Hanford Site Environmental Monitoring Plan

Prepared for the U.S. Department of Energy, Richland Operations Office

DOE/RL-91-50, Rev. 8

The front cover depicts a metallic green bee (*Agapostemon* species) foraging for pollen on Blue Mountain Prairie Clover (*Dalea ornata*). Metallic green bees can be found throughout the Hanford Site, most commonly in the late summer months. The flowers of Blue Mountain Prairie Clover begin blooming in a wreath at the bottom of the spike and travel up the spike as the season progresses. The extended bloom of this species provides food for pollinators like the metallic green bee through the hot summer months. In turn, the bees spread pollen from flower to flower as they forage for food, enabling plant reproduction.

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Hanford Site Environmental Monitoring Plan

September 2018

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY | Richland Operations Office
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EXECUTIVE SUMMARY

The *Hanford Site Environmental Monitoring Plan* (EMP) implements the requirements of DOE O 436.1, *Departmental Sustainability*, DOE O 458.1, *Radiation Protection of the Public and the Environment*, and the Hanford Site Air Operating Permit 00-05-006. DOE O 436.1 requires all U.S. Department of Energy (DOE) organizations and sites under their purview to develop and implement an Environmental Management System that is certified to, or conforms with, the ISO 14001 Standard, *Environmental Management Systems – Requirements with Guidance for Use*. One element of the ISO standard addresses environmental monitoring and measurement. It states that “the organization shall establish, implement and maintain procedure(s) to monitor and measure, on a regular basis, the key characteristics of its operations that can have a significant environmental impact” (ISO 14001).

The environmental monitoring requirements for radiation are specified in DOE O 458.1, *Radiation Protection of the Public and the Environment.* The purpose of DOE O 458.1 is to establish requirements to protect the public and the environment against undue risk from radiation associated with activities conducted under the control of DOE pursuant to the *Atomic Energy Act of 1954*, as amended. Environmental monitoring is performed to determine radiological impacts to the public and the environment.

This EMP contains the rationale for the required environmental monitoring programs including design criteria, sampling locations and schedules, quality assurance requirements, laboratory analytical procedures, and reporting requirements. Guidance provided in DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*, is included in the rationale and design criteria presented in this EMP.

Environmental monitoring consists of the following six major activities, addressed in separate sections of this EMP:

1. **Effluent Monitoring:** The collection and analysis of samples or measurements of air and liquid effluents for the purpose of characterizing and quantifying contaminants, assessing radiation exposures of members of the public, providing a means to control effluents at or near the point of discharge, and demonstrating compliance with applicable standards and permit requirements. These activities are discussed in Section 2.0.

2. **Environmental Surveillance:** The collection and analysis of environmental samples or direct measurements of air, water, soil, foodstuff, biota, and other media from the Hanford Site and its environs for the purpose of determining compliance with applicable standards and permit requirements; assessing radiation exposures of members of the public; and assessing the effects, if any, on the local environment. These activities are discussed in Sections 3.0 and 4.0.

3. **Groundwater Monitoring:** The collection and analysis of samples or measurements of groundwater for the purpose of characterizing and quantifying contaminants, monitoring contaminant plumes, assessing the effectiveness of groundwater remediation activities, and assuring the public that Hanford Site contaminants are not present offsite. These activities are discussed in Section 5.0.

4. **Meteorological Monitoring:** The collection of representative meteorological data (e.g., wind speed and direction, precipitation, temperature, humidity, and atmospheric pressure) to provide information needed to support and interpret the results of other monitoring and surveillance activities, particularly for air dispersion modeling. These activities are discussed in Section 6.0.

5. **Ecological Monitoring:** The collection and analysis of ecological data to assess the abundance, vigor/condition, and distribution of biota on the Hanford Site. The monitoring data are used by DOE and Hanford Site contractors to support environmental cleanup and restoration activities, mitigation actions, and land use planning while maintaining compliance with ecological resource laws and regulatory requirements. These activities are discussed in Section 7.0.

6. **Cultural Resource Monitoring:** The collection of data to assess the condition of known cultural resources that have the potential to be impacted by natural processes and human activities. These activities are discussed in Section 8.0.

Personnel from the U.S. Department of Energy, Richland Operations Office (DOE-RL), Mission Support Alliance (MSA), CH2M Hill Plateau Remediation Company, and various subcontractors contributed to this plan. The MSA Environmental Integration Services (EIS) Department's Ecological Monitoring and Environmental Surveillance organization coordinated document production and maintains this EMP. This EMP was written to meet the needs of the Hanford Site's DOE offices and their contractors. In addition to periodic updates to this EMP, EIS produces an Annual Site Environmental Report for the Hanford Site. The annual report summarizes monitoring results and compliance status of all environmental monitoring programs and includes detailed background on the Hanford Site and surrounding area. These reports are available on the web at: https://msa.hanford.gov/page.cfm/EnviroReports. Questions or concerns about this EMP should be directed to Thomas Ferns, DOE-RL, thomas.ferns@rl.doe.gov.

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ACRONYMS

ADR	anomalous data report
AEA	*Atomic Energy Act*
ALARA	as low as reasonably achievable
AMP	Air Monitoring Plan
AOP	Air Operating Permit
ARAR	Applicable or Relevant and Appropriate Requirements
ARPA	*Archaeological Resources Protection Act*
CAA	*Clean Air Act*
CERCLA	*Comprehensive Environmental Response Compensation and Liability Act of 1980*
CHRP	Cultural and Historic Resources Program
CWA	*Clean Water Act*
DMR	Discharge Monitoring Report
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DQO	data quality objectives
Ecology	Washington State Department of Ecology
EDE	effective dose equivalent
EMC	Ecological Monitoring and Compliance
EMP	Environmental Monitoring Plan
EMS	Environmental Management System
EPA	U.S. Environmental Protection Agency
ETF	Effluent Treatment Facility
HEIS	Hanford Environmental Information System
HMS	Hanford Meteorology Station
ISMS	Integrated Safety Management System
MCL	maximum contaminant level
MEI	maximally exposed individual
MSA	Mission Support Alliance
NEPA	*National Environmental Policy Act*
NESHAP	*National Emission Standards for Hazardous Air Pollutants*
NHPA	*National Historic Preservation Act*
NOC	Notice of Construction
NRHP	*National Register of Historic Places*
QA	quality assurance
QAPjP	Quality Assurance Project Plan
QC	quality control
RCRA	*Resource Conservation and Recovery Act of 1976*
RESRAD	RESidential RADiation
RI/FS	Remedial Investigation/Feasibility Study
RIMS	Richland Integrated Management System
SALDS	State Approved Land Disposal Site
SAP	sampling and analysis plan
TED	total effective dose

TEDE	total effective dose equivalent
TEDF	Treated Effluent Disposal Facility
TLD	thermoluminescent dosimeter
TSD	treatment, storage, or disposal
WDOH	Washington State Department of Health
WTP	Waste Treatment Plant

1.0 INTRODUCTION

The Hanford Site Environmental Monitoring Program is implemented on two distinct and independent levels. This approach was established to evaluate and ensure that Hanford Site activities are not negatively impacting human health, ecological health, natural resources, or cultural resources.

The first level of the program addresses the operational aspects of environmental protection. DOE O 436.1, *Departmental Sustainability,* requires contractors to implement an Environmental Management System (EMS) that is certified to or conforms with the ISO 14001 Standard, *Environmental Management Systems – Requirements with Guidance for Use,* through their respective Contractor Requirements Document. Additionally, contractors are required to perform effluent or environmental surveillance, as appropriate, at or near active and inactive facilities onsite. Required state and federal laws, regulations, and permits are also addressed at this level.

The second level of the program ensures protection of Hanford Site workers, the public, and environmental resources on and around the Hanford Site from all operations at the Hanford Site. As part of this effort, DOE and its contractors must implement the requirements of DOE O 436.1 and DOE O 458.1, *Radiation Protection of the Public and the Environment*. The activities at this level include groundwater monitoring, sitewide environmental surveillance, meteorological monitoring, natural and cultural resources monitoring, and cumulative environmental impact assessment related to Hanford Site activities.

The U.S. Department of Energy, Richland Operations Office Integrated Safety Management System is called the Richland Integrated Management System (RIMS). RIMS describes aspects of the Hanford Site's Environmental Monitoring Program in terms of the following environmental surveillance requirements:

- Ensure the early identification of and appropriate response to potentially adverse environmental impacts associated with DOE operations. This includes preoperational characterizations and assessments, effluent and emissions monitoring, and environmental surveillance on and off the Hanford Site.

- Provide the mechanisms and information through which DOE demonstrates compliance with applicable environmental compliance; public health; and resource protection laws, regulations, and DOE Orders.

- Demonstrate that Hanford Site operations are being conducted to ensure protection of the workers and the public.

- Provide assurance that Hanford Site activities are conducted in ways that are protective of the air, water, land, other natural resources, and cultural resources.

- Mandate participation in the Hanford Site's land-use planning activities, human health and ecological risk assessments, and long-term stewardship plans. The environmental monitoring plans and resource management plans ensure the consideration of environmental protection requirements throughout each activity's planning, operation, closure, and post-closure lifecycle.

- Ensure that environmental surveillance sample collection methods, sample analyses, data interpretations, and reporting are consistent across the Hanford Site, to ensure comparability of the data.

Environmental surveillance activities involve multiple DOE organizations and Hanford Site contractors driven by different missions and regulatory requirements. Surveillance activities are closely aligned with the needs of ongoing environmental cleanup, restoration, and assessment activities at the Hanford Site. Surveillance and monitoring information is used extensively by numerous projects under the purview of the Hanford Site's DOE field offices. Quality assurance is an integral part of all environmental surveillance and monitoring activities and ensures data quality is known and documented and that the data meet DOE and contractor needs.

In addition, environmental surveillance activities are integrated throughout the Hanford Site to the extent practicable to avoid collection of duplicative data. Such integration minimizes duplication of capabilities and resources at the Hanford Site, optimizes operational efficiencies, maximizes the amount of useful information generated, and results in lower costs to DOE. Surveillance activities are conducted in a manner that ensures the capture, preservation, perpetuation, and use of the institutional knowledge obtained through 50-plus years of monitoring on and near the Hanford Site.

1.1 ENVIRONMENTAL MONITORING PROGRAM OVERVIEW

The primary elements of Hanford's Environmental Monitoring Program include effluent monitoring, near-facility environmental monitoring, far-field environmental surveillance, far-field environmental surveillance, groundwater monitoring, meteorological monitoring, ecological monitoring, cultural resource monitoring, and independent oversight activities of the Washington State Department of Health (WDOH). The following paragraphs briefly describe each element.

1.1.1 Effluent Monitoring

Effluent monitoring of airborne emissions and liquid effluents at Hanford is driven by DOE and Environmental Protection Agency (EPA) requirements, state and federal regulations, and facility operating permits. The monitoring is conducted in accordance with approved monitoring procedures and the results are reported in the Hanford Annual Site Environmental Report.

Hanford Site contractors perform sampling and monitoring of liquid effluent and airborne emissions at each facility to characterize and quantify contaminants, assessing radiation exposures of members of the public, controlling effluents at or near the point of discharge, and demonstrating compliance with applicable standards and permit requirements. Liquid and airborne effluents from facilities are monitored for radiological and non-radiological parameters. Section 2.0 of this plan describes these monitoring activities.

1.1.2 Environmental Surveillance

Environmental surveillance is a multimedia environmental monitoring effort conducted to assess impacts of Hanford Site operations to human health and the environment from exposures to radionuclides and chemicals. The surveillance program consists of near-facility environmental monitoring and far-field environmental surveillance.

1.1.2.1 Near-Facility Environmental Monitoring. Near-facility environmental monitoring, also known as onsite or near-field environmental surveillance, is conducted near active facilities and operations and at inactive contaminated facilities (e.g., former waste storage and disposal facilities) that have the potential to significantly impact the Hanford Site environment. Media that are sampled as part of this monitoring include ambient air, soil, and biota. Parameters routinely monitored include radionuclide concentrations, radiation exposure levels, and radiation dose rates.

Onsite surveillance is performed independent of facility-related environmental monitoring programs to assess the effectiveness of effluent controls, monitor for fugitive contaminant releases from cleanup and remediation locations, monitor for releases caused by wildfires or other disturbances from contaminated or potentially contaminated areas, and establish contaminant concentration baselines in the event of an unplanned contaminant release. Annual design reviews are performed to ensure project activities are aligned with current Hanford Site operations and missions, and focused on those contaminants with the greatest potential for contributing to offsite doses.

This monitoring is performed to protect workers and the environment adjacent to nuclear facilities; waste storage, treatment, and disposal sites; and remediation sites in compliance with applicable federal, state, and local environmental regulations and requirements. The objectives of near-facility environmental monitoring are to evaluate the following:

- Compliance with federal, state, and local environmental radiation protection requirements and guides
- Performance of radioactive waste confinement systems
- Concentration trends of radioactive materials in the near-facility environment.

Section 3.0 of this plan describes these monitoring activities and provides details about the environmental media sampled, monitoring locations, extent and frequency of monitoring and measurements, procedures for laboratory analyses, quality assurance requirements, and implementing procedures.

1.1.2.2 Far-Field Environmental Surveillance. Far-field environmental surveillance is closely related to and coordinated with near-facility environmental monitoring (see Section 3.0), groundwater monitoring (see Section 5.0), and WDOH's oversight of Hanford's environmental programs. The surveillance activities are closely aligned with and support the Hanford Site's environmental cleanup, restoration, and assessment missions. Far-field environmental surveillance sampling is performed to measure radionuclide and chemical contaminants in various environmental media and is designed to be more of a sitewide surveillance program and less facility- or source-specific. Media that are sampled include ambient air, surface water, sediment, soil, natural vegetation, agricultural products, and wildlife on and around the Hanford Site. These samples are analyzed for concentrations of radionuclides attributable to natural sources, worldwide fallout from nuclear weapons testing, and Hanford Site operations. The sampling design for the far-field environmental surveillance program is based on radiological and chemical pathway analyses of contaminant sources described in facility effluent monitoring plans and from data obtained by the near-facility environmental monitoring program. The pathway analyses and radiological dose assessments use dispersion data obtained from the Hanford Site meteorological monitoring program (see Section 6.0).

The Hanford Annual Site Environmental Report documents the environmental compliance status of the Hanford Site, environmental conditions on and around the Site, and potential onsite and offsite radiological exposures resulting from Hanford Site operations. The report provides a historical and current accounting of Hanford Site operations and their impact on humans and the environment to the public, stakeholders, Tribal Nations, trustees, and regulatory agencies. The report also provides DOE information to better manage risk associated with those operations.

Section 4.0 provides the detailed rationale and design criteria for the Environmental Surveillance program including media sampled, sampling locations, contaminants of concern, extent and frequency of monitoring and measurements, procedures for laboratory analyses, and QA requirements.

1.1.3 Groundwater Monitoring

The CH2M Hill Plateau Remediation Contractor Soil and Groundwater Remediation Project is responsible for assessing the distribution and movement of existing groundwater contamination (both radiological and chemical) and for identifying and characterizing potential and emerging groundwater contamination problems. Monitoring activities are performed to comply with requirements of the *Resource Conservation and Recovery Act*, *Atomic Energy Act*, Washington State regulations, requirements for operational monitoring around retired reactors and chemical processing facilities, and requirements for environmental surveillance. Groundwater monitoring is performed during cleanup investigations under the requirements of the *Comprehensive Environmental Response, Compensation, and Liability Act*. Groundwater samples are currently collected from approximately 1,063 wells, both on and off the Hanford Site.

Section 5.0 describes the Hanford Site's groundwater monitoring activities. Groundwater information discussed in this plan includes program design, well locations, sampling frequencies, sampling procedures, analyses performed, data reviews, and rationale for the level of effort devoted to each activity.

Additional information is available in the Environmental Protection section of the Groundwater Protection Management Program sub-section within RIMS.

1.1.4 Meteorological Monitoring

Meteorological and climatological services are coordinated through the operation of the Hanford Meteorology Station (HMS). HMS provides climatological and operational meteorological support to DOE and its contractors for Hanford Site operations, sitewide emergency preparedness, construction, remediation, environmental restoration, and safety-related activities. Information is provided to onsite organizations performing work that could be severely affected by adverse meteorological conditions (i.e., thunderstorms, strong winds, dense fog, and snow or ice storms). The day-to-day meteorological data is essential for ensuring work activities are conducted efficiently and under the safest conditions possible. Timely meteorological data is also provided in the event of a suspected or actual release of radioactive or hazardous material to the atmosphere. This ensures personnel responding to the event can make appropriate and timely decisions. The data are integral to the Hanford Site's annual estimates of potential public radiation exposures. Comprehensive climatological data records are maintained for use in a variety of other applications such as post-accident analysis, dose reconstruction, building design, and environmental impact assessments. The HMS maintains a long-term meteorological computer database and produces an annual climatological data summary for the Hanford Annual Site Environmental Report.

Section 6.0 describes the rationale and design of the HMS including the number and location of weather stations, instruments used, forecasting capabilities, data management efforts, diffusion modeling activities, and emergency response capabilities.

1.1.5 Ecological Monitoring

The Ecological Monitoring and Compliance (EMC) Program has multiple objectives that support activity-specific ecological compliance requirements and sitewide requirements to ensure protection of the Hanford Site's natural resources. The EMC Program personnel monitor the abundance, vigor, and distribution of plant and animal populations on the Hanford Site and evaluate the cumulative impacts of Hanford Site operations on these resources. In addition, EMC Program personnel perform baseline ecological resource surveys to document the occurrence of protected resources, evaluate potential impacts from proposed actions to protected species and habitats as required by the *National Environmental Policy Act of 1969* and the *Endangered Species Act*, facilitate cost-effective regulatory compliance, and ensure fulfillment of DOE natural resource protection responsibilities.

Section 7.0 provides additional detail about the types of studies and activities performed to monitor the status of important resources on and near the Hanford Site while ensuring compliance with state and federal resource protection laws.

1.1.6 Cultural Resource Monitoring

The Cultural and Historic Resources Program performs baseline cultural resources surveys to document the occurrences of protected resources; evaluate and document impacts to protected resources as required by the *National Historic Preservation Act*, the *American Indian Religious Freedom Act*, and the *Archaeological Resources Protection Act*; facilitate cost-effective regulatory compliance; and ensure fulfillment of DOE cultural resources protection responsibilities.

Section 8.0 provides a detailed description of the Cultural and Historic Resources Program including requirements, rationale, objectives, and survey design. Additional information is available in DOE/RL-98-10, *Hanford Cultural Resources Management Plan*.

1.1.7 Independent Verification of Hanford Site Environmental Monitoring Programs

The WDOH, through a grant from DOE, conducts an independent verification of the quality of DOE environmental programs at the Hanford Site. The grant provides funds for sample collection and analysis, data compilation and interpretation, and report preparation. In addition, the WDOH participates in periodic collaborative studies with the Hanford Site environmental monitoring programs to address specific environmental concerns and/or data needs. The WDOH periodically publishes the results of its independent activities in a report produced through their Environmental Radiation Program (e.g., WDOH 320-115, *Hanford Environmental Oversight Program 2015 Data Summary Report*).

1.2 ENVIRONMENTAL ALARA PROGRAM

The as low as reasonably achievable (ALARA) process is used at the Hanford Site to manage and control releases of radioactive material to the environment to levels that are acceptable to the public and regulators but do not put undue burdens on project operations and activities. The driving requirements behind the environmental ALARA program are DOE O 458.1, *Radiation Protection of the Public and the Environment*, and WAC 246-247, *Radiation Protection – Air Emissions*. DOE O 458.1, requires the ALARA process be used for all activities that result in public doses. WAC 246-247 also mandates the ALARA program be used as a standard for controlling radioactive air emissions.

The ALARA program does not define distinct limits, numerical values, or discrete thresholds for doses but rather defines a philosophy, process, or goal of attaining doses as far below the applicable limit as is reasonably achievable. The environmental ALARA process is a logical procedure for identifying projects, operations, and activities that result in radioactive releases to the environment and evaluating ways to reduce radiation exposures and minimize releases to the extent practical. The final product of an ALARA process is a preferred system (from among several candidate radiological protection alternatives) that provides maximum benefit at the lowest cost. The ALARA process is essentially one of optimization and cost-benefit analysis.

The ALARA process is applicable to any activity on the Hanford Site that has the potential to expose members of the public or the environment to radiological releases. The primary Hanford Site sources of potential public and environmental radiation exposures are from facility and fugitive air emissions, the processing and transport of radionuclide liquid wastes, and the discharge of groundwater contaminated by past waste disposal practices into the Columbia River.

Typical ALARA program evaluations for radiation protection purposes primarily consider human health. The environmental ALARA process also considers societal, technological, economic, and public policy factors. Some examples of these factors are impacts to sensitive species and habitats, effects on cultural and historic resources, real or perceived restrictions to land use, sociopolitical aspects, and public perception.

Implementation of the environmental ALARA process occurs through integrated environment, safety, and ISMS core functions, as well as EMS elements. The planning element and the implementation and operation core elements of the EMS addresses the first three core functions of the ISMS: 1) define the scope of work, 2) analyze the hazards, and 3) develop and implement hazards controls. The ALARA process is simply another requirement blended into the ISMS core functions during job hazards analyses. In general, the ALARA process is analogous to the DOE O 436.1 definition of an EMS:

> *…a continuous cycle of planning, implementing, evaluating, and improving processes and actions undertaken to achieve environmental missions and goals*.

The integration of the ALARA process and the EMS into the ISMS provides a unified strategy for management of resources; control and attenuation of risks; and establishment and achievement of environment, safety, and health goals.

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2.0 EFFLUENT MONITORING

2.1 INTRODUCTION

Effluent monitoring is defined in DOE O 458.1 as "the collection and analysis of samples of liquid and gaseous effluents or measurements of liquid and gaseous effluents performed to characterize and quantify radiological contaminants and process stream characteristics, assess radiation exposures of members of the public, and demonstrate compliance with applicable standards." Monitoring of non-point source emissions, such as area and diffuse sources, is conducted through the environmental surveillance and ambient air sampling program described in more detail in Sections 3.0 and 4.0. The purpose of effluent sampling and monitoring programs is to demonstrate compliance with applicable regulatory and permit requirements and standards, evaluate the effectiveness of effluent treatment and control equipment at or near the point of discharge, and characterize and quantify the volume and mass of effluent constituents released to the ambient environment. Quantified effluent releases documented in annual reports are used to assess any offsite impacts to human health and the environment through ecological pathway analysis and exposure assessments.

The U.S. Department of Energy (DOE) contracts require Hanford facilities and their operating contractors to comply with all applicable DOE directives, laws, and regulations. Historically, DOE Orders and business contracts were the primary drivers mandating the development and implementation of an effluent monitoring program. Today, the primary regulatory drivers requiring effluent monitoring are the *Clean Air Act* (CAA), *Clean Water Act*, federal and state implementing regulations, and the permits issued via these regulations. The *Comprehensive Environmental Response Compensation and Liability Act of 1980* (CERCLA) projects incorporate effluent monitoring requirements, as necessary, through the Applicable or Relevant and Appropriate Requirements (ARAR) process. The CERCLA statue established that administrative requirements, such as effluent permits, are not necessary in the interest of efficient and timely environmental cleanup efforts. Activities related to effluent monitoring cut across Hanford Site facility boundaries and include interfaces with multiple contractor organizations, several DOE organizations, and regulatory agencies including the Washington State Department of Health (WDOH), Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency (EPA). The EPA has delegated authority to Ecology to oversee air and liquid effluents from Hanford Site facilities under authority of the CAA and *Clean Water Act*. EPA has also delegated authority for 40 CFR 61 Subpart H to the WDOH to oversee radionuclide air emissions under the CAA. Executive Order 12580 enables the EPA, DOE, or other agencies to act as lead providing oversight for CERCLA projects. The lead regulatory agency for individual CERCLA projects is established within the framework of the *Hanford Federal Facility Agreement and Consent Order* (also known as the Tri-Party Agreement) (Ecology et al. 1998).

2.2 AIR EFFLUENTS

2.2.1 Radionuclide Air Emissions

The Hanford Site historically operated in excess of 100 air emission point sources that emitted or had the potential-to-emit radionuclides in airborne effluent released to the ambient environment. The transition from nuclear materials production to environmental cleanup has reduced the need for operating ventilation systems; current operations utilize less than 50 point sources over the last 6 years. These air emission point sources, also referred to as stacks or vents, are active exhaust systems powered by fans ventilating filtered air from facilities that store, treat, process or otherwise work with radioactive materials and radioactive waste. The operating stacks are located throughout all of the Hanford Site operating areas and were built with a wide variety of configurations, as illustrated by release heights ranging from 1 to 40 m (3.28 to 131.2 ft) above grade. Over time, some new stacks are constructed, permitted, and operations initiated for specific projects; older stacks are closed and demolished as the Hanford cleanup mission progresses. DOE/RL-2018-05, *Radionuclide Air Emissions Report for the Hanford Site Calendar Year 2017*, shows the current number of operating stacks and includes detailed descriptions of locations, results of sample measurements and release estimates, and current operating status.

Other numerous physically smaller emission units that emit, or have the potential-to-emit, radionuclides are periodically used on the Hanford Site. Examples of these emission units include portable powered ventilation devices such as high-efficiency particulate air filtered vacuum cleaners, small moveable air emission units, high-efficiency particulate air filtered vacuums engineered into a truck, and passive vents from waste tanks. These types of emission units are not amenable to standard stack sample collection protocols and do not contribute significant quantities of radioactive material released to the ambient environment as compared to stack emissions.

2.2.1.1 Key Requirements. DOE O 458.1, *Radiation Protection of the Public and the Environment*, establishes requirements for airborne radioactive effluents. Airborne radioactive effluents need to comply with EPA regulatory standards. DOE contractors must establish and implement procedures and practices for radioactive effluents. Additional requirements include emissions of radon-220 and radon-222 emissions from certain DOE facilities. The as low as reasonably achievable process is also required. A public dose standard of 100 mrem/yr is established from all possible exposure pathways.

The 40 CFR 61, *National Emission Standards for Hazardous Air Pollutants* (NESHAP), Subpart H, establishes the limits for the release of radionuclide emissions other than radon to the air from DOE facilities and specifies sampling and monitoring requirements, annual reporting, and recordkeeping. The emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr. Compliance is demonstrated by calculating annual doses to the public at offsite or uncontrolled onsite locations using CAP88 dispersion modeling software. The *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities* (ANSI/HPS 1999) requirements for how to conduct stack sampling and monitoring are prescribed in this regulation. This regulation does not establish any formal prescriptive requirements for the abatement, treatment, or control of actual emissions. Although 40 CFR 61, Subpart H establishes requirements for evaluating only emissions from point sources, a "Memorandum of Understanding Between the U.S. Environmental Protection Agency and the U.S. Department of Energy Concerning the Clean Air Act Emission Standards for Radionuclides 40 CFR Part 61 Including Subparts H, I, Q & T" (DOE 1995) requires the collection, analysis, and review of emissions data from diffuse sources. The MOU documents DOE concurrence that dose standards in the regulation are applicable to diffuse sources as well as point sources. EPA published a compendium of various approaches for monitoring diffuse and fugitive sources in *Methods for Estimating Fugitive Air Emissions of Radionuclides from Diffuse Sources at DOE Facilities* (Eastern Research Group 2004).

ANSI/HPS (1999) establishes the guidelines and performance criteria for sampling the emissions of airborne radioactive substances in the air discharge ducts and stacks of nuclear facilities. The standard requires characterizing the effluent and stack hardware to ensure a representative sample can be collected. Emphasis is on sample extraction from a location in the stack where the air flow is turbulent and well mixed. ANSI/HPS (1999) provides performance-based criteria, whereas the 1969 version of the standard prescriptively emphasized isokinetic sampling of airborne radioactive material from stacks. Some operating Hanford Site stacks that have not undergone facility modifications or new construction are still subject to the older ANSI/HPS 1969 requirements. The CERCLA incorporates effluent monitoring requirements, as necessary, through the ARAR process. Examples of typical ARAR requirements pertaining to effluent monitoring would be continuous sampling, analyzing effluent samples for radionuclides contributing 10% of the potential-to-emit dose, and a 10 mrem/yr offsite public dose limit. The ARAR requirements are documented in project-specific Air Monitoring Plans (AMP).

WAC 246-247, "Radiation Protection – Air Emissions," adopts the federal 40 CFR 61 requirements and adds a multitude of state only requirements. The state only requirements includes mandatory diffuse and fugitive monitoring, state approval for methods of periodic confirmatory sampling for some stacks, and requirements for Best Available Radionuclide Control Technology or As Low As Reasonably Available Control Technology for abatement and control of emissions.

Several guidance documents relevant to effluent monitoring are DOE-STD-1196-2011, *Derived Concentration Technical Standard*; DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*; and NCRP (1999).

2.2.1.2 Notice of Construction Application. Federal and state regulations require that some new or modified emissions units prepare a document called a Notice of Construction (NOC) application. The NOC document is an air permit application that describes in detail the nature and scope of the project, details of sampling hardware, sample collection and analyses, and estimated emissions. Review and approval by WDOH is required before the new or modified unit begins operation. Stacks operating under CERCLA projects prepare and submit to EPA an AMP that is equivalent in technical content to NOC documents. Most stacks on the Hanford Site are currently operating under project-specific NOC permit approvals or CERCLA AMPs. The applicable NOC approval orders or AMPs specify detailed prescriptive limitations and requirements on operation, sampling, monitoring, filtration, and emissions from the units. After approval order issuance, the individual air permits are incorporated into the Hanford Site Air Operating Permit (AOP) (Ecology 2016) issued by Ecology under authority of the CAA Title V. CERCLA AMPs are not required to be incorporated into the AOP.

2.2.1.3 Sample Locations and Sampling Equipment. Based on the potential-to-emit radionuclides, some stacks require radionuclide emission measurement systems that fully comply with the detailed requirements contained in ANSI/HPS (1999) while other stacks do not. The phrase potential-to-emit is defined in regulations as the estimated release rates and are based on the discharge of the effluent that would result if all pollution control equipment did not exist but the facilities operations were otherwise normal. Starting on October 9, 2002, new or modified stacks with a potential-to-emit radionuclides into the air in quantities that could cause an effective dose equivalent in excess of 1% of the 10 mrem/yr public dose standard are required to build, operate, and maintain sample systems fully compliant with ANSI/HPS (1999) including continuous real-time monitoring and continuous sampling. Stacks with a potential-to-emit in excess of 1% of the dose standard operating prior to October 9, 2002, are required to operate and maintain sample systems compliant with the 1969 version of ANSI N13.1. Most stacks operating on the Hanford Site subject to ANSI N13.1 were designed or modified and constructed to the 1999 requirements. A few older stacks subject to ANSI N13.1 requirements follow the 1969 version. Stacks with a potential-to-emit below 1% of the 10 mrem/yr public dose standard do not have to follow ANSI/HPS (1999) requirements and may instead use periodic confirmatory sample collection during routine operations to verify low emissions. Methods to implement periodic confirmatory measurements are not explicitly defined in regulations but must be approved by the WDOH through the NOC process or other channels.

2.2.1.4 Target Analytes. Federal and state requirements specify the following criteria that determine which isotopes must be sampled, measured, and reported:

- All radionuclides that could contribute greater than 10% of the potential-to-emit dose to the maximally exposed individual (MEI) shall be measured

- All radionuclides that could contribute greater than 0.1 mrem/yr potential-to-emit dose to the MEI shall be measured

- All radionuclides that could contribute greater than 25% of the dose to the MEI due to actual releases emitted after filtration and pollution control equipment, shall be measured.

Although the most common form of radionuclides sampled for in effluents is particulate, these contribute a small fraction of the annual MEI dose. Over the previous 20 years, radioactive gases from two stacks have contributed an average of 98% to the annual MEI dose. Tritium from the 325 Building was the isotope contributing the largest fraction with an average of 98% of the MEI dose in 17 of the 20 years. Radon from the 325 Building contributed an average of 59% in 2 years and iodine-129 from the Plutonium Uranium Extraction Plant contributed 71% of the MEI dose in 1 year.

2.2.1.5 Analytical Methods. All stack samples are analyzed using procedures conforming to 40 CFR 61, Appendix B, Method 114, *Test Methods for Measuring Radionuclide Emissions from Stationary Sources*. The Method 114 provides requirements for 1) stack monitoring and sample collection methods, 2) radiochemical methods used in determining the quantity of radionuclides collected on stack samples, and 3) quality assurance methods conducted in conjunction with these measurements. The following summarize these analytical methods:

- Radionuclides as particulates are collected on high-efficiency filter media selected from ANSI/HPS (1999) and then measured as:

  - Gross beta measured by direct counting gas proportional chamber
  - Gross alpha measured by direct counting gas proportional chamber
  - Gamma-emitting isotopes measured with gamma energy analysis and spectrometry
  - Alpha-emitting isotopes prepared by radiochemistry followed by alpha spectrometry
  - Strontium-90 prepared by radiochemistry followed by beta counting.

- Tritium in the form of water vapor is collected from the effluent by silica gel sorption and measured using liquid scintillation spectrometry.

- Tritium in the form of gas is oxidized using a metal catalyst to tritiated water and collected by silica gel sorption then measured by liquid scintillation spectrometry.
- Iodine is collected by sorption on metal zeolite or charcoal sample media and measured by gamma energy analysis and spectrometry.

2.2.2 Criteria and Toxic Air Pollutants

The CAA identified six common air pollutants of concern called criteria pollutants. The criteria pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. Criteria pollutants are air pollutants with national air quality standards that define acceptable concentrations of these substances in ambient air. At the Hanford Site there are 70 individual non-radiological emission sources, or groups of emission sources, listed in the Title V AOP Attachment 1 (Ecology 2016). Approximately 70% of these emission sources are fossil fuel combustion units such as diesel generators, portable light plants, and sources of hot water and steam. Point sources of toxic air pollutants are also present on the Hanford Site with permit driven sampling, monitoring, and reporting requirements.

2.2.2.1 Key Requirements. WAC 173-400, “General Regulations for Air Pollution Sources,” establishes the regulatory framework for systematic control of air pollution and establishment of general emission standards and limits, registration and permitting, prevention of significant deterioration, and new source reviews. Federal air pollution rules are adopted in this WAC. The EPA has delegated authority to Ecology for state implementation and enforcement.

WAC 173-401, “Operating Permit Regulation,” implements the Federal CAA Title V Air Operating Permit Program (Ecology 2016). The Hanford Site AOP consists of 1,733 pages and is comprised of hundreds of individual project-specific air permits issued on the Hanford Site. The Hanford AOP is perhaps one of the more complicated Title V permits issued in the United States as affected parties include two federal agencies (EPA, DOE), two state agencies (Ecology, WDOH), one local agency (Benton County Clean Air Authority) and six major contractors working on the Hanford Site (Mission Support Alliance, Washington River Protection Solutions, CH2M HILL Plateau Remediation Company, Pacific Northwest National Laboratory, Johnson Controls, Inc., Bechtel National, Inc.).

WAC 173-460, “Controls for New Sources of Toxic Air Pollutants,” contains non-source specific requirements applicable to any air pollution sources that emit compounds listed in the regulation. The CAA promulgated a list of 187 compounds considered hazardous air pollutants, while this regulation adds over 300 hundred additional state only toxic compounds. The regulation contains emission value thresholds for emission limits, permitting, dispersion modeling, and de minimis. Individual air permit approval orders specify the compounds and frequency of sampling and monitoring needed to demonstrate compliance.

CERCLA projects identify applicable elements of the federal and state regulatory requirements through the ARAR process and implement with an AMP.

2.2.3 Quality Assurance

DOE contractors are required to follow several important quality assurance requirements documents including DOE O 414.1D, *Quality Assurance*; the quality principles of 10 CFR 830, “Nuclear Safety Management”; and ASME NQA-1, “Quality Assurance Requirements for Nuclear Facility Applications.” The development and implementation of a quality assurance (QA) program relies upon the graded approach. The general quality assurance requirements of the environmental monitoring are applicable to the effluent sampling and monitoring program in addition to some effluent-specific requirements. The emission monitoring requirements in 40 CFR 61, Subpart H includes the implementation of a QA program that meets the requirements described in 40 CFR 61, Appendix B, Method 114. The ANSI/HPS (1999) standard applicable to many stacks on the Hanford Site also outlines a QA program with details specific to radioactive effluent sampling and monitoring.

2.2.4 Reporting

Several annual reports document the results of emissions monitoring and sampling programs and are intended to demonstrate compliance with DOE orders, as well as regulatory and permit requirements. The annual Radionuclide NESHAP report documents the quantity of radioactive curies release to the ambient environment and the public dose impact per the requirements of 40 CFR 61, Subpart H and WAC 246-247. This report is the primary compliance document for the annual NESHAP dose limit of 10 mrem/yr.

The primary method of source monitoring and reporting non-radiological emission is the annual air emissions inventory report required by WAC 173-400-105 and the AOP. Actual emissions from sources are estimated from measurements, where available, and calculations created using source operating parameters (e.g., hours of operation, fuel consumption, and emission factors provided in EPA references). Criteria pollutants, federally listed hazardous pollutants, and state listed toxic pollutants are included in this report.

The annual Hanford Site Environmental Report required by DOE O 231.1B, *Environmental, Safety and Health Reporting*, summarizes emissions from all other reports and satisfies DOE and contractual reporting requirements.

2.3 LIQUID EFFLUENTS

From the 1940s through the 1990s, during peak operating and production years at the Hanford Site, billions of gallons of effluent waste containing millions of metric tons of pollutants from reactor operations and chemical fuel processing were discharged to the Columbia River and to the soil column at hundreds of locations. Most of the discharges occurred in the 100 Reactor Areas along the river, 200-East Area, 200-West Area, and the 300 Area. As the mission of the Hanford Site shifted from production of nuclear materials to environmental cleanup, all untreated and non-permitted discharges to the environment ceased. Today, Hanford Site facilities operate two permitted liquid effluent discharges to the ground and no discharges to the Columbia River. The groundwater remediation project operates six pump–and-treat facilities under CERCLA requirements.

2.3.1 Introduction

Liquid effluents are disposed on the Hanford Site via three mechanisms: discharge to the ground, evaporation via the 200-West sewage lagoon, and discharge to the City of Richland's sewer system. Each type of disposal is governed by applicable regulations and permits.

2.3.2 Key Requirements

Multiple requirement documents are applicable to the discharge, sampling, and reporting of liquid effluents. The following sections summarize important requirements and source documents.

2.3.2.1 DOE Orders. The Environmental Management System required by DOE O 436.1, *Departmental Sustainability,* requires compliance with applicable environmental protection requirements including federal and state statutes, regulations, and standards. The Order also requires all DOE organizations conduct environmental monitoring. Compliance with federal and state regulatory requirements is the primary driver behind liquid effluent sampling and monitoring activities conducted today.

2.3.2.2 National Pollution Discharge Elimination System. The *Clean Water Act of 1977*, as amended, applies to discharges to surface waters in the United States. At the Hanford Site, regulations are applied through 40 CFR 122, "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System." The last permitted discharges to the Columbia River stopped operating in March 2011. DOE does not currently conduct any liquid discharges directly to the Columbia River.

2.3.2.3 WAC 173-216 State Waste Discharge Permit Program. Ecology's Wastewater Discharge Permit program regulates discharges to state waters, including groundwater. This regulation and permit program is applicable to the discharge of waste materials from industrial, commercial, and municipal operations. Six Ecology state waste discharge permits, all held by DOE, are currently in effect:

- ST4500 – 200 Area Effluent Treatment Facility
- ST4502 – 200 Area Treated Effluent Disposal Facility
- ST4511 – Miscellaneous and industrial storm water
- ST45514 – 200 Area Evaporative Sewage Lagoon
- WAG-50-5180 – Sand and Gravel Permit for Concrete Batch Plant
- WAG-50-5181 – Sand and Gravel General Permit for Pit 30 Quarry.

Ecology's wastewater discharge permits page is located at https://fortress.wa.gov/ecy/nwp/permitting/WWD/.

2.3.2.4 WAC 246-272A Onsite Sewage Systems. This regulation governs the location, design, installation, operation, maintenance, and monitoring of onsite sewage systems intended to treat and limit the discharge of contaminants to waters of the state. The goal is to protect public health by minimizing exposure and adverse effects.

2.3.2.5 City of Richland Permit. The buildings in the 300 Area are connected to a sewage system that ultimately discharges to the City of Richland. The City of Richland regulates industrial wastewater discharges to its sewer collection system in accordance with City of Richland Code Chapter 17.30, *Richland Pretreatment Act*. DOE holds Permit No. CR-IU010, which allows discharges from the 300 Area facilities. The current Permit was reissued in 2018 and will expire March 6, 2023.

2.3.2.6 Comprehensive Environmental Response Compensation and Liability Act. The CERCLA and the *Superfund Amendments and Reauthorization Act*, which are implemented through EPA regulations in 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," establish groundwater monitoring requirements for inactive past-practice waste sites. Pursuant to these acts, three general areas of the Hanford Site (100, 200, and 300 Areas) are currently listed on the National Priorities List.

2.3.3 Effluent Streams

2.3.3.1 Effluent Treatment Facility – State Approved Land Disposal Structure. Hanford's Effluent Treatment Facility (ETF) located in the 200-East Area treats liquid waste and has been in operation since 1995. The ETF influent consists of individual waste streams from multiple Hanford facilities. Source streams received for treatment include process condensate from the 242-A Evaporator and leachate from land waste disposal sites. Most liquid waste streams to be treated at ETF are initially stored at the Liquid Effluent Retention Basin, located near the ETF. The ETF waste treatment system removes toxic metals, radionuclides, and ammonia in addition to destroying organic compounds. The ETF waste treatment system does not remove tritium, a radioactive isotope of hydrogen that cannot be easily removed. After the liquid is treated, it is stored in tanks, sampled and analyzed, and then discharged to the ground at the State Approved Land Disposal Site (SALDS). The SALDS is located north of the 200-West Area (Figure 2-1). The ETF is the only Hanford Site facility permitted to discharge radioactive effluents to the ground. The sampling, monitoring, and reporting requirements for ETF discharges to SALDS are specified in State Waste Discharge Permit Number ST0004500.

The ETF contaminants of concern with corresponding effluent limits are: acetone, acetophenone, benzene, carbon tetrachloride, chloroform, n-nitrosodimethylamine, tetrachloroethylene, tetrahydrofuran, total organic carbon, arsenic, beryllium, copper, ammonia, nitrate, nitrite, sulfate, and total suspended solids. Effluent sampling monitoring, and reporting requirements are specified in the discharge permit. Quarterly Discharge Monitoring Reports (DMR) are submitted electronically within the state operated website WQWebDMR.

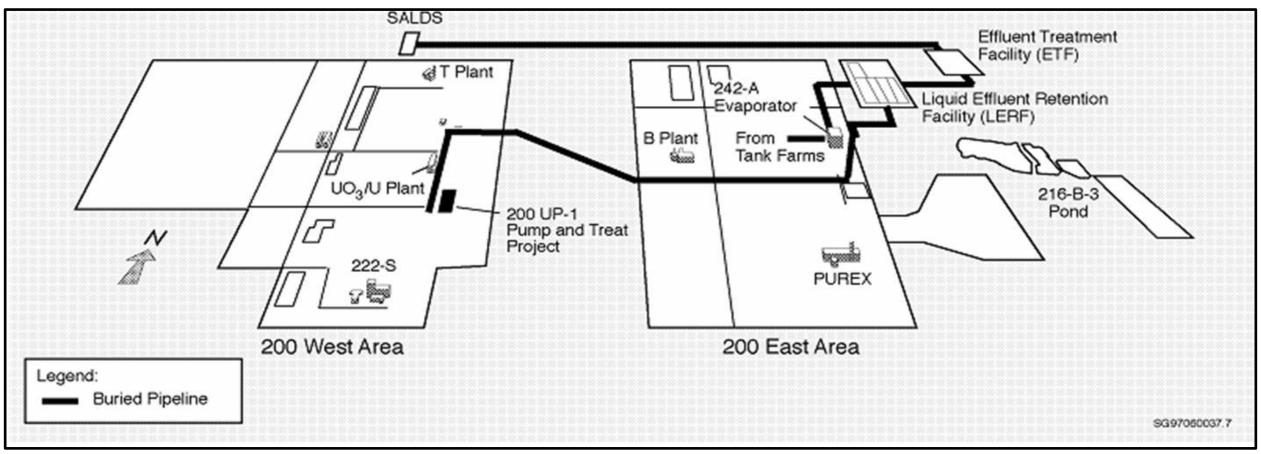

Figure 2-1. Location of the Effluent Treatment Facility and State Approved Land Disposal Site

2.3.3.2 Treated Effluent Disposal Facility. The Treated Effluent Disposal Facility (TEDF) provides a collection, conveyance, and disposal system for treated effluent from buildings in the 200 Areas (Figure 2-2). It is located in the 200-East Area and consists of an 18-km (11-mi)-long pipeline and two adjacent 2-ha (5-ac) infiltration ponds. The TEDF is a piped collection system that does not have any treatment or retention capacity. Wastewater generating processes include: cooling water, steam condensate, dryer condensate, air conditioning condensate, reverse osmosis unit brine, potable water, raw water, rainwater, miscellaneous effluents, water softener regenerant, filter backwash, boiler blowdown, and cooling tower blowdown. The water from individual waste streams must be treated prior to transfer to TEDF. State Waste Discharge Permit Number ST0004502 provides the terms and conditions that regulate the discharge of this wastewater to the ground and ensures the discharges meet state standards in WAC 173-200, "Water Quality Standards."

The TEDF contaminants of concern with corresponding effluent limits are: Bis (2-ethylhexyl) phthalate, total trihalomethane, carbon tetrachloride, chloroform, methylene chloride, arsenic, cadmium, chromium, iron, manganese, mercury, lead, chloride, nitrate, and total dissolved solids. Effluent sampling monitoring, and reporting requirements are specified in the discharge permit. Quarterly DMR are submitted electronically within the state-operated website WQWebDMR.

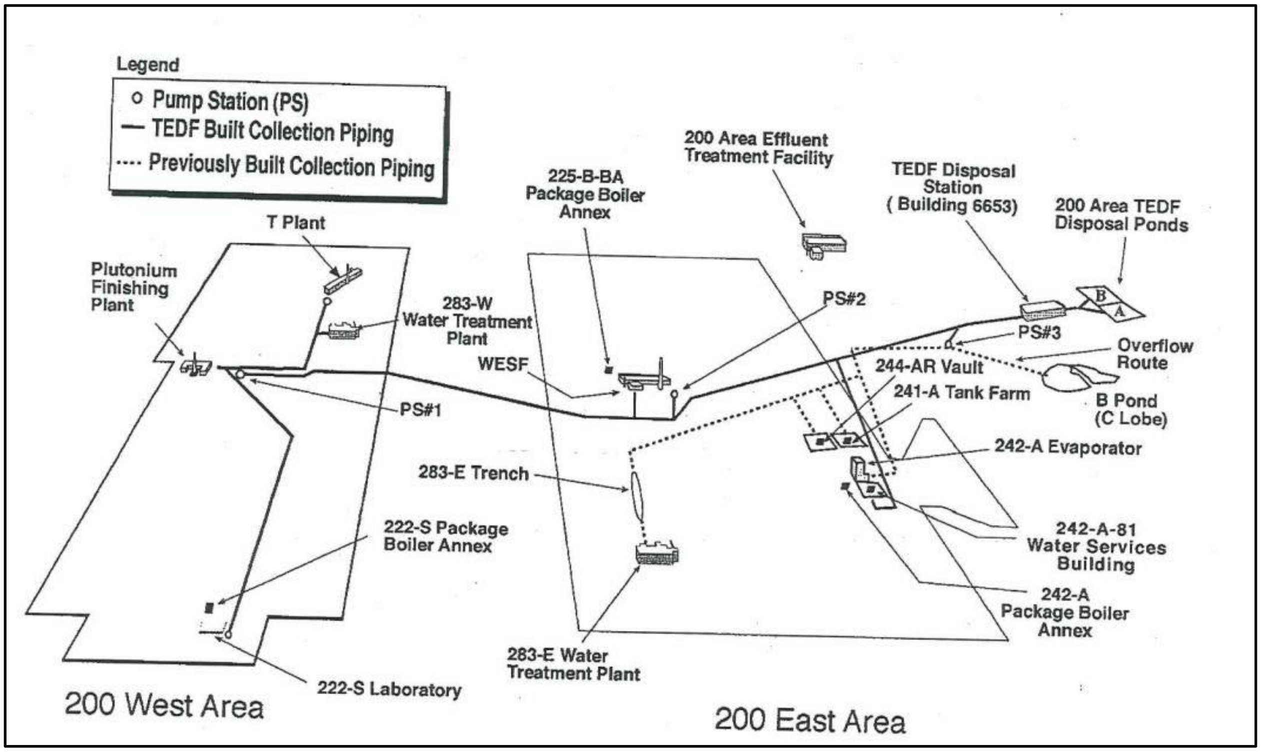

Figure 2-2. Location of the Treated Effluent Disposal Facility.

2.3.3.3 Industrial Non-point Sources. Nonpoint source discharges are effluents described as diffuse that occur over an area and are not easily attributed to a single point source. An example of a nonpoint source discharge is rain water or snowmelt runoff. Several nonpoint discharges are permitted on the Hanford Site. Routine operations conducted at various locations on the Hanford Site periodically generate discharges of liquid waste. These types of miscellaneous wastewater discharges include hydrotesting water, construction, and maintenance wastewater; the discharge of cooling water and condensate; and the collection and the discharge of industrial stormwater. The terms and conditions regulating these wastewater discharges are included in a categorical State Waste Discharge Permit Number ST0004511, Miscellaneous Streams.

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) operates two state-permitted sand and gravel locations. The concrete batch plant facility supports the construction of the WTP with the primary function of making concrete. The Pit 30 Quarry also supports the construction of the WTP with the primary function of making gravel. The types of discharges include process water, stormwater, and activities associated with sand and gravel operations and rock quarries. Permit conditions require the permit holder to provide environmental protection through best management practices and wastewater treatment.

2.3.3.4 Sewage Lagoon. The 200-West Area Evaporative Sewage Lagoon is a domestic wastewater treatment facility located northeast of the 200-West Area of the Hanford Site (Figure 2-3). The facility consists of double-lined evaporative lagoons and is designed and operated to have zero liquid discharge to the ground. The system provides domestic wastewater treatment for domestic wastewater transported from other locations within the Hanford Site. The DOE constructed the 200-West Area Evaporative Sewage Lagoon to replace the previously existing 100-N Sewage Lagoon, which was near the end of its service life. The majority of future Hanford Site cleanup activities are anticipated to be located in the vicinity of the 200 Areas and the siting of this treatment facility near the 200-West Area better serves the cleanup mission over time. Although this facility is not permitted to discharge, except in the case of emergencies, State Waste Discharge Permit Number ST0045514 governs the operation and maintenance of this facility.

2.3.3.5 Groundwater Pump and Treat Facilities. The groundwater remediation project at the Hanford Site currently operates six pump-and-treat facilities. Each pump-and-treat system includes an extraction well network, a treatment building, an injection well network, conveyance piping, and support equipment and components. Water is pumped from the extraction wells to collection tanks, then to the treatment building for removal of chemical and radionuclide contaminants of concern, and returned to groundwater via the injection well network. Table 2-1 lists the six pump-and-treat facilities. Section 5.0 Groundwater Monitoring provides a more detailed description of the monitoring requirements.

2.3.4 Reporting Requirements

The DMRs are the most common form of reporting liquid effluents. The format, content, and frequency of the DMRs are listed in applicable discharge permits. The Hanford Annual Site Environmental Report and CERCLA documents also provide a forum to report liquid effluent discharge information.

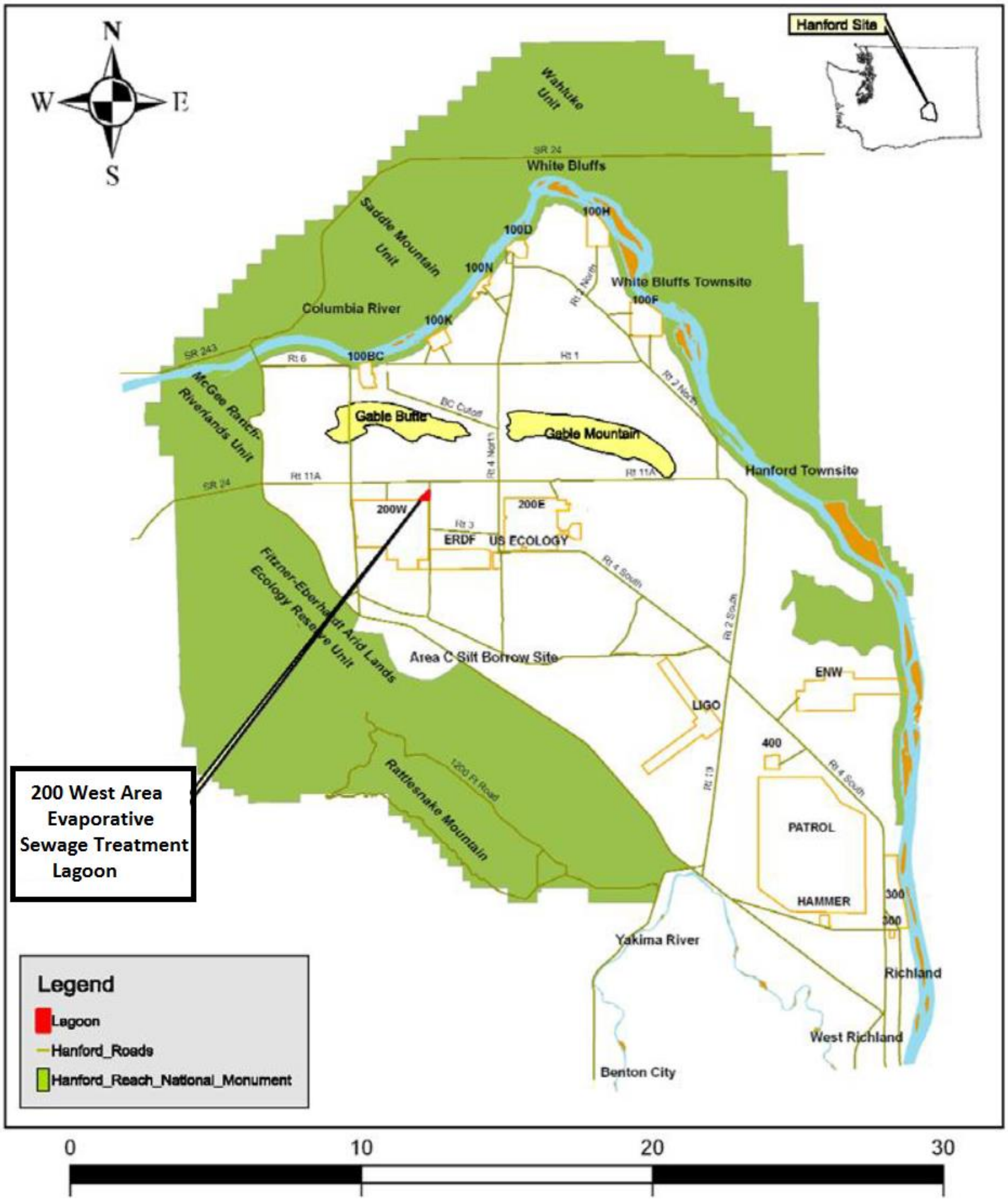

Figure 2-3. Location of the Evaporative Sewage Treatment Lagoon

Table 2-1. Groundwater Pump and Treat Systems.

Pump and Treat System	Location	Number of Extraction Wells	Number of Injection Wells	Design Capacity (gallons per minute)
DX	100-D Area	48	15	775
HX	100-H Area	38	17	900
KW	100-K Area	11	4	330
KR4	100-K Area	11	5	330
KX	100-K Area	21	10	900
200W	200-West Area	26	27	2,500

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3.0 NEAR-FACILITY ENVIRONMENTAL MONITORING

3.1 INTRODUCTION

Near-facility environmental monitoring is directed by Mission Support Alliance (MSA) in accordance with DOE O 231.1B, Chg. 1, *Environment, Safety and Health Reporting*; DOE O 436.1, *Departmental Sustainability*; DOE M 435.1-1, Chg. 2, *Radioactive Waste Management Manual*; the Hanford Site Air Operating Permit (AOP) 00-05-06; and QA criteria specified in MSC-PLN-EI-23333, *Environmental Quality Assurance Program Plan*. Near-facility environmental monitoring consists of both preoperational monitoring surveys and operational monitoring. Preoperational monitoring surveys are performed to obtain environmental baseline information that can be used to design a routine operational environmental monitoring program. Operational monitoring is performed near active facilities and operations that have the potential to significantly impact the Hanford Site environment and inactive contaminated facilities (e.g., former waste storage and disposal facilities).

3.2 PREOPERATIONAL ENVIRONMENTAL SURVEY

Preoperational characterization, assessment, and site evaluation are required by DOE O 436.1 and DOE M 435.1-1. Requirements are as follows:

- Proposed locations for low-level waste facilities shall be evaluated to identify relevant features that should be avoided or must be considered in facility design and analysis.
- Contractors must ensure the early identification of an appropriate response to potential adverse environmental impacts associated with DOE operations including, as appropriate, preoperational characterization and assessment, as well as effluent and surveillance monitoring.

Preoperational monitoring of a new disposal site or the expansion of an existing disposal site to determine baseline conditions will be conducted as required by DOE M 435.1-1 as part of the Site Evaluation (DOE M 435.1-1, Section IV.M.(1)). This activity needs to be performed for at least 1 year prior to construction of a disposal facility. Because much of the environmental data collected by monitoring programs are influenced by seasonal events, 1 year of data represents an absolute minimum for data collection for new disposal sites. Longer periods of baseline monitoring data collection extending to 5 or more years provide a better database. Media selected for monitoring need to be those most likely to be affected by site development and waste disposal operations. Monitoring locations for all media are selected to provide an uninterrupted stream of data throughout site development, facility operations, facility closure, and post-closure. Preoperational monitoring provides site characterization information, site suitability information, and records for public information.

General guidelines for conducting a preoperational environmental survey can be found in DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*, and DOE/LLW-13Tg, *Environmental Monitoring for Low Level Waste Disposal Sites*.

3.2.1 User Identification

Primary users of a preoperational environmental survey may include the following:

- Planning and construction organization. Demonstrates compliance with DOE O 231.1B,; DOE O 436.1; DOE O 451.1B, *National Environmental Policy Act Compliance Program*; and DOE M 435.1-1.

- Facility operating and environmental restoration organizations. Shows that containment systems for stored chemicals and waste remain adequate in compliance with DOE O 231.1B; DOE O 436.1; and DOE M 435.1-1.

- Program staff. Provides adequate data for determining the need to modify the existing near-facility monitoring objectives and to determine effluent trends and environmental conditions.

- Far-Field Environmental Surveillance Program. The Program may adjust or supplement monitoring locations if needed.

- Legal counsel. Provides input to plaintiff requests and demonstrates regulatory compliance.

- Regulatory agencies and the public. Verifies compliance with laws, regulations, and protection of the environment.

3.2.2 Survey Design

A preoperational environmental survey is designed to monitor the media specified in DOE-HDBK-1216-2015 and DOE/LLW-13Tg. To assist in designing this survey, existing documents are reviewed (e.g., unplanned-release reports, occurrence reports, operational and site environmental reports, historical photographs, environmental impact statements, and preliminary safety analysis reports).

Before initiating preoperational sampling of any new or modified facility or process, a sampling and analysis plan is prepared and issued. The sampling and analysis plan describes the project and sampling design rationale and identifies the media to be sampled and analyses to be performed.

Once preoperational monitoring is completed and analytical data are available, a final preoperational environmental monitoring report is prepared.

3.3 ROUTINE NEAR-FACILITY ENVIRONMENTAL MONITORING

Facility-specific environmental monitoring is provided to protect the environment adjacent to nuclear facilities and waste storage, treatment, and disposal sites in compliance with applicable federal, state, and local environmental regulations and requirements.

The objectives of routine near-facility monitoring are to evaluate the following:

- Compliance with federal, state, and local environmental radiation protection requirements and guides

- Performance of radioactive waste confinement systems

- Concentration trends of radioactive materials in the environment at and adjacent to nuclear facilities, waste disposal sites, and remedial-action activities.

Specifically, near-facility environmental monitoring entails the following:

- Monitoring inactive, existing, and new low-level waste disposal sites to assess radiological and non-radiological hazards (DOE O 435.1 and DOE M 435.1-1)
- Determining the effectiveness of treatments and controls used to reduce effluent and emissions (DOE-HDBK-1216-2015)
- Detecting and quantifying unplanned releases (DOE-HDBK-1216-2015 ; 40 CFR 302, *Designation, Reportable Quantities, and Notification*; WAC 173-303, *Dangerous Waste Regulations*; and DOE O 232.1A, *Occurrence Reporting and Processing of Operations Information*)
- Monitoring fugitive emissions (i.e., diffuse sources) from contaminated areas for compliance with national emission standards for hazardous air pollutants (40 CFR 61, *National Emission Standards for Hazardous Air Pollutants*; DOE-HDBK-1216-2015); toxic air emissions (40 CFR 265, *Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*, Subparts AA and B13); state operating permits (40 CFR 70); and source registration (WAC 246-247, *Radiation Protection – Air Emissions*)
- Monitoring new and existing sites, processes, and facilities to determine potential environmental impacts and releases of contaminants (DOE O 231.1B; DOE-HDBK-1216-2015
- Monitoring and assessing environmental radioactive contamination and potential exposure to employees and the public (DOE O 231.1B; DOE O 436.1; and DOE O 458.1, Chg 2, *Radiation Protection of the Public and the Environment*).

The primary justifications for near-facility environmental monitoring include the following:

- Providing regulatory compliance
- Providing a level of assurance that effluent and contamination controls for the various facilities and waste sites are effective
- Monitoring a diversity of operations, activities, and programs managed by several different organizations (accordingly, direction and integration are needed to ensure consistency, technical quality, and cost effectiveness)
- Providing data to ensure safe access to a site
- Ensuring the public that the environment is protected.

Near-facility environmental monitoring personnel are responsible for planning, directing, and executing the effective, technically sound monitoring of selected media and for ensuring regulations and requirements are satisfied. These responsibilities include establishing the basis and scope of the monitoring, developing sampling and surveying schedules, and ensuring that schedules and procedures are followed by the performing organizations. Monitoring personnel serve as primary contacts within and outside of Hanford Site contractors in technical matters pertaining to near-facility environmental monitoring and represent Hanford Site contractors in support of the DOE at meetings with environmental regulators regarding this type of work.

A list of federal, state, and Hanford Site documents regulating environmental monitoring activities is provided in Table 3-1.

3.4 REVIEW

The scope of near-facility environmental monitoring is reviewed by management and staff at least annually to ensure work complies with current regulations, appropriate effluent and emissions are being monitored, and monitoring locations are positioned to best determine and quantify potential releases.

Table 3-1. Governing Documents for Environmental Monitoring. 2 Pages

Document Number	Title
40 CFR 61	*National Emission Standards for Hazardous Air Pollutants*
40 CFR 70	*State Operating Permit Programs*
40 CFR 264	*Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*
40 CFR 265	*Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*
40 CFR 302	*Designation, Reportable Quantities, and Notification*
40 CFR 1501	*NEPA and Agency Planning*
DOE M 450.4-1	*Integrated Safety Management System Manual*
DOE O 231.1B Chg. 1	*Environment, Safety and Health Reporting*
DOE O 232.1A	*Occurrence Reporting and Processing of Operations Information*
DOE O 435.1	*Radioactive Waste Management*
DOE O 436.1	*Departmental Sustainability*
DOE O 451.1B	*National Environmental Policy Act Compliance Program*
DOE O 458.1, Chg 2	*Radiation Protection of the Public and the Environment*
DOE-HDBK-1216-2015	*Environmental Radiological Effluent Monitoring and Environmental Surveillance*
DOE/LLW-13Tg	*Low-Level Waste Management Handbook Series, Environmental Monitoring for Low-Level Waste Disposal Sites*
DOE/RL-91-50 (as amended)	*Environmental Monitoring Plan, United States Department of Energy, Richland Operations Office*
#FF-01	*Hanford Site Radioactive Air Emissions License #FF-01*
MSC-PLN-EI-23333	*Environmental Quality Assurance Program Plan*
MSC-PRO-EI-15333	*Environmental Protection Processes*

Table 3-1. Governing Documents for Environmental Monitoring. 2 Pages

Document Number	Title
MSC-PRO-EI-15334	*Effluent and Environmental Monitoring*
WAC 173-303	*Dangerous Waste Regulations*
WAC 173-400	*General Regulations for Air Pollution Sources*
WAC 246-247	*Radiation Protection - Air Emissions*

3.5 DESIGN

3.5.1 Sampling Locations, Sampling Frequencies, Media Sampled, and Parameters Monitored

Media near active/inactive facilities to be sampled include ambient air particulates, soil, and biota. Parameters routinely monitored include, as appropriate, radionuclide concentrations, radiation exposure levels, radiation dose rates, and hazardous constituent concentrations. Sample types, collection and measurement frequencies, and analytes and parameters routinely monitored are summarized in Table 3-2. A routine near-facility environmental monitoring schedule is developed, reviewed, and approved by MSA in corroboration with other Hanford Site contractors as needed.

Table 3-2. Near-Facility Sample Types, Collection or Measurement Frequencies, and Analytes and Parameters Routinely Monitored.

Sample Types	Collection or Measurement Frequencies	Analytes/Parameters Monitored
Air	Biweekly Semiannual	Gross alpha and beta Strontium, plutonium, thorium, uranium, gamma
Air	Monthly (4-week)	Tritium
Air	Weekly	Carbon-14
Air	Month	Iodine-129
Soil	Annual	Strontium, plutonium, uranium, thorium, gamma, gross alpha, gross beta
Vegetation	Annual	Strontium, plutonium, uranium, gamma, gross alpha, gross beta
Animals	Annual	Strontium, plutonium, uranium, gamma
Thermoluminescent dosimeter	Quarterly	External radiation dose
Survey point	Annual	External radiation dose

3.5.2 Monitoring Locations

Information regarding specific sampling locations can be found in the *Hanford Site Environmental Surveillance Master Sampling Schedule for Calendar Year 2018* (DOE/RL-2013-53). The criteria for establishing monitoring locations for each sample type listed in Table 3-2 are as follows:

- **Air** – downwind, typically within 500 m (1,640 ft) of a source. Unless documented site-specific evidence exists to justify otherwise, the sample(s) will be collected in a location free from unusual localized effects or other conditions (i.e., near a large building, vehicular traffic, trees) that could result in artificially high or low concentrations.

- **Soil and vegetation** – on or near sites and/or facilities with the potential for deposition and/or biological intrusion.

- **Animals** – on or near sites and/or facilities with the potential for biological intrusion. Animals are sampled opportunistically.

- **External dose rate** – at or near facilities that may cause elevated dose rates including active/inactive sites, waste handling facilities, effluent discharge points, and other suspected pathways for radiation exposure.

- **Radiation surveys** – at inactive waste sites; outdoor radiological control areas; tank farm perimeters and associated diversion boxes, lift stations, and vent stations; perimeters of active or uncovered waste sites (e.g., retention basins, ponds, solid waste burial grounds, ditches); underground pipelines; and road and rail bed surfaces. The radiation survey frequencies for particular sites are based on site history, radiological conditions, and general maintenance. Special surveys may be conducted at intervals that are more frequent if conditions warrant (e.g., growth of deep-rooted vegetation is noted at a waste site). Radiological surveys are conducted to detect surface contamination that may be a result of biological intrusion, erosion, wind deposition of contaminated particulates, and site maintenance conditions.

3.5.3 Sampling and Measurement Methods

Sampling methods are reviewed to determine equipment efficiency and to comply with current federal (U.S. Environmental Protection Agency [EPA]) and industry (ANSI-N545-1975; ASTM 1976) standards. The following sampling methods are routinely used for near-facility environmental monitoring.

3.5.3.1 Ambient Air. Air sampling stations collect samples at a height of approximately 2 m (6.56 ft) above ground level and use a vacuum pump to pull air through a 47-mm (0.08-in.) filter at a nominal flow rate of 0.057 m^3/min (2 ft^3/min). A timer and flow-rate meter are used to determine sample time and flow rate, respectively. Sample volumes are calculated using the average flow rate measurements and hours of exposure. Filters are collected biweekly to prevent dust loading on the sample filter and impaired flows.

Samples for tritium analysis are collected on silica gel. Airflow rates (190 mL/min [6.42 oz/min]), sampling volumes, and exposure periods (nominally 28 days) are such that the gel is not likely to be saturated during the sampling period, minimizing the likelihood of sample loss due to breakthrough. Silica gel saturation is monitored using a color-change indicator in the gel, which also is useful in diagnosing problems in the sampling system (i.e., leaks). Flow rates for adsorbent samples are measured at the beginning and end of each sampling period using a device with a documented accuracy of ±20%. Sample volumes are calculated using the average flow rate measurements and hours of exposure.

- **Soil** – Soil sampling equipment may be one of three types: 1) spade, 2) core sampler (split spoon) for special soil sampling, or 3) plug (cookie cutter) sampler for routine samples. All equipment is easily decontaminated or is single-use disposable. Samples are placed in a sealable plastic bag or other suitable container and, if necessary, into an appropriate container for shipment.

- **Vegetation** – Vegetation sampling equipment consists of pruning shears, loppers, saws, a core drill, or a machete. Samples are cut to length, placed in a plastic bag, and, if necessary, into an appropriate container for shipment.

- **Animals** – Animal samples are usually collected as a result of pest control activities. The animals are checked for radioactive contamination by radiation control staff; those animals found to be contaminated may be retained for analysis. The samples are put in a plastic bag and, if necessary, into an appropriate container for shipment.

- **External dose rates** – Ambient dose rates are taken by two methods:

  – Harshaw 8807™ environmental thermoluminescent dosimeters (TLDs) and micro-rem meters. The TLDs consist of two lithium fluoride (TLD-700) and two calcium fluoride dysprosium (TLD-200) chips sealed in a plastic holder supplied by the dosimetry lab. Three TLDs are placed at each measurement location at 1 m (3.25 ft) above the ground.

  – A Bicron micro-rem meter with a tissue equivalent organic scintillator is used to measure relative dose rates.

- **Radiation surveys** – Radiation survey locations may include roads, cribs, stabilized burial grounds, covered ponds and ditches, tank farm perimeters, active burial ground perimeters, unplanned release sites, and other radiation areas. The following are two general types of radiation surveys.

- **Road surveys** are performed with a mobile surface contamination monitor or a vehicle equipped with sodium iodide detectors or plastic scintillators. The detector height is adjustable in all cases and the average survey height is 0.3 m (0.98 ft). When activity is detected, the vehicle is stopped and a thorough survey is made with an Eberline Model BNW-1™ portable survey instrument equipped with a P-11 probe to identify the extent of the contamination.

- **Waste sites and other radiation area** surveys may be conducted with vehicles equipped with radiation detection instruments or with handheld field instruments. Wherever possible, smear surveys are made on the surface of exposed equipment within a radiation area. Vegetation, animal burrows, and animal feces also are monitored to detect biological transport. Detailed survey practices and procedures are described in MSC-5173, *Radiological Control Manual*, and MSC-13536, *MSC Radiological Control Procedures*.

3.5.4 Parameters Monitored

The parameters monitored for each medium vary and may include the following:

- Ambient air – isotopic or total gamma, gross alpha and beta, strontium, plutonium, americium, thorium, tritium, uranium, carbon-14, and iodine-129 at selected locations.
- Soil – isotopic or total gamma, strontium, plutonium, americium, thorium, and uranium.
- Vegetation – isotopic or total gamma, strontium, plutonium, and uranium.
- Animals – isotopic or total gamma, strontium, plutonium, and uranium.
- External dose rate – measured in the area where samples are taken to identify any increasing or decreasing trends in radiation that may affect the environment, workers, or the public.
- Radiation surveys – performed to measure the surface and background radiation in the area in which the measurement is taken.

Best professional judgment and a review of historical information is used to locate initial sampling sites and select analytical parameters to monitor the near-facility environment.

3.6 QUALITY ASSURANCE

Quality assurance (QA) may be defined as the actions necessary to ensure the precision, accuracy, representativeness, completeness, and comparability of a program. The near-facility environmental monitoring QA program consists of procedures and guidelines to demonstrate that environmental monitoring techniques and analyses are performed within established limits of acceptance. Documentation is provided in the *Environmental Quality Assurance Program Plan* (MSC-PLN-EI-23333) and the *Quality Assurance Project Plan – Ecological Monitoring and Environmental Surveillance* (MSC-OTHER-EMES-60873).

Written operating procedures are an integral part of near-facility environmental monitoring QA. Procedures for field operations are provided in MSA procedures. The following briefly describes the essential components of the near-facility environmental monitoring QA program.

3.6.1 Documentation

Record keeping is a vital part of any environmental monitoring program. Maintenance of environmental data is important from a QA standpoint, regulatory standpoint, and for trend analyses and optimization of environmental monitoring procedures. Each phase of near-facility environmental monitoring is documented. This documentation includes environmental sample logbooks, quarterly reports, annual reports, and occurrence reports.

3.6.2 Sample Replication

Replicate sampling and subsequent analyses are the primary means of assessing sample variability. Duplicate samples of air, soil, and vegetation are collected.

3.6.3 Data Analysis

Environmental data are reviewed to determine compliance with applicable federal and state regulatory criteria. The data are analyzed both graphically and by standard statistical tests to determine trends and impacts on the environment. Newly acquired data are compared with historical data, natural background levels, and regulatory standards. Routine environmental data are stored on electronic media (i.e., in a computer environment).

3.6.4 Analytical Procedures

Laboratories that provide analytical support to the near-facility environmental monitoring program include: GEL Laboratories (Charleston, South Carolina), Test America Laboratory (Richland, Washington), and the MSA Dosimetry Laboratory. Laboratory analytical methods are specified in contracts with the laboratories and are performed according to appropriate methods. The analysis of air samples are performed according to 40 CFR 61, Subpart H; therefore, air samples are analyzed as required by 40 CFR 61, Appendix B, Method 114. All other media are analyzed by laboratory-specific or EPA methods (e.g., *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* [SW-846]), as well as other methods as accepted during the procurement process.

Instruments (e.g., scales, thermometers) for field measurements are calibrated and operated according to the manufacturer's instructions. Each instrument is assigned a unique number that is tracked on field and calibration documentation.

3.7 REFERENCES

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4.0 FAR-FIELD ENVIRONMENTAL SURVEILLANCE

4.1 INTRODUCTION

This section describes the plan for conducting far-field surveillance on and around the Hanford Site. Far-field environmental surveillance is conducted to measure contaminants of potential concern in various environmental media and ensure legal and regulatory requirements are met. Reporting requirements governing far-field surveillance include DOE O 458.1, Chg 2, *Radiation Protection of the Public and the Environment*; DOE O 436.1, *Departmental Sustainability*; DOE O 231.1B, *Environment, Safety and Health Reporting*; and the guidance of DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

Far-field surveillance personnel collect samples of air, surface water, sediment, soil, natural vegetation, agricultural products, fish, and wildlife on and around the Hanford Site. These samples are analyzed for concentrations of radionuclides attributable to natural sources, worldwide fallout from nuclear weapons testing, and Hanford Site operations. Data also are collected to monitor several chemicals and metals with Hanford and non-Hanford sources in Columbia River water, sediment, fish, and wildlife.

Activities inherent in the operation of the environmental surveillance program include surveillance design and implementation, procedure development, sample collection, sample analysis, database management, data review and evaluation, radiological dose assessment, and reporting. Other elements of the project include project management, quality assurance (QA) and quality control (QC), staff supervision, training, records management, and equipment maintenance.

Surveillance activities focus on radionuclides and chemicals that are, have been, or potentially could be released from U.S. Department of Energy (DOE) facilities on the Hanford Site; however, unplanned releases and releases from non-DOE operations on and near the Site also are considered. Surveillance results are provided annually through the Hanford Site Environmental Report to DOE; federal, state, and local regulatory agencies; Hanford Site contractors; environmental groups; regional communities and governments; the public; and Indian Tribes and Nations. In addition, unusual results or trends are reported to DOE when they occur. Although the scope of the Environmental Surveillance Program includes chemical surveillance, the primary focus of this surveillance plan is on radiological contaminants.

This section relates to other sections in this report in several respects. The sampling design described in this EMP is based on radiological and chemical pathway analyses from data obtained by near-facility environmental monitoring program and facility effluent monitoring plans described in Sections 2.0 and 3.0. The pathway analyses and radiological dose assessments, as well as the radiological dose assessments reported in the Hanford Annual Site Environmental Reports, are taken from the dispersion data provided by the Hanford Meteorological and Climatological Services Program described in Section 6.0. The ecological monitoring and compliance assessment studies discussed in Section 7.0 can be integrated with environmental surveillance contaminant monitoring data to assess potential effects of Hanford Site contaminants on individuals and populations. The pathway analyses and radiological dose assessment results for this section include the contribution to dose from the groundwater pathway discussed in Section 5.0.

The environmental pathways through which contaminants are transported to people and biota, and the significance of the media and contaminants to total radiological dose are strongly influenced by environmental settings. The Hanford Site's environmental setting is summarized in the *Hanford Site National Environmental Policy Act (NEPA) Characterization Report* (PNNL-6415) and is not described here.

4.2 REQUIREMENTS AND OBJECTIVES FOR ENVIRONMENTAL SURVEILLANCE

General requirements and objectives for environmental surveillance are provided in DOE O 436.1; DOE O 458.1, Chg 2 and DOE O 231.1B, *Environment, Safety and Health Reporting*. Overall surveillance objectives are to demonstrate Hanford Site compliance with legal and regulatory environmental requirements, ensure conformity with DOE environmental protection policies, and support environmental management decisions. The primary objective stated in state and federal regulations, DOE Orders, and other guidance, including DOE-HDBK-1216-2015, is to support determination of DOE's compliance with applicable environmental quality standards, public exposure limits, and applicable laws and regulations. This includes compliance with the requirements of DOE O 436.1, DOE O 458.1, Chg 2, DOE O 231.1B, and environmental commitments made in environmental impact statements, environmental assessments, contractor work plans, state permits, safety analysis reports, or other official DOE documents.

Additional objectives based on the primary objective include the following:

- Assessing preoperational environmental conditions
- Assessing radiological doses to the public and biota from site operations
- Assessing radiological doses from other local sources
- Reporting environmental releases and potential radiological doses exceeding reporting limits (DOE O 458.1, Chg 2)
- Preparing a comprehensive annual (calendar year) site environmental report
- Maintaining an environmental monitoring plan as part of an Environmental Management System
- Determining reference contaminant levels and site contributions of contaminants in the environment
- Determining long-term accumulations of site-related contaminants in the environment and documenting concentration trends
- Determining the effectiveness of treatments and controls for site effluent and emissions
- Detecting and quantifying unplanned contaminant releases
- Identifying and quantifying new or existing environmental quality problems.

The DOE-HDBK-1216-2015 indicates that subsidiary objectives for surveillance should be considered. Subsidiary objectives applicable to the Hanford Site include the following:

- Obtaining data and maintaining the capability to assess the consequences of accidents or occurrences that release contaminants to the environment
- Providing public assurance and addressing issues of concern to government officials, regulatory agencies, Hanford Natural Resource Trustee Council, and other stakeholders (e.g., public, local businesses, people or businesses considering relocating to the Hanford area, Hanford Site workers, and local American Indian Tribes)
- Enhancing public understanding of the Hanford Site's impact on the environment through public involvement activities and reporting
- Providing environmental data and assessments to assist the DOE in environmental management of the Hanford Site
- Providing environmental data and assessments to assist contractors in managing construction, cleanup, remediation, remedial investigation, and risk assessment activities.

DOE Orders require that the content of surveillance programs be determined on a site-specific basis and must reflect specific facility or site characteristics; applicable regulations; hazard potentials; quantities and concentrations of materials released or potentially released to the environment; the extent and uses of affected air, land, and water; and specific local public, contractor, stakeholder, and regulatory agency interests and concerns.

4.3 FAR-FIELD ENVIRONMENTAL SURVEILLANCE DESIGN

Far-field environmental surveillance is designed to meet the objectives listed in the previous section while considering the environmental characteristics of the Hanford Site and potential and actual releases from site operations. Surveillance activities focus on identifying potential environmental exposures and compliance with public health and environmental standards or protection guides, rather than providing detailed radiological and chemical characterization. Experience gained from environmental surveillance activities and studies at the Hanford Site for more than 50 years provides the foundation for far-field environmental surveillance design.

This section discusses the rationale and criteria for Hanford Site environmental surveillance, surveillance design, and the annual surveillance design review process.

4.3.1 Rationale and Design Criteria

The rationale and criteria for Hanford Site Far-Field Environmental Surveillance is based on the following:

- DOE O 436.1 and DOE O 458.1, Chg 2

- DOE-HDBK-1216-2015
- Results of radiological and chemical pathways analyses
- Ongoing or anticipated cleanup, remediation, construction, remedial investigation, and risk assessment activities
- Site- or activity-specific local, state, and federal regulatory requirements
- Other site commitments.

Minimum criteria for establishing the elements and design of an environmental surveillance program are provided in DOE-HDBK-1216-2015 Tables 6-1 and 6-2.

Based on current radiological levels and doses, and the above referenced objective criteria, periodic surveillance measurements are required a minimum of every 5 years to confirm that doses are below the objective criteria. However, conducting only confirmatory surveillance measurements at the Site and surrounding regions every 5 years would not fully meet some of the primary surveillance objectives or satisfy the subsidiary objectives. The rationale and criteria for additional sampling in each medium are discussed further in the sections that follow. Some general considerations exist that are factors in decisions about the content of the surveillance design.

The application of objective criteria from DOE-HDBK-1216-2015 to the radiological pathway analysis addresses only surveillance for routine releases and does not consider the very large inventory of legacy radioactive materials potentially available for release. Likewise, the onsite inventory of hazardous chemical waste generated during historical operations is believed to be very large.

Routine surveillance is required for cleanup and remediation actions under the *Hanford Federal Facility Agreement and Consent Order* (also known as the Tri-Party Agreement; Ecology et al. 1989) and will continue over the next several decades. These cleanup and remediation actions may increase the potential for contaminant releases to, and migration within, the environment. The design for routine surveillance includes establishing contaminant concentration baselines for assessing the effects of cleanup and remediation actions throughout the Hanford Site, and for monitoring trends in contaminant concentrations related to those actions.

Design rationale and criteria that apply to most environmental media are summarized in the following paragraphs.

4.3.1.1 Media Selections. The highest sampling priority is given to media such as air and water that could be directly ingested or inhaled and affect members of the public. Other media are selected for sampling based on their sensitivity as indicators of loss of materials control, potential use for predicting contaminant accumulations and trends, potential to function as indicators of environmental quality, potential to serve as indicators of biotic impacts, and potential for bioaccumulation in food products (e.g., milk).

4.3.1.2 Sampling Locations. Environmental samples are collected to determine background and contamination levels. Surveillance personnel establish reference sampling locations in areas reasonably expected to be unaffected by Hanford Site discharges for all media contaminant combinations that are routinely sampled or likely would be sampled to assess the environmental impacts of unusual or accidental contaminant releases. Sampling locations near potential onsite contaminant sources are selected to maximize the probability of detecting a loss of containment and help assess the magnitude and effects of releases. Sampling stations, near or just inside the Hanford Site boundary, are positioned to estimate conditions at the nearest points at which members of the public can be exposed. Exposures at these locations are typically the maximum that any member of the public (not working on the Hanford Site) could receive. Finally, sampling is conducted in nearby communities to obtain data where most potential exposures may occur to provide assurance to the communities that contaminant levels are well below standards established to protect public health and the environment.

4.3.2 Sampling and Analysis Frequencies

Sampling frequencies are based on the need to obtain time-representative samples, environmental factors that may impact collection efficiencies, limitations of sampling equipment or sampling substrates, and sample availability. Most routine samples are collected biweekly, monthly, or quarterly. However, some are collected semi-annually, annually, biennially, or every 3 to 5 years. Most samples are submitted for analysis immediately following collection. Some are retained at the analytical laboratory for several weeks or months and composited with other samples to increase time representativeness and make it possible to detect contaminants present at very low concentrations. The exposure or sample compositing period may be up to 6 months. Holding times and analysis frequencies are specified in environmental surveillance program-specific analytical laboratory contracts.

4.3.2.1 Sample Collection and Handling Methods. Sample collection and handling procedures for the Environmental Surveillance Program are described in environmental surveillance program procedures. Steps are incorporated in the sampling procedures to avoid misidentification and cross-contamination of the samples being collected. Chain-of-custody procedures ensure the integrity of the samples throughout the collection, transport, and analysis processes.

4.3.3 Analytical Detection and Precision

The general strategy for obtaining the lowest levels of detection practical is to use standard analytical procedures and take into consideration practical sampling strategy tradeoffs (e.g., time and location compositing versus discrete samples). Where technically feasible and practical, the minimum objective for a given medium and radiological contaminant combination is to detect a concentration that is equal to or below the concentration that would result in a dose to humans of 1 millirem/yr effective dose equivalent if exposure to that concentration was sustained for 1 year. This dose estimate assumes that the radionuclide is being transported to subsequent compartments of the exposure pathways and that the individual is exposed to all subsequent compartments. For example, the pathway for air assumes not only inhalation but also exposure to airborne materials deposited on the ground and to contaminants from the air taken up in locally grown foods. One millirem is 10% of the public exposure level that must be reported to DOE and is 10% of the federal dose limit (40 CFR 61) for the air pathway. Generally, most radionuclide concentrations in environmental samples collected around the Hanford Site result in an annual dose below 1 millirem.

4.3.4 Quality Assurance

The Far-Field Environmental Surveillance Quality Assurance Program consists of procedures and guidelines to demonstrate that environmental monitoring techniques and analyses are performed within established limits of acceptance. Documentation is provided in the *Environmental Quality*

Assurance Program Plan (QA Plan) (MSC-PLN-EI-23333) and the *Quality Assurance Project Plan – Ecological Monitoring and Environmental Surveillance* (QAPjP) (MSC-OTHER-EMES-60873).

Written operating procedures are an integral part of far-field environmental surveillance QA. Procedures for field operations are provided in Mission Support Alliance (MSA) procedures for the Environmental Surveillance Program. As part of the project's QA program, selected sediment, surface water, food and farm products, wildlife, soil, and vegetation samples are provided to Washington State Department of Health (WDOH) for comparative analyses. In addition, analytical laboratories reporting Hanford Site environmental data participate in managed QA and QC programs (e.g., DOE Consolidated Audit Program, Mixed Analyte Performance Evaluation Program, EPA-compliant performance evaluation and proficiency testing studies, and laboratory performance inter-comparison studies). These managed programs use standardized audit methods, processes, and procedures to assess the validity, reliability, and defensibility of data from the contract laboratories.

4.3.5 Reporting Levels and Comparison Values

For samples originating in the Hanford Environmental Information System database (http://ehs.hanford.gov/eda/), concentrations of selected radionuclides are compared to threshold limits established by the program. Each concentration that does not meet the threshold limit is considered anomalous; the computer generates an anomalous data report (ADR) and issues a request for data review. Project personnel review the ADR to determine the validity of the result and whether additional information is needed from the analytical laboratory. The ADRs are maintained as part of the environmental surveillance program record.

For human/public consumable media, the reporting levels are functions of the contaminant concentrations in the edible portions of the medium. For soil, the reporting levels are functions of external exposures to radionuclides other than cesium-137 and strontium-90. Reporting levels for these two radionuclides are nominally equivalent to doses of 10 millirem if the soil concentrations and exposures are sustained for 1 year. The natural variability of cesium-137 and strontium-90 concentrations in soil samples makes it impractical to report a 1 millirem difference between samples. The 1- and 10-millirem levels provide an early indication of conditions that might require reporting to DOE as defined by DOE O 458.1, Chg.2. All reporting levels provide early indications of conditions that might eventually require reporting. Reporting levels are presented in Table 4-1.

Concentrations of chemicals in water samples are evaluated against comparison values, including WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," and 40 CFR 131.36, "Toxics Criteria for those states not Complying with Clean Water Act." Concentration thresholds that require notification to DOE have not been established for chemical contaminants.

4.3.6 Exposure Pathways and Dose Assessments

Exposure pathway evaluation and dose assessments are conducted as follows:

- Annually to assess site compliance with the DOE public exposure limit (DOE O 458.1, Chg.2) and the criteria in 40 CFR 61

- Annually to determine the minimum requirements for environmental surveillance as defined in DOE-HDBK-1216-2015

- At least every 5 years to assess compliance with the DOE interim dose limit for native aquatic organisms (DOE O 458.1, Chg.2)
- As necessary when exposure conditions have changed.

Exposure pathways and dose assessment results are reported annually in the Hanford Annual Site Environmental Report. Radionuclide concentrations in soil, water, and sediment also are compared to ecological dose-based screening levels following DOE-STD-1153-2002, *DOE Technical Standard*, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*.

4.4 SURVEILLANCE DESIGN

The Environmental Surveillance Program historically has focused on monitoring radionuclide concentrations in various media and measuring non-radiological water quality parameters. However, surveillance for non-radiological constituents, including hazardous chemicals, also is conducted. Contaminant-related assessments of ecological risk along portions of the Columbia River's Hanford Reach shoreline have been completed (DOE/RL-2007-21, *River Corridor Baseline Risk Assessment*; WCH-398, *Data Summary Report for the Remedial Investigation of Hanford Site Releases the Columbia River, Hanford Site, Washington*). The analyses and results from these assessments help guide the selection of chemicals of concern, sample media, and sampling locations for the Environmental Surveillance Program.

A radiological pathway analysis and exposure assessment is performed annually. The pathway analysis is based on source-term data and on the comprehensive pathway and dose assessment methodology included in the Generation II (GENII) Version 2.10 computer code (PNNL-14583) used to estimate radiation doses to the public from Hanford Site operations. Biota dose evaluations are conducted using DOE Standard DOE-STD-1153-2002. Implementation tools for the biota dose evaluations include the RESidential RADiation (RESRAD)-BIOTA computer code, Version 1.5 (DOE/EH-0676). The results of the pathway analysis, exposure assessment, and the biota dose screening evaluation serve as the basis for future years' surveillance program designs.

Exposure is defined here as the interaction of an organism with a physical or chemical agent of interest. Thus, exposure can be quantified as the amount of chemical or physical agent available for absorption at the organism's exchange boundaries (i.e., dermal contact, lungs, gut). An exposure pathway is identified based on 1) examination of the types, locations, and sources of contaminants (contaminated soil, raw effluent); 2) principal contaminant release mechanisms; 3) probable environmental fate and transport (including persistence, partitioning, and intermediate transfer) of contaminants of interest; and 4) locations and activities of the potentially exposed populations. Environmental processes or mechanisms that could influence the fate and movement of chemical or physical agents through the environment and the amount of exposure a person might receive at various receptor locations are listed below.

Once a radionuclide or chemical is released into the environment, it may be:

- Transported (e.g., migrate downstream in solution or on suspended sediment, travel through the atmosphere as a gas or associated with airborne particles, or be carried offsite in contaminated wildlife)

- Physically or chemically transformed (e.g., volatilized, photolyzed, oxidized, reduced, hydrolyzed, or changed through radioactive decay)

- Biologically transformed (e.g., biodegraded, metabolized)

- Accumulated in the receiving media (e.g., sorbed in water, soil, or sediment or stored in organism tissues).

The primary pathways for movement of radionuclides and chemicals from the Hanford Site to biota and the public are the atmosphere, groundwater, and surface water. The significance of each pathway is determined from measurements and calculations that estimate the amounts of radioactive materials or chemicals transported along each pathway by comparing contaminant concentrations or potential doses to environmental and public health protection standards or guides. Pathways also are evaluated based on prior studies and observations of radionuclide and chemical movement through the environment and food chains. Calculations based on effluent data have historically shown the expected contaminant concentrations off the Hanford Site to be low for all Hanford-produced radionuclides and chemicals and are often below the levels that can be detected by current measurement technologies.

The far-field surveillance design uses a geographically stratified sampling approach to monitor these pathways. Samples are collected and radionuclide and chemical concentrations are measured in three general far-field surveillance zones that extend from onsite operational areas to the offsite environs.

The first surveillance zone extends from near the Hanford Site's operational areas to the Site perimeter. The environmental concentrations of contaminants from facilities and fugitive sources (e.g., non-stack releases from facilities or resuspension of contaminated soils) generally would be the highest and, therefore, most easily detected in this zone. The second surveillance zone consists of a series of perimeter sampling stations positioned near or just inside the Site boundary along State Route 240, which runs through the Site from Richland to the Yakima Barricade and along the Columbia River. Exposures at these locations are typically the maximum that any member of the public (not working on the Hanford Site) could receive. The third surveillance zone consists of nearby and distant community locations within a80-km (50-mi radius of the Hanford Site's operational areas. Surveillance is conducted in communities to obtain measurements at locations where a large number of people potentially could be exposed to Hanford Site releases and to confirm that contaminant levels are well below standards established to protect public health and the environment.

In addition to the three far-field surveillance zones, reference (background) concentrations are measured at locations distant from the Hanford Site and are compared to concentrations measured onsite and at perimeter and community locations. Reference locations are essentially unaffected by site operations but may be affected by other man-made sources of contaminants such as global fallout from nuclear weapons testing. A comparison of reference concentrations to concentrations measured on or near the Hanford Site may indicate the impact of site operations.

The amounts of most radioactive materials released from site operations are small. Often it is not possible to distinguish levels resulting from worldwide fallout and natural sources from those associated with Hanford Site releases. Therefore, offsite doses are estimated using the following methods:

- Doses from monitored air emissions and liquid effluent released to the Columbia River are estimated by applying environmental transport and dose calculation computer models to measured effluent monitoring data and selected environmental measurements.
- Doses from fugitive liquid releases (e.g., groundwater seeping into the Columbia River) are estimated by evaluating differences in contaminant concentrations measured in the Columbia River upstream and downstream from the Hanford Site.

4.5 ANNUAL DESIGN/REVIEW PROCESS

The surveillance design is reviewed and evaluated annually based on the above considerations and an awareness of planned waste management and environmental restoration activities. Periodic reevaluations may be needed during the year to respond to changing operations or environmental conditions. Key steps in the process include the following:

- Performing a pathway analysis – The design process starts with a radiological pathway analysis performed for the calendar year just ended. This analysis is based on facility emissions, effluent information (e.g., DOE/RL-2017-17), and environmental surveillance results from the previous calendar year. The pathway analysis serves as the basis for the design review.
- Producing the Hanford Annual Site Environmental Report – The annual environmental report summarizes the findings of environmental surveillance, effluent monitoring, and cleanup activities conducted during the previous calendar year. A comparison of the previous year's results with pathway analysis conclusions helps identify changes in environmental conditions that may lead to modifications to the sampling design.
- Projecting future site activities – Because the pathway analysis and the annual report are retrospective, an activities projection from Hanford Site contractors (e.g., remediation, facility decommissioning, site closure) identifies future activities to be considered in the surveillance design.
- Evaluating surveillance design – The design evaluation includes field inspections of sampling and measurement locations to determine whether conditions at the sampling locations continue to meet site selection or sampling design criteria. The evaluation also includes an effort to identify and review new surveillance compliance requirements (e.g., DOE Orders, directives, or other applicable federal or state requirements) and DOE-HDBK-1216-2015 updates.
- Submitting scope and budget information for upcoming fiscal years – Based on the results of the annual surveillance design evaluation, scope and budget information is prepared for upcoming fiscal years. The detail in this scope and budget information is general in nature; however, it does provide a basis for future planning and future scope and budget development.

- Obtaining scope and budget approval – The scope and budget for the project are reviewed and approved by DOE. Approval of the scope and budget is documented by a DOE signature on the current fiscal year project-specific documentation package.

- Developing an annual Master Sampling Schedule for the upcoming calendar year – An annual sampling schedule (e.g., DOE/RL-2013-53) is prepared based on the results of the annual design review process.

4.6 AIR SURVEILLANCE

Small amounts of radioactive particles and gases continue to be released to the atmosphere from the Hanford Site. Point sources (stacks and vents) release materials during routine operations. Cleanup and remediation activities and wind-blown dust are potential sources of contaminants. Once released into the environment, these materials are diluted as they are transported to locations where people may be directly exposed to radionuclides through inhalation and immersion or indirectly exposed through deposition of contaminants onto farm crops, native vegetation, and surface soil. Each year, a radiological pathway analysis and exposure assessment is performed.

Air samplers operate continuously on and around the Hanford Site. They provide data to estimate annual doses from Hanford Site operations and data that could be used to estimate exposure and dose following an unplanned release of contaminants.

4.6.1 Objectives

The objectives of air surveillance include the following:

- Obtaining radiological air concentration measurements at locations of actual and potential public residence to verify that doses to the public from DOE operations meet applicable standards

- Detecting potential increases in airborne exposures and contamination of the environment

- Providing surveillance data for areas near waste units scheduled for treatment and/or restoration to help assess the integrated effects of individual site actions and actions conducted over time

- Obtaining measurements at the site perimeter and in nearby communities to provide assurance to the public that the degree of contamination from DOE operations is known

- Sampling air onsite and offsite continuously to assess the environmental effects and radiological doses from unusual releases

- Providing data to evaluate and improve the computer models used to predict and assess public dose compliance and environmental contamination.

4.6.2 Plan Rationale and Criteria

The criteria for air sampling are identified in DOE-HDBK-1216-2015 and in the *Hanford Site Radioactive Air Emissions License #FF-01*. The locations, media, sampling frequencies, samples that are temporally composited, analyses, and analysis frequencies to meet Hanford Site air surveillance objectives and criteria are provided in an annual sampling schedule (e.g., DOE/RL-2013-53). Sampling locations may change annually. The rationale and any additional specific criteria for these selections are discussed below.

4.6.2.1 Media Selection. Air is sampled according to the primary form in which the radionuclides occur. Most of the radionuclides of interest occur in particulate form at the Hanford Site. Past measurements indicate that some radionuclides (e.g., tritium, iodine) occur predominantly as gases.

4.6.2.2 Analyte Selections. Radionuclides identified for routine collection and analysis are those that 1) are released in measurable quantities from Hanford Site facilities (i.e., stack effluent), 2) have the potential to be released under plausible abnormal conditions, 3) are calculated to contribute more than 10% of the maximally exposed individual dose, or 4) are of special public or agency interest. Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each medium.

4.6.2.3 Sampling Methods. Air samples are collected using methods to avoid loss of sample mass, cross contamination, or misidentification. Exchanging whole sample collection media containers, rather than handling the collection media in the field, accomplishes this as well as labeling and sealing or storing each sample so that sample integrity is maintained. Airflow control for all radiological samples is maintained with mechanical flow controllers. Sampler plumbing is designed to minimize fluctuations in flow throughout the sampling period; this is important for ensuring the collection of a sample representative of the entire sampling interval (i.e., results are not biased toward one portion of the interval).

Air samples analyzed for gross beta, gross alpha, strontium-90, plutonium isotopes, uranium isotopes, and gamma emitters are collected by continuously drawing air through high-efficiency glass fiber filters. The filters have a sampling efficiency of at least 99% for 0.3-micrometer-diameter particles at the flow rate being used (0.05 m^3/min [2 ft^3/min]). Flow rates for particle filters are checked and readjusted (if needed) at the end of the sampling period, and sample volumes are calculated using flow rate and sample collection duration measurements.

Samples for iodine-129 analysis are collected on petroleum-based (low-background) charcoal cartridges. Iodine cartridges are preceded in the sampling train by a disposable glass fiber filter to remove particles. The collection efficiency of the cartridges has been verified at a flow rate of 0.05 m^3/min (2 ft^3/min). The cartridges have a 2.5-cm (0.98-in.) bed depth and have a nominal exposure period of 28 days.

Samples for carbon-14 analysis are collected on GELsorb cartidges. These cartridges are preceded in the sampling train by a disposable glass fiber filter to remove particles. The collection efficiency of the cartridges has been verified at a flow rate of 1 L/min (0.26 gal/min). The cartridges have a nominal exposure period of 7 days.

Samples for tritium analysis are collected on silica gel. Airflow rates (190 mL/min [6.42 oz/min]), sampling volumes, and exposure periods (nominally 28 days) are such that the gel is not likely to be saturated during the sampling period, minimizing the likelihood of sample loss due to breakthrough.

Silica gel saturation is monitored using a color-change indicator in the gel, which also is useful in diagnosing problems in the sampling system (i.e., leaks). Flow rates for adsorbent samples are measured at the beginning and end of each sampling period using a device with a documented accuracy of ±20%. Sample volumes are calculated using the average flow rate measurements and hours of exposure.

4.6.2.4 Sampling and Analysis Frequencies. Air sampling locations are visited every other week. Experience indicates that air-particulate fiberglass filters must be collected at this frequency to avoid occasional excess particulate buildup on the filters. Following collection, each particulate sample is analyzed for gross alpha and gross beta to provide an early indication of any unplanned contaminant release that may require expedited analysis of samples and/or additional or special sampling. Biweekly filter samples from a single location are composited for semi-annual analyses (e.g., gamma emitters, uranium isotopes, plutonium isotopes, strontium-90) to track trends that are not likely to be detectable by the gross activity measurements.

Tritium silica gel columns are collected approximately every 4 weeks. This is an operationally practical sampling period for these samplers and has been observed to be short enough to preclude significant breakthrough of the silica gel sampler and loss of sample (PNL-10690, *Evaluation of an Ambient Air Sampling System for Tritiated Water Vapor Using Silica Gel Adsorbent Columns*).

When iodine-129 in air is monitored, the charcoal cartridges are collected every 4 weeks and may subsequently be composited every quarter or as needed to meet project-specific requirements.

When carbon-14 in air is monitored, the GELsorb cartridges are collected every 7 days and may subsequently be composited every 4 weeks or as needed to meet project-specific requirements.

4.6.2.5 Sampling Locations. Samplers are located to obtain measurements representative of open areas (i.e., away from trees, large structures). This approach is expected to provide better comparability of data between sampling locations. Samplers generally are placed outside of building wake zones, away from vegetation, and usually on flat terrain. Sampling inlets are located 2 m (6.56 ft) above the ground to provide measurements representative of radionuclide concentrations inhaled by humans.

Sitewide. Air samplers primarily are located around the operational areas to maximize the amount of radiological material collected. Sampling locations are determined based on several factors including access, power availability, and atmospheric dispersion modeling results. Some samplers around the 200 Areas were installed to improve the likelihood of detecting an unusual occurrence. The potential for diffuse radiological emissions from underground waste storage tanks and resuspension and dispersion of contaminated soil makes it necessary to locate multiple samplers around these areas.

Air samplers are strategically located to provide measurements representative of the integrated effects of the areas being monitored, a goal that may require a tradeoff with the goal of measuring the maximum exposure.

Perimeter. Sampling stations are located at the perimeter of the Hanford Site to measure the concentrations of radionuclides at locations accessible by members of the public.

Offsite. Offsite air samplers are located: 1) near the historical locations of the maximally exposed individual to attempt to verify such exposures, 2) in the nearest downwind communities (Tri-Cities) to determine the maximum population exposures, and 3) in a few selected distant communities.

One reference air surveillance location that is more than 20 km (12.4 mi) upwind from the Hanford Site is sampled routinely. Samples from this reference location are analyzed for all the radionuclides identified in Section 4.6.2.2. Information about individual sampling locations can be found in the annual report *Hanford Site Environmental Surveillance Master Sampling Schedule for Calendar Year 2018* (DOE/RL-2013-53).

4.7 SURFACE WATER SURVEILLANCE

The Columbia River flows through the northern portion of the Hanford Site and forms part of the Site's eastern boundary. The Hanford Reach of the Columbia River extends 82 km (51 mi) from Priest Rapids Dam to the head of Lake Wallula (the impoundment created by McNary Dam). Priest Rapids Dam is the nearest dam upstream of the Hanford Site and McNary Dam is the nearest dam downstream.

The Columbia River has been developed extensively for hydroelectric power, flood control, navigation, irrigation, and industrial water supplies. The river is used as a source of drinking water at onsite facilities, as well as at communities located downstream of the Hanford Site. In addition, the river and its shoreline are used for a variety of recreational activities (e.g., hunting, fishing, boating, waterskiing, wind surfing, picnicking, and swimming). The Hanford Reach of the Columbia River and some of the surrounding lands are part of the Hanford Reach National Monument (65 FR 37253), which is home to diverse wildlife populations including approximately 46 species of mammals, 145 species of birds, 10 species of reptiles, 5 species of amphibians, and 45 species of fish (PNNL-6415).

In addition to the Columbia River, a limited number of ephemeral surface waters exist at or near the Hanford Site. These include West Lake, Saddle Mountain Pond, Rattlesnake Springs, and two intermittently flowing streams (Dry and Cold creeks), as well as other small springs on the Rattlesnake Unit (Fitzner/Eberhardt Arid Lands Ecology Reserve) of the Hanford Reach National Monument. Riverbank seeps (i.e., groundwater discharge) occur along the Hanford shoreline of the Columbia River as well.

Pollutants resulting from past and current operations at the Hanford Site, both radiological and chemical, are known to enter the Columbia River from contaminated groundwater that emerges along the banks of the river (seeps) and upwellings that emerge up through riverbed (WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*). In addition to the U.S. Environmental Protection Agency (EPA)-permitted direct discharges of liquid effluent from onsite facilities, contaminants from past waste disposal practices enter the river through riverbank seeps and subsurface groundwater discharges. Hence, the surface water pathway (Columbia River) consistently has been one of the primary contributors to the potential dose received by the public as a result of operations at the Hanford Site. Therefore, periodic sampling of surface waters, including the Columbia River, is conducted as part of Hanford Site surface water surveillance. Such sampling also provides a means to verify the effectiveness of the Hanford Site's facility-related effluent control and effluent monitoring systems. Unplanned releases, long-term contaminant trends, and changes in environmental conditions that may be related to contaminants also may be detected by routinely sampling these media.

It is important to know the inventory of contaminants entering the Columbia River along the Hanford Reach shoreline. Periodic sampling of known riverbank seeps provides this information and helps monitor the contaminants identified in groundwater samples collected from wells located near the seeps. Shoreline surface water surveillance sampling includes the collection of water from flowing riverbank seeps.

Under Ecology surface water quality standards (WAC 173-201A), the Class A (Excellent) designated uses criteria include separate designations for aquatic life uses, recreational uses, water supply uses, and miscellaneous uses. For the Columbia River downstream of Grand Coulee Dam, the aquatic life designation is “spawning, rearing,” which provides for the protection of spawning and rearing of salmon, trout, and other associated aquatic life. The recreational uses designation for the Columbia River downstream of Grand Coulee Dam is “primary contact,” which provides for activities that may involve complete submersion by the participant. The entire Columbia River is designated for all water supply and miscellaneous uses by the state of Washington.

The Columbia River and the potential impact of Hanford Site operations on the quality of river water and sediment have received significant public scrutiny during recent years. Surface water surveillance activities to address public concerns and to provide public reassurance will be continued.

4.7.1 Objectives

The objectives of surface water surveillance include the following:

- Assessing the impact of Hanford Site operations on Columbia River water quality
- Identifying significant changes in contaminant concentrations (radiological and chemical) in surface water
- Characterizing contaminants in the surface water environment
- Determining the status of the Hanford Site’s compliance with applicable water quality standards and criteria
- Providing assurance to the public that Hanford-derived contaminant exposure risks associated with the use of the Columbia River are continually monitored and evaluated.

4.7.2 Plan Rationale and Criteria

The basis for the design of the surface water surveillance program is discussed in DOE-HDBK-1216-2015.

4.7.2.1 Media Selections. Contaminants are known to enter the Columbia River as a result of past and current operations at the Hanford Site. Consumption of water or biota from the Columbia River or foodstuffs produced on land irrigated with Columbia River water could potentially expose the public to radiological and chemical contaminants. Additionally, direct exposures to radiological or chemical contaminants from water recreation could occur. The Columbia River is routinely monitored to measure the potential exposures from these pathways.

Riverbank seep water (groundwater discharge), potentially containing contaminants, enters the river along the Hanford Reach shoreline. The seeps are monitored periodically to document the locations and levels of contaminants entering the river.

West Lake, an onsite pond, while not directly accessible to the public, is used by migratory waterfowl and wildlife. West Lake is monitored to determine the potential for wildlife exposures from this pathway and to verify existing effluent controls at selected facilities.

Offsite irrigation water withdrawn from the Columbia River downstream of the Hanford Site may be affected by Site operations. Consumption of food irrigated with water withdrawn from the Columbia River downstream of the Hanford Site historically has been identified as a pathway contributing to the potential dose to the hypothetical maximally exposed individual. Periodic monitoring provides reassurance to the public that irrigation water quality is not affected by Hanford Site operations.

The following sections describe monitoring activities specific to surface waters of the Hanford Site.

4.7.2.2 Columbia River

Analyte Selections. Columbia River water samples are analyzed for those constituents that, as determined by pathway analyses, represent a significant fraction of the potential public dose from the water pathway. In general, analyses are conducted for those contaminants known or suspected to be present in the river water as a result of past or current Hanford Site operations. Additional environmental factors may be included in determining chemical/physical monitoring of nitrate, conductivity, metals, pH, temperature, hexavalent chromium, and volatile organic compounds. Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each medium.

Radionuclides monitored in water samples can include selected gamma emitters (gamma scan), tritium, isotopic uranium, strontium-90, technetium-99, plutonium-238, and plutonium-239/240. Gamma scans provide the ability to monitor for numerous specific gamma-emitting radionuclides. Radionuclides of interest are selected based on their importance in verifying the effectiveness of effluent control and monitoring systems, and in determining Hanford Site compliance with applicable water quality standards.

Sampling Methods. The sample types, collection methods, sample sizes, and sampling and analysis frequencies are discussed in the following paragraphs. Specific sampling methods are documented in Environmental Surveillance Program sampling procedures. The selection of sampling methods and equipment depends on the potential for fluctuations in contaminant concentrations, variability in the effluent release into the receiving water, potential for significant environmental or human impact, and characteristics of the contaminant of interest. Water samples collected in the field are stored at the laboratory in a manner that preserves sample integrity for the required analytical method. Examples of preservation methods include refrigeration, amber bottles for light-sensitive materials, and the addition of acid preservatives.

Two types of automatic water sampling systems are used to collect samples of Columbia River water for radiological analyses: 1) a cumulative system that collects a fixed volume of water at set intervals at each location during each sampling period and 2) a system that continuously collects waterborne radionuclides from the river on a series of filters and a mixed-bed ion-exchange resin column. Flow-proportional sampling is desirable; however, because of the large size of the Columbia River, such a system is not practical. Manual composites (grab samples) are collected in those cases where the use of automatic units is not feasible to cover periods of equipment downtime. The requirements of the analytical method to be used and the required levels of analytical sensitivity determine sample volume.

Grab samples of Columbia River water are collected biannually or annually along cross sections at transect locations for analyses of various radiological and chemical/physical water quality parameters. Special care is taken to obtain water from a flowing portion of the river, avoiding stagnant backwater areas. Surface debris and bottom sediment are avoided during sampling by collecting the samples from approximately mid-depth. Following collection, samples are delivered to an analytical laboratory.

Sampling Locations. Samples are collected upstream of Hanford Site facilities at Priest Rapids Dam and near the Vernita Bridge to provide reference data from locations unaffected by site operations. Samples are collected downstream of Hanford Site facilities at the Richland Pumphouse to identify any increase in contaminant concentrations caused by site operations. This downstream location provides an upper estimate of the amount of radioactive material in the water supply of the potentially affected population groups.

Priest Rapids Dam is located approximately 8 km (4.97 mi) upstream of the Hanford Site boundary and 20 km (12.4 mi) upstream of the 100-B/C Area. The water sampler at Priest Rapids Dam is positioned approximately midstream within the dam and collects water from the reservoir behind the dam. The Vernita Bridge sampling location is approximately 6 km (3.7 mi) upstream of the 100-B/C Area.

The Richland Pumphouse is located approximately 4 km (2.48 mi) downstream of the Hanford Site boundary. It is operated by the City of Richland and is the first downstream from Hanford Site point of river water withdrawal for a public drinking water supply. The Environmental Surveillance Program water sampling station is located on the intake structure on the Benton County shoreline. The structure's water intake is located approximately 9 m (29.5 ft) horizontally into the river at mid-river depth.

Transect surface water sampling is conducted near the Vernita Bridge, 100-N Area, 100-H Area, Hanford Townsite, 300 Area, and Richland Pumphouse. Transect sampling is performed to determine the distribution of contaminants across the river at these locations. Transect sampling along the Hanford Site shoreline is used to determine the localized zone of influence near known discharges of contaminated groundwater via riverbank seeps. The representativeness of the single-point-intake sampling system located at the Richland Pumphouse also is evaluated using results of the transect sampling. Samples are collected at approximately mid-depth at several points (up to 5) along a transect line (across the river). Transect sampling will identify those contaminants that are measurable in the river and may be influenced by proximity to the contaminated groundwater plume.

4.7.3 Riverbank Seeps

4.7.3.1 Analyte Selections. Water samples collected at these locations are analyzed for constituents known or suspected to be present in the local groundwater. The primary radionuclides of interest include tritium, uranium, and strontium-90. Chemical contaminants of interest include metals (primarily chromium), volatile organic compounds (primarily trichloroethylene), and anions (primarily nitrate).

Additional chemical/physical monitoring may include alkalinity, conductivity, dissolved oxygen, pH, and temperature. Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each medium.

4.7.3.2 Sampling Methods. Samples are typically collected using a stainless bowl and/or a peristaltic pump placed directly in an improved discharge zone to avoid agitation of the sediment. The sampling zone of the riverbank seeps is improved by scooping sediment from the discharge area to form a small pool and allowing any sediment in the pool water to settle into the stainless bowl before the sampling pump is used. Riverbank seep samples also may be collected using a shallow-depth drive point when seepage is not readily visible or in areas where forming a small pool is not practical. Riverbank seep samples are handled and transported in a manner similar to the river water samples discussed above. River stage-specified sampling has been instituted as a guideline to help reduce variability of results by following established trends for capturing contaminant levels that exist during low-level river periods (e.g., fall) (WCH-380). Specific sampling methods are documented in Environmental Surveillance Program sampling procedures.

4.7.3.3 Sampling Frequency. Samples are collected at least annually during low river level periods (fall) when contaminant concentrations are readily detected.

4.7.3.4 Sampling Locations. Riverbank seep samples are collected along the shoreline of the 100-B/C, 100-K, 100-N, 100-D, 100-H, 100-F Areas; at the primitive Hanford Townsite boat launch; downstream of the Hanford Townsite; and at the 300 Area. Groundwater enters the Columbia River at these locations with some contaminant concentrations significantly higher than reference site concentrations.

4.7.4 Onsite Ponds

4.7.4.1 Analyte Selections. Unfiltered aliquots of pond water samples are analyzed for tritium, technetium-99, and isotopic uranium at West Lake. Sediment samples are also collected at West Lake (see Section 4.9). Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each medium.

4.7.4.2 Sampling Methods. Grab samples are collected and care is taken to avoid surface debris and resuspension, as well as inadvertent collection of bottom sediments. Specific sampling methods are documented in the Environmental Surveillance Program sampling procedures.

4.7.4.3 Sampling Frequency. Samples are collected biannually based on biota dose exposure periods and when relatively high concentrations of contaminants are expected.

4.7.5 Sampling Locations

One onsite pond is routinely sampled. West Lake, located north of the 200-East Area, is recharged from groundwater (ARH-CD-775, *Geohydrologic Study of the West Lake Basin*). This lake has not received direct effluent discharges from Hanford Site facilities and radionuclide concentrations are influenced by the local groundwater levels.

4.7.6 Offsite Irrigation Water

4.7.6.1 Analyte Selections. Irrigation water samples are analyzed for gross alpha, gross beta, gamma emitters, tritium, and strontium-90. Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each medium.

4.7.6.2 Sampling Methods. Grab samples of irrigation water are collected. Specific sampling methods are documented in Environmental Surveillance Program sampling procedures.

4.7.6.3 Sampling and Analysis Frequencies. Samples are collected three times during the irrigation season.

4.7.6.4 Sampling Locations. Samples are collected from two irrigation water supplies that obtain water from the Columbia River downstream of the Hanford Site and one irrigation supply obtained from water upstream of the Hanford Site.

4.8 COLUMBIA RIVER SEDIMENT SURVEILLANCE

As a result of historical Hanford Site operations, large quantities of radioactive materials and chemicals were discharged to the Columbia River. When released to the river, most contaminants were rapidly dispersed. Some contaminants were sorbed onto inorganic particles and detritus, incorporated into aquatic biota, or deposited on the riverbed as sediment. Fluctuations in the Columbia River flow rate as a result of the operation of hydroelectric dams, annual spring freshets, and occasional floods have resulted in the resuspension, transport, and redeposition of the contaminated sediment over time.

Since the shutdown of the eight single-pass-cooling reactors, the radionuclide burden in the river surface sediment has decreased as a result of radioactive decay and the subsequent deposition of uncontaminated material on top of the contaminated sediment. However, releases of some radionuclides and chemicals to the Columbia River still occur through the seepage of contaminated groundwater into the river.

The accumulation of radionuclides and chemicals in sediment potentially can lead to contaminant exposures to humans as well as river and shoreline biota. Human exposure can occur through ingestion of aquatic species exposed to contaminated sediment, ingestion of river water containing resuspended contaminants, or as an external radiation source to people who are fishing, wading, sunbathing, or participating in other recreational activities associated with the river and shoreline. Currently, public exposures to contaminants in Columbia River sediment are well below the levels at which routine surveillance of the sediments is required (DOE-HDBK-1216-2015). However, periodic sampling is necessary to ensure that no significant changes have occurred over time that may increase the potential exposure to the public through the sediment pathway.

4.8.1 Objectives

The objectives of Columbia River sediment surveillance include the following:

- Verifying exposures to biota caused by Hanford Site operations through the sediment pathway sampling and analysis

- Providing an indication of changes in environmental conditions that have the potential to increase public exposures

- Providing assurance to the public that site surveillance activities are credible and that the radiological conditions and potential exposure pathways are understood and receive the appropriate attention.

4.8.2 Plan Rationale and Criteria

The basis for sampling sediment from surface water locations is discussed in DOE-HDBK-1216-2015. The locations, sampling frequencies, and analyses performed routinely on Columbia River sediment samples are established annually (DOE/RL-2013-53). Additional rationale and specific criteria are described in the following paragraphs.

4.8.2.1 Media Selections. Routine sediment sampling is necessary to meet site-specific surveillance requirements (DOE-HDBK-1216-2015). It is important to know where contaminants potentially enter the Columbia River along the Hanford Reach and their fate after entering the river. Elevated contaminant concentrations in sediment are most likely to be encountered in areas that contain deposits of fine-grained materials (e.g., sloughs). Routine sampling of the sediment also provides the public with a degree of assurance that concerns about contaminant levels in the river are being considered and addressed appropriately.

4.8.2.2 Analyte Selections. Sediment samples are analyzed for radiological contaminants of concern known or suspected to be present as a result of past or current operations at the Hanford Site. Groundwater monitoring reports and remedial investigation studies (WCH-398) identify those contaminants near the river and potentially entering the river that must be considered in the sampling plan. Historical reports documenting past releases or sediment contaminant concentrations are reviewed to determine contaminants of concern as a result of past operations.

Sediment samples are analyzed for nitrate, hexavalent chromium, gamma-emitting radionuclides (gamma scan), strontium-90, uranium, and plutonium isotopes. Such analyses are consistent with past and current releases and historical data relative to contaminants in the sediments. In addition, sediment samples may be analyzed for carbon-14, metals, and total organic carbon. Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each medium.

4.8.2.3 Sampling Methods. Because of the depth and swiftness of the river at various sediment-sampling locations, samples are collected using a dredge-type mechanical sampler deployed from a boat. In some cases, primarily in the shallow water sloughs along the Hanford Reach, the dredge is deployed by an individual wading in the river to better control the sample depth. Sediment sampling at riverbank seep locations is typically not done when the sampling location is underwater. Samples at riverbank seeps are collected with a handheld ladle, plastic scoop/shovel, or a stainless steel spoon. Specific sampling methods are documented in Environmental Surveillance Program sampling procedures.

4.8.2.4 Sampling and Analysis Frequencies. Sampling and analysis of Columbia River sediments are performed annually. Sampling occurs after the spring freshet to provide a consistent and more easily interpreted information base. The spring freshet may redistribute some of the contaminated sediments, particularly the sediment deposited in sloughs.

Sediment samples characterize the fate and buildup of contaminants in a river environment over time. Commensurate with findings of past sampling activities, and in consideration of future activities that may resuspend and redistribute contaminants, sediment samples may be collected periodically.

4.8.2.5 Sampling Locations. Sediment sampling locations are evaluated and selected based on the likelihood of detecting Hanford-derived contaminants in depositional environments along the Hanford Reach. Extensive riverwide sediment sampling efforts undertaken during the past decade have helped illustrate the distribution and fate of Hanford Site releases in sediment environments within the Columbia River (WCH-380, DOE/RL-2007-21, DOE/RL-2005-42, WCH-398, WCH-352).

Sediment samples are collected upstream of the Hanford Site (upgradient from groundwater discharges and the influence of historic Hanford Site liquid effluent discharges) behind Priest Rapids Dam. Samples are collected throughout the Hanford Reach and downstream of the Hanford Site at Richland and behind McNary Dam (the nearest downstream impoundment). This provides additional information relative to the distribution of contaminants in the sediments across the river. Sediment samples are collected along the Benton County shoreline of the Hanford Reach, at locations near the discharges (past and current), in areas where material is known to be deposited, and in areas commonly used by the public. Some sediment sampling is conducted along the Franklin County shoreline of the Hanford Reach at locations adjacent to islands that have historically shown a potential for contaminant buildup.

In addition to the routine sediment sampling, sediment samples are collected periodically from the upstream and downstream impoundments to determine the fate and distribution of the contaminants present as a result of past Hanford Site operations. The frequency of sediment sampling depends on the findings of past sampling activities and anticipated activities with the potential to affect the river and/or the sediment in the McNary Dam impoundment.

4.9 POND SEDIMENT SURVEILLANCE

West Lake has not received direct effluent discharges from Hanford Site facilities; however, it is influenced by precipitation and changing water table elevations that are related to historic discharges of water to the ground in the 200 Areas. The pond has a small amount of standing water in the winter and spring and is nearly dry in the summer.

4.9.1 Plan Rationale and Criteria

West Lake is not accessible to the public but may be used by migratory waterfowl and other wildlife, creating a potential pathway for the dispersion of contaminants from surface water and sediment.

4.9.1.1 Media Selection. Water and sediment are collected at West Lake. High suspended-sediment loading makes water analyses difficult for some radionuclides; therefore, the surveillance of these radionuclides has been combined in an attempt to provide pathway potentials regardless of the sediment load.

4.9.1.2 Analyte Selection. West Lake sediment samples are analyzed for radionuclides including gross alpha, gross beta, gamma emitters, strontium-90, technetium-99, and uranium isotopes. Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each media.

4.9.1.3 Sampling Methods. Samples are scooped or spooned from the surface sediment beneath the pond water. Specific sampling methods are documented in Environmental Surveillance Program sampling procedures.

4.9.1.4 Sampling Frequency. Samples are collected and analyzed biannually.

4.10 FOOD AND FARM PRODUCTS SURVEILLANCE

Agricultural products are major contributors to the economy of the Columbia Basin. Large tracts of arable land surround the Hanford Site and surveillance of agricultural products (including dairy milk) produced on this land are an important element of environmental surveillance. Radioactivity of Hanford Site origin can reach agricultural areas by atmospheric transport and deposition of facility and fugitive emissions or from irrigation with Columbia River water potentially contaminated as a result of historic Hanford groundwater and effluent discharges to the Columbia River. Radioactivity also can be present in agriculture due to the uptake of long-lived radionuclides from historical operations that remain in the environment. A variety of food and farm product samples are collected annually near the Hanford Site and analyzed to monitor the potential deposition and uptake of recently released contaminants and the uptake of radiological materials that may persist in the soil from historical contributions.

Food and farm product samples are collected from distant locations that have not been exposed to Hanford contaminants so that reference levels can be determined. The reference levels are compared to levels measured in samples collected on and near the Hanford Site so that the amounts of Hanford-related radionuclides in the samples can be estimated.

4.10.1 Objectives

The objectives of food and farm product surveillance include the following:

- Verifying that radiological exposures related to the food and farm products remain acceptable and quantifiable as required by DOE-HDBK-1216-2015
- Providing assurance to producers and consumers of agricultural products grown near the Hanford Site that the degree of contamination caused by site operations and cleanup activities is known and documented in publicly available reports (e.g., the Hanford Annual Site Environmental Report)
- Providing baseline data to quantify contaminant level changes due to fugitive or accidental releases of Hanford Site radiological materials
- Monitoring the potential radiological exposure resulting from irrigation water withdrawn from the Columbia River downstream of the Hanford Site.

4.10.1.1 Plan Rationale and Criteria. Pathway analyses indicate that emissions and effluent of Hanford origin can reach agricultural products through atmospheric deposition at downwind locations and by the application of irrigation water withdrawn from the Columbia River downstream from the Hanford Site. Specific agricultural pathways target a variety of local representative food and farm products identified in DOE-HDBK-1216-2015 and emphasize the concern for public assurance.

Current levels of Hanford-produced radionuclides in food and farm products are at or below analytical detection limits. Assurance that regional agricultural products are not contaminated is important to the public, the region's agribusinesses, and DOE; therefore, periodic sampling must be conducted in a manner and frequency to maintain that assurance.

Sampling procedures are designed to ensure that sample collections are performed safely and consistently and meet the objectives of the monitoring programs that use the data. Sampling objectives are reviewed annually. Scheduling changes or media substitutions are made, as needed, to address those objectives.

4.10.1.2 Media Selections. Selections of specific media are based on their potential for human exposure. The following are food and farm product media routinely monitored:

- Milk – Whole raw milk is collected from dairies downwind of the Hanford Site, near the Site perimeter, and at a control location generally upwind and distant from the Hanford Site.

- Farm produce – Fruits (e.g., apples, grapes, cherries, and tomatoes), vegetables (potatoes), and leafy vegetables are collected seasonally at locations around the Hanford Site perimeter. Specific crops are collected by area and not all areas yield the same types of produce.

- Alfalfa or grass hay– Samples of fresh alfalfa are collected from one upwind reference location and three locations adjacent to the Hanford Site perimeter.

- Wine must – Vintage (current year) red and white wine must produced from grapes harvested at vineyards located around the Hanford Site are collected and analyzed.

4.10.1.3 Analyte Selections. Food and farm product samples are routinely analyzed for radionuclides that: 1) are found in historical Hanford Site effluent discharges and emissions (historical and current), 2) contribute to modeled doses associated with potential exposure pathways, and 3) are of concern to the public and to agribusiness. The radionuclides, routinely monitored in most samples, include carbon-14, strontium-90, and gamma emitters (including cesium-137). Some samples (e.g., milk, wine must, and tomatoes) also are analyzed for tritium. Milk is also analyzed for iodine-129. These contaminants can be transferred to humans and other biota via various consumption pathways. Onsite cleanup and remediation activities may prompt analyses for specific contaminants in some products; however, non-radionuclides are not routinely analyzed in food and farm products. These contaminants will be identified on a case-by-case basis as cleanup and remediation work progresses. Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each medium.

4.10.1.4 Sampling Methods. Food and farm products are collected from the field or from the grower in adequate amounts to meet analytical detection limits. Locational data are recorded for all farm product samples except milk, which is routinely collected at the same historical locations. Perishable agricultural samples, such as milk, are kept on ice in a cooler or refrigerated following collection. Fruits and vegetables are packaged in plastic bags; samples are refrigerated or frozen to minimize spoilage. Specific sampling methods are documented in Environmental Surveillance Program sampling procedures.

4.10.1.5 Sampling and Analysis Frequencies. Food and farm products are collected during the harvest season and are analyzed following collection. Samples of some products are collected annually from locations that have the greatest potential for exposure to Hanford Site effluent and emissions. Specific products are sampled in alternating years or on a 3-year cycle, as indicated in DOE/RL-2013-53. Milk samples are collected and analyzed quarterly.

4.10.1.6 Sampling Locations. Routine food and farm product samples are collected offsite at locations that are likely to contain the highest concentrations of Hanford Site contaminants (i.e., locations downwind or downstream of Hanford Site facilities [DOE-HDBK-1216-2015]).

Food and farm products are sampled from established sampling areas around the Hanford Site. Areas to the east and north of the Hanford Site are considered downwind locations. Areas to the west of the Hanford Site are considered upwind or distant. The Riverview and Horn Rapids sampling areas are agricultural areas located downstream of the Hanford Site that use Hanford Reach water for irrigation. Reference samples are collected at locations upwind, upstream, or distant from the Hanford Site.

4.11 FISH AND WILDLIFE SURVEILLANCE

Fish and wildlife on and off the Hanford Site are valued natural and recreational resources. Fish from the Hanford Reach may be caught and consumed by anglers, and wildlife residing onsite (elk, deer, rabbits, upland game birds, and waterfowl) may move offsite and be harvested by the public for consumption. Fish may be exposed to radiological and chemical contaminants present in Hanford Site groundwater entering the Columbia River via shoreline seeps. Wildlife onsite could be exposed to contaminants at waste storage sites, at former waste disposal locations, in contaminated areas, and in Columbia River shoreline seep water. Unplanned contaminant releases and releases from cleanup activities also could lead to contamination of edible wildlife tissues. It is important, therefore, that consumable fish and wildlife on and near the Hanford Site be sampled to document levels of potential contaminants. Additionally, potential collection of certain species with small home ranges that live near operating and cleanup areas on the Hanford Site may assist in verifying the effectiveness of onsite contaminant controls.

Samples of fish and wildlife are collected from distant locations that have not been exposed to Hanford contaminants so that reference levels can be determined. The reference levels are compared to levels measured in samples collected on and near the Hanford Site so that the amounts of Hanford-related radionuclides in the samples can be estimated.

4.11.1 Objectives

The objectives of fish and wildlife surveillance include the following:

- Verifying that radiological exposure and dose to consumers of fish and wildlife remain quantifiable as required by DOE-HDBK-1216-2015

- Providing assurance to consumers of fish and wildlife collected near the Hanford Site that the degree of contamination caused by site operations and cleanup activities is known and documented in publicly available reports (e.g., the Hanford Annual Site Environmental Report)

- Monitoring the occurrence and accumulation of long-lived radionuclides and trace metals in fish and wildlife tissues.

4.11.2 Plan Rationale and Criteria

Fish and wildlife species on and around the Hanford Site are sampled based on their likelihood of exposure to contaminants, potential for accumulating contaminants, and potential for moving off the Hanford Site and being consumed by humans (i.e., hunters or anglers). Consideration is given to species that may be consumed by various cultures.

Sampling procedures are designed to ensure that sample collections are performed safely and consistently and meet the objectives of the monitoring programs that use the data. Fish and wildlife species selected for sampling are found in sufficient abundance to ensure sampling will not affect population stability. Sampling and data quality objectives are reviewed annually; scheduling changes or media substitutions are made, as needed, to address those objectives.

4.11.2.1 Media Selections. Specific biota are selected based on their significance to human and ecological dose. The biotic media that are routinely monitored include the following:

- Aquatic biota – Whitefish historically have been sampled because of their value to recreational fishing and their propensity to accumulate radionuclides; however, carp, walleye, and bass also are sampled. For human dose assessment purposes, two sample types are obtained: edible muscle and carcass (bone and fin). Liver samples may be collected to assess accumulation of trace metals. A number of species other than game fish may be sampled because they represent potential ecological sentinels on the Hanford Site. These species include sculpin, clams, crayfish, and macroinvertebrates.

- Terrestrial biota – Terrestrial biota are collected to monitor contaminant concentrations of Hanford Site-sourced radionuclides. Routinely collected species include elk, deer, rabbits, geese, and upland game birds (usually pheasant or quail, but may include chukar). Muscle, bone, and sometimes liver are also collected. Several other organisms also may be collected because they best represent potential ecological sentinels on the Hanford Site. These organisms include invertebrates, small mammals, amphibians, and birds.

4.11.2.2 Analyte Selections. Fish and wildlife samples are analyzed for 1) radionuclides, and in some cases chemicals, that are found in Hanford Site effluent and emissions; 2) radionuclides that contribute to doses associated with various potential human and biota exposure pathways; and 3) radionuclides and chemicals that are of concern to DOE, the public, American Indian Tribes, activist groups, environmental organizations, public officials, and regulatory agencies. Fish and wildlife samples are analyzed for the following:

- Strontium-90, which accumulates in bones
- Gamma emitters (specifically cesium-137), which accumulates in muscle tissues

- Uranium in some fish samples
- Plutonium in selected deer, elk, and rabbit samples
- Metals are analyzed in livers, when sampled
- Mercury is analyzed in some fish.

Onsite cleanup, remediation activities, and special studies may require analyses for specific contaminants in some samples. These contaminants will be identified on a case-by-case basis. Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each medium.

4.11.2.3 Sampling or Measurement Methods. Wildlife samples are collected from animals killed by traffic or by permitted trapping or hunting. Specific wildlife sampling procedures are described in the Environmental Surveillance Program sampling procedures. Fish are obtained using rod and reel, electroshocking, or seine nets. Tissue, bone, and organ samples are taken from animals in the field or in the laboratory. Special care is taken to ensure that samples are not contaminated with skin, hair, or materials from the gastrointestinal tract. Samples are generally double-bagged in plastic, and stored samples are refrigerated or frozen. Most metals analyses are done by inductive coupled plasma mass spectrometry. Cold vapor atomic absorption spectrometry is used for mercury analyses.

4.11.2.4 Sampling and Analysis Frequencies. Fish and wildlife are collected annually from Hanford Reach locations; however, each species is only collected in alternating years (biennially). Reference samples are periodically collected. Wildlife populations undergo natural fluctuations, and routinely scheduled species are not always abundant or easily collected. When this occurs, the sampling and data quality objectives are reviewed annually and scheduling changes or species substitutions are considered. The current level of sampling is consistent with meeting DOE concerns for public assurance about contamination levels in fish and game in the region, emphasis on cleanup activities on the Hanford Site, and concerns about contaminants in the Columbia River.

4.11.2.5 Sampling Locations. Routine fish and wildlife samples are collected at locations that are likely to have the highest concentrations of Hanford Site contaminants (i.e., locations downwind or downstream of Hanford Site facilities) (DOE-HDBK-1216-2015). Onsite sampling locations are selected to monitor operational, cleanup, and remediation areas that have the potential to release radioactive materials and potentially contaminated Columbia River shoreline locations.

Fish are collected from the Columbia River near or downstream of locations where contaminated water is known to enter the river. Wildlife is sampled from locations that provide the highest potential for both exposure to Hanford Site contaminants and areas of highest potential interaction with the public. Non-routine, opportunistic surveillance samples also are collected when road-strikes occur onsite or along Highway 240.

Reference samples of fish and wildlife are collected at locations upwind, upstream, or distant from the Hanford Site. Reference sample organisms for fish are distant, upstream Columbia River residents that have a low probability of moving upstream from the Hanford Reach and passing over upstream dams. Reference sites for game species also are distant from the Hanford Site, demonstrate a climate proximal to the Site, and are generally upwind of Hanford Site operations.

4.12 SOIL AND VEGETATION SURVEILLANCE

Surveillance of soil and native vegetation is designed to monitor atmospheric deposition of contaminants at offsite locations not influenced by agriculture and at onsite locations adjacent to potential sources of environmental radioactivity. Atmospheric data and computer models indicate that Hanford Site emissions can be dispersed in the environment on and off the Hanford Site and deposited onto the land where there is then the potential for accumulation. Soil and vegetation on portions of the Columbia River shoreline bordering the Hanford Site are monitored because they may be exposed to contaminants present in Hanford Site groundwater and shoreline seeps. Soil and vegetation at publicly accessible areas near and downwind of the Hanford Site must be monitored to provide assurance to DOE and the public that these media are not significantly contaminated by particulate and gaseous emissions from the Hanford Site. Samples of soil and vegetation are also collected from distant locations to help determine reference levels.

4.12.1 Objectives

The objectives of soil and vegetation surveillance include the following:

- Verifying that radiological doses related to the soil exposure pathways remain acceptable and quantifiable as required by DOE-HDBK-1216-2015
- Providing assurance to people living near the Hanford Site that the degree of contamination caused by site operations and cleanup activities is known and documented in publicly available reports (e.g., the Hanford Annual Site Environmental Report)
- Providing baseline data to quantify contaminant level changes due to fugitive or accidental releases of Hanford Site radiological materials
- Monitoring trends in environmental contamination and possible long-term accumulation of radionuclides in onsite and offsite soil and vegetation from the deposition of airborne releases.

4.12.2 Plan Rationale and Criteria

Routine soil and vegetation sampling supports air monitoring efforts to document fugitive radioactive emissions that settle on the ground surface. Special sampling is conducted, as needed, for site cleanup and decommissioning activities and to facilitate the transfer of Hanford Site property to other federal, state, or local agencies.

Environmental concentrations of routinely monitored radionuclides in soil and vegetation are often below detection limits. Soil and vegetation monitoring is conducted at locations on the Hanford Site with the potential for elevated concentrations at downwind locations around the perimeter of the Site and at an upwind location distant from the Site. Special onsite sampling may focus on soil and vegetation along the Columbia River shoreline where contaminated groundwater enters the river, aquatic vegetation in the river where groundwater seepage occurs, and soil and vegetation at selected cleanup and remediation sites.

Soil and vegetation sampling procedures ensure that sample collections are performed safely and consistently and meet the objectives of the monitoring programs that use the data. Sampling and data quality objectives are reviewed annually; scheduling changes or media substitutions are made, as needed, to address those objectives.

4.12.2.1 Media Selections. Native vegetation samples consist of the current year's growth (leaves and limbs) collected from shrub species in proportion to their estimated abundance at the sampling site. Surface soil samples are collected to a depth of 2.5 cm (0.98 in.). Far-field soil and vegetation samples are collected every 3 to 5 years.

4.12.2.2 Analyte Selections. Soil and vegetation samples are analyzed for radionuclides in Hanford Site effluent and emissions; for radionuclides that contribute to doses associated with various potential exposure pathways; and for radionuclides and chemicals that are of concern to DOE, the public, American Indian Tribes, activist groups, environmental organizations, public officials, and regulatory agencies. Soil samples are routinely analyzed for the radionuclides common to Hanford Site operations: gamma emitters, strontium-90, uranium isotopes, plutonium isotopes, and for selected samples (e.g., americium-241). These radionuclides have relatively long half-lives and are indicative of past site operations. Onsite cleanup, remediation activities, and special studies may require analyses for specific contaminants. Metals and organics (i.e., polychlorinated biphenyls [PCBs] and pesticides) may be monitored in soil. Contaminants will be identified on a case-by-case basis. Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each medium.

4.12.2.3 Sampling or Measurement Methods. Soil is sampled with a shallow (cookie cutter) coring device. The samples are 2.5 cm (0.98 in.) deep and 11 cm (4.3 in.) in diameter. Five cores are combined to create one sample. Areas with heavy vegetation cover are avoided and any vegetation in the samples is removed. Samples are dried and sieved prior to analysis.

Vegetation is sampled by clipping new growth from the dominant shrubs at the sampling site (usually sagebrush and rabbitbrush).

Soil and vegetation samples are packaged in two plastic bags (double bagged). Stored vegetation samples are refrigerated or frozen to minimize deterioration.

4.12.2.4 Sampling and Analysis Frequencies. Far-field soil and vegetation samples are collected every 3 to 5 years. This collection cycle is adequate to monitor long-term trends in environmental radioactivity and is consistent with DOE-HDBK-1216-2015 requirements and the Hanford Site's cleanup mission.

4.12.2.5 Sampling Locations. Soil and vegetation samples are collected from several locations on and around the Hanford Site. Samples may not be collected from all sampling locations during each collection period. Routine samples are collected offsite at undisturbed, unirrigated locations that may contain detectable concentrations of Hanford Site contaminants (i.e., locations downwind or downstream of Hanford Site facilities) (DOE-HDBK-1216-2015). Onsite sampling locations are selected to monitor operational, cleanup, and remediation areas with the potential to release radioactive materials and to monitor contaminant concentrations along the Columbia River shoreline. Reference samples are collected at locations upwind, upstream, or distant from the Hanford Site.

Soil and vegetation sampling locations are in undisturbed areas to facilitate monitoring of long-term accumulations of contaminants. When possible, soil and vegetation samples are collected near established air sampling locations to facilitate interpretation of results (DOE-HDBK-1216-2015). Sampling locations offsite and along the Hanford Reach shoreline are selected to monitor the potential for public exposure.

4.13 DOSE ASSESSMENT METHODS

The radiological dose that the public potentially receives during a calendar year from Hanford Site operations is calculated in terms of the total effective dose equivalent (TEDE). The TEDE is the sum of the effective dose equivalent (EDE) from external sources and the committed EDE for internal exposure. The EDE is the sum of doses to organs and tissues that is weighted to account for the sensitivity of the organ or tissue to the effects of radiation and for the biological effectiveness of the type of radiation causing the dose. These dose quantities are given in units of millirem for individuals and in units of person-rem for the collective dose received by the total population within an 80-km (50-mi) radius of Hanford Site operations areas. These quantities provide a way to uniformly express the radiological dose regardless of the type, source of radiation, or the means by which it is delivered.

Concentrations of radionuclides from Hanford Site releases usually are too low to be measured in offsite air and food crops; therefore, environmental radionuclide concentrations are estimated from effluent measurements by using environmental transport models. The air dose calculations employ environmental transport modeling based on measurements made at the point of release (stacks and vents) (see Section 2.0). The water pathway dose calculations are based on measurements of releases to the Columbia River from the 100 Areas and the difference in detectable radionuclide concentrations measured upstream and downstream of the Hanford Site.

The transport of radionuclides in the environment to points of exposure is predicted using mathematical models of the physical processes underlying the various exposure pathways. These models are used to calculate radionuclide levels in air, soil, and locally raised foods at offsite locations. Long-lived radionuclides deposited on the ground become potential sources for long-term external exposure and uptake by agricultural products. Radionuclides taken into the body by inhalation or ingestion may be distributed among different organs and tissues and retained in the body for various lengths of times. Agricultural, behavioral, and dosimetric models are applied to calculate radionuclide intakes and radiological doses to the public from annual-average radionuclide concentrations in the exposure media.

Computer programs are used to implement these mathematical models using Hanford Site-specific dispersion and uptake parameters. These programs are incorporated in a master code—*GENII - The Hanford Environmental Radiation Dosimetry Software System, Version 2.10* (PNNL-14583, PNNL-14584, PNNL-19168)—that employs the internal dosimetry methodology described in International Commission on Radiological Protection Publication 60 (ICRP 1991) and external dose coefficients described in Federal Guidance Report 12 (EPA 1993). GENII Version 2.10 is a Microsoft Windows®-based version that incorporates environmental modeling improvements (e.g., plume depletion during atmospheric transport) relative to Version 1.485. In addition, the current EPA-approved version of the CAP88-PC software (EPA 2014) is used to demonstrate compliance with the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) radionuclide air emissions standards as specified in the *Clean Air Act* regulations under 40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities," and DOE O 458.1, Chg.2.

4.13.1 Types of Dose Calculations Performed

Potential radiological doses to the public and biota are evaluated annually to determine compliance with pertinent regulations and limits. Calculations of radiological doses to the public from radionuclides released into the environment are performed to demonstrate compliance with applicable standards and regulations. DOE O 458.1, Chg.2 provides general requirements for demonstrating compliance with the public dose limit of 100 millirem total effective dose in a year. Specific guidance is provided in DOE-HDBK-1216-2015.

The calculation of the TEDE takes into account the long-term (50-year) internal exposure from radionuclides taken into the body during the current year. The TEDE is the sum of individual committed (50-year) organ doses multiplied by weighting factors that represent the proportion of the total health-effect risk that each organ would receive from uniform irradiation of the whole body. Internal organs also may be irradiated from external sources. The external exposure received during the current year is added to the committed internal dose to obtain the total TEDE. The TEDE is frequently expressed in rem (or millirem). The numerous exposure and transfer factors used for pathway and dose calculations have been documented in GENII Version 2.10 (PNNL-14583, PNNL-14584, PNNL-19168, PNNL-13421). Parameters used with the CAP88-PC software are documented in the current *CAP88-PC Version 4.1 User Guide* (EPA 2014).

The following types of radiological doses are estimated at Hanford:

- Dose to a hypothetical, maximally exposed individual (MEI) at an offsite location, evaluated by using a multimedia pathway assessment.

  Maximally exposed individual (MEI) all-pathways dose (millirem) – The maximally exposed individual is a hypothetical member of the public whose location and lifestyle make it unlikely that any actual individuals would receive higher doses. The location of the MEI can vary from year-to-year depending on relative contributions of the different operational areas to radioactive emissions released to the air, contribution of radionuclide releases to the Columbia River from Hanford Site facilities, and year-to-year differences in meteorology affecting wind dispersion. The potentially significant exposure pathways considered to identify the location of the MEI include the following:

  - Inhalation of airborne radionuclides.
  - External exposure from submersion in airborne radionuclides.
  - Ingestion of foodstuffs contaminated by radionuclides deposited on vegetation and the ground by both airborne deposition and irrigation water drawn from the Columbia River downstream of Hanford Site discharges.
  - Incidental ingestion of soil and external exposure to ground contaminated by airborne deposition and/or irrigation water.
  - Ingestion of drinking water drawn from the Columbia River.
  - Consumption of fish from the Hanford Reach of the Columbia River.

- Recreation along the Hanford Reach including boating, swimming, and exposure to sediments during shoreline activities.

- Collective dose to the population residing within 80 km (50 mi) of Hanford Site operation areas:
  - 80-km (50-mi) Collective Population Dose (person-rem) – Collective dose is defined as the sum of doses to all individual members of the public within an 80-km (50-mi) radius of Hanford Site operating areas (100, 200, 300, and 400 Areas). The pathways assigned to the MEI are assumed to be applicable to the offsite population. The exposure pathways for the collective dose calculations are as follows:
    - Drinking water – The cities of Richland and Pasco obtain all or part of their municipal water directly from the Columbia River, downstream of the Hanford Site. The city of Kennewick obtains its municipal water indirectly from wells adjacent to the river.
    - Irrigated food – Columbia River water is withdrawn for irrigation of small vegetable gardens and farms in the Riverview area of Pasco in Franklin County. Commercial crops are irrigated by Columbia River water in the Horn Rapids area of Benton County and the Ringold Area of Franklin County.
    - Columbia River recreation – Activities include fishing, swimming, boating, and shoreline recreation.
    - Fish consumption – Population doses from the consumption of fish obtained locally from the Columbia River (without reference to a specified human group of consumers).

- Doses for air pathways calculated using regulation-specified EPA methods for comparison to the *Clean Air Act* standards in 40 CFR 61, Subpart H (Section 4.2.3).
  - Maximally exposed individual air pathway dose (milllirem) – The maximally exposed individual is a hypothetical member of the public whose location and lifestyle make it unlikely that any actual individual would receive higher doses from radionuclides released to the atmosphere, including monitored sources and potential sources of fugitive radionuclide emissions. This individual may reside offsite in a residence, school, business, or work at a non-DOE facility within the Hanford Site boundary. All potentially significant exposure pathways from airborne radionuclides to this hypothetical individual are considered, including the following:
    - Inhalation of airborne radionuclides.
    - Submersion in airborne radionuclides.
    - Ingestion of foodstuffs contaminated by airborne radionuclides deposited on vegetation and the ground.
    - Exposure to ground contaminated by airborne deposition.

- Doses from recreational activities including hunting and fishing.

- Doses to a worker consuming drinking water on the Hanford Site.

- Doses from non-DOE industrial sources on and near the Hanford Site:

  – Absorbed doses received by biota exposed to radionuclide releases to the Columbia River and to radionuclides in onsite surface water bodies

- Doses to Non-Human Biota. In addition to radiological doses to the public, radiological doses to aquatic and terrestrial organisms are estimated using the tiered approach described in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE-STD-1153-2002), in conjunction with the RESRAD-BIOTA computer code-derived biota concentration guides (DOE/EH-0676). Biota concentration guides are concentrations that could result in a dose rate of 1 rad/day for aquatic biota or 0.1 rad/day for terrestrial organisms.

  – Biota dose assessments are conducted at selected locations for Columbia River water, shoreline seep water, river sediment, pond water, pond sediment, and soil using sample media collected according to DOE/RL-2013-53. Both internal and external doses to aquatic biota, riparian, and terrestrial wildlife and plants are included in the screening process. For locations with multiple exposure media (e.g., sediment and water) and/or multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide and medium. If the sum of fractions exceeds 1.0, then the dose limit has been exceeded. If the initial estimated screening value (Tier 1) exceeds the dose limit (sum of fractions more than 1.0), additional screening calculations are performed using RESRAD-BIOTA (Tier 2 or Tier 3) to more accurately evaluate exposure of the biota to the radionuclides. Tier 1 biota concentration guides are provided in Table 4-2.

4.13.1.1 Data. Doses to humans are assessed using both measured and calculated results, depending on the exposure scenario. The data needed to perform dose calculations based on measured effluent releases include information on initial transport through the atmosphere or river, transfer or accumulation in terrestrial and aquatic pathways, and public exposure. By comparison, radiological dose calculations based on measured concentrations of radionuclides in food require data describing only dietary and recreational activities and exposure times. These data are discussed in the following sections.

Population Distribution and Atmospheric Dispersion. Geographic distributions of the population residing within an 80-km (50-mi) radius of the four Hanford Site operating areas are based on the 2010 Bureau of the Census data (PNNL-20631, Hanford Site Regional Population – 2010 Census). These data influence the population dose by providing estimates of the number of people exposed to radioactive effluents and their proximity to the points of release.

Atmospheric dispersion and transport parameters are calculated annually using meteorological data collected during the reporting year. These data describe the transport and dilution of airborne radioactive materials that influence the concentrations of radionuclides in air at specific locations, as well as deposition rates onto the ground surface.

Terrestrial and Aquatic Transport Pathways. Important parameters affecting the movement of radionuclides within potential exposure pathways, (e.g., irrigation rates), growing periods, element-specific transfer factors, and similar parameters are provided in the Hanford Annual Site Environmental Report. For human exposure, certain parameters are specific to the lifestyles of either maximally exposed or population-average individuals. For exposure to terrestrial and aquatic biota, sediment, water, and soil contaminant concentrations are compared to nuclide-specific biota concentration guides for the limiting receptor for each medium (Table 4-2).

Public Exposure Rate Parameters. The potential offsite radiological dose is related to the extent of external exposure to or intake of radionuclides released from Hanford Site operations. Parameters describing food consumption rates, inhalation rate, residency periods, and the attributes of river recreation activities assumed for maximally exposed and population-average individuals are tabulated in the Hanford Annual Site Environmental Report.

4.13.2 Dose Calculation Documentation

Dose calculation is performed using approved models, as identified in Section 4.13.1. The numerous exposure and transfer factors used for pathway and dose calculations have been documented in GENII Version 2.10 (PNNL-14583; PNNL-14584; PNNL-19168; and PNNL-13421). Parameters used with the CAP88-PC software are documented in the current CAP-88 User's Guide (EPA 2014). Dose evaluation for biota follows DOE-STD-1153-2002 and the current version of RESRAD-BIOTA (DOE/EH-0676).

4.14 DATA MANAGEMENT, ANALYSIS, AND STATISTICAL TREATMENT

This section describes the objectives for management, analysis, and statistical treatment of environmental surveillance data. These objectives are implemented through EIS-PRO-EMES-60972, *Environmental Surveillance Data Verification, Data Validation, and Data Quality Assessment Objectives*.

Good data management, data analysis, and statistical treatment practices are essential for the production of quality results. The following are objectives for analyzing environmental surveillance data:

- Managing data in a manner that ensures their timely collection, verification, and reporting in accordance with the annual sampling schedule and their traceability from scheduling to archiving in the Hanford Environmental Information System database

- Estimating contaminant concentrations at each sampling and/or measurement point for each sampling and/or measurement time and estimating accuracy and precision

- Comparing the contaminant concentrations at each sampling and/or measurement point to previous concentrations measured at the same point to recognize changes or inconsistencies in concentration levels

- Comparing the contaminant concentrations at each sampling and/or measurement point to reporting (notification) limits

- Comparing the contaminant concentrations at individual sampling and/or measurement points to those measured at reference sites or other points and evaluating the results of those comparisons.

4.14.1 Analytical Protocol

Laboratory analytical methods are specified in contracts with the laboratories and are performed according to appropriate methods. The analysis of air samples are performed according to 40 CFR 61, Subpart H; therefore, air samples are analyzed as required by 40 CFR 61, Appendix B, Method 114. All other media are analyzed by laboratory-specific or EPA methods (e.g., *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* [SW-846, as amended] or *Methods for the Determination of Inorganic Substances in Environmental Samples* [EPA 600/R-93/100]), or other methods accepted during the procurement process.

Instruments for field measurements (e.g., pH, specific conductance, temperature, and turbidity) are calibrated using standard solutions and are operated according to the manufacturer's instructions. Each instrument is assigned a unique number that is tracked on field and calibration documentation.

4.15 QUALITY ASSURANCE AND QUALITY CONTROL

To achieve the surveillance objectives identified in previous sections it is imperative that the accuracy, precision, traceability, and limitations of data are known. The generation of quality reports and documents requires controlled and verified data. It is also important to maintain and document appropriate methodology to ensure control and legitimacy of program documentation. All components of the surveillance program are under an appropriate level of QA/QC scrutiny.

The goal of a QA/QC program is to ensure that accurate and defensible data are produced. Sections 4.15.1 and 4.15.2 describe the elements of the Environmental Surveillance QA/QC Program and how they are implemented. Management commitment to the QA/QC program is assured through established management philosophies that are implemented through the QA Plan and QAPjP (MSC-PLN-EI-23333 and MSC-OTHER-EMES-60873). The result of this commitment is accurate and defensible data and calculations in support of environmental surveillance objectives, including characterization and assessment of potential radiological doses to the public and the environment.

4.15.1 Requirements

DOE QA requirements are contained in DOE O 414.1D, *Quality Assurance*. DOE O 414.1D requires that QA plans be developed and documented, as well as recommends the judicious and selective application of appropriate and recognized standards. DOE O 414.1D identifies 10 management, performance, and assessment criteria that must be addressed in a QA plan.

4.15.1.1 Quality Assurance Plan. Environmental surveillance is conducted under a programmatic QA plan (MSC-PLN-EI-23333) and a QAPjP (MSC-OTHER-EMES-60873) that addresses the applicable criteria in DOE O 414.1D and EPA guidance (EPA 240/B-01/003).

4.15.1.2 Assessments. Assessments are performed on surveillance program activities and procedures to ensure compliance with program, MSA, and DOE QA/QC requirements. The U.S. Department of Energy, Richland Operations Office program manager and Environmental

Surveillance program manager, media task leader, or quality engineer may initiate these assessments on a routine and/or random basis. Assessment results are documented and, if appropriate, provided to the Environmental Surveillance program manager and media task leaders for review. Corrective actions are documented and verified (e.g., field performance review), as applicable.

4.15.2 Quality Control

4.15.2.1 Procedures. QC for quality-affecting activities is maintained through written procedures. Activities that affect quality and require written procedures are identified in the QAPjP plan. In addition, QA/QC for services is defined in statements of work issued to the service organization. The services are performed according to QA procedures established for those services, unless a statement of work identifies special requirements.

4.15.2.2 Analytical Quality Control Program. Contracted analytical laboratories are required to maintain and perform internal analytical QC programs that are used to monitor and evaluate analytical precision and accuracy, and to verify that the laboratories are operating according to procedures included in their statement of work. QC samples must be included in each analytical batch processed and in total must comprise no less than 15% of all ordered. Deficiencies in the QC data are identified and investigated. If corrective actions are implemented, they are documented and implementation is verified (e.g., laboratory audits).

Analytical laboratories are evaluated through their analysis and reporting of blank, replicates, and matrix-spiked duplicate samples.

In addition to each laboratory's internal QC program, these laboratories participate in EPA-defined and DOE national comparison studies. For these studies, blind samples containing specific amounts of contaminants are distributed to the participating laboratories. The laboratories analyze the samples and submit their analytical results to study providers for comparison and evaluation. The results of the comparisons and evaluations are provided to the QA task leader.

Additional QC data may be generated by sending split or collocated samples to intercomparison program analytical laboratories, as well as to other laboratories (i.e., WDOH), or challenging the laboratory with spiked (blind) reference samples. Reference materials for spiked samples are obtained from the National Institute of Standards and Technology, DOE, EPA, or other sources that have proven reliability and accountability. Criteria used for judging contract laboratory performance on QC samples are derived from appropriate references (EPA 600/4-81/004; EML-608).

4.15.3 Analytical Accuracy and Precision Criteria

Precision and accuracy requirements are identified in Table 4-3.

4.16 RECORDS MANAGEMENT AND REPORTING

This section identifies record keeping and reporting requirements for environmental surveillance activities.

4.16.1 Record Keeping

The environmental surveillance record keeping requirements are implemented by the project-specific QA plan, which conforms to the requirements of DOE O 414.1D and 10 CFR 830.120, "Quality Assurance Requirements*.*"

DOE O 458.1, Chg 2 covers information regarding records and retention of records associated with releases of radioactive materials to the environment and the impact on the public.

4.16.1.1 Reporting. Reporting requirements associated with the potential radiological exposure of members of the public are in DOE O 458.1, Chg 2. The reporting requirements applicable to environmental surveillance are contained in the following DOE Orders:

- DOE O 231.1B
  - Assures timely collection, reporting, analysis, and dissemination of environmental information.
  - Requires the preparation of the Hanford Annual Site Environmental Report and requires its submission to DOE-HQ and the public by October 1 of the following year.
  - Requires that surveillance results be formally reported through the Hanford Annual Site Environmental Report. The distribution of the report is reviewed each year to ensure that potentially affected federal, state, and local governments and agencies; Indian Nations; environmental interest groups; and businesses are notified about the environmental status of the Hanford Site and surroundings.
  - Requires the reporting of unusual, off normal, or emergency occurrences that occur on the Hanford Site.
- DOE O 225.1A, *Accident Investigations*
  - Defines accident investigation reporting requirements pertaining to release of hazardous substances, materials, waste, or radionuclides.
- DOE O 458.1, Chg 2
  - Requires reporting when requirements of this order will not be or have not been met.
  - Requires reporting actual or potential exposures of the public that could result in either: 1) a dose from DOE sources exceeding 10 millirem EDE in a year, exceeding any limit or failing to meet any other requirement specified, or any other legal or applicable limits; or 2) a combined dose equal to or greater than 100 millirem EDE in a year from DOE and other man-made sources.

Unusual results or trends in surveillance data that occur between issuances of the Hanford Annual Site Environmental Report are reported to the DOE and the appropriate contractor. Dose-based reporting limits have been established based on environmental concentrations that would lead to an offsite public dose of either 1 or 10 millirem/year, depending on the media and assuming that the condition persisted for an entire year. Dose-based reporting limits used by the Environmental Surveillance Program are shown in Table 4-1.

Table 4-1. Surface Environmental Surveillance Project Dose-Based Reporting Limits [a, b, c]

	Tritium	Carbon-14	Cobalt-60	Strontium-90	Technetium-99	Iodine-129	Cesium-137	Europium-152	Europium-154	Europium-155	Uranium-234	Uranium-235	Uranium-238	Plutonium-238	Plutonium-239/240	Americium-241
Air (pCi/m^3)	2.6E+03	8.2E+01	1.5E+00	2.9E-01	3.6E+00	4.9E-01	1.2E+00	1.1E+00	8.9E-01	6.9E+00	5.0E-03	5.6E-03	5.9E-03	4.3E-04	3.9E-04	4.9E-04
Air (pCi/m^3)	1.5E+02	1.0E+00	1.7E-03	1.9E-03	1.4E-02	9.1E-04	1.9E-03	2.0E-03	2.3E-03	5.9E-02	7.7E-04	7.1E-04	8.3E-04	2.1E-04	2.0E-04	1.9E-04
River Water (pCi/L)	5.9E+03	4.3E+02	7.3E+01	8.1E+00	3.9E+02	2.3E+00	1.9E+01	1.8E+02	1.2E+02	7.8E+02	5.1E+00	5.3E+00	5.1E+00	1.1E+00	1.0E+00	1.2E+00
Milk (pCi/L)	1.7E+04	1.3E+03	2.2E+02	2.4E+01	1.1E+03	6.7E+00	5.6E+01	5.2E+02	3.7E+02	2.3E+03	1.5E+01	1.5E+01	1.5E+01	3.2E+00	2.9E+00	3.7E+00
Leafy Vegetables (pCi/g fresh wt)	3.8E+02	2.7E+01	4.7E+00	5.2E-01	2.5E+01	1.4E-01	1.2E+00	1.1E+01	7.9E+00	5.0E+01	3.2E-01	3.4E-01	3.3E-01	6.9E-02	6.4E-02	7.9E-02
Other Vegetables (pCi/g fresh wt)	4.2E+01	3.0E+00	5.1E-01	5.7E-02	2.7E+00	1.6E-02	1.3E-01	1.2E+00	8.7E-01	5.4E+00	3.6E-02	3.7E-02	3.6E-02	7.6E-03	7.0E-03	8.7E-03
Fruits (pCi/g fresh wt)	5.9E+01	1.8E+00	7.2E-01	8.0E-02	3.8E+00	2.2E-02	1.9E-01	7.3E-01	5.1E-01	3.2E+00	5.0E-02	5.2E-02	5.1E-02	1.1E-02	9.8E-03	1.2E-02
Wildlife Meat (pCi/g fresh wt)	6.9E+01	5.0E+00	8.5E-01	9.5E-02	4.5E+00	2.6E-02	2.2E-01	2.1E+00	1.5E+00	9.1E+00	5.9E-02	6.1E-02	6.0E-02	1.3E-02	1.2E-02	1.5E-02
Livestock Meat (pCi/g fresh wt)	5.4E+01	3.9E+00	6.6E-01	7.3E-02	3.5E+00	2.0E-02	1.7E-01	1.6E+00	1.1E+00	7.0E+00	4.6E-02	4.8E-02	4.7E-02	9.8E-03	9.0E-03	1.1E-02
Soil (pCi/g)	1.8E+05	1.2E+04	1.1E-01	5.5E+01	6.4E+03	4.6E+01	5.1E-01	2.5E-01	2.3E-01	9.5E+00	1.5E+02	2.3E+00	1.1E+01	3.3E+01	3.1E+01	2.0E+01
Vegetation and alfalfa (pCi/g fesh wt)	3.2E+01	1.9E+00	2.0E+00	2.2E-01	2.1E+01	1.2E-02	1.3E-01	1.9E+02	1.3E+02	8.3E+02	4.5E-01	4.7E-01	4.6E-01	5.8E+01	5.3E+01	3.3E+01
Sediment (pCi/g)	2.1E+06	1.5E+05	1.5E+01	2.3E+03	1.3E+05	7.8E+02	7.1E+01	3.5E+01	3.2E+01	1.3E+03	1.8E+03	2.8E+02	8.6E+02	3.9E+02	3.6E+02	4.2E+02
Fish (pCi/g fresh wt)	1.1E+02	7.6E+00	1.3E+00	1.4E-01	6.9E+00	4.0E-02	3.4E-01	3.2E+00	2.2E+00	1.4E+01	9.0E-02	9.4E-02	9.2E-02	1.9E-02	1.8E-02	2.2E-02
Seep Water (pCi/L)	1.9E+06	6.2E+04	7.2E+03	1.1E+03	4.4E+04	3.3E+02	3.0E+03	2.3E+04	1.5E+04	8.7E+04	6.8E+02	7.2E+02	7.5E+02	1.5E+02	1.4E+02	1.7E+02

[a] Concentrations are based on a 1 mrem/yr dose threshold, except where noted.
[b] Food ingestion pathways use annual intake rates; 100% of each food is assumed to originate in the impacted area.
[c] Internal dose coefficients published in ICRP (1991) and external dose coefficients for an infinite soil depth (EPA 1993) were employed.

Key Pathway-Specific Exposure Assumptions.

Air: Based on 16.3 m^3/day inhalation rate (EPA/600/R-09/052F, Table ES-1) for 350 d/yr.
Air: Based on existing DOH reporting threshold of: 10% of EPA 40 CFR 61, Appendix E Table 2 values for determining compliance with Subpart I.
River Water: Based on 95th percentile drinking water ingestion rate of 3.1 L/day (EPA/600/R-09/052F, Table ES-1) for 350 d/yr.
Milk: Based on 95th percentile ingestion rate for children ages 1 to <6 yr (approximately 1 L/day, EPA/600/R-09/052F).
Leafy Vegetable: Based on 95th percentile vegetable ingestion rate (5.9 g/kg-day for an 80-kg adult; EPA/600/R-09/052F, Table ES-1), assuming 10% of total vegetables are leafy.
Other Vegetable: Based on 95th percentile vegetable ingestion rate (5.9 g/kg-day for an 80-kg adult; EPA/600/R-09/052F, Table ES-1), assuming 90% of total vegetables are non-leafy.
Fruit: Based on 95th percentile ingestion rate (3.8 g/kg-day for an 80-kg adult; EPA/600/R-09/052F, Table ES-1).
Wildlife meat Meat: Based on 95th percentile game meat ingestion rate (3.2 g/kg-day for an 80-kg adult; EPA/600/R-09/052F, Table 13-41).
Livestock Meat: Based on 95th percentile total meat ingestion rate (4.1 g/kg-day for an 80-kg adult; EPA 2011, Table ES-1).
Soil: Based on inadvertent ingestion (100 mg/day; EPA/600/R-09/052F, Table ES-1) and external radiation (350 d/yr) exposure pathways.
Vegetation and alfalfa (assume use as fodder): Based on a transfer factor model of uptake by milk cows, and the 95th percentile milk ingestion rate described above.
Sediment: Based on inadvertent ingestion (100 mg/day; EPA/600/R-09/052F, Table ES-1) and external radiation (6 hr/day and 60 day/yr; Casual User recreational scenario, DOE/RL-2007-21 Rev 0, Volume II) exposure pathways.
Fish: Based on 95th percentile fin fish ingestion rate (2.1 g/kg-day for an 80-kg adult; EPA/600/R-09/052F, Table ES-1)
Seep Water: Based on published DOE Derived Concentrations Standards; Table 5 of DOE-STD-1196-2011. These standards use a 100 mrem/yr dose threshold.

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Table 4-2. Biota Concentration Guides for Water, Sediment, and Soil.

Radionuclide	Water (pCi/L) [a]	Limiting Organism	Sediment (pCi/g) [a]	Limiting Organism	Soil (pCi/g) [a]	Limiting Organism
Am-241	4.38E+02	Aquatic Animal	5.15E+03	Riparian Animal	3.89E+03	Terrestrial Animal
C-14	6.09E+02	Riparian Animal	5.90E+04	Riparian Animal	4.76E+03	Terrestrial Animal
Co-60	3.76E+03	Aquatic Animal	1.46E+03	Riparian Animal	6.92E+02	Terrestrial Animal
Cs-137	4.26E+01	Riparian Animal	3.12E+03	Riparian Animal	2.08E+01	Terrestrial Animal
Eu-152	2.55E+04	Aquatic Animal	3.04E+03	Riparian Animal	1.52E+03	Terrestrial Animal
Eu-155	2.64E+05	Aquatic Animal	3.16E+04	Riparian Animal	1.58E+04	Terrestrial Animal
H-3	2.65E+08	Riparian Animal	3.74E+05	Riparian Animal	1.74E+05	Terrestrial Animal
Pu-238	1.76E+02	Aquatic Animal	5.73E+03	Riparian Animal	5.27E+03	Terrestrial Animal
Pu-239 [d]	1.87E+02	Aquatic Animal	5.86E+03	Riparian Animal	6.11E+03	Terrestrial Animal
Sr-90	2.78E+02	Riparian Animal	5.82E+02	Riparian Animal	2.25E+01	Terrestrial Animal
Tc-99	6.67E+05	Riparian Animal	4.22E+04	Riparian Animal	4.49E+03	Terrestrial Animal
U-234	2.02E+02	Aquatic Animal	5.27E+03	Riparian Animal	5.13E+04	Terrestrial Animal
U-235	2.17E+02	Aquatic Animal	3.73E+03	Riparian Animal	2.77E+03	Terrestrial Animal
U-238	2.23E+02	Aquatic Animal	2.49E+03	Riparian Animal	1.58E+03	Terrestrial Animal

[a] Source: RESRAD-BIOTA computer code, Version 1.5 (DOE/EH-0676)

[b] BCGs for plutonium-239 are applied as surrogate comparison values for routine analysis of plutonium-239/240 in these media.

Table 4-3. Accuracy and Precision Requirements. 3 Pages

Analyte[a]	QC Element	Acceptance Criteria		Corrective Action
		Water	Soil	
General Chemical Parameters				
Alkalinity Hexavalent Chromium pH Total Residue Total Dissolved Solids Total Suspended Solids Total Organic Carbon	MB[b]	< MDL < 5% sample concentration		Flagged with "C"
	LCS	±25% RPD[c]	±30% RPD[c]	Data reviewed[d]
	DUP or MS/MSD	≤ 20% RPD[c]	≤ 30% RPD[c]	Data reviewed[d]
	MS[b]	75 – 125% recovery[c]	75 – 125% Recovery[c]	Flagged with "N"
Anions				
Anions by IC	MB	< MDL < 5% sample concentration		Flagged with "C"
	LCS	80 – 120% recovery[c]	70 – 130% recovery[c]	Data reviewed[d]
	DUP or MS/MSD	±25% RPD[c]	±30% RPD[c]	Data reviewed[d]
	MS	75 – 125% recovery[c]	75 – 125% recovery[c]	Flagged with "N"
Metals				
ICP Metals ICP/MS Metals Mercury	MB	< RDL < 5% sample concentration		Flagged with "C"
	LCS	80 – 120% recovery[c]	70 – 130% recovery[c]	Data reviewed[d]
	MS	75 – 125% recovery(c)	75 – 125% recovery[c]	Flagged with "N"
	MSD	75 – 125% recovery[c]	75 – 125% recovery[c]	Flagged with "N"
	DUP or MS/MSD	±25% RPD[c]	±30% RPD[c]	Data reviewed[d]
Volatile Organic Compounds				
Volatiles by GC/MS Total Petroleum Hydrocarbons by GC	MB	< MDL[f] < 5% sample concentration		Flagged with "B"
	LCS	Statistically derived[c]		Data reviewed[d]
	MS	%Recovery statistically derived[c]		Flagged with "T" if analyzed by GC/MS, otherwise "N" based on FEAD
	MSD	%Recovery statistically derived[c]		Flagged with "T" if analyzed by GC/MS, otherwise "N" based on FEAD
	DUP or MS/MSD	%RPD statistically derived[c]		Data reviewed[d]

Table 4-3. Accuracy and Precision Requirements. 3 Pages

Analyte[a]	QC Element	Acceptance Criteria		Corrective Action
		Water	Soil	
	SUR	Statistically derived[c]		Data reviewed[d]
Semivolatile Organic Compounds				
PCBs by GC Pesticides by GC Semivolatiles by GC/MS	MB	< MDL[f] < 5% sample concentration		Flagged with "B"
	LCS	Statistically derived[c]		Data reviewed[d]
	MS	%Recovery statistically derived[c]		Flagged with "T" if analyzed by GC/MS, otherwise "N" based on FEAD
	MSD	%Recovery statistically derived[c]		Flagged with "T" if analyzed by GC/MS, otherwise "N" based on FEAD
	DUP or MS/MSD	%RPD statistically derived[c]		Data reviewed[d]
	SUR	Statistically derived[c]		Data reviewed[d]
Radiochemical Parameters				
Gamma Scan Gross Alpha Gross Beta Iodine-129 Americium (isotopic) Carbon-14 Plutonium (Isotopic) Strontium-89/90 Technetium-99 Tritium Tritium (low level) Uranium (Isotopic) Uranium (total)	MB	<MDC or <5% sample concentration		Flagged with "B"
	LCS	70 – 130% recovery		Data reviewed[d]
	DUP[e]	±25 – 30% RPD[c]	± 30% RPD[c]	Data reviewed[d]
	MS[g]	60 – 140% recovery		Flagged with "N"
	Tracer (where applicable)	20 – 105% recovery		Data reviewed[d]
	Carrier (where applicable)	30 – 105% recovery		Data reviewed[d]

[a] Specific analytes and method for determination are defined in the SOW.
[b] Does not apply to pH, conductivity, total residue, total suspended solids, total dissolved solids or alkalinity.
[c] Determined by the laboratory based on historical data or statistically-derived control limits. Limits are reported with the data. Where specific acceptance criteria are listed, those acceptance criteria may be used in place of statistically derived acceptance criteria.
[d] After review, corrective actions are determined on a case-by-case basis.
[e] Applies to only in cases where both results are greater than 5 times the MDC.
[f] For common laboratory contaminants such as acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the acceptance criteria is < 5X MDL.
[g] Applies only to isotopic technetium-99, total uranium by ICP-MS, and tritium.

Data Flags:
B, C = Possible laboratory contamination (analyte was detected in the associated method blank).
N = result may be biased (associated matrix spike result was outside the acceptance limits).
T = VOA and Semi-VOA GC/MS Matrix Spike outlier.

Table 4-3. Accuracy and Precision Requirements. 3 Pages

Analyte[a]	QC Element	Acceptance Criteria		Corrective Action
		Water	Soil	

DUP = Laboratory matrix duplicate
FEAD = format for electronic analytical data
GC = Gas chromatography
GC/MS = Gas chromatography-mass spectrometry
IC = Ion Chromatography
ICP = Inductively coupled plasma
ICP/MS = Inductively coupled plasma-mass spectrometry
LCS = Laboratory control sample
MB = Method blank
MDL = Minimum detection limit
MS = Matrix spike
MSD = Matrix spike duplicate
PCBs = polychlorinated biphenyls
RDL = required detection limit
RPD = Relative percent difference
SUR = Surrogate

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5.0 GROUNDWATER MONITORING

5.1 INTRODUCTION

Groundwater monitoring is a critical element of the U.S. Department of Energy's (DOE) environmental monitoring program at the Hanford Site. In the past, disposal and leakage of hazardous and radioactive waste contaminated the vadose zone and unconfined aquifer. Groundwater from the unconfined aquifer enters the Columbia River, which is a potential pathway for transport of contaminants to human and ecological receptors.

Groundwater monitoring is conducted at the Hanford Site to: 1) monitor the potential impacts of specific waste sites, 2) monitor regional contaminant plumes, 3) assess the effectiveness of groundwater remediation activities, and 4) assure the public that Hanford Site contaminants are not present offsite. DOE prepares groundwater monitoring plans to meet the needs of each site or regulated unit. This section summarizes the overall groundwater monitoring program and cites individual monitoring plans.

5.2 REGULATORY DRIVERS

The regulatory framework governing groundwater monitoring at the Hanford Site consists of DOE Orders, federal and state regulations, and agreements.

5.2.1 Atomic Energy Act

The *Atomic Energy Act* (AEA), which is implemented through DOE Orders, establishes requirements for sitewide groundwater monitoring that detects, characterizes, and responds to releases of radionuclides. Groundwater monitoring is required sitewide to protect human health and the environment from potential risks associated with radioactive materials. Section 5.9 summarizes AEA groundwater monitoring.

DOE conducts groundwater monitoring on the Hanford Site to comply with AEA requirements identified in DOE O 435.1, *Radioactive Waste Management*; DOE O 436.1, *Departmental Sustainability*; and DOE O 458.1, *Radiation Protection of the Public and the Environment*.

DOE O 435.1 is relevant to the continued operation of low-level waste disposal facilities at the Hanford Site. This order requires a disposal authorization statement for continued operation of existing low-level waste disposal facilities. The following four facilities on the Hanford Site are authorized to transfer, receive, process, and dispose of low-level radioactive waste:

- 200-East Area Low-Level Burial Grounds
- 200-West Area Low-Level Burial Grounds
- Integrated Disposal Facility
- Environmental Restoration Disposal Facility.

DOE O 436.1 requires that all DOE organizations and all sites under their purview assure that the site Integrated Environment, Safety, and Health Management Systems include implementation of an

Environmental Management System that provides for 1) the systematic planning, integrated execution, and evaluation of programs for protecting public health and the environment; 2) pollution prevention; and 3) assuring site compliance with applicable environmental protection requirements. Monitoring is addressed via the requirement for an Environmental Management System (DOE O 436.1). The AEA monitoring requirements of DOE O 458.1 were established to characterize the offsite environment and calculate radiological doses to offsite individuals who may be affected by DOE site conditions. Monitoring is conducted for the duration of the hazard and is used as part of the basis for determining when it is acceptable to release or clear property.

5.2.2 Comprehensive Environmental Response, Compensation, and Liability Act

The *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) and the *Superfund Amendments and Reauthorization Act*, which are implemented through the U.S. Environmental Protection Agency (EPA) regulations in *National Oil and Hazardous Substances Pollution Contingency Plan* (40 CFR 300), establish groundwater monitoring requirements for inactive past-practice waste sites. Pursuant to these acts, three general areas of the Hanford Site (100, 200, and 300 Areas) are currently listed on the National Priorities List (40 CFR 300, Appendix B). Section 5.8 summarizes CERCLA groundwater monitoring.

5.2.3 Resource Conservation and Recovery Act

The *Resource Conservation and Recovery Act of 1976* (RCRA) establishes regulatory standards for the generation, transportation, storage, treatment, and disposal of hazardous waste that applies to active waste management facilities and facilities undergoing closure. Groundwater monitoring is required at certain RCRA-regulated facilities for detection, evaluation, and remediation of contamination from the facilities. As authorized by the EPA, the state of Washington implements RCRA through its dangerous waste regulations (WAC 173-303). Section 5.7 summarizes RCRA groundwater monitoring.

5.2.4 State Waste Discharge Permit Program and Minimum Functional Standards for Solid Waste Handling

Washington State's *Waste Discharge Permit Program* (WAC 173-216), which deals with permitted liquid discharges to the ground, and the *Solid Waste Handling Standards* (WAC 173-350) contain groundwater protection and monitoring requirements for landfills that do not dispose of dangerous waste. Section 5.7.3 summarizes groundwater monitoring under these WAC requirements.

5.2.5 Integration of Regulatory Requirements

The DOE, EPA, and Washington State Department of Ecology (Ecology) established the *Hanford Federal Facility Agreement and Consent Order* (also known as the Tri-Party Agreement [Ecology et al. 1989]) to coordinate the actions of various regulatory authorities and provide a strategy to achieve regulatory compliance and waste site cleanup. The agreement specifies that both active and inactive treatment, storage, or disposal (TSD) units that have received RCRA permits will be managed and closed under RCRA regulations, including groundwater monitoring requirements. Past-practice waste sites will be addressed under CERCLA or jointly under RCRA corrective action and CERCLA. Contaminated groundwater will be addressed under CERCLA. However, the agreement dictates that all CERCLA actions will meet RCRA corrective action standards. Under criteria established in the Tri-Party Agreement, a lead regulatory agency is designated for each operable unit to avoid duplication of effort.

5.3 GENERAL GROUNDWATER MONITORING INFORMATION

This section provides general information for groundwater monitoring regardless of the specific purpose or regulatory driver.

Many Hanford Site wells are sampled for multiple objectives and requirements (e.g., RCRA, CERCLA, and AEA*)*. The work is conducted to manage any overlap, eliminate redundant sampling, optimize the schedule, and meet the needs of each sampling objective.

5.3.1 Data Quality Objectives

To determine the type of groundwater data required, staff apply the EPA's data quality objectives (DQO) process as described in EPA/240/B-06/001, *Guidance on Systematic Planning Using the Data Quality Objectives Process*. The DQO process is a standard working tool to determine the type, quantity, and quality of data needed to reach defensible decisions or make credible estimates. The process is applied to individual RCRA TSD units or CERCLA groundwater operable units for a particular monitoring purpose (e.g., to determine if a waste facility is leaking or if a remedial action is effective). Results of unit-specific DQO assessments may be published or summarized in sampling and analysis plans or as separate documents for individual units.

The DQO process also was applied broadly to support the choice of sample collection methods, analytical protocols, and quality control (QC) processes. The process was used to define reporting limits, precision, accuracy, and completeness, which are described in a quality assurance (QA) plan for groundwater monitoring.

Limits for precision and accuracy for chemical analyses are based on criteria stipulated in the methods (e.g., SW-846). Precision and accuracy limits for radiochemical results are specified in laboratory contracts or equivalent documents. Completeness is defined as the percentage of data points judged to be valid. The completeness goal each quarter is 85%.

5.3.2 Construction and Maintenance of Wells

Since the mid-1980s, Hanford Site monitoring wells have been designed to meet state requirements (WAC 173-160). Wells are constructed to maintain the integrity of the monitoring well borehole and prevent contamination from the surface or other zones from reaching the aquifer. The well casing isolates the sampled interval of the well from the vadose zone and other non-sampled intervals of the aquifer. Screens are used to filter out sediment particles and enhance collection of representative groundwater samples from the aquifer. Most monitoring wells are constructed with stainless-steel casing and screens. In the 200 Areas, Ecology has approved the use of longer well screens than specified in WAC 173-160. In those areas, the water table is declining because waste water is no longer disposed to the ground, so long well screens (up to 10.7 m (35 ft) in length) increase the monitoring life of the well.

Most monitoring wells constructed prior to 1987 on the Hanford Site are 10, 15, or 20 cm (4, 6, or 8 in.) in diameter and are constructed with casing made of carbon steel; they may also have perforated casing instead of screens. These wells are used most extensively in sitewide monitoring of existing plumes for the objectives of the AEA and CERCLA.

Sampling points in the aquifer adjacent to the Columbia River on the Hanford Site provide information about water quality near the point of groundwater discharge. These sampling points are known as aquifer sampling tubes or aquifer tubes. Aquifer tubes are small diameter flexible tubes that have a screen on the lower end. They are installed by driving a temporary steel casing with a drive tip into the ground adjacent to the river. The drive tip on the end of the temporary casing is knocked out and a 0.36-cm (0.25-in.)-diameter flexible tube, with the screened end lowered first, is inserted into the casing. The temporary steel casing is then pulled out, leaving the tube in place. Water is withdrawn from the tube using a peristaltic pump. The head of the tubes are on dry ground when the Columbia River is at low to moderate levels. Most of the tubes become submerged when river stage is high, although some have been extended so they can be sampled at high river stage.

Maintenance of wells and aquifer tubes is conducted as needed if problems arise. Routine well maintenance may be scheduled to meet specific requirements.

5.3.3 Sampling and Analysis Protocol

This section summarizes protocols for equipment decontamination, water-level monitoring, sample collection, preservation, and analysis.

5.3.3.1 Equipment Decontamination. Most monitoring wells in use on the Hanford Site are equipped with dedicated sampling pumps. When temporary pumps, bailers, or other special devices are used, they are decontaminated between wells according to a documented procedure. Wherever possible, sampling sequence is from lower levels of contamination to the higher levels of contamination. Other non-dedicated equipment (e.g., water-level tapes and drilling equipment) is also decontaminated in accordance with documented procedures.

5.3.3.2 Water-Level Monitoring. Procedures for measuring water levels were developed in accordance with the techniques described in SGW-38815, *Water-Level Monitoring Plan for the Hanford Site Soil and Groundwater Remediation Project*. Water levels are measured primarily with laminated-steel electrical sounding tapes, although graduated-steel tapes are used occasionally.

The water level is measured before each well is sampled, unless that is impossible (e.g., no access for steel tape; used as a pumping well). Additional measurements are made as part of sitewide water table mapping and as required by individual monitoring plans (e.g., for RCRA sites or CERCLA operable units). Some wells are equipped with pressure transducers that provide high-frequency water level data, which are useful for determining hydraulic gradients in areas with variable conditions. The automated water level network is connected by a telemetry network to a central base station.

5.3.3.3 Sample Custody. Groundwater samplers maintain sample custody in accordance with existing protocols in DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD). Personnel follow chain-of-custody protocols throughout sample collection, transfer, analysis, and disposal to ensure sample integrity is maintained. A chain-of-custody record is initiated in the field at the time of sampling and accompanies each set of samples shipped to any laboratory.

Shipping requirements determine how sample containers are prepared for shipment. The chain-of-custody form indicates the analysis requested for each sample. Each time the responsibility for the custody of the sample changes, the new and previous custodians sign the record and note the date and time. The sampler makes a copy of the signed record before sample shipment.

5.3.3.4 Sample Collection and Shipment. Groundwater monitoring follows a QA plan that meets EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans*. The work follows documented procedures for sample collection, which are summarized in this section.

Project personnel schedule sampling events; initiate paperwork; and oversee sample collection, shipping, and analyses. Quality requirements for any work subcontracted meet HASQARD and are specified in statements of work or contracts.

Water samples are collected according to the current revision of applicable operating methods. Field personnel measure water levels in each well before sampling and then purge stagnant water from the well. Samples are collected after pH, temperature, specific conductance, and turbidity have stabilized. Stabilization is considered after two consecutive measurements are within the following:

- 0.2 units for pH
- 0.2 °C for temperature
- 10% for specific conductance
- less than 5 nephelometric turbidity units).

If a well is purged to dryness, it is allowed to recover and then sampled. Preservatives are required for certain types of samples. Samples may require filtering in the field, as noted on the chain-of-custody forms.

Deviations from standard sampling procedures are allowed when circumstances warrant. For instance, a number of wells are subject to high turbidity; therefore, the less than 5 nephelometric turbidity units requirement cannot be met. The samples from those wells may be filtered per direction from scientific staff. Deviations from standard sampling procedures are documented on field records.

Sample packaging, transfer, and shipping are performed in accordance with applicable transportation regulations and DOE requirements.

5.3.4 Analytical Protocols

Instruments for field measurements (e.g., pH, specific conductance, temperature, and turbidity) are calibrated using standard solutions before use and are operated according to the manufacturer's instructions. Each instrument is assigned a unique number that is tracked on field and calibration documentation.

Groundwater monitoring plans for individual units identify analytical methods as do contracts with the laboratories. The standards for analytical methods are found in SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*; EPA/600/R-93/100, *Methods for the Determination of Inorganic Substances in Environmental Samples*; or other methods, as approved. Radiological parameters are analyzed by EPA or laboratory-specific methods.

5.4 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and QC requirements are documented in site-specific monitoring plans. These plans include Quality Assurance Project Plans that establish the quality requirements for environmental data collection (e.g., planning, implementation, and assessment of sampling tasks; field measurements; laboratory analysis; and data review). Requirements and controls are based on the QA elements found in the following documents:

- EPA/240/B-01/003, EPA Requirements for Quality Assurance Project Plans
- HASQARD
- Sections 6.5 and 7.8 of the Tri-Party Agreement (Ecology et al. 1989)
- Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Ecology 2004)
- EPA 240/R-02/009, Guidance for Quality Assurance Project Plans.

5.5 DATA REVIEW AND USABILITY

This section addresses the QA activities that occur after data collection. Implementation of these activities determines whether the data conform to the specified criteria, thus satisfying the project objectives. Data quality review is conducted to evaluate the precision, accuracy, representativeness, completeness, comparability, and sensitivity of the chemical and radiological measurements. An overview of this process is presented in the following subsections.

5.5.1 Data Review and Verification

Project staff perform data review and verification to confirm that sampling and chain-of-custody documentation are complete. This review includes linking sample numbers to specific sampling locations; reviewing sample collection dates and sample preparation and analysis dates to assess whether holding times, if any, have been met; and reviewing QC data to determine whether analyses have met the data quality requirements.

The criteria for verification include, but are not limited to, review for contractual compliance (samples were analyzed as requested), use of the correct analytical method, transcription errors, correct application of dilution factors, appropriate reporting of dry weight versus wet weight, and correct application of conversion factors. Any errors are documented and resolved.

Technical staff review data to determine if groundwater quality is changing. Data reviews may result in submittal of a request for data review on questionable data. The laboratory may be asked to check calculations or reanalyze the sample, or the well may be resampled. Results of the formal data review process are used to ensure that data of known quality are entered in the Hanford Environmental Information System (HEIS) database.

5.5.2 Data Validation

Data validation is a formal data review process typically conducted by an independent third party. These activities are performed at the discretion of the operable unit project manager. If performed, data validation activities are based on EPA functional guidelines and reported independently. Any additional data qualifiers identified through the validation process will be appropriately assigned to data in HEIS.

5.5.3 Reconciliation with User Requirements

The data quality assessment process compares completed field sampling activities to those proposed in corresponding sampling documents and provides an evaluation of the resulting data. The purpose of the assessment is to determine whether quantitative data are of the correct type and are of adequate quality and quantity to meet data quality objectives. For routine groundwater monitoring, the data quality assessment is captured in the QC summary associated with the annual groundwater report, which evaluates field and lab QC and the usability of data. Further data quality assessments are performed at the discretion of project managers.

5.6 DATA MANAGEMENT AND REPORTING

This section describes how analytical and field data are loaded into the HEIS database and how data are reported.

5.6.1 Loading Data into the Database

The contract laboratories report analytical results electronically and on hard copy. The electronic results are loaded directly into the HEIS database. Hard copy data reports and field records are considered to be the record copies and are stored in project files.

Field data such as specific conductance, pH, temperature, turbidity, and depth-to-water are recorded on field records. Project staff enter these into the HEIS database manually through computer data entry screens and verify each value against the hard copy.

5.6.2 Interpretation

After data is validated and verified, the acceptable data is used to interpret groundwater conditions at the Hanford Site. Interpretive tools include the following:

- **Hydrographs** – Plots water levels versus time at monitoring locations to determine decreases, increases, seasonal, or manmade fluctuations in groundwater levels.

- **Plume maps** – Map distributions of chemical or radiological constituents in the aquifer to determine extent of contamination.

- **Changes in plume distribution over time** – Aid in determining movement of plumes and direction of flow.

- **Water table maps** – Use water table elevations from multiple wells to construct contour maps to estimate groundwater flow directions and velocity. Groundwater flow is generally assumed to be perpendicular to lines of equal potential.

- **Trend plots** – Graph concentrations of chemical or radiological constituents versus time to determine increases, decreases, and fluctuations. May be used in tandem with hydrographs and/or water table maps to determine if concentrations relate to changes in water level or groundwater flow directions.

- **Contaminant ratios** – Illustrates relative abundances, which can sometimes be used to distinguish between different sources of contamination.

5.6.3 Reporting

Reports on results of groundwater monitoring are issued annually (e.g., DOE/RL-2016-67). These reports include pertinent information for CERCLA, RCRA, Washington Administrative Code, and AEA groundwater monitoring and electronic files of groundwater data retrieved from the HEIS database. Chemistry and water level data are also available in the HEIS database shortly after they are received. Results of RCRA monitoring are informally reported to Ecology quarterly and semiannually. Unusual results for CERCLA operable units are summarized in letter reports or other informal reports (e.g., reports via e-mail or presented at unit manager's meetings). Unusual results for AEA groundwater monitoring are summarized in informal reports.

5.7 GROUNDWATER MONITORING AT REGULATED UNITS

There are 25 RCRA sites (i.e., TSD units or waste management areas) that require groundwater monitoring on the Hanford Site (Table 5-1 and Figure 5-1). These sites are monitored to: 1) comply with state and federal requirements, 2) assess potential impact on groundwater quality, and 3) provide an early warning of unexpected occurrences and trends. In the *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste* (WA7890008967), Ecology and the EPA designated the Hanford Site as a single RCRA facility that originally contained approximately 70 TSD units. Some of the units have been closed, thereby reducing the number. Some TSD units do not require groundwater monitoring. Single-shell tanks and low-level burial grounds are divided into multiple waste management areas. The 1324-N Surface Impoundment and 1324-NA Percolation Pond are combined into a single waste management area for groundwater monitoring.

The Tri-Party Agreement (Ecology et al. 1989) recognized that all of the units cannot be permitted simultaneously and set up a schedule to submit unit-specific RCRA Part B dangerous waste permit applications and closure plans to Ecology and the EPA. As of 2017, 25 of the RCRA sites are monitored under interim status requirements (WAC 173-303-400 and by reference 40 CFR 265) until they are incorporated into the permit as scheduled in the Tri-Party Agreement. The other sites are already incorporated into the permit and are monitored under final status requirements (WAC 173-303-645). Table 5-1 lists the RCRA sites and status of monitoring as of 2017 and provides references for site-specific RCRA groundwater monitoring plans.

Table 5-1. RCRA Interim and Final Status Groundwater Monitoring (2017). 3 Pages

TSD Unit or Waste Management Area	Monitoring Phase	Year TSD Incorporated into *Permit* (closed or operating)	Monitoring Plan and Comments
1301-N Liquid Waste Disposal Facility	Final Status Detection	1999 (closed)	*Hanford Facility Hazardous Waste Treatment, Storage, and Disposal Facility Permit*, Part V, Closure Unit 2, Chapter 3.0 (WA7890008967).
1325-N Liquid Waste Disposal Facility	Final Status Detection	1999 (closed)	*Hanford Facility Hazardous Waste Treatment, Storage, and Disposal Facility Permit*, Part V, Closure Unit 1, Chapter 3.0 (WA7890008967).

Table 5-1. RCRA Interim and Final Status Groundwater Monitoring (2017). 3 Pages

TSD Unit or Waste Management Area	Monitoring Phase	Year TSD Incorporated into *Permit* (closed or operating)	Monitoring Plan and Comments
1324-N Surface Impoundment and 1324-NA Percolation Pond	Final Status Detection	1999 (closed)	*Hanford Facility Hazardous Waste Treatment, Storage, and Disposal Facility Permit,* Part V, Closure Unit 3, Chapter 3.0, (WA7890008967).
183-H Solar Evaporation Basins	Final Status Corrective Action	1994 (closed)	*Hanford Facility Hazardous Waste Treatment, Storage, and Disposal Facility Permit*, Part VI, Postclosure Unit 2, Chapter 3.0 (WA7890008967).
216-A-29 Ditch	Interim Status Detection	Submitted 2006 (clean closure)[a]	*216-A-29 Ditch Closure Plan (D-2-3),* DOE/RL-2008-53, Rev. 1,
216-A-36B Crib	Interim Status Detection	TBD (closing)	*Interim Status Groundwater Monitoring Plan for the 216-A-36B PUREX Plant Crib,* DOE/RL-2010-93, Rev. 2.
216-A-37-1 Crib	Interim Status Detection	TBD (closing)	*Interim Status Groundwater Monitoring Plan for the 216-A-37-1 PUREX Plant Crib,* DOE/RL-2010-92, Rev. 3
216-B-3 Pond	Interim Status Detection	Submitted 2003 (clean closure)[a]	*Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond,* DOE/RL-2008-59, Rev. 2.
216-B-63 Trench	Interim Status Detection	Submitted 2006 (clean closure)[a]	*Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench,* DOE/RL-2008-60, Rev. 1.
216-S-10 Pond and Ditch	Interim Status Detection	Submitted 2006 (closing)	*Interim Status Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch,* DOE/RL-2008-61, Rev. 0
316-5 Process Trenches	Final Status Corrective Action	1996 (closing)	*Hanford Facility Hazardous Waste Treatment, Storage, and Disposal Facility Permit,* Part VI, Postclosure Unit 1, Chapter 3.0 (WA7890008967).
Integrated Disposal Facility	Final Status Detection	2006 (operating)	*Hanford Facility Hazardous Waste Treatment, Storage, and Disposal Facility Permit*, Operating Unit 11, Chapter 5.0 (WA7890008967).
Liquid Effluent Retention Facility	Final Status Detection	1998 (operating)	*Hanford Facility Hazardous Waste Treatment, Storage, and Disposal Facility Permit*, Operating Unit 3, Addendum D (WA7890008967)
Low-Level WMA 1	Interim Status Detection	Submitted 2002 (operating)	*Interim Status Groundwater Monitoring Plan for the LLBG WMA-1,* DOE/RL-2009-75, Rev. 0
Low-Level WMA 2	Interim Status Detection	Submitted 2002 (operating)	*Interim Status Groundwater Monitoring Plan for the LLBG WMA-2,* DOE/RL-2009-76, Rev. 0
Low-Level WMA 3	Interim Status Detection	Submitted 2002 (operating)	*Interim Status Groundwater Monitoring Plan for the LLBG WMA-3,* DOE/RL-2009-68, Rev. 2

Table 5-1. RCRA Interim and Final Status Groundwater Monitoring (2017). 3 Pages

TSD Unit or Waste Management Area	Monitoring Phase	Year TSD Incorporated into *Permit* (closed or operating)	Monitoring Plan and Comments
Low-Level WMA 4	Interim Status Detection	Submitted 2002 (operating)	*Interim Status Groundwater Monitoring Plan for the LLBG WMA-4,* DOE/RL-2009-69, Rev. 2
Nonradioactive Dangerous Waste Landfill	Interim Status Detection	TBD (closing)	*Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill,* PNNL-12227
Single-Shell Tanks WMA A-AX	Interim Status Assessment	TBD (closing)	*RCRA Assessment Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site,* PNNL-15315
Single-Shell Tanks WMA B-BX-BY	Interim Status Assessment	TBD (closing)	*Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area B-BX-BY,* DOE/RL-2012-53, Rev. 0
Single-Shell Tanks WMA C	Interim Status Assessment	TBD (closing)	*Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area* C, DOE/RL-2009-77, Rev. 0
Single-Shell Tanks WMA S-SX	Interim Status Assessment	TBD (closing)	*Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area* S-SX, DOE/RL-2009-73, Rev. 0
Single-Shell Tanks WMA T	Interim Status Assessment	TBD (closing)	Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area T, DOE/RL-2009-66, Rev. 1
Single-Shell Tanks WMA TX-TY	Interim Status Assessment	TBD (closing)	*Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area* TX-TY, DOE/RL-2009-67, Rev. 1
Single-Shell Tanks WMA U	Interim Status Assessment	TBD (closing)	*Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area* U, DOE/RL-2009-74, Rev. 1

[a] If clean closure is approved, no post-closure groundwater monitoring is required.

Ecology = Washington State Department of Ecology.
TBD = to be determined.
TSD = treatment, storage, and disposal (unit).
WMA = waste management area.

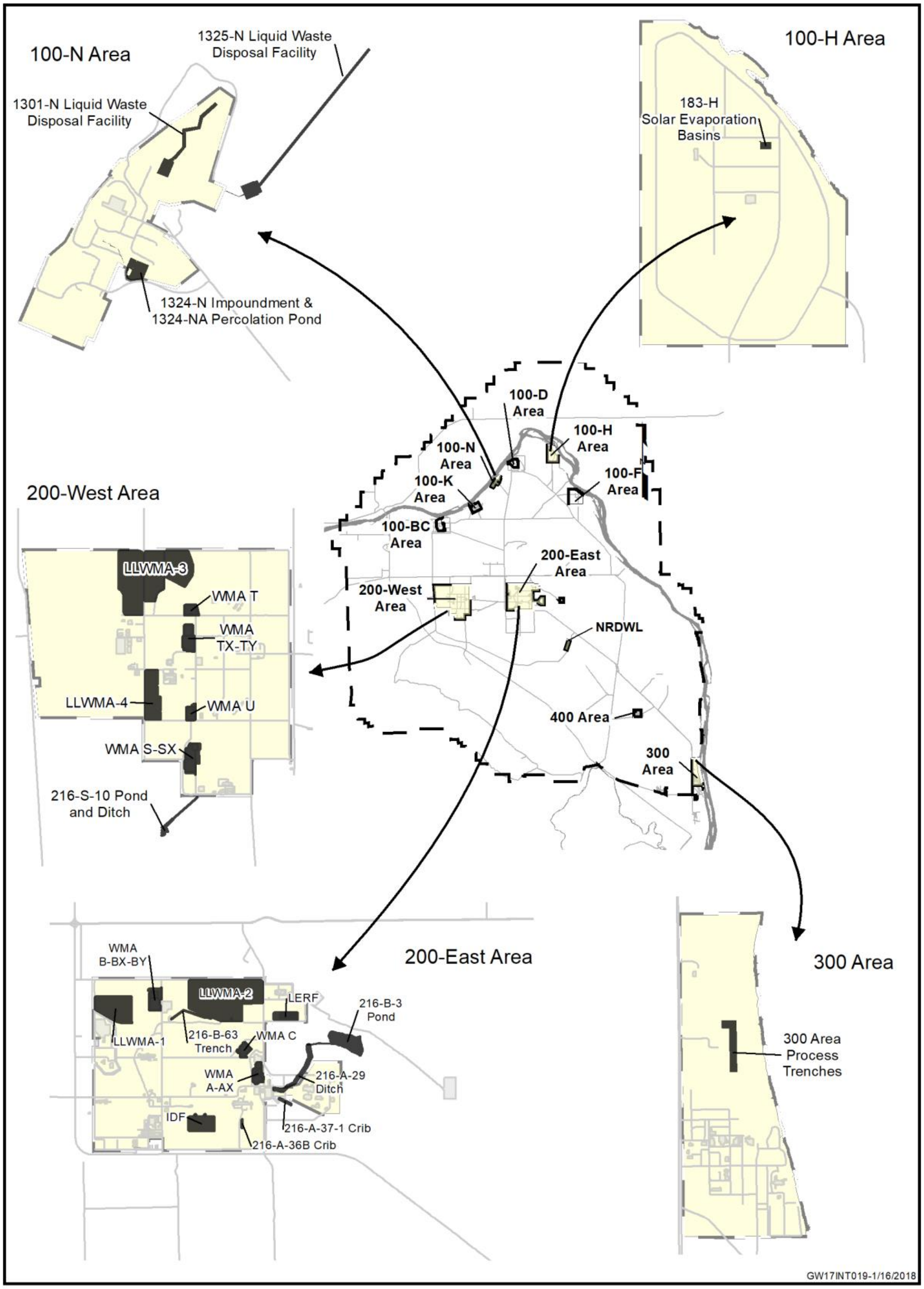

Figure 5-1. Hanford Site Regulated Units Requiring Groundwater Monitoring

5.7.1 RCRA Interim Status

For RCRA sites under interim status, data from quarterly samples collected the first year are evaluated statistically to establish initial background groundwater quality. After the first year, sampling and analysis are conducted annually, at a minimum, for the parameters related to groundwater quality and semiannually for the indicator parameters related to groundwater contamination (i.e., pH, specific conductance, total organic carbon, and total organic halides). Statistical comparison values are recalculated, as needed, when the well network, flow direction, or baseline (i.e., background concentration) changes.

If indicator parameters show a confirmed statistically significant increase (or decrease for pH) over background levels, DOE notifies Ecology and develops a groundwater quality assessment monitoring plan. The objective of assessment monitoring is to determine if dangerous waste or dangerous waste constituents from the regulated unit have entered the groundwater. If so, the objective is to determine the concentration, rate, and extent of migration of the constituents in the groundwater. Monitoring must continue during the active life of the facility and the post-closure care period unless the unit is clean closed, by which all hazardous wastes and constituents have been removed.

5.7.2 RCRA Final Status

For final status RCRA units, there are three stages of groundwater monitoring and follow-up activities: detection, compliance, and corrective action (WAC 173-303-645). Two additional types of monitoring programs (integrated and alternative) are allowed at the Hanford Site under special circumstances. The monitoring requirements are included in attachments to the *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Permit* (Hanford Facility Dangerous Waste Permit [WA789000967]) and, in most cases, in groundwater monitoring plans. Each plan specifies methods to collect and interpret groundwater monitoring data. The choice of an appropriate statistical method depends on the monitoring stage and the nature of the data.

The final status detection monitoring program is designed to determine whether a RCRA-regulated unit has adversely affected groundwater quality in the uppermost aquifer beneath the Hanford Site. This is accomplished by testing for statistically significant evidence of contamination at a downgradient compliance monitoring well relative to baseline levels. Depending on the appropriate statistical technique chosen, these baseline levels may be obtained from upgradient (background) wells or historical measurements from that same well. If a statistically significant increase (or pH decrease) over baseline conditions occurs in a downgradient compliance well, a compliance monitoring program might be required. The DOE must institute a compliance monitoring program if they cannot successfully demonstrate that a source other than the regulated unit has caused the contamination or that the increase resulted from an error in sampling, analysis, or evaluation.

In a compliance monitoring program, the monitoring objective is to determine whether groundwater protection standards have been exceeded. This is accomplished by routine monitoring (at least semi-annually) to compare the concentration of a constituent obtained from samples collected at the point of compliance to groundwater protection standards (e.g., drinking water standard, health-based standard, or any other standard that constitutes an applicable, relevant, and appropriate requirement). Monitoring must continue through the post-closure care period.

Maximum concentration limits in groundwater are identified for the dangerous constituents identified for the unit. Alternate concentration limits may be proposed after considering the observed concentrations of chemical constituents in the groundwater that might originate from the regulated unit in question. The area background, natural background, and other standards and requirements that are applicable, relevant, and appropriate are evaluated when proposing an alternate concentration limit.

If, during compliance-level monitoring, the referenced concentration limit(s) for a given groundwater parameter(s) is significantly exceeded, a corrective action program is developed and implemented to protect human health and the environment. Details for the corrective action program are specified in the unit-specific permit applications or closure plans. Additionally, a groundwater monitoring plan used to assess the effectiveness of the corrective action measures is submitted. That monitoring plan is similar in scope to the compliance-level groundwater monitoring program and includes all relevant information pertaining to the location and description of monitoring wells, monitoring network, well construction and development, sampling and analysis plans, statistical methods, and quality procedures.

In accordance with the Hanford Facility Dangerous Waste Permit, General Condition II.K.7 (WA789000967), RCRA-unit closures can be integrated with other cleanups, such as those required under CERCLA. An integrated monitoring program may be proposed when one or more of the following conditions arise:

- A compliance, corrective action, or alternative monitoring program is not appropriate
- An integrated monitoring program is more cost-effective
- An integrated monitoring program will allow alignment of remedial action objectives with RCRA closure.

When an integrated monitoring program is chosen for a RCRA site, monitoring requirements are determined on a case-by-case basis with Ecology. Because groundwater cleanup at RCRA units is typically deferred to the CERCLA operable unit cleanup, an integrated monitoring program might initially just monitor the existing groundwater conditions until the final cleanup begins.

When an alternative monitoring program is chosen for a RCRA site, monitoring requirements are determined on a case-by-case basis with Ecology. An alternative monitoring program may be established in accordance with WAC 173-303-610(1)(e) when Ecology determines that:

> *(i) A dangerous waste unit is situated among other solid waste management units or areas of concern, a release has occurred, and both the dangerous waste unit and one or more of the solid waste management units or areas of concern are likely to have contributed to the release; and*
>
> *(ii) It is not necessary to apply the requirements of this section (or the unit-specific requirements referenced in subsection (2)(b) of this section) because the alternative requirements will protect human health and the environment.*

For detection and compliance programs, all wells at each RCRA unit must be sampled at least semi-annually. The default sampling procedure requires that a sequence of at least four samples be taken over a time interval that ensures, to the greatest extent technically feasible, that an independent sample is obtained. Alternative sampling procedures may be approved by the regulator(s) (40 CFR 264.97; WAC 173-303-645). For integrated or alternative monitoring programs, sampling frequencies are determined on a case-by-case basis with Ecology. Specific sampling frequencies and statistical evaluation methods are provided in the unit-specific groundwater monitoring documentation in the *Hanford Facility Dangerous Waste Permit* (WA789000967).

5.7.3 Other Regulated Units

In addition to RCRA facilities, there are non-dangerous waste operational facilities on the Hanford Site that are regulated under Washington State regulations and Tri-Party Agreement requirements (Ecology et al. 1989); these facilities also require groundwater monitoring. The facilities include disposal facilities that receive treated effluents from the 200 and 600 Areas. In December 1991, an agreement was reached to include all miscellaneous waste streams and/or any new waste stream discharges to the ground under the waste discharge permit system defined in WAC 173-216. Groundwater monitoring is conducted at the State-Approved Land Disposal Site. Current operations and groundwater monitoring conducted at the Solid Waste Landfill are regulated by WAC 173-350-500. Current groundwater monitoring plans for these three facilities are referenced in Table 5-2.

Table 5-2. Other Regulated Units (2017).

Regulated Unit	Applicable Regulation	Monitoring Plan
State-Approved Land Disposal Site	WAC 173-216	*Groundwater Monitoring and Tritium-Tracking Plan for the 200 Area State-Approved Land Disposal Site* (RPP-RPT-59750; ST 4500 Permit)
Solid Waste Landfill	WAC 173-350	*Groundwater Monitoring Plan for the Solid Waste Landfill* (PNNL-13014)

5.8 GROUNDWATER MONITORING OF CERCLA OPERABLE UNITS

Groundwater monitoring is conducted to support the CERCLA objectives at inactive sites. For the purpose of conducting these activities, the waste sites (called past-practice sites) and associated contaminated groundwater have been grouped into operable units. The operable units, defined in the Tri-Party Agreement, are designated as either RCRA-CERCLA past-practice units or CERCLA past-practice units. RCRA-CERCLA past practice units are addressed by RCRA corrective action and CERCLA cleanup regardless of the date the waste was received or discharged. CERCLA past practice units are addressed for responsive action. This discussion uses the term CERCLA for simplicity. The DOE, EPA, and Ecology determine methods for remediating contaminated groundwater via formal documents called records of decision.

There are source (waste site) operable units and groundwater operable units. Groundwater operable units are linked to numerous source operable units, which may have contributed to regional plumes of contamination. Groundwater operable units are treated separately from the source operable units for remediation in the 100 and 200 Areas National Priorities List sites. In addition, the Hanford Site has been divided into groundwater interest areas based on the official operable units. The interest areas extend beyond the operable unit boundaries and facilitate monitoring by assuring that all parts of the Hanford Site are geographically within a groundwater interest area. Figure 5-2 illustrates the groundwater operable units and groundwater interest areas.

CERCLA groundwater operable units are monitored to assess the performance of groundwater remediation, characterize the nature and extent of contamination for decision making, or track plumes and trends (long-term monitoring). Table 5-3 shows a listing of the groundwater operable units, sampling and analysis plans, the current status of each relative to their record of decision, and the general category of groundwater monitoring.

Four of the groundwater operable units have records of decision for final action remedies (Table 5-3). Four operable units have records of decision for interim remedial action and are continuing with the CERCLA process toward final remediation. Three operable units did not require interim action and are proceeding with the CERCLA process toward final remediation.

The 1100-EM-1 Operable Unit (Richland North Area) has a record of decision calling for natural attenuation of volatile organic compounds. The operable unit has been removed from the National Priorities List but groundwater is monitored to determine the success of this approach. Since fiscal year 2001, volatile organic compound concentrations have remained below their target levels.

Based on groundwater characterization activities and interim pump-and-treat operations, the final remedy for the 200-ZP-1 Operable Unit (northern 200-West Area) was developed and formalized in the *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington* (EPA et al. 2008). The list of contaminants of concern includes major contaminant plumes exceeding drinking water standards (i.e., carbon tetrachloride, trichloroethene, iodine-129, technetium-99, nitrate, hexavalent chromium, total chromium, and tritium). The remedial action objectives will be achieved through four remedy components: 1) monitored natural attenuation, 2) institutional controls, 3) flow-path controls, and 4) pump-and-treat of the contaminated groundwater. The 200-West pump-and-treat began operations in 2012 to implement part of the selected remedy.

The 300-FF-5 Operable Unit (300 Area and satellite areas to the north) has the *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1* (EPA and DOE 2013) that calls for enhanced attenuation of uranium using sequestration by phosphate application and monitored natural attenuation of cis-1,2-dichloroethene, trichloroethene, tritium, and nitrate.

The 100-FR-3 Operable Unit is included in the *Record of Decision Hanford 100 Area Superfund Site 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* (EPA and DOE 2014). Monitored natural attenuation is the preferred alternative for groundwater remediation of hexavalent chromium, nitrate, strontium-90, and trichloroethene.

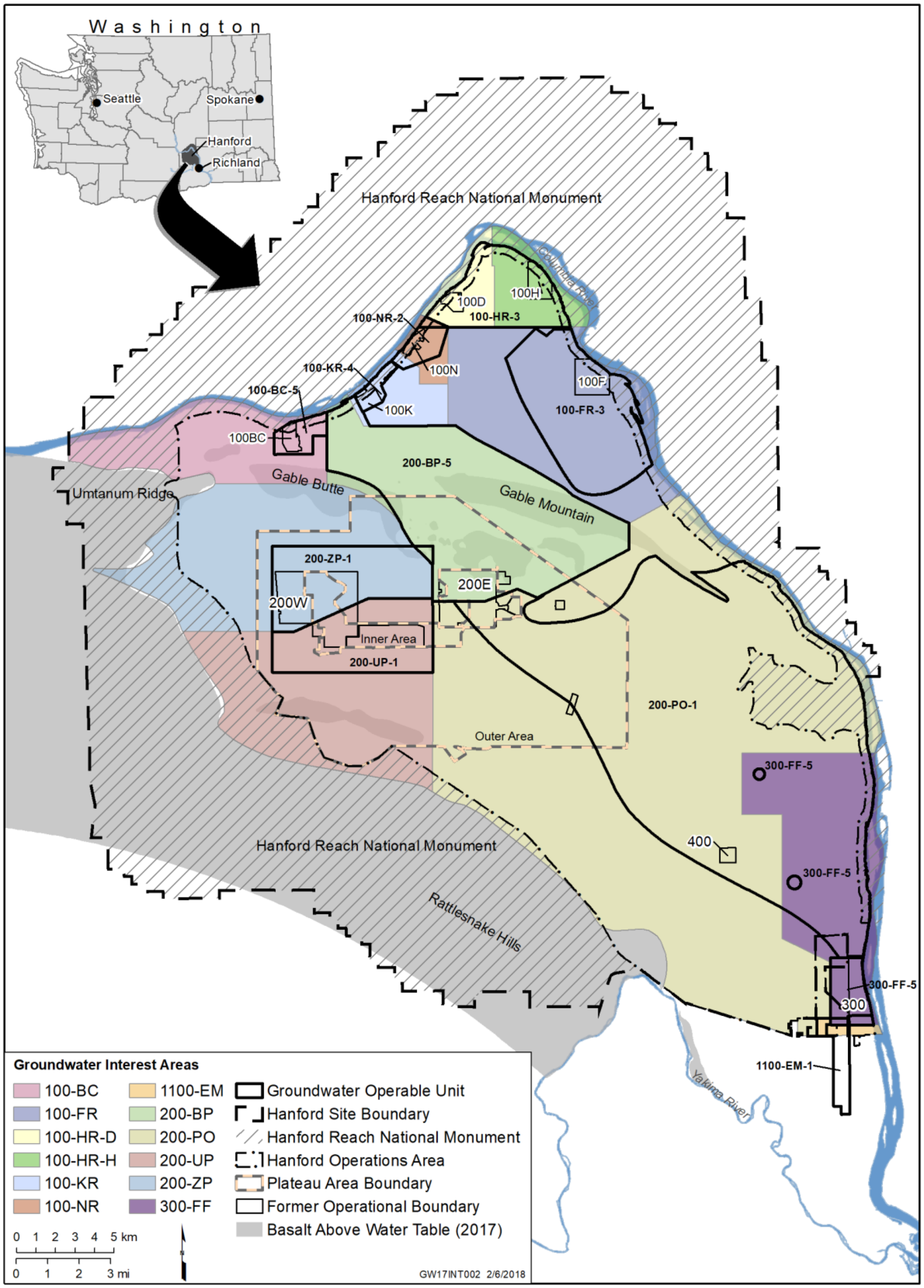

Figure 5-2. Locations of Groundwater Operable Units and Interest Areas on the Hanford Site.

Table 5-3. Groundwater Operable Unit Monitoring (2017).

Operable Unit Designation	SAP Reference	Monitoring Category
Operable Units with Records of Decision for Final Remedy		
1100-EM-1	No groundwater monitoring required (TPA-CN-679)	Monitored natural attenuation
100-FR-3	*Remedial Design Report/Remedial Action Work Plan Addendum for the 100-F/IU Groundwater,* DOE/RL-2014-44-ADD2	Monitored natural attenuation
200-ZP-1	*Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action,* DOE/RL-2009-115 *200 West Area Pump-and-Treat Facility Operations and Maintenance Plan*, DOE/RL-2009-124	Pump-and-treat and monitored natural attenuation
300-FF-5	*300-FF-5 Operable Unit Remedy Implementation Sampling and Analysis Plan*, DOE/RL-2014-42	Enhanced attenuation and monitored natural attenuation
Operable Units with Records of Decision for Interim Remedial Action		
100-HR-3	Sampling and Analysis Plan for 100-HR-3 Groundwater Operable Unit Monitoring, DOE/RL-2013-30	Interim action (pump-and-treat and ISRM)
100-KR-4	*Remedial Design/Remedial Action Work Plan for the 100-KR-4 Groundwater Operable Unit Interim Action,* DOE/RL-2013-33; *Sampling and Analysis Plan for KW Pump and Treat System Rebound Study*, DOE/RL-2016-42.	Interim action (pump-and-treat)
100-NR-2	*Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit*, DOE/RL-2001-27	Interim action
200-UP-1	Performance Monitoring Plan for the 200-UP-1 Groundwater Operable Unit Remedial Action, DOE/RL-2015-14	Interim action
Operable Units with No Records of Decision for Groundwater to Date		
100-BC-5	*100-BC-5 Operable Unit Sampling and Analysis Plan,* DOE/RL-2003-38	Long-term monitoring
200-BP-5	*Sampling and Analysis Plan for the 200-BP-5 Groundwater Operable Unit*, DOE/RL-2014-33	Long-term monitoring
200-PO-1	*Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit*, DOE/RL-2003-04	Long-term monitoring
Multiple	*Sampling and Analysis Plan for Aquifer Sampling Tubes,* DOE/RL-2000-59	Aquifer sampling tubes[a]

[a] DOE/RL-2000-59 includes aquifer sampling tubes in all of the operable units of the River Corridor. As operable unit SAPs are revised, they are incorporating aquifer tubes as appropriate. After all of the SAPs have been revised, DOE/RL-2000-59 will be retired.

ISRM = in situ redox (reduction-oxidation) manipulation
SAP =sampling analysis plan

At the following four operable units, groundwater monitoring is focused on evaluating the performance of groundwater interim remedial measures. This monitoring also provides information to support records of decision for final remediation.

100-HR-3 (100-D and 100-H Areas). Hexavalent chromium may pose a threat to aquatic organisms in the Columbia River. Interim records of decision require two interim remedial actions to address chromium contamination: pump-and-treat systems in the 100-D and 100-H Areas, and an in situ treatment method in the south 100-D Area. Chromium concentrations in compliance wells remained above interim cleanup targets. However, chromium plume areas generally continue to decline and the operable unit is making progress toward a final remedy. Ecology accepted DOE's Remedial Investigation/Feasibility Study (RI/FS) report in 2014 (DOE/RL-2010-95).

100-KR-4 (100-K Area). An interim record of decision requires a pump-and-treat system as an interim remedial action to address chromium contamination (EPA/ROD/R10-96/134). Chromium concentrations in compliance wells remained above cleanup targets. In 2016 all groundwater monitoring locations in the KW pump–and-treat systems were below the 20 µg/L interim remedial action groundwater target concentration for hexavalent chromium. This prompted a rebound study at the KW pump-and-treat system and the system was shut down on May 16, 2016. The study found that hexavalent chromium increased in wells between the 105-KW Reactor and 183.1 Headhouse. This suggests that several areas of secondary source material continue to cause elevated concentrations of hexavalent chromium. The KW pump–and-treat system was restarted on April 12, 2017. The draft Feasibility Study and Proposed Plan for a final remedy underwent review in 2012. DOE began to revise the draft feasibility study and proposed plan in 2017 to incorporate supplemental data characterization activities. It is likely that the RI/FS will recommend continued pump–and-treat operation. The RI/FS is projected to be issued in 2019 depending on funding.

100-NR-2 (100-N Area). Strontium-90 concentrations remain much higher than the drinking water standard in wells at the river shore. A permeable reactive barrier has been installed along the shoreline as an interim remedial action. The barrier reduces the amount of strontium-90 migrating from groundwater into the river. Overall strontium-90 concentrations have decreased since the start of apatite injections in 2008. The operable unit is making progress toward a final remedy and Draft A of the RI/FS report was submitted in 2013 for review and comment resolution continued through 2017. A Draft B RI/FS will be prepared and issued in 2019 for review.

200-UP-1 (200-West Area). A record of decision for interim action includes a pump-and-treat system near single-shell tanks and a planned groundwater extraction system to remediate uranium and technetium-99. In 2015, a performance monitoring plan was prepared to address the specific remedy described in DOE/RL-2015-14, Performance Monitoring Plan for the 200-UP-1 Groundwater Operable Unit Remedial Action. A groundwater extraction system was implemented in 2011 and began operating in 2015.

At 200-BP-5 (200-East Area), a groundwater contamination removal action has been implemented under an action memorandum that implements a pump-and-treat action to address areas of groundwater exhibiting contamination by uranium and technetium-99 that exceed drinking water standards by more than a factor of 10 times.

At the 100-BC-5, 200-BP-5, and 200-PO-1 Operable Units, there are no other imminent threats to human health and the environment; therefore, no interim remedial actions are required. Waste sites and plumes will continue to be monitored until there are records of decision after the remedial investigation/feasibility study (RI/FS) is process is completed.

5.9 SITEWIDE ENVIRONMENTAL SURVEILLANCE OF GROUNDWATER

Additional groundwater monitoring is required to meet requirements of the AEA, as implemented by DOE O 436.1, DOE O 458.1, and DOE O 435.1. In 2015, the *Hanford Atomic Energy Act Sitewide Groundwater Monitoring Plan* (DOE/RL-2015-56) was established to address these requirements and implement DOE Orders under one sampling and analysis plan (SAP). The primary objective is protection of human health and the environment from potential risks associated with radioactive materials. The AEA groundwater monitoring SAP (DOE/RL-2015-56) supersedes all radionuclide monitoring in RCRA groundwater monitoring plans and all radionuclide monitoring not associated with a performance assessment. Performance monitoring integrated into the AEA SAP includes the low-level burial grounds, the integrated disposal facility, environmental restoration disposal facility, state-approved land disposal site, and the 100-K Area fuel storage basins. Table 5-4 lists monitoring plans for AEA sites.

The sitewide AEA SAP divides the Hanford Site into regional groundwater interest areas that encompass CERCLA operable units (Figure 5-2). Where possible, wells associated with CERCLA monitoring are co-sampled with AEA monitoring and analytical requirements. Data from other groundwater monitoring programs (e.g., RCRA, CERCLA) are integrated with information from wells monitored under the AEA SAP.

Groundwater monitoring for the AEA SAP establishes baseline conditions, provides input for the Environmental Management System, verifies compliance with DOE Orders, confirms functional performance, identifies radionuclide source contributions and dispersal pathways, and calculates dose to human health and the environment. This monitoring provides input for decisions regarding release of lands after CERCLA and RCRA closures.

5.9.1 AEA Groundwater Monitoring

Approximately 828 wells have been selected under the AEA groundwater monitoring program and sampling will be spread out over a 3-year period. Sampling began in 2016 and varies quarterly to triennially, depending on specific monitoring objectives and concentration variability in the well. DOE O 458.1 and DOE-HDBK-1216-2015, *DOE Handbook Environmental Radiological Effluent Monitoring and Environmental Surveillance,* provide guidance for monitoring and frequency based on dose calculations and dose exposure to human health and the environment. Wells are monitored for radionuclides and selected nonradionuclide contaminants. Radionuclides to be monitored were selected based on review of historical groundwater monitoring results for the entire Hanford Site. Radioactive groundwater contaminants are measured against dose-based standards developed by DOE and specified in DOE O 458.1 and against the dose-based drinking water standards developed under 40 CFR 141, "National Primary Drinking Water Regulations." Additional groundwater monitoring requirements for radioactive waste disposal facilities are specified in DOE O 435.1 and integrated into the overall groundwater monitoring plan.

All groundwater wells monitored under the AEA SAP are evaluated against principal study questions and identified outcomes and actions. The principal study questions and actions are described in DOE/RL-2015-56, Appendix A, Table A-8. Each of these principal study questions are reviewed each year and used to assess the adequacy and continuing need for selected aspects of the monitoring program. Principal study questions are tested against null hypotheses and alternative hypotheses to determine applicability and further use of the principal study question as an assessment tool. There are quantitative and qualitative principal study questions. Quantitative evaluations are measured against metrics set forth in DOE orders and AEA for radiological doses to the public. These metrics are evaluated on an individual well basis. Qualitative evaluations are applied broadly to assess adequacy, performance, frequency, and extent of the overall groundwater monitoring program.

Quantitative evaluations determine continued monitoring needs and/or corrective actions at individual wells based upon the following six conditions:

- Will contaminated groundwater beneath the Hanford Site contribute to a total effective dose (TED) more than 100 mrem/yr to offsite human receptors or biota?
- Does groundwater contaminated by radionuclides beneath the Hanford Site cause drinking water sources to exceed drinking water standards?
- Are residual radionuclide contaminant sources contributing to Hanford groundwater contamination such that the TED to an offsite receptor could exceed 5 mrem/yr?
- Is radionuclide-contaminated groundwater beneath the Hanford Site migrating toward exposure points such that the 100 mrem/yr TED to offsite receptors may be exceeded?
- Does the confined aquifer exhibit evidence of intercommunication with radionuclide contamination from the overlying unconfined aquifer system?
- Does groundwater at locations receiving discharges of liquid effluent exhibit increases in radionuclide contaminant concentration or changes in geochemistry of hydrogeologic conditions that could result in increased total effective dose to an offsite receptor?

Qualitative evaluations determine continued monitoring needs, incentive to modify the monitoring network, assess monitoring network sufficiency for DOE orders and regulatory programs, and evaluate further need for institutional controls at monitoring locations. The actions and outcomes are determined by the following eight conditions:

- Is the current monitoring network adequate to identify the potential for exposures in excess of 5 mrem/yr TED to offsite receptors?
- Is the monitoring network adequate to identify current and future release from existing sources that could lead to TED in excess of 5 mrem/yr to offsite receptors?
- Is the monitoring network adequate to track the migration of radionuclide-contaminated groundwater toward exposure points for plumes with potential to exceed 5 mrem/yr TED to an offsite receptor?
- Is there an offsite or non-DOE contribution to groundwater contamination beneath the Hanford Site that could affect identification of DOE-related dose?
- Is the background contribution of radionuclides adequately defined?

- Is sampling for AEA integrated with other regulatory programs sufficient to meet the requirements under DOE O 458.1?
- Do groundwater conditions indicate the need for continued institutional controls?
- Is monitoring under AEA adequate to detect and/or identify new or unexpected groundwater contamination conditions or contributions from previously unidentified sources?

Wells selected for the AEA SAP address the following objectives, many of which are common with RCRA or CERCLA monitoring objectives.

Monitoring contaminant source areas. Source areas include regions with active waste disposal facilities, facilities that have generated or received waste in the past, and planned disposal facilities. These data are generally provided by facility-specific monitoring networks. Performance assessment monitoring of low-level burial grounds (DOE/RL-2000-72) and the integrated disposal facility (RPP-PLAN-26534) is performed to meet the requirements of DOE O 435.1. The groundwater monitoring components of these plans are designed specifically to address potential releases of radionuclides from the facilities to the underlying groundwater. Monitoring for non-radioactive hazardous chemicals at permitted treatment, storage, and disposal facilities is performed per RCRA monitoring requirements. Monitoring of the 100-K Area fuel storage basins is performed to evaluate past leakage from the K-Basins at the 100-KW and 100-KE Reactor Buildings (PNNL-14033). Until 2004, these basins contained irradiated fuel, principally from the 100-N Reactor, a small amount of miscellaneous fuel debris from other reactors, and radioactive sludge built up from years of operation. The basin water contains dissolved radionuclides and is a potential source of groundwater contamination. Presently, irradiated fuel from the fuel storage basins have been removed to long-term storage; the 100-KE fuel storage basin has been decommissioned and demolished. The 100-KW fuel storage basin remains in service and contains primarily fuel sludge residues.

Tracking known contaminant plumes. Wells located within known contaminant plumes are monitored to characterize and identify trends in the concentrations of radiological or chemical constituents. These wells are also monitored to quantify existing groundwater quality problems and to provide baselines of environmental conditions against which future changes can be assessed.

Protecting water supplies. Potable and industrial water-supply wells on and near the Hanford Site (including those at the Fast Flux Test Facility), wells used for production of dust control water, and wells used by the City of Richland potentially provide a route for human exposure to contaminants in groundwater. Monitoring wells near these water-supply wells and, in some cases, the water-supply wells themselves are monitored to identify the potential impact to water quality.

Protecting the Columbia River. Aquifer tubes near the Columbia River are monitored to assess the quality of groundwater as it leaves the unconfined aquifer (DOE/RL-2000-59). The Columbia River forms the discharge boundary for groundwater beneath the Hanford Site and provides a pathway for contaminants to leave the Hanford Site and potentially enter a drinking water supply. Fish and other wildlife could also be exposed to contaminants at the Columbia River, including the riparian zone. Data from this area help evaluate existing and potential offsite impacts of groundwater contaminants, establish a baseline of groundwater quality, and assess existing and emerging groundwater quality problems.

Determining vertical distribution of contaminants. Staff will sample wells completed in the basalt-confined aquifer and deep in the Ringold Formation sediment to assess the distribution of contamination and assess potential pathways for offsite migration of contaminants.

Assessing remediation performance. Staff monitor groundwater to assess the performance of groundwater remedial actions.

Monitoring offsite groundwater quality. Groundwater is used for domestic and agricultural purposes outside the Hanford Site. Offsite wells may be monitored periodically to ensure that contaminants from Hanford Site sources are not present and to maintain a baseline of information on offsite water quality.

Monitoring background areas. Wells in areas upgradient from Hanford Site operations are sampled to provide information on background groundwater quality. These data are needed to assess the impact of site operations on groundwater and identify contaminants contributed by offsite upgradient sources.

Monitoring for public assurance. To meet the objectives above, data are presented to the public in summary reports to communicate how the public's safety is being addressed. Some additional data may be collected to address public concerns in areas of particular visibility or interest. The data are communicated through the Annual Si Environmental Report, the summary for the annual Hanford Site groundwater monitoring report, and through presentations to groups (e.g., Hanford Advisory Board). The AEA monitoring well network is modified in response to changing hydraulic conditions, contaminant distributions, and remedial activities.

Table 5-4. Monitoring Plans for Atomic Energy Act (2017).

Site or Scope	Monitoring Plan
KE and KW Basins	*Hanford Atomic Energy Act Sitewide Groundwater Monitoring Plan* (DOE/RL-2015-56)
Environmental Restoration Disposal Facility	*Performance Assessment Monitoring Plan for the Environmental Restoration Disposal Facility, formerly WCH-579 Rev. 1* (CP-60152)
Integrated Disposal Facility	*Integrated Disposal Facility Operational Monitoring Plan to Meet DOE Order 435.1* (RPP-PLAN-26534)
Low-Level Burial Grounds	*Performance Assessment Monitoring Plan for the Hanford Site Low-Level Burial Grounds* (DOE/RL-2000-72)
State-Approved Land Disposal Site	*Groundwater Monitoring and Tritium-Tracking Plan for the 200 Area State-Approved Land Disposal Site (*PNNL-13121)
Columbia River shoreline, Richland North, Ringold confined aquifers, upper basalt-confined aquifers, radionuclides at waste management areas B-BX-BY, C, S-SX, T-TX-TY, and U, and waste water discharge areas	*Hanford Atomic Energy Act Sitewide Groundwater Monitoring Plan* (DOE/RL-2015-56)

5.9.2 Data Needs and Sampling Frequency

During the 3-year implementation cycle of the AEA monitoring network, baseline groundwater conditions will be determined and evaluated using measurement performance and acceptance criteria.

Initial sample monitoring and frequency is determined for each measurement location based on the following:

- Actual or potential exposure points exist
- Dynamic concentration conditions exist
- Potable or nonpotable water is extracted from groundwater for use
- Known and/or potential release points
- Locations of uncertain impact.

Long-term sampling frequency is determined by the applicable principal study question(s) for each location or individual well. Below are measurement frequency requirements for long-term monitoring.

At identified human health and the environment exposure points on the Hanford Site, measurement of radionuclide and nonradionuclide indicator chemicals in groundwater will be monitored on a frequency based on TED. If the TED is greater than the 100 mrem/year limit, monitoring will take place, as required, to ensure mitigation of contaminant. Monitoring will take place on a monthly frequency if the TED is between 50 and 100 mrem/yr. Annual sampling is required if TED is between 1 and 50 mrem/yr. Biannual or triennial sampling is established for TED greater than 0 but less than 1 mrem/yr.

Monitoring needs for measurement of radionuclides in groundwater that is a source of drinking water beneath the Hanford Site will take place at annual sampling intervals if conditions are less than one-half of the maximum contaminant level (MCL). If the conditions are greater than one-half of the MCL than sampling will be set at a semi-annual frequency.

Measurements of radionuclide concentrations in groundwater near source areas will be monitored on an annual basis if dynamic conditions are identified. Biannual to triennial sampling is recommended for more distant wells. If no contamination has been attributed to a specific source at a well then 6-year sampling is recommended.

Wells downgradient of source areas and across the Hanford Site will be monitored annually if dynamic conditions exist, biannually to triennially at plume boundaries, and every 6 years if plumes are stable for 6 years.

Confined aquifers and proximal contaminated wells will be monitored biannually if aquifer intercommunication is indicated and every 6 years if no aquifer intercommunication is indicated. Treated groundwater sent to pump–and-treat injection wells will be measured annually for minimum requirements. The minimum measurement requirement for treatment effluent is quarterly sampling.

Wells within the Hanford Site boundary that are, or may be, affected by offsite and/or non-DOE groundwater contamination sources will be monitored annually if dynamic conditions exist, biannually to triennially at plume bounding locations, and every 6 years if contaminant plumes are stable for 6 years.

Existing data, modeling results, principal study questions, and annual reports will be used to evaluate adequacy of the existing monitoring network. At groundwater data from background monitoring locations a single measurement set should be adequate unless events alter the background. For selected radionuclides and stable contaminants, concentrations in groundwater monitoring takes place every 6 years. Actions on the part of DOE is taken when thresholds are exceeded. Action levels are established by DOE O 458.1 for TED, 40 CFR 141 for drinking water standards, and DOE-STD-1196-2011, *Derived Concentration Technical Standard*, for individual contributing isotopes. Wells and locations will be regularly assessed for adequacy and applicability via data quality assessment and corrective actions. Unusable wells will not be included in decision-making processes for the monitoring network.

5.9.3 Decision Rules

Decision rules have been developed for each principal study question. These rules dictate necessary responses to the monitoring results based on possible positive and negative outcomes of comparison of measurements to action levels and changes in groundwater conditions. Responses may include assessment of monitoring needs based on groundwater contaminant changes, evaluation of adequacy of monitoring network, and incentive to identify mitigating contaminants. These rules ensure that the adequacy of the network is assessed and modified, as necessary, to maintain compliance with DOE O 458.1 and DOE O 436.1.

5.9.4 Data Reduction

Reduction of groundwater monitoring data will be implemented through systematic evaluation of data quality followed by evaluation of impacts to human health and the environment based on calculation of TED to an offsite receptor. This is assessed via applicable principal study question actions and decisional rules for each location and/or well. Sufficient data must be provided to support data reduction at wells to assert that members of the public are not or will not receive unacceptable TED from radionuclides. The processes for reducing data and sampling frequency are outlined below.

1. Data quality assessment
2. Calculation of TED
3. Calculation of cumulative drinking water dose
4. Calculation of cumulative alpha emitters
5. Calculation of uranium mass concentration
6. Spatial analysis of calculate TED and MCL contribution
7. Consideration of specific commitments made for monitoring as part of compliance with DOE O 435.1
8. Evaluation of effects of liquid effluents on groundwater.

5.9.5 Evaluation of Liquid Effluent Water Releases

DOE O 458.1 requires monitoring of liquid effluent to prevent unacceptable exposure of human health and the environment to radiation. There are three general categories of liquid effluent at the Hanford Site that must be monitored: 1) effluent from processes that remove all contaminants except tritium and operate under a discharge exemption, 2) effluent from processes that effectively treat/remove radioactive contaminants and operate under a CERCLA record of decision with effluent that meets specific discharge requirements, and 3) effluent from processes that do not treat/remove radioactive contaminants and operate under a CERCLA record of decision with effluent that does not have established discharge requirements for all constituents. These effluent streams include the Effluent Treatment Facility (ETF), 200-West pump-and-treat systems, and 100 Area pump-and-treat systems. For the ETF and 200-West pump-and-treat systems, effluent concentrations measured in routine monitoring are compared to discharge screening criteria identified by DOE. Information collected from routine operations at ETF and 200-West pump-and-treat systems provide sufficient information to determine AEA compliance. No further actions are required at the ETF and 200-West pump-and-treat systems as long as the effluent meets discharge specifications. More information regarding liquid effluent is discussed in Section 2.0 of this plan.

At the 100 Area, pump-and-treat systems groundwater extraction wells may be capturing elevated levels of radionuclides and transporting them to the treatment system with subsequent discharge to the aquifer via injection wells. In the 100-HR Operable Unit, quarterly monitoring of effluent is conducted for selected nuclides because of the relatively low radionuclide concentration and localized nature of contamination. The 100-KR Operable Unit exhibits elevated concentrations of radionuclide contamination that are routinely captured by extraction wells. This condition is evaluated by quarterly sampling and analysis of process effluent, and sampling and analysis of groundwater collected from wells downgradient and proximal to injection wells. A graded monitoring approach is used here to determine sampling frequency.

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6.0 METEOROLOGICAL MONITORING

6.1 INTRODUCTION

This section describes the plan for conducting meteorological and climatological monitoring on and around the Hanford Site. The monitoring plan is designed to meet the environmental protection objectives stated in DOE O 436.1, *Departmental Sustainability*, with DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental*, used as guidance.

The specific components of the Hanford Site meteorological monitoring program include the following:

- Collecting meteorological data for dose assessment calculations
- Collecting meteorological measurements
- Inspecting, maintaining, and calibrating equipment
- Summarizing and archiving data
- Quality assurance (QA).

The following sections discuss the composition of the Hanford Site meteorological monitoring program as it relates to DOE O 436.1 and DOE-HDBK-1216-2015.

6.2 METEOROLOGICAL AND CLIMATOLOGICAL SERVICES PROGRAM

The Mission Support Alliance (MSA) Meteorological and Climatological Services Program provides the Hanford Site U.S. Department of Energy field offices and contractors with meteorological and climatological support for emergency response, weather forecasting, climatological data, and related special requests through the operation of the Hanford Meteorology Station (HMS). The Program responds to Hanford Site needs through a program that includes the following:

- Extensive data acquisition through a sitewide meteorological monitoring network

- Site-specific forecasts using weather satellite imagery and National Weather Service products

- Standard hourly surface weather observations and 6-hour synoptic observations

- Climatological data through monthly summaries, meteorological input to annual environmental reports, and responses to ad hoc requests.

6.3 METEOROLOGICAL MONITORING NETWORK

The Hanford Site covers an area with significant variations in topography and with elevations ranging from approximately 100 to nearly 1,100 m (328 to 3,608.9 ft) above sea level. To characterize the meteorological conditions on and around the Hanford Site, 29 monitoring stations have been installed on and near the Site (Table 6-1 and Figure 6-1). Station locations were selected to reflect the influence of the varied topography, especially on wind speed and direction, and provide appropriate data for atmospheric transport, diffusion modeling, and site characterization.

Table 6-1. Hanford Site Meteorological Monitoring Towers.

Site No.	Site Name	Tower Height (meters)	Instrumentation
1	Prosser Barricade	9.1	WS, WD, T, P
2	Emergency Operations Center	9.1	WS, WD, T, P
3	Army Loop Road	9.1	WS, WD, T, P
4	Rattlesnake Springs	9.1	WS, WD, T, P
5	Edna	9.1	WS, WD, T
6	200-East Area	9.1	WS, WD, T, P, AP, DP, RH, WBGT
7	200-West Area	9.1	WS, WD, T, P
8	Beverly	9.1	WS, WD, T, P
9	Fast Flux Test Facility	61	WS, WD, T, TD, DP, P, AP, RH
10	Yakima Barricade	9.1	WS, WD, T, P, AP
11	300 Area	61	WS, WD, T, TD, DP, P, AP, RH, WBGT, PWS, FZRA
12	Wye Barricade	9.1	WS, WD, T, P, PWS, FZRA
13	100-N Area	61	WS, WD, T, TD, DP, P, AP, RH, WBGT, PWS
14	WNP-2	9.1	WS, WD, T, P
15	Franklin County	9.1	WS, WD, T
16	Gable Mountain	9.1	WS, WD, T
17	Ringold	9.1	WS, WD, T, P
19	Plutonium Finishing Plant	3.0	WS, WD, T, AP
20	Rattlesnake Mountain	9.1	WS, WD, T, P, DP, RH, S
21	Hanford Meteorology Station	124.3	WS, WD, T, TD, DP, ST, P, AP, RH, WBGT, S, CL, PWS, FZRA
22	Pasco	9.1	WS, WD, T, P
23	Gable West	9.1	WS, WD, T
24	100-F Area	9.1	WS, WD, T, P
25	Vernita Bridge	9.1	WS, WD, T
27	Vista	9.1	WS, WD, T, P
29	100-K Area	3.05	WS, WD, T
30	HAMMER	9.1	WS, WD, T, WBGT
31	233-S	9.1	WS, WD, T
32	Integrated Disposal Facility	3.0	WS, WD, T

AP	= atmospheric pressure	T	= temperature
DP	= dew-point temperature	TD	= temperature difference
RH	= relative humidity	WD	= wind direction
P	= precipitation	WS	= wind speed
S	= solar radiation	WBGT	= wet bulb global temperature
ST	= subsurface soil temperature	FZRA	= freezing rain detection
PWS	= present weather sensor	CL	= ceilometer

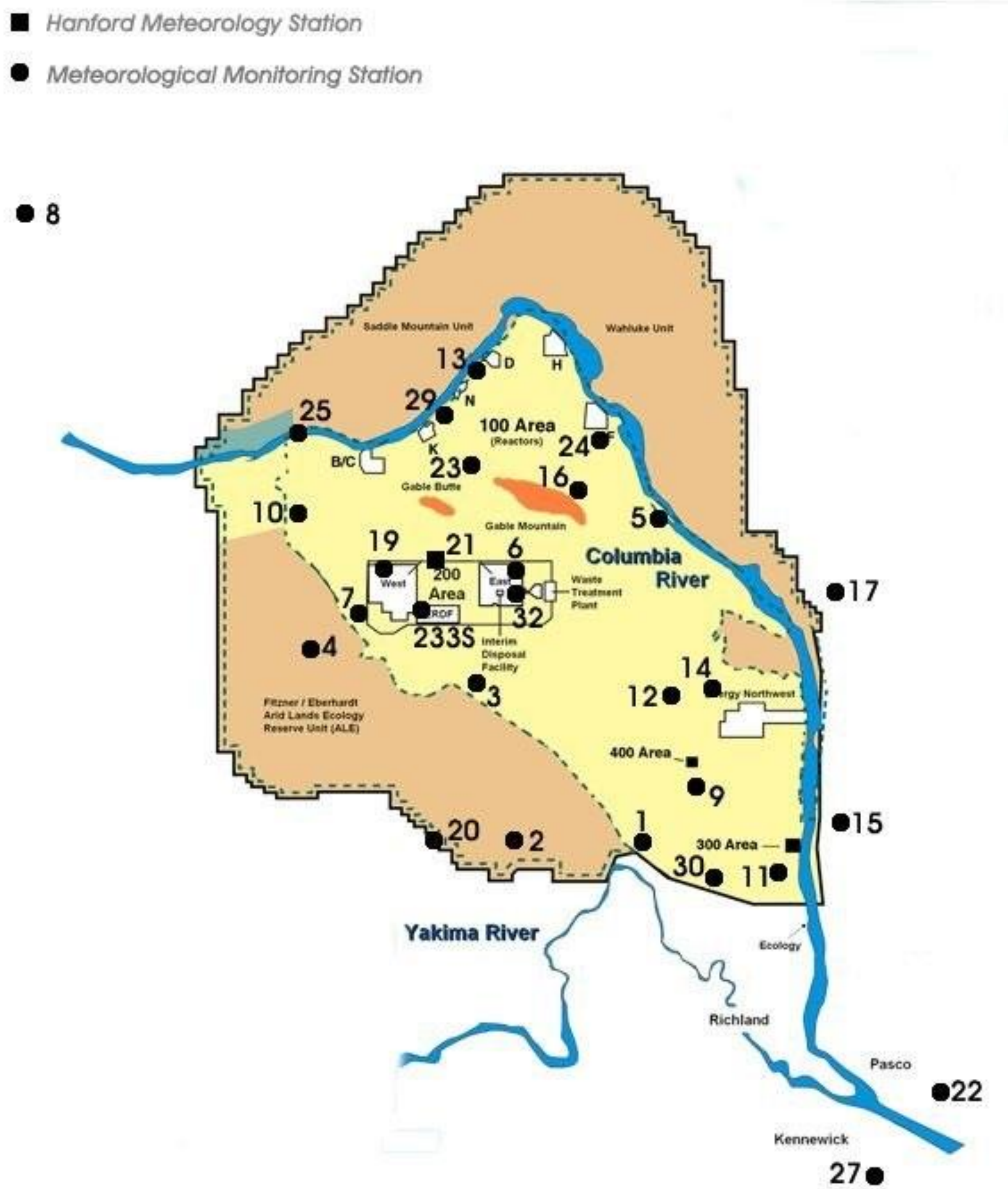

Figure 6-1. Meteorological Monitoring Stations on the Hanford Site and in Surrounding Areas

The station selection process is based on an understanding of the effects of synoptic- and meso-scale meteorological events on wind flow over the Hanford Site and on model studies of atmospheric transport that are run specifically to indicate areas where additional wind data are required.
The meteorological monitoring network was designed to the following:

- Represent implicitly the effect of the varying topography of the Hanford Site on atmospheric circulations by strategic siting of individual stations

- Monitor and collect real-time meteorological data at locations where operations are conducted that could have a possible negative impact on workers, the public, biota, and the environment in an emergency situation

- Provide meteorological data for daily operational forecasting for Hanford Site activities

- Provide real-time meteorological data for atmospheric transport and diffusion modeling

- Provide climatological data for environmental assessments, environmental impact statements, and facilities planning.

A 124.3-m (407.8-ft) tower, located at the HMS, has instruments at multiple levels to measure wind speed, direction, and temperature. This tower has been used to collect data since the mid-1940s. Three 61-m (200-ft) monitoring stations, with instruments at multiple levels, are also located onsite where significant operations are, and have been, conducted. These stations provide additional information necessary to atmospheric transport and diffusion models. Twenty-three 9.1-m (29.8-ft) towers have instruments for wind speed and direction (at 9.1 m [29.8 ft]), as well as temperature (at 1.5 m [4.9 ft]); three 3-m (9.8-ft) towers have instruments for wind speed and direction (at 3.0 m [9.8-ft]), as well as temperature (at 1.5 m [4.9 ft]). Most stations also record precipitation.

6.3.1 Meteorological Instrumentation

The meteorological instrumentation provides data, including wind speed and direction, temperature, vertical temperature difference, dew-point temperature, and precipitation. Other data are collected via the surface observation program, including sky condition, cloud type and amount, ceiling height, mixing depth, atmospheric pressure, weather and obstructions to visibility, relative humidity, and solar radiation.

Wind. Wind speed and direction are measured at the 9.1-m (29.8 ft) level at most meteorological monitoring stations; at the 3-m (9.8-ft) level at the tower at Station 19, 29, and 32; at the 25- and 60-m (82- and 196.8-ft) levels on the three 61-m (200-ft) towers onsite (Table 6-1); and at the 15.2-, 61-, and 121.9-m (49.8-, 200-, 399.9-ft) levels on the 124.3-m (407.8-ft) tower at the HMS.

Wind speed at most monitoring stations (except Station 20 [Figure 6-1]) is measured using sensors (3-cup heavy-duty aluminum anemometer) with a low starting threshold over a wide range of wind speeds. At Station 20, located on the top of Rattlesnake Mountain where light winds are unusual and sustained wind speeds in excess of 45 m/sec (147.6 ft/sec) are common, a sturdier anemometer (with a higher starting threshold but a greater range) is used. The wind speed sensor specifications, by station number, are provided in Table 6-2.

Wind direction sensors at most of the monitoring stations, except Station 20 where wind monitors are used, are counterbalanced, lightweight vanes attached to a shaft coupled to a precision low-torque potentiometer. These sensors have low starting thresholds and fast dynamic response. The wind direction sensor specifications, by station number, are provided in Table 6-3.

Table 6-2. Wind Speed Sensor Specifications by Station Number.

Station	Sensor Specifications	Wind Speed
All Stations except 20	Threshold Operating range Accuracy	0.22 m/sec (0.72 ft/sec) 0 to 56 m/sec (0 to 183.7 ft/sec) 0.07 m/sec (0.22 ft/sec) or 1.0%, whichever is greater
Station 20	Threshold Operating range	1 to 2 m/sec (3.28 to 6.56 ft/sec) 0 to 90 m/sec (0 to 295.2 ft/sec) (gust survivability to 90 + m/sec [295.2+ ft/sec])

Table 6-3. Wind Direction Sensor Specifications by Station Number.

Station	Sensor Specifications	Wind Direction
All Stations except 20	Threshold Operating range Accuracy Damping ratio Distance constant	0.22 m/sec (0.72 ft/sec) 0 to 360 degrees ±2 degrees 0.4 at 10 degrees initial angle of attack 1.1 m (3.6 ft)
Station 20	Threshold Operating range Accuracy	1 m/sec (3.28 ft/sec) 0 to 360 degrees mechanical (0 to 355 degrees electrical) ±5 degrees

The wind speed and wind direction sensors at all monitoring locations, except Station 20, are heated to minimize the accumulation of rime and/or freezing precipitation during the winter.

Temperature. Air temperature is measured at 1.5 m (4.9 ft) at all of the monitoring stations, with additional measurements at the 10- and 60-m (32.8- and 196.8-ft) levels (for measurement of ΔT for atmospheric stability designation) at the three 61-m (200-ft) monitoring stations (Table 6-1). Temperature is measured at the 0.9-, 9.1-, 15.2-, 30.5-, 61.0-, 76.2-, 91.4-, and 121.9-m (2.9-, 29.8-, 49.8-, 100-, 200-, 250-, 300-, 400-ft) levels on the 124.3-m (407.8-ft) tower.

The temperature sensor (on all but the 124.3-m [407.8-ft] tower) is an epoxy coated thermistor composite that exhibits relatively large resistance changes in response to small temperature changes. Fast-response sensors (with a time constant of 3.6 seconds) are used. All the 9.1-m (29.8-ft) monitoring stations have naturally aspirated radiation shields; the three 60-m (196.8-ft) stations have mechanically aspirated shields. The thermistor temperature sensor specifications are as follows:

- Probe accuracy ±0.15 °C
- Range -30.0 °C to 50.0 °C
- Time constant 3.6 seconds.

On the 124.3-m (407.8-ft) tower, temperatures are measured using a platinum resistance temperature device contained in a 15-cm (5.9-in.) long stainless steel housing mounted in a mechanically aspirated radiation shield. The platinum resistance temperature sensor specifications are as follows:

- Probe accuracy ±0.1 °C
- Range -50.0 °C to 100.0 °C
- Time constant 15 seconds.

Subsurface soil temperature measurements also are made at depths of 1.27, 38, and 91 cm (0.5, 15, and 36 in.). The same sensors are used as on the 124.3-m (407.8-ft) tower.

Temperature Differencing. Temperature differencing is one of several methods used to determine atmospheric stability, which is one of the parameters used in transport and diffusion calculations. Atmospheric stability is a measurement of the buoyancy of a parcel of air. The buoyancy of a parcel of air depends on its density relative to the density of the environment at the same level. If a parcel is heavier than its environment, it will tend to sink (stable); if a parcel is lighter than its environment, it will tend to rise (unstable); and if the weight is the same, it will remain at the same level as its environment (neutral). Stability classes can be determined by measuring the difference between air temperatures at two levels.

The ΔT calculation at the 124.3-m (407.8-ft) tower is made using the difference between actual temperatures measured at the 61- and 9.1-m (200- and 29.8-ft) levels of the tower. At the three 61-m (200-ft) monitoring stations, the ΔT calculation is made using the difference between actual temperatures measured at 10 and 60 m (32.6 and 196.8 ft). The temperature sensors used are discussed above.

Relative Humidity. Relative humidity at Stations 6, 9, 11, 13, 20, 21, and 28 is measured at the 1.5-m (4.9-ft) level of the 9.1-m (29.8-ft) tower. The relative humidity sensor is housed in a mechanically aspirated radiation shield. The relative humidity is measured by a thin polymer film that either absorbs or exudes water vapor as the relative humidity of the ambient air rises or drops. The dielectric properties of the polymer film depend on the amount of water contained in it. As the relative humidity changes, the dielectric properties of the film change and, therefore, the capacitance of the sensor changes. The electronics of the instrument measure the capacitance of the sensor and convert it into a relative humidity reading. The relative humidity sensor specifications are as follows:

- Operating range -40 to 60 °C
- Accuracy at 20 °C ±2% relative humidity (from 0% to 90% relative humidity) ±3% relative humidity (from 90% to 100% relative humidity)
- Time constant 15 seconds.

Dewpoint temperature can be calculated from temperature and relative humidity.

Precipitation. Precipitation measurements using tipping bucket rain gauges are made at 22 of the 29 monitoring stations. Each rain gauge has an opening 20 cm (7.8 in.) in diameter to collect precipitation. Two compartments alternately fill with precipitation and tip (emptying the compartment), causing momentary closure of a switch. The funnels are electrically heated to measure the water equivalent of frozen precipitation. The heater is thermostatically controlled to be activated when the ambient temperature drops to 4 °C. These gauges are sensitive to 0.25 mm (0.009 in.) and are accurate to 0.5% for a rainfall rate of 12.70 mm/hr (0.5 in./hr).

Atmospheric Pressure. Atmospheric pressure is measured at the 1.5-m (4.9-ft) level at the 10 sites indicated in Table 6-1. The sensors are located within the data logger enclosures. The pressure sensor specifications are as follows:

- Scaling range 800 to 1,100 millibars
- Nonlinearity ±0.05% of full scale
- Full-scale accuracy ±0.1% of full scale or ±0.3 millibar.

6.4 INSTRUMENT CALIBRATION AND MAINTENANCE

All measurement and test equipment is calibrated on an annual basis and the calibrations are spread throughout the year. However, because data are reviewed hourly by the forecaster on duty, any apparent problems with data from a particular station are immediately noted and the instrument specialists are advised. Instruments are recalibrated after any repair before being returned to use. Because of the large number of monitoring locations and the distances involved, it is not practical to perform total system calibration on a more frequent basis. Again, because of the large number of monitoring locations that contribute data to the meteorological monitoring system, the temporary loss of data from one or two locations is not critical to the operation of the system as a whole. Even so, every attempt is made to keep the amount of downtime to a minimum.

MSA maintains the procedures to calibrate all measurement and test equipment used by Meteorological and Climatological Services. Primary, secondary, and traveling calibration standards are traceable to the standards in the National Institute of Standards and Technology. On completion of calibration, a record of calibration is generated and copies of the record are provided to the applicable instrument laboratory, instrument custodian, and MSA's periodic maintenance program.

6.5 DATA ACQUISITION

Data are acquired and processed at each monitoring station using a data logger and a radio telemetry unit. Most data loggers are powered commercially; however, units at nine sites (4, 5, 7, 19, 22, 24, 25, 29, and 31) are powered by batteries charged by solar panels. The data logger acquires and processes the signals from the individual instruments and the radio telemetry unit transmits the processed data to the HMS. The data logger scans its channels for information every 1 second, stores the information for 15 minutes, and sends the 15-minute averaged values to the HMS. Values are transmitted at 15-minute intervals.

The data transmitted from the remote monitoring stations are received at a base station located at the HMS and are saved to a personal computer running the data collection software.

6.6 ATMOSPHERIC TRANSPORT AND DIFFUSION

The Air Pollutant Graphical Environmental Modeling System is an atmospheric dispersion model that predicts ground-level concentrations and deposition fields of air contaminants released from point sources given contaminant release rates, source configurations and meteorological observations of winds, mixing heights, precipitation rates, and atmospheric stability. The data from the Hanford Meteorological Monitoring Network is critical for the Air Pollutant Graphical Environmental Modeling System, which is a primary model used in the Unified Dose Assessment Center of the Emergency Operations Center. Data files for this software are transmitted to the servers every 15 minutes, shortly after the data are processed.

6.7 QUALITY ASSURANCE

QA for the Meteorological and Climatological Services Program is covered by MSC-26661, *Environmental Quality Assurance Program Plan*.

6.8 DATA MANAGEMENT

Meteorological data from the monitoring network are collected, processed, and archived on a dedicated network of personal computers at the HMS. MetView® software is used for data display and verification.

The 15-minute averaged data from the monitoring network are used as input to atmospheric transport and diffusion models for emergency response. These files are saved on the data collection computer as well as the HMS server that transmits the files to the Emergency Operations Center.

At the beginning of every month, the monthly data on the personal computer network are processed prior to permanent storage. All data are reviewed using QA computer programs that check all data for the following types of potential errors:

- Parameters out of range (e.g., January temperature more than 16.7 °C)
- Unreasonable changes in parameter magnitude from 1 hour to the next (e.g., temperature change more than 5.6 °C)
- Parameter conflict (e.g., visibility below a specific threshold value with no obstructing phenomena indicated [e.g., fog, snow]).

These programs generate error listings that allow for the resolution of possible data irregularities. These computer-generated error listings are maintained on file; however, errors that can be readily resolved are corrected and archived. If they cannot be corrected, the data are indicated as missing.

On completion of these monthly QA checks, the final data are archived on multiple hard disks and are available for additional processing (e.g., joint frequency distributions, wind roses, data summaries), as necessary.

6.9 REFERENCES

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DOE O 436.1. 2011. *Departmental Sustainability*, U.S. Department of Energy, Washington, D.C. CRD O 436.1, Supplemented Rev. 0, *Departmental Sustainability,* U.S Department of Energy, Richland Operations Office, Richland, Washington.

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7.0 ECOLOGICAL MONITORING AND COMPLIANCE

7.1 INTRODUCTION

Ecological monitoring and ecological compliance assessment are aspects of the U.S. Department of Energy's (DOE) requirements for an environmental resources protection plan. They are designed to meet the environmental resources protection objectives stated in DOE O 436.1, *Departmental Sustainability*, with DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental*, used as guidance when investigating potential ecological impacts. DOE O 436.1, assures DOE sites have an Integrated Environment, Safety, and Health Management Systems, which includes implementation of an Environmental Management System defined in the ISO 14001 Standard, *Environmental Management Systems – Requirements with Guidance for Use*. The Environmental Management System creates programs that protect public health and the environment and ensure compliance with applicable environmental protection requirements. Activities conducted under the Ecological Monitoring and Compliance (EMC) Program directly support Hanford Site and DOE compliance with federal statutes, regulations, and directives pertaining to ecological resource protection and preservation including the *National Environmental Policy Act* (NEPA) and DOE Implementation Procedures (10 CFR 1021), the *Endangered Species Act*, *Bald and Golden Eagle Protection Act*, *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* , and the *Migratory Bird Treaty Act*. Additionally, this work element provides a basis for incorporating U.S. Fish and Wildlife Service; Washington Department of Fish and Wildlife; Washington Natural Heritage Program; and special species laws, regulations, and policies into Hanford Site activities, as warranted.

Specific components of the EMC Program may include the following:

- Ecological monitoring
- Ecological compliance, protection, and mitigation
- Ecological impact assessment and risk characterization
- Data management
- Quality assurance (QA).

This section identifies the data required to support EMC assessment activities and other ecological information important to these activities.

7.2 ECOLOGICAL MONITORING AND COMPLIANCE PROGRAM

Mission Support Alliance's (MSA) EMC Program provides the Hanford Site DOE field offices and contractors with ecological characterization, monitoring, and compliance support. The Program provides data and information to fulfill the U.S. Department of Energy, Richland Operations Office's needs to achieve conservation and compliance with natural resource-related legal and regulatory requirements for the biological resources found on the Hanford Site. Under this Program, surveys and monitoring of resources and key biota are conducted to assess abundances, vigor or conditions, and distributions of populations and species on the Hanford Site. When possible, data collection and analysis are integrated with the monitoring of biotic and abiotic media under the Environmental Surveillance Program to characterize any potential risks or impacts to the biota.

Ecological monitoring and ecological compliance activities support multiple objectives for completing the Hanford Site's waste management and environmental restoration missions. The Program responds to Hanford Site needs by including the following:

- Conducting ecological compliance reviews to provide environmental analysis and survey data. These data are used to make resource conservation, impact, and mitigation decisions in addition to ensuring DOE projects comply with NEPA and other federal regulations including the *Endangered Species Act* and the *Migratory Bird Treaty Act*.

- Implementing DOE/RL 96-32, *Hanford Site Biological Resources Management Plan* (BRMP); DOE/RL-94-150, *Bald Eagle Management Plan for the Hanford Site*; DOE/RL-2000-27, *Threatened and Endangered Species Management Plan: Salmon, Steelhead, and Bull Trout*; and interactions with the U.S. Fish and Wildlife Service, Washington Department of Fish and Wildlife, and National Oceanic and Atmospheric Administration Fisheries to facilitate DOE operations and reduce potential liabilities resulting from *Endangered Species Act* issues.

- Collecting and maintaining the data needed to provide the ecological information and potential impact assessments that enable the DOE to make technically defensible environmental management decisions; reduce DOE liability; and inform the public, stakeholders, and trustees about the status of ecological resources at the Hanford Site.

- Integrating and evaluating spatially explicit information describing the occurrences and distributions of ecological resources, which may be receptors in areas with known or probable legacy contaminants. This information can be used to assess potential site-specific and sitewide impacts to support ecological risk analyses.

- Maintaining current and historical ecological data to support Hanford Site issues and litigation needs (e.g., offsite wildfire and wildlife issues), land-use planning (e.g., wildland fire issues, high-value biological resources), and mitigation action planning.

Activities inherent in the operation of the EMC Program include study design and implementation, data collection, sample analysis, database management, data review and evaluation, resource inventory, and reporting. Other elements of the project include project management, QA, training, and records management.

7.3 ECOLOGICAL MONITORING

Monitoring and characterization activities on the Hanford Site involve collecting and analyzing the appropriate ecological data to assess potential impacts and detect population trends for species. The work includes collecting population-level information for biota in key habitat types and collecting and analyzing community and population-level data over long time periods to detect changes in population sizes and conditions. These data can be used to assess relative resource values, presence or absence of

organisms as risk receptors with respect to legacy contaminants in the environment, and detect changes in population sizes that may or may not be related to Hanford Site operations.
Results from these inventory and monitoring efforts are maintained in the project records and are a critical component for implementing the BRMP. Analyses of these results provide early indications of any potential impacts to biota from Hanford Site operations and the resulting information to describe potential ecological receptors found in habitats on the Hanford Site.

7.3.1 Population Monitoring and Trend Analysis

Populations monitored on the Hanford Site may include deer, bald eagles, ferruginous hawks, geese, salmon/steelhead, bivalves, amphibians, rare plants, vegetation in key habitats, and other species or guilds. Sampling methods, frequencies, and timing are based on the species and habitats of interest, and reviews of the best and standard scientific practices available. Standard sampling procedures are maintained in project records.

Not all populations are surveyed annually. Surveys focus on: 1) monitoring those plant and animal species or habitats with specific regulatory protections or requirements; 2) species of concern to state or federal authorities (e.g., species listed by state or federal agencies as threatened and endangered or candidates for listing as threatened and endangered); 3) BRMP resource levels 3 through 5; 4) significant interest to federal, state, or Tribal governments; and 5) species that appear to have higher potentials for exposures to, or impacts from, legacy contaminants present on the Hanford Site. Annual surveys may include the following:

- Surveys to describe the relative abundance and distribution of wildlife inhabiting the Hanford Site may include, but are not limited to, the following:
  - Nesting raptors
  - Elk on central Hanford
  - Ground squirrel colony size and distribution
  - Jackrabbit distribution and population estimates
  - Location of bat maternal and wintering roost sites
  - Burrowing owls
  - Snake hibernacula location
  - Herpetofauna habitat monitoring for presence and absence of sensitive species
  - Winter surveys of mule deer residing in areas adjacent to the Hanford Reach
  - Breeding birds in shrub-steppe and riparian habitats.

The following aerial surveys document significant salmon and steelhead spawning areas in the Hanford Reach:

- Salmon redd surveys during the peak spawning period for fall Chinook salmon (usually late October through November) to provide data on the numbers and locations of visible redds in the Hanford Reach.

- Steelhead redd surveys during the spring months to provide preliminary data on the occurrence and distribution of spawning steelhead in the Hanford Reach. Steelhead are considered part of the upper Columbia River Evolutionarily Significant Unit, listed as endangered under the *Endangered Species Act*.

- Mapping Hanford Site plant communities and special habitats to update information about habitat quality, successional status of native communities, and the distribution of unique habitats.

- Rare Plant Monitoring. Field surveys and data analyses to map and monitor new and existing populations of plant species of federal and state concern that might be impacted by onsite activities. At least 47 of the more than 700 plant species found on or near the Hanford Site are listed by the Washington Natural Heritage Program as endangered, threatened, sensitive, review, or watch. More than 100 populations of plant species of concern have been located across the Hanford Site. Field surveys are conducted to search for target species in potential habitat areas and for any and all plant species of concern that could inhabit the surveyed areas.

Species and habitat inventories and field monitoring also are conducted at appropriate times to develop and provide spatial data sets that are maintained in the EMC Program data sets. These data sets map the locations of threatened and endangered species and document physical habitat characteristics for special status species in a geographic information system used by the EMC Program and other Hanford Site projects requiring resource map layers for project planning. The following are examples of spatial data sets developed and maintained by the EMC Program:

- Locations of plant species of concern
- Bald eagle nesting and roosting areas
- Ferruginous hawk nesting sites
- Locations of riparian and terrestrial vegetation cover types
- Locations of Hanford Reach fall Chinook salmon spawning areas
- Critical habitats for sagebrush-obligate species.

7.4 ECOLOGICAL COMPLIANCE, PROTECTION, AND MITIGATION

The Hanford Site contains significant remnants of native Washington State shrub-steppe and semi-arid riparian habitats that are relatively undisturbed by agricultural and industrial development. The wildlife and plants found on the Hanford Site are subject to regulation by federal and state authorities. To ensure compliance with these regulations, appropriate regulatory drivers are required that protect specific resources of concern or develop meaningful mitigation strategies for Hanford Site resources of concern. The ecological compliance assessment portion of the EMC Program: 1) ensures DOE compliance with federal and state wildlife resource regulations; 2) analyzes impacts of site operations on ecological resources, including state and federally listed species and rare or unusual habitats or plant communities; 3) prepares documentation in support of site NEPA analyses; 4) prepares mitigation plans for minimizing impacts to protected species and habitats; and 5) conducts informal consultations with the U.S. Fish and Wildlife Service when warranted. The BRMP guides ecological compliance assessment on the Hanford Site.

7.4.1 Routine Reviews

Ecological compliance reviews are performed for Hanford Site activities that have the potential to adversely impact species or habitats of concern. Hanford Site contractors can submit a request for an ecological compliance review using the MSA Service Request System. Upon receipt of a review request, EMC personnel conduct an initial screening to determine if the proposed action could have direct ecological impacts. Criteria used in this review include those defined in the BRMP. The project files are examined to determine whether a field survey was carried out in the area of the proposed action within the last year. If previous survey information is not available, a biological review of the proposed site is conducted. A letter report is completed for each review that includes the following:

- Brief project description
- Description of the basis for the review, including review methods, dates, and personnel involved
- Results of the survey
- Conclusions regarding impacts
- Recommendations regarding mitigation of impacts, if needed
- Specific information on ecological resources of concern, habitat descriptions, and species lists are included as appropriate.

7.4.2 Federally Threatened or Endangered Species Protection

The EMC Program assists DOE and Hanford Site contractors in complying with the *Endangered Species Act*. Assistance includes developing biological assessments, maintaining and updating management plans, posting restricted areas and maintaining the signs, educating Hanford Site personnel about rules, regulations, and responsibilities, and communicating with the appropriate regulatory agencies regarding compliance issues. EMC personnel regularly monitor known and potential use areas to determine current spawning areas for endangered fish species and habitats for plants species that are proposed for listing under the *Endangered Species Act*. The assessment of activities potentially affecting these use areas requires, at a minimum, regular informal interactions with the appropriate federal agencies.

7.4.3 Protection of State Listed or Other Special Status Species

EMC staff coordinate protection measures for selected state-listed species such as ferruginous hawks and other special status species (e.g., bald eagles). These protection measures may include the installation of signs to limit intrusion into nesting or night roost buffer areas, and education/training sessions for site personnel.

7.5 ECOLOGICAL IMPACT AND RISK CHARACTERIZATION

In some instances, sampling and species inventory surveys are conducted to characterize impacts and risks for key indicator species with high potential for exposure to and uptake of contaminants. These sampling and survey efforts are coordinated with contaminant monitoring activities conducted through the Environmental Surveillance Program. Key species are selected based on biological, ecological, and physiological attributes that could influence potential contaminant exposures. Sampling is prioritized based on: 1) the likelihood of exposure, 2) risk assessment data gaps, 3) public interest in ecological resources, and 4) stakeholder concerns. Organisms are sampled at locations with known contaminant concentrations and analyzed to document the occurrence or absence of anatomical or morphological effects, diseases, or parasitism. Frequencies and timing of sampling efforts are determined based on the life history characteristics of the species under consideration. When feasible, the results of environmental surveillance contaminant monitoring are used to assess whether organism health can be related to tissue concentrations of specific contaminants. Typical ecological sampling may include the following:

- Sampling small mammals in key terrestrial and riparian habitats to provide species inventories, seasonal abundances, recruitment estimates, information on exposures to legacy contaminants, and evaluations of reproductive conditions.
- Surveys of amphibian breeding pools and sampling of juvenile amphibians to determine exposures to contaminants and conditions of organisms.
- Sampling macro-invertebrates and vertebrates in key aquatic habitats to provide species inventories, abundances, age demographics, recruitment estimates, information on exposures to legacy contaminants, and evaluations of histological conditions.

7.6 DATA MANAGEMENT

Ecological data from monitoring, compliance reviews, and assessment activities are processed and archived in electronic files residing on dedicated share drives. Files contain historical and recent ecological data collected by Hanford Site contractors and selected data sets collected by federal, state, and private agencies. Metadata are archived to capture the following project and investigation-specific information: sampling objectives, responsible contractor, collection dates, geographic areas, methods used, and types of data collected. Backups of the EMC Program and related files are performed regularly.

Annual summary reports are prepared for each monitoring effort; these reports are made available to the public on the MSA external web page (http://www.hanford.gov/page.cfm/EcologicalMonitoring). Information on this web page is updated as needed and at a minimum annually.

7.7 QUALITY ASSURANCE

QA for EMC-related activities is established and implemented based on formal QA requirements contained in the *Environmental Quality Assurance Program Plan* (MSC-PLN-EI-23333). The EMC QA program conforms to the requirements of DOE O 414.1D.

The MSA QA department conducts surveillances and audits of project activities and procedures to ensure compliance with the *Quality Assurance Program Description* (MSC-MP-599). A DOE monitor, the EMC program manager, or MSA quality engineer can initiate these surveillances and audits routinely or randomly.

7.8 REFERENCES

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8.0 CULTURAL RESOURCES

8.1 INTRODUCTION

The Hanford Site is rich in cultural resources important to Native Americans, interested parties, and the public. The U.S. Department of Energy, Richland Operations Office's (DOE-RL) Cultural and Historic Resources Program (CHRP) has monitored cultural resources sites (defined as archaeological sites, historic structures, traditional use areas, and cemeteries) since 1989 as part of U.S. Department of Energy's responsibilities under Section 110 of the *National Historic Preservation Act* (NHPA). A vital part of this program involves monitoring cultural resources to identify and address past and current impacts.

Cultural resources personnel from Mission Support Alliance's CHRP perform monitoring on a quarterly basis. In addition to monitoring the conditions of cultural resources sites, the CHRP provides cultural resources education to Hanford Site workers and the public, performs cultural resources surveys, and reviews the potential effects of onsite activities to Hanford Site cultural resources. Local Native American Tribes and Bands conduct their own cultural resources activities that include cultural resources site monitoring and surveys. CHRP activities are performed in compliance with multiple regulatory drivers including Sections 106 and 110 of the NHPA; *National Environmental Policy Act*; the *Archaeological Resources Protection Act (ARPA)*; *Native American Graves Protection and Repatriation Act*; and DOE P 141.1, *Department of Energy Management of Cultural Resources*.

Analytical data from monitoring are used to track areas of concern and general site conditions. DOE-RL uses this information to make effective management decisions that affect conservation of important archaeological, cultural, and historic resources.

8.2 OBJECTIVES

The following objectives are part of cultural resources monitoring:

- Obtain baseline data to quantify current conditions of cultural resources.
- Monitor cultural resources sites and identify impacts that need to be addressed.
- Document violations of the ARPA.
- Provide a cooperative cultural resources monitoring effort through Native American participation.
- Monitor locations that may contain human remains. Human remains may become exposed as a result of erosion or other disturbances and may be subject to the *Native American Graves Protection and Repatriation Act*.
- Collect and manage data including written descriptions, field observations, global positioning system (GPS) coordinates, geographic information systems data, and photographs.

- Add to knowledge of the cultural resources monitored on the Hanford Site.
- Integrate observations from cultural resource site condition monitoring into the permanent site records.

8.3 PROGRAM RATIONALE AND CRITERIA

The CHRP has evolved over the last 25 years to include inspections at approximately 10 to 20 places and/or sites per year. Specific program rationale and criteria are discussed in the following subsections.

8.4 MONITORING LOCATIONS

DOE-RL is the steward of all Hanford Site archaeological resources, traditional-use areas, cultural landscapes, and historic period properties. Categories of sites monitored include archaeological sites, traditional use areas, historic buildings, and areas associated with human remains. Focus is put on places eligible for listing on the *National Register of Historic Places* (NRHP) and locations at risk for disturbance. As time allows, additional areas such as cultural landscapes, newly recorded archeological resources, and traditional use areas are added to the monitoring schedule. Those sites that are at risk that have not been evaluated for NRHP eligibility will be considered for evaluation and nomination based on monitoring observations. Each year a set of sites is selected for monitoring; should there be unplanned or unexpected events (e.g., high Columbia River water levels or severe river water level fluctuations, inadvertent discoveries, or an increase in looting), the year's site selections can be modified. Site selections are based primarily on the documented presence of human remains, their eligibility for the NRHP, and the observation of significant risks or impacts. Site-specific monitoring information is culturally sensitive and its use may be restricted under Section 304 of the NHPA and Section 9(a) of the ARPA, which require protection of sensitive information about historic properties from disclosure to the public and define penalties for violation of federal law resulting in damage to archaeological sites. All site information and monitoring evaluations are stored by the CHRP in a secure records repository.

8.5 MONITORING CRITERIA

Cultural resources sites are monitored for impacts from environment (e.g., wind, water), animals, and humans. Baseline data from a records search and past field observations are included in field monitoring forms. New impacts are added to baseline data if discovered during monitoring activities. Observations are made about active impacts, impacts not previously observed, or impacts sustained since the last monitoring visit, as well as any newly identified cultural material. The following three categories of GPS and photographic data are recorded at each monitoring site, if observed:

- Areas with new features, tools, or diagnostic artifacts that can add cultural knowledge of the site. These locations are GPS mapped and generally only photographed once unless a threat to the location is perceived or active. They are assessed at every visit.

- Overview locations where a general view of the site/location condition is possible. These locations are GPS mapped and photographs are replicated at every visit.

- Locations of specific impact. These locations are GPS mapped and the frequency of replicated photographs depends on whether the impact is active.

8.6 MONITORING FREQUENCIES

A set number of locations are core sites such as human remains locations, which are monitored annually. The remaining sites, which may be part of a rotation, can be monitored semiannually, annually, biennially, or every 3 to 5 years depending on the type of site and amount of damage observed in the past. For example, a site that is eligible for listing on the NRHP may be monitored every 5 years if little damage was observed during the previous monitoring visits and the risk to it is perceived as low. Monitoring frequency at individual sites is reassessed after each monitoring visit.

8.7 HANDLING OF MONITORING INFORMATION

All photographs and site monitoring forms are stored in the CHRP records repository. Individuals with a need-to-know may access monitoring information with the appropriate authorization. Impacts observed during monitoring visits are documented on standardized forms. In order to maintain consistent and recognized standards, National Park Service definitions for general site condition are included and used as part of the site condition summary.

8.8 QUALITY CONTROL METHODS

Hanford cultural and historic resources monitoring is conducted and documented by CHRP personnel in accordance with written procedures. CHRP personnel leading the monitoring efforts, authoring monitoring reports, and overseeing the monitoring program are qualified archaeologists meeting the U.S. Secretary of the Interior's Professional Qualification Standards for Archaeology. At the end of each fiscal year, CHRP personnel review all monitoring results and develop a summary report based on recorded data.

8.9 REPORTING IMPACTS AND VIOLATIONS

ARPA violations require immediate notification of the DOE-RL CHRP manager so that appropriate Native American Tribes and Bands can be notified of violations in a timely manner. Impacts are also noted on a cultural resources site monitoring form and stored in the cultural resources site file located in the Mission Support Alliance CHRP repository.

8.10 REFERENCES

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