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Revision 7

Hanford Site Environmental Monitoring Plan

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

U.S. DEPARTMENT OF ENERGY | Richland Operations Office
P.O. Box 550
Richland, Washington 99352

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PREFACE

The *Hanford Site Environmental Monitoring Plan* (EMP) implements the requirements of the U.S. Department of Energy (DOE) Order (O) 436.1, Supp Rev.0, *Departmental Sustainability*. The DOE O 436.1, Supp Rev. 0 requires all DOE organizations, and all sites under their purview, to ensure the site Integrated Environment, Safety, and Health Management Systems (ISMS) include implementation of an Environmental Management System (EMS) (as defined in ISO 14001). The EMS is required to provide for 1) the systematic planning, integrated execution, and evaluation of programs for protecting public health and the environment; 2) pollution prevention; and 3) site compliance with applicable environmental protection requirements. In addition, the Order requires that all DOE organizations conduct environmental monitoring, as appropriate, to support their ISMS and EMS.

The DOE-Richland Operations Office (RL) ISMS (called the Richland Integrated Management System [RIMS]) includes a section specifically addressing components of the Hanford Site's Environmental Monitoring Program. This program is responsible for implementing the environmental monitoring requirements specified in DOE O 436.1, Supp Rev. 0, *Departmental Sustainability*.

The RIMS identifies this EMP as the mechanism through which environmental monitoring requirements are implemented at the site. 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.

This plan is written to comply with DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

Personnel from DOE-RL, Mission Support Alliance (MSA) and CH2M Hill Plateau Remediation Company (CHPRC) and its subcontractors contributed to this plan. The MSA Public Safety and Resource Protection Program (PSRP) coordinated document production. This plan was written to meet the needs of the Hanford Site's DOE offices and their contractors. Questions or concerns about this plan should be directed to Kevin Leary, DOE-RL, (Kevin.Leary@rl.gov).

ACRONYMS

Each section in this report is considered to be independent from each other with respect to the use of acronyms. Any acronym used in a table or on a figure is provided thereon. For the convenience of the reader, below is a list of all the acronyms used in the entire report.

ADR	anomalous data report
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
APGEMS	Air Pollutant Graphical Environmental Modeling System
ASTM	American Society for Testing and Materials
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act*
CFR	Code of Federal Regulations
CHPRC	CH2M Hill Plateau Remediation Company
CRD	contract requirements document
CVAA	cold vapor atomic absorption
DOE	U.S. Department of Energy
DOE-RL	DOE Richland Operations Office
DQO	data quality objective
Ecology	Washington State Department of Ecology
EDE	effective dose equivalent
EMC	Ecological Monitoring and Compliance (Project)
EMP	environmental monitoring plan
EMS	Environmental Management System
EPA	U.S. Environmental Protection Agency
FDA	U.S. Food and Drug Administration
FEMP	Facility Effluent Monitoring Plan
GENII	Generation II (computer code)
GIS	geographic information system
GPS	global positioning system
HCRP	Hanford Cultural Resources Project
HEIS	Hanford Environmental Information System
HEO	Hanford Environmental Oversight (Project)
HMS	Hanford Meteorology Station
HQ	Headquarters (DOE)
ISMS	Integrated Environment, Safety, and Health Management System
MCSP	Meteorological and Climatological Services Project
MSA	Mission Support Alliance
NEPA	*National Environmental Policy Act*
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NHPA	*National Historic Preservation Act*
NIST	National Institute of Standards and Technology
NPL	National Priorities List
NRHP	National Register of Historic Places
NTU	nephelometric turbidity unit
PCB	polychlorinated biphenyl

PNNL	Pacific Northwest National Laboratory
PSRP	Public Safety and Resource Protection (Program)
QA	quality assurance
QC	quality control
RCRA	*Resource Conservation and Recovery Act*
RI/FS	remedial investigation/feasibility study
RIMS	Richland Integrated Management System
SBMS	Standards-Based Management System
SPMU	Special Protection Management Units
TLD	thermoluminescent dosimeter
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
TSD	treatment, storage, or disposal (unit)
UDAC	Unified Dose Assessment Center
USFWS	U.S. Fish and Wildlife Services
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington State Department of Health
WNHP	Washington Natural Heritage Program

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TABLES

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1.0 INTRODUCTION

The Hanford Site Environmental Monitoring Program is implemented on two distinct and independent levels, in part due to the large size of the Hanford Site, the diversity of activities performed onsite, and the number of contractors responsible for the various activities. This structure was established to ensure that potential impacts associated with Hanford Site activities are evaluated and that operations at Hanford are not having a negative impact on human or ecological health or natural and cultural resources.

The first level of the program addresses the operational aspects of environmental protection. Contractors are required to implement the environmental protection requirements stated in DOE O 436.1, Supp Rev. 0, *Departmental Sustainability,* through their respective contract requirements document (CRD). This document includes requirements for major contractors to integrate their Environmental Management System (EMS) into their respective Integrated Environment, Safety, and Health Management System (ISMS) and perform effluent or environmental monitoring as appropriate at or near active and inactive facilities onsite. Required state and federal laws, regulations, and permits related to facilities also are addressed at this level.

The second level of the program ensures protection of site workers, the public, and environmental resources on and around the site from all operations at Hanford. To accomplish this, DOE and its contractors must implement the requirements of DOE O 436.1, Supp Rev. 0, *Departmental Sustainability*, and DOE O 458.1, Chg 2, *Radiation Protection of the Public and the Environment* through their respective CRD. The activities at this level include groundwater monitoring, site-wide environmental surveillance, meteorological monitoring, natural and cultural resources monitoring, and cumulative environmental impact assessment related to Hanford Site activities.

The Richland Integrated Management System (RIMS) describes the site's Environmental Monitoring Program in terms of the following environmental monitoring 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 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 so that protection of the workers and the public is ensured.
- Provide assurance that Hanford Site activities are conducted in ways that are protective of the air, water, land, and other natural and cultural resources.
- Mandate participation in the site's land-use planning activities, human health and ecological risk assessments, and long-term stewardship plans. Environmental monitoring plans (EMPs) 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 monitoring sample collection methods, sample analyses, data interpretations, and reporting are consistent throughout the site, as appropriate, to ensure consistency and comparability of the data.

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

In addition, environmental monitoring activities are integrated throughout the site to the extent practicable to avoid collection of duplicative data. Such integration minimizes duplication of capabilities and resources at Hanford, optimizes operational efficiencies, maximizes the amount of useful information generated, and results in lower costs to DOE. Monitoring 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 site.

1.1 Environmental Monitoring Program

The primary elements of Hanford's Environmental Monitoring Program include the Effluent Monitoring Program, Public Safety and Resource Protection (PSRP) Program, Soil and Groundwater Remediation Project, 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 at Hanford is conducted in accordance with approved monitoring procedures, and the results are reported in the annual Hanford Site Environmental Report. Effluent monitoring consists of 1) monitoring facility effluent and emissions, and 2) environmental monitoring near facilities that have the potential to discharge, or have discharged, stored, or disposed of radioactive and hazardous materials (i.e., near-facility or near-field monitoring).

1.1.1.1 Facility Effluent Monitoring

Hanford Site contractors perform real-time monitoring of liquid effluent and airborne emissions at each facility to assess the effectiveness of effluent and emissions treatment and control systems and pollution management practices and determine facility and Hanford Site compliance with state and federal regulatory requirements. A facility effluent monitoring plan (FEMP) may be prepared and maintained for each existing, new, or modified facility having the potential to 1) release quantities of airborne radioactive materials that could cause a radiation dose in excess of 0.1 millirem per year effective dose equivalent (EDE) to any member of the public; 2) discharge a liquid effluent regulated by *EPA Administered Permit Programs: The National Pollutant Discharge Elimination System* (40 CFR 122), and containing sufficient radionuclides to potentially cause an EDE greater than 4.0 millirem per year to any member of the public via the drinking water pathway; or 3) release large quantities of nonradioactive hazardous materials in amounts exceeding the reportable quantities listed in *Designation, Reportable Quantities, and Notification* (40 CFR 302). Each FEMP contains the rationale and design criteria for the effluent monitoring program at the facility, information on the extent and frequency of monitoring and measurements, procedures for analyses of monitoring samples, QA requirements, and program implementation procedures. A discussion of Hanford Site FEMPs is not included in this document because many FEMPs contain information that is considered sensitive.

Questions or inquiries about Hanford Site FEMPs should be directed to Thomas Ferns, DOE-RL, Richland, Washington (thomas.ferns@rl.doe.gov).

1.1.1.2 Near-Facility Environmental Monitoring

Near-facility environmental monitoring is conducted to protect workers and the environment adjacent to 1) nuclear facilities; 2) waste storage, treatment, and disposal sites; and 3) 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.

Sections 2 and 4 of this plan describe these monitoring activities and provide details about the environmental media sampled; monitoring locations; extent and frequency of monitoring and measurements; procedures for laboratory analyses; QA requirements; and program implementation procedures.

1.1.2 Public Safety and Resource Protection

Environmental surveillance, meteorological services, ecological surveys, and natural and cultural resource protection activities on the Hanford Site are managed through the PSRP Program. The PSRP provides environmental information obtained independent of the Hanford Site contractors. Program personnel monitor the Hanford environment to provide assurance that the site operates in compliance with applicable environmental regulations assess potential site impacts to ensure protection of public and worker safety and significant ecological and cultural resources. This information is necessary for DOE and site contractors to manage environmental risk on the Hanford Site.

Sections 2 through 7 provide details on the various components of the PSRP. These sections also describe inter-program integration and links between PSRP components and other environmental monitoring, waste site cleanup, environmental restoration, and assessment activities on the Hanford Site.

The PSRP is instrumental in ensuring that the Hanford Site is in compliance with DOE directives, environmental and resource protection laws, and regulations, including the *Clean Water Act* (CWA), *Clean Air Act* (CAA), *National Environmental Policy Act* (NEPA), *Endangered Species Act* (ESA), *Migratory Bird Treaty Act (MBTA)*, *Bald and Golden Eagle Protection Act*, *National Historic Preservation Act* (NHPA), and the *Native American Grave Protection and Repatriation Act (NAGPRA)*. In addition to this environmental monitoring plan, project personnel are responsible for preparing, maintaining, and implementing the following environmental monitoring and resource protection plans for the Hanford Site:

- *Hanford Site Biological Resources Management Plan* (DOE/RL-96-32).
- *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (DOE/RL-94-150).
- *Threatened and Endangered Species Management Plan: Salmon, Steelhead* and Bull Trout (DOE/RL-2000-27, Rev. 2).

- *Hanford Cultural Resources Management Plan* (DOE/RL-98-10).

The PSRP, which is managed and operated as an integrated unit, consists of the following five component projects:

Hanford Environmental Oversight. The Hanford Environmental Oversight (HEO) Project is responsible for managing the PSRP, integrating activities performed within the PSRP, and coordinating related environmental assessment and resource protection activities across the site. In addition, the HEO is responsible for PSRP self-assessments, performance assessments, and design reviews. The HEO also provides production coordination of this Hanford Site EMP, consistent with 65 FR 24595, *Greening the Government through Leadership in Environmental Management*, and DOE O 436.1, Supp Rev. 0, *Departmental Sustainability.*

Environmental Surveillance. Environmental Surveillance is a multimedia environmental monitoring effort conducted to assess onsite and offsite human health exposures to radionuclides and chemicals and evaluate potential impacts of Hanford Site operations on the environment. 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 site operations and missions and focused on those contaminants with the greatest potential for contributing to offsite doses.

Environmental Surveillance is closely related to and coordinated with near-facility environmental monitoring (see Section 2), groundwater monitoring (see Section 8), and WDOH's oversight of Hanford's environmental programs. In addition, surveillance activities are closely aligned with and support the site's environmental cleanup, restoration, and assessment missions.

Environmental Surveillance personnel are responsible for preparing the annual Hanford Site Environmental Report. The 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 operations. The report provides a historical and current accounting of 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 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.

Meteorological and Climatological Services. The Meteorological and Climatological Services Project (MCSP) operates the Hanford Meteorology Station (HMS) to provide operational meteorological support to DOE and its contractors for site operations, site-wide emergency preparedness, construction, remediation, environmental restoration, and safety-related activities. The MCSP provides information to onsite organizations performing work that could be severely affected by adverse meteorological conditions (thunderstorms, strong winds, dense fog, and snowstorms). The day-to-day meteorological data MSCP generates are essential for ensuring work activities are conducted efficiently and under the safest conditions possible. The MCSP also provides timely meteorological data 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 also are integral to the 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 MCSP maintains a long-term meteorological computer database and produces an annual climatological data summary for the Hanford Site Environmental Report.

Section 5 describes the rationale and design of the MCSP, including the number and location of weather stations, instruments used, forecasting capabilities, data management efforts, diffusion modeling activities, and emergency response capabilities.

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

Section 6 provides additional detail about the types of studies and activities performed to monitor the status of important resources on and near the site, while ensuring compliance with state and federal resource protection laws.

Cultural Resources. The Hanford Cultural Resources Project (HCRP) 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 7 provides a detailed description of the HCRP, including requirements, rationale, objectives, and survey design. Additional information is available in the Cultural Resources section of RIMS.

1.1.3 Groundwater Monitoring

The 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* (RCRA), state of Washington 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* (CERCLA). Groundwater samples are currently collected from approximately 780 wells, both on and off the site.

Section 8 describes the 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 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 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 320-106, *Hanford Environmental Oversight Program 2013 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 projects operations and activities. The driving requirements behind the environmental ALARA program are DOE O 458.1, Chg 2, *Radiation Protection of the Public and the Environment;* and WAC 246-247, *Radiation Protection – Air Emissions*. DOE O 458.1, Chg 2, 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 and 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, Supp Rev. 0, *Departmental Sustainability* definition of an EMS as *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 NEAR-FACILITY ENVIRONMENTAL MONITORING

2.1 Introduction

Near-facility environmental monitoring is an important element of the Public Safety and Resource and Protection Program. This monitoring is directed by MSA in accordance with DOE O 231.1B, *Environment, Safety and Health Reporting*; DOE O 436.1, Supp Rev. 0, *Departmental Sustainability*; DOE M 435.1-1, *Radioactive Waste Management Manual*; Air Operating Permit (AOP) 00-05-06; and QA criteria specified in MSC-23333, *Environmental Quality Assurance Program Plan*. Near-facility environmental monitoring consists of both pre-operational monitoring surveys and operational monitoring. Pre-operational 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 environment and at inactive contaminated facilities, such as former waste storage and disposal facilities.

2.2 Pre-Operational Environmental Survey

Pre-operational characterization, assessment, and site evaluation are required by DOE O 436.1, Supp Rev. 0, *Departmental Sustainability,* and DOE M 435.1-1, *Radioactive Waste Management Manual*. 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 and 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 one year prior to construction of a disposal facility. Because much of the environmental data collected by monitoring programs are influenced by seasonal events, one year of data represents an absolute minimum for data collection for new disposal sites. Longer periods of baseline monitoring data collection extending to five 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 provides records for public information.

General guidelines for conducting a pre-operational 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*.

2.3 User Identification

Primary users of a pre-operational environmental survey may include:

1. The planning and construction organization (to demonstrate compliance with DOE O 231.1B, *Environment, Safety and Health Reporting;* DOE O 436.1, Supp Rev. 0, *Departmental Sustainability*; DOE O 451.1B, *National Environmental Policy Act Compliance Program*; and DOE M 435.1-1).
2. The facility operating and environmental restoration organizations (to show that containment systems for stored chemicals and waste remain adequate in compliance with DOE O 231.1B, *Environment, Safety and Health Reporting* DOE O 436.1, Supp Rev. 0, *Departmental Sustainability*; and DOE M 435.1-1).
3. The program staff (to provide adequate data for determining the need to modify the existing near-facility monitoring objectives and to determine effluent trends and environmental conditions).
4. Far-Field Environmental Surveillance Program may adjust or supplement monitoring locations if needed.
5. Legal counsel (to provide input to plaintiff requests and demonstrate regulatory compliance).
6. Regulatory agencies and the public (to verify compliance with laws and regulations and protection of the environment).

2.4 Survey Design

A pre-operational environmental survey is designed to monitor the media specified in DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*; and DOE/LLW-13Tg, *Environmental Monitoring for Low Level Waste Disposal Sites*. To assist in designing this survey, existing documents (e.g., unplanned-release reports, occurrence reports, operational and site environmental reports, historical photographs, environmental impact statements, and preliminary safety analysis reports) are reviewed.

Before initiating pre-operational 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 pre-operational monitoring is completed and analytical data are available, a final pre-operational environmental monitoring report is prepared (e.g., HNF-4401, *Preoperational Environmental Survey of the Project W-314 Pipeline*; and HNF-6150, *Preoperational Environmental Survey of the Spent Nuclear Fuel Project Facilities*).

2.5 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:

- 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:

- Monitoring inactive, existing, and new low-level waste disposal sites to assess radiological and non-radiological hazards (DOE O 435.1, *Radioactive Waste Managemen*t, 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, *Environment, Safety and Health Reporting*; DOE-HNBK-1216-2015.
- Monitoring and assessing environmental radioactive contamination and potential exposure to employees and the public (DOE O 231.1B, *Environment, Safety and Health Reporting;* DOE O 436.1, Supp Rev. 0, *Departmental Sustainability*; and DOE O 458.1, Chg 2, *Radiation Protection of the Public and the Environment*).

The primary justifications for near-facility environmental monitoring include:

- 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 2.1.

2.6 Review

The scope of near-facility environmental monitoring is reviewed by management and staff at least annually to ensure the 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 2.1. Governing Documents for Environmental Monitoring

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	*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, Supp Rev. 0	*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*
MSC-23333	*Environmental Quality Assurance Program Plan*
MSC-PRO-EI-15333	*Environmental Protection Processes*
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*

2.7 Design

2.7.1 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 2.2. A routine near-facility environmental monitoring schedule is developed, reviewed, and approved by MSA in corroboration with CH2M Hill Plateau Remediation Company (CHPRC) and Washington Closure Hanford LLC (WCH).

Table 2.2. 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, uranium, gamma
Soil	Annual	Strontium, plutonium, uranium, gamma
Vegetation	Annual	Strontium, plutonium, uranium, gamma
Animals	Annual	Strontium, plutonium, uranium, gamma
Thermoluminescent dosimeter	Quarterly	External radiation dose
Survey point	Annual	External radiation dose

2.7.2 Monitoring Locations

Information regarding specific sampling locations can be found in the annual *Hanford Site Environmental Surveillance Master Sampling Schedule*. The criteria for establishing monitoring locations for each sample type listed in Table 2.2 are as follows:

- **Air** – downwind, typically within 500 meters (1640 feet) 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 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); 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).

2.7.3 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 (American National Standards Institute [ANSI-N545-1975]; American Society for Testing and Materials [ASTM 1976]) standards. The following sampling methods are routinely used for near-facility environmental monitoring:

- **Ambient air** – Air sampling stations collect samples at a height of approximately 2 meters above ground level and use a vacuum pump to pull air through a 47-millimeter filter at a nominal flow rate of 0.057 cubic meters per minute (2.0 cubic feet per minute). A timer and flow-rate meter are used to determine sample time and flow rate, respectively. Filters are collected biweekly to prevent dust loading on the sample filter and impaired flows.
- **Soil** – Soil sampling equipment may be one of three types: a 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 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 MS). Three TLDs are placed at each measurement location at 1 meter (3.25 feet) 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.

Road surveys – 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 meter. 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 areas – Surveys at waste sites and other radiation areas may be conducted with vehicles equipped with radiation detection instruments or with hand-held 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*.

2.7.4 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, and uranium 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 is used to locate initial sampling sites to monitor the near-facility environment.

2.8 Quality Assurance

Quality assurance may be defined as the actions necessary to ensure the accuracy 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-23333).

Written operating procedures are an integral part of near-facility environmental monitoring QA. Procedures for field operations are provided in *Near-Facility Environmental Monitoring* (PSRP-DI-0611). The following briefly describes the essential components of the near-facility environmental monitoring QA program.

2.8.1 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.

2.8.2 Sample Replication

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

2.8.3 Data Analysis

Environmental data are reviewed to determine compliance with applicable federal and company guides. 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) and hard-copy printouts.

2.8.4 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. Samples are analyzed in accordance with prescribed procedures and quality control guides that meet the requirements of the ANSI-N545-1975 Environmental Measurements Laboratory (EML 1972); ASTM 1976; American Public Health Association (APHA 1980), and EPA (EPA 600/4-79-020).

3.0 EFFLUENT MONITORING

3.1 Introduction

Monitoring radioactive and nonradioactive effluents in air and liquid is conducted at the Hanford Site in accordance with federal and state monitoring requirements and technical guidance documents including DOE O 436.1, Supp Rev. 0, *Departmental Sustainability;* DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*; 40 CFR 61 Subpart H, *National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities*; WAC 246-247, *Radiation Protection – Air Emissions*; and site-wide permits issued by state agencies. *Hanford Site air emission sources are operated in accordance with the Radioactive Air Emissions License for the Department of Energy Richland Operations Office Hanford Site, License Number FF-01 issued by WDOH in 2012. The Washington Department of Ecology (Ecology)* is the permitting authority for the *Hanford Air Operating Permit* (AOP), which incorporates underlying regulations from Ecology, WDOH, and the Benton Clean Air Agency (BCAA). Ecology regulates the Hanford AOP as a whole and non-radioactive toxic and criteria air emissions, WDOH regulates radioactive air emissions, and Benton Clean Air Agency (BCAA) regulates asbestos *National Emission Standards for Hazardous Air Pollutants* (NESHAP) and outdoor burning.

Hanford Site prime contractors that generate effluents must have facility-specific procedures to ensure adequate control over and defensibly quantify the effluents for operational and reporting purposes. Emission units (stacks) are regularly inspected by state agency representatives to ensure sampling and emission abatement systems are operating properly, extracting representative samples, and maintained in accordance with periodic calibration and operational requirements. Currently, the Hanford Site has about 50 operating stacks that emit radioactive material to the ambient air. The radioactive material emitted from these stacks is filtered to the extent that concentrations of gross alpha and gross beta radiation at the point of release are frequently less than those measured at locations remote from the Hanford Site.

3.2 Radiological Effluents: Air and Liquid

Radiological effluents are monitored at the Hanford Site to quantify the amounts emitted and calculate the radiological does that could be received from Hanford Site operations. Radioactive air effluents are almost exclusively associated with point sources, known generally as stacks and vents, which are equipped with powered and filtered ventilation systems. A comprehensive sampling and analysis program ensures these emissions are representatively sampled and accurately characterized to ensure that operations are conducted so as not to pose an undue risk to human and environmental health. . Reporting requirements mandate calculation of dose to a hypothetical, maximally exposed individual (MEI) at an offsite location using a multimedia pathway assessment (DOE O 458.1). In addition, 40 CFR 61 Subpart H, *Radiation Protection, Department of Energy Facilities* and WAC 246-247, *Radiation Protection – Air Emissions*, require a yearly determination of compliance with the individualized dose standard of 10 millirem per year equivalent dose estimate (EDE). The outcome of this determination is published in annual reports for the Hanford Site, including the *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2014* (DOE/RL-2015-12), which includes summary data on stack emissions, as well as radon and fugitive radioactive emissions. The *Hanford Site Environmental Report for Calendar*

Year 2014 (DOE/RL-2014-52) presents fewer specific data but includes the overall releases and radiological dose association with those releases.

Minor sources of radioactive emissions include portable devices such as high-efficiency particulate air filters (HEPA)-filtered industrial vacuums, small moveable radioactive air emission units, and single large HEPA-filtered vacuums engineered into a truck.

Radioactive liquid effluents at the Hanford Site historically consisted of discharges to surface waters (i.e., the Columbia River) and to the ground. Discharges to ground largely ceased in the late 1990s. In March 2011, the last source of radioactive discharge to the Columbia River ceased. Only one radioactive discharge to ground continues, which is the State-Approved Land Disposal Site located in the 200 West Area. The single reportable radionuclide of measurable interest in this discharge stream is tritium and the usual annual total generally has been inconsequential in terms of its effects on human health and the environment.

3.3 Nonradiological Effluents: Air and Liquid

Prescribed methods of monitoring are applied to nonradioactive effluents, and the results are reported in accordance with regulatory requirements of the Clean Air Act, Clean Water Act, and state and local regulations. Analytical results are compared, as needed, against reportable quantities listed in 40 CFR 302.4, *Designation of Hazardous Substances*, and the list of hazardous/dangerous substances in WAC 173-200, *Water Quality Standards for Groundwater's of the State of Washington*. The principal goal of these regulations is to protect the public and the environment by eliminating and/or reducing, as much as reasonably feasible, environmental releases of any contaminants of Hanford Site origin.

Routine nonradioactive liquid discharges at the Hanford Site occur as a result of hydrotesting, construction, maintenance, industrial stormwater, and employee sanitary sewage. These discharges are routinely shipped to a treatment lagoon. Monitoring data from samples collected at these liquid discharge sites are evaluated to determine whether the effluents comply with applicable limits. The limits are imposed by permits, which require regular reporting via discharge monitoring reports.

3.4 Quality Assurance

Regulations and guidance documents, including DOE O 458.1, Chg 2, *Radiation Protection of the Public and the Environment*; DOE O 414.1D, *Quality Assurance*; 40 CFR 61, Appendix B Method 114; WAC 246-247; and DOE-HDBK-1216-2015 require a quality assurance program that covers environmental monitoring activities at the Hanford Site and is consistent with applicable elements of NQA-1 of the American Society of Mechanical Engineers.

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, Supp Rev. 0, *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 operations. Data also are collected to monitor several chemicals and metals with Hanford and non-Hanford sources in Columbia River water and sediment, and 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, 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 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; 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 facility effluent monitoring plans and the near-facility environmental monitoring program described in Section 2. The pathway analyses and radiological dose assessments, and the radiological dose assessments reported in the annual Hanford Site Environmental Report are taken from the dispersion data provided by the Meteorological and Climatological Services Project described in Section 5. The ecological monitoring and compliance assessment studies discussed in Section 6 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 8.

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, Supp Rev. 0, *Departmental Sustainability*; DOE O 458.1, Chg 2, *Radiation Protection of the Public and the Environment*; 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 the *Environmental Radiological Effluent Monitoring and Environmental Surveillance* guidance (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, Supp Rev. 0, *Departmental Sustainability*; DOE O 458.1, Chg 2; DOE O 431.1A; 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 *Environmental Radiological Effluent Monitoring and Environmental Surveillance* guidance (DOE-HDBK-1216-2015) indicates that subsidiary objectives for surveillance should be considered. Subsidiary objectives applicable to the Hanford Site include:

- Obtaining data and maintaining the capability to assess the consequences of accidents or occurrences that release contaminants to the environment.

- Providing public assurance; addressing issues of concern to government officials, regulatory agencies, Hanford Natural Resource Trustee Council, and other stakeholders including the public, local businesses, people or businesses considering relocating to the Hanford area, Hanford Site workers, and local American Indian Tribes.
- Enhancing public understanding of Hanford'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 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; hazards 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 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:

- Requirements in DOE O 436.1, Supp Rev. 0, *Departmental Sustainability* and DOE O 458.1, Chg 2.
- Requirements in DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*
- 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 objective criteria for determining the content of surveillance projects are provided in DOE-HDBK-1216-2015, Tables 5-1 and 5-2; and EPA 520/1-80-012, Section 7, Table 4.

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 background 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 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 3 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 Project are described in the environmental surveillance program Sampling Desk Instructions. 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-per-year 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 (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-23333).

Written operating procedures are an integral part of far-field environmental surveillance QA. Procedures for field operations are provided in PSRP-DI-001, *Environmental Surveillance Sampling.* As part of the project's QA program, selected sediment, surface water, food and farm products, wildlife, soil, and vegetation samples are provided to WDOH for comparative analyses. In addition, analytical laboratories reporting Hanford Site environmental data participate in managed QA and QC programs, such as the DOE Consolidated Audit Program (DOECAP), Mixed Analyte Performance Evaluation Program (MAPEP), EPA-compliant performance evaluation and proficiency testing studies, and laboratory performance intercomparison studies. These managed programs use standardized audit methods, processes, and procedures to ensure, on an annual basis, the validity, reliability, and defensibility of data from the contract laboratories.

4.3.5 *Reporting Levels and Comparison Values*

When concentrations of selected radionuclides are entered into the Hanford Environmental Information System (HEIS) database (http://ehs.hanford.gov/eda/), the computer compares them to threshold limits established by the project. Each concentration that does not meet the threshold limits is considered anomalous, and 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 project record.

Concentrations that require DOE-HQ notification also have been established for radionuclides in some media. 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 required by DOE O 458.1, Chg.2. All reporting levels provide early indications of conditions that might eventually require reporting to DOE-HQ as required by DOE O 458.1, Chg.2. Reporting levels are presented in Table 4.1.

Concentrations of chemicals in water samples are evaluated against comparison values, including the *Water Quality Standards for Surface Waters of the State of Washington* (WAC 173-201A) and EPA's *Toxics Criteria for those states not Complying with Clean Water Act* (40 CFR 131.36). 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 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 Project 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.

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, Rev. 3) 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 and exposure assessment, and the biota dose screening evaluation, serve as the bases 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, and 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 a 50-mile (80-kilometer) radius of the 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 Hanford 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 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 re-evaluations may be needed during the year to respond to changing operations or environmental conditions. Key steps in the process include:

- 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 and effluent information (e.g., DOE/RL-2015-12) and environmental surveillance results from the previous calendar year. The pathway analysis serves as the basis for the design review.
- Producing the Hanford 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. Resources useful in anticipating future environmental surveillance needs include the *Record of Decision for the Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, and Ecology et al. (1989), various contractor effluent and operational environmental monitoring plans, results from previous years' monitoring, and periodic technical exchanges between the environmental monitoring, *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) cleanup and risk assessment, and environmental surveillance personnel working for the various site contractors.
- 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. Plans for future years are discussed with appropriate Hanford Site contractors to ensure assumptions in surveillance design availability of related monitoring data are valid and to determine whether recent data indicate conditions or trends that must be considered in the design. The results of this annual surveillance design evaluation, and any actions taken in response to the evaluation, are documented in the project files and in updates to the project documentation package and the environmental surveillance annual sampling schedule (e.g., DOE/RL-2013-053, *Hanford Site Environmental Surveillance Master Sampling Schedule*). Plans for the upcoming calendar year are discussed with other contractors to coordinate related activities, including site accessibility and restrictions, and potential modification to utilities. Plans also are discussed with representatives from the WDOH to identify those samples to be collected by environmental surveillance personnel and provided to the WDOH.
- 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 a few 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.

- Preparing a project documentation package for the next fiscal year – Specific surveillance objectives, work scope, and budget are provided in the project-specific documentation package written for the upcoming (next) fiscal year. The package sets forth the plans and organization that will be used to conduct, control, and document project activities and represents an agreement between the DOE and the PSRP program about the objectives, scope, and work to be performed during that fiscal year.
- 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 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 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:

- 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 public and worker exposures, and contamination of the environment, through measurements of actual and potential emissions to the air from facilities and areas with surface contamination and buried waste.
- 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's radioactive AOP (#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 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 (2.0 cubic feet per minute). 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 2.0 cubic feet per minute. The cartridges have a 2.5-centimeter bed depth and have a nominal exposure period of 28 days.

Samples for tritium analysis are collected on silica gel. Airflow rates (190 milliliters per minute), 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 by the laboratory using the average initial and final 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 beta to provide an early indication of any unplanned contaminant release that may require expedited analysis of samples and/or additional or special sampling. For the same reason, some particulate samples are analyzed for gross alpha. Biweekly filter samples from a single location or from multiple locations are composited for quarterly analysis (gamma emitters, uranium isotopes, plutonium isotopes, strontium-90) to track trends that are not likely to be detectable by the gross activity measurements. Radiochemical analyses of filters are performed quarterly to provide data to estimate or bound the human annual dose standards.

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. These monthly samples are composited and analyzed quarterly.

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. Far-field samplers generally are placed outside of building wake zones, away from vegetation and usually on flat terrain. Sampling inlets are located 2 meters above the ground to provide measurements representative of radionuclide concentrations inhaled by humans.

Site-Wide. Air samplers primarily are located around the operational areas to maximize the amount of radiological material collected. The current sampling locations were 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 trade-off with the goal of measuring the maximum exposure.

Perimeter. Sampling stations are located at the perimeter of the 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 kilometers upwind from the site is sampled routinely. Samples from this reference location are analyzed for all the radionuclides identified in the Analyte Selections Section4.6.6.2. Information about individual sampling locations can be found in the annual Hanford Site Environmental Surveillance Master Sampling Schedule (e.g., 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 51 miles (82 kilometers) 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, including 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 (Fitzner/Eberhardt Arid Lands Ecology Reserve) Unit of the Hanford Reach National Monument. Riverbank seeps (i.e., groundwater discharge) occur along the Hanford shoreline of the Columbia River as well. Other surface waters include the Fast Flux Test Facility (FFTF) process water ponds, 200-East Area retention water ponds, and offsite irrigation systems that use Columbia River water obtained immediately downstream of the Hanford Site.

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 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 and 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 will be 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:

- 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 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.

Onsite ponds, while not directly accessible to the public, are used by migratory waterfowl and wildlife. Onsite ponds are 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. Most constituents that have been documented to be consistently below measurable levels have been removed from the sampling schedule. Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each medium.

Radionuclides monitored in water samples can include gross alpha, gross beta, selected gamma emitters (gamma scan), tritium, isotopic uranium, strontium-90, technetium-99, iodine-129, plutonium-238, and plutonium-239/240. Gross alpha and gross beta measurements provide a general indication of radioactive contamination. Gamma scans provide the ability to monitor for numerous specific gamma-emitting radionuclides, including cobalt-60, ruthenium-106, antimony-125, cesium-137, and europium-152 and europium-154, as well as others. Radionuclides of interest are selected based on their importance in verifying the effectiveness of effluent control and monitoring systems, and in determining 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 Project sampling desk instructions. 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 semi-annually or annually along cross sections at transect and near-shore 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. Samples are collected according to an established sampling schedule (e.g., DOE/RL-2013-53).

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 group(s).

Priest Rapids Dam is located approximately 8 kilometers upstream of the site boundary and 20 kilometers 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 kilometers upstream of the 100-B/C Area.

The Richland Pumphouse is located approximately 4 kilometers downstream of the Hanford Site boundary and approximately 5.5 kilometers downstream of the effluent discharge farthest downstream. It is operated by the city of Richland and is the first downstream point of river water withdrawal for a public drinking water supply. The Environmental Surveillance Project water sampling station is located on the city of Richland’s drinking water supply intake structure on the Benton County shoreline. The structure’s water intake is located approximately 9 meters into the river.

Transect and near-shore surface water sampling is conducted near the Vernita Bridge, 100-N Area, Hanford Townsite, 300 Area, and Richland Pumphouse. Transect sampling is performed to determine the distribution of contaminants across the river at these locations. Near-shore and transect sampling are 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

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, and anions. Analyte selection is reviewed annually as part of the Master Sampling Schedule planning for each medium.

Sampling Methods. Samples are typically collected using a hand pump or 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 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 desk instructions.

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

Sampling Locations. Riverbank seep samples are collected along the shoreline of the 100-B/C Area, 100-K Area, 100-N Area, 100-D Area, 100-H Area, 100-F Area, 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

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

Sampling Methods. Grab samples are collected and care is taken to avoid surface debris and resuspension and inadvertent collection of bottom sediments. Specific sampling methods are documented in the Environmental Surveillance Project sampling desk instructions.

Sampling Frequency. Samples are collected quarterly or semi-annually 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 site facilities, and radionuclide concentrations are influenced by the local groundwater.

4.7.6 Offsite Irrigation Water

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

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

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

Sampling Locations. Samples are collected from two irrigation water supplies that obtain water from the Columbia River downstream 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 re-suspended 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:

- Verifying that 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 (e.g., 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 sediment contaminant concentrations in sediment are most likely to be encountered in areas that contain deposits of fine-grained materials, such as 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. Effluent discharge reports are reviewed to identify contaminants of potential concern currently entering the river. Groundwater monitoring reports and remedial investigation studies (e.g., 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 gamma-emitting radionuclides (gamma scan), strontium-90, and 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 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 typically is not done when the sampling location is underwater. Samples at riverbank seeps are collected with a hand-held ladle. Specific sampling methods are documented in Environmental Surveillance Program sampling desk instructions.

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 core samples characterize the fate and buildup of contaminants in river sediment over time. Commensurate with findings of past core-sampling activities and in consideration of future activities that may resuspend and redistribute contaminants sediment core 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 river-wide 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 the influence of Hanford Site liquid effluent and groundwater discharges) behind Priest Rapids Dam. Samples are collected downstream of the Hanford Site at Richland and behind McNary Dam (the nearest downstream impoundment). Samples are collected behind each dam. 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.

In addition to the routine sediment sampling, sediment core 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 core 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, but it is influenced by precipitation and changing water-table elevations that are related to discharges of water to the ground in the 200 Areas. The pond has a small amount of standing water in the winter 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

Sediment is collected at West Lake because high suspended-sediment loading makes water analyses difficult for some radionuclides; therefore, the surveillance of these radionuclides has been shifted from water to sediment.

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 medium.

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 desk instructions.

4.9.1.4 Sampling Frequency

Samples are collected and analyzed semi-annually.

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 products) 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 with Hanford effluent. 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 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 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:

- 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 annual Hanford 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 and data quality objectives are reviewed annually, and 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 food and farm product media routinely monitored are described below.

- 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 site.
- Farm produce – Fruits (e.g., apples, grapes, cherries, tomatoes), vegetables (potatoes), and leafy vegetables are collected seasonally at locations around the site perimeter. Specific crops are collected by area, and not all areas yield the same types of produce.
- Alfalfa – Samples of fresh alfalfa are collected from one upwind reference location and three locations adjacent to the Hanford Site perimeter.
- Wine – Red and white wines produced from grapes harvested at vineyards located around the 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 Hanford Site effluent and emissions; 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 strontium-90 and gamma emitters (including cesium-137). Some samples (milk, wine, tomatoes) also are analyzed for tritium. 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 for milk, which is routinely collected at the same locations. Perishable agricultural samples, such as milk, are kept on ice in a cooler with a temperature blank and/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 desk instructions.

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 effluent and emissions. Specific products are sampled in alternating years or on a 3-year cycle as indicated in annual sampling schedules (e.g., DOE/RL-2013-53). Milk samples are collected and analyzed quarterly for some contaminants and semi-annually for others.

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 site facilities, DOE-HDBK-1216-2015.

Food and farm products are sampled from established sampling areas around the Hanford Site. Areas to the east of the site are considered downwind locations. Areas to the west of the 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 or upstream of, 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 site be sampled to document levels of potential contaminants. The collection of certain species with small home ranges that live near operating and cleanup areas on the Hanford Site assists 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 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:

- 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 annual Hanford Site Environmental Report).
- Monitoring the occurrence and accumulation of long-lived radionuclides and trace metals in fish and wildlife tissues.
- Evaluating radionuclide concentrations and associated exposure to key wildlife near onsite operational areas to determine the degree of risk to biological resources.

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 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, and 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:

- Aquatic biota – Whitefish historically have been sampled because of their value to recreational fishing and their propensity to accumulate radionuclides; however, carp, sturgeon, and bass also are sampled. For human dose assessment purposes, two sample types are obtained: edible muscle and offal (i.e., the eviscerated remnants including the head, skin, fins, and bones). 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 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 strontium-90, which accumulates in bones, and gamma emitters, specifically cesium-137, which accumulates in muscle tissues. Some fish samples are analyzed for uranium; selected deer, elk, and rabbit samples may be analyzed for plutonium. When sampled, livers are analyzed for metals, and some fish are analyzed for mercury. Onsite cleanup and 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 desk instructions. 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. Tissue samples must be kept free of dirt because contaminant levels in the soil can impact concentration measurements in the tissues. 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 (CVAA) 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) or every third year (triennially). 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 site, and concerns about contaminants in the Columbia River.

4.11.2.5 Sampling Locations

Routine fish and wildlife samples are collected offsite at locations that are likely to have the highest concentrations of Hanford Site contaminants (i.e., locations downwind or downstream of 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 or upstream of, or distant from, the Hanford Site. Reference samples are collected from areas expected to receive approximately the same contribution of fallout radioactivity (i.e., similar elevation, precipitation regime) as 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 site, demonstrate a climate proximal to the site, and are generally upwind of Hanford 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 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 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 Hanford. Samples of soil and vegetation also are collected from distant locations to help determine reference levels.

4.12.1 Objectives

The objectives of soil and vegetation surveillance include:

- 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 annual Hanford 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 accumulation of long-lived 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 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, and 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 centimeters. 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, americium-241. These radionuclides have relatively long half-lives and are indicative of past site operations. Onsite cleanup and remediation activities and special studies may require analyses for specific contaminants. Metals and organics (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 centimeters deep and 11 centimeters 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).

4.12.2.4 Sampling and Analysis Frequencies

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 are likely to have detectable concentrations of Hanford Site contaminants (i.e., locations downwind or downstream of 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 or upstream of, 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 a 50-mile (80-kilometer) radius of Hanford Site operations areas. These quantities provide a way to uniformly express the radiological dose, regardless of the type or source of radiation or the means by which it is delivered. This section describes how doses are calculated.

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) as described in Section 3, Effluent Monitoring. 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)—which 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 (Rosnick 2007) 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, 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 requirements for demonstrating compliance with the public dose limit of 100 millirem (1 millisievert) total effective dose in a year.

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, Rev. 3; PNNL-14584; PNNL-19168; and PNNL-13421). Parameters used with the CAP88-PC software are documented in the current User's Guide (Rosnick 2007).

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 DOE O 458.1 Section 4.2.1)
  - 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 1) relative contributions of the different operational areas to radioactive emissions released to the air, 2) contribution of radionuclide releases to the Columbia River from Hanford Site facilities, and 3) year-to-year differences in meteorology affecting wind dispersion. Based on experience since 1990 from environmental transport modeling and environmental surveillance monitoring, four locations have been considered as the MEI location: 1) Riverview, across the Columbia River from the city of Richland; 2) Ringold, along the Columbia River 16 miles (26 kilometers) east of separations facilities in the 200 Areas; 3) Sagemoor, approximately 0.87 mile (1.4 kilometers) directly across the river from the 300 Area; and 4) Horn Rapids, an industrial area just south of the Hanford Site boundary.

The potentially significant exposure pathways considered to identify the location of the MEI include:

  - 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 r, including boating, swimming, and exposure to sediments during shoreline activities.

- Collective dose to the population residing within 50 miles (80 kilometers) of Hanford Site operation areas (Section 4.2.2)

- Fifty-Mile (Eighty-Kilometer) Collective Population Dose (person-rem [person-sievert]) – Collective dose is defined as the sum of doses to all individual members of the public within a 50-mile (80-kilometer) radius of Hanford Site operating areas (100, Area, 200 Area, 300 Area, and 400 Area)(DOE O 458.1, Chg.3, Section 4.e([d]). 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, and 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, *National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities* (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 individuals 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:
        - 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 (Section 4.2.4.1)

- Dose to a worker consuming drinking water on the Hanford Site (Section 4.2.4.2)

- Doses from non-DOE industrial sources on and near the Hanford Site (Section 4.2.5)

- Absorbed dose received by biota exposed to radionuclide releases to the Columbia River and to radionuclides in onsite surface water bodies (Section 4.2.6)
    - 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 per day for aquatic biota or 0.1 rad per 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 according to the Master Sampling Schedule media collection (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.

4.13.1.2 Population Distribution and Atmospheric Dispersion

Geographic distributions of the population residing within a 50-mile (80-kilometer) radius of the four Hanford Site operating areas are based on 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.

4.13.1.3 Terrestrial and Aquatic Transport Pathways

Important parameters affecting the movement of radionuclides within potential exposure pathways, such as irrigation rates, growing periods, element-specific transfer factors, and similar parameters are provided in the annual Hanford 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 activities are compared to nuclide-specific biota concentration guides for the limiting receptor for each medium (Table 4.2).

4.13.1.4 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 annual Hanford Site Environmental Report.

4.13.2 Dose Calculation Documentation

Dose calculation is performed using approved models, as identified above. The numerous exposure and transfer factors used for pathway and dose calculations have been documented in GENII Version 2.10 (PNNL-14583, Rev. 3; PNNL-14584; PNNL-19168; and PNNL-13421). Parameters used with the CAP88-PC software are documented in the current User's Guide (Rosnick 2007). 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 primarily achieved through the use of the HEIS database. The HEIS database provides computer-based access to Hanford Site environmental data and is used to manage the data generated by the ongoing sampling efforts on and around the Hanford Site. HEIS is available online at http://environet.hanford.gov/eda/.

4.14.1 Objectives

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

- Managing data in a manner that ensures their timely collection, verification, and reporting in accordance with an annual sampling schedule (e.g., DOE/RL-2013-53) and their traceability from scheduling to archiving in the HEIS 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.

4.14.2 Data Management Overview

The HEIS database is used as a repository for data gathered during environmental monitoring and cleanup activities at the Hanford Site. It is intended to provide current and consistent data to its users. The system and its data are accessible by all Hanford Site personnel. The components of HEIS are a database, data entry screens, and tools to access the data. The HEIS database is implemented using current industry standards, including a UNIX operating system, an Oracle database management system, Microsoft Access® software (data entry screens), and a structured query language (reports and queries). The HEIS computer is managed by the CH2M Hill Plateau Remediation Company Environmental Data Management organization.

In accordance with an annual sampling schedule (e.g., DOE/RL-2013-53), the data management task leader generates sample identification labels and chain-of-custody forms weekly. The data management task leader also generates laboratory composite sheets to identify individual samples that are combined to form composite samples. Analytical results are provided by the laboratories and reported in both electronic and hard copy formats. The laboratories directly upload the results into HEIS. A tool is then used to generate various status and result reports for project personnel review to ensure prompt identification of unusual results.

4.14.2.1 Sample Scheduling

The Environmental Surveillance Project, PSRP staff and managers revise the annual sampling schedule (e.g., DOE/RL-2013-53) to meet monitoring needs each calendar year. The sampling locations, sample types, sample analyses, and frequencies of collection are identified and documented in the annual schedule. In accordance with the annual schedule and availability of samples, labels and forms are created and sample and data tracking are initiated weekly.

4.14.2.2 Sample Collections

When a sample is collected, a chain-of-custody form is completed, and a sample identification label is attached to the sample container. The sample identification label identifies the type of sample (i.e., air, water, biota, soil, sediment), sample identification number, collection date, and analyses required. The chain-of-custody form identifies the samples to be collected on a given day and includes the sample type, sample identification number, sampling location, and collection date for each sample. The chain-of-custody form accompanies samples to the analytical laboratory where they are relinquished into the custody of laboratory personnel. The completed chain-of-custody form (or in some cases, a copy of the form) is returned to the environmental surveillance data manager and becomes a permanent project record verifying sample collection and delivery to the analytical laboratory. Sample collection and handling procedures are contained in the Environmental Surveillance Project sampling desk instructions.

Each month or quarter, depending on the sample type, composite sheets that identify individual samples to be combined to form composite samples are generated. These sheets are forwarded to the analytical laboratory responsible for compiling the composite samples.

4.14.2.3 Tracking Sample Collections

The HEIS database is capable of tracking samples from the time the sample labels are produced until sample results are entered into the database. This allows for accountability of sample collection and sample analysis. After the sample is collected, the collection date is entered into the database, satisfying the sample collection portion and allowing the laboratory to upload the analytical results.

4.14.2.4 Loading Data into the Database

The contract laboratories report analytical results electronically and on hard copy. The electronic results are loaded into the HEIS database, and those not received electronically are manually entered and verified against the hard copy report. The hard copy reports are considered to be the record copies and are stored in the project files.

4.14.2.5 Reporting of Analytical Data

Samples are analyzed for the constituents identified on the sample label, which can include radiochemical or chemical analyses. Results are reported in association with a 2-sigma overall propagated uncertainty. In the case of radiochemical results, a 2-sigma counting uncertainty also is reported. Data are reported electronically or on hard copy and are entered into the database. The minimum required data that are stored in the HEIS database include:

- Sample identification number
- Sampling location
- Sample collection date
- Analytical laboratory
- Analysis
- Analytical result
- Unit for the analytical result
- Sample volume
- Comments, as appropriate

4.14.2.6 Data Verifications

As radiochemical results are entered into the database, several mathematical tests (verifications) are performed to determine whether selected results are within the range of established limits. The tests and supporting data include:

- Test 1: Was the required detection level met?
- Test 2: Was the low limit exceeded?
- Test 3: Was the high limit exceeded?
- Supporting Data Statistics A: The new result is compared to the maximum, minimum, and average of the last 10 results for this same sample type for this sampling location.
- Supporting Data Statistics B: The new result is compared to the maximum, minimum, and average of results for this same sample type at all locations for the previous 12 months.

As data are collected, the results are compared to previous results to help identify unusual measurements that require investigation or further statistical evaluation. If the result is unusual and fails any of the above tests, it is considered an anomaly and a one-page ADR is generated.

Outliers can represent a true extreme value or can indicate errors in sample collection, preparation, measurement, or equipment malfunctions. To assist the media task leader in determining the value of a questionable result, the contract analytical laboratory may be asked to perform a data recheck, which consists of reviewing the calculations, aliquot size, yield, counter background, counting efficiency, and other data pertinent to the reported analytical results; perform a recount of a sample by recalculating the concentration of the radionuclide in question; or perform a re-analysis of the preserved unused portion of a sample. Following these investigations, the task leader, with the approval of the project manager, decides how to handle the suspect datum. These decisions are documented on an ADR, which becomes a permanent record in the project files.

4.14.2.7 Tracking Sample Analyses

To aid in the tracking of sample analyses, a maximum turnaround time for reporting results is established with the analytical laboratory. This turnaround time, coupled with the sample submission date, provide a projected due date for the results from each analytical test ordered. If no result has been reported by the projected due date, the data management task leader generates a 'late results' report and may contact the analytical laboratory for a projected report date for the late result. An outstanding result will continue to appear on the late results report until the result is received and the accountability record has been completely satisfied.

4.14.2.8 Data Retrievals

One of the primary reasons for using a data management system is to store data and provide efficient and easy access to the thousands of analytical results obtained each year. The HEIS database contains Hanford Site environmental surveillance analytical data back to 1971, which can be retrieved by using Microsoft Access® software.

4.14.3 Database Security

The HEIS database uses auto-archiving to prevent the loss of data because of fire, power failure, or other causes. The archived file can be used to recover from equipment failures that may occur during operational hours. Lockheed Martin Information Technology performs a nightly backup of the HEIS database. In the event of a major system failure, a backup system would be available within 24 hours of the failure.

4.14.4 Quality Assurance

Records of data and other information developed during the operation of the HEIS database are controlled and managed in compliance with the requirements in a project QA plan, which conforms to the requirements of *Quality Assurance* (DOE Order 414.1D) and *Nuclear Safety Management* (10 CFR 830.120). HEIS database integrity is ensured through the use of rules and constraints, which are automatically executed when data are entered into the database.

4.14.5 Data Analysis and Statistical Treatment

Analytical results are reported and recorded with estimates of their uncertainty. The database contains the results as reported by the analytical laboratories, including negative results and results that are less than the estimated quantitative detection limits.

Data contained in the database vary in sample type (i.e., air, water, biota, soil, sediment), and any subset of data of a given sample type may or may not fit probability distributions typical of that type for a variety of reasons (e.g., sample size, mixed populations).

Parametric or non-parametric statistical tests to determine concentration differences and contaminant effects are based on sample size, distributions of the particular sample set being tested, and the hypothesis being tested.

Tests for precision and accuracy are addressed in the subsection entitled Quality Assurance and Quality Control in Section1.15.3.

4.14.5.1 Analytical Protocol

Laboratory analytical methods are specified in contracts with the laboratories and are performed according to appropriate standard methods. The analysis of air samples are performed according to

40 CFR 61, Subpart H, *National Emissions Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities*; 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, 1993]), or other methods, as approved.

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 also is important to maintain and document appropriate methodology to ensure control and legitimacy of project documentation. All components of the surveillance project 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. This subsection describes 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 *Environmental Quality Assurance Program Plan* (MSC-23333) and the PSRP QA plan. 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. DOE O 414.1D requires that QA plans be developed and documented and recommends the judicious and selective application of appropriate and recognized standards. The DOE order 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-23333) and a project-specific QA plan 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 project activities and procedures to ensure compliance with project, and DOE QA/QC requirements. The DOE-RL program manager and PSRP project 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 project 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 project-specific QA 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 participate in analytical QC programs that are used to determine analytical precision and accuracy, and to verify that the laboratories are operating according to contractually approved procedures or to procedures included in their statement of work. The project QA task leader generates periodic reports (monthly or quarterly) to summarize intra-laboratory QC data and performance. The media task leaders review these reports, along with the applicable minimum detectable concentrations and method detection limit determinations, and 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).

In addition to each laboratory's internal QC program, these laboratories participate in EPA 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 EPA or DOE for comparison and evaluation. The results of the comparisons and evaluations are provided to the project QA task leader.

The contracted analytical laboratory participates in two national comparison studies. The contracted laboratory is required to analyze applicable radionuclide-media samples from the DOE Mixed Analyte Performance Evaluation Program operated by the Radiological and Environmental Sciences Laboratory, and EPA Environmental Radioactivity Laboratory Intercomparison Studies Program. Additional QC data are generated by sending split or collocated duplicate samples to the DOE and EPA comparison laboratories and to other laboratories (i.e., WDOH), and challenging the contracted laboratory with spiked (blind) reference samples. The spiked (blind) reference samples are used to evaluate the capabilities of the contracted laboratory in important radionuclide-media pathways and in historically weak analytical areas. Reference sample materials are obtained from the National Institute of Standards and Technology (NIST), 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).

Radiological Analyses. Most intra-laboratory QC programs include analyzing blanks, replicates, and NIST traceable spiked samples (which must comprise no less than 15% of all ordered tests) and maintaining data that validate determinations of current minimum detectable concentrations. Quarterly reports are generated by the project QA task leader to summarize intra-laboratory QC data and performance.
Data accuracy (precision) requirements for internal analytical QC programs are addressed in the section Analytical Accuracy and Precision Criteria in Section 4.15.34-38.

Performances on blind samples (split or spiked) are evaluated by project QC technical support personnel and reported to project management. These reports are reviewed by management and task leaders and corrective actions (e.g., follow-up audits) are taken if necessary.

Chemical (Non-Radiological) Analyses. The analytical laboratories are evaluated by submitting blank and replicate samples, matrix-spiked and matrix-spiked duplicate samples and laboratory control samples for analysis. The analytical laboratory reports the data from these evaluation samples along with the data from the surveillance samples.

Additional QC data may be generated by sending split, or collocated samples to the intercomparison program analytical laboratories as well as to other laboratories (i.e., WDOH) and challenging the laboratory with spiked (blind) reference samples. Reference materials for spiked samples are obtained from NIST, DOE, EPA, or other sources that have proven reliability and accountability.

Performances on blind-split or spiked samples are evaluated by project QC technical support personnel and an evaluation report is prepared and provided to project management. These reports are reviewed and corrective actions (i.e., follow-up audits) are taken if necessary.

4.15.3 Analytical Accuracy and Precision Criteria

Data-accuracy criteria for radiological samples require that the analytical results for 95% of spiked samples be within 20% to 30% of the known spike values (Table 4-3).

Precision requirements are met when replicate sample results (above detectable concentrations) fall within ±30% relative percent difference for water samples and within three standard deviations for all other media samples.

The accuracy and precision of analytical results are assessed by analyzing spikes, blanks, and replicate samples. Such samples comprise no less than 15% of all ordered radiochemical tests.

For non-radiochemical tests ordered, QC criteria are defined in the Chemical Analysis in Section 4.15.2.2. Spikes and blanks are included in each batch of samples. Spikes have, insofar as possible, the matrix, volume, and other relevant characteristics of the actual samples being analyzed. Blanks are matrix or reagent blanks. Reagent and sample media blanks will be analyzed with each batch of samples.

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.

DOE O 458.1, Chg 2 covers information regarding records and retention of records associated with releases of radioactive materials to the environmental and their 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, *Environment, Safety and Health Reporting*:
  - Assures timely collection, reporting, analysis, and dissemination of environmental information.
  - Requires the preparation of the annual Hanford 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 annual Hanford 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 site and surroundings.
  - Requires the reporting of unusual, off normal or emergency occurrences that occur on the 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, *Radiation Protection of the Public and the Environment*:
  - 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, or 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 annual Hanford 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 per year, depending on the media, assuming that the condition persisted for an entire year. Dose-based reporting limits used by the Environmental Surveillance Project are shown in Table 4.1.

Table 4.1. Far-Field Environmental Surveillance Project Dose-Based Reporting Limits [a,b,c]

Sample	Tritium	C-14	Co-60	Sr-90	Tc-99	I-129	Cs-137	Eu-152	Eu-154	Eu-155	U-234	U-235	U-238	Pu-238	Pu-239/240	Am-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	0.1	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	0.1	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	0.1	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 fresh wt)	3.2E+01	1.9E+00	2.0E+00	2.2E-01	2.1E+01	0.1	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)	2.8E+01	2.1E+00	3.5E-01	3.9E-02	1.9E+00	1.1E-02	9.2E-02	8.5E-01	6.0E-01	3.7E+00	5.0E-02	5.0E-02	5.0E02	5.2E-03	4.8E-03	6.0E-03
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/year 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.

	320.3571	144.361	98.27496	135.5816	113.04832	145.72635	156.5655	129.2669	120.435	111.76368	133.76314	136.86624	145.742625	138.50025	140.5075	136.493

Key Pathway-Specific Exposure Assumptions.
Air: Based on 16.3 m3/day inhalation rate (EPA/600/R-09/052FF, 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 days/year.
Milk: Based on 95th percentile ingestion rate for children ages 1 to <6 year (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.
Fruits: 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: 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/600/R-09/052F, Table ES-1).
Soil: Based on inadvertent ingestion (100 mg/day; EPA/600/R-09/052F, Table ES-1) and external radiation (350 d/year) 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 hours/day and 60 day/year; Casual User recreational scenario, DOE/RL-2007-21, Rev 0, Volume II) exposure pathways.
Fish: Based on Native American fish ingestion rate of 620 g/day (Confederated Tribes of the Umatilla Indian Reservation scenario, DOE/RL-2007-21, Rev 0, Volume II).
Seep Water: Based on published DOE Concentrations Standards; Table 5 of DOE-STD-1196-2011. These standards use a 100 mrem/yr dose threshold.

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. Precision Requirements for Radiological Analyses

Type of Analysis	Precision
Gamma Spectrometry	±20%
Liquid Scintillation	±20%
Liquid Scintillation with chemical separation	±30%
Alpha Spectrometry	±25%
Beta Proportional	±30%
Alpha Proportional	±30%
Uranium total, fluorimetry or phosphorimetry	±30%
Uranium isotopic, gamma (low-energy photon spectroscopy)	±30%

5.0 METEOROLOGICAL MONITORING

5.1 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, Supp Rev. 0, *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:

- 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, Supp Rev. 0, *Departmental Sustainability;* and DOE-HDBK-1216-2015.

5.2 Meteorological and Climatological Services Project

The Mission Support Alliance (MSA) Meteorological and Climatological Services Project provides the Hanford Site DOE 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 project responds to Hanford Site needs through a program that includes:

- Extensive data acquisition through a site-wide 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.

5.3 Meteorological Monitoring Network

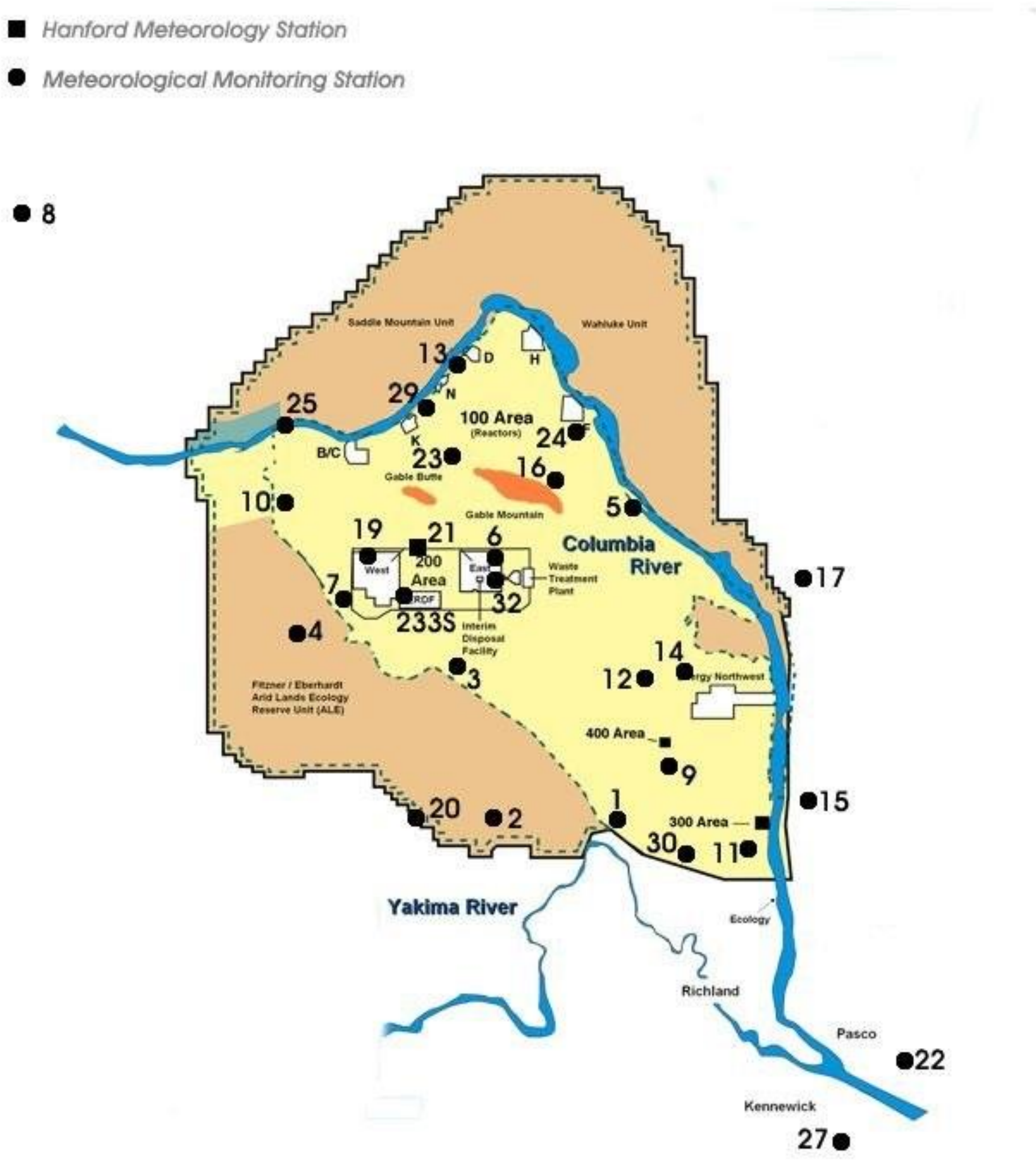
The Hanford Site covers an area with significant variations in topography and with elevations ranging from approximately 100 to nearly 1,100 meters above sea level. To characterize the meteorological conditions on and around the Hanford Site, 28 monitoring stations have been installed on and near the site (Table 5.1 and Figure 5.1). 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 and diffusion modeling, and site characterization.

Table 5.1. Hanford Site Meteorological Monitoring Towers

Site No.	Site Name	Tower Height, m	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
12	Wye Barricade	9.1	WS, WD, T, P
13	100-N Area	61	WS, WD, T, TD, DP, P, AP, RH, WBGT
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	200-West (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
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, AP, RH
30	HAMMER	9.1	WS, WD, T
31	200-West (233-S)	9.1	WS, WD, T
32	200-East (Integrated Disposal Facility)	3.0	WS, WD, T

AP = Atmospheric pressure.
DP = Dew-point temperature.
RH = Relative humidity.
P = Precipitation.
S = Solar Radiation.
ST = Subsurface soil Temperature
T = Temperature.
TD = Temperature difference.
WD = Wind direction.
WS = Wind speed.
WBGT = Wet Bulb Global Temperature.

Figure 5.1. 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:

- 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-meter tower, located at the HMS, has instruments at multiple levels to measure wind speed and direction and temperature. This tower has been used to collect data since the mid-1940s. Three 61-meter 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-five 9.1-meter towers have instruments for wind speed and direction (at 9.1 meters) and temperature (at 1.5 meters), and one 3.0-meter tower has instruments for wind speed and direction (at 3.0 meters) and temperature (at 1.5 meters). Most stations also record precipitation.

5.3.1 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-meter level at most meteorological monitoring stations, at the 3-meter level at the tower at Station 19, at the 25- and 60-meter levels on the three 61-meter towers onsite (see Table 5.1), and at the 15.2-, 61.0-, and 121.9-meter levels on the 124.3-meter tower at the HMS.

Wind speed at most monitoring stations (except Station 20, see Figure 5.1) 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 meters per second 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 5.2:

Table 5.2. Wind Speed Sensor Specifications by Station Number

Station	Sensor Specifications	Wind Speed
All Stations except 20	Threshold Operating range Accuracy	0.22 meter per second 0 to 56 meters per second 0.07 meter per second or 1.0%, whichever is greater
Station 20	Threshold Operating range	1 to 2 meters per second 0 to 90 meters per second (gust survivability to 90 + meters per second)

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 Table 5.3.

Table 5.3. 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 meter per second 0 to 360 degrees ±2 degrees 0.4 at 10 degrees initial angle of attack 1.1 meters
Station 20	Threshold Operating range Accuracy	1 meter per second 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 meters at all of the monitoring stations, with additional measurements at the 10- and 60-meter levels (for measurement of ΔT for atmospheric stability designation) at the three 61-meter monitoring stations (see Table 5.1). Temperature is measured at the 0.9-, 9.1-, 15.2-, 30.5-, 61.0-, 76.2-, 91.4-, and 121.9-meter levels on the 124.3-meter tower.

The temperature sensor (on all but the 124.3-meter 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-meter monitoring stations have naturally aspirated radiation shields, and the three 60-meter stations have mechanically aspirated shields. The thermistor temperature sensor specifications are given below:

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

On the 124.3-meter tower, temperatures are measured using a platinum resistance temperature device contained in a 15-centimeter-long stainless steel housing mounted in a mechanically aspirated radiation shield. The platinum resistance temperature sensor specifications are given below:

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 0.5, 15, and 36 inches. The same sensors are used as on the 124.3-meter tower (described in the preceding paragraph).

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-meter tower is made using the difference between actual temperatures measured at the 61- and 9.1-meter levels of the tower. At the three 61-meter monitoring stations, the ΔT calculation is made using the difference between actual temperatures measured at 10 and 60 meters. The temperature sensors used are discussed above in the Temperature paragraph.

Dew-Point Temperature. At the HMS, a hygrothermometer system is used to measure the dew-point temperature. The monitor is located 1.5 meters above the ground and uses a chilled mirror system to monitor the dew point. The specifications for the hygrothermometer are the following:

Operating temperature	-50°C to +50°C
Relative humidity	5% to 100%
Ambient temperature	±1°C from -50°C to 50°C accuracy
Dew-point accuracy	±1°C when less than 0°C.

Relative Humidity. Relative humidity at Stations 6, 9, 11, 13, 20, and 28 is measured at the 1.5-meter level of the 9.1-meter tower. The Humicap® 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.

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.

Precipitation. Precipitation measurements, using recording rain gauges, are made at 23 of the 30 monitoring stations. Each rain gauge has an opening 20 centimeters 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 millimeter and are accurate to 0.5% for a rainfall rate of 12.70 millimeters per hour.

Atmospheric Pressure. Atmospheric pressure is measured at the 1.5-meter level at the 10 sites indicated in Table 5.1. The sensors are located within the data logger enclosures. The pressure sensor specifications are given below:

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.

5.4 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 (NIST). 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.

5.5 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 six sites (4, 7, 19, 22, and 25) 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.

5.6 Atmospheric Transport and Diffusion

The Air Pollutant Graphical Environmental Modeling System (APGEMS) 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 APGEMS, which is a primary model used in the Unified Dose Assessment Center (UDAC) of the Emergency Operations Center (EOC). Data files for this software are transmitted to the servers every 15 minutes, shortly after the data are processed.

5.7 Quality Assurance

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

5.8 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 EOC.

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 [fog, snow, etc.]).

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.

6.0 ECOLOGICAL MONITORING AND COMPLIANCE ASSESSMENT

6.1 Introduction

Ecological monitoring and ecological compliance assessment are additional aspects of DOE's requirements for an environmental resources protection plan. They are designed to meet the environmental resources protection objectives stated in DOE O 436.1, Supp Rev. 0, *Departmental Sustainability* with DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental* used as guidance. Activities conducted under the Ecological Monitoring and Compliance (EMC) Project 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* (ESA); *Bald and Golden Eagle Protection Act*; CERCLA; and the *Migratory Bird Treaty Act* (MBTA*)*. Additionally, this work element provides a basis for incorporating U.S. Fish and Wildlife Service (USFWS), Washington Department of Fish and Wildlife (WDFW), Washington Natural Heritage Program (WNHP), and special species laws, regulations, and policies into Hanford Site activities, as warranted.

Specific components of the EMC Project include:

- 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.

6.2 Ecological Monitoring and Compliance Project

MSA's EMC Project provides the Hanford Site DOE field offices and contractors with ecological characterization, monitoring, and compliance assessment support. The project provides data and information to fulfill DOE-RL'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 project, 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 Project 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 project responds to Hanford Site needs through a program that includes:

- 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 the *Hanford Site Biological Resources Management Plan* (DOE/RL 96-32), *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (DOE/RL-94-150), *Threatened and Endangered Species Management Plan: Salmon, Steelhead, and Bull Trout* (DOE/RL-2000-27), and interactions with the USFWS, WDFW, 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 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 receptors in areas with known or probable legacy contaminants. This information can be used to assess potential site-specific and site-wide impacts to support ecological risk analyses.
- Maintaining current and historical ecological data to support Hanford 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 Project 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.

6.3 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 key 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 are 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.

Inventory and monitoring efforts are prioritized each year based on the current status of the species inhabiting the site, public and stakeholder concerns, and project sampling and ecological characterization needs. Results from these inventory and monitoring efforts are maintained in the project databases and are a critical component for implementing the *Hanford Site Biological Resources Management Plan* (DOE/RL-96-32). 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.

Population Monitoring and Trend Analysis. Populations monitored on the Hanford Site may include deer, bald eagles, ferruginous hawks, geese, salmon/steelhead, bivalves, crayfish, 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) *Hanford Site Biological Resources Management Plan* resource levels 3-5; 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:

- Surveys to describe the relative abundance and distribution of wildlife inhabiting the site, including, but not limited to:
  - 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.
- Aerial surveys to 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 list. 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 Project 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 Project 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 Project:

- 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.

6.4 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 project: 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 habitat; and 5) conducts informal consultations with the U.S. Fish and Wildlife Service when warranted. DOE/RL-96-32 guides ecological compliance assessment on the Hanford Site.

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 DOE/RL-96-32. 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.

Federally Threatened or Endangered Species Protection. The EMC Project assists DOE and site contractors in complying with the *Endangered Species Act*. Assistance includes developing and maintaining management plans, posting restricted areas and maintaining the signs, educating Hanford Site personnel about rules 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.

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 such as 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.

6.5 Ecological Impact and Risk Characterization

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 Project. 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:

- 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.

6.6 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 project files 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.

6.7 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-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 MSA PSRP manager, EMC project manager, or MSA quality engineer can initiate these surveillances and audits routinely or randomly.

7.0 CULTURAL RESOURCES

7.1 Introduction

The Hanford Site is rich in cultural resources important to Native Americans, interested parties, and the public. DOE-RL's 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 DOE'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 MSA's CHRP perform monitoring on a quarterly basis. Personnel from other Hanford Site contractors also support RL's CHRP. 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 conduct their own cultural resources activities that include cultural resources site monitoring and surveys. CHRP activities are performed in compliance with Sections 106 and 110 of the NHPA; NEPA; the *Archaeological Resources Protection Act*; the *Native American Graves Protection and Repatriation Act*; and the *Department of Energy Management of Cultural Resources* policy (DOE P 141.1).

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.

7.2 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 *Archaeological Resources Protection Act*.
- 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 (GIS) 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.

7.3 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.

7.4 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 *Archaeological Resources Protection Act*. All site information and monitoring evaluations are stored by the CHRP.

7.5 Monitoring Criteria

Cultural resources sites are monitored for impacts from environment (wind, water, etc.), animals, and humans. Baseline data from a records search and field observations are included in field monitoring forms, and new impacts are added if discovered. Observations are made about active impacts, impacts not previously observed or sustained since the last monitoring visit, and newly identified cultural material. Three kinds of locations are recorded at monitored locations. The first kind are 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 them is perceived or active. They are assessed at every visit. The second are 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. The third kind are locations of specific impact, whether human, animal, or environmental. They are GPS mapped. The frequency of replicated photographs depends on whether the impact is active.

7.6 Monitoring Frequencies

Monitoring locations are grouped for efficient use of trip time, and prioritized for each visit by site type. Trips have been organized geographically to be implemented with scheduling software and progress tracked. A set number of these 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 each site is reassessed after each monitoring visit.

7.7 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 addition, National Park Service definitions for general site condition are included and used as part of the site condition summary.

7.8 Quality Control Methods

Hanford cultural and historic resources monitoring is conducted and documented by CHRP personnel in accordance with written procedures. At the end of each fiscal year, CHRP personnel review all monitoring results which are compiled in a summary report.

7.9 Reporting Impacts and Violations

Archaeological Resources Protection Act violations require immediate notification of the Hanford CHRP manager so that appropriate Native American tribes and bands can be notified of violations in a timely manner. Major impacts also are reported to the Hanford CHRP manager. Minor impacts also are noted on a cultural resources site monitoring form and stored in the cultural resources site file located in the MSA CHRP repository.

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8.0 GROUNDWATER MONITORING

8.1 Introduction

Groundwater monitoring is a critical element of DOE's environmental monitoring program at the Hanford Site. Disposal and leakage of hazardous and radioactive waste in the past 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 chapter summarizes the overall groundwater monitoring program and cites individual monitoring plans.

8.2 Regulatory Drivers

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

8.2.1 DOE Orders

DOE conducts groundwater monitoring on the Hanford Site to comply with Atomic Energy Act (AEA) requirements identified in DOE Order (O) 435.1, *Radioactive Waste Management*; DOE O 436.1, *Departmental Sustainability*; and DOE O 458.1, *Radiation Protection*.

DOE O 435.1, *Radioactive Waste Management*, 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. Four facilities on the Hanford Site are authorized to transfer, receive, process, and dispose of low-level radioactive waste: the 200 East Area Low-Level Burial Grounds, 200 West Area Low-Level Burial Grounds, the Integrated Disposal Facility, and Environmental Restoration Disposal Facility (ERDF).

DOE O 436.1, *Departmental Sustainability,* requires that all DOE organizations, and all sites under their purview, assure that the site Integrated Environment, Safety, and Health Management Systems (ISMS) include implementation of an Environmental Management System (EMS) 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 (4)(c)(3)).

The AEA monitoring requirements of DOE O 458.1, *Radiation Protection*, 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.

8.2.2 Comprehensive Environmental Response, Compensation, and Liability Act

CERCLA and the *Superfund Amendments and Reauthorization Act*, which are implemented through 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 8.8 summarizes CERCLA groundwater monitoring.

8.2.3 Resource Conservation and Recovery Act

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 8.7 summarizes RCRA groundwater monitoring.

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

Washington's *Waste Discharge Permit Program* (WAC 173-216), which deals with permitted liquid discharges to the ground, and the state's *Solid Waste Handling Standards* (WAC 173-350) contain groundwater protection and monitoring requirements for landfills that do not dispose of dangerous waste. Section 8.7.3 summarizes groundwater monitoring under these WAC requirements.

8.2.5 Integration of Regulatory Requirements

The DOE, EPA, and 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.

8.3 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, *Atomic Energy Act*). The work is conducted to manage any overlap, eliminating redundant sampling, optimizing the schedule, and meeting the needs of each sampling objective.

8.3.1 Data Quality Objectives

To determine the type of groundwater data required, staff apply the EPA's data quality objectives (DQO) process as described in *Guidance on Systematic Planning Using the Data Quality Objectives Process*, EPA/240/B-06/001 (QA/G-4, 2006, as revised). 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 TSD units or 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 QC processes. The process was used to define reporting limits, precision, accuracy, and completeness, which are described in a QA plan for groundwater monitoring.

Limits for precision and accuracy for chemical analyses are based on criteria stipulated in the methods (e.g., EPA/SW-846 or EPA 6000 series). 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 percent.

8.3.2 Construction and Maintenance of Wells

Since the mid-1980s, Hanford Site monitoring wells have been designed to meet state requirements (WAC 173-160, *Minimum Standards for Construction and Maintenance of Wells*). 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. Ecology has approved the use of longer well screens than specified in WAC 173-160 in the 200 Areas. In those areas, the water table is declining because liquid waste is no longer disposed to the ground, so long well screens (up to 10.7 meters (35 feet) in length) increase the monitoring life of the well.

Most older monitoring wells on the Hanford Site are 10, 15, or 20 centimeters in diameter and are constructed with casing made of carbon steel and may have perforated casing instead of screens. These wells are used most extensively in site-wide monitoring of existing plumes for the objectives of the *Atomic Energy Act* 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 one end. They are installed by driving a temporary steel casing into the ground adjacent to the river. The drive-tip on the casing end is knocked out and the screened end of a 0.25-inch diameter, flexible tube is inserted into the casing. The 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 samplers identify a problem. Routine well maintenance may be scheduled to meet specific requirements.

8.3.3 Sampling and Analysis Protocol

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

8.3.3.1 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, such as water-level tapes and drilling equipment, is also decontaminated in accordance with documented procedures.

8.3.3.2 Water-Level Monitoring

Procedures for measuring water levels were developed in accordance with the techniques described in American Society for Testing and Materials (1988), Garber and Koopman (1968), OSWER 9950.1, and U.S. Geological Survey (1977). 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 site-wide 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.

8.3.3.3 Sample Custody

Groundwater samplers maintain sample custody in accordance with existing protocols. 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 analyses 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.

8.3.3.4 Sample Collection and Shipment

Groundwater monitoring follows a QA plan that meets *EPA Requirements for Quality Assurance Project Plans*, EPA/240/B-01/003 (EPA QA/R-5, March 2001, as revised). 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 EPA/240/B-01/003 (EPA QA/R-5, March 2001, as revised) 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 (i.e., after two consecutive measurements are within 0.2 units for pH, 0.2°C for temperature, 10% for specific conductance, and turbidity is <5 nephelometric turbidity units [NTUs]). If a well is purged to dryness, it is allowed to recover and then sampled. For certain types of samples, preservatives are required. 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 so the <5 NTUs 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.

8.3.4 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. They are standard methods from *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, 1993), or other methods, as approved. Radiological parameters are analyzed by EPA or laboratory-specific methods.

8.4 Quality Assurance and Quality Control

Quality assurance (QA) and quality control (QC) requirements are documented in site-specific monitoring plans. These plans include Quality Assurance Project Plans (QAPP) that establish the quality requirements for environmental data collection, including 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 Requirements for Quality Assurance Project Plans* (EPA/240/B-01/003, EPA QA/R-5, March 2001, as revised)
- *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD, DOE/RL-96-68)
- Sections 6.5 and 7.8 of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement [TPA]) Action Plan (Ecology et al. 1989)
- *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies* (Washington State Department of Ecology Publication No. 04-03-030)

- EPA/240/R-02/009, Guidance for Quality Assurance Project Plans (EPA QA/G-5).

8.5 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.

8.5.1 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 or if data may be erroneous. Data reviews may result in submittal of a request for data review on questionable data. The laboratory may be asked to check calculations or re-analyze the sample, or the well may be resampled. Results of the formal data review process are used to correct or flag the data appropriately in the HEIS database.

8.5.2 Data Validation

Data validation activities are performed at the discretion of the operable unit project manager. If performed, data validation activities are based on EPA functional guidelines.

8.5.3 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 QC 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.

8.6 Data Management and Reporting

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

8.6.1 Loading Data into the Database

The contract laboratories report analytical results electronically and on hard copy. The electronic results are loaded 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.

8.6.2 Interpretation

After data are validated and verified, the acceptable data are used to interpret groundwater conditions at the site. Interpretive tools include:

- **Hydrographs** – Plot water levels versus time 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 flow directions. 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** – Illustrate relative abundances, which can sometimes be used to distinguish between different sources of contamination.

8.6.3 Reporting

Annual reports on results of groundwater monitoring are issued (e.g., DOE/RL-2014-32). These reports include pertinent information for CERCLA, RCRA, WAC, and *Atomic Energy Act* groundwater monitoring and electronic files of groundwater data. Chemistry and water-level data also are 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).

8.7 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 8.1 and Figure 8.1). 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 Dangerous Waste Permit* (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, and 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 May 2015, 18 of the 25 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 8.1 lists the RCRA sites and status of monitoring as of May 2015 and provides references for site-specific RCRA groundwater monitoring plans.

Table 8.1. RCRA Interim and Final Status Groundwater Monitoring, May 2015

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).
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)]	*Interim Status Groundwater Monitoring Plan for the 216-A-29 Ditch,* DOE/RL-2008-58, Rev. 0.
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. 1.
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. 1
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. 0.
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.

Table 8.1. RCRA Interim and Final Status Groundwater Monitoring, May 2015

TSD Unit or Waste Management Area	Monitoring Phase	Year TSD Incorporated into *Permit* (closed or operating)	Monitoring Plan and Comments
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
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

Table 8.1. RCRA Interim and Final Status Groundwater Monitoring, May 2015

TSD Unit or Waste Management Area	Monitoring Phase	Year TSD Incorporated into *Permit* (closed or operating)	Monitoring Plan and Comments
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.
DOE = U.S. Department of Energy.
Ecology = Washington State Department of Ecology.
RCRA = *Resource Conservation and Recovery Act of 1976*.
TBD = To be determined.
TSD = Treatment, storage, and disposal (unit).
WMA = Waste management area.

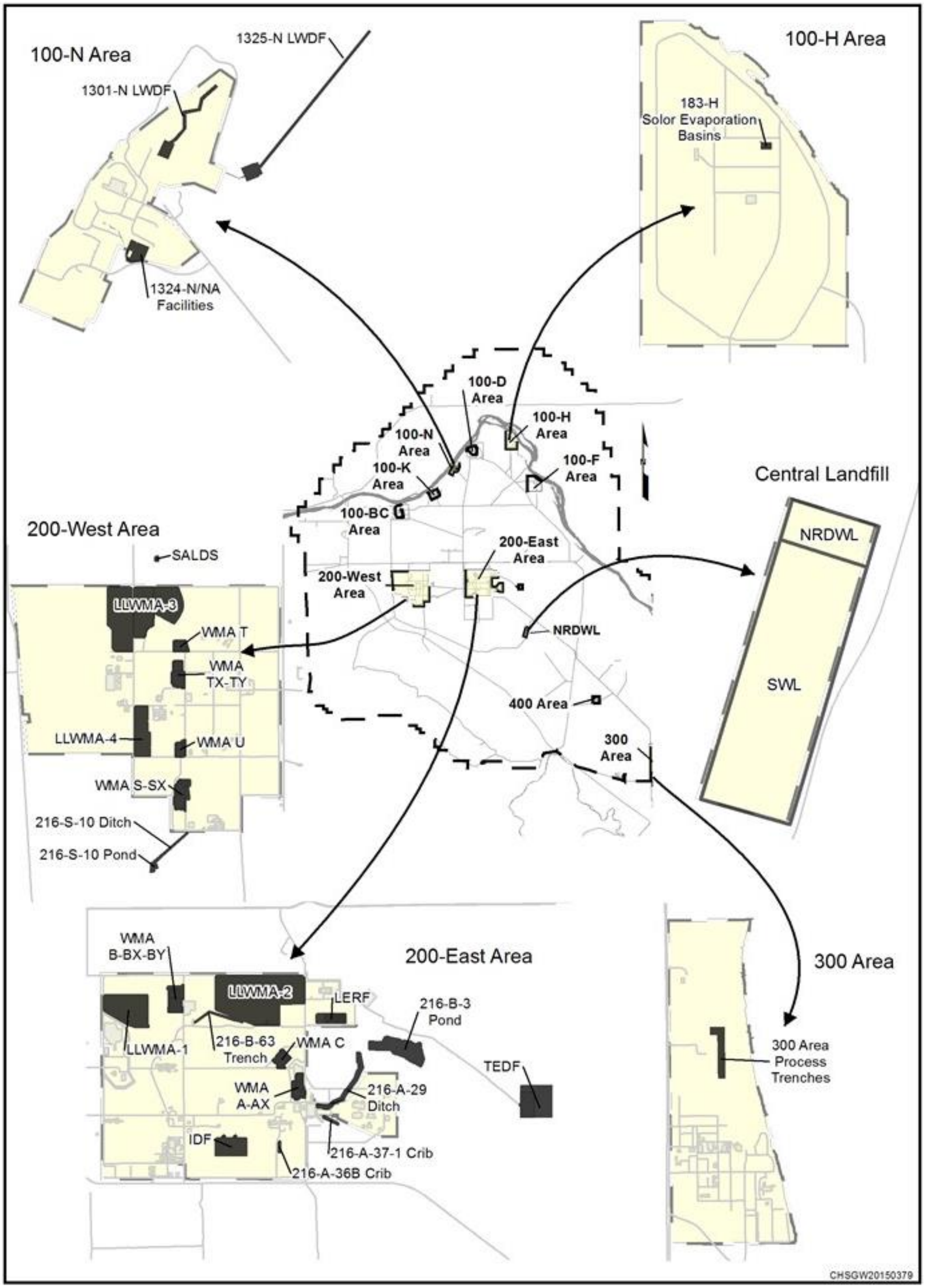

Figure 8.1. Hanford Site Regulated Units requiring Groundwater Monitoring

8.7.1 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 at least annually for the parameters related to groundwater quality and semi-annually 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, the 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 and, if so, 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.

8.7.2 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 Hanford under special circumstances. The monitoring requirements are included in attachments to the *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 from 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, such as a 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.

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.*

When an alternative monitoring program is chosen for a RCRA site, monitoring requirements are determined on a case-by-case basis with Ecology.

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).

8.7.3 Other Regulated Units

In addition to RCRA facilities, there are non-dangerous waste operational facilities on the Hanford Site that are regulated under the requirements of Washington State regulations and the Tri-Party Agreement (Ecology et al. 1989). These 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 (see Figure 9-1). 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 8.2.

Table 8.2. Other Regulated Units, May, 2015

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, PNNL-13121, Permit ST4500
Solid Waste Landfill	WAC 173-350	Groundwater Monitoring Plan for the Solid Waste Landfill, PNNL-13014

8.8 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. 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 integrated with the source operable units in the 100 Area National Priority List (NPL) site and are treated separately from the source operable units for remediation in 200 Area NPL site. 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 8.2 illustrates the groundwater operable units and groundwater interest areas.

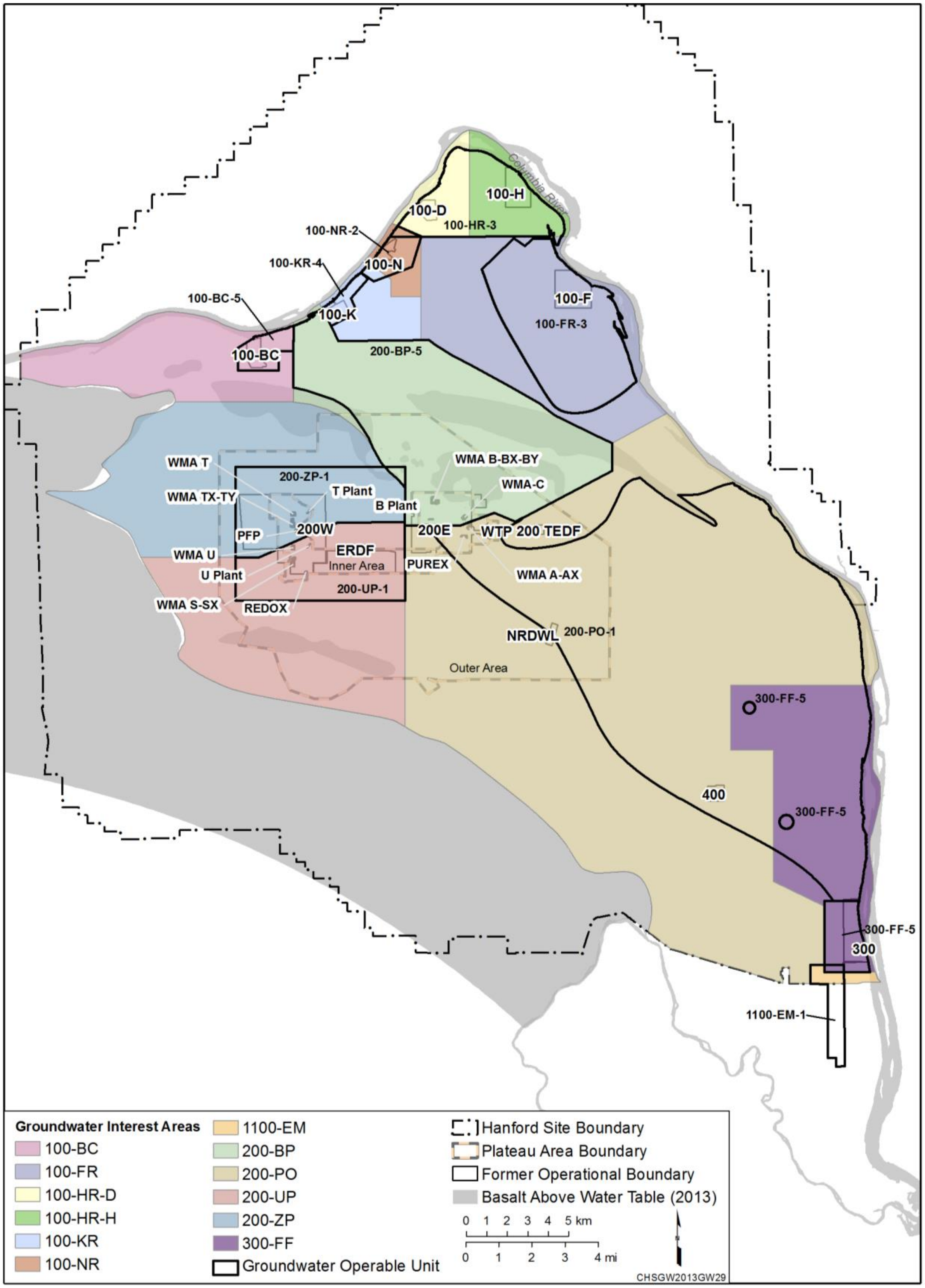

Figure 8.2. Locations of Groundwater Operable Units and Interest Areas on the Hanford Site

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). 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 is given in Table 8.3.

Four of the groundwater operable units have records of decision for final action remedies (Table 8.3). 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.

Operable unit 1100-EM-1 (Richland North Area), has a record of decision calling for natural attenuation of volatile organic compounds. The operable unit has been removed from the NPL, but groundwater is monitored to determine the success of this approach. Since fiscal year 2001, contaminant 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 a record of decision (EPA et al. 2008). The list of contaminants of concern includes major contaminant plumes exceeding drinking water standards: 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 contamination. The 200 West pump-and-treat began operations in 2012.

The 300-FF-5 Operable Unit (300 Area and satellite areas to the north) has an 2013 record of decision (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 a 2014 record of decision (EPA and DOE 2014). Monitored natural attenuation is the preferred alternative for groundwater remediation of hexavalent chromium, nitrate, strontium-90, and trichloroethene.

Table 8.3. Groundwater Operable Unit Monitoring, May 2015

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	*100-FR-3 Operable Unit Sampling and Analysis Plan*, DOE/RL-2003-49	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

Table 8.3. Groundwater Operable Unit Monitoring, May 2015

Operable Unit Designation	SAP Reference	Monitoring Category
300-FF-5	*300-FF-5 Operable Unit Sampling and Analysis Plan,* DOE/RL-2002-11	Enhanced attenuation and monitored natural attenuation
Operable Units with Records of Decision for Interim Action		
100-HR-3	*Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units,* DOE/RL-96-90; Sampling and Analysis Plan for In-Situ Redox Manipulation Project, DOE/RL-2003-63	Interim action (pump-and-treat and ISRM)
100-KR-4	*Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units,* DOE/RL-96-90	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	*200-UP-1 Groundwater Operable Unit Remedial Design/Remedial Action Work Plan* (DOE/RL-2013-07)	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	*Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit,* DOE/RL-2001-49	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*

ISRM = In situ redox (reduction-oxidation) manipulation.
ROD = Record of decision.
SAP= Sampling analysis plan.
*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.

At four of the 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. The operable unit is making progress toward a final remedy; Ecology accepted DOE's Remedial Investigation/Feasibility Study (RI/FS) report in 2014.

- **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. Chromium concentrations in compliance wells remained above cleanup targets. The draft Feasibility Study and Proposed Plan for a final remedy underwent review in 2012, and DOE is incorporating the results of supplemental source characterization activities.
- **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. The operable unit is making progress toward a final remedy and Draft A of the RI/FS report was revised in 2014 in response to Ecology comments.
- **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.

At the 100-BC-5, 200-BP-5, and 200-PO-1 Operable Units, there are no imminent threats to human health or 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.

8.9 Site-Wide Environmental Surveillance of Groundwater

Additional groundwater monitoring is required to meet requirements of the *Atomic Energy Act*, as implemented by DOE O 436.1 and DOE O 435.1. A primary objective is tracking contaminant plumes and trends. This objective is shared with CERCLA monitoring in some groundwater operable units. In addition, facility-specific monitoring is performed at burial grounds and waste storage facilities that have the potential to impact groundwater but where monitoring requirements are not completely covered by other regulatory drivers. These facilities include low-level burial grounds, the integrated disposal facility, and the 100-K Area fuel storage basins. Table 8.4 lists monitoring plans for Atomic Energy Act sites.

Data from other groundwater monitoring programs (e.g., RCRA, CERCLA) are integrated with information from wells monitored specifically for the *Atomic Energy Act*. The site-wide monitoring program divides the Hanford Site into regional groundwater interest areas that encompass CERCLA operable units (see Figure 8.2). DOE presents interpretations of groundwater data in annual reports (e.g., DOE/RL-2014-32).

Wells selected for *Atomic Energy Act* sampling 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 or with facilities that have generated or received waste in the past. 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 saturated zone. Monitoring for non-radioactive hazardous chemicals 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 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.

- **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** – Water-supply wells on and near the site, including those at FFTF and those 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 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. 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 sample wells completed in the basalt-confined aquifer and deep in the Ringold Formation sediment to assess the depth of contamination and to 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 also to identify contaminants contributed by offsite upgradient sources.
- **Monitoring for public assurance** – Data to meet the objectives above are presented to the public in less technical summaries to communicate how their 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 site environmental report, the summary for the annual Hanford Site groundwater monitoring report, and through presentations to groups such as the Hanford Advisory Board.

Sampling frequency for *Atomic Energy Act* monitoring varies from quarterly to triennially, depending on specific monitoring objectives and concentration variability in the well. Results of site-wide groundwater monitoring are discussed in annual groundwater reports.

Table 8.4. Monitoring Plans for Atomic Energy Act, May 2015

Site or Scope	Monitoring Plan
KE and KW Basins	*Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins* (PNNL-14033)
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)
Richland North, Ringold confined aquifers, upper basalt-confined aquifers, radionuclides at WMA S-SX and U	*Surveillance Groundwater Monitoring on the Hanford Site* (DOE/RL-2012-59)
Upcoming Atomic Energy Act sampling and analysis plan	Planned publication in 2015. Will replace DOE/RL-2012-59.

NOTE: Data collected under RCRA (Table 8.1) and CERCLA (Table 8.2) also contribute to Atomic Energy Act groundwater monitoring objectives.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601 et seq.
RCRA = *Resource Conservation and Recovery Act of 1976*, 42 USC 6901 et seq.

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