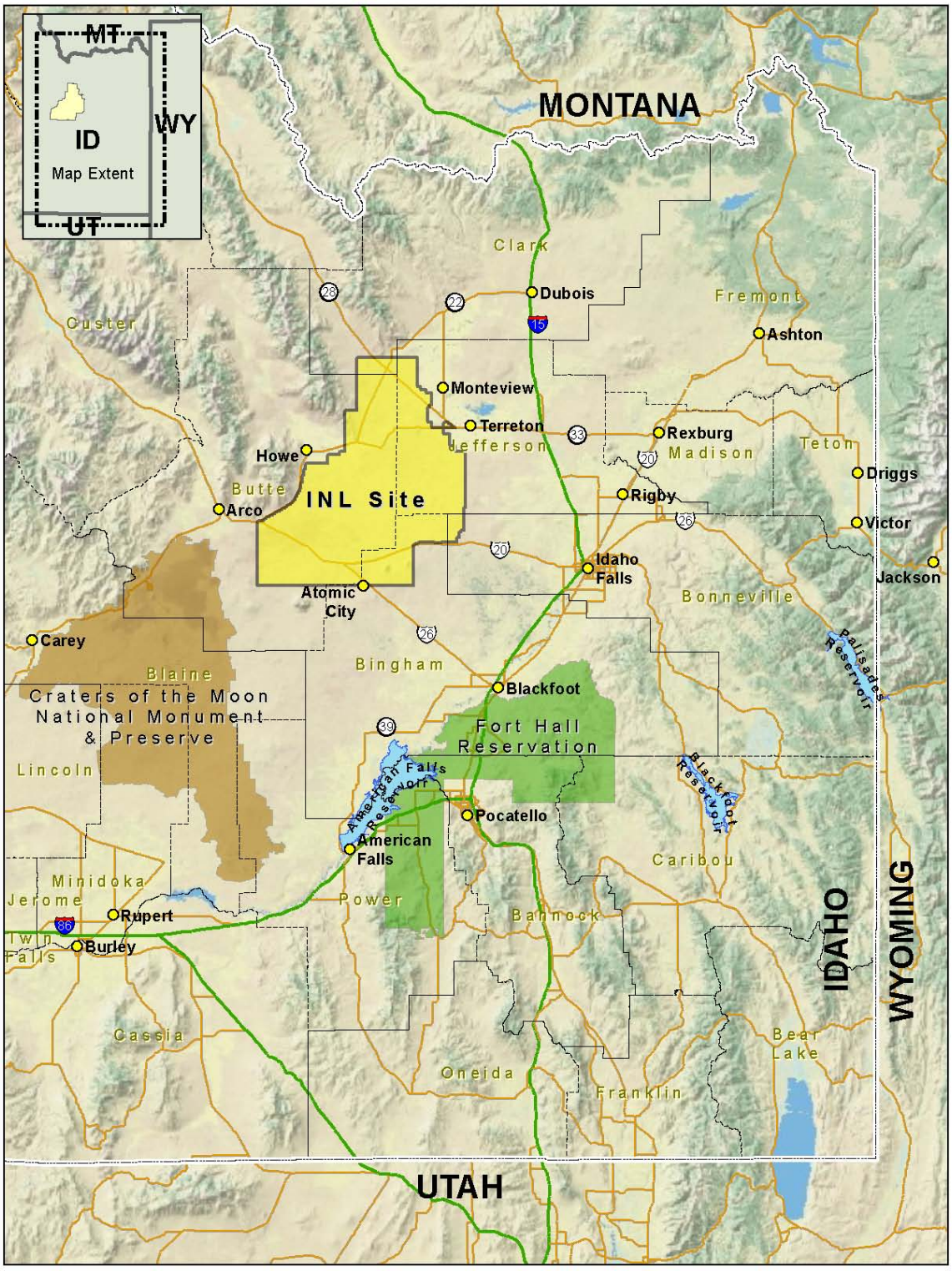

Figure 2-1. Location of the Idaho National Laboratory Site.

The physical nature of eastern Idaho, especially the hydrology and meteorology, plays a major role in how substances can travel from individual facilities to receptors in the region. These aspects are discussed in more detail in Sections 2.1.1 and 2.1.2 below.

2.1.1 Hydrology

The INL Site is located within the Pioneer Basin on the western boundary of the Eastern Snake River Plain (ESRP) (see Figure 2-2). The Pioneer Basin has no surface drainage out of the basin; all the drainages flow to either the playas or the sinks, and there is no outflow from them. Natural surface water near or on the INL Site consists of three streams draining intermountain valleys to the north and northwest of the Site: the Big Lost River (BLR), Birch Creek, and the Little Lost River. All of the channels terminate on the INL Site. Flows from Birch Creek and the Little Lost River seldom reach the INL Site because of irrigation withdrawals upstream. The BLR and Birch Creek may flow onto the INL Site before the irrigation season or during high-water years, but the terminal reaches are usually dry.

The Big Lost River is the major surface water feature on the INL Site. Its waters drain the northeastern portion of the Pioneer Range and southwestern portion of the Little Lost River Range. When flow in the BLR reaches the INL Site, it is either diverted at the INL diversion dam near the RWMC to the spreading areas (a series of four natural depressions) or flows northward across the INL Site. All flow of the BLR that enters onto the INL Site, except for evaporation losses, is recharged to the subsurface.

The need for flood control on the INL Site was first recognized in the early 1950s when downstream facilities (ATR Complex and INTEC) were threatened by localized flooding because of ice jams in the Big Lost River. The INL diversion dam was constructed in 1958 to divert high runoff flows from downstream INL Site facilities.

The primary groundwater source of the region is the Eastern Snake River Plain Aquifer (ESRPA). The ESRPA is approximately 320 km (199 mi) long, 32–97 km (20–60 mi) wide, and encompasses an area of approximately 24,993 km^2 (9,650 mi^2) (Figure 2-3). As such, it is a source of drinking water for more than 300,000 people and supplies irrigation water to a large regional agricultural and aquaculture economy.

The depth to the ESRPA varies from approximately 61 m (200 ft) in the northern part of the INL Site to more than 274 m (900 ft) in the southern part. The aquifer is recharged from infiltrating precipitation and irrigation seepage, runoff from the surrounding highlands, and groundwater underflows from the surrounding watersheds. Groundwater in the ESRPA flows generally to the southwest, although locally the direction of flow is influenced by recharge from rivers, surface water, spreading areas, and heterogeneities in the aquifer. Groundwater flow rates in the vicinity of the INL Site range from approximately 1.5–6.1 m (5–20 ft) per day (Lindholm 1996). The SRPA has been designated as a sole-source aquifer under the Safe Drinking Water Act of 1974 (42 USC § 300f to 300j–26).

All water used at the INL Site comes from the ESRPA via production wells. Upstream of the INL Site, the Big Lost River, Little Lost River, and Birch Creek are used as sources of water for agriculture. The surface water that reaches the INL Site is not used for any purpose. No surface water streams flow off the INL Site with the potential exception of diverted water exiting Spreading Area D during extremely wet or high-water conditions (see Figure 2-2).

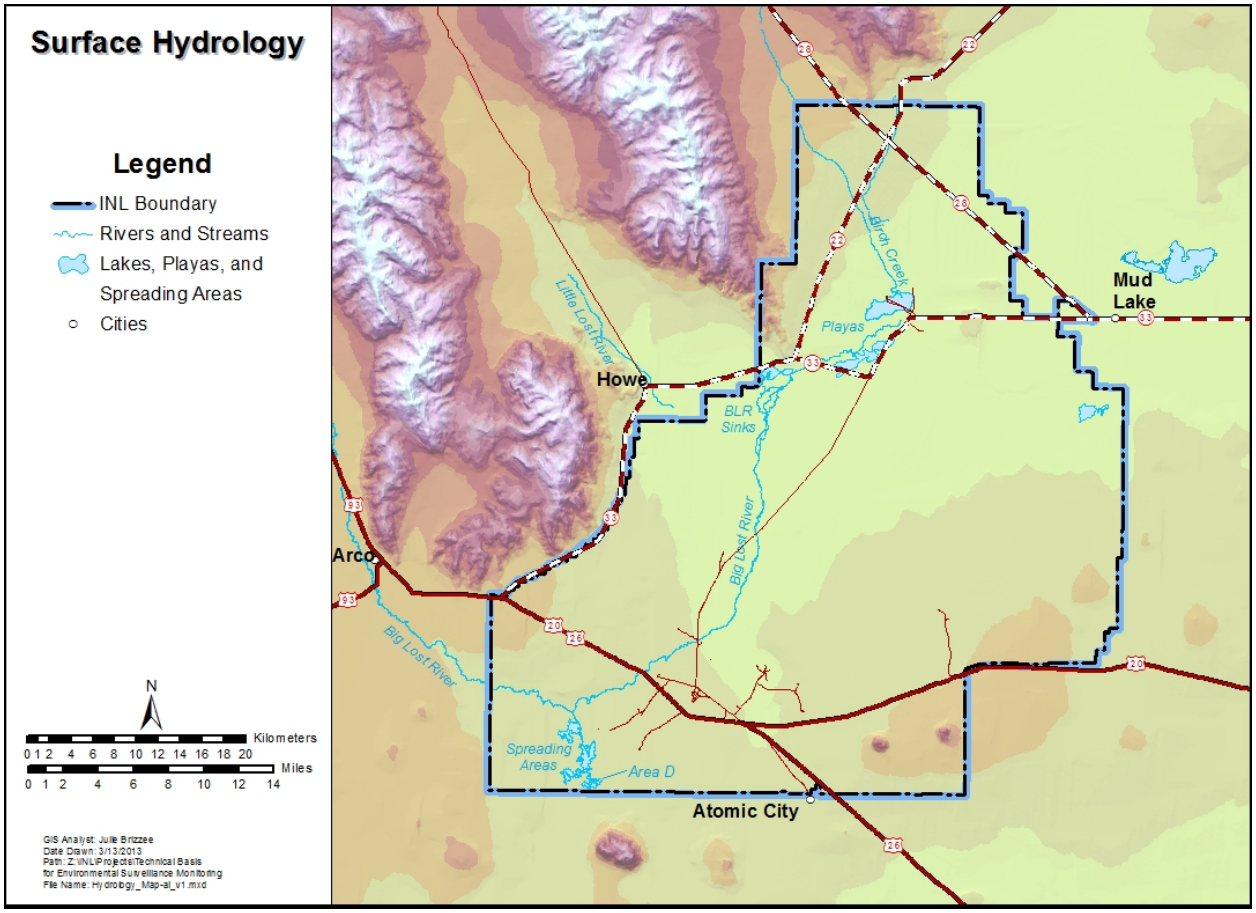

Figure 2-2. Surface hydrology of the Idaho National Laboratory Site showing sinks, playas, spreading areas, and rivers.

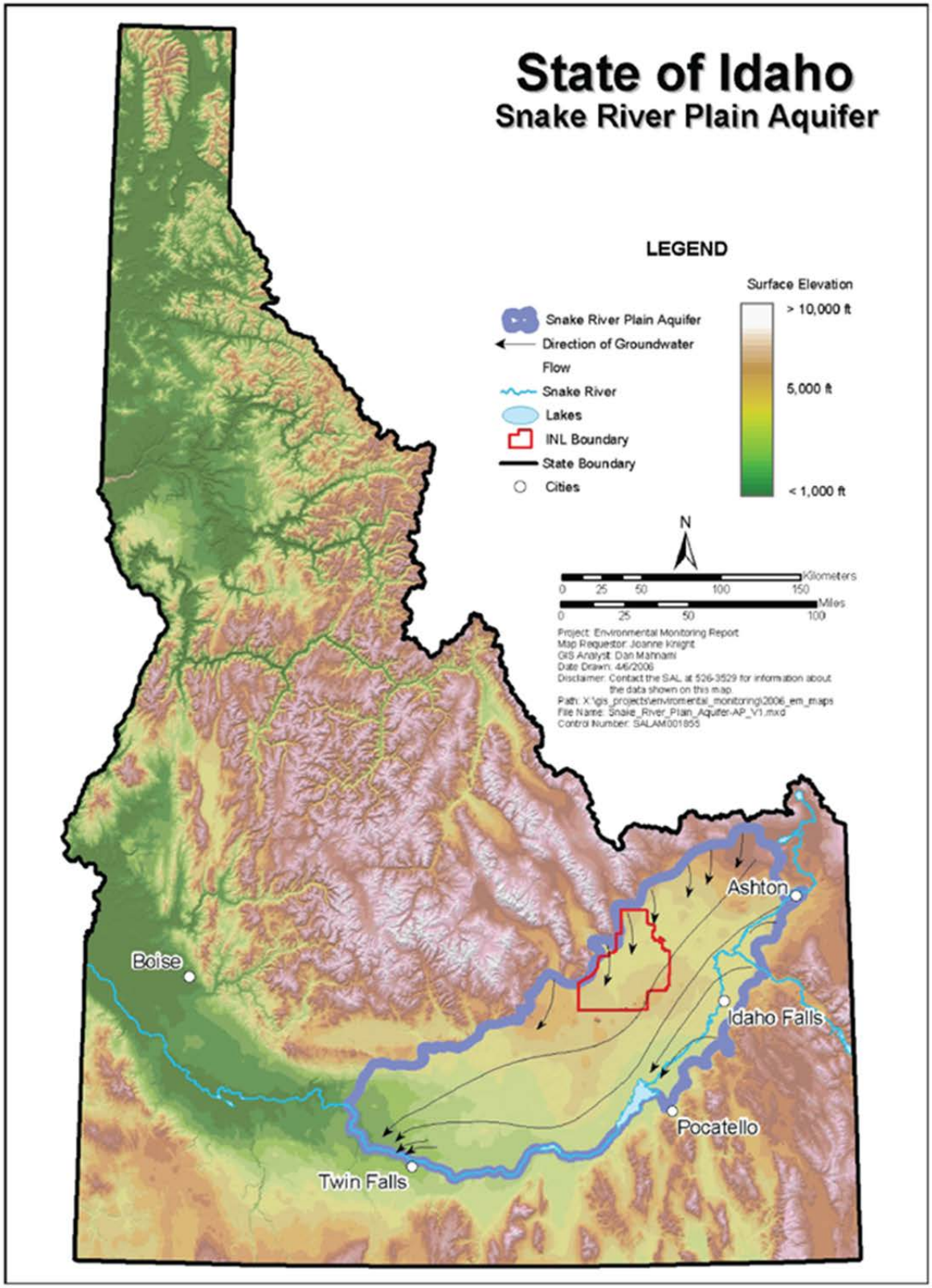

Figure 2-3. Location of the eastern Snake River Plain aquifer.

2.1.2 Meteorology

Meteorology dictates the transport of airborne contamination from sources to exposure media or directly to the receptor. Under differing meteorological conditions, source contaminants may be transported in any direction. However, a southwest wind predominates over the region; the second most frequent winds blow from the northeast (Figure 2-4). Data used to produce the figure were obtained from the NOAA Air Research Laboratory Field Research Division which operates a 33-station, technologically advanced, INL Meteorological Monitoring Network (Mesonet) across and around the INL Site. A description of the INL Mesonet may be found at http://www.noaa.inel.gov/projects/INLMet/INLMet.htm.

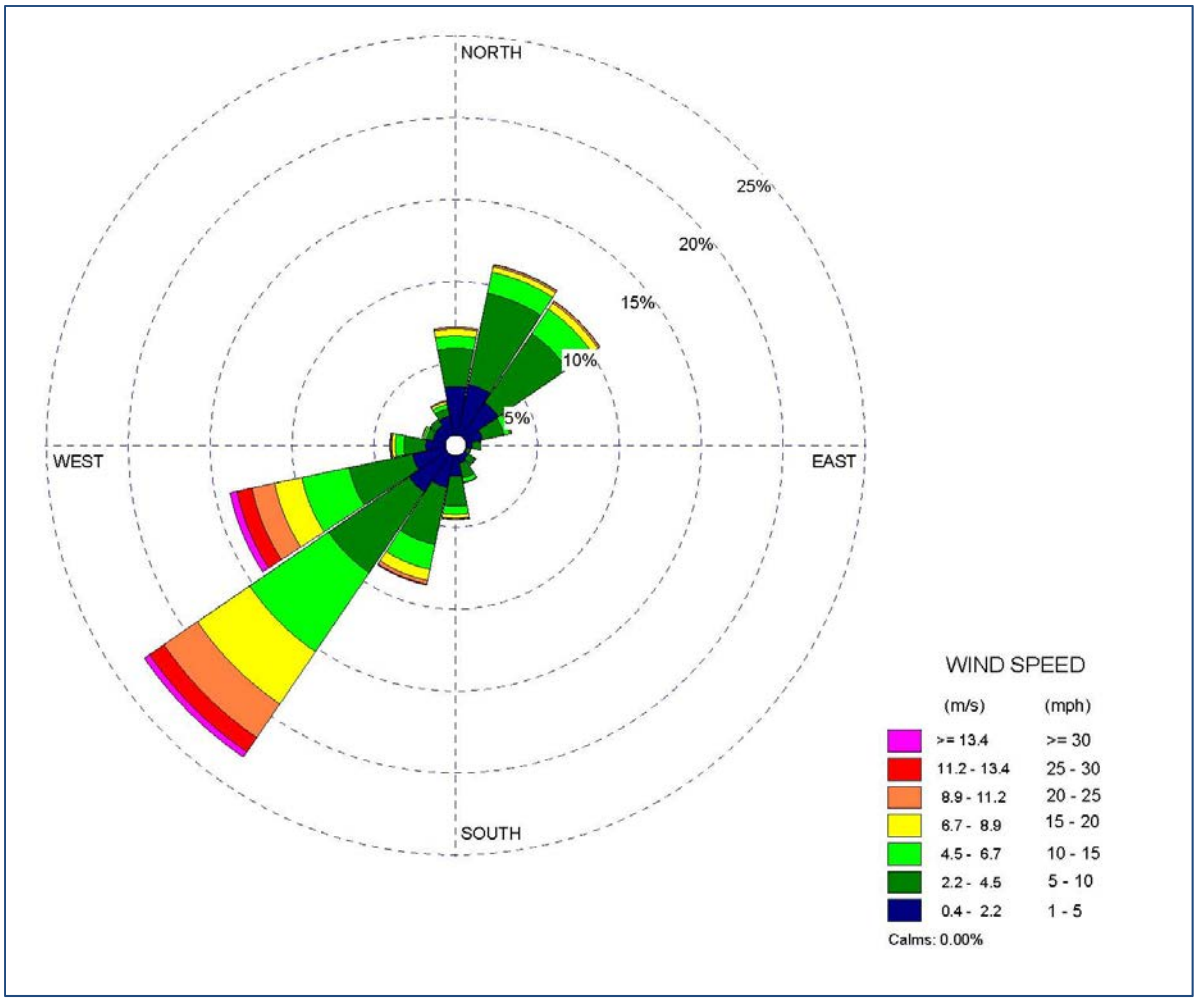

Figure 2-4. Wind rose for the INL Site (January 2000 through December 2004).

Winds at the INL Site are also influenced by:

- Northwesterly, down-valley winds that develop in the Little Lost River and Birch Creek Valleys and blow out onto the Eastern Snake River Plain toward the southeast
- Mountains that realign the westerly winds aloft with the ESRP
- Elevated terrain to the north of the INL Site, above which air cools and descends at night to develop northerly or northeasterly winds
- Reversals in wind direction that occur when shallow surface-layer winds are overcome by winds aloft moving in opposite directions as a result of surface heating or cooling (DOE-ID 1989).

2.2 Demography and Land Use

2.2.1 Demography

Populations potentially affected by INL Site activities include government, contractor, and subcontractor personnel employed at the INL Site, Shoshone-Bannock tribal members whose aboriginal homelands included the INL Site area, ranchers who graze livestock in areas on or near the INL Site, occasional hunters on or near the INL Site, visitors to the INL Site, highway travelers along U.S. Highway 20/26, and residential populations in neighboring communities. No residents are located within the INL Site boundary.

2.2.1.1 On-Site Populations

According to employment statistics from the primary contractors at the INL Site, as of February 2013 the ICP employed 1,009 and the INL employed 3,775 contractor personnel. Approximately 38% of the work force is located in Idaho Falls, Idaho, and 62% is employed at the INL Site (Table 2-1). The Department of Energy has approximately 212 employees in Idaho Falls and 18 at Site facilities.

Table 2-1. Approximate number of employees at INL Site facilities in February 2013.

Work Location	BEA	CWI	ITG
Idaho Falls	1,777	209	62
Advanced Test Reactor Complex	479	0	0
Central Facilities Area	459	0	0
Idaho Nuclear Technology and Engineering Center	39	621	0
Materials and Fuels Complex	819	43	0
Radioactive Waste Management Complex	4	136	554
Test Area North	198	0	0

Authorized groups, visitors, and subcontracted employees also visit the area. Non-INL-Site visitor traffic occurs at the Experimental Breeder Reactor I (EBR-I) Visitors Center, located along U.S. Highway 20/26. Open during the summer months and available for scheduled tour groups the rest of the year, the EBR-I facility receives approximately 10,000 visitors annually.

2.2.1.2 Off-Site Populations

The INL Site is located primarily in Butte County; however, it also occupies portions of Bingham, Bonneville, Clark, and Jefferson counties (Figure 2-1). Major communities include Blackfoot in Bingham County, Idaho Falls in Bonneville County, Arco in Butte County, and Rigby in Jefferson County. Populations of the counties surrounding the INL Site and selected population centers in these counties are shown in Table 2-2 (U.S. Census Bureau 2010). The community nearest to the INL Site is Atomic City, located south of the Site border on U.S. Highway 20/26. Other population centers near the INL Site include Arco, west of the INL Site on U.S. Highway 20/26; Howe, west of the INL Site on U.S. Highway 22/33; and Mud Lake and Terreton on the northeast border of the INL Site.

Table 2-2. Populations of counties and selected cities surrounding the Idaho National Laboratory Site (U.S. Census Bureau 2010).

Location	Population (2010 Census)
Bingham County	**45,607**
Atomic City	29
Blackfoot	11,899
Bonneville County	**104,234**
Idaho Falls	56,813
Clark County	**982**
Dubois	677
Jefferson County	**26,140**
Mud Lake	358
Rigby	3,945
Butte County	**2,891**
Arco	995

2.2.1.3 Shoshone-Bannock Tribal Interests

The Shoshone-Bannock Tribes of the Fort Hall Indian Reservation are a federally recognized Indian tribe and sovereign government. The Fort Bridger Treaty of July 3, 1868, secured the Fort Hall Reservation as the permanent homeland of the Shoshone-Bannock peoples (15 Stat. 673). The 1868 Treaty also reserved aboriginal rights to these peoples that extend to the areas of unoccupied land in Idaho and surrounding states, allowing access for cultural, political, and economic activities essential to the tribes' survival. Though the INL Site is occupied land, DOE-ID protects cultural resources and allows tribal members access to certain areas of cultural and religious significance. An Agreement-in-Principle between DOE-ID and the Shoshone-Bannock Tribes promotes tribal involvement in a wide variety of DOE activities (DOE-ID 2013, Appendix B).

2.2.2 Land Ownership and Use

The U.S. Bureau of Land Management (BLM) controlled most of the land before the National Reactor Testing Station was established in 1949. Public land orders in the 1940s withdrew the land from the public domain. Lands owned by the State of Idaho and private parties were also obtained to form the Arco Naval Proving Ground in the 1940s (DOE-ID 1996). Buildings and structures at the INL Site are clustered within defined facility areas, which are typically less than a square mile in size and separated from each other by miles of primarily undeveloped land.

2.2.2.1 Current Land Use

The Department of Energy controls all land within the INL Site (Figure 2-5). Public access is restricted to public highways, DOE-ID sponsored tours, special-use permits, and the EBR-I Visitors Center. In addition, DOE-ID supports the Shoshone-Bannock tribal members' need for access to certain areas on the INL Site for cultural and religious purposes. Currently, over half of the INL Site is open to grazing for cattle and sheep through BLM-administered permits. Dairy cattle are not permitted. The BLM classified the area within the INL Site (230,671 hectares [570,000 acres]) as industrial and mixed use (DOE 1991). The current primary use of INL Site land is to support facility and program operations. Large tracts of land are reserved as buffer and safety zones along the boundary of the INL Site. Portions within the central area are reserved for INL Site operations. The remaining land within the core of the reservation, which is largely undeveloped, supports a variety of projects and environmental research.

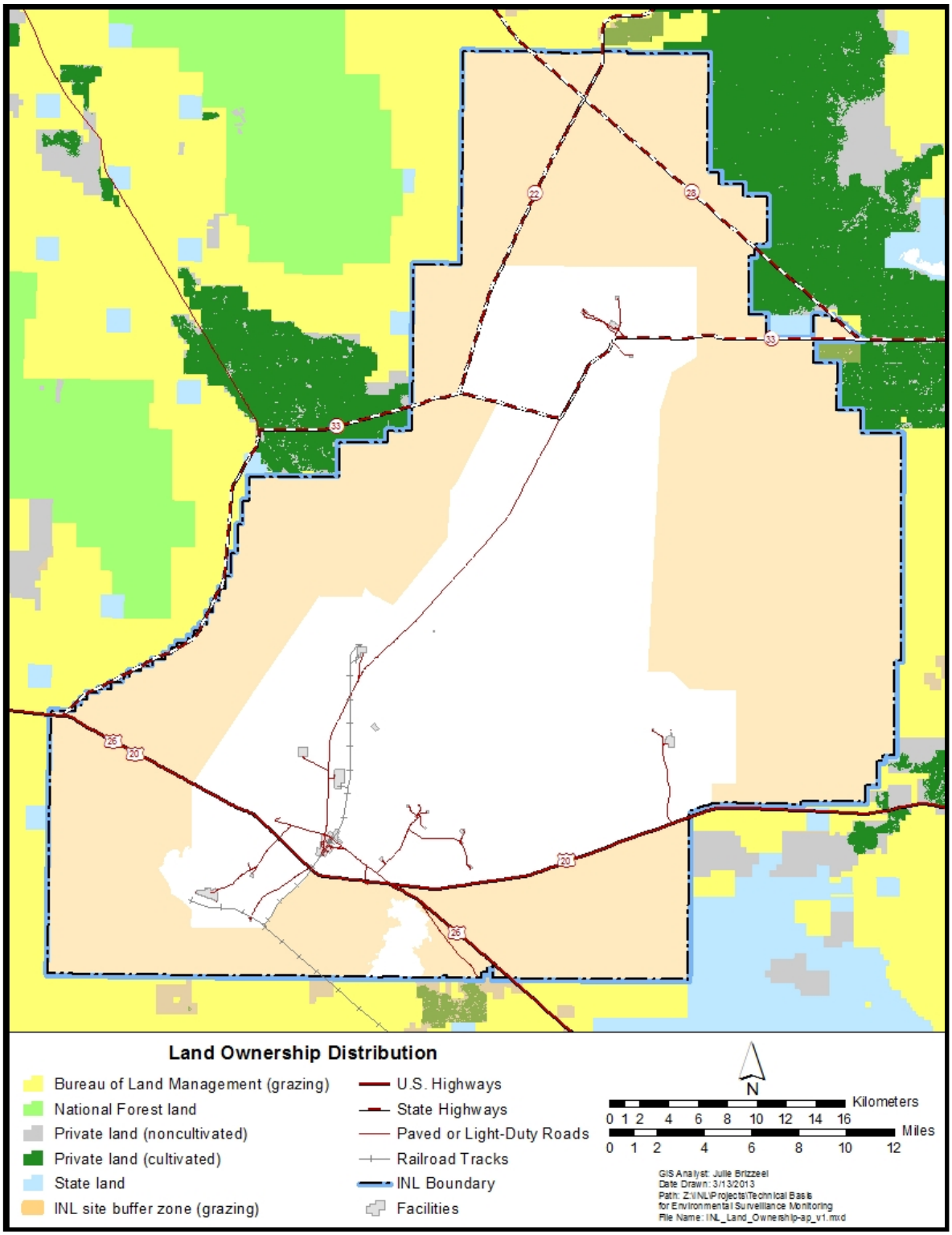

Figure 2-5. Land ownership in the vicinity of the Idaho National Laboratory Site.

Depredation hunts of game animals managed by the Idaho Department of Fish and Game are permitted on-Site within the buffer zone during selected years. Hunters are allowed access to an area that extends 0.8 km (0.5 mi) inside the INL Site boundary on portions of the northeastern and western borders of the Site (Becker et al. 1996).

State Highways 22, 28, and 33 cross the northeastern portion of the Site, and U.S. Highways 20 and 26 cross the southern portion. Ninety miles of paved highways used by the general public pass through the INL Site (DOE 1991), and 22.5 km (14 mi) of Union Pacific railroad tracks traverse the southern portion of the Site. A government-owned railroad, a spur of the Union Pacific railroad, passes through the CFA to INTEC and terminates at the Naval Reactors Facility (Figure 2-5).

In the counties surrounding the INL Site, approximately 45% of the land is used for agriculture, 45% is undeveloped land, and 10% is urban (DOE-ID 1995; Figure 2-6). Livestock uses include the production of sheep, cattle, hogs, poultry, and dairy cattle (Bowman et al. 1984). The major crops produced on land surrounding the INL Site include wheat, alfalfa, barley, potatoes, oats, and corn (Table 2-3). Sugar beets are grown within about 64 km (40 mi) of the INL Site in the vicinity of Rockford, Idaho, southeast of the INL Site in central Bingham County (Table 2-3). The BLM administers most of the U.S. Government property in the area adjacent to the INL Site.

Table 2-3. Acreage of major crops harvested on land surrounding the Idaho National Laboratory Site (USDA 2007).

County	Total Harvested Cropland	Wheat	Barley	Potatoes	Sugar Beets	Orchards	Oats	Silage Corn	Forage[a]
Bingham	295,664	118,896	13,980	74,371	20,022	15	18,864	3,846	61,510
Bonneville	193,410	51,322	64,111	27,162	----	38	210	4,200	44,422
Butte	47,347	2,288	9,238	----[b]	----	----	----	----	35,111
Clark	29,945	5,382	2,163	----	----	----	----	----	18,303
Jefferson	206,259	36,831	40,641	28,911	----	----	900	8,898	86,006

a. Land used for all hay, haylage, grass silage, and greenchop.

b. ---- signifies no acreage or data withheld to avoid disclosing data for individual farms.-

2.2.2.2 Future Land Use

Future land use is addressed in the *Idaho National Laboratory Comprehensive Land Use and Environmental Stewardship Report* (INL 2011). Because future land-use scenarios are uncertain, assumptions were made in the Long-Term Land Use Future Scenarios document for defining factors such as development pressure, advances in research and technology, and ownership patterns. The following assumptions were applied to develop forecasts for land use within the INL Site:

- The INL Site will remain under federal government management and control through at least the year 2095. Portions of the INL Site will remain under federal government management and control in perpetuity.
- To the extent practical, new building construction will be encouraged in existing facility areas to take advantage of existing infrastructure.
- As contaminated facility areas become obsolete, environmental remediation, decommissioning, and decontamination will be required. The environmental remediation, decommissioning, and decontamination process will be completed in accordance with the existing regulatory structure.
- No residential development (e.g., housing) will occur within the INL Site boundaries within 100 years.

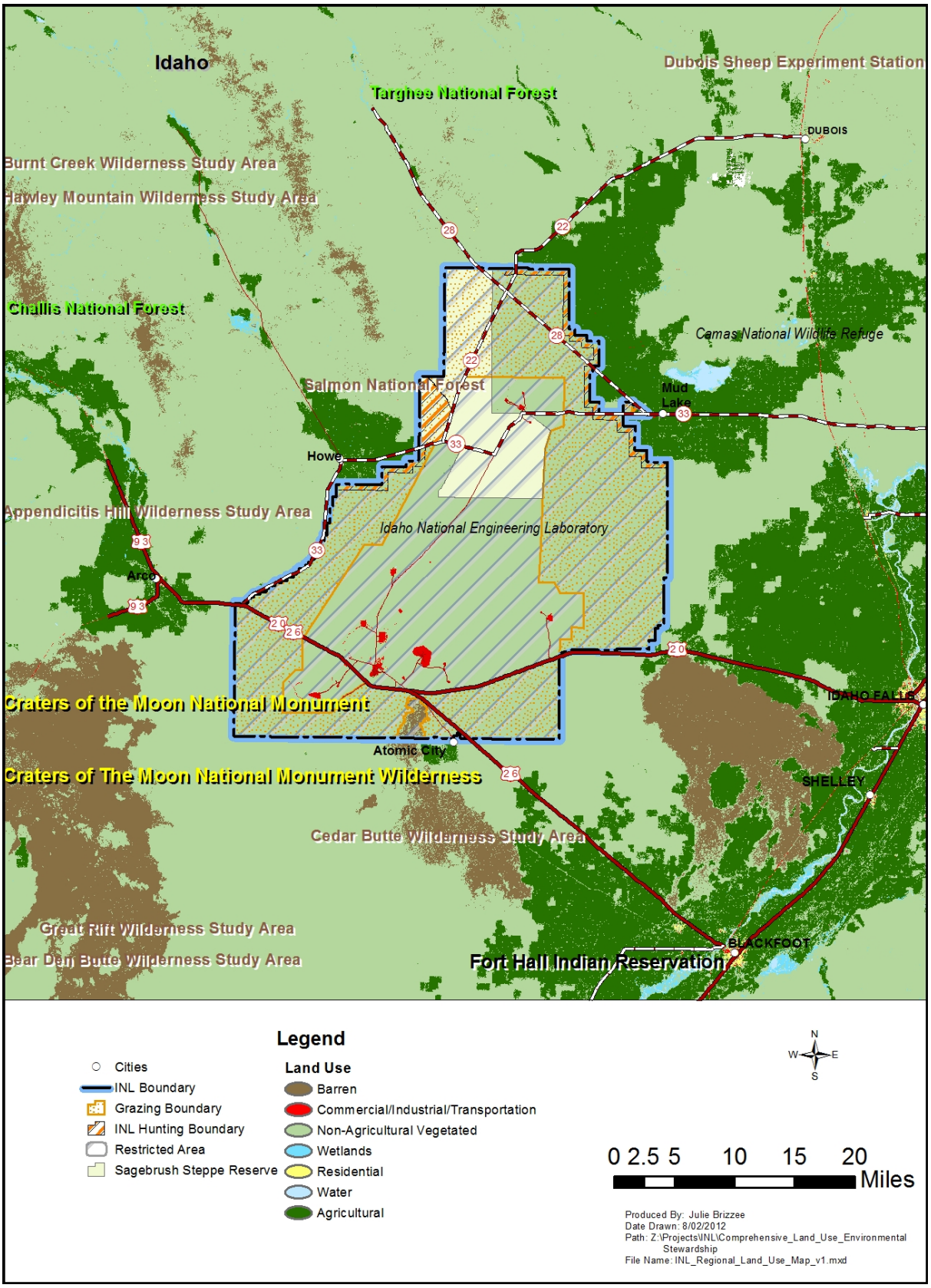

Figure 2-6. Land use at the INL Site and Surrounding Area.

Projections for future land use at the INL Site call for most of the developed areas of the Site to remain occupational for at least the next 100 years. Included in the future land use plan for the INL Site is the assumption that new development will, to the extent practicable, be encouraged in developed facility areas to take advantage of existing infrastructure.

2.3 References

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3. RADIOLOGICAL EMISSIONS

This chapter discusses the facilities and processes that produce radiological emissions at the INL Site and at Idaho Falls Facilities. The INL Site consists of eight major facilities at the Site as well as several laboratories and administrative buildings located in Idaho Falls, Idaho. The eight major facilities at the INL Site are the ATR Complex, CFA; the Materials and Fuels Complex (MFC), the Critical Infrastructure Test Range Complex (CITRC), which includes the Power Burst Facility (PBF), Test Area North (TAN), which includes the Specific Manufacturing Capability (SMC), INTEC, and the RWMC (Figure 3-1). The Naval Reactors Facility (NRF) is owned by the Naval Reactors Idaho Branch Office. The Naval Nuclear Propulsion Program is exempt from DOE requirements and maintains a separate environmental monitoring program; therefore, NRF is not included in this report.

Small quantities of radionuclides may be released at the INL Research Center (IRC), a partially developed 35-acre site located on the north side of the City of Idaho Falls. The INL Site and IRC are owned by the U.S. Department of Energy (DOE) and administered through its Idaho Operations Office (DOE-ID).

INL Site facility operations produce airborne and liquid effluents that can contain radiological constituents. INL Site implements engineering and administrative controls (see definitions) to prevent releases and/or to reduce release volumes and concentrations.

Airborne contaminants are monitored because air transport is the most important pathway from the INL Site (DOE-ID 2012b). Airborne effluent can be released from individual point sources, such as laboratory ventilation systems or stacks, or diffuse sources such as re-suspension of contaminated soil. Some INL Site sources require continuous monitoring for compliance (e.g., continuous stack monitors). Every year, an estimate of the annual radionuclide emissions at the INL Site is prepared in accordance with the Code of Federal Regulations, Title 40, “Protection of the Environment,” Part 61, “National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities” or NESHAPS (e.g., DOE-ID 2012a). The report includes estimation of the effective dose equivalent (EDE) to a maximally exposed individual (MEI) member of the public and comparison to the 10 mrem/yr standard. The EDE is estimated using numerous conservative assumptions, such as 1) the source is active for 100 years to allow accumulation of radionuclides in the environment, and 2) a rural scenario which allows for uptake/contamination of plants and animals that make up a portion of the diet (EPA 2007). The dose estimates consider immersion dose from direct exposure to airborne radionuclides, internal dose from inhalation of airborne radionuclides, internal dose from ingestion of radionuclides in plants and animals, and external dose from direct exposure to radionuclides deposited on soil. In 2011, the estimated EDE from activities at the INL Site to an MEI located at Frenchman’s Cabin (south of the RWMC) was 0.0458 mrem/year, or 0.46 percent of the standard. The estimated EDE from activities in Idaho Falls to an MEI located near the southern boundary of the Idaho Research Center (IRC) was 0.00951 mrem/yr.

Liquid effluents are discussed in greater detail in Chapter 5.

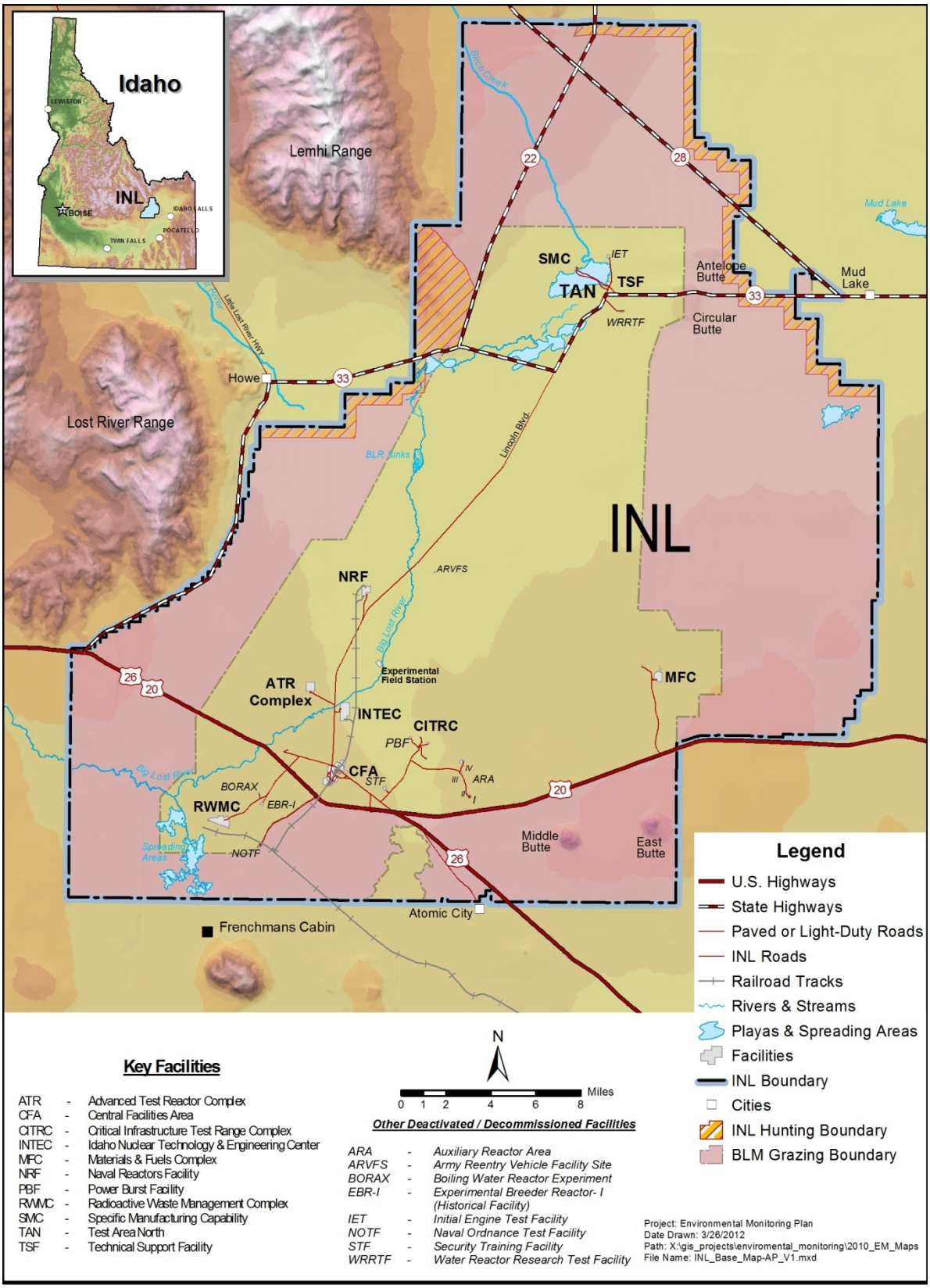

Figure 3-1. Major facilities at the INL Site.

3.1 INL Site Facilities

3.1.1 Current Emissions

3.1.1.1 Advanced Test Reactor Complex

The Advanced Test Reactor (ATR) Complex (formerly known as the Reactor Technology Complex [RTC] and the Test Reactor Area, [TRA]) was established in the early 1950s for studying the effects of radiation on materials, fuels, and equipment. Three major reactors have been built at the ATR Complex, including the Materials Test Reactor (MTR), the Engineering Test Reactor (ETR), and the ATR. The MTR and ETR have undergone decontamination and decommissioning (D&D); the ATR is currently the only operating reactor at the ATR Complex. The ATR tests materials for the nation's next generation of nuclear power plants. ATR is also used to manufacture a significant portion of the nation's medical nuclear isotopes.

Radiological air emissions from the ATR Complex are primarily associated with operation of the ATR. These emissions include noble gases, iodines, and other mixed fission and activation products. Other radiological air emissions are associated with sample analysis, site remediation, research and development activities, and decommissioning and demolition activities. In 2011, air emissions at the ATR Complex were primarily from activities at the facilities listed below (DOE-ID 2012a; Figure 3-2). Facilities that contributed at least one percent of the total estimated dose to the MEI are in bold.

1. TRA-603: MTR D&D
2. TRA-670: ATR Reactor
3. TRA-678: Radiation Measurements Laboratory
4. TRA-710: MTR stack
5. **TRA-770: ATR Main Stack**
6. **TRA-715: TRA Evaporation Pond**
7. TRA-1627: Radioanalytical Chemistry Laboratory
8. TRA-610: MTR Fan House D&D
9. **TRA-632: Hot Cell Building D&D**

In 2011, about 1,500 curies were estimated to have been released to the air at the ATR Complex (DOE-ID, 2012a). Table 3-1 summarizes the radiological air emissions at the ATR Complex that were greater than one curie or contributed at least one percent of the total estimated dose to the MEI.

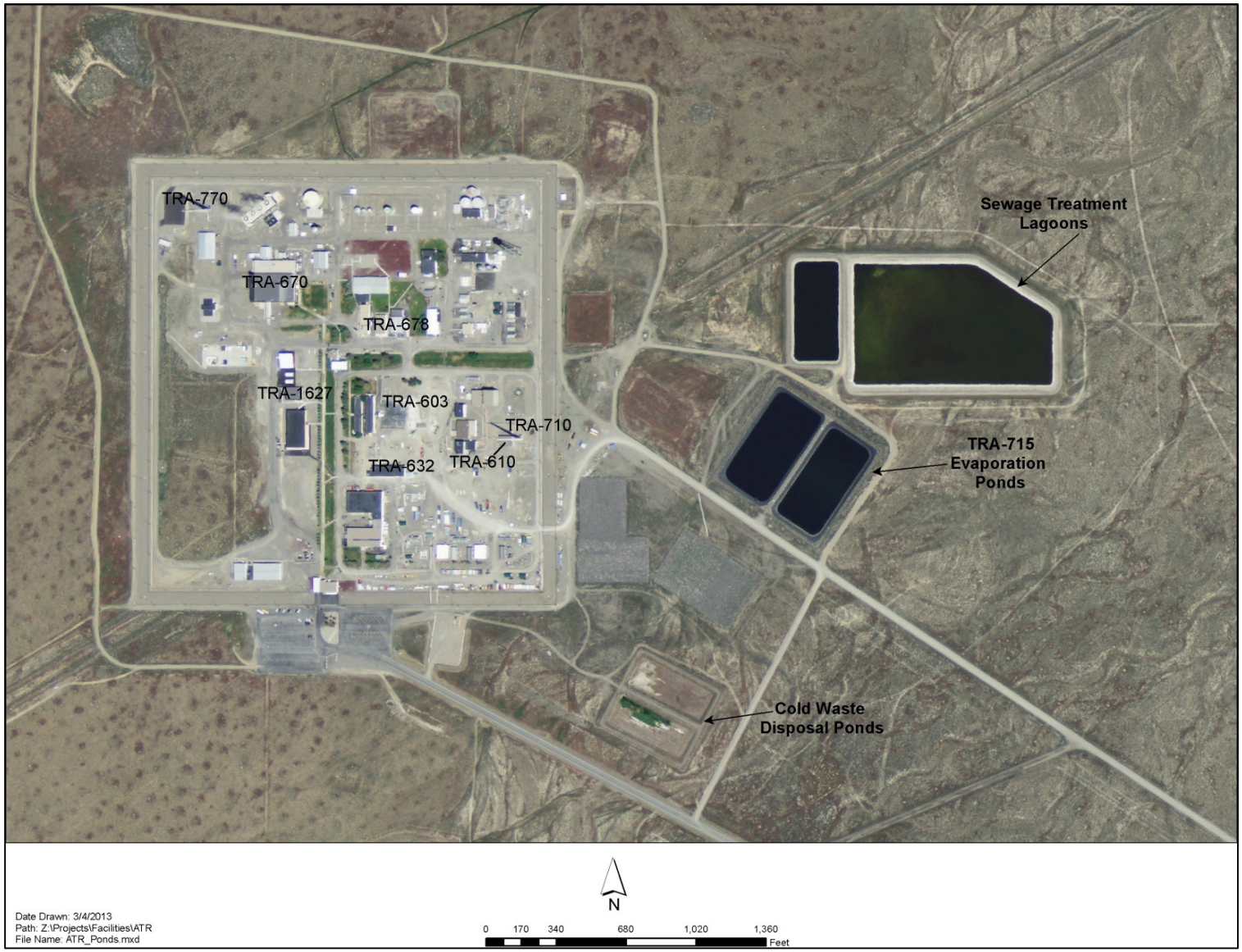

Figure 3-2. Major facilities at the ATR Complex.

Table 3-1. Estimated radiological air emissions at the ATR Complex in 2011 that were greater than one curie or contributed at least one percent of the total dose to the MEI (DOE-ID 2012a).

Radionuclide	Estimated 2011 Emissions (Ci)	Contribution to Total Dose at MEI (Percent)
Argon–41	1,130	9.13
Cesium–137	0.024	1.47
Cobalt–60	0.061	1.2
Krypton–85m	4.4	<1
Krypton–87	11.5	<1
Krypton–88	10.2	<1
Strontium–90	0.033	3.97
Tritium	276.8	4.43
Xenon–133	1.05	<1
Xenon–135	19.2	<1
Xenon–135m	9.35	<1
Xenon–138	42.1	<1
Percent Contribution from ATR Complex to the MEI Dose		~21

Radiological wastewater generated at the ATR Complex is discharged to the TRA-715 Evaporation Pond. The pond is double-lined to prevent infiltration into the subsurface. Additional information on the evaporation pond is presented in Chapter 5.

3.1.1.2 Central Facilities Area

The first buildings at the CFA were constructed in the 1940s and 1950s to house the U.S. Navy's gunnery range personnel. The facilities have been modified over the years to fit the changing needs of the laboratory and now house centralized support services for contractors and the DOE. The CFA houses technical and support services, including administrative offices, monitoring and calibration laboratories, fire protection, medical services, warehouses, vehicle and equipment pools, and bus operations.

Minor emissions occur from CFA facilities where work with small quantities of radioactive materials is routinely conducted, such as the CFA Laboratory Complex (CFA-625; Figure 3-3). Prior to June 2011, preparation of low-level radiological performance-testing samples at the Radiological Environmental Sciences Laboratory (RESL; CFA-690) contributed to the estimated emissions from CFA. In 2011, the primary radionuclide estimated to be released to the air at CFA was about one curie of tritium from the use of contaminated groundwater, primarily from evaporation from the sewage treatment lagoons (DOE-ID, 2012a; Table 3-2). The sewage lagoons contain relatively low concentrations of tritium and iodine-129 because the groundwater at CFA is contaminated from historical discharges at INTEC (see Section 5.2).

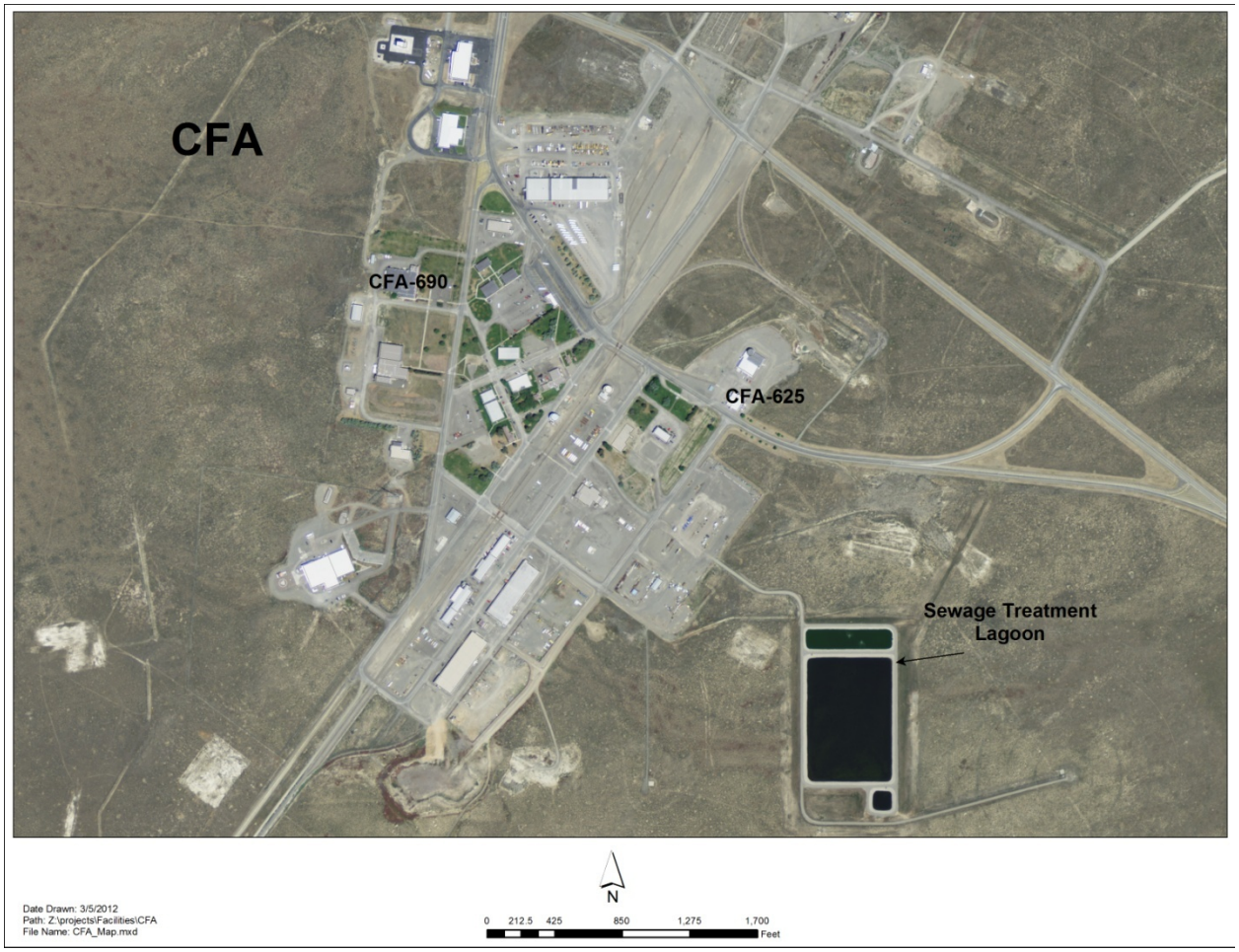

Figure 3-3. Location of selected facilities at the CFA.

Table 3-2. Estimated radiological air emissions at CFA in 2011 that were greater than one curie or contributed at least one percent of the total dose to the MEI (DOE-ID 2012a).

Radionuclide	Estimated 2011 Emissions (Ci)	Contribution to Total Dose at MEI (Percent)
Tritium	1.06	<1

3.1.1.3 Idaho Nuclear Technology and Engineering Center

INTEC was established in the 1950s to recover usable uranium from spent nuclear fuel generated in government reactors and to store spent nuclear fuel. Radiological air emissions from INTEC sources are primarily associated with liquid-waste operations, including effluents from the Tank Farm Facility, Process Equipment Waste Evaporator, and Liquid Effluent Treatment and Disposal, which are exhausted through the Main Stack. These radioactive emissions include particulates and gaseous radionuclides. Additional radioactive emissions are associated with decommissioning and decontamination activities, wet-to-dry spent nuclear fuel transfers, environmental remediation, remote-handled transuranic waste management, radiological and hazardous-waste storage facilities, and contaminated-equipment maintenance. In the near future, the Integrated Waste Treatment Unit (IWTU) will become operational to process the remaining sodium-bearing liquid waste at INTEC.

In 2011, air emissions at INTEC were primarily from activities at the facilities listed below (DOE-ID, 2012a; Figure 3-4). Facilities that contributed at least one percent of the total estimated dose to the MEI are in bold.

1. CPP-603: Irradiated Fuels Storage Facility
2. CPP-653: EPA Radiological Dispersion Device Decontamination Project
3. CPP-659: New Waste Calcine Facility
4. CPP-663: Maintenance Building Hot Shop
5. CPP-684: Remote Analytical Laboratory
6. CPP-708: Main Stack
7. CPP-749: Spent Fuel Storage Vaults
8. CPP-767: FAST Stack
9. CPP-1608: Manipulator Repair Cell
10. **CPP-1774, TMI-2 Independent Spent Storage Installation**
11. CPP-1778, Sewage Treatment Plant
12. CPP-1791, INTEC percolation ponds
13. CPP-2707, dry cask storage pad
14. **Idaho CERCLA Disposal Facility (ICDF)**
15. Contaminated soils

About 1,650 curies were estimated to have been released to the air at INTEC in 2011 (DOE-ID, 2012a). Table 3-3 summarizes the radiological air emissions at the INTEC that were greater than one curie or contributed at least one percent of the total estimated dose to the MEI.

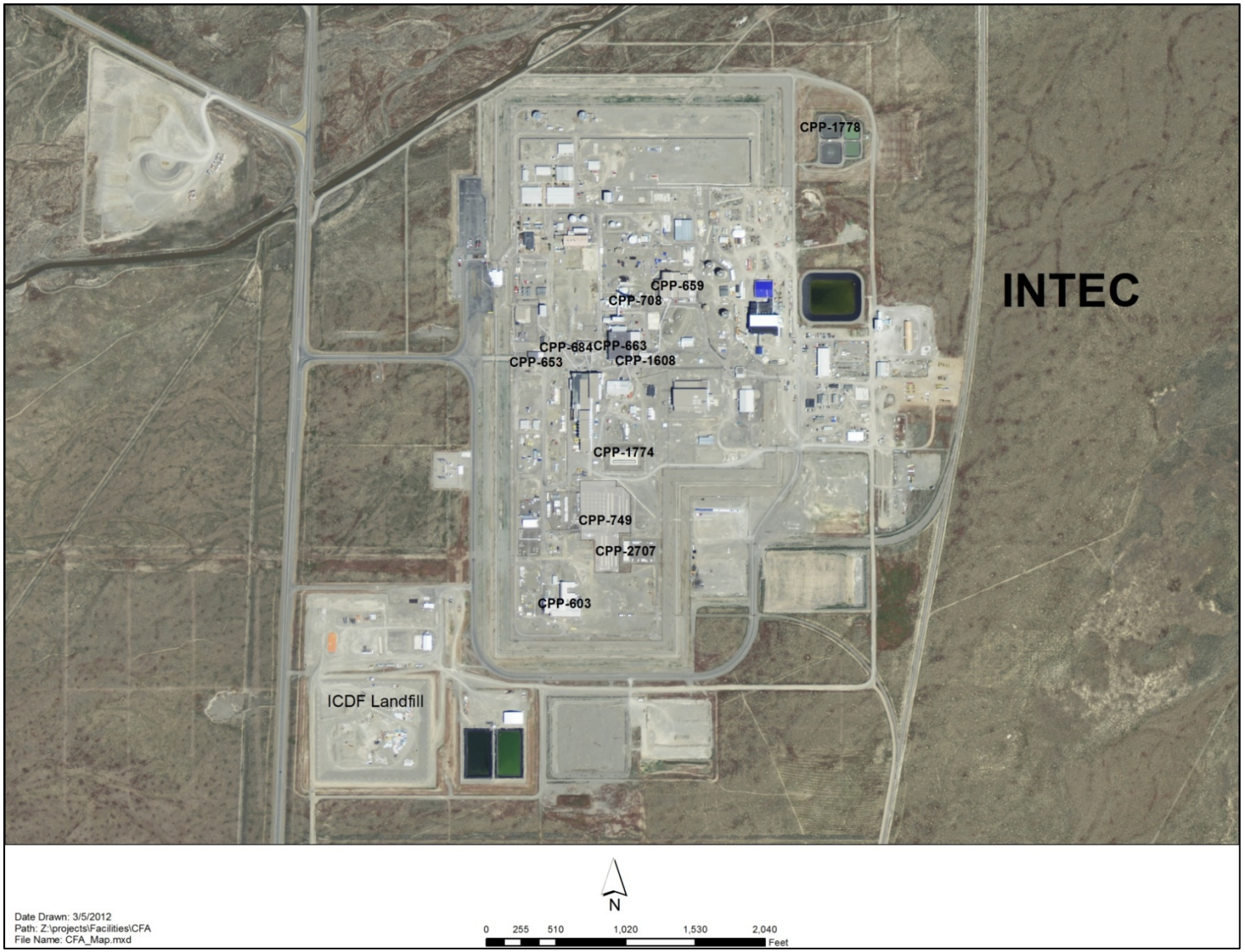

Figure 3-4. Selected facilities at INTEC.

Table 3-3. Estimated radiological air emissions at INTEC in 2011 that were greater than one curie or contributed at least one percent of the total dose to the MEI (DOE-ID 2012a).

Radionuclide	Estimated 2011 Emissions (Ci)	Contribution to Total Dose at MEI (Percent)
Cesium–137	0.024	1.78
Cobalt–60	0.0614	1.34
Iodine–129	0.03	3.80
Krypton–85	1,450	<1
Plutonium–239	0.000323	1.06
Strontium–90	0.0136	1.80
Tritium	200	6.12
Percent Contribution from INTEC to the MEI Dose		~16

Radiological liquid wastes generated at INTEC are treated at the Process Evaporator Waste system and/or containerized for proper disposal. Liquid waste generated from CERCLA investigations at the INL Site, such as purge water from groundwater sampling activities, are discharged to the lined evaporation pond at the Idaho CERCLA Disposal Facility (ICDF).

3.1.1.4 Materials and Fuels Complex

MFC, originally called Argonne National Laboratory–West, was established in the 1950s to research and develop nuclear reactors and fuel. Four reactors have been constructed at MFC: Transient Reactor Test Facility, Experimental Breeder Reactor II (EBR-II), Zero Power Physics Reactor and Neutron Radiography Reactor (NRAD). Only one of these reactors, NRAD, is currently operating. Today, the MFC is the prime testing center in the U.S. for demonstration and proof-of-concept of nuclear energy technologies. Research and development activities at MFC are focused on areas of national concern, including energy, nuclear safety, spent nuclear fuel treatment, nuclear material disposal, nonproliferation, decommissioning and decontamination technologies, projects to support space exploration, and homeland security.

Radiological air emissions are primarily associated with spent-fuel treatment at the Fuel Conditioning Facility (FCF) and waste characterization at the Hot Fuel Examination Facility (HFEF). Both of these facilities are equipped with continuous emission monitoring (CEM) systems. On a monthly basis, the effluent streams from FCF, HFEF, and other non-CEM radiological facilities are sampled and analyzed for particulate radionuclides. The FCF and HFEF are also sampled monthly for gaseous radionuclides. Gaseous and particulate radionuclides may also be released from other MFC facilities during laboratory research activities, sample analysis, waste handling and storage, and maintenance operations. Both measured and estimated emissions from MFC sources are consolidated for NESHAPS reporting on an annual basis.

In 2011, air emissions at MFC were primarily from activities at the facilities listed below (DOE-ID, 2012a; Figure 3-5). None of the facilities at MFC contributed at least one percent of the total estimated dose to the MEI.

1. MFC-704: Fuel Manufacturing Facility stack
2. MFC-720: Transient Reactor Test Facility reactor cooling air exhaust
3. MFC-752: Laboratory and Office Building
4. MFC-764: EBR-II/FCF Main Stack
5. MFC-766: Sodium Boiler Building D&D

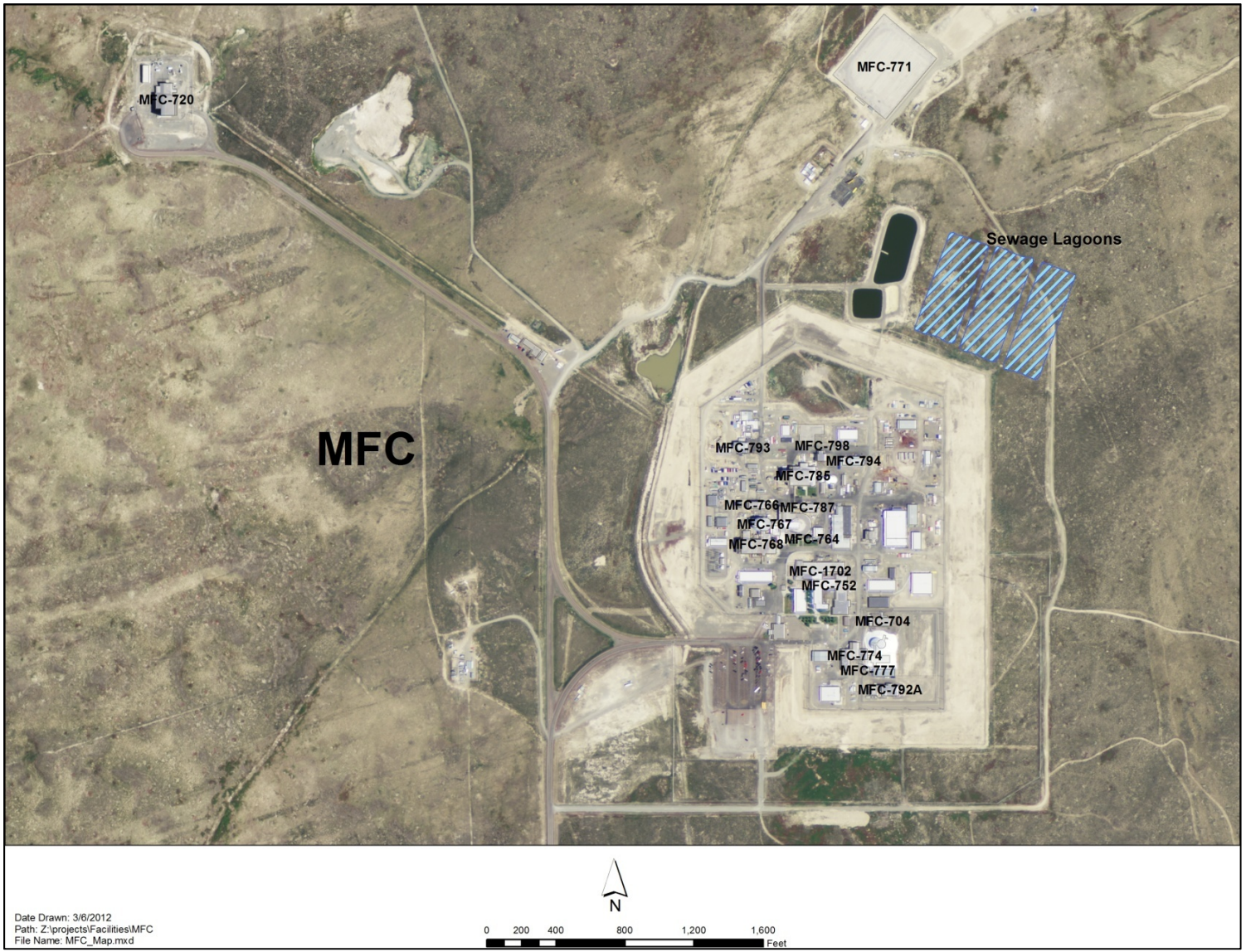

Figure 3-5. Selected facilities at MFC.

6. MFC-767: EBR-II Reactor Plant Building D&D
7. MFC-768: Power Plant (Health Physics area)
8. MFC-771: Radioactive Scrap Waste Facility
9. MFC-774: Electron Microscopy Laboratory
10. MFC-777: Zero Power Physics Reactor
11. MFC-785: Hot Fuel Examination Facility
12. MFC-787: Fuel Assembly and Storage Building
13. MFC-792A: Space, Security and Power Facility
14. MFC-793: Sodium Components Maintenance Shop
15. MFC-794: Contaminated Equipment Storage Building
16. MFC-798: Radioactive Liquid Waste Treatment Facility
17. MFC-1704: Radiochemistry Laboratory

About 0.1 curie was estimated to have been released to the air at MFC in 2011; none of the emissions contributed at least one percent of the total estimated dose to the MEI (DOE-ID, 2012a).

Radiological liquid waste generated at the MFC is treated at the Radioactive Liquid Waste Treatment Facility (MFC-798).

3.1.1.5 Radioactive Waste Management Complex

The RWMC, located in the southwestern corner of the INL Site, is a controlled-access area with a primary mission to dispose of INL Site-generated low-level radioactive waste and to temporarily store contact-handled and remote-handled transuranic waste that will be shipped to other designated facilities for disposal. The Accelerated Retrieval Project (ARP), regulated under CERCLA, is removing targeted waste from the Subsurface Disposal Area (SDA), disposing of transuranic waste at an off-Site facility, and remediating and closing the SDA. To fulfill these missions, the RWMC maintains facilities and processes in separate areas for administrative and operations support, and waste storage and disposal. Administrative and Operations Area buildings are used for security and access control, personnel offices, lunchrooms, change and shower rooms, equipment and materials storage, craft and maintenance shops, and radiological control.

Current operations at the RWMC include the Advanced Mixed Waste Treatment Project (AMWTP). The AMWTP includes the retrieval of mixed transuranic waste from temporary storage, characterizing the waste, treating the waste to meet disposal criteria, and packaging the waste for shipment to the Waste Isolation Pilot Plant in Carlsbad, New Mexico. Radiological air emissions from the AMWTP may result from the retrieval, characterization, and treatment of transuranic waste, alpha-contaminated low-level mixed waste (alpha LLMW), and low-level mixed waste (LLMW).

In 2011, air emissions at the RWMC were primarily from activities at the facilities listed below (DOE-ID, 2012a; Figure 3-6). Facilities that contributed at least one percent of the total estimated dose to the MEI are in bold.

1. WMF-601: Health Physics Laboratory
2. **WMF-697: Accelerated Retrieval Project (ARP)-I**
3. **WMF-1612: ARP-II**
4. **WMF-1614: ARP-III**
5. **WMF-1615: ARP-IV**
6. **WMF-1617: ARP-V**

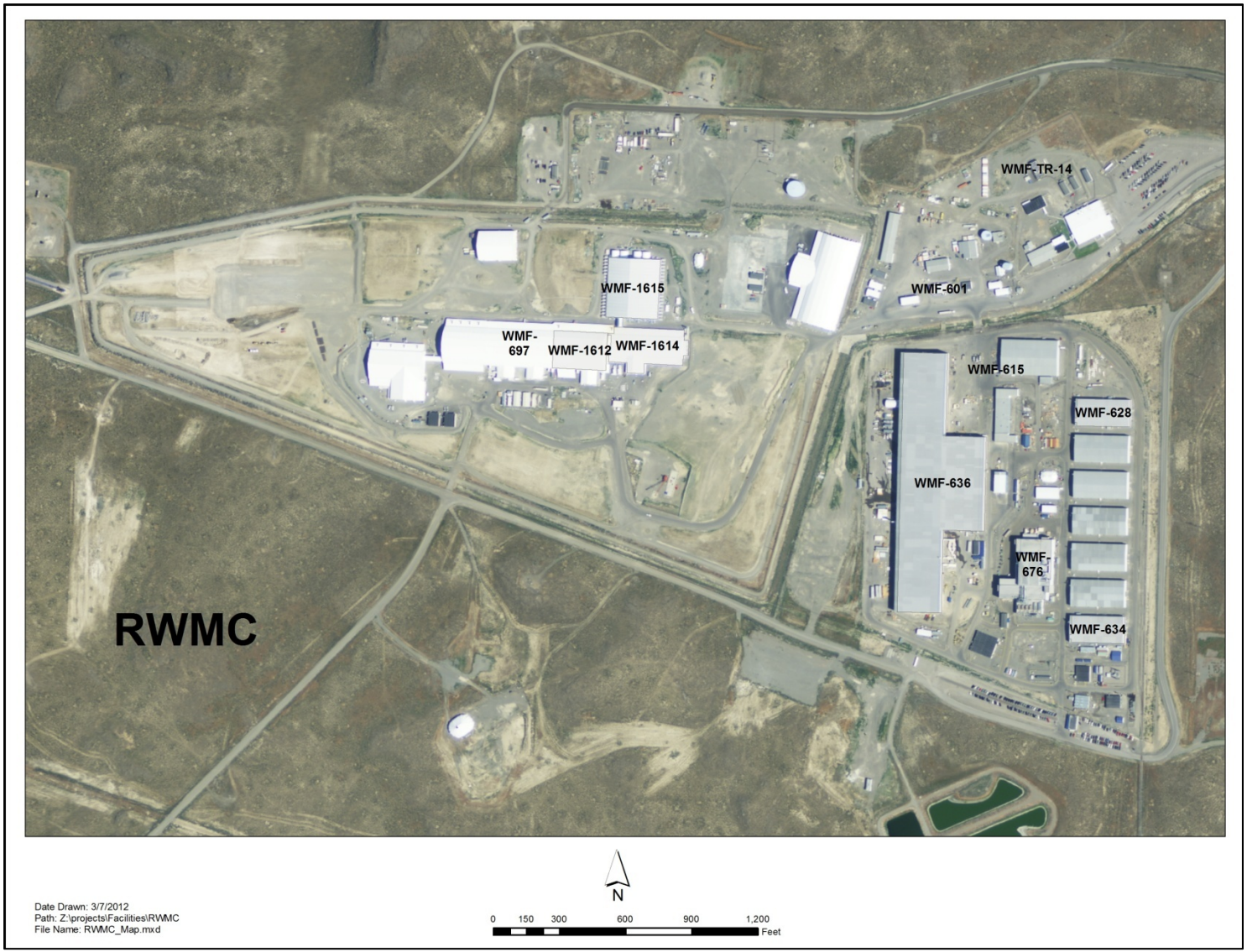

Figure 3-6. Selected facilities at the RWMC.

7. **WMF-1617: ARP-V**
8. **WMF-1618: ARP-VI**
9. **Tritium emissions from beryllium blocks buried in the SDA**
10. CERCLA remediation activities
11. Waste Management Facility (WMF)-615-001, Drum Vent Facility
12. **WMF-628: Drum Treatment Facility**
13. WMF-634: Characterization Facility
14. WMF-636: Transuranic Storage Area
15. WMF-676: Advanced Mixed Waste Treatment Facility
16. WMF-TR-14: Analytical Laboratory

About 357 curies were estimated to have been released to the air at the RMWC in 2011 (DOE-ID 2012a). Table 3-4 summarizes the radiological air emissions at the RWMC that were greater than one curie or contributed at least one percent of the total estimated dose to the MEI.

Table 3-4. Estimated radiological air emissions at the RWMC in 2011 that were greater than one curie or contributed at least one percent of the total dose to the MEI (DOE-ID 2012a).

Radionuclide	Estimated 2011 Emissions (Ci)	Contribution to Total Dose at MEI (Percent)
Americium–241	0.00414	18.97
Plutonium–238	0.00112	5.88
Plutonium–239	0.00275	15.6
Plutonium–240	5.14E–04	2.92
Tritium	357	15.6
Percent Contribution from RWMC to the MEI Dose		~59%

3.1.1.6 Test Area North

TAN is the northernmost developed area within the INL Site. It was originally established to support the Aircraft Nuclear Propulsion Program, which operated from 1951 to 1961. Since 1961, TAN buildings have been adapted for use by various other programs, including current operations at the SMC facility. The TAN-SMC Project is a manufacturing operation that produces an armor package for the U.S. Department of the Army. The TAN-SMC Project was assigned to the laboratory in 1983. Operations at TAN-SMC include material development, fabrication, and assembly work to produce armor packages. The operation uses standard metal-working equipment in fabrication and assembly. Other activities include developing tools and fixtures and preparing and testing metallurgical specimens. Radiological air emissions from TAN-SMC are associated with processing of depleted uranium. Potential emissions are uranium isotopes and associated radioactive progeny.

In 2011, air emissions at TAN were primarily from activities at the facilities listed below (DOE-ID, 2012a; Figure 3-7). A total of about one curie (primarily bromine isotopes) was estimated to have been released to the air at TAN in 2011. The releases from TAN account for about 0.02% of the total dose to the MEI.

1. TAN-629: Assembly Building
2. TAN-679: Manufacturing and Assembly Building
3. TAN-681: Process Reclamation Facility
4. TAN-1611: Pump and Treat Facility

Figure 3-7. Selected facilities at TAN/SMC.

3.1.2 Summary of Historic INL Site Releases

This section contains a brief summary of historic releases. More detailed discussions are available in other publications, including CDC (2002), annual Site environmental reports, NESHAPS reports, and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) documents available in the INL Administrative Record (http://ar.inl.gov/).

3.1.2.1 Airborne Effluents

The INL Site was originally established as a government site to build, test, and operate nuclear reactors. During the period from 1952-1989, approximately 13.5 million Ci of radionuclides, primarily fission products, released from the INL Site in airborne effluents were characterized as operational releases (DOE-ID 1991). By comparison, an estimated 800,000 Ci were released as episodic releases during the same period. DOE-ID (1991) classified atmospheric releases as operational or episodic because of differing requirements for atmospheric dispersion calculations. Operational releases are continuous, somewhat uniform releases that occur over a year or portion of a year that spans a variety of meteorological conditions. Episodic releases refer to short-term operations, experiments, tests, and other events that took place over a short period of time (typically a few hours). Mohler et al. (2004) ranked the routine releases from 1952–1992 using screening models developed by the National Council on Radiation Protection and Measurements (NCRP) for atmospheric releases (NCRP 1996). The ranking values for specific radionuclides indicate that the majority of doses to individuals from all pathways (inhalation, ingestion, and external exposure) were related to iodine–131, strontium–90, and cesium–137. Figure 3-8 shows the amounts of total radionuclides, iodine–131, strontium–90, and cesium–137 released to the

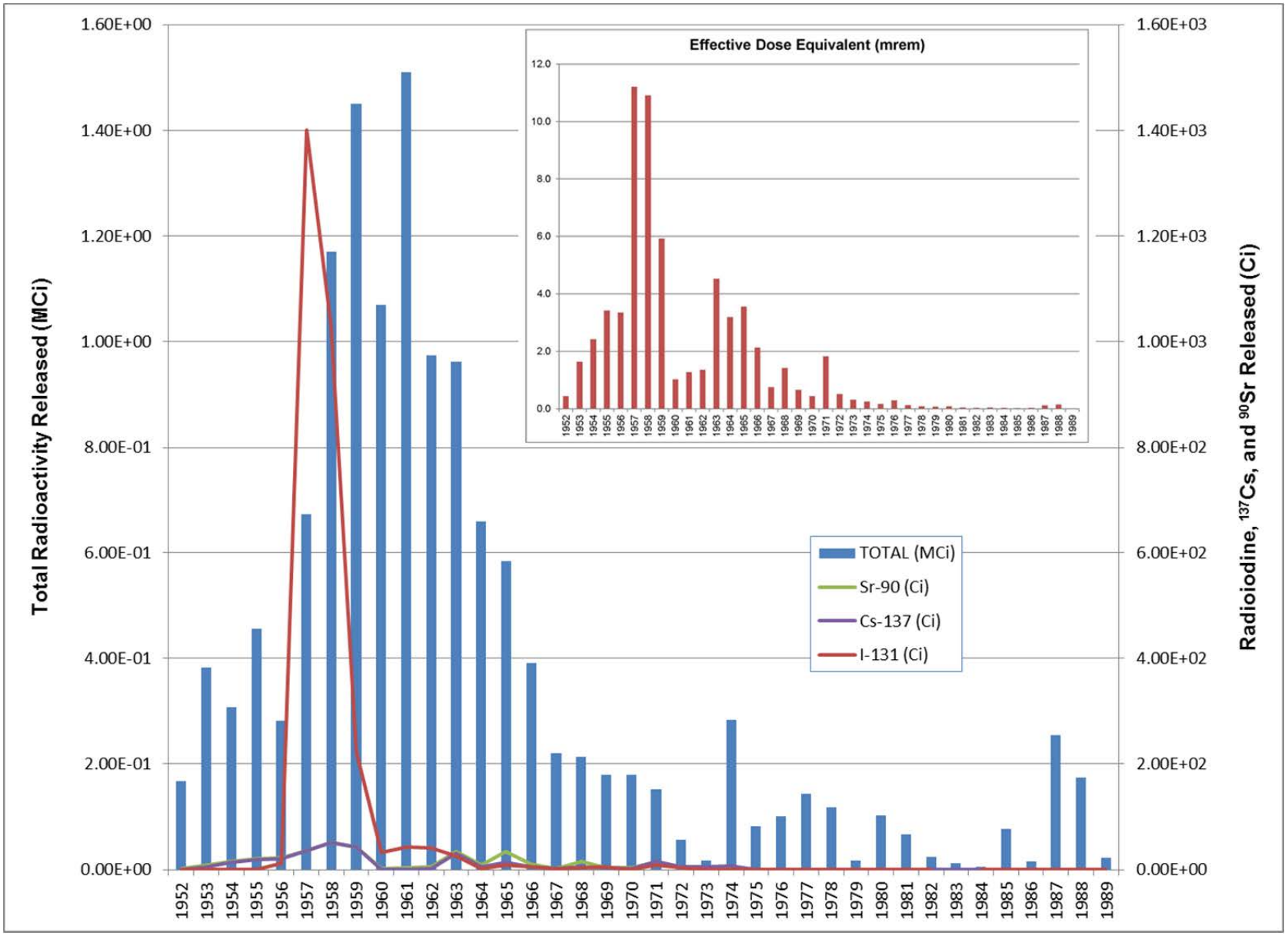

Figure 3-8. Total radionuclide, radioiodine, cesium–137, and strontium–90 atmospheric releases from the INL Site and estimated EDE to the maximally exposed adult from 1951 through 1989. (Data from DOE-ID 1991).

atmosphere from 1952 through 1989, as well as the doses estimated in the historical dose evaluation conducted in 1991 (DOE-ID 1991). The highest doses occurred from 1957 through 1959 and were primarily due to iodine–131 releases from fuel reprocessing at the Idaho Chemical Processing Plant (located at the current INTEC facility and decommissioned in 2002). Radioiodine is no longer in the environment due to its short half-life (8 days). Some strontium–90 and cesium–137 from past INL Site operations may still remain in the soil due the longer half-lives of 28 and 30 years, respectively.

Radionuclide releases since 1989 reflect the changing missions of the INL Site. Only two reactors (ATR and NRAD) currently remain in operation, as most of the other reactors, as well as major nuclear facilities, have been decommissioned and decontaminated. Since 1989, the estimated dose to the MEI has never exceeded one mrem. The highest dose since 1989 was estimated to be 0.13 mrem in 2008. Airborne releases are the largest active source of radiological effluent at the INL Site. The facilities that contribute to airborne emissions include: AMWTP, CFA, INTEC, CITRC, MFC, RWMC, TAN, ATR Complex, and SMC. Once emitted to the atmosphere, the airborne emissions are uncontrolled and can be transported through the air or be deposited to surface waters, soils, or vegetation. Figure 3-9 illustrates the total releases and dose to the MEI reported in the annual NESHAP reports for 2001–2011. The emissions have generally decreased over time. The majority of radioactive airborne activity is in the form of noble gases, e.g., argon, krypton, and xenon (Figure 3-10). Most of the remaining activity is from tritium, with lesser contributions from iodine, uranium, plutonium, and americium.

The percent of the total emissions from ATR Complex, INTEC, MFC, RWMC, and TAN during the past ten years are shown in Figure 3-11. Sources of these airborne emissions include point sources (stacks and vents) and non-point sources such as radioactive waste ponds, contaminated soils, and decontamination and demolition of inactive facilities. As can be seen in Figures 3-9 to 3-11, the amount

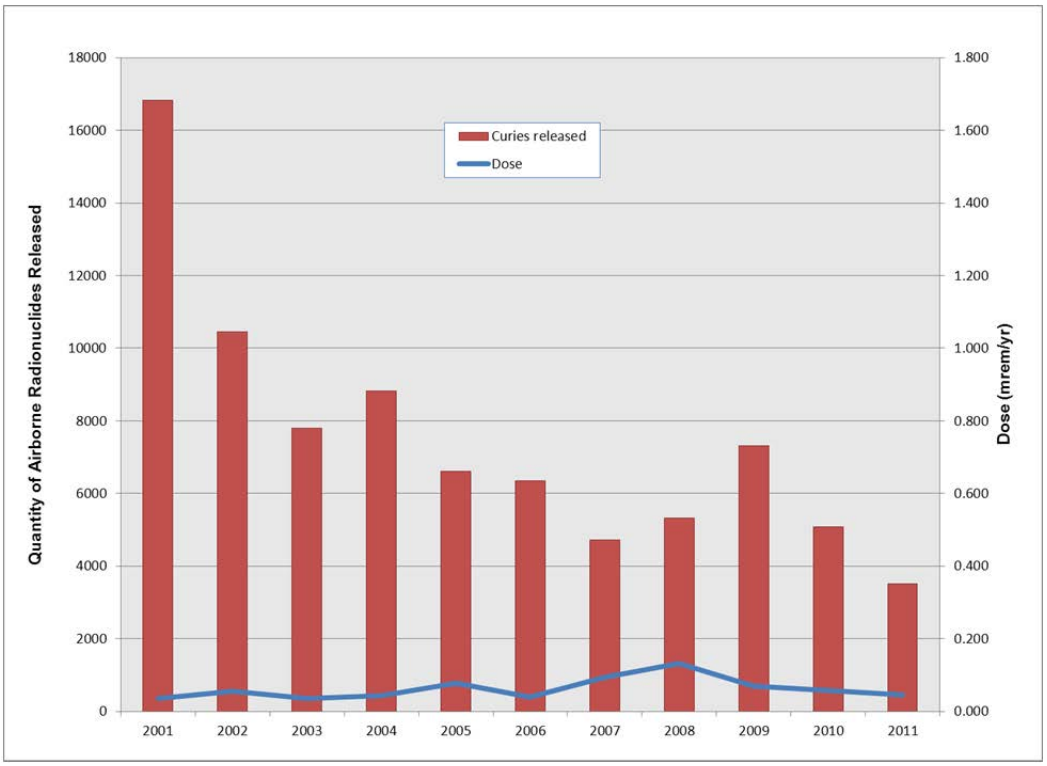

Figure 3-9. Total curies released in air and dose to the MEI calculated by CAP-88 (2001–2011).

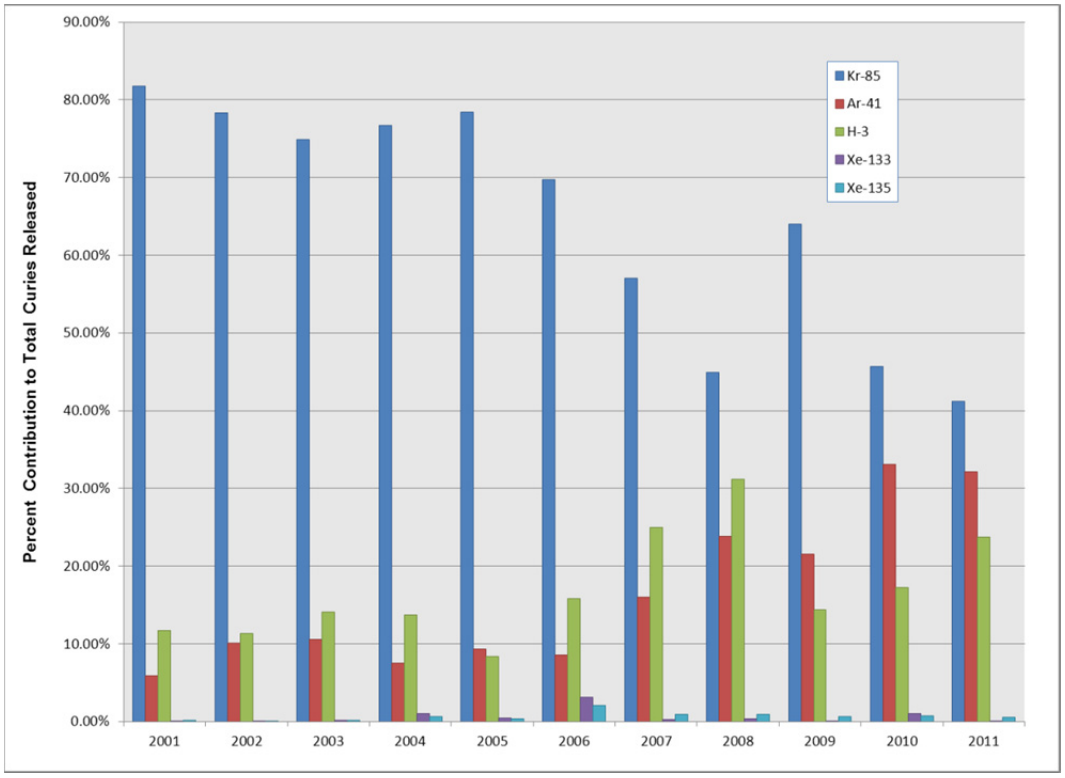

Figure 3-10. Principal radionuclides in the estimated air emissions at the INL Site (2001–2011).

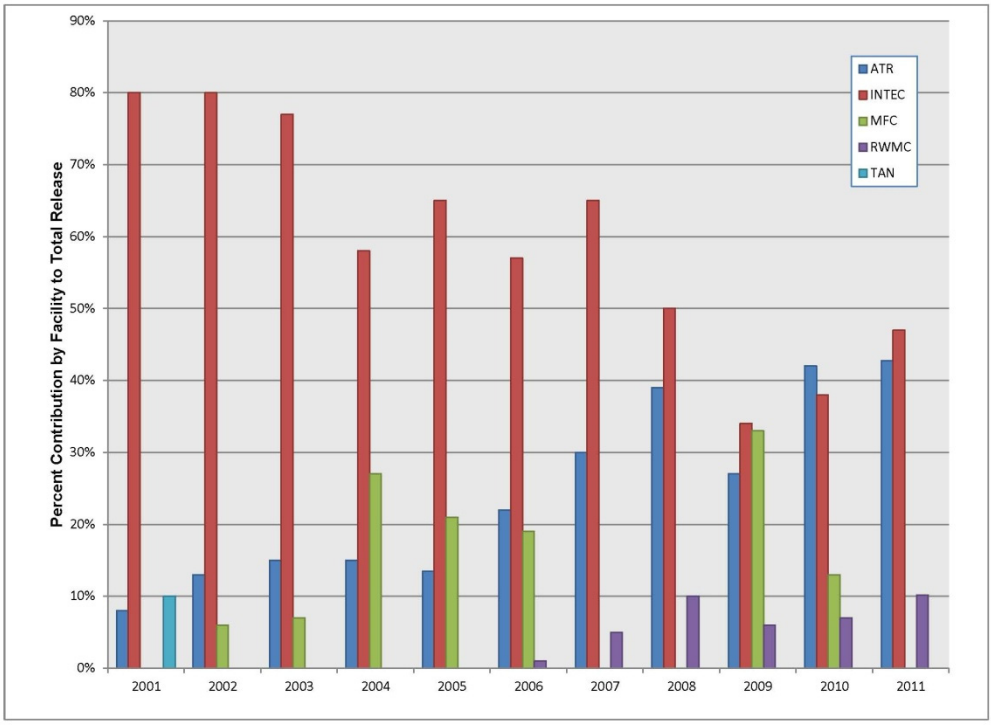

Figure 3-11. Percent contributions, by facility, of INL Site airborne radionuclide releases (2001–2011).

and composition, as well as the facility contributions, has changed as a function of changing Site mission. For example, decommissioning of TAN facilities excludes the area as a measurable contributor to total releases after 2001. Similarly, the relative contribution of ATR has increased, as it is now the only continuously functioning reactor at the INL Site. The RWMC's contribution has also increased since 2006 as activities such as waste retrieval at ARP have been added to its operations. INTEC's contribution has decreased from greater than 75% during the years 2001–2003, to less than 70% of the total during 2004–2011. The largest facility contributors to the airborne emissions are currently INTEC, MFC, ATR Complex, and RWMC.

For the purpose of this technical basis document, 2007–2011 are considered to be representative of current emissions. Tritium (H–3), argon–41, strontium–90, iodine–129, cesium–137, americium–241, plutonium–238, plutonium–239, and plutonium–240 were the top dose contributors, each representing greater than three percent of the annual dose estimated for the MEI from 2007–2011 (Figure 3-12). The relative ranking of these radionuclides for each year are shown in Table 3-5.

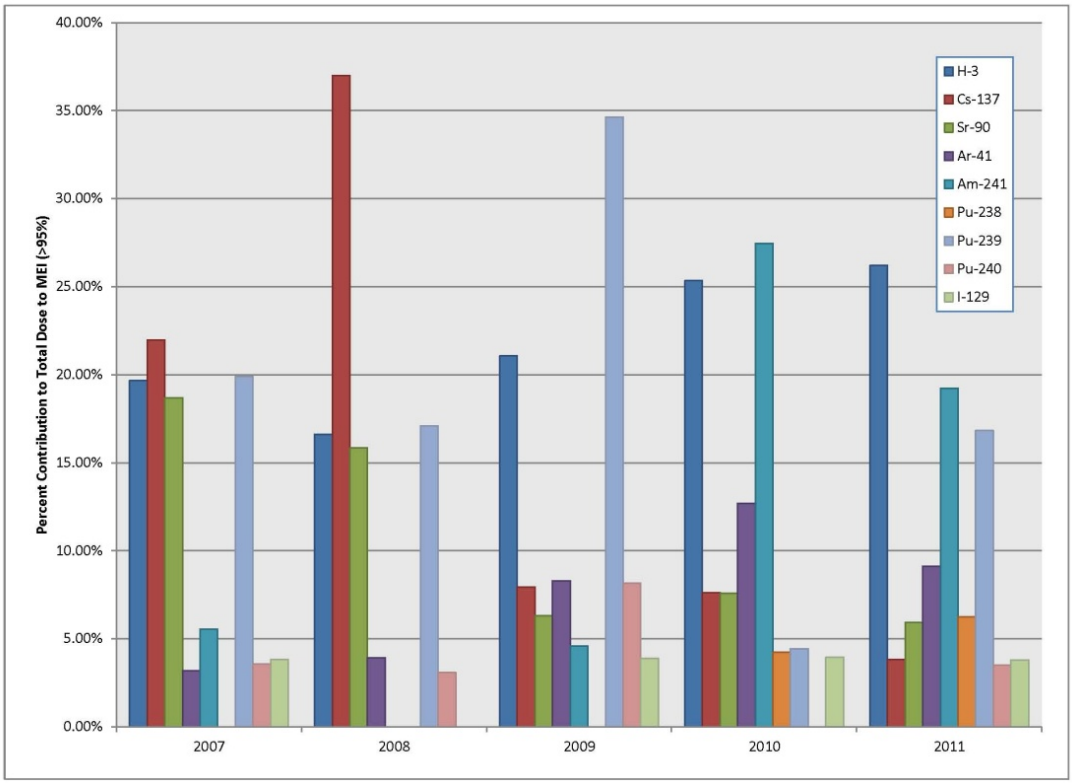

Figure 3-12. Percent contribution by radionuclides contributing greater than 3% to dose to the MEI calculated in NESHAP reports for 2007–2011.

Table 3-5. Ranking of radionuclides released to the air during routine operations from 2007–2011.

Relative Rank[a]	2007	2008	2009	2010	2011
1	Cs–137	Cs–137	Pu–239	Am–241	H–3
2	Pu–239	Pu–239	H–3	H–3	Am–241
3	H–3	H–3	Ar–41	Ar–41	Pu–239
4	Sr–90	Sr–90	Pu–240	Cs–137	Ar–41
5	Am–241	Ar–41	Cs–137	Sr–90	Pu–238
6	Pu–240	Pu–240	Sr–90	Pu–238	Sr–90
7	I–129		Am–241	Pu–239	Cs–137
8	Ar–41		I–129	I–129	I–129
9					Pu–240

a. Ranked according to contribution to the total dose calculated by CAP88-PC for compliance with NESHAP.

3.1.2.2 Liquid Releases

Liquid radioactive effluents have not, to this date, produced measurable exposure to an off-Site member of the public. In the past, liquid radioactive materials were disposed of directly to the Eastern Snake River Plain Aquifer through injection wells. This practice was discontinued in 1984. Unlined surface water disposal ponds were used to dispose of low-level radioactive liquids until 1993. Water from these ponds percolated through the soil and basalt to the aquifer. Some of the radionuclides sorbed on the soil column before they could reach the aquifer. Others, mainly tritium, migrated with water through the soil column to the aquifer.

Most of the liquid discharge occurred during the period from 1954 through 1979. The peak occurred in 1959, when approximately 4800 Ci was released (DOE-ID 1991). The total released from 1952 through 1989 was about 76,000 Ci (DOE-ID 1991). Although the quantity of radionuclides released is small compared to that of airborne effluents, some radionuclides (primarily tritium, Sr–90, and I–129) are still detected in the aquifer below the INL Site. The extent of radioactivity in the aquifer has been reported by the U.S. Geological Survey (USGS) for many years (Bartholomay 2009; Davis 2010; Davis, Bartholomay, and Rattray 2013). Because tritium is equivalent in chemical behavior to hydrogen, a key component of water, it has formed the largest plume of any of the liquid-borne radionuclides. The configuration and extent of tritium contamination, based on the most recent published USGS data is shown in Figure 3-13 (Davis, Bartholomay, and Rattray 2013). The concentration of tritium, as measured in two wells representing the maximum measured concentrations in the aquifer, has decreased over time, as shown in Figure 3-14 (DOE-ID 2012b). Wells USGS–065 and USGS–077 are down gradient of the ATR Complex.

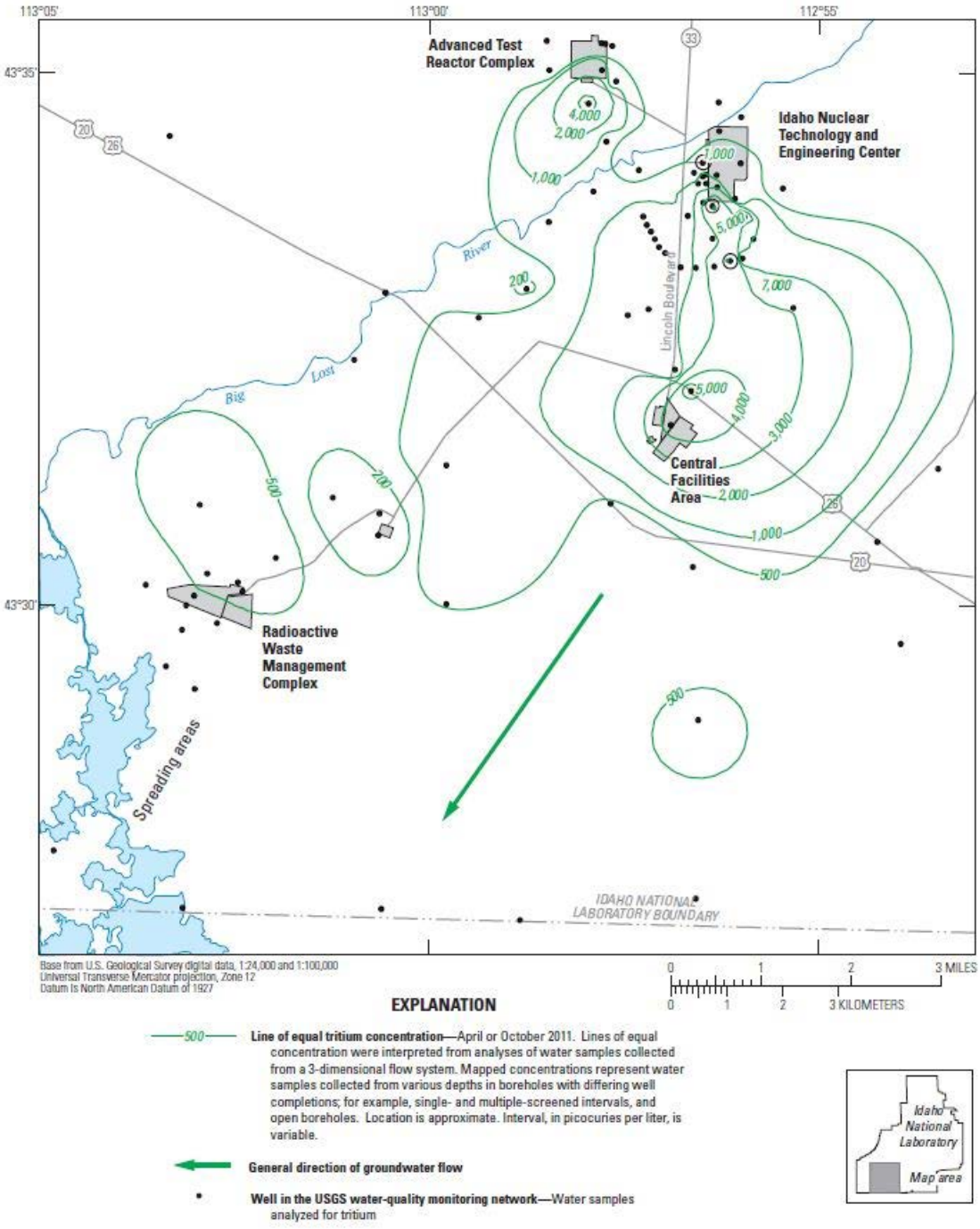

Figure 3-13. Distribution of tritium in water from wells at and near the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, Central Facilities Area, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, April or October 2011. (from Davis, Bartholomay, and Rattray 2013).

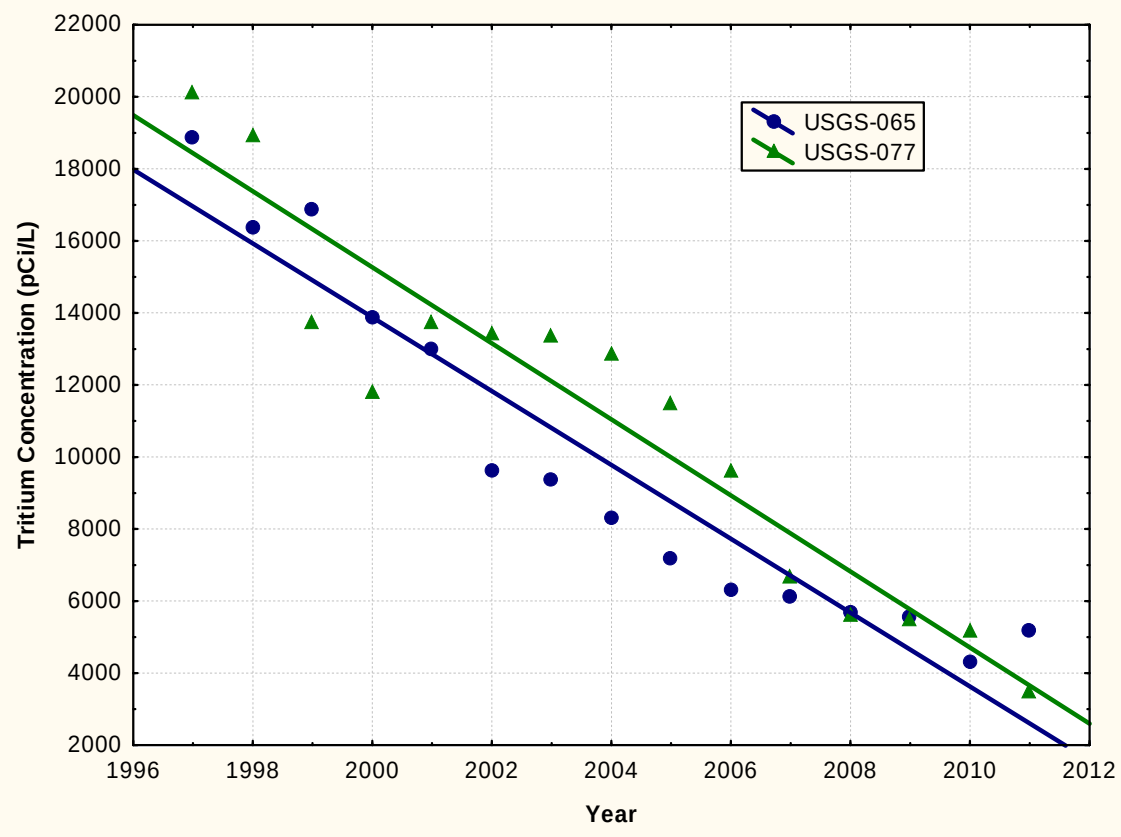

Figure 3-14. Long-term trend of tritium in wells USGS–065 and 077 (1997–2011).

3.2 Idaho Falls Facilities

Small quantities of radionuclides may be released at the INL Research Center (IRC) Complex, a partially developed 35-acre site located on the north side of the City of Idaho Falls (Figure 3-15), which is the only Idaho Falls location with estimated radiological air emissions (DOE-ID 2012a). In 2011, estimated emissions were calculated for the following facilities:

1. IF-603: IRC Laboratory Building
2. IF-611: National Security Laboratory
3. IF-638: IRC Physics Laboratory
4. IF-683: Radiological and Environmental Sciences Laboratories

The IRC Laboratory Building consists of over 60 laboratories that are dedicated to research in robotics, genetics, biology, chemistry, metallurgy, modeling and computational science, and physics. Other disciplines may include earth sciences and environmental engineering, biotechnology, physical systems modeling, systems engineering, intelligent automation and remote systems, applied engineering, nuclear science, materials processing, chemical separations and processing, and sensing and diagnostics. Fundamental and applied research and development (R&D) serves government agencies, private companies, universities, and nonprofit organizations. The Radiological and Environmental Sciences Laboratory (RESL) prepares radiological performance-testing samples at IF-683. RESL began operations at IF-683 in the third quarter of 2011.

In 2011, less than one curie of radioactivity was estimated to have been released to the air at the IRC (DOE-ID 2012a). Table 3-6 summarizes the releases that contribute at least one percent of the 0.00951 mrem/year total dose calculated for an individual located 0.1 km south of the IRC (DOE-ID 2012a). Prior to 2011, compliance with the 10-mrem dose standard at IRC was demonstrated by use of the possession limits in 40 CFR 61, Appendix E.

Figure 3-15. Selected facilities at the INL Research Center in Idaho Falls.

Table 3-6. Estimated radiological air emissions at the INL Research Center in 2011 that contributed at least one percent of the calculated total dose to the MEI (DOE-ID 2012a).

Radionuclide	Estimated 2011 Emissions (Ci)	Contribution to Total Dose at MEI (Percent)
Plutonium–239	1.32E–07	30.5
Americium–241	1.04E–07	20.8
Plutonium–238	8.59E–08	18.8
Xenon–133	0.68	17.2
Uranium–233	4.8E-05	3.57
Iodine–125	2E–03	3.41
Radium–226	7.59E–08	1.91
Uranium–232	3.51E–08	1.44

3.3 References

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4. CRITICAL ENVIRONMENTAL PATHWAYS

Environmental surveillance is the collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media in the environs of a nuclear facility or contaminated area. Prior to implementation of an environmental surveillance program, a critical pathway analysis (radionuclide/media) should be performed (DOE 1991). This is to ensure the acquisition of appropriate data to meet the overall program purposes and identify the critical radionuclides, pathways, and exposed individuals (NCRP 2010).

A critical pathway analysis is used to identify environmental pathways by which radioactivity or radiation from a facility or site can reach human or biotic receptors. The analysis is also used to identify important radionuclides which can contribute significantly to the estimated radiation dose along a critical path to a reasonably maximally-exposed individual offsite. This individual is a hypothetical person residing in a local community (NCRP 2010). The primary purpose of a pathway analysis is thus to indicate those critical pathways and significant radionuclides that require monitoring as part of the environmental surveillance program.

The pathways assessed in this chapter are associated with INL Site. The critical pathway analysis for the INL Site is very broad in scope because of the history and complexity of the Site – the INL Site has been in operation since 1949, includes a variety of facilities and areas of historical contamination, and has been monitored for radionuclides and radioactivity since its inception. As such, the critical pathway analysis does not support a preoperational design but rather confirms the adequacy of the existing environmental surveillance to ensure that program objectives are met.

A critical pathway analysis for the facilities in Idaho Falls would be developed if necessary based on the preliminary monitoring.

4.1 Critical Environmental Pathways from INL Site Releases

Radiological environmental surveillance has been a component of INL Site operations since 1949. The basic objective of radiological environmental surveillance is to protect the public and the environment by monitoring potential contaminant releases from INL Site activities and by determining the types, concentrations, and distribution of these contaminants in the environment (DOE 1991; DOE Order 458.1). To do this, a multifaceted and integrated program has been developed which conducts radiological surveillance both on and off the INL Site. On-Site monitoring for radionuclides focuses on source-term releases, radionuclide types, radionuclide concentrations, and distribution in a variety of media within INL Site environs. Off-Site environmental surveillance assesses the distribution and concentrations of radionuclides outside the INL Site boundary to estimate the dispersal pattern in the environs, characterize the transport pathways, and determine the impacts to off-Site population centers and the surrounding environment. This integrated approach permits an overall assessment of the radiological impacts resulting from routine INL Site operations to the public and the environment. The resulting network of on-Site and off-Site surveillance activities is also capable of detecting any unplanned acute releases. Finally, the integrated approach provides an array of data to develop predictive capabilities for modeling behavior and distribution of radionuclides and impacts on humans and biota resulting from INL Site releases. Figure 1-1 illustrates the site conceptual model developed for potential pathways from the INL Site to humans. Over five decades of environmental surveillance data have been used to identify and characterize the pathways by which radionuclides could potentially expose humans to radiation from INL Site emissions. The conceptual model is complex because the INL Site and its history are complex. The extent and magnitude of radionuclide movement through the environment from the source to humans is addressed in the following discussion by each significant pathway. Each pathway of concern is presented in simplified illustrations in the following sections, using information detailed in Figure 1-1.

4.1.1 Air

4.1.1.1 Exposure pathways to humans living off the INL Site

Air is considered to be the most critical pathway from the INL Site to off-Site receptors (Apostoaei 2005; Maheras and Thorne 1993; DOE-ID 1991). This is because radionuclides from INL Site operations are released to air within permitted or allowable limits and air is the most direct and continuous route to humans. As shown in Figure 4-1, people living off the INL Site could be exposed to radiation from a number of pathways:

- External exposures because of direct radiation from radionuclides in the plume or deposited on the ground
- Internal exposures because of inhalation of radionuclides in the air or ingestion of foods or soil that have been contaminated by radioactive materials.

To monitor the pathways shown in Figure 4-1, environmental surveillance on and off the INL Site focuses on:

- Air, through the use of air samplers (Chapter 6) and precipitation and air moisture samplers (Chapter 7)
- Direct radiation (Chapter 8)
- Soil (Chapter 10)
- Agricultural products (Chapter 11)
- Game Animals (Chapters 12 and 13)

The magnitude of human exposure to atmospheric releases of radionuclides depends on atmospheric transport, diffusion, and deposition processes. If possible, dose assessments should be based on results of measurements of air concentrations, ground concentrations, agricultural product concentrations, and radiation fields resulting from these releases. While each of these media is monitored, the low concentrations are often indistinguishable from background and mathematical models must be used to estimate the impact of radionuclide releases to air to humans through exposure to the impacted media. Compliance with dose limits established by the Environmental Protection Agency (EPA) is calculated each year using the reported INL Site airborne emissions and the EPA air-dispersion code CAP88-PC (EPA 2007). CAP88-PC uses site-specific meteorology to model the transport of airborne radionuclides from stacks or areas through various environment media (for example air, soil, and agricultural products) to the off-Site receptors.

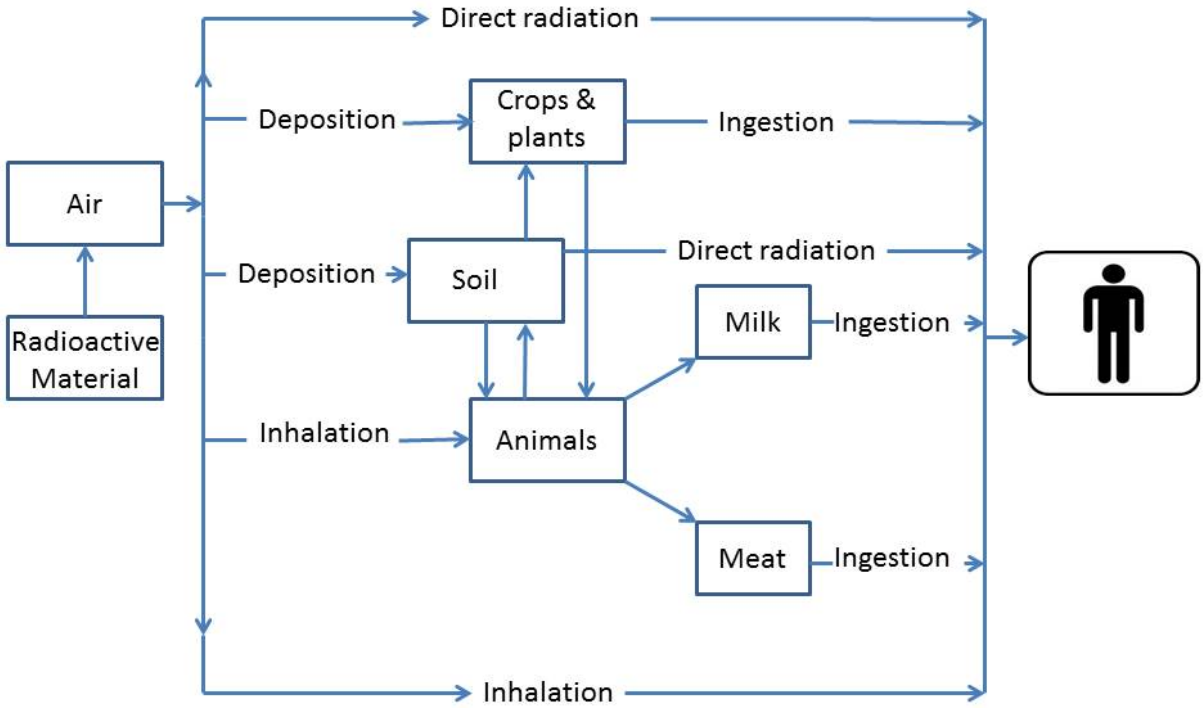

Figure 4-1. Potential pathways from air to humans living off the INL Site.

4.1.1.2 Significant Radionuclides

Each year, the estimated air emissions of about 180 radionuclides from the INL Site are modeled with CAP88-PC. Of the radionuclides released at the INL Site, most of the calculated dose is from about nine radionuclides (Table 3-5 and Figures 3-9 through 3-12). Figure 4-2 summarizes the average contribution of each radionuclide for 2007-2011. The major pathways contributing to the majority of doses to human receptors, and the radionuclides associated with them, as calculated by CAP88-PC using a unit release, are shown in Table 4-1. The results indicate that inhalation is a major exposure pathway for transuranics (americium and plutonium); immersion is a major pathway for noble gases; and food represents a major pathway for tritium, Sr-90, I–129, and Cs–137 (Table 4-1).

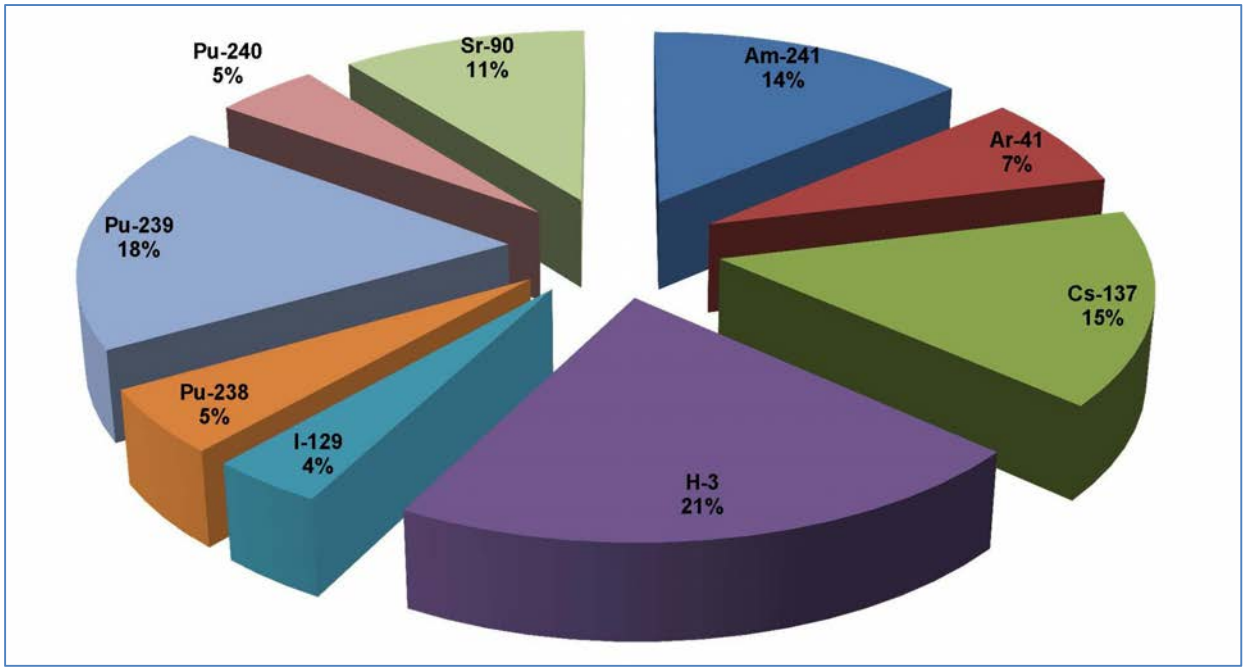

Figure 4-2. Average percentage contribution to total dose to the hypothetical Maximally Exposed Individual from INL Site releases (2007–2011).

Table 4-1. Major radionuclides released in air at the INL Site and primary exposure routes.

Percent of Total Dose Per Radionuclide by Exposure Route							
Nuclide	Vegetables	Meat	Milk	Inhalation	Immersion	Ground Surface	TOTAL (per radionuclide)
Am–241	1.36%	0.00%	0.01%	98.63%	0.00%	0.00%	100.00%
Ar–41	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	100.00%
Cs–137	35.74%	48.36%	11.82%	0.54%	0.01%	3.53%	100.00%
I–129	31.13%	52.71%	15.96%	0.13%	0.00%	0.07%	100.00%
Pu–238	1.36%	0.01%	0.00%	98.62%	0.00%	0.00%	100.00%
Pu–239	1.39%	0.00%	0.00%	98.61%	0.00%	0.00%	100.00%
Pu–240	1.36%	0.01%	0.00%	98.62%	0.00%	0.00%	100.00%
Sr–90	35.74%	48.36%	11.82%	0.54%	0.01%	3.53%	100.00%
Tritium	51.66%	16.86%	19.93%	11.54%	0.00%	0.00%	100.00%

The majority of the radioactive airborne effluent released at the INL Site over the last several years was in the form of noble gases: argon, krypton, and xenon. The noble gases are chemically inert and therefore do not participate in biological processes and are not transported through the food chain (ANL 2007). Consequently, the noble gases contribute to dose primarily through immersion in air. Table 4-2 summarizes the noble gases released at the INL Site, primarily from reactor operations at ATR and spent fuel storage at INTEC. The table illustrates that most of the noble gases are short-lived and this, combined with the fact that noble gases are volatile, disperse quickly, and become diluted in air, make them unlikely to contribute measureable doses to off-Site receptors.

Table 4-2. Principal noble gases released at the INL Site in 2011 (DOE-ID 2012b).

Isotope	Estimated Quantity Released (Ci)	Half Life	Decay Mode	Comments
Argon–41	1130	1.827 hours	Beta, gamma	Neutron activation product
Krypton–85	1450	10.72 years	Beta	Fission product
Krypton–85m	4.40	4.48 hours	Beta	Fission product
Krypton–87	11.50	76.3 minutes	Beta	Fission product
Krypton–88	10.2	2.84 hours	Beta	Fission product
Xenon–133	1.05	5.245 days	Beta	Fission product
Xenon–135	19.2	9.09 hours	Beta	Fission product
Xenon–135m	9.35	15.29 minutes	Gamma	Fission product
Xenon–138	42.1	14.17 minutes	Beta	Fission product

Transuranics are those radionuclides with an atomic number greater than that of uranium (92). Only americium and plutonium are important for the air pathway at the INL Site. Most transuranics at DOE sites were produced in nuclear reactors by neutron capture. The radioactive properties of selected transuranics are summarized in Table 4-3. Transuranics pose a risk because of their relatively long half-lives, combined with their emission of alpha particles, which pose a hazard if they are taken into the body, where they tend to accumulate in the bones and liver. The most common form of americium and plutonium in the environment is the oxide form. Americium and plutonium are typically very insoluble, with the oxide being less soluble in water than ordinary sand (quartz). They adhere tightly to soil particles and tend to remain in the top few centimeters of soil as the oxide. In aquatic systems, americium and plutonium tend to settle out and adhere strongly to sediments, again remaining in upper layers. This results in inhalation being the dominant pathway (ANL 2007).

Table 4-3. Principal transuranics released at the INL Site in 2011 (DOE-ID 2012b).

Isotope	Estimated Quantity Released (Ci)	Half Life	Decay Mode
Americium–241	4.24E–03	432.2 years	Alpha
Plutonium–238	1.25E–03	87.74 years	Alpha
Plutonium–239	3.13E–03	24,065 years	Alpha
Plutonium–240	6.99E–04	6,537 years	Alpha

Other radionuclides important to the air pathway at the INL Site include cesium–137, iodine–129, strontium–90, and tritium (Figure 4-2). Cesium–137 is a fission product with a relatively high yield of about 6% (meaning about 6 atoms of cesium–137 are produced per 100 fissions). Consequently, cesium-137 is a major radionuclide in spent nuclear fuel, high level radioactive wastes resulting from the processing of spent nuclear fuel, and radioactive wastes associated with the operation of nuclear reactors and fuel reprocessing plants. Cesium–137 has a half-life of 30 years and decays by beta emission to Barium–137m which emits an energetic gamma ray that is the primary dose contributor. When taken into the body, cesium–137 behaves in a manner similar to potassium and distributes uniformly throughout the body. Cesium has been shown to biomagnify in aquatic food chains. Radioactive cesium is present in soil around the world largely as a result of fallout from past atmospheric nuclear weapons tests. The concentration of cesium-137 in surface soil from fallout ranges from about 0.1 to 1 picocurie (pCi)/g,

averaging less than 0.4 pCi/g. Cesium is also present as a contaminant at certain locations, such as nuclear reactors and facilities that process spent nuclear fuel. Cesium is generally one of the less mobile radioactive metals in the environment. It preferentially adheres quite well to soil, and the concentration associated with sandy soil particles is estimated to be 280 times higher than in interstitial water (water in the pore space between soil particles); concentration ratios are much higher (about 2,000 to more than 4,000) in clay and loam soils. Thus, cesium is generally not a major contaminant in groundwater at DOE sites or other locations (ANL 2007).

Iodine–129 is a fission product of uranium–235. The fission yield of iodine–129 is about 1%. Iodine-129 is persistent in the environment because of its long half-life (15.7 million years) and tends to accumulate in the thyroid. The ratio of stable iodine-127 to radioactive iodine-129 in the environment is more than 10 million to 1. The human body contains 10 to 20 milligrams of iodine, of which more than 90% is contained in the thyroid gland. Iodine-129 is present in soil around the world as a result of fallout from past atmospheric nuclear weapons tests. Iodine may also be found as a contaminant at facilities where spent nuclear fuel was processed. Iodine-129 is one of the more mobile radionuclides in soil and can move downward with percolating water to groundwater. Iodine concentrations in sandy soil are about the same as in interstitial water (in the pore spaces between soil particles). It binds more preferentially to loam, where the concentration in soil is estimated to be 5 times higher than in interstitial water (ANL 2007).

Strontium–90 is a beta emitter with a half-life of about 29 years. It is only a health hazard if taken into the body, where it behaves similar to calcium and concentrates in the bone. Beyond the four stable isotopes naturally present in soil, strontium-90 is also present in surface soil around the world as a result of fallout from past atmospheric nuclear weapons tests. Current strontium-90 levels in surface soil typically range from 0.01 to 1 picocurie per gram (pCi/g), reflecting various rainfall and wind patterns, elevation, and terrain; most levels fall between 0.05 and 0.5 pCi/g, with 0.1 pCi/g as a general average.

Strontium-90 is relatively mobile and can move down through soil with percolating water to groundwater. Environmental transport of strontium is strongly influenced by its chemical form. Strontium preferentially adheres to soil particles, and the amount in sandy soil is typically about 15 times higher than in interstitial water (in the pore spaces between soil particles); concentration ratios are typically higher (110) in clay soil. As a note, many years ago the U.S. Environmental Protection Agency (EPA) established a maximum contaminant level for strontium-90 in public drinking water supplies. That value based on extant dosimetry models is 8 pCi per liter (pCi/L). The value using current, improved dosimetry models would be 36 pCi/L (ANL 2007).

Tritium is a radioactive isotope of hydrogen that is formed by natural processes as well as by the nuclear activities of man. Tritium is primarily a fission product, although a small amount of tritium is produced naturally from the interaction of cosmic radiation with gases in the upper atmosphere. It follows the hydrologic cycle because most of it combines with oxygen to form HTO, or tritiated water, so it behaves the same as water in the environment and in the body. It has a half-life of about 12 years and decays via beta emission. The transport of tritium in the biosphere can be predicted on the basis of knowledge of the hydrologic cycle.

4.1.2 Groundwater and Surface Water

The eastern Snake River Plain (ESRP) aquifer is one of the most productive aquifers in the United States (Knobel, Bartholomay, and Rousseau 2005). The aquifer is the water source for nearly all municipal and domestic needs in the area as well as for irrigation, aquaculture, and industrial needs (Cosgrove et al. 1999). Recharge to the ESRP aquifer is affected by local surface drainage. The aquifer primarily is recharged from infiltration of irrigation water, infiltration of stream flow, groundwater inflow from adjoining mountain drainage basins, and infiltration of precipitation. The Big Lost River, which flows through the INL Site, drains more than 1,400 mi^2 of mountainous area that includes parts of the Lost River Range and Pioneer Range west of the INL Site (Knobel, Bartholomay, and Rousseau 2005).

Flow in the BLR infiltrates to the ESRP aquifer along its channel and at sinks and playas at the river's terminus at the Big Lost River Sinks on the INL Site.

Water in the ESRP aquifer primarily moves through fractures and interflow zones in basalt, generally flows southwestward, and eventually discharges at springs along the Snake River near Twin Falls, Idaho, about 100 miles southwest of the INL Site. Estimated discharge from the springs was about 3.13 million acre-feet per year for water year 2011 (Davis, Bartholomay, and Rattray 2013).

4.1.2.1 Exposure pathways

Radiochemical and chemical wastewater discharged since 1952 to infiltration ponds and disposal wells at the INL Site has affected water quality in the eastern Snake River Plain (ESRP) aquifer and in perched groundwater zones beneath the INL Site. The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Energy, maintains aquifer and perched groundwater monitoring networks at the INL Site to determine hydrologic trends and to delineate the movement of radiochemical and chemical wastes in the ESRP aquifer and in perched groundwater zones (Davis, Bartholomay, and Rattray 2013).

Groundwater is not considered to be a significant contributor to the dose of a member of the public off the INL Site. The INL and ICP contractors currently monitor drinking water at drinking water systems on the INL Site in order to ensure the safety of workers and comply with state of Idaho and EPA drinking water requirements. Doses due to tritium have been estimated to be decreasing with time and well below drinking water maximum contaminant levels established by EPA (DOE-ID 2012b). Detectable concentrations of radiochemical constituents in water samples from aquifer wells or multilevel monitoring system equipped wells in the ESRP aquifer at the INL Site generally decreased or remained constant during 2009–11 (Davis, Bartholomay, and Rattray 2013). Decreases in concentrations were attributed to radioactive decay, changes in waste-disposal methods, and dilution from recharge and underflow. The tritium plume extends south-southwestward in the general direction of groundwater flow.

Surface water is sampled on the INL Site and springs and drinking water are sampled off-Site because of the importance of the ESRP aquifer. Figure 4-3 shows the potential pathways to people living off the INL Site. The primary pathway of concern is:

- internal exposure because of ingestion of drinking water that could have been contaminated by radioactive materials.

To monitor the pathways shown in Figure 4-3, environmental surveillance on and off the INL Site focuses on:

- the Big Lost River, springs down gradient of the INL Site, drinking water off the INL Site (Chapter 9).

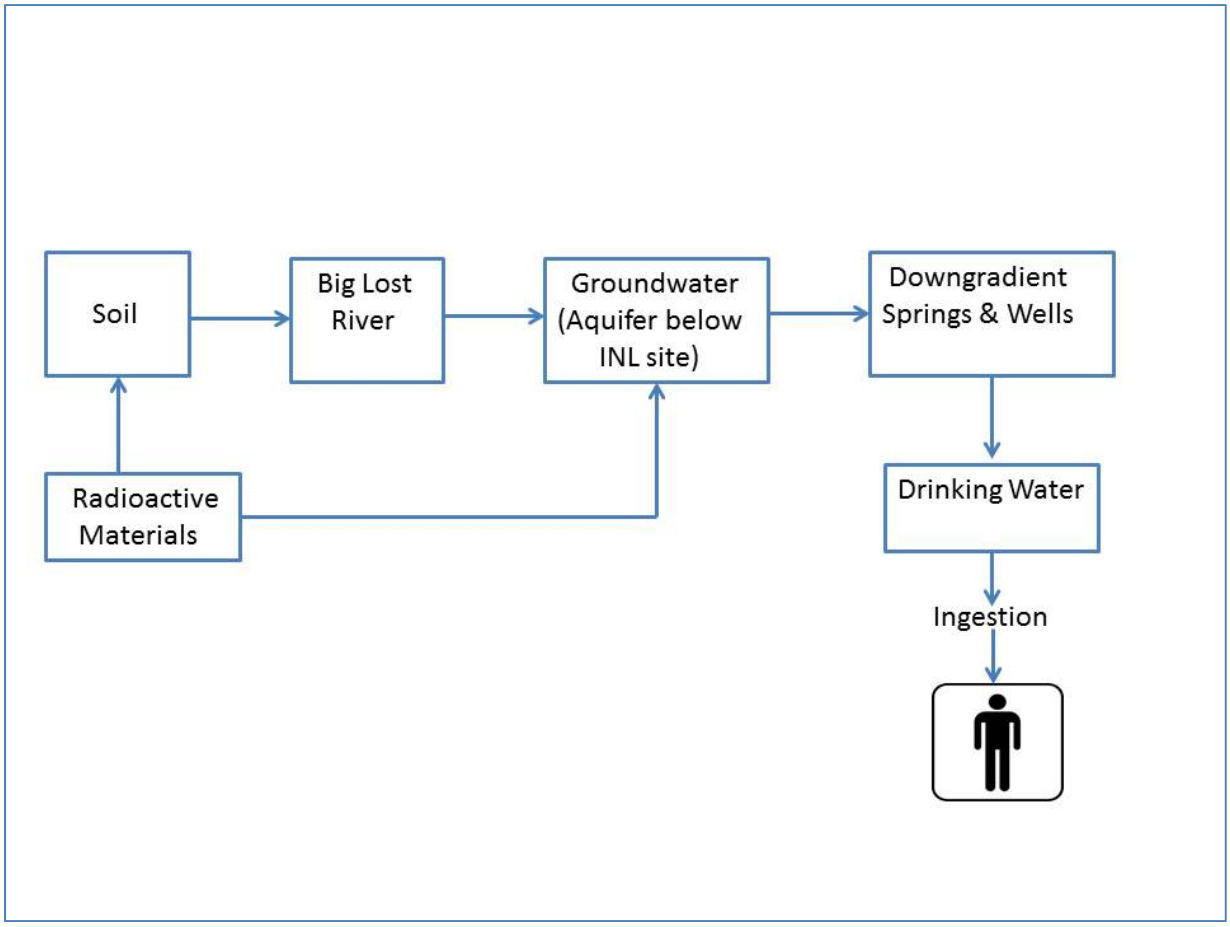

Figure 4-3. Primary potential pathways from surface water and groundwater to humans living off the INL Site.

4.1.2.2 Significant radionuclides

Historic waste disposal practices have produced localized areas of radiochemical contamination beneath the INL Site in perched water and the ESRP aquifer. These areas are regularly monitored by the U.S. Geological Survey (USGS) and reports are published showing the extent of contamination plumes (Davis 2010; Davis, Bartholomay, and Rattray 2013). Selection of radiochemical and chemical constituents for analyses by USGS are based on waste-disposal history. The radionuclides monitored by the USGS in the ESRP aquifer at the INL Site are primarily tritium and strontium–90. Tritium is considered the most important because of the relatively large activity disposed and because it is the most mobile radionuclide and therefore a leading indicator of how far the contamination has moved (Davis, Bartholomay, and Rattray 2013). The USGS also uses gross alpha and beta measurements to screen for radioactivity in the aquifer as a possible indicator of groundwater contamination.

Contaminated soil particles could become entrained and run off surface soil into the Big Lost River. Past studies (Martin, Halford, and Marty 2001) of the Big Lost River Sink sediments do not indicate that this has occurred.

4.1.3 Soil

4.1.3.1 Exposure Pathways

As shown in Figure 4-4, humans can be exposed to contaminated soil through:

- direct radiation
- ingestion of soil
- inhalation of resuspended particles (i.e., soil particles that are suspended in air through the action of wind.)

To monitor the potential pathways shown in Figure 4-4, environmental surveillance on and off the INL Site focuses measurement of radionuclides in:

- soil (Chapter 10).

While this probably is not a critical pathway, in terms of dose, to humans off the INL Site, soil samples are collected because we have measured contaminants of INL Site origin in soils around specific facilities (Table 4-4) and know that INL Site air emissions are dispersed and deposited off the Site.

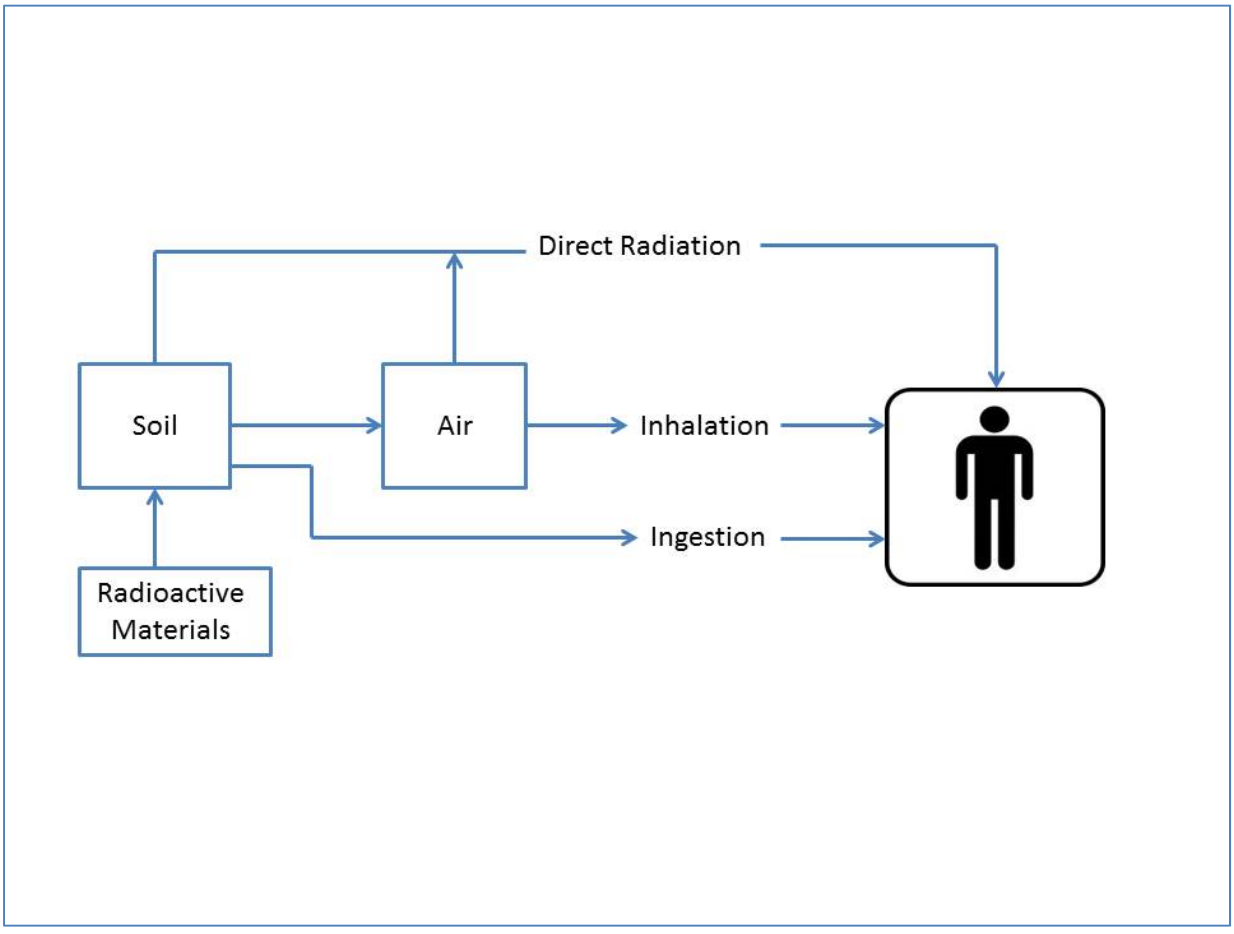

Figure 4-4. Potential pathways from soil to humans living off the INL Site.

4.1.3.2 Significant Radionuclides

Table 4-4 shows the concentrations of radionuclides of concern in contaminated soils around specific INL Site facilities. Particulates containing these radionuclides could become resuspended and airborne as a result of wind. While it is highly unlikely that resuspended particulates contribute significantly to dose, these radionuclides are also present in air emissions (Table 4-1) which could be deposited in soils and should therefore be monitored in off-Site soils.

Table 4-4. Radionuclides detected in on-Site soil samples (DOE-ID 2012b).

Location[a]	Radionuclide	Detected Concentration (pCi/g)[b]	
		Minimum	Maximum
ARA	Cesium-134	5.00×10^{-2}	8.00×10^{-2}
	Cesium-137	9.00×10^{-2}	1.62
	Uranium-238	-----[c]	5.47
	Strontium-90	2.10×10^{-1}	3.70×10^{-1}
	Plutonium-238	------	3.90×10^{-3}
	Plutonium-239/240	1.30×10^{-2}	1.80×10^{-2}
	Americium-241	5.50×10^{-3}	8.50×10^{-3}
ATR	Cobalt-60	3.00×10^{-2}	1.10×10^{-1}
	Cesium-134	2.00×10^{-2}	1.00×10^{-1}
	Cesium-137	8.00×10^{-2}	8.30×10^{-1}
	Europium-152	------	7.80×10^{-1}
	Americium-241	------	4.00×10^{-2}
	Strontium-90	------	5.82×10^{-2}
	Plutonium-238	5.90×10^{-3}	4.30×10^{-2}
	Plutonium-239/240	1.70×10^{-2}	2.18×10^{-2}
CITRC	Cesium-134	5.80×10^{-2}	8.00×10^{-2}
	Cesium-137	1.60×10^{-1}	1.70×10^{-1}
MFC	Cobalt-60	-----	2.00×10^{-1}
	Cesium-134	5.00×10^{-2}	7.00×10^{-2}
	Cesium-137	1.00×10^{-1}	2.20×10^{-1}
	Uranium-238	-----	2.58
	Plutonium-239/240	1.50×10^{-2}	2.90×10^{-2}
	Americium-241	4.30×10^{-3}	1.20×10^{-2}
INTEC	Cobalt-60	-----	3.30×10^{-2}
	Cesium-134	5.00×10^{-2}	8.00×10^{-2}
	Cesium-137	5.30×10^{-1}	2.72
	Uranium-238	4.20	5.56
	Strontium-90	4.90×10^{-1}	7.10×10^{-1}
	Plutonium-238	2.50×10^{-2}	4.30×10^{-2}
	Plutonium-239/240	1.10×10^{-2}	2.90×10^{-2}
	Americium-241	6.10×10^{-3}	8.10×10^{-3}
Large Grid	Cesium-134	6.00×10^{-2}	6.30×10^{-2}
	Cesium-137	1.30×10^{-1}	2.40×10^{-1}
	Strontium-90	------	1.10×10^{-1}
	Plutonium-238	3.30×10^{-3}	4.00×10^{-3}
	Plutonium-239/240	1.00×10^{-2}	2.50×10^{-2}
	Americium-241	5.50×10^{-3}	8.50×10^{-3}
NRF	Cesium-134	3.00×10^{-2}	8.00×10^{-2}
	Cesium-137	1.4×10^{-1}	1.60×10^{-1}
	Uranium-238	3.96	4.31
	Plutonium-239/240	5.70×10^{-3}	1.60×10^{-2}
	Americium-241	4.30×10^{-3}	9.70×10^{-3}

Table 4-4. (continued).

Location[a]	Radionuclide	Detected Concentration (pCi/g)[b] Minimum	Maximum
RWMC	Cesium-134	6.00×10^{-2}	8.00×10^{-2}
	Cesium-137	8.00×10^{-2}	2.10
	Sr-90	1.23×10^{-2}	1.78×10^{-1}
	Americium-241	2.02×10^{-2}	4.63×10^{-1}
	Plutonium-238	2.19×10^{-3}	1.51×10^{-2}
	Plutonium-239/240	3.6×10^{-2}	5.25×10^{-1}
TAN/SMC	Cesium-134	4.00×10^{-2}	6.00×10^{-2}
	Cesium-137	1.10×10^{-1}	3.7×10^{-1}
	Uranium-238	------	4.33
	Plutonium-239/240	1.25×10^{-2}	1.74×10^{-2}
	Americium-241	3.20×10^{-3}	5.70×10^{-3}
ALL LOCATIONS[d]	Cobalt-60	3.00×10^{-2}	2.00×10^{-1}
	Cesium-134	2.00×10^{-2}	1.00×10^{-1}
	Cesium-137	8.00×10^{-2}	2.72
	Europium-152	------	7.80×10^{-1}
	Strontium-90	1.23×10^{-2}	7.10×10^{-1}
	Uranium-238	3.96	5.56
	Plutonium-238	2.19×10^{-3}	4.30×10^{-2}
	Plutonium-239/240	5.70×10^{-3}	5.25×10^{-1}
	Americium-241	4.30×10^{-3}	4.63×10^{-1}

a. ARA = Auxiliary Reactor Area; ATR = Advance Test Reactor Complex; CITRC = Critical Infrastructure Test Range Complex; Large Grid = A 24- mile radius around INTEC; MFC = Materials and Fuels Complex; INTEC = Idaho Nuclear Technology and Engineering Center NRF = Naval Reactors Facility; RWMC = Radioactive Waste Management Complex; TAN/SMC = Test Area North/Specific Manufacturing Capability.

b. Legend:
- Results measured in 2012 using in situ gamma spectroscopy (see Table 7-2.)
- Results measured by laboratory analyses of soil samples collected in 2005
- Results measured by laboratory analyses of soil samples collected in 2006
- Results measured by laboratory analyses of soil samples collected in 2012.

c. '-----' indicates that only one measurement was taken and is reported as the maximum result.

d. Summarizes all facilities.

4.1.4 Game Animals

4.1.4.1 Exposure pathways

Game animals are considered a critical exposure pathway because they can ingest soil, water, and vegetation contaminated by radionuclides released by the INL Site and then in turn become consumed by hunters living off-Site (Figure 4-5). Ducks migrating through the INL Site can land on ponds which receive liquid effluents (most notably the ATR Complex Evaporation Pond discussed in 5.1.2). The ponds are lined to prevent infiltration to the aquifer, however radionuclides can build up in pond sediments. Rooted vegetation and water can be ingested by waterfowl. The waterfowl, in turn, can fly off the INL Site and be hunted on an off-Site body of water and then be consumed. Historical studies have demonstrated that ducks spending time on radioactive effluent ponds at the INL Site can become contaminated (Warren, Majors, and Morris 2001).

Big game animals (elk, pronghorn, and mule deer) can forage on contaminated soils and vegetation and have been observed drinking from liquid effluent ponds on the INL Site. The soils and vegetation can either be contaminated on-Site or off-Site (via air). Animals can then in turn be hunted and eaten.

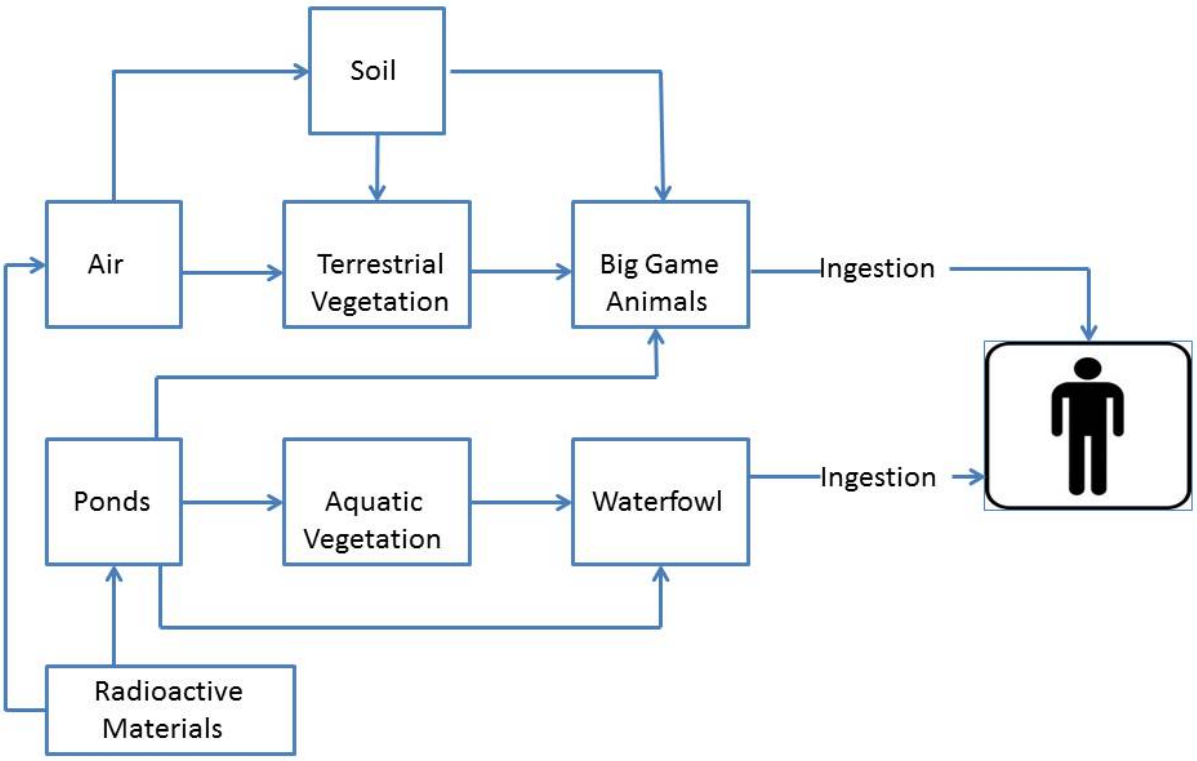

Figure 4-5. Potential pathways via game animals to humans living off the INL Site.

To monitor the exposure pathways to humans shown in Figure 4-5, environmental surveillance on the INL Site focuses on sampling:

- waterfowl on ponds at the INL Site (Chapter 13)
- big game animals which have been killed on roads at the INL Site (Chapter 12).

4.1.4.2 Significant Radionuclides

Potential doses to humans from game animals have been estimated by analyzing tissues from waterfowl accessing wastewater ponds at the INL Site and tissues from big game animals killed by vehicles on or near the INL Site. Conservative estimates were made using radionuclide concentrations measured in edible tissues. Assumptions used in the analyses included:

- Maximum concentrations of radionuclides were used
- The animal would be consumed soon after leaving the INL Site (i.e., no biological or radioactive decay occurred prior to consumption).

The doses estimated for consumption of waterfowl collected from the ATR Complex Evaporation Pond and reported in the ASERs from 2007 to 2011 are shown in Table 4-5. Cesium–137, cobalt–60, strontium–90, and zinc–65 are common constituents in the wastewater discharged to the pond (note the effluent to the pond is not analyzed for transuranics; see Table 5-3). The estimated doses are from 8% to 100% of the annual doses calculated from airborne pathways. The 2010 waterfowl dose is approximately equivalent to that modeled for airborne releases. The assumptions used in the dose calculations from consumption of waterfowl from the INL Site are very conservative and produce doses to the public well below regulatory standards. Monitoring this media is important due to mobility of these media and public concern.

Table 4-5. Estimated doses (mrem/yr) from consuming waterfowl collected at wastewater ponds.

Year	Am-241	Pu-238	Pu-239	Co-60	Cs-137	Sr-90	Zn-65	Total Dose
2007	3.99E–04	ND	ND	1.19E–04	1.47E–02	ND	ND	1.52E–02
2008	4.54E–02	ND	ND	2.29E–04	5.87E–03	1.97E–03	9.03E–04	5.15E–02
2009	ND	ND	ND	6.95E–05	2.45E–03	1.70E–03	1.57E–03	5.78E–03
2010	ND	8.62E–05	1.91E–03	3.01E–04	3.09E–02	2.41E–02	1.71E–03	5.90E–02
2011	ND	ND	ND	1.54E-04	1.58E-03	ND	2.29E–03	4.02E–03

The doses estimated for consumption of big game animals (antelope, deer, or elk) have ranged from 4.0E–03 to 2.27E–01 mrem/yr for 2007-2011. In each case, the only radionuclide detected in the meat was Cs–137, a fall-out product. The maximum dose was from deer tissue collected in 2008. The Cs–137 concentration was the highest detected since 1988. The deer was collected near the RWMC. The source of the contamination was most likely contaminated forage, soil, or water consumed by the animal. In 1998 and 1999, four pronghorn, five elk, and eight mule deer muscle samples were collected as background samples from hunters across the western United States, including three from central Idaho, three from Wyoming, three from Montana, four from Utah, and one each from New Mexico, Colorado, Nevada, and Oregon (DOE-ID 2002). Each background sample had small, but detectable, Cs-137 concentrations in its muscle. These concentrations likely can be attributed to the ingestion of plants containing radionuclides from fallout associated with aboveground nuclear weapons testing. Allowing for radioactive decay since the time of the study, background measurements would be expected to range from about 4 to 11 pCi/kg in 2012. With the exception of an immature deer sampled in 2008 that had elevated Cs-137 concentrations, all detected values have been within the expected range of background (about 4 and 11 pCi/kg) (DOE-ID 2012b).

Based on the measurements made during 2007-2011, the radionuclides of concern for consumption of waterfowl are gamma-emitting radionuclides, strontium–90, and transuranic radionuclides (americium–241, plutonium–238, and plutonium–239/240). The media contributing to contaminants in waterfowl are wastewater ponds and sediment within those ponds.

The radionuclides of concern for consumption of game animals are gamma-emitting radionuclides (primarily Cs–137). Because this is a radionuclide associated with global fallout (see Section 4.2), it is always conservatively assumed that any detection of this radionuclide comes from the INL Site.

4.1.5 Summary of Pathways Monitored with Respect to DOE Guidance

Table 4-6 summarizes the potential environmental pathways and the significant radionuclides included in the on-Site and off-Site environmental surveillance programs, based on recommendations for consideration in DOE (1991).

Table 4-6. Environmental pathways and exposure routes for radiological emissions at the INL Site (based on recommendations of DOE [1991]).

Exposure Route	Environmental Pathway	Potential Dose to Receptor		Significant Radionuclides	Modeling/Monitoring Programs			Comments
		On-Site	Off-Site		On-Site Monitoring	Off-Site Modeling	Off-Site Monitoring	
External	Direct Facility Radiation	Yes	No	Gamma-emitters, neutrons	External Radiation	None	External Radiation	contractor radiation control programs evaluate occupational exposures
	Immersion in Airborne Plume	Yes	Yes	Noble gases	External Radiation	NESHAPS	External Radiation	
	Contaminated Land	Yes	Yes	Gamma-emitters	External Radiation, Soil	NESHAPS	External Radiation, Soil	
	Aquatic Recreation (boating/swimming)	No	No	None	None	None	None	No INL Site facilities discharge liquid effluent directly to lakes or streams
Inhalation	Airborne Plume	Yes	Yes	Tritium, gamma-emitters, transuranics, Sr-90	Atmospheric moisture, Air	NESHAPS	Atmospheric moisture, Air	
	Resuspended Material	Yes	Yes	Gamma-emitters, transuranics, Sr-90	None	NESHAPS	Air	
Ingestion of Terrestrial Foods	Vegetables, Fruit, Cereal Grains	No	Yes	Gamma-emitters, Sr–90	None	NESHAPS	Agricultural products	
	Animal Products (milk, cheese, meat, eggs)	No	Yes	Gamma-emitters, Sr-90	None	NESHAPS	Agricultural products	
	Big Game Animals	No	Yes	Gamma-emitters	Big Game Animals	None	Big Game Animals	
	Waterfowl	No	Yes	Transuranics, Sr–90, gamma-emitter	Waterfowl	None	Waterfowl	

Exposure Route	Environmental Pathway	Potential Dose to Receptor		Significant Radionuclides	Modeling/Monitoring Programs			Comments
		On-Site	Off-Site		On-Site Monitoring	Off-Site Modeling	Off-Site Monitoring	
Ingestion of Aquatic Foods	Fish	No	No	None	None	None	None	No INL Site facilities discharge liquid effluent directly to lakes or streams.
Ingestion of Soil	Grazing Animals	Yes	Yes	Transuranics, Sr–90, gamma-emitters	Soil	NESHAPS	Soil	
	Humans (Children)	No	Yes	Transuranics, Sr–90, gamma-emitters	Soil	None	Soil	
Ingestion of Drinking Water	Surface Water	No	No	Tritium gross alpha and beta, gamma-emitters	Surface Water (BLR)	None	None	No INL Site facilities discharge liquid effluent directly to lakes or streams. Drinking water in the area is from wells but BLR recharges the aquifer.
	Well Water	Yes	Yes	Tritium, Cs–137, Sr–90, Tc–99, I-129 On-Site Tritium, gross alpha and beta Off-Site	See Comments	NESHAPS, CERCLA investigations, USGS	Drinking Water	On-Site monitoring programs are described in DOE-ID (2012c) and DOE-ID (2011).
	Rain Water	No	No	None	None	None	None	Drinking water in the area is from wells.

4.2 Background Radioactivity

Radioactivity from natural and fallout sources is detectable as background in all environmental media. Natural sources of radiation include: radiation of extraterrestrial origin (called cosmic rays), radionuclides produced in the atmosphere by cosmic ray interaction with matter (called cosmogenic radionuclides), and 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.

4.2.1 Natural Sources

Natural radiation and radioactivity in the environment, that is natural background, represent a major source of human radiation exposure (NCRP 1987; NCRP 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 2011 to receive an average dose of about 381 mrem/yr from natural background sources of radiation on earth (Figure 4-6). These sources include cosmic radiation and naturally occurring radionuclides.

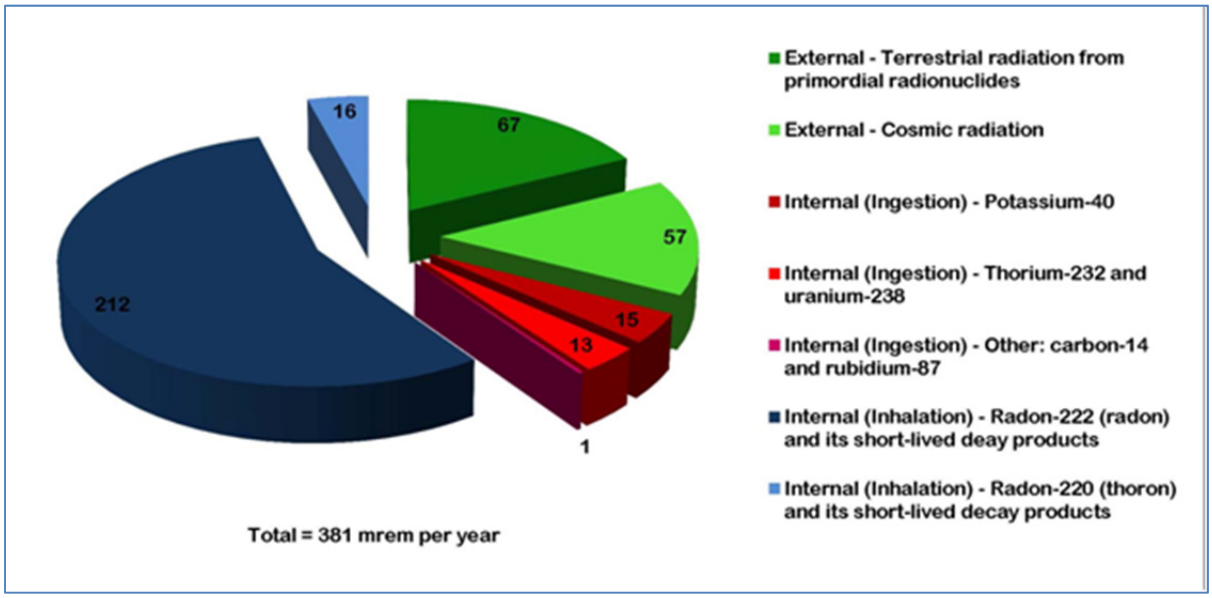

Figure 4-6. Calculated doses (mrem per year) from natural background sources for an average individual living in southeast Idaho (2011).

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 to a typical individual living in southeast Idaho (Figure 4-6). 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 tritium (hydrogen–3), beryllium–7, sodium–22, and

carbon–14. Cosmogenic radionuclides, particularly tritium and carbon–14, 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 carbon–14, that might be received by an adult living in the United States (NCRP 2009). Tritium and beryllium–7 are routinely detected in environmental samples collected by environmental monitoring programs on and around the INL Site (Table 4-7), but contribute little to the dose which might be received from natural background sources.

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, uranium–238, and thorium–232—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 4-7). The external dose to an adult living in southeast Idaho from terrestrial natural background radiation exposure (68 mrem/yr) has been estimated using concentrations of potassium–40, uranium–238, and thorium–232 measured in soil samples collected from areas surrounding the INL Site from 1976 through 1993. Uranium–238 and thorium–232 are also estimated to contribute 13 mrem/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 according to NCRP [2009]). Rubidium–87, another primordial radionuclide, contributes a small amount (<1 mrem/y) to the internal dose received by people, but is not typically measured in INL Site samples.

Uranium–238 and thorium–232 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 uranium–238. The most familiar element in the uranium series is radon, specifically radon–222. This is a gas that can accumulate in buildings. Radon and its progeny are responsible for most of the inhalation dose (an average of 200 mrem/yr nationwide) produced by naturally occurring radionuclides (Figure 4-6). The parent radionuclide of the thorium series is thorium–232. Another isotope of radon (radon–220), called thoron, occurs in the thorium decay chain of radioactive atoms. Uranium–238, thorium, and their progeny often are detected in environmental samples (Table 4-7).

Table 4-7. 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	2.7E+6 yr	Cosmic rays	Rain, air
Tritium	12.3 yr	Cosmic rays	Water, rain, air moisture
Potassium–40	1.26E+9 yr	Primordial	Water, air, soil, plants, animals
Thorium–232	1.4E+10 yr	Primordial	Soil
Uranium–238	4.5E+9 yr	Primordial	Water, air, soil
Uranium–234	2.5E+5 yr	U–238 progeny	Water, air, soil
Radium–226	1,620 yr	U–238 progeny	Water

4.2.2 Anthropogenic Radionuclides

The United States, the USSR, and China tested nuclear weapons in the atmosphere in the 1950s and 1960s, which resulted in the release of radionuclides into the upper atmosphere. This 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, though. France continued atmospheric testing until 1974, and China until 1980. Additional fallout, but to a substantially smaller extent, was produced by the Chernobyl nuclear accident in 1986 and by the Fukushima Daiichi Nuclear Power Plant reactors accident in 2011.

Aboveground nuclear weapons testing resulted in many radionuclides being distributed throughout the world via atmospheric deposition. Most of the radionuclides associated with nuclear weapons testing and the Chernobyl accident 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 strontium–90 and cesium–137. Strontium-90, a beta-emitter with a 29-year half-life, is important because it is chemically similar to calcium and tends to lodge 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. Plutonium–238, plutonium–239/240, and americium–241 are long-lived radionuclides that are detected in soil because of global fallout, but could also be present from INL Site operations. All of these radionuclides are of particular interest because of their abundance resulting from nuclear fission events (e.g., cesium–137 and strontium–90) or from their persistence in the environment due to long half-lives (e.g., plutonium–239/240, with a half-life of 24,110 years).

4.3 References

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5. LIQUID EFFLUENT MONITORING

It is the policy of DOE to conduct wastewater monitoring to determine whether the public and environment are adequately protected during DOE operations and whether operations are in compliance with DOE and other applicable Federal, State, and local regulations and requirements (DOE 1991). On the INL Site, wastewater is discharged to numerous infiltration and evaporation ponds located in proximity to the major facilities. These discharges have the potential to impact groundwater, affect air quality via evaporation or fugitive dust emissions, or contaminate waterfowl. Facilities in Idaho Falls discharge wastewater to the City of Idaho Falls sewer.

As summarized in Table 5-1, wastewater monitoring is performed to demonstrate compliance with:

1. Requirements in wastewater reuse permits issued according to the Idaho Department of Environmental Quality Rules, Idaho Administrative Procedures Act (IDAPA) 58.01.17, "Recycled Water Rules"
2. Requirements in a City of Idaho Falls industrial wastewater acceptance permit issued according to the City of Idaho Falls Sewer Use Ordinance, Chapter 1, Section 8.
3. Requirements in an air quality permit to construct issued according to the Idaho Department of Environmental Quality Rules, IDAPA 58.01.01, "Rules for the Control of Air Pollution in Idaho."
4. Guidance in DOE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance" (DOE 1991)
    a. Demonstrate compliance with the applicable requirements of DOE 458.1
    b. Quantify radionuclides discharged from each discharge point
    c. Alert affected process supervisors of upsets in processes and emission controls.
5. Requirements in DOE Order 458.1, "Radiation Protection of the Public and the Environment"
    a. Characterize planned and unplanned releases of liquids containing radionuclides
    b. Comply with the as low as reasonably achievable (ALARA) process requirements
    c. Conduct activities to ensure that liquid releases containing radionuclides from DOE activities are managed in a manner that protects groundwater resources
    d. Conduct activities to ensure that liquid discharges containing radionuclides from DOE activities do not exceed the annual average concentrations identified in the Order
    e. Ensure that radionuclides from DOE activities contained in liquid effluents do not cause private or public drinking water systems to exceed the drinking water limits
    f. Prohibit the use of soil columns.

Table 5-1. Summary of liquid-effluent monitoring at INL Site and Idaho Falls facilities.

Facility	Monitoring Requirements			
	DOE Orders/ Guidance	Idaho Air Quality Permit	Idaho Wastewater Reuse Permit	City of Idaho Falls Permit
ATR Complex Cold Waste Pond	X		X	
ATR Complex Evaporation Pond	X	X		
ATR Complex Sewage Treatment Lagoons	No Routine Monitoring			
CFA Sewage Treatment Facility	X		X	
INL Research Center				X
INTEC Percolation Ponds	X		X	
MFC Industrial Waste Ditch and Industrial Waste Pond	X		X	
MFC Secondary Sanitary Sewage Lagoon (replaced with HDPE-lined evaporation ponds in November 2012)	X			
RWMC Municipal Wastewater Lagoons	No Routine Monitoring			
SMC Wastewater Lagoons	No Routine Monitoring			

5.1 Advanced Test Reactor Complex

The ATR Complex consists of buildings and structures utilized to conduct research associated with developing, testing, and analyzing materials used in nuclear and reactor applications and both radiological and nonradiological laboratory analyses. There are three wastewater disposal facilities at the ATR Complex: the Cold Waste Pond, the Evaporation Pond, and the Sewage Treatment Lagoons (Figure 5-1).

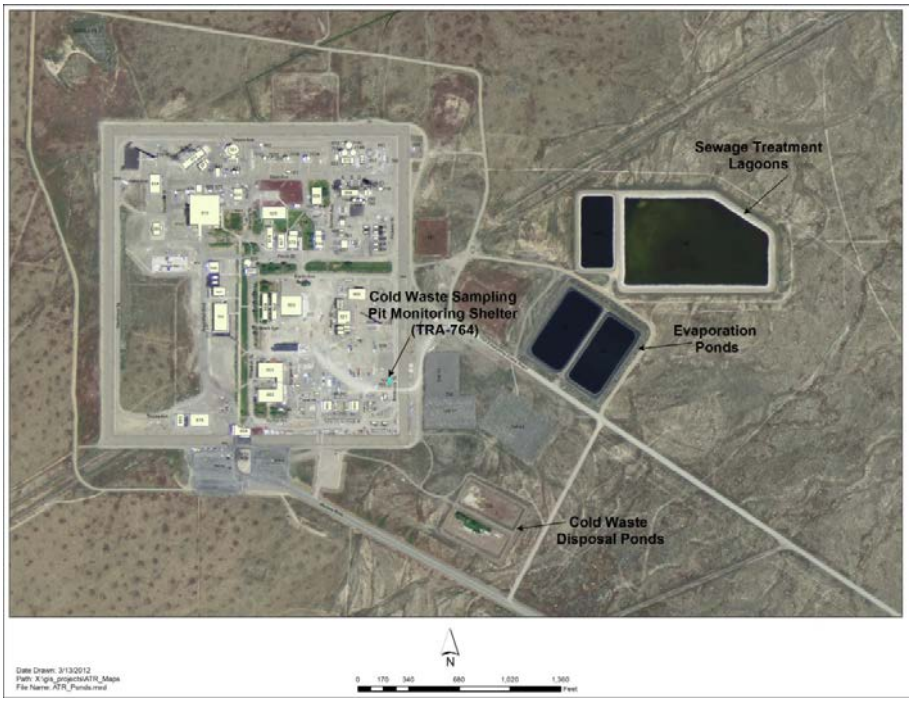

Figure 5-1. Wastewater ponds at the ATR Complex.

5.1.1 ATR Complex Cold Waste Pond

5.1.1.1 Drivers for Sampling Program

The wastewater discharged to the pond is sampled to demonstrate compliance with the Industrial Wastewater Reuse Permit (IWRP) issued by the Idaho Department of Environmental Quality in February 2008 (DEQ 2008).

Environmental surveillance monitoring at the ATR Complex Cold Waste Pond (CWP) is performed to meet the following requirements:

- DOE Order 458.1, "Radiation Protection of the Public and the Environment"
- DOE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance."

5.1.1.2 Background

The CWP is located approximately 450 ft from the southeast corner of the ATR Complex compound and approximately 3/4 of a mile southwest of the Big Lost River channel (Figure 5-1). The existing CWP was excavated in 1982. It consists of two cells, each with dimensions of 180 × 430 ft across the top of the berms, and a depth of 10 ft. Total surface area for the two cells at the top of the berms is approximately 3.55 acres. Maximum capacity is approximately 10,220,000 gal (31.3 acre ft).

Wastewater discharged to the CWP consists primarily of noncontact cooling tower blowdown, once-through cooling water for air conditioning units, coolant water from air compressors, secondary system drains, and other nonradioactive drains throughout the ATR Complex. Chemicals used in the cooling tower and other effluent streams discharged to the CWP include commercial biocides and corrosion inhibitors (INL 2006a). Examples include chlorine dioxide biocide generated by mixing sulfuric acid and sodium chlorate/sodium chloride, and phosphate-based corrosion inhibitors. The pond receives non-contact cooling water from the ATR, so radionuclides are not discharged to the cold waste pond under normal operating conditions. In the event of radioactive contamination in the cold drain system from an upset condition or design basis event the wastewater can be routed to the evaporation pond (Rasch 2006).

The wastewater flows through collection piping to the TRA-764 Cold Waste Sample Pit, where the flow rate is recorded and samples are collected. The wastewater then flows to the Cold Waste Sump Pit (TRA-703). The sump pit contains submersible pumps that route the water to the appropriate CWP cell through 8 in. valves.

Wastewater enters the pond through concrete inlet basins located near the west end of each cell. Most of the water percolates into the porous ground a short distance from the inlet basins. The entire floor of a cell is rarely submerged. If the water level rises significantly in a cell (e.g., 5 ft), the flow would be diverted to the adjacent cell, allowing the first cell to dry out. An overflow pipe connects the two cells at the 9-ft level.

Approximately 166 million gallons are discharged to the Cold Waste Pond annually (INL 2012a).

The cold waste pond was evaluated during the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) investigation at the INL Site as site ID TRA-08, and arsenic and cesium–137 were identified as contaminants of concern (COCs). The presence of cesium–137 is believed to be from windblown soil contamination originating from the warm waste pond, and the presence of arsenic is the result of historical disposal practices at the cold waste pond (DOE-ID 2007). Post-Record of Decision sampling data (DOE-ID 1998a) confirmed that the pond sediments are below the 18.3-mg/kg final remediation goal for arsenic and the Resource Conservation and Recovery Act (RCRA) toxicity characteristic leaching procedure's regulatory limit. The elimination of arsenic as a COC reduced the number of COCs at the pond from two to one, which doubled the final remediation goal for

cesium-137 from 11.7 to 23.3 pCi/g (DOE-ID 1997, DOE-ID 2000). Remedial actions were conducted at the cold waste pond in 1999. Approximately 80 yd^3 of cesium–137-contaminated soil was removed from the northern ponds and transported to Cell 1957 of the warm waste pond for disposal. Institutional controls were established, thereby restricting the site to industrial land use until residential risk is $<10^{-04}$ (DOE-ID 2007).

5.1.1.3 Sampling Basis and Design

Samples of the effluent to the ATR Complex CWP are analyzed for radiological and non-radiological constituents to demonstrate compliance with the wastewater reuse permit and DOE orders. Samples are collected at the weir impoundment located at the TRA–764 Monitoring Shelter, which, per DOE (1991), is located downstream of the last component stream and is protected from the elements to prevent freezing of the sampling line. Locating the sampler near the flow meter in TRA–764 simplified collection of the flow-proportional samples required by the wastewater reuse permit. Samples are collected with a Sigma 900 Max refrigerated sampler, which collects the sample aliquots via a peristaltic pump into a carboy in a refrigerated unit to minimize biological growth. DOE (1991) recommends sampling materials that are compatible with the effluent, so inert components such as Teflon, stainless steel, polyvinyl chloride or silicone tubing, and high-density polyethylene plastic are used. To meet the recommendation for a redundant sample collection system in DOE (1991), spare parts and portable samplers are kept on hand.

The wastewater reuse permit requires collection of a 24-hour flow proportional sample every month. Samples are collected on a randomly selected date. Flow proportional sampling meets the requirements of DOE (1991), and because flow rates seldom fluctuate more than 50% over a 24-hour period, the sampling strategy also approximates another acceptable sampling strategy: off-line sequential sampling. Therefore, samples for environmental surveillance monitoring are collected in the same manner as the samples required for the wastewater reuse permit. The surveillance samples are collected at the same time as the permit samples to minimize sampling costs.

Einerson (1996) developed a risk-based approach to liquid-effluent monitoring using historical data. The approach was based on the likelihood of exceeding a release limit paired with the response time for corrective action. Einerson (1996) remains generally applicable because discharge to the pond is still dominated by secondary cooling water from the reactor.

"An Implementation of the Risk Based Approach to Liquid Effluent Monitoring at the INEL" (Einerson 1996) noted that sulfate and total dissolved solids (TDS) concentrations in the cold waste pond effluent had historically exceeded the release limits and recommended continued monitoring for these constituents and a process review/change. Einerson (1996) recommended quarterly monitoring for the other constituents in Table 5-2 to demonstrate concentrations were below release levels; however, when the wastewater reuse permit was issued in 2008, the sampling frequency was increased to monthly to match the permit requirements. Based on the data collected for the permit, INL has requested DEQ eliminate the monitoring requirements for arsenic, barium, cadmium, chromium, cobalt, copper, fluoride, iron, manganese, mercury, selenium, and silver because they are typically not detected or are an order of magnitude below the drinking water standard (INL 2012b).

Einerson (1996) suggested quarterly sampling for volatile organic compounds (VOCs) because of a limited number of detections of methylene chloride and Freon–11 in the early 1990s. Analyses for VOCs were performed on quarterly samples until the second quarter of 1997 when VOC analyses were discontinued because most compounds were not detected, with the exception of sporadic detections of methylene chloride (a common laboratory contaminant) and Freon–11 at very low concentrations.

Samples for a broad spectrum of radionuclides are collected to monitor for upset conditions in the reactor cooling system or accidental releases and to demonstrate compliance with DOE orders (Table 5-2). Samples for gamma spectroscopy, gross alpha, and gross beta are collected monthly. These

analyses provide a relatively inexpensive screening for gross radioactivity and a variety of fission and activation products. Samples for strontium–89/90, tritium, and iodine–129 have been collected annually (Table 5-2). The analyte list was reviewed with personnel from the ATR Complex who determined that the most likely scenario for the release of radionuclides to the Cold Waste Pond was failure of containment of the primary coolant water (E. King, personal communication, February 21, 2013). The resultant release profile would be similar to releases to the ATR Complex evaporation pond (see Section 5.1.2.2). The following changes to the surveillance monitoring at the CWP are recommended:

1. Discontinue the annual analysis for strontium–89/90 because of the contingency analysis for strontium–90 if the gross beta concentration in a monthly sample exceeds 15 pCi/L.
2. Discontinue analyses for iodine–129 because numerous fission products (e.g., europium, cesium) are included in the analyte list for gamma spectroscopy.
3. Increase frequency of tritium sampling to monthly.

Constituent concentrations were well below the screening release levels during 2010–2011 (Table 5-2).

Table 5-2. Summary of environmental monitoring at the ATR Complex Cold Waste Pond.

Analyte	Sampling Frequency	Driver[a]	Screening Level	2010-2011	
				Minimum	Maximum
Metals (µg/L)					
Aluminum	Monthly	GW	None	<25	<25
Antimony	Monthly	Einerson (1996)	2,200[b]	<0.25	1.3
Arsenic	Monthly	DEQ, Einerson (1996)	5,000[c]	<5	7.5
Barium	Monthly	DEQ, Einerson (1996)	100,000[c]	46.6	171
Beryllium	Monthly	DEQ, Einerson (1996)	60[b]	<0.8	<0.8
Cadmium	Monthly	DEQ, Einerson (1996)	1,000[c]	<1	<1
Chromium	Monthly	DEQ, Einerson (1996)	5,000[c]	2.8	11.1
Cobalt	Monthly	DEQ	None	<2.5	<2.5
Copper	Monthly	DEQ, Einerson (1996)	None	<1	10.8
Iron	Monthly	DEQ, Einerson (1996)	None	<25	201
Lead	Monthly	Einerson (1996)	5,000[c]	<0.25	<0.25
Manganese	Monthly	DEQ, Einerson (1996)	1.3E+08[b]	<2.5	13.4
Mercury	Monthly	DEQ, Einerson (1996)	200[c]	<0.2	<0.2
Nickel	Monthly	Einerson (1996)	54,000[b]	<2.5	<2.5
Selenium	Monthly	DEQ, Einerson (1996)	1,000[c]	1	5.2
Silver	Monthly	DEQ, Einerson (1996)	5,000[c]	<5	<5
Sodium	Monthly	Einerson (1996)	None	8,060	38,500
Thallium	Monthly	Einerson (1996)	24[b]	<0.25	<0.25
Zinc	Monthly	Einerson (1996)	5E+06[b]	<2.5	18.6
Non-Metals (mg/L)					
Chloride	Monthly	DEQ, Einerson (1996)	None	10.2	40.9
Fluoride	Monthly	DEQ, Einerson (1996)	2.1E+05[b]	0.131	0.491
Sulfate	Monthly	DEQ, Einerson (1996)	None	21.2	709

Table 5-2. (continued).

Analyte	Sampling Frequency	Driver[a]	Screening Level	2010-2011	
				Minimum	Maximum
Total Dissolved Solids	Monthly	DEQ, Einerson (1996)	None	241	1290
Total Suspended Solids	Monthly	DEQ	100[d]	<4	6.8
Nitrate+nitrite as nitrogen	Monthly	DEQ, Einerson (1996)	See total nitrogen	0.848	3.55
Total Kjeldahl nitrogen (TKN)	Monthly	DEQ	See total nitrogen	0.156	0.531
Total nitrogen (sum of TKN and nitrate+nitrite as nitrogen)	Monthly	DEQ	20[d]	1.051	4.081
Radionuclides (pCi/L)					
Gamma Spectroscopy	Monthly	DOE, Einerson (1996)			
Silver-108m			Not calculated[e]	ND[f]	ND
Silver-110m			90[e]	ND	ND
Americium-241			15[e]	ND	ND
Cerium-144			30[e]	ND	ND
Cobalt-58			300[e]	ND	ND
Cobalt-60			100[e]	ND	ND
Cesium-134			80[e]	ND	ND
Cesium-137			200[e]	ND	ND
Europium-152			200[e]	ND	ND
Europium-154			60[e]	ND	ND
Europium-155			600[e]	ND	ND
Potassium-40			None	ND	39.7±9.14
Manganese-54			300[e]	ND	ND
Niobium-95			300[e]	ND	ND
Radium-226			Naturally occurring[g]	ND	ND
Ruthenium-103			200[e]	ND	ND
Ruthenium-106			30[e]	ND	ND
Antimony-125			300[e]	ND	ND
Uranium-235			66[h]	ND	ND
Zinc-65			300[e]	ND	ND
Zirconium-95			200[e]	ND	ND
Gross alpha	Monthly	DOE, Einerson (1996)	15[g,i]	ND	4.46±1.08
Gross beta[j]	Monthly	DOE, Einerson (1996)	4 mrem/yr[i]	ND	23.3±2.18
Strontium-89/90	Annually	DOE	8[i]	ND	ND

Table 5-2. (continued).

Analyte	Sampling Frequency	Driver[a]	Screening Level	2010-2011 Minimum	2010-2011 Maximum
Tritium	Annually	DOE	20,000[i]	ND	ND
Iodine–129	Annually	DOE	1[e]	ND	ND

a. DOE = DOE orders for radiation protection; DEQ = Industrial Wastewater Reuse Permit, GW = Analyte for groundwater samples collected for the Industrial Wastewater Reuse Permit
b. Screening release levels for surface pathway from Ansley et al. (1997).
c. From 40 CFR 261.24 (toxicity characteristic)
d. Maximum thirty (30) day average concentrations from IDAPA 58.01.017.600.06 (rapid infiltration systems).
e. Maximum Contaminant Level (MCL) from EPA (2000)
f. ND = not detected.
g. The limit is 5 pCi/L if process-derived radium–226 is present in the wastewater.
h. Calculated from the MCL of 30 µg/L. The specific activity for uranium–234 was used to calculate the MCL for uranium-233/234.
i. Primary Constituent Standard (PCS) from IDAPA 58.01.11.
j. If the gross beta activity in the sample exceeds 15 pCi/L, the sample is analyzed for strontium–90.

In addition to the composite samples collected for the permit and environmental surveillance, bi-weekly grab samples are collected at the TRA–764 Monitoring Shelter by ATR operations personnel and analyzed on site for gamma spectroscopy.

5.1.1.4 Decision Limits and Actions

The screening levels for discharge to the pond are in Table 5-2. In the event the reported concentration of a constituent exceeds a screening level, environmental management and facility personnel are notified and an assessment is performed to determine whether additional action is necessary. If a permit limit is exceeded, it must be reported in the monthly self-disclosure log submitted to the DEQ. Additional samples are collected if warranted.

5.1.2 ATR Complex Evaporation Pond

5.1.2.1 Drivers for Sampling Program

The DEQ issued the initial Air Quality Permit to Construct (PTC) for the ATR (then the Test Reactor Area or TRA) Evaporation Pond in 1990. The current revision of the PTC was issued in 2002 (DEQ 2002). The Air Quality PTC for the evaporation pond requires the following analyses:

1. A daily grab sample to demonstrate compliance with the nonvolatile radionuclide emission limits specified in the permit (42.6 curies per month and 510.9 curies per year).
2. A composite sample analyzed on a monthly basis using liquid scintillation to determine compliance with the volatile-radionuclide emission limits in the permit (27.1 curies per month and 324.3 curies per year).

5.1.2.2 Background

The TRA–715 evaporation pond is a fenced five acre pond located about 1500 feet east of the ATR Complex that has been in operation since 1993. The pond is divided into two double lined compartments each measuring 550 ft × 225 ft × 10 ft deep. The combined volume of both compartments is about 18 million gallons. The leak-detection system consists of perforated pipes in the sand layer between the Hypalon® surface liner and the polyvinyl chloride subsurface liner. The pipes drain into two manholes located in the berm separating the two compartments.

The evaporation pond receives low-level radioactively contaminated wastewater ("warm" wastewater) from the warm wastewater system at the ATR Complex and includes infrequent discharges from sources outside the ATR Complex. The warm wastewater system consists of two 50 ft^3 mixed-ion exchange beds in each of two warm waste-treatment facilities. The ion exchange beds are designed to remove radioactive impurities. Approximately 98–99% of the warm wastewater discharged to the evaporation pond is from ion-exchange-treated ATR primary coolant (radioactive) (Rasch 2006). The ion-exchange media are bypassed in situations involving high-conductivity water and/or treatment of water where there would be no appreciable reduction in emissions.

The PTC requires monitoring of the effluent stream to the evaporation pond with a sodium iodide or equivalent detector to monitor for gross gamma radiation. The detector triggers an alarm if the discharge-stream radionuclide loading is much higher than normal levels, and the discharge stream can be diverted to interim storage tanks.

The estimated, decay-corrected cumulative activity of gamma-emitting radionuclides discharged to the pond is in Table 5-3. Routine gamma-emitting radionuclides discharged to the pond from the ATR are typically dominated by cobalt–60, chromium–51, and sodium–24. The facility does not calculate a cumulative total for radionuclides that are not gamma-emitters, such as tritium or strontium; annual discharges to the pond have ranged from 0.084 to 59.7 mCi/year strontium–89, 2.64 to 396 mCi/year strontium–90, and 32.5 to 124.5 Ci/year tritium. Tritium is the primary volatile radionuclide discharged to the pond.

Table 5-3. Estimated total decay-corrected activity (millicuries) of gamma-emitting radionuclides discharged to the ATR Complex Evaporation Pond from August 13, 1993 to January 20, 2012.

Isotope	Activity	Isotope	Activity	Isotope	Activity	Isotope	Activity
Ag–110m	1.76	Cs–134	12.99	I–131	0.23	Ru/Rh–106	3.17
Am–241	22.20	Cs–137	6630.04	I–133	0.02	Sb–122	0.04
Ba–140	0.27	Eu–152	135.94	Mn–54	11.77	Sb–124	1.15
Ce–141	0.96	Eu–154	118.37	Mo–99	1.49	Sc–46	1.23
Ce–144	65.37	Eu–155	23.10	Na–24	38.98	Ta–182	2.04
Co–58	11.30	Fe–59	1.20	Nb–95	0.57	W–187	0.06
Co–60	4176.58	Hf–175	1.80	Np–239	0.20	Zn–65	24.77
Cr–51	1105.34	Hf–181	29.81	Re–188	4.34	Zr–95	1.65

5.1.2.3 Decision Limits

The limits for volatile and nonvolatile radionuclide discharges specified in the PTC are summarized in Table 5-4. A summary of the activity discharged to the pond is submitted to the DEQ each calendar quarter.

Table 5-4. Radionuclide discharge limits for the ATR Complex Evaporation Pond.

Description	Radionuclides	
	Curies/Month	Curies/Year
Volatile radionuclide discharges	27.1	324.3
Nonvolatile radionuclide discharges	42.6	510.9

5.1.3 ATR Complex Sewage Treatment Lagoons

5.1.3.1 Drivers for Sampling Program

To ensure the public and environment are adequately protected, the ATR Complex Sewage Lagoons undergo periodic seepage tests in lieu of routine environmental monitoring. Laboratory analyses may be required to demonstrate that non-routine discharges to the lagoons meet the wastewater acceptance criteria for the sewage lagoons, which prohibits discharges that exceed the drinking water standards for radionuclides (INL 2007).

5.1.3.2 Background

The ATR Complex Sewage Treatment Lagoons were constructed in 1995 and receive domestic wastewater from approximately forty buildings inside the ATR Complex. Domestic wastewater is sanitary wastewater from basic sanitation activities associated with personnel and office administrative areas such as urinals/toilets, restroom and lunchroom sinks, shower rooms (not emergency showers or eyewash stations), and janitorial sinks not in process areas. Examples of sanitary wastewater include, but are not limited to, raw sewage, mop water, cleaning solutions used to disinfect, soaps and detergents, floor wash residue, and blowdown from water softeners (INL 2007). The lagoons are evaporative, non-discharging lagoons and have the following characteristics:

- Gravity flow collection system
- Wet well/lift station that pumps wastewater to the lagoons
- Lagoon 1 2.9 acres at an 8 ft depth
- Lagoon 2 13.8 acres at an 8 ft depth
- Bentonite lined lagoons.

The lagoons were designed to treat up to 60,000 gallons per day (gpd) with current flows averaging around 28,000 gpd. Wastewater flows by gravity from Lagoon 1 to Lagoon 2 through a transfer structure located on the north end of the berm between the lagoons.

Seepage tests were performed at the ATR Complex Sewage Lagoons during June and July 2010. The 15-day seepage rate for Lagoon 1 was 0.1243 inches/day; the seepage rate for Lagoon 2 was 0.0199 inches/day. The seepage tests were performed to demonstrate compliance with the allowable seepage rate of 0.25 inches/day required for lagoons constructed prior to April 15, 2007 (IDAPA 58.01.16, "Wastewater Rules). A seepage test is required every ten years after the initial test.

5.2 Central Facilities Area Sewage Treatment Facility

5.2.1 Drivers for Sampling Program

The wastewater applied to the land surface at the CFA Sewage Treatment Facility (STF) is sampled to demonstrated compliance with the Municipal Wastewater Reuse Permit issued by the Idaho Department of Environmental Quality in March 2010 (DEQ 2010a). Samples of the effluent to the irrigation pivot are collected monthly at sampling location CFA–STF while land-applying wastewater (Figure 5-2).

Environmental surveillance monitoring at the CFA STF is performed to meet the following requirements:

- DOE Order 458.1, "Radiation Protection of the Public and the Environment"
- DE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance."

5.2.2 Background

As shown in Figure 5-2, the sewage treatment facility consists of a:

- 1.7-acre partial-mix, aerated lagoon (Lagoon No. 1)
- 10.3-acre facultative lagoon (Lagoon No. 2)
- 0.5-acre polishing pond (Lagoon No. 3)
- 73.5-acre wastewater land application area consisting of desert steppe and crested wheatgrass vegetative communities
- Computerized center-pivot, sprinkler irrigation system.

The treatment facility, which was constructed in the 1990s and has been operational since 1995, serves all major CFA facilities (INL 2011). The wastewater is derived from bus and vehicle maintenance areas; boiler blowdown; heating, ventilation, and air conditioning systems; employee showers and restrooms; laboratories; craft shops; a fire station; and a medical dispensary. Additional wastewater may be transported from other area comfort stations, septic tanks and portable toilets. About 1.22 million gallons of wastewater was land-applied to the irrigation area in 2011(INL 2012c).

A 350- gpm pump moves wastewater from the lagoons to the center-pivot sprinkler system, which waters the land application area at low pressures (about 30 lb/in^2) to minimize aerosols and spray drift.

As stipulated in the permit, no grazing of domesticated animals or cultivation of crops for human consumption occurred in the application area.

Seepage tests were performed on the lagoons in 2006. The calculated seepage rates were 0.028 in. per day for Lagoon No. 1, 0.046 in. per day for Lagoon No. 2; and 0.054 in. per day for Lagoon No. 3 (INL 2006c). The seepage tests were performed to demonstrate compliance with the allowable seepage rate of 0.25 inches/day required for lagoons constructed prior to April 15, 2007 (IDAPA 58.01.16, “Wastewater Rules”).

Due to historical releases to the CFA sewer system, access points are posted with a Special Instruction to contact INL radiation control prior to accessing the system. Small quantities of radionuclides are used for radiochemical research and development at the CFA Laboratory Complex (CFA–625); any radiological liquid wastes that may be generated are containerized for off-Site disposal. In addition, historical releases to an injection well and percolation ponds at INTEC have resulted in groundwater contamination at CFA which, in turn, is eventually discharged to the wastewater lagoons. Tritium and iodine–129 are the principal radionuclide contaminants of interest (see Table 5-5).

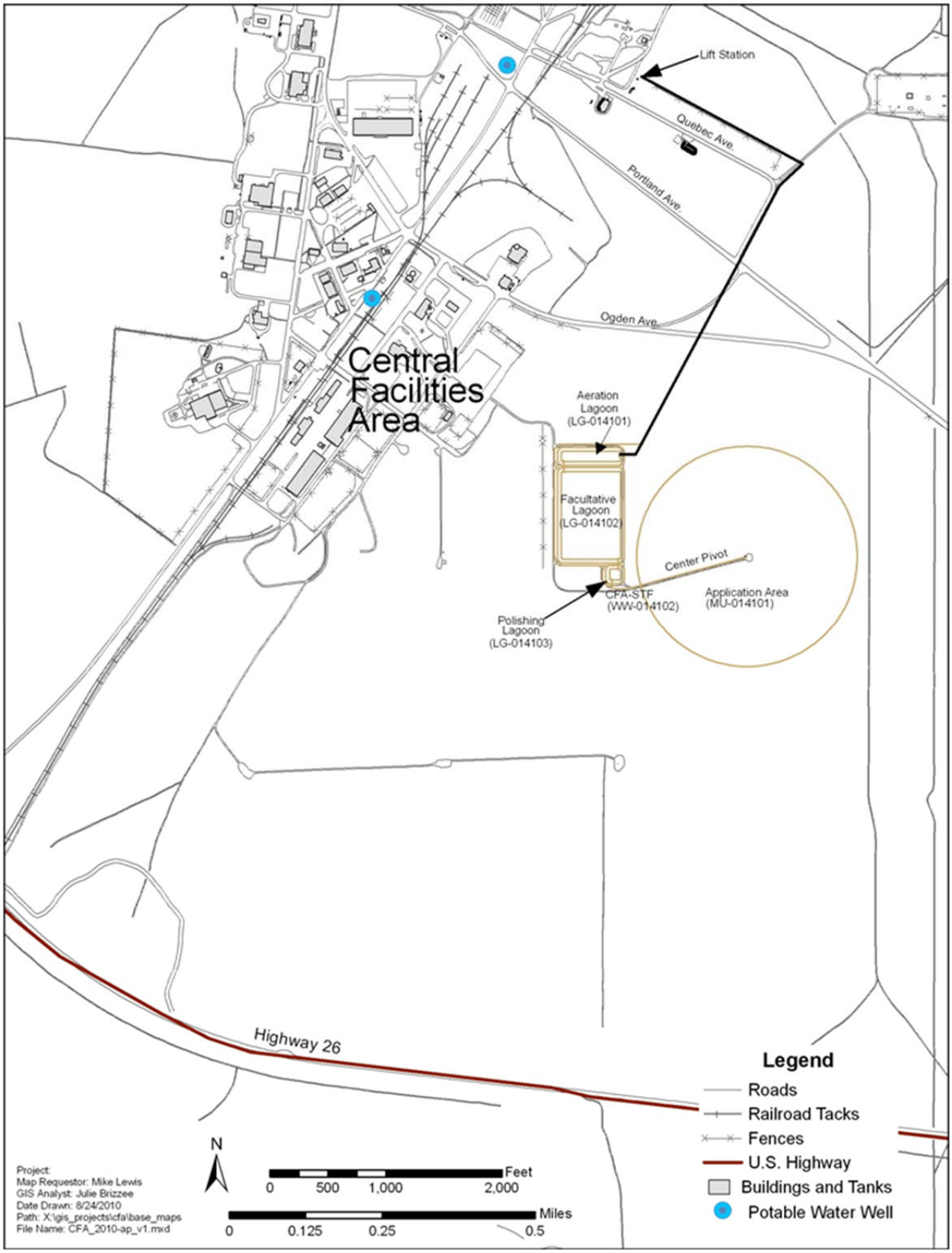

Figure 5-2. CFA Sewage Treatment Facility. Samples are collected at the irrigation pump pivot, sampling point CFA–STF.

5.2.3 Sampling Basis and Design

Samples of the wastewater land-applied at the CFA Sewage Treatment Facility are analyzed for radiological and non-radiological constituents to demonstrate compliance with the wastewater reuse permit and DOE orders. DOE (1991) recommends sampling at a location downstream of the last component stream that provides complete mixing; thus, the samples are collected from the wastewater in the pump pit, just prior to discharge to the pivot. The wastewater reuse permit requires collection of a 24-hour flow-proportional sample, which equates to time-proportional sample because the pump rate to the pivot is nearly constant. This sampling method is equivalent to off-line sequential sampling in DOE (1991), which is "suitable for quantifying uniformly low concentrations of radionuclides being released via effluent lines to the environs." Consequently, environmental surveillance samples are collected in the same manner as the samples for the permit. Samples are collected monthly during a randomly selected week per the schedule specified in the wastewater reuse permit. Since 2009, wastewater land application has only occurred during one month in the summer, so only one sample has been collected, typically in August.

Samples are collected with a Sigma 900 Max portable sampler, which collects the sample aliquots via a peristaltic pump into a carboy. The carboy used for samples that may be affected by biological growth is packed in blue ice. DOE (1991) recommends sampling materials that are compatible with the effluent, so inert components such as Teflon, stainless steel, polyvinyl chloride or silicone tubing, and high-density polyethylene plastic are used. To meet the recommendation for a redundant sample-collection system in DOE (1991), an extra portable sampler is kept on hand.

Einerson (1996) evaluated the historical data for the CFA STF and recommended that characterization monitoring for antimony, arsenic, barium, beryllium, cadmium, chloride, chromium, copper, fluoride, iron, lead, mercury, manganese, nickel, pH, radioactivity, silver, sodium, selenium, sulfate, thallium, total dissolved solids, zinc, and methylene chloride continue quarterly for two years. The detections of methylene chloride are suspect because of blank contamination or laboratory estimation. Sampling for VOCs continued through August 1996: low levels of methylene chloride were detected in the samples, but again, the results were suspect because methylene chloride was also detected in the blanks. Analyses for the other constituents evaluated by Einerson (1996) have continued to demonstrate concentrations below the screening levels (Table 5-5).

Samples for gamma spectroscopy, gross alpha, gross beta, strontium–89/90, tritium, and iodine–129 are collected annually if wastewater is land-applied. Gamma spectroscopy, gross alpha, and gross beta are relatively inexpensive analyses; additional samples can be collected if elevated concentrations are reported in the samples for gross activity. Tritium and iodine–129 are present in the lagoons because of historical groundwater contamination from INTEC (Table 5-5). The annual analysis for strontium–89/90 can be discontinued because of the contingency analysis for strontium–90 if the gross-beta concentration in a monthly sample exceeds 15 pCi/L.

CFA–625 does not have any "hot" drains to the sewer system and all radioactive waste is properly disposed. To evaluate accidental releases at CFA–625, the source term published in INL (2009) was assumed to be released into one year of total estimated discharge to the CFA STF (about 76,000,000 liters; INL 2010a). The resultant calculated concentration was compared to the associated derived concentration standard (DCS) for water ingestion in (DOE 2011); only the calculated concentrations of americium–243, uranium–232, and uranium–233 exceeded the corresponding standard. The same calculation was performed for the unsealed sources, primarily liquids, at CFA–625 in February 2013; only the calculated concentrations of curium–244 and uranium–233 exceeded the DCSs. The ratio of the calculated concentration to the DCS were 2.46 and 1.81 for curium–244 and uranium–233, respectively. Additional analyses for these alpha emitters can be performed if the gross alpha concentration exceeds the screening limit of 15 pCi/L.

Table 5-5. Summary of environmental monitoring at the CFA Sewage Treatment Facility.

Analyte	Sampling Frequency	Driver[a]	Screening Level[b]	2010-2011	
				Minimum	Maximum
Metals (µg/L)					
Aluminum	Annually[c]	TAL	1E+06	<25	<25
Antimony	Annually	Einerson (1996)	85	<0.25	<0.25
Arsenic	Annually	Einerson (1996)	34	<5	<5
Barium	Annually	Einerson (1996)	15,000	55.1	66.4
Beryllium	Annually	Einerson (1996)	12	<0.8	<0.8
Cadmium	Annually	Einerson (1996)	78	<1	<1
Chromium	Annually	Einerson (1996)	370	<2.5	<2.5
Cobalt	Annually	TAL	None	<2.5	<2.5
Copper	Annually	Einerson (1996)	61,000	1.1	1.3
Iron	Annually	Einerson (1996)	220,000	70.6	93.7
Lead	Annually	Einerson (1996)	5,000	<0.25	<0.25
Manganese	Annually	Einerson (1996)	8,100	3.1	3.6
Mercury	Annually	Einerson (1996)	64	<0.2	<0.2
Nickel	Annually	Einerson (1996)	4,300	<2.5	<2.5
Selenium	Annually	Einerson (1996)	530	0.89	1.2
Silver	Annually	Einerson (1996)	1,100	<5	<5
Sodium	Annually	Einerson (1996)	6.7E+06	176,000	254,000
Thallium	Annually	Einerson (1996)	17	<0.25	<0.25
Zinc	Annually	Einerson (1996)	64,000	<2.5	<2.5
Non-Metals (mg/L)					
Chemical Oxygen Demand	Monthly[c]	DEQ	None	47.6	59.8
Chloride	Annually	Einerson (1996)	None	429	599
Coliform, Total	Monthly	DEQ	None	3	16
Fluoride	Annually	Einerson (1996)	13	0.382	0.385
Phosphorus, Total	Monthly	DEQ	None	0.374	0.888
Sulfate	Annually	Einerson (1996)	None	65.8	87.4
Total Dissolved Solids	Monthly	DEQ	None	1,200	1,460
Nitrate+nitrite as nitrogen	Monthly	DEQ	36 (as nitrate) 3.6 (as nitrite)	0.25 U	0.151
Total Kjeldahl nitrogen (TKN)	Monthly	DEQ	None	1.99	4.58
Field Parameters					
Electrical conductivity (µmhos/cm)	Monthly	No	None	1,747	2,260
Hydrogen ion (pH) (standard units)	Monthly	DEQ, Einerson (1996)	2.5–12.5	9.11	9.59

Table 5-5. (continued).

Analyte	Sampling Frequency	Driver[a]	Screening Level[b]	2010-2011 Minimum	2010-2011 Maximum
Radionuclides (pCi/L)					
Gamma Spectroscopy	Annually	DOE, Einerson (1996)			
Silver–108m			Not calculated[e]	ND[f]	ND
Silver–110m			90[e]	ND	ND
Americium–241			15[e]	ND	ND
Cerium–144			30[e]	ND	ND
Cobalt–58			300[e]	ND	ND
Cobalt–60			100[e]	ND	ND
Cesium–134			80[e]	ND	ND
Cesium–137			200[e]	ND	ND
Europium–152			200[e]	ND	ND
Europium–154			60[e]	ND	ND
Europium–155			600[e]	ND	ND
Potassium–40			None	ND	32.8±12.4
Manganese–54			300[e]	ND	ND
Niobium–95			300[e]	ND	ND
Radium–226			Naturally occurring[g]	ND	ND
Ruthenium–103			200[e]	ND	ND
Ruthenium–106			30[e]	ND	ND
Antimony–125			300[e]	ND	ND
Uranium–235			66[h]	ND	ND
Zinc–65			300[e]	ND	ND
Zirconium–95			200[e]	ND	ND
Gross alpha	Annually	DOE, Einerson (1996)	15[g,i]	ND	ND
Gross beta[j]	Annually	DOE, Einerson (1996)	4 mrem/yr[i]	13.1±2.07	14.9±1.85
Strontium–89/90	Annually	DOE	8[i]	ND	ND
Tritium	Annually	DOE	20,000[i]	1,950±275	2,870±326
Iodine–129	Annually	DOE	1[e]	ND	0.193±0.07

a. DOE = DOE orders for radiation protection; DEQ = Municipal Wastewater Reuse Permit, TAL=standard metals target analyte list in INL (2006a).

b. Screening release levels are from INL (2006d) unless otherwise noted.

c. When land-applying wastewater.

d. Maximum thirty (30) day average concentrations from IDAPA 58.01.017.600.06 (rapid infiltration systems).

e. Maximum Contaminant Level (MCL) from EPA (2000)

f. ND = not detected.

g. The limit is 5 pCi/L if process-derived radium–226 is present in the wastewater.

h. Calculated from the MCL of 30 µg/L. The specific activity for uranium–234 was used to calculate the MCL for uranium–233/234.

i. Primary Constituent Standard (PCS) from IDAPA 58.01.11.

j. If the gross beta activity in the sample exceeds 15 pCi/L the sample is analyzed for strontium–90.

5.2.4 Decision Limits and Actions

The screening levels for discharge to the pond are in Table 5-5. In the event the reported concentration of a constituent exceeds a screening level, environmental management and facility personnel are notified and an assessment is performed to determine whether additional action is necessary.

5.3 INL Research Center

5.3.1 Background

A meeting was held with personnel with the City of Idaho Falls on December 5, 2006, to determine which of the facilities in Idaho Falls required an Industrial Wastewater Discharge Permit (IWA) from the City of Idaho Falls (City of Idaho Falls 2007). The City of Idaho Falls determined it would not issue permits to the minor facilities in Idaho Falls occupied by the INL because the facilities did not meet the criteria for issuance of an IWA (City of Idaho Falls 2007; Smith 2009). These facilities include:

1. Energy Storage Technology Lab (IF–605)
2. Records Storage Building (IF–663)
3. Willow Creek (IF–616/617)
4. Engineering Research Office Building (IF–654)
5. Firewater Pump House #2 (IF–731)
6. Technical Support Building and Technical Support Annex (IF–604A and B)
7. Idaho National Lab Administration Building (IF–606)
8. Information Operations and Research Center (IF–608)
9. North Boulevard Annex (IF–613)
10. May Street North (IF–614) (no longer in use)
11. May Street South (IF–615) (no longer in use)
12. Bus Dispatch (IF–631) (no longer in use)
13. North Holmes Laboratory (IF–639)
14. North Yellowstone Laboratory (IF–651)
15. Bonneville County Technology Center (IF–670)
16. Idaho Innovation Center (IF–673) (no longer in use)
17. International Way Building (IF–674).

The City of Idaho Falls determined that an IWA was required for the IRC, which includes the following buildings:

1. Radiological and Environmental Sciences Office (IF–601)
2. INL Research Center (IRC) Office Building (IF–602)
3. IRC Laboratory Building (IF–603)
4. National Security Building (IF–611)
5. Systems Analysis Facility (IF–627)
6. IRC Physics Laboratory (IF–638)
7. IRC Chemical Storage Facility (IF–655)

8. INL Engineering Demonstration Facility (IF–657)
9. Fire Water Pump House #1 (IF–732).

The estimated discharge to the City of Idaho Falls sewer system from the INL Research Center was about 20,000 gallons per day in 2008; however, in 2010 two water-cooled air compressors were replaced with air-cooled units, reducing the estimated daily discharge to about 13,000 gallons (INL 2008; Doug Hilde, personal communication, March 13, 2012). Most of the wastewater discharged to the sewer is sanitary waste and cooling water; an estimated 3,200 gallons per day is process water from:

1. IRC Laboratory Building (~2,000 gallons)
2. National Security Building (~150 gallons)
3. INL Engineering Demonstration Facility (~1,000 gallons)
4. IRC Physics Laboratory (~50 gallons).

There are over 60 small laboratories in the IRC Laboratory Building that contain utility sinks and floor drains (sealed where practical) that drain to the city sewer. Unlike a production facility, the IRC typically uses very small quantities of chemicals.

A meeting was held with a representative of the City of Idaho Falls Sewer Department to determine whether a Wastewater Acceptance Permit would be required when the DOE Radiological and Environmental Sciences Laboratory (RESL) moved into IF–683 in 2011. Based on the information provided, the City of Idaho Falls determined the new RESL building did not meet any of the criteria of a significant industrial user or categorical industrial user and would not require a permit (Henricksen 2009). The evaluation of potential radionuclide discharge to the Idaho Falls sewer developed by RESL and presented at the meeting with the City of Idaho Falls Sewer Department is shown in Table 5-6.

Table 5-6. Potential discharge to the Idaho Falls publicly-owned treatment works (POTW) from RESL.

Radionuclide	Drinking Water MCL's (pCi/L)	RESL Sample Concentration (pCi/L)	RESL Impact to POTW assume 1% loss RESL Sample (pCi)	Monthly Facility Discharge estimated 10,000 L/month (pCi/L)
Americium–241	15	17	0.17	0.000017
Cobalt–57	1,000	511	5.11	0.000511
Cobalt–60	100	465	4.65	0.000465
Cesium–137	200	180	1.80	0.000180
Iron–55	2,000	1,300	13.00	0.001300
Manganese–54	300	396	3.96	0.000396
Plutonium–238	15	23	0.23	0.000023
Plutonium–239	15	23	0.23	0.000023
Strontium–90	8	195	1.95	0.000195
Technetium–99	900	391	3.91	0.000391
Uranium–234	NA	75	0.75	0.000075
Uranium–238	NA	78	0.78	0.000078
Zinc–65	300	368	3.68	0.000368
Tritium	20,000	8,900	89.00	0.008900

5.3.2 Drivers for Sampling Program

The wastewater discharged to the City of Idaho Falls sewer from the INL Research Center is sampled by City of Idaho Falls personnel to meet the requirements of the City of Idaho Falls Industrial Waste Acceptance Permit (Table 5-7; City of Idaho Falls 2013). In addition, daily pH measurements are recorded at the IRC pH building retention tank (IF–705) and submitted monthly to the City of Idaho Falls. During 2010–2011 the results were all within the limits established by the permit. Among other things, the permit prohibits "wastewater containing any radioactive wastes or isotopes except as specifically approved by the Director in compliance with applicable State or Federal regulations."

Einerson (1996) concluded "It is not recommended that sampling for radionuclides be done [at IRC] since there is virtually no potential for radionuclide contamination. This is because under normal operations, radionuclide sources are either sealed or containerized." Einerson (1996) further states "Monthly self-monitoring at this location is not recommended based on the low probability of exceeding a limit."

Routine discharges to IRC sinks and drains are limited to unregulated and nonhazardous material. Administrative controls have been instituted at the laboratories to control discharges from the sinks to maintain compliance with sewer permit requirements (INL 2005). The laboratory sinks are posted with a notice of the sewer discharge limits, including the prohibition of radioactive isotopes. The limits are also specified in laboratory procedures. Engineering controls, such as plugging the floor drains in the laboratories, have also been utilized. In addition, there are tanks with 5,400 gallons of holding capacity that can be used to contain the effluent in the event of a pH excursion or inadvertent release of a prohibited material (INL 2005). Administrative controls, training requirements, and the spill-notification procedure for the IRC are in INL (2010b).

The HSS assessment noted "The ability to demonstrate compliance with the provisions of DOE Order 5400.5 can only be achieved through sampling and/or radionuclide quantity limits low enough to ensure the DCGs [derived concentration guides] cannot be exceeded based on concentration calculations using average facility-specific discharge volumes" (HSS 2010). This issue was evaluated by calculating effluent concentrations assuming the entire inventory of liquid and powder sources at the IRC was lost to the sanitary sewer over a period of one year. DOE Order 458.1 cancelled 5400.5 in 2011, and derived concentrations standards (DCSs) from DOE (2011) replaced the DCGs as guidance for the design and conduct of radiological environmental protection programs at DOE facilities. The DOE Derived Concentration Technical Standard (DOE 2011) states that for known mixtures of radionuclides, the sum of the ratios of the observed concentration of each radionuclide to its corresponding DCS must not exceed 1.0 (DOE 2011). The calculated concentrations were compared to the DCSs, and added to ensure the sum was less than one (Table 5-8). The sum was only 0.03; therefore, no monitoring is required at the IRC. The source-term calculations will be performed annually, and whenever there is a significant change in the representative source term at the IRC and evaluated to determine if monitoring is recommended.

Table 5-7. Monitoring requirements in the City of Idaho Falls Wastewater Acceptance Permit for the INL Research Center.

Parameter	Sampling Frequency	Sample Type	Permit Limit	2010-2011	
				Minimum	Maximum
pH	discretion of City of Idaho Falls	grab	5.0–9.0	7.2	8.0
Biochemical Oxygen Demand (mg/L)	discretion of City of Idaho Falls	grab	None	15	150
Total Suspended Solids (mg/L)	discretion of City of Idaho Falls	grab	None	8	160
Flow	discretion of City of Idaho Falls	water meter	None	Not reported	Not reported
pH	Daily (INL)	retention tank at IF–705	5.0–9.0	In range	In range
pH	semiannual[a]	Grab	5.0–9.0	Not reported	Not reported
Arsenic (mg/L)	semiannual[a]	composite	0.04	<0.002	<0.002
Cadmium (mg/L)	semiannual[a]	composite	0.26	<0.0005	0.0006
Chromium (mg/L)	semiannual[a]	composite	2.77	<0.002	0.003
Copper (mg/L)	semiannual[a]	composite	1.93	0.022	0.105
Cyanide (mg/L)	semiannual[a]	Composite from grab samples	1.04	<0.005	<0.005
Lead (mg/L)	semiannual[a]	composite	0.29	<0.001	0.003
Mercury (mg/L)	semiannual[a]	composite	0.002	<0.0002	<0.0002
Molybdenum (mg/L)	semiannual[a]	composite	None	0.001	0.691
Nickel (mg/L)	semiannual[a]	composite	2.38	<0.005	0.014
Selenium (mg/L)	semiannual[a]	composite	None	<0.001	<0.001
Silver (mg/L)	semiannual[a]	composite	0.43	<0.0002	<0.0002
Zinc (mg/L)	semiannual[a]	composite	0.90	0.026	0.144

a. In addition to the semiannual samples the City of Idaho Falls commonly collects one or two unscheduled samples per year. The results of the unscheduled samples are included in the data summarized in this table.

Table 5-8. Comparison of IRC inventory as of January 2012 to DCSs for water ingestion, assuming entire inventory of liquid and powder sources is released in the estimated sewage effluent for a one year period (18,000,000 liters).

Radionuclide	Inventory (µCi)	Effluent Concentration if Inventory Released over One Year (µCi/L)	DCS for Water Ingestion (µCi/L)	Ratio of Estimated Annual Concentration to DCS
Americium–241	2.50E–06	1.39E–13	1.90E+01	7.32E–15
Carbon–14	1.00E+00	5.56E–08	6.20E–02	8.96E–07
Curium–244	4.86E–08	2.70E–15	2.60E–04	1.04E–11
Cobalt–60	2.16E–04	1.20E–11	7.20E–03	1.67E–09
Cesium–134	6.63E–02	3.68E–09	2.10E–03	1.75E–06
Cesium–137	1.31E–01	7.30E–09	3.00E–03	2.43E–06
Iodine–125	1.00E+03	5.56E–05	2.10E–03	2.65E–02
Iodine–129	2.30E–08	1.28E–15	3.30E–04	3.87E–12
Potassium–40	1.02E–01	5.65E–09	4.80E–03	1.18E–06
Plutonium–238	9.61E–04	5.34E–11	1.50E–04	3.56E–07
Plutonium–239	7.26E–06	4.03E–13	1.40E–04	2.88E–09
Radium–226	2.76E–04	1.53E–11	8.70E–05	1.76E–07
Ruthenium–106	7.57E–04	4.21E–11	4.10E–03	1.03E–08
Antimony–125	1.04E–03	5.78E–11	2.70E–02	2.14E–09
Strontium–90	2.21E–03	1.23E–10	1.10E–03	1.12E–07
Technetium–99	1.70E+00	9.43E–08	4.40E–02	2.14E–06
Thorium–228	3.03E–04	1.69E–11	3.40E–04	4.96E–08
Thorium–230	2.11E–07	1.17E–14	1.60E–04	7.33E–11
Thorium–232	2.95E–04	1.64E–11	1.40E–04	1.17E–07
Uranium–233	4.80E+01	2.67E–06	6.60E–04	4.04E–03
Uranium–234	1.27E+00	7.04E–08	6.80E–04	1.03E–04
Uranium–235	3.25E–02	1.81E–09	7.20E–04	2.51E–06
Uranium–236	1.67E–03	9.28E–11	7.20E–04	1.29E–07
Uranium–238	4.42E–01	2.46E–08	7.50E–04	3.28E–05
Sum				3.06E–02

5.4 Idaho Nuclear Technology and Engineering Center New Percolation Ponds

5.4.1 Drivers for Sampling Program

The wastewater discharged to the INTEC New Percolation Ponds is sampled to demonstrate compliance with the Municipal and Industrial Wastewater Reuse Permit issued by the Idaho Department of Environmental Quality in March 2012 (DEQ 2012).

In addition to the monitoring performed for the permit, environmental surveillance samples are collected to meet the following requirements:

- DOE Order 458.1, "Radiation Protection of the Public and the Environment"
- DOE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance."

5.4.2 Background

The New Percolation Ponds are comprised of two unlined ponds excavated into the surficial alluvium and surrounded by bermed alluvial material (Figure 5-3). Each pond is approximately 305 × 305 ft at the top of the berm and is about 10 ft deep. Each pond is designed to accommodate a continuous wastewater discharge rate of approximately three million gallons per day (MG/day). The New Percolation Ponds began receiving wastewater discharges from the Service Waste System on August 26, 2002 (ICP 2009). On December 2, 2004, the treated effluent from the Sewage Treatment Plant was combined with the Service Waste System wastewater and discharged to the ponds.

During normal operation, wastewater discharges to only one pond at a time. Unless an operational need is identified or a special request is received, the ponds are normally switched quarterly to minimize algae growth and maintain good percolation rates. Wastewater depth in the ponds is recorded monthly using permanently mounted staff gauges. The ponds also are inspected monthly to check for dike erosion, excessive vegetative growth, leaks, and adequate freeboard.

The New Percolation Ponds receive discharge of only nonhazardous industrial and municipal wastewater. During the 2011 reporting year (November 1, 2010 to October 31, 2011), an average of 0.472 MG/day of service waste was generated. Sanitary wastes from restrooms, porta potties, comfort stations, shower trailers, septic tanks, and the INTEC cafeteria are discharged to the Sewage Treatment Plant, which is treated and combined with the service waste and disposed of to the New Percolation Ponds. Two sets of electric pumps transfer wastewater from CPP–797 to the New Percolation Ponds.

5.4.2.1 Sanitary Waste System Description and Operation

The Sewage Treatment Plant is located east of INTEC, outside the INTEC security fence, and treats sanitary and other related wastes at INTEC (Figure 5-4). The Sewage Treatment Plant also receives routine discharges of septage from porta potties, comfort stations, shower trailers, and septic tanks generated at other ICP locations. The Sewage Treatment Plant consists of:

- Two aerated lagoons (Cell Nos. 1 and 2)
- Two quiescent, facultative stabilization lagoons (Cell Nos. 3 and 4)
- Five control stations (weir boxes)
- Lift Station used to pump the treated effluent to the Service Waste System.

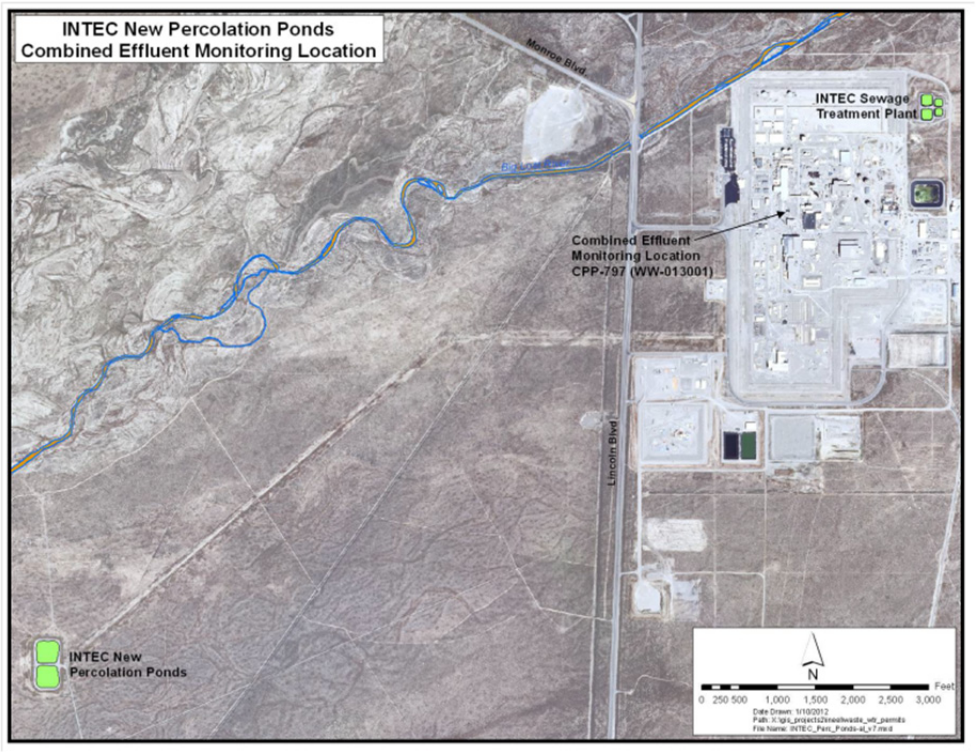

Figure 5-3. Idaho Nuclear Technology and Engineering Center new percolation ponds and combined effluent monitoring location CPP–797.

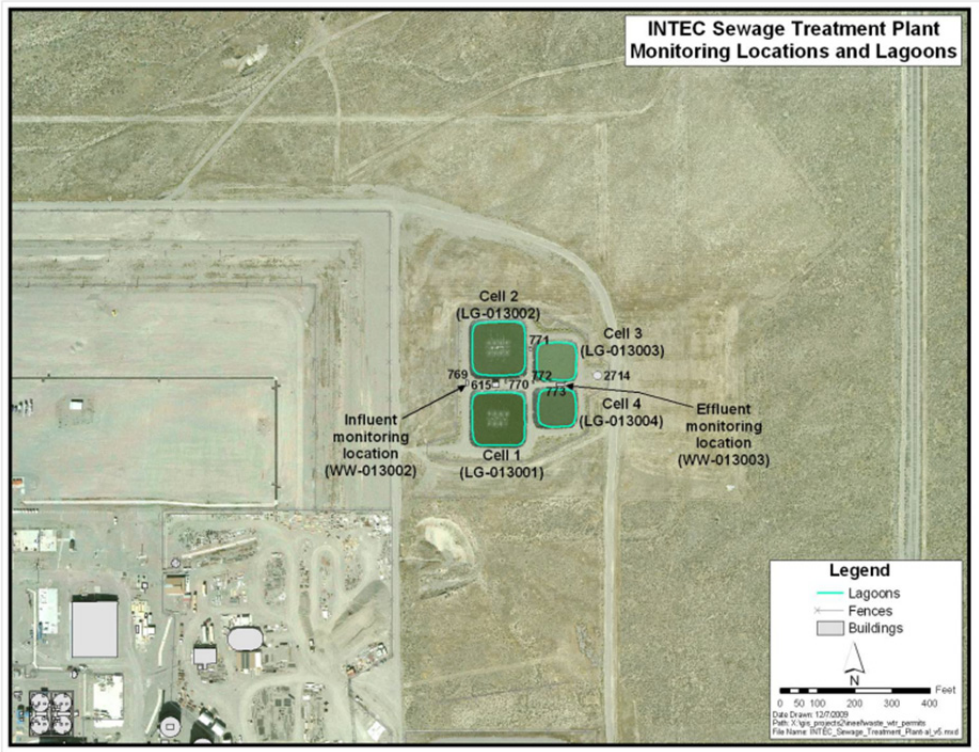

Figure 5-4. INTEC Sewage Treatment Plant and monitoring locations CPP–769 (WW–013002) and CPP-773 (WW–013003).

Because the Sewage Treatment Plant depends on natural biological and physical processes (digestion, oxidation, photosynthesis, respiration, aeration, and evaporation) to treat the wastewater, the five control stations are used to direct the wastewater flow to the proper sequence of lagoons. After treatment in the lagoons, the effluent is gravity-fed to a lift station where it is pumped to the Service Waste System.

5.4.2.2 Service Waste System Description and Operation

The Service Waste System (SWS) serves all major facilities at INTEC. Industrial wastewater from INTEC operations consists primarily of noncontact cooling water, steam condensates, and water treatment effluent (e.g., water-softener regeneration), boiler blowdown wastewater, storm water, and other nonhazardous, non-radioactive liquids.

The INTEC facilities and processes that could potentially release radioactive contamination to the SWS have controls and barriers that effectively prevent the release of such material. In addition, the operation of a continuous monitoring and diversion system protects the percolation ponds from the potential failure of engineered barriers and controls.

The Eastside Monitoring and Diversion Station (CPP–753/754) monitors the radioactivity of service waste before it is discharged to the Eastside Waste Monitoring Building (CPP–797). Upon a high-level radiation alarm at monitoring station CPP–753, the flow is diverted from diversion station CPP–754, to the service waste-diversion collection tank (VES–WM–191) via the CPP–750 Diversion Pump Station (ICP 2010a). The diversion point is downstream from the radiation monitor to allow for the time lag between detection and diversion; thus, radioactive service wastewater does not reach the percolation ponds. If the waste operations Distributive Control System is out of service, the flow can be manually diverted at CPP–754. In CPP–797 the combined flows are measured, the effluent is monitored for radioactivity, and samples are collected periodically for analyses. CPP–797 provides the last monitoring and sampling of the waste before it is discharged to the percolation ponds. If the concentration of radioactivity in the service waste at CPP–797 exceeds a predetermined set point, an alarm sounds, the flow is manually diverted at CPP–754 to VES–WM–191, and the source of the contamination is located and eliminated.

5.4.3 Sampling Basis and Design

Samples of the effluent to the INTEC New Percolation Ponds are analyzed for radiological and non-radiological constituents to demonstrate compliance with the wastewater reuse permit and DOE orders. Samples are collected from the influent to the sewage treatment plant (CPP–769), the effluent from the sewage treatment plant (CPP–773), and the combined effluent prior to discharge to the New Percolation Ponds (CPP–797).

Per DOE (1991), sample locations are located downstream of the last component stream and are protected from the elements to prevent freezing of the sampling line. Samples of the sewage influent and effluent are collected with a Sigma 900 Max all-weather refrigerated sampler which collects the sample aliquots via a peristaltic pump into a carboy in a refrigerated unit to minimize biological growth. Daily, flow-proportional samples are also collected at CPP–797 using a group of four Masterflex sample pumps. DOE (1991) recommends sampling materials that are compatible with the effluent, so inert components such as Teflon, stainless steel, polyvinyl chloride or silicone tubing, and high-density polyethylene plastic are used. To meet the recommendation for a redundant sample-collection system (DOE 1991), spare parts and portable samplers are kept on hand.

The wastewater reuse permit requires collection of a 24-hour flow proportional sample (except for total coliform and pH grab samples) every month at CPP–769, CPP–773, and CPP–797 during normal operating conditions. Radioactivity analyses at CPP–797 are performed on flow-proportional samples composited over an entire month. Flow proportional sampling meets the requirements of DOE (1991); therefore, samples for environmental surveillance monitoring are collected in the same manner as the samples required for the wastewater reuse permit.

In 2004, a study was performed to review the potential source term that may enter the wastewater and determine if the current monitoring methods (gamma spectroscopy and gross alpha) of the wastewater samples were adequate to comply with DOE Order 5400.5 (INEEL 2004). The study concluded current monitoring methods were adequate; however, the report recommended including gross beta analyses.

Tables 5-9 to 5-11 summarize the monitoring performed on the wastewater streams discharged to the INTEC New Percolation Ponds.

Table 5-9. Summary of environmental monitoring performed on the influent to the INTEC Sewage Treatment Plant (CPP-769).

Analyte	Sampling Frequency	Driver[a]	Limit[b]	2010-2011	
				Minimum (mg/L)	Maximum (mg/L)
Biochemical oxygen demand (BOD) (5-day)	Monthly	DEQ	None	183	828
Nitrate+nitrite as nitrogen	Monthly	DEQ	None	<0.05	0.694
Total Kjeldahl nitrogen (TKN)	Monthly	DEQ	None	61.6	153
Phosphorus, total	Monthly	DEQ	None	5.61	16.5
Total Suspended Solids	Monthly	DEQ	None	100	995

a. DEQ = analysis required by the wastewater reuse permit.
b. Limits from ICP (2010b).

Table 5-10. Summary of environmental monitoring performed on the effluent from the INTEC Sewage Treatment Plant (CPP-773).

Analyte	Sampling Frequency	Driver[a]	Limit[b]	2010-2011	
				Minimum (mg/L)	Maximum (mg/L)
Non-Metals (mg/L)					
Biochemical oxygen demand (BOD) (5-day)	Monthly	DEQ	None	7.24	50.8
Nitrate+nitrite as nitrogen	Monthly	DEQ	None	0.499	14.5
Total Kjeldahl nitrogen (TKN)	Monthly	DEQ	None	8.34	72.2
Phosphorus, total	Monthly	DEQ	None	3.75	11.3
Total Suspended Solids	Monthly	DEQ	None	4	55.1
Radionuclides (pCi/L)					
Gamma Spectroscopy	Semi-annually	DOE			
Silver–108m			Not calculated	ND[c]	ND
Silver–110m			None	ND	ND
Americium–241			15	ND	ND
Cerium–144			30	ND	ND
Cobalt–58			None	ND	ND
Cobalt–60			100	ND	ND
Cesium–134			80	ND	ND
Cesium–137			200	ND	ND
Europium–152			200	ND	ND
Europium–154			60	ND	ND
Europium–155			600	ND	ND
Potassium–40			None	ND	ND
Manganese–54			None	ND	ND
Niobium–95			None	ND	ND
Radium–226			Naturally occurring[d]	ND	ND
Ruthenium–103			None	ND	ND
Ruthenium–106			30	ND	ND
Antimony–125			300	ND	ND
Uranium–235			Not calculated	ND	ND
Zinc–65			None	ND	ND
Zirconium–95			None	ND	ND
Gross alpha	Semi-annually	DOE	15[d]	ND	ND
Gross beta	Semi-annually	DOE	4 mrem/yr	15.3±2.19	37.7±3.45
Strontium–90	Semi-annually	DOE	8	ND	ND

a. DOE = DOE orders for radiation protection; DEQ = Wastewater Reuse Permit.
b. Limits are from ICP (2008) or ICP (2010b).
c. ND = not detected.
d. The limit is 5 pCi/L if process-derived radium–226 is present in the wastewater.

Table 5-11. Summary of environmental monitoring performed on the combined effluent discharged to the INTEC New Percolation Ponds (CPP–797).

Analyte	Sampling Frequency	Driver[a]	Limit[b]	2010-2011	
				Minimum (mg/L)	Maximum (mg/L)
Non-Metals (mg/L)					
Biochemical oxygen demand (BOD) (5-day)	Monthly	DEQ	None	<2	20.3
Nitrate+nitrite as nitrogen	Monthly	DEQ	10	1.1	3.64
Total Kjeldahl nitrogen (TKN)	Monthly	DEQ	None	0.294	3.88
Phosphorus, total	Monthly	DEQ	None	0.374	1.31
Total Suspended Solids	Monthly	DEQ	100	<4	9.3
Chloride	Monthly	DEQ	250	19.5	260
Fluoride	Monthly	DEQ	4	0.193	0.268
Total Dissolved Solids	Monthly	DEQ	500	254	707
Metals (µg/L)					
Aluminum	Monthly	DEQ	200	<25	26.9
Arsenic	Monthly	DEQ	50	2.5	3.4
Cadmium	Monthly	DEQ	5	<1	<1
Chromium	Monthly	DEQ	100	3.2	8.4
Copper	Monthly	DEQ	1300	1	8
Iron	Monthly	DEQ	300	<25	132
Manganese	Monthly	DEQ	50	<2.5	5.5
Mercury	Monthly	DEQ	2	<0.2	<0.2
Selenium	Monthly	DEQ	50	1	5.5
Silver	Monthly	DEQ	100	<5	<5
Sodium	Monthly	DEQ	None	14,200	149,000
Radionuclides (pCi/L)					
Gamma Spectroscopy	Monthly	DOE			
Silver–108m			Not calculated	ND[c]	ND
Silver–110m			None	ND	ND
Americium–241			15	ND	ND
Barium–137m			None	ND	ND
Cerium–144			30	ND	ND
Cobalt–58			None	ND	ND
Cobalt–60			100	ND	ND
Cesium–134			80	ND	ND
Cesium–137			200	ND	ND

Table 5-11. (continued).

Analyte	Sampling Frequency	Driver[a]	Limit[b]	2010-2011	
				Minimum (mg/L)	Maximum (mg/L)
Europium–152			200	ND	ND
Europium–154			60	ND	ND
Europium–155			600	ND	ND
Potassium–40			None	ND	ND
Manganese–54			None	ND	ND
Niobium–95			None	ND	ND
Radium–226			Naturally occurring[d]	ND	ND
Ruthenium–103			None	ND	ND
Ruthenium–106			30	ND	ND
Antimony–125			300	ND	ND
Uranium–235			Not calculated	ND	ND
Zinc–65			None	ND	ND
Zirconium–95			None	ND	ND
Gross alpha	Monthly	DOE	15[d]	ND	4.62±1.18
Gross beta	Monthly	DOE	4 mrem/yr	ND	12±1.77
Strontium–90	Monthly	DOE	8	ND	ND

a. DOE = DOE orders for radiation protection; DEQ = Wastewater Reuse Permit.
b. Limits are from ICP (2008) or ICP (2010b).
c. ND = not detected.
d. The limit is 5 pCi/L if process-derived radium–226 is present in the wastewater.

5.4.4 Decision Limits and Actions

The screening levels for discharge to the pond are in Tables 5-10 and 5-11. In the event the reported concentration of a constituent exceeds the corresponding limit, environmental management and facility personnel are notified and an assessment is performed to determine if additional action is necessary.

5.5 Materials and Fuels Complex

The MFC is located on approximately 60 acres in the southeastern portion of the INL Site, approximately 35 miles west of Idaho Falls, Idaho, in Bingham County. The MFC consists of buildings and structures for research and development on nuclear technologies, nuclear environmental management, and space radioactive power-source development.

Sanitary wastes are discharged to evaporative lagoons and industrial wastewater is routed to an unlined pond (Figure 5-5). Radioactive liquid waste generated at MFC is treated via evaporation at the Radioactive Liquid Waste Treatment Facility and disposed off-Site.

5.5.1 MFC Industrial Waste Pond

5.5.1.1 Drivers for Sampling Program

The wastewater discharged to the pond is sampled to demonstrate compliance with the Industrial Wastewater Reuse Permit issued by the Idaho Department of Environmental Quality in April 2010. The permit-required monitoring is documented in DEQ (2010b) and INL (2012d). The wastewater sampling locations specified by the reuse permit (WW–016001 and WW–016002) are shown in Figure 5-5.

Analytical results for samples collected since permit-required monitoring began in May 2010 are summarized in Table 5-12. Note that the screening release levels in Table 5-12 were based on potential groundwater contamination assuming a discharge rate of 26 million gallons per year. Estimated discharge rates are about 6.2 million gallons per year from the Industrial Waste Pipeline and 0.8 million gallons per year from the Industrial Waste Water Underground Pipe (INL 2012d), therefore the screening levels are conservative and should be adjusted upward proportionally. Consequently, the single sample from the Industrial Waste Water Underground Pipe which exceeded the release level for total dissolved solids is not cause for concern. A flow meter is being installed on the Industrial Waste Pipeline and the screening levels will be revisited as additional flow data becomes available.

Environmental surveillance monitoring at the MFC Industrial Waste Pond is performed to meet the following requirements:

- DOE Order 458.1, "Radiation Protection of the Public and the Environment"
- DE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance"
- Continued monitoring of potential COCs identified during the CERCLA investigation of the pond.

5.5.1.2 Background

The MFC Industrial Waste Pond (IWP) covers approximately three acres and was excavated in 1959. The pond is located northwest of MFC and has been used for the management of industrial wastewater since 1962. The pond has a design capacity of 285 MG at a maximum water depth of 13 ft.

Most of the industrial wastewater generated at MFC flows through collection piping to a lift station where it is pumped into the Industrial Waste Pipeline and discharged to the pond (Figure 5-5). A flow meter and composite sampler are located on the pipeline near the western boundary of MFC (Figure 5-5, WW–016001).

Industrial wastewater discharged to the IWP system consists primarily of noncontact cooling water, boiler blowdown, cooling tower overflow and drain, air wash flows, and steam condensate. Small amounts of industrial wastewater from the MFC facility process holdup tanks may also be discharged to the IWP system, once approved by the facility supervisor and environmental compliance staff. The IWP also receives storm water runoff from MFC and immediate environs.

Wastewater composed of cooling water blowdown, intermittent reverse-osmosis effluent, and discharge to floor drains and a laboratory sink is transported from the MFC–768 Power Plant to Ditch C via the Industrial Waste Water Underground Pipe (Figure 5-5). The wastewater discharged to Ditch C seldom flows more than a few tens of feet past the sampling point (WW–016002) before it evaporates, infiltrates, or is taken up by plants. About seven million gallons of industrial wastewater were discharged to the pond during the 2011 permit year (INL 2012d).

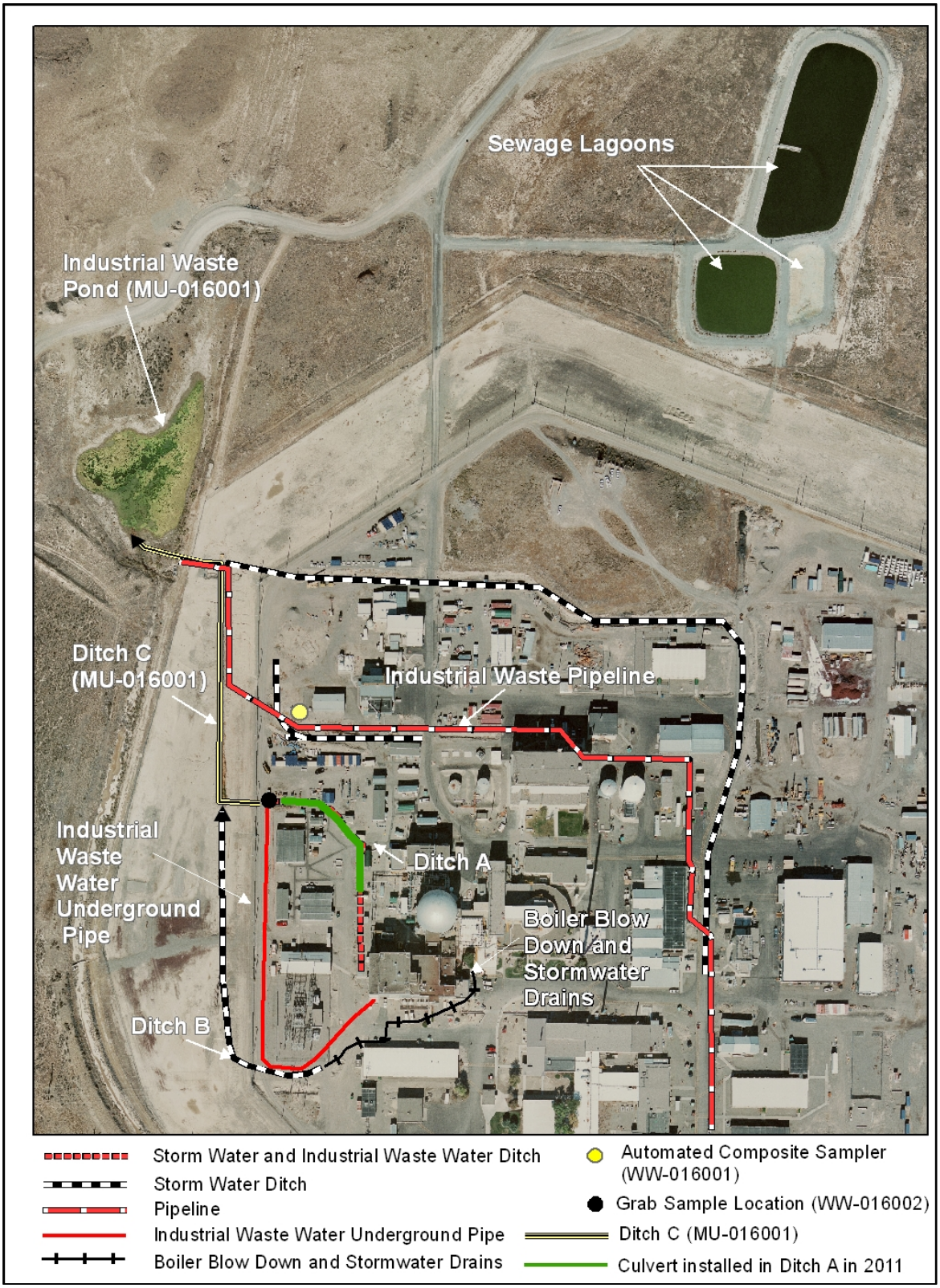

Figure 5-5. Wastewater ponds at the Materials and Fuels Complex.

Table 5-12. Summary of monitoring at the Industrial Waste Pipeline and the Industrial Waste Water Underground Pipe.

Analyte	Driver[a]	Limit[b]	Industrial Waste Pipeline May 2010–December 2011 Minimum	Industrial Waste Pipeline May 2010–December 2011 Maximum	Industrial Waste Water Underground Pipe May 2010–December 2011 Minimum	Industrial Waste Water Underground Pipe May 2010–December 2011 Maximum
Metals (µg/L)						
Arsenic	DEQ	77	<2.5	3.6	3.6	11
Barium	DEQ	17,000	33	40	58	145
Cadmium	DEQ	7.9	<1	<1	<1	<1
Chromium	DEQ	150	<2.5	3.1	3	18.7
Iron	GW	18,000	26.9	162	59.4	1,860
Lead	DEQ	290	<0.25	1.2	0.39	3.4
Manganese	GW	420	<2.5	16.2	3.2	90.1
Mercury	DEQ	39	<0.2	<0.2	<0.2	<0.2
Selenium	DEQ	77	<0.5	3.9	1.1	3.5
Silver	DEQ	1,700	<5	<5	<5	<5
Sodium	GW	390,000	18,800	63,300	40,100	119,000
Zinc	DEQ	13,000	7.3	24.4	16.5	111
Anions, Nutrients, and Solids (mg/L)						
Chloride	DEQ	390	21	98.9	40.3	128
Fluoride	DEQ	6.2	0.545	0.7	1.2	2.74
Sulfate	DEQ	390	16.6	21.7	34.7	109
Nitrate+nitrite as nitrogen	DEQ	15 (nitrate) 1.5 (nitrite)	1.8	2.38	3.75	12.3
Total Kjeldahl nitrogen (TKN)	DEQ	None	0.175	1.49	0.552	1.22
Total nitrogen (sum of TKN and nitrate+nitrite, as nitrogen)	DEQ	20[c]	2.156	3.32	4.533	13.52
Total phosphorus	DEQ	None	0.0995	0.609	0.658	1.13
Total dissolved solids	DEQ	770	247	376	437	1160
Total suspended solids	DEQ	100[c]	<4	8	<4	<4

a. DEQ = required by wastewater reuse permit; GW = groundwater monitoring parameter required by wastewater reuse permit.
b. Screening release levels calculated for the Industrial Waste Pond from INL (2006d) unless otherwise noted.
c. Maximum thirty (30) day average concentration from the industrial wastewater reuse permit.

Sediment samples were collected from the bottom of the pond in the 1980s and again in 1994 (Lee et al. 1997). Cesium–137 was detected at up to 29.2 pCi/gram and determined to be a potential human health risk if use of the pond were discontinued (Lee et al. 1997, DOE-ID 1998b). In the ecological risk evaluation, chromium, mercury, selenium, silver, and zinc were identified as potential threats to burrowing animals if the pond were allowed to dry (DOE-ID 1998b). The maximum metals concentrations in the sediments are in Table 5-13.

Table 5-13. Concentrations of contaminants of concern identified in the ecological risk assessment for the Industrial Waste Pond sediments.

Metal	Maximum Concentration in Pond Sediment (mg/kg)	Concentration in Pond Water (µg/L)	
		2008	2009
Chromium	11,400	4.2	5
Mercury	6.8	<0.2	<0.2
Selenium	3.3	1.7	0.98
Silver	33	<5	<5
Zinc	5,850	3.6	4

The Industrial Waste Pond sediments contained low levels of cesium–137 that pose unacceptable risks to humans (DOE-ID 2007). The pond sediments also contained four inorganics (i.e., chromium, mercury, selenium, and zinc) that posed unacceptable risks to ecological receptors. In 2004, the decision was made to implement the contingent remedy of excavation and disposal rather than phytoremediation at this site because of potential future projects at MFC. The excavation and disposal activities were completed in 2004, with the soil being transported to the Idaho CERCLA Disposal Facility (ICDF). A total of 1,351 tons of soil was removed during the first campaign, and confirmation sampling indicated one hot spot remained for chromium that exceeded the remediation goal. Consequently, a second campaign of excavation and disposal was conducted in November 2004 that removed all of the soil from this hot spot down to the basalt. The hot spot removal resulted in 136 tons of soil that was transported to the ICDF in November 2004.

Tables 20 and 24 of the *Data Quality Assessment Report for the Post-Remedial Action Confirmation Sampling of the ANL-W CERCLA Sites* (Portage 2005) show the statistical calculation of each COC for the surface and subsurface soils, respectively. After remediation, each of the five contaminants was below the established remediation goals for the surface and subsurface data sets, with the exception of chromium in the surface soils. The chromium in the surface soils had a mean concentration of 433 mg/kg and a calculated upper confidence limit (UCL) of 626 mg/kg, which exceeded the 500-mg/kg remediation goal. However, the State of Idaho and EPA agreed that since the pond will continue to be used as a pond, no vegetation (bunch grass) could grow underwater; thus, no pathway exists. The IWP requires institutional controls under CERCLA: specifically, warning signs around the site perimeter. The signs were in good condition during the 2006 inspection (DOE-ID 2006).

5.5.1.3 Sampling Basis and Design

Since at least the late 1980s, ANL–W personnel sampled the IWP monthly from April to October for alpha and beta activity, tritium, gamma-emitting radionuclides, sulfate, phosphate, chloride, and selected metals (Witbeck 1988). The sampling plan was reviewed with the issuance of the Industrial Wastewater Reuse Permit for the MFC Industrial Waste Ditch and IWP in 2010 (DEQ 2010b). The wastewater reuse permit requires sampling for anions, solids, total Kjeldahl nitrogen, and metals in the influent to the pond, so sampling of the pond for non-radionuclides was discontinued in 2010 in lieu of sampling the influent. The concentrations of the metals identified in the ecological risk evaluation were deemed to be sufficiently low in the annual pond water samples collected in 2008 and 2009 to discontinue sampling for metals (Table 5-13).

Table 5-14 summarizes the current monitoring program at the MFC IWP. The pond typically has a maximum depth of about five feet. The residence time of the water in the pond was estimated by dividing the volume of the pond by the flow into the pond. Assuming the pond covers about three acres and is an average of three feet deep, its capacity would be about 2,900,000 million gallons. Using an estimated discharge of seven million gallons and ignoring gains for surface runoff and losses to evaporation, the residence time for water in the pond is about five months, which is sufficient to support a quarterly sampling schedule. The quarterly sampling dates are selected randomly; annual samples are collected during the third quarter to ensure no more than about one year will pass between sampling events.

The radiological analyte list was originally developed by ANL–W. Samples for gamma spectroscopy, gross alpha, and gross beta are collected quarterly. These analyses provide a relatively inexpensive screening for gross radioactivity and a variety of fission and activation products. Americium–241, curium, plutonium, uranium, and strontium–90 are sampled annually. Rather than attempting to assess each of the numerous facilities and processes at MFC, the sampling program was reviewed with radiation control personnel from MFC (Larry Burke, personal communication, March 4, 2013). The following changes were recommended:

1. Discontinue sampling for curium isotopes. Curium is a transuranic that is relatively rare compared to other transuranic isotopes.
2. Discontinue sampling for iron–55; a relatively minor activation product.

The current analyte list includes the primary nuclides at MFC specifically listed in INL (2010c): americium–241, cesium–137, cobalt–60, plutonium, strontium–90, and uranium.

Constituent concentrations were well below the screening release levels during 2010–2011 (Table 5-14).

5.5.1.4 Decision Limits and Actions

The screening levels for discharge to the pond are in Tables 5-12 and 5-14. In the event the reported concentration of a constituent exceeds a screening level, environmental management and facility personnel are notified and an assessment is performed to determine whether additional action is necessary. If a permit limit is exceeded, it is reported in the monthly self-disclosure log submitted to the DEQ. Additional samples are collected if warranted.

5.5.2 MFC Secondary Sanitary Sewage Lagoon

5.5.2.1 Drivers for Sampling Program

Environmental surveillance monitoring at the MFC Secondary Sanitary Lagoon is performed to meet the following requirements:

- DOE Order 458.1, “Radiation Protection of the Public and the Environment”
- DE/EH-0173T, “Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance”
- Comparison to samples collected at the MFC Industrial Waste Pipeline and the Industrial Waste Water Underground Pipeline for the Industrial Wastewater Reuse Permit for the MFC Industrial Waste Ditch and Industrial Waste Pond
- Continued monitoring of potential COCs identified during the CERCLA investigation of the pond.

Table 5-14. Summary of surveillance monitoring at the MFC Industrial Waste Pond.

Analyte	Sampling Frequency	Driver[a]	Limit	2010–2011	
				Minimum	Maximum
Radionuclides (pCi/L)					
Gamma Spectroscopy	Quarterly	CERCLA, DOE			
Silver–108m			Not calculated[b]	ND[c]	ND
Silver–110m			90[b]	ND	ND
Americium–241			15[b]	ND	ND
Cerium–144			30[b]	ND	ND
Cobalt–58			300[b]	ND	ND
Cobalt–60			100[b]	ND	ND
Cesium–134			80[b]	ND	ND
Cesium–137			200[b]	ND	1.75±0.709
Europium–152			200[b]	ND	ND
Europium–154			60[b]	ND	ND
Europium–155			600[b]	ND	ND
Potassium–40			None	ND	41.8±12.2
Manganese–54			300[b]	ND	ND
Niobium–95			300[b]	ND	ND
Radium–226			Naturally occurring[d]	ND	ND
Ruthenium–103			200[b]	ND	ND
Ruthenium–106			30[b]	ND	ND
Antimony–125			300[b]	ND	ND
Uranium–235			66[e]	ND	ND
Zinc–65			300[b]	ND	ND
Zirconium–95			200[b]	ND	ND
Gross alpha	Quarterly	CERCLA, DOE	15[d,f]	ND	3.57±1.15
Gross beta	Quarterly	CERCLA, DOE	4 mrem/yr[f]	ND	15.3±1.6
Tritium	Quarterly	DOE	20,000[f]	ND	ND
Strontium–90	Annually[g]	DOE	8[f]	ND	ND
Plutonium–238	Annually	DOE	15[b]	ND	ND
Plutonium–239/240	Annually	DOE	15[b]	ND	ND
Plutonium–236	Annually	DOE	15[b]	ND	ND
Plutonium–242	Annually	DOE	15[b]	ND	ND
Plutonium–241	Annually	DOE	Not calculated[b]	ND	ND
Americium–241	Annually	CERCLA, DOE	15[b]	ND	ND
Curium–242	Annually	DOE	15[b]	ND	ND
Curium–243/244	Annually	DOE	15[b]	ND	ND
Uranium–233/234	Annually	CERCLA, DOE	186,000[e]	1.41±0.189	1.5±1.99
Uranium–235	Annually	CERCLA, DOE	66[e]	ND	ND
Uranium–238	Annually	CERCLA, DOE	9.9[e]	0.69±1.17	0.739±0.121
Iron–55	Annually	DOE	2000[b]	ND	ND

a. CERCLA = potential CERCLA contaminant of concern for the sewage lagoon or analyte for CERCLA groundwater samples; DOE = DOE orders for radiation protection.
b. Maximum Contaminant Level (MCL) from EPA (2000)
c. ND = not detected.
d. The limit is 5 pCi/L if process-derived radium–226 is present in the wastewater.
e. Calculated from the MCL of 30 µg/L. The specific activity for uranium–234 was used to calculate the MCL for uranium–233/234.
f. Primary Constituent Standard (PCS) from IDAPA 58.01.11.
g. If the gross beta activity in a quarterly sample exceeds 15 pCi/L the sample is analyzed for strontium–90.

5.5.2.2 Background

The sanitary sewage lagoons are located at the Sanitary Sewage Treatment Facility, north of the MFC (Figure 5-5). The southwest lagoon is used for primary treatment. As the primary lagoon fills, the wastewater cascades over a divider into the north lagoon, referred to as the Secondary Sanitary Sewage Lagoon, for secondary treatment. The southeast lagoon is used as an emergency overflow and has not been in operation since 1965. The two south lagoons were constructed in 1965, and the north lagoon was built in 1974. According to engineering drawings, the three sanitary sewage lagoons cover approximately two acres. The lagoons' approximate dimensions are (SW Lagoon) 46 × 46 × 2.1 m (150 × 150 × 7 ft), (SE Lagoon) 15 × 30 × 2.1 m (50 × 100 × 7 ft), and (North Lagoon) 38 × 122 × 2.1 m (125 × 400 × 7 ft). The lagoons receive all sanitary wastes originating at MFC, with the exception of the Transient Reactor Test Facility, Sodium Process Facility, and the Sodium Components Maintenance Shop. Sanitary waste is discharged from rest rooms, change facilities, drinking fountains, and the cafeteria. The three lagoons are sealed with a 0.32 to 0.63-cm (0.125 to 0.25-in.) bottom bentonite liner and are situated approximately 183 m (600 ft) above the groundwater.

A large leak in the northeast corner of the north lagoon was detected after its construction in 1974. This leak resulted in the loss of over a million gallons of waste water through fissures that were not sealed by the bentonite. This was rectified by using a 30-mil hypalon liner over the northeast corner and sealing the seams. Seepage tests performed in 1992 (Braun 1992) estimated a seepage rate of 0.20 inch per day for the primary lagoon and 0.02 inch per day for the secondary lagoon. The seepage tests confirmed that the Sanitary Lagoons are functioning as evaporative ponds and not as percolating ponds, suggesting that the bentonite and hypalon liner has remained intact.

Between 1975 and 1981, photo processing solutions were discharged from the Fuel Assembly and Storage Building to the Sanitary Waste Lift Station, which discharges to the lagoons. The manager of the Fuel Assembly and Storage Building during that period estimated that approximately 1.32 Troy ounces of silver were discharged to the Sanitary Waste Lift Station. It has not been confirmed whether the silver was released to the sanitary lagoons or if it remained in the lift station. However, risk calculations show that the estimated silver concentration (68 mg/kg) for the given amount (1.32 Troy oz.) is well below that required to exceed a risk greater than 1E–6 (327 mg/kg). Photo processing was discontinued at the Fuel Assembly and Storage Building in 1981.

Lee et al. (1997) noted that with the exception of an occasional point source of low-level medical radionuclides, there were no known releases of radioactivity into the Sewage Lagoons. Periodic sampling of the Sewage Lagoon and a radionuclide detector placed in the lift station (Sanitary Waste Lift Station–788) supplying the Sewage Lagoons support these conclusions. However, tritium was detected in the lagoon in November 2006, presumably from an incident at the Hot Fuel Examination Facility in October 2006. At the MFC, radioactive liquid wastes are treated at the Radioactive Liquid Waste Treatment Facility. Radioactive liquid wastes and decontamination solutions are not discharged to the sanitary sewer system.

Because no prior sludge samples were analyzed for metals and radionuclides, seven sludge samples were collected in 1994. The results from this sampling were used in a Track 1 risk evaluation in 1995 (ANL–W 1996), which indicates that the maximum concentrations of arsenic and chromium (i.e., 10.4 mg/kg and 76.4 mg/kg, respectively) exceed risk-based soil concentrations (i.e., 0.366 mg/kg and 24.9 mg/kg, respectively). The arsenic and chromium were screened from COCs after the ANL–W sludge concentrations were compared to typical sewage sludge concentrations. This assumes that all the chromium is hexavalent chromium.

The ANL Sewage Lagoons were eliminated from the WAG 9 risk evaluation because it was determined they were not a viable source (Lee et al. 1997). However, it was determined that elevated mercury in the lagoon sediments represented a risk to ecological receptors so the site was placed in Operable Unit (OU) 10–08 for administrative control (Hain 2005). The Record of Decision for OU 10–08

states *"when the ANL–04 lagoons are closed and resampled and risks recalculated, the contingent remedy of removal and disposal from the OU 9–04 ROD will be implemented if the site poses an unacceptable risk. If there is no unacceptable risk, no action will be taken under CERCLA. This OU 10–08 ROD will be modified to formalize the appropriate remedy for ANL–04"* (DOE-ID 2009).

An estimated 4.2 million gallons were discharged to the sewage lagoons in 2011 (John Gill, personal communication, 2012). IDAPA 58.01.16.493 requires all existing wastewater lagoons to have a seepage test by April 15, 2012, and every 10 years after initial testing. The MFC sewage lagoons have not had a seepage test since 1992, and DEQ has granted a waiver on the requirement for a seepage test because the lagoons were scheduled to be replaced with lined ponds in November 2012.

5.5.2.3 Sampling Basis and Design

Since at least the late 1980s, ANL–W personnel sampled the wastewater in the secondary sanitary lagoon monthly from April to October for alpha and beta activity, tritium, gamma-emitting radionuclides, plutonium, biochemical oxygen demand, dissolved oxygen, and pH (Witbeck 1988). In addition, the sampling plan specified collection of samples for alpha-, beta-, and gamma-emitting nuclides at the sanitary waste lift station upon receipt of an alarm from the in-line monitor (Witbeck 1988). The sampling program has been modified and refined over the years. Currently, samples are collected annually for the same constituents required by the wastewater reuse permit for the MFC IWP to aid in the interpretation of groundwater data.

The residence time of the water in the sewage lagoons was estimated to be about 7.5 months, assuming an average water depth of five feet and an annual discharge of 4.2 million gallons. Samples are collected on the same dates as the samples at the IWP: the quarterly sampling dates are selected randomly, and annual samples are collected during the third quarter to ensure no more than about one year will pass between sampling events.

Table 5-15 summarizes the current sampling program at the MFC secondary sewage lagoon. The radiological analyte list was originally developed by ANL–W. Samples for gamma spectroscopy, gross alpha, and gross beta are collected quarterly. These analyses provide a relatively inexpensive screening for gross radioactivity and a variety of fission and activation products. Americium–241, curium, plutonium, uranium, and strontium–90 are sampled annually. Rather than attempting to assess each of the numerous facilities and processes at MFC, the sampling program was reviewed with radiation control personnel from MFC (Larry Burke, personal communication, March 4, 2013). The following changes were recommended:

1. Discontinue sampling for curium isotopes. Curium is a transuranic that is relatively rare compared to other transuranic isotopes.
2. Discontinue sampling for iron–55; a relatively minor activation product.

The current analyte list includes the primary nuclides at MFC specifically listed in INL (2010d): americium–241, cesium–137, cobalt–60, plutonium, strontium–90, and uranium.

The sewage lagoons were replaced with new, HDPE-lined evaporation ponds located east of the existing lagoons in November 2012. Per request from MFC environmental personnel, the sampling program will be continued at the new lagoons for one year and then evaluated.

Constituent concentrations were well below the screening release levels during 2010–2011 (Table 5-15).

Table 5-15. Summary of surveillance monitoring at the MFC Secondary Sanitary Sewage Lagoon.

Analyte	Sampling Frequency	Driver[a]	2010–2011	
			Minimum	Maximum
Metals (µg/L)				
Arsenic	Annually	CERCLA, IWRP	<2.5	<2.5
Barium	Annually	IWRP	49	60.6
Cadmium	Annually	IWRP	<1	<1
Chromium	Annually	CERCLA, IWRP	<2.5	<2.5
Iron	Annually	IWRP	101	406
Lead	Annually	IWRP	0.33	0.78
Manganese	Annually	IWRP	58.4	75.3
Mercury	Annually	CERCLA, IWRP	<0.2	<0.2
Selenium	Annually	IWRP	1.7	2.2
Silver	Annually	IWRP	<5	<5
Sodium	Annually	IWRP	88,300	132,000
Zinc	Annually	IWRP	9.8	22.4
Anions, Nutrients, and Solids (mg/L)				
Chloride	Annually	IWRP	113	177
Fluoride	Annually	IWRP	0.23	0.347
Sulfate	Annually	IWRP	34.6	58.1
Nitrate+nitrite as nitrogen	Annually	IWRP	<0.1	3.24
Total Kjeldahl nitrogen	Annually	IWRP	17.1	53.4
Total phosphorus	Annually	IWRP	6.11	9.21
Chemical oxygen demand	Annually	Treatment effectiveness	238	288
Total dissolved solids	Annually	IWRP	546	958
Total suspended solids	Annually	IWRP	23.9	73.4
Radionuclides (pCi/L)				
Gamma Spectroscopy	Quarterly	CERCLA, DOE		
Silver-108m			ND[b]	ND
Silver-110m			ND	ND
Americium-241			ND	ND
Cerium-144			ND	ND
Cobalt-58			ND	ND
Cobalt-60			ND	ND
Cesium-134			ND	ND
Cesium-137			ND	ND
Europium-152			ND	ND
Europium-154			ND	ND
Europium-155			ND	ND

Table 5-15. (continued).

Analyte	Sampling Frequency	Driver[a]	2010–2011	
			Minimum	Maximum
Potassium-40			ND	85.4±10.1
Manganese-54			ND	ND
Niobium-95			ND	ND
Radium-226			ND	ND
Ruthenium-103			ND	ND
Ruthenium-106			ND	ND
Antimony-125			ND	ND
Uranium-235			ND	ND
Zinc-65			ND	ND
Zirconium-95			ND	ND
Gross alpha	Quarterly	DOE	ND	ND
Gross beta	Quarterly	DOE	34±2.8	64.9±4.79
Strontium-90	Annually[c]	DOE	ND	ND
Tritium	Quarterly	DOE	ND	ND
Plutonium-238	Annually	DOE	ND	ND
Plutonium-239/240	Annually	DOE	ND	ND
Plutonium-236	Annually	DOE	ND	ND
Plutonium-242	Annually	DOE	ND	ND
Plutonium-241	Annually	DOE	ND	ND
Americium-241	Annually	CERCLA, DOE	ND	ND
Curium-242	Annually	DOE	ND	ND
Curium-243/244	Annually	DOE	ND	ND
Uranium-233/234	Annually	CERCLA, DOE	0.344±0.0856	0.438±0.101
Uranium-235	Annually	CERCLA, DOE	ND	ND
Uranium-238	Annually	CERCLA, DOE	0.0876±0.04	0.189±0.0625
Iron-55	Annually	DOE	ND	ND

a. CERCLA = potential CERCLA contaminant of concern for the sewage lagoon or analyte for CERCLA groundwater samples; IWRP = comparison to samples collected at the MFC Industrial Waste Pipeline and the Industrial Waste Water Underground Pipeline for the Industrial Wastewater Reuse Permit for the MFC Industrial Waste Ditch and Industrial Waste Pond; DOE = DOE orders for radiation protection.

b. ND = not detected.

c. If the gross beta activity in a quarterly sample exceeds 15 pCi/L the sample is analyzed for strontium-90.

5.5.2.4 Decision Limits and Actions

Because the sanitary lagoon is evaporative, there are no release limits for the lagoon. However, facility management and environmental personnel are notified if man-made radionuclides are detected in the lagoon.

5.6 RWMC Municipal Wastewater Lagoons

The RWMC uses a series of four evaporation ponds to manage sewage water emanating from various non-radioactive operations within the RWMC. The evaporation ponds are located near the southeast corner of RWMC (Figure 3-6). They comprise four lagoons. Sewage water is first discharged into Lagoon No. 1, which then overflows into Lagoon No. 2. The overflow form Lagoon No.2 is then discharged into both Lagoon No. 3 and Lagoon No. 4. Lagoons 1 and 2 are lined with an impermeable, 60-mil thick, single-ply sheet of high density polyethylene (HDPE) geo-membrane, which is covered by 12 in. of fine grain soil. Lagoons 3 and 4 are lined with 12 in. of polymer-treated clay, which is covered with 6 in. of untreated clay and 6 in. of loose gravel (ICP 2013).

Seepage testing of the four RWMC sewage ponds was completed in October 2011. The purpose of this testing was to satisfy IDAPA 58.01.16 "Wastewater Rules" which requires that average 5-day seepage rates within sewage lagoons remain below 0.25 in/day (the maximum seepage rate allowed for lagoons built prior to April 15, 2007). Results of the seepage tests found average seepage rates ranging from 0.0184 in/day (for Lagoon No. 3) to 0.044 in/day (for Lagoon No. 4) (ICP 2013). The seepage tests for Lagoons 1 and 2 were conducted at normal operating depths of 63 in. and 62 in., respectively, while seepage tests for Lagoons 3 and 4 were tested at depths of 36.5 in. and 36.25 in., respectively (ICP 2013). No routine environmental monitoring is performed at the RWMC municipal wastewater lagoons.

5.7 Specific Manufacturing Capability Wastewater Lagoons

5.7.1 Drivers for Sampling Program

Based on historical sampling data and the evaporative characteristics of the lagoons, routine environmental surveillance is no longer performed at the SMC facility wastewater lagoons. To ensure continued protection of the public and environment, seepage tests are periodically performed at the lagoons. Radiological discharges to the lagoons are not allowed (SMC 1991).

5.7.2 Background

The SMC facility wastewater lagoons consist of three cells that were installed in the 1990s. The cells are double-lined with a high density polyethylene (HDPE) liner over an “impermeable” compacted silty clay base (Butler Engineering 1993). Two cells are alternately used for sanitary wastewater; Cell 1 is 230 ft × 185 ft and Cell 2 is 230 ft × 440 ft (Figure 5-6). The third cell is 230 ft × 185 ft and used for boiler water.

Use of the lagoons began in about 1994 and included tying in non-radiological effluent lines from the Loss of Fluid Test Facility (LOFT). File records indicate that the concern at the time was the potential for the new lagoons to be contaminated by effluent from LOFT. Sampling was performed in 1996–1997 and the results were summarized as “radioactivity in all samples from the pond was shown to be entirely from outside or natural sources, and did not come from LOFT or SMC” (Barg 1997). The lagoons receive only non-radiological process/sanitary wastewater. Radioactively contaminated wastewater at SMC is collected in an entirely separate system and processed in the Waste Treatment Building (TAN–681). No radiological discharges to the SMC lagoons are allowed or expected (SMC 1991).

Figure 5-6. SMC evaporation lagoons.

Approximately 5.5 million gallons of process and sanitary wastewater were discharged to the wastewater lagoons in 2010. The effluent to the boiler pond is not metered but is estimated to be 1–5% of the discharge to the wastewater lagoons (Edwards 2011). The seepage rates of the lagoons range from 0.018 to 0.019 inch/day, well below the maximum allowable rate of 0.125 inch/day (Harris and Starr 2009).

SMC had an extensive monthly wastewater sampling program for non-radiological constituents when wastewater was discharged to the old LOFT pond. This was partially because "Liability for effluent composition from SMC was a major concern between [Babcock and Wilcox] and EG&G" (Jackson 1994a). Sampling throughout that time period showed "levels of chemical constituents far below regulatory concern or which would trigger reporting under RCRA or SARA (This includes radionuclides)." Historical data, combined with the new lagoon design (evaporative rather than seepage) was the basis for significantly reducing sampling and analysis when discharges to the new lagoon began (Jackson 1994a, 1994b).

Routine sampling and analysis at the new lagoons consisted of quarterly radiological sampling of boiler and sanitary effluents, and supply water. Quarterly sampling occurred until approximately 2002 when sampling was discontinued due to the continued absence of any contamination (above background) and analytical laboratory cost escalation. Radiological sampling was conducted at the SMC lagoons in 2009; results were consistent with background levels (Kirchner 2009).

5.7.3 Sampling Basis and Design

Based on the historical data and the low seepage rates of the ponds, no environmental surveillance samples are collected at the SMC wastewater lagoons.

5.8 Quality Assurance

Offsite analytical laboratories must possess a Nuclear Regulatory Commission (NRC) license for handling radioactive material and participate in the DOE Consolidated Audit Program. In addition, the off-Site laboratories must participate in the DOE Mixed Analyte Performance Evaluation Program and demonstrate acceptable performance.

The minimum detection limits must be below the release limits or correspond to a maximum count time of 1000 minutes.

Quality assurance samples, such as duplicates or blanks, are typically submitted at a frequency of 10% or at the discretion of the project lead. Blind spikes prepared by the DOE RESL are also used to evaluate laboratory performance.

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6. AIR

6.1 Program Basis

Environmental monitoring of air is conducted because air is the primary exposure pathway to humans from contaminants released to the atmosphere from current activities and from re-suspension of soil contaminated from INL Site airborne releases or fallout. Humans and terrestrial biota can receive a radiation dose from inhalation of, ingestion of, or external exposure to radionuclides in the air (Figure 1-1).

Airborne emissions at the INL Site are generated from various facilities during operations, research, and scientific activities. Engineering controls such as high-efficiency particulate air (HEPA) filters, as well as administrative controls are implemented to prevent, reduce, and/or eliminate air pollutants from the environment. Air surveillance and facility emissions monitoring are completed to assess the adequacy of these controls to protect human health and determine any impact of air pollutants on the environment. This chapter discusses air surveillance involving analysis of particulate matter or gaseous radioiodine collected on filters or trapped in a collection medium and not facility emissions monitoring. Facility emissions that have the potential to exceed National Emission Standards for Hazardous Air Pollutants (NESHAP) limits are either monitored at the source or calculated to show compliance with DOE requirements, federal and state laws and regulations, and industry standards.

Ambient air monitoring is conducted to meet the requirements and criteria set forth in DOE/EH-0173T (DOE 1991).The INL Site ambient air monitoring program consists of two components: 1) the on-Site component, performed primarily within the INL Site boundaries by BEA personnel and 2) the GSS Environmental Surveillance, Education, and Research (ESER) component focuses on monitoring along and outside of the INL Site boundary. In addition, limited regional air monitoring is also performed by BEA at locations co-sampled with the ESER contractor and the State of Idaho, Department of Environmental Quality, INL Oversight program (IOP). The BEA off-Site monitoring is performed to provide comparison and verification for the monitoring results of all INL Site airborne monitoring programs (on-Site, regional, and IOP). The intended duplication of some of the monitoring provides cross-check and ascertains data reliability through independent results.

BEA monitors atmospheric levels of radioactive particulates released from INL Site facilities, natural radioactivity (radon and daughters), and fallout from worldwide nuclear detonations or nuclear accidents using a network of low-volume air monitors. The monitor locations allow comparisons of air concentrations at on-Site locations with those measured at locations distant from the INL Site (i.e., Blackfoot, Idaho Falls, Rexburg, and Craters of the Moon National Monument). If INL Site operations have a measurable effect on the environment, samples from on-Site locations would be expected to have higher concentrations than those from the control locations. These samples are measured to determine whether radiation doses to the public are within limits established in DOE Order 458.1. These activities also provide documentation of ambient air concentrations in the event of a non-routine or an unplanned release.

The ESER environmental surveillance program also measures airborne concentrations of radionuclides—which include naturally occurring and fallout radionuclides and potentially those released by the INL Site—using low-volume air monitors. The majority of these monitors are located at the INL Site boundary (Arco, Atomic City, Blue Dome, Federal Aviation Administration Tower, Howe, Monteview, and Mud Lake) and at locations distant from the INL Site (Blackfoot, Craters of the Moon, Dubois, Idaho Falls, Jackson, and Rexburg). Three are located on-Site at the Experimental Field Station (EFS), Main Gate, and Van Buren Gate. These three sampler sites are not part of the on-Site BEA program, which focuses on monitoring near specific facilities on the INL Site. Rather, the three locations were selected by ESER to correspond with on-Site areas projected by meteorological modeling to potentially have the highest airborne concentrations due to wind dispersion of emissions from all facilities on the INL Site. On-Site measurements are compared with boundary and distant location results to ascertain if INL Site releases have been detected off-Site.

6.2 Program Drivers

Air monitoring conducted on and around the INL Site for environmental surveillance purposes is collectively termed “ambient air monitoring” for the purpose of this technical basis. Ambient air monitoring is performed on and around the INL Site to meet the following requirements and criteria for environmental surveillance of DOE facilities:

- DOE Order 458.1, “Radiation Protection of the Public and the Environment”
- DOE/EH-0173T, “Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance”

Other key drivers include:

- Stakeholder inputs and values
- Potential environmental risks posed by contaminants originating from the INL Site.

Because radiological releases from INL Site operations and scientific activities could impact human health and the environment, the emissions surveillance program is required by DOE/EH-0173T states that all DOE operations shall properly and accurately measure radionuclides in their effluents and in the ambient environmental media with provisions for the detection and quantification of unplanned releases of radionuclides to the environment (DOE 1991). This document also specifies that the surveillance program shall characterize the radiological conditions at off-Site environment locations, estimate public doses, confirm predictions of public dose based on effluent monitoring data and modeling, and provide compliance data for all applicable environmental regulations. It also states that surveillance may be necessary for legal reasons, public concerns, and/or state and local commitments. As discussed in this section, the ambient air monitoring program meets or exceeds the DOE/EH-0173T guide criteria, including sample collection numbers, frequencies, locations, analytes, methods, and equipment.

6.3 Results of Related Studies/Surveillance

As discussed in Chapters 3 and 4, the INL Site can release radioactive material to the atmosphere which could potentially reach local populations, and re-suspension of previously contaminated soil can occur. As shown in Chapter 4, the routes by which these radioactive materials may be transported from the INL Site to nearby populations are directly through atmospheric transport or, indirectly, through soil, foodstuffs, and animals, with air shown to be the most significant pathway. For the operations with the potential to release enough material to cause a dose of greater than 0.1 mrem/yr (one percent of the 10 mrem/yr standard for airborne emissions of radionuclides in 40 CFR 61.92) to a member of the public, continuous stack samples are collected. However, many of the INL Site’s activities are characterized by small sources of radionuclides that are not individually monitored, and for these sources the quantities released are estimated. The INL uses measured and estimated releases and employs an atmospheric-dispersion model (CAP88-PC) prescribed by the Environmental Protection Agency to calculate the dose to the maximally exposed individual (MEI) for NESHAP. The model estimates are conservative (i.e., they use very conservative assumptions and therefore tend to overestimate the doses that could be realistically received.) Therefore, to help determine more realistic potential doses to the public and to differentiate site releases from worldwide fallout and natural activity, a robust network of monitoring locations is required to directly sample atmospheric radionuclides and show actual air concentrations on and off the INL Site.

Routine ambient air monitoring[a] at the INL Site and in the surrounding region began in the 1950s (http://www.gsseser.com/Annuals/2010/PDFs/Monitoring-History-Supplement%202010%20Final.pdf). The results of decades of monitoring are available publicly in annual site environmental reports and in the reports referenced below. The adoption of a 10 mrem effective dose equivalent standard for airborne emissions of radionuclides in 40 CFR 61.92 accentuated the need for fully documented and verified measurements. The annual NESHAP reports that present these data are submitted to EPA annually and are also available to the public.

Many of the current regional sampling locations were selected before federal guidance for sampling-network design existed. Low-volume air samplers, which collect particulates by filtering ambient air, have operated at about 2 cfm since 1952, but the filter materials, analyses, and methods have evolved with advances in technology.

The present method of laboratory analysis for weekly particulate filters was started in 1967, with analyses for gross alpha, gross beta, and I–131. Regular analysis for specific gamma emitters began in about 1970, although any filters with high gross counts were analyzed for specific isotopes before then. The 1969 Annual Report of the Health Services Laboratory (AEC 1970) reports that filters were collected from eight on-Site and eight off-Site samplers. Analysts compared the on-Site and off-Site results to determine if releases from the National Reactor Testing Station (NRTS), which is now called the INL Site, were measureable off-Site.

By 1972, air samplers were located at nine on-Site locations, six boundary sites (Arco, Monteview, Reno Ranch, Butte City, Howe, and Mud Lake), and three distant background sites (Idaho Falls, Blackfoot, and Pocatello) (AEC 1973) (Figure 6-1). The NRTS positioned the on-Site air monitors close to the facilities where electrical power was available and the sampler could be readily accessed by vehicle. The samplers were capable of detecting a ground level release or a stack emission under fumigation conditions (i.e., meteorological conditions that limit the vertical dispersion to the area between the ground and the base of an inversion), otherwise the sampler was unlikely to detect a short-term release from the stack at its facility. Hence, the need for the air network to help ensure detection of any releases from facilities on the INL Site. The boundary samples were located in communities, when possible, or in locations near the INL Site boundary to encompass the Site perimeter. The distant samples were typically crosswind and remote from the Site (Figure 6-1) to ensure that detections were from sources other than the Site. The network was designed to provide comprehensive surveillance of particulate atmospheric radioactivity and make it possible to differentiate INL Site releases from worldwide fallout and natural radioactivity.

The air sampling setup included a membrane prefilter for removal of particulates, followed by an in-line activated charcoal-impregnated cellulose-fiber filter for removal of radioiodine from the air stream. Gross alpha and beta analyses were performed on the membrane filters, and gross beta analyses alone (assuming any activity was due to I–131) were performed on the charcoal filters. The charcoal-impregnated filters were replaced in 1992 by charcoal cartridges, which were analyzed for I–131 by gamma spectrometry. At the end of each calendar quarter, the particulate filters from selected locations were composited and analyzed for gamma-emitting radionuclides and Sr–90. Analyses for plutonium were also performed on the quarterly composites on alternate quarters beginning in 1973. Analysis results were compared by location groups (i.e., on-Site, boundary, and distant stations). Statistical comparisons of the air sampling results collected at distant and boundary locations were first reported in 1975 (ERDA 1976).

Eighteen air sampler locations are currently monitored on-Site, with two additional, duplicate QC samplers that are rotated every two years. The environmental surveillance program includes seven

a. Ambient monitoring is defined in this document as sampling of environmental (outside) air and incorporates near-facility monitoring and environmental surveillance programs.

boundary-monitoring locations are Arco, Atomic City, Blue Dome, the Federal Aviation Administration Tower, Howe, Monteview, and Mud Lake as well as six distant locations at Blackfoot, Craters of the Moon, Dubois, Idaho Falls, Jackson, and Rexburg (Figure 6-2). The Jackson station was installed in 2001 in response to stakeholder concerns.

The measurement of weekly gross alpha and gross beta activity on membrane filters is a screening technique to give timely information in the event of Site releases or worldwide fallout. This information may be difficult to interpret because of local variations at any given time or location and the fact that the activity represents a range of alpha-emitting or beta-emitting radionuclides which are indistinguishable. However, the data have been useful in determining temporal patterns and in confirming that the monitors track each other closely and have generally not indicated any Site releases in recent years (Figure 6-3).

Specific radionuclide analyses have proven to be more sensitive indicators of Site releases than gross alpha or gross beta analyses. Positive detections of specific radionuclides have generally been attributed to natural sources such as worldwide fallout from nuclear weapons testing or accidents such as Chernobyl or Fukushima, or statistical variations in the analyses, rather than to Site operations. Cesium–137 and Sr–90, associated with worldwide fallout, are the most frequently measured man-made radionuclides detected in composited air filters. However, the regional air monitoring program has detected releases of specific radionuclides released from the INL Site. These include Sb–125, a radionuclide released from the Idaho Chemical Processing Plant during the dissolution of fuel at the FAST facility, which is no longer in operation. Substantial releases of Sb–125 occurred in 1980, 1981, 1986, 1987 and 1988. In 1987 Sb–125 was detected at almost all on-Site stations in each of the first three quarters and at two-thirds of the on-Site stations in the fourth quarter (DOE-ID 1988). During the year, Sb–125 was found on off-Site filters as well—on 11 of 27 filter composites from boundary stations and on two of 16 filters from distant locations. The results demonstrate the efficacy of the regional-scale, multi-sampler network.

The identity and quantity of radionuclides routinely released from Site facilities is reported annually in the NESHAP Idaho National Laboratory Report for Radionuclides (e.g., DOE-ID 2012a). The majority of radioactive effluent is in the form of noble gases (e.g., argon, krypton, and xenon), which cannot be measured through particulate sampling. Because of this, the impact of Site operations on the surrounding region began to be calculated using known amounts of radionuclides released and atmospheric dispersion modeling. Beginning in 1973, the NOAA Air Resources Laboratory Field Research Division at the NRTS produced, using their MDIFF air transport and dispersion model, the annual map of time-integrated-air concentrations (TICs) for the purpose of dose calculations (Figure 6-4). The map was based on the year's meteorological observation data obtained from NOAA's Mesonet system of 22 meteorological monitors located on and off the NRTS. The sources were assumed to be emitted from the major on-Site stack at the Idaho Chemical Processing Plant. The maximum projected off-Site air concentration was used to estimate doses to a hypothetical MEI and the population residing within 50 miles of the INL Site.

The dose to the 50-mile population around the Site is still calculated using the annual NOAA-generated TIC maps, which have evolved to incorporate the current Mesonet system of 35 meteorological observation stations. MDIFF is used for annual or other long-term simulations (Sagendorf, Carter, and Clawson 2001). A detailed description of the MDIFF model and its capabilities may be found at http://www.noaa.inel.gov/capabilities/modeling/MDIFFTechMemo.pdf. MDIFF utilizes wind speeds and directions from the one-hour Mesonet database. The model predicts average annual air concentrations, resulting from INL Site airborne effluent releases, at each of over 10,000 grid points on and around the INL Site (Figure 6-5). Contours of the predicted time-integrated concentrations are projected by NOAA. As with past TIC maps, the most current TIC map shows a southwest and northeast dispersion pattern, as would be expected from observation of a current wind rose (Figure 6-6). However the on-Site concentration pattern has changed with the removal of sources such as TAN in the north part of the INL Site (Figure 6-7). In addition, the TIC maps are now prepared considering the percent contribution of each major facility to the total annual INL Site release, rather than treating the INL Site as a single release point.

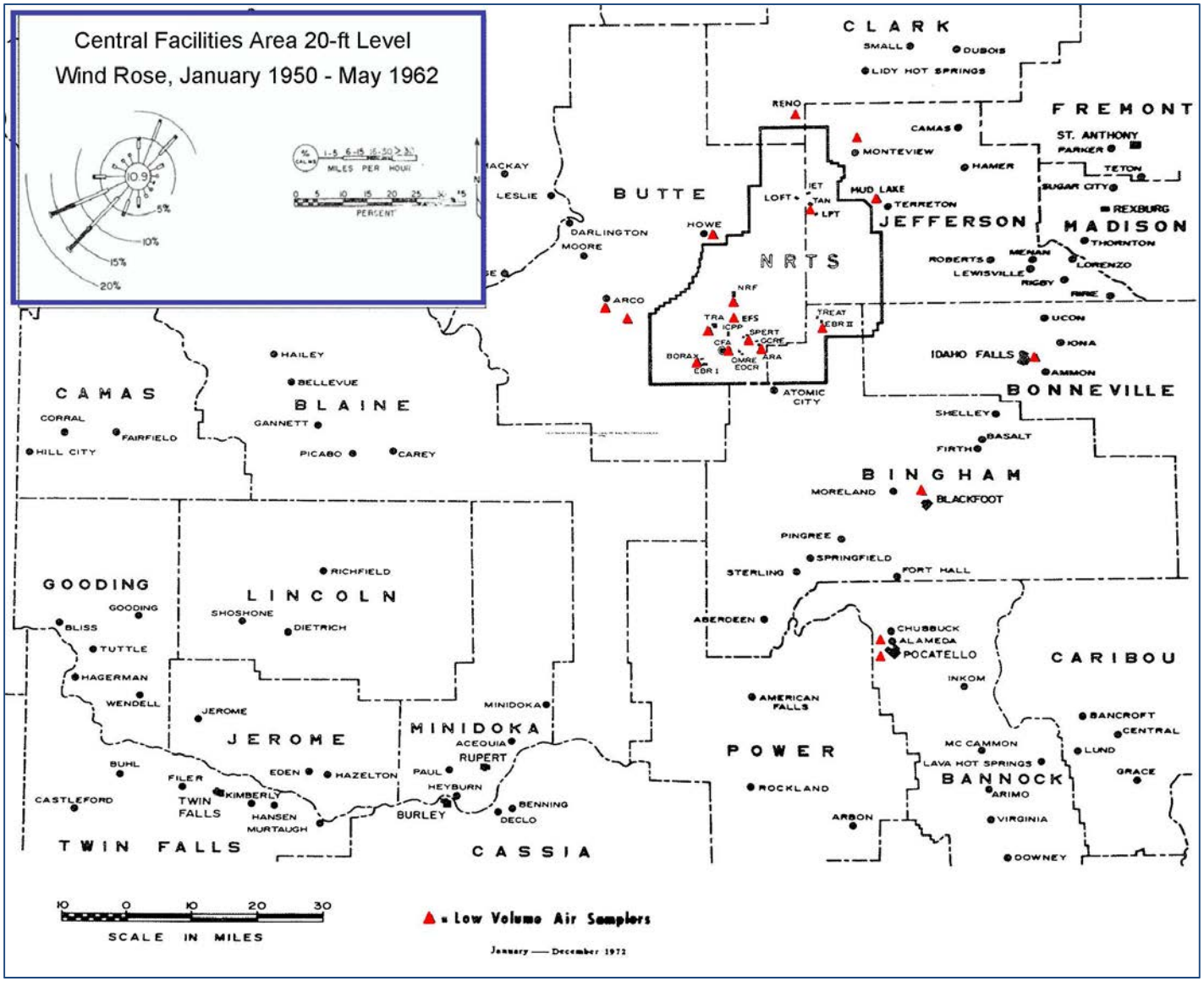


Figure 6-1. Low-volume air sampling locations in 1972 (AEC 1973) and Site wind rose (from Yanskey, Markee, and Richter 1966).

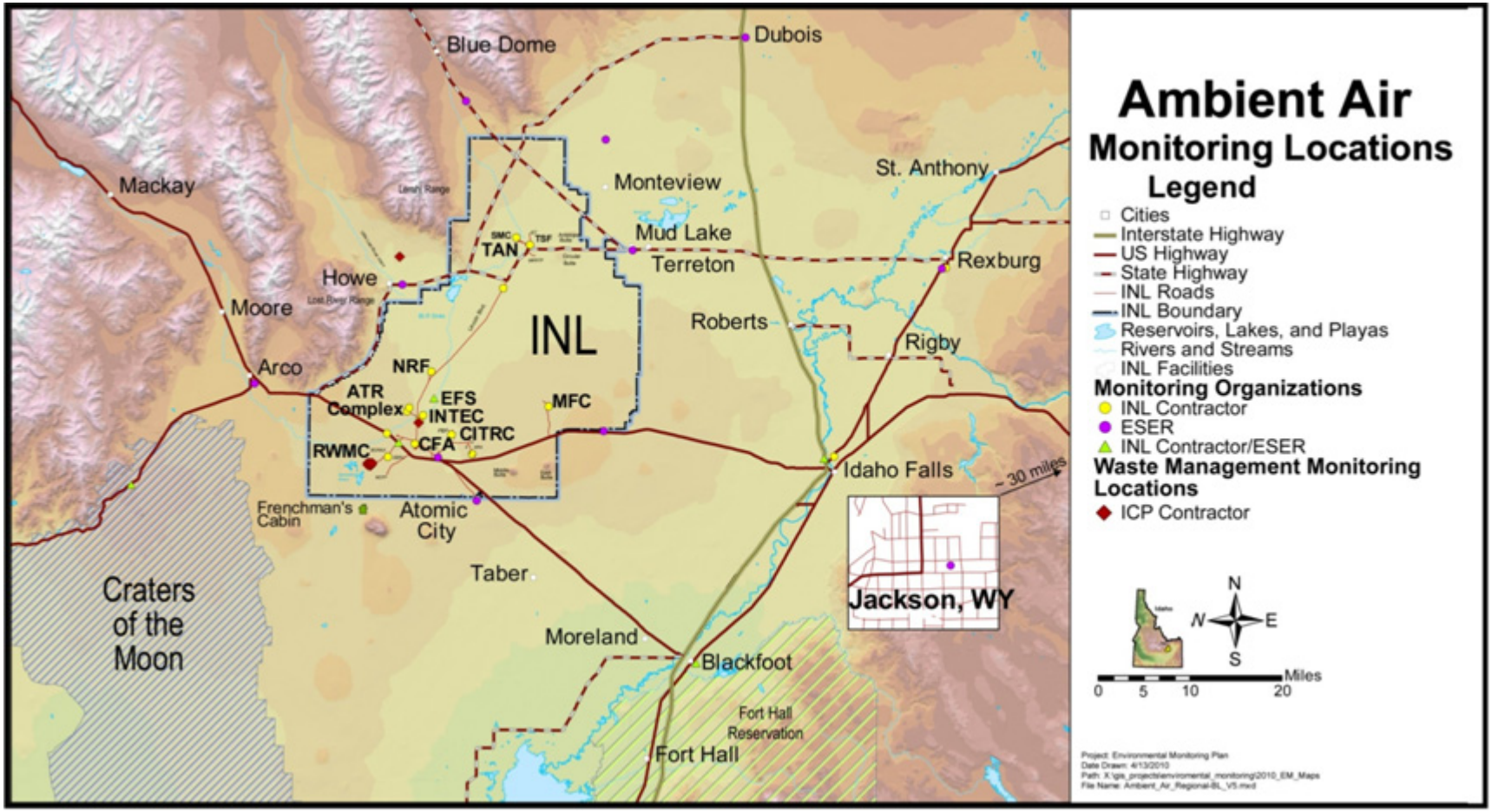
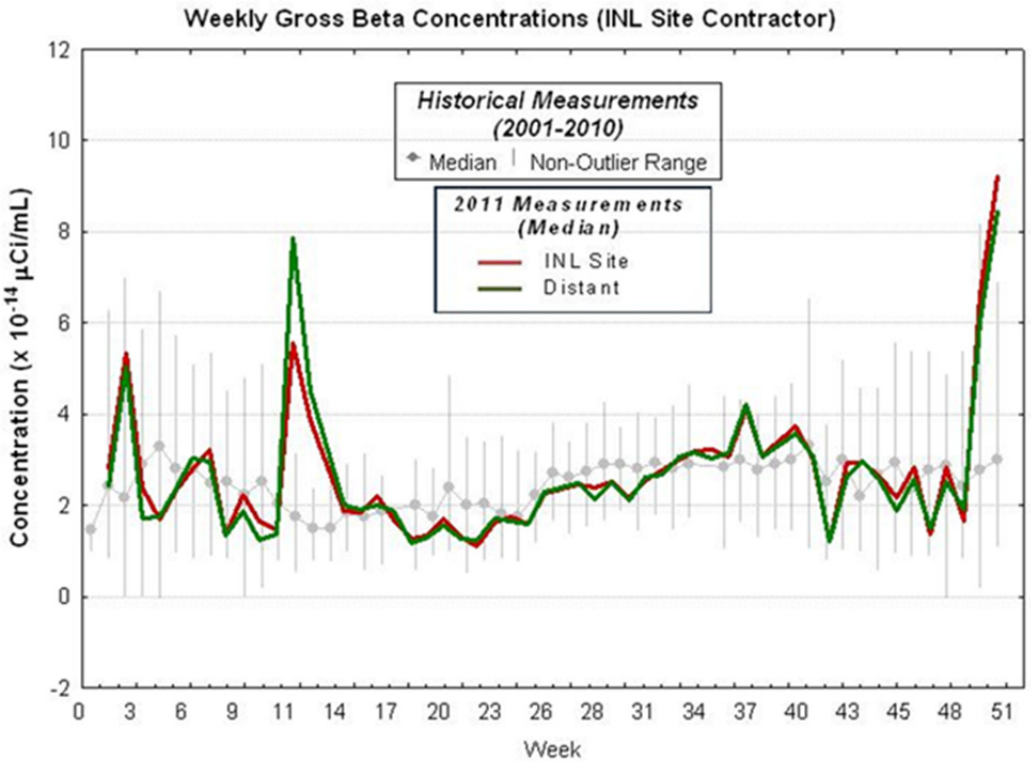


Figure 6-2. INL Site ambient air monitoring locations (2011).



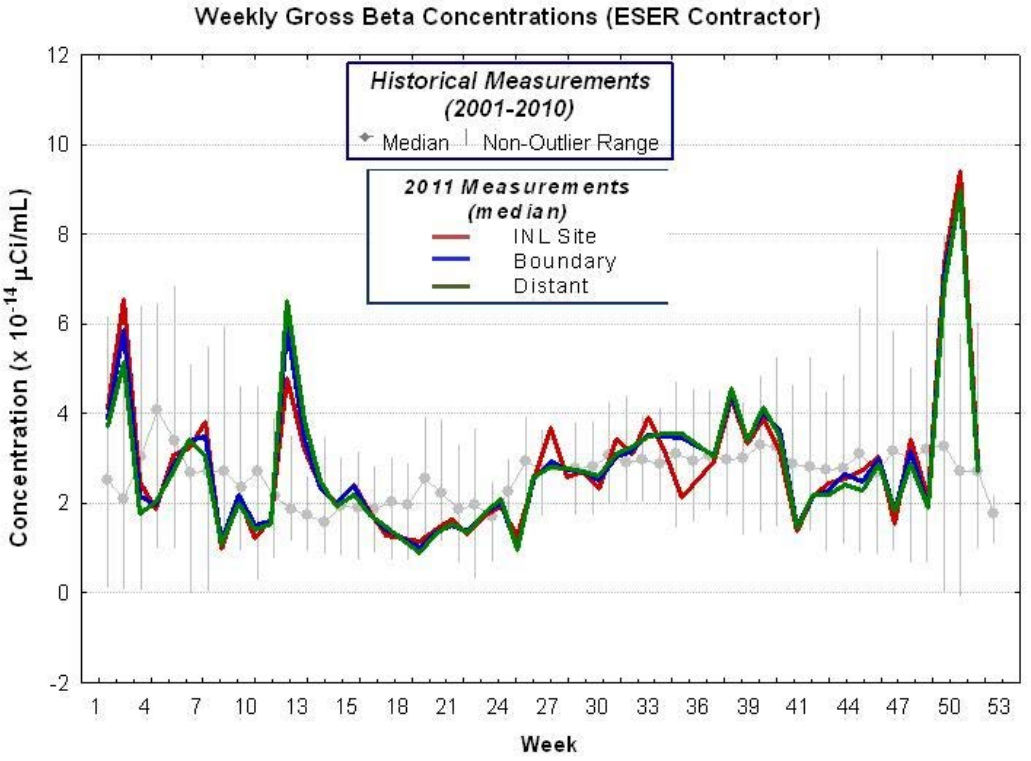


Figure 6-3. Median weekly gross beta concentrations in air (2001–2011). The first figure represents the results from the BEA ambient air monitoring program. The second figure represents the results from the ESER component of the ambient air monitoring program (DOE-ID 2012b).

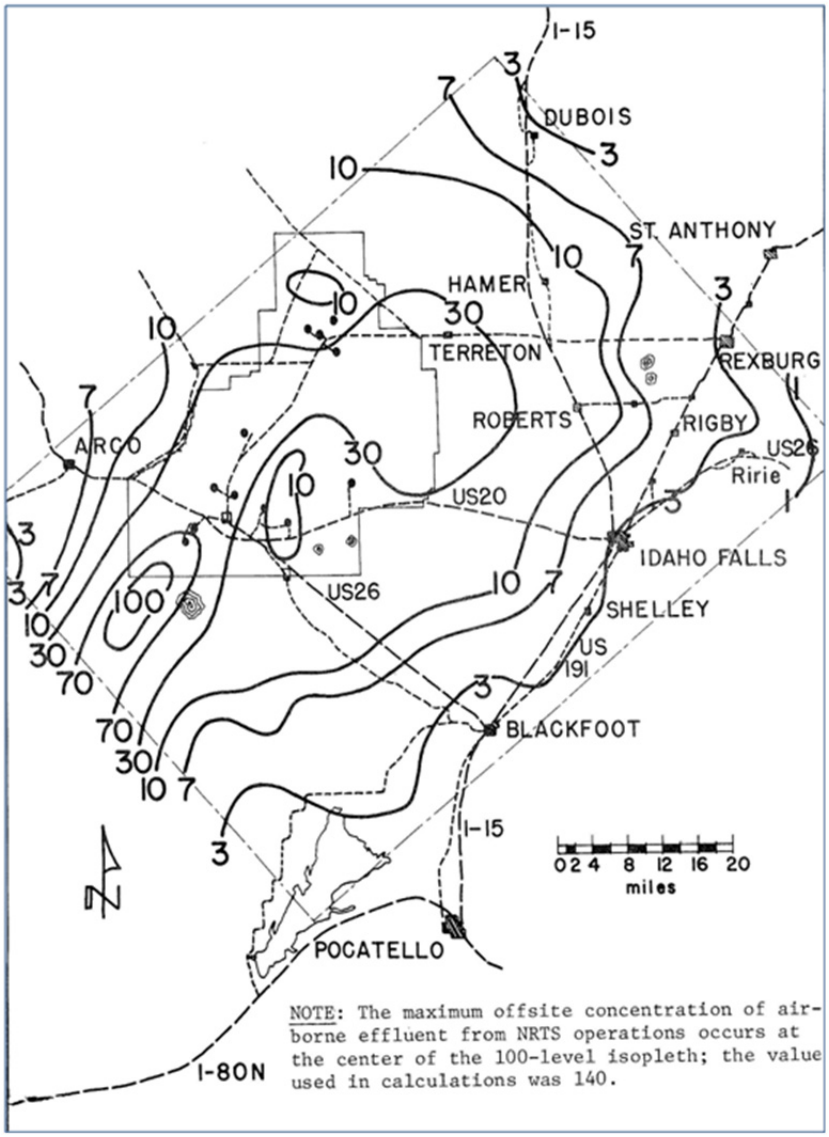


Figure 6-4. Mesoscale dispersion isopleths of time-integrated air concentrations (TICs) normalized to a unit release rate for calendar year 1973. Units are $10^{-9}hr^2/m^3$ (AEC 1974).

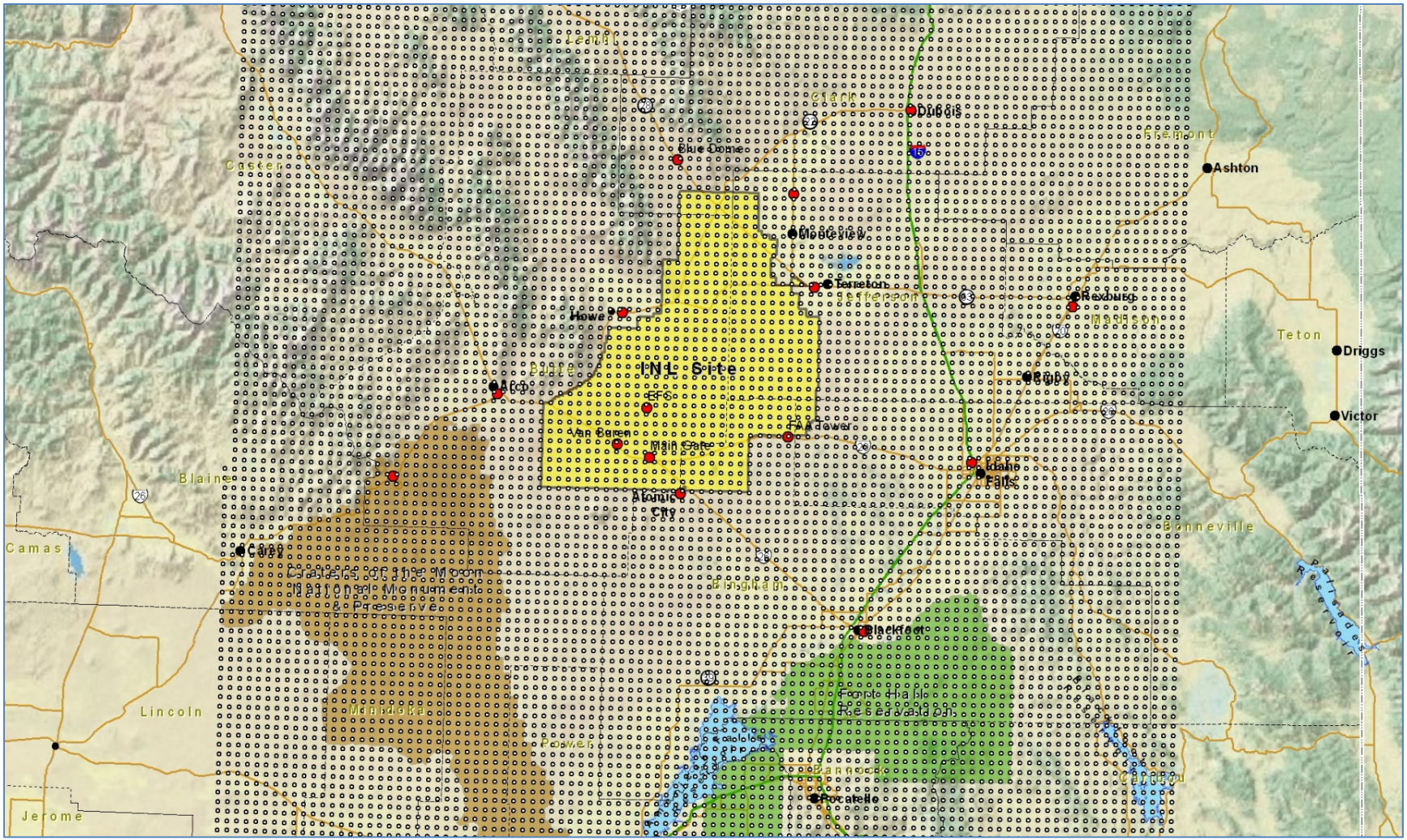


Figure 6-5. INL Site mesoscale grid currently used in MDIFF simulations of INL Site air dispersion annual TICs. Red circles represent current ESER air monitoring locations.

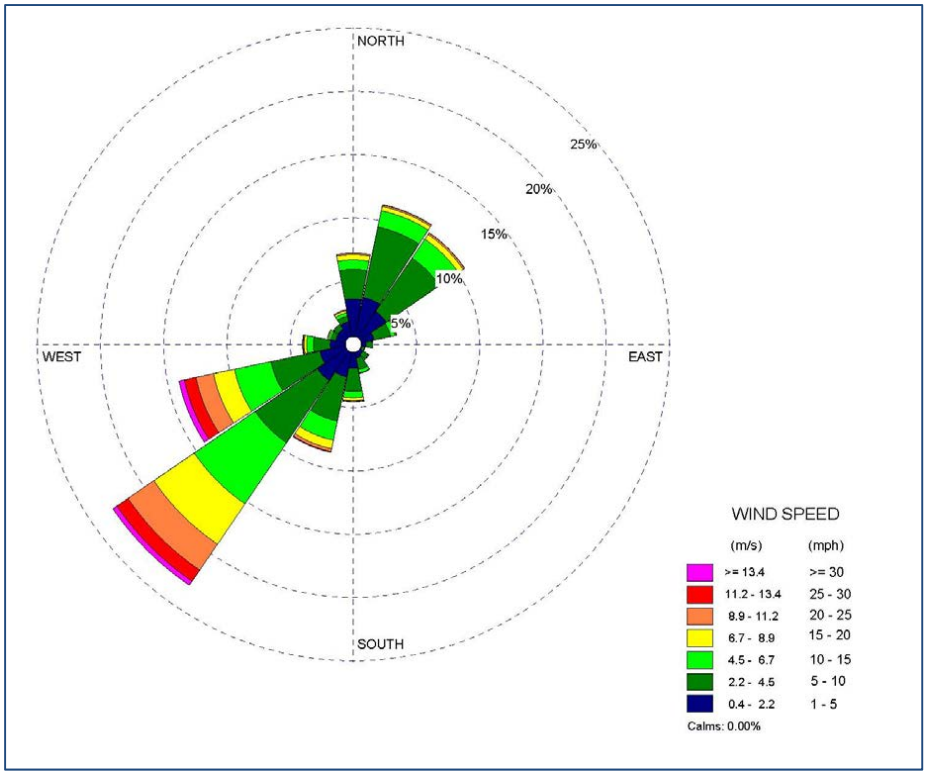


Figure 6-6. INTEC (Grid 3) 10-m level wind rose, January 2000 through December 2004.

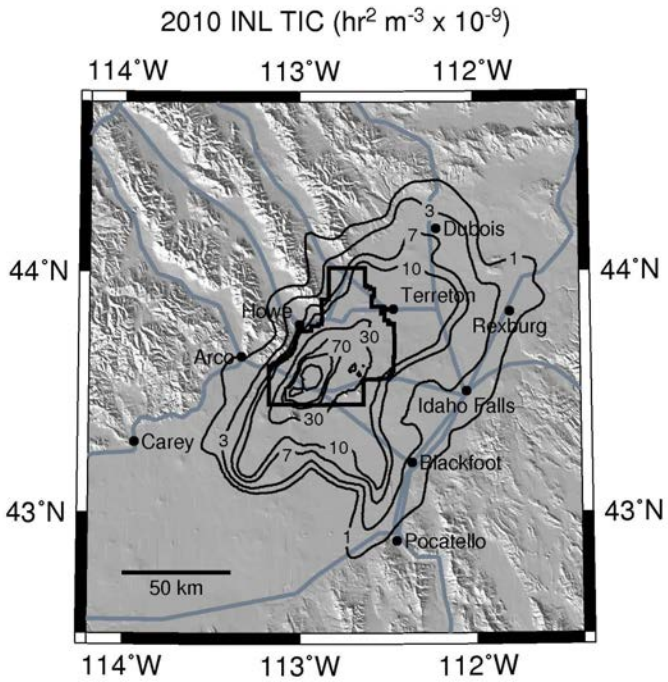


Figure 6-7. Mesoscale dispersion isopleths of time-integrated air concentrations normalized to a unit release rate for calendar year 2010. Units are $10^{-9}hr^2/m^3$ (DOE-ID 2011).

The dose to the MEI at locations surrounding the INL Site was calculated using the TIC map until 1986, when the EPA specified that an EPA air-dispersion model be used to demonstrate compliance with 40 CFR 61, Subpart H. This regulation limits quantities of airborne radionuclides from nuclear facilities. The standard requires the dose received by any member of the public must be less than 10 mrem/yr. At no time since 1986 (when the EPA standard was adopted) has the dose to the maximally exposed individual been calculated to exceed even 10% of the10 mrem/yr standard. The doses for the past ten years at the location of the off-Site hypothetical MEI (typically at Frenchman's Cabin) have not exceeded 1% of the 10 mrem/yr dose limit. Additionally, the population dose has always been less than 0.01% of that received from natural background. However, the adoption of the 10 mrem effective dose equivalent accentuates the need for fully documented and verified measurements.

6.4 Program Goals

In general, the primary goal of the ambient air monitoring program is to determine the status of the INL Site's compliance with applicable public health and environmental quality standards and to complement NESHAP emissions monitoring and modeling by confirming that emissions control and measurement equipment is functioning, and that diffuse and unmonitored emissions are not causing unacceptable doses off-Site. Specific program objectives that are derived from these goals and other drivers include:

- Measure background concentrations of radionuclides in air
- Measure concentrations of radionuclides in air at locations which could be impacted by routine INL Site operations
- Determine INL Site contributions of airborne radionuclides to the environment
- Detect and report trends in measured concentrations of airborne radionuclides
- Compare measured concentrations to reference levels based on derived concentration standards tabulated in DOE-STD-1196-2011, "Derived Concentration Technical Standard" (DOE 2011)
- Detect and quantify unplanned releases
- Prepare a comprehensive analysis of surveillance results and dose calculations for reporting to the public in the annual site environmental report or letter reports.

6.5 Sampling Boundaries

The logistics of implementing the program objectives involves consideration of spatial and temporal limits, as well as consideration of practical constraints. The DOE criteria and requirements for environmental surveillance, as presented in DOE/EH-0173T, address the dose to an individual at the Site boundary and a 50-mile population. For this reason, the regional environmental surveillance program focuses on the area within 50 miles of any Site facility (Figure 6-8), particularly in areas that are projected by meteorological modeling to have potentially higher concentrations of airborne contaminants through dispersion forces unique to the region (Figure 6-10). It considers long-term meteorology and receptor populations. As can be seen in this figure there is a predominant dispersion pattern in the northwest/southeast directions from the INL Site.

The temporal boundary for air-surveillance monitoring is easily defined. INL Site facilities and operations are conducted 24-hours a day, 7-days a week. As such, the potential for radiological emissions is ever-present, thus requiring continuous air monitoring. The low-volume air samplers (particulate, I–131, and tritium) are configured for 24-hour, 7-day (24/7) operation at each sample location. With the exception of planned and unplanned power outages, these air samplers run continuously, effectively providing uninterrupted monitoring of the radiological conditions of the ambient air, which meets the criteria in DOE/EH-0173T.

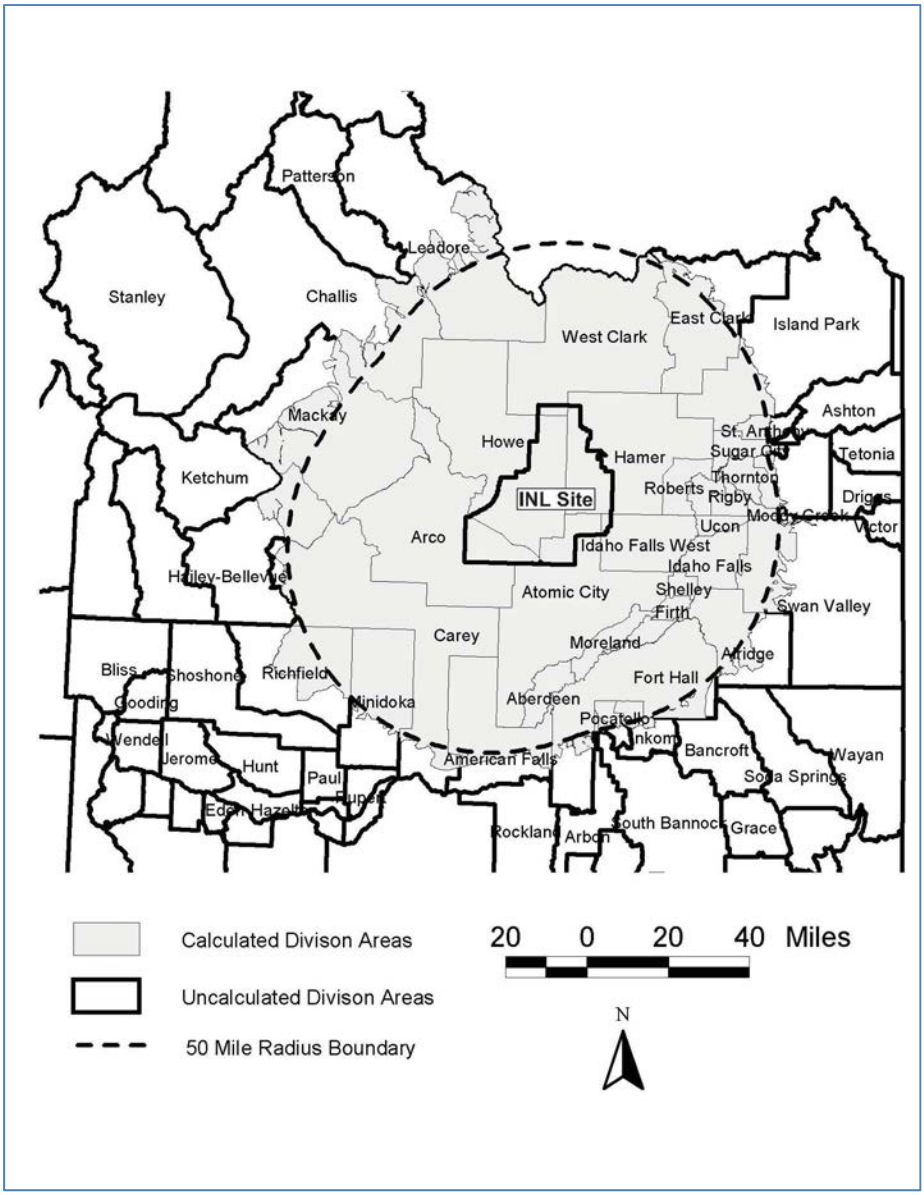


Figure 6-8. Region within 50 miles of INL Site facilities. Census divisions used in the 50-mile population dose calculation are shown.

During the wildfire season, high-volume air samplers are deployed at 17 locations both on and off INL Site. These “event air monitors” are located at NOAA weather towers in southeast Idaho (Figure 6-9). Although the NOAA towers are not located to detect contamination, but to provide weather data, they are the only locations that are currently configured for remote activation of event monitors in the event of an unplanned release. However, in addition to the fixed locations at NOAA towers, portable event air monitors are staged for deployment. The temporal boundary for an unplanned release depends on the nature and duration of the release. The maximum duration that an event air monitor will be allowed to operate is 24 hours prior to collecting the filter for analysis.

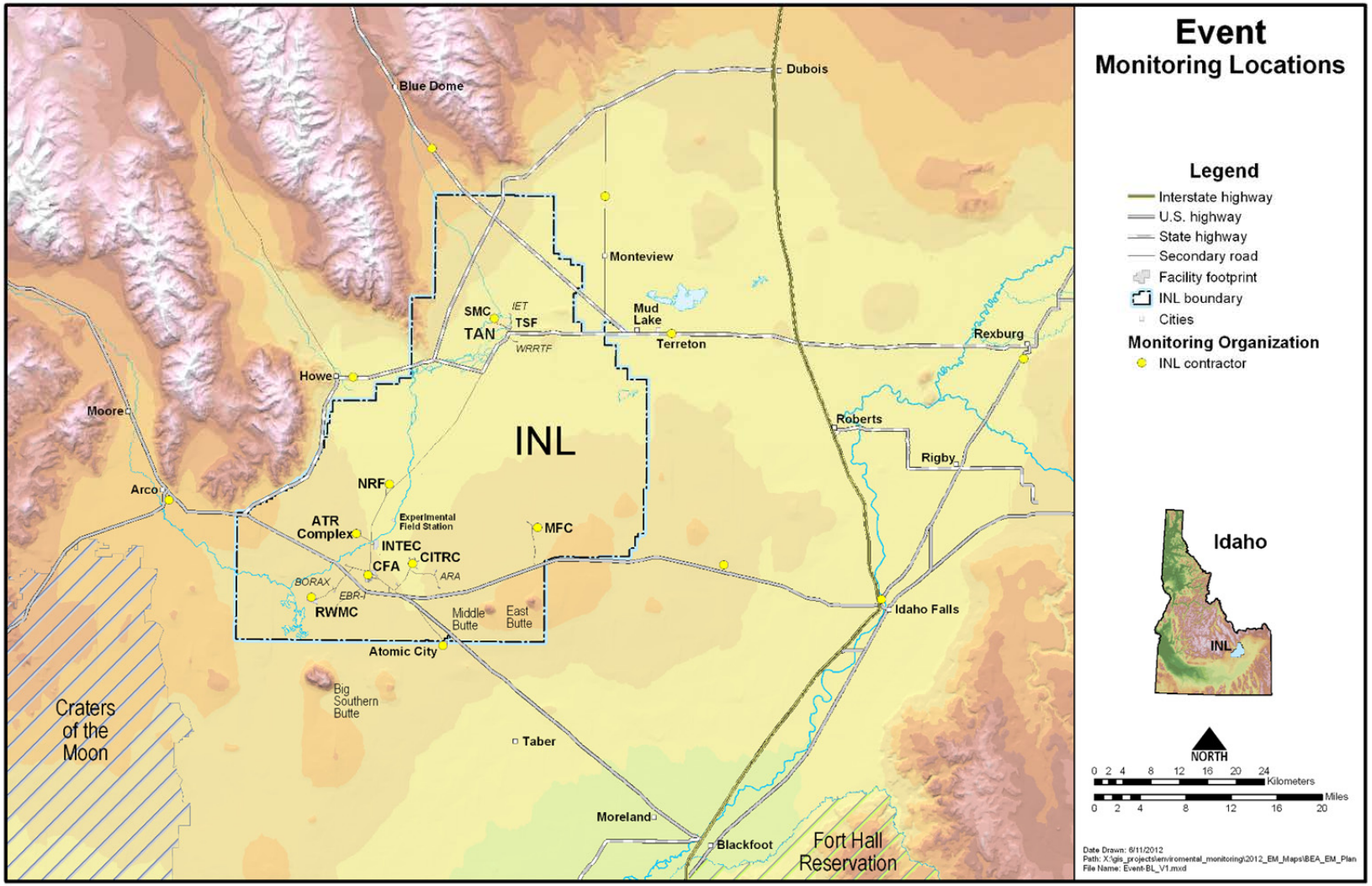


Figure 6-9. NOAA tower and event monitor locations.

6.6 Sampling Design

Selection of locations, frequency of collection, collection and measurement techniques, and analytical detection and precision goals form the basis of the ambient air monitoring program. Design of the regional air sampling network to include both air sampling on the INL Site and off the INL Site achieves program goals using a comprehensive, consistent approach. The overall sampling design (including sampling location placement, collection frequency, flow rates, filter types, analytes, etc.) conforms to DOE 1991, the accepted federal radiological effluent monitoring and environmental surveillance guide that assists DOE-controlled facilities in running technically defensible programs that meet DOE requirements, as discussed in the following sections.

The environmental surveillance air monitoring program is intended for routine surveillance of environmental concentrations of radionuclides on-Site and in the surrounding region, and not for real-time detection of INL Site facility releases or for regulatory emissions monitoring. Although the routine ambient air monitoring program can provide valuable information in the event of an emergency, it is primarily oriented towards confirming that concentrations in ambient air are consistent with the expected level of routine emissions, and providing an indication of emissions caused by situations that are off-normal, but not necessarily emergencies (Waite 1973). The regional environmental surveillance component supplements the on-Site air component. The on-Site INL air-monitoring component is designed to monitor planned and unplanned releases downwind of and closer to specific facilities and source areas. These samplers are more likely to detect chronic releases of small amounts of activity. When combined with other on-Site and boundary samplers, the network can result in a high probability of detecting small, short-duration releases. Ritter et al. (2003) estimated that a 10 mCi acute release of Cs-137 from the ground at INTEC, corresponding to <0.1 mrem at INEL Site MEI location, would be detected using the current combined INL Site monitoring network.

The elements used in the design of the ambient air monitoring program (including both on-Site and regional components) are discussed below.

6.6.1 Sampling Locations

The ambient air monitoring network includes monitors at each major on-Site facility, in the predominant wind directions several miles from the facilities, and in several distant locations, including the towns of Idaho Falls, Rexburg, and Blackfoot, Idaho, Jackson, Wyoming, and Craters of the Moon National Monument west of Arco, Idaho. Additional information is provided below. Ambient air surveillance began in the late 1950s (DOE-ID 1991), and many of the current sampling locations were selected before the government released guidance for sampling-network design. However, the general guidelines for selecting sample locations (downwind of major sources, near population centers, etc.) used for the initial sampling network are still valid today.

6.6.1.1 BEA

The air monitoring network includes monitors at each major on-Site facility, at several central locations on the INL Site, and several distant locations. BEA samples at facility perimeters for the analytes released or potentially released by the facility, the requested detection limits correspond to estimates of dose, and the sampling methods and frequencies are those suggested by DOE guidance. BEA is exploring a modeling study to determine the adequacy of these historic locations versus the modeled optimal locations. The INL contractor maintains low-volume air samplers at 21 locations and rotates two additional duplicate QC samplers every two years. See Table 6-1 for a list of the current and proposed air monitor locations. Seventeen of the 21 low-volume air sampler locations are on the INL Site. Several of the on-Site air samplers are located adjacent to facility perimeters (e.g., INTEC and the ATR Complex) with consideration given to the predominant wind directions (northeast and southwest). INL also maintains a number of on-Site low-volume air samplers in locations several miles from the major facilities within the predominant northeast/southwest air flows (e.g., Experimental Field Station,

Highway 20 Rest Area). Off-Site, BEA has low-volume air samplers in the towns of Idaho Falls, Rexburg, and Blackfoot, Idaho, and at Craters of the Moon National Monument west of Arco, Idaho.

In response to the HSS 2010 assessment, BEA placed a low-volume air sampler in Idaho Falls for the purpose of assessing potential impacts from IRC and RESL operations on the public. The location is directly south of these facilities between potential release sources and the Idaho Falls population, corresponding with the location of the MEI from operations at IRC (DOE-ID 2012a). In addition, in response to the HSS 2010 assessment, BEA moved the MFC air monitor out of the parking lot to a location adjacent to the facility.

Table 6-1. Final locations selected for the BEA component of the ambient air monitoring network.

Location	Proposed action	Rationale
ARA	Keep	Adjacent to large radionuclide contaminated soil area
Blackfoot	Keep	Background location
CFA	Keep	Indicator of site releases; largest on-Site population outside fenced facilities
CPP	Keep	Indicator of facility releases
Craters of the Moon	Keep	Background Location
EBR-I	Keep	Indicator of site releases
EFS	Keep	Indicator of site releases
Gate 4	Keep	Indicator of site releases
Idaho Falls	Keep	Background location
INTEC	Keep	Indicator of facility releases
NRF	Keep	Indicator of facility releases
PBF	Keep	Indicator of facility releases
REST	Keep	Indicator of site releases
RTC	Keep	Indicator of facility releases
RWMC	Keep	Indicator of facility releases
Rexburg	Keep	Background location
SMC	Keep	Indicator of facility releases
TAN	Remove	Inactive Facility. Move this monitor to IRC
TRA	Keep	Indicator of facility releases
Van Buren Boulevard	Keep	Indicator of site releases
IRC	Place new monitor	Indicator of facility releases

6.6.1.2 ESER Environmental Surveillance Program

The current regulatory guidance for siting air samples is prescriptive and emphasizes expert judgment, evaluation of planned or potential releases, and evaluation of long-term meteorological and regional demographic data. Additionally, monitoring locations may be chosen to address stakeholder and community concerns. Prime locations may not be viable due to a lack of electricity. DOE guidance (DOE 1991) concerning the number and placement of air monitors in a regional monitoring network recommends that a method similar to that developed by Waite (1973, 1976) may be used. The Waite method incorporates a calculation of weighting factors, based on demographic and meteorological data, to guide the distribution of air-sampling locations around nuclear facilities. The method is useful for single sources with nearby population centers. However, the maximum applicable population distance is limited to 10 miles except for very large nuclear facilities. This method clearly has limited applicability for the INL Site, which has multiple facilities spread out over 890 square miles and distant population centers.

Another method often used to design a regional air sampling network is the use of a Gaussian plume model (PNNL 2010). At the INL Site, CAP88-PC is used to estimate the dose to the hypothetical MEI to demonstrate compliance with NESHAPs (DOE-ID 2012a). It uses annual INL Site wind direction and wind-speed frequency data and straight-line Gaussian plume calculations to estimate the dose to the nearest off-Site human receptors. However, it is constrained by model assumptions that are valid only for a fixed set of meteorological conditions which do not represent real-world transport of airborne contaminants over time and an expansive regional geography, such as that represented by the INL Site and surrounding areas.

A more refined method to design a regional air-monitoring network is to employ a puff-trajectory model. This kind of model treats plumes as a succession of plume segments (puffs) that are transported according to a wind-field model, and disperse their centers during transport. It accounts for changes in meteorological conditions during transport. MDIFF is a puff-trajectory model developed by NOAA to model atmospheric dispersion at the INL Site and surrounding region. It is a particularly powerful tool because it can be used with meteorological data measured hourly throughout the region of MESONET coverage and can track results at each node of a large grid overlain on the region of interest (Figure 6-5). Thus, it is possible to evaluate the TIC at actual or hypothetical sampling locations.

Figure 6-10 shows the 2010 INL Site TIC projections displayed as contours. The TIC projections portray similar patterns in recent years (DOE-ID 2008, 2009, 2010, 2011, and 2012a) and therefore it is appropriate to use one year to represent all years. The TICs are based on one year of meteorological data and a unit release rate of 1 Ci/yr from the Site. The model assumes that the release is distributed among the Site facilities according to the percent contribution of the total source term (e.g., INTEC represents 38% of the release.) The regional airborne-particulate-monitoring stations are also shown in Figure 6-10. Most of the annual releases from the INL Site consist of noble gases, which are either short-lived or cannot be detected by particulate air samplers. In addition, noble gases are of little health concern in the environment because they are not transported through food chains and do not generally concentrate in biological tissues. It is thus more feasible to determine their impact in the environment by measuring direct exposure (i.e., external radiation) resulting from them rather than by sampling and analysis (DOE 1991). DOE 1991 also does not recommend ambient sampling for Kr–85 unless the dose to the MEI is >5 mrem. Tritium is another nonparticulate radionuclide of concern which is typically released as tritiated water vapor and must be collected using methods that sample moisture from the air, as discussed in Chapter 7.

To evaluate the adequacy of the current and potential new airborne–particulate-sampling locations, it was first determined what concentrations of gamma-emitting radionuclides can be detected using the current analytical methods. Gross alpha and beta activity is detected on virtually all of the particulate filters, but specific gamma emitters of interest to the environmental surveillance program are not detected as often. The majority of longer-lived particulates released from INL Site facilities and areas are fission and activation products, such as Cs–137 and I–131, which if present, can be easily identified on membrane filters and charcoal cartridges using gamma analyses. The detection limit is slightly lower for Cs–137 than for I–131. In addition, Cs–137, with a half-life of 30 years, persists in the environment much longer than I–131, with a half-life of 8 days. For these reasons, the detection capability was evaluated for Cs–137.

The Idaho State University Environmental Assessment Laboratory employs six gamma detectors to analyze the ESER environmental surveillance program quarterly composited air filters, which are collected weekly. The average minimum detectable activity (MDA) for Cs–137 is 0.37 pCi per quarterly composited filter sample. Assuming this MDA and a five-year (2006–2010) annual average INL Site release rate of 0.5 Ci of Cs–137, the minimum TIC at which Cs–137 released by INL Site facilities could be detected was calculated using the following algorithm:

$TIC_D = MDA/(V*R)$

where

TIC_D = time-integrated concentration at which average annual Cs–137 release is detectable by air samplers (hr/m^3)

MDA = minimum detectable activity (Ci/sample)

V = volume sampled by air samplers over 13 weeks (one quarter) (m^3)

R = average rate of release of ^{137}Cs to air from INL Site facilities during the year (Ci/hr).

TIC_Ds were estimated for three potential sample collection rates (2 cfm, 2.5 cfm, and 3 cfm). The 2.0 cfm flow rate is currently used, but the pumps are capable of higher flow rates which can result in increased total collection volumes and, thus, lower minimum detection concentrations [MDCs]. Furthermore, increasing air volume results in better counting statistics (Boothe et al. 2008). The pumps are capable of collecting up to 4.0 cfm; however, with increased volume, there is more particulate load and stress on the pumps and a large decrease in iodine-collection efficiency of the charcoal cartridges (see Figure 6-12 and discussion in Section 6.6.3). For this reason, the maximum flow rate assessed was 3.0 cfm.

The TIC_Ds were converted to annual average TIC_Ds, for comparison with MDIFF estimates, by multiplying by the number of hours in one year (8760). The results are presented in Table 6-2. According to Table 6-2, 5.1E–9 hr^2/m^3 is the minimum TIC_D at which an average annual release of 0.5 Ci of Cs–137 could be detected in a quarterly composited air sample. This value was compared to those TICs generated by NOAA for specific sampling locations, according to the grid shown in Figure 6-5. These data are presented for each of the five years evaluated (2006–2010) and as an average in Table 6-3. A visual summary of the TIC_Ds for the five years analyzed at each of the current and proposed locations is presented in Figure 6-11

To establish a network to evaluate the impact of potential INL Site releases on the environment, ESER environmental surveillance program air sampler locations were categorized, using the calculated TIC_Ds and other considerations, and assigned to the following groups:

1. Distant samplers – Samplers in this group are used to represent areas of minimal impact from INL Site releases and are used as controls[b]. Criteria used to accept locations into this network are:
    a. Samplers are located toward the periphery of the Snake River Plain area surrounding the INL Site but close enough to be representative of conditions at the INL Site. For example, samplers cannot be located in the mountains west of the INL Site because ecological factors which can affect radionuclide transport differ from those associated with the Snake River Plain ecosystem associated with the INL Site.
    b. Samplers encircle the INL Site, ideally at or near population centers.
    c. Samplers are located in minimally impacted areas. This can be represented numerically when the average calculated TIC (blue bar in Figure 6-11) is near or below the minimum detectable TIC for Cs-137 (orange line).
2. Boundary samplers – Samplers in this group are used to represent areas that are located off the INL Site but can be impacted by Site releases radionuclides. The criteria used to accept locations into this network are:
    a. Samplers encircle the INL Site to help insure detection of any emissions that are dispersed beyond the boundary.

b. A control sample is used for comparison to determine if a contaminant of interest is present in a sample of interest. It is collected near the same time and under similar conditions as a sample suspected of containing the contaminant.

b. Samplers are located near or beyond the INL Site boundary in areas where members of the public reside and the potential impacts from all INL Site releases are the greatest. The impact can be represented numerically when the average calculated TIC (blue bar in Figure 6-11) is above the minimum detectable TIC for Cs-137 (orange line).

3. INL Site samplers – Samplers in this group are used to represent areas on the INL Site that are most likely to be impacted by all facility emissions. The criteria used to select

   a. Samplers are located outside individual facility perimeters.

   b. Samplers are located in areas that do not conflict with security requirements (e.g., outside fenced-in security areas.)

   c. Samplers are located on the INL Site at areas which theoretically have the highest predicted impact from facility airborne releases, as demonstrated by being within the highest TIC isopleths in Figure 6-10.

In addition to the conditions described above, consideration must be given in each to availability of electricity, accessibility during all seasons of the year, and limited access to minimize the possibility of vandalism. The locations which meet all three of these conditions off the INL Site are the NOAA enclosures used for the MESONET meteorological equipment. For locations off the INL Site, preference was therefore given to NOAA MESONET stations.

Six of the current distant monitoring locations (Arco, Blackfoot, Blue Dome, Craters of the Moon, Idaho Falls, and Rexburg) fall below the cutoff value of 5.1E–9 hr^2/m^3 for inclusion as control locations. That is, they are situated where the impact of site releases has a probability of being minimal. Blue Dome and Craters of the Moon do not meet all the criteria mentioned above for inclusion in the control network, however should remain in the network. Blue Dome should be kept, even though it is not near a population center, because it is the only station located north of the INL Site. Craters of the Moon should be kept, even though it is not near a population center, because the importance of monitoring the air quality at the National Monument is of great state and national interest. The Idaho Falls location represents the highest portion of the estimated 50-mile population dose, even though the TIC is usually below the detectable level. Moreover, an EPA RadNet monitoring station is located there and can provide independent, confirmatory data.

Jackson is not representative of the Snake River Plain ecosystem and is not located within the MDIFF mesoscale system, however it was established in response to stakeholder concerns in 2001 and should be maintained for that special purpose and not as part of the distant network as a control location.

A few new locations were evaluated to enhance or possibly replace stations in the current boundary network. Frenchman's Cabin, which is located along the southern boundary just south of RWMC and near the Big Southern Butte, is typically identified as the location of the MEI and was therefore included for further examination. Other than Atomic City, no other inhabitants have been identified along the southern boundary. However, Taber, which has a small population located about 11.5 miles from Atomic City along Highway 26, lies within the same MDIFF isopleth as the FAA Tower (see Figure 6-10.) For this reason, it was evaluated as a potential new air-monitoring location.

The census division of Hamer, located downwind of the INL Site in the northeast direction (see Figure 6-10), was also examined further as the MEI has sometimes been historically identified in this region. In addition, there are only 2,300 individuals living in this census division, yet the population dose estimated for this region represents about 10% of the total 1.6 person-rem (0.016 person-Sv) dose estimated for the entire 50-mile population (over 307,000 people) surrounding the INL Site. Potential new sites in the area were selected at NOAA Mesonet meteorological stations at Hamer and Roberts, which both have power. A visual inspection of the Hamer station revealed that the location could be inaccessible in the winter and has severe erosion issues which could impact long-term maintenance of the sampler. For this reason, only Roberts was selected as a prospective new location in the Hamer census division.

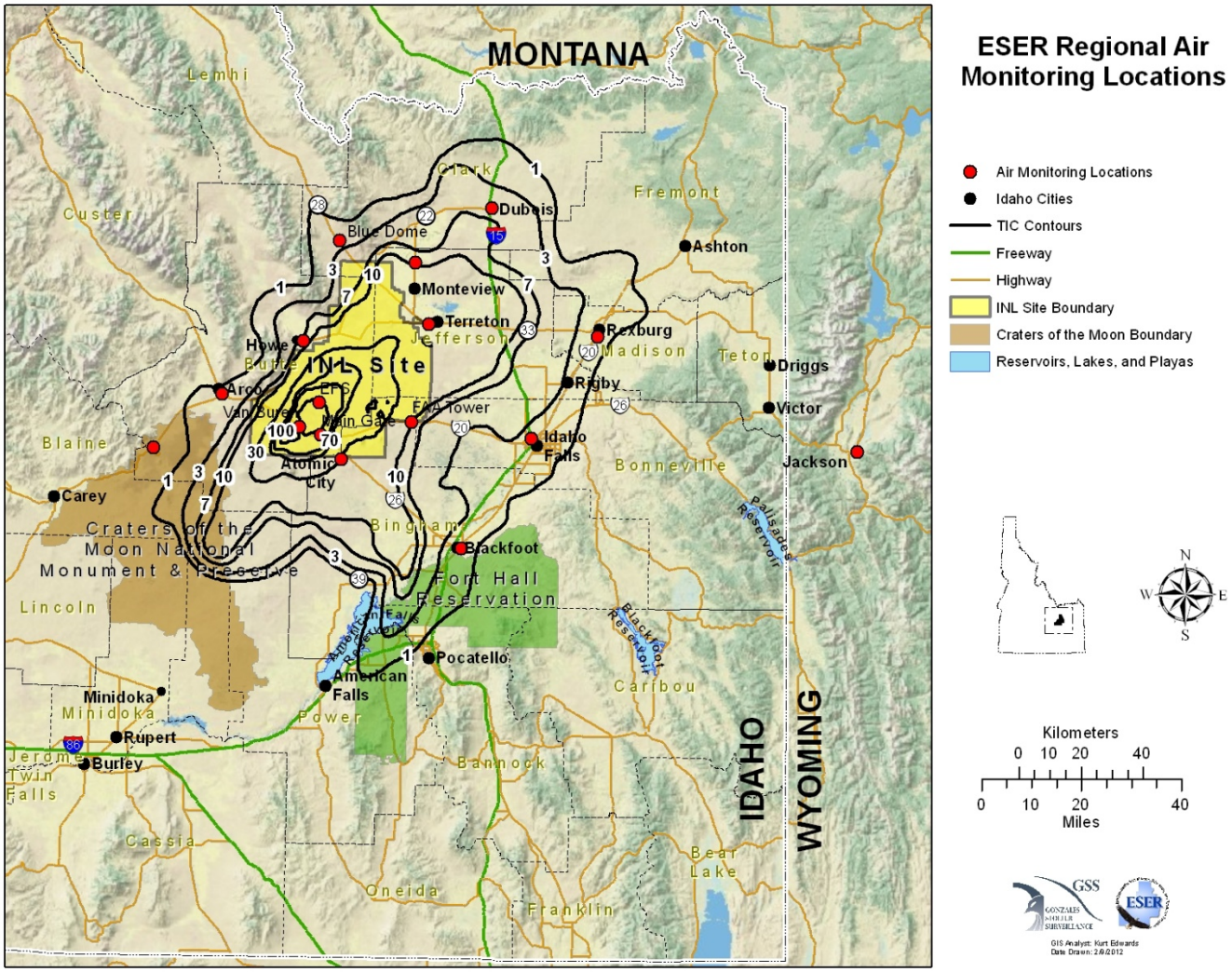


Figure 6-10. INL Site time-integrated concentrations (10^{-9}hr^2/m^3) projected by MDIFF for the year 2010. Current regional air monitoring locations are also shown on the map.

Table 6-2. Estimated time integrated concentrations at which average annual Cs-137 release from INL Site facilities can be detected by low-volume air samplers.

Sampling rate (cfm)	Sample Volume[a] (m3)	Cs-137 release rate (Ci/hr)[b]	MDA[c] (Ci/sample)	TIC_D[d] (hr/m^3)	Annual TIC_D (hr^2/m^3)[e]
2	7421	5.7E–05	3.7E–13	8.7E–13	7.6E–9
2.5	9277	5.7E–05	3.7E–13	7.0E–13	6.1E–9
3	11132	5.7E–05	3.7E–13	5.8E–13	5.1E–9

a. Volume collected by sampler per 13-week quarter.

b. Based on an average (2006-2010) annual release rate of 0.5 Ci Cs–137 per year.

c. MDA = minimum detectable activity of detector (average of six detectors)

d. TIC_D = Time Integrated Concentration at which Cs–137 is detectable by low-volume air samplers.

e. Annualized TIC_D estimated by multiplying by the number of hours in one year (8760).

Table 6-3. Time Integrated Concentrations (TICs) at current and proposed air sampling stations.

Station	MDIFF-Generated Time Integrated Concentration (hr^2m^{-3} x 10^{-9})						MDIFF TIC greater than detectable TIC estimated for INL Site ^{137}Cs release?		
	2006	2007	2008	2009	2010	5-year average	>7.59 E–9[a]?	>6.07E–9[b]?	>5.06E–9[c]?
Arco	6.95E–10	1.18E–09	6.51E–10	6.99E–10	2.26E–09	1.1E–09	No	No	No
Atomic City	1.86E–08	1.92E–08	2.13E–08	2.73E–08	9.46E–08	3.62E–08	Yes	Yes	Yes
Blackfoot	9.79E–10	1.44E–09	1.48E–09	1.63E–09	5.47E–09	2.2E–09	No	No	No
Blue Dome	1.97E–09	2.03E–09	1.11E–09	1.75E–09	3.84E–09	2.14E–09	No	No	No
Craters of the Moon	2.51E–10	6.44E–10	2.45E–10	3.02E–10	6.51E–10	4.19E–10	No	No	No
Dubois	3.58E–09	4.66E–09	3.63E–09	3.74E–09	1.13E–08	5.38E–09	No	No	Yes
EFS	5.36E–08	1.38E–07	1.55E–07	1.1E–07	2.51E–07	1.42E–07	Yes	Yes	Yes
FAA Tower	7.49E–09	9.18E–09	1.02E–08	1E–08	3.69E–08	1.48E–08	Yes	Yes	Yes
Frenchman's Cabin[d]	3.1E–08	4.4E–08	3.54E–08	3.48E–08	3.99E–07	1.09E–07	Yes	Yes	Yes
Hamer	6.32E–09	7.69E–09	7.73E–09	4.76E–09	1.94E–08	9.17E–09	Yes	Yes	Yes
Idaho Falls	1.49E–09	3.44E–09	2.05E–09	1.65E–09	7.17E–09	3.16E–09	No	No	No
Jackson	Jackson is outside the MDIFF projection region (see Figure 6-5)						No	No	No
Main Gate	1.81E–07	8.62E–08	2.2E–07	3.19E–07	1.31E–06	4.23E–07	Yes	Yes	Yes
Monteview	7.37E–09	6.6E–09	6.53E–09	7.41E–09	2.13E–08	9.85E–09	Yes	Yes	Yes
Mud Lake	2.4E–08	2.49E–08	3E–08	2.27E–08	7.64E–08	3.56E–08	Yes	Yes	Yes
Rexburg	1.63E–09	1.96E–09	2.18E–09	1.26E–09	5.05E–09	2.42E–09	No	No	No
Roberts	4.47E–09	6.36E–09	7.9E–09	4.95E–09	1.79E–08	8.31E–09	Yes	Yes	Yes
Taber	9.21E–09	1.81E–08	1.37E–08	2.15E–08	1.42E–08	1.53E–08	Yes	Yes	Yes
Van Buren	1.17E–07	1.8E–07	1.34E–07	1.58E–07	4.67E–07	2.11E–07	Yes	Yes	Yes

a. Based on a release rate of 0.5 Ci Cs–137 per year and a volume of 7421 m^3 collected per quarter by an air sampler running at 2.0 cfm.

b. Based on a release rate of 0.5 Ci Cs–137 per year and a volume of 9277 m^3 collected per quarter by an air sampler running at 2.5 cfm.

c. Based on a release rate of 0.5 Ci Cs–137 per year and a volume of 11132 m^3 collected per quarter by an air sampler running at 3.0 cfm.

d. There is no sampling station at Frenchman's Cabin. The location is based on coordinates used for the annual NESHAP MEI calculations.

According to Figure 6-11, there are nine stations off the INL Site, current and proposed, which could be used to evaluate the impact of INL Site releases. They are (in ascending order of potential impact): Dubois, Howe, Roberts, Monteview, FAA Tower, Taber, Mud Lake, Atomic City, and Frenchman's Cabin. Dubois barely meets the first criterion for inclusion in the boundary group and should be placed in the distant sampler group. Frenchman's Cabin, which is not occupied year-round and does not represent a community, should nevertheless be considered for future inclusion in the boundary network because it is the location of the MEI calculated by NESHAP calculations. Unfortunately, Frenchman's Cabin does not have AC power available.

The three on-Site monitors maintained by the ESER contractor (Main Gate, EFS and Van Buren) have the highest TIC_Ds and have consistently fallen within the highest concentration contours predicted for the INL Site (Figure 6-10). These stations should be retained by the ESER environmental surveillance program for comparison with off-Site monitors for the purpose of helping to determine potential INL Site contributions of airborne contaminants to the off-Site environment.

Table 6-4 summarizes the final location design and basis for selection of the ESER environmental surveillance program sites. According to this table, there are eight distant locations (including Jackson), six boundary locations, and three INL Site locations. Two new boundary locations are recommended for investigation and possible inclusion in the boundary network.

6.6.2 Frequency of Sample Collection and Analysis

The sampling and analysis frequencies are in accordance with the criteria in DOE 1991, which suggests that samples be recovered on a fixed frequency, typically 1 to 2 weeks, but no greater than biweekly. It is determined in Section 6.6.3 of this document that the volume collected in one week is sufficient to detect gross beta activity. The air surveillance program is not limited by physical problems associated with retrieving samples from each location at this frequency. Therefore, weekly sample collection should continue.

DOE criteria provide the minimum sample collection and analysis requirements as a function of the EDE to the MEI. For an estimated EDE to the MEI <1 mrem, as is the case at the INL Site, it is recommended that, at a minimum, the program should consist of:

- Analysis of air particulate samples (collected weekly or biweekly) for total alpha and total beta activity
- Gamma spectroscopy of an annual air particulate composite.
- Gamma spectroscopy is completed on air samples composited quarterly, rather than annually, for earlier alerts if unusual releases occur. It has been determined that quarterly composited air samples are of sufficient volume that Cs–137 released from the INL Site in excess of normal levels could theoretically be detected the off-Site environs (see Section 6.6.1).
- Alpha spectroscopy, particle size determination, and analyses for noble gases, halogens (radioiodine), and tritium are not considered necessary at the dose level estimated for the INL Site (DOE 1991). However, the ESER environmental surveillance program performs radiochemical analyses of quarterly composited air filters for specific alpha emitters (Pu and Am–241) and specific beta emitters (Sr–90). This is because these radionuclides were ranked as one of the top contributors to dose calculated for compliance with NESHAPs (Table 3-5) and because they have been detected historically on air filters. Past detections are likely due to fallout from previous weapons testing, in the case of Sr–90, or re-suspension of soil previously contaminated by plutonium and Am–241.

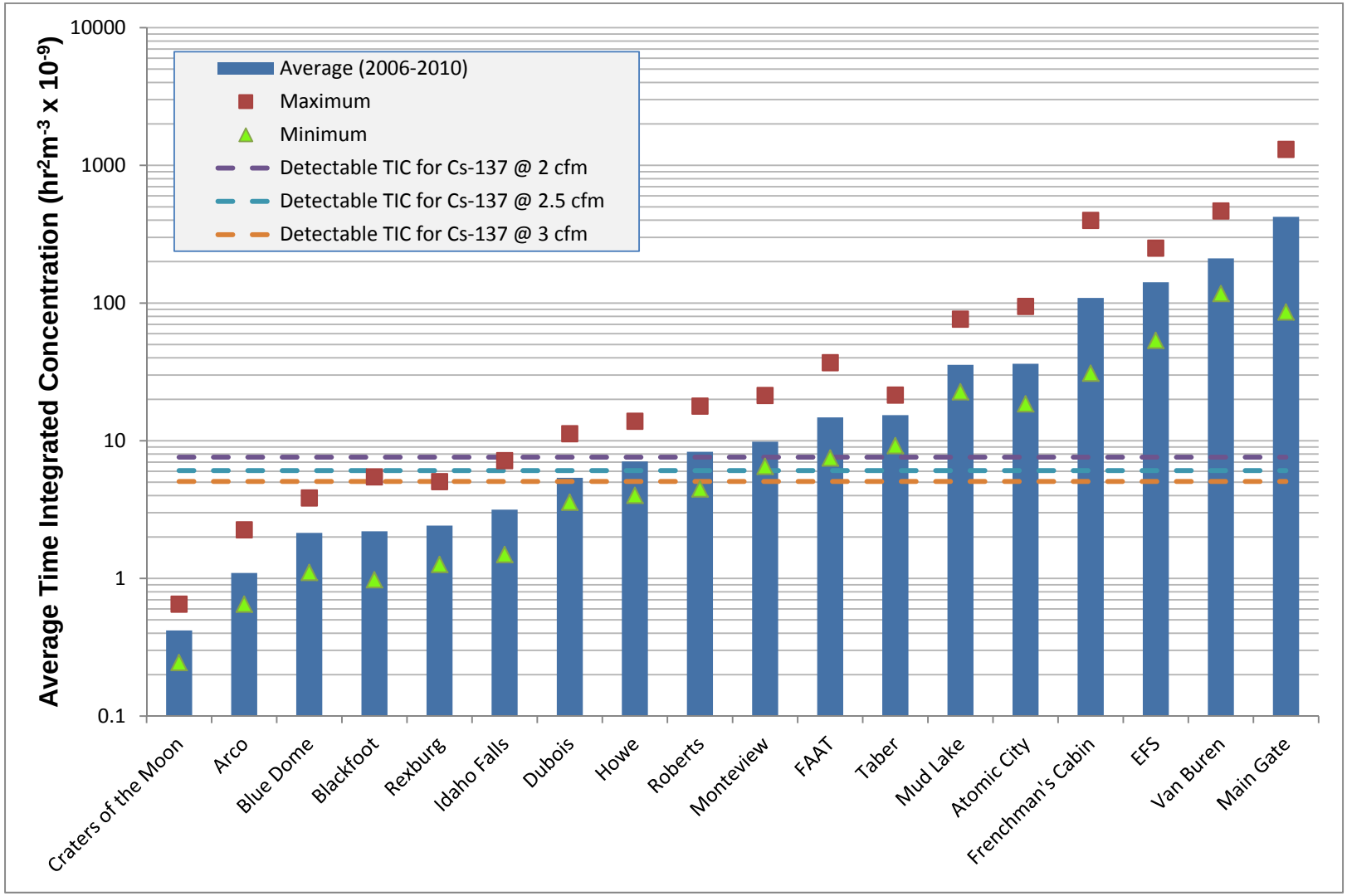


Figure 6-11. INL Site time-integrated concentrations (10^{-9}hr$^{2/}$m^{3}) projected by MDIFF at select locations during the years 2006–2010.

Table 6-4. Final ESER locations selected for the regional air-monitoring network.

Location	Surveillance Group	Proposed action	Comments
Arco	Distant	Retain	Below the detectable 5.1 E–09 TIC_D for Cs–137. West population center.
Atomic City	Boundary	Retain	Above 5.1 E–09 TIC_D for ^{137}Cs (potential INL Site influence). Only southern boundary population.
Blackfoot	Distant	Retain	Below the detectable 5.1 E–09 TIC_D for Cs–137. Southeast population center.
Blue Dome	Distant	Retain	Below the detectable 5.1 E–09 TIC_D for Cs–137. Only location north of INL Site.
Craters of the Moon	Distant	Retain	National Monument.
Dubois	Distant	Retain	Slightly above 5.1 E–09 TIC_D for Cs–137 Only distant population center located northeast of INL Site.
EFS	INL Site	Retain	Within highest modeled TICs on the INL Site.
FAAT	Boundary	Retain	Above 5.1 E–09 TIC_D for Cs–137 (potential INL Site influence). Southeast boundary location.
Frenchman's Cabin	Potential boundary	Investigate adding to boundary group	The location of MEI, however no power here. Investigate if possible to add the sampler to the network.
Howe	Boundary	Retain	Above 5.1 E–09 TIC_D for Cs–137 (potential INL Site influence).Only population center located on northwest boundary of INL Site.
Idaho Falls	Distant	Retain	Average TIC value below 5.1 E–09 TIC_D for Cs–137, but location of highest estimated population dose. Located SSE of INL Site. Collocated with EPA RadNet monitor.
Jackson	Distant (not control)	Retain	Stakeholder interest.
Main Gate	INL Site	Retain	Highest modeled TIC on the INL Site.
Monteview	Boundary	Retain	Above 5.1 E–09 TIC_D for Cs–137 (potential INL Site influence).
Mud Lake	Boundary	Retain	Above 5.1 E–09 TIC_D for Cs–137 (potential INL Site influence). Northeast of INL Site.
Rexburg	Distant	Retain	Below the detectable 5.1 E–09 TIC_D for Cs–137. Northeast population center.
Roberts	Boundary	Add	Above 5.1 E–09 TIC_D for Cs–137 (potential INL Site influence). In Hamer census division which accounts for 10% of estimated MDIFF population dose. Power available at NOAA Mesonet site.
Taber	Potential boundary	Investigate adding to boundary group	Above 5.1 E–09 TIC_D for Cs–137 (potential INL Site influence), but accounts for little of the calculated population dose. South of INL Site. Power available at NOAA Mesonet site. May not be readily accessible in winter.
Van Buren	INL Site	Retain	Within highest modeled TICs on the INL Site. Co-sampled with BEA for data comparison.

Both the BEA and ESER environmental surveillance components of the ambient air-monitoring program use charcoal cartridges to collect I–131 on a weekly basis. Radioiodine is monitored because of the potential for releases of radioiodine from the ATR or an unplanned release.

Weekly gross alpha and gross beta analyses are performed on the V-1200 particulate filters in gas flow proportional counters. Filter analysis is delayed for five days to allow for naturally occurring radon and thoron decay products to decay. Charcoal cartridges are screened using gamma spectroscopy within three days of collection to measure I–131 before it decays (the half-life is 8 days.) At the end of each quarter, the particulate filters from each location are composited. All composites are then analyzed for gamma-emitting radionuclides. Selected ESER sample composites are analyzed for Sr–90 or actinides (Pu–238, Pu–239/240, and Am–241) each quarter on a rotating basis. BEA screens for these radionuclides using gross alpha/beta activity and gamma analyses and requests additional analyses if results are anomalous.

6.6.3 Sample Collection and Handling Methods

According to DOE/EH-0173T, air particulate sampling for gross alpha, gross beta, and gamma spectroscopy is the minimum monitoring required if the annual effective dose equivalent (EDE) is <1 mrem to the MEI. Sample collection for radioiodine is recommended if the EDE is >1 mrem and <5 mrem to the MEI. Although estimated dose contributions to the MEI are much smaller than this range, radioiodine is sampled because it is a good indicator of a nuclear event, such as a potential unplanned INL Site release or the reactor accident at Fukushima. Low-volume samplers are used because of their durability and reliability and their capability of pulling the air volume needed for monitoring radioactive materials potential released by INL Site operations (see the discussion about sample volume and MDA in Section 6.6.1).

Low-volume air samples are typically used throughout the DOE system for regional air monitoring. The INL contractor performs air monitoring using microprocessor-controlled low-volume air samplers consisting of oil-less carbon-vane vacuum pumps and constant air-flow regulators that pull air through a combination head that holds a 2–in. paper filter and a charcoal cartridge. Each sample inlet is positioned in the breathing zone for adults in accordance with the recommendations in DOE 1991. Using a flow rate of approximately 2 cfm, the INL contractor collects the particulate air filters (for gross alpha/beta analysis) and charcoal cartridge (for I–131 analysis) samples weekly from the air-surveillance network (see Figure 6-2). In addition to the weekly analysis for gross alpha and beta emitters, the particulate filters are composited quarterly by location and analyzed using gamma spectrometric analysis. Again, each of these analyses and their frequency meet the requirements in Table 5-2 of DOE 1991, which describes the minimum air sample collection frequencies and analysis types as a function of the EDE to the MEI. The weekly collection schedule takes into account the limitations of the samplers (e.g., dust loading) and the physical problem of retrieving samples from each location in the wide-spread network. The weekly collection schedule meets the frequency range in DOE 1991 of one to two weeks and is comparable to other DOE sites collection schedules, as described in Bauman (1999).

The regional component of the ambient-monitoring program low-volume air samplers consists of a dual membrane filter and cartridge holder, a vacuum gauge, a Gast rotary vacuum pump, and either Hi-Q Model D-AFC-3 digital flow meters or microprocessor-controlled data loggers. These samplers can maintain an air flow up to 4 cfm (113 liters per minute) through a set of two filters: a non-woven, nylon-backed polyvinyl acrylonitrile support membrane prefilter (e.g., Gelman Versapor-1200) followed by an activated-charcoal cartridge (SAIC/RADeco BG-300). The membrane prefilter has a pore size of 1.2 μm and an efficiency of greater than 99% for particles greater than 0.3 μm in diameter. This approximately encompasses the range (0.1–3 μm) of the optimum size of particles for deposition in the upper respiratory system and meets the efficiency criteria in DOE/EH-0173T. The filter also retains a high percentage of smaller particles, which can be inhaled. The BG-300 cartridge has more than 99% collection efficiency for methyl iodide at pump flow rates of 1 cfm, about 96% collection efficiency at 2 cfm, and about 92%

collection efficiency at 3 cfm (http://www.radecoinc.com/index.php?option=com_content&view=article&id=23&Itemid=47). It drops to about 85% collection efficiency at 4 cfm. The sample flow rate is limited to ≤3 cfm because of the relatively steep drop in efficiency above this rate (Figure 6-12).

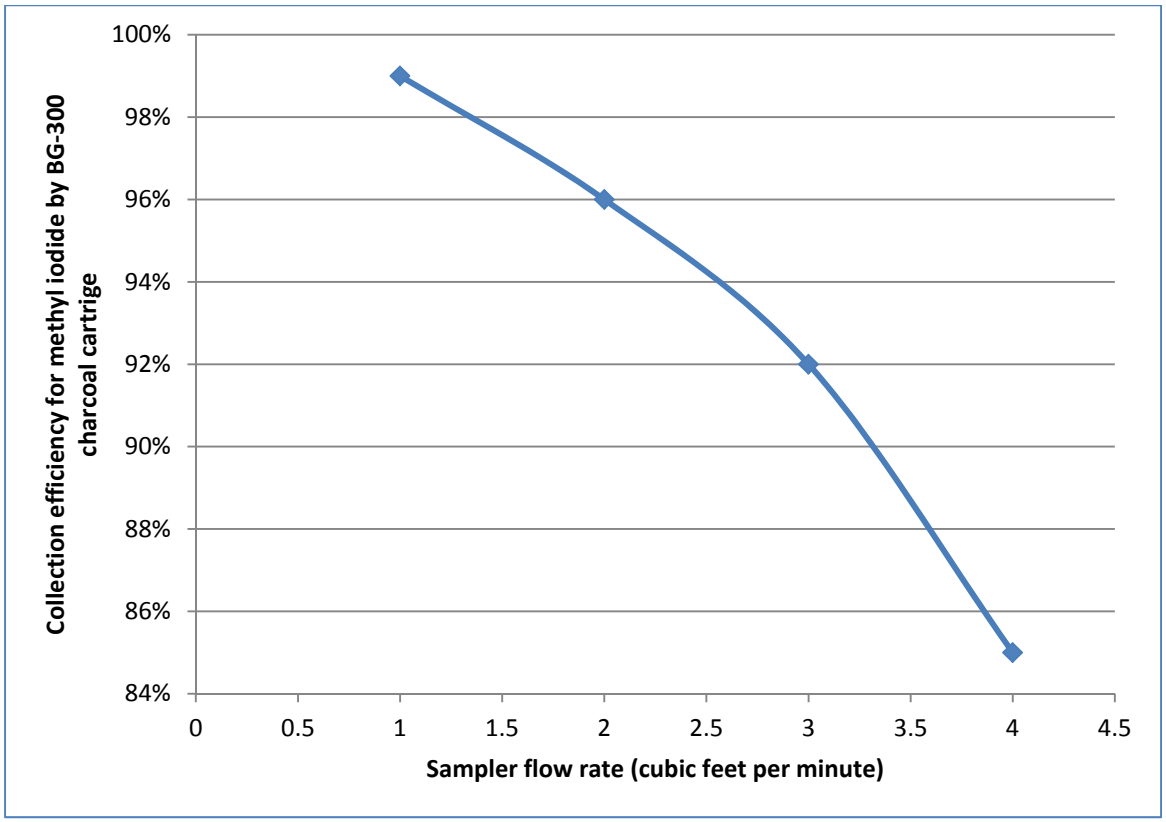


Figure 6-12. Collection efficiency of charcoal cartridges as a function of air sampler flow rate.

Gross beta activity is detected in virtually all membrane filters collected. This is because the median background concentration is easily detected by proportional counters. The median background measured in the vicinity of the INL Site is approximately 2.5E–14 µCi/mL, which is approximately 1.6E-05 µCi, assuming a week's collection at a rate of 2 cfm. The laboratory MDA is 4.28E–7 µCi per filter, which is easily achieved by all air flow rates on a weekly basis. The median activities per filter are 1.43E–5 µCi, 1.78E–5 µCi, and 2.14E–5 µCi at 2, 2.5, and 3 cfm, respectively. The detectable gross beta activity is thus not limited by the flow rate used. However, the counting statistics for gross beta activity are improved by increasing the flow rate and, thus, volume of air collected. Using methods outlined in Boothe et al. (2008), the theoretical 96% standard deviation (SD) associated with counting beta activity collected on filters at various flow rates is plotted in Figure 6-13. The %SD increases with increasing flow rate but almost levels off at around 3 cfm.

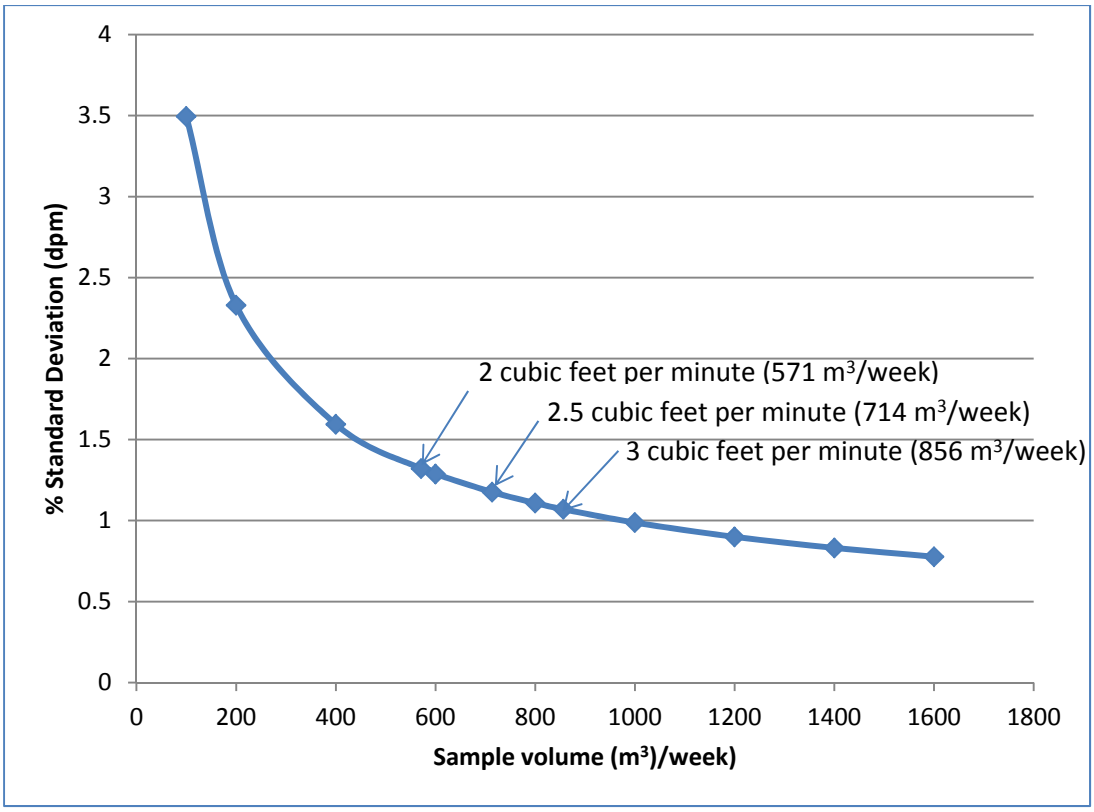


Figure 6-13. Percent theoretical standard deviation for gross beta counting versus sample volume.

6.7 Analytical Methods

The DOE Environmental Measurements Laboratory (EML) Procedures Manual, HASL-300, has served as a significant resource for development of laboratory procedures (http://www.orau.org/ptp/PTP%20Library/library/DOE/eml/hasl300/HASL300TOC.htm). Analytical methods have been further refined by the individual laboratories contracted by the program to meet required detection limits.

The INL contractor uses the dose limit established in the NESHAP, Subpart H, to derive the radiological air-surveillance target-analyte list and the required detection limits (RDLs). Table 6-5 lists all target analytes of interest as well as the RDLs.

Table 6-5. Detection limits for the INL contractor—air pathways[a].

Radionuclide	Ci/nanorem	CAP88 Air Path[b] (µCi/ml per mrem)	RDL[c] (µCi/ml)
Ag–110m	7.19E–05	8.69E–14	8.69E–15
Am–241	1.77E–07	2.14E–16	2.14E–17
Be–7	1.83E–02	2.22E–11	2.22E–13
Ce–141	3.62E–03	4.36E–12	4.36E–13
Ce–144	1.82E–04	2.20E–13	2.20E–14
Co–58	6.02E–04	7.27E–13	7.27E–14
Co–60	1.46E–05	1.77E–14	1.77E–15
Cr–51	3.89E–02	4.70E–11	4.70E–12
Cs–134	2.67E–05	3.23E–14	3.23E–15

Table 6-5. (continued).

Radionuclide	Ci/nanorem	CAP88 Air Path[b] (µCi/ml per mrem)	RDL[c] (µCi/ml)
Cs–137	1.44E–05	1.74E–14	1.74E–15
Eu–152	1.53E–05	1.84E–14	1.84E–15
Eu–154	1.90E–05	2.29E–14	2.29E–15
Eu–155	4.31E–04	5.20E–13	5.20E–14
Fe–59	6.71E–04	8.10E–13	8.10E–14
H–3	6.85E–02	1.34E–10	1.34E–11
Hf–181	1.29E–03	1.56E–12	1.56E–13
Hg–203	6.85E–04	8.27E–13	8.27E–14
I–131b	1.25E–03	6.74E–14	6.74E–15
Mn–54	2.30E–04	2.78E–13	2.78E–14
Na–22	2.58E–05	3.11E–14	3.11E–15
Nb–94	3.38E–06	4.08E–15	4.08E–16
Nb–95	6.37E–04	7.69E–13	7.69E–14
Pu–238	2.93E–07	3.54E–16	3.54E–17
Pu–239/240	2.72E–07	3.28E–16	3.28E–17
Ru–103	1.76E–03	2.12E–12	2.12E–13
Ru/Rh–106	1.20E–04	1.45E–13	1.45E–14
Sb–124	3.91E–04	4.72E–13	4.72E–14
Sb–125	1.43E–04	1.72E–13	1.72E–14
Sc–46	2.79E–04	3.36E–13	3.36E–14
Sr–90	2.12E–05	2.56E–14	2.56E–15
Ta–182	1.71E–05	2.07E–14	2.07E–15
U–234	7.25E–07	8.75E–16	8.75E–17
U–235	7.63E–07	9.22E–16	9.22E–17
U–238	8.09E–07	9.77E–16	9.77E–17
Zn–65	7.46E–05	9.01E–14	9.01E–15
Zr–95	8.40E–04	1.01E–12	1.01E–13

a. Based on NESHAP report screening spreadsheets.
b. Ci release from ground level at INTEC (each nuclide) that would result in 1 nanorem (1E–6 mrem) dose to MEI at Frenchman's cabin.
c. Required detection limit (RDL) to be met by the analytical laboratory.

The detection limits selected by the off-Site environmental surveillance program are based on those suggested by the DOE Oak Ridge Institute for Science and Education (ORISE) (http://orise.orau.gov/environmental-assessments-health-physics/capabilities/radiochemical-analyses.aspx) for the off-Site environmental surveillance program. The MDAs, shown in Table 6-6, are below the concentration measured in background samples.

Table 6-6. Detection limits for radionuclides in ESER quarterly composited air filters.

Approximate sample size	Radionuclide	MDA (pCi per sample)	MDC (µCi/ml)
13 filters	Am–241	0.029	4.6E-18
	Pu–238	0.022	3.49E-18
	Pu–239/240	0.022	3.49E-18
13 filters	Sr-90	0.215	3.41E-17
13 filters	Cs–137[a]	0.7	1.2E-16

a. Representative gamma emitter. Any measurable gamma-emitting radionuclide present in the sample may be detected.

6.8 Radionuclides Assessed

In the period 2006–2010, the airborne dose from INL Site operations was estimated by EPA air dispersion code CAP88- PC, to range from 0.039 to 0.131 mrem for the MEI at Frenchman's Cabin just off the INL Site. The top contributors (those isotopes contributing >95% of the total dose) to the dose are shown in Table 6-7. Those radionuclides routinely contributing, i.e. ≥3 years in the 5-year period, to 95% of the dose are recommended for routine analysis, with the exception of Ar–41, H–3, and I–129.

As discussed previously, Ar–41 is a noble gas and cannot be measured through particulate sampling. It is best measured as part of the external radiation exposure program. Tritium is collected in atmospheric moisture and precipitation and is discussed in Chapter 7.

6.9 Quality Assurance

The surveillance program employs an effective quality assurance (QA) program to ensure the collection of high quality data. The QA programs are detailed in their respective documents, for example the Offsite Environmental Surveillance Program Quality Assurance Project Plan (QAPjP) and the on-Site Environmental Support and Services Monitoring Services Surveillance Plan. These plans serve to ensure that all data collected are of known and defensible quality, and to meet the requirements of all applicable federal and state regulations and US DOE orders, specifically DOE Order 414.1A, ASMENQA-1-2000, EPA QA/R-5, ANSI/ASQC E-4, IDQTF UFP-QAPP and ISO 9000.

The analytical laboratories participate in the DOE Mixed Analyte Performance Evaluation Program (MAPEP), performance-evaluation tests, and some are audited by the DOE Consolidated Audit Program.

Measurements of precision and accuracy in the on-Site and regional air sampling programs are made through the use of duplicate air samplers, recounts of air filters, blanks, and blind spiked samples.

Table 6-7. Percent radionuclide contributions to total dose, estimated by CAP88-PC, for NESHAPS at the MEI location (Frenchman's Cabin) and recommended inclusion in air monitoring program. Recommended radionuclides are highlighted in blue.

Radionuclide	2006	2007	2008	2009	2010	Include in routine analysis?[a]	Comments
Am–241	2.8%	5.6%	1.85%	3.99%	27.02%	Yes	
Am243	—	—	—	—	2.59%	No	
Ar–41	—	3.2%	3.92%	8.29%	12.69%	No	Gas cannot be collected by a particulate filter.
Ba–137m	14.2%	—	—	—	—	No	Short-lived daughter of Cs–137.
C–14	2.8%	—	—	—	—	No	
Co–60	2.9%	—	—	—	—	No	
Cs–137	4.2%	22.0%	36.01%	6.60%	7.12%	Yes	Other gamma-emitting radionuclides may also be detected by gamma spectrometry.
Eu–152	8.0%	—	—	—	—	No	
Eu–154	3.7%	—	—	—	—	No	
H–3	24.2%	19.7%	17.05%	20.03%	25.06%	No	Collected in precipitation and air moisture.
I–129	12.8%	3.8%	2.02%	3.81%	3.69%	No	Long-lived radionuclide which accumulates and is more easily detected in soil.[b]
Pu–238	1.4%	—	—	0.87%	3.84%	Yes	
Pu–239	8.2%	19.9%	15.44%	34.54%	4.32%	Yes	
Pu–240	2.8%	3.6%	2.78%	8.13%	1.28%	Yes	
Pu–241	1.8%	—	—	—	—	No	
Sr–90	4.4%	18.7%	15.55%	6.05%	7.56%	Yes	
U–238	0.6%	—	—	—	—	No	
TOTAL	94.8%	96.5%	94.6%	94.9%	95.2%		

a. Not considered if does *not* routinely contribute to 95% of the dose (i.e., ≥ three times in five years) or for reasons presented in "Comments".

b. Iodine–129 cannot easily be measured on an air filter using low-energy gamma spectrometry due to the long half-life (15.7 million years) and small amount present. Mass spectrometry, an expensive method, is typically used on environmental samples. Because historical INL Site releases (~0.2 Ci, according to R.C. Morris, unpublished report), have been deposited in the INL Site environment, primarily in soil, it would be more appropriate to measure I–129 in soil.

6.10 Decision Limits and Actions

Per DOE Order 458.1, DOE radiological activities must be conducted so that exposure of members of the public to ionizing radiation will: not cause a total effective dose (TED) exceeding 100 mrem (1 mSv) in a year, an equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year, or an equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose. This does not include doses from radon and its decay products in air, doses received by patients from medical sources of radiation, dose from background radiation, and dose from occupational exposure.

Years of environmental monitoring on and around the INL Site show that DOE dose limits have never been exceeded or even approached. The surveillance program thus looks for instances when background or historical measurements are exceeded. The off-Site environmental surveillance program, for example, has developed action levels for the laboratory to use as criteria to notify ESER personnel if an unusual result is observed. The action levels were developed based on an assessment of the data from 2001 to 2011. The action levels developed for air samples are shown in Table 6-8, and are also used by BEA.

Table 6-8. Action levels for radionuclides measured in air.

Gross Alpha:	5E–15 µCi/ml
Gross Beta:	8E–14 µCi/ml
Cesium-137 and other gamma emitters (excluding naturally occurring beryllium-7 and lead-210):	>3σ[a]
Sr-90:	>3σ
Pu-238:	>3σ
Pu-239/40:	>3σ
Am-241:	>3σ
a. σ is the counting uncertainty reported with each result.	

If radionuclides detected are above background and exceed historical measurements (i.e., exceed action levels), the following actions are taken:

- Determine if the concentration is an anomalous measurement by comparison with historical data, meteorological conditions, other contractor data, communication with the analytical laboratory, and other actions.
- If verifiable, inform DOE-ID and determine if any further action is needed.

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7. PRECIPITATION AND ATMOSPHERIC MOISTURE

7.1 Program Basis

The amount of tritium present in the environment as a result of nuclear bomb testing in the early 1960s is decreasing, but anthropogenic sources such as the nuclear fuel cycle, fusion test experiments, and military and industrial use of tritium inject the isotope into the atmosphere (Uchrin et al. 1993). The present environmental tritium level is governed by three main sources: 1) naturally produced tritium; 2) tritium from nuclear explosions and nuclear facilities; and 3) consumer products (Uchrin et al. 1993).

Tritium has been measured in precipitation since the beginning of bomb tests in late 1952 (http://www-naweb.iaea.org/napc/ih/documents/userupdate/description/Precip1.html). Sampling precipitation for radioactive contaminants is one way to help public health officials ensure that food and water supplies are safe for the public. Contamination from nuclear incidents typically travels through the air in the form of particulates, although some contamination may be gaseous or become waterborne. Measuring precipitation provides a good way to determine the amount of contamination which is stripped from the air by rain or snow and deposited on the ground (EPA 2008).

The most common forms of tritium are tritium gas and tritiated water (ANL 2007). Therefore the monitoring programs at the INL Site sample atmospheric moisture to assess this isotope. The ESER environmental surveillance program also samples precipitation at three locations, two on the INL Site and one in Idaho Falls as a control. Other isotopes could be addressed as well in precipitation and atmospheric moisture samples. However, the INL on-Site monitoring and environmental surveillance programs effectively address the presence of other isotopes through the use of air, soil, and environmental radiation programs. These methods are effective for isotopes other than tritium because of their particulate nature. Tritium is primarily present in water, both liquid and vapor (ANL 2007), hence the basis for sampling this media for tritium.

7.2 Program Drivers

Monitoring for tritium in precipitation and atmospheric moisture fulfills:

- Requirements and criteria in Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE 1991)
- The need to protect the public and environment from INL Site radionuclides which could potentially reach and be transported beyond the INL Site boundaries
- The need to assess the movement (quantity and extent) of radionuclides produced by INL Site Operations (determining where and how much)
- The responsibility to address stakeholder and public concerns regarding media, locations, and parameters that should be monitored
- Requirements of DOE Order 458.1 (DOE 2011a).

Environmental surveillance uses these data to assess potential risk and to determine the nature and extent of the contamination leading to this risk.

7.3 Results of Related Studies/Surveillance

The earliest records on file for precipitation and atmospheric moisture sampling around the INL Site are in 1968 (AEC 1969) and the mid- 1970s (DOE 1991b), respectively. Tritium in snow, rain, and stream water was being evaluated as a research and development project (AEC 1969). Tritium in atmospheric moisture has been measured in Idaho Falls, the Experimental Field Station (EFS) and at Van Buren (on the INL Site) since 1976 (DOE-ID 1991). The development of the system was reported in the 1970 report (AEC 1971); some limited sampling may have been done before 1973.

The ESER environmental surveillance program has atmospheric moisture monitors located in Idaho Falls, Atomic City, Blackfoot and Rexburg to monitor for tritium in water vapor. The ESER environmental surveillance program also collects precipitation samples to measure tritium washed from air. One sampler is located in Idaho Falls as a control or background sampler, and two others are located at the Site, one at CFA and the other at the Experimental Field Station (Figure 7-1). The Idaho Falls station is operated as part of the EPA's RadNet Program, the results of which can be found at http://www.epa.gov/enviro/facts/radnet/index.html.

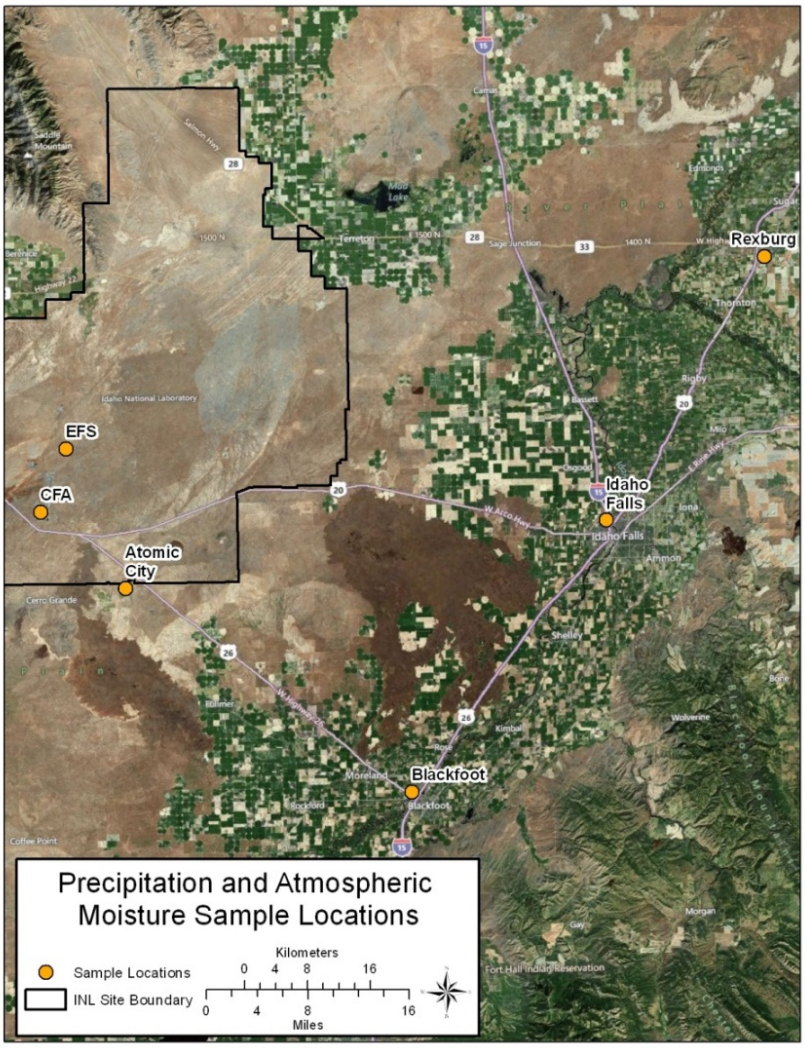

Figure 7-1. Current precipitation and atmospheric moisture sampling locations.

The on-Site program collects atmospheric water vapor in a molecular sieve material. The program collects the samples at the EFS and Van Buren Boulevard locations, which are in the predominant wind directions (northeast and southwest) from the most significant routine emissions (i.e., RWMC, INTEC, and ATR-Complex). The on-Site program has background tritium monitors at Craters of the Moon National Monument and in Idaho Falls. The sampling locations are collocated with air surveillance monitors at these locations.

The tritium monitors at all locations run continuously at 100–150 cc/min, and samples are collected when the molecular sieve is nearly expended and sent to a commercial laboratory for tritium analyses. Typical sample duration ranges are between four and six weeks, depending on absolute humidity. Based

on the INL Site's Effective Dose Equivalent (EDE) to the Maximally Exposed Individual (MEI) calculated from the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) (DOE-ID 2012), the monitoring and surveillance program collection of tritium samples meets the criteria in DOE/EH 0173T (DOE 1991).

7.4 Program Goals

The primary aim of precipitation and atmospheric sampling is to obtain data about the concentration of tritium in the environment in order to:

- Assessing impacts to public health and the environment
- Verifying that radiological doses related to the precipitation and atmospheric moisture exposure pathways are quantifiable and as low as reasonably achievable as required by DOE/EH-0173T (DOE 1991)
- Providing baseline data to quantify contaminant level changes due to fugitive or accidental releases of INL Site radiological materials.

The results of environmental surveillance will demonstrate if radionuclides have been transported off-Site and provide data to assess what the impacts are to human populations. The results require further assessment when they:

- Exceed background measurements
- Demonstrate an increasing trend over time
- Result in a dose to a member of the public which approaches regulatory limits (100 mrem/yr). This may be done with actual dose calculations based on tritium concentrations in the media or comparing those tritium concentrations to Derived Concentration Standards (DCS) (DOE 2011b).

The sampling the ESER environmental surveillance program conducts must evaluate the potential pathways of exposure to radionuclides in precipitation and atmospheric moisture by:

- Distinguishing these contaminants as background, fallout, or within historical levels
- Determining whether contaminants from the INL Site reach locations off-Site.

7.5 Sampling Boundaries

Sampling boundaries should be developed to provide adequate capability regionally to evaluate whether tritium levels present a potential hazard to the public and environment. The average mean detectable activity in tritium for precipitation and atmospheric moisture in environmental surveillance samples was 5.25 E–8 µCi/mL (ISU 2011).

The logistics of implementing the program objectives involves consideration of spatial and temporal limits, as well as consideration of practical constraints. The DOE regulatory guidance for environmental surveillance, as presented in DOE (1991), addresses the dose to an individual at the Site boundary and a 50-mile population. For this reason, the regional tritium precipitation and atmospheric moisture surveillance program focuses on the area within 50 miles of any site facility, particularly in areas that are in the predominant downwind direction of the INL Site (Figure 7-2). It considers long-term meteorology and receptor populations. Releases from the INL Site can occur at any time during the year. For this reason, precipitation and atmospheric-moisture sampling is conducted on a continual basis.

7.6 Sampling Design

BEA atmospheric moisture monitoring is conducted continuously at two INL Site locations. The monitors are located in the predominant wind directions from the ATR Complex, INTEC, and RWMC facilities, which release most of the airborne tritium at the INL Site. The BEA program background samplers are located at Craters of the Moon and in Idaho Falls. Monitoring is conducted in accordance with the criteria of DOE (1991). The ESER environmental surveillance program has atmospheric moisture monitors located in Idaho Falls, Atomic City, Blackfoot and Rexburg which (excluding Atomic City) are predominant population areas. The environmental surveillance program also collects precipitation samples to measure tritium washed from air at the INL Site. One sampler is located in Idaho Falls as a control or background sampler, and two others are located at the Site, one at Central Facilities Area (CFA) and the other at the Experimental Field Station (EFS) (Figure 7-1).

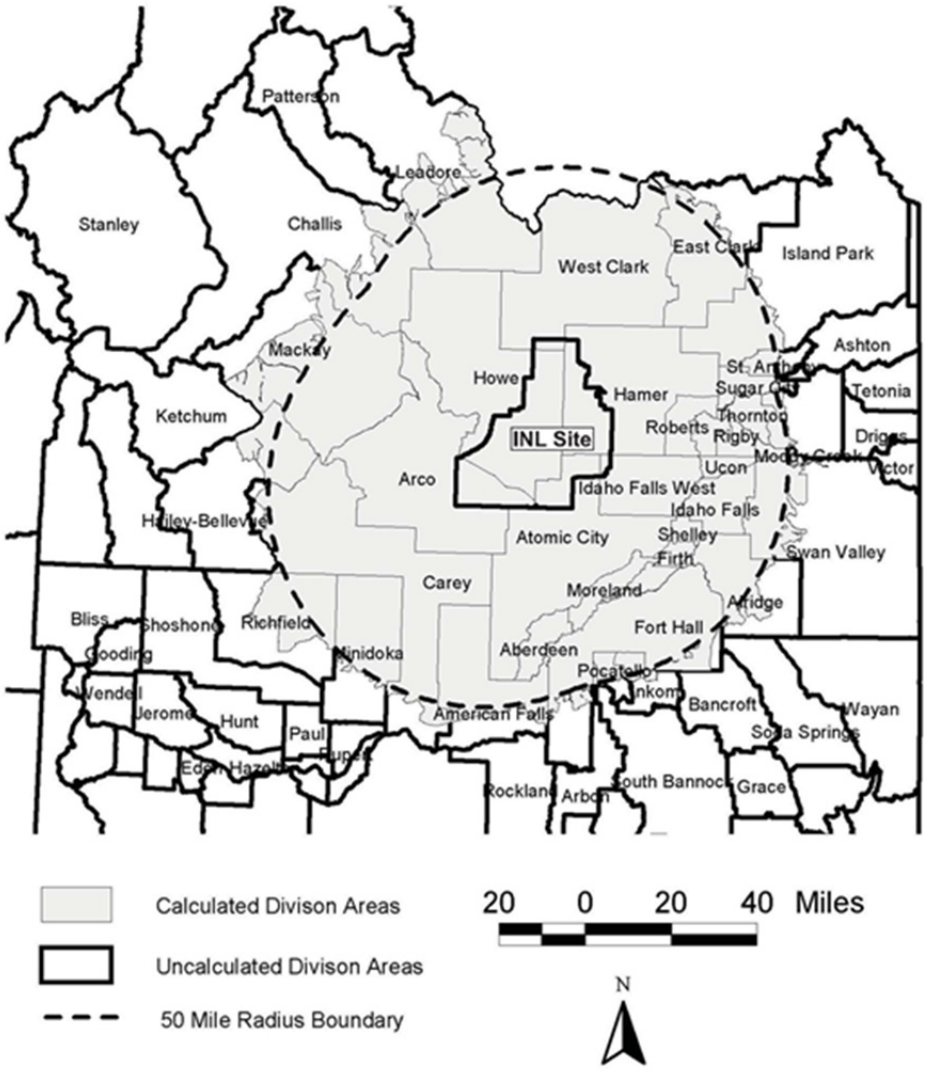

Figure 7-2. Region within 50 miles of INL Site facilities. Census divisions used in the 50-mile population dose calculation are shown.

7.6.1 Sampling Locations

As with air sampling, the environmental surveillance program evaluated atmospheric moisture using time-integrated concentrations projected by MDIFF for 2010 (DOE-ID 2011) (Figure 7-3). This illustrates that sampling atmospheric moisture and precipitation for tritium at Arco to the west (16.4 miles from RWMC), Atomic City to the southeast (12.2 miles from RWMC), Howe to the northwest (15.7 miles from TAN), and Mud Lake to the northeast (11 miles from TAN) may improve risk assessment of tritium over the current sampling locations at Idaho Falls, Blackfoot and Rexburg.

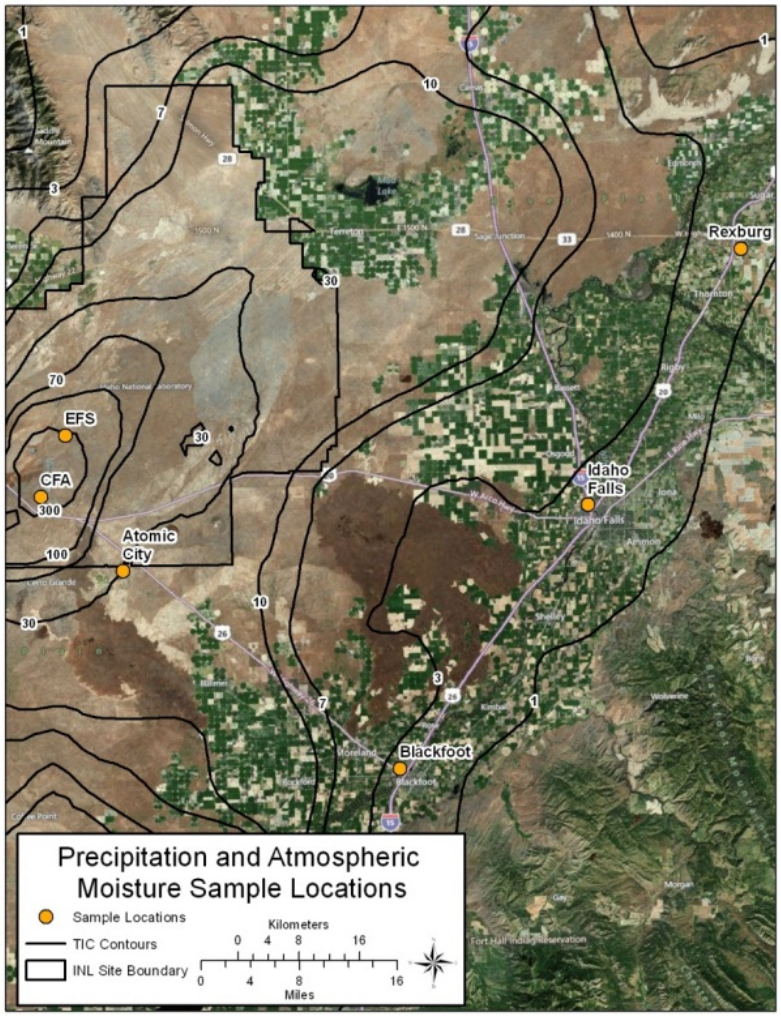

Figure 7-3. INL Site time-integrated concentrations ($hr^2m^{-3} \times 10^{-9}$) projected by MDIFF for the year 2010. Current precipitation and atmospheric moisture sampling locations are shown.

Using a X/Q value of 2E–6 s/m^3 at 1 km (0.62 mi.) times the released concentration, divided by the distance squared to a population center (NCRP 1979), the environmental surveillance program calculated the air concentrations of tritium at the closest communities discussed above. Based on the 2010 release rates from INL Site facilities closest to bordering communities (DOE-ID 2011), tritium air concentrations at Arco, Atomic City, Howe and Mud Lake would be 8.91E–14 µCi/ml, 1.61E–13 µCi/ml, 6.85E–18 µCi/ml and 1.37E–17 µCi/ml, respectively. Idaho Falls, Rexburg and Blackfoot (current locations except Atomic City) would be 7.23E-16 µCi/ml, 4.12E-15 µCi/ml, and 1.45E-14, respectively. These concentrations are below the minimum detected value of tritium, 2.7E–13 µCi/ml, reported from 2007–2011 (INL Annual Site Environmental Reports http://www.gsseser.com/publications.htm).

Sampling tritium at any off-Site location may not provide data that can be evaluated due to the relatively small predicted concentrations. However, Atomic City approaches the minimum detected value and could provide a detectable concentration for a larger release. The environmental surveillance program also collects precipitation samples to measure tritium washed from air. One sampler is located in Idaho Falls as a control or background sampler, and two others are located at the Site, one at CFA and the other at the Experimental Field Station (Figure 7-1). The Idaho Falls station is operated as part of the EPA's RadNet Program. Based on these analyses, the previously described monitoring locations fulfill the objective of environmental surveillance to determine whether unacceptable risk from tritium exists and to determine the nature and extent of the contamination leading to this risk.

The average ground-level air concentration of and associated doses from tritium released from a stack, which precipitation and atmospheric moisture samples measure, would be a factor of 20 lower 5 km (3.1 mi.) from the release point because the concentration decreases at a rate that is proportional to the inverse of the distance from the release point (NCRP 1979; SRS 1993). Tritium concentrations have decreased by over 50% over the last 10 years (DOE-ID 2011). Because of this and the fact that concentrations have been historically been below detection limits at off-site locations, indicates that sampling at all air monitoring stations may not be warranted. However, relocating tritium samplers to locations closer to release point, if feasible, is recommended.

7.6.2 Frequency of Collection

If concentration increases are detected at the source term by direct monitoring, then the ESER environmental surveillance program, using atmospheric moisture and precipitation, would only be able to detect those increases if they exceeded the minimum detected value (2.7E–7 µCi/ml). Due to the ubiquitous nature of tritium (Uchrin et al. 1993) and its rapid dissipation, sampling should be conducted constantly.

Sample duration ranges between four to six weeks, depending upon relative humidity and temperature. The sample columns are changed when the column is expended (as indicated by the color of the indicating molecular sieve, which changes from blue to a buff color when moisture is adsorbed).

7.6.3 Sampling Methods

Environmental tritium can be found in two forms: tritiated molecular hydrogen gas and tritiated water vapor. In terms of exposure potential, tritiated water vapor yields a dose equivalent approximately 25,000 times that of tritium gas for the same concentration (ISO 1975). Thus, air sampling techniques should employ methods that collect moisture from the air (DOE 1991). This is the basis for sampling both precipitation and atmospheric moisture for tritium. The current sampling methods meet this basis.

Precipitation samples are collected by the ESER environmental surveillance program at two locations on the INL Site: the CFA and the EFS. One location distant from the INL Site, Idaho Falls, is sampled to serve as a control or background sample. The EFS location is sampled weekly; the other two samples are collected monthly. The Idaho Falls station is operated as part of the Environmental Protection Agency's RadNet program. Materials and supplies for RadNet sampling may be obtained through the Environmental Protection Agency National Air and Radiation Environmental Laboratory (GSS 2011a).

The adsorbent used to collect the tritiated water vapor is a 4-Å molecular sieve. This molecular sieve was chosen for its ability to effectively adsorb water vapor at a relative humidity as low as 1% and its ability to retain moisture at elevated temperatures. An indicating agent that changes color with moisture saturation is included in the molecular sieve to aid the sampler in determining when the sample column is nearing saturation.

Atmospheric moisture is collected by the ESER environmental surveillance program on the INL Site boundary at Atomic City, and at the distant locations of Idaho Falls, Rexburg and Blackfoot in order to monitor for tritium in air. The samplers collected moisture from the atmosphere using a column of

molecular sieve material contained in the apparatus. Air passes through the columns at the rate of 0.65 ft^3/hr. Columns are changed when a sufficient quantity of moisture has been collected to obtain a 20-ml sample. Moisture content of the column is shown by the change of color of an indicator in the molecular sieve (blue beads turn a light bluish-gray in color). This collection frequency may range from two weeks during the summer periods to up to ten weeks during cold weather (GSS 2011b).

For the BEA program, an air sampler provides a constant airflow through the sample column with a flow range of 0.21–0.32 ft^3/hr. A digital data logger collects and stores sample information. The sample column is a 250-ml glass moisture trap enclosed in a polycarbonate cylinder for protection against breakage. Each cylinder holds approximately 180 g of sample media.

Although both the ESER environmental surveillance and BEA monitoring aspects effectively monitor tritium, it is recommended that a more consistent approach be developed including identical sampling media and air sampler flow rates to provide a consistent overall tritium monitoring program.

7.6.4 Analytical Methods

Tritium in water samples is measured using the standard method of counting the sample in a liquid scintillation counter (EPA 1987). The MDC is typically less than 100 pCi/L (or 1E–7 µCi/mL). Another method involves using an electrolytic enrichment method with a much lower MDC of 10 to 14 pCi/L. This is an expensive and time consuming process. Moreover, the standard method is sufficient to measure background concentrations measured historically in water samples collected.

7.7 Radionuclides Assessed

In the period 2006–2010, the airborne dose from INL Site operations was estimated by EPA air dispersion code CAP88-PC, to range from 0.039 to 0.131 mrem for the MEI at Frenchman's Cabin, just off the INL Site. The top contributors (those isotopes contributing >95% of the total dose) to the dose included tritium (see Chapters 4 and 6), contributing an average of about 24% of the total dose (Table 7-1). As discussed previously, measuring precipitation provides a feasible method to determine the amount of tritium which is stripped from the air by rain or snow and deposited on the ground (EPA 2008) while tritiated water vapor (or atmospheric moisture) yields a dose equivalent approximately 25,000 times that of tritium gas for the same concentration (ISO 1975).

Table 7-1. Percent tritium contributions to total dose, estimated by CAP88-PC, for NESHAPS at the MEI location (Frenchman's Cabin).

2006	2007	2008	2009	2010	Average
24.2%	19.7%	16.2%	32.2%	25.3%	23.5%

Tritium is a naturally occurring radioactive form of hydrogen that is produced in the atmosphere when cosmic rays collide with air molecules. Since tritium behaves like hydrogen chemically, it is usually found attached to molecules in place of hydrogen. For example, a water molecule may exchange one of its hydrogen atoms for a tritium atom, resulting in "tritiated water." Tritiated water is sometimes referred to as HTO to distinguish it from H_2O, ordinary water with two ordinary hydrogen atoms in each molecule. Tritium is found in very small or trace amounts in groundwater throughout the world. It is also a byproduct of the production of electricity by nuclear power plants. Tritium emits a weak form of radiation, a low-energy beta particle similar to an electron. Tritium radiation does not travel very far in air and cannot penetrate the skin. Tritium is the radionuclide historically assessed in precipitation and atmospheric moisture samples collected near the INL Site (DOE-ID 2011).

About 80–90% of tritium in the environment today was released in the 1950s and early 1960s by above-ground nuclear-weapons testing conducted by many countries (Okada and Momoshima 1993). Tritium is also used in a variety of consumer products, such as illuminated watches, thermostat dials, and airplane exit lights. Both the natural and man-made sources have contributed (and continue to contribute) to a world-wide background level of tritium.

The half-life of tritium is 12.3 years. This means that the concentration of tritium in the environment is reduced by one-half every 12 years, disregarding newly generated tritium.

The environmental behavior of tritiated water is like that of water, and it can be present in surface water, precipitation, and atmospheric moisture. Tritium enters the food chain through surface water that animals drink, as well as from plants (DOE-ID 2011). Tritium can be taken into the body by drinking water, eating food, or breathing air. It can also be taken in through the skin. Nearly all (up to 99%) inhaled HTO can be taken into the body from the lungs, and circulating blood then distributes it to all tissues. Ingested tritium oxide is also almost completely absorbed, moving quickly from the gastrointestinal tract to the bloodstream. Within minutes, it is found in varying concentrations in body fluids, organs, and other tissues. Skin absorption of airborne tritium oxide can also be a significant route of uptake, especially for exposure to high concentrations of tritiated water vapor, as could occur under conditions of high humidity during hot weather, because of the normal movement of water through the skin. For someone immersed in a cloud of airborne HTO, the uptake by absorption through the skin would be about half that associated with inhalation. No matter how it is taken into the body, tritium is uniformly distributed through all biological fluids within one to two hours. Tritium is eliminated from the body with a biological half-life of 10 days, the same as for water. During the time it is in the body, a small fraction of the tritium is incorporated into easily exchanged hydrogen sites in organic molecules (ANL 2007).

7.8 Quality Assurance

The ESER environmental surveillance program employs an effective quality assurance (QA) program to ensure the collection of high quality data. The QA programs are detailed in Environmental Surveillance Program Quality Assurance Project Plan (QAPjP). This plan serves to ensure that all data collected are of known and defensible quality, and to meet the requirements of all applicable federal and state regulations and United States Department of Energy (DOE) orders, specifically DOE Order 414.1A, ASMENQA-1-2000, EPA QA/R-5, ANSI/ASQC E-4, IDQTF UFP-QAPP and ISO 9000.

The analytical laboratory participates in the DOE Mixed Analyte Performance Evaluation Program (MAPEP) and performance evaluation tests.

7.9 Decision Limits and Actions

According to DOE Order 458.1 (DOE 2011a), DOE radiological activities must be conducted so that exposure of members of the public to ionizing radiation will not cause:

- A total effective dose (TED) exceeding 100 mrem (1 mSv) in a year
- An equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year
- An equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose excepting:
    - Dose from radon and its decay products in air. (Radon is regulated separately e.g., under Paragraphs 4.f. and 4.h.[1][d] in this Order and under 40 CFR 61, Subparts Q and T.)
    - Dose received by patients from medical sources of radiation, and by volunteers in medical research programs.

- Dose from background radiation.
- Dose from occupational exposure under NRC or Agreement State license or to general employees regulated under 10 CFR Part 835, and DOE O 458.1 2-11-2011.

The results of years of monitoring air moisture and precipitation show that DOE dose limits have never been exceeded or even approached. The surveillance program thus looks for instances when background or historical measurements are exceeded. The ESER environmental surveillance program, for example, has developed action levels for the laboratory to use as criteria to notify ESER personnel if an unusual result is observed. The action levels were developed based on an assessment of the last ten years of data (unpublished ESER assessment). The action level developed for atmospheric moisture samples is 4E-7 µCi/mL.

If radionuclides detected are above background and exceed historical levels, assessors will determine whether the concentration is an anomalous measurement by one of the following methods:

- Review of historical monitoring results at that location to see if the measurement is consistent with past monitoring results
- Consultation with other INL Site surveillance components and the Idaho Department of Environmental Quality INL Oversight Program
- Review to determine if this location is affected by recent activities or events
- Review of any other factors which may have contributed to the result.

If the concentration is verified, it may signal the need for further action dependent upon the concentration level and/or a trend showing elevated concentrations over a period of time.

7.10 References

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8. EXTERNAL ENVIRONMENTAL RADIATION

8.1 Program Basis

Environmental radiation should be monitored because it is one of the critical pathways of exposure for population groups living within the vicinity of DOE nuclear facilities (Denham 1979). It is also a more feasible approach to determining the impact of short-lived gases (such as Ar–41) rather than by sampling and analysis (DOE 1991). That is, any large increases in the release of Ar–41, or any other radionuclide for that matter, from INL Site facilities could be correlated with increases in exposure rates. Although historical measurements generally demonstrate that background levels and DOE regulatory limits are not exceeded in the environment around the INL Site, monitoring of direct radiation using environmental dosimeters is relatively easy and inexpensive. It is also useful for determining natural external radiation from terrestrial and cosmic sources.

BEA and GSS ESER personnel perform semi-annual external exposure monitoring (DOE-ID, 2010a) to meet the recommendations set forth in DOE/EH-0173T (DOE 1991). The BEA external exposure component emphasis is monitoring within the INL Site boundaries. The ESER external exposure component focuses on monitoring off the INL Site and along the INL Site boundary. In addition, off-Site monitoring is also performed by BEA at locations co-sampled with the ESER contractor and the INL Oversight Program (IOP). The BEA off-Site monitoring is performed to provide comparison and verification for the monitoring results of all INL Site external exposure monitoring programs (on-Site, off-Site, and IOP). The intended duplication of some of the monitoring provides cross-check and ascertains data reliability through independent results.

8.2 Program Drivers

External-exposure monitoring is performed on and around the INL Site to meet the following regulatory requirements and guidance for environmental surveillance of DOE facilities:

- DOE Order 458.1, “Radiation Protection of the Public and the Environment”
- DOE/EH-0173T (DOE 1991), “Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance”

Other key drivers include:

- Public perception regarding where and what to monitor
- Stakeholder inputs and values
- Potential environmental risks posed by contaminants originating from the INL Site.

8.3 Results of Related Studies/Surveillance

Background 24-hour readings of external exposure were first made in 1951 across the INL Site using small, detachable ionization chambers installed at the EBR Site, CFA, and the Meteorological Station at Midway (Singlevich et al. 1951). Natural background radiation levels prior to when nuclear operations began at the Site were on the order of 100–150 mrem per year (AEC 1966a).

Intermittent testing of film badges was started in 1959, and a continuous program started in 1960 (AEC 1960). The badges were placed at 118 locations along highways traversing the INL Site and at various agricultural areas in the surrounding perimeter. The badges were collected and read monthly. The average total dose for the year was less than 160 mrem for gamma radiation. As the sensitivity of the film reading techniques was 10–20 mrem per film and the results reflected all sources of radiation, it was not possible to define any contribution from site operations by this method.

In 1961, film badges were located around the perimeter of the INL Site at the same 14 locations as the air-sampling equipment. The sensitivity of the badges was 10 mrem for gamma or beta radiation. The

only indication of levels above background was noted in the first quarter of the year, most likely because of the SL–1 accident on January 3, 1961 (AEC 1961).

Off-site film badges were replaced by thermoluminescent dosimeters (TLDs) during the fourth quarter of 1966 (AEC 1966b). At each location, a dosimeter containing five individual Harshaw TLD-700 chips was placed 1 m above the ground. TLDs measure penetrating radiation (gamma plus beta radiation >200keV). TLDs were chosen as a better method of long-term low-dose accumulation. The TLDs were collected semi-annually at 12 off-Site locations. Aberdeen, Carey, Dietrich, Idaho Falls, and Minidoka were locations used to determine background radiation exposure. The off-Site locations near the INL Site were Arco, Atomic City, Howe, Reno Ranch, Monteview, Mud Lake, and Roberts. In subsequent years, natural background levels (100–150 mrem/yr) were not exceeded, which indicates no significant radiation added by INL Site operations.

The boundary and off-Site component of the TLD network has changed little over the years. The current locations, monitored by ESER, are shown in Figure 8-1. Results have continued to show that external exposure measured at perimeter locations does not differ significantly from that measured at distant communities. This indicates that the INL Site does not add to background radiation levels. Mean environmental radiation exposures measured for the years 2006–2010 by ESER and BEA are shown in Table 8-1.

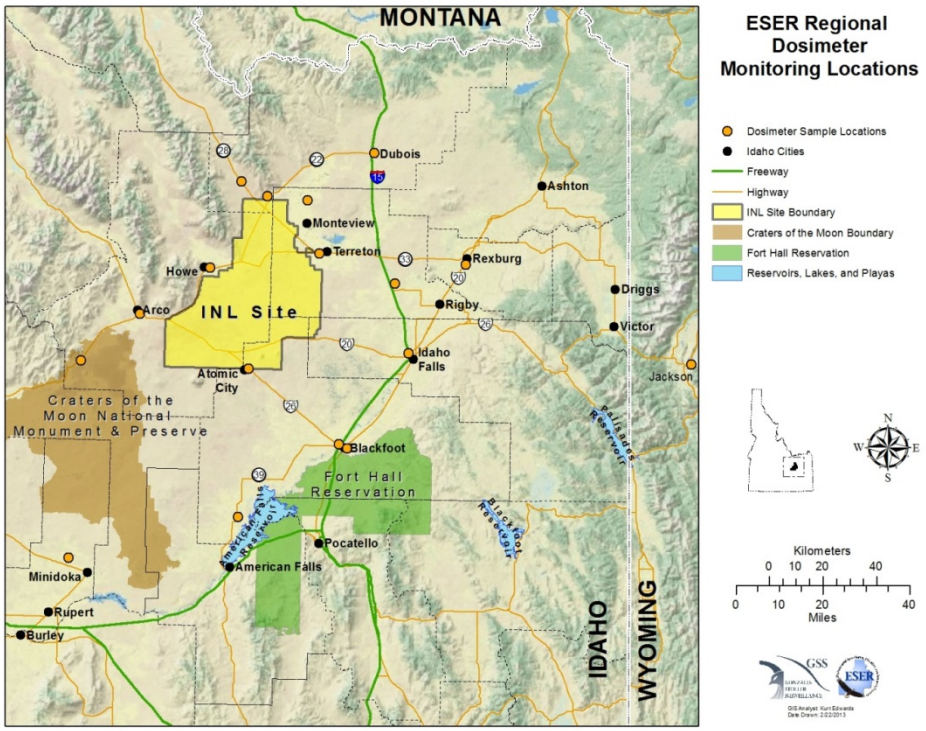

Figure 8-1. Current dosimeter locations around the INL Site (2012).

Table 8-1. Annual environmental radiation exposures in mrem (2006–2010).

Location	2006		2007		2008		2009		2010	
	ESER[a]	INL[b] Contractor	ESER	INL Contractor	ESER	INL Contractor	ESER	INL Contractor	ESER	INL Contractor
Distant Group										
Aberdeen	129 ± 6	127 ± 6	128 ± 9	132 ± 9	130 ± 6	128 ± 9	130 ± 6	128 ± 9	130 ± 6	133 ± 9
Blackfoot	109 ± 5	109 ± 5	110 ± 8	111 ± 8	110 ± 6	113 ± 8	110 ± 6	113 ± 8	113 ± 6	114 ± 8
Craters of the Moon	120 ± 6	129 ± 6	116 ± 8	117 ± 8	120 ± 5	125 ± 9	120 ± 5	125 ± 9	121 ± 5	135 ± 9
Dubois[c]	101 ± 5	N/A	100 ± 7	N/A	103 ± 5	NA	103 ± 5	NA	104 ± 5	NA
Idaho Falls	123 ± 2	119 ± 6	121 ± 8	117 ± 8	120 ± 6	121 ± 8	120 ± 6	121 ± 8	124 ± 6	121 ± 8
Jackson[c]	97 ± 5	N/A	102 ± 7	N/A	102 ± 5	NA	102 ± 5	NA	102 ± 5	NA
Minidoka	109 ± 5	111 ± 5	109 ± 8	112 ± 8	111 ± 5	111 ± 8	111 ± 5	111 ± 8	114 ± 6	119 ± 8
Rexburg	145 ± 7	120 ± 6	135 ± 9	116 ± 8	138 ± 7	118 ± 8	138 ± 7	118 ± 8	152 ± 7	128 ± 9
Roberts	137 ± 7	133 ± 7	129 ± 9	132 ± 9	130 ± 6	130 ± 9	130 ± 6	130 ± 9	--[d]	143 ± 10
Mean	119 ± 6	121 ± 6	117 ± 8	120 ± 8	119 ± 6	121 ± 8	119 ± 6	121 ± 8	120 ± 6	126 ± 9
Boundary Group										
Arco	115 ± 8	111 ± 8	127 ± 6	125 ± 6	119 ± 8	121 ± 8	121 ± 6	124 ± 9	128 ± 6	129 ± 9
Atomic City	119 ± 8	112 ± 8	129 ± 6	124 ± 6	126 ± 9	120 ± 8	122 ± 6	120 ± 8	127 ± 6	122 ± 8
Blue Dome[c]	101 ± 7	N/A	104 ± 5	N/A	106 ± 7	N/A	107 ± 5	NA	105 ± 5	NA
Howe	108 ± 8	105 ± 7	118 ± 6	120 ± 6	117 ± 8	116 ± 8	116 ± 6	117 ± 8	117 ± 6	119 ± 8
Monteview	110 ± 8	107 ± 7	115 ± 6	119 ± 6	115 ± 8	120 ± 8	116 ± 5	119 ± 8	119 ± 6	128 ± 9
Mud Lake	119 ± 8	120 ± 8	128 ± 6	132 ± 6	128 ± 9	129 ± 9	130 ± 6	135 ± 9	134 ± 7	138 ± 10
Birch Creek Hydro	104 ± 7	103 ± 7	111 ± 5	109 ± 5	110 ± 8	114 ± 8	112 ± 6	113 ± 8	--[e]	NA
Mean	111 ± 8	110 ± 8	119 ± 6	121 ± 6	117 ± 8	120 ± 8	118 ± 6	121 ± 8	122 ± 6	127 ± 9

a. ESER = Environmental, Surveillance, Education and Research
b. INL = Idaho National Laboratory
c. The INL contractor does not sample at this location.
d. Dosimeter was missing at one of the collection times.
f. Reader malfunctioned during measurement of dosimeter.

When the current on-Site monitoring group was established in 2006, BEA personnel collected the TLDs semi-annually at 137 on-Site and 13 off-Site locations. These TLD locations had been essentially the same for decades. In 2008, there were 51 on-Site locations. In 2011, two project-related monitoring locations were added at facilities in Idaho Falls. The first location was IF-627 near to the DOE-ID Radiological and Environmental Sciences Laboratory (RESL) and the second location was IF-675 adjacent to the Portable Isotopic Neutron Spectroscopy (PINS) facility. In 2012, three additional on-Site locations ("Hwy22 T28 O-1," "Hwy28 N2300 O-2," and "Hwy33 T17 O-3") were added in the northern portion of the INL Site to provide baseline monitoring for the Radiological Response Training Range (DOE-ID, 2010b) and the proposed Stand-Off Experiment Range (DOE-ID, 2011a). Also in 2012, three additional project-related locations were added around the perimeter of the IF-675 facility. These additions result in a current total of 54 on-Site and 18 off-Site locations. The current BEA monitoring locations are shown in Figures 8-5 through 8-15.

Beginning in 2010, BEA personnel began to test use of the Optically Stimulated Luminescence dosimeter (OSLD) manufactured by Landauer, Inc., and began exclusively using OSLDs for the on-Site monitoring program in October 2013. The OSLD also measures ambient ionizing radiation. OSLDs and TLDs are similar in that both dosimeters respond to the absorption of energy from ionizing radiation by trapping electrons that are excited to a higher energy band. However, unlike TLDs, in which these electrons are released by the exposure to heat, the trapped electrons in the OSLD are released by exposure to green light from a laser. The primary advantages of the OSLD are:

- Minimal dose detection: 5 mrem for InLight OSLD, compared to 10 mrem for TLD
- A faster processing time
- Not dependent on normal variation of temperature and humidity
- Empties only a small fraction of trapped electrons, so it can be reread. TLDs cannot be reanalyzed
- A high degree of environmental stability (It does not suffer from significant fading with various conditions).

Beginning in 2011, following the on-Site monitoring component protocol, the off-Site environmental surveillance program began to test OSLD technology to replace the TLDs for off-Site monitoring. OSLD technology has never been tested simultaneously in the field and laboratory for environmental radiation surveillance application.

OSLDs and TLDs have been co-deployed at 16 locations on the INL Site perimeter and at more distant locations for two six-month periods (November 2011–May 2012 and June 2012–October 2012). The data from the OSL and TL dosimeters were compared prior to converting the off-Site environmental surveillance program ionizing-radiation-exposure program exclusively to OSLDs in October 2012. A laboratory validation study of OSLDs and the field study of differences between TLDs and OSLDs were conducted by Idaho State University researchers and were documented in Appendix B of the 2012 ASER (DOE-ID 2013). Also, it was concluded by these researchers that the OSLD performance exceeded laboratory test criteria and that OSLD and TLD field measurements were highly correlated, although slightly different due to the difference in technologies. It was concluded that OSLDs can be used for environmental measurements. Field results will also be compared with the BEA data and evaluated in the 2013 ASER.

The PINS facility (IF-675) utilizes 14 MeV Deuterium-Tritium (D-T) neutron generators, 2.5 MeV Deuterium-Deuterium (D-D) neutron generators, and Cf–252 neutron sources. A modeling study of the dose profile (Chichester et al. 2009) indicated a maximum dose of 8.4E–2 mrem/hr at the IF-675 facility fence during operation. INL Radiation Control used neutron dosimeters to monitor neutron doses quarterly at three locations around the perimeter of IF-675 from 2007 to 2011. The highest quarterly measured neutron dose was 42 mrem in the first quarter of 2009 (Schrader 2012), although the 2009

neutron readings are thought to be in error because inconsistencies were found in measured neutron doses with the operating time of the neutron generator and because personnel dosimetry of facility workers showed no neutron exposure. Other than the 2009 quarterly measurements, the next highest quarterly showed no neutron exposure. Other than the 2009 quarterly measurements, the next highest quarterly measurement was 13 mrem. A hypothetical scenario using the neutron dose measurements from 2009 in a scenario involving a member of the public who was intermittently present at the fence resulted in an annual MEI dose to the public of 6 mrem.

Neutron dosimetry has been conducted at the PINS facility (IF-675) by BEA beginning in November of 2011 using a neutron area block dosimeter on the eastern facility fence. This dosimeter was in place until November 2012. Unfortunately, the corresponding control dosimeter was not maintained for the same period of time, precluding a usable measurement. In 2013 BEA switched to Landauer Neutrak (CR-39) fast/intermediate/thermal neutron dosimeters. The selected Neutrak dosimeter has a dose-measurement range that begins at 10 mrem. These Neutrak dosimeters were placed at three locations around the IF-675 facility fence and will be read in November 2013.

8.4 Program Goals

The primary purpose of the INL Site external radiation monitoring program is to determine the status of the DOE's compliance with applicable environmental quality standards and to protect the public and environment. This requires not only external radiation monitoring around specific facilities, but also on the INL Site boundary and distant locations up to 50 miles to assess movement of radioactive contaminants off the INL Site.

Specific on-Site external-radiation-monitoring program objectives and their drivers include:

- Assess the actual or potential radiation dose to persons in the site environs (DOE 1991, Section 5.4)
- Make on-Site radiation measurements to include the location of predicted maximum air concentration(s) as well as other locations needed to help interpret the off-Site results (DOE 1991, Section 5.5.3)
- Factors in selecting indicator locations based on expected sources of external radiation including (DOE 1991, Section 5.5.1):
  - Monitor for noble gas plumes
  - Monitor soil-deposited atmospheric particulars released from the site facilities
  - Monitor direct radiation from on-Site radiation-generating facilities or large radiation sources
  - Monitor along potential routes of waste transport from the site
  - Monitor impacts to the local population distribution
  - Monitor in the prevailing wind directions
- Factors to avoid in selecting indicator locations including (DOE 1991, Section 5.5):
  - Differing geology
  - Locations where the proximity of structures could alter measurement results
  - Valleys or hollows (where precipitation or runoff could accumulate or where topography could shield dosimeters from the possible passage of airborne effluents)
- Locate control or background measurement locations at a minimum distance of 15–20 km from the larger (radiation) sites (on-Site facilities) and in areas of typical geology, away from buildings, and at similar elevations (DOE 1991, Section 5.5.2)
- Provide baseline monitoring for two years in advance of new nuclear facilities (NRC 1999)

- Provide confirmation of off-Site monitoring results (this is a programmatic goal, with no specific driver).

Specific program objectives for boundary and off-Site external radiation monitoring include:

- Measure background environmental radiation;
- Measure environmental radiation at locations which could be impacted by routine INL Site operations
- Determine INL Site contributions to environmental radiation
- Detect and report trends in measured environmental radiation
- Compare measured values to reference doses in DOE (2011)
- Determine environmental alert levels and any potential radiological doses exceeding the reporting limit Prepare a comprehensive analysis of surveillance results and dose calculations for reporting to the public in the annual site environmental report or letter reports.

8.5 Sampling Boundaries

The logistics of implementing the program objectives involve consideration of spatial and temporal limits, as well as consideration of practical constraints. The DOE regulatory guidance for environmental surveillance, as presented in DOE (1991), addresses the dose to an individual through external-exposure monitoring at both on-Site and off-Site locations.

Onsite monitoring is required to meet the program goals outlined previously. Offsite monitoring is required to evaluate the dose to an individual at the Site boundary and a 50-mile population. For this reason, the regional external-radiation-surveillance program focuses on the area within 50 miles of any site facility (Figure 8-2), particularly in areas that are downwind of the INL Site. The monitoring program considers long-term meteorology and receptor populations.

8.6 Sampling Design

8.6.1 Locations

Information needed for determining monitoring locations includes time-predicted air concentrations and wind directions. The predicted time-integrated air concentrations (DOE-ID 2011b) are shown in Figure 8-3. The location with the maximum simulated concentration is on-Site and in the vicinity of the southern INL Site facilities. A wind rose (Figure 8-4) demonstrates the two predominant downwind directions at the INL Site.

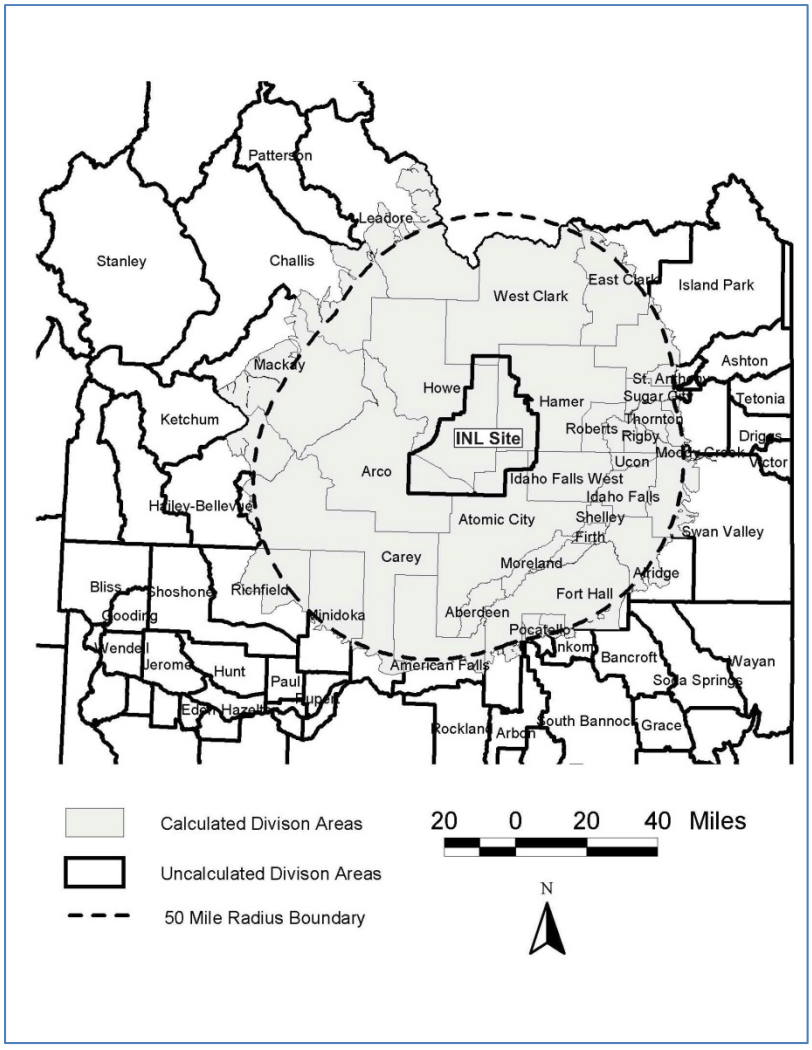

Figure 8-2. Region within 50 miles of INL Site facilities. Census divisions used in the 50-mile population dose calculation are shown.

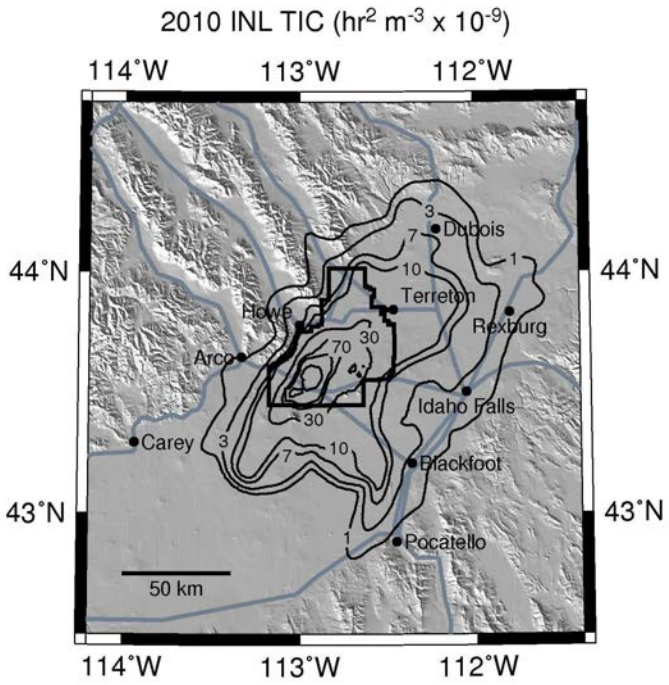

Figure 8-3. Mesoscale dispersion isopleths of time-integrated air concentrations normalized to a unit release rate for calendar year 2010. Units are $10^{-9}hr^2/m^3$ (DOE 2011b).

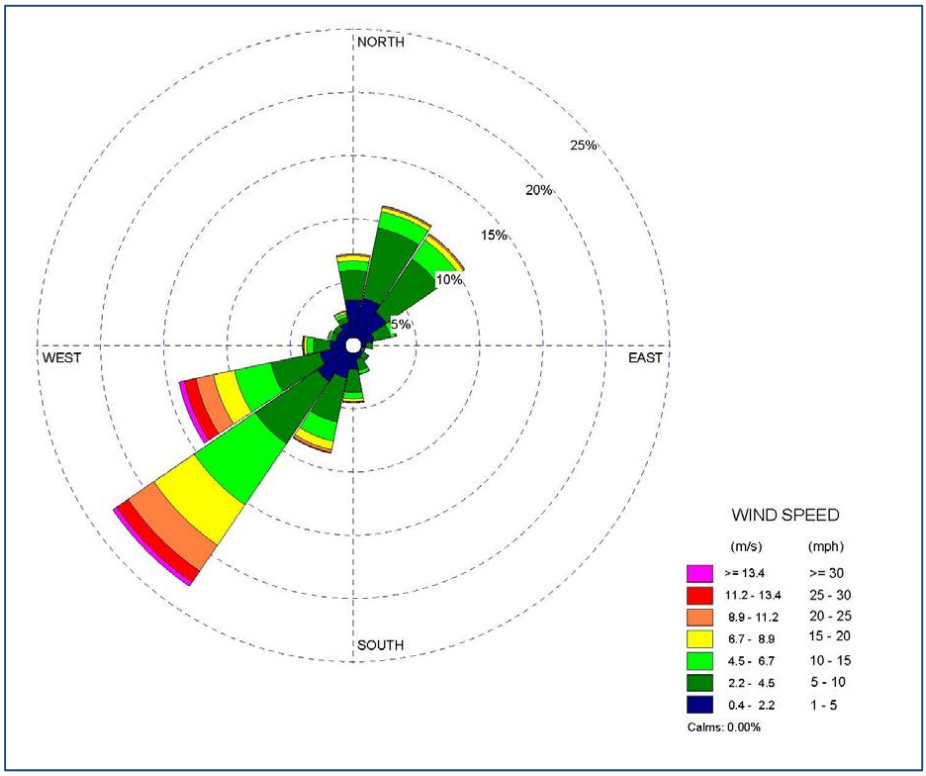

Figure 8-4. INTEC (Grid 3) 10-m level wind rose, January 2000 through December 2004.

The BEA on-Site program TLD monitoring locations currently in use were placed at facility perimeters, near radioactive-materials storage areas, and along roads (see Figures 8-5 through 8-18). These current monitoring locations meet the DOE (1991) monitoring guidance for the following general reasons:

- From Section 3.1.1, the primary facilities that have atmospheric releases are the ATR Complex, INTEC, and RWMC with lesser releases from the other facilities. Although the predominant wind directions are from the NE and SW, the wind can and does blow from all compass points (see Figure 8-4). Therefore, surrounding the facility perimeters with dosimeters allows for monitoring external radiation dose from wind-aided transport of release from current operations including fixed release points such as stacks and radioactive material storage areas.
- Facility perimeter monitoring locations are essentially at the closest accessible points to the facility sources and are therefore at the locations with the highest potential exposures.
- The perimeter monitoring also allows for monitoring direct exposure from soil contamination areas outside facilities that have resulted from historical operations.

Given the low topographic relief around the INL Site facilities, the perimeter monitoring locations meet the recommendation to avoid areas of low topography that could result in shielding or precipitation accumulation.

The reason or reasons for each monitoring location are shown next in this section, using criteria drawn from the program goals listed previously. These criteria are:

A. Assess actual radiation dose to persons in the site environs

B. Make on-Site radiation measurements in vicinity of predicted maximum air concentration(s)

C. Assess dose from soil-deposited atmospheric particulate

D. Assess dose from on-Site radiation-generating facilities or large radiation sources

E. Assess dose from potential routes of waste transport from the site

F. Assess dose to the local population distribution

G. Assess dose in the prevailing wind directions

H. Measure background dose at locations that are a minimum distance of 15–20 km from on-Site facilities

I. Provide baseline monitoring for two years in advance of new nuclear facilities

J. Provide confirmation of monitoring results by the off-Site environmental surveillance program and State Oversight radiation exposure monitoring programs.

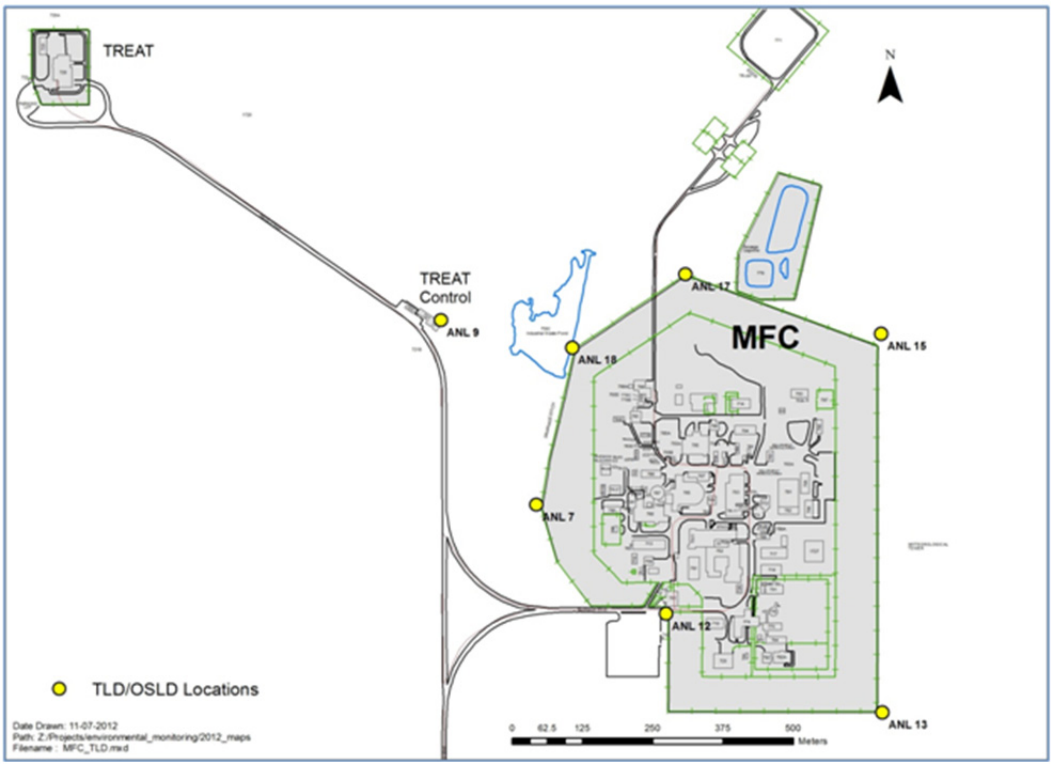

Figure 8-5. TLD/OSLD locations at MFC (formerly ANL–W).

Figure 8-6. TLD/OSLD location at the Auxiliary Reactor Area-II (ARA-II).

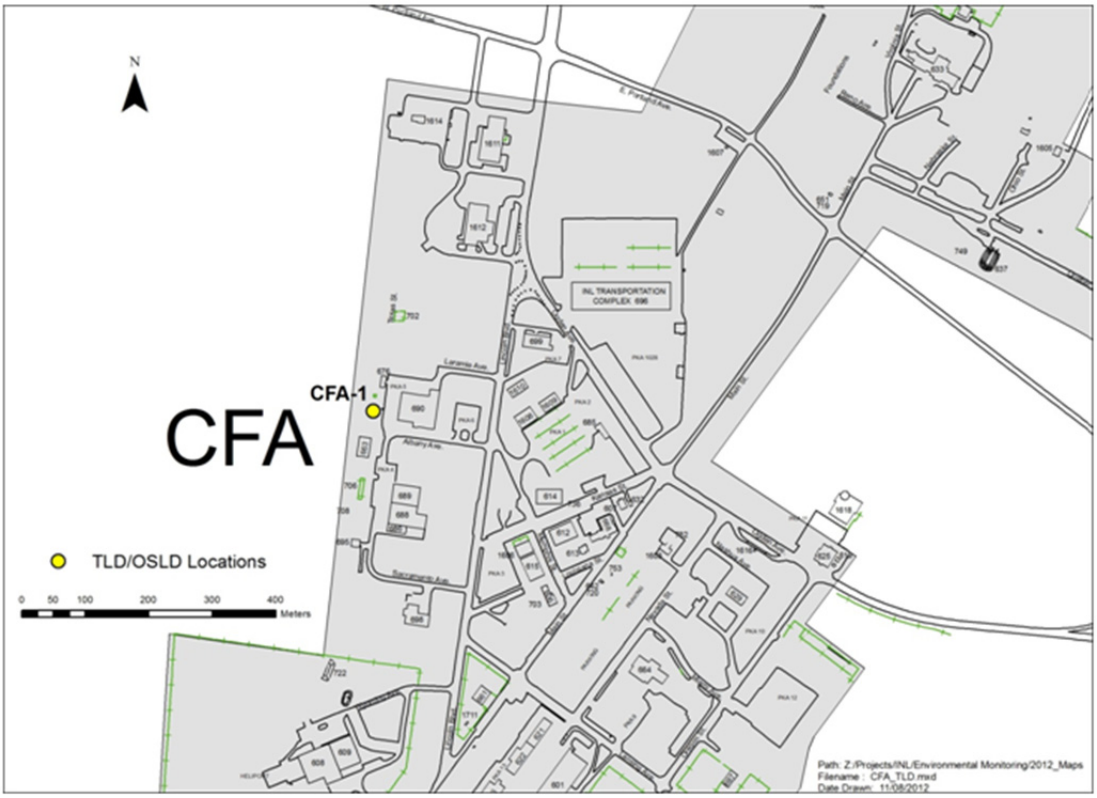

Figure 8-7. TLD/OSLD locations at CFA.

Figure 8-8. TLD/OSLD location at EBR-I.

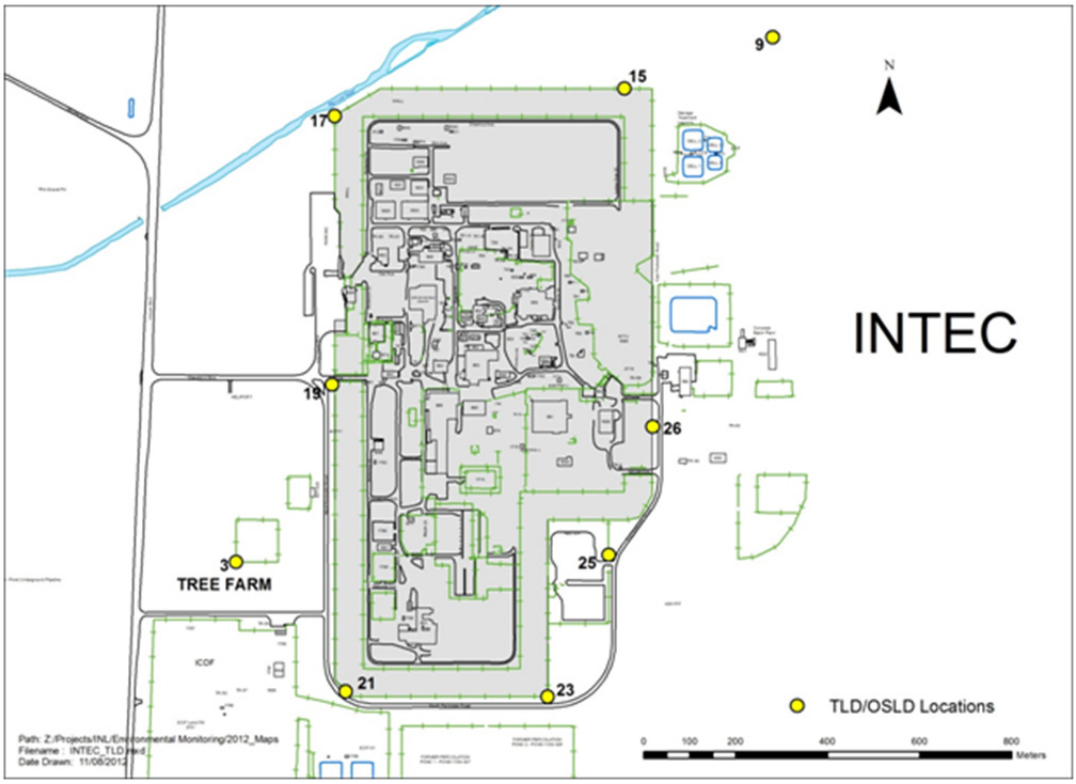

Figure 8-9. TLD/OSLD locations at INTEC (formerly ICPP).

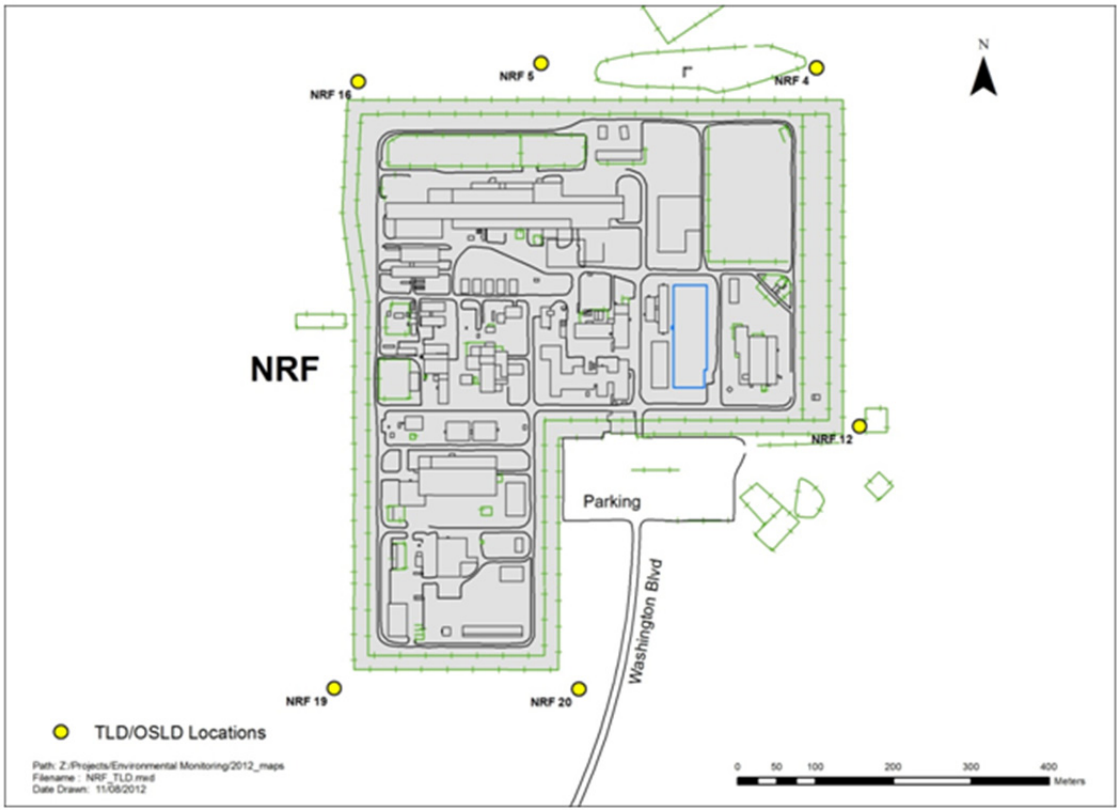

Figure 8-10. TLD/OSLD locations at the NRF.

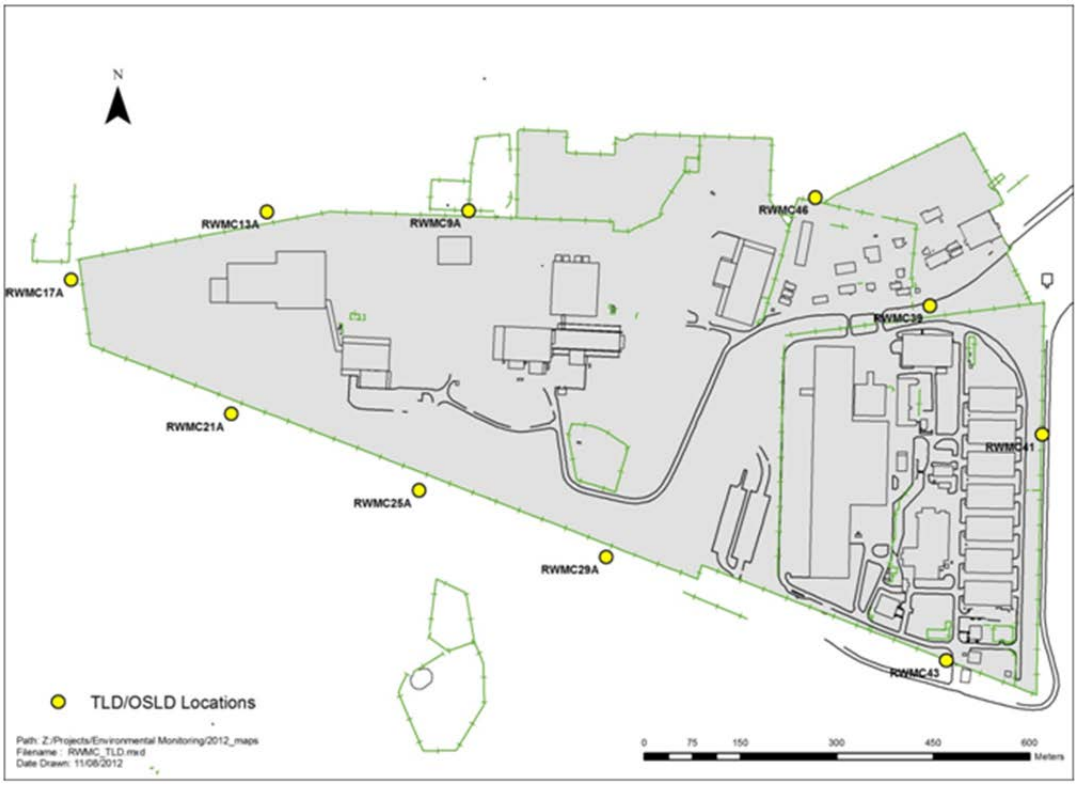

Figure 8-11. TLD/OSLD locations at the RWMC.

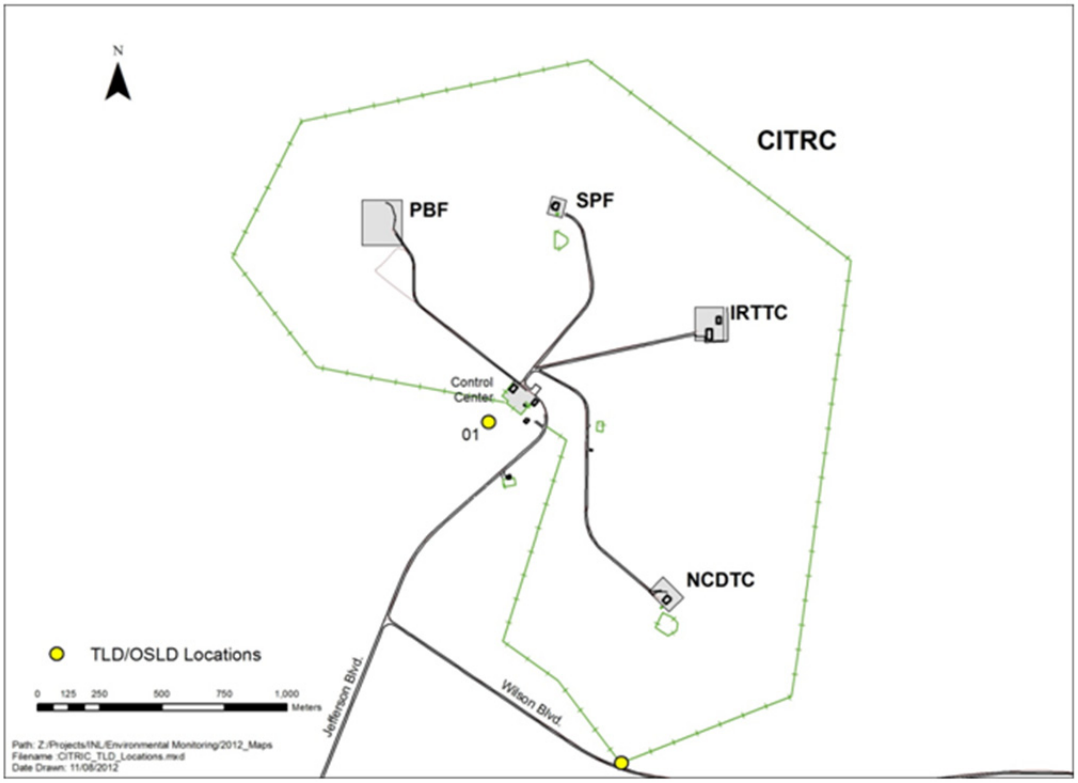

Figure 8-12. TLD/OSLD location at PBF.

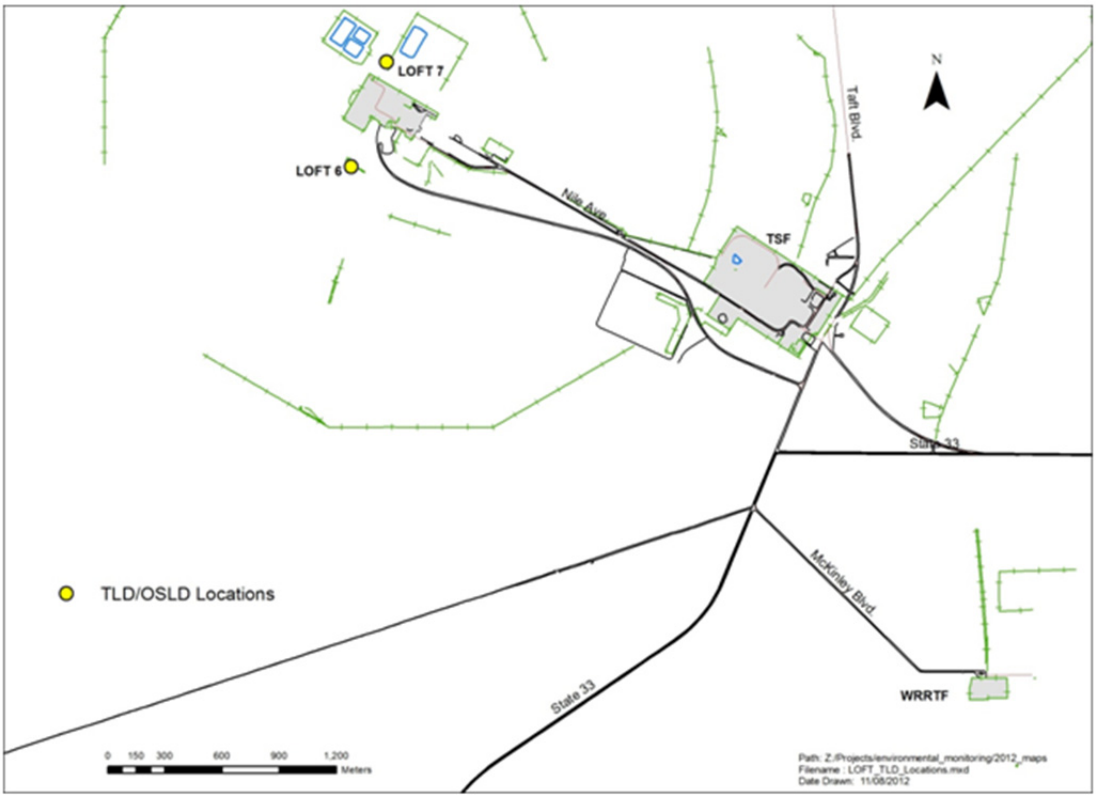

Figure 8-13. TLD/OSLD locations at the LOFT.

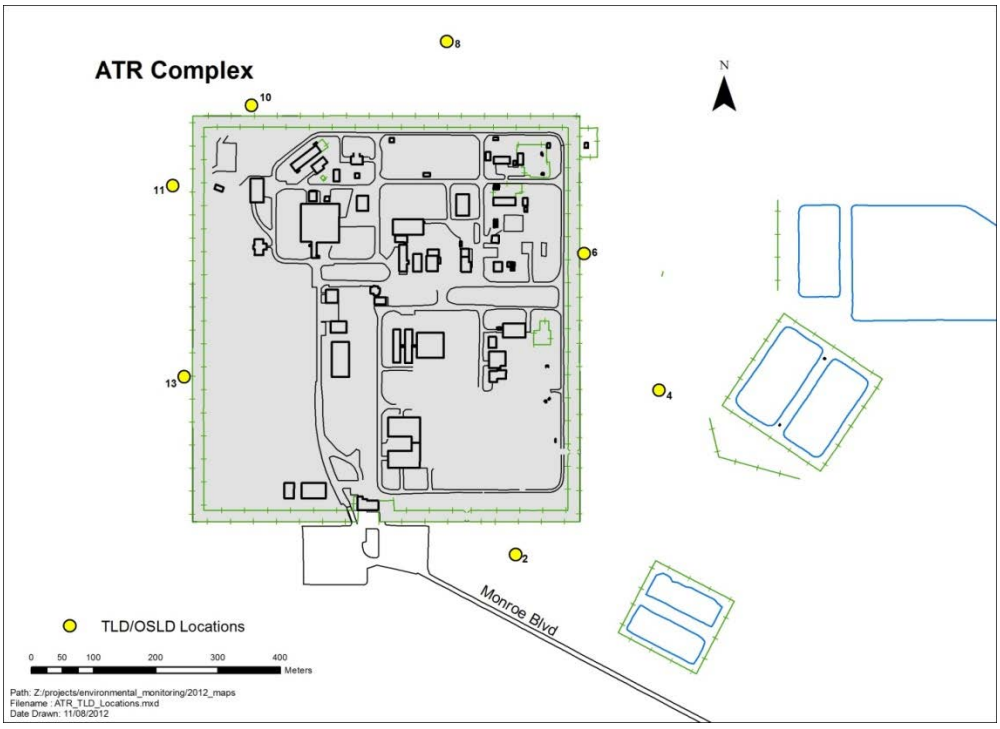

Figure 8-14. TLD/OSLD locations at the ATR Complex (formerly TRA).

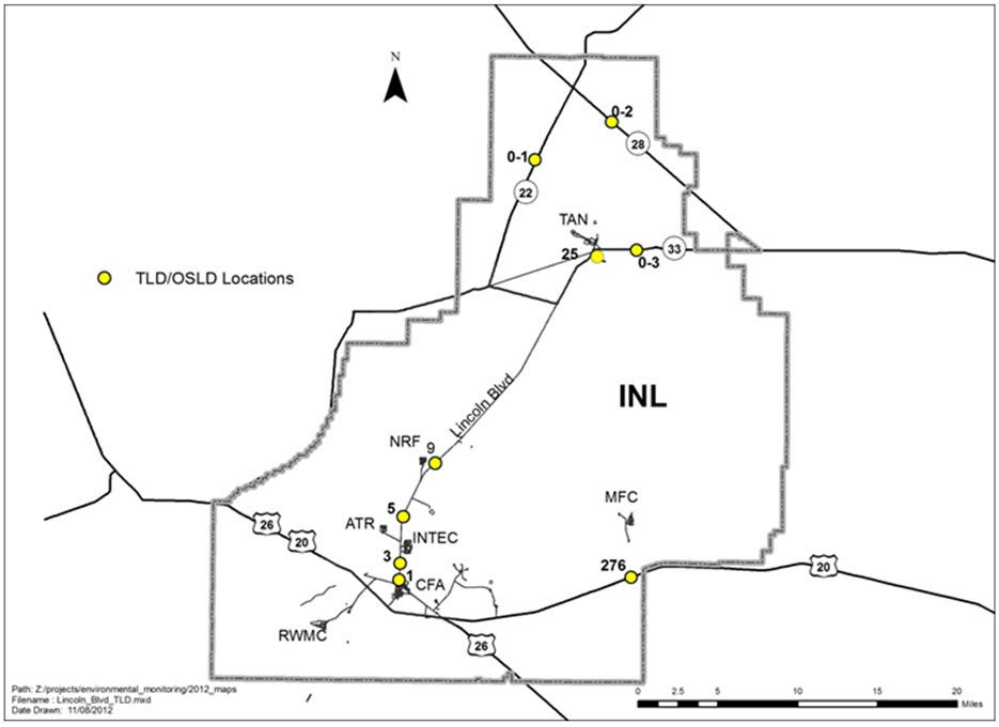

Figure 8-15. TLD/OSLD locations along Lincoln Boulevard, Highway 20, Highway 22, Highway 28, and Highway 33.

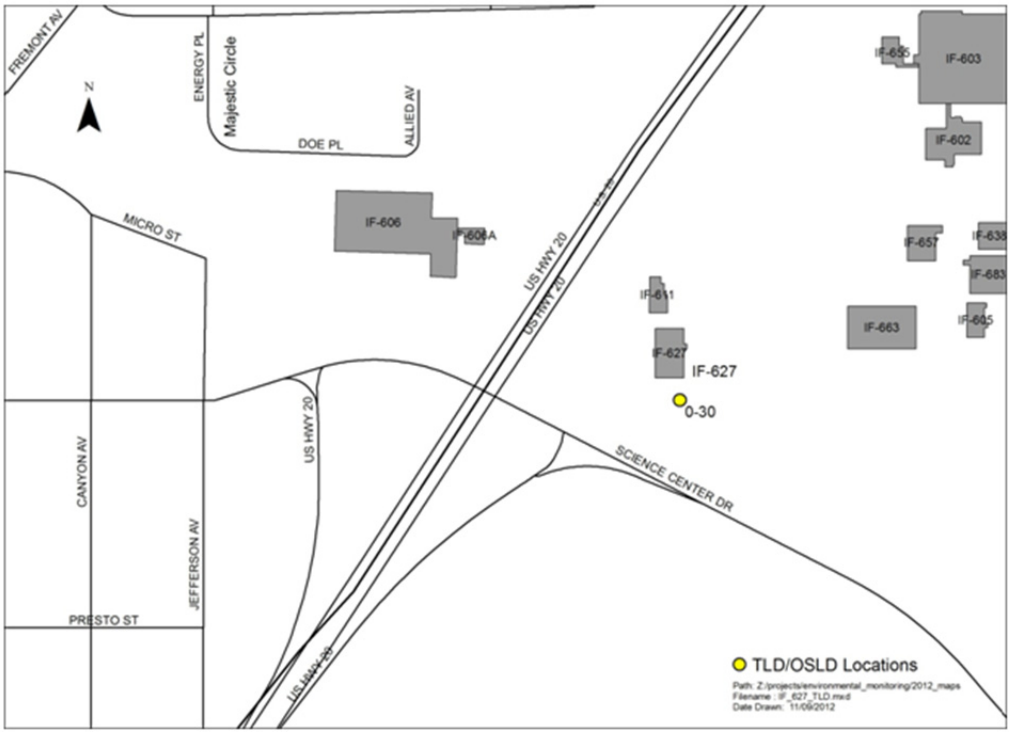

Figure 8-16. TLD/OSLD location at Idaho Falls facility IF-627.

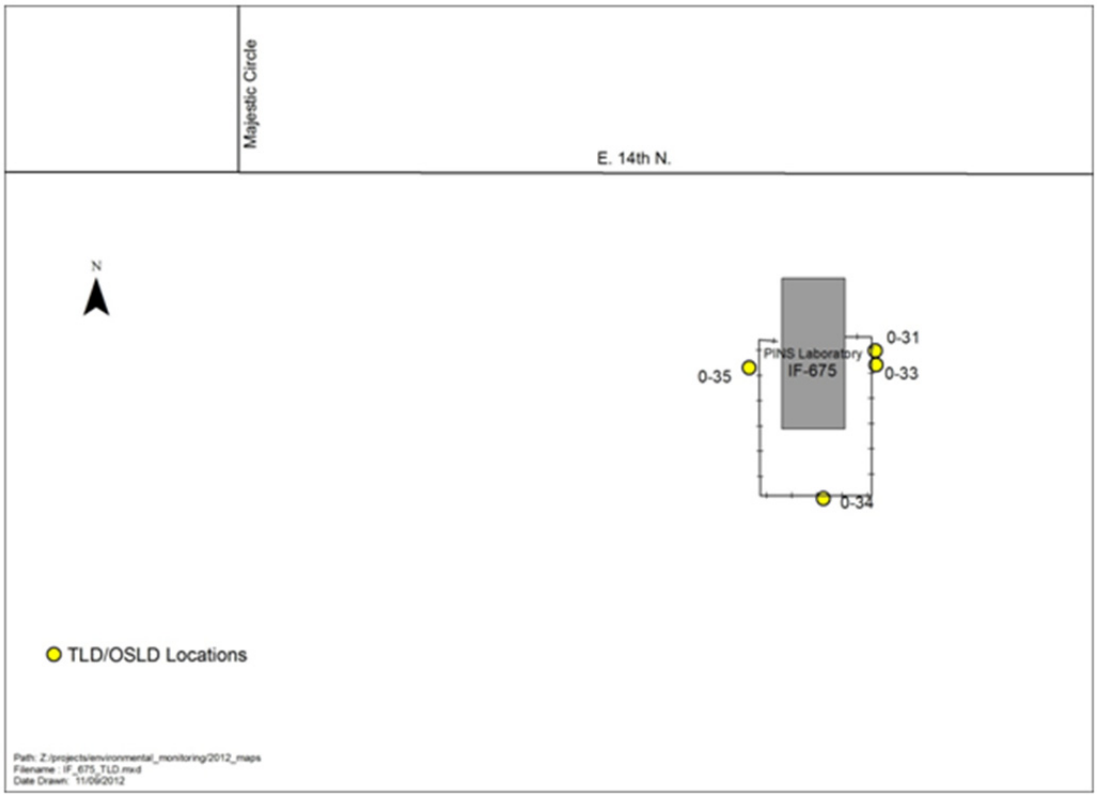

Figure 8-17. TLD/OSLD locations at Idaho Falls facility IF-675.

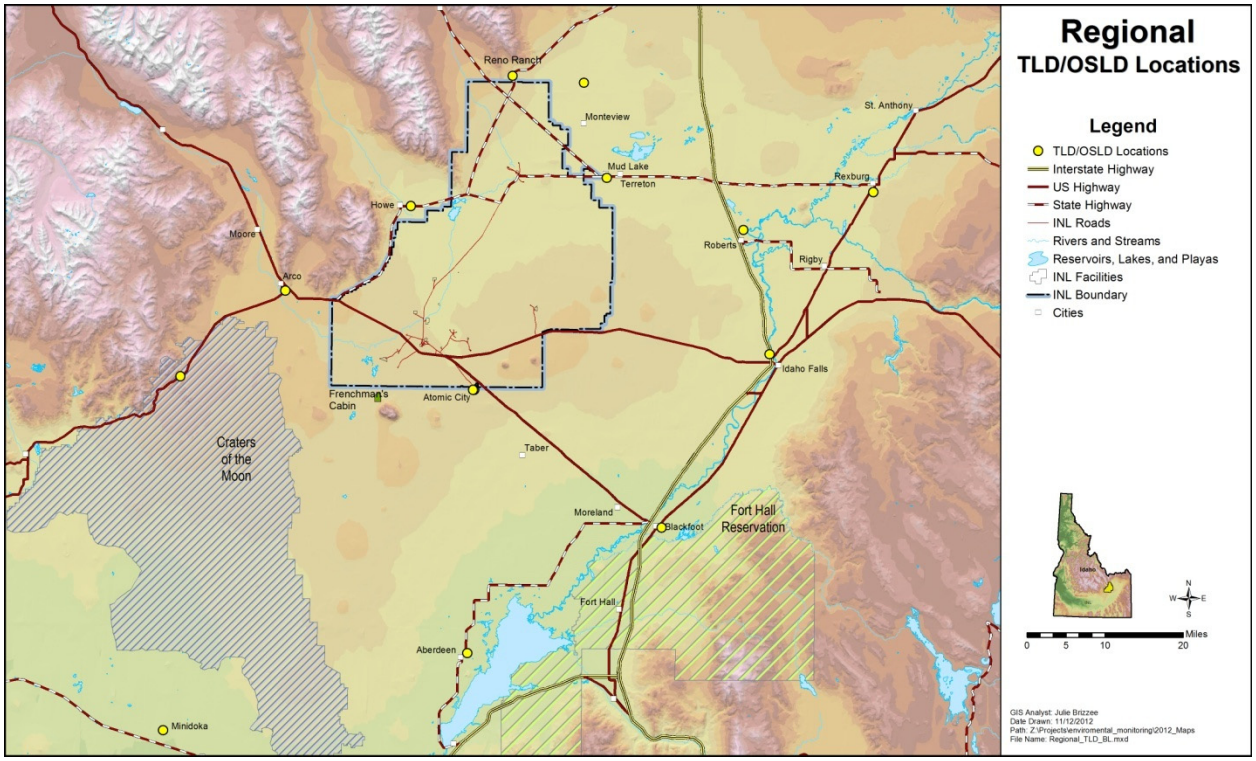

Figure 8-18. BEA Regional TLD/OSLD locations.

The justifications for monitoring at each TLD/OSLD location that will be retained are presented below in Table 8-2, using the alphabetic characters from this list to assign the rationale for each location.

The majority of the current BEA monitoring locations are for measuring radiation around each active facility, primarily in the southern portion of the INL Site. Two BEA off-Site locations are proposed for deletion to be consistent with the ESER off-Site monitoring program. These locations served as additional background monitoring locations. In the future, only the background monitoring locations at Craters of the Moon and Reno Ranch will be used. These two locations are both cross wind from the predominant wind directions and cover a range of elevations. The off-Site monitoring program is proposing three on-Site locations (EFS, Main Gate, Van Buren Gate), and these same three locations are indicated for addition in the table for the same reason of consistency with the off-Site program.

Table 8-2. Locations selected for BEA environmental radiation monitoring.

Location	Proposed Action	Criteria
ANL W O-12	Retain	C, D
ANL W O-13	Retain	C, D
ANL W O-15	Retain	C, D
ANL W O-17	Retain	C, D
ANL W O-18	Retain	C, D
ANL W O-7	Retain	C, D
ANL W O-9	Retain	C, D
ARA I&II O-1	Retain	A, C
CFA O-1	Retain	B, C
EBR I O-1	Retain	B, C
Hwy20 Mile O-276	Retain	C, E
Hwy22 T28 O-1	Retain	A, C, G, I
Hwy28 N2300 O-2	Retain	A, C, G, I
Hwy33 T17 O-3	Retain	A, C, G, I
ICPP O-15	Retain	B, C, D
ICPP O-17	Retain	B, C, D
ICPP O-19	Retain	B, C, D
ICPP O-21	Retain	B, C, D
ICPP O-23	Retain	B, C, D
ICPP O-25	Retain	B, C, D
ICPP O-26	Retain	B, C, D
ICPP O-9	Retain	B, C, D
ICPP Tree Farm O-3	Retain	B, C, D
IF-627 O-30	Retain	C, D
IF-675E O-31	Retain	C, D
IF-675D O-33	Retain	C, D
IF-675S O-34	Retain	C, D
IF-675W O-35	Retain	C, D
Lincoln Blvd O-1	Retain	B, C, E
Lincoln Blvd O-25	Retain	E, C, G
Lincoln Blvd O-3	Retain	B, C, E
Lincoln Blvd O-5	Retain	B, C, E
Lincoln Blvd O-9	Retain	B, C, E
NRF O-12	Retain	C, D

Table 8-2. (continued).

Location	Proposed Action	Criteria
NRF O-16	Retain	C, D
NRF O-19	Retain	C, D
NRF O-20	Retain	C, D
NRF O-4	Retain	C, D
NRF O-5	Retain	C, D
PBF SPERT O-1	Retain	A, C, D
RWMC O-13A	Retain	B, C, D
RWMC O-17A	Retain	B, C, D
RWMC O-21A	Retain	B, C, D
RWMC O-25A	Retain	B, C, D
RWMC O-29A	Retain	B, C, D
RWMC O-39	Retain	B, C, D
RWMC O-41	Retain	B, C, D
RWMC O-43	Retain	B, C, D
RWMC O-46	Retain	B, C, D
RWMC O-9A	Retain	B, C, D
TAN LOFT O-6	Retain	A, C
TAN LOFT O-7	Retain	A, C
TRA O-10	Retain	B, C, D
TRA O-11	Retain	B, C, D
TRA O-13	Retain	B, C, D
TRA O-2	Retain	B, C, D
TRA O-4	Retain	B, C, D
TRA O-6	Retain	B, C, D
TRA O-8	Retain	B, C, D
Aberdeen O-8	Delete	Not downwind
Arco O-1	Retain	C, J
Atomic City O-2	Retain	C, J
Blackfoot O-9	Retain	C, F
Craters of Moon O-7	Retain	C, J, H
Howe O-3	Retain	C, J
Idaho Falls O-10	Retain	C, J, F
Minidoka O-11	Delete	>50 miles from an INL Site facility
Monteview O-4	Retain	C, J, G
Mud Lake O-5	Retain	C, J, G
Reno Ranch O-6	Retain	C, H
Rexburg O-12	Retain	C, J, F, G
Roberts O-13	Retain	C, J, G
EFS	Add	A, C, G, J
Main Gate	Add	A, C, J
Van Buren Gate	Add	A, B, C, J

The OSLDs should ideally be collocated with the air samplers for the following reasons:

- The air samplers are placed in on-Site and off-Site locations most likely to intercept any releases from the INL Site. These locations have been determined using air dispersion modeling (see Chapter 6).
- Doses received by a hypothetical receptor at each location can be evaluated by inhalation of and exposure to airborne radionuclides at that location.

The final proposed selection of off-Site program OSLD stations are presented in Table 8-3. The proposed deletions will not affect the ability to meet program goals.

Table 8-3. Final locations selected for the ESER environmental surveillance program radiation monitoring network.

Location	Proposed action	Criteria
Aberdeen	Delete	Not an air sampling location
Arco	Retain	Distant air sampling location
Atomic City	Retain	Only southern boundary population. Boundary air sampling location
Birch Creek Hydro	Delete	Not an air sampling location
Blackfoot	Retain	Distant air sampling location
Blue Dome	Retain	Area of minimal impact. Retain as distant, not boundary, air sampling location
Craters of the Moon	Retain	Distant air sampling location. National Monument of great state and national interest.
Dubois	Retain	Distant air sampling location
EFS	Add	Indicator of INL Site air sampling location. One of higher airborne dispersion coefficients modeled by NOAA outside of facility perimeters within the INL Site.
FAA Tower	Add	Southern boundary air sampling location
Frenchman's Cabin	Add	Location of MEI; however, no power here for air sampler. OSLD would be the only continual environmental measurement here.
Howe	Retain	Only location on west Boundary air sampling location
Idaho Falls	Retain	Distant air sampling location. Area of minimal impact but highest estimated population dose. Collocated with EPA RadNet monitor.
Jackson	Retain	Stakeholder interest
Main Gate	Add	INL Site air sampling location. One of higher airborne dispersion coefficients modeled by NOAA outside of facility perimeters within the INL Site.
Minidoka	Delete	Not an air sampling station
Monteview	Retain	Boundary air sampling location
Mud Lake	Retain	Boundary air sampling location
Rexburg	Retain	Distant air sampling location
Roberts	Retain	A proposed boundary air sampling location
Taber	Investigate adding	A proposed boundary air sampling location, pending investigation of winter accessibility
Van Buren	Add	INL Site air sampling location. One of higher airborne dispersion coefficients modeled by NOAA outside of facility perimeters within the INL Site.

8.6.2 Frequency of Collection

The criteria in DOE (1991) states that dosimeters should be exposed long enough, typically one calendar quarter, to produce a readily detectable dose. The BEA on-Site program will continue to collect dosimeters biannually to allow for a long-term, low-dose accumulation.

The neutron dosimeters at the IF-675 facility will be collected semi-annually. The program goal is to eventually collect the neutron dosimeters annually. Given the limited time that neutron sources run at the facility and the history of low exposures from INL Radiation Control monitoring at the facility fence, this longer exposure time will increase the likelihood of detecting a measureable dose.

The off-Site program OSLDs will continue to be collected biannually to allow for long-term, low-dose accumulation.

8.6.3 Sampling Methods

For both on-Site and off-Site programs at each monitoring location, a dosimeter containing four individual Landauer InLight OSL chips will be placed 1 m above the ground. At the IF-675 facility, Landauer Neutrak CR-39 fast/intermediate/thermal dosimeters will be collocated with the OSLDs.

8.6.4 Analytical Methods

For the off-Site program, OSL chips will be read individually with a Landauer MicroStar reader at ISU Environmental Measurements Laboratory. The on-Site program sends OSLDs to Landauer, Inc., for reading.

8.7 Quality Assurance

Performance testing of the OSLDs will be performed by ISU and will include:

- ANSI N13.29 performance criteria test
  - Category I, II, and III of laboratory phase test
- Verification of Landauer Technical specifications report on the InLight OSL dosimeter
- Environmental performance requirement according to International Electrotechnical Commission (IEC) 62387-1
  - Measuring fading factors under several coefficients
  - Dose build up, self-irradiation
  - Reader stability.

Field blanks will be used as part of the quality control program.

8.8 Decision Limits and Actions

Figure 8-19 shows the 2011 annualized TLD and OSLD dose equivalent measurements from the BEA on-Site monitoring program. A vertical purple line divides the on-Site locations from the off-Site locations with the on-Site locations on the left and the off-Site locations on the right. A horizontal line is included at 150 mrem, the upper range of the historical pre-nuclear operation background measurements (AEC 1966a). As can be seen, some on-Site locations exceed the 150 mrem dose equivalent line. Although only the 2011 monitoring results are shown, this data set is representative of recent years.

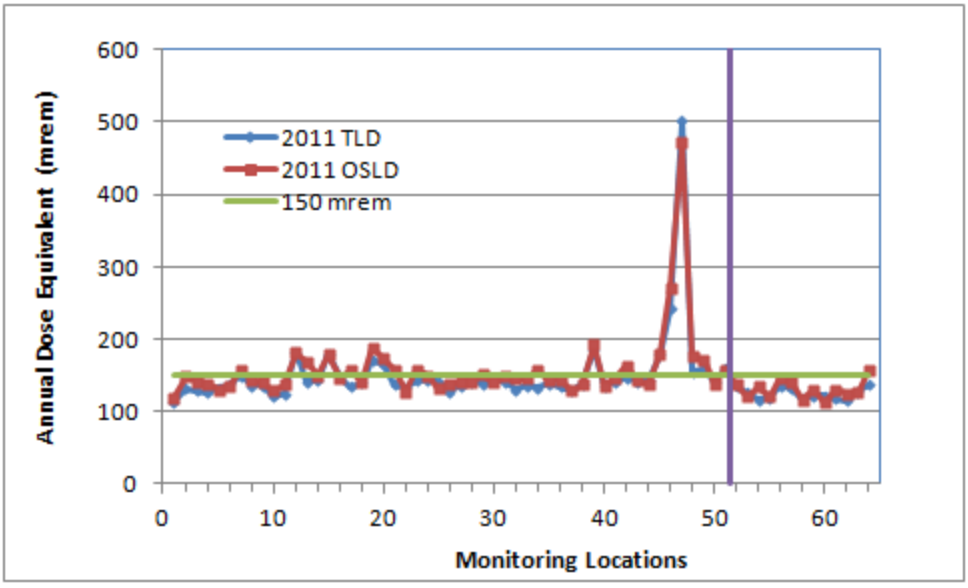

Figure 8-19. BEA 2011 annual measured direct exposures at sixty-four locations.

If the OSLD measurement at any location exceeds the action level of 150 mrem/year (the upper limit of pre-operational background measurements) the following actions will be taken:

- The possibility of an anomalous measurement will be determined by one or more of the following:
  - Review of the previous three years monitoring results at that location to see if the measurement is consistent with recent monitoring results
  - Consultation with other INL Site surveillance components and programs
  - Review to determine if this location is affected by previously known soil contamination or is in proximity to controlled radioactive-material areas where movement and storage of materials during the year impacted the measurement
  - Review of any other factors which may have contributed to the result.
- If the cause is verifiable, additional action will be taken to address the cause as needed.

8.9 References

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9. SURFACE AND DRINKING WATER

9.1 Program Basis

The surface water and groundwater pathways to humans are not considered to be the critical dose pathways from the INL Site (see Section 4.1.2.1). However, the public perceives drinking water and surface water to be two of the most important surveillance media, after air, to be monitored (MWH 2002). For this reason, surface and drinking water should be sampled. Surface water is collected from natural and man-made sources such as rivers, streams, ponds, lakes or irrigation sources while drinking water is collected from a municipal water source that has been through a water treatment facility or a well (Mud Lake) used for drinking water purposes. In southeastern Idaho the public/drinking water source is primarily derived from groundwater.

9.2 Program Drivers

Environmental surveillance monitoring of radioactivity in surface and drinking water is performed on and around the INL Site to meet the following regulatory requirements and guidance for environmental surveillance of DOE facilities:

- DOE Order 458.1, "Radiation Protection of the Public and the Environment"
- DOE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance."

Other key drivers include:

- Public perception regarding where and what to monitor
- Stakeholder inputs and values
- Potential environmental risks posed by contaminants originating from the INL Site.

9.3 Results of Related Studies/Surveillance

There are two main sources of water that could potentially be contaminated from activities on the INL Site: 1) the eastern Snake River Plain (ESRP) aquifer and 2) the Big Lost River (BLR). The ESRP aquifer is the source of regional drinking water and supplies irrigation water to a large, regional agricultural and aquaculture economy. Most of the basalt lava flows that host the aquifer and comprise the overlying vadose zone are very porous and permeable. The subsiding Eastern Snake River Plain and the high elevations of the surrounding recharge areas comprise a large drainage basin that receives enormous amounts of precipitation and feeds high-quality groundwater into the aquifer. Numerous studies suggest the hydraulic gradient of the ESRP aquifer is to the south/southwest (Figure 9-1), with velocities ranging from 0.5–6.1 m/day (2–20 ft/day) (DOE-ID 2011). This velocity is much faster than most studied aquifers and is attributed to the Eastern Snake River Plain architecture and porous media.

Historic waste-disposal practices have produced localized areas of contamination in the ESRP aquifer beneath the INL Site (DOE-ID 2011). The Idaho Nuclear Technology and Engineering Center (INTEC) used direct injection as a disposal method up to 1984. This wastewater contained elevated concentrations of tritium, strontium–90, and iodine–129. Injection at INTEC was discontinued in 1984, and the injection well sealed in 1989. When direct injection ceased, INTEC wastewater was directed to shallow percolation ponds where the water infiltrated into the subsurface. Disposal of low- and intermediate-level radioactive waste solutions to the percolation ponds ceased in 1993 with the installation of the Liquid Effluent Treatment and Disposal Facility. The old percolation ponds were taken out of service to be closed, and the new INTEC percolation ponds went into operation in August 2002.

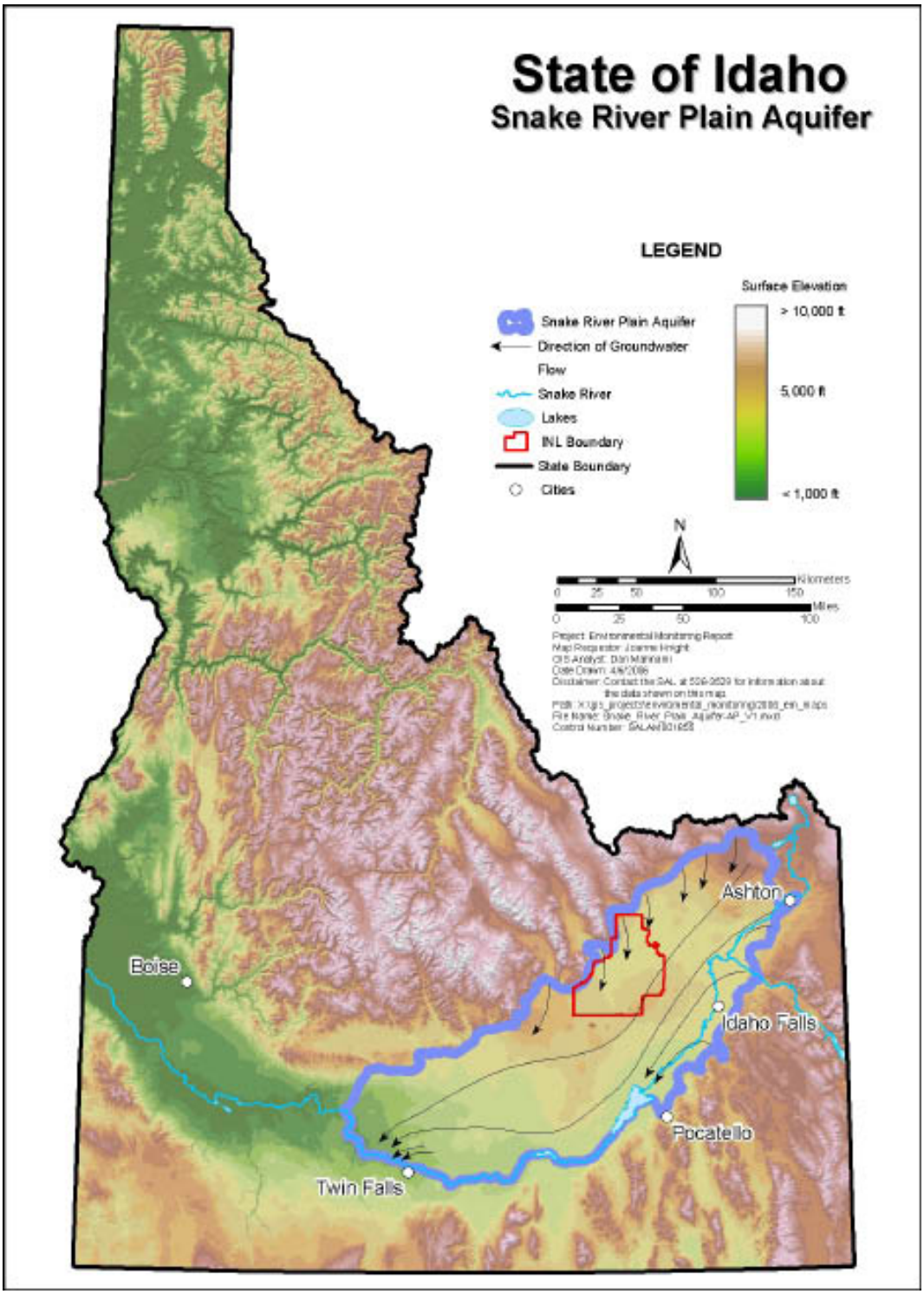

Figure 9-1. Location of the Idaho National Laboratory Site in relation to the Eastern Snake River Plain Aquifer.

The ATR Complex, formerly known as the TRA and the RTC, also had a disposal well, but primarily discharged contaminated wastewater to a shallow percolation pond. The ATR Complex pond was replaced in 1993 by a flexible, plastic (hypalon)-lined evaporative pond to stop the input of radioactive wastewater to groundwater.

Because tritium is equivalent in chemical behavior to hydrogen, a key component of water, it has formed the largest plume of any of the radiochemical pollutants at the INL Site. The configuration and extent of the tritium contamination area, based on the most recent published USGS data (2008), are shown in Figure 9-2 (DOE-ID 2011). Two monitoring wells down gradient of ATR Complex (USGS-065) and INTEC (USGS-077) have continually shown the highest tritium concentrations in the aquifer over time (Figure 9-3). For this reason, these two wells are considered representative of maximum concentration trends in the rest of the aquifer. The average tritium concentration in USGS–065 near ATR Complex decreased from 5,560 pCi/L in 2009 to 5,190 pCi/L in 2010; the tritium concentration in USGS-077 south of INTEC decreased from 5,480 pCi/L in 2009 to 4,290 pCi/L in 2010. Tritium produced by the INL Site should, therefore, not be detected in wells, springs, and surface water samples collected off-Site.

The Sr–90 trend over the past 20 years (1990–2010) in Wells USGS–047, USGS–057 and USGS–113 has varied through time, but also indicates a general decrease (DOE-ID 2011). Strontium–90 produced by the INL Site should, therefore, not be detected in wells, springs, and surface water samples collected off-Site.

In 2007, the USGS collected samples for I–129 from 19 wells that are used to monitor the aquifer south of INTEC and from 2 wells that are used to monitor perched zones at INTEC. The average concentration of 19 wells sampled in 2003 and 2007 did not differ; however, slight increases and decreases of concentrations in several areas around the INTEC were evident in the aquifer. The decreases are attributed to the discontinued disposal and to dilution and dispersion in the aquifer. The localized increases may be due to the movement into the aquifer of remnant perched water below INTEC. Iodine–129 concentrations do not appear to be increasing off the INL Site and has not been detected in wells, springs, and surface water samples collected off-Site.

The BLR is an intermittent, ephemeral body of water that flows only during periods of high spring runoff and releases from the Mackay dam, which impounds the river upstream of the INL Site. The river enters the INL Site about 7.5 miles west of the public rest stop on U.S. Highway 20/26, flows north through the INL Site, and enters a depression where the water flows into the ground, called BLR Sinks (see Figure 9-4). The river then emerges about 100 miles (160 km) away at Thousand Springs near Hagerman and other springs downstream of Twin Falls. The BLR watershed includes the Little Lost River, Big Lost River, Birch Creek, and associated tributary channels, playas, and sinks. No streams or rivers flow from within the Site to locations outside the boundaries, and most years, the channels of the Big Lost River system on the INL Site are dry.

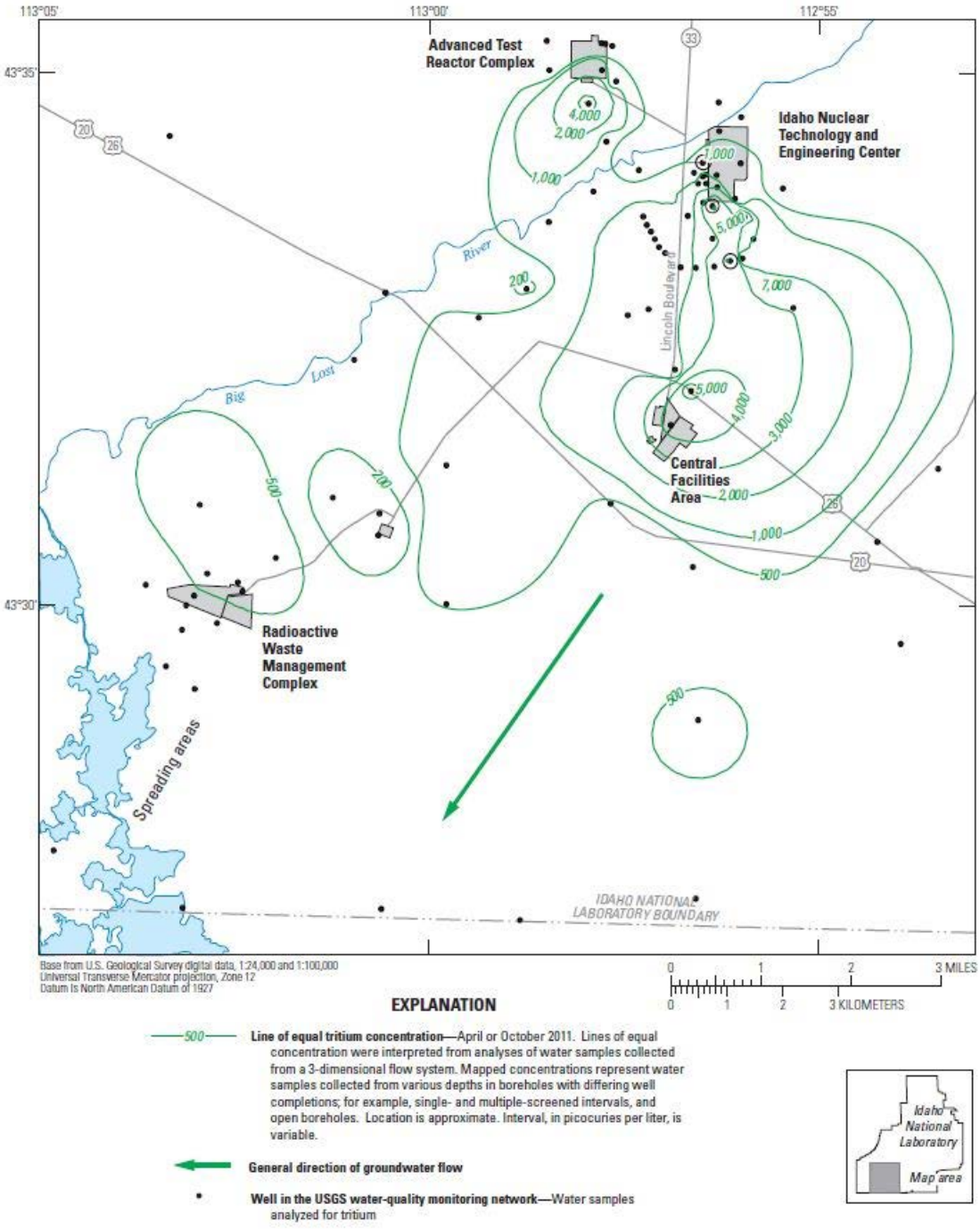

Figure 9-2. Distribution of tritium in water from wells at and near the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, Central Facilities Area, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, April or October 2011. (Davis, Bartholomay and Rattray 2013).

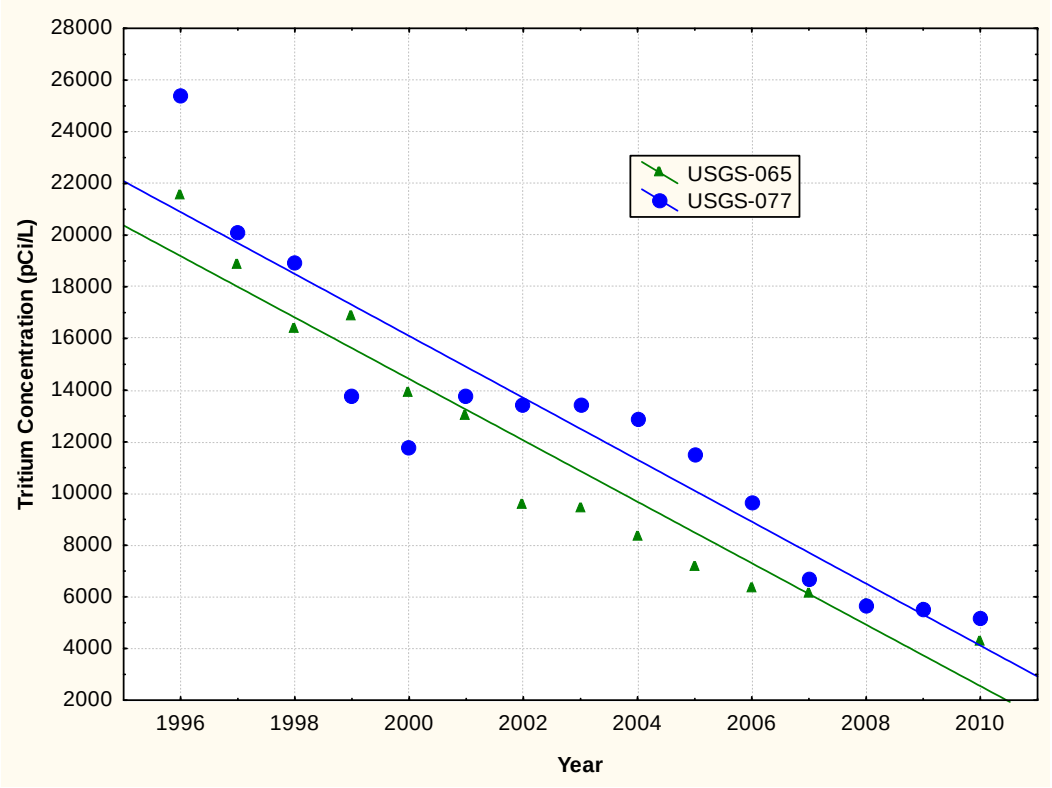

Figure 9-3. Long-term trend of tritium in wells USGS-065 and 077 (1995–2010) (DOE-ID 2011).

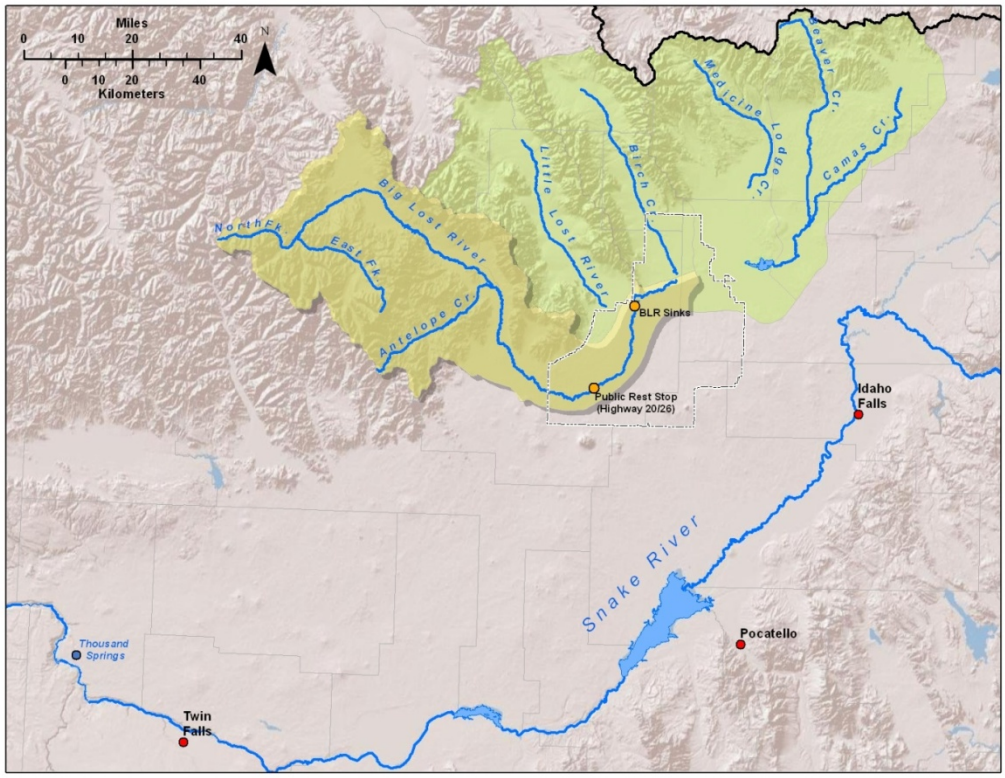

Figure 9-4. Big Lost River watershed and Snake River.

Initial monitoring of groundwater wells and surface water off the INL Site in surrounding communities was conducted in 1951 to establish an upper limit of natural radioactivity (Singlevich et al. 1951). Samples were obtained in the communities of Midway, Taber, Idaho Falls, Blackfoot, Pocatello, Dubois, Arco, and wells at farm houses, particularly in the region between the INL Site and the Snake River in the direction of the Thousand Springs area. In addition, samples were taken in streams, rivers, lakes and springs of the region. Thirty-one locations were sampled, and the samples were analyzed for gross beta emitters, plutonium and uranium mixture, uranium (six samples), and radon (six samples) using various radiochemical and counting techniques. Unfortunately, the exact locations of many of the samples were not documented, and a complete picture of trends could not be established. However, it could be concluded from the samples that could be located that the natural uranium content is higher in the vicinity of Thousand Springs on the Snake River than it is at the INL Site. This phenomenon is still observed in current samples.

Extensive routine monitoring of off-Site wells began in 1952 and continued through 1965 with 27–32 locations sampled on a bi-monthly to quarterly basis per year. Figure 9-5 shows the sample station layout for 1963, which typifies the sampling design used during this period (AEC 1966 No. 18). The sample stations were generally located at communities around the INL Site and areas southwest of the INL Site in the direction of groundwater flow. Samples were analyzed for gross alpha and beta activity. The analytical detection limit for gross beta activity, 1.5E–7 µCi/mL, was considered to provide assurance that any Sr-90 contribution (which would be less than 25% of any total fission product activity detected) would be well below 4.5E-8 µCi/mL, the maximum permissible concentration for this isotope. Tritium was added to the analytes in 1961 because a study of test wells around INTEC and ATR Complex indicated the presence of tritium. The detection level for tritium, 4E–6 µCi/mL, was not exceeded in off-Site samples during the period from 1961 through 1963. After 1963, only gross beta was reported (AEC 1964 No. 14) until 1968 when tritium reporting was resumed mid-year (AEC 1968 No. 23).

Because the above detection limit was not exceeded the number of off-Site groundwater sample locations was reduced to twelve in 1966. This decision was based on a thorough review of previous monitoring results. Since the beginning of routine sampling in 1952, there was no evidence of any INL Site contribution to the natural activity in the off-Site water (AEC 1966 No. 18). The 1966 samples were collected at 10 communities surrounding the INL Site—Arco, Howe, Monteview, Terreton, Menan, Idaho Falls, two Taber, Atomic City, Carey, and Aberdeen—and two down gradient communities (Shoshone and Minidoka) in 1968. Samples were collected semi-annually and analyzed for gross alpha and gross beta activities. In addition to groundwater samples, two surface water samples were also collected from the Snake River at Idaho Falls and Bliss. Tritium analysis was added in July 1968. At this time, the minimum detectable activities for gross alpha, gross beta, and tritium was 3E–9 µCi/mL, 5E–9 µCi/mL, and 4E–7 µCi/mL, respectively. Two additional wells were added in 1978 along the southern boundary of the INL Site by USGS to provide better coverage of the aquifer to the south of major facilities because on-Site water sampling indicated that the tritium plume had moved to within 3 miles (5 km) of the Site boundary. At that time USGS conducted most of the monitoring of groundwater on-Site and at a few locations beyond the southern and western boundaries. The environmental surveillance program remained essentially the same until the second half of 1989, when three surface water locations in the Magic Valley area (Twin Falls and points west) were added to the program.

Co-sampling with the State of Idaho DEQ IOP will continue for comparative purposes and public interest. The DEQ has co-sampled seven locations off Site since 1994. This includes three surface water sampling locations in the Magic Valley (Buhl, Hagerman, and Twin Falls) and four drinking-water locations (Minidoka, Shoshone, Atomic City, and Mud Lake).

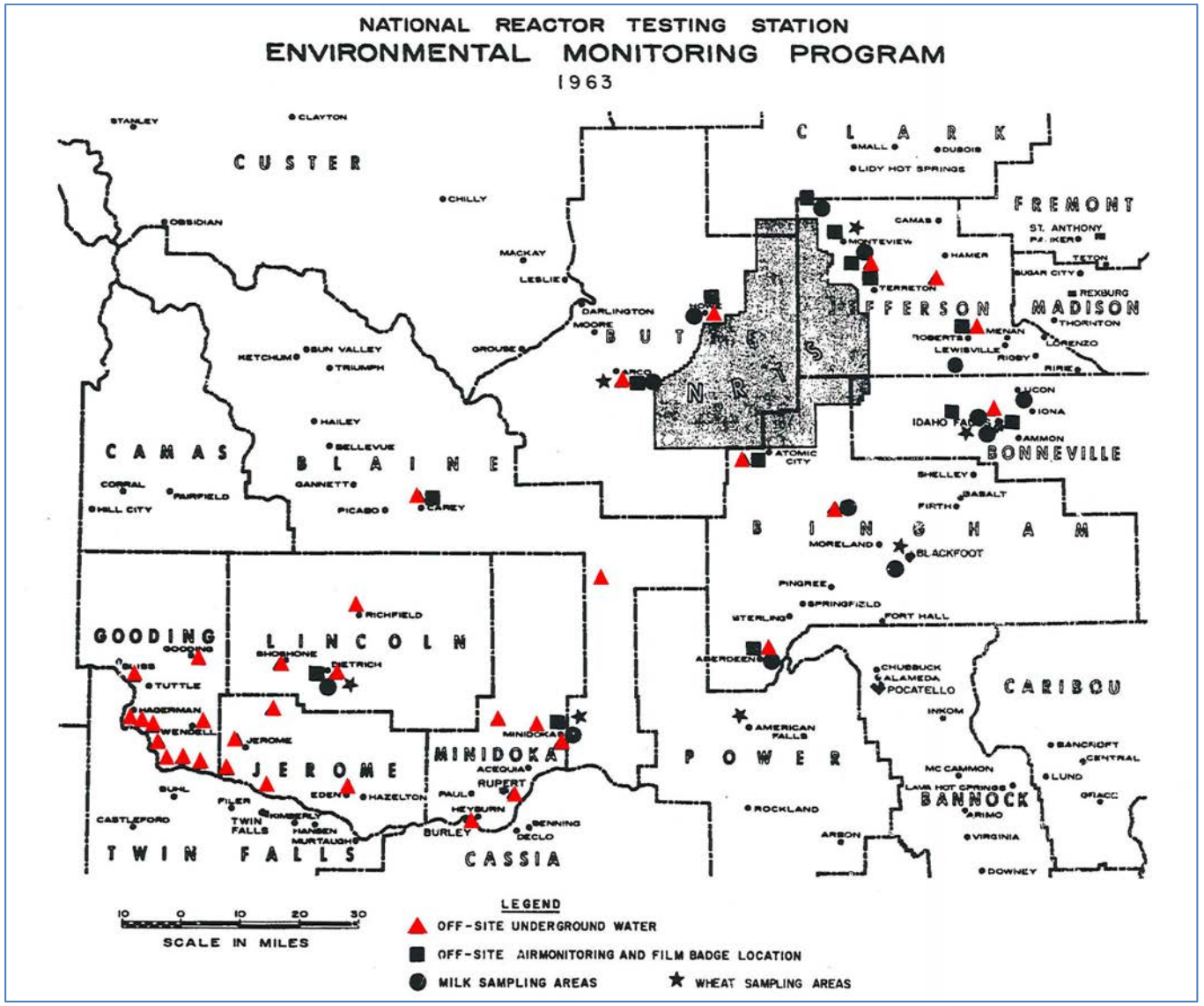

Figure 9-5. Off-Site groundwater sample locations in 1963.

The off-Site water-monitoring program changed little through 2006 (Figure 9-6). The historical data were then reviewed, and it was concluded that no evidence showed that the INL Site contributed to radioactivity in off-Site samples. The off-Site drinking-water and surface water program was suspended in 2007.

The program was reintroduced in 2010, at the direction of DOE-ID due to stakeholder interest. The sampling design was amended based on a review of the historical data and other program drivers. In addition, sampling of the Big Lost River on the INL Site was initiated when water was present both on and around the INL Site. The changes are discussed in Section 9.6.1.

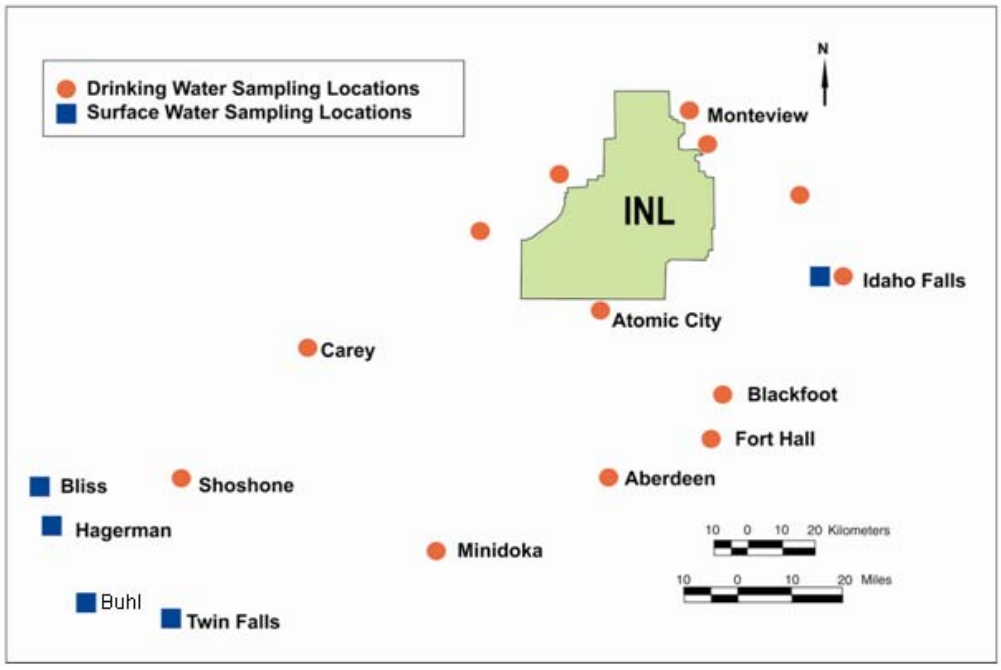

Figure 9-6. Offsite drinking and surface water sample locations (2006).

9.4 Program Goals

Water-monitoring sites are sampled for the purposes of examining trends of INL Site contaminants and other general groundwater quality indicators and for verifying DOE monitoring results. Specific program objectives that are derived from these objectives and other drivers include:

- Measure background concentrations of radionuclides in surface and drinking water
- Measure concentrations in drinking and surface water at locations which could be impacted by routine INL Site operations
- Determine INL Site contributions of waterborne radionuclides to the environment
- Detect and report trends in measured concentrations of waterborne radionuclides
- Compare measured concentrations to reference levels based on derived concentration standards (DCSs) tabulated in DOE-STD-1196-2011, “Derived Concentration Technical Standard” (DOE 2011a)
- Determine environmental alert levels and any potential radiological doses exceeding the reporting limit
- Prepare a comprehensive analysis of surveillance results in the annual site environmental report.

9.5 Sampling Boundaries

Sites sampled include groundwater locations (wells and springs) and surface water locations (streams). Ample groundwater sample sites have been selected to aid in identifying INL Site impacts on the ESRP aquifer. These are categorized as up-gradient or down-gradient wells. Up-gradient locations are not impacted by INL Site operations and are considered representative of background groundwater quality conditions. Down-gradient locations are south of the INL Site in the direction of groundwater flow from potential sources of INL Site contamination. These locations provide trends in water quality down-gradient of INL and include wells and springs used for irrigation, public water supply, livestock, domestic, and industrial purposes. Surface water stations include select locations on the BLR and the Snake River. The BLR stations provide information on soil contaminants potentially entrained by the river's flowing through the INL Site.

9.6 Sampling Design

9.6.1 Locations

Upon review of the monitoring data collected through 2006, it was apparent that samples collected at the locations selected for the drinking- and surface water program have yielded results (gross alpha, gross beta, and tritium) that are well below regulatory concern and DOE guidance (DOE 1991) and do not indicate any movement of water-borne radioactive contamination from the INL Site to the public. For this reason alone, the program was redesigned primarily to address the public interest in drinking water and surface water. In general, the changes are:

- Add the U.S. Highway 20/26 Rest Area, which is the only public water source that is located close to the mapped tritium plume from the INL Site
- Sample from Howe because it is near the INL Site Boundary and near the BLR Sinks
- Sample drinking water from a public water source at Craters of the Moon, which is distant from the INL Site and can be compared, as a background sample, with other samples currently collected. Craters of the Moon is also an area of public concern because of its relatively pristine setting
- Sample Idaho Falls drinking water from a public water source because it is a populated area distant from the groundwater plume. This location is sampled for the EPA RADNET Program; thus, results can be compared with another federal agency
- Add a bottled-water control sample for comparison with drinking-water samples
- Continue the surface water sampling on the BLR through the INL Site because it has the potential to carry contaminated soil to the BLR Sinks. Gamma spectroscopy of these samples for Cs–137 and other gamma-emitting radionuclides was added because it is a soil contaminant at the INL Site.
- Include sampling surface water at Birch Creek for comparison with BLR samples
- Eliminate other locations which offer no scientific insight into the surface water/drinking water pathway. These include:
    - Drinking water from a public source at Aberdeen, Arco, Blackfoot, Carey, Fort Hall, Monteview, Roberts, and Taber, which are not located down-gradient of the INL Site
    - Surface water at Bliss, which is down-gradient of the Thousand springs area
    - Surface water at Idaho Falls, which is not down-gradient of the INL Site.

The final drinking water and surface water sampling design is presented in Table 9-1 and shown in Figures 9-7 and 9-8.

9.6.2 Sample Collection and Analysis Frequencies

The frequency of collection and analysis that has been used in the past programs was maintained at a semiannual basis (in May and November). This is basically to coincide with the DEQ IOP's sampling frequency and with that used historically for comparison purposes.

The Big Lost River is sampled when and if it is flowing in the spring and fall.

9.6.3 Sample Collection and Handling Methods

Samples are collected and preserved using methods recommended in DOE (1991) and by EPA (1987) and documented in ESER environmental surveillance sample collection procedures. Sample sizes are such that program MDAs are achieved.

9.6.4 Analytical Methods

The standard analytical method to determine gross alpha and gross beta activities in drinking water is the use of gas-proportional counters (EPA 1987). The sample is first reduced in volume though drying and then plated onto a planchet, which is counted in the counter. The volume and counting time are determined by the desired MDC. The MDC for gross alpha activity is approximately 1 pCi/L (1E-9 µCi/mL) and for gross beta activity is approximately 1.5 pCi/L (1.5E-9 µCi/mL).

Tritium in water samples is measured using the standard method of counting the sample in a liquid-scintillation counter (EPA 1987). The MDC is typically less than 100 pCi/L or 1E-7 µCi/mL. The State of Idaho DEQ IOP analyzes some of their samples using an electrolytic enrichment method with a much lower MDC of 10–14 pCi/L. This is an expensive and time-consuming process. Moreover, the standard method is sufficient to measure background concentrations as measured historically in water samples collected.

Surface water samples collected from the BLR are also analyzed for gamma-emitting radionuclides using gamma spectrometry. The MDA for Cs–137 is approximately 2 pCi/L (2E-9 µCi/mL).

9.7 Radionuclides Assessed

Tritium is a naturally occurring radioactive form of hydrogen that is produced in the atmosphere when cosmic rays collide with air molecules. Tritium has also been produced historically by INL Site activities. The environmental behavior of tritiated water is like that of water, and it can be present in drinking and surface water. Tritium is therefore analyzed in all water samples collected off the INL Site.

Gross alpha and gross beta activities are measured in surface and drinking water for screening purposes and as indicators of naturally occurring radionuclides and Sr–90 (a beta-emitter which was historically injected into the aquifer). Additionally, gamma-emitting radionuclides, particularly Cs-137, are included for Big Lost River samples since INL Site surface soils may be historically contaminated with gamma-emitting radionuclides. The Maximum Contaminant Level (MCL) for gross alpha established in the National Primary Drinking Regulations (40 CFR 141) is 15 pCi/L. Historical results have never approached this level and to conduct analyses routinely for Am-241, Pu-238, and Pu-239/240 is not warranted. However, if any samples exceed historical levels for gross alpha, specific isotopic analyses may be performed to ascertain if Am-241, Pu-238, and Pu-239/240 or naturally occurring radionuclides (primarily radium and uranium) resulted in exceeding the historical levels.

Table 9-1. Current drinking and surface water monitoring program design.

Drinking Water Program				
Location	Status	Sampling Frequency	Radionuclide Analysis	Sampling Basis
Atomic City	Established	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program; other ESER environmental surveillance sample(s) collected here
Control sample (bottled water)	New	Semiannual	Gross alpha/beta, tritium	For QA purposes
Craters of the Moon	New	Semiannual	Gross alpha/beta, tritium	Distant location for comparison with other samples
Howe	Established	Semiannual	Gross alpha/beta, tritium	Near the INL Site Boundary and the BLR Sinks - could potentially be down gradient
Idaho Falls	Established	Semiannual	Gross alpha/beta, tritium	Distant from INL plume for comparison with down gradient samples; EPA samples here
Minidoka	Established	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program
Mud Lake	Established	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program; other ESER environmental surveillance sample(s) collected here
Public rest stop on Highway 20/26	New	Semiannual	Gross alpha/beta, tritium	Only public drinking-water site located close to the mapped tritium plume from the INL Site
Shoshone	Established	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program
Surface Water Program				
Location	Status	Sampling frequency	Radionuclide Analysis	Sampling Basis
Big Lost River[b]	Established	Dependent on flow	Gross alpha/beta, tritium, specific gamma	Only surface water going through INL Site; could contact contaminated soils
Birch Creek (Control)	New	Semiannual	Gross alpha/beta, tritium, specific gamma	Background for comparison with BLR.
Buhl (Clear Springs)	Established	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program
Hagerman (Bill Jones Fish Farm)	Established	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program
Twin Falls (Alpheus Springs)	Established	Semiannual	Gross alpha/beta, tritium	Co-sampled with DEQ INL Oversight Program: BLR emerges here

a. Semiannual = May and November sampling campaigns
b. At Highway 20/26 Rest Stop, Lincoln Blvd by INTEC, EFS, Lincoln Blvd by NRF, and BLR Sinks, when water is available.

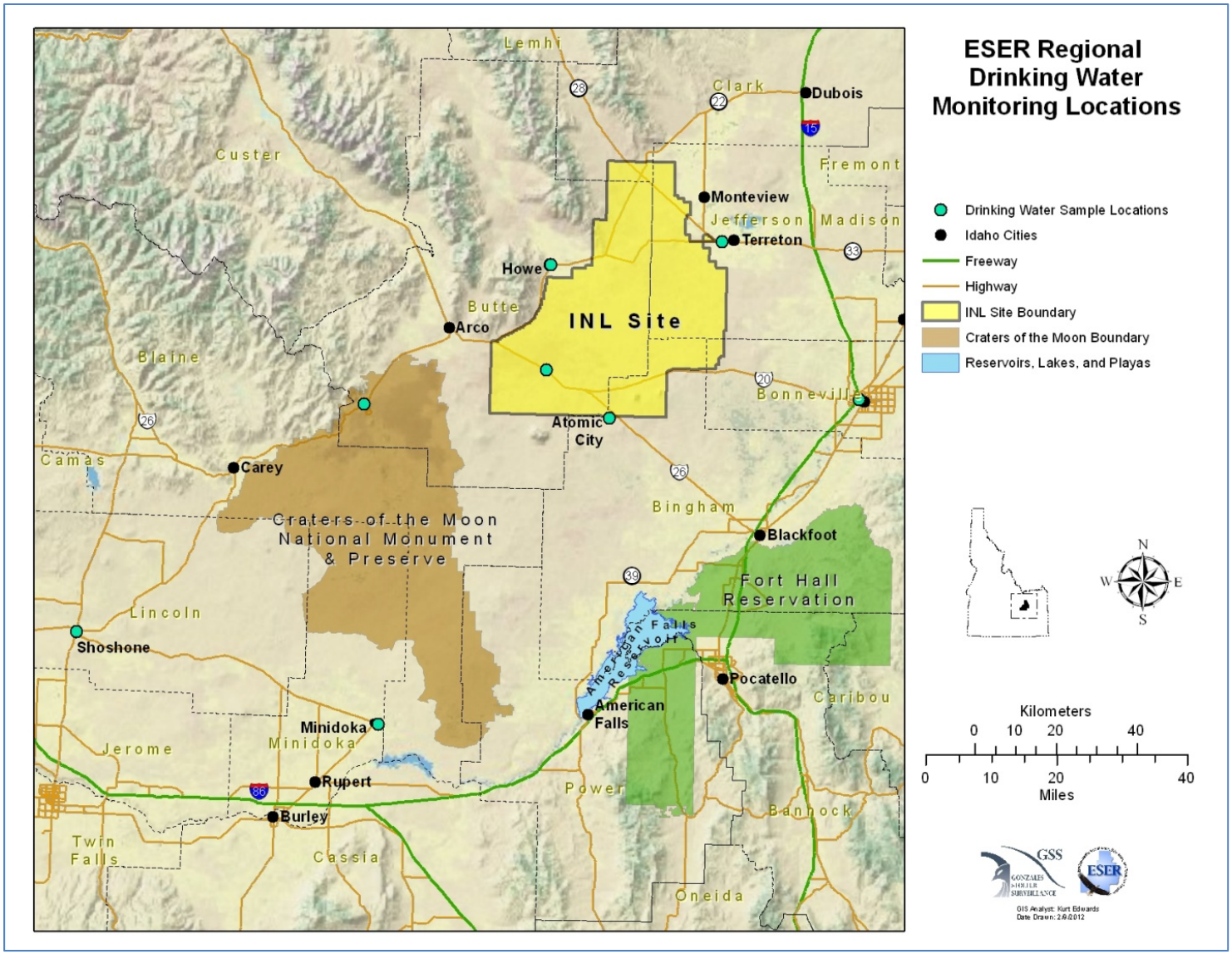

Figure 9-7. ESER environmental surveillance regional drinking water monitoring locations (2011).

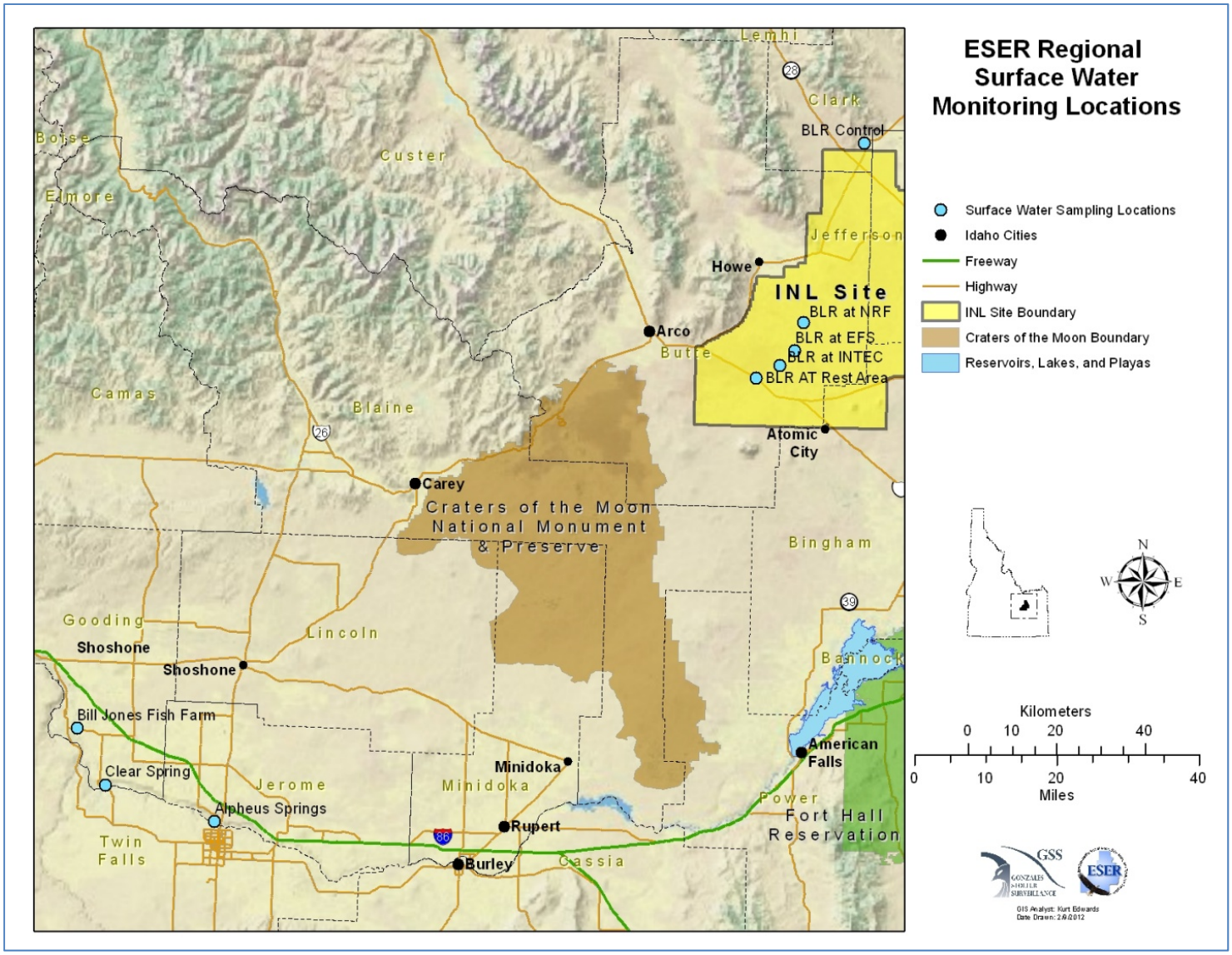

Figure 9-8. ESER environmental surveillance regional surface water monitoring locations (2011).

9.8 Quality Assurance

The off-Site environmental surveillance program employs an effective QA program to ensure the collection of high-quality data. The program is detailed in the Offsite Environmental Surveillance Program Quality Assurance Project Plan (QAPjP). The QAPjP serves to ensure that all data collected are of known and defensible quality, and to meet the requirements of all applicable federal and state regulations and DOE orders, specifically DOE Order 414.1A, ASMENQA-1-2000, EPA QA/R-5, ANSI/ASQC E-4, IDQTF UFP-QAPP and ISO 9000.

Measurements of precision and accuracy in the air-sampling program are made through the use of replicated water samples, recounts of samples, blanks, and blind spiked samples.

9.9 Decision Limits and Actions

DOE radiological activities (DOE 2011b) must be conducted so that exposure of members of the public to ionizing radiation will not cause a TED exceeding:

- 100 mrem (1 mSv) in a year
- An equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year
- An equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose.

The results of 60 years of environmental monitoring of drinking and surface water around and down gradient of the INL Site show that DOE dose limits have never been achieved or even approached. The off-Site environmental surveillance program thus looks for instances when background or historical measurements are exceeded. The off-Site environmental surveillance program has developed action levels for the laboratory to use as criteria to notify us if an unusual result is observed. The action levels were developed based on an assessment of the last ten years of data (unpublished ESER assessment). The action levels developed for water samples are shown in Table 9-2.

Table 9-2. Action levels for radionuclides in surface and drinking water.

Radionuclide	Surface water	Drinking water
Gross Alpha	3E–9 µCi/mL	3E–9 µCi/mL
Gross Beta	1.3E–8 µCi/mL	1.3E–8 µCi/mL
Tritium	3E–7 µCi/mL	3E–7 µCi/mL
Cesium-137	>3σa	–b

a. σ is the counting uncertainty reported with each result.
b. Not analyzed for this constituent.

If the measurement at any location exceeds the action level, the following actions will be taken:

- The possibility that the concentration is an anomalous measurement is determined by one of the following methods:
  - Review of historical monitoring results at that location to see if the measurement is consistent with past monitoring results
  - Consultation with other INL Site surveillance components and the Idaho DEQ INL Oversight Program
  - Review to determine if this location is affected by recent activities or events
  - Review of any other factors which may have contributed to the result.
- If the concentration is verified, it may signal the need for further action dependent upon the concentration level and/or a trend showing elevated concentrations over a period of time.

9.10 References

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10. SOIL

10.1 Program Basis

The purposes of environmental soil-monitoring programs are to assess potential radiation exposure to the public, confirm control measures, detect trends in known contamination areas, and provide first measurements in the event of an accidental release. As stated in DOE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance" (1991), "Soil provides an integrating medium that can account for contaminants released to the atmosphere, either directly in gaseous effluents or indirectly from re-suspension of on-Site contamination. Hence, soil sampling and analysis should be used to evaluate the long-term accumulation trends and to estimate environmental radionuclide inventories."

The on-Site emphasis is monitoring within the INL Site boundaries by in-situ gamma measurements to determine if long-term deposition of radioactive materials has resulted in a buildup of radionuclides in the environment. The off-Site focuses on regional monitoring along and outside of the INL Site boundary. Soils on the INL Site contain both natural and manmade radionuclides. Natural radioactivity exists in soil on the INL Site at every soil depth, just as it does in all soils worldwide (UNSCEAR 2008). In addition, all INL Site surface soils (the top few inches) contain manmade radionuclides from fallout unrelated to INL Site activities, such as past above-ground nuclear weapons tests (Payne 2006). Surface soils (and in some cases, soil at greater depths) at the INL Site also contain radionuclides from past INL Site releases. The primary potential exposure pathways for surface-soil contamination to reach humans are (a) inhalation (or ingestion) of re-suspended material and (b) external exposure. The primary manmade radionuclide in most INL Site locations, Cs–137 (Rood, Harris, and White 1996), is bound tightly to surface soils and high wind can lift it into the air. Other radionuclides present in surface soils include Sr-90, uranium and plutonium isotopes and Am-241 (Rood, Harris, and White 1996). Like natural elements in soil, manmade radionuclides can also be taken up by plants, which can be eaten by animals or moved by wind. Based on these exposure pathways and widespread distribution, Cs–137 and other radionuclide concentrations in soil are measured across the INL Site and in adjacent areas.

10.2 Program Drivers

Monitoring of radioactivity in soils is performed to meet the requirements for environmental surveillance monitoring programs at DOE facilities. These include:

- DOE Order 458.1, "Radiation Protection of the Public and the Environment"
- DOE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance."

Generally, radionuclide-contaminated soils that are present due to past INL Site releases are addressed by remedial investigation/feasibility studies under CERCLA, which uses risk based approaches and EPA-developed soil-screening levels to determine the need for and extent of cleanup and remediation.

10.3 Results of Related Studies/Surveillance

Before 1963, the United States and other countries conducted more than 500 atmospheric nuclear weapons tests. Surface soils worldwide contain traces of radionuclides due to fallout from these tests. INL Site can generate airborne emissions from various facilities during operations, research, and scientific activities that can also be deposited on the soil. BEA implements engineering controls, such as high efficiency particulate air (HEPA) filters, and administrative controls to prevent the introduction of and reduce and/or eliminate air pollutants from the environment. BEA conducts both air surveillance and facility emissions monitoring to assess the adequacy of these controls to protect human health and determine any impact of air pollutants on people and the environment. Past INL Site activities have also

contaminated soil in defined locations that can be detected above the worldwide fallout background. The largest of these locations include low-level radionuclide-contaminated surface-soil areas centered on INTEC and SL–1 that are elongated in predominant wind directions. Control and monitoring of all of these contamination areas on-Site are under the purview of the CERCLA program and are not part of the routine environmental surveillance program.

For on-Site surveillance, BEA generally uses in-situ measurements rather than collecting physical soil samples. Because Cs–137 is the predominant anthropogenic radionuclide in the known radionuclide-contaminated soil areas, and because it is relatively easy to detect even at low concentrations using the in-situ instruments, BEA surveillance focuses on Cs–137 to confirm the success of on-Site contamination-control measures and detect trends inside of and adjacent to known contamination areas. Between 2006 and 2010, BEA performed a series of studies to compare in situ gamma analysis results with soil sampling and laboratory analysis at various on-Site sampling locations. For example, at 34 locations in 2007, 10 split-spoon samples were collected from a predetermined array centered at the in-situ location out to 30 ft. Each of the 10 split-spoon samples were removed and divided by one-in. depth to form twelve composite samples. Each of these 1-in. composite samples from the 34 in-situ locations was then analyzed Cs-137in the laboratory to determine the cesium–137 depth profiles for the in-situ measurement technique (Giles, Oertel and Reynolds 2008). These data are still used for today's in-situ measurements and data analysis.

For the ESER environmental surveillance program, soil sampling is a useful approach to determine the accumulation of initially airborne radionuclides that have been deposited on the ground and generally serves a supplementary role in environmental surveillance monitoring programs (Gallegos 1995, Hardy and Krey 1971, DOE 1997). Soil sampling is, however, of questionable value in attempting to estimate small increments of deposition over a period of a few years or less.

Soil samples can be indicators of long-term buildup of radionuclides so analytical results can be compared to those found in previous years to note any trends in the data. The prime contractor at the INL Site, through the Environmental Restoration and Waste Management Program, maintains a database of historical soil-sample results. No DOE Derived Concentration Standard exists for soil.

10.4 Program Goals

10.4.1 On-Site

The BEA surveillance monitoring program for soils complements emissions and air monitoring. The specific goals of soil monitoring are to:

- Assess the impact of INL Site operations on the concentrations of man-made radionuclides in soil
- Determine concentrations of radionuclides (natural and fallout) in soils
- Detect and report trends in measured concentrations of radionuclides in soil
- Assess any buildup of radioactivity due to INL Site operations

10.4.2 Off-Site

Off-Site monitoring is conducted to determine whether radionuclides have been transported off-Site and to assess what the impacts are to human populations. Soil monitoring data are also factored into biota dose calculations.

10.5 Sampling Boundaries

At the INL Site, surface soil is an integrating medium that accounts for contaminants released primarily from routine atmospheric releases from facility operations, historical non-routine episodic releases, resuspension of onsite contamination, and infiltration of soils by water contacting buried waste and becoming contaminated during past flooding events. Due to low precipitation (8 inches annually),

resulting in low downward migration, surface soils are the best media to evaluate deposition on specific areas. This is demonstrated by soil profiles developed by collecting and analyzing soil samples at one-inch increments to a depth of 6 inches at various locations on the INL Site (DOE-ID 2010). The cesium-137 and strontium-90 data consistently follow exponential trends when concentration is plotted against depth, with the majority of activity detected in the first few inches of soil (DOE-ID 2013). There is no particular trend over time for the transuranics which is consistent with radionuclides with long half-lives (DOE-ID 2013).

The routine on-Site program focuses on the region within the INL Site boundary, particularly at areas around active facilities and locations known to be historically contaminated.

The off-Site program concentrates on the region outside of the INL Site boundary and specifically on locations at or near air monitoring stations and/or historical sample locations.

10.6 Sampling Design

10.6.1 Sampling Locations

10.6.1.1 On-Site

Surface soils around major facility areas are monitored annually based upon an optimized design that takes into account air emissions data, locations of elevated radiological concentrations detected during historical sampling events, and modeling data (meteorological, emissions, kriging). Because one of the program goals is to assess long-term buildup of long-lived radionuclides due to INL Site operations, sampling locations overlap from year to year for comparison and trending. These locations generally correspond to those established by DOE in the 1990's and more recently by BEA's analysis of current operations. Planning for annual sampling includes reviewing prior year data and locations to determine if sufficient data have been collected to establish a valid baseline and therefore do not need to be re-sampled, and to determine if changing operations necessitate establishing new locations or eliminating locations which are unlikely to serve as good references for assessing INL Site operational impacts. Locations are identified and documented using global positioning system coordinates to ensure sample points can be accurately relocated each year. Planned locations include soil measurements collocated with on-Site air monitoring locations, consistent with the HSS assessment recommendation (HSS 2010) to "Consider collection of some fraction of soil samples concurrently with other media, such as air, to provide comparable results." BEA has 23 air-monitor locations, including the two duplicate locations. Collocated air and soil data will allow site-specific correlation between these two potential exposure pathways. BEA is evaluating where the collocated samples will be collected in the future and how the remainder of sample locations will be optimized to ensure programmatic goals are accomplished.

During off-normal events, additional in-situ sample collection locations are determined by best professional judgment, and measurements are sometimes constrained by weather conditions or on-Site conditions such as fires.

No off-Site locations are monitored as background locations. Instead, in situ results are compared to historical mean background concentrations as documented in INEL-94/0250, "Background Dose Equivalent Rates and Surficial Soil Metal and Radionuclide Concentrations for the Idaho National Engineering Laboratory" (Rood, Harris and White, 1996).

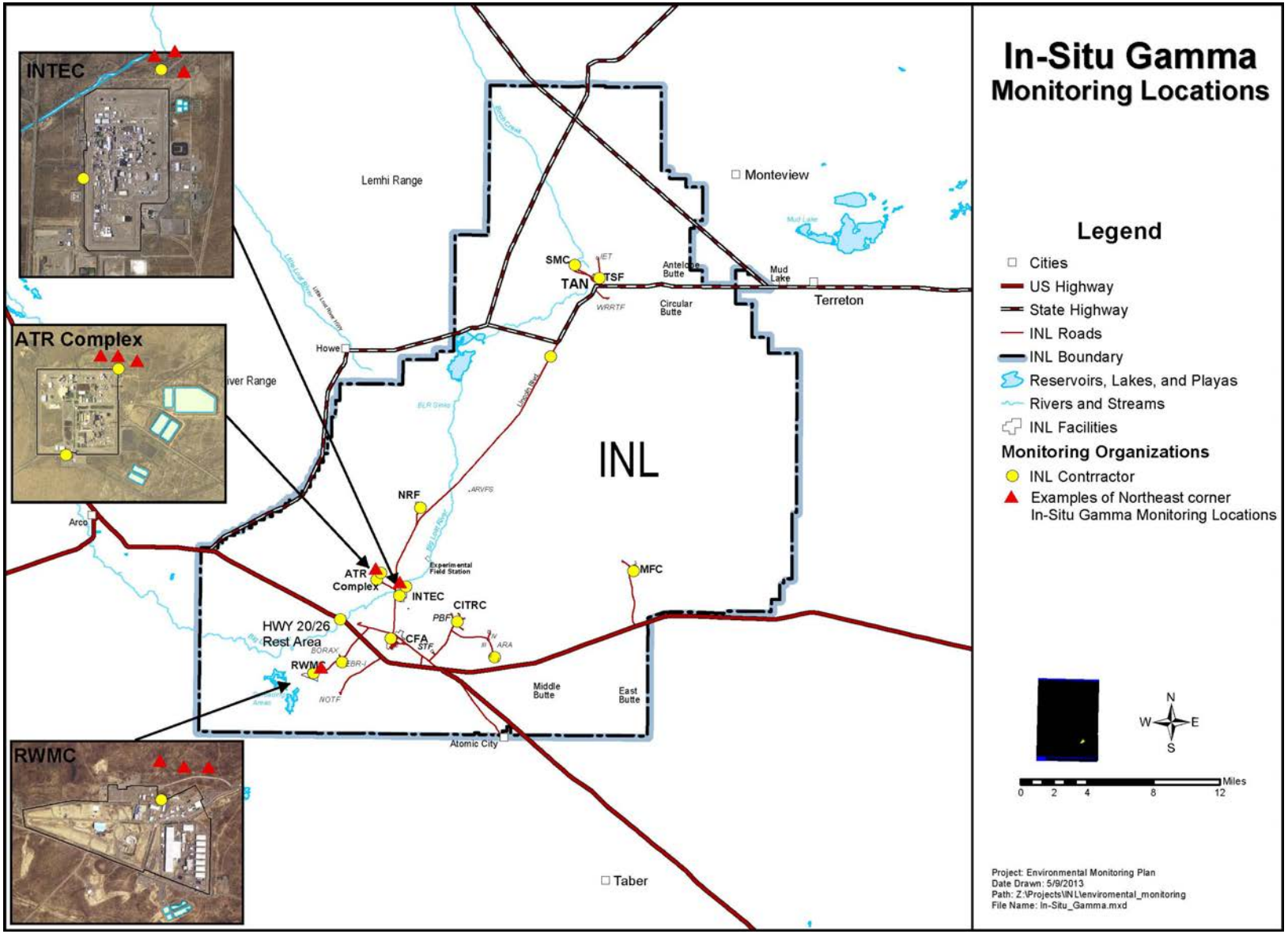

Figure 10-1. Regional soil monitoring locations.

10.6.1.2 Off-Site

Sampling locations for each medium have been chosen based on DOE Order 458.1 (DOE 2011); DOE/EH-0173T (DOE 1991) and NRC guidance (NUREG 1.109; NRC 1977). Collecting duplicate samples of various media and comparing results ensure the representativeness of the sampling methods used. Measurements are reported in standard units, as prescribed by DOE orders or other available guidance.

Due to the vast area to be monitored, judgmental sampling is the preferred sampling method. Judgmental sampling is the subjective selection of sampling locations at a site based on historical information, visual inspection, and on best professional judgment. Judgmental sampling is used to identify contaminants present at areas having highest concentrations (i.e., worst-case conditions) (IAEA 2004).

The current biennial soil sampling program for off-Site monitoring for the INL Site was established around 1975. The sampling locations were based on the closest undisturbed sagebrush habitat to traditional air sampling locations for Howe, Monteview, Mud Lake, Atomic City, Blackfoot and the Federal Aviation Administration (FAA) Tower. Butte City is the closest sagebrush habitat to Arco, and Reno Ranch is the former location of the sampler now at Blue Dome. Carey was a proxy for Craters of the Moon, and St. Anthony was a proxy for Rexburg. The basis for selection of Crystal Ice Caves is not known, but it may serve as a proxy for Aberdeen, which was not an air-sampling location, but a water/TLD/NOAA station (Figure 10-2). Predominant wind directions (Figure 10-3) as well as the transport and dispersion of contaminants by winds as projected by the MDIFF model to develop a contour map with time-integrated concentrations (Figure 10-4; DOE-ID 2011) were also considered in sampling-location development.

As illustrated in Figure 10-4, off-Site soil sampling locations are within the predominant wind and highest potential concentration areas. Wind roses and atmospheric dispersion calculations provide useful guidance in selecting appropriate soil sampling locations (DOE 1997). Carey and Crystal Ice Caves are considered background locations while Frenchman's Cabin (southwestern location nearest INL Site southern boundary) is the location for the maximally exposed individual. The distribution of the soil sampling location based on historical data and judgmental selection provide a valid distribution for determining the presence of contaminants potentially released from INL Site operations. Off-Site air-sampling locations were also validated using the meso scale differential model (MDIFF) (see Chapter 6) enabling use of off-Site soil data and on-Site soil monitoring data when assessing the impacts of potential radiological contaminants on the public and environment.

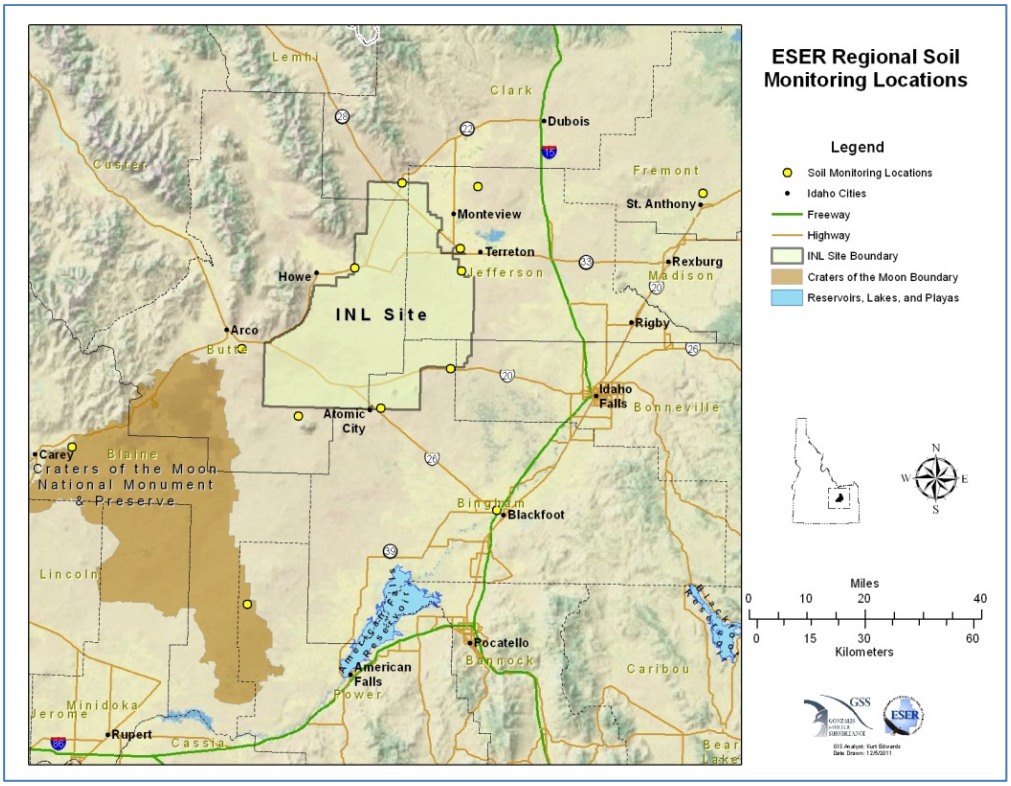

Figure 10-2. Off-Site soil-sampling locations.

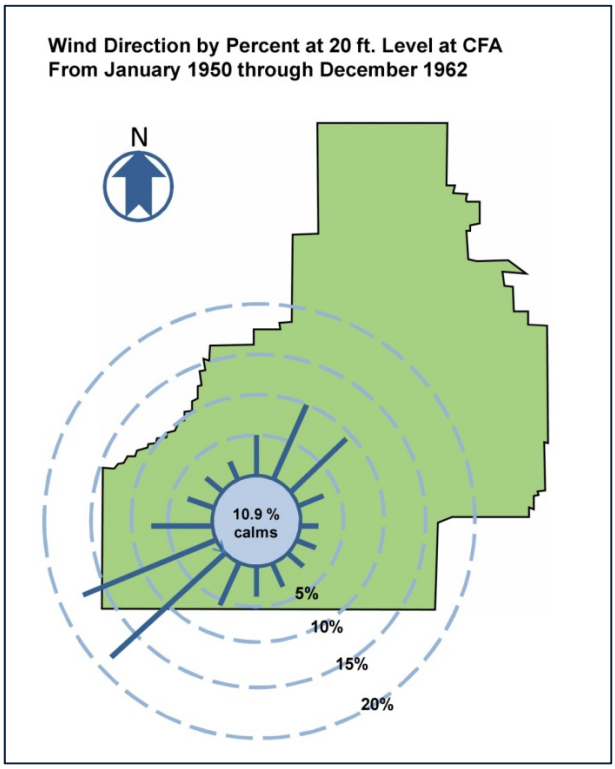

Figure 10-3. Predominant wind directions on the INL Site (based on Clawson, Start, and Ricks 1989). Direction is the direction from which the wind is blowing.

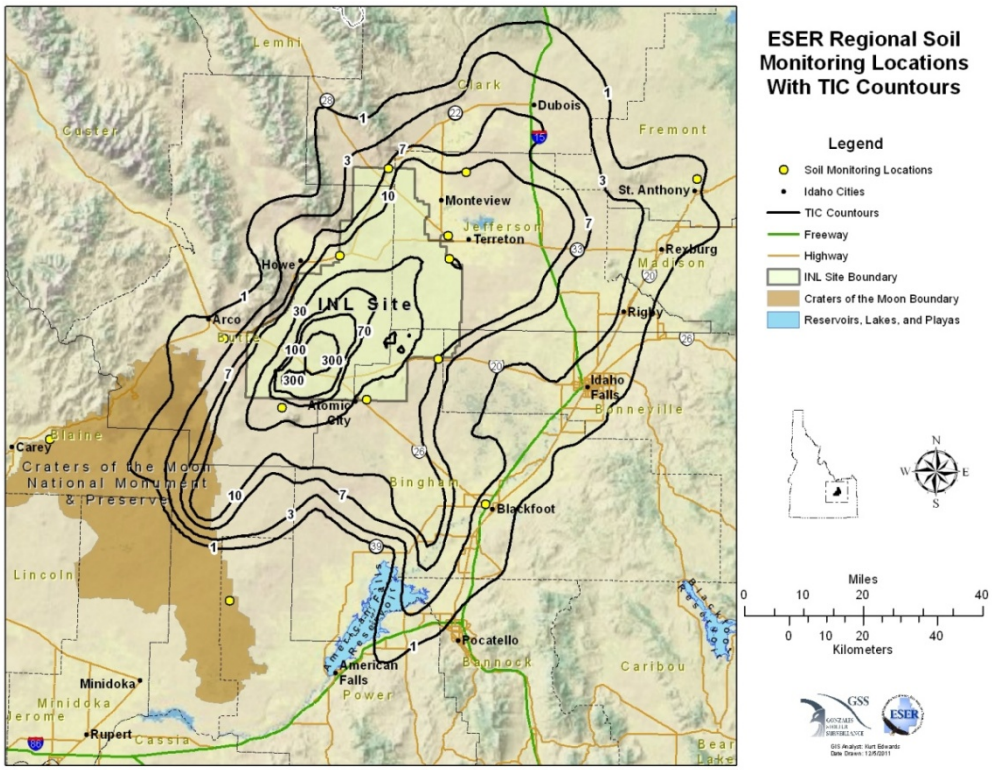

Figure 10-4. Off-Site soil-monitoring locations with air-concentration isopleths.

10.6.2 Frequency of Collection

10.6.2.1 On-Site

Soils are analyzed on a yearly rotation schedule around all INL Site facilities and regionally using portable in situ gamma spectrometers capable of detecting gamma-emitting radionuclides.

Soil monitoring activities are conducted primarily to determine if long-term deposition of airborne materials released from INL Site facilities have resulted in a build-up of radionuclides in the environment. Soils are analyzed on a yearly rotation schedule around all INL Site facilities and regionally using portable in situ gamma spectrometers capable of detecting gamma-emitting radionuclides. Roadways and Site facility perimeters are monitored on an annual basis using vehicle-mounted radiation detectors. These systems provide background-corrected count rate and isotopic concentration data, which is mapped for each measured roadway or facility perimeter. Geostatistical and trend analyses are performed on the radiological data to evaluate the soil radionuclide concentrations over time at the INL Site (DOE 2013).

10.6.2.2 Off-Site

Soil samples are used to establish background levels of radionuclides (both natural and those resulting from fallout from nuclear weapons testing) and to detect any long-term buildup of radionuclides from the INL Site in off-Site soils. Soil is taken from 12 off-Site locations during even-numbered years for Sr-90 and transuranic and gamma-emitting radionuclide analyses (DOE 2013) based on historical results (Figure 10-5). These results show a downward trend due to radioactive decay as well as a lack of buildup indicating that there is no consistent source of anthropogenic radiation contributing to off-Site soil concentrations. Based on these results, the downward trend of concentrations, the low rates of deposition, and the very small likelihood of unknown release events, biennial sampling will adequately assess whether additional contamination was added to off-Site soils.

10.6.3 Sampling Methods

10.6.3.1 On-Site

BEA began using in-situ measurements using portable detectors that are designed for rapid determination of gamma-ray-emitting radionuclides present in INL Site soils in 1999. The near real-time in-situ gamma measurements have a number of advantages over conventional soil sampling and laboratory analyses, including the ability to evaluate inhomogeneous materials and to measure radioactivity over a relatively large area (about 60 ft radius; 3 to 4 in. depth), providing a measurement of exposure less influenced by localized heterogeneity in the soil. In-situ measurements are also more cost effective than grab samples when the sample population consists of more than 50–100 points. However, exclusive use of in-situ gamma measurement does not provide data for non-gamma emitters such as Sr–90. Measurements are performed using portable high-purity germanium radiation detectors. These detectors allow for collection of high-resolution gamma-ray spectra at each measurement location. Data is stored locally and then analyzed using the method outlined in DOE (1997). This analysis was developed by the DOE Environmental Measurements Laboratory and uses raw spectral data combined with detector information and soil depth profiles to calculate soil radionuclide concentrations.

Although Cs–137 is a good indicator of trends and potential issues, BEA is evaluating the feasibility of collecting soil samples for laboratory analyses for radionuclides generally not detectable by the in-situ system, such as plutonium isotopes and Sr–90. DOE 1991 states, “it is desirable to assess, document, and periodically reassess the distribution and fate of radionuclides in the environment, especially plutonium in soil samples.” This evaluation will be coordinated with the previously mentioned plan to assess collocating soil and air sample locations in the future.

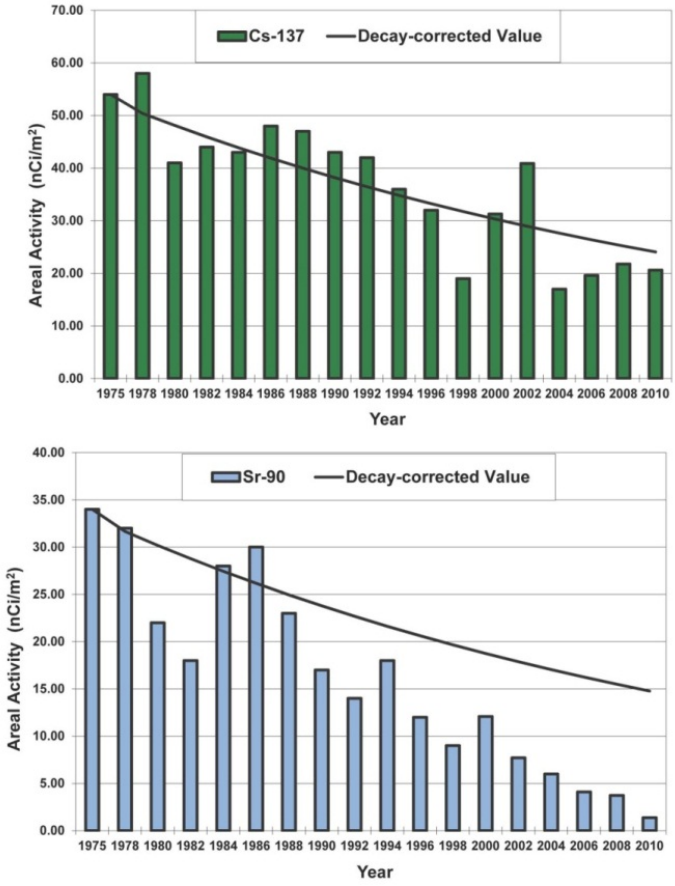

Figure 10-5. Historical radionuclide concentrations in off-Site soils outside the INL Site boundary.

10.6.3.2 Off-Site

Each off-Site environmental surveillance program sample is a composite of five cores from one of two depths: 0–5 cm and 5–10 cm. All samples are analyzed for gamma-emitting radionuclides; samples from the 0–5 cm depth are also analyzed for Sr–90 and transuranics (Pu–238, Pu–239/240, and Am–241). Samples are taken from the corners and center of a 10-m grid at each sample location. The 5 samples from 0–5 cm and 5–10 cm are composited in separate containers and oven-dried before submittal for analysis.

Due to distance, low predicted concentrations, and low precipitation (8 in. annually) sampling the top 10 cm of soil biennially will permit sufficient data to determine if:

- Radionuclides from the INL Site reach locations off-Site
- Radionuclides build-up in soil over time
- Radionuclides exceed historical values
- Soil concentrations of these radionuclides in off-Site locations exceed Federal Guidance levels (EPA 1993)
- Soil concentrations pose a hazard to the public or biota.

Samples are normally submitted for analysis when all of the samples for a year have been collected and processed (once annually). Optionally, samples may be submitted in smaller groups as they are prepared, particularly those samples being analyzed for gamma spectrometry. Five hundred milliliter Marinelli containers are submitted to a subcontracted laboratory for gamma spectrometry, and the 70-ml vials are submitted to a subcontracted laboratory for Sr–90 and transuranic analyses.

10.6.4 Analytical Methods

On-Site soils are analyzed in the field for gamma-emitting radionuclides using in-situ portable detectors described in Section 10.6.3.1. Detection capabilities are described in Section 10.7.1.

Off-Site soil samples are placed in 500-ml Marinelli containers and analyzed in the laboratory for gamma-emitting radionuclides using gamma spectrometry. Subsamples are placed in small vials and sent to the radiochemistry laboratory for analysis for strontium-90 and transuranics. The radionuclides of interest are separated chemically and then counted using a beta spectrometer for strontium-90 and alpha spectrometer. The separation methods were developed using the DOE Environmental Measurement Laboratory (EML) procedures manual (HASL-300), which may found at (http://www.orau.org/ptp/PTP%20Library/library/DOE/eml/hasl300/HASL300TOC.htm.

The sample volumes and counting times are driven by the desired minimum detection limits (Table 10-1).

Table 10-1. Detection limits for radionuclides in ESER environmental surveillance soil samples.

Approximate sample size	Radionuclide	MDA (pCi per sample)	MDC (pCi/g)
500 mL (~750 g)	Cs–137[a]	0.7	0.001
5 g	Am–241	0.029	0.006
5 g	Pu–238	0.022	0.004
5 g	Pu–239	0.022	0.004
5 g	Sr–90	0.215	0.043

10.7 Radionuclides Assessed

10.7.1 On-Site

In response to the HSS 2010 assessment (HSS 2010), BEA reports other isotopes in addition to Cs–137 through the in-situ measurement technique. Table 10-2 shows a representative list of these isotopes along with historical background values and estimated minimum detectable concentrations based on an 8-hour count time. Minimum detectable concentrations are influenced by many factors, including gamma-ray energy, gamma-ray intensity, soil composition, soil moisture, geometry (detector size and height above ground), amount of naturally occurring soil radionuclides, and external sources of radiation. As mentioned, BEA is evaluating future physical soil sampling and analyses for non-gamma emitters (uranium-234 and plutonium isotopes; strontium–90) at an off-Site laboratory because these isotopes are not detectable using in-situ detectors.

Table 10-2. BEA nuclides of interest and detection limits for soils.

Current Nuclides of Interest	$t_{½}$	INL Background (pCi/g)	Estimated MDC (pCi/g)
Co-60	5.27y		0.0009
Sb-125	2.8y		0.004
Cs-134	2.1y		0.005
Cs-137	30.17y	0.96	0.0018
Eu-152	13.5y		0.014
U-235	7.04E+8y		0.036
U-238	4.47E+9y	1.54	0.11
Am-241	432.7y	0.014	0.014

10.7.2 Off-Site

Although many different radionuclides have resulted from INL Site operations (DOE-ID 2011), it is impractical and cost-prohibitive to perform complete analyses on them all. Therefore, radionuclides that contribute significantly to dose are readily taken up by the body and that build up in the environment were assessed. Radionuclides historically assessed in soils collected around the INL Site are (DOE-ID 2011):

- Gamma–emitting radionuclides (with cesium–137 being the gamma emitter of interest)
- Strontium–90
- Transuranics (plutonium–238, plutonium–239/240, and americium–241). These transuranics were selected because they are often measured in INL Site effluents (DOE-ID 2011) and could be distributed and deposited on soils off of the INL Site.

Strontium–90 is an important radionuclide because it behaves like calcium and can deposit in bones. Strontium–90, like cesium–137, is produced in high yields from nuclear reactors or detonations of nuclear weapons. It has a half-life of 28 years and can persist in the environment. Strontium tends to form compounds that are soluble, compared to cesium–137, and is therefore comparatively mobile in ecosystems (DOE-ID 2011). About 8% of the ingested activity remains in the body after 30 days, and this decreases to about 4% after 1 year. This activity is mainly in the skeleton. Strontium preferentially adheres to soil particles, and the amount in sandy soil is typically about 15 times higher than in interstitial water (in the pore spaces between soil particles); concentration ratios are typically even higher (110 times the concentration in solution) in clay soil (ANL 2007).

Cesium–137 is chemically analogous to potassium in the environment and behaves similarly. It has a half-life of about 30 years and tends to persist in soil, and, if in soluble form, 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 re-suspension of previously contaminated soil particles (DOE-ID 2011). Cesium tends to concentrate in muscles because of their relatively large mass. Like potassium, cesium is excreted from the body fairly quickly. In an adult, 10% is excreted with a biological half-life of 2 days, and the rest leaves the body with a biological half-life of 110 days. Clearance from the body is somewhat quicker for children and adolescents. This means that if someone is exposed to radioactive cesium and the source of exposure is removed, much of the cesium will readily clear the body along the normal pathways for potassium excretion within several months.

Atmospheric testing of nuclear weapons, which ceased worldwide by 1980, generated most environmental americium and plutonium. Accidents and other releases from weapons-production facilities have caused localized contamination. Americium oxide is the most common form in the environment. Average americium–241 levels in surface soil are about 0.01 pCi/g. Americium is typically quite insoluble, although a small fraction can become soluble through chemical and biological processes. It adheres very strongly to soil, with americium concentrations associated with sandy soil particles estimated to be 1,900 times higher than in interstitial water (the water in the pore spaces between the soil particles); it binds more tightly to loam and clay soils, so those concentration ratios are even higher. At DOE sites such as Hanford, americium can be present in areas that contain waste from the processing of irradiated fuel (ANL 2007).

Americium can be taken into the body by eating food, drinking water, or breathing air. Gastrointestinal absorption from food or water is a likely source of internally deposited americium in the general population. After ingestion or inhalation, most americium is excreted from the body within a few days and never enters the bloodstream; only about 0.05% of the amount taken into the body by ingestion is absorbed into the blood. After leaving the intestine or lung, about 10% clears the body. The fraction that enters the bloodstream deposits about equally in the liver and skeleton, where it remains for long periods of time with biological retention half-lives of about 20 and 50 years, respectively (per simplified models that do not reflect intermediate redistribution). The amount deposited in the liver and skeleton depends on the age of the individual, with fractional uptake in the liver increasing with age. Americium in the skeleton is deposited uniformly on cortical and trabecular surfaces of bones and slowly redistributes throughout the volume of mineral bone over time.

About 10,000 kg of plutonium were released to the atmosphere during weapons tests. Average plutonium levels in surface soil from fallout range from about 0.01 to 0.1 picocurie per gram (pCi/g). Accidents and other releases from weapons production facilities have caused greater localized contamination. The most common form in the environment is plutonium oxide. Plutonium is typically very insoluble, with the oxide being less soluble in water than ordinary sand (quartz). It adheres tightly to soil particles and tends to remain in the top few centimeters of soil as the oxide. In aquatic systems, plutonium tends to settle out and adhere strongly to sediments, again remaining in upper layers. Typically one part of plutonium will remain in solution for every 2,000 parts in sediment or soil. A small fraction of plutonium in soil can become soluble through chemical or biological processes, depending on its chemical form. While plutonium can bioconcentrate in aquatic organisms, data have not indicated that it biomagnifies in aquatic or terrestrial food chains. When plutonium is inhaled, a significant fraction can move from the lungs through the blood to other organs, depending on the solubility of the compound. Little plutonium (about 0.05%) is absorbed from the gastrointestinal tract after ingestion, and little is absorbed through the skin following dermal contact. After leaving the intestine or lung, about 10% clears the body. The fraction that enters the bloodstream deposits about equally in the liver and skeleton, where it remains for long periods of time with biological retention half-lives of about 20 and 50 years, respectively, per simplified models that do not reflect intermediate redistribution. The amount deposited

in the liver and skeleton depends on the age of the individual, with fractional uptake in the liver increasing with age. Plutonium in the skeleton deposits on the cortical and trabecular surfaces of bones and slowly redistributes throughout the volume of mineral bone with time.

Iodine–129 cannot easily be measured on an air filters using low-energy gamma spectrometry due to the long half-life (15.7 million years) and small amount present in air. Mass spectrometry is typically used on environmental samples. Because historical INL Site releases of I-129 (~0.2 Ci, according to R. C. Morris, Unpublished Report), have been deposited in the INL Site environment, primarily in soil, it would be more appropriate to measure I–129 in soil. Other studies on the INL Site have shown uptake of I-129 by biota (Markham et al. 1983; Fraley, Bowman and Markham 1984; Halford and Markham 1984). Of the fourteen major radioactive isotopes of iodine, only iodine–129 has a half-life sufficiently long to warrant concern for DOE environmental management sites. Iodine–129 decays by emitting a beta particle with a half-life of about 16 million years; the half-lives of all other iodine radionuclides are less than 60 days. The very long half-life of iodine–129 (with its subsequent low specific activity) combined with the low energy of its beta particle and minimal gamma radiation limit the hazards of this radionuclide. Future soil monitoring may involve analyzing a representative subset of samples for I-129 for comparison to historical INL Site releases to determine if this radionuclide is present in INL Site soils above expected concentrations. Iodine–131 has a short half-life (8 days) and is not generally a major isotope of concern for DOE environmental management sites (ANL 2007).

10.8 Quality Assurance

The QA programs are detailed in their respective documents, for example the Offsite Environmental Surveillance Program Quality Assurance Project Plan (QAPjP) and the on-Site BEA Surveillance Plan.

10.8.1 Onsite

Measurement acquisition times are 3600 seconds at each location. Duplicate measurements are performed at 10% of the yearly locations. These are performed using a different detector than was used for the original count. Duplicate measurements with different detectors are completed to demonstrate that the method is repeatable. Repeating the measurement with the same detector is likely to give the same, or nearly the same, answer within the realm of counting statistics. Being able to obtain the same answer with different instruments lends credibility to calibration and data collection and analysis methodologies. Annual detector energy and efficiency calibrations and daily detector quality control checks are performed using NIST-traceable gamma-ray mixed-isotope point sources.

10.8.2 Off-Site

Quality assurance and quality-control (QA/QC) samples are analyzed in addition to field samples and provide information on the variability and usability of environmental sample results. They assist in identifying the origin of analytical discrepancies to help determine how the analytical results should be used. They are used mostly to validate analytical results. Field replicated, collocated, background, and rinsate blank samples are the most commonly collected field QA/QC samples. Performance evaluation, matrix spike, and matrix-spike duplicate samples, either prepared for or by the laboratory, provide additional measures of control for the data generated. QA/QC results may suggest the need for modifying sample collection, preparation, handling, or analytical procedures if the resultant data do not meet site-specific quality assurance objectives.

10.9 Decision Limits and Actions

DOE radiological activities (DOE 2011) must be conducted so that exposure of members of the public to ionizing radiation will not cause:

- A TED exceeding 100 mrem (1 mSv) in a year
- An equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year

- An equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose excepting:
  - Dose from radon and its decay products in air. (Radon is regulated separately, e.g., under Paragraphs 4.f. and 4.h.[1][d] in this Order and under 40 CFR 61, Subparts Q and T.)
  - Dose received by patients from medical sources of radiation, and by volunteers in medical research programs.
  - Dose from background radiation.
  - Dose from occupational exposure under NRC or Agreement State license or to general employees regulated under 10 CFR 835 and DOE O 458.1 (DOE 2011).

If measured radionuclide concentrations exceed the BEA posting criteria for a soil contamination area, then the results will be discussed with the appropriate BEA operational personnel.

While there are no specific DOE limits for radionuclide concentrations in soil, concentration guides have been developed for areas decontaminated and decommissioned at the INL Site (EGG 1986). These guides provide concentrations which could result in a dose of 100 mrem/yr during the first year after cleanup and release of the property. The guides were derived assuming a conservative farming scenario (i.e., a farm is established on the contaminated soil and food is grown on that soil and consumed by the farmer.) The guides for radionuclides of interest to the surveillance programs are:

- Sr–90 50 pCi/g
- Cs–137 10 pCi/g
- Co–60 4 pCi/g
- Pu-–238, 239, 240 300 pCi/g
- Am–241 80 pCi/g

Radionuclide concentrations detected in soils collected on-Site and regionally are reported in the INL Site Annual Site Environmental Report (DOE-ID 2011). The maximum concentrations of radionuclides in INL Site soils have never exceeded the concentrations guides shown above.

In light of this, the surveillance programs look for instances when background or historical measurements are exceeded. For the on-Site program, soil concentrations exceeding three times background are investigated and, if verified, using a duplicate measurement with a different detector (see section 10.8.1), are communicated to DOE-ID. When soil concentrations exceeding three times background are verified, additional investigations will be completed in the field to begin characterizing the concentrations, extent, and potential source. At that time additional investigations could be planned to determine concentrations of non-gamma emitting radionuclides through soil sampling and laboratory analysis. The ESER environmental surveillance program has developed action levels for the laboratory to use as criteria to immediately notify ESER personnel if an unusual result is observed. The action levels were developed based on an assessment of ten years of data. The action levels developed for soil samples are shown in Table 10-3.

Table 10-3. Action levels for radionuclides measured in soil by the ESER environmental surveillance program.

Radionuclide	Action level
Gross Alpha	5E–15 µCi/mL
Gross Beta	8E–14 µCi/mL
Cs–137	1.25E-06 µCi/g
I–131	$>3\sigma$[a]
Sr–90	4.0E-07 µCi/g
Pu–238	8.0E-08 µCi/g
Pu–239, 240	6.9E-08 µCi/g
Am–241	4.0E-08 µCi/g

a. σ is the counting uncertainty reported with each result.

If radionuclides detected are above background and exceed the action levels established in Table 10-3, ESER personnel first determine whether the concentration is an anomalous measurement through one of the following methods:

- Review of historical monitoring results at that location to see if the measurement is consistent with past monitoring results
- Consultation with other INL Site surveillance components and the Idaho DEQ INL Oversight Program
- Review to determine if this location is affected by recent activities or events
- Review of any other factors which may have contributed to the result.

10.10 References

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11. AGRICULTURAL (FOOD) PRODUCTS

11.1 Program Basis

The determination of radionuclide concentration in the diet or individual food items constitutes an important element of an integrated program of radiological surveillance and assessment. Food is analyzed to determine: 1) the level of contamination at the point of production, or 2) the level of intake of the contaminant for the consumer or a particular population group (DOE 1997). For surveillance purposes for the INL Site, the first factor is most applicable due to the low levels of anticipated contamination and the distances of major population zones from the INL Site.

One method of food monitoring is to sample individual foods at the point of production. This is most useful for relating contaminations to local conditions of fallout, soil content, or farming practice (DOE 1997). The geographic area to be sampled is generally relatively small. This sampling system is used, for example, by the Food and Drug Administration (FDA) in their program of food monitoring near power reactors (Stroube and Jelinek 1985).

As specified in U. S. Department of Energy Regulatory Guide 0173T (DOE 1991), representative samples of the pathway-significant agricultural products grown within 10 miles (16 km) 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: the place of expected maximum radionuclide concentrations and a background location unlikely to be affected by radionuclides released from the site.

Additionally, cow milk, and in certain localities goat milk, is widely consumed by all age groups. Therefore, milk is frequently one of the most important foods contributing to the radiation dose to people if dairy animals are pastured near a nuclear site. If dairy herds or “family” cows (or goats) are present in the vicinity of the site (within 10 miles), representative milk samples should be taken and analyzed for radionuclides potentially present from site operations. The frequency of sampling will depend on the magnitude of the radiation doses potentially received via this source. No particular sampling techniques are required, other than to guard against cross-contamination and souring or curdling of the milk. For the levels of contamination expected at most DOE sites, a 4 L sample is necessary to achieve the required detection level. However, for goat’s milk, a 1 L sample may be all that can be obtained, especially from a single goat.

Guide 0173T (DOE 1991) also recommends vegetation sampling. Vegetation includes three categories: vegetables, grains, and fruit. (If vegetation [i.e., vegetables, grains, and fruit] is not one of the contributing pathways involved in determining the dose to humans from the site, native vegetation can be used as indicator species.) Collection and analysis of vegetation samples can serve three useful purposes: evaluating the potential radiation doses received by people consuming such vegetation; estimating the possible concentrations in meat, eggs, and milk from animals consuming contaminated forage (and resultant radiation doses to consumers of the animal products); and monitoring trends in environmental contamination and possible long-term accumulation of radionuclides.

11.2 Program Drivers

Monitoring agricultural products outside the INL Site boundaries:

- Addresses monitoring in Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE 1991)
- Provides data to assess public and environmental impacts
- Assesses the movement (quantity and extent) of INL Site Operations-produced radionuclides off-Site (by determining where and how much)

- Addresses stakeholder and public concerns regarding media, locations, and parameters that should be monitored.

Off-Site environmental surveillance uses these data to determine whether unacceptable risk exists and to determine the nature and extent of the contamination leading to this risk.

11.3 Related Studies/Surveillance

The earliest records on file for agricultural sampling around the INL Site are from a 1966 annual report (AEC 1968). The report states that "all samples collected in 1966 were found to be below applicable AEC (Atomic Energy Commission) guide values." Agricultural sampling has continued with current and historical results (DOE-ID 2011) being comparable to those reported over 40 years ago (AEC 1968).

The current agricultural program, locations, and sampled media (Figure 11-1) fulfill several recommendations of DOE Regulatory Guide 0173T (DOE 1991):

- Sampling considers pathway-significant agricultural products grown and collected within 10 miles of the INL Site
- The samples are collected in at least two locations: the place of expected maximum radionuclide concentrations and a "background" location unlikely to be affected by radionuclides released from the site
- If dairy herds or "family" cows (or goats) are present in the vicinity of the site (within 10 miles), representative milk samples are taken and analyzed for radionuclides potentially present from site operations
- The sampling considers representative vegetation (fruits, grains, and vegetables).

11.4 Program Goals

The primary aim of agricultural product sampling is to get accurate data about the concentration levels of INL Site-related radionuclides in agricultural products consumed by humans and farm animals in order to evaluate potential public health and environmental impacts from INL Site operations. The sampling that the environmental surveillance program conducts must evaluate the potential pathways of exposure to radionuclides in off-Site agricultural products by:

- Determining whether INL Site-related radionuclides reach off-Site receptors in this pathway
- Evaluating the likelihood of ingestion of farm grown and homegrown produce that may have been contaminated via INL Site operations
- Distinguishing these radionuclides as background, fallout, or within historical levels previously measured resulting from INL Site operations
- Determining when agricultural product radionuclide concentrations in off-Site locations exceed or are approaching regulatory limits
- Identifying when agricultural product concentrations in off-Site locations pose a hazard to the public.

The results of environmental surveillance identify whether radionuclides have been transported off-Site and allow us to assess what the impacts are to human populations. The results require further assessment when they:

- Exceed background measurements
- Demonstrate an increasing trend over time
- Result in an estimated dose to a member of the public which approaches regulatory limits.

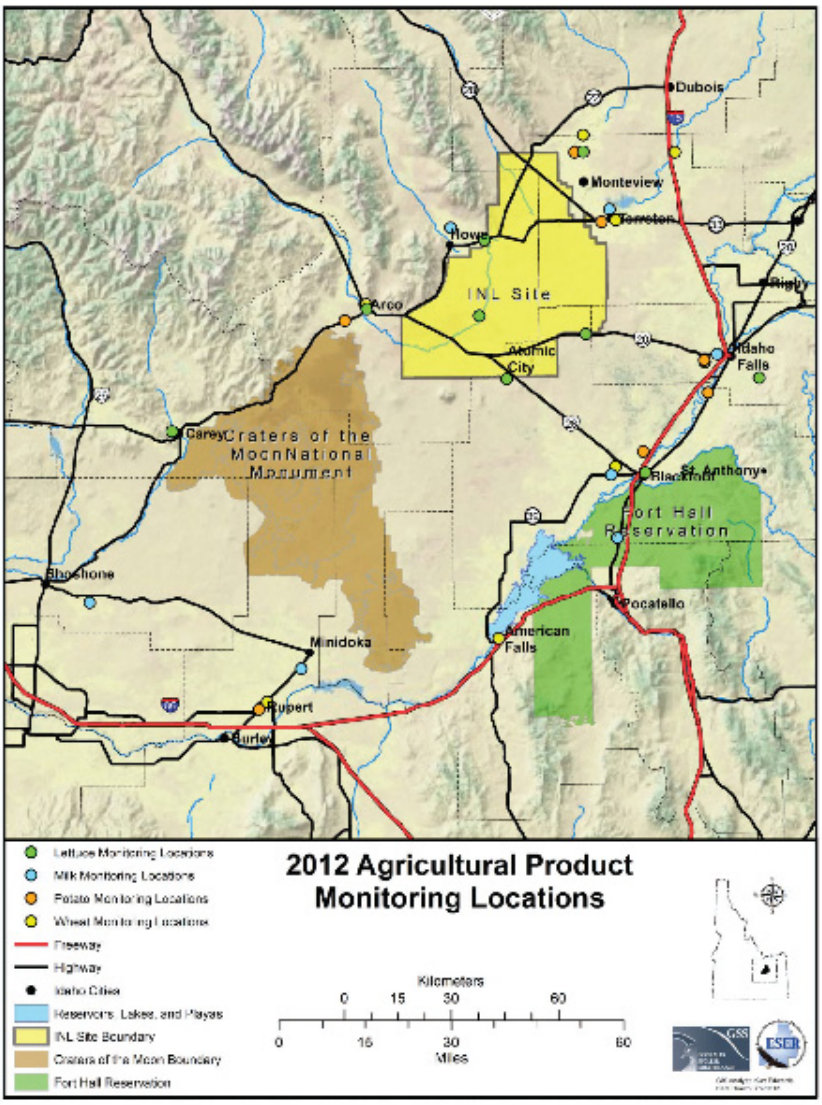

Figure 11-1. Agricultural product sampling locations around the INL Site.

11.5 Sampling Boundaries

As stated in Regulatory Guide 0173T (DOE 1991) samples should be collected 10 miles from the INL Site. Thus, sampling boundaries should focus on agricultural areas within this area. Due to the size and irregularity of the INL Site boundary, the area of focus would be within 10 miles of the boundary (Figure 11-1). However, locations outside this area can be sampled to evaluate the downwind extent of distribution.

11.6 Sampling Design

As per Regulatory Guide 0173T (DOE 1991), samples will be taken inside 10 miles from the INL Site boundary (Figure 11-1). Sampling plots are selected to represent areas within this area as well as representing locations that may receive the highest concentrations from wind distributed radionuclides (Figure 11-2). To assess distribution distances and impacts of radionuclides from INL Site operations, agricultural samples are taken from areas outside of the 10-mile radius recommended by DOE Regulatory Guide 0173T (DOE 1991) (Figure 11-1).

Samples representing grain, vegetables and milk will be taken. Since fruit is not a major agricultural product in this region (see Chapter 2) this food type will not be evaluated. Although historically sampled, the last beef samples were collected in 1986. Beef sample collection was suspended because they grazed infrequently on the site and historical data indicated radionuclide levels were essentially background. Sheep that grazed on the INL Site were sampled annually through 2006. Data indicated that radionuclides detected in INL samples were not different than those collected at control locations and have not changed since 2002 (DOE-ID 2007). Therefore, sampling this media was discontinued after 2006. Neither of these animals have access to INL Site institutionally controlled waste areas.

11.6.1 Frequency of Collection

The representative food samples for southeastern Idaho in the 10-mile area outside of the INL Site are collected at the following frequencies:

- Lettuce (vegetables, sampled annually when available)
- Wheat and barley (grain, sampled annually during fall harvest)
- Potatoes (subterranean vegetables, sampled annually during fall harvest)
- Milk (sampled weekly in Idaho Falls and monthly in dairies near INL Site)
- Alfalfa (sampled annually after the first cutting of summer, beginning in 2010 at the recommendation of the Office of Health, Safety and Security [HSS 2010]).

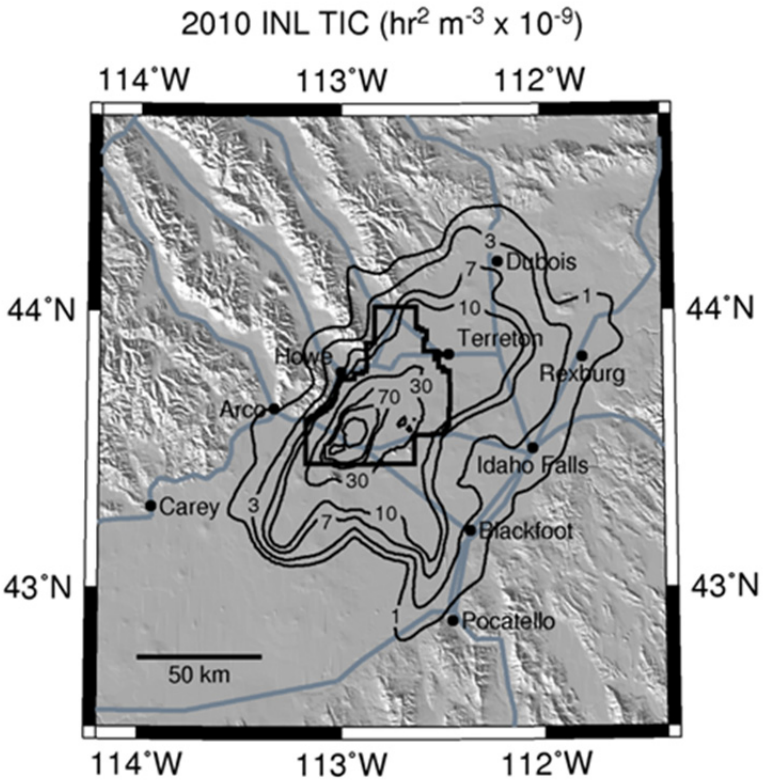

Figure 11-2. Time-integrated concentrations based on NOAA meteorological monitoring data at the INL Site (DOE-ID 2011).

11.6.2 Sampling Methods

Lettuce samples are collected from locations bordering the INL Site and at locations distant from the INL Site (Figure 11-1). Samples are collected annually from private gardens and analyzed for gamma-emitting radionuclides and strontium–90. The off-Site environmental surveillance program also uses prototype self-contained lettuce planters at the sampling locations in Atomic City and at the Experimental Field Station on the INL Site and at FAA Tower, Arco, and Monteview off the INL Site. These locations are relatively remote and have no access to water, requiring that a self-watering system be developed. This method allows for the placement and collection of lettuce at areas previously unavailable to the public (i.e., on the INL Site). The planters are set out in the spring with lettuce grown from seed. This method also allows for the accumulation of deposited radionuclides on the plant surface throughout the growth cycle. Lettuce samples are processed, dried, and sent to analytical laboratories.

Wheat samples are collected annually from local growers at 12 locations around the INL Site (and one outside of the state of Idaho) annually (Figure 11-1). The samples are collected from combines or trucks. The samples are sent to analytical laboratories and analyzed for gamma-emitting radionuclides and strontium–90.

Potato samples are collected annually from local potato growers at nine locations around the INL Site (Figure 11-1) and at least location outside of Idaho. The samples are dried and processed and sent to analytical laboratories for analysis for gamma-emitting radionuclides and strontium-90.

Milk is collected weekly at Reed's Dairy in Idaho Falls and monthly at six dairies outside and within 50 miles of the INL Site boundary (Figure 11-1). Samples are sent to analytical laboratories for analysis for gamma-emitting radionuclides and strontium-90.

11.7 Analytical Methods

Potato and lettuce samples are processed, dried, milled, placed in small vials and sent to the analytical laboratories for analysis for strontium-90 and gamma-emitting radionuclides. Forage samples are dried and milled and analyzed for gamma-emitting radionuclides. Wheat samples are sent to the laboratories for the same analyses, but are not dried or milled. Milk is sent to the laboratories in 2-liter containers for analysis for gamma-emitting radionuclides and for strontium–90. Half of the samples are also analyzed for tritium. The radionuclides of interest are separated chemically and then counted using a beta spectrometer for strontium–90.

The separation and analysis methods were developed using the DOE Environmental Measurement Laboratory (EML) procedures manual (HASL-300), which may found at http://www.orau.org/ptp/PTP%20Library/library/DOE/eml/hasl300/HASL300TOC.htm.

The sample volumes and counting times are driven by the desired minimum detection limits (Table 11-1).

Table 11-1. Detection limits for radionuclides in ESER environmental surveillance agricultural product samples.

Medium	Approximate sample size	Radionuclide	MDA (pCi per sample)	MDC (pCi /L or pCi/g)
Milk	0.5 L	Sr–90	0.15	0.3
	1 L	Cs–137	1.2	1.2
	150 mL	H–3	13	87
Potato	5 g	Sr–90	0.215	0.043
	500 g	Cs–137	0.7	0.0014
Lettuce	5 g	Sr–90	0.215	0.043
	12 g	Cs–137	0.7	0.14
Wheat	5 g	Sr–90	0.215	0.043
	500 g	Cs–137	0.7	0.14
Forage	5 g	Sr–90	0.215	0.043
	12 g	Cs–137	0.7	0.14

11.8 Radionuclides Assessed

Although there are several more radionuclides, it is impractical and cost-prohibitive to perform complete analyses on all of them. Therefore, radionuclides that contribute significantly to dose and are readily taken up by the body should be assessed. Radiological analyses historically performed on agricultural products collected near the INL Site are (DOE-ID 2011):

- Gamma spectrometry in all media (with cesium–137 being the gamma emitter of interest)
- Gamma spectrometry of alfalfa
- Strontium–90 in potatoes, grain and lettuce
- Strontium–90, tritium, and iodine–131 in milk.

Strontium–90 is an important radionuclide because it behaves like calcium and can deposit in bones. Strontium–90, like cesium–137, is produced in high yields from nuclear reactors or detonations of nuclear weapons. It has a half-life of 28 years and can persist in the environment. Strontium tends to form compounds that are soluble, compared to cesium–137, and therefore comparatively mobile in ecosystems (DOE-ID 2011). About 8% of the ingested activity remains in the body after 30 days, and this decreases to about 4% after 1 year. This activity is mainly in the skeleton. Strontium preferentially adheres to soil particles, and the amount in sandy soil is typically about 15 times higher than in interstitial water (in the pore spaces between soil particles); concentration ratios are typically even higher (110 times the concentration in solution) in clay soil (ANL 2007).

Cesium–137 (gamma spectrometry), the predominant gamma-emitter and largest gamma contributor to dose for waterfowl (Halford, Millard, and Markham 1981) (assuming it behaves similarly no matter which media it is from), is chemically analogous to potassium in the environment and behaves similarly. It has a half-life of about 30 years and tends to persist in soil and, in soluble form, can readily enter the food chain through plants. It is widely distributed throughout the world from historic nuclear weapons detonations from the period between 1945 and 1980 and has been detected in all environmental media at the INL Site. Regional sources of cesium include releases from INL Site facilities and re-suspension of previously contaminated soil particles (DOE-ID 2011). Cesium tends to concentrate in muscles because of their relatively large mass. Like potassium, cesium is excreted from the body fairly quickly. In an

adult, 10% is excreted with a biological half-life of 2 days, and the rest leaves the body with a biological half-life of 110 days. Clearance from the body is somewhat quicker for children and adolescents. This means that if someone is exposed to radioactive cesium and the source of exposure is removed, much of the cesium will readily clear the body along the normal pathways for potassium excretion within several months.

Iodine is an essential nutrient element and is readily assimilated by cows eating 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 cesium–137, can dominate the ingestion dose regionally after a severe nuclear event such as the Chernobyl accident (Kirchner 1994). Iodine–131 has a short half-life (8 days) and, therefore, does not persist in the environment. Iodine can be taken into the body by eating food, drinking water, or breathing air. It is a constituent of thyroid hormone and, as such, is a required element for humans. Iodine is readily taken into the bloodstream from both the lungs and the gastrointestinal tract (essentially 100%) after inhalation and ingestion. Upon entering the bloodstream, 30% is deposited in the thyroid, 20% is quickly excreted in feces, and the remainder is eliminated from the body within a short time (per simplified models that do not reflect intermediate redistribution) (ANL 2007).

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 it 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 animals drink, as well as in plants that contain water (DOE-ID 2011). Tritium can be taken into the body by drinking water, eating food, or breathing air. It can also be taken in through the skin. Nearly all (up to 99%) inhaled HTO can be taken into the body from the lungs, and circulating blood then distributes it to all tissues. Ingested tritium oxide is also almost completely absorbed, moving quickly from the gastrointestinal tract to the bloodstream. Within minutes it is found in varying concentrations in body fluids, organs, and other tissues. Skin absorption of airborne tritium oxide can also be a significant route of uptake, especially for exposure to high concentrations of tritiated water vapor, as could occur under conditions of high humidity during hot weather, because of the normal movement of water through the skin. For someone immersed in a cloud of airborne HTO, the uptake by absorption through the skin would be about half that associated with inhalation. No matter how it is taken into the body, tritium is uniformly distributed through all biological fluids within one to two hours. Tritium is eliminated from the body with a biological half-life of 10 days, the same as for water. During the time it is in the body, a small fraction of the tritium is incorporated into easily exchanged hydrogen sites in organic molecules (ANL 2007).

11.9 Quality Assurance

The ESER environmental surveillance program employs an effective quality assurance (QA) program to ensure the collection of high quality data. The program is detailed in the Offsite Environmental Surveillance Program Quality Assurance Project Plan (QAPjP). The QAPjP serves to ensure that all data collected are of known and defensible quality, and to meet the requirements of all applicable federal and state regulations and United States Department of Energy (DOE) orders, specifically DOE Order 414.1A, ASMENQA-1-2000, EPA QA/R-5, ANSI/ASQC E-4, IDQTF UFP-QAPP and ISO 9000.

11.10 Decision Limits and Actions

DOE radiological activities (DOE 2011) must be conducted so that exposure of members of the public to ionizing radiation will not cause:

- A TED exceeding 100 mrem (1 mSv) in a year
- An equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year

- An equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose excepting:
  - Dose from radon and its decay products in air. (Radon is regulated separately e.g., under Paragraphs 4.f. and 4.h.[1][d] in this Order and under 40 CFR 61, Subparts Q and T.)
  - Dose received by patients from medical sources of radiation, and by volunteers in medical research programs.
  - Dose from background radiation.
  - Dose from occupational exposure under NRC or agreement state license or to general employees regulated by 10 CFR Part 835, and DOE Order 458.1.
  - The results of years of environmental monitoring by the ESER environmental surveillance program around the INL Site show that DOE dose limits have never been exceeded or even approached off the INL Site. The surveillance program thus looks for instances when background or historical measurements are exceeded. The ESER environmental surveillance program has developed action levels for the laboratory to use as criteria to immediately notify ESER personnel if an unusual result is observed. The action levels were developed based on an assessment of the last ten years of data (unpublished ESER assessment). The action levels developed for agricultural samples are shown in Table 11-2.

Table 11-2. Action levels for radionuclides measured in agricultural products by ESER the environmental surveillance program.

Radionuclide	Action level
Cs–137	>3σ[a]
I–131	>3σ
Sr–90 (milk)	2E-09 µCi/mL
Sr–90 (other)	2.5E-07 µCi/g

a. σ is the counting uncertainty reported with each result.

If radionuclides detected are above background and exceed historical levels, a determination of whether the concentration is an anomalous measurement will be made using one of the following methods:

- Review historical monitoring results at that location to see if the measurement is consistent with past monitoring results.
- Consult with the Idaho DEQ INL Oversight Program
- Review to determine if this location is affected by recent activities or events (e.g., Fukushima fallout event).
- Review any other factors which may have contributed to the result.

If the concentration is verified, it may signal the need for further action dependent upon the concentration level and/or a trend showing elevated concentrations over a period of time. Further investigation may include performing a calculation of the highest potential dose to humans using the conservative method of employing maximum radionuclide concentrations, or comparing detected concentration levels to other federal standards, such as the U.S. Food and Drug Administration's derived intervention levels, as was done during the Fukushima accident (FDA 2004)

11.11 References

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12. BIG GAME ANIMALS

12.1 Program Basis

Prior to 1984, no elk were known to reside on the INL Site, but by 1990 more than 200 elk were documented to be using the Site (Peek and Comer 2000) and continue to do so (Whiting 2010). Pronghorn (Hoskinson 1977) and deer (Reynolds et al. 1986) migrate through or reside on the INL Site as well. Both elk and pronghorn are known to be associated with radioactively contaminated areas and/or facilities on the INL Site and migrate from the INL Site (Hoskinson 1977, R. Long, Idaho State University, Personal Communication 2012). Therefore, some animals from the INL Site could be harvested by hunters because hunting is permitted one half mile inside the northeast border and up to three miles inside the northwest border of the INL Site. Some animals may also migrate long distances from the INL Site (Long 2013) and could be harvested by hunters.

Because these animals have historically been documented to uptake some level of radioactive contaminants (Markham et al. 1982, Markham, and Halford 1985, Markham et al. 1980, Markham, Halford and Autenrieth 1980), sampling of big game is important to ascertain the potential impacts of these contaminants on the animals as well as the humans potentially consuming them.

12.2 Program Drivers

Monitoring INL Site big game animals fulfills:

- Regulatory requirements for assessing the movement of radionuclides from the INL Site
- Regulatory requirements for assessing the protection of the public and environment
- Regulatory requirements for assessing the impacts to biota
- Desire to address public concern regarding movement of INL Site produced radionuclides off-Site
- Desire to address public concern that big game animals harvested near the INL Site may contain radionuclide concentrations above background levels.

12.3 Results of Related Studies/Surveillance

Vegetation contaminated by radionuclides released from INL Site facilities including buried waste areas (Warren 1999) could be consumed by big game animals present on the INL Site. Big game have been documented on the INL Site for decades, and a sampling program was established in the early 1970s (Markham et al. 1982; Markham and Halford 1985; Markham et al. 1980; Markham, Halford and Autenrieth 1980). Analyses indicated that big game could become contaminated with radionuclides and could not only receive a radiological dose themselves, but also potentially provide a dose to persons consuming them (Markham et al. 1982; Markham and Halford 1985; Markham et al. 1980; Markham, Halford and Autenrieth 1980). Thus, INL Site Operations could potentially impact big game coming in contact with radioactive-waste areas or contaminated areas outside of waste areas as well as moving contaminants off-Site and being harvested and consumed by the public. Therefore, there is a valid basis for sampling big game from the INL Site to assess the radionuclide concentrations. These data enable biota dose assessment to evaluate impacts on biota foraging and watering on the Site using INL Site waste ponds as well provide data to humans consuming big game potentially containing these radiological contaminants.

Historically, big game were observed and specifically collected by Idaho Department of Fish and Game for DOE-ID near INL Site Facilities (Markham et al. 1982; Markham and Halford 1985; Markham et al. 1980; Markham, Halford and Autenrieth 1980). This occurred through 1978. No big game samples were collected in 1979; in 1980, collection of road-killed animals began (DOE-ID 1981).

In 2011, at the recommendation of the Health, Safety and Security Assessment of the INL Site Environmental Monitoring Program (HSS 2010), vegetation samples were collected at areas frequented by elk (Figure 12-1). The vegetation species sampled were known elk forage species (based on field observations). Biased samples were collected from areas with the highest soil concentrations (collected by the on-Site contractor) near the Radioactive Waste Management Complex on the west side of the INL Site and analyzed for gamma and transuranic radionuclides. Water samples were also collected near the Materials and Fuels Complex (MFC) on the east side of the INL Site and analyzed for gamma radionuclides (Figure 12-1). Control samples were collected near Craters of the Moon National Monument (Figure 12-1). None of the gamma or transuranic results exceeded the action level (defined as exceeding 3 sigma). This may indicate that vegetation and water (from MFC) may not be a significant pathway in distributing radionuclides to game animals.

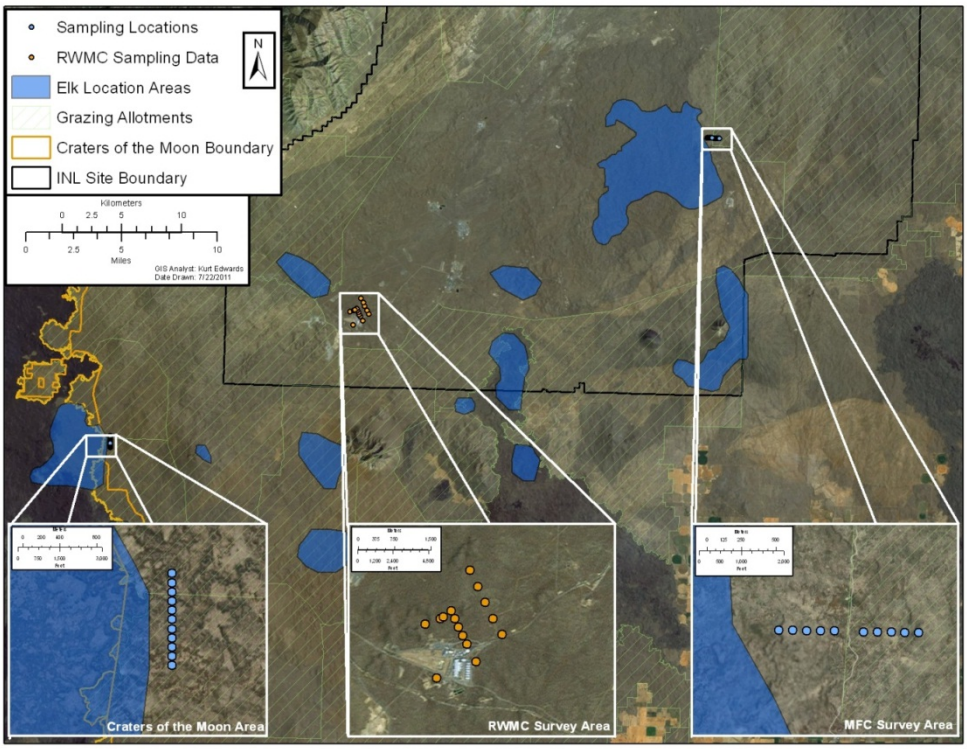

Figure 12-1. Elk forage sampling locations.

Due to limited water resources on the INL Site, radioactive waste ponds could provide a pathway for ingestion of radionuclides by big game animals. To ascertain this, cameras were placed at the MFC Industrial Waste Pond. The video observations indicated that all big game species (elk, pronghorn, and mule deer) on the INL Site used the pond as a water source (In Figure 12-2, the water is on the right. One elk is standing in the water and another is drinking). However, as described above, no detectable gamma or transuranic radionuclides were present in MFC water samples. MFC water results from the on-Site monitoring program showed detection of two uranium isotopes (which the environmental surveillance program did not analytically assess) (U-233/234 and U-238). U-238 is a naturally occurring radionuclide as is U-234. U-233 is man-made. The concentrations shown in Table 5-14 are not above the 3 σ error criteria and would be termed as undetected for analyses or evaluation. Additionally the ingestion transfer coefficient of ingestion to beef muscle is $2x10^{-4}$ (Baes et al 1984) making uranium undetectable in big game samples. Therefore continued analysis of water from MFC or adding uranium isotopes to the analytical suite for big game is not justifiable.

Figure 12-2. Camera recording of wildlife activity around the MFC pond.

Preliminary data from a current elk telemetry study on the INL Site indicates elk move substantial distances across and outside the INL Site and come in close contact with INL Site facilities (Figures 12-3 and 12-4).

Map 1

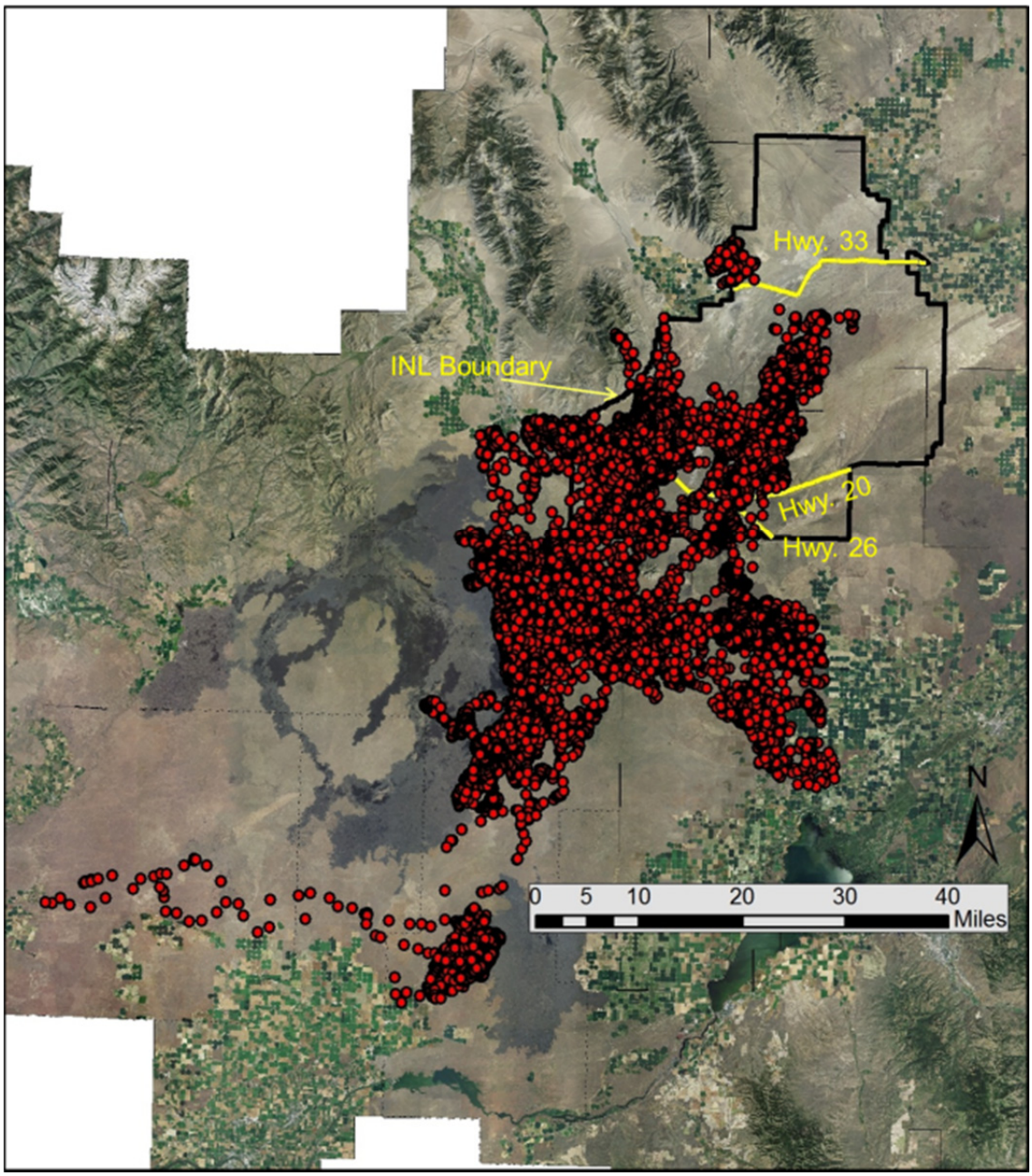

Figure 12-3. Elk movements on and around the INL Site.

Map 2

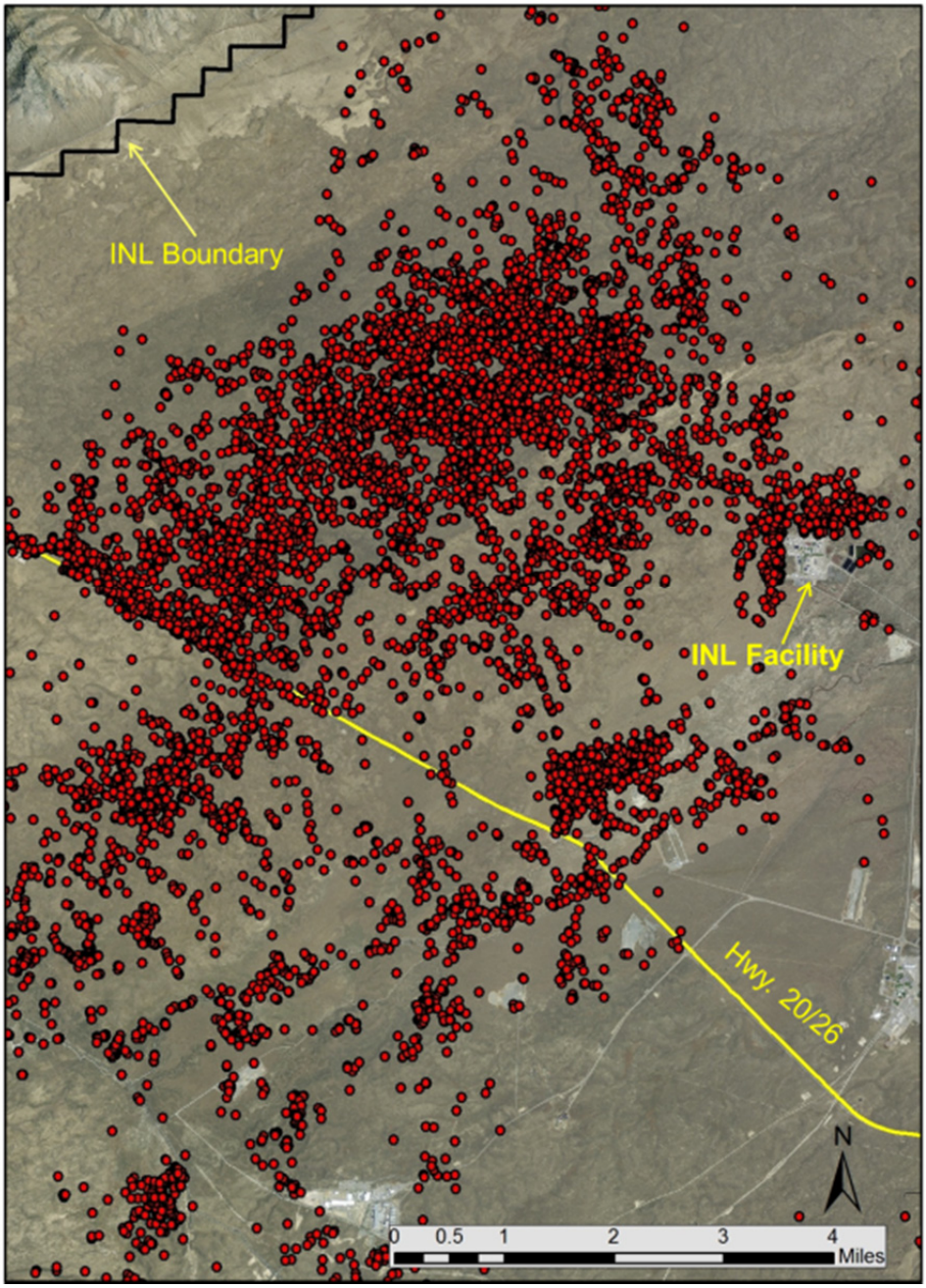

Figure 12-4. Elk movements near INL Site facilities.

12.4 Program Goals

If radionuclide concentrations in environmental media or site biota sampling data (applying appropriate media- and radionuclide-specific transfer factors for media to game animal) indicate that a human could receive a dose of no more than 1 mrem/year through consumption of game animals, then intensive sampling of game animals may not be warranted (DOE 2005). However, random, opportunistic sampling as is currently performed by the environmental surveillance program is based on public concern. This sampling (largely of game killed on-Site in collisions with vehicles) provides verification that dose from INL Site big game animals are well below regulatory and health guidelines.

Previous studies and data document that big game do uptake radionuclides present on the INL Site (Markham et al. 1982; Markham and Halford 1985; Markham et al. 1980; Markham, Halford and Autenrieth 1980). Big game receives doses from radionuclides ingested or present externally from their use of the INL Site (Markham et al. 1982; Markham, Halford and Autenrieth 1980). Some big game are migratory and move off-Site, some considerable distances (Long, ISU, personal communication 2012, Hoskinson and Tester 1980; Reynolds 1984; Comer 2000). Members of the public consume big game and could potentially harvest big game that has used the INL Site (Markham et al. 1982; Markham and Halford 1985; Markham et al. 1980; Markham, Halford and Autenrieth 1980).

The DOE-established general public dose limit is 100 mrem/yr; the DOE-established dose guideline for terrestrial animals is 0.1 rad/day (DOE 2002, DOE 2011). Sample collection and analysis provide data to verify that radiological doses related to the game-animal exposure pathways remain low and quantifiable as required by DOE/EH-0173T (DOE 1991). Data further provide assurance to consumers of game animals from the INL Site that the degree of contamination caused by site operations and cleanup activities is monitored and documented in publicly available reports (e.g., the Annual Site Environmental Report) and provide data baseline to quantify contaminant level changes due to fugitive or accidental releases of INL Site radiological materials.

12.5 Sampling Boundaries

Due to the mobility and diversity of habitat big-game use, samples should be taken within the boundaries of the INL Site. Samples should be taken from animals known to frequent areas of contamination, and these will be compared to background samples that should be collected at least 25 miles from the INL Site.

12.6 Sampling Design

The sampling design must assess and determine whether radionuclides attributable to past and current INL site releases are measurable, above background, in potential forage and water sources used by big game animals and in big game animals which currently use the INL Site and migrate off-Site. Based on the above discussions of vegetation and water analyses, it is not technically justifiable to continue sampling these media to assess contaminant uptake in big game animals. Specific sampling of vegetation and water may be warranted after a known release of radionuclides from INL Site facilities:

- If levels of radionuclides measured in these big game animals represent a dose to the animal population which exceeds biota dose limits
- If levels of radionuclides measured in big game animals produce a dose to a human consuming the animal which exceeds human dose limits.

Based on the historical and recent data on radionuclide uptake and animal movement, the most technically feasible design would collect big game known to access or utilize contaminated areas on the INL Site. Big game monitoring will continue so long as there is potential for them to access to contaminated areas, vegetation and/or water on the INL Site. However, it is recommended that all historical big game radionuclide monitoring data be evaluated to determine if continued monitoring of radionuclide uptake in big game animals on the INL Site is technically defensible and perhaps reduce the frequency of sampling or sampling altogether. A key factor to consider during this assessment will be stakeholder concerns.

12.6.1 Frequency of Collection

At least three samples must be collected annually for a minimal statistically significant number of samples. Samples will be collected as road kill, opportunistically. Because radio telemetry data will only be collected for another year (through 2013), collection of specific animals cannot be done over the long-term.

12.6.2 Sampling Methods

The method chosen for sampling involves opportunistically collecting big game that are accidentally killed on INL Site roads. This provides a level of randomness which may be comparable to harvesting an animal that may contain contaminants. Sampling involves collection of muscle, liver and thyroid tissues.

12.6.3 Analytical Methods

Analysis of the collected tissue samples involves grinding and blending the samples for homogeneity. Analysis detects gamma-emitting radionuclides and iodine–131 in thyroid tissues through gamma spectrometry.

12.7 Radionuclides Assessed

Only gamma spectrometry will be completed for game-animal muscle and liver tissue. Cesium–137 is the predominant gamma-emitter and largest gamma contributor to dose for waterfowl (Halford, Millard, and Markham 1981), assuming it behaves similarly no matter which faunal medium it is from, and is chemically analogous to potassium in the environment. Thus, it behaves similarly. It has a half-life of about 30 years and tends to persist in soil. 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 facilities and re-suspension of previously contaminated soil particles (DOE-ID 2011). Cesium tends to concentrate in muscles because of their relatively large mass. Like potassium, cesium is excreted from the body fairly quickly. This means that the body of someone who is exposed to radioactive cesium will readily be cleared along the normal pathways for potassium excretion within several months once the source of exposure is removed.

Iodine–131 will be assessed in thyroid tissues primarily to assess the biota dose to game animals. Iodine is an essential nutrient element and is readily assimilated by cows eating 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 cesium–137, can dominate ingestion dose regionally after a severe nuclear event such as the Chernobyl accident (Kirchner 1994). Iodine–131 has a short half-life (8 days) and, therefore, does not persist in the environment. Iodine can be taken into the body by eating food, drinking water, or breathing air. It is a constituent of thyroid hormone and, as such, is a required element for humans. Iodine is readily taken into the bloodstream from both the lungs and the gastrointestinal tract (essentially 100%) after inhalation and ingestion. Upon entering the bloodstream, 30% is deposited in the thyroid, 20% is quickly excreted in feces, and the remainder is eliminated from the body within a short time (per simplified models that do not reflect intermediate redistribution) (ANL 2007).

12.8 Quality Assurance

Quality of sample analysis is assured in a variety of ways. The laboratory used will be experienced in analysis of biota. The laboratory must participate in the DOE Mixed Analyte Performance Evaluation Program (MAPEP) performance evaluation tests for biota and show acceptable performance.

The minimum detection limit of the most likely detected gamma-emitting radionuclide (Cs–137) must be below the concentration measured in background samples. At least three samples must be collected for a minimal statistically significant number of samples, and these will be compared with background samples that must be collected at least 25 miles off the INL Site.

12.9 Decision Limits and Actions

DOE radiological activities (DOE 2011) must be conducted so that exposure of members of the public to ionizing radiation will not cause:

- A TED exceeding 100 mrem (1 mSv) in a year
- An equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year
- An equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose excepting:
  - Dose from radon and its decay products in air. (Radon is regulated separately e.g., under Paragraphs 4.f. and 4.h.[1][d] in this Order and under 40 CFR 61, Subparts Q and T.)
  - Dose received by patients from medical sources of radiation, and by volunteers in medical research programs.
  - Dose from background radiation.
  - Dose from occupational exposure under NRC or agreement state license or to general employees regulated by 10 CFR Part 835 and DOE O 458.1 2-11-2011.

The results of years of environmental monitoring by the ESER environmental surveillance program around the INL Site show that DOE dose limits have never been exceeded or even approached off the INL Site. The surveillance program thus looks for instances when background or historical measurements are exceeded. The ESER environmental surveillance program has developed action levels for the laboratory to use as criteria to immediately notify ESER personnel if an unusual result is observed. The action levels were developed based on an assessment of the last ten years of data (unpublished ESER assessment). The action level developed for large game animals for Cs-137 is 1.5E–08 µCi/g.

If Cs–137 is detected above background and exceeds the action level, the highest potential dose to humans will be determined using the conservative technique of calculating maximum radionuclide concentrations. The highest potential dose to the biota will be similarly calculated, using the graded approach. Additional monitoring, determination of change in the source term, and an attempt to determine whether the animal had spent considerable time near contaminated areas are permissible.

If the dose to big game is above biota dose limits (DOE 2002; DOE 2011), then a Site-specific biota dose assessment will be conducted involving problem formulation, analysis, and risk characterization protocols similar to those recommended by EPA (1998).

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13. WATERFOWL

13.1 Program Basis

Waterfowl use INL Site waste ponds and can potentially become contaminated with radionuclides and receive a dose from those radionuclides. Waterfowl are hunted and consumed by humans who could receive a dose from ingestion of radionuclides in waterfowl tissues. Therefore, radionuclide concentrations in waterfowl tissues should be assessed.

13.2 Program Drivers

Monitoring INL Site waterfowl fulfills:

- Regulatory requirements for assessing the movement of radionuclides from the INL Site
- Regulatory requirements for assessing the protection of the public and environment
- Regulatory requirements for assessing the impacts to biota
- The desire to address public concern regarding movement of INL Site produced radionuclides off-Site.

13.3 Results of Related Studies/Surveillance

Water containing radionuclides has been disposed of on the INL Site in several lined or unlined ponds for decades. These ponds offer an attractive environment to many species of wildlife which may, in turn, uptake and remove those radionuclides off-Site (Warren, Majors, and Morris 2001; Halford, Millard, and Markham 1981). Waterfowl have been documented using many of the radioactive wastewater ponds on the INL Site, and a sampling program was established in the early 1970s (Warren, Majors, and Morris 2001; Halford, Millard, and Markham 1981; Halford, Markham, and Dickson 1982; Halford, Markham, and White 1983; Morris 1993). Analyses indicated that waterfowl became contaminated with radionuclides both internally and externally and could not only receive a radiological dose themselves, but also potentially provide a dose to persons consuming them (Halford, Millard, and Markham 1981). Thus, INL Site Operations could potentially impact waterfowl coming in contact with radioactive waste ponds. The impacted waterfowl could then move contaminants off-Site and be harvested and consumed by the public. Therefore, there is a valid basis for sampling waterfowl from INL Site radioactive waste ponds to assess the radionuclide concentrations. These data enable biota dose assessment to evaluate impacts on biota using these ponds as well provide data on humans consuming waterfowl with these radiological contaminants.

Previous studies have indicated that waterfowl uptake a variety of radionuclides from the ponds, but the levels have decreased substantially over the years (Warren, Majors, and Morris 2001) due to decommissioning of some ponds and the reduction of radionuclide concentrations in the effluents sent to these ponds. Wastewater ponds are still present on the INL Site and are visited by migratory waterfowl. Waterfowl provide a logical and accessible media for determining biotic uptake of radionuclides, assessing biota dose, evaluating potential movement of radionuclides off-Site, and evaluating dose to man from consumption of waterfowl.

13.4 Program Goals

The goals of waterfowl sampling and assessment are to evaluate the impacts to waterfowl and off-Site human population from radioactive contaminants in waterfowl tissue attained at the INL Site. Previous studies and data document waterfowl uptake radionuclides from these wastewater ponds (Warren, Majors, and Morris 2001; Halford, Millard, and Markham 1981; Halford, Markham, and Dickson 1982; Halford, Markham, and White 1983; Halford and Markham 1984; Markham et al. 1988; Morris 1993). Waterfowl receive doses from radionuclides ingested or present externally from their use of the INL Site wastewater

ponds (Halford, Markham, and Dickson 1982; Halford, Markham, and White 1983; Halford and Markham 1984; Markham et al. 1988).

Waterfowl are migratory and move off-Site, some considerable distances. Members of the public consume waterfowl and could potentially harvest waterfowl that have used the INL wastewater ponds (Halford, Millard, and Markham 1981; Warren, Majors, and Morris 2001).

The DOE-established dose limit for the general public is 100 mrem/yr and the DOE-established technical standard for aquatic animals is 1 rad/day (DOE 2002; DOE 2011). Data obtained from sample collection and laboratory analysis for INL Site-related radionuclides are used to verify that radiological doses related to the waterfowl exposure pathways are quantifiable and remain in compliance with DOE and other applicable radiation standards and requirements as recommended by DOE/EH-0173T (DOE 1991). Data also provide assurance to consumers of waterfowl from the INL Site that the degree of contamination caused by site operations and cleanup activities is monitored and documented in publicly available reports (e.g., the Annual Site Environmental Report) and establish a baseline to quantify contaminant level changes due to fugitive or accidental releases of INL Site radiological materials.

13.5 Sampling Boundaries

Sampling is to be conducted on the INL Site at the ATR Complex Evaporation Pond and the MFC Industrial Waste Pond, which are utilized by waterfowl and are potentially contaminated from historic and/or current liquid effluents. The ATR Complex Evaporation Pond is lined; waterfowl are not taken from this pond to prevent damage to the lining. Off-Site environmental surveillance program procedures (GSS 2011) instruct that no birds are to be collected directly from or over contaminated ponds. Instead, waterfowl are collected from the sewage ponds adjacent to the lined pond. Based on historical observations and data, the probability of waterfowl collected at the sewage ponds having used the adjacent radioactive waste ponds is reasonable and provides a representative assessment of the contaminant uptake (Warren, Majors, and Morris 2001; Morris 1993).

Radionuclides released to ponds are primarily gamma-emitting due to fission and activation products of nuclear reactors. Because of the high biological elimination rates of radionuclides (Halford, Markham, and White 1983) and migratory patterns (Warren, Majors, and Morris 2001), background waterfowl should be collected north, east and southeast of the INL Site boundary (birds are migrating from the north and moving south and southwest [Warren, Majors, and Morris 2001]). The highest numbers of waterfowl at contaminated ponds occur during the spring and fall migratory period (Warren, Majors, and Morris 2001). Therefore, the highest probability of harvest by a hunter would occur during the fall migratory/hunting season.

13.6 Sampling Design

Sampling is limited to INL Site unlined wastewater ponds. Samples are collected by shooting. Waterfowl samples are collected by INL Security personnel with firearms training. Background samples will be obtained from locations at least 25 miles off the INL Site. These samples will be collected by area hunters.

Waterfowl monitoring will continue until there are no radioactive wastewater ponds accessible to waterfowl on the INL Site. If new facilities are constructed with a radioactive-wastewater pond, waterfowl monitoring will be initiated after use by waterfowl is determined.

13.6.1 Frequency of Collection

Samples will be collected annually during the fall waterfowl migration. At least three samples must be collected from each location for a minimal statistically significant number of samples. Samples will be collected during the fall because that is the period when contaminated birds could be harvested.

13.6.2 Analytical Methods

Analysis of sampled waterfowl carcasses will proceed by first dividing them into edible tissue, external tissue (skin, feathers, feet, and bill), and remainder. The edible tissue can be used for ingestion doses, the external tissue indicates external contamination, and the remainder adds to overall inventory. Tissues will be ground and blended for homogeneity, then analyzed by gamma spectrometry for gamma-emitting radionuclides and by yttrium–90 separation for strontium–90. Alpha spectrometry will be used to determine the presence and levels of transuranics.

13.7 Radionuclides Assessed

Although up to 29 different radionuclides have been detected in waterfowl tissues collected from INL Site radioactive waste ponds (Halford, Millard, and Markham 1981), it is impractical and cost-prohibitive to perform complete analyses on them all. Therefore, radionuclides that contribute significantly to dose and are readily taken up by the body were assessed. Radionuclides historically assessed in waterfowl collected on INL Site ponds are (GSS 2011):

- Cesium–137 (the primary gamma emitter of interest), by gamma spectrometry.
- Strontium–90, by yttrium–90 separation.
- Transuranics (Pu–238, Pu–239/240, and Am–241). These transuranics were selected because they are often measured in INL Site effluents (DOE-ID 2011) and are of concern to stakeholders.

Strontium–90 is an important radionuclide because it behaves like calcium and can deposit in bones. Strontium–90, like cesium–137, is produced in high yields from nuclear reactors or detonations of nuclear weapons. It has a half-life of 28 years and can persist in the environment. Strontium tends to form compounds that are soluble, in contrast to cesium–137 and is therefore comparatively mobile in ecosystems (DOE-ID 2011). About 8% of the ingested activity remains in the body after 30 days, and this decreases to about 4% after 1 year. This activity is mainly in the skeleton. Strontium preferentially adheres to soil particles, and the amount in sandy soil is typically about 15 times higher than in interstitial water (in the pore spaces between soil particles); concentration ratios are typically even higher (110 times the concentration in solution) in clay soil (ANL 2007).

Cesium–137, the predominant gamma-emitter and largest gamma contributor to dose for waterfowl (Halford, Millard, and Markham 1981) assuming it behave similarly no matter which media it is from, is chemically analogous to potassium in the environment and behaves similarly. It has a half-life of about 30 years and tends to persist in soil. In soluble form, it can readily enter the food chain through plants. It is widely distributed throughout the world from historic nuclear weapons detonations and has been detected in all environmental media at the INL Site. Regional sources include releases from INL Site facilities and re-suspension of previously contaminated soil particles (DOE-ID 2011). Cesium tends to concentrate in muscles because of their relatively large mass. Like potassium, cesium is excreted from the body fairly quickly. In an adult, 10% is excreted with a biological half-life of 2 days, and the rest leaves the body with a biological half-life of 110 days. Clearance from the body is somewhat quicker for children and adolescents. This means that the body of someone who is exposed to radioactive cesium will readily be cleared along the normal pathways for potassium excretion within several months once the source of exposure is removed.

Plutonium and americium were dispersed world-wide from atmospheric testing of nuclear weapons conducted during the 1950s and 1960s. The fallout from these tests left very low concentrations of plutonium and americium in soils around the world (EPA Radiation Protection http://www.epa.gov/radiation/radionuclides/). Accidents and other releases from weapons production facilities have caused localized contamination. Americium oxide is the most common form in the environment. Average americium–241 levels in surface soil are about 0.01 pCi/g. Americium is typically quite insoluble, although a small fraction can become soluble through chemical and biological processes.

It adheres very strongly to soil, with americium concentrations associated with sandy soil particles estimated to be 1,900 times higher than in interstitial water (the water in the pore spaces between the soil particles); it binds more tightly to loam and clay soils, so those concentration ratios are even higher. At DOE sites such as Hanford, americium can be present in areas that contain waste from the processing of irradiated fuel (ANL 2007).

Americium can be taken into the body by eating food, drinking water, or breathing air. Gastrointestinal absorption from food or water is a likely source of internally deposited americium in the general population. After ingestion or inhalation, most americium is excreted from the body within a few days and never enters the bloodstream; only about 0.05% of the amount taken into the body by ingestion is absorbed into the blood. After leaving the intestine or lung, about 10% clears the body. The rest of what enters the bloodstream deposits about equally in the liver and skeleton where it remains for long periods of time, with biological retention half-lives of about 20 and 50 years, respectively (per simplified models that do not reflect intermediate redistribution). The amount deposited in the liver and skeleton depends on the age of the individual, with fractional uptake in the liver increasing with age. Americium in the skeleton is deposited uniformly on cortical and trabecular surfaces of bones and slowly redistributes throughout the volume of mineral bone over time.

About 10,000 kg of plutonium were released to the atmosphere during weapons tests. Average plutonium levels in surface soil from fallout range from about 0.01 to 0.1 pCi/g. Accidents and other releases from weapons-production facilities have caused greater localized contamination. The most common form in the environment is plutonium oxide. Plutonium is typically very insoluble, with the oxide being less soluble in water than ordinary sand (quartz). It adheres tightly to soil particles and tends to remain in the top few centimeters of soil as the oxide. In aquatic systems, plutonium tends to settle out and adhere strongly to sediments, again remaining in upper layers. Typically, one part of plutonium will remain in solution for every 2,000 parts in sediment or soil. A small fraction of plutonium in soil can become soluble through chemical or biological processes, depending on its chemical form. While plutonium can bioconcentrate in aquatic organisms, data have not indicated that it biomagnifies in aquatic or terrestrial food chains.

When plutonium is inhaled, a significant fraction can move from the lungs through the blood to other organs, depending on the solubility of the compound. Little plutonium (about 0.05%) is absorbed from the gastrointestinal tract after ingestion, and little is absorbed through the skin following dermal contact. After leaving the intestine or lung, about 10% clears the body. The rest of what enters the bloodstream deposits about equally in the liver and skeleton where it remains for long periods of time, with biological retention half-lives of about 20 and 50 years, respectively, per simplified models that do not reflect intermediate redistribution. The amount deposited in the liver and skeleton depends on the age of the individual, with fractional uptake in the liver increasing with age. Plutonium in the skeleton deposits on the cortical and trabecular surfaces of bones and slowly redistributes throughout the volume of mineral bone with time.

Other radionuclides present in INL Site waste ponds include Cs-134 and I-131 and these may warrant consideration for dose assessment due to their biological uptake and their contribution to overall dose (Halford, Markham, and Millard 1981). Both have relatively short half-lives (2.1 years for Cs-134 and 8 days for I-131) and do not pose a long-term dose hazard. However, at least periodic assessment of these isotopes may be warranted to ascertain if they are major contributing factors to dose relative to the other isotopes being assessed.

13.8 Quality Assurance

Quality of sample analysis is assured in a variety of ways. The laboratory used will be experienced in analysis of biota. The laboratory must participate in the DOE Mixed Analyte Performance Evaluation Program (MAPEP) performance evaluation tests for biota and show acceptable performance.

The minimum detection limit of the most likely detected gamma-emitting radionuclide (Cs–137) must be below the concentration measured in background samples. At least three samples must be collected for a minimal statistically significant number of samples, and these will be compared with background samples that must be collected at least 25 miles off the INL Site.

13.9 Decision Limits and Actions

DOE radiological activities (DOE 2011) must be conducted so that exposure of members of the public to ionizing radiation will not cause:

- A TED exceeding 100 mrem (1 mSv) in a year
- An equivalent dose to the lens of the eye exceeding 1500 mrem (15 mSv) in a year
- An equivalent dose to the skin or extremities exceeding 5000 mrem (50 mSv) in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose excepting:
  - Dose from radon and its decay products in air. (Radon is regulated separately e.g., under Paragraphs 4.f. and 4.h.[1][d] in this Order and under 40 CFR 61, Subparts Q and T.)
  - Dose received by patients from medical sources of radiation, and by volunteers in medical research programs.
  - Dose from background radiation.
  - Dose from occupational exposure under NRC or agreement state license or to general employees regulated under 10 CFR Part 835, and DOE O 458.1 2-11-2011.

If radionuclides detected are above background and exceed historical levels (per the action levels shown in Table 13-1), a determination of whether the concentration is an anomalous measurement will be made. If the concentration is verified, the highest potential dose to humans will be calculated using the conservative method of employing maximum radionuclide concentrations. These calculations will be used to assess the highest potential dose to biota, using a graded approach. In turn, this assessment will be used to determine whether the dose to humans is above the regulatory limits or the Action Levels listed in Table 13-1.

Table 13-1. Action levels for radionuclides in biota.

Radionuclide	Action Level
Cs–137	3.5 E–7 µCi/g
I–131	positive detection >3 σ
Sr–90	1.0 E–7 µCi/g
Pu–238	positive detection >3 σ
Pu–239/240	positive detection >3 σ
Am–241	positive detection >3 σ

If the dose to humans is approaching or above regulatory limits or above the Action Levels listed above, then further investigation and action may be warranted. These may include additional monitoring, determination of change in source term and attempt to determine if the sample animal had spent considerable time on the source pond. If the dose to waterfowl is above biota dose limits (DOE 2002; DOE 2011), then a Site-specific biota dose assessment will be conducted involving problem formulation, analysis, and risk characterization protocols similar to those recommended by EPA (1998). The program will then consider methods to discourage waterfowl from using ponds

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14. IDAHO CLEANUP PROJECT WASTE MANAGEMENT FACILITIES

14.1 Program Basis

It is the policy of the U.S. Department of Energy (DOE) to conduct environmental surveillance programs that are adequate to determine whether the public and the environment are adequately protected during DOE operations and whether operations are in compliance with DOE and other applicable Federal, State, and local radiation standards and requirements. It is also DOE policy that monitoring and surveillance programs be capable of detecting and quantifying unplanned releases and meet high standards of quality and credibility. It is DOE's objective that all DOE operations properly and accurately measure radionuclides in ambient environmental media (DOE 1991).

DOE Order 435.1, "Radioactive Waste Management," establishes requirements to protect the public and the environment against undue risk from radiation associated with radiological activities conducted under the control of the Department of Energy pursuant to the Atomic Energy Act of 1954. The objective of this Order is to ensure that all DOE radioactive waste is managed in a manner that is protective of worker and public health and safety, and the environment. The Order requires that radioactive waste management facilities, operations, and activities meet the environmental monitoring requirements of DOE Order 458.1, "Radiation Protection of the Public and the Environment," which captures the environmental monitoring requirements formerly documented in cancelled DOE Orders 5400.1, "General Environmental Protection Program," and 5400.5, "Radiation Protection of the Public and the Environment."

The Idaho Cleanup Project (ICP) contractor (CH2M-WG Idaho, LLC [CWI]) Environmental Surveillance Program conducts environmental surveillance for all waste management facilities at the INL Site. Currently, ICP waste management operations occur in the Radioactive Waste Management Complex (RWMC) Surface Disposal Area (SDA) and Idaho Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Disposal Facility (ICDF) at the Idaho Nuclear Technology and Engineering Center (INTEC).

Radiological surveillance and monitoring at the Idaho National Laboratory (INL) Site radioactive waste management facilities are essential to meet the environmental monitoring requirements of DOE Orders. The development of a technical basis for surveillance and monitoring activities ensures the most efficient and effective sampling processes, methods, and media are used.

14.2 Program Drivers

Environmental surveillance monitoring at ICP waste management facilities is performed in the vicinity of those facilities to according to the following DOE requirements:

- DOE Order 435.1, "Radioactive Waste Management"
- DOE Manual 435.1-1, "Radioactive Waste Management Manual
- DOE Order 458.1, "Radiation Protection of the Public and the Environment"
- DOE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance."

14.3 Radiological Emissions from Waste Management Facilities

14.3.1 Emissions from RWMC

The RWMC, located in the southwestern corner of the INL Site, is a controlled-access area with a primary mission to dispose of INL Site-generated low-level radioactive waste and to temporarily store contact-handled and remote-handled transuranic waste that will be shipped to other designated facilities for disposal. To fulfill these missions, the RWMC maintains facilities and processes in separate areas for

administrative and operations support, and waste storage and disposal. Administrative and Operations Area buildings are used for security and access control, personnel offices, lunchrooms, change and shower rooms, equipment and materials storage, craft and maintenance shops, and radiological control.

Current operations at the RWMC include the Advanced Mixed Waste Treatment Project (AMWTP) currently operated by Idaho Treatment Group (ITG). The AMWTP includes the retrieval of mixed transuranic waste from temporary storage, characterizing the waste, treating the waste to meet disposal criteria, and packaging the waste for shipment to the Waste Isolation Pilot Plant in Carlsbad, New Mexico. Radiological air emissions from the AMWTP may result from the retrieval, characterization, and treatment of transuranic waste, alpha-contaminated low-level mixed waste (alpha LLMW), and low-level mixed waste (LLMW).

Radiological air emission point sources operated by ICP at RWMC include three vapor vacuum extraction units in the Subsurface Disposal Area (SDA) and the Accelerated Retrieval Project (ARP) excavation enclosures. The ARP, regulated under CERCLA, is removing targeted waste from the SDA, disposing of transuranic waste at an off-Site facility, and remediating and closing the SDA. The ARP shows compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) standard using ambient air measurements, which is an approach approved by the Environmental Protection Agency (EPA) and meets the requirements specified by the NESHAP (40 CFR 61.93 (g)).

In 2011, air emissions at the RWMC were primarily from activities at the facilities listed below (DOE-ID, 2012; Figure 14-1). Facilities that contributed at least one percent of the total estimated dose to the MEI are in bold.

1. WMF-601: Health Physics Laboratory
2. **WMF-697: ARP-I**
3. **WMF-1612: ARP-II**
4. **WMF-1614: ARP-III**
5. **WMF-1615: ARP-IV**
6. **WMF-1617:ARP-V**
7. **WMF-1618: ARP-VI**
8. **Tritium emissions from beryllium blocks buried in the SDA**
9. CERCLA remediation activities
10. Waste Management Facility (WMF)-615-001, Drum Vent Facility
11. **WMF-628: Drum Treatment Facility**
12. WMF-634: Characterization Facility
13. WMF-636: Transuranic Storage Area
14. WMF-676: Advanced Mixed Waste Treatment Facility
15. WMF-TR-14: Analytical Laboratory

About 357 curies were estimated to have been released to the air at the RMWC in 2011 (DOE-ID 2012). Table 14-1 summarizes the radiological air emissions at the RWMC that were greater than one curie or contributed at least one percent of the total estimated dose to the MEI.

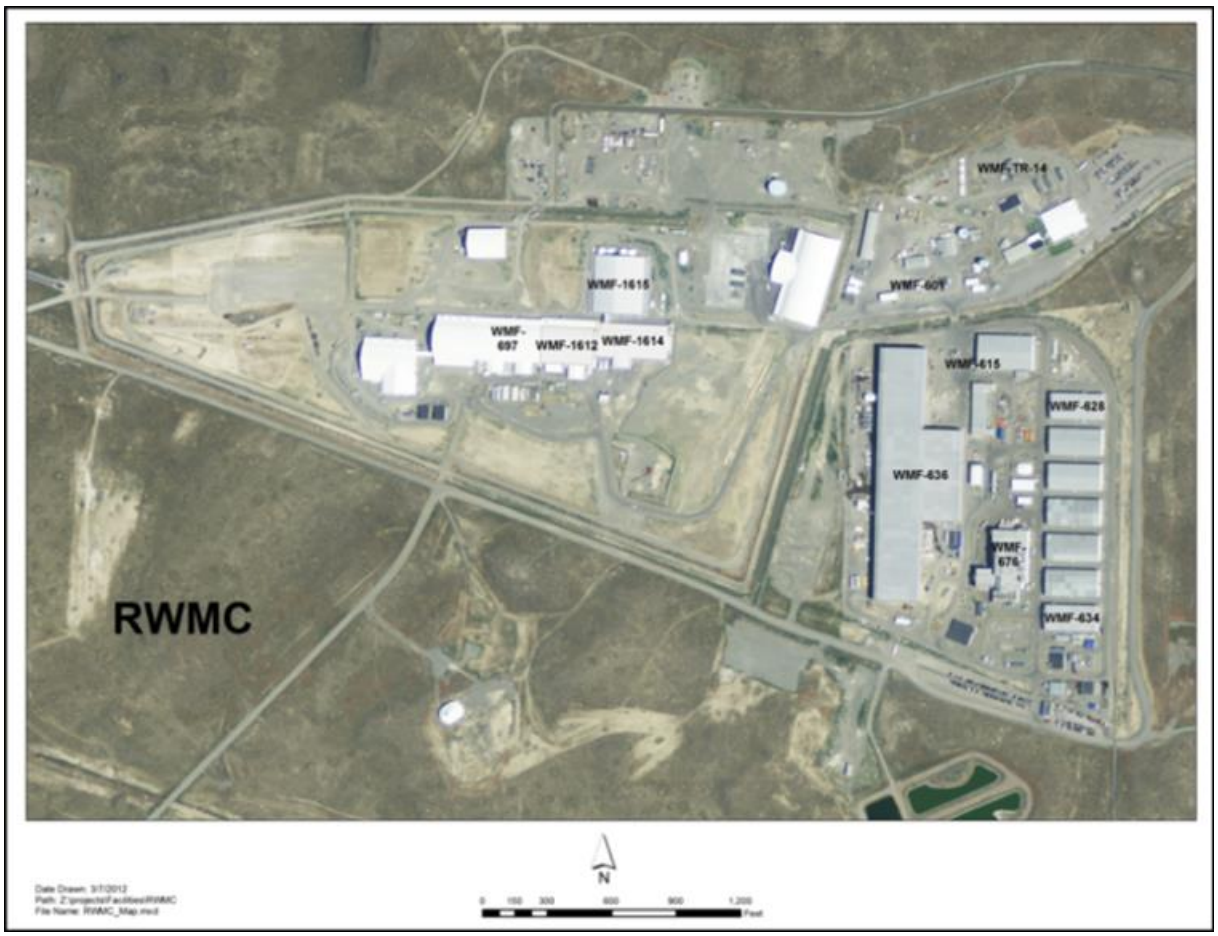

Figure 14-1. Selected Facilities at RWMC.

Table 14-1. Estimated radiological air emissions at the RWMC in 2011 that were greater than one curie or contributed at least one percent of the total dose to the MEI (DOE-ID 2012).

Radionuclide	Estimated 2011 Emissions (Ci)	Contribution to Total Dose at MEI (Percent)
Americium–241	0.00414	18.97
Plutonium–238	0.00112	5.88
Plutonium–239	0.00275	15.6
Plutonium–240	5.14E–04	2.92
Tritium	357	15.6
Percent Contribution from RWMC to the MEI Dose		~59%

14.3.2 Emissions from INTEC

INTEC was established in the 1950s to recover usable uranium from spent nuclear fuel generated in government reactors and to store spent nuclear fuel. Radiological air emissions from INTEC sources are primarily associated with liquid-waste operations, including effluents from the Tank Farm Facility, Process Equipment Waste Evaporator, and Liquid Effluent Treatment and Disposal, which are exhausted through the Main Stack. These radioactive emissions include particulates and gaseous radionuclides. Additional radioactive emissions are associated with decommissioning and decontamination activities,

wet-to-dry spent nuclear fuel transfers, environmental remediation, remote-handled transuranic waste management, radiological and hazardous-waste storage facilities, and contaminated-equipment maintenance. In the near future, the Integrated Waste Treatment Unit (IWTU) will become operational to process the remaining sodium-bearing liquid waste at INTEC.

In 2011, air emissions at INTEC were primarily from activities at the facilities listed below (DOE-ID, 2012; Figure 14-2). Facilities that contributed at least one percent of the total estimated dose to the MEI are in bold.

1. CPP-603: Irradiated Fuels Storage Facility
2. CPP-653: EPA Radiological Dispersion Device Decontamination Project
3. CPP-659: New Waste Calcine Facility
4. CPP-663: Maintenance Building Hot Shop
5. CPP-684: Remote Analytical Laboratory
6. CPP-708: Main Stack
7. CPP-749: Spent Fuel Storage Vaults
8. CPP-767: FAST Stack
9. CPP-1608: Manipulator Repair Cell
10. **CPP-1774, TMI-2 Independent Spent Storage Installation**
11. CPP-1778, Sewage Treatment Plant
12. CPP-1791, INTEC percolation ponds
13. CPP-2707, dry cask storage pad
14. **ICDF**
15. Contaminated soils

About 1,650 curies were estimated to have been released to the air at INTEC in 2011 (DOE-ID, 2012). Table 14-2 summarizes the radiological air emissions at the INTEC that were greater than one curie or contributed at least one percent of the total estimated dose to the MEI.

Radiological liquid wastes generated at INTEC are treated at the Process Evaporator Waste system and/or containerized for proper disposal. Liquid waste generated from CERCLA investigations at the INL Site, such as purge water from groundwater sampling activities, are discharged to the lined evaporation pond at the ICDF. Liquid effluent monitoring is discussed in Chapter 5 of this document.

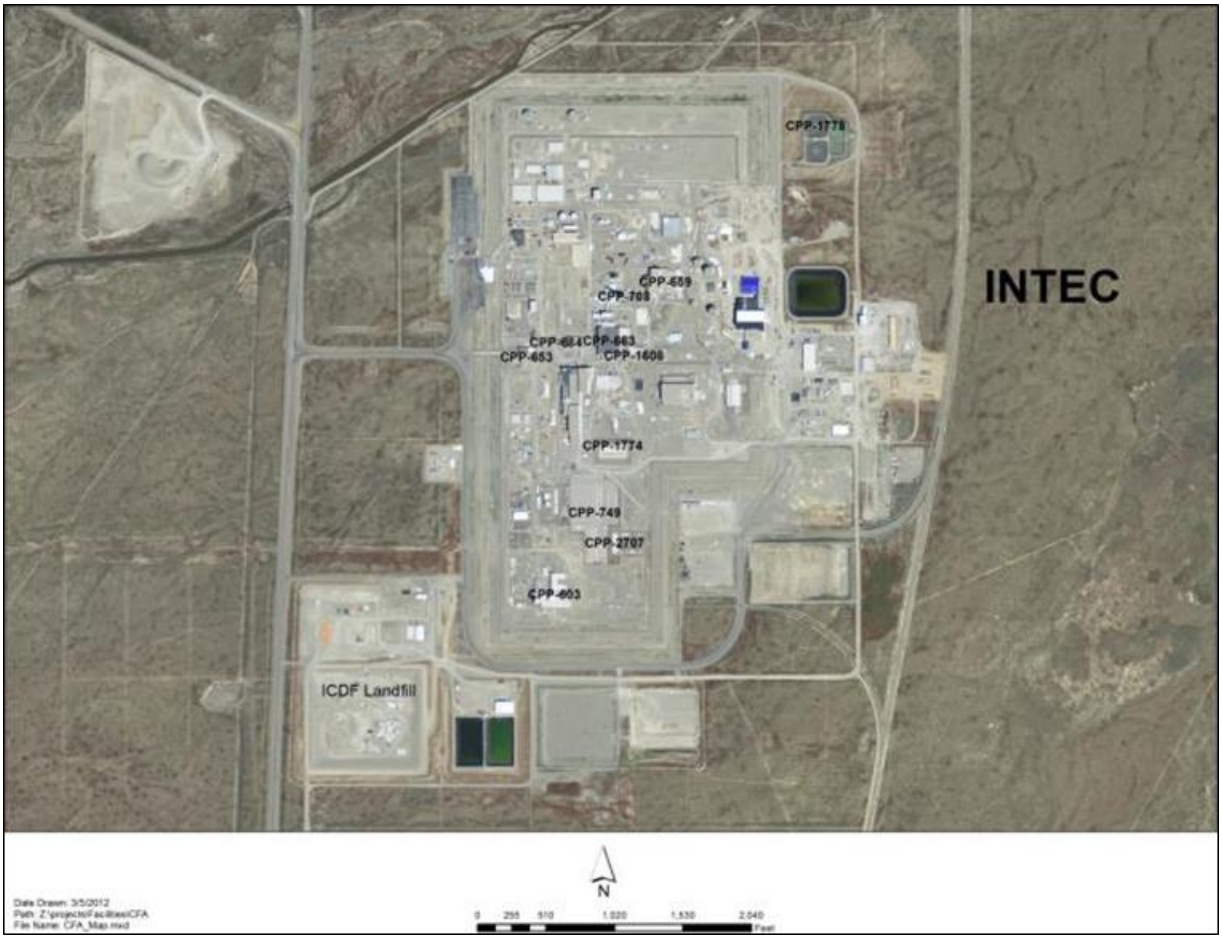

Figure 14-2. Selected facilities at INTEC.

Table 14-2. Estimated radiological air emissions at INTEC in 2011 that were greater than one curie or contributed at least one percent of the total dose to the MEI (DOE-ID 2012).

Radionuclide	Estimated 2011 Emissions (Ci)	Contribution to Total Dose at MEI (Percent)
Cesium–137	0.024	1.78
Cobalt–60	0.0614	1.34
Iodine–129	0.03	3.80
Krypton–85	1,450	<1
Plutonium–239	0.000323	1.06
Strontium–90	0.0136	1.80
Tritium	200	6.12
Percent Contribution from INTEC to the MEI Dose		~16

14.4 Environmental Dose Pathways

During routine operations at INL Site facilities, radioactive materials are released to the environment. Various environmental processes may transport these materials from the INL Site to nearby populations off the INL Site. These processes include wind, flowing water in the subsurface or surface, or movement of biota. The environmental pathways were ranked for the INL Site and can be applied to waste management facilities as well for purposes of determining the environmental media to be monitored. Based on the analysis presented in Chapter 4 of this document (Environmental Pathways and Exposure Routes) the following are monitored in proportion to the relative ranking of the transport pathway involved for ICP waste management facilities:

- Air, soil, biota, and surface water at RWMC
- Air at ICDF
- Penetrating radiation monitoring (gamma surface surveys) at RWMC and ICDF.

That is, most of the monitoring program is directed at characterizing airborne releases, mostly from resuspension of radioactive materials fugitive dusts. Groundwater monitoring is not included in routine environmental surveillance at waste management facilities but is conducted by other organizations and programs, including the U.S. Geological Survey, CERCLA, and a Resource Conservation and Recovery Act post-closure permit.

14.5 Program Objectives

The ICP Environmental Surveillance Program has the following general objectives:

- Support the overall programmatic objectives of the INL Site Environmental Monitoring Program
- Comply with applicable DOE requirements regarding environmental surveillance
- Identify trends in concentrations of radioactivity in environmental media near ICP waste management facilities and concentrations of contaminants in environmental media near ICP facilities
- Provide indications of confinement integrity at ICP radioactive waste storage and disposal facilities
- Make environmental surveillance data available to DOE-ID, other federal agencies, INL Site contractor personnel, state of Idaho officials, and other programs conducting activities such as performance assessment, pathways analyses, dose estimation, and site environmental report preparation
- Collect data in support of special studies.

Environmental surveillance programs and their components are determined on a site-specific basis by the field organization. Consequently, the ICP Environmental Surveillance Program mission does not include all aspects of environmental surveillance, but only those components that have been identified by DOE-ID Environmental Programs as appropriate to the operations at the INL Site. The technical objectives provided in this section for each specific activity are designed to meet the aspects of the ICP Environmental Surveillance Program addressed by that activity.

14.5.1 Ambient Air Monitoring

The specific objectives of ambient air monitoring are as follows:

- Determine concentrations of radionuclides in ambient air in the vicinity of ICP waste management facilities and at appropriate background locations
- Detect and report significant trends in measured concentrations of airborne radionuclides

- Compare measured concentrations of radionuclides to reference levels based on derived concentration guides for the public given in DOE Order 458.1
- Measure the ambient air concentrations of radionuclides in the event of a nonroutine or unmonitored release
- Report comparisons of measured concentrations to reference levels based on derived concentration guides for the public given in DOE Order 458.1.

14.5.2 Surface Soil Sampling

The specific objectives of surface soil sampling are as follows:

- Determine concentrations of radionuclides (natural and fallout) in soils
- Detect and report significant trends in measured concentrations of radionuclides in soil
- Assess any buildup of radioactivity due to INL Site operations.

14.5.3 Surface Water Sampling

The specific objectives of surface water sampling are as follows:

- Determine concentrations of radionuclides in any surface waters with the potential of leaving RWMC.
- Report comparisons of measured concentrations against reference levels based on derived concentration guides for the public given in DOE Order 458.1
- Detect and report significant trends in measured concentrations of radionuclides in surface waters with the potential of leaving RWMC.

14.5.4 Biotic Surveillance

The specific objectives of routine biotic surveillance are as follows:

- Determine if biota are transporting radionuclides from buried waste or contaminated soil
- Detect and report significant trends in the radionuclides and concentrations in biotic samples.

14.5.5 Radiation Monitoring

The specific objectives of radiation monitoring are as follows:

- Characterize direct radiation levels at specific points of interest at ICP waste management facilities
- Detect and report significant trends in measured levels of penetrating radiation.

14.6 Program Design

In addition to the DOE drivers previously discussed, the program design is based upon the data quality objective (DQO) process described in Section 7 of PLN 720 (CWI 2012). The primary concern is that the design meets the criteria and constraints established in Stages I and II of the DQO development. Resources used for guidance in the design stage include regulatory requirements and guidance specific to data collection systems, current technical references, and technical peer review.

14.6.1 Sampling Locations

14.6.1.1 Ambient Air

Airborne materials from RWMC and ICDF are predominantly fugitive dusts with small amounts of sorbed radionuclides. The general approach to monitoring an area source, such as the fugitive dusts at RWMC and ICDF, is to monitor around the periphery of the facility. Monitors were, thus, located in predominant wind paths from disposal activities to ensure a high probability of detection (Bryan 1991). The series of samplers that monitor for particulates around the RWMC SDA are shown in Figure 14-3. A control location is situated north of Howe, Idaho (Figure 14-4). This location was selected because it is close enough to be representative of the area being monitored and yet in an area that would not be influenced by the INL Site facilities.

Airborne particulates are also monitored downwind of the ICDF (Figure 14-5). The Howe location is also used for the control location for the ICDF.

Figure 14-3. Locations of Low-volume Air Samplers at the RWMC Subsurface Disposal Area.

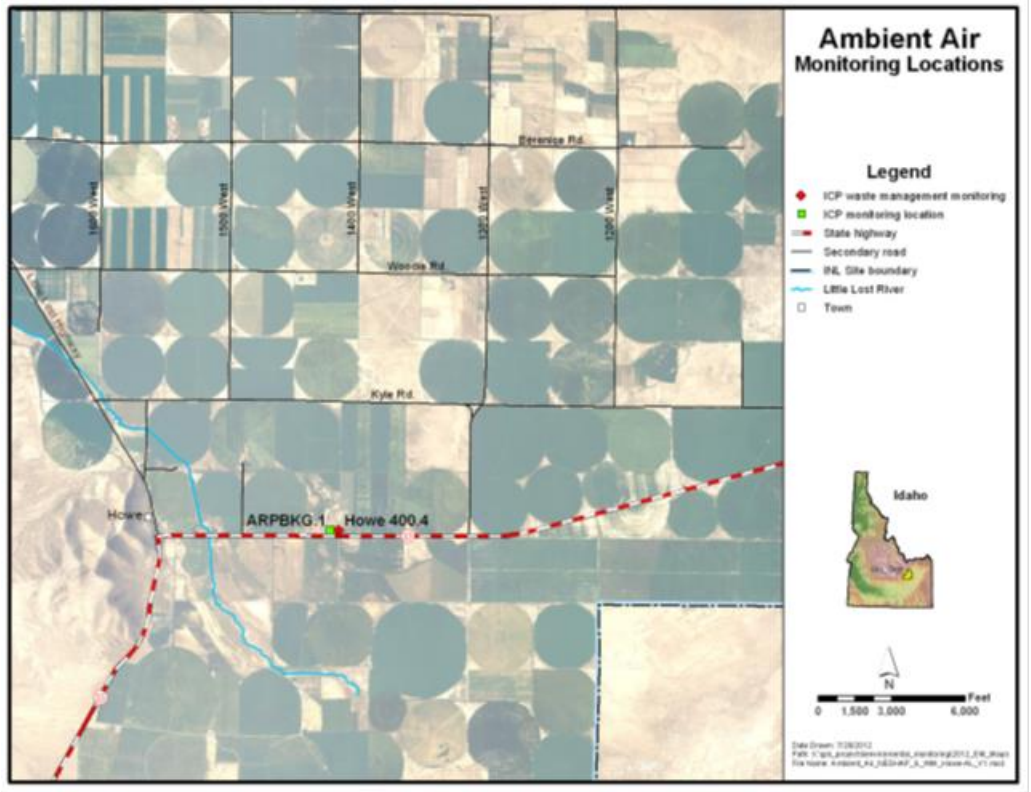

Figure 14-4. Background ambient air monitoring location in Howe.

Figure 14-5. Locations of Low-volume Air Samplers at Idaho CERCLA Disposal Facility.

14.6.1.2 Surface Soil

Surface and near-surface soils at RWMC have become contaminated from past flooding of open pits, waste handling, and biotic intrusion. Of particular concern are measured concentrations of Pu-239 and Am-241, caused by past flooding, in surface soils inside and outside the northeast corner of the SDA (Markham, Puphal and Filer 1978). Figure 14-6 shows soil sampling locations (four major areas) for long-term trend studies. The major areas have been defined by the current and past burial practices at the SDA and historical flooding (EG&G 1988). The areas are:

1. Active areas—areas that are directly affected by operations and may be frequently recovered with lakebed soils.
2. Inactive area—areas that are not directly affected by operations and not frequently recovered with lakebed soils
3. Pad A—An aboveground, earth-covered disposal site at the SDA where approximately 10,168^3 (13,300 yd^3) of containerized waste was placed on an asphalt pad from 1972 to 1978; the waste is composed primarily of nitrate salts, depleted uranium, and sewer sludge received from the Rocky Flats Plant.
4. Previously flooded area—soils previously contaminated by flooding of pits containing Rocky Flats waste (mainly transuranic materials) in 1962 and 1969.

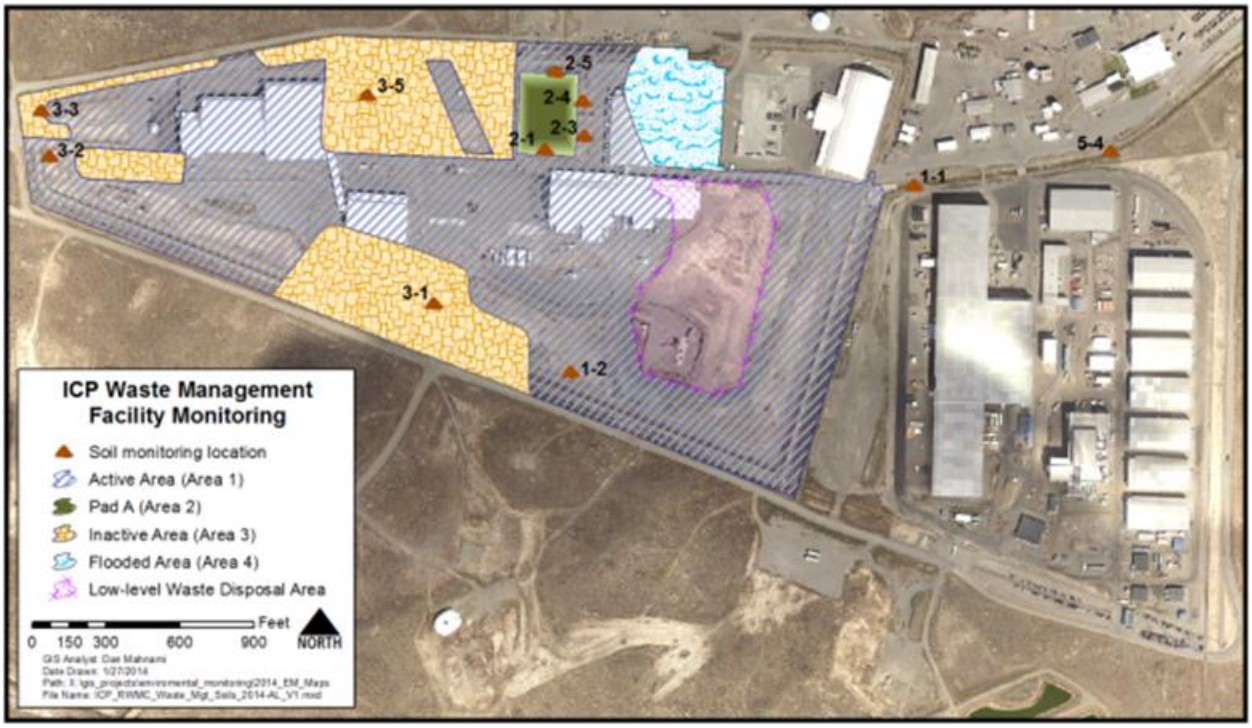

Figure 14-6. Surface Soil Sampling Locations at the RWMC Subsurface Disposal Area.

14.6.1.3 Biotic Surveillance

Vegetation is sampled because of the possibility that radionuclides in buried waste may be brought to the surface through root uptake. Arthur (1982) documented radionuclides in crested wheatgrass and Russian thistle growing in the vicinity of RWMC. He observed greater radionuclide concentrations in Russian thistle than crested wheatgrass and attributed this to the thistle's deeper rooting depth and spreading growth. Vegetation is collected to correlate with the four major soil areas (Figure 14-7) (EG&G 1989). A background sample is collected at Frenchman's Cabin off the INL Site south of RWMC (Figure 4-10).

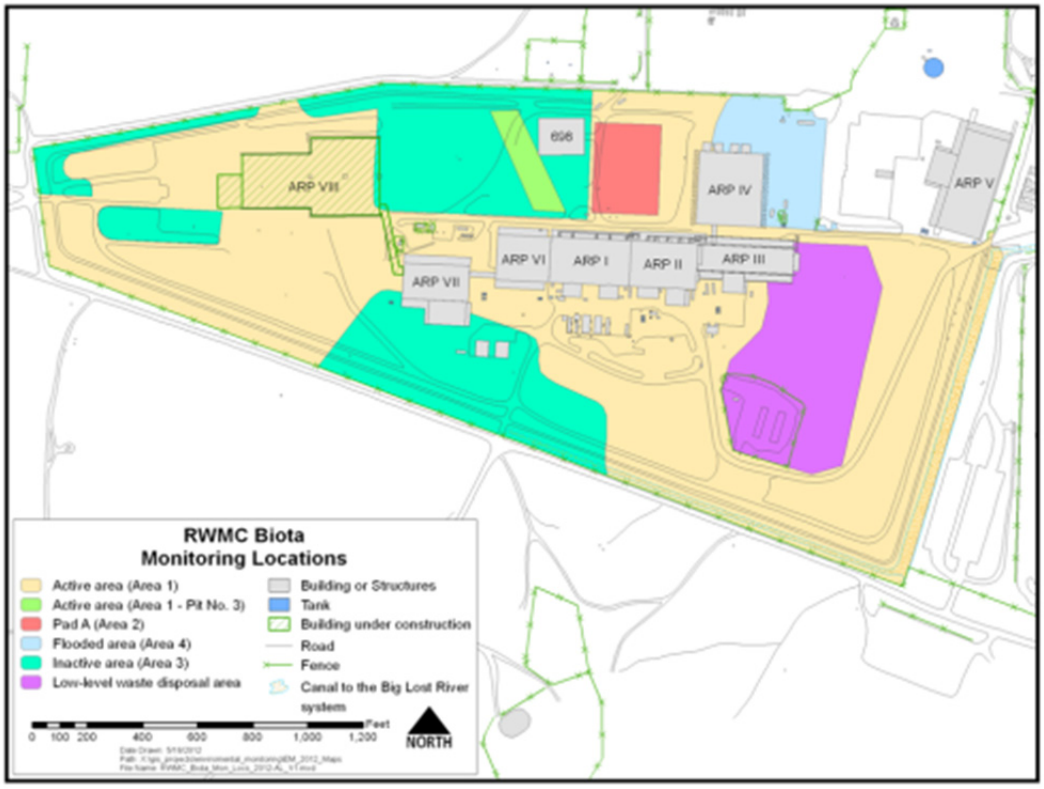

Figure 14-7. Four Vegetation Sampling Areas at the RWMC Surface Disposal Area.

14.6.1.4 Surface Water

Radionuclides could be transported outside the boundaries of RWMC via surface water run-off. Surface water run-off occurs at the SDA only during periods of snowmelt or heavy precipitation. At these times, water runs off the SDA into a lift station. The lift station pumps water into a canal, which also carries outside run-off that has been diverted around RWMC. Samples are collected at the lift station when available (Figure 14-8).

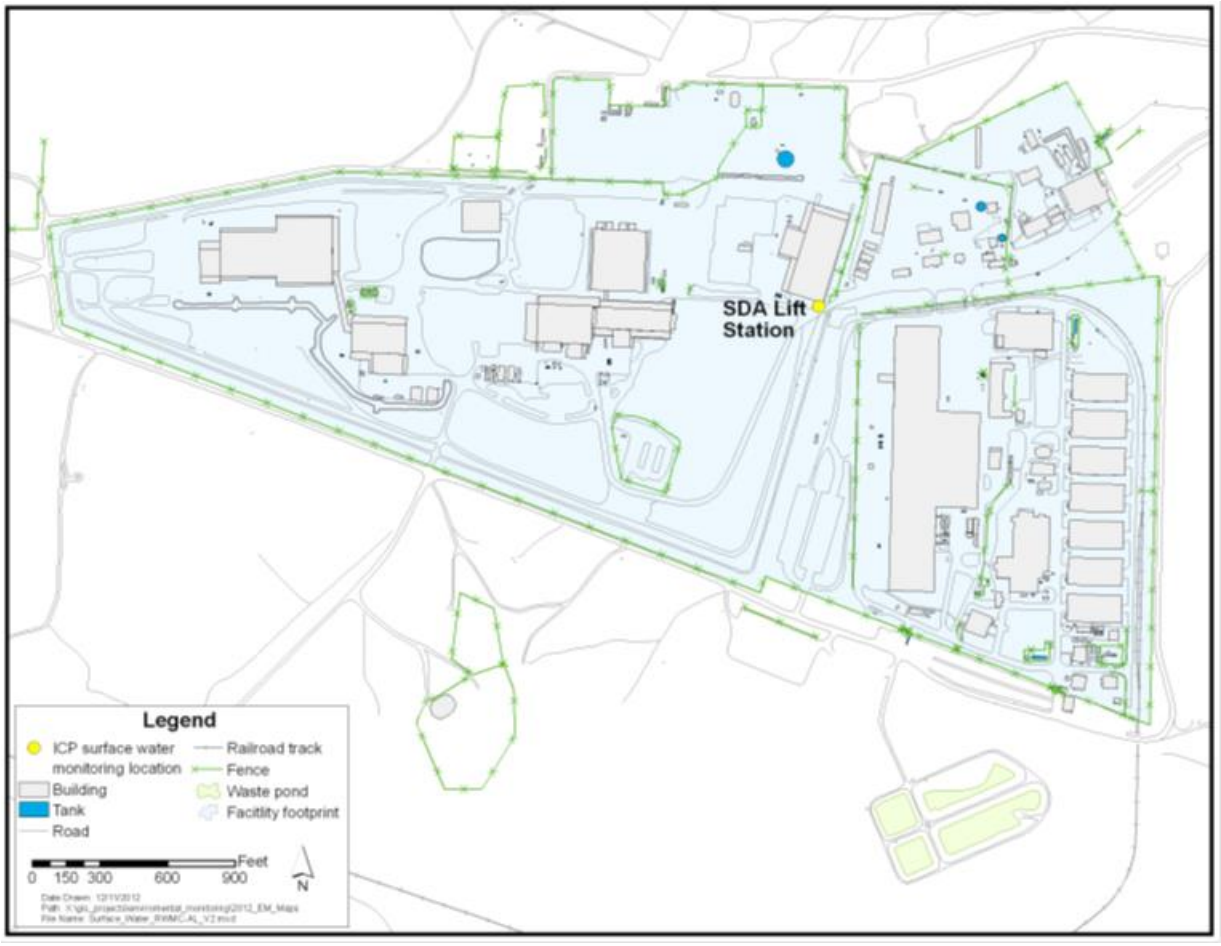

Figure 14-8. Surface Water Sampling Location at RWMC Subsurface Disposal Area.

14.6.1.5 Radiation Monitoring

Radiation surveys are conducted annually to detect soils that have become contaminated with gamma-emitting radionuclides (Figure 14-9). The survey is performed over the entire SDA surface with a global positioning radiometric scanner system mounted on a four-wheel drive vehicle. Soil surface radiation surveys complement soil sampling conducted at RWMC.

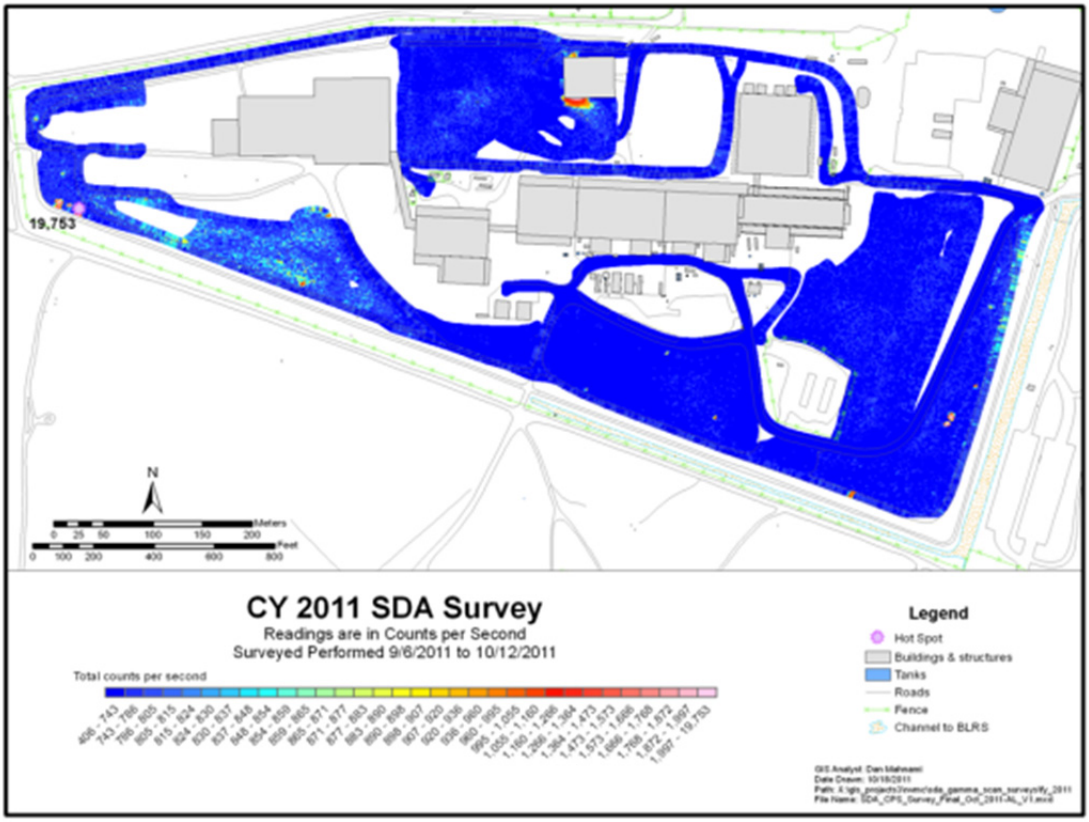

Figure 14-9. RWMC Surface Disposal Area Surface Radiation Survey (2011).

14.6.1.6 Frequency of Collection

Collection frequencies are shown in Table 14-3. The sampling and analysis frequencies follow the recommendations in DOE/EH-0173T (DOE 1991), data quality objectives, and past project reviews. Any changes or additions to the current program are driven by changes in operation and periodic procedure reviews.

Table 14-3. ICP Environmental Surveillance Program Activities.

Media	Analysis	Collection Frequency	Location		Description
			INL (Onsite)	Distant	
Air	Gross alpha Gross beta Gamma spectrometry Radiochemistry[a]	Semimonthly Composited Monthly Composited Quarterly	RWMC/SDA	NA	Seven SP[b] air samplers operate at 0.113 m^3/min (includes one control and one replicate, excludes one blank)
	Gross alpha Gross beta Gamma spectrometry Radiochemistry[a]	Semimonthly Composited Monthly Composited Quarterly	NA	Howe (see Figure 14-4)	One SP air sampler operates at 0.113 m^3/min
	Gross alpha Gross beta Gamma spectrometry Radiochemistry	Semimonthly Composited Monthly Composited Quarterly	Idaho CERCLA Disposal Facility	NA	One SP air sampler operates at 0.113 m^3/min
Soil	Gamma spectrometry Radiochemistry[a]	Triennially	RWMC/SDA	NA	Four locations in each of four major areas (see Figure 14-7) (plus two control areas)
Surface Water	Gamma spectrometry Radiochemistry[a,c]	Quarterly, depending on precipitation	RWMC/SDA	NA	Surface run-off samples from SDA and control location
Biota	Gamma spectrometry Radiochemistry	Annually, but species sampled varies each year depending on availability	RWMC	Frenchman's Cabin (see Figure 4-10)	Vegetation—Three composites in each of four major areas (see Figure 14-8) (plus one control area)
Penetrating Radiation (Surface)	External radiation levels	Annually	RWMC/SDA	NA	Surface gamma radiation—truck-mounted GPRS[d] gamma-radiation detector system

a. Analysis for Am-241, Pu-238, Pu-239/240, U-235, U-238, and Sr-90.

b. SP—suspended particulate.

c. Exact number of samples may vary due to availability.

d. GPRS—global positioning radiometric scanner.

14.6.1.7 Sampling Methods

Monitoring activities are performed using the methods described below for each media area.

Biota

Four representative areas of the RWMC are sampled. During odd-numbered years, samples of crested wheat and either rabbitbrush or sagebrush (dependent upon availability) are collected within each area. Crested wheatgrass samples are collected by clipping the individual species at ground level. Rabbitbrush and sagebrush are collected by clipping some new growth and old branches off the plants. During even-numbered years, Russian thistle is sampled in each area by pulling up the entire plant within a 1-m square frame. Control samples are collected using similar methods from the area around Frenchman's Cabin, located south of the SDA at the base of Big Southern Butte (Figure 14-10). Samples are weighed, dried, milled, reweighed, and submitted to the analytical laboratory for gamma spectroscopy analyses. The mill is cleaned after each sample is processed and each sample is placed in a separate container to avoid cross-contamination.

Ambient Air

Suspended particulate samples are collected every two weeks using low-volume air samplers drawing air through a 4-inch Gelman Versapor-1200 filter at a flow rate of approximately 4 cubic feet per minute. At the time of filter change-out, pertinent data are recorded from the sampler, including total volume, elapsed time, flow rate, and sample time. Filters are shipped to the analytical lab for gross alpha and gross beta analyses of each biweekly sample, and composited by location and analyzed monthly for gamma-emitting radionuclides and quarterly for Am-241, Pu-238, Pu-239/240, U-235, U-238, and Sr-90. Low-volume air samples are collected from five locations at RWMC, one location at INTEC, and a control location offsite northwest of RWMC in Howe.

Surface Soil

Sample locations are mapped and documented based upon historical collection points and are relocated using global positioning system (GPS) coordinates. At each GPS point, a stainless steel sampling ring (12 cm diameter, 6 cm deep) is pressed into the soil until it of flush with the ground surface. After loose debris, large rocks, and vegetation are removed from the surface sample area, a stainless steel scoop is used to collect the entire volume of soil out of the sampling ring into a disposable aluminum pan. The same steps are completed for collecting subsamples 7 m north, south, east, and west of the center of the initial sample location which are deposited into the aluminum pan and composited with the initial sample. The composited soil sample is then thoroughly mixed, screened, and transferred to another container for weighing and analysis. Four composited samples are collected from each of the four major representative locations every three years and from two control locations. Gamma spectroscopy analyses are performed on each composited sample and a subset of those samples is analyzed for Am-241, Pu-238, Pu-239/240, U-235, U-238, and Sr-90, dependent upon the presence and concentration of Am-241 and Cs-137 detected in the gamma analyses.

Surface Water

After significant rainfall or when weather warms up enough in spring to cause snowmelt, water levels at the SDA lift station are visually observed to determine if sufficient water has collected for sampling (samples are collected quarter when surface water is present or as requested by facility personnel). If sufficient water is present, a 4-L sample is collected using a disposable bailer or a peristaltic pump. Water level is measured in inches at the time using a measuring stick. Samples are submitted to the analytical lab for gamma spectroscopy analyses and radiochemistry analyses for Am-241, Pu-238, Pu-239/240, U-235, U-238, and Sr-90.

Surface Radiation

Surface radiation is monitored using the Global Positioning Radiometric Scanner (GPRS) system. The GPRS is mounted on a four-wheel drive vehicle and uses two plastic scintillation detectors mounted 1-m aboveground, allowing a view of approximately 7-m diameter. The radiological data and geographical coordinates are recorded on an onboard computer. A background reading is collected near the area being surveyed using a MicroR meter and the GPRS. The vehicle is driven over the area to be surveyed at 5 miles per hour or less. The GPRS collects real-time data, allowing numerous data points to be recorded in a short timeframe. The data are differentially corrected and transmitted via satellites, and geographic coordinates are recorded at least every 2 seconds. The data are reviewed to ensure that ambient radiation levels remain near background levels. The SDA is approximately 100 acres in size and usually requires about one week to survey all accessible areas within its boundaries.

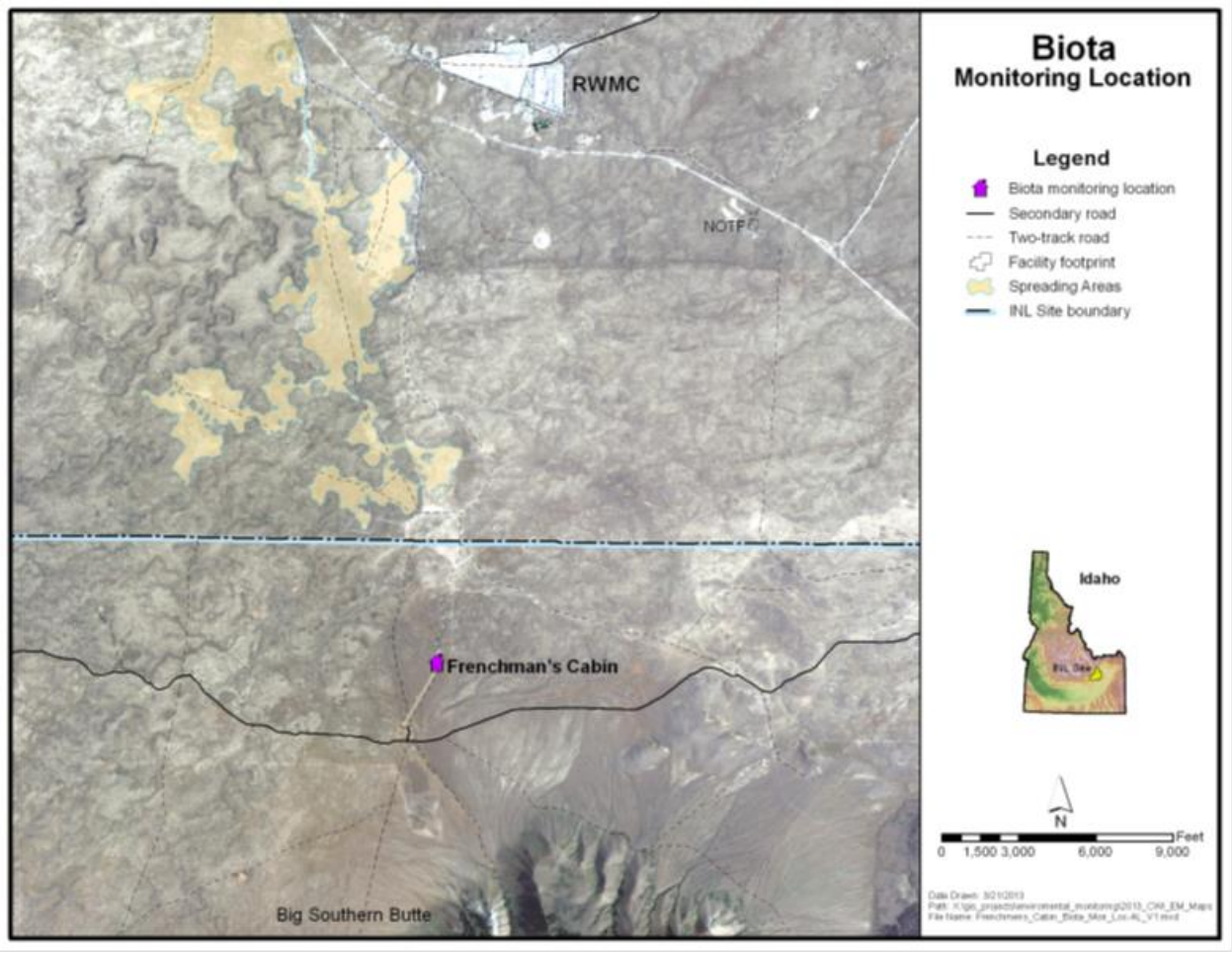

Figure 14-10. Background soil and biota monitoring location at Frenchman's Cabin.

14.6.1.8 Analytical Methods

Analytical methods and parameters meet the detection levels required in the task order statement of work with the laboratory and are based on requirements in PLN-720.

14.6.2 Radionuclides Assessed

14.6.2.1 Ambient Air

Because the radionuclides shown in Table 14-4 are included in the source term, it is recommended that routine analysis and trending of these radionuclides must continue to fulfill DOE Order 435.1 requirements. These radionuclides have been detected over previous years at waste management facilities, and details of these detections have been reported in Annual Site Environmental Reports.

Table 14-4. Select Radionuclides Considered for Routine Analysis.

RWMC	INTEC
Am-241	Am-241
Gamma-emitting	Gamma-emitting
Pu-238	Pu-238
Pu-239/240	Pu-239/240
Sr-90	Sr-90

Radiochemical analyses are conducted of quarterly composited air filters for Sr-90, Am-241, and Pu-239/240. Strontium-90 was detected in many filters collected from RWMC and INTEC. However, it was detected in some Howe filters and blank filters, indicating that it may be of laboratory origin. Since these detections, a new contract was assigned to a different analytical laboratory. Plutonium-238 was detected once in the INTEC filter and a few times in SDA filters collected during 2007 through 2011. Plutonium-239/240 and Am-241 are occasionally detected in filters from RWMC. These detections are expected because soil in the northwest corner and vicinity of the SDA has been shown to be contaminated with transuranic radionuclides from past flooding events.

Gamma spectroscopy of the composite air filters are analyzed for those radionuclides that are typically associated with the source term in the waste stream. Cesium-137 has occasionally been detected at RWMC but not at INTEC during the past five years.

The biweekly air filters are analyzed for gross alpha/beta activity for screening purposes. Figure 14-11 presents the average results for gross beta activity in filters from 2007 through 2011. Gross beta activity has been detected in almost all filters collected, indicating background levels. The seasonal pattern of results (lowest in the spring and summer and highest in the fall and winter) also confirm this because inversion conditions typically occur during these seasons. In addition the RWMC and INTEC results appear to track each other closely. Any changes in pattern or unusually high results can be investigated further to determine if a specific radionuclide or radionuclides are present at higher levels than expected. If an abnormal trend is identified, additional investigations are initiated and actions taken if warranted. For this reason, the measurement of gross activity should continue.

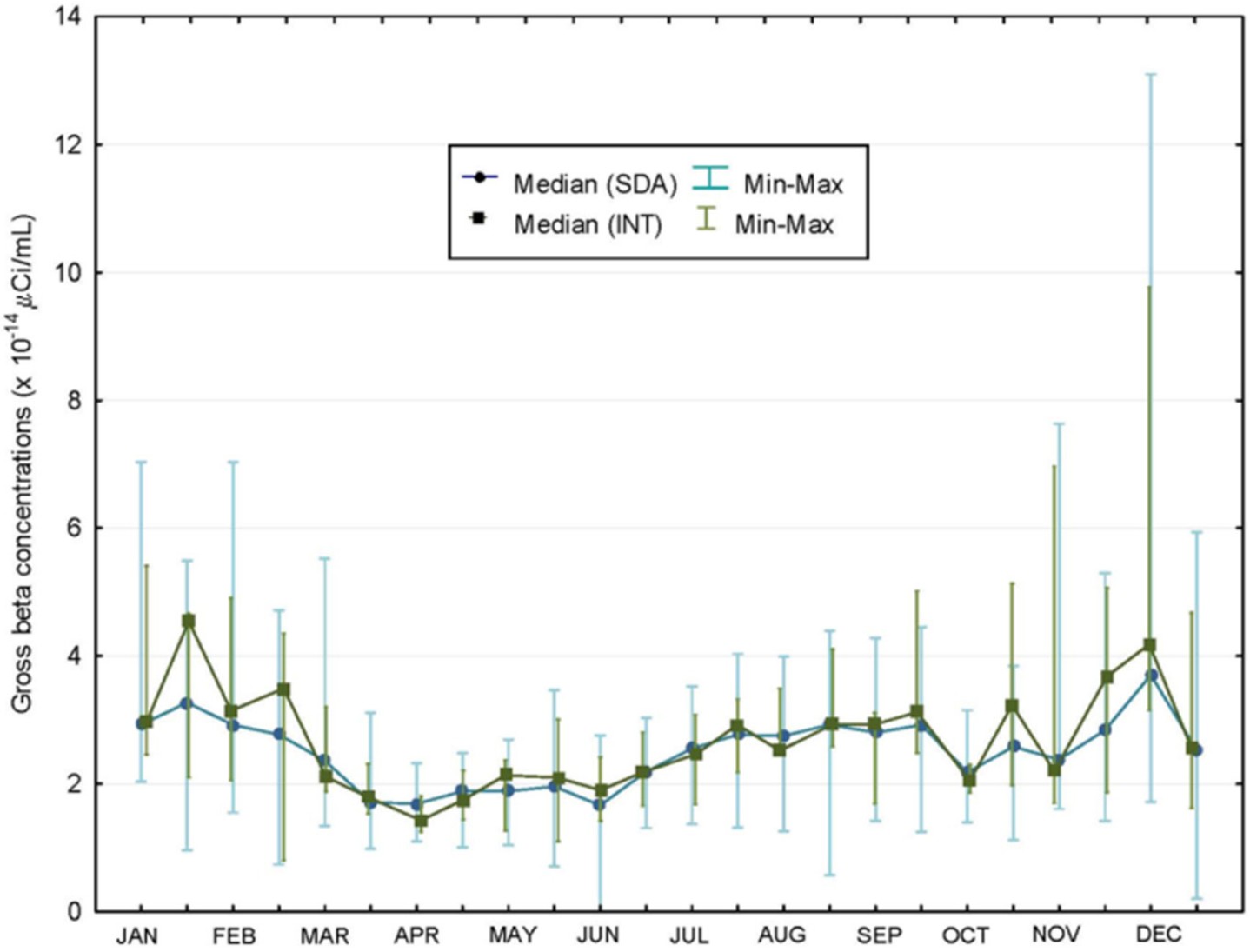

Figure 14-11. Median Biweekly Gross Beta Concentrations in Air Filters Collected at RWMC and INTEC (2007-2011).

14.6.2.2 Surface Soil

The radionuclides released from RWMC can be deposited on surface soil. Soil sampling at RWMC has been conducted for many years, primarily because of the potential for release from buried waste and events that contaminated soils (such as the flooding in 1962 and 1969). Analysis of the soils for transuranics (plutonium isotopes, uranium isotopes, Sr-90, and Am-241) and gamma-emitting radionuclides is justified, based on the source term and results of the last sample analyses conducted in 2009 (Table 14-5).

Table 14-5. Radionuclides Detected in RWMC soil samples (2009).

Parameter	Minimum Concentration[a] (pCi/g)	Maximum Concentration[a] (pCi/g)	% ECG[b] (pCi/g)
Cesium-137	0.044 ± 0.014	0.528 ± 0.042	5.3
Americium-241	0.063 ± 0.020	0.123 ± 0.028	0.15
Plutonium-239/240	0.062 ± 0.017	0.092 ± 0.021	0.03

a. Result ± 1s. Results shown are ≥ 3s.
b. ECG = Environmental Concentration Guide (EG&G 1986).

14.6.2.3 Biota

Vegetation is collected during odd-numbered years. Vegetation was not available at RWMC during 2007 due to recontouring and construction activities in 2007. Perennials were not available during 2009 because of the same activities. Some crested wheatgrass was available, but no radionuclides were detected in the samples collected. Rabbit brush and crested wheatgrass were collected in 2011. The radiochemistry results are shown in Table 14-6. Due to the source term and detection of the specific alpha- and beta-emitting radionuclides shown in Table 14-6, particularly in the perennial rabbit brush samples, these radiochemical analyses should continue. Gamma analysis should also continue.

14.6.2.4 Surface Radiation

Because these surveys are concerned with detecting and reporting trends and characterizing radiation levels, surface radiation surveys take measurements of gross gamma radiation within the SDA. No measurements of specific gamma-emitting radionuclides are made.

Table 14-6. Radiochemistry Results of Vegetation Samples at RWMC (2011).

	Am-241 (pCi/g)	Pu-238 (pCi/g)	Pu-239/240 (pCi/g)	Sr-90 (pCi/g)
Rabbit Brush				
RWMC Area 1 Collected 9/29/11	Undetected (sample value <3 sigma)	Undetected (sample value <3 sigma)	$(7.06 \pm 1.60) \times 10^{-4}$	$(3.32 \pm 0.50) \times 10^{-2}$
RWMC Area 2 Collected 9/29/11	$(5.51 \pm 0.55) \times 10^{-3}$	Undetected (sample value <3 sigma)	$(1.93 \pm 0.25) \times 10^{-3}$	$(2.55 \pm 0.38) \times 10^{-2}$
RWMC Area 3 Collected 9/29/11	$(7.61 \pm 1.92) \times 10^{-4}$	$(2.68 \pm 0.87) \times 10^{-4}$	$(6.42 \pm 1.40) \times 10^{-4}$	$(8.48 \pm 1.00) \times 10^{-0}$
Frenchman's Cabin (control) Collected 9/28/11	Undetected (sample value <3 sigma)	$(6.48 \pm 1.55) \times 10^{-4}$	$(3.37 \pm 1.01) \times 10^{-4}$	$(2.29 \pm 0.35) \times 10^{-2}$
Crested Wheat Grass				
RWMC Area 1 Collected 7/13/11	Undetected (sample value <3 sigma)	Undetected (sample value <3 sigma)	Undetected (sample value <3 sigma)	Undetected (sample value <3 sigma)
RWMC Area 2 Collected 7/13/11	$(1.07 \pm 0.18) \times 10^{-3}$	Undetected (sample value <3 sigma)	$(1.04 \pm 0.17) \times 10^{-3}$	Undetected (sample value <3 sigma)
RWMC Area 3 Collected 7/13/11	$(3.32 \pm 0.35) \times 10^{-3}$	Undetected (sample value <3 sigma)	$(4.31 \pm 0.52) \times 10^{-3}$	$(1.59 \pm 0.72) \times 10^{-2}$
Frenchman's Cabin (control) Collected 8/8/11	Undetected (sample value <3 sigma)	Undetected (sample value <3 sigma)	Undetected (sample value <3 sigma)	$(1.61 \pm 0.28) \times 10^{-2}$

14.6.2.5 Surface Water

Strontium-90 and transuranic radionuclides have been detected in surface water samples collected from 2008 through 2011 (surface water at the pumping stations was not available in 2007). Sr-90 and other man-made gamma/alpha-emitting radionuclides should be continued to be analyzed for because the source term contains these radionuclides and has a potential for release outside of RWMC.

14.7 Quality Assurance

The Quality Assurance Program developed by the ICP Environmental Surveillance Program may be found in PLN-720, "Environmental Surveillance Program Plan."

Quality Assurance Objectives (QAOs) are qualitative and quantitative specifications for quality of data. They include evaluation of acceptable conformance with established sampling procedures and criteria for evaluating the results of analyses of QA/QC samples. QAOs provide a continuing measure of performance for the activity.

EPA has identified five areas relating to QAOs. These are sometimes referred to as the PARCC parameters:

- Precision
- Accuracy
- Representativeness
- Completeness
- Comparability.

Three of the five PARCC parameters lend themselves to quantitative measures of data quality for ICP environmental surveillance. They are precision, accuracy, and completeness. The remaining two, representativeness and comparability, are addressed in qualitative terms.

The Environmental Surveillance Program evaluates precision and accuracy of measurements using QC samples. The precision and accuracy of measurements are evaluated using field duplicates and spiked environmental samples. Periodic reviews of procedures and field operations are conducted to assess the representativeness and comparability of data. Various QC processes designed to evaluate the PARCC of data are integrated in the project's detailed procedures.

14.8 Decision Limits and Actions Levels

Action levels have been established, where appropriate. These levels can be found in the program plan and in applicable procedures. Decision limits are specified by conservative guidelines and action levels established for the monitoring programs. Based on the regulatory driver for waste management facilities (DOE Order 435.1), data trending is used as the basis and justification for actions when necessary.

14.9 References

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