DOE/RL-2003-59

Hanford Site Risk-Based End State Vision

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management
Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

United States
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P.O. Box 550
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K. M. Thompson
U.S. Department of Energy, Richland Operation

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Release Approval		Date

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Acronyms

ALE	Arid Lands Ecology Reserve
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLUP	Comprehensive Land-Use Plan
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
Ecology	Washington State Department of Ecology
EM	Office of Environmental Management
EPA	U.S. Environmental Protection Agency
FFTF	Fast Flux Test Facility
HAMMER	Hazardous Materials Management and Emergency Response
HQ	U.S. Department of Energy Headquarters
NEPA	National Environmental Policy Act
NPL	National Priorities List
ORP	Office of River Protection
PUREX	Plutonium-Uranium Extraction (Plant)
RBES	risk-based end states
RCRA	Resource Conservation and Recovery Act
REDOX	Reduction-Oxidation (Plant)
RL	Richland Operations Office
USDA	U.S. Department of Agriculture

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Maps

The following maps are included as attachments to this document:

1.0 Introduction

The purpose of this document is to present the site-specific risk-based end state cleanup vision for the U.S. Department of Energy's (DOE) Hanford Site. This document is the primary tool for communicating Hanford's risk-based end state (RBES) vision to DOE, the site contractors, the regulators, tribal nations, and public stakeholders. This document responds to the requirements of DOE Policy 455.1, *Use of Risk-Based End States*, and was prepared following DOE's *Guidance for Developing a Site-Specific Risk-Based End State Vision*. The purpose of the policy is to focus DOE on conducting cleanup that protects human health and the environment for the planned future use of each defined area on each site. The policy requires DOE to continue to comply with applicable federal, state, community and treaty requirements. It is not a license to do less, but rather to link decision making to a larger perspective.

In September 1999, DOE issued the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (CLUP) (DOE 1999a), which was the basis for developing Hanford's RBES vision presented in this document. The plan evaluated the potential environmental impact associated with implementing a 50-year comprehensive land-use plan for the Hanford Site. DOE's selected alternative anticipates multiple uses of the Hanford Site, including consolidating waste management operations in the Central Plateau, allowing industrial development in the eastern and southern portions of the site, increasing recreational access to the Columbia River, and expanding the Saddle Mountain National Wildlife Refuge to include all of the Wahluke Slope, and the management of the Fitzner/Eberhardt Arid Lands Ecology Reserve (ALE) by the U.S. Fish and Wildlife Service.

In 2002, DOE's Office of Environmental Management (EM) established a set of Corporate Projects to lead its response to the Top-to-Bottom Review (DOE 2002a). The Corporate Projects are intended to change the way DOE-EM and, in some cases, DOE does business. One of these Corporate Projects, "A Cleanup Program Driven by Risk-Based End States Project," resulted in DOE Policy 455.1 being issued in 2003 along with guidance and implementation documents. This policy is consistent with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), and the Atomic Energy Act of 1954, which either explicitly or implicitly direct the consideration of future land use and risk in making cleanup decisions. This RBES approach attempts to gain a common acceptance of the post-remediation future for Hanford prior to implementing final remediation measures.

During 2003, DOE, the U.S. Fish and Wildlife Service, and the Washington Department of Fish and Wildlife were joint stewards of the Hanford Reach National Monument (Figure 1.1). The U.S. Fish and Wildlife Service administers three major management units of the monument totaling about 66,775 hectares (165,000 acres), including:

1. Fitzner/Eberhardt Arid Land Ecology Reserve – a 312 square kilometer (120 square mile) tract of land in the southwestern portion of the Hanford Site

2. Saddle Mountain Unit – a 130 square kilometer (50 square mile) tract of land on the north-northwest side of the Columbia River, generally south and east of State Highway 24

3. Wahluke Unit – a 225 square kilometer (87 square mile) track of land located north and east of both the Columbia River and the Saddle Mountain Unit.

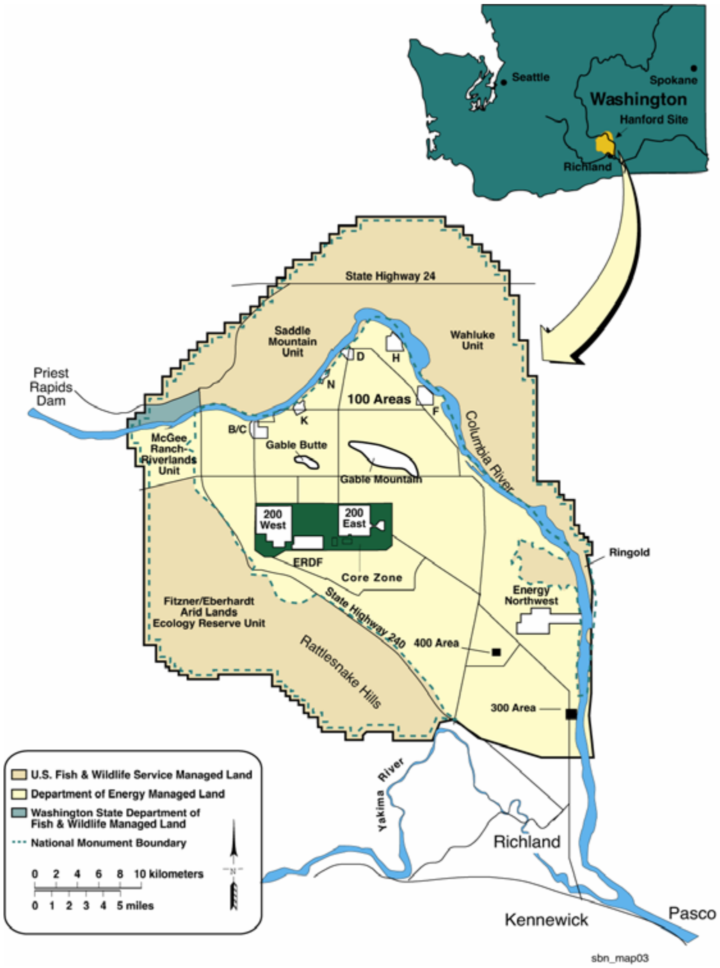


Figure 1.1. The Hanford Site (586 square miles) in South-eastern Washington State

The portion of the monument administered by DOE includes the McGee Ranch/Riverlands Unit (north and west of State Highway 24 and south of the Columbia River), the Columbia River islands in Benton County, the Columbia River Corridor (0.4 kilometer [0.25 mile] inland from the Hanford Reach shoreline) on the Benton County side of the river, and the sand dunes area located along the Hanford side of the Columbia River north of the Columbia Generating Station. Approximately 162 hectares (400 acres) along the north side of the Columbia River, west of the Vernita Bridge and south of State Highway 243, were managed by the Washington Department of Fish and Wildlife.

In total, these land areas encompass 67,178 hectares (166,000 acres) and are now part of the Hanford Reach National Monument have served as a safety and security buffer zone for Hanford Site operations since 1943, resulting in an ecosystem that has been relatively untouched for nearly 60 years.

1.1 Organization of the Report

Information in this document has been taken wherever possible from existing documents. This report is organized into three main sections. Chapter 2 provides a general conceptual model for risk to the public and the ecology at Hanford. Chapter 2 also provides a regional context for RBES using several regional maps.

Chapter 3 was drawn extensively from the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999a). The chapter describes the RBES on a Hanford Site scale. The chapter includes current state and RBES vision.

Chapter 4 relies heavily on the numerous documents developed to reach decisions on cleanup of the Hanford Site including interim action records of decision. The chapter contains the hazard-specific descriptions. The chapter is organized by major areas of the Hanford Site (100 Area, 200 Area, 300 Area, 400 Area, 600 Area, and 1100 Area) and the specific types of hazards that exist in each area (e.g., liquid waste sites, burial grounds, facilities, residual vadose zone contamination, groundwater). Current state and RBES vision conceptual site models are included.

The end-state conceptual site model narrative also includes a description of the mechanisms assumed in the RBES vision that will ensure sustainable protection or safety for at-risk receptors and the uncertainties or risks of failure that could adversely affect these assumptions.

Chapter 5 is a discussion of the variance between the RBES vision and current cleanup plans for the DOE Hanford Site. This document provides an initial discussion of these variances; however, it is anticipated that additional variances will be identified through discussions with regulators, the affected governmental organizations, adjacent landowners, and the general public during the development of the RBES vision.

1.2 Site Mission

From its creation in 1943 until the late 1980s, the Hanford Site was dedicated first to the production of plutonium for national defense and later to management of the resulting waste. The plutonium production activities produced about 2,600 waste sites on the Hanford Site. The severity of contamination at individual waste sites ranges from contaminated tumbleweeds to radioactive and chemical waste in underground tanks. The waste and nuclear material inventory remaining from the plutonium production mission contains about 390 million curies of radioactivity and 362,874 to 544,311 metric tons (400,000 to 600,000 tons) of chemicals (Gephart 2003), as shown in Table 1.1. There are significant unknowns in this inventory, especially for specific radionuclides and their chemical forms.

Table 1.1. Hanford Site Waste and Nuclear Material Inventory

Waste Source	Radioactivity (million curies)	Chemicals	Volume
Tank Waste	195	217, 724 metric tonnes (240,000 tons)	2e+008 liters (53 million gallons)
Solid Waste	6	63,503 metric tonnes (70,000 tons)	707,921 cubic meters (25 million cubic feet)
Soil and Groundwater	2	90,718 to 272,155 metric tonnes (100,000 to 300,000 tons)	9.9e+008 cubic meters (35 billion cubic feet)
Facilities	1	--	5,663,369 cubic meters (200 million cubic feet)
Nuclear Material	185	--	708 cubic meters (25,000 cubic feet)

Major operational areas (Figure 1.1) were created at the Hanford Site to carry out this mission:

- The 100 Areas (on the south shore of the Columbia River) are the sites of nine retired plutonium production reactors, including the dual-purpose N-Reactor. The 100 Areas occupy approximately 11 square kilometers (4 square miles).

- The 200-West and 200-East Areas are located within the Central Plateau, approximately 8 and 11 kilometers (5 and 7 miles), respectively, south of the Columbia River. Historically, these areas have been dedicated to fuel reprocessing and to waste management and disposal activities. The 200 Areas cover approximately 16 square kilometers (6 square miles).

- The 300 Area, located just north of the city of Richland, once contained fuel fabrication facilities and is currently the site of nuclear research and development. This area covers 1.5 square kilometers (0.6 square mile).

- The 400 Area is approximately 8 kilometers (5 miles) northwest of the 300 Area. The 400 Area contains the Fast Flux Test Facility, which was used in the testing of breeder reactor systems. Also included in this area is the Fuels and Materials Examination Facility.

- The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, and 400 Areas.

- The former 1100 Area (now called Richland North) is located south of the Hanford Site in the northern portion of the city of Richland. This is a support area that includes general stores, transportation maintenance, and the DOE and contractor facilities. The 1100 Area has been remediated and removed from the U.S. Environmental Protection Agency's (EPA's) National Priorities List (NPL). Title of approximately 324 hectares (800 acres) has been transferred to the Port of Benton for industrial development.

Non-DOE activities on Hanford Site leased land include commercial power production on the land occupied by the Energy Northwest Washington Nuclear Plant (WNP)-2 plant, as well as the partially completed WNP-1 and WNP-4 plants, and operation of a commercial low-level waste burial site by US Ecology, Inc. Immediately adjacent to the southern boundary of the Hanford Site, Framatome ANP, Richland Inc. operates a commercial nuclear fuel fabrication facility, and Pacific EcoSolutions operates a low-level waste decontamination, super compaction, and packaging disposal facility. The Laser Interferometer Gravitational-Wave Observatory is located between the 200 and 400 Areas.

Since the closeout of the plutonium production mission, the Hanford Site has transitioned to an environmental restoration and waste management mission. In the past 14 years, efforts have shifted to the development of new waste treatment and disposal technologies, and to characterization and cleanup of nuclear materials and contamination left from historical operations.

Currently, the primary mission includes cleaning up and shrinking the site footprint from approximately 1,517 square kilometers (586 square miles) to approximately 194 square kilometers (75 square miles) by 2012. The online report *Hanford 2012: Accelerating Cleanup and Shrinking the Site* (DOE 2000a) states that the cleanup mission includes three strategies:

1. Restore the Columbia River corridor by continuing to clean up Hanford Site sources of radiological and chemical contamination that threaten the air, groundwater, or Columbia River. It is expected that most River Corridor projects will be completed by 2012.

2. Transition the Central Plateau (200-East and 200-West Areas) from primarily waste storage areas to waste characterization, treatment, storage, and disposal operations that are expected to take another 40 years.

3. Prepare the Hanford Site for future activities such as long-term stewardship, other DOE and non-DOE federal missions, and other public and private use.

On May 15, 1989, DOE, EPA, and the Washington State Department of Ecology (Ecology) signed a comprehensive agreement for cleaning up the Hanford Site. The *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1998), or Tri-Party Agreement, is an agreement for achieving compliance with the CERCLA remedial action provisions and the RCRA treatment, storage, and disposal unit regulations and corrective action provisions. The Tri-Party Agreement (1) defines and ranks CERCLA and RCRA cleanup commitments, (2) establishes responsibilities, (3) provides a basis for budgeting, and (4) reflects aggressive goals for site remediation, with enforceable milestones to ensure compliance.

1.3 Status of Cleanup Program

This section presents the evolution of Hanford's thinking on risk-based strategies for cleaning up the Hanford Site, from a 1995 study commissioned by Mr. Grumbly to the present day status of the cleanup program.

A Risk-Based Approach to Cleanup. In June 1995, the existing Hanford Site contractors (Pacific Northwest Laboratory, Westinghouse Hanford Company, and Bechtel Hanford, Inc.) produced a document titled *Development of a Risk-Based Approach to Hanford Site Cleanup* (Hesser et al. 1995) in response to a request from Mr. Grumbly, then Assistant Secretary for Environmental Management. Mr. Grumbly asked Hanford to develop a conceptual set of risk-based cleanup strategies that (1) protected the public, the workers, and the environment from unacceptable risks, (2) were technically executable, and (3) fit within an expected annual funding profile of $1.05 billion. A systems engineering approach was used to develop mortgage-based, risk-based, and land-based cleanup strategies that differed in terms of the work to be performed, its sequence, and the resulting end states. The report recommended adoption of a risk-based cleanup strategy. The major decisions identified by the alternatives examined in the report were

- Retrieval and treatment versus in-place disposal of tank waste
- Retrieval and treatment versus in-place disposal of post-1970 transuranic waste
- Treatment and confinement versus restriction of the contaminated groundwater
- Demolition and removal versus entombment of major facilities

Central Plateau Risk Framework. DOE, EPA, and Ecology initiated the Central Plateau Risk Framework in October 2001. Through a series of technical workshops attended by all the Central Plateau programs, initial agreements were made on the basic assumptions for the risk framework. This framework was then taken to the Hanford Advisory Board, the tribal nations, the Oregon Hanford Waste Board, and the Hanford Site Board of Trustees. Salient points of the risk framework include the following items:

- The Core Zone (200 Areas including B Pond [main pond] and S Ponds) will have an industrial scenario for the foreseeable future (Figure 1.2).

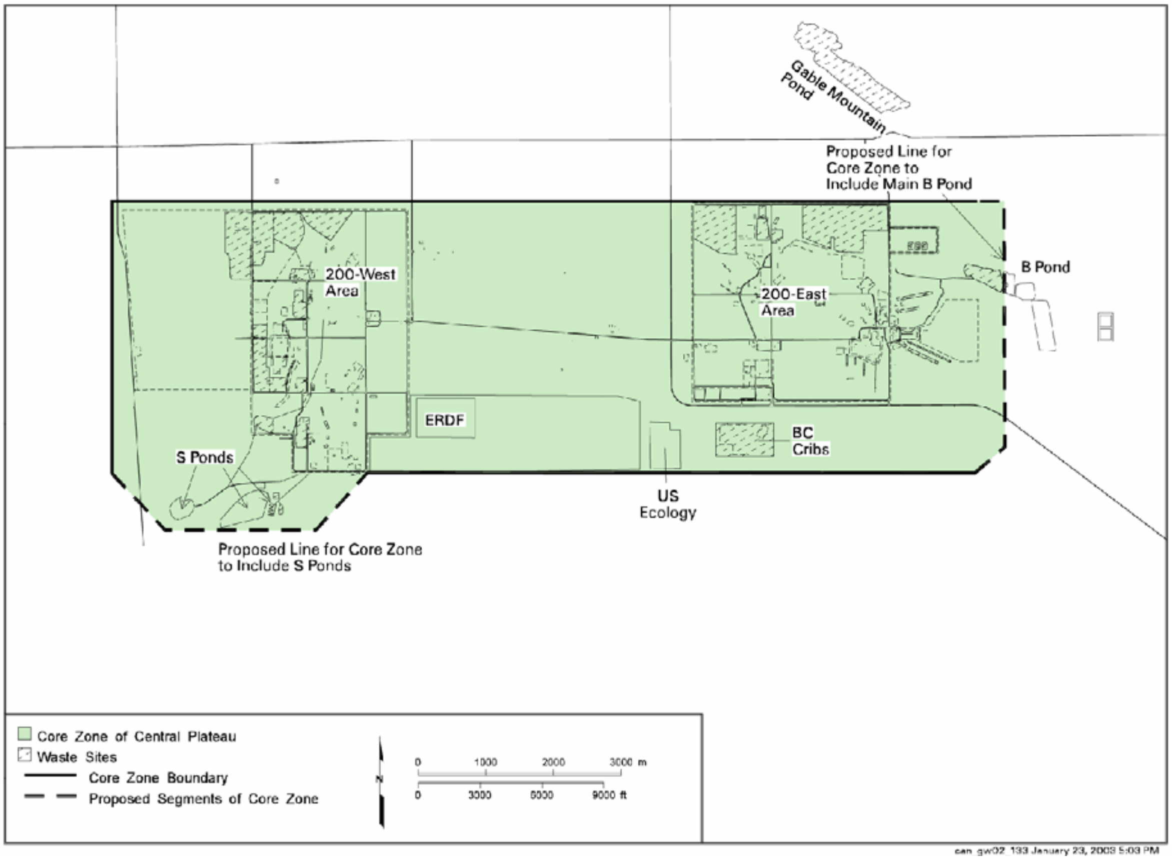


Figure 1.2. Central Plateau Core Zone Map

- The Core Zone will be remediated and closed allowing for other uses consistent with an industrial scenario (environmental industries) that will maintain active human presence in this area, which in turn will enhance the ability to maintain the institutional knowledge of the wastes left in place for future generations. Exposure scenarios used for this zone should include a reasonable maximum exposure to a worker/day user, to possible Native American users, and to intruders. An assumption of industrial land use will be used to set cleanup levels.

- DOE will follow the required regulatory processes for groundwater remediation (including public participation) to establish the points of compliance and remedial action objectives. It is anticipated that groundwater contamination under the Core Zone will preclude beneficial use for the foreseeable future, which is at least the period of waste management and institutional controls (150 years). It is assumed that the tritium and iodine-129 plumes beyond the Core Zone boundary to the Columbia River will exceed the drinking water standards for the period of the next 150 to 300 years (less for the tritium plume). It is expected that other groundwater contaminants will remain below or will be restored to drinking water levels outside the Core Zone.

- Drilling for water use would be limited in the Core Zone. An intruder scenario will be calculated for assessing the risk to human health and the environment.

- Waste sites outside the Core Zone but within the Central Plateau (200-N, Gable Mountain Pond, 100-B/C crib area) will be remediated and closed based on an evaluation of multiple land-use scenarios to optimize land use, institutional control cost, and long-term stewardship.

- Other land-use scenarios (e.g., residential, recreational) may be used for comparison purposes to support decision-making, especially for
  - the post-active institutional controls period (>150 years)
  - sites near the Core Zone perimeter to analyze opportunities to "shrink the site"
  - early (precedent-setting) closure/remediation decisions

This framework does not deal with the tank retrieval decision.

Groundwater Institutional Controls. The requirements for engineered barriers and institutional controls are found in the Hanford cleanup decision documents. CERCLA records of decision stipulate the selected cleanup remedy or the closeout process once cleanup is completed for a particular site, which may include the implementation of engineered barriers and institutional controls. The requirements for institutional controls under CERCLA response actions are listed in *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (FHI 2002a), along with descriptions of their implementation and maintenance.

Institutional controls are used to augment the engineered components associated with the cleanup of waste to minimize the potential for human exposure to contamination and are primarily administrative in nature. Approximately 259 square kilometers (100 square miles) of Hanford groundwater has been affected (e.g., drinking water standards are exceeded) because of past waste management practices. A significant portion of the remainder of the site continues to serve as a buffer zone for safety and emergency response purposes, and to protect human health and the environment from remaining hazards. DOE will control access and use of the Core Zone and the buffer zone for the duration of the cleanup, including restrictions on the drilling of new groundwater wells in the existing plumes or their paths. It is expected that institutional controls will be enforced until the remedial action objectives have been obtained. In the event that DOE transfers property with groundwater use restrictions to another entity, the appropriate use restrictions are attached to the real estate transaction to ensure that specific institutional controls will remain in place.

Groundwater use on the Hanford Site is generally restricted, except for the purposes of monitoring and treatment, as approved by EPA or Ecology. Groundwater use is also controlled through excavation permits and the land-use process. A limited number of wells are currently in operation for purposes other than research or testing, including those that supply drinking water at the Fast Flux Test Facility in the 400 Area, the Hanford Patrol Training Center, the Yakima Barricade, and Energy Northwest. Other wells provide backup fire protection, emergency cooling water, and aquatic studies (FHI 2002a).

Drinking water systems are operated in accordance with the Washington State Department of Health *Washington Administrative Code*. In addition, new wells are registered with Ecology. The control measures used to protect groundwater for drinking water systems are described in the *Hanford Site Wellhead Protection Plan* (WASTREN 1995).

Top-to-Bottom Review. In February 2002, the Top-to-Bottom Review Team presented their report, *A Review of the Environmental Management Program* (DOE 2002a) to Jessie Roberson, the new Assistant Secretary for DOE-EM. The review issued four major findings:

- The manner in which DOE-EM developed, solicited, selected, and managed many contracts was not focused on accelerating risk reduction and applying innovative approaches to doing the work.
- DOE-EM's cleanup strategy was not based on comprehensive, coherent, technically supported risk prioritization.
- DOE-EM's internal business processes were not structured to support accelerated risk reduction or to address its current challenges of uncontrolled cost and schedule growth.
- The scope of the DOE-EM program included activities that were not focused on or supportive of an accelerated, risk-based cleanup and closure mission.

To address these weaknesses, the team recommended an aggressive course of action to change DOE-EM's approach to its cleanup and closure mandate. All the recommended changes were designed to focus the program on one result – reducing risk to public health, workers, and the environment on an accelerated basis.

Hanford Performance Management Plan. In August 2002, DOE, Richland Operations Office (RL) submitted the *Performance Management Plan for the Accelerated Cleanup of the Hanford Site* (Hanford Performance Management Plan) to DOE Headquarters (HQ; DOE 2002b) in response to the Top-To-Bottom Review. The plan lays out DOE-RL's goals for accelerated completion of the DOE-EM mission at Hanford and to high-quality, comprehensive cleanup that protects public health and the environment. The six strategic initiatives outlined in the plan call for DOE to:

1. Restore the Columbia River corridor by 2012 – completing remediation of 50 burial grounds, 551 waste sites, 261 excess facilities, and seven plutonium production reactors, thereby reducing risk to the river and shrinking the Hanford Site by about 85%.
2. Take several near-term actions to ensure the tank waste program ends by 2035, including increasing the capacity of the planned Waste Treatment Plant; demonstrating tank closure and starting to close tanks within five years; and demonstrating alternative treatment and immobilization solutions for lower-risk tank waste.
3. Accelerate the stabilization and shipment offsite of nuclear materials – including cleaning up K Basins spent nuclear fuel, sludge, debris, and water 10 months early; stabilizing and securely storing remaining plutonium nine years sooner; demolishing the Plutonium Finishing Plant seven years earlier; and evaluating the benefits of moving Hanford's water-stored cesium and strontium capsules to a secure dry storage facility before shipping them directly (non-vitrified) to the national geologic repository.
4. Address waste issues by accelerating treatment and disposal of mixed low-level waste, retrieving and shipping transuranic waste offsite years ahead of current plans, and coordinating remaining waste site remediation with tank closure.

5. Use Hanford's massive decommissioned chemical separations buildings as waste disposal facilities, and accelerate the disposition of the Central Plateau's 900 excess facilities and more than 800 non-tank-farm waste sites by using regional and other grouping strategies.

6. Protect groundwater resources by removing or isolating contaminant sources on the Central Plateau, remediating other contamination sources, dramatically reducing the conditions that have the potential to drive contaminants into the groundwater, treating groundwater, and integrating monitoring requirements.

Hanford's Long-Term Stewardship Program. DOE is committed to protecting human health and the environment and to meeting its long-term, post-cleanup obligations in a safe and cost-effective manner. Hanford's long-term stewardship's vision statement is

> *"The vitality of human, biological, natural, and cultural resources is sustained over multiple generations."*

The long-term stewardship's mission statement serves as the charter for the program:

> *"The mission of the LTS Program is to provide for continuous human and environmental protection, and the conservation and consideration of use of the biological, natural, and cultural resources, following the completion of the cleanup mission. This will be accomplished through the following functions:*
>
> 1. *Managing post-cleanup residual risks*
> 2. *Managing Site resources*
> 3. *Managing stewardship information*
> 4. *Using science and technology*
> 5. *Providing post-cleanup infrastructure*
> 6. *Integrating long-term stewardship responsibilities"*

Cleanup Progress To Date. DOE, Ecology, and EPA have worked hard to bring a well-defined and manageable focus to Hanford cleanup: restoring the lands along the Columbia River Corridor and transitioning the Central Plateau to a modern waste management operation. Substantial progress has been made toward reducing risk and achieving the cleanup outcomes identified in the Tri-Party Agreement documents. Substantive integration between the DOE Office of River Protection (ORP) and DOE-RL of performance and risk assessment methods, information and results has been noticeably improved. Arrangements to coordinate individual project performance assessments with DOE Order required cumulative risk assessment efforts has been facilitated by the co-location of key contractor personnel and joint direction by DOE-ORP and DOE-RL staff.

Major underground radioactive tank waste safety issues have been resolved and all tanks have been removed from the Congressional watch list. Also, 98% of the pumpable liquids remaining has been removed from the single-shell tanks included in the Interim Stabilization Consent Decree (over 11.4 million liters [3 million gallons]). The Plutonium-Uranium Extraction (PUREX) Plant and B Plant chemical processing plants were the first in the DOE complex to be deactivated to a low-cost maintenance state. Spent nuclear fuel is being taken out of wet storage and moved away from the Columbia River to safe, dry storage on the Central Plateau. Plutonium is being stabilized and packaged for safe, secure, long-term storage and disposition. Construction of the Waste Treatment Plant for tank waste treatment and immobilization has begun. Additionally, work is progressing on the evaluation and potential deployment of supplemental treatment methods to support completion of Tri-Party Agreement milestones for accelerating the pace of retrieval and disposal of tank waste.

DOE-ORP has aggressively pursued a tank farm corrective action program to quantify the extent and the risk-based impacts of past leaks in the tank farms. This soil-leak characterization program is the basis for long-term predictions of tank residual performance that will be used for risk-based closure of the tank farms. Risk has been incorporated into the selection of tank retrieval sequences and communicated to Ecology.

DOE is actively addressing contaminated groundwater plumes. Reactor complexes are being dismantled and reactor cores cocooned for interim safe storage. All unpermitted discharges to the soil have stopped. More than 3.6 million metric tons (4 million tons) of contaminated soil have been moved away from the Columbia River shoreline and into the Environmental Restoration Disposal Facility near the center of the Hanford Site. Over 1 million curies of radioactivity have been removed from contaminated facilities near the city of Richland, and nearly 1,000 metric tons (1,102 tons) of excess uranium has moved offsite. Over 1,100 drums of transuranic waste have been sent to the Waste Isolation Pilot Plant for disposal. All of this progress has been made while transforming the site safety environment to be among the best in the DOE complex.

2.0 Regional Context Risk-Based End State Description

The Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau in southeast Washington State. The site occupies approximately 1,517 square kilometers (586 square miles) north of the city of Richland, Washington. About 6% of the land has been disturbed and is actively used. The Columbia River flows eastward through the northern part of the Hanford Site and then turns south, forming part of the eastern boundary. The Yakima River flows near a portion of the southern boundary of the Hanford Site before it joins the Columbia River south of the city of Richland.

Hanford is a dry area, known for its sandy soil, basalt ridges, and shrub-steppe vegetation. A description of the Hanford Site can be found in the annual environmental report (Poston et al. 2003). Details about Hanford Site groundwater can be found in the annual monitoring report (Hartman et al. 2003). Unconfined and confined aquifers underlie the Hanford Site. In general, groundwater flows from the higher elevation of Rattlesnake Mountain and the Central Plateau toward the Columbia River.

Looney and Falta (2000) describe a conceptual model as a detailed technical description of the system that answers the question "How do we believe the system actually operates?" Conceptual models are evolving hypotheses that identify the important features, events, and processes controlling fluid flow and contaminant transport at a specific field site and in the context of a specific problem. Figure 2.1 presents a high level, simplified conceptual model for the release of contaminants from Hanford's facilities, transport of the contaminants through the environment, and the potential impact of those contaminants on living systems.

2.1 Conceptual Models

This information is presented schematically in a conceptual model for risk assessment in Figure 2.2. This conceptual illustration portrays a linear flow of information. In general, contaminants in a waste site inventory may be released to the atmospheric, vadose zone, and Columbia River pathways. In the past, releases have occurred directly to the groundwater through reverse wells and to the Columbia River from the single-pass reactors. During chemical separation plant operation, release occurred to the atmosphere. The atmosphere, groundwater, Columbia River and riparian zone provide opportunities for humans and other living things to be

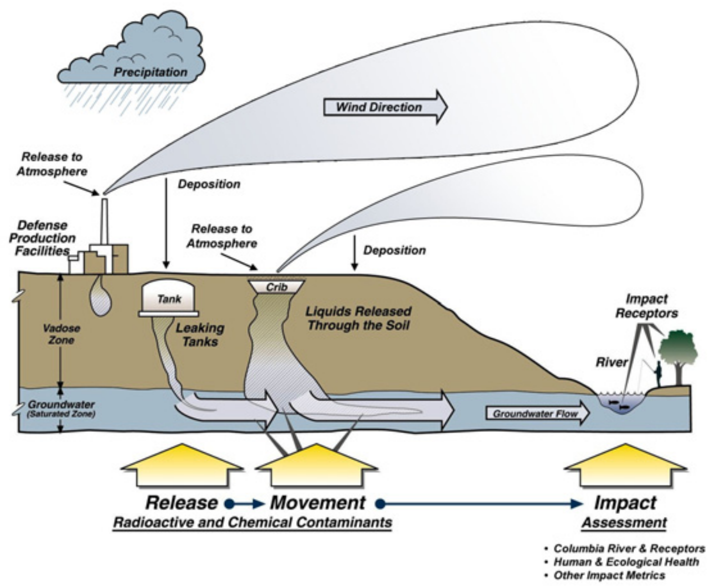


Figure 2.1. A Simplified Conceptual Model for the Release of Contaminants from Hanford's Facilities, Transport through the Environment, and Potential Impact

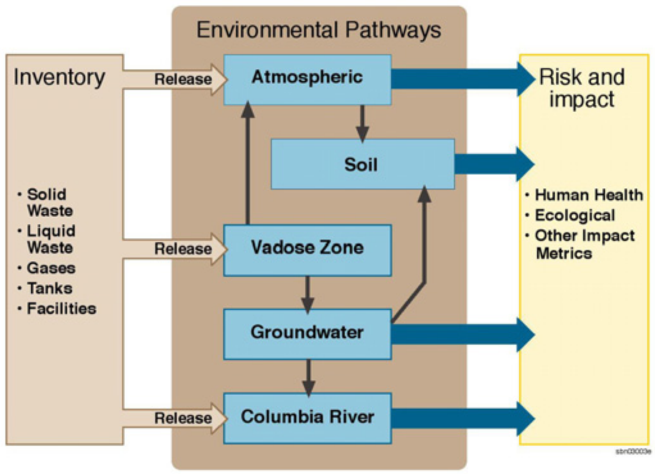


Figure 2.2. Conceptual Model for Risk Assessment

exposed to the contaminants leading to a potential health risk or other impact. A conceptual model for each element of this model is presented in the following paragraphs.

Inventory Conceptual Model. The vast majority of the radioactive waste inventory at the Hanford Site was created during the production of plutonium for atomic weapons. A conceptual model of the Hanford Site during the production operations is shown in Figure 2.3. There were three distinct steps in the production process: fuel fabrication, fuel irradiation, and chemical separation. Other processes were carried out on sites that contributed to waste inventory, such as uranium recovery from the tanks and final processing of plutonium carried out at the Plutonium Finishing Plant. During the first decades at the Hanford Site, it was common to locate waste disposal sites relatively close to waste-generating facilities.

This practice resulted in numerous and varied disposal sites. The most dangerous radioactive waste was stored in large single-shell tanks in the 200 Areas (Agnew 1997; Kupfer et al. 1997). Large volumes of solid waste (e.g., contaminated tools and protective clothing) were disposed in burial grounds, and large volumes of relatively low-level radioactive liquid waste were discharged to shallow subsurface cribs, French drains, injection (or reverse) wells, and specific retention trenches. More recently, all fuel fabrication and reactor operations ended and cleanup of past-practice units began in the 300 and 100 Areas. Low-level waste from ongoing operations is disposed in burial grounds in the 200-West and 200-East Areas. Most liquid discharges of radioactive waste have been discontinued, an exception being tritium disposal to the State-Approved Land Disposal Site, which receives treated water from the 200 Area Effluent Treatment Facility.

To determine an inventory estimate at a moment in time (e.g., now or at site closure), one needs to amend the conceptual model shown in the figure to include two aspects. First, the quantities of radionuclides and chemicals imported and exported from the Hanford Site are introduced or extracted at several points in the operation (e.g., materials fed into the fuel fabrication process, chemicals fed into the reactor operation and chemical separation processes, and uranium and other special nuclear materials left the Hanford Site). Second, the figure presents the production mission, and needs to be overlaid with the current cleanup mission. Decisions regarding the remediation, decontamination and decommissioning, and disposal actions will impact virtually all facilities and wastes depicted in the conceptual model. These cleanup actions will define the end-state configuration (i.e., both location and stability or form) of the waste.

Waste Form Release Conceptual Model. Waste containment facilities have a number of features that influence the rate at which contaminants can be released from waste. Those features are illustrated in

Figure 2.4. The waste may be placed in a trench or reside in a tank. The trench, tank, or other engineered structure may have features that serve as barriers preventing infiltrating water from making contact with and transporting contaminants from the waste to the vadose zone. Waste inside an engineered structure (e.g., trench) may also be contained in a waste package (e.g., a metal drum or high-integrity concrete container). The drum or concrete container acts as an additional barrier preventing transport of the contaminants from the waste. Major containment materials for Hanford waste are concrete, steel, and bituminous layers and coatings. The stability and permeability of containment materials change over time. Time affects which features dominate the water or contaminant migration in containment materials. Surface covers on an engineered system and liners (geomembrane and geosynthetic) and leachate collection systems further restrict infiltrating water from transporting contaminants to the vadose zone. Surface covers are particularly important because migration of infiltrating pore water may be limited as long as the cover maintains its integrity.

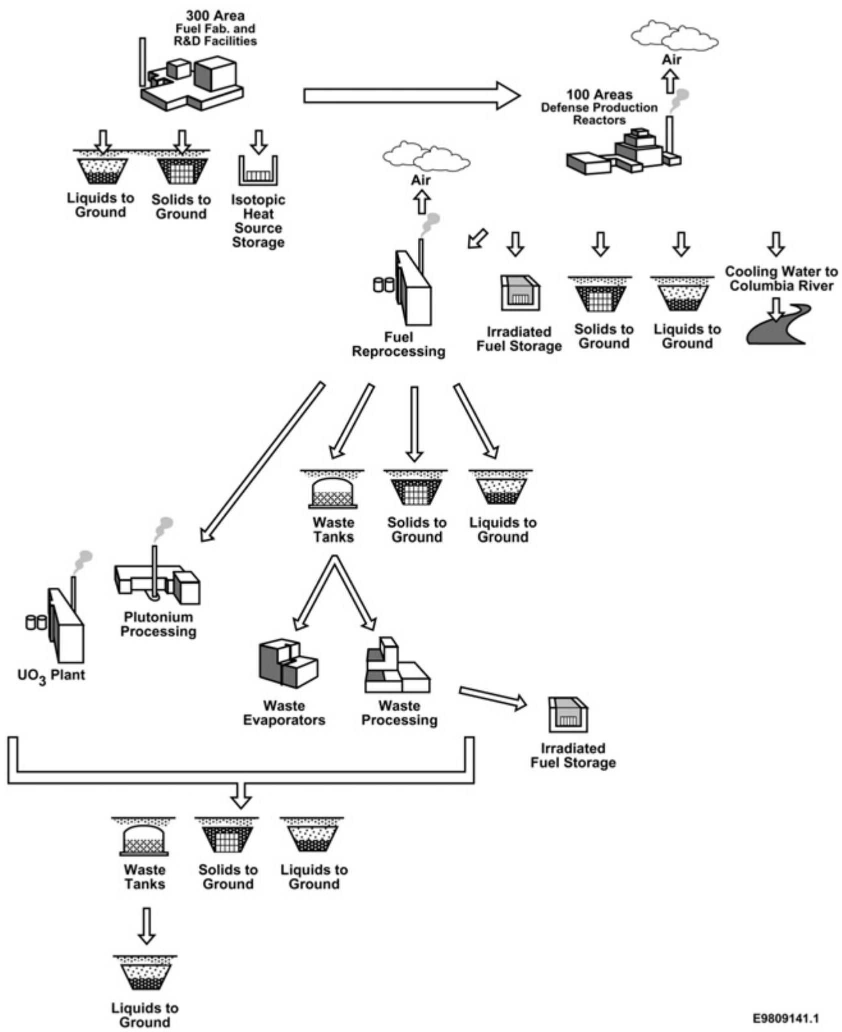


Figure 2.3. Hanford Plutonium Production Process and Waste Disposal Conceptual Model

Individual waste sites may have one or more of the features shown in Figure 2.4. However, it is unlikely that a waste site will have all of the features in the conceptual model and many of Hanford's early waste sites were constructed without engineered barriers.

A number of key processes govern how much contaminant at any given time is released from the waste to the infiltrating water. One process is the affinity of contaminants to be retained by the waste (e.g., sorption to soil or waste material). Another process is the ability of waste to dissolve, and in some cases, to form new precipitates allowing some contaminants to be released to the infiltrating water while

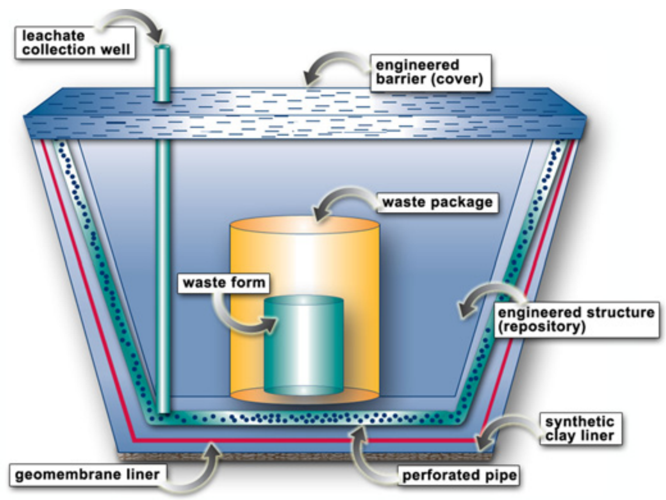


Figure 2.4. Basic Features of a Waste Containment Facility

others remain trapped in the precipitated solids. Release from the waste may also be limited by the solubility of the contaminant in the infiltrating water.

Water infiltrating an engineered system may contact and react with fill materials (e.g., soil, basalt, or grout), containment materials in various states of degradation, and different types of waste. Reaction with these materials will change the water chemistry and physical and hydraulic properties over time. The water composition, pH, and redox state at any given time will influence the extent to which these processes influence contaminant release from the waste.

Vadose Zone Conceptual Model. Vadose zone contamination is primarily the result of liquid waste being released to ponds, ditches, and cribs, leakage from retention basins, and, to a lesser degree, the accidental release of contaminants through low-volume spills and dry waste burial grounds. Billions of liters of wastewater have created large contamination plumes within the vadose zone.

The primary forces for contaminant transport are the source/release events and recharge events. The dominant transport pathway is downward through the vadose zone sediment. Stratigraphic layering, variations in the hydraulic properties, and the presence of impeding features (e.g., caliche layers) can locally alter and redirect the movement of contaminants laterally. Discordant features (either natural or manmade – for example fractures, unsealed boreholes) can provide preferential pathways capable of concentrating or contributing to phenomena such as fingering and funnel flow. Wilson et al. (1995) describes flow within the vadose zone as dynamic and characterized by periods of unsaturated flow at varying degrees of partial saturation punctuated by episodes of preferential, saturated flow in response to hydrologic events or releases of liquids.

The movement of contaminants in the vadose zone is affected by their sorption in the far field and sometimes by complex dissolution/precipitation reactions between the waste liquids of extreme pH and the slightly alkaline sediment in the near-field. The significance of sorption is that it delays downward movement of the contaminant and allows degradation processes (e.g., radioactive decay) to occur and for some contaminants, rather irreversible incorporation into the sediment. The sorptive capacity of vadose zone sediment is fairly high; however, the amount of sorption is a function of many factors including mineral surface area and type, contaminant type (speciation) and concentration, overall solution chemistry and concentration, and reaction rates for the control adsorption or precipitation, dissolution, and hydrolysis reactions. Some contaminants do not sorb at all and are moved along with the bulk solution.

Contaminants that exist in the gas phase (e.g., carbon tetrachloride) are subject to atmospheric venting. Contaminants near the soil surface are subject to animal and plant uptake. Contaminants that are consumed by microbes are subject to degradation into other compounds that may or may not pose a risk to humans and the environment. Specific topics of interest to the Hanford Site include the following subsurface events:

- subsurface contamination (i.e., characteristics of past disposal and leak age, including chemistries, volume, and distribution)
- surface hydrologic features and processes (e.g., winter rain and snow melt, water line leaks, infiltration, deep drainage, and evaporation rates)
- subsurface geologic and hydraulic features and processes (e.g., stratigraphy, structures, physical properties, geochemistry, and microbiology of the sediments above the water table) (DOE 1999b).

Atmospheric Transport Conceptual Model. Contaminants can be released to the atmosphere at ground level through volatilization of contaminants in the vadose zone or releases from Hanford subsurface disposal sites and at elevated points through releases from Hanford processing plant stacks. The distance and direction of transport of contaminants through the atmosphere is affected by the wind speed and direction (at the surface and at the release height). Ambient air temperature affects how the plume rises as it is transported through the atmosphere. The temperature of the effluent can also effect plume-rise. Dispersion of the contaminant plume is determined by the thickness of the atmospheric mixing-layer and the atmospheric stability class. Contaminants are considered to be one of three types for the evaluation of deposition in numerical models: noble gas, iodine, or particle. Contaminants that do not deposit on the ground but are available for inhalation are treated as noble gases; iodine and particles are both deposited on the ground, but have different deposition characteristics. The deposition of contaminants is controlled by atmospheric conditions and surface roughness. Precipitation (rain and snow fall) results in wet deposition of contaminants. In numerical applications, any portion of contaminant that is deposited on the ground is removed from the atmospheric plume to maintain a mass balance.

Groundwater Conceptual and Implementation Model. The state-of-knowledge concerning characterization, modeling, and monitoring of the groundwater system, described in DOE (1999b), provides the primary basis for the groundwater conceptual model discussed. The key components needed for contaminant flow and transport through the groundwater element are schematically depicted in Figure 2.5. The groundwater conceptual model is an interpretation or working description of the characteristics and dynamics of the physical hydrogeologic system, and it consolidates Hanford Site data (e.g., geologic, hydraulic, transport, and contaminant) into a set of assumptions and concepts that can be quantitatively evaluated.

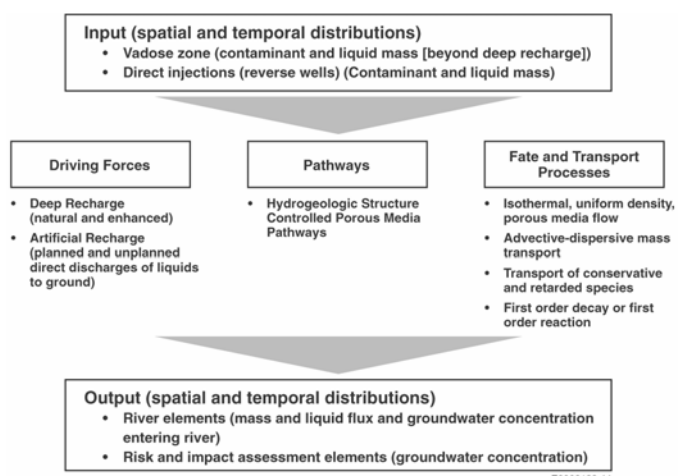


Figure 2.5. Some Primary Conceptual Model Components for Flow and Transport of Contaminants through Groundwater

The groundwater flow system affects the potential for contaminants to migrate from the Hanford Site through the groundwater pathway. To understand this system, the geology and hydrology of the site must be determined because they control the movement of contaminants in groundwater. This information provides the basis for analysis of groundwater flow and contaminant plume migration which is central to many risk assessments used in decision support at Hanford. This section provides an overview of the hydrogeologic conditions of the Hanford Site and describes key components of groundwater within the unconfined and confined aquifer systems.

The Hanford Site lies in the Columbia Plateau, a broad plain situated between the Cascade Range to the west and the Rocky Mountains to the east. This plateau was formed by a thick sequence of Miocene-Age tholeiitic basalt flows, called the Columbia River Basalt Group, which emanated from fissures in northcentral and northeastern Oregon, eastern Washington, and western Idaho (Swanson et al. 1979). In the central and western sections of the Columbia Plateau, where the Hanford Site is located, the Columbia River Basalt Group is underlain by continental sedimentary rocks from earlier in the Tertiary Period.

In addition to the Columbia River Basalt Group, stratigraphic units underlying the Hanford Site include, in ascending order,

- **Ringold Formation** – a heterogeneous mix of variably cemented and compacted gravel, sand, silt, and clay deposited by the ancestral Columbia and Snake Rivers. The system that deposited the sediment was a braided stream channel with the two rivers joining in the area of the present White Bluffs.

- **Plio-Pleistocene unit and Early Palouse soil** – a sequence of sidestream alluvial deposits and buried soil horizons with significant caliche in some areas. The unit overlies the Ringold Formation and is found only in the western part of the Hanford Site.

- **Hanford Formation and Pre-Missoula gravels** – a series of coarse-grained sediments, ranging from sand to cobble and boulder size gravel deposited from a series of cataclysmic floods during the Pleistocene Age. The floods occurred when ice dams broke, releasing water from Lake Missoula, a large glacial lake that formed in the Clark Fork River Valley. Pre-Missoula (flood) gravels underlie the Hanford formation gravel deposits in the central part of the Hanford Site. The pre-Missoula deposits are difficult to distinguish from the Hanford gravels, so they are usually grouped together.

- **Holocene surficial deposits** – a discontinuous veneer of alluvium, colluvium, and/or eolian sediment. In the 200-West Area and southern part of the 200-East Area, these deposits consist dominantly of laterally discontinuous sheets of wind-blown silt and fine-grained sand. They are generally found above the water table.

Groundwater within these sediments is present under both unconfined and confined aquifer conditions. The unconfined aquifer is contained in the unconsolidated to semiconsolidated Ringold and Hanford formations that overlie the basalt bedrock. In some areas, low permeability mud layers within the Ringold formation form aquitards that create locally confined hydraulic conditions within the aquifer system.

The water table lies within the Hanford formation over most of the eastern and northern parts of the Hanford Site (Figure 2.6). The Hanford formation lies entirely above the water table in the western part of the site and in some other localized areas. Within these areas, the water table is generally found in hydrogeologic units associated with the Ringold Formation. Also shown in Figure 2.6 are areas on the Hanford Site where the surface basalt bedrock features crops out above the water table in the vicinity of Gable Butte and Gable Mountain. Another basalt bedrock feature associated with the a subsurface extension of the Yakima Ridge found to be above the water table is also shown in the southwest part of the Hanford Site.

Figure 2.7 shows a geologic cross section of the Hanford Site and the location of the water table between Cold Creek Valley and the Columbia River. This cross section represents A-A' on the map in Figure 2.6 and shows that the saturated sediment of the Hanford formation represents a small portion of the total saturated sediments above basalt when compared to the total saturated thickness of the Ringold Formation.

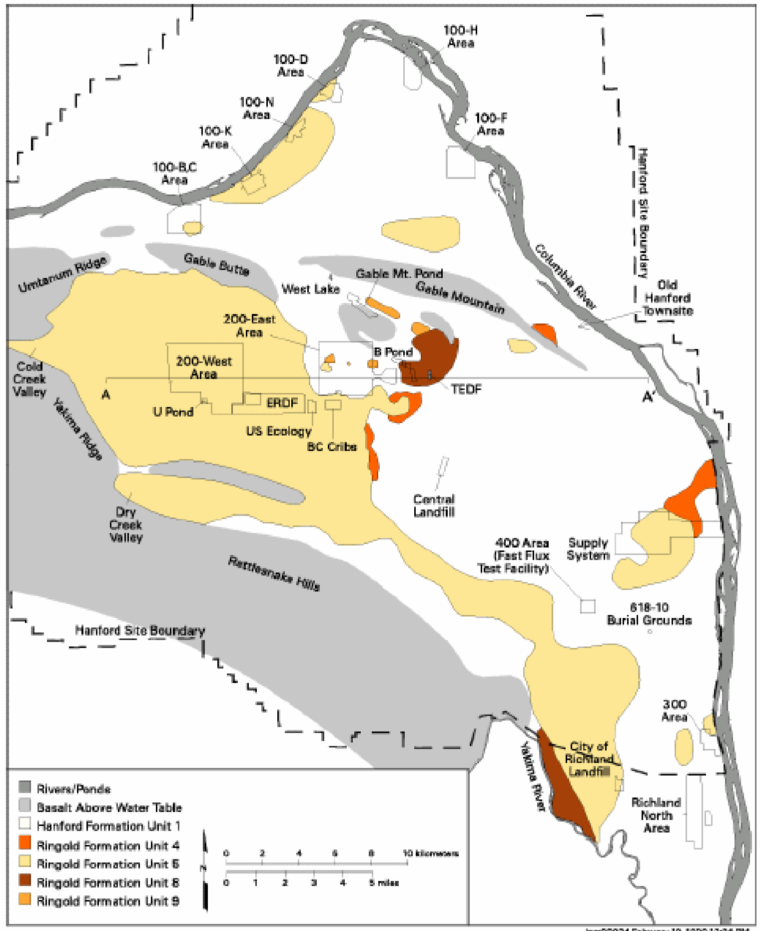


Figure 2.6. Major Hydrogeologic Units at the Water Table in March 1999

The major stratigraphic and the corresponding hydrogeologic units contained within the Hanford and Ringold formations, provided in Figure 2.8, show key differences in sediment characteristics among the major units. The geologic column on the right defines the lithostratigraphic units, based on mapping and physical properties of the sediment, modified from Lindsey (1995). The hydrogeologic column on the left defines hydrostratigraphic units based on hydraulic properties (Thorne et al. 1993).

The current conceptual model of the unconfined aquifer system has identified up to nine major hydrogeologic units (Thorne and Chamness 1992, Thorne and Newcomer 1992, and Thorne et al. 1993, 1994) within the sediments above the underlying basalt bedrock. Although nine hydrogeologic units were defined, only seven are found below the water table under present day and anticipated future conditions. The Hanford formation combined with the pre-Missoula gravel deposits were designated as a major hydrogeologic unit. Within the Ringold Formation, six different major hydrogeologic units have been identified including three predominantly coarse grained sediment and three predominantly fine-grained sediment with low permeability. The early Palouse soil and Plio-Pleistocene deposits, form two other hydrogeologic units but these units are largely above the existing water table and are not considered

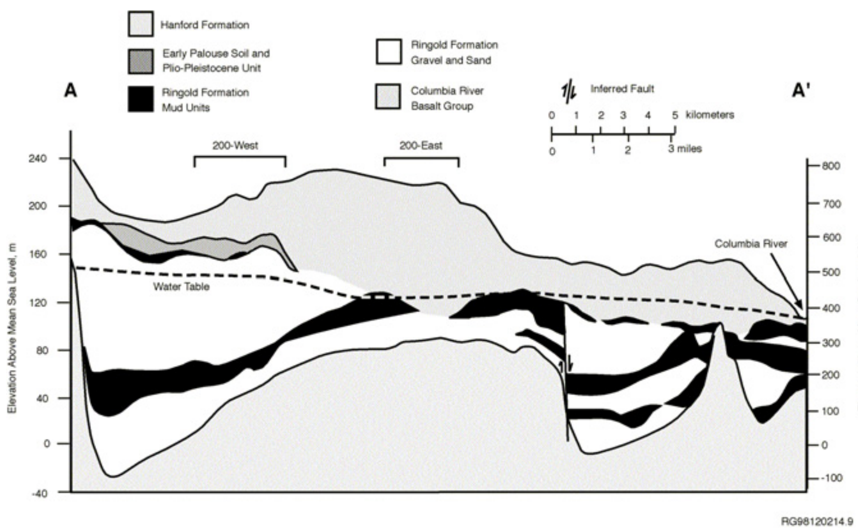


Figure 2.7. West-East Cross Section Showing Major Hydrogeologic Units at the Hanford Site and the Water Table in 1999

important units within the unconfined aquifer system. The Holocene alluvium, colluvium, and/or eolian sediments are also well above the water table and are not considered important to the unconfined aquifer system.

A sequence of basalt-confined aquifers is present within the Columbia River Basalt Group beneath the Hanford Site. These aquifers are composed of sedimentary interbeds and the relatively permeable tops of basalt flows. The dense interior sections of the basalt flows form confining layers. The most recent basalt flow underlying the Hanford Site is the Elephant Mountain Member of the Saddle Mountains Basalt. However, the younger Ice Harbor Member is found in the southern part of the site (DOE 1988). The Rattlesnake Ridge interbed is the uppermost laterally extensive hydrogeologic unit of these sedimentary interbeds and this unit represents the uppermost confined aquifer unit.

The local unconfined aquifer flow system is bounded by Yakima River and basalt ridges on the south and west and by the Columbia River on the north and east. The Columbia River represents a point of regional discharge for the unconfined aquifer system. Groundwater in the unconfined aquifer generally flows from upland areas in the west and southwest parts of the Hanford Site either north through the gap between Gable Butte and Gable Mountain or east toward the Columbia River where it eventually discharges into the Columbia River. Groundwater in the basalt-confined aquifers also generally flows from elevated regions at the edge of the Pasco Basin toward the Columbia River (Spane and Webber 1995). However, the discharge zone locations are also influenced by geologic structures that increase the vertical permeability of the confining basalt layers.

The amount of groundwater within the unconfined and confined aquifers discharging to the Columbia River and the lower reaches of the Yakima River is a function of the local hydraulic gradient between the groundwater elevation adjacent to the river and the river stage elevation. This hydraulic gradient is highly variable because the river stage is affected by releases from upstream dams. Estimates made using the site-wide model indicate that groundwater discharging to the Columbia River from the Hanford side of the river would be less than one-tenth of one percent of the average annual flow in the river of about 2,832 cubic meters (100,000 cubic feet) per second.

Existing plumes of tritium and iodine-129 migrating east from 200-East Area discharge into the Columbia River near the Hanford town site. Plumes of tritium and technetium-99 also migrating north through the gap between Gable Mountain and Gable Butte have reached the river in the 100-B/C Area. Plumes of various constituents also discharge into the river in vicinity in all of the 100 Areas and the 300 Area.

Recharge to the unconfined aquifer system occurs from several sources including

- infiltration of precipitation falling across the Hanford Site.
- infiltration of runoff from elevated regions along the western and southwest boundary of the Hanford Site
- infiltration of spring water and upwelling of groundwater that originates from the basalt-confined aquifer system
- artificial recharge in vicinity of onsite wastewater facilities, offsite irrigation, and nearby municipal city of Richland water supply systems.

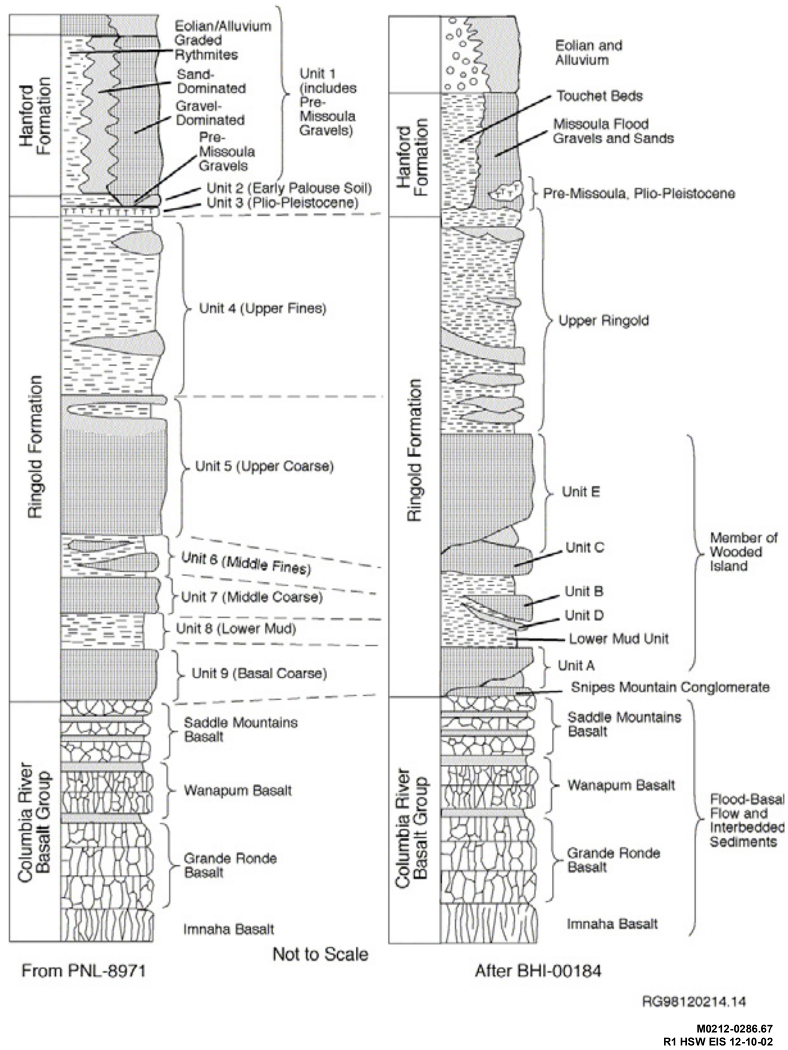


Figure 2.8. Comparison of Generalized Hydrogeologic and Geologic Stratigraphy (from Thorne et al. 1993 and after Lindsey 1995)

Recharge from infiltration of precipitation is highly variable, both spatially and temporally, and ranges from near zero to greater than 100 millimeters per year, depending on climate, vegetation, and soil texture (Gee et al. 1992; Fayer and Walters 1995). Recharge from precipitation is highest in coarse-textured soil with little or no vegetation, which is the case for most of the industrial areas on the Hanford Site. A recharge distribution applied in the site-wide model, described in Cole et al. (1997, 2001) and shown in Figure 2.9, is based on distributions of soil and vegetation types.

The majority of runoff from elevated regions along the western and southwest boundary of the Hanford Site infiltrate into the unconfined aquifer system within Cold Creek and Dry Creek Valleys and along the base of Rattlesnake Hills along the west and southwest boundaries of the Hanford Site.

The aquifer also receives recharge from upper reaches of the Yakima River where the stage is above the regional water table.

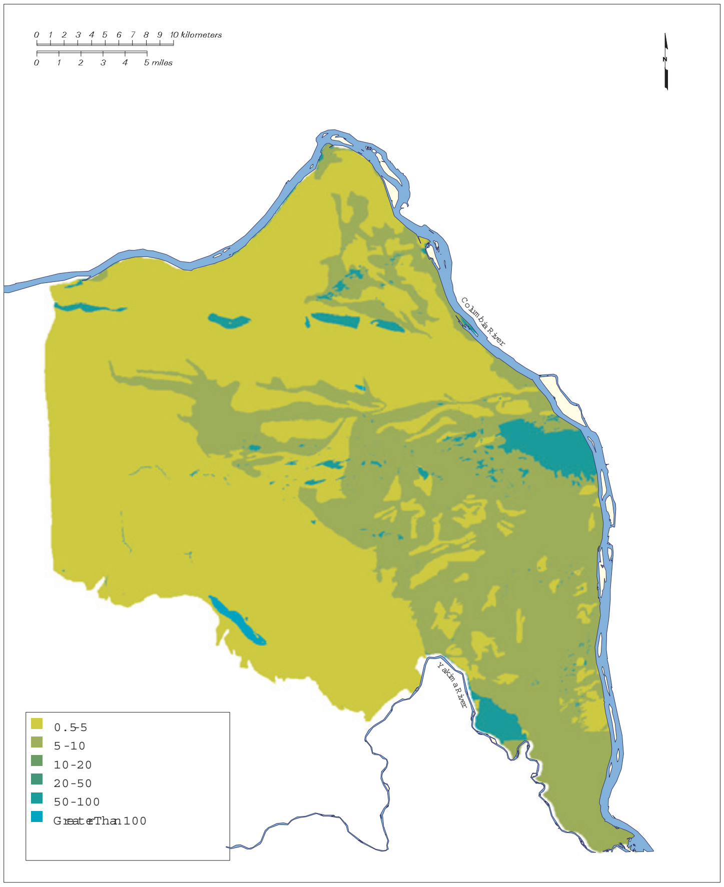


Figure 2.9. Estimates (in millimeters) of Recharge for 1979 Conditions (Fayer and Walters 1995)

Intercommunication between the unconfined aquifer and the uppermost basalt-confined aquifer occurs from several leakage processes. The major sources of leakage include

- areally distributed leakage through the uppermost basalt confining layer (that is, the Elephant Mountain Member of the Saddle Mountains Basalt
- leakage at an erosional windows through the uppermost confining unit near Gable Mountain/Gable Butte and near B Pond
- leakage along two thrust fault zones north of Gable Mountain and Gable Butte and north of the Yakima Ridge.

Since the start of Hanford Site operations in the mid-1940s, the unconfined aquifer system has also been significantly impacted by artificial recharge from onsite wastewater disposal facilities has been several times greater than the estimated recharge from natural sources. This caused an increase in the water-table elevation over most of the Hanford Site and the formation of groundwater mounds beneath major wastewater disposal facilities. The regional rise in water table was at its highest historical levels in the early to mid-1980s when the mounds in 200-East and 200-West Areas were about 10 and 22 meters (33 and 66 feet) higher than estimated pre-Hanford water-table conditions, respectively.

Beginning in 1988, production activities on the Hanford Site closed, which resulted in a decrease of wastewater disposal and subsequent decreases in water-table elevation over much of the site. Remnants of the groundwater mounds that formed during the historical periods of highest wastewater discharge are still evident in vicinity of major discharge facilities near the 200-East and 200-West Areas.

The unconfined aquifer system has also been impacted locally by other sources of artificial recharge as a result of irrigation in the upper Cold Creek Valley in the western part of the site, in agricultural areas south of the Hanford Site, and in the vicinity of the recharge basin/withdrawal well system used by the city of Richland for municipal water supply.

These past and current hydraulic impacts on the unconfined aquifer system are predicted to subside in the future and the aquifer system is expected return to more natural flow conditions over the next 300 to

400 hundred years. Previous modeling analysis by Cole et al. (1997) suggest that as water levels drop in the vicinity of central areas in the Hanford Site where the surface basalt features associated with Gable Butte and Gable Mountain crop out above the water table, the saturated thickness of the unconfined aquifer will decrease and the aquifer may actually dry out in certain areas. This thinning/drying of the aquifer is predicted to occur in the area just north of the 200-East Area between Gable Butte and the outcrop south of Gable Mountain, and a potential exists for this northern area of the unconfined aquifer to become hydrologically separated from the area south of Gable Mountain and Gable Butte.

Several key processes important to evaluating contaminant fate and transport in groundwater include advection and dispersion, first order radioactive decay, chemical interactions with the water and sediment, and contaminant density. A broader range of chemical processes including the effects of multi-phase behavior, density, and alternative degradation (that is, abiotic and biotic degradation) processes may be important to consider in evaluating the historical and future behavior of an another constituent of interest, carbon tetrachloride, in vicinity of source areas in 200-West Area. Recent vadose modeling of historical carbon tetrachloride transport have been initiated and will examine the effects of these broader range of chemical processes to evaluate their importance in plume development and transport in groundwater near source areas. Another factor that may be important to evaluating contaminant behavior for certain source areas is thermal effects. These effects are being considered in close proximity to tank farms with detailed vadose zone modeling but because of the modulating effect of the thick vadose zone in these areas, the thermal impact of these types of waste sources on contaminant behavior in groundwater is not expected to be significant or important.

Columbia River Conceptual Model. The Columbia River is the largest North American River to discharge into the Pacific Ocean. The river originates in Canada and flows south 1,953 kilometers (1,212 miles) to the Pacific Ocean. The watershed drains a total of 670,000 square kilometers (258,620 square miles) and receives waters from seven states and one Canadian province. Key contributors to the flow are runoff from the Cascade Mountains in Washington and Oregon and from the western slopes of the Rocky Mountains in Idaho, Montana, and British Columbia. Average annual flows below Priest Rapids and The Dalles dams are approximately 3,360 cubic meters (120,000 cubic feet) per second and 5,376 cubic meters (192,000 cubic feet) per second, respectively. Numerous dams within the United States and Canada regulate flow on the main stem of the Columbia River. Priest Rapids Dam is the nearest dam upstream of the Hanford Site, and McNary Dam is the nearest downstream (Figure 2.10). The dams on the lower Columbia River greatly increase the water travel times from the upper reaches of the river to the mouth, subsequently reducing the sediment loads discharged downstream. The increased travel times also allow for greater radionuclide deposition and decay.

The Snake, Yakima, and Walla Walla Rivers all contribute suspended sediment to the Columbia River; contributions from the Snake River are the most significant. Since construction of McNary Dam (completed in 1953), much of the sediment load has been trapped behind the dam. However, at McNary Dam and other Columbia River dams, some of the trapped sediment is re-suspended and transported downstream by seasonal high discharges. As expected, much of this material is re-deposited behind dams located farther downstream. Sediment accumulates faster on the Oregon shore than on the Washington shore because sediment input from the Snake and Walla Walla Rivers stay near the shore on the Oregon side.

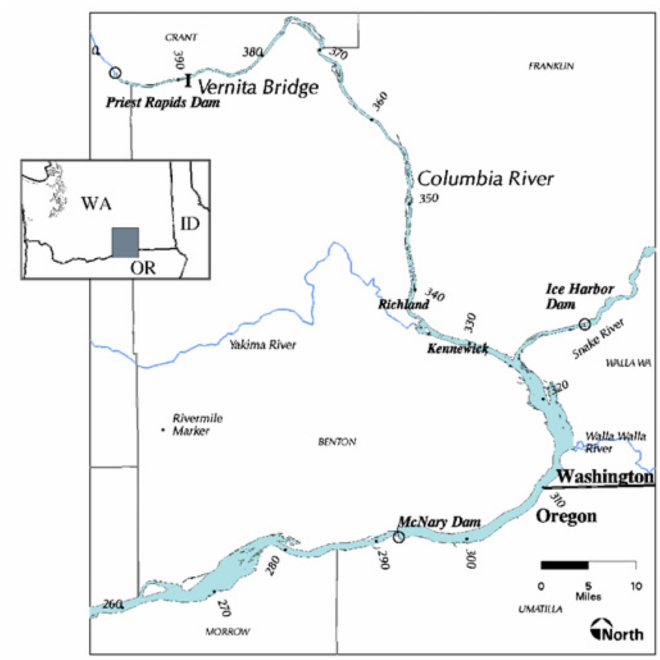


Figure 2.10. Columbia River Showing the Area Between Priest Rapids Dam and McNary Dam

Sediment monitoring samples taken for the Hanford Surface Environmental Surveillance Project indicated cobble and coarse and fine sand bed sediment at sampling locations along the Hanford Site (Blanton et al. 1995). Silt and clay sediment was observed at the McNary Dam sampling site. The conceptual model used in the initial assessment included the environmental pathways and transport processes that affect contaminant transport in surface water systems. These pathways and processes are illustrated in Figure 2.11.

Several sources cause uncertainty in the mathematical representation of the conceptual model. These include the choice of temporal and spatial scales, initial and boundary conditions, model parameters, and the physical processes themselves. Examples of uncertainty in physical processes are fluid turbulence and cohesive sediment transport. Uncertainty also arises when selecting parameters such as channel roughness coefficients, porosity, and sediment-contaminant interaction coefficients as well as the influx of contaminants through the interface with groundwater.

Human Health Conceptual Model. The conceptual human health model (Figure 2.12) includes exposure pathways of ingestion, inhalation, dermal/contact, and direct radiation exposure from all abiotic and biotic media.

The Human Health Risk conceptual model shares many features with the Ecological Impacts conceptual model. Concentrations of contaminants in Columbia River water, groundwater, seep/spring water, soils, and sediments are the starting points. Irrigation is included from water sources to soils, which is a human-induced

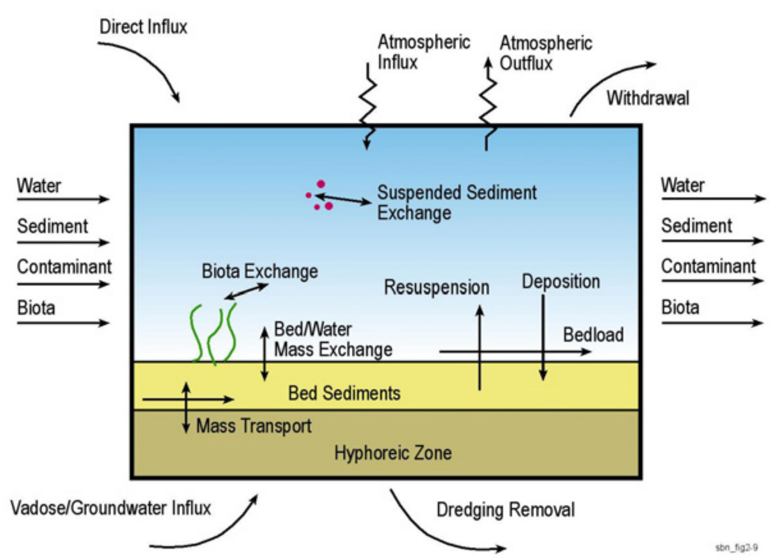


Figure 2.11. Schematic of the Transport and Fate Processes in the River Conceptual Model

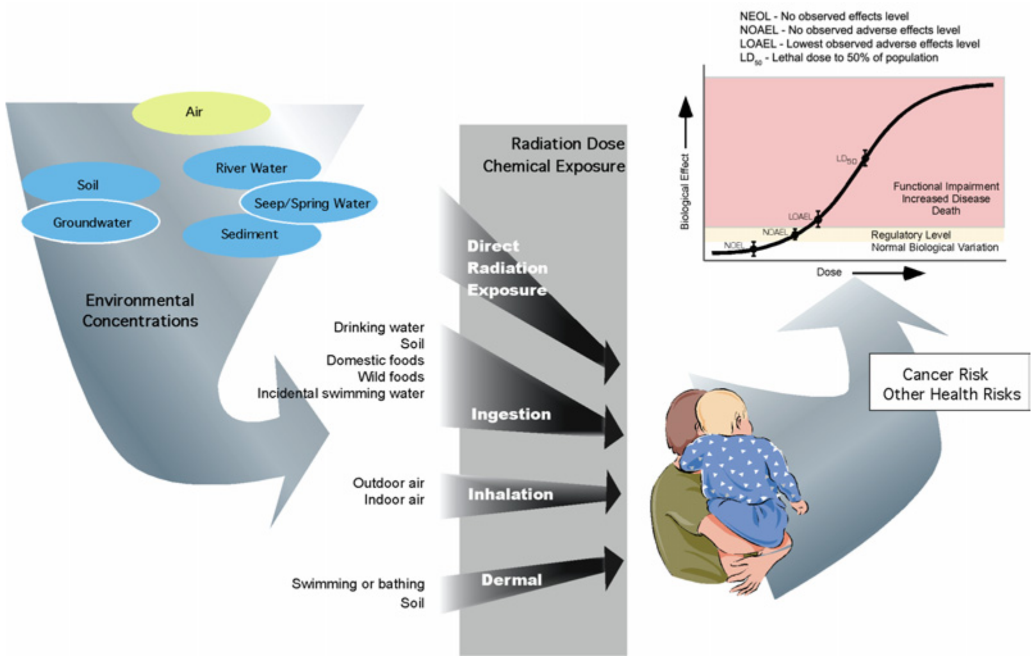


Figure 2.12. Conceptual Human Health Model

transport mechanism that results in the introduction of contaminated non-riparian agricultural soils. The process of irrigation also adds a process to the contamination of plants; that of foliar deposition and retention. A currently unmodeled exposure mechanism is the potential for future human disruption of the waste disposal systems, which would contaminate surface soils in the vicinity of the waste sites.

As a result of the accumulation processes in farm products that are parallel to those of the Ecological model, humans may be exposed to contaminants in physical media and food products. Farm animal products such as milk, meat, or eggs may be contaminated by input from feed and water sources. Another process that differentiates the human from the ecological exposures is that of the human food distribution systems. People ship crops around the country and pipe water from place to place. During this transfer, other processes that modify the contaminant concentrations occur, such as water purification and food preparation. Ultimately, people eat, drink, inhale or are otherwise exposed to the contaminants. As a result, individual health effects may occur. Relative exposures to these sources depend on individual lifestyles or exposure scenarios. Exposure scenarios include those of a resident farmer using groundwater from upland areas or river sources, several Native American lifestyles, river recreational users, and Richland residents.

There may be interactions between chemicals, or between radiation dose and chemical intake, but the effects of radiation exposure and toxic chemical exposure are evaluated separately. Human health risks are evaluated and summed across exposures.

The human health model may be run multiple times to evaluate various individual Impact Scenarios. The Impact Scenarios are the combinations of exposure mode and duration that define specific time/location/pathway/activity combinations that have been requested by the analyst. The Human Risk module is designed to allow multiple evaluations of this nature, in order to answer the types of "what if" questions that often arise in discussions of risk.

Ecological Conceptual Model. The conceptual model for assessing ecological risk/impact has two parts: quantifying exposure to contaminants and translating exposure into effect. Organisms in the Hanford environment are or can be exposed in one or more habitats: within the Columbia River, in the riparian zone along the river, and in the upland habitat. Plants and animals in the Columbia River may be exposed to contaminants in surface water, sediment, or pore water (Figure 2.13). Contaminants enter these media by direct discharge (no longer occurring), through influx of contaminated groundwater to the river, or as background from upstream sources. A very small portion of the total contaminant influx has been and will be via atmospheric deposition; the bulk of the exposure arises from groundwater influx. Consequently, the primary zones of exposure in the river are associated with contaminant plumes entering from the 100 and 300 Areas, and the large, broad plumes from the 200 Areas that intercept the Columbia River from the Hanford town site to the northern end of the 300 Area.

As shown in the Figure 2.13, organisms using the Columbia River are primarily exposed in the zone where groundwater intercepts the river, i.e., the exposure is to pore water (mixed groundwater and river water) and sediments in chemical equilibrium with the pore water. Because of the large river flows relative to groundwater influx, concentrations reach background levels within a few centimeters of the river bottom at these influx areas.

Once contaminants enter the biological environment, they may be transported through the food chain. For example, contaminants in groundwater may enter aquatic plants and accumulate in edible tissues. Herbivores (e.g., snails, carp) consume this plant material, along with any contaminants deposited on the plant surface as particulate matter. They may also ingest sediment directly (e.g., clams), and also consume river water that contain diluted contaminants. The tissues of herbivores will then reflect their accumulated exposure to contaminants. Omnivores and carnivores will thus consume prey that have integrated the various contaminants they have encountered through their lifetime. A conceptual food chain is shown in the figure above, which also indicates relative exposure of the various trophic components to sediment, pore water, and surface water.

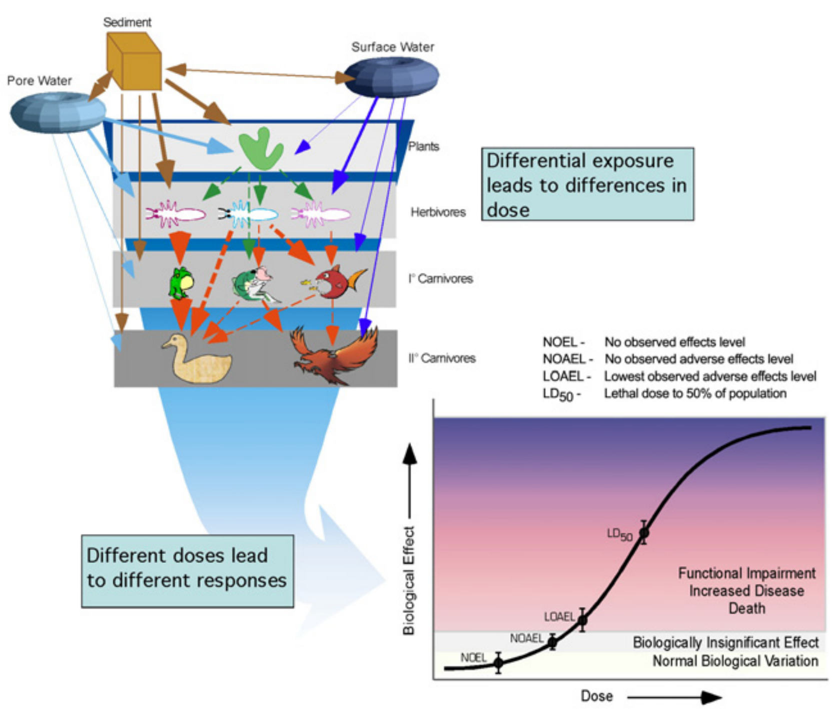


Figure 2.13. Ecological Conceptual Model

Organisms in the riparian zone are exposed to contaminants either in the shallow groundwater (through animal burrowing or plant root penetration) or in the river and its associated sediments. Contaminants in soils may also be transported to leaves and stems through vapor or particulate deposition resulting from wind erosion or rainsplash. Terrestrial (i.e., air-respiring) animals may be exposed to contaminants via ingestion of contaminated food or water, dermal exposure to contaminated soil or water, and/or inhalation of airborne contaminants.

Finally, organisms in the upland areas may be exposed to contaminants in groundwater via deep-rooted plants, such as trees, asparagus, and sagebrush, whose roots penetrate as much as 15 meters (49 feet) below the ground surface. This pathway is only available where the groundwater is relatively shallow, i.e., along the Columbia River margins, at the southern portion of Gable Mountain, and at the Hanford town site area. Otherwise, groundwater is too deep to be accessed by plants.

Contaminant exposure may have one of three consequences depending on the duration and level of exposure: no effect, an adaptive response, or an adverse effect. No effects result when exposure levels are below the threshold of significant physiological response. At higher exposure levels, some contaminants may induce an adaptive response in the exposed organism. Adaptive responses include behavioral changes (e.g., avoiding some threshold of contaminants), biochemical/physiological changes (e.g., induction of enzymatic pathways to detoxify contaminants or repair deoxyribonucleic acid [DNA]), or structural changes (e.g., proliferation of metal exchange sites on gills). Adverse effects arise when the exposure exceeds the organism's capacity to deal adaptively with the chemical or radionuclide.

Radiological effects are a function of the energy deposited in the receiving biological tissues and the relative biological effectiveness of the radiation. Chemical effects arise from specific actions on the structural, genetic, and enzymatic components in the exposed organism. Effects of Hanford-derived contaminants include narcosis (e.g., carbon tetrachloride), neural toxicity (e.g., mercury), and enzymatic disruption (e.g., copper). In combination, contaminants effects may be independent, additive, synergistic, or suppressive. The conceptual model accounts for multiple contaminants by grouping those with similar modes of action and treating them as additive unless research data are available that suggest otherwise. For the purposes of screening analyses, de minimus levels are set by DOE's population-protection radiation exposure standards for ionizing radiation effects and by lowest observed effects levels obtained from regulatory agencies and the literature for chemical effects (Figure 2.13).

Effects on individuals can alter populations and communities if the effect is severe enough and includes a sufficient fraction of the population. Higher-order effects include such responses as decreased population sizes, decreased population growth rates, increased rates of tumors, or evolutionary (genetic) changes. The key consideration here is that higher order effects do not appear without effects occurring at the individual level of organization. Thus, toxic effects of contaminants on certain populations (e.g., benthic insect larvae) can affect other, less-exposed ecosystem components (such as juvenile salmon) through alterations in prey base or habitat. These indirect effects are evaluated as part of the approach to risk-based standards.

2.2 Physical and Surface Interface

The regional discussion of the physical and surface interface has been included in the site-specific discussions in Chapter 3. Figures 2.14, 2.15, and 2.16 show the current state of the region surrounding the Hanford Site.

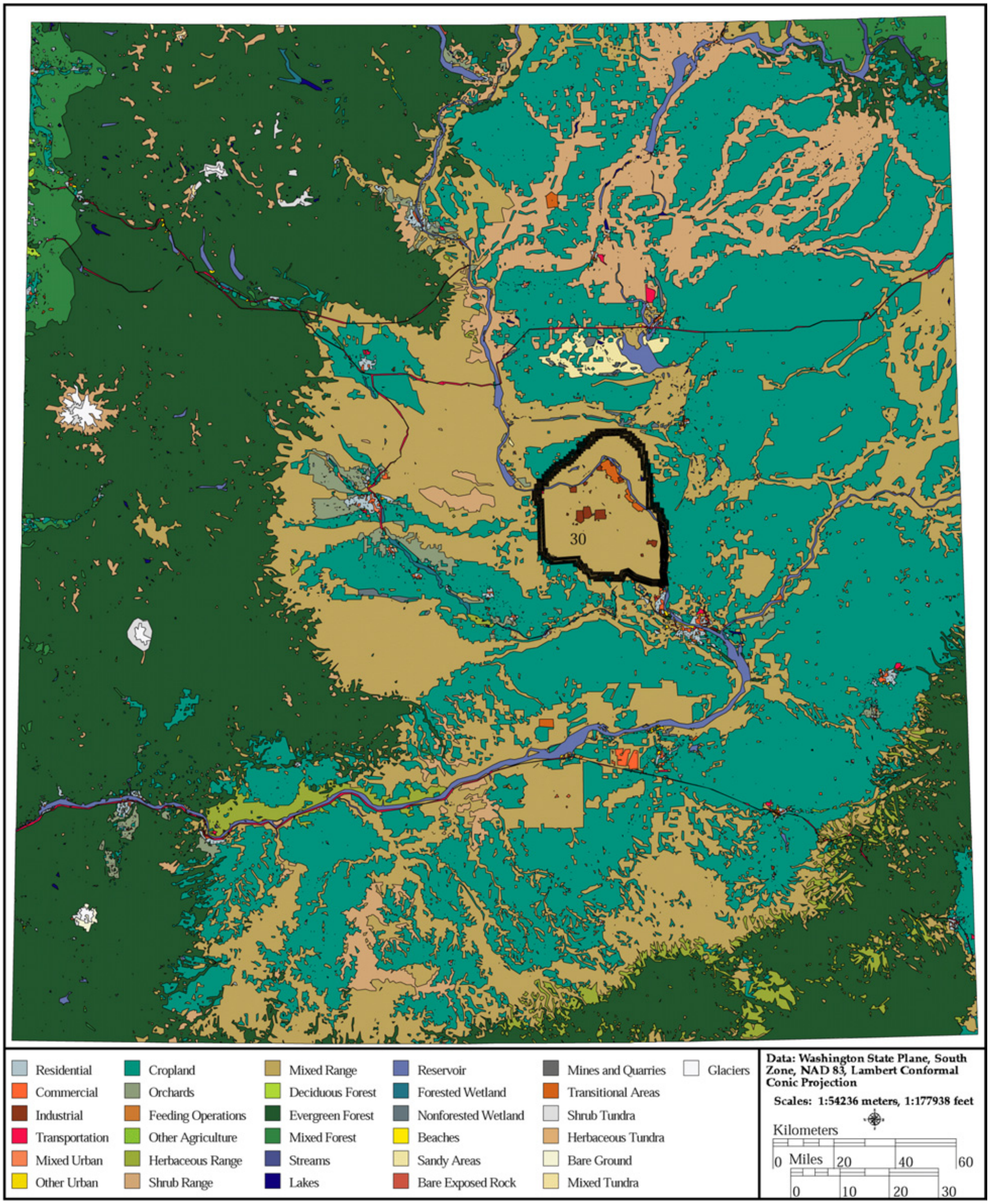


Figure 2.14. Land Use and Land Cover Around the Hanford Site – Current State

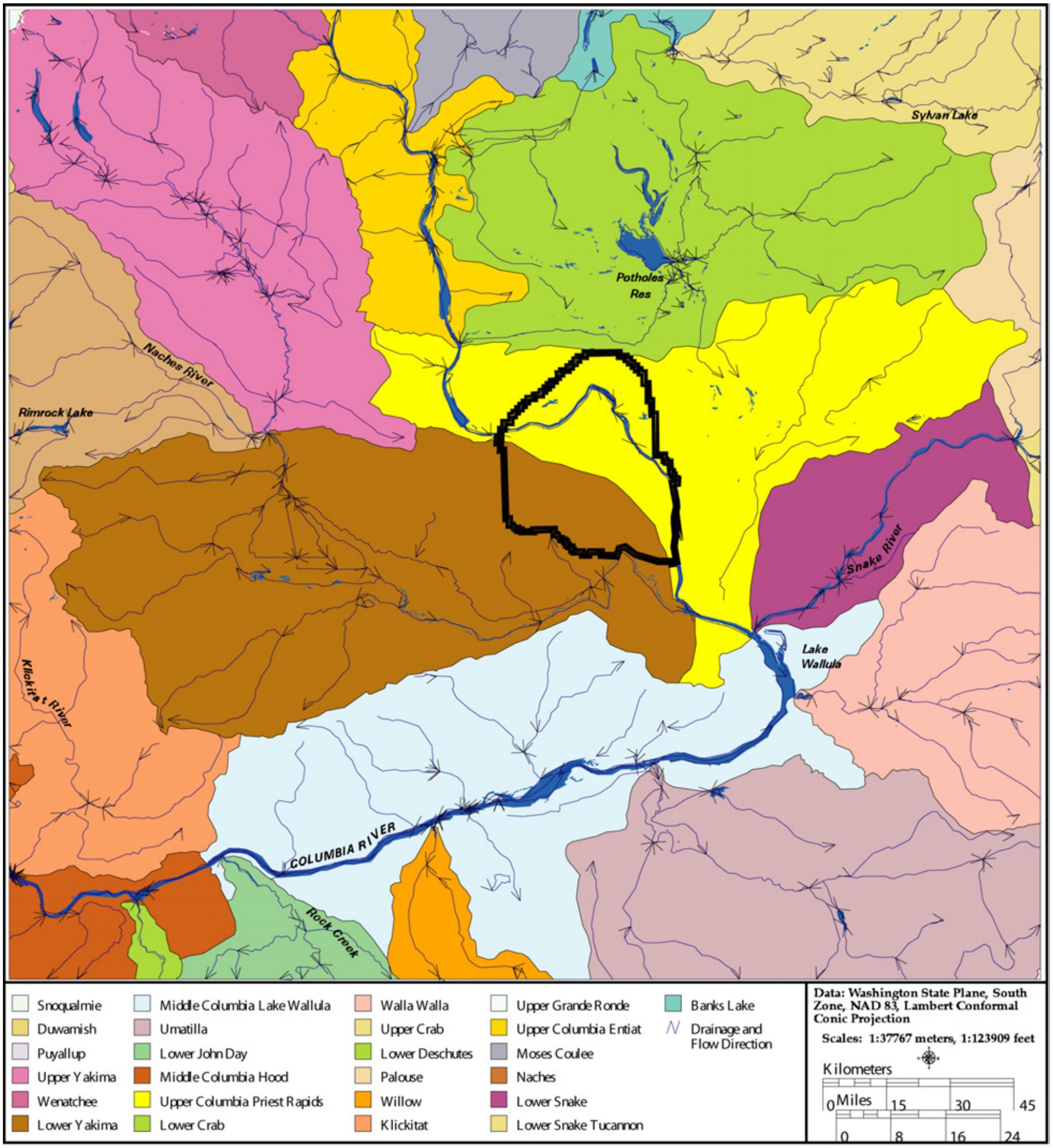


Figure 2.15. Columbia River Watershed – Current State

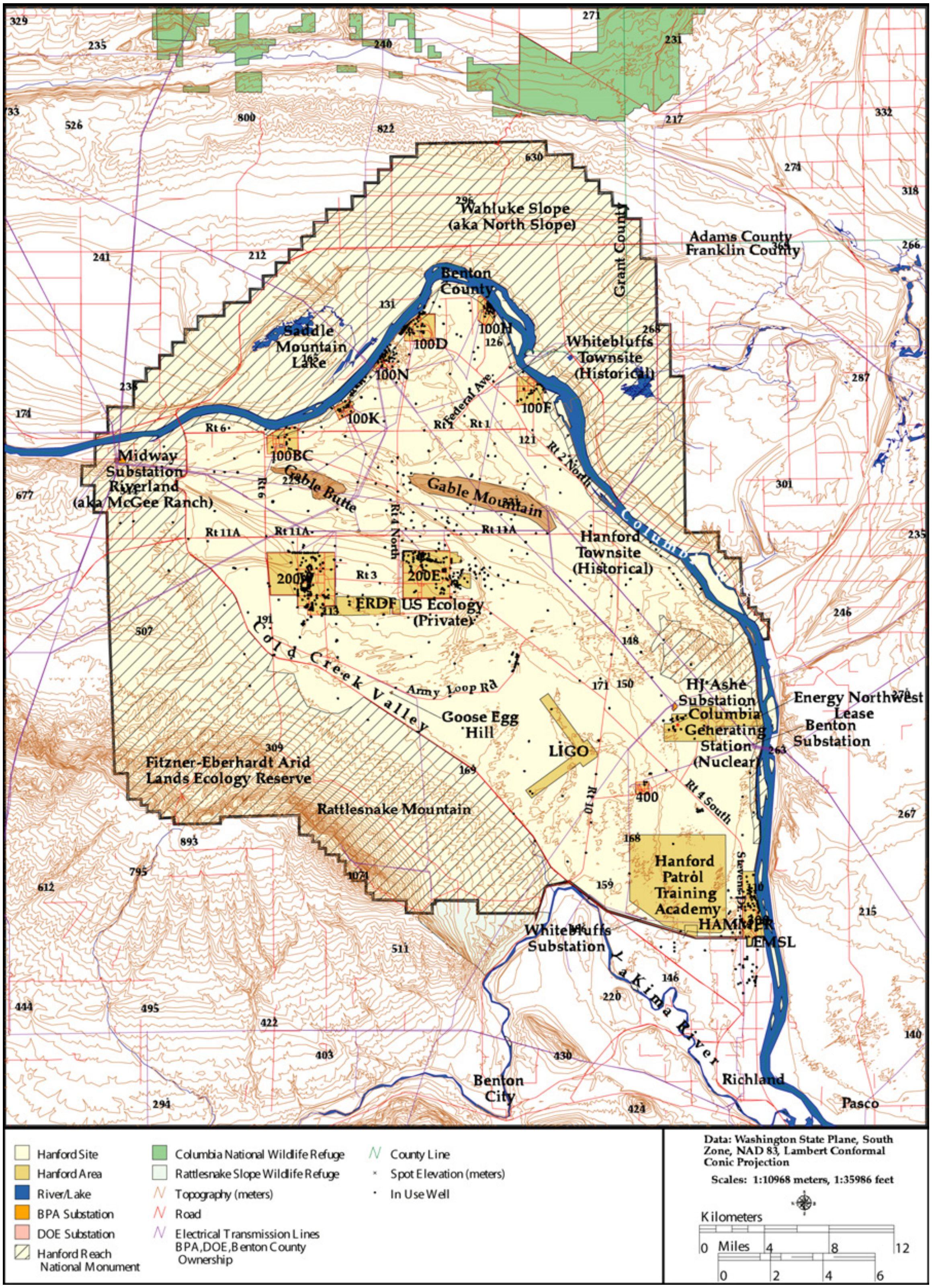


Figure 2.16. Hanford Site Base Map – Current State

2.3 Human and Ecological Land Use

The regional discussion of the human and ecological land use has been included in the site-specific discussions in Chapter 3. Figures 2.14, 2.15, and 2.16 show the current state of the land use and land cover surrounding the Hanford Site.

3.0 Site-Specific Risk-Based End State Description

This section describes the end state of the Hanford Site in terms of physical and surface interfaces, human and ecological land use, legal ownership, and demographics. The information is based on DOE's selected alternative from the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999a). DOE's selected alternative anticipates multiple uses of the Hanford Site, including anticipated future DOE missions, non-DOE federal missions, and other public and private-sector land uses (Figure 3.1). DOE's selected alternative includes the following elements:

- *Cleanup Mission* – consolidate waste management operations on 50.1 square kilometers (20 square miles) in the Central Plateau of the Hanford Site

- *Economic Development Mission* – allow industrial development in the eastern and southern portions of Hanford and increase recreational access to the Columbia River

- *Natural Resource Trustee Mission* – expand the existing Saddle Mountain National Wildlife Refuge to include all of the Wahluke Slope, consistent with the 1994 Hanford Reach environmental impact statement (DOI 1994) and 1996 Hanford Reach record of decision (DOI 1996); place the ALE Reserve under U.S. Fish and Wildlife Service management by permit so it may be included in the overlay wildlife refuge.

Based on the extensive public comments received, the following changes were also included in the selected alternative:

- All conservation (mining and grazing) was changed to conservation (mining).

- The National Wildlife Refuge designation was extended to include the ALE Reserve, the Riverlands, and McGee Ranch; and all river islands not in Benton County. The selected alternative clarifies that the refuge will be an overlay wildlife refuge (without a transfer of title from DOE), and that DOE retains the right to mine a portion of ALE for cover materials.

- A railroad right-of-way through the Riverlands portion of the proposed Refuge was given status as a preexisting condition and was included in the U.S. Fish and Wildlife Service permit to manage the Refuge.

- The White Bluffs town site was added to the selected alternative map (Figure 3.1) as low-intensity recreation to serve as the White Bluffs Memorial.

- The low-intensity recreation comfort stations along the river, which could eventually serve as anchor points for a river trail from Richland to the Vernita Bridge, were moved to ensure that they have both river and road access.

- A high-intensity recreation triangle was added to the selected alternative map near Horn Rapids Park on the Yakima River.

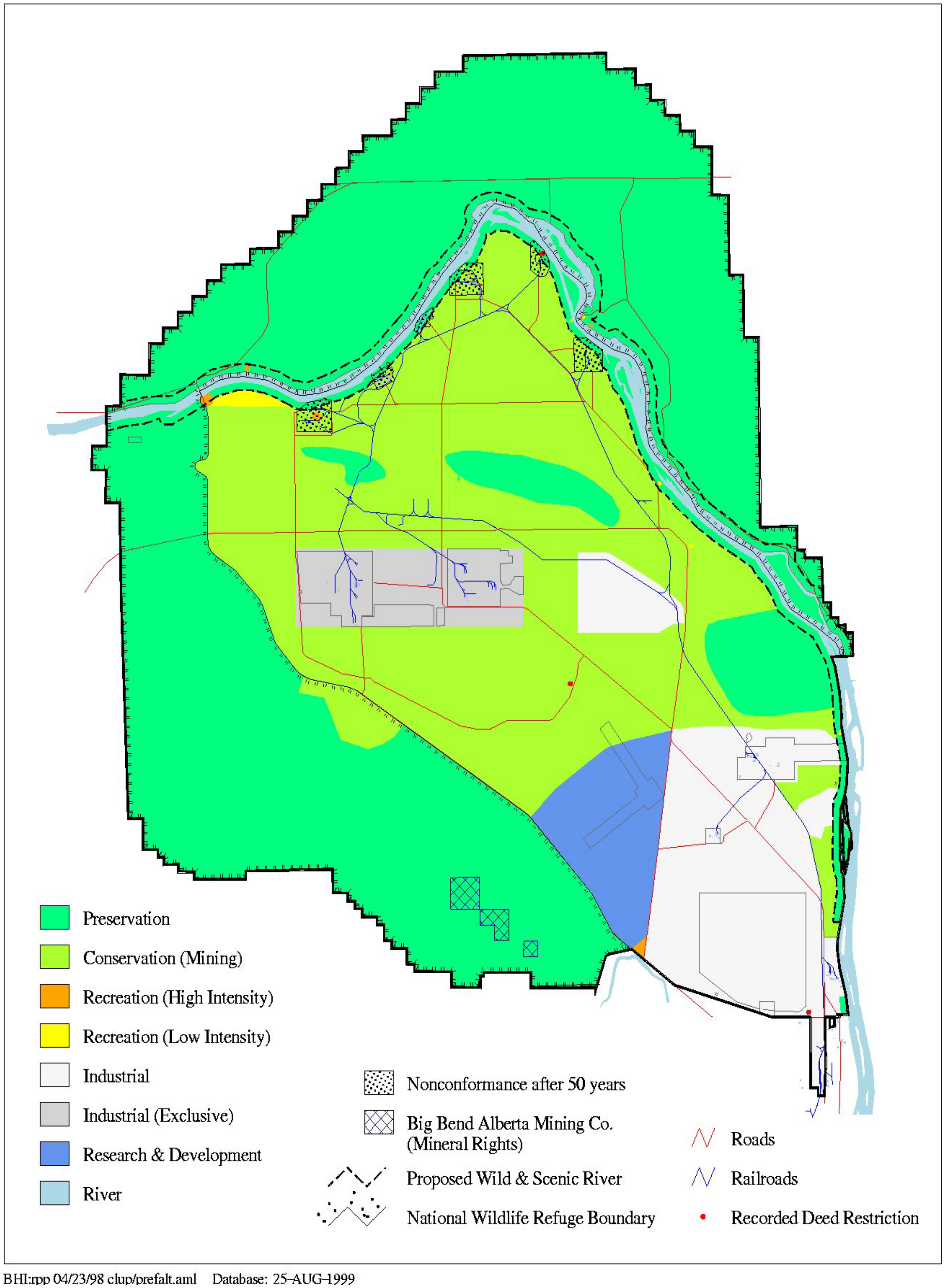


Figure 3.1. DOE's Selected Land-Use Alternative (DOE 1999a)

3.1 Physical and Surface Interface

The Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau in southeastern Washington State. The site occupies an area of approximately 1,517 square kilometers (586 square miles) north of the confluence of the Yakima River with the Columbia River. Within the geographic boundary of the site, there are 36.42 square kilometers (14.1 square miles) of Columbia River surface water, and one section (2.6 square kilometers [1 square mile]) of land owned by the state of Washington.

The Hanford Site is about 50 kilometers (30 miles) north to south and 40 kilometers (24 miles) east to west. The Columbia River flows through the northern part of the site and, turning south, forms part of the site's eastern boundary. The Yakima River runs near the southern boundary and joins the Columbia River below the city of Richland, which bounds the Hanford Site on the southeast. Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge form the southwestern and western boundaries, and the Saddle Mountains form the Site's northern boundary. Two small east-west ridges, Gable Butte and Gable Mountain, rise above the plateau of the central part of the site. Adjoining lands to the west, north, and east are principally agricultural and range land. The cities of Richland, Kennewick, and Pasco (also referred to as the Tri-Cities) constitute the nearest population center and are located immediately southeast of the Hanford Site.

The production of nuclear materials for defense at the Hanford Site since the 1940s has necessitated the exclusion of public access and most non-government-related development on the Hanford Site. As a result of its defense-related mission, the Hanford Site has also provided *de facto* protection of the natural environment and cultural resources (National Park Service 1994); however, the defense nuclear production mission has left the Hanford Site with an extensive waste legacy. Nuclear weapons production and associated activities at the Hanford Site during the past five decades have generated a variety of radioactive, hazardous, and other wastes that have been disposed of or discharged to the air, soil, and water at the Hanford Site.

Figure 2.16 shows the current physical and surface interface on the Hanford Site.

3.2 Human and Ecological Land Use

For many years, tribal nations used the Columbia River corridor extensively for fishing, hunting, gathering, and pasturing of livestock. In addition, the river supplied an endless cycle of vegetable crops. The Cayuse, Umatilla, Walla Walla, and Nez Perce people became very skillful at breeding horses in the 1700s. When Lewis and Clark first came down the Columbia River, there were great herds of horses grazing the hills of southeastern Washington and northeastern Oregon. Although the horse meant greater mobility, these people maintained traditional migratory patterns. Most bands gathered at winter sites on or near the Columbia River. The Tribes and their ancestors used these sites for thousands of years. The routes of migration followed ancient patterns, with the band stopping at the same spot it camped the year before. In the early spring, family bands would leave the main encampment on the river and travel to the uplands to dig roots. They timed their returns to utilize the main salmon run in the spring and fall. When they had a sufficient stockpile of dried salmon, they would return to the mountains to gather berries and hunt for game until the snows would push them back to the lowlands near or on islands in the Columbia, where they gathered together in the large wintering sites and spent the colder months.

Land uses at the Hanford Site have changed dramatically over the past 100 years. By the turn of the century, settlers had moved into the area, developing irrigated farmland and practicing extensive grazing. In 1943, the federal government acquired the Hanford Site for production of nuclear materials to be used in development of the atomic bomb.

Existing Land Uses in the Vicinity of the Hanford Site

Existing land uses within the vicinity of the Hanford Site include urban and industrial development, wildlife protection areas, recreation, irrigated and dryland farming, and grazing. According to the 1992 Census of Agriculture, Benton, Franklin, and Grant counties had a total of 9,586 square kilometers (3,745 square miles) of land in farms, of which 6,670 square kilometers (2,606 square miles) were in cropland. Approximately 46% of cropland was irrigated in 1992, and approximately 40% of cropland in 1992 was used as pastureland. According to the 1992 census, the total market value of agricultural products in the three counties was $935 million, including $758 million for crops and $177 million for livestock. In 1994, wheat represented the largest single crop (in terms of area) planted in Benton and Franklin counties. The total area planted in the two counties was 975 square kilometers (376 square miles) and 120 square kilometers (46.4 square miles) for winter and spring wheat, respectively. Other major crops such as alfalfa, apples, asparagus, cherries, corn, grapes, and potatoes are also produced in Benton and Franklin counties. In 1994, the Conservation Reserve Program of the U.S. Department of Agriculture (USDA)[1] included 102.8 square kilometers (39.7 square miles) in Benton County, 93.6 square kilometers (36.1 square miles) in Franklin County, and 101.1 square kilometers (39 square miles) in Grant County.[2]

In 1992, the Columbia Basin Project, a major irrigation project north of the Tri-Cities, produced gross crop returns of $552 million, representing 12.5% of all crops grown in Washington State. Also, in that year, the average gross crop value per irrigated acre was $1,042. The largest percentage of irrigated acres produced alfalfa hay (26.1% of irrigated acres), wheat (20.2%), and feed-grain corn (5.8%).

Other land uses in the vicinity of the Hanford Site include a low-level radioactive waste decontamination, super-compaction, plasma gasification and vitrification unit (operated by Pacific EcoSolutions) and a commercial nuclear fuel fabrication facility (operated by Framatome ANP).

Existing Hanford Site Land Uses

Land-use categories at the Hanford Site include reactor operations, waste operations, administrative support, operations support, sensitive areas, and undeveloped areas. Remedial activities are currently focused within or near the disturbed areas. Much of the Hanford Site is undeveloped, providing a safety and security buffer for the smaller areas used for operations. Public access to most facility areas is restricted.

Wahluke Slope. The area north of the Columbia River encompasses approximately 357 square kilometers (138 square miles) of relatively undisturbed or recovering shrub-steppe habitat. The northwest

1 Agricultural lands at risk for soil erosion set aside to enhance wildlife.
2 Personal conference with Rod Hamilton, Conservation Program Specialist with the U.S. Drug Administration, Farm Service Agency, in Spokane, Washington, October 1997.

portion of the area is managed by the U.S. Fish and Wildlife Service under a permit issued by DOE in 1971 as the Saddle Mountain National Wildlife Refuge. The permit conditions require that the refuge remain closed to the public as a protective perimeter surrounding Hanford operations. The closure has benefited migratory birds, such as curlews, loggerhead shrikes, and waterfowl.

Until recently, in the northeast portion of the Wahluke Slope, the Washington Department of Fish and Wildlife operated the Wahluke State Wildlife Recreation Area, which was established in 1971. In April 1999, the Washington Department of Fish and Wildlife and the U.S. Fish and Wildlife Service notified DOE of their intent to modify their management responsibilities on the Wahluke Slope under the 1971 agreement, leaving only a small portion (about 324 hectares [800 acres] northwest of the Vernita Bridge under Washington Department of Fish and Wildlife permit. The U.S. Fish and Wildlife Service informed DOE that it intends to allow essentially the same uses permitted by the state of Washington under the Washington Department of Fish and Wildlife's management of the Wahluke Slope. Therefore, transfer of management of the Wahluke Slope from the Washington Department of Fish and Wildlife to the U.S. Fish and Wildlife Service involves only a change in the agency managing the property and does not involve any change in the management activities for the Wahluke Slope. Management of the entire Wahluke Slope by the U.S. Fish and Wildlife Service as an overlay wildlife refuge is consistent with the 1996 U.S. Department of Interior (DOI) record of decision for the Hanford Reach environmental impact statement (DOI 1996). The record of decision recommended the Wahluke Slope be designated a wildlife refuge and the Hanford Reach a Wild and Scenic River, and that the wildlife refuge be managed by the U.S. Fish and Wildlife Service.

The Washington Department of Fish and Wildlife had leased a total of approximately 43 hectares (107 acres) of the Wahluke State Wildlife Recreation Area for sharecropping. The purpose of these agricultural leases is to produce food and cover for wildlife and manage the land for continued multi-purpose recreation. In addition, the Washington Department of Fish and Wildlife issued a grazing permit for approximately 3,756 hectares (9,280 acres), allowing up to 750 animal-unit-months to graze the parcel. This grazing lease was allowed to expire on December 31, 1998. But under State Environmental Protection Act regulations, for up to 10 years after the expiration of the lease, the Washington Department of Fish and Wildlife can reinstate the grazing lease without public review.

The Wahluke Wildlife Recreation Area is open to the public for recreational uses during daylight hours. According to data published in the *Hanford Reach of the Columbia River, Comprehensive River Conservation Study and Environmental Impact Statement Final - June 1994* (National Park Service 1994), the Wahluke State Wildlife Recreation Area has more than 40,000 visits per year by recreationalists. Most recreational visits are related to sport fishing in the Columbia River.

The Wahluke Slope once contained small, non-radioactively contaminated sites (e.g., military and farmstead landfills). These sites were subject to an expedited response action and were remediated by DOE in 1997. Although remediation took place, the landfills could still have hazardous materials that should not be disturbed. DOE is not planning to alter the current land uses of the Wahluke Slope and is specifically prohibited from causing any adverse impact on the values for which the area is under consideration for Wild and Scenic River or National Wildlife Refuge status (DOI 1996).

Columbia River Corridor. Portions of the 111.6 square kilometers (43.1 square miles) of the Columbia River Corridor, which is adjacent to and runs through the Hanford Site, is used by the public and Tribes for boating, water skiing, fishing, and hunting of upland game birds and migratory waterfowl. While public access is allowed on certain islands, access to other islands and adjacent areas is restricted because of unique habitats and the presence of cultural resources.

The 100 Area NPL site occupies approximately 68 square kilometers (26 square miles) along the southern shoreline of the Columbia River Corridor. The area contains all of the facilities in the 100 Areas, including nine retired plutonium production reactors, associated facilities, and structures. The primary land uses are CERCLA remedial actions, reactor decommissioning, and undeveloped areas used by wildlife. Future use restrictions will be placed as appropriate on the CERCLA sites, such as institutional controls on activities that potentially extend beyond 4.6 meters (15 feet) below ground surface.

The area known as the Hanford Reach includes an average of a 402-meter (1,320-foot) strip of federally-owned land on either side of the Columbia River. The Hanford Reach is the last unimpounded, non-tidal segment of the Columbia River in the United States. In 1988, Congress passed Public Law 100-605, *Study: Hanford Reach, Washington*, which required the Secretary of the Interior to prepare an environmental impact study (in consultation with the Secretary of Energy) to evaluate the outstanding features of the Hanford Reach and its immediate environment.

Alternatives for preserving the outstanding features also were examined, including the designation of the Hanford Reach as part of the National Wild and Scenic Rivers system. The results of the study can be found in the final *Hanford Reach of the Columbia River, Comprehensive River Conservation Study and Environmental Impact Statement Final - June 1994* (National Park Service 1994). The record of decision issued as a result of this document recommended that the Hanford Reach be designated a recreational river, as defined by the National Wild and Scenic Rivers Act of 1968. The record of decision also recommended that the remainder of the Wahluke Slope be established as a National Fish and Wildlife Refuge. Finally, the record of decision recommended that the approximately 728 hectares (1,800 acres) of private land located in the Hanford Reach Study Area be included in the recreational river boundary but not the refuge boundary.

On June 9, 2000, the President signed a proclamation creating the Hanford Reach National Monument (65 FR 37253). The monument encompasses 793 square kilometers (306 square miles) of lands already owned by the federal government that were planned for preservation or conservation in the land-use plan (DOE 1999a). No changes have occurred to related land uses since the monument designation.

The U.S. Fish and Wildlife Service is writing a comprehensive conservation plan environmental impact statement for all lands within the monument (with DOE-RL as a cooperating agency), which should be completed in 3 years.

DOE-RL is working on a phased approach to transfer most of the monument land to DOI by September 2005. DOE-HQ agrees with DOE-RL and will provide support and direction as needed. Current plans under consideration include the following:

- Transfer most ALE monument land to DOI by September 2004
- Transfer most McGee/Riverland and Wahluke Slope lands by 2005

Central Plateau. The 200-East and 200-West Areas occupy approximately 51 square kilometers (19.5 square miles) in the Central Plateau of the Hanford Site. Facilities located in the Central Plateau were built to process irradiated fuel from the production reactors. The operation of these facilities resulted in the storage, disposal, and unplanned release of radioactive and non-radioactive waste. The primary land uses are waste operations and operations support. Deed or land-use restrictions for activities that potentially may extend beyond 4.6 meters (15 feet) below ground surface are expected for CERCLA and RCRA remediation areas in the Central Plateau geographic study area.

In 1964, a 410-hectare (1,000-acre) tract was leased to Washington State to promote nuclear-related development. A commercial low-level radioactive waste disposal facility, run by US Ecology, Inc., currently operates on 41 hectares (100 acres) of the leasehold. The rest of the leasehold was not used by the state, and this portion of the leasehold recently reverted to DOE. DOE constructed the Environmental Restoration Disposal Facility on this tract.

The Environmental Restoration Disposal Facility is operated on the Central Plateau to provide disposal capacity for environmental remediation waste (e.g., low-level, mixed low-level, and dangerous wastes) generated during remediation of the 100, 200, and 300 Areas of the Hanford Site. The facility is currently about 65 hectares (160 acres) and can be expanded up to 414 hectares (1,023 acres), as additional waste disposal capacity is required.

All Other Areas. The All Other Areas geographic area is 689 square kilometers (266 square miles) and contains the 300, 400, 600, and 1100 Areas; Energy Northwest facilities; and a section of land currently owned by the state of Washington.

The 300 Area is located just north of the city of Richland and covers 1.5 square kilometers (0.6 square mile). The 300 Area is the site of former reactor fuel fabrication facilities and is also the principal location of nuclear research and development facilities serving the Hanford Site. The Environmental Molecular Sciences Laboratory and associated research programs provide research capability to advance technologies in support of DOE's mission of environmental remediation and waste management.

The 400 Area, located southeast of the 200-East Area, is the site of the Fast Flux Test Facility (FFTF). FFTF is a 400-megawatt thermal, liquid metal (sodium-cooled) nuclear research test reactor that was constructed in the late 1970s and operated from 1982 to 1992. Although not designed nor operated as a breeder reactor, FFTF operated during these years as a national research facility for the Liquid Metal Fast Breeder Reactor Program to test advanced nuclear fuels, materials, components, systems, nuclear operating and maintenance procedures, and active and passive safety technologies. The reactor was also used to produce a large number of different isotopes for medical and industrial users, generate tritium for the United States fusion research program, and conduct cooperative, international research.

FFTF has been permanently shutdown and is currently being deactivated including removal and washing of fuel and draining of liquid sodium coolant. In May 2003, DOE, EPA, and Ecology signed into agreement the FFTF series of Tri-Party Agreement milestones to govern the deactivation activities currently underway. A small-business solicitation was published in September 2003 seeking offers to achieve a safe and accelerated closure of FFTF by 2012, while reducing risk to the public and workers, streamlining essential operations, minimizing costs, and introducing new and innovative approaches for the deactivation and decommissioning of FFTF facilities. FFTF site tours and one-on-one sessions with interested potential bidders were held in early October 2003. It is anticipated that a contract will be awarded by June 30, 2004.

The 1100 Area, located just north of Richland, served as the central warehousing, vehicle maintenance, and transportation operations center for the Hanford Site. A deed restriction has been filed with Benton County for the Horn Rapids Landfill, which restricts future land uses in the vicinity of the landfill because of asbestos disposal there. The Horn Rapids Landfill was included in the 1100 Area CERCLA cleanup, although it is located on the Hanford Site to the north of Horn Rapids Road; it remains in federal ownership. Also, DOE transferred approximately 318 hectares (786 acres) of the former 1100 Area to the Port of Benton. DOE prepared an environmental assessment (DOE 1998) that resulted in a finding of no significant impact on August 27, 1998, for the transfer of this portion of the 1100 Area and the southern rail connection to the Port of Benton. The Port officially took ownership and control of the 1100 Area (consisting of 318 hectares [786 acres], 26 buildings, and 26 kilometers [16 miles] of railroad track) on October 1, 1998. This portion of the 1100 Area is no longer under DOE control.

Together with the Washington State Department of Transportation and Legislature Transportation Committee, the Port of Benton is currently funding a major study ($600,000) to determine the feasibility of reconnecting the Hanford main rail line to Ellensburg, Washington (as it was in the 1970s), as an alternative route for Yakima Valley rail traffic flowing between the Puget Sound and the Tri-Cities. The current Yakima Valley route passes directly through all the cities in the Valley, including the cities of Yakima and Kennewick, which have plans to develop their downtown areas to be more people friendly. Specifically, the Port has expressed a desire to use the Hanford rail system and extend the current system upriver where there is currently only an abandoned railroad grade.

Additional land uses in all other geographic areas include the following:

- The Hazardous Materials Management and Emergency Response (HAMMER) Volpentest Training and Education Center, which is used to train hazardous materials response personnel. The HAMMER Volpentest Training and Education Center is located north of the 1100 Area and covers about 32 hectares (80 acres).

- Land was leased to Energy Northwest to construct three commercial power reactors in the 1970s. One plant, WNP-2, was completed and is currently operating. Activities on the other two plants were terminated and the plants will not be completed.

- In 1980, the Federal government sold a 259-hectare (640 acre) section of land south of the 200-East Area, near State Route 240, to the state of Washington for the purpose of non-radioactive hazardous waste disposal. This parcel is uncontaminated (although the underlying groundwater is contaminated) and undeveloped. The deed requires that if it were used for any purpose other than hazardous waste disposal, ownership would revert to the Federal government.

- The Laser Interferometer Gravitational-Wave Observatory, built by the National Science Foundation on the Hanford Site, detects cosmic gravitational waves for scientific research. The facility consists of two underground optical tube arms, each 4 kilometers (2.5 miles) long, arrayed in an "L" shape. The facility is sensitive to vibrations in the vicinity, which can be expected to constrain nearby land uses.

Fitzner/Eberhardt Arid Lands Ecology (ALE) Reserve. The Fitzner/Eberhardt Arid Lands Ecology Reserve (also designated as the Rattlesnake Hills Research Natural Area, or the ALE Reserve) encompasses 308.7 square kilometers (119.2 square miles) in the southwestern portion of the Hanford Site and is managed as a habitat and wildlife reserve and environmental research center. A "research natural area" is a classification used by federal land management agencies to designate lands on which various natural features are preserved in an undisturbed state solely for research and educational purposes. The ALE Reserve remains the largest research natural area in the state of Washington.

The mineral rights to a 518-hectare (1,280-acre) area on the ALE Reserve are owned by a private company. There are also two ongoing research and development projects under way on the ALE Reserve: gravity experiments in underground Nike bunkers located in the southern portion of the Reserve, and online science education, teacher training, and astronomy research in the observatory on the top of Rattlesnake Mountain. Both are long-term projects using existing facilities.

Because public access to the ALE Reserve has been restricted since 1943, the shrub-steppe habitat is virtually undisturbed and is part of a much larger Hanford tract of shrub-steppe vegetation. This geographic area contained a number of small contaminated sites that were remediated in 1994 and 1995 and have been revegetated. There are two landfills on the ALE Reserve, at least one of which was used for disposal of a non-radioactive hazardous waste. Although remediated, one of the landfills may still contain hazardous materials.

DOE granted a permit and entered into an agreement with U.S. Fish and Wildlife Service to manage the ALE Reserve consistent with the existing ALE Facility Management Plan. The U.S. Fish and Wildlife Service is preparing a comprehensive conservation plan pursuant to the National Wildlife Refuge System Improvement Act of 1997 to identify refuge management actions and to bring the ALE Reserve into the national wildlife refuge system.

DOE's RBES Vision (Selected Alternative from 64 FR 61615)

In developing the selected alternative, DOE took into account its role as the long-term caretaker for the Hanford Site for at least the next 50 years. Information considered by DOE includes

- All surface waste sites, including those remediated
- Groundwater contaminants and flow direction
- Cultural and biological resources
- Exclusive-use zones and emergency planning zones associated with DOE and other Hanford activities (e.g., Energy Northwest's nuclear power reactor; US Ecology, Inc.'s low-level waste disposal site; Laser Interferometer Gravitational-Wave Observatory)

DOE believes that the selected alternative would fulfill the statutory mission and responsibilities of the agency and give adequate consideration to economic, environmental, technical, and other factors. DOE's selected alternative would establish policies and implementing procedures that would place Hanford's land-use planning decisions in a regional context.

DOE's selected alternative is illustrated in Figure 3.1 and represents a multiple-use theme of industrial-exclusive, industrial, research and development, high-intensity recreation, low-intensity recreation, conservation (mining), and preservation land uses that have been identified by the public, cooperating agencies, and consulting tribal governments as being important to the region:

- DOE, as a federal agency, has a responsibility to protect tribal interests.
- DOE has a responsibility to consult with and recognize the interests of the cooperating agencies. DOE continues to support DOI's proposal to expand the Saddle Mountain National Wildlife Refuge to include all of the Wahluke Slope, consistent with the 1994 Hanford Reach environmental impact statement (DOI 1994) and 1996 Hanford Reach record of decision (DOI 1996). DOE will support economic transition and potential industrial development by the city of Richland or the Port of Benton by encouraging the use of existing utility infrastructure on the Hanford Site as appropriate.
- The public will continue to support protection of cultural and natural resources on the Hanford Site, especially on the Wahluke Slope, the Columbia River Corridor, the McGee Ranch, and the ALE Reserve.
- Mining of onsite geologic materials will be needed to construct surface barriers as required by Hanford Site remediation activities.

Remediation of the Hanford Site will continue and, where necessary, the institutional controls currently in place or selected as part of remedial actions will continue to be required at some level for as long as necessary or for at least the next 50 years. Institutional controls are transferable and can be shared with other governmental agencies.

Plutonium production reactor blocks will remain in the 100 Areas throughout the planning period and will be considered a pre-existing, nonconforming use.

Vadose zone contamination will persist in all other areas, the Central Plateau, and 100 Area. Contaminated groundwater will remain unremediated in all other areas, the Central Plateau, and 100 Area.

The public will support preservation of the Manhattan Project's historical legacy and development of a high-intensity recreation area, consistent with the B Reactor Museum proposal.

- The public will support access to the Columbia River for recreational activities and public restrictions consistent with the protection of cultural and biological resources.
- Areas will be set aside specifically for research and development projects. Sufficient area will be retained to support current and expected DOE facility safety authorization basis.
- An adequate land base and utility infrastructure will be maintained to support possible industrial development associated with future DOE missions.

The following paragraphs discuss the RBES vision for specific areas of the Hanford Site.

Wahluke Slope. DOE's selected alternative allowed expansion of the existing Saddle Mountain National Wildlife Refuge as an overlay wildlife refuge to include all of the Wahluke Slope consolidating management of the Wahluke Slope under the U.S. Fish and Wildlife Service, consistent with the Hanford Reach record of decision (DOI 1996). An overlay refuge is one where the land belongs to one or more Federal agency, but it is managed by the U.S. Fish and Wildlife Service. DOE granted a permit and entered into an agreement with U.S. Fish and Wildlife Service to manage most of the Wahluke Slope.

The entire Wahluke Slope was designated preservation, with the exceptions near the Columbia River. The major reason for designating this area as preservation is to protect sensitive areas or species of concern (e.g., wetlands, sand dunes, steep slopes, or the White Bluffs) from impacts associated with intensive land-disturbing activities.

A comprehensive conservation plan for the Wahluke Slope is being developed by U.S. Fish and Wildlife Service in accordance with the National Wildlife Refuge System Improvement Act of 1997. This act provides significant guidance for management and public use of refuges allowing for wildlife-dependent recreation uses such as hunting, fishing, wildlife observation and photography, and environmental education and interpretation. The U.S. Fish and Wildlife Service is consulting with DOE during the development of this plan to ensure necessary and appropriate buffer zones for ongoing and potential future missions at the Hanford Site.

Columbia River Corridor. The Columbia River Corridor has historically contained reactors and associated buildings to support Hanford's former defense production and energy research missions. Nevertheless, remediation planning documents, public statements of advisory groups, and such planning documents as the environmental impact statement for reactor decommissioning (DOE 1992a) have determined that remediation and restoration of the Columbia River Corridor would return the corridor to a non-developed, natural condition. Restrictions on certain activities at many remediated waste sites may continue to be necessary to prevent the mobilization of contaminants, the most likely example of such restrictions being on activities that discharge water to the soil or excavate below 4.6 meters (15 feet). Although the surplus reactor record of decision (DOE 1989) calls for the reactor buildings to be demolished and the reactor blocks to be moved to the Central Plateau, this action might not take place until 2068. As a result, the reactor buildings could remain in the Columbia River Corridor throughout the 50-year-plus planning period addressed by the environmental impact statement (64 FR 61615) and would be considered a pre-existing non-conformance into the future.

The Columbia River Corridor would include high-intensity recreation, low-intensity recreation, conservation (mining), and preservation land-use designations. The river islands and a 0.4-kilometer (0.25-mile) buffer zone would be designated as preservation to protect cultural and ecological resources. Those islands not in Benton County would be included in the refuge.

The Hanford CLUP indicates on page 3-21 that four sites, away from existing contamination, would be designated high-intensity recreation to support visitor-serving activities and facilities development. The B Reactor would be considered for a museum and the surrounding area could be available for museum-support facilities. The high-intensity recreation area near Vernita Bridge (where the current Washington State rest stop is located) would be expanded across State Highway 240 and to the south to include a boat ramp and other visitor facilities. Two areas on the Wahluke Slope would be designated as high-intensity recreation for potential exclusive tribal fishing (DOE 1999a).

The plan also indicates that six areas would be designated for low-intensity recreation. The area west of the B Reactor would be used as a corridor between the high-intensity recreation areas associated with the B Reactor and the Vernita Bridge rest stop and boat ramp. A second area near the D/DR Reactors site would be used for visitor services along a proposed recreational trail. The third and fourth areas, the White Bluffs boat launch, and its counterpart on the Wahluke Slope, are located between the H and F Reactors and would be used for primitive boat launch facilities. A fifth area, near the old Hanford High School, would accommodate visitor facilities and access to the former town site and provide visitor services for hiking and biking trails that could be developed along the Hanford Reach. A sixth site, just north of Energy Northwest, would also provide visitor services for recreational trails (e.g., hiking and biking) along the Hanford Reach. On the Wahluke Slope side of the Columbia River, the White Bluffs boat launch would remain managed as is, with a low-intensity recreation designation. A low-intensity recreation designation for the water surface of the Columbia River would be consistent with current management practices and the wishes of many stakeholders in the region.

The remainder of land within the Columbia River Corridor outside the 0.4-kilometer (0.25-mile) buffer zone would be designated for conservation (mining). Mining would be permitted only in support of governmental missions or to further the biological function of wetlands (i.e., conversion of a gravel pit to a wetland by excavating to groundwater). A conservation (mining) designation would allow DOE to provide protection to sensitive cultural and biological resource areas, while allowing access to geologic resources. Activities that use or effect groundwater would continue to be restricted.

A preservation land-use designation for the Columbia River islands would be consistent with the Hanford Reach record of decision (DOI 1996) and would provide additional protection to sensitive cultural areas, wetlands, floodplains, Upper Columbia Run steelhead, and bald eagles from impacts associated with intensive land-disturbing activities. Remediation activities would continue in the 100 Areas (i.e., 100-B/C, 100-KE, 100-KW, 100-N, 100-D, 100-DR, 100-H, and 100-F Areas), and would be considered a pre-existing, non-conforming use in the preservation land-use designation.

DOE is considering whether each of these designations is appropriate under the designation of the Hanford Reach as a National Monument. For land which under the control of the U.S. Fish and Wildlife Service future uses will be dealt with through the Comprehensive Conservation Plan.

Central Plateau. The Central Plateau (200 Areas) geographic area would be designated for industrial-exclusive use. An industrial-exclusive land-use designation would allow for continued waste management operations within the Central Plateau geographic area. This designation would also allow expansion of existing facilities or development of new compatible facilities. Designating the Central Plateau as industrial-exclusive would be consistent with the Future Site Uses Working Group's recom-mendations, current DOE management practice, other governments' recommendations, and many public stakeholder values throughout the region.

Tank Farm Specific End States. DOE and its predecessor agencies, dating back to the Manhattan Project, created a variety of radioactive and chemical waste as by-products of producing fissile materials for defense purposes. Today, approximately 53 million gallons of liquid, sludge, and saltcake waste containing approximately 195 million curies of radioactive material are stored in 149 single-shell tanks and 28 double-shell tanks. Those tanks are distributed among 18 tank farms within the 200 East and 200 West Areas on the Hanford Central Plateau. DOE-ORP was created to execute cleanup of the

Hanford tank farms. Its responsibilities include retrieving wastes from the tanks in accordance with the Hanford Federal Facilities Agreement and Consent Order (Tri-Party Agreement; Ecology et al. 1998), treating and dispositioning the waste to authorized disposal locations, executing targeted remediation actions when necessary if soil and/or ancillary equipment contamination levels so warrant, and closing the tank farms in a manner that will protect human health and the environment for extremely long times (hundreds or thousands of years) into the future.

DOE-ORP's cleanup approach integrates its commitments under the Tri-Party Agreement with its responsibilities under the Atomic Energy Act of 1954, the National Environmental Policy Act (NEPA), and applicable DOE Orders and environmental regulations that flow from those acts. While the Tri-Party Agreement cleanup and closure requirements are relatively prescriptive, the Tri-Party Agreement and the regulations it encompasses do include moderate levels of flexibility to deploy risk-based solutions for cleanup and closure actions. Examples include Appendix H to the Tri-Party Agreement (Ecology et al. 1998), which provides for alternative retrieval levels if the 99% goal cannot be reasonably attained. Under Appendix H, a balance can be struck between long-term risk, risk to workers, technical practicality, and cost to arrive at alternate levels. Similarly, while Tri-Party Agreement's RCRA roots tend to focus on achieving clean closures, provisions exist that can lead to landfill closures based on similar tradeoffs considered under Appendix H. The result is that while some cleanup actions will be taken to meet prescriptive objectives, exercising the flexibilities within Tri-Party Agreement will result in protective conditions existing at the completion of cleanup and closure with risk analyses being a factor in determining the final end states. The tank farm end states are within the final closure of the Hanford Site and groundwater protection that are regulated under the CERCLA using risk-based principles.

The end state envisioned by DOE-ORP for the tank farms is that the bulk of the radionuclides will be disposed of offsite as high-level waste, and the bulk of the contaminated chemical waste equipment (e.g., pumps, piping, and tanks) will be disposed of onsite in a protective manner that complies with Tri-Party Agreement and appropriate laws, regulations, and DOE Orders. Further details regarding the end state are as follows:

1. Waste will be retrieved at, near, or beyond the goals established by Tri-Party Agreement barring currently unforeseen obstacles. This should result in approximately 99% of the waste volume being retrieved and treated.

2. High-level waste, containing >90% of the current total tank radioactive material inventory, will be vitrified and, following several years of interim onsite storage, disposed of at the national high-level waste and spent nuclear fuel repository.

3. Transuranic waste retrieved from the tanks will be treated, packaged, and characterized in a manner that should enable disposal off-site at the Waste Isolation Pilot Plant Transuranic geologic repository (pending current NEPA actions on SA-4, waste certification, and the supplemental Waste Isolation Pilot Project environmental impact statement).

4. Low-activity waste and secondary low-level mixed waste will be treated and put into stabilized forms that enable disposal onsite within the Hanford Central Plateau in DOE authorized and Washington Department of Ecology permitted (RCRA) mixed waste disposal facilities (pending NEPA and supplemental low-activity waste treatment test results).

5. Residual materials that cannot be removed from the tanks will be stabilized with grout formulations and/or other materials engineered to isolate and contain any radioactive and hazardous constituents associated with the residuals. The tank void space (above the stabilized residual level) will be back-filled with natural and/or engineered materials selected to both contribute to the defense-in-depth containment and isolation of the wastes and to stabilize the tank against structural failure, e.g., dome collapse.

6. Above grade structures within the tank farms will be decommissioned and brought to grade level. Contaminated rubble and other materials will be disposed of in RCRA and/or CERCLA compliant facilities. Ancillary equipment, pits, and piping will have any liquids removed to the extent it is possible to do so and be backfilled to fill major void spaces prior to final closure (pending the single-shell tank closure plan and single-shell closure environmental impact statement).

7. Engineered barriers (modified RCRA, Hanford barrier, hybrid barrier) will be placed over the tank farms to divert precipitation from contacting residual wastes in the tanks, ancillary equipment, and the soil column underlying the tank farms. The surface barriers will also provide protection against plants, animals, and certain forms of possible human intrusion, e.g., shallow excavations.

8. Tanks and tank farms will be landfill closed under the Tri-Party Agreement, which integrates the RCRA and CERCLA processes and provides for RBES analyses. Active and passive institutional controls (guards; fences; permanent surface and embedded markers; government held land, water, and mineral rights; extensive public records delineating the location and content of the closed tank farms) will be used to reduce the risk of inadvertent intrusion, e.g., major excavation or drilling to obtain groundwater for irrigation or potable purposes. Monitoring systems will be put into place and maintained for an indefinite period of time in the future (hundreds of years) to measure parameters that affect contaminant transport and determine whether any waste migration may be occurring. Specific approaches will be determined nearer the time when final closure of the Hanford Site occurs using appropriate information/technology available at that time.

All Other Areas. Within all other geographic areas, the selected alternative would include industrial, research and development, high-intensity recreation, low-intensity recreation, conservation, and preservation land-use designations. The majority of all other areas would be designated conservation (mining).

Gable Mountain, Gable Butte, the area west of State Highway 240 from the Columbia River across Umtanum Ridge to the ALE Reserve, and the active sand dunes areas would be designated for Preservation, which would provide additional protection of these sensitive areas. The extant railroad grade across the Riverlands area would be considered an active permitted infrastructure.

Fitzner/Eberhardt Arid Lands Ecology (ALE) Reserve. Nearly all of the ALE Reserve geographic area would be designated as Preservation. This designation would be consistent with current management practices of the Rattlesnake Hills Research Natural Area and the U.S. Fish and Wildlife Service permit. A portion of the ALE Reserve would be managed as conservation (mining) during the remediation of the Hanford Site as a trade-off developed during the cooperating agencies discussions for preservation of a wildlife corridor through the McGee Ranch and after public comment, the inclusion of the McGee Ranch within the Refuge designation. The wildlife corridor through the McGee Ranch/Umtanum Ridge area had been identified by DOE as the preferred quarry site for basalt rock and silty soil materials that could be required for large waste-management area covers (RCRA caps or the Hanford Barrier) in the Central Plateau. In addition to the wildlife corridor function, the mature shrub-steppe vegetation structure in the McGee Ranch area has greater wildlife value than the cheat grass in the ALE Reserve quarry site.

The Hanford Site land holdings consist of three different real property classifications (Figure 3.2):

1. Lands acquired in fee by DOE or its predecessor agencies
2. Bureau of Land Management public domain lands withdrawn from the public domain for use as part of the Hanford Site
3. Lands the Bureau of Reclamation has withdrawn from the public domain or acquired in fee as part of the Columbia Basin Project.

In addition, Figure 3.3 shows the ownership of land on a regional basis, beyond the boundary of the Hanford Site.

The Bureau of Reclamation agreed to transfer custody, possession, and use of certain acquired and withdrawn lands situated within the control zone of the Hanford Works to the U.S. Atomic Energy Commission on February 27, 1957. These lands consisted of a checkerboard pattern of alternating square-mile sections on the Wahluke Slope.

The alternating square-mile sections that would eventually revert to the Bureau of Land Management or Bureau of Reclamation are an important consideration that complicates land-use planning. Figure 3.3 shows the features and federal land ownership around the Hanford Site.

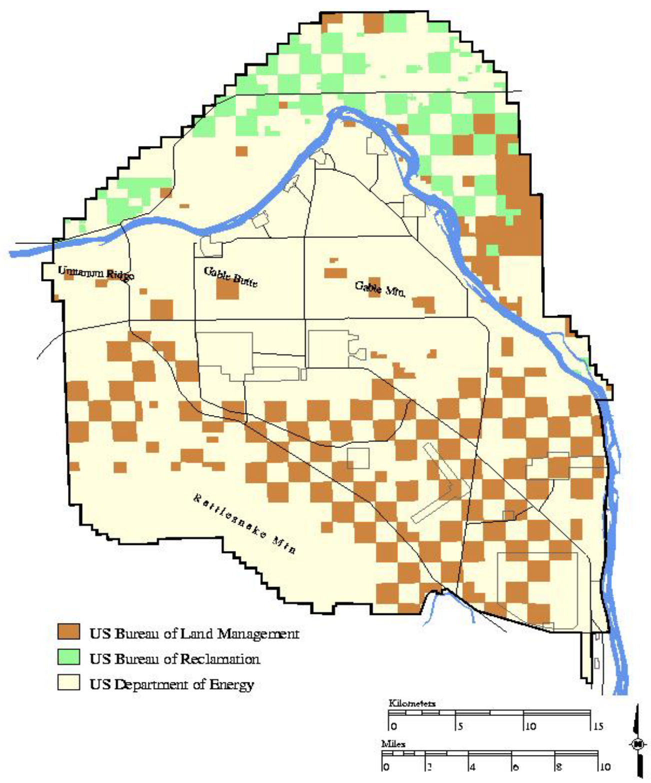


Figure 3.2. Ownership of Hanford Site Land Holdings

3.3 Site Context Demographics

An estimated total of 147,600 people lived in Benton County and 51,300 lived in Franklin County during 2002, for a total of 198,900, which is up almost 4% from 2000 (OFM 2002). According to the 2000 Census, population totals for Benton and Franklin counties were 142,475 and 49,347, respectively (Census 2003). Both Benton and Franklin counties grew at a faster pace than Washington as a whole in the 1990s. The population of Benton County grew 26.6%, up from 112,560 in 1990. The population of Franklin County grew 31.7%, up from 37,473 in 1990 (Census 2003).

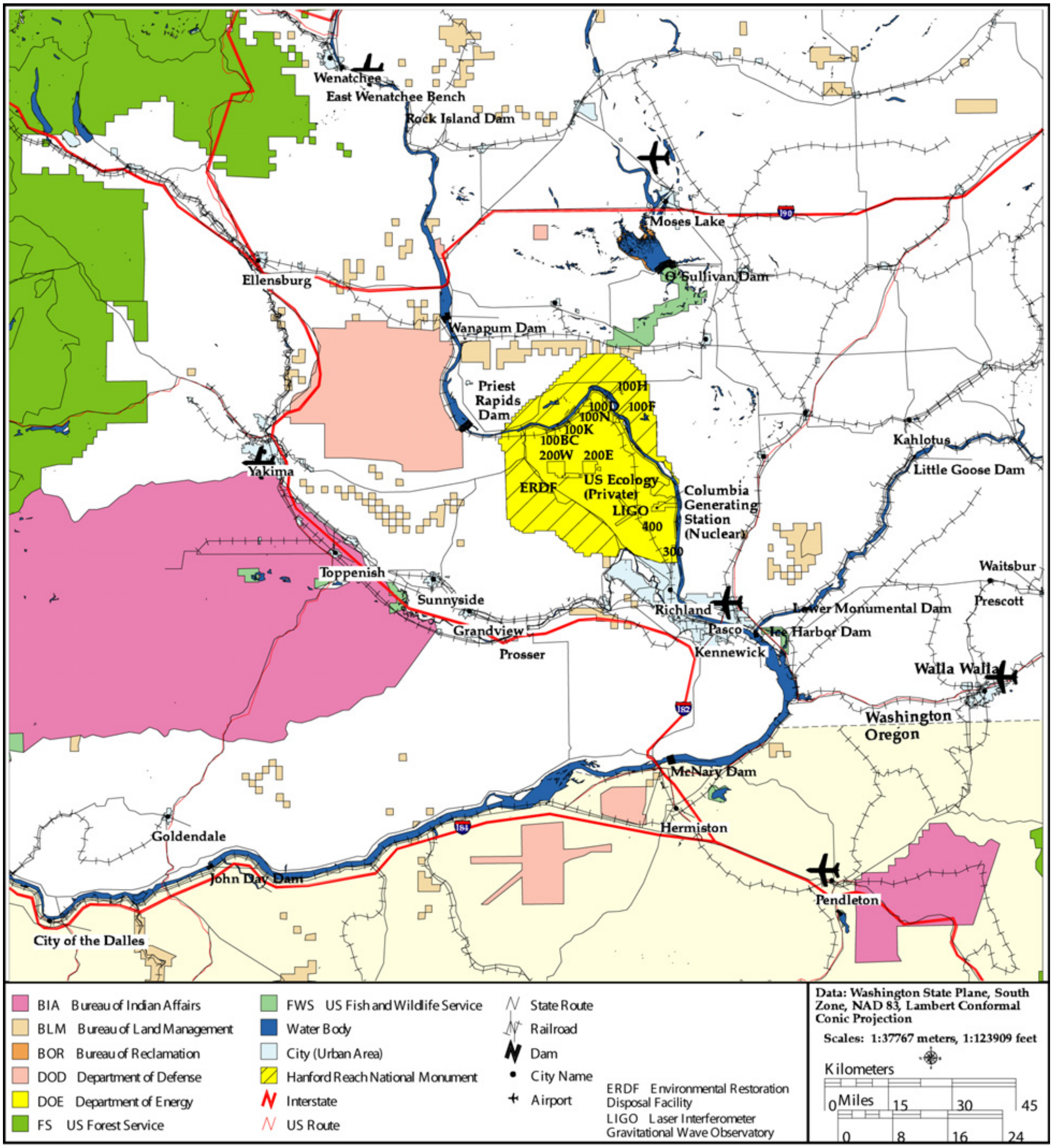


Figure 3.3. Features and Federal Land Ownership Around the Hanford Site – Current State

The distribution of the Tri-Cities population by city is as follows: Richland 40,150; Pasco 34,630; and Kennewick 56,280. The combined populations of Benton City, Prosser, and West Richland totaled 16,560 during 2001. The unincorporated population of Benton County was 34,610. In Franklin County, incorporated areas other than Pasco had a total population of 3,755. The unincorporated population of Franklin County was 12,915 (OFM 2002).

The 2000 population figures by race and Hispanic origin indicate that in Benton and Franklin counties, Asians represent a lower proportion, and individuals of Hispanic origin represent a higher proportion of the population than in the state of Washington as a whole. Benton and Franklin counties exhibit distributions as indicated by the data in Table 3.1.

During 2002, Benton and Franklin counties accounted for 3.3% of Washington's population. The population demographics of Benton and Franklin counties are quite similar to those found within Washington. In general, the population of Benton and Franklin counties is somewhat younger than that of Washington. The 0-to-14-year-old age group accounts for 25.4% of the total bi-county population as compared to 20.9% for Washington. The population in Benton and Franklin counties under the age of 35 is 53.3%, compared to 48.9% for Washington State. During 2002, the 65-year-old and older age group constituted 10% of the population of Benton and Franklin counties compared to 11.2% for Washington (OFM 2003). Table 3.1 represents population estimates and percentages by race and Hispanic origin for Benton, Franklin, Grant, Adams, and Yakima counties, and the 80-kilometer (50-mile) radius of the Hanford Site.

Table 3.1. Population Estimates and Percentages by Race and Hispanic Origin within each County in Washington State and the 80-Kilometer (50-mile) Radius of Hanford (2000 Census - Census 2003)

Subject	Washington State	Percent	Benton/Franklin/Grant/ Adams/Yakima	Percent	Benton County	Franklin County	Grant County	Adams County	Yakima County	80-km (50-mi) Radius of Hanford[a]
Total Population	5,894,121	100	505,529	100	142,475	49,347	74,698	16,428	222,581	482,300
Single Race	5,680,602	96.4	489,206	96.8	138,646	47,302	72,451	15,977	214,830	482,280
White	4,821,823	81.8	367,283	72.7	122,879	30,553	57,174	10,672	146,005	347,047
Black or African American	190,267	3.2	5,494	1.1	1,319	1,230	742	46	2,157	5,507
American Indian/Alaska Native	93,301	1.6	12,468	2.5	1,165	362	863	112	9,966	10,288
Asian	322,335	5.5	6,809	1.3	3,134	800	652	99	2,124	6,681
Native Hawaiian/Pacific Islander	23,953	0.4	482	0.1	163	57	53	6	203	479
Other Race	228,923	3.9	96,670	19.1	9,986	14,300	12,967	5,042	54,375	96,625
Two or More Races	213,519	3.6	16,323	3.2	3,829	2,045	2,247	451	7,751	15,654
Hispanic Origin (of any race)[b]	441,509	7.5	150,951	29.9	17,806	23,032	22,476	7,732	79,905	149,588

(a) Includes a portion of Oregon.
(b) Hispanic origin is not a racial category. It may be viewed as the ancestry, nationality group, lineage, or country of birth of the person or person's parents or ancestors before arrival in the United States. Persons of Hispanic origin may be of any race and are counted in the racial categories shown.

4.0 Hazard Specific Discussion

There were originally four areas at the Hanford Site on EPA's NPL – the 100, 200, 300, and 1100 Areas. However, remedial actions at the 1100 Area have been completed and the area has been deleted from the NPL.

A systematic evaluation of the condition of Hanford groundwater was performed in the early 1990s as a follow-on effort to ceasing, treating, and re-routing contaminated liquid waste discharges across the site. This effort focused on identifying groundwater plumes requiring early action on the basis of imminent risk or need for containment actions to stop plume growth and reduce the mass of contaminants in the groundwater. The results of this evaluation set the course of groundwater remediation for the next 10 years.

This evaluation used the hierarchy of restoration to highest beneficial use. This hierarchy is to first stop plume growth, then reduce toxicity, mobility, and mass. The evaluation also dealt with the need for aquatic resource protection within the Columbia River from attendant groundwater discharges to surface water. Groundwater beneath the Hanford Site in the unconfined aquifer meets all of the criteria necessary to be classified as a potable water supply, except in areas contaminated by Hanford sources.

Each of the four NPL areas were reviewed to identify plumes and assess the need for early action. At that point, several plumes were identified as plumes requiring early action either through treatability testing or interim action. Other plumes were determined not to represent imminent risk or require containment and would undergo continued monitoring until source control measures were in-place.

Twelve separate groundwater plumes have been identified throughout the four NPL areas at Hanford. These plumes are identified on Figures 4.1, 4.2, and 4.3 and illustrate the current hazards across the Hanford Site including groundwater contamination:

- **100 Area Operable Unit Plumes** – The 100 Area is comprised of five primary contaminant plumes in the groundwater, which for the most part correspond to individual reactor areas. These groundwater operable units are 100-BC-5, 100-FR-3, 100-HR-3, 100-KR-4, and 100-NR-2.

- **200 Area Operable Unit Plumes** – The 200 Area is also composed of five plumes, four of which are operable units based: 200-ZP-1, 200-UP-1, 200-PO-1, and 200-BP-5, as well a smaller plume of volatile organics around the Nonradioactive Dangerous Waste landfill.

- **300 Area Operable Unit Plumes** – The 300 Area contains a single operable unit, 300-FF-5. This unit does contain two localized areas of contamination outside of the well-defined plume beneath the industrial area. The two localized plumes are a tritium plume near the 618-11 burial ground and a uranium plume beneath the 618-10 burial ground and the 316-4 liquid waste crib.

- **1100 Area Operable Unit Plume** – The 1100-EM-1 Operable Unit plume was associated with the Horn Rapids Landfill.

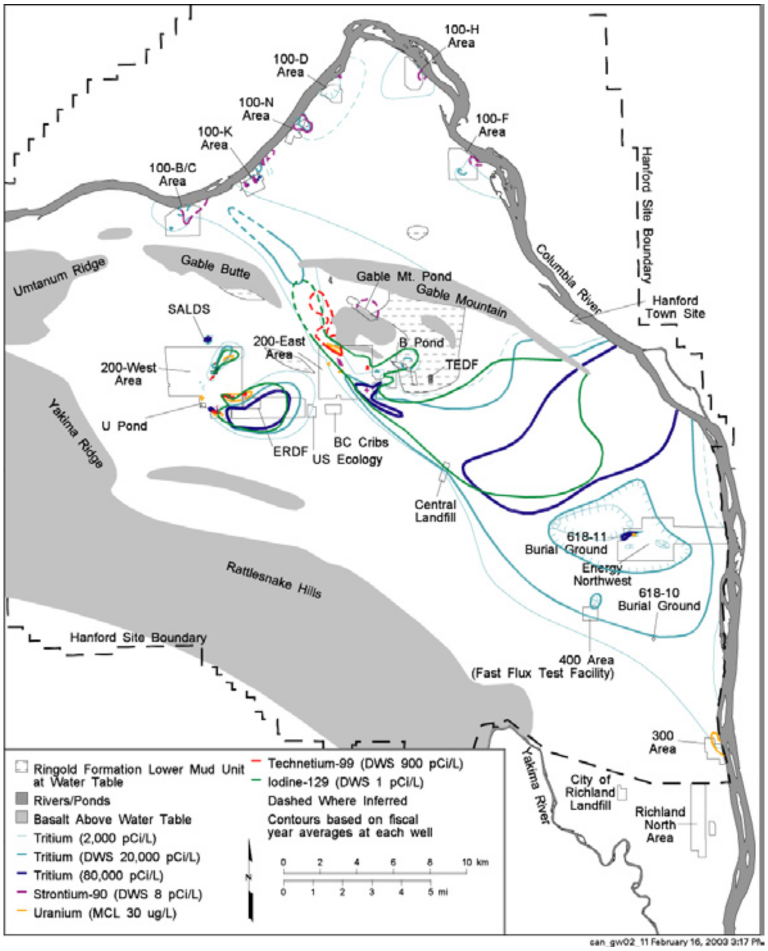


Figure 4.1. Distribution of Major Radionuclides in Groundwater at Concentrations Above Maximum Contaminant Levels or Drinking Water Standards During Fiscal Year 2002

4.1 100 Areas

Scope and History. The 100 Areas are located on the Columbia River shoreline, where nine nuclear reactors operated from 1944 to 1987 (Table 4.1). The years of operation are also the years of the highest amount of contaminated waste disposal. The 600 Area includes all of the Hanford Site not occupied by the other areas. Within the 600 Area are many miscellaneous waste sites; those that are near the Columbia River and those on the "North Slope" (the part of the Hanford Site that lies north of the Columbia River) are included as part of the 100 Area NPL. Two operable units (100-IU-1 and 100-IU-3), containing 600 Area waste sites, have been partially deleted from the NPL.

The 100 Area reactor waste areas occupy about 11 square kilometers (4 square miles) of the 68 square kilometers (26 square miles) of this NPL site. Some of the reactor areas contain one and some contain two nuclear reactors: the B and C, KE and KW, N, D and DR, H, and F Areas. The associated maps (Maps 1 through 6) show each of these areas along with the CERCLA waste sites (including those already remediated) contained in each area.

The mission of each area was to produce plutonium in a reactor. Each reactor had numerous support facilities, such as powerhouses, water treatment and pumping facilities, laboratories, railroad offloading facilities, office buildings, septic systems, and waste disposal facilities for reactor effluent. The main component of each reactor was a large stack (pile) of graphite blocks that had tubes and pipes running through it. The tubes held the fuel elements while they were being irradiated, and the pipes carried water to cool the graphite pile. Placing large numbers of uranium fuel elements into the reactor piles created an intense radiation field, and a nuclear chain reaction that converted some uranium atoms to plutonium atoms. Other atoms, both uranium and non-radioactive atoms in the pile structure, were converted into radioactive fission products and activation products that were disposed of.

The first eight reactors (except N Reactor) used large quantities of water from the Columbia River for direct cooling of the pile; the water was then discharged through large pipes into retention basins for short periods of time, then discharged into the river or to subsurface cribs and trenches. The discharged cooling water contained primarily activation products from impurities in the river water made radioactive by neutron activation, and radioactive materials that escaped from the fuel elements or tube walls during the irradiation process (Poston et al. 2000).

The ninth reactor, the N Reactor, was a modified design that re-circulated purified waste through the reactor core in a closed-loop cooling system. It was the only dual-purpose reactor, as it was used to produce electricity as well as plutonium.

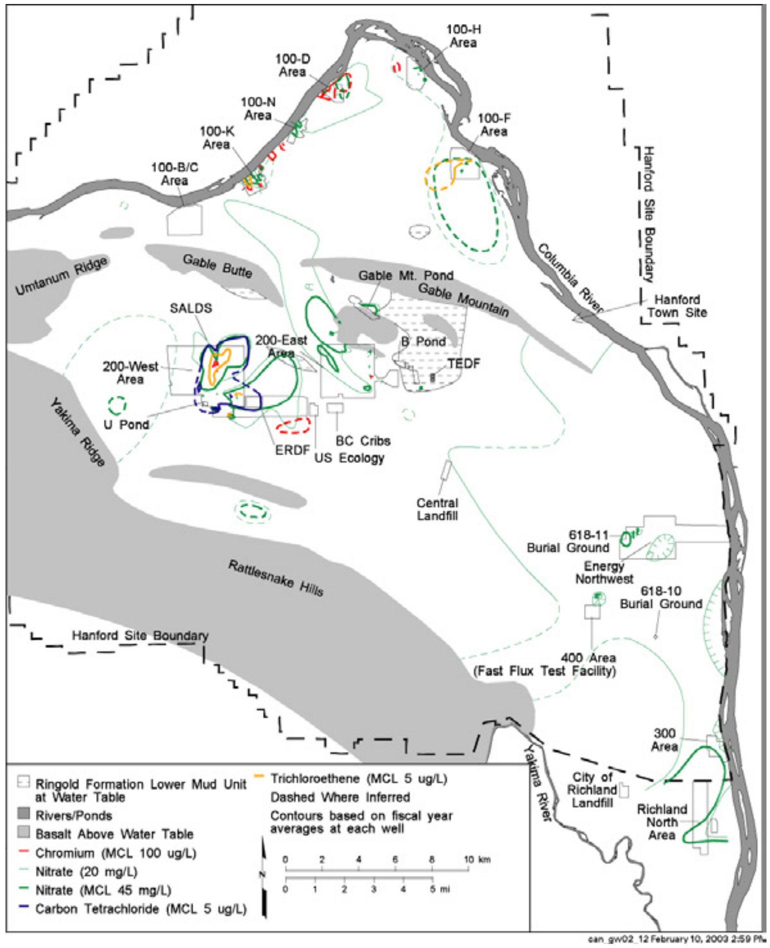


Figure 4.2. Distribution of Major Hazardous Chemicals in Groundwater at Concentrations Above Maximum Contaminant Levels During Fiscal Year 2002

CERCLA Actions. All of the Hanford production reactors have been shut down and deactivated, and each of the 100 Areas is in some stage of cleanup, decommissioning, or restoration. Full scale remediation of 100 Area waste sites began in 1996 and has continued since then (Poston et al. 2003). Virtually all of the currently known 100 Area CERCLA waste sites (426 sites) are covered by an interim action record of decision. Of these 426 sites, 101 have been remediated and closed as of September 2003; other sites are in progress. There are currently nine approved interim action records of decision, amendments, or explanations of significant difference (Waste Information Data System [WIDS] database) that document the decisions to remediate the sites. In addition, many of the 100 Area facilities (such as the reactors and support buildings) are being addressed under separate CERCLA action memorandums.

All CERCLA actions in the 100 Areas are being completed to attain the same remedial action objectives (DOE 2000b). The remedial action objectives were initially established in 1995 in the first record of decision for the 100 Area waste sites (EPA 1995a). At that time, the final land use for the 100 Area had not been established. Per EPA (1995) "For the purposes of this interim action, the remedial action objectives are for 'unrestricted use.' Remedial action objectives and cleanup goals will be re-evaluated if

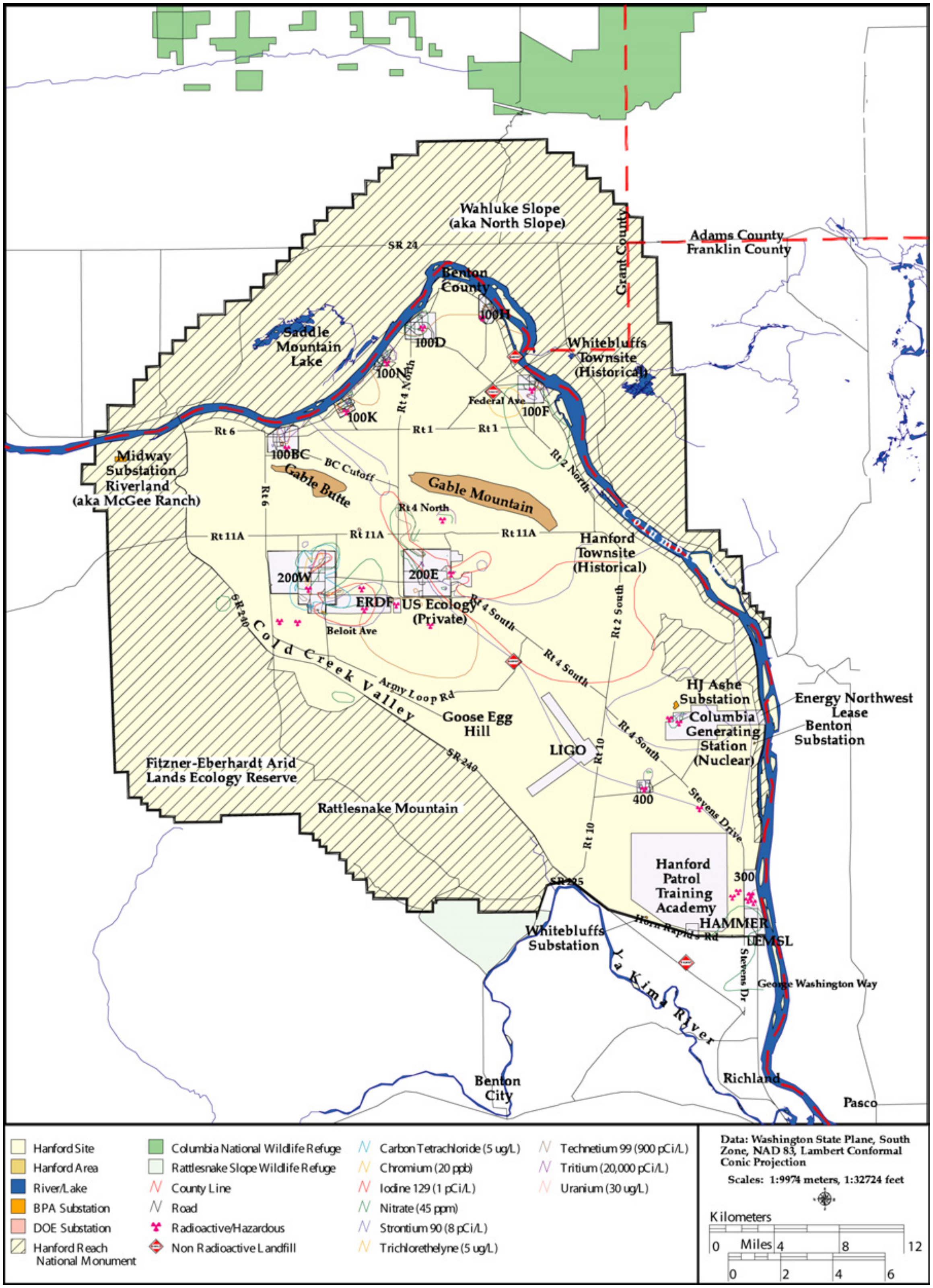


Figure 4.3. Hanford Site-Wide Hazard Map – Current State

future land use and groundwater use determinations are inconsistent with the goals presented in this ROD." The remedial action objectives currently used in the 100 Areas per the approved interim action records of decision (DOE 2000b) are:

1. Protect human and ecological receptors from exposure to contaminants in soils, structures, and debris by dermal exposure, inhalation, or ingestion of radionuclides, inorganics, or organics. This is to be achieved through excavation of the waste site to the Washington State Model Toxics Control Act (WAC 173-340) levels for organic and inorganic chemical constituents in soil to support unrestricted (residential) use, and draft EPA and U.S. Nuclear Regulatory Commission proposed protection of human health standards of 15 mrem per year above background for radionuclides in soil. The point of compliance is from ground surface to 4.6 meters (15 feet) below the ground surface. This represents a reasonable estimate of the depth of soil that could be excavated and distributed at the soil surface as a result of site development activities.

2. Control the sources of groundwater contamination to minimize the impact to groundwater resources, protect the Columbia River from further adverse effects, and reduce the degree of groundwater cleanup that may be required under future actions. This will be achieved by assuring that contaminants remaining in the soil after remediation do not result in an adverse impact to groundwater that could exceed maximum contaminant levels and non-zero maximum contamination level goals under the Safe Drinking Water Act.

3. To the extent practicable, return soil concentrations to levels that allow for unlimited future use and exposure. Where it is not practicable to remediate to levels that will allow for unrestricted use in all areas, institutional controls and long-term monitoring will be required.

The interim action records of decision indicate that to establish numerical remedial goals to protect human health, the remedial action objectives will be met by using the residential exposure scenario. Because cleanup levels to meet remedial action goals to protect human health are lower than ecological cleanup levels, it was concluded that meeting human health standards for contaminants would also protect ecological receptors. For example, removal of soil and debris exceeding human health-based goals and replacement (i.e., backfilling) with clean material is expected to meet the objective of protection of ecological receptors. However, to evaluate this further, a pilot risk assessment is underway in the 100-B/C Area and planning has been initiated for a River Corridor risk assessment.

Table 4.1. Reactor Operational Dates

Reactor	Began Operations	End of Operations
B	1944	1968
C	1952	1969
KE	1955	1971
KW	1955	1970
N	1963	1987
D	1944	1967
DR	1950	1964
H	1949	1965
F	1945	1965

While residual contamination more than 4.6 meters (15 feet) below the surface will protect groundwater and the Columbia River, it may not meet the direct exposure remedial action objectives for soil less than 4.6 meters (15 feet) deep. Thus, for some sites, institutional controls to prevent uncontrolled drilling or excavating below 4.6 meters (15 feet) are required.

A record of decision (EPA 2000a) for cleanup actions has been changed for site 116-N-1 to invoke the balancing factors in determining the extent of additional excavation below 4.6 meters (15 feet) below ground surface. One of the standard assumptions normally used to determine allowable residual contaminant concentrations is an allowance for 75 centimeters (30 inches) per year of irrigation on the remediated sites. The balancing factors evaluation in the explanation of significant difference (EPA 2003) indicated that institutional controls as required by the record of decision, including a prohibition on irrigation, will protect human health and the environment. In addition, the explanation of significant difference noted that the reasonably expected future uses of the area do not include uses involving irrigation. The record of decision was changed, via the explanation of significant difference, to include a prohibition on irrigation consistent with the balancing factors criteria.

Future Land Use. In 1999, DOE published the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999a) and the record of decision (64 FR 61615).

The environmental impact statement and record of decision evaluated "the potential environmental impacts associated with implementing a comprehensive land-use plan for the Hanford Site for at least the next 50 years."

The land-use alternative chosen for the majority of the Hanford Site was Conservation (Mining) (DOE 1999a). Land use for specific area includes preservation for a 0.4-kilometer (0.25-mile) buffer zone along the Columbia River and the river islands to protect cultural and ecological resources. High-intensity recreation is designated at four sites for visitor-serving activities and facilities development. These four sites are the B Reactor (proposed to be converted into a museum), a boat ramp near the Vernita Bridge, and two Wahluke Slope areas designated for potential tribal fishing sites. Also part of the chosen land-use alternative is low-intensity recreation west of the B Reactor, a boat launch at White Bluffs, and visitor facilities near the old Hanford High School.

Conceptual Models. The current conceptual models accompanying each section are based on the conceptual model presented in DOE (1999c). The potential receptors are based on recreational, unrestricted rural residential, and restricted rural residential scenarios, and ecological pathways. There is no current recreational or residential use of the 100 Areas; these scenarios were chosen to reflect a range of possibilities until a future land use was selected. These conceptual models do not directly show any tribal use scenarios, but the unrestricted rural residential scenario may approximate a tribal scenario.

The recreational scenario in the current conceptual models assumes that an individual camps and otherwise recreates at a waste site for 7 days a year, 24 hours a day. The unrestricted rural residential scenario assumes a resident with a home with a basement in exposed contamination. The restricted rural residential scenario assumes that residents are prevented by institutional controls and physical barriers from building on the waste sites or coming into direct contact with waste site contents. Surface use of the waste sites could occur but subsurface activities such as excavation, well drilling, and farming of waste sites would be restricted.

For the end state conceptual models, which do not consider residents living on or near the waste sites based on the CLUP (DOE 1999a), the scenarios presented are only recreational and biota. However, because the future exposure pathways associated with each site have been removed by virtue of removal of the wastes to meet the remedial action objectives, a future resident building a home with a basement in a former waste (unrestricted rural residential) site would also be protected, as they continue to be remediated under the current interim action record of decisions. A rural residential scenario may likely also be protective of tribal scenarios.

4.1.1 Liquid Waste Sites

Four liquid waste records of decision or amendments cover 91 of the CERCLA waste sites in the 100 Areas. Sixty-two of these waste sites are already closed (WIDS database), and many of the rest are currently undergoing remediation.

Cooling water from the single-pass reactors along the Columbia River was routinely routed to retention basins prior to return to the river. Thermal shock from the hot cooling water cracked the basins so that cooling water leaked into the vadose zone. In addition, trenches were sometimes used for direct disposal of cooling water. The disposed cooling waters contained fission and neutron activation products and some chemicals and actinides. Of biggest concern are the impact of tritium, strontium-90, nitrate, and chromium migrating through the vadose zone to groundwater, and ultimately, to the Columbia River (Neitzel 2003).

Highly contaminated cooling water, such as water that had contacted broken fuel rods, was routed to trenches rather than being directly returned to the river. These fluids contained large quantities of fission and neutron activation products. Dorian and Richards (1978) estimated (via extensive boreholes and sampling) the amount of residual radioactivity in the retired 100 Area (at that time, all but the 100-N Area) retention basins, diversion cribs and trenches, pipelines, and leakage areas that were assumed to hold the bulk of the residual contamination. They estimated that the deactivated 100 Area liquid waste sites contained a total radioactive inventory of 4,400 curies (as of 1978). The principal radionuclides remaining in the facilities were reported to be europium-152, europium-154, europium-155, cobalt-60, cesium-137, strontium-90, carbon-14, helium-3, plutonium-239/240, and nickel-63. DOE (1994) reported a 1988 inventory of 10,056 curies of radionuclides (cobalt-60, strontium-90, ruthenium-106, cesium-134, cesium-137, and plutonium-239) in the two main 100-N Area liquid waste sites. Additional non-radioactive contaminants, such as sodium dichromate, are also common in the liquid waste sites.

As remediation has proceeded on the liquid waste sites, many plumes of radioactive contamination have been discovered. These plumes are the result of past leaks from the retention basins and pipelines and unexpected lateral spread of contaminants disposed of to the soil in cribs and trenches. These plumes make estimating the total area covered by the liquid waste sites difficult.

Figures 4.4 and 4.5 are conceptual exposure models of the liquid waste sites showing the potentially contaminated media and receptors. These figures show the current state, assuming no remediation and range of receptors that includes a rural resident per the interim action record of decision, and a future land-use end state per the land-use plan (DOE 1999a) with only a recreationalist and biota as receptors. The secondary sources of contamination from liquid waste sites are intrusion of biota (roots and burrowing animals) into the waste sites, infiltration to the groundwater, and outflow of the groundwater to the Columbia River via springs and upwelling under the river. These contaminants could then be taken up by biota or humans using the river. Volatilization and direct contact with the soil are less significant pathways, and the groundwater has no consumptive uses. Biota intrusion into the waste sites is discouraged by the soil cover (sandy cobbles that are kept free of vegetation). Infiltration from the vadose zone to the groundwater is currently very low because of the lack of a driver (large volumes of water flowing

Primary Contaminant Source	Potentially Contaminated Media	Potential Exposure Routes	Potential Receptors: Humans – Restricted Recreational Use	Humans – Unrestricted Rural Residential Use	Humans – Inadvertent Intruder	Biota[(a)]
Liquid Waste Sites	Soil	External Radiation	S	S	S	S/——[(b)]
		Ingestion/Uptake	S	S	S	S
		Inhalation	S	S	S	S
		Dermal Contact	S	——	S	S
	Air	External Radiation	——	——	——	——
		Ingestion/Uptake	——	——	——	——
		Inhalation	S	S	S	S
		Dermal Contact	——	——	——	——
	Biota	External Radiation	——	——	——	——
		Ingestion/Uptake	S	——	S	S
		Inhalation	——	——	——	——
		Dermal Contact	——	——	——	——
	Groundwater	External Radiation	——	——	——	•
		Ingestion/Uptake	——	——	S	•
		Inhalation	——	——	——	——
		Dermal Contact	——	——	——	•

Symbol	Meaning
•	Primary Exposure Pathway
S	Secondary Exposure Pathway
——	Incomplete or Inconsequential Exposure Pathway

Figure 4.4. 100 Area Liquid Waste Sites Conceptual Exposure Pathway Model, Current State

Notes:
(a) Biota - Burrowing animals and deep-rooted plants.
(b) Secondary pathway for animals; inconsequential pathway for plants.

Primary Contaminant Source	Potentially Contaminated Media	Potential Exposure Routes	Potential Receptors: Humans – Restricted Recreational Use	Potential Receptors: Biota[a]
Liquid Waste Sites	Soil	External Radiation	——	——
		Ingestion/Uptake	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Air	External Radiation	——	——
		Ingestion/Uptake	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Biota	External Radiation	——	——
		Ingestion/Uptake	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Groundwater	External Radiation	——	——
		Ingestion/Uptake	——	——
		Inhalation	——	——
		Dermal Contact	——	——

- • Primary Exposure Pathway
- S Secondary Exposure Pathway
- —— Incomplete or Inconsequential Exposure Pathway

Figure 4.5. 100 Area Liquid Waste Sites Conceptual Exposure Pathway Model, End State

Notes:
(a) Biota - Burrowing animals and deep-rooted plants.

through the vadose zone to the groundwater). A potential future pathway at the time the interim action record of decision was approved, the construction of a home and 4.6-meter (15-foot-deep) basement by a hypothetical future resident, was the scenario chosen to determine the remedial action objectives. As the liquid waste sites continue to be remediated per the liquid waste interim action record of decision, these pathways will continue to be eliminated. While these future conceptual models do not show additional release of contaminants to the groundwater because of the remedial actions taken, past contamination of the groundwater from waste sites may still be present. This contamination is addressed in Section 4.1.6.

The primary receptors at risk due to unremediated waste sites are salmon eggs or hatchlings in the Columbia River that may be in the areas of groundwater upwelling and recreationalists or hypothetical residents exposed to contaminated soil and springs (Conceptual Model Figure 4.4). Following completion of remedial activities (which are designed to stop any future infiltration of deep contaminants from the vadose zone to the groundwater), and assuming land use as determined by the CLUP (DOE 1999a), there will be no future exposure pathways from remediated waste sites.

4.1.2 100 Area Burial Grounds

Forty-five burial grounds in the 100 Area reactor areas are addressed under a separate interim action record of decision (EPA 2000). Burial grounds are defined as areas used for near-surface disposal of solid waste containing hazardous substances (radioactive and non-radioactive). The feasibility study (DOE 1999c) and interim action record of decision (EPA 2000) exclude decontamination and demolition sites where subsurface concrete foundations and other building materials were left in place or disposed. They also exclude domestic landfills remaining in the Hanford and White Bluffs town sites.

The primary burial grounds are all large (over 30 meters by 30 meters[98.4 feet by 98.4 feet]), but the secondary burial grounds are as small as 2 meters by 2 meters (6.6 feet by 6.6 feet). Radioactive waste in the 100 Areas was segregated as soft waste (combustibles) or hard waste (greater than 99% metallic). The radioactive hard waste include process tubes, fuel element spacers, equipment, tools, and control rods. Most of the burnable waste from reactor operations was burned in open pits or in a natural draft incinerator in the 100-K Area burial ground. Biological studies generated low-level soft waste containing radioactive tracers and low-level fission and activation products, which are buried in the 100-F Area.

The majority of the chemical elements contained in the burial grounds are boron, cadmium, lead, and nickel, with lesser amounts of lithium-aluminum alloy, mercury, palladium, and zirconium. Additional miscellaneous debris consists of aluminum and steel.

Several large waste items are in the burial grounds, including

- one railroad tank car (possibly two) used to dissolve animal carcasses in caustic chemicals
- two concrete vaults filled with gravel
- one concrete vault with 140 metric tons (154 tons) of lead and cadmium
- one metal tank used to store radioactive steel balls
- two vertical concrete pipes used to hold wastes from the P-10 tritium separations project

Only low-level waste is known to have been disposed in the burial grounds; waste containing plutonium or any other alpha emitters, cobalt-60 in amounts greater than 1 millicurie/gram, or beryllium was packaged and shipped to the 200 Area for burial in designated trenches. The main radionuclides are europium-152, europium-154, europium-155, cobalt-60, cesium-137, strontium-90, carbon-14, helium-3, nickel-63, and silver-108m. Because disposal records prior to the late 1960s were not detailed, the estimates of the radionuclide inventory are uncertain and largely drawn from evaluations of analogous sites. The predominant radionuclides anticipated in the 45 burial grounds (compiled) are: tritium – 18,600 curies; cobalt-60 – 3,000 curies; nickel-63 – 2,200 curies; strontium-90 – 9 curies; cesium-137 – 9 curies; and silver-108m – 60 curies.

The mechanisms for release of contaminants to the environment, and the potential of occurrence (as reported in DOE 1999c) are:

- erosion of the clean soil covering the burial ground by wind or water (low potential, because of the coarse gravel and cobbles covering the burial grounds)
- excavation of buried wastes by burrowing animals (potential)
- excavation of buried wastes by human activity (potential)
- plant uptake (potential)
- dissolution of contaminants by infiltrating precipitation, and transport to the groundwater or contact by groundwater (potential at only one 100-F Area burial ground)

The approved interim action record of decision (EPA 2000) directed that remedial actions at the burial grounds will involve removal, treatment if appropriate, and disposal of contaminated material at Environmental Restoration Disposal Facility. The same cleanup criteria (remediation goals) as used at the rest of the 100 Area waste sites are being used.

Figures 4.6 and 4.7 are conceptual exposure models of the solid waste burial ground waste sites showing the potentially contaminated media and receptors. These figures show the current state, assuming no remediation and range of receptors that includes a rural resident per the interim action record of decision, and a future land-use end state per the land-use plan (DOE 1999a) with only a recreationalist and biota as receptors. Because solid waste burial grounds are expected to have little to no migration of contaminants from the solid waste to the underlying soil, by removing the contaminated material and disposing of it in Environmental Restoration Disposal Facility, all pathways of contamination to humans or the environment are expected to be eliminated.

4.1.3 100 Area Reactor Cores

Nine water-cooled, graphite-moderated plutonium production reactors were constructed along the Columbia River by the U.S. government between 1943 and 1963. Eight of the reactors (B, C, D, DR, F, H, KE, and KW) were included in *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE 1989), which examined the alternatives for dispositioning the reactors. The ninth reactor, N Reactor, had not been declared surplus at the time of the environmental impact statement, so it is to be addressed separately for interim safe storage.

Primary Contaminant Source	Potentially Contaminated Media	Potential Exposure Routes	Potential Receptors: Humans: Restricted Recreational Use	Unrestricted Rural Residential Use	Inadvertent Intruder	Biota[a]
Burial Ground	Hard Waste	External Radiation	•	•	•	•/——[b]
		Ingestion/Uptake	S	S	S	S
		Inhalation	——	——	——	——
		Dermal Contact	——	——	——	——
	Soil	External Radiation	S	S	S	S/——[c]
		Ingestion/Uptake	S	S	S	S
		Inhalation	S	S	S	S
		Dermal Contact	S	——	S	S
	Soft Waste	External Radiation	S	——	S	S/——[a]
		Ingestion/Uptake	S	——	S	S
		Inhalation	——	——	——	——
		Dermal Contact	——	——	——	——
	Air	External Radiation	——	——	——	——
		Ingestion/Uptake	——	——	——	——
		Inhalation	S	S	S	S
		Dermal Contact	——	——	——	——
	Biota	External Radiation	——	——	——	——
		Ingestion/Uptake	S	——	S	S
		Inhalation	——	——	——	——
		Dermal Contact	——	——	——	——
	Groundwater	External Radiation	——	——	——	——[d]
		Ingestion/Uptake	——	——	S	——[c]
		Inhalation	——	——	——	——[c]
		Dermal Contact	——	——	——	——[c]

•	Primary Exposure Pathway
S	Secondary Exposure Pathway
——	Incomplete or Inconsequential Exposure Pathway

Figure 4.6. 100 Area Burial Ground Conceptual Exposure Pathway Model, Current State

Notes:
(a) Biota - Burrowing animals and deep-rooted plants.
(b) Primary pathway for animals; inconsequential pathway for plants.
(c) Secondary pathway for animals; inconsequential pathway for plants.
(d) Possible secondary pathway for aquatic biota associated with 118-F-2.

Primary Contaminant Source	Potentially Contaminated Media	Potential Exposure Routes	Potential Receptors: Humans – Restricted Recreational Use	Potential Receptors: Biota[a]
Burial Ground	Hard Waste	External Radiation	——	——/——[b]
		Ingestion/Uptake	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Soil	External Radiation	——	——/——[c]
		Ingestion/Uptake	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Soft Waste	External Radiation	——	——/——[c]
		Ingestion/Uptake	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Air	External Radiation	——	——
		Ingestion/Uptake	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Biota	External Radiation	——	——
		Ingestion/Uptake	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Groundwater	External Radiation	——	——[d]
		Ingestion/Uptake	——	——[d]
		Inhalation	——	——[d]
		Dermal Contact	——	——[d]

•	Primary Exposure Pathway
S	Secondary Exposure Pathway
——	Incomplete or Inconsequential Exposure Pathway

Figure 4.7. 100 Area Burial Ground Conceptual Exposure Pathway Model, End State

Notes:
(a) Biota - Burrowing animals and deep-rooted plants.
(b) Primary pathway for animals; inconsequential pathway for plants.
(c) Secondary pathway for animals; inconsequential pathway for plants.
(d) Possible secondary pathway for aquatic biota associated with 118-F-2.

Each reactor building contains a reactor block, control room, spent-fuel discharge area, fuel storage basin, fans and ducts for ventilation water cooling systems, and supporting offices and labs. A typical reactor facility was 76 meters (249 feet) long by 70 meters (230 feet) wide by 29 meters high (95 feet). The blocks (cores) have reinforced concrete walls (0.9 to 1.5 meters thick [3 to 4.9 feet]) to provide shielding. The reactor block is located near the center of the facility, and weighs approximately 8,100 metric tons (8,929 tons), with overall dimensions of 14 meters wide, 12.2 meters (40 feet) deep, and 14 meters (46 feet) high. The KE and KW blocks are larger than those in the other (older) reactors, and are about 11,000 metric tons (12,125 tons) each. The blocks rest on massive concrete bases.

As of March 1985, the total radioactive inventory estimated for all eight of the reactors is tritium – 98,100 curies; carbon-14 – 37,400 curies; chlorine-36 – 270 curies; cobalt-60 – 74,400 curies; cesium 137 – 267 curies; and uranium-238 – 0.013 curies. The dose to workers contributed by cobalt-60 and cesium-137 is one of the main drivers leading to the decision to place the reactor cores in in situ stabilization for 75 years. After that time, the dose to workers will be significantly reduced by decay to allow for removal of the cores to the 200 Area for long-term disposal without excessive worker exposure (DOE 1989).

As of October 2003, the in situ stabilization of the C Reactor has been completed (with regulator approval) and the reactor is cocooned for storage. The in situ stabilization construction has been completed for the D, DR, and F Reactors, but they are awaiting regulator approval of completion activities. The H Reactor in situ stabilization is in progress, and the B Reactor in situ stabilization is on hold until a decision on its status as a museum is made.

Figures 4.8 and 4.9 are conceptual exposure models of reactors showing the potentially contaminated media and receptors. These figures show the current state, assuming no remediation and range of receptors that includes a rural resident per the interim action record of decision, and a future land-use end state per the land-use plan (DOE 1999a) with only a recreationalist and biota as receptors. The secondary sources of contamination for the reactors is human exposure, especially to workers, animal intrusion, such as pigeons and bats, and past leakage of the fuel storage basins to the vadose zone, which then could lead to the groundwater and the Columbia River. The in situ stabilization actions seal the reactors against animal intrusion, and worker entry into the cocoon for inspection is at 5-year intervals, greatly limiting these exposure pathways. With the fuel and sludge removed from the fuel storage basins and the concrete structure of the basins removed and/or turned into rubble depending on contamination levels or depth, this secondary exposure pathway has been removed (e.g., EPA 1998).

Additional materials that may be considered hazardous substances are, or have been, present in the reactors, including mercury, friable asbestos, polychlorinated biphenyls, cadmium, and lead (DOE 1989).

Just as for the liquid and solid waste sites, the cleanup criteria for the removed parts of the facility and the adjacent soil include protection of the groundwater and Columbia River from infiltration of vadose-zone contaminants. The cleanup criteria are a direct exposure radionuclide dose of 15 mrem per year above background for soil in the top 4.6 meters (15 feet) and a predicted drinking water dose of less than 4 mrem per year, with individual radionuclides not to exceed their maximum concentration levels for groundwater. No material is left behind that would cause these criteria to be exceeded (EPA 1998). Thus, no future receptors are predicted to be at risk of receiving a radionuclide dose above these cleanup criteria.

Primary Contaminant Source	Potentially Contaminated Media	Potential Exposure Routes	Potential Receptors: Humans – Recreational Land Use	Potential Receptors: Humans – Restricted Land Use	Potential Receptors: Humans – Unrestricted Land Use	Potential Receptors: Biota[(a)]
Reactors	Facility (Core)	External Radiation	•	•	•	•
		Ingestion	——	——	——	——
		Inhalation	——	——	——	——
		Dermal Contact	——	——	——	——
	Underlying Soil	External Radiation	S	S	S	S
		Ingestion	S	S	S	S
		Inhalation	S	S	S	S
		Dermal Contact	S	——	S	S
	Air	External Radiation	——	——	——	——
		Ingestion	——	——	——	——
		Inhalation	S	S	S	S
		Dermal Contact	——	——	——	——
	Biota	External Radiation	——	——	——	——
		Ingestion	S	——	S	S
		Inhalation	——	——	——	——
		Dermal Contact	——	——	——	——
	Groundwater	External Radiation	——	——	——	——
		Ingestion	——	——	S	——
		Inhalation	——	——	——	——
		Dermal Contact	——	——	——	——

• Primary Exposure Pathway
S Secondary Exposure Pathway
—— Incomplete or Inconsequential Exposure Pathway

Figure 4.8. 100 Area Reactors Conceptual Exposure Pathway Model, Current State

Notes:
(a) Biota - Animals only.

Primary Contaminant Source	Potentially Contaminated Media	Potential Exposure Routes	Potential Receptors: Humans – Recreational Land Use	Potential Receptors: Biota[(a)]
Reactors	Facility (Core)	External Radiation	——	——
		Ingestion	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Underlying Soil	External Radiation	——	——
		Ingestion	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Air	External Radiation	——	——
		Ingestion	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Biota	External Radiation	——	——
		Ingestion	——	——
		Inhalation	——	——
		Dermal Contact	——	——
	Groundwater	External Radiation	——	——
		Ingestion	——	——
		Inhalation	——	——
		Dermal Contact	——	——

- • Primary Exposure Pathway
- S Secondary Exposure Pathway
- —— Incomplete or Inconsequential Exposure Pathway

Figure 4.9. 100 Area Reactors Conceptual Exposure Pathway Model, End State

Notes:
(a) Biota - Animals only.

While the N Reactor does not yet have any similar decision documents for decommissioning, it is expected to follow the same pathway to in situ stabilization and future removal of the core to the 200 Area for long-term storage.

4.1.4 100 Area Residual Vadose Zone Contamination

Residual vadose zone contamination consists of any remaining contaminants after a remedial action has been completed. This contamination will primarily be deeper than 4.6 meters (15 feet) below ground at liquid waste sites and in the foundations of demolished facilities. As noted in Section 4.1, the remedial action objectives may result in residual contamination below a 4.6-meter (15-foot) depth, so long as that contamination will not cause the groundwater or Columbia River to exceed the remedial action objectives. The radionuclide components of the contamination will continue to decay.

4.1.5 100 Area Remaining Sites

More than 200 additional sites in the 100 Area NPL have been addressed under the 'remaining sites' interim action record of decision (EPA 1999a). The sites are scattered across the 100 and 600 Areas of the Hanford Site. These sites include liquid waste and solid waste sites that received low levels of contaminants, oil spills, burn pits, foundations of previously removed facilities, septic systems, and sites (such as landfills) remaining from the former Hanford and White Bluffs town sites. While some sites were chosen for removal actions, the presence of contamination in most of these sites is uncertain, so the remedial alternative chosen in the interim action record of decision is confirmatory sampling with removal of any waste that is found to exceed the overall 100 Area cleanup criteria.

Because of the uncertainties contingent with the remaining sites, there are no estimates of contamination that may be found in these sites. However, overall the levels of both radioactive and non-radioactive contaminants are expected to be considerably less than the levels in the liquid waste sites or burial grounds, and the infiltration of any contamination is expected to be much shallower than with the other waste sites.

Unlike the liquid waste sites and burial grounds, because of the lower levels of contamination expected, many of these sites are not kept free of vegetation. Thus, there is more potential for use by biota. There is no current recreational use of the area near these waste sites. Because of the wide variety of types of remaining sites, no conceptual models are included. At the time of completion of the remedial actions directed by the interim action record of decision, these sites will meet the same remedial action objectives specified for the other, larger waste sites, which will eliminate the human health risk pathways, and likely the ecological pathways as well.

4.1.6 100 Areas Groundwater

Current Status. Groundwater beneath the 100-D, 100-H, and 100-K Areas was determined to represent a potential imminent risk to aquatic life in the Columbia River. These plumes as well as many of the seeps and springs exceed the aquatic water quality criteria for hexavalent chromium. Chromium in this chemical form is highly mobile in the Hanford subsurface and due to the risk it represents to certain aquatic species at very low concentrations (well below drinking water standards) will most likely represent a continuing potential impact until source control actions are complete.

In the 100-N Area, groundwater contains strontium-90 at concentrations that far exceed the drinking water standard. Although no aquatic water quality criteria exists for strontium-90, the concern remains that the concentrations in the riverbed sediments and entering the river could impact the aquatic ecosystem along the shoreline near 100-N Area. Strontium-90, unlike chromium, is highly sorbed or bound to vadose zone soils and aquifer sediments. Slow release of Strontium-90 from these materials will represent a continuing source even after source control measures are complete.

Groundwater plumes present beneath the 100-B/C Area and the 100-F Area contain much lower concentrations of chromium with only isolated springs and seeps above the aquatic water quality criteria. In addition, strontium-90 is present in only a very limited number of wells within these areas.

End State. The basic strategy for achieving appropriate end state conditions for 100 Area groundwater is based on completing source control actions on an area-by-area basis.

Upon completion of these source control actions, DOE is required to submit closeout verification packages for each waste site, pipeline, or unplanned release. Those packages are then consolidated into reports that document these actions achieved the required degree of cleanup. A new strategy is being implemented concurrent to the implementation to the interim remedy decisions in the 100 and 300 Areas. A River Corridor risk assessment will be developed to use as a basis for determining cleanup levels and to support final remedy decisions in both the 100 and 300 Areas. Until these final remedy decisions are in place, the interim decision will continue to be implemented.

With many of the most significant sources of groundwater contamination already subject to ongoing remedial action, it is anticipated that groundwater plumes for chromium and other mobile contaminants should begin to attenuate. Within the 100-D, 100-H, and 100-K Areas, the combination of source control and the ongoing interim actions are expected to return this groundwater to future beneficial use. For the 100-B/C and 100-F Areas, where no interim actions were taken, chromium concentrations should meet remedial action objectives through monitored natural attenuation, which will protect the Columbia River ecosystem, achieve drinking water standards, and return the area to potential future use status well before 2012.

In the past, contaminant plumes from 200 Area waste sites have migrated northward through Gable Gap and into the 100 Areas. These plumes were driven northward by the large volume discharges of cooling water to ponds and ditches in the Central Plateau. With the secession of these discharges, significant movement of contaminants from Central Plateau sources through the 100 Areas is not expected.

For the 100-N Area, strontium-90 represents the primary contaminant of concern in returning the groundwater beneath the area to a beneficial use status. At this time, it appears that future use restrictions will be necessary for this groundwater long after source control actions are complete. Without a significant breakthrough in the technology to recover strontium-90 from both the groundwater and associated sediments, radioactive decay appears to be the only plausible solution and will likely require hundreds of years to a achieve groundwater beneficial use status.

During the year following completion of the source control actions in each of the areas, groundwater monitoring and well decommissioning activities are scheduled. The goal of these efforts is to upgrade the monitoring networks to meet the requirements for long-term stewardship and issue an approved operations and maintenance plan for each groundwater operable unit.

4.2 Central Plateau Core Zone

The 200 Areas of the Hanford Site were used to process the irradiated fuel rods from the 100 Area reactors to obtain the plutonium. Chemical separations process facilities were sited in both the 200-East and 200-West Areas. The 200-North Area temporarily stored irradiated fuel rods, allowing certain short-lived radionuclides to decay before being shipped to separations plants. With the startup of the separation plants, large quantities of liquid wastes (primarily water) containing minor concentrations of radionuclides and chemicals were discharged to the soil column and percolated into the vadose zone. Depending on contaminant concentrations and a consequent need for isolation, liquid wastes were discharged either to surface ponds and ditches or to underground cribs, reverse wells, and French drains. These infiltration facilities were generally located in the 200 Areas near the processing plants and in the surrounding 600 Areas.

Key radionuclides with half-lives longer than 10 years that were discharged to the soil column include cesium-137, barium-137m, iodine-129, strontium-90, yttrium-90, technetium-99, uranium, carbon-14, americium-241, plutonium, and tritium (as tritiated water). Two-thirds of the radioactivity in liquids discharged to the ground is from tritiated water, which has a 12.3-year half-life. The least contaminated liquids were discharged to surface ponds and ditches, but comprise over 90%, by volume, of all liquid waste discharges. Conversely, the low volume streams carried 95% of all radionuclides into the vadose zone.

Major chemicals in liquids discharged to ground (based on quantities) include nitrate, sodium, phosphate, sulfate, ammonia, carbon tetrachloride, and fluoride. Inorganic chemicals were used and discharged in much greater quantities than organics. The greatest amount of hazardous chemicals were contained in the liquids discharged from 1945 to 1958 (WHC 1991).

Solid waste such as failed equipment, tools, and protective clothing containing radionuclides and hazardous materials have also been buried in the ground. The radioactive inventory in solid waste burial grounds represents approximately 1% of the total Hanford Site radioactivity.

The vadose zone underlying these waste sites consists of sediment particles of various sizes and geochemical constituents, soil moisture, vapor, and organic or vegetative matter. The flow of liquid waste through the unsaturated soils in the vadose zone depends in complex ways on several factors, including most significantly the moisture content of the soil and its hydraulic properties. Lateral and vertical gradations or discontinuities in soil-column parameters result in site-specific infiltration characteristics. In addition, waste-stream-specific characteristics of the liquid wastes, such as viscosity and volume, affect the ability of the liquid itself to infiltrate and migrate within the soil column. Contaminants will be transported by migrating water or, in the case of volatile contaminants, by the soil vapor. The resulting distribution of contaminants in the soil column depends on the degree to which different contaminants are retained by adsorption to soil particles or precipitated from the fluid along the migration pathway.

Because the 200-West, 200-East, and 200-North Areas are located on an elevated, flat area, often referred to as the 200 Areas Plateau, the underlying vadose zone is relatively thick, providing additional opportunities for sorption during migration. The increased thickness of the vadose zone in the 200 Areas also increases the travel time for contaminants to reach groundwater. The vadose zone beneath the 200-West Area ranges in thickness from less than 50 meters (165 feet) to more than 100 meters

(328 feet); the vadose zone beneath the 200-East Area ranges in thickness from 37 meters (123 feet) to about 104 meters (317 feet); and the vadose zone beneath the 200-North Area ranges in thickness from about 49 meters (160 feet) to 50 meters (165 feet). The inland location of the 200 Areas, relative to the Columbia River, also increases the travel time for contaminants that do reach groundwater to migrate to the river.

The discharge of large volumes of liquid waste to the soil columns under the 200 Areas provided the primary driving force for liquid and contaminant migration through the vadose zone toward groundwater. With the nearly complete cessation of these liquid discharges, this driving force has been largely eliminated, and the principal driving force has become natural recharge provided by rainfall and snowfall. Because the mean annual precipitation, approximately 17.3 centimeters/year (6.8 inches/year), is relatively low at the Hanford Site, the natural recharge of water that can drive contaminants through the vadose zone toward groundwater is relatively low.

Plants may redistribute and concentrate contaminants through root uptake followed by either transpiration to the atmosphere or consumption by animals. Contaminants brought to the surface by burrowing animals may be further redistributed by wind or other animals. The average maximum depth to which plant roots penetrate is approximately 3 meters (10 feet); this is also deeper than the maximum depths reported for animal burrowing. Most of the more radioactively contaminated liquids were discharged to structures buried to depths of 4 to 10 meters (12 to 35 feet), but have not always been beyond the reach of surface-based organisms.

4.2.1 Waste Site Groupings

Waste sites in the 200 Areas were grouped according to site characteristics. Chemical processes, type of contamination (e.g., uranium, plutonium, organics), and waste site type (e.g., pond, crib, burial ground) were the primary factors used to categorize sites. The following waste categories were developed:

- Process condensate and process waste sites
- Steam condensate, cooling water, and chemical sewer sites
- Chemical laboratory waste sites
- Miscellaneous waste sites
- Tank and scavenged waste sites
- Septic tanks and drain fields
- Unplanned releases
- Tanks, lines, pits, and boxes
- Landfills and dumps

The nine major process categories defined above are the primary sources of contamination in the 200 Area waste sites. Contaminants were introduced to the environment by surface and subsurface liquid discharges and surface and subsurface solid waste placements, resulting in nine secondary contaminant sources that are primary waste site types identified in the conceptual site models in Figures 4.10 through 4.17 for each of the waste categories. Current or potential future secondary release of contaminants occurs through the mechanisms listed in these figures. Secondary contaminant release can occur through

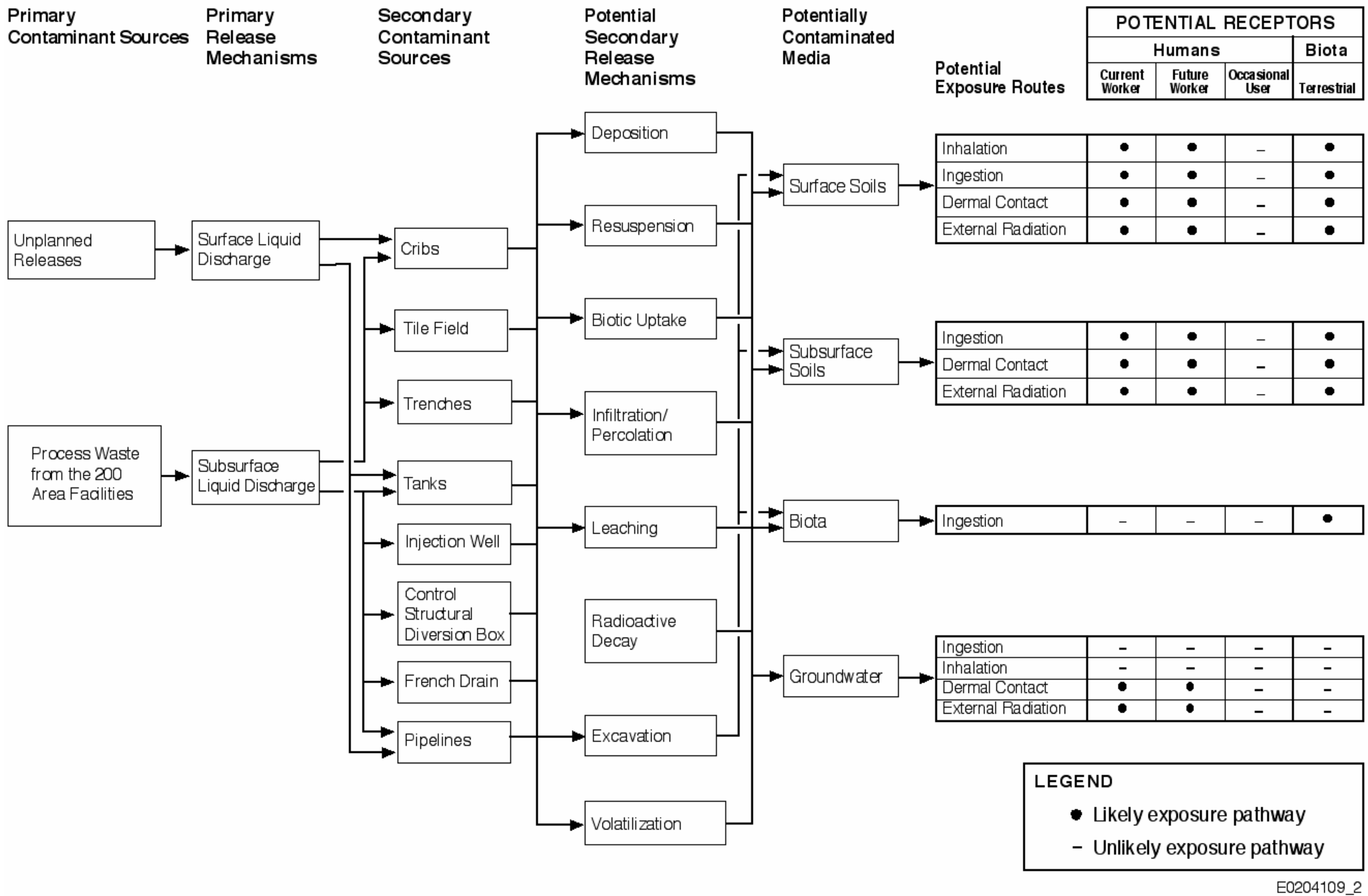


Figure 4.10. Process Condensate and Process Waste Sites, Current State

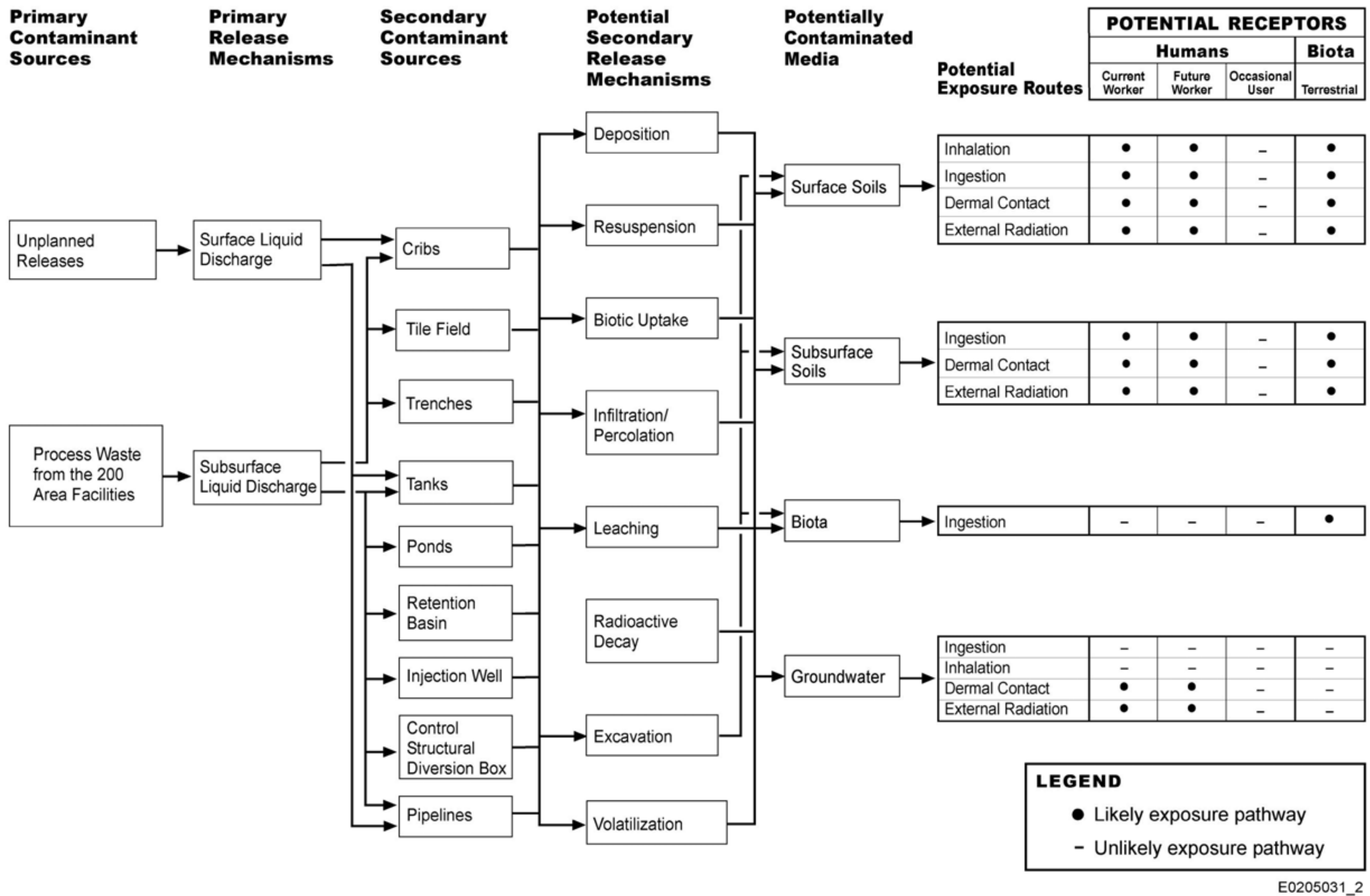


Figure 4.11. Steam Condensate, Cooling Water, and Chemical Sewer Sites, Current State

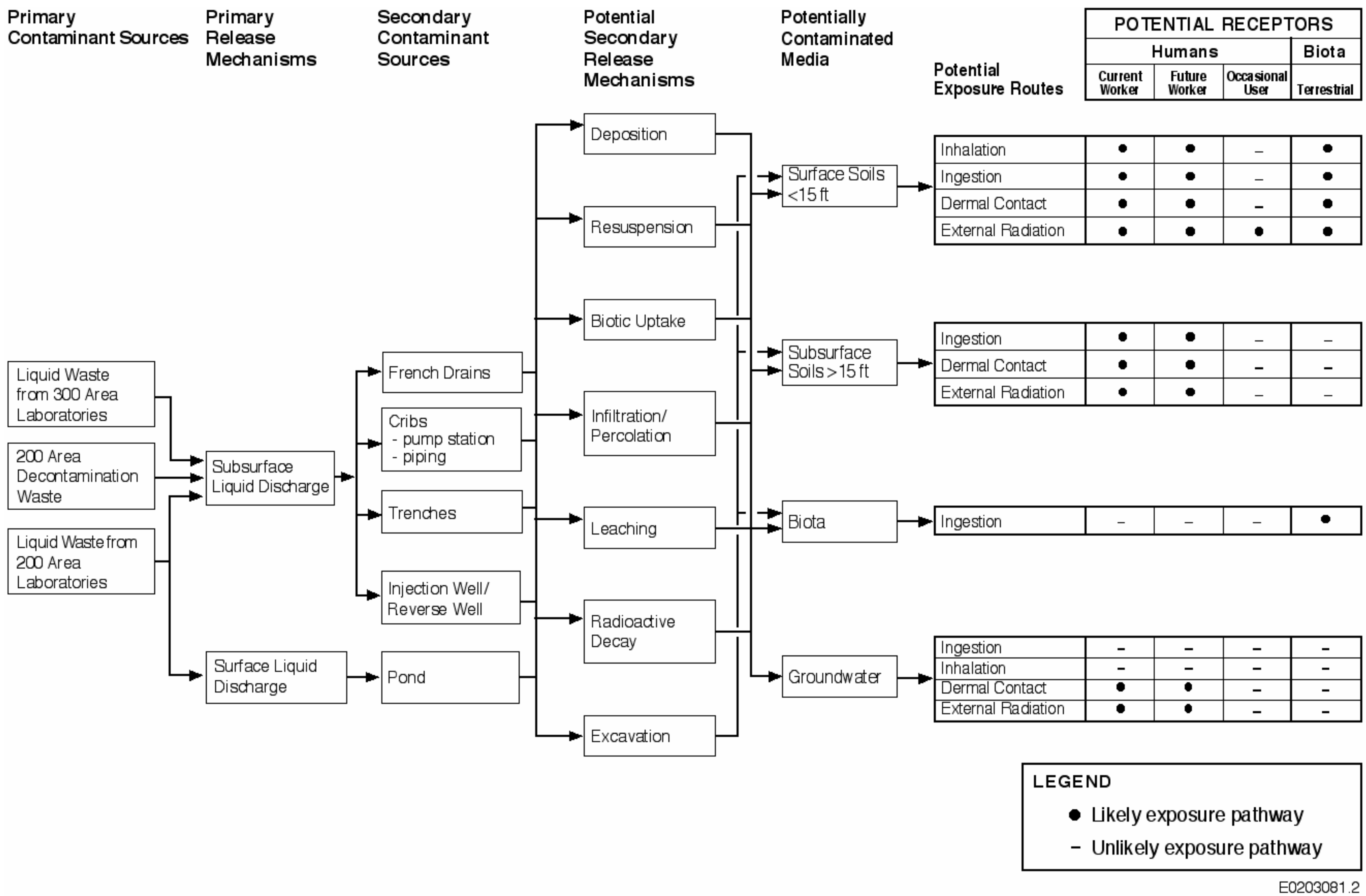


Figure 4.12. Chemical Laboratory Waste Sites, Current State

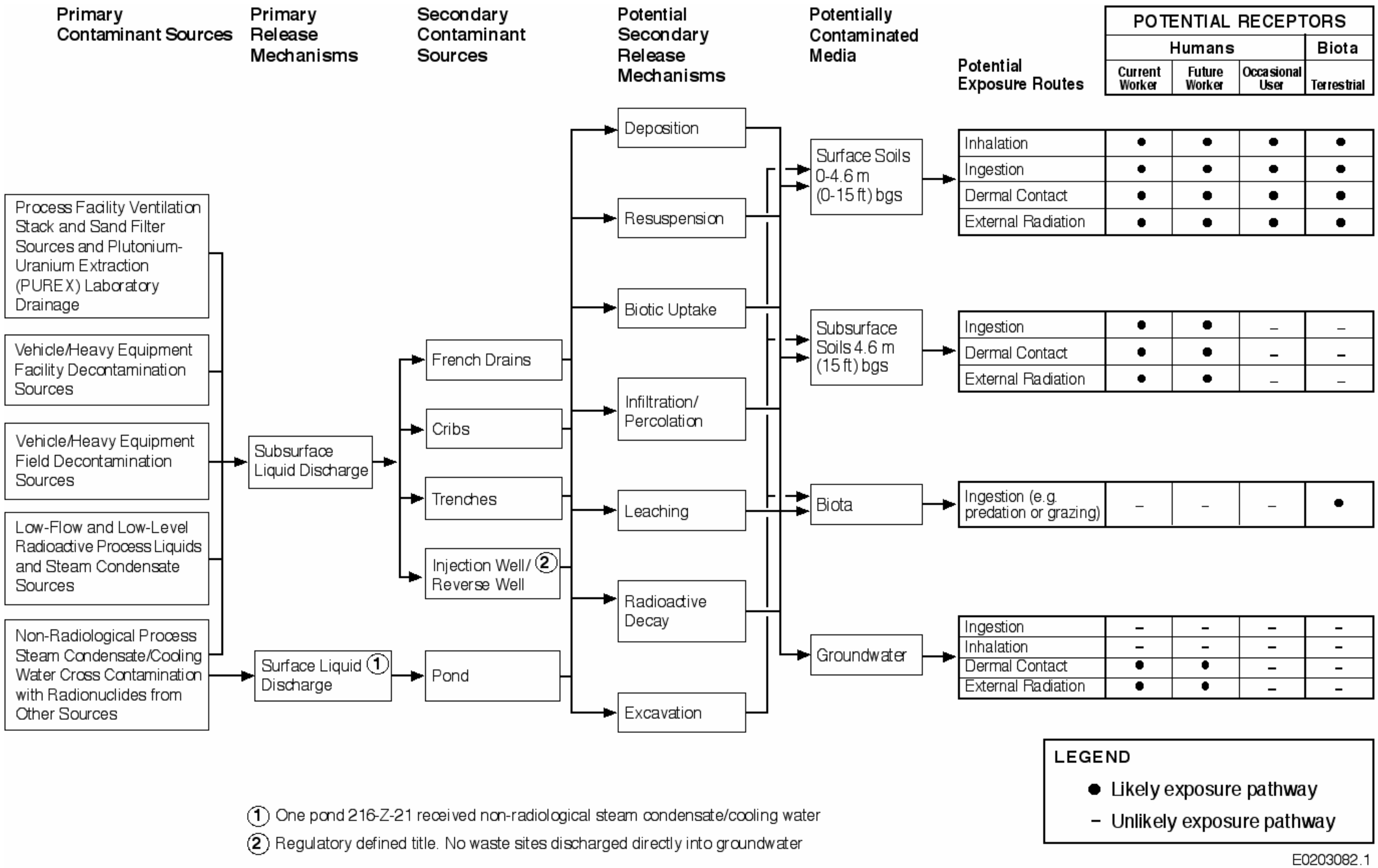


Figure 4.13. Miscellaneous Waste Sites, Current State

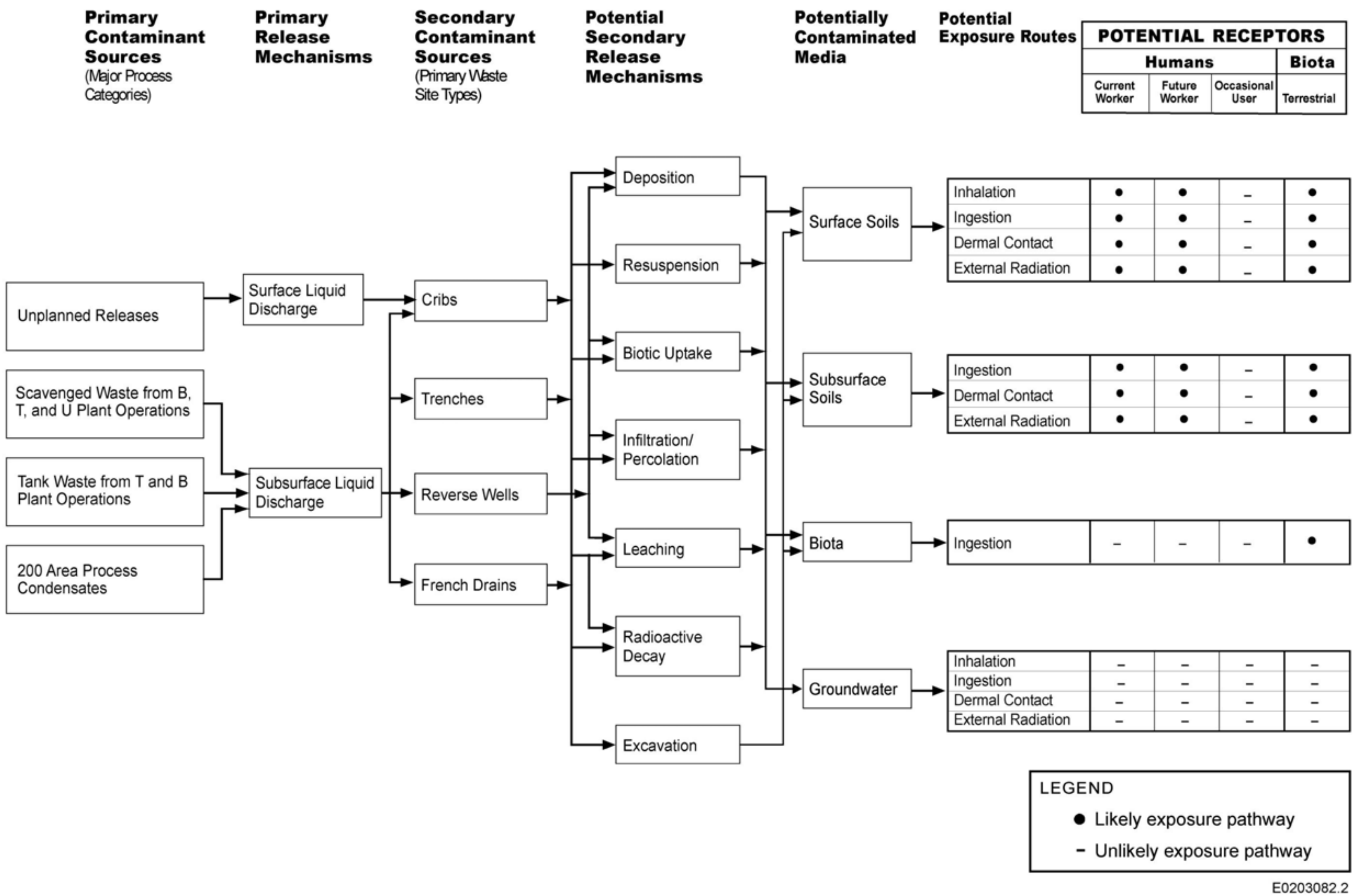


Figure 4.14. Tank and Scavenged Waste Sites, Current State

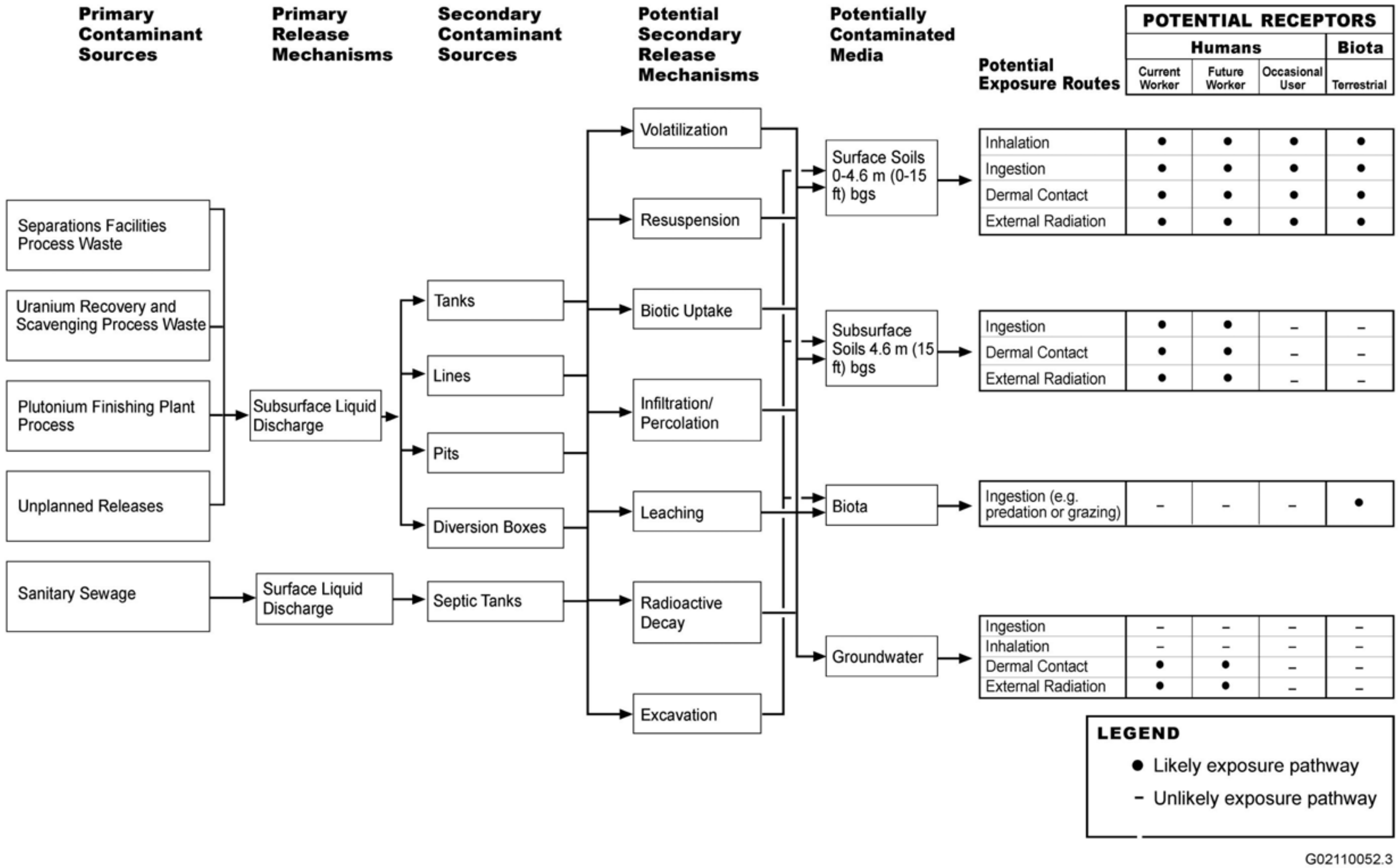
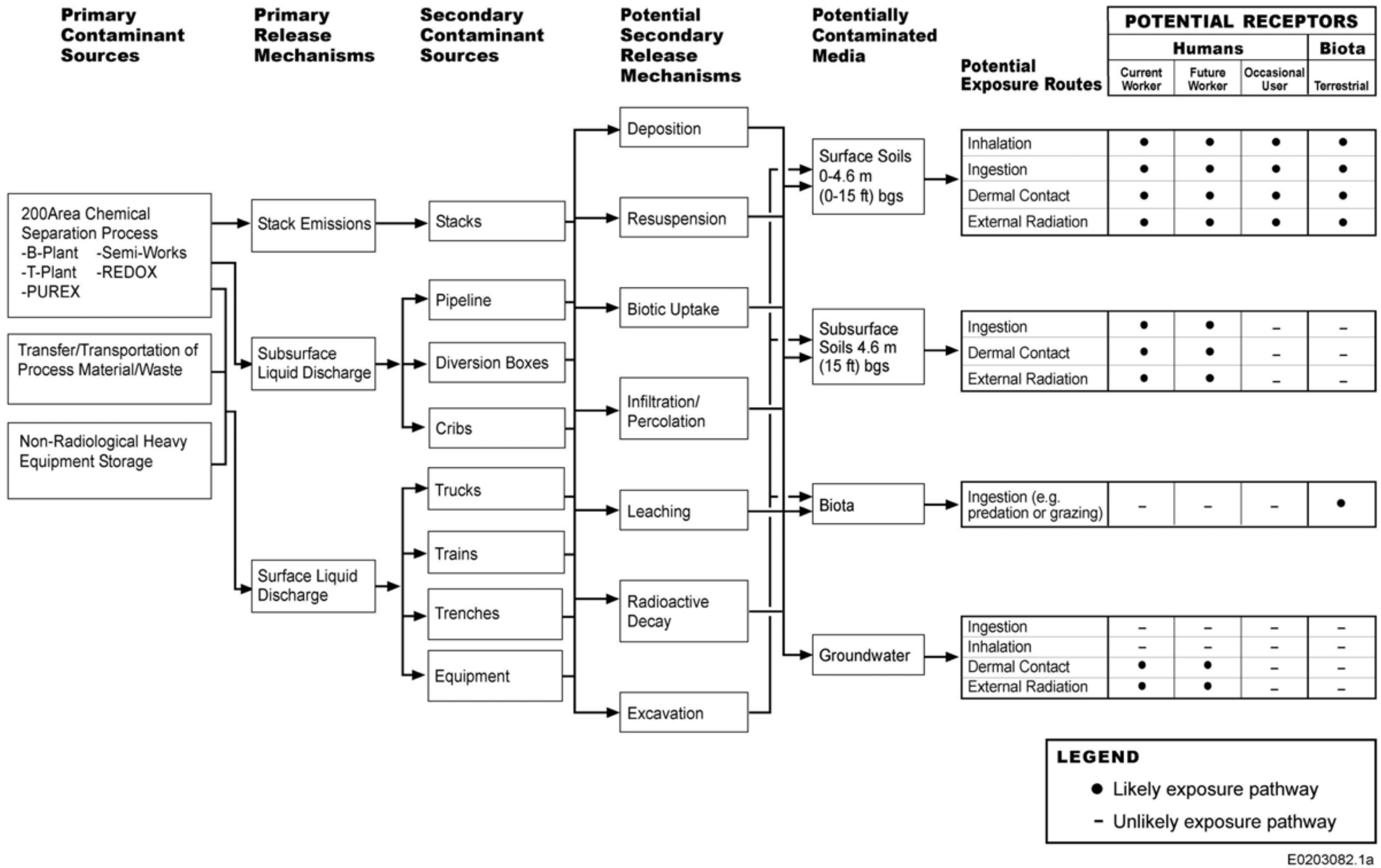


Figure 4.15. Tanks, Lines, Pits, and Boxes, Current State



Potentially Contaminated Media	Potential Exposure Routes	Current Worker	Future Worker	Occasional User	Terrestrial
Surface Soils 0-4.6 m (0-15 ft) bgs	Inhalation	●	●	●	●
	Ingestion	●	●	●	●
	Dermal Contact	●	●	●	●
	External Radiation	●	●	●	●
Subsurface Soils 4.6 m (15 ft) bgs	Ingestion	●	●	–	–
	Dermal Contact	●	●	–	–
	External Radiation	●	●	–	–
Biota	Ingestion (e.g. predation or grazing)	–	–	–	●
Groundwater	Ingestion	–	–	–	–
	Inhalation	–	–	–	–
	Dermal Contact	●	●	–	–
	External Radiation	●	●	–	–

Figure 4.16. Unplanned Releases, Current State

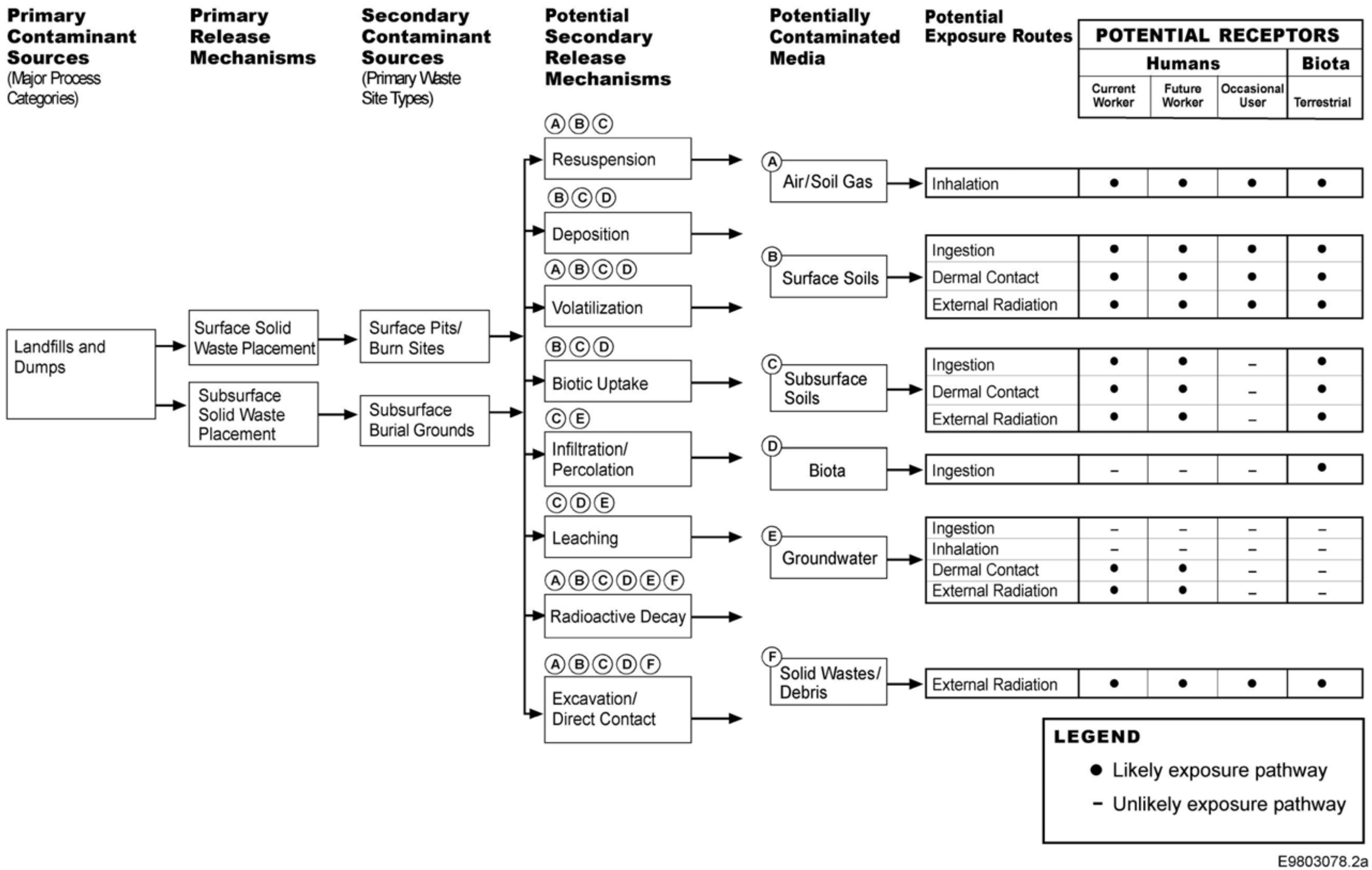


Figure 4.17. Landfill and Dumps, Current State

resuspension of contaminated soils via wind erosion or excavation activities; volatilization of contaminants from wastes and soils into the air or as soil gas; biotic uptake of contaminants via direct contact with soils or ingestion of soils, vegetation, or other animals; migration of contaminated liquids through the soil column via infiltration or percolation; leaching of contaminants from soil to groundwater; external radiation (gamma); and excavation or direct contact with contaminated soil. Media potentially contaminated via primary and secondary releases to the environment are also listed in the figures. Potential receptors (humans and biota) may be exposed to contaminated media through several exposure pathways, including inhalation of volatilized contaminants or suspended dust; ingestion of contaminants in soils, vegetation, or animals or of suspended dust; direct dermal contact with contaminants in soils; and/or direct exposure to external radiation (gamma). Potential human receptors include future workers, future occasional users of a site, and an inadvertent intruder. Potential ecological receptors include terrestrial and aquatic plants and animals.

Process Condensate and Process Waste. This category includes waste sites that are typically below ground liquid waste disposal structures (e.g., cribs and trenches). Process condensate is generally water condensed from the closed process system that was in direct contact with radioactive and chemical materials. Process waste is low-level and/or hazardous waste that directly contacted radioactive material and may contain organic complexants that could enhance their mobility. Due to the small quantities of radionuclides, this waste was disposed to underground sites such as cribs, reverse wells, and trenches. The primary contaminants noted in this category include helium-3, iodine-129, cesium-137, strontium-90, ruthenium-106, technetium-99, uranium-238, plutonium-239/240, organics, nitrates, and a number of inorganic components. Figure 4.10 provides a conceptual site model for this waste category.

Steam Condensate, Cooling Water and Chemical Sewer Waste. This category includes site types that were typically, but not exclusively, constructed at ground level (e.g., ponds, ditches, retention basins). In all cases, the waste streams were run in a non-contact manner; that is, a barrier separated the liquids in this category from contaminated process liquids, with little consequent potential for routine radiological contamination. However, contamination did enter these streams in generally negligible to very small quantities through pinhole leaks or through rare pipe ruptures. By virtue of the quantities of liquids used, significant inventories of contaminants were built up at the waste sites.

All separations facilities generated these three waste stream types, but only the Reduction Oxidation (REDOX), PUREX, and B Plant waste fractionization processes had waste sites specifically dedicated for each stream. The bismuth-phosphate processes at B, T, and U Plants discharged the three waste streams to their pond systems. Cooling water accounted for over 90% of all liquids discharged to the soil column. Chemical sewers, typically discharged to unlined ditches, were intended to receive nonradioactive, dilute chemical waste from the major solvent extraction processing facilities. Steam was used to heat process solutions at certain steps in all major process facilities, and the condensed liquid was usually discharged to cribs. Figure 4.11 provides the conceptual site model for this waste category.

Chemical Laboratory Waste. This category includes sites that received laboratory process wastes or laboratory decontamination wastes. Developmental laboratories in the 300 Area (324, 325, 327, 328, and 331 Laboratories) generated significant quantities of liquid wastes that were collected at the 340 complex and transported to selected 200 Area cribs and trenches by truck or rail. In addition, cooling water contaminated by a 1965 fuel rod rupture at the 309 Reactor facility was trucked to the 216-BC cribs. More recently, the 340 complex waste has been shipped to the 204-AR vault for disposal to the A Tank

Farms. The waste inventory is generally very low for all radionuclides, but instances of significant values of uranium, plutonium, and fission products are known. In the 200 Areas, the 222 Laboratory facilities at the S, T, U, and B Plants provided analytical services for process control to the major processing plants and generated liquid wastes that were discharged to French drains, cribs, reverse wells, and, for solid wastes, to underground vaults. These waste streams are generally very low in radionuclide concentrations, although significant inventories of plutonium, uranium, and fission products are known. Sodium dichromate is reported at several waste sites. Liquid volumes are typically low. Figure 4.12 provides the conceptual site model for this waste category.

Miscellaneous Waste. This category contains most of the French drains onsite plus a few cribs and reverse wells. Most streams in this category were very low in radionuclide and chemical constituents, except for several waste streams associated with the PUREX facility, and were not routinely monitored. These sites received liquid wastes associated with plant ventilation and stack drainage, equipment decontamination, and a number of small-to-medium volume radioactive waste streams from multiple sources. Figure 4.13 provides the conceptual site model for this waste category.

Tanks/Scavenged Waste. This category consists of streams that have received the most highly contaminated wastes sent to the ground. These wastes are associated, directly or indirectly, with tank wastes collected from the bismuth-phosphate process. The streams are characterized by significant concentrations of both radionuclides and inorganic chemicals. The scavenged waste stream was derived from certain uranium-rich bismuth-phosphate wastes generated by the Uranium Recovery Project at the 221-U Plant. The wastes were treated with a scavenging agent, ferrocyanide, that precipitated out most of the fission products remaining after uranium extraction. Treatment was initiated at the tail end of the Uranium Recovery Project and also in the 241-CR vault at the C Tank Farms. Scavenged wastes were sent to the ground in limited quantities at a number of 200 East Area cribs and trenches under a specific retention discharge philosophy that restricted the volume of liquids released at any one site. The tank wastes stream consisted of lower activity liquids overflowed to the ground at cribs and trenches from two of the less contaminated, bismuth-phosphate high-activity tank farm waste streams. In addition, a medium-level waste stream derived from process vessel rinses and drainage was sent to the ground at cribs and reverse wells. Fission products in the waste were precipitated out during cooling and storage in the tanks, and the residual liquid was released to the ground in small to moderate quantities. Figure 4.14 provides the conceptual site model for this waste category.

Tanks/Lines/Pits/Boxes Waste. This category consists of structures used to convey or control the conveyance of waste from source generating facilities to tank farms or other processing facilities. The category consists of those facilities used to handle the high-level plant wastes generated from separations or volume reduction processes. No wastes were intentionally released to the ground from this category, but a number of unplanned releases are known. The category was established as a means to identify high-level waste lines outside tank farms and processing facilities, but with the recognition that remediation of these facilities will ultimately be associated with tank farms stabilization. Diversion boxes, valve pits, sampler pits, pipelines, and other waste site types constructed in support of a soil column disposal waste site will be considered within the group in which the waste site has been placed. Figure 4.15 provides the conceptual site model for this waste category.

Unplanned Release. This category are waste sites resulting from the loss of control over a liquid, gaseous, or solid, radiological or hazardous material in the course of processing, handling, or shipping the material onsite. All unplanned releases not specifically associated with a waste site were categorized under the Unplanned Release category. Unplanned releases that are associated with particular waste sites are placed in that group and will be characterized with the respective waste site. Figure 4.16 provides the conceptual site model for this waste category.

Septic Tanks and Drain Fields Waste. This category contains sites that have received or continue to receive largely non-radioactive, non-hazardous, sanitary sewer waste. Wastes include human waste as well as shower water, janitorial and lunchroom water, and drinking water. The potential for radiological contamination does exist through the shower and janitorial sink sources, but is expected to be very small. Chemical constituents such as soaps and detergents are expected in very small quantities. The quantities of liquids discharged were not tracked. Figure 4.15 provides the conceptual site model for this waste category.

Landfills and Dumps Waste. This category contains solid waste burial and debris sites includes both radiologically and non-radiologically contaminated waste sites. The non-radiological group consists of a number of waste sites including large volume contaminants placed in specific engineered locations, such as power plant fly ash at the 284-E and 284-W ash pits, and the Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill for unused laboratory and plant chemicals. Small to medium construction debris and dump sites are known, and recent discovery sites are tracked in waste information data system. Sites included in the radiologically contaminated group consist of constructed or excavated sites (218 burial grounds) that received either low-level or transuranic waste. Ten major burial grounds with a number of trenches in each were or continue to be used in both the 200-East and 200-West Areas. Prior to 1970, transuranic and low-level waste was disposed to the same burial ground trenches, but wastes thereafter were segregated according to the low-level or transuranic designation. Transuranic waste was placed in underground concrete caissons at burial grounds after 1970. Wastes were largely solid materials and mostly from onsite; but offsite and liquid wastes (tightly packed and sealed in drums) are known. These waste sites have the highest inventory of radionuclides of soil column disposal sites. Figure 4.17 provides the conceptual site model for this waste category.

Contaminant distribution below waste disposal units is generally affected by the volume discharged and the type of disposal unit. The volume of liquid discharged to a waste site impacts the distribution of contaminants through its effect on the moisture content of the soil column. Discharges that maintain saturated conditions in the vadose zone result in deeper contaminant distributions. Contaminant distribution models have been developed for waste sites that have been characterized as part of the remedial investigation/feasibility study process. Conceptual contaminant distribution models have been developed for sites prior to characterization activities. Maps 7, 8, and 9 show the distribution models for 200 Area waste sites.

Contaminant distribution below waste disposal units is also affected by the type of disposal unit and the source of wastewater. Some generalizations with regard to these aspects are:

- Pond sites (and associated ditches) may have accumulated significant inventories of contaminants due to the large quantities of water discharged to the sites.
- Cribs generally received waste streams with somewhat higher concentrations of radionuclides for long periods of time.

- Reverse wells received smaller quantities of more contaminated wastes relative to crib waste and introduced that waste deeper into the soil column.

- Specific retention trenches and cribs were used with the intent of not saturating the soil column so that small volumes of some of the most contaminated waste streams could be discharged to the ground. Trenches and cribs tended to receive waste with higher levels of chemical constituents.

- French drains received small volumes of waste from miscellaneous non-process sources that had generally low concentrations of contamination.

End-State Decisions. The remedial decision-making process is only in its early stages for the 200 Area waste sites. The implementation plan (DOE 1999d) provides a preliminary screening of technologies and development of remedial alternatives. The seven remedial alternatives discussed in Appendix A represent the most likely remedial alternatives and end states for the waste sites in the 200 Areas.

In the 200-West Area, containment and mass reduction interim actions are underway to limit future degradation of groundwater outside the boundaries of the Central Plateau due to uranium and technetium-99 from 200-UP-1 Operable Unit and from carbon tetrachloride contamination from the 200-ZP-1 Operable Unit. Actions were initiated in these locations due to the elevated concentrations of these contaminants in the groundwater and the massive inventory of these substances that remain unaccounted for in the vadose zone. Future source control measures are some years out, unless funds can be obtained to accelerate these remedies.

For carbon tetrachloride in the 200-ZP-1 Operable Unit, the classical approach to volatile organic remediation has been pursued. Early initiation of soil vapor extraction to recover volatile carbon tetrachloride before it reaches the groundwater started in 1992. Pump-and-treat actions began in the mid-1990s to contain the expansion of the 1 part per million contour of the plume. Follow-on investigations are now under way to determine the nature and extent of contamination and to assess the deep unconfined aquifer for the presence of dense, nonaqueous phase liquids.

Carbon tetrachloride, uranium, and technetium-99 represent the most serious future threat to the degradation of the groundwater resources beneath the Hanford Site. An exit strategy for these contaminants is many years out and at present these plumes are still expanding into uncontaminated portions of the unconfined aquifer making protection of the groundwater resource a difficult challenge.

Based on the presumed remedial actions (see Appendix A and Table A.1), Figures 4.18 to 4.25 present the end-state conceptual site models for each category showing the pathways to receptors being broken.

4.2.2 200 Area Facilities

Canyon Facilities

U Plant. The U Plant is located in the 200-West Area of the Hanford Site. The U Plant is an inactive surplus facility that was constructed in 1944 as one of three chemical separations plants but was never used for its original purpose. In 1952, U Plant was converted to the tributyl phosphate process to recover

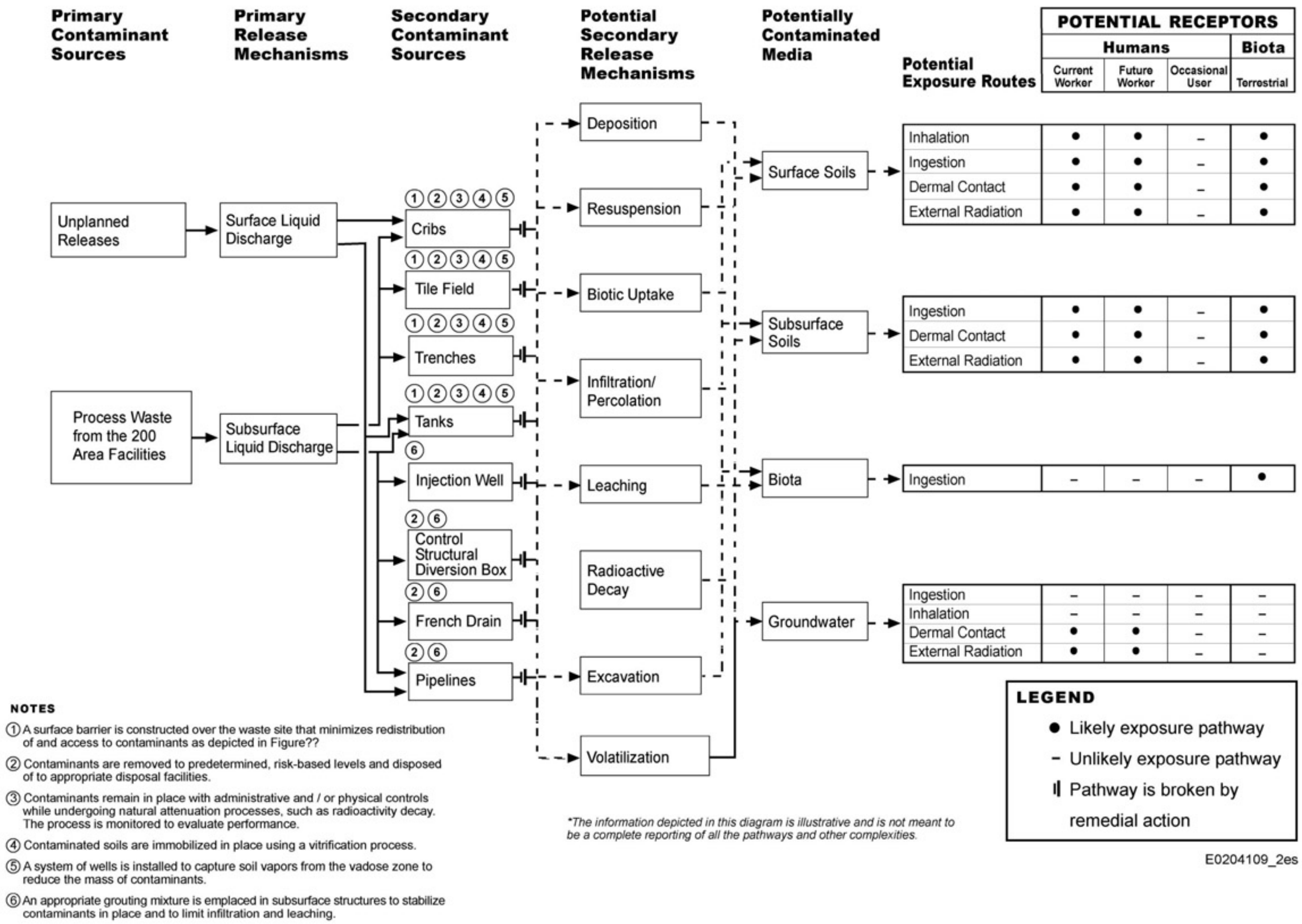


Figure 4.18. Process Condensate and Process Waste Sites, End State

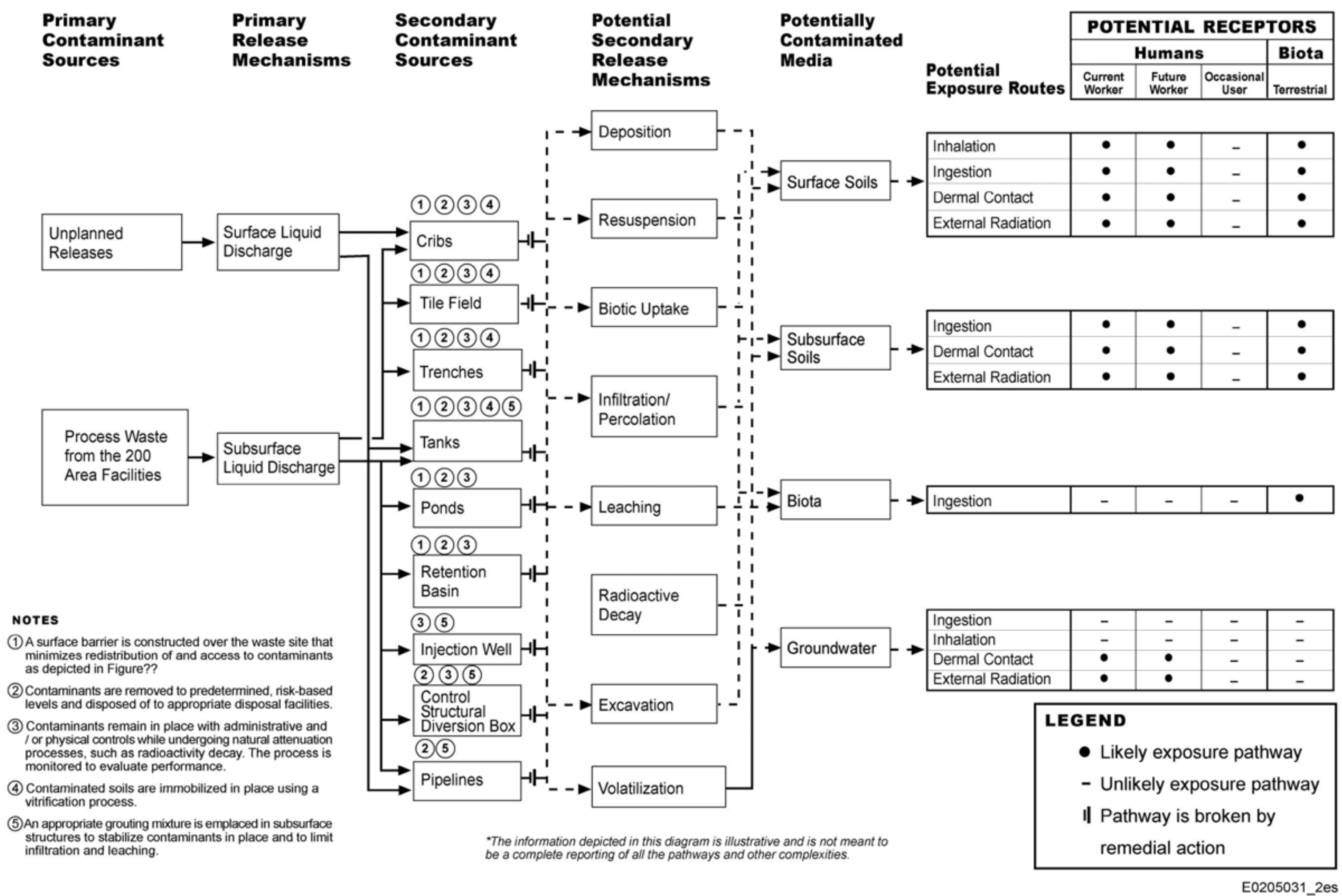


Figure 4.19. Steam Condensate, Cooling Water, and Chemical Sewer Sites, End State

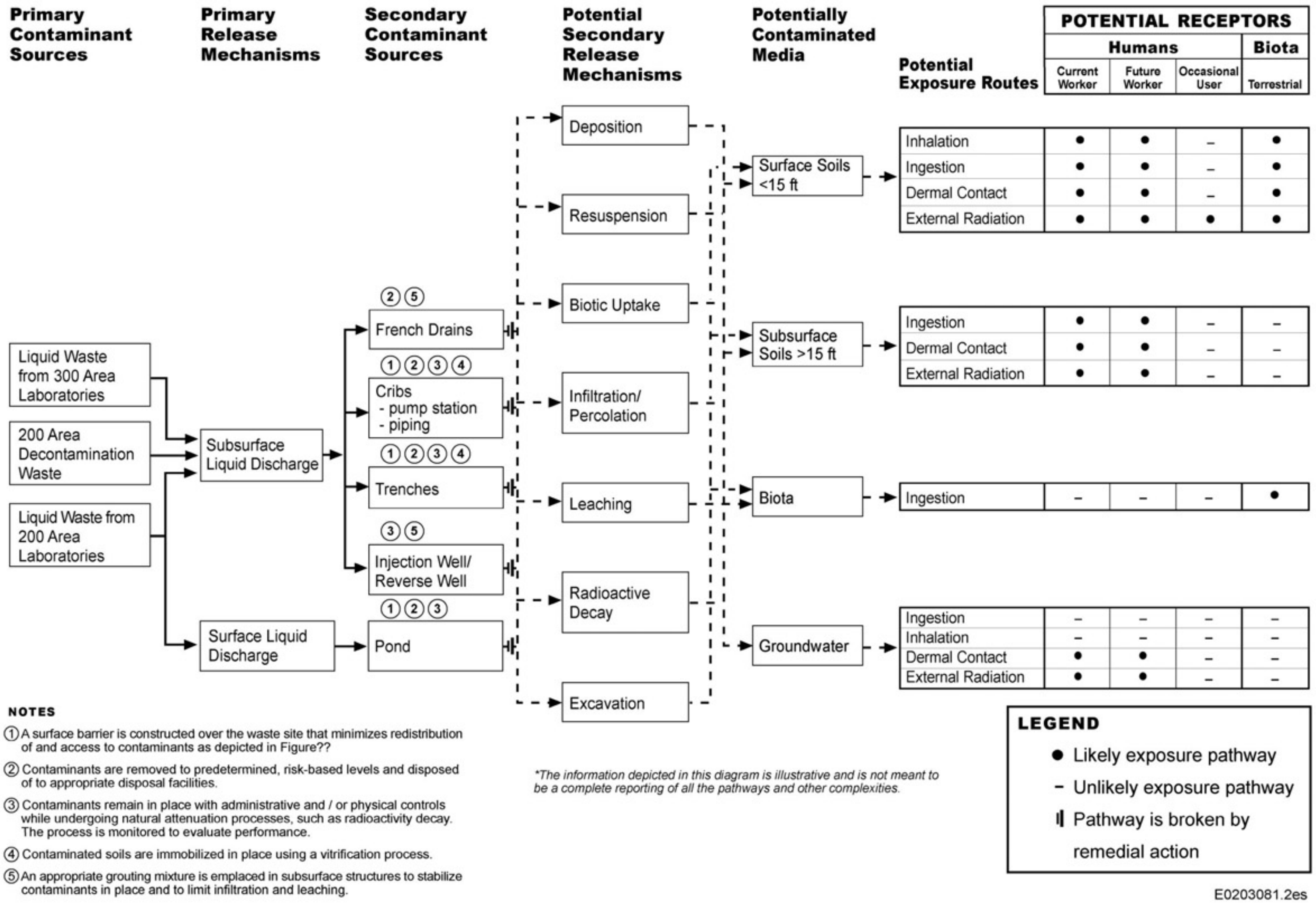


Figure 4.20. Chemical Laboratory Waste Sites, End State

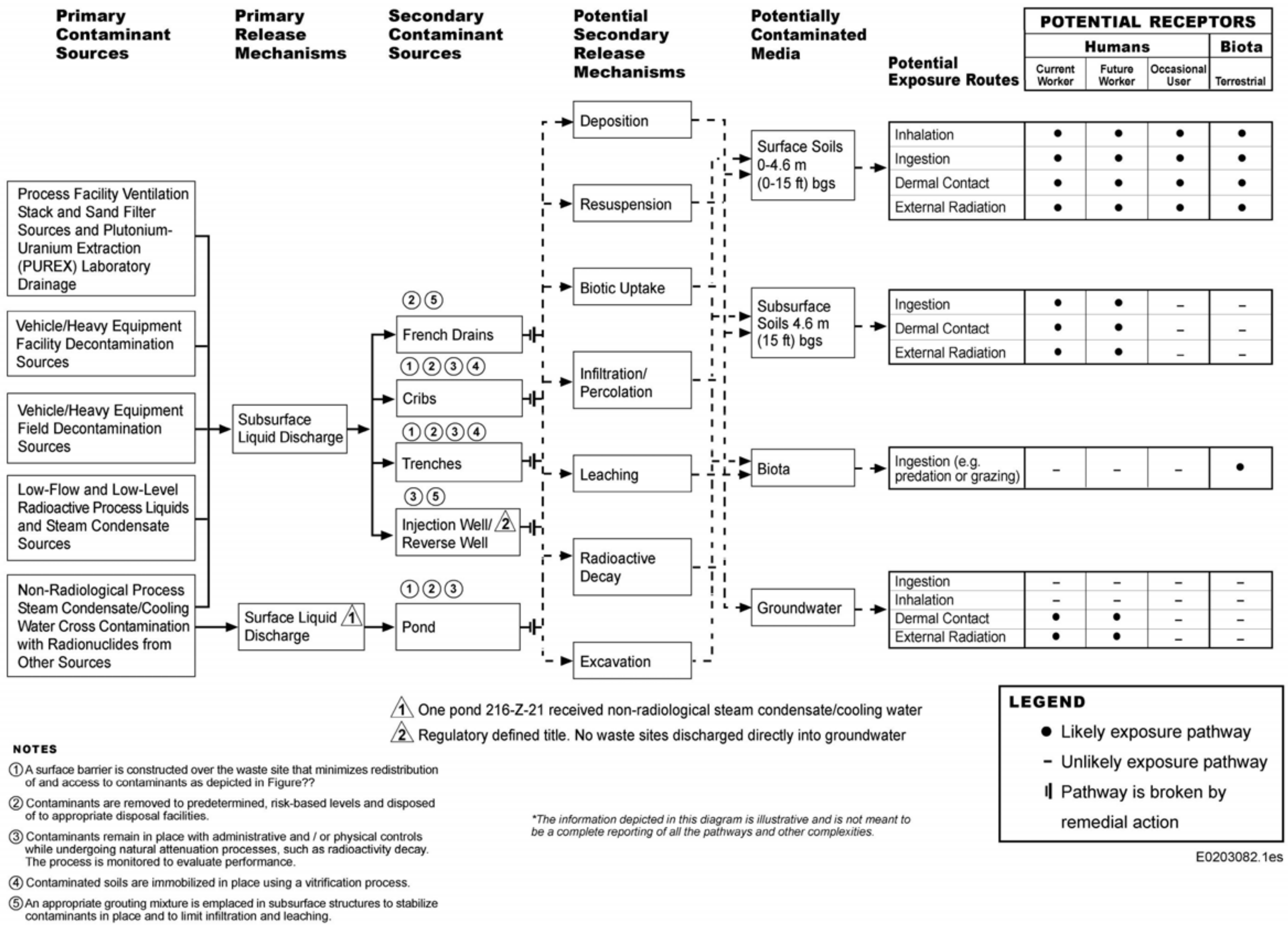


Figure 4.21. Miscellaneous Waste Sites, End State

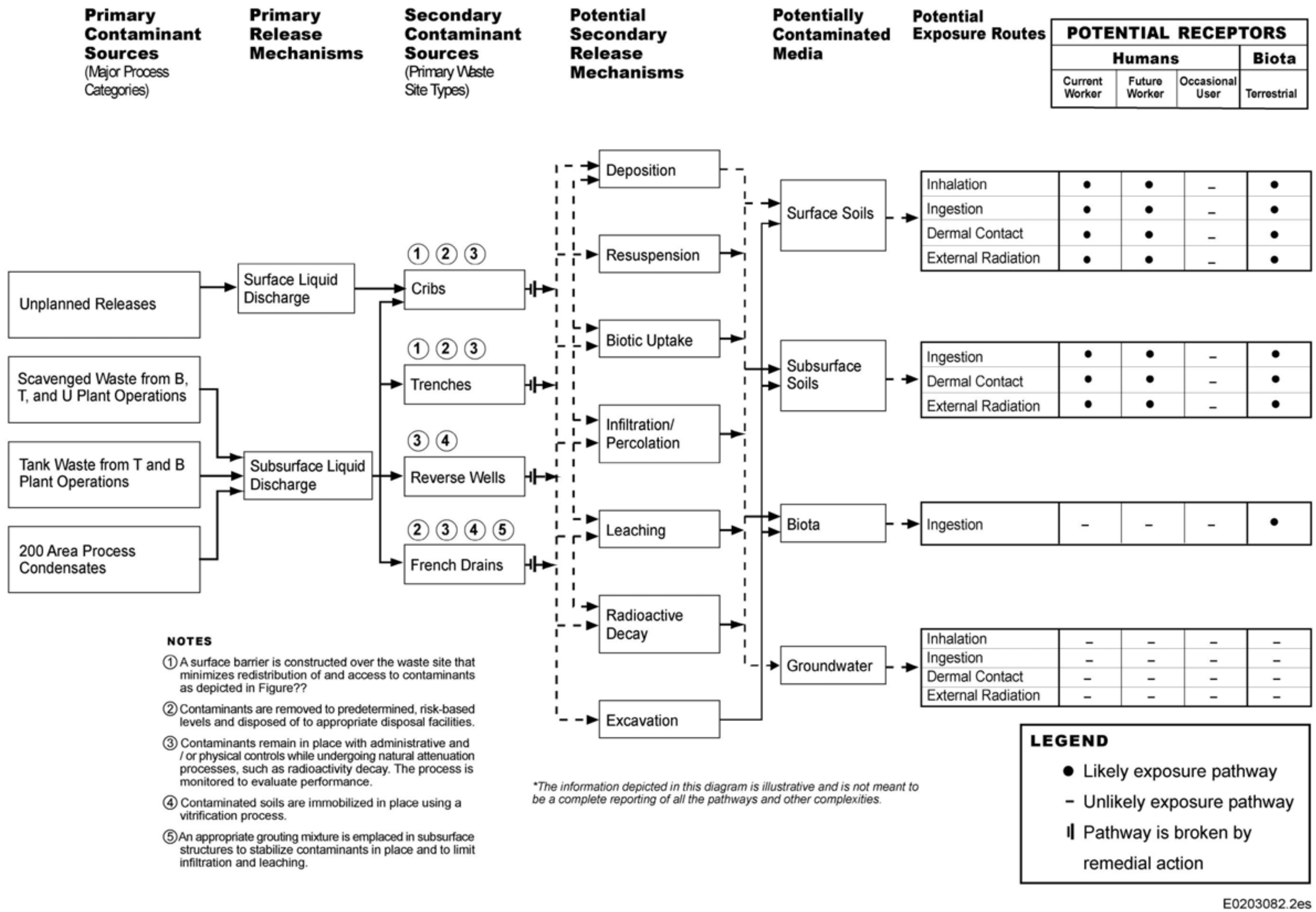


Figure 4.22. Tank and Scavenged Waste Sites, End State

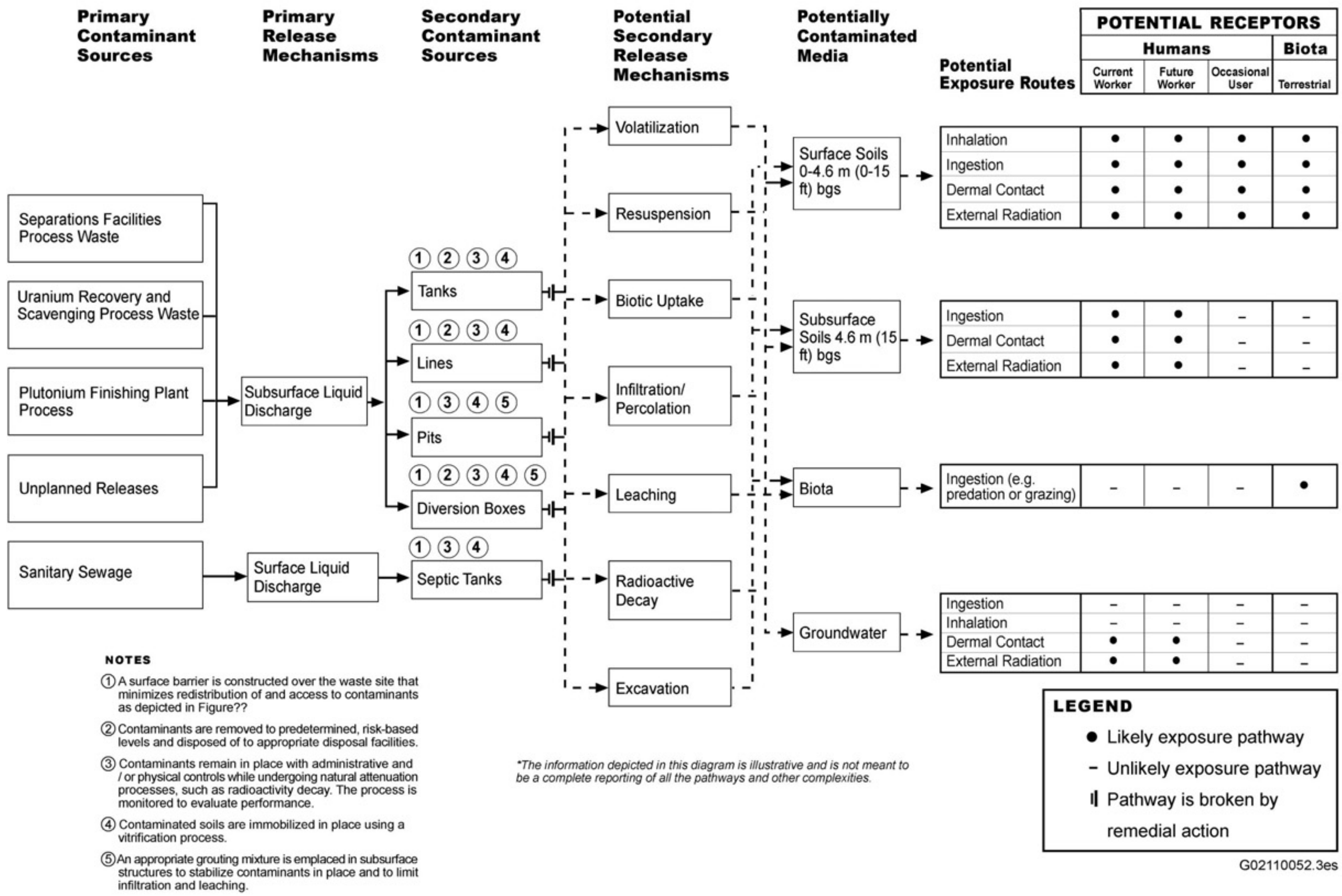


Figure 4.23. Tanks, Lines, Pits, and Boxes, End State

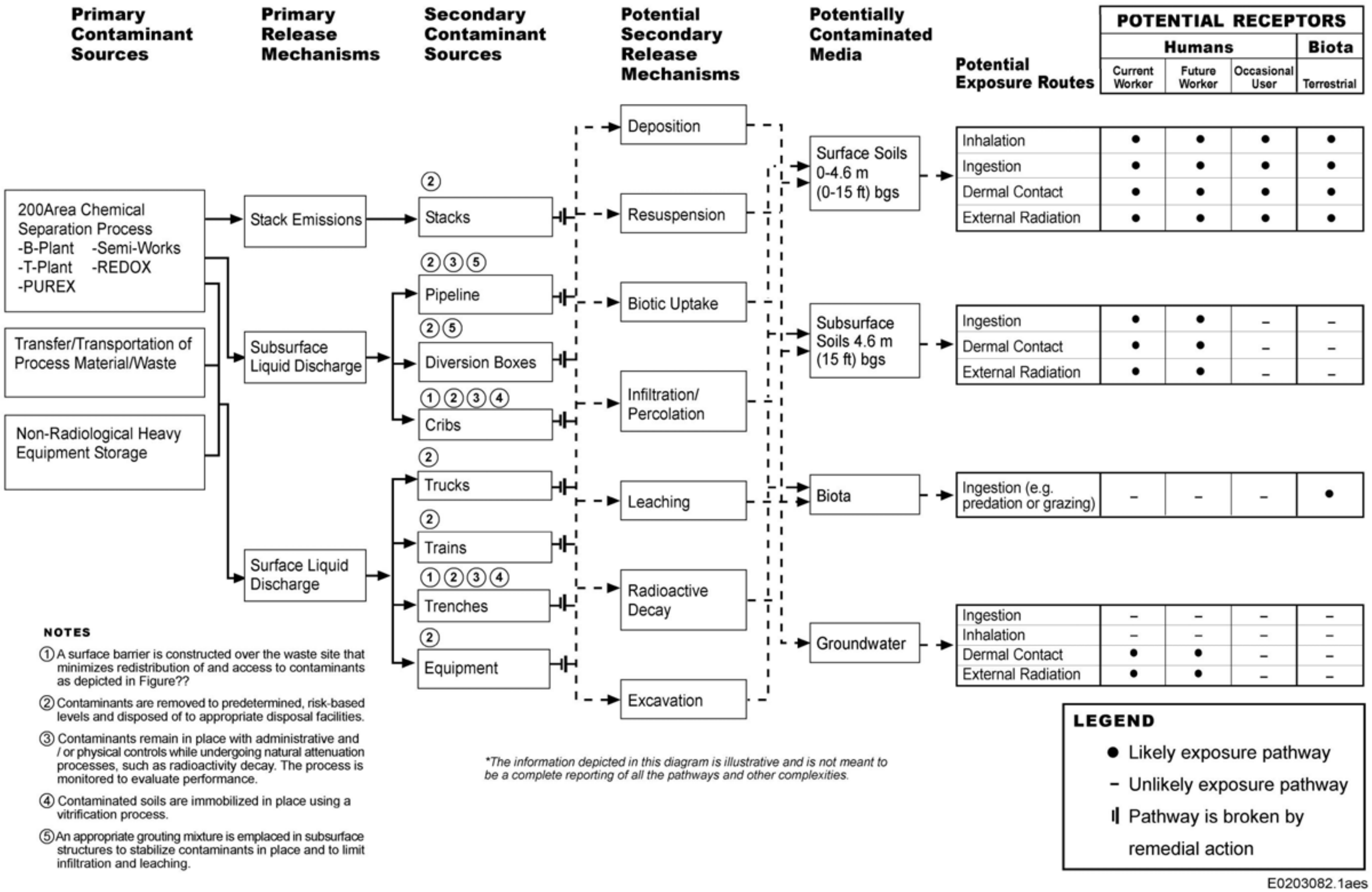


Figure 4.24. Unplanned Releases, End State

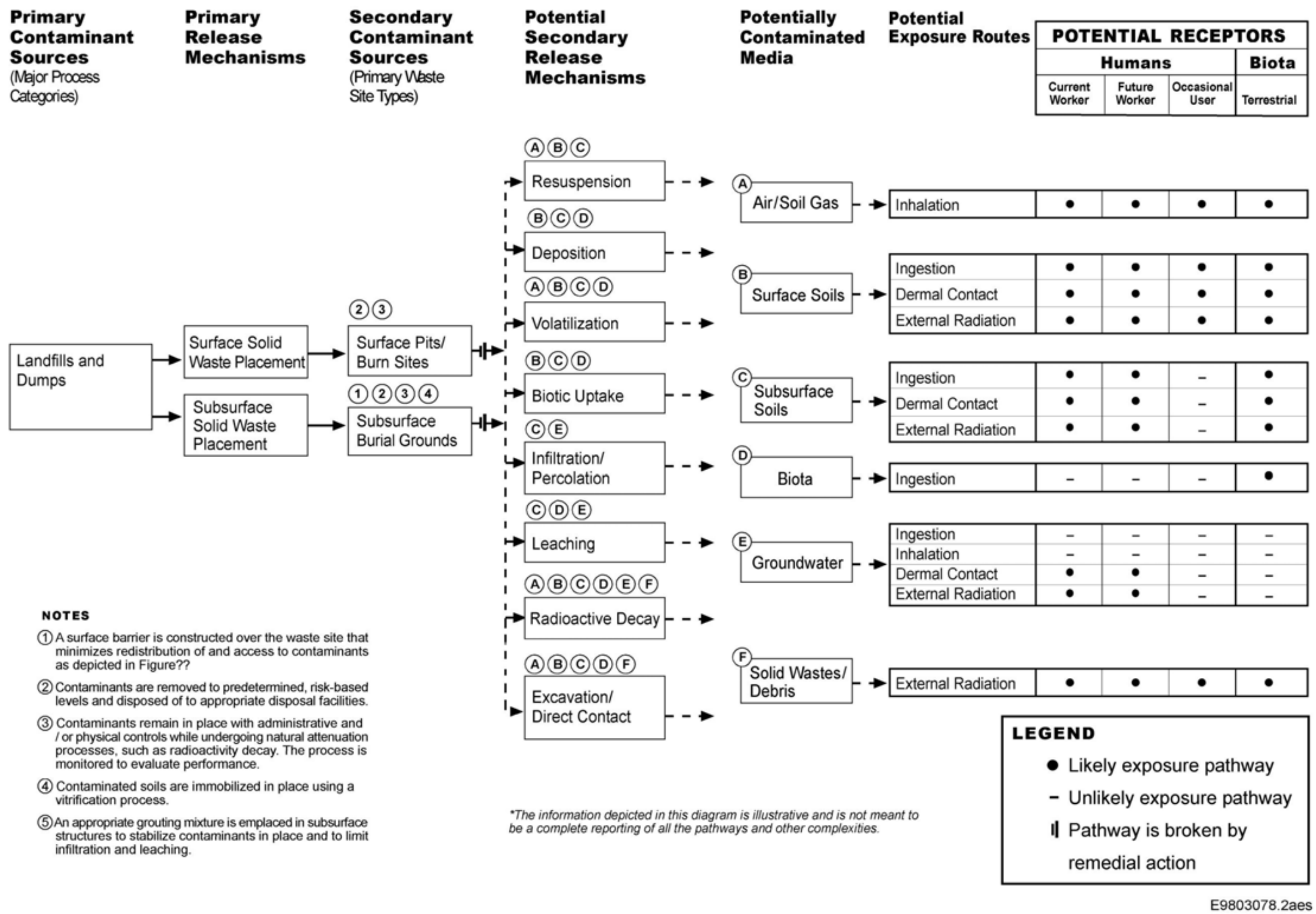


Figure 4.25. Landfills and Dumps, End State

uranium from process waste. In 1958, U Plant was placed in standby mode, and since that time it has been used to store contaminated equipment from other facilities. The surveillance and maintenance operations for U Plant were transferred to Bechtel Hanford, Inc. in July 1994 under the Environmental Restoration Contract to DOE-RL. The surveillance and maintenance operations have focused on ensuring that the building and its equipment are safely stored. In 1997, studies were initiated to select the selected alternative for the ultimate disposition of U Plant (DOE 1997a). Long-term surveillance and maintenance operations were again transferred in July 2002 to Fluor Hanford, Inc.

The UO_3 Facility was used to convert uranyl nitrate hexahydrate solution from the PUREX Plant into a solid uranium oxide powder. The UO_3 Facility's processing schedule was determined by the PUREX uranium inventory buildup. The last operating campaign was completed in June 1993. Deactivation of the facility began as soon as the campaign was finished to prepare for the transfer from the EM-60 program to the EM-40 program. Following deactivation, surveillance and maintenance responsibilities for the UO_3 Facility were transferred from Westinghouse Hanford Company to Bechtel Hanford, Inc. In July 2002, surveillance and maintenance and canyon disposal responsibilities were transferred to Fluor Hanford, Inc.

The purpose of the deactivation project was to establish a passively safe and environmentally secure configuration for the UO_3 Facility and to preserve that configuration for a 10-year time frame. When deactivation was completed, the plant was unoccupied, emptied of portable equipment and furniture, and locked, only to be entered for periodic surveillance or to correct deficiencies identified during the surveillance entries.

The Canyon Disposition Initiative was established to define alternatives for the ultimate disposition of canyon buildings in the 200 Areas, as required by CERCLA. A safety evaluation was performed to identify and analyze the hazards associated with the Canyon Disposition Initiative (BHI 1998a). The Canyon Disposal Project was included within the safety evaluation report, and the justification for interim operation for surveillance and maintenance of the U Plant complex and was approved (DOE 1998b). U Plant was selected as the pilot to initiate the decision process, and characterization work is planned in the 221-U Building.

Continuing characterization and assessment activities under the Canyon Disposal Project (DOE 1997b; BHI 2001a) will reduce the uncertainties regarding residual inventories in key areas of U Plant. Areas of interest include (1) visual inspection and non-destructive characterization of the canyon cells, (2) robotic investigation of selected remote access areas of U Plant (e.g., railroad tunnel, wind tunnel, and canyon drain), (3) various physical samples of structure materials, and (4) physical samples of contaminants related to various building structures and components. Additional data will be gathered or information will be confirmed related to excess equipment currently placed on the deck in an effort to define final disposition of the equipment. The major pieces of equipment are former process components from facilities such as T Plant, B Plant, REDOX, and PUREX that were decontaminated and stored for potential reuse. Other pieces of equipment include shipping containers and structural pieces that were held for potential reuse. Also found on the deck are various containers and aids required for lifts, cleanup, and canyon maintenance activities (BHI 1999a).

The Canyon Disposal Project work control requirements may include the following:

- Restricting access to the U Plant canyon to essential personnel (e.g., crane and health physics personnel) during movement of cover blocks or other heavy lifts
- Operating the 291-U exhaust system during cover block movements
- Prohibiting cover block movement during robotic activities that require isolation of the 291-U exhaust system
- Updating crane operating and maintenance procedures

The U Plant and the UO_3 Facility have been deactivated and are expected to remain in deactivated status until the year 2011 or later. This section defines activities authorized until final disposition of these facilities. In general, there are two broad categories of activities being authorized: (1) specified surveillance and maintenance activities and (2) limited characterization.

Inventory of Radioactive Materials in the U Plant. Table 4.2 depicts the historical radiological inventory data reviewed to define the radiological inventory. The table also shows the source of the data and provides remarks concerning the data. The inventory is based on

- Assumptions made in the calculation of the loading on the 291-U sand filter
- Limited inventory data of the contaminated equipment from other facilities that is staged in the 221-U Building
- Historical data regarding the contamination remaining cells from former process activities

Table 4.2. U Plant Radiological Inventory Data

	Inventory	Source Document	Remarks
Bounding Inventory - 221-U Building	1.0E+05 Ci ^{90}Sr 5.7E+01 Ci ^{239}Pu 1.5E+01 Ci ^{240}Pu 2.6E+01 Ci ^{241}Am	Assumed for this document	The previously approved safety basis provided a bounding estimate of fission products at 10, 015 Ci, conservatively assumed to be ^{90}Sr (inhalation). The evaluations of BHI 2001b provide a bounding estimate for the TRU components.
Bounding Inventory - 291-U Sand Filter	7.9E+02 Ci ^{90}Sr, 6.8E+03 Ci ^{137}Cs, 4.1E+01 Ci ^{239}Pu	BHI 1998b (page 6)	Estimated inventory based on stack emission data and assumed sand filter efficiency of 99.95%. All alpha contamination was assumed to be ^{239}Pu as a worst-case scenario.
Bounding Inventory - 241-WR Vault	60 Ci ^{90}Sr		Inventory is present as contaminated solutions in tanks, cell and cell sumps, and surface contamination. This inventory is determined to be a conservative representation of the residual contamination in 241-WR vault based upon best engineering judgment and past process knowledge.
TRU = Transuranic (waste).			

The predominance of hazardous material is assumed to be residue affixed to the surfaces of the equipment and to the interior of process vessels and piping.

Additional inventory is also added from supplemental characterization results as part of the Canyon Disposal Initiative Project (BHI 2001b). (An unreviewed safety question evaluation concluded there was an increase in the estimated fissionable material in the canyon inventory.)

The inventory for the 291-U sand filter (shown in Table 4.2) is considered in the hazard and accident analyses. This inventory is based on known U Plant stack emissions and a comparison to REDOX Plant stack emissions, as discussed in BHI (1998b).

The inventory for the 241-WR vault is based on a literature review of historical documents pertaining to the vault. An inventory of 60 curies of strontium-90 was assumed based on the review of historical information.

Because the potential exists for release of hazardous or contaminated materials during abnormal conditions, a monitoring program is in place and special instruments are used to monitor for hazardous materials where appropriate. These monitoring practices help operations limit the spread of contamination, thus simplifying future decontamination and decommissioning activities. However, older design methodologies and past practices have resulted in significant contamination spread in some Fluor Hanford, Inc. facilities slated for decontamination and decommissioning.

The facilities and process equipment will be decontaminated and decommissioned in compliance with applicable regulations, when equipment is obsolete or there is no continuing need for the facilities. Decontamination and decommissioning activities will be planned and evaluated to address the decontamination of the buildings and the process equipment required to eliminate the need for active maintenance of the facilities being decommissioned. If any of the Fluor Hanford, Inc. facilities are identified for future use, an appropriate maintenance plan will be instituted.

The Tri-Party Agreement (Ecology et al. 1998) is the result of negotiation among DOE, Ecology, and EPA that defines key project milestones, applicable regulatory compliance methods, and responsibilities for the Hanford cleanup efforts. This is an agreement for achieving compliance with CERCLA remedial action provisions and with RCRA treatment, storage, and disposal unit regulations and corrective action provisions under an agreed upon plan of action between the three affected parties. Decontamination and decommissioning activities will involve highly complex RCRA and CERCLA regulatory issues that will be negotiated under the Tri-Party Agreement. Disposition of U Plant is determined under the Canyon Disposal Project and may be demolished prior to 2011.

The canyon building, 221-U, and the attached administrative building, 271-U, and 276-U will be further characterized, deactivated, and readied for final disposition of the structure. Deactivation activities in the 271-U Building will likely include isolation of the water supply, isolation of drains, relocation of the remote monitoring equipment, and removal of other hazards that are required for the final disposition. Notable deactivation activities for the 221-U Building will likely include grouting of the cell drain header, stabilization of sludge in the 5-6 tank in Cell 10, removal of transuranic material from a tank in Cell 30, decontamination and fixative application, and crane lay-up.

Above grade ancillary structures will be demolished. These facilities are independent segments of U Plant and contain no or only small amounts of radiological contamination. The ancillaries, therefore, are less than nuclear, hazard category 3 facilities.

The following list shows buildings that are included as candidates for demolition:

- 203 U
- 203 UX
- 211 U
- 211 UA
- 222 U
- 224 U
- 224 UA
- 2709 U
- 2714 U
- 2715 U
- 2715 UA
- 2716 U
- 2726 U
- 272 U
- 275 UR
- 276 U

Risk. The U Plant Zone contains sites including single-shell tanks, that are currently under investigation to determine the potential extent of risk to human health and the environment from migration of mobile tank wastes, including technetium-99, tritium, and iodine-129, from past tank leaks and from potential leak losses during retrieval operations. Past discharges to liquid disposal sites within the zone contribute to this risk.

Contamination levels will be reduced consistent with the U Plant zone record of decision. A portion of the U Plant canyon building will be demolished and a barrier that also covers many of the adjacent waste sites will be placed over the canyon. Adjacent structures will be demolished to grade. Final closure will include surface barriers, contaminant removal, chemical fixation, or other appropriate actions protective of human health and the environment. The U Plant zone will be closed by the end of fiscal year 2035. The assumed completion date of key activities include April 2004 – issuance of a U Plant canyon/waste site record of decision; 2006 – completion of pump-and-treat operations; FY 2006 – decontamination and decommissioning of several key adjacent structures; remediation of U Plant; FY 2012 – partial demolition of the U Plant canyon building and installation of a canyon barrier; and 2025 – closure of waste sites.

B Plant. The B Plant complex at the 200-East Area is located in the south-central region of Washington State. B Plant was constructed between 1943 and 1945 to process spent nuclear fuels in support of the Manhattan Project. After its original mission was completed in 1952, the plant was modified between 1961 and 1967 for the recovery, separation, and purification of strontium and cesium contained in the mixed fission product waste stream generated during fuel reprocessing operations. At first, the cesium and strontium products were shipped from B Plant in casks through the 212-B Building for further processing and testing at other facilities. From 1970 through 1973, while the Waste Encapsulation and Storage Facility was being constructed on the west end of B Plant, cesium and strontium were stored in B Plant canyon cells vessels. The recovered, purified, and concentrated strontium and cesium solutions were then transferred to the newly constructed (1974) Waste Encapsulation and Storage Facility for conversion, encapsulation, and storage. The strontium and cesium separation campaigns were conducted at B Plant from 1968 to 1985.

In May 1991, DOE-RL eliminated B Plant from any future processing missions because of difficulties to bring a 46-year-old facility into compliance with current environmental standards. Between 1991 and 1995, B Plant was maintained to ensure safe storage and management of substantial radioactive contamination and residual inventory from past operations, as well as supporting safe storage of approximately 150 megacuries of encapsulated strontium and cesium in Waste Encapsulation and Storage Facility.

In September 1995, DOE directed Fluor Hanford, Inc. to deactivate the B Plant facility, place it in surveillance and maintenance phase, and decouple B Plant from Waste Encapsulation and Storage Facility. The facility will continue its mission of providing safe storage and management of Hanford's strontium and cesium capsule inventory.

Deactivation activities were designed to isolate the facility and prevent contamination migration to the environment. Facility hazards were minimized through the removal, stabilization, disposal, or excessing of major radioactive sources, hazardous materials and waste. Activities included removing stored radioactive and hazardous materials, shutting down all process and support systems (e.g., the electrical power distribution system and heating, ventilation, and air conditioning), and installing operational systems required to support surveillance and maintenance.

Operational installed systems included a new canyon exhaust system, a passive vent system for the retired filters of the old ventilation system, an electrical power and lighting system in the surveillance routes, and a liquid-level detection system in Cell 10 of the 221-B canyon and in the deactivated filter vaults.

An end point criteria process was used for deactivating B Plant. The endpoints are documented in *B Plant End Point Document* (WHC 1996). This method ensured a safe, stable, and environmentally sound facility, suitable for long-term surveillance and maintenance.

B Plant is currently unoccupied and remains locked. Deactivation of B Plant resulted in a vast reduction of the hazards and risks associated with this facility and greatly reduced the costs of surveying and maintaining the facility until the final disposition phase is initiated.

The most significant hazards at B Plant involve the remaining radiological inventory in the canyon building and the retired filters. No significant hazards are associated with chemicals because the liquid chemical inventories have been removed and the dry chemical remaining in the canyon is stable tri-sodium phosphate.

The most significant risks associated with the remaining radiological inventories in the canyon and the retired filters are postulated to be initiated by natural phenomena (e.g., seismic event, ash/snow load causing roof collapse, or stack collapse on the retired filters) and explosion (e.g., hydrogen explosion in the retired filters).

Less consequential hazards resulting in potential releases from the canyon and/or the retired filter vaults were identified. These hazards include impacts to the new canyon exhaust system from missiles or vehicles, the retired filter risers by vehicles and passive vent system, or by fires in or adjacent to the structures.

Aging of the structures by natural phenomena (e.g., rain or freeze/thaw cycles) could cause degradation to the structures that are relied on to contain their radiological inventory. The degradation of structural integrity could eventually lead to release of radiological inventory caused by structural collapse.

PUREX/Tunnels. The PUREX facility was designed and operated to recover plutonium, uranium, and neptunium from irradiated fuel elements received from N Reactor and the single-pass reactors on the Hanford Site. Construction of PUREX began in 1952 and the facility began operating in 1956. The operation was shut down in September 1972. The facility was maintained in wet-standby mode until 1978, with process and support equipment operating on a regular basis. Failed equipment was either upgraded or replaced. From 1978 to 1983, the facility progressed from wet standby through cold start-up tests and resumed operations to recover plutonium from irradiated fuel in November 1983. The PUREX facility was fully operational until 1988 when it was again shut down. The facility began transitioning into a cold-standby mode in October 1990, and was placed in cold standby in September 1992. In December 1992, planning was started to change the status of the PUREX facility from cold-standby mode to deactivation mode (or transition to shutdown). Deactivation was completed in 1998 and the facility has been in surveillance and maintenance mode since that time.

The PUREX facility is composed of the main canyon (202-A) building and several support structures, including two annex buildings (the office annex and the laboratory annex) located on the north side of the canyon. Two below-grade tunnels containing contaminated equipment extend southward from the east end of the 202-A Building. In addition, other facilities (tank farms, cribs, and retention basins) were used to support PUREX during processing operations.

There are currently no operating processes at the PUREX facility, since it is in surveillance and maintenance mode. During the current facility life cycle stage, planned facility activities will consist primarily of surveillance and maintenance and storage of cage processing materials, but will also include limited deactivation activities that are necessary to address identified corrective actions.

Based on the facility inventory and potential energy sources, all three facility segments (202-A Building and exhaust system, Tunnel No. 1, and Tunnel No. 2) are categorized as hazard category 2 nuclear facilities. For criticality, the facility is classified as a limited control facility. This means that greater than one-third of a minimum critical mass is present and criticality is not a credible scenario.

Since the facility was placed into the surveillance and maintenance mode, a new roof (FHI 2002b) was placed over the 202-A canyon and aqueous makeup areas. Conditions in the facility have been relatively stabile since deactivation. Minor exceptions include roof leaks, which have been resolved with the installation of the new roof. Other changes that have been observed include residual chemical leaks and contamination in the aqueous makeup areas (BHI 2001c), radiological contamination changes in the laboratory and piping and operating area (BHI 2001d), and changing radiological conditions in the craneway elevations (BHI 2001e). While none of the contamination issues resulted in an unreviewed safety question, they warrant continued surveillance to ensure that safe working conditions are maintained.

Summary of Remaining PUREX/Tunnels Inventory. The PUREX deactivation project removed, reduced, or stabilized the major radioactive sources and waste within the PUREX facility. Radiological contamination throughout PUREX consists of uranium, plutonium, and other transuranics, and/or mixed fission products. The radioactive material inventory remaining at the end of deactivation is primarily in the form of contaminated equipment and surfaces, dust and debris, with some remaining plutonium and oxide dust stabilized in gloveboxes. The PUREX facility and tunnels are identified as limited control facilities for criticality.

Hazardous materials that remain are a relatively minor risk, as there are no substantial volatiles, caustics, or reactives remaining. Former process solution and stocks were removed as part of deactivation. Only residual quantities remain in the tank, vessels, and piping system that were pumped, emptied, and/or flushed. A summary of the remaining inventory of hazardous materials is provided in Appendix C, Table C-23, in FHI (2003).

202-A Building Inventory. As part of the hazards assessment and categorization process, an estimate of the total remaining radioactive material within the PUREX facility was performed. This estimate was based on the best available data, process knowledge, and experience. The high-end estimates are considered conservative and bounding, based on the data available.

Five areas within the 202-A Building, other than the canyon, were identified as containing significant quantities of plutonium: L-cell, which is estimated to contain between 3 and 4 kilograms (6.6 to 8.8 pounds) plutonium in stable, immobile material on the floor; deep-bed Filters No. 1 and No. 2, each containing 100 to 200 grams (0.22 to 0.44 pounds) of plutonium; N-cell/product removal room, which contains 2 to 3 kilograms (4.4 to 6.6 pounds) of plutonium material in gloveboxes; the E-cell skip, which contains approximately 400 grams (0.88 pounds) of plutonium; and the white room, with 50 to 500 grams (0.11 to 1.1 pounds) of plutonium. Table 4.3 provides a summary of the 202-A Building inventory as measured and estimated during the PUREX deactivation project.

Table 4.3. Summary Inventory for the PUREX Facility

Material	202-A Building[(a)]	Tunnel No. 1[(b)]	Tunnel No. 2[(b)]
Total Plutonium	14,000	5,000	5,500
Americium-241	350	130	98
Cesium-137	130	120	3,800
Strontium-90	70	60	1,300

(a) Including ventilation system.
(b) Grams to 2 significant figures.

The canyon estimated inventory identified in Table 4.3 is assumed to include any surface contamination. In the final hazard category determination and the consequence analysis, it is necessary to identify the appropriate isotopic distribution of the plutonium. The isotopic distribution and inventory including all key isotopes for consequence analysis is presented in Appendix C. Table 4.4 presents a summary of the 202-A Building inventory for the isotopes of concern. This inventory includes the ventilation system inventory.

PUREX Tunnels Inventory. The inventory for PUREX Tunnels No. 1 and No. 2 was developed in Appendix B of *Plutonium-Uranium Extraction (PUREX) Facility Storage Tunnel Hazard Analysis* (B&W 1996). The inventory was developed based on a review of the data regarding the curies estimated for the PUREX equipment storage locations. In B&W (1996), process knowledge of the PUREX process was used to identify the isotopic distribution of the estimated inventory from the PUREX equipment. This isotopic distribution adjusted for decay is used for the hazard categorization and consequence analysis.

Table 4.4. 202-A Building Inventory

Isotopes	Total Inventory (g)	Total Inventory (Ci)
Plutonium-238	1.01E+01	1.73E+02
Plutonium-239	1.20E+04	7.44E+02
Plutonium-240	1.89E+03	4.31E+02
Plutonium-241	6.60E+01	6.80E+03
Plutonium-242	3.94+01	1.55E-01
Americium-241	3.50E+02	1.20E+03
Strontium-90	6.55E+01	8.94E+03
Yittrium-90	1.64E-02	8.94E+03
Cesium-137	1.26E+02	1.10E+04
Total	**1.45E+04**	**3.82E+04**

Additionally, during the PUREX deactivation project some material from the 324 facility was placed in Tunnel No. 2. Appendix B of *PUREX Deactivated End-State Hazard Analysis* (FHI 1999) presents the inventory and description of the 324 Building waste added to Tunnel No. 2. The only dispersible material in this waste is the two items of remote-handled mixed waste from 324 Building B-cell. This material is described as dispersible debris and dried melter feed. The remaining 324 waste material is glass canisters and storage cans and is identified in Appendix B of FHI (1999). For evaluation of the final hazard categorization for the PUREX facility, the inventory of these dispersible items is included in the Tunnel No. 2 inventory. Only transuranic isotopes and the dominant fission product isotopes (strontium-90, yittrium-90, cesium-137) were included in the inventory. These isotopes are the major contributors to dose, with the other isotopes estimated to result in an increase of less than 1% in the total dose. A summary of the total dispersible inventory of the tunnels used for the hazard category determination and the consequence analysis is presented in Table 4.5.

Table 4.5. PUREX Tunnels Isotopic Inventory

Inventory	Tunnel No. 1 (g)	Tunnel No. 2 (g)
Plutonium-238	3.46E+00	4.52E+00
Plutonium-239	4.26E+03	4.71E+03
Plutonium-240	6.67E+02	7.37E+02
Plutonium-241	1.92E+01	6.42E+01
Plutonium-242	1.39E+01	1.53E+01
Americium-241	1.29E+02	9.75E+01
Strontium-90	5.99E+01	1.25E+03
Yittrium-90	1.50E-02	3.13E-01
Cesium-137	1.16E+02	3.79E+03

The increase in americium-241 within the PUREX facility will continue through the year 2040 and result in an increase in the dose consequences presented here of slightly less than 10%. After 2040, the dose consequences will decrease.

The PUREX zone contains sites, including single-shell tanks that are currently under investigation to determine the potential extent of risk to human health and the environment from migration of mobile tank wastes including technetium-99, tritium, and iodine-129, from past tank leaks and from potential leak losses during retrieval operations. The PUREX zone waste sites have the potential to release additional iodine-129 and tritium at concentrations requiring active groundwater remediation. The PUREX cribs and trenches are in need of remediation to limit infiltration and slow the migration of contaminants in the vadose zone. As described earlier, the PUREX building equipment and vessels present a significant radiological inventory. The PUREX zone is slated to be closed by the end of FY 2025. The completion dates of key activities include: 2010 – PUREX cribs and trenches are scheduled for remediation; and FY 2017 – remediation of PUREX, partial demolition of the canyon building, and installation of a canyon barrier.

REDOX Facility. The REDOX facility is located in the 200-West Area of the Hanford Site. The facility is composed of deactivated buildings and associated process equipment used for dissolution and separation of uranium, neptunium, and plutonium, as well as deactivated equipment formerly used for waste concentration, waste neutralization, and solvent recovery. In addition to the main processing building (i.e., the 202-S canyon building), the REDOX facility includes buildings formerly used for the storage of chemicals and materials, and support systems (e.g., ventilation).

The REDOX facility was the first large-scale, continuous-flow, solvent- extraction process plant built in the United States for the recovery of plutonium from irradiated uranium fuel. Operations began in 1952 and continued until the facility was shut down in 1967. Deactivation started in 1967 and was completed in 1969. Since deactivation, surveillance and maintenance operations have been performed at the facility. The conduct of surveillance and maintenance activities constitutes the current facility mission.

The 202-S canyon building is a reinforced concrete structure housing nine process cells and supporting operating, piping, and sample galleries, and a tower process area (referred to as the silo). The process cells (e.g., dissolver cell A, south extraction cell F) contain deactivated processing equipment. The silo contains deactivated solvent-extraction columns. The 202-S canyon building is serviced by the 291-S exhaust ventilation system. Exhaust air passes through a sand filter prior to discharge to the environment.

The REDOX facility consists of a former fuel processing facility (i.e., the 202-S canyon building) and ancillary support structures. Planned activities include continued surveillance and maintenance of the facilities to ensure that the residual contaminants are properly confined or disposed. Limited deactivation activities may be performed should deterioration, degradation lead to risk reduction actions. There are no process operation remaining in the REDOX facility.

The REDOX facility has been determined to be a hazard category 2 facility, based on (1) the sum-of-ratios approach prescribed in DOE (1997a). The facility segments that comprise the nuclear categorization include the 202-S canyon, the 291-S exhaust system (including the wind tunnel, exhaust fan equipment, and stack) and the 292-S Building (condensate collection for the exhaust system). Buildings that may be used to stage waste containers (e.g., burial boxes and drummed waste) are also considered to be nuclear based on the need to stage waste for disposal. These include the 2715-S Building, the loading dock on the west end of the 202-S Building, and various external locations within the fenced area about REDOX. Other buildings of the REDOX facility may contain radiological contamination; however, the quantities are negligible to minor.

Barriers and postings are used to prevent unwarranted access to hazardous areas and to inform personnel of conditions that exist at the REDOX facility. Examples include locks and tags, door locks, fencing, confined space postings, and radiological area postings. Installation and inspection of barriers and postings is conducted as part of the surveillance and maintenance activities, as specified in work instructions. Any discrepant conditions regarding barriers or postings are identified on associated data/ inspection sheets.

Inventories of hazardous substances, radiological material and hazardous materials, were removed as part of the deactivation efforts. The remaining materials consists of residual contaminations that remain after flushing, draining and other inventory reduction activities, and contamination that remains in the exhaust system (primarily in the sand filter). No process material or chemical stocks remain. The only chemicals that are introduced are thus associated with decontamination, stabilization and pest control.

The majority of the radiological inventory at the REDOX facility is located in the 202-S Building and 291-S exhaust system sand filter. Relatively minor quantities exist in other buildings, typically as residues or surface contamination. Table 4.6 presents the inventories for the 202-S canyon building and sand filter. The values in the table below are based on the best available data. For radiological consequence calculation purposes, the alpha activity is assumed to be plutonium-239, and the beta activity is assumed to be strontium-90. These assumptions are conservative in that plutonium-239 and strontium-90 have the largest dose conversion factors of those radionuclides potentially present in significant quantities.

Table 4.6. REDOX Facility Radiological Inventory

Facility	Inventory/Location	Source Document	Remarks
202-S Canyon Building, silo, railroad tunnel and process cells, piping, and equipment	1,500 Ci alpha (24,500 g of ^{239}Pu) 9,000 Ci beta (64 g of ^{90}Sr) Assumed distributed about the facility.	RHO (1982)	Based on historical published data, the basis of which is unknown. Estimated that greater than 99% of the inventory is located in the process cells, piping, and equipment (see Section 3.4.2.1.2). Assumption is that all alpha is $^{239/240}$Pu and all beta is ^{90}Sr.
202-S north sample gallery	140 Ci of ^{239}Pu (2,155 g ^{239}Pu) 840 Ci of ^{90}Sr (6.0 g of ^{90}Sr)	BHI (1997a)	
291-S sand filter	340 Ci alpha (5,600 g of ^{239}Pu) 8,000 Ci beta (57 g of ^{90}Sr)	BHI (1998b)	Estimated inventory based on stack emission data and assumed sand filter efficiency of 99.95%.

Within the EF-4 tank and the E4-L2 transfer line, a higher concentration of neptunium-237 may exist because a special neptunium-237 recovery campaign was performed. The actual concentration of neptunium-237 is unknown; however, isotopic analyses for the 233-S Building process vessels show neptunium-237 to be approximately 4%, which may be taken as the upper concentration limit. In addition, D cell was used as late as 1982 for transferring radioactive liquid waste from the 222-S Laboratory to the tank farms. This transfer operation would tend to dilute residuals within the process vessels. For the neptunium-237 to be a bioassay concern, the plutonium-239 to neptunium-237 ratio must be greater than 6 to 1; therefore, the neptunium-237 is assumed to be plutonium-239.

In general, detailed radionuclide characterization data (i.e., form, quantity, and location) for the 202-S Building do not exist. The values listed in Table 4.6 are based on best available information. Recent surveys (BHI 1997a) have identified significant accumulations of residual materials in the north sample gallery, located primarily in product removal cage processing equipment. Evaluation (BHI 2000) of characterization (BHI 1999b) of the product removal cage confirmed the plutonium inventory estimates presented in BHI (1997a) and showed that nearly all of the inventory is contained within the processing equipment. BHI (1999b) also confirmed earlier indications (BHI 1997a) that americium-241 and neptunium-237 are present in the product removal cage. Evaluation of the sample data and other technical references (BHI 2000) indicates that the residual waste in the vessels and piping of the product removal cage is likely to have an activity ratio of approximately 3 to 1 for plutonium-239/240 to americium-241.

The summary of fissionable material listed in Tables 4.7 is based on limited features of the product removal cage; however, the likelihood that other vessels and piping associated with the product removal cage contain significant fissionable inventories is low. Because of the extensive chemical cleaning of the process vessels and piping followed by weekly flushing with water (Foster 1977), the radioactive material remaining in these confinement systems are likely encrusted and fixed to the internal surfaces and not easily dislodged. The balance of the radioactive material is assumed to be loose surface contamination distributed throughout the structure.

The total alpha radiation released for the 291-S-1 stack in 1980 was a factor of 20 greater than the total release for any subsequent year. The total alpha released is likely to have included large contributions from short-lived radon daughters. The bounding doses reported in Table 4.7 for each of the stacks are likely to be a factor of 10 to 1,000 larger than what would be estimated from more recent emissions data.

The REDOX zone contains sites, including single-shell tanks, which are currently under investigation to determine the potential extent of the risk to human health and the environment. The REDOX zone will be closed by the end of fiscal year 2035. The assumed completion dates of key activities include: 2004 – deactivation and decommissioning of the 233-S plutonium concentration facility; and FY 2033 – the 222-S Laboratory will be closed.

Non-Canyon Facilities

231-Z Building. The 231-Z Building is located in the 200-West Area of the Hanford Site, about 183 meters (600 feet) north of the Plutonium Finishing Plant (234-5 Building). The 231-Z Building was constructed in 1944 and was originally designated the 231-Z Isolation Building, housing the final step of the plutonium extraction process that began at T Plant on the Hanford Site. Its original purpose was the

Table 4.7. Summation of REDOX Stack Releases

Stack 296-S-2, HEPA Filter Year of the Largest Release: 1981			
Original Annual Release		Decontamination Factor of 3,000	
Alpha (Ci)	Beta (Ci)	Alpha (Ci)	Beta (Ci)
5 E-07	5 E-06	1.5 E-03	1.5 E-02
Stack 296-S-4 (Deactivated), HEPA Filter Year of Largest Release: 1980			
2 E-06	2 E-05	6 E-03	6 E-02
Stack 296-S-6 (Deactivated), HEPA Filter Year of Largest Release: 1980			
7 E-06	8 E-05	2.1 E-02	2.4 E-01
Stack 291-S-1, Sand Filter Year of Largest Release: 1980			
Original Annual Release		Decontamination Factor of 2,000	
Alpha (Ci)	Beta (Ci)	Alpha (Ci)	Beta (Ci)
2 E-05	4 E-04	0.04	0.8
Total Release		Decontamination Factor of 2,000	
		Alpha (Ci)	Beta (Ci)
		0.069	1.12
HEPA = High-efficiency particulate air. Source: Adam (1995).			

purification and drying of the plutonium nitrate solution produced at the 224-T Bulk Reduction Building. It operated in this capacity from 1945 until 1957, when the function of the building shifted to plutonium metallurgy. Plutonium metallurgical research, fabrication development, and metallurgy work for weapons development was carried out until 1975. At that time, weapons design work was phased out. During the years of 1978 to 1982, a cleanup effort of gloveboxes and equipment was undertaken. In 1982, a soils and sedimentation characterization laboratory was established in the building. Experiments in the characterization of contaminated crib soils were conducted during the 1980s.

The 231-Z Building was originally a two-story, flat-roofed, reinforced concrete frame building. The overall dimensions were approximately 44.8 meters (147 feet) long by 57.9 meters (190 feet) wide by 7.5 meters (24.5 feet) tall, with a total floor area of approximately 2,601 square meters (28,000 square feet). In the 1960s, a one-story 316-square-meter (3,400-square-foot) office wing was added on the south side and below-grade piping was modified to connect the 231-Z Building to waste disposal crib (216-Z-16). In the 1970s, a waste crib (216-Z-19) was added, a 344-square-meter (3,700-square-foot) one-story concrete block addition was placed on the north side of the building, and a second 297-square meter (3,200-square foot) one-story addition was completed on the south side. Active utilities include building electrical and sanitary water service. There is an active fire detection and fire suppression (automated sprinkler) system.

There are currently no operating processes at the 231-Z Building, since it is in shutdown mode. During the current facility life cycle stage, planned facility activities will consist primarily of surveillance and maintenance and storage of incidental cage processing supplies and materials related to surveillance and maintenance activities, but will also include limited deactivation activities that are necessary to address identified corrective actions. Active facility systems are limited to the fire suppression system and general utilities.

Table 4.8 presents the radiological inventory as identified by the nondestructive assay performed by Pacific Northwest National Laboratory.[1] Only the data associated with plutonium and americium holdup are presented here and used to determine the dose consequences. This is appropriate since the quantities of other isotopes are negligible. The letter report[1] provided gram quantity estimates for plutonium-239 and americium-241 for most locations in the 231-Z Building, based on high-resolution gamma spectroscopy with a high-purity germanium detector. For some locations, only americium-241 was detected.

Table 4.8. 231-Z Building Inventory Mass by Location

Location	^{238}Pu (g)	^{239}Pu (g)	^{240}Pu (g)	^{241}Pu (g)	^{242}Pu (g)	^{241}Am (g)
Room 46	4.41E-03	2.98E+01	1.94E+00	1.14E-02	9.57E-03	2.45E+00
Cell 1	8.02E-05	5.42E-01	3.53E-02	2.07E-04	1.74E-04	2.67E-02
Cell 2	3.96E-07	2.67E-03	1.74E-04	1.02E-06	8.59E-07	1.57E-06
Cell 3	5.56E-03	3.76E+01	2.45E+00	1.44E-02	1.21E-02	2.08E-01
Cell 4	4.29E-05	2.90E-01	1.89E-02	1.11E-04	9.32E-05	2.20E-03
Cell 5	1.91E-03	1.29E+01	8.38E-01	4.92E-03	4.14E-03	3.35E-02
Cell 6A	1.92E-04	1.30E+00	8.45E-02	4.96E-04	4.17E-04	7.62E-04
Cell 6B	7.72E-04	5.22E+00	3.40E-01	1.99E-03	1.68E-03	1.53E-02
E-4 Exhaust	2.59E-03	1.75E+01	1.14E+00	6.70E-03	5.63E-03	2.26E-02
Totals	**1.56E-02**	**1.05E+02**	**6.85E+00**	**4.02E-02**	**3.38E-02**	**2.76E+00**

The total plutonium mass and the breakdown by plutonium isotope can be obtained from the measured plutonium-239 mass if the isotopic composition of the plutonium is known. Based on process knowledge of the 231-Z Building, the plutonium processed there would have been weapons grade and would have had the following isotopic composition at 180 days after discharge from the reactor:

- Plutonium-238: 0.02%
- Plutonium-239: 93.5%
- Plutonium-240: 6.1%
- Plutonium-241: 0.34%
- Plutonium-242: 0.03%.

[1] Letter from G. Mapili (Pacific Northwest National Laboratory) to JE Ham (Fluor Hanford, Inc.), *NDA Summary Report*, dated December 5, 2002.

Assuming the last plutonium processing was done in March 1956, and by decaying the plutonium isotopes over the intervening 46.8 years, the following corrected isotopic compositions are calculated:

- Plutonium-238: 0.014%
- Plutonium-239: 93.8%
- Plutonium-240: 6.11%
- Plutonium-241: 0.036%
- Plutonium-242: 0.03%.

Therefore, the current total mass of plutonium is the measured plutonium-239 mass divided by the corrected isotopic mass fraction for plutonium-239. The current mass of each plutonium isotope is given by the current total plutonium mass multiplied by the respective corrected isotope fractions. This method was used to determine the isotopic distribution presented.

Additionally, for those locations where americium-241 was detected but no plutonium-239 was evident, a conservative approach was taken. Plutonium-239 was assumed to be present but not detected. The assumed plutonium-239 concentration was calculated by multiplying the measured americium-241 concentration by the largest measured value of the plutonium-239/americium-241 activity ratio found anywhere else in the facility. From the data in the letter report,[1] the maximum ratio of 30.787 was measured in the E-4 exhaust at location 80.

There are no significant quantities of non-radiological hazardous materials remaining in the building. Small quantities of decontamination agents may be used in the surveillance and maintenance activities. Residual processing agents are anticipated in the former process areas.

The closure of 231-Z is an assumption related to the Plutonium Finishing Plant zone closure, with the estimated date of closure to be by 2018.

224-B Building. The 224-B Building was originally operated as a plutonium concentration facility for B Plant from 1945 until 1976. It is presently designated as an inactive, surplus facility awaiting final disposition and has been in surveillance and maintenance mode since 1992. The building is a deactivated plutonium concentration facility that was formerly associated with the B Plant complex. The B Plant complex is located in the northwest quadrant of the 200-East Area of the Hanford Site. The 224-B Building is located south of the 221-B canyon building and west of the 222-B laboratory.

The 224-B Building was used to purify and concentrate diluted plutonium nitrate solution that was the product of the 221-B (B Plant) bismuth-phosphate process. The solution was then shipped to the 231-Z Isolation Building in the 200-West Area of the Hanford Site. Plutonium concentration operations were performed in conjunction with B Plant separations activities from approximately 1944 to 1952. The building's process components were deactivated shortly thereafter. Subsequent to the deactivation, occupancy of the building included plant support and plant forces personnel, pipe fabrication activities, and decommissioning staff. The decommissioning staff that was preparing to start decommissioning in the mid-1980s was the buildings last occupant. The decommissioning staff moved out later in the 1980s, following the deferment of the decommissioning project.

[1] Letter from G. Mapili (Pacific Northwest National Laboratory) to JE Ham (Fluor Hanford, Inc.), *NDA Summary Report*, dated December 5, 2002.

The 224-B Building is a single canyon-type building containing six process cells and an associated operating gallery, offices, and support areas. Cell C was the receiving cell for product solutions from the 221-B Building and waste generated within the 224-B Building. Chemical processing of the crude product was performed in Cells A, D, and E. The B cell was initially a standby cell but was also used to augment operations in D cell. The F cell was the final concentration area. At one time, there were plans to convert the west half of F cell into a process area designated as G cell; however, this modification was never implemented. The area north of F cell is known as the load-out area (Table 4.9).

Table 4.9. Total 224-B Transuranic Inventory[(a)]

Location	^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu	^{242}Pu	^{241}Am
Cell A	2.89E-03	1.75E+01	1.14E+00	1.30E-02	5.62E-03	5.07E-02
Cell B	4.25E-03	2.57E+01	1.68E+00	1.91E-02	8.27E-03	7.46E-02
Cell C	9.81E-03	5.94E+01	3.87E+00	4.42E-02	1.91E-02	1.72E-01
Cell D	4.11E-03	2.49E+01	1.63E+00	1.85E-02	8.01E-03	7.23E-02
D-3	1.01E-01	6.10E+02	3.98E+01	4.54E-01	1.96E-01	1.77E+00
Cell E	3.27E-03	1.98E+01	1.29E+00	1.47E-02	6.36E-03	5.74E-02
Cell F	6.40E-02	3.88E+02	2.53E+01	2.89E-01	1.25E-01	1.13E+00
Totals	**1.89E-01**	**1.15E+03**	**7.47E+01**	**8.52E-01**	**3.68E-01**	**3.32E+00**
(a) In grams.						

The purpose of the surveillance and maintenance phase includes the following:

- Maintain confinement of residual inventories of radioactive materials and other contaminants until the facility is ultimately dispositioned
- Prevent deterioration of confinement structures
- Respond to potential accident conditions requiring response and mitigation
- Provide for the safety of workers involved in the surveillance and maintenance phase
- Provide the basis for evaluation and selection of ultimate disposal alternatives

Residual radionuclides are located in all process cells, the majority of which are found in D and F cells. Only relatively insignificant amounts of residual hazardous chemicals are found in the facility. The exact composition and location of these materials is unknown, although the preponderance of material is adherent films and residues encrusted in deactivated process vessels, piping, and ventilation system ductwork. The estimate of total inventory at the 224-B Building is based upon characterization measurements performed in 1985.

The 224-B Building was constructed in accordance with the design codes, standards, and regulations in place at the time of construction. The surveillance and maintenance of the 224-B Building is conducted in accordance with the programmatic requirements outlined in Chapter 5 and the technical safety requirements defined in Appendix D of BHI (2002). The 224-B Building is expected to remain in surveillance and maintenance mode until the year 2003, after which it may be transitioned into decontamination and decommissioning phase. The facility is scheduled for demolition to "slab on grade" during FY 2006.

224-T Building. The 224-T Building is located in the 200-West Area of the Hanford Site, approximately 45.7 meters (150 feet) to the south and parallel to the T Plant (221-T) canyon. Completed in 1944 and originally designated the 224-T Bulk Reduction Building, its purpose was to concentrate the plutonium nitrate solution produced in the first major step in the plutonium recovery process conducted at T Plant. It operated in this capacity from January 16, 1945, until early 1956, when T Plant was retired from active service as a chemical processing facility. The 224-T Building was idle for several years before being modified in 1975 to meet the requirements for storing plutonium-bearing wastes. In 1985, the building became the 224-T Transuranic Waste Storage and Assay Facility and operated in that capacity until the early 1990s.

The 224-T Building is a three-story, reinforced concrete structure containing 21 rooms (in its original configuration) and five process cells, with a large operating gallery located on the third floor. A sixth process cell was provided in 1950 to boost production. The first and second floors have outside dimensions of approximately 60.0 meters (197 feet) by 18.3 meters (60 feet). The third floor is 44.2 meters (145 feet) by 18.3 meters (60 feet). A 30-centimeter (12-inch) thick concrete wall divides the building into two main sections. Offices and operating galleries were originally located on the northwest side of the dividing wall. The walls, floors, and ceiling are constructed of reinforced concrete. The process cells are located on the southeast side of the dividing wall and have been sealed from the northwest section for over 25 years.

As documented in Atlantic Richfield Hanford Company (ARCHO 1972), the 224-T Building was upgraded to provide tornado resistance. (However, tornado resistance is no longer required for Hanford Site non-reactor facilities.) The modifications were as follows:

- Steel beams were attached horizontally to the original reinforced concrete walls and supported at column lines so that these walls were braced adequately to withstand a 280-kilometer (175-mile) per hour wind and a 53-gram per square centimeter (0.75-pound per square inch) negative pressure transient.
- Shields over the exterior ventilation openings were provided to protect the containers stored in the building from tornado-generated missiles.

As noted in ARCHO (1971), the 224-T Building was also upgraded to provide seismic resistance. The modifications were as follows:

- Six vertical concrete buttresses were installed on the northeast side and five concrete buttresses were installed on the southeast side.
- Un-reinforced block walls were removed and replaced with reinforced concrete.

There are currently no operating processes at the 224-T Building, since it is in shutdown mode. During the current building life cycle phase, planned activities will consist primarily of surveillance and maintenance and incidental storage of supplies and materials related to surveillance and maintenance activities and limited deactivation activities. Active building systems are limited to the fire suppression system and general utilities.

Surveillance and maintenance activities that may be performed within the 224-T Building include scheduled operational surveillances, routine radiological surveys, and preventive maintenance on the fire suppression system as defined by the fire hazard analysis.

Table 4.10 presents the radiological inventory as identified by the nondestructive assay performed by Pacific Northwest National Laboratory.[1,2] Only the data associated with plutonium and americium holdup are presented here and used to determine the dose consequences. This is appropriate since the quantities of other isotopes are negligible. Two assay techniques were employed. Tanks in the cells were surveyed using a high-purity germanium gamma detector to measure plutonium-239 and americium-241 activity present and centrifuges and tanks on the mezzanines of the cells were assayed with passive neutron detectors that measure effective plutonium-240 mass, except for Cell F where gamma assay was employed.

Table 4.10. 224-T Building Inventory Mass by Location

Location	^{238}Pu (g)	^{239}Pu (g)	^{240}Pu (g)	^{241}Pu (g)	^{242}Pu (g)	^{241}Am (g)
Cell A	1.20E-03	8.10E+00	5.27E-01	3.09E-03	2.60E-03	4.43E-01
Cell B	1.44E-03	9.72E+00	6.33E-01	3.72E-03	3.12E-03	1.44E+00
Cell C[(a)]	1.33E-03	8.96E+00	5.84E-01	3.42E-03	2.88E-03	6.39E-02
Cell D	1.39E-04	9.37E-01	6.10E-02	3.58E-04	3.01E-04	7.08E-02
Cell E	4.75E-04	3.21E+00	2.09E-01	1.23E-03	1.03E-03	4.68E-01
Cell F[(b)]	2.38E-03	1.61E+01	1.05E+00	6.15E-03	5.17E-03	2.60E+00
F-10	1.52E-03	1.03E+01	6.71E-01	3.94E-03	3.31E-03	3.32E-01
Total	**8.48E-03**	**5.73E+01**	**3.73E+00**	**2.19E-02**	**1.84E-02**	**5.42E+00**

(a) Includes estimated inventory for submerged tanks.
(b) Not including F-10.

The total plutonium mass and the breakdown by plutonium isotope can be obtained from the measured plutonium-239 value (or plutonium-240 in the case of the total neutron measurements) if the isotopic composition of the plutonium is known. Based on process knowledge of the 224-T Building, the plutonium processed there would have been weapons grade and would have had the following isotopic composition at 180 days after discharge from the reactor:

- Plutonium-238: 0.02%
- Plutonium-239: 93.5%

[1] Letter from G. Mapili (Pacific Northwest National Laboratory) to G. Chronister, *224-T Nondestructive Assay of Tanks in Cells A Thru F*, dated January 31, 2002.
[2] Letter report KAS-01-1425, from KA Smith (Duratek Federal Services, Richland, Washington) to JE Hodgson (Fluor Hanford, Inc.), *209E Characterization*, dated May 14, 2001.

- Plutonium-240: 6.1%
- Plutonium-241: 0.34%
- Plutonium-242: 0.03%

Assuming that the last plutonium processing was done in March 1956 and by decaying the plutonium isotopes over the intervening 46.8 years, the following corrected isotopic compositions are calculated:

- Plutonium-238: 0.014%
- Plutonium-239: 93.8%
- Plutonium-240: 6.11%
- Plutonium-241: 0.036%
- Plutonium-242: 0.03%

Therefore, the current total mass of plutonium is the measured plutonium-239 (or plutonium-240) mass divided by the corrected isotopic mass fraction for plutonium-239 (or plutonium-240). The current mass of each plutonium isotope is given by the current total plutonium mass multiplied by the respective corrected isotopic fractions. This methodology used to determine the isotopic distribution presented in Table 4.10. The americium mass for each cell (except Cell F) in Table 4.10 is the sum of the measured americium mass for the tanks in the cell and an inferred value for the mezzanine centrifuges and tanks that were measured by total neutron counting, which provides no americium data. The inferred americium value was conservatively taken as 16% of the total plutonium mass, as was measured for Cell F.

The 224-T Building is scheduled for demolition to "slab on grade" during FY 2006.

209-E Facility. The 209-E facility is located in the 200-East Area of the Hanford Site. The facility was constructed in 1960. It was designed to provide a heavily shielded reactor room where quantities of plutonium or uranium in solution could be brought into critical configurations under carefully controlled and monitored conditions. In the late 1980s, Pacific Northwest National Laboratory was directed by DOE to prepare the facility for an unoccupied status by December 31, 1988 (PNL 1989).

The 209-E facility is an L-shaped reinforced concrete structure that includes spaces for offices, a control room, shops, an equipment room, a change room, the mix room, and the critical assembly room. The rooms that contain contaminated equipment and material include the critical assembly room, the mix room, and the "hot side" of the change room. These three rooms are the only radiological areas at the 209-E facility and are the primary areas addressed in the preliminary hazards analysis.

The 209-E facility has a current inventory of 563 grams (1.24 pounds) of plutonium. This inventory is primarily contained within the tanks and contaminated equipment within the critical assembly room and mix rooms (Tables 4.11 through 4.14). The facility inventory is based on the best available information as contained in PNL (1989) and supplemented in Tiffany (1998). There is no inventory assigned to the facility heating, ventilation, and air conditioning system ducting or filters.

In March 2000, a pre-existing condition review of the facility was performed, as part of the responsibility transfer for the 209-E facility to the 200 Area Facility Deactivation organization. This review

Table 4.11. 209-E Nominal Radiological Inventory for the Critical Assembly Room

Tank	Plutonium Inventory (g)	^{239}Pu (Ci)	^{238}Pu (Ci)	^{240}Pu (Ci)	^{241}Pu (Ci)	^{241}Am (Ci)
Tk-101	1.0	6.22E-02	6.47E-03	1.58E-02	3.42E-01	1.96E-02
Tk-102	Residual U only	0	0	0	0	0
Tk-103	8.0	4.98E-01	5.18E-02	1.27E-01	2.74E+00	1.57E-01
Tk-104	15.0	9.33E-01	9.70E-02	2.38E-01	5.13E+00	2.94E-01
Tk-105	38.0	2.36E+00	2.46E-01	6.02E-01	1.30E+01	7.46E-01
Tk-106	123.0	7.65E+00	7.96E-01	1.95E+00	4.21E+01	2.41E+00
Tk-108	0.0	0	0	0	0	0
Tk-141	36.0	2.24E+00	2.33E-01	5.70E-01	1.23E+01	7.07E-01
Tk-161	4.0	2.49E-01	2.59E-02	6.34E-02	1.37E+00	7.85E-02
Tk-162	4.0	2.49E-01	2.59E-02	6.34E-02	1.37E+00	7.85E-02
Total	**229.0**	**14.24**	**1.48**	**3.63**	**78.32**	**4.50**

Table 4.12. 209-E Nominal Mix Room Tanks, Equipment, and Inventory

Tank	Plutonium Inventory (g)	^{239}Pu (Ci)	^{238}Pu (Ci)	^{240}Pu (Ci)	^{241}Pu (Ci)	^{241}Am (Ci)
Tk-213	1.0	6.22E-02	6.47E-03	1.58E-02	3.42E-01	1.96E-02
Tk-206 Tk-215 Tk-216	2.0	1.24E-01	1.29E-02	3.17E-02	6.84E-01	3.93E-02
Tk-231	42.0	2.61E+00	2.72E-01	6.65E-01	1.44E+01	8.25E-01
Tk-232	31.0	1.93E+00	2.01E-01	4.91E-01	1.06E+01	6.09E-01
Tk-233	47.0	2.92E+00	3.04E-01	7.44E-01	1.61E+01	9.23E-01
Tk-234	33.0	2.05E+00	2.14E-01	5.23E-01	1.13E+01	6.48E-01
Tk-235	3.0	1.87E-01	1.94E-02	4.75E-02	1.03E+00	5.89E-02
Pump P-203	5.0	3.11E-01	3.23E-02	7.92E-02	1.71E+00	9.82E-02
Pump P-201	15.0	9.33E-01	9.70E-02	2.38E-01	5.13E+00	2.94E-01
Valve area	5.0	3.11E-01	3.23E-02	7.92E-02	1.71E+00	9.82E-02
Total	**184.0**	**11.44**	**1.19**	**2.91**	**62.93**	**3.61**

Table 4.13. 209-E Critical Assembly Room "Bounding" Inventory

Tank	Nominal ^{239}Pu (g)	Bounding ^{239}Pu (g)	Bounding ^{239}Pu (Ci)	Bounding ^{238}Pu (Ci)	Bounding ^{240}Pu (Ci)	Bounding ^{241}Pu (Ci)	Bounding ^{241}Am (Ci)
Tk-101	1.0	1.35	8.40E-02	8.73E-03	2.14E-02	4.62E-01	2.65E-02
Tk-102	Residual U only	0	0	0	0	0	0
Tk-103	8.0	10.8	6.72E-01	6.99E-02	1.71E-01	3.69E+00	2.12E-01
Tk-104	15.0	20.25	1.26E+00	1.31E-01	3.21E-01	6.93E+00	3.98E-01
Tk-105	38.0	51.3	3.19E+00	3.32E-01	8.13E-01	1.75E+01	1.01E+00
Tk-106	123.0	166.05	1.03E+01	1.07E+00	2.63E+00	5.68E+01	3.26E+00
Tk-108	0.0	0	0	0	0	0	0
Tk-141	36.0	48.6	3.02E+00	3.14E-01	7.70E-01	1.66E+01	9.54E-01
Tk-161	4.0	5.4	3.36E-01	3.49E-02	8.55E-02	1.85E+00	1.06E-01
Tk-162	4.0	5.4	3.36E-01	3.49E-02	8.55E-02	1.85E+00	1.06E-01
Total	**229.0**	**309.15**	**19.23**	**2.00**	**4.90**	**105.73**	**6.07**

Table 4.14. 209-E Mix Room "Bounding" Inventory

Tank	Nominal ^{239}Pu (g)	Bounding ^{239}Pu (g)	Bounding ^{239}Pu (Ci)	Bounding ^{238}Pu (Ci)	Bounding ^{240}Pu (Ci)	Bounding ^{241}Pu (Ci)	Bounding ^{241}Am (Ci)
Tk-213	1.0	1.35	8.40E-02	8.73E-03	2.14E-02	4.62E-01	2.65E-02
Tk-206							5.30E-02
Tk-215	2.0	2.7	1.68E-01	1.75E-02	4.28E-02	9.23E-01	
Tk-216							
Tk-231	42.0	56.7	3.53E+00	3.67E-01	8.98E-01	1.94E+01	1.11E+00
Tk-232	31.0	41.85	2.60E+00	2.71E-01	6.63E-01	1.43E+01	8.22E-01
Tk-233	47.0	63.45	3.95E+00	4.11E-01	1.01E+00	2.17E+01	1.25E+00
Tk-234	33.0	44.55	2.77E+00	2.88E-01	7.06E-01	1.52E+01	8.75E-01
Tk-235	3.0	4.05	2.52E-01	2.62E-02	6.42E-02	1.39E+00	7.95E-02
Pump P-203	5.0	6.75	4.20E-01	4.37E-02	1.07E-01	2.31E+00	1.33E-01
Pump P-201	15.0	20.25	1.26E+00	1.31E-01	3.21E-01	6.93E+00	3.98E-01
Valve area	5.0	6.75	4.20E-01	4.37E-02	1.07E-01	2.31E+00	1.33E-01
Total	**184.0**	**248.40**	**15.45**	**1.61**	**3.93**	**84.96**	**4.88**

identified a number of conditions labeled as "pre-existing conditions that require immediate corrective actions." These deficiencies required actions to ensure that facility activities are consistent with the applicable requirements. In addition, a number of conditions requiring corrective actions, but of a less immediate nature, were also identified. Key corrective actions included the following activities:

- Verifying "empty" tanks to facilitate the deactivation planning
- Characterizing the critical assembly room and mix rooms for beryllium

- Evaluating the roof over the critical assembly room and mix rooms
- Decontaminating the critical assembly room of smearable contamination hot spots

There are no active processes that are currently operating at the 209-E facility, since it is in shutdown mode. During the current facility life-cycle stage, planned facility activities will consist primarily of surveillance and maintenance, and storage of 200 Area Facility Deactivation materials, but will also include limited accelerated deactivation activities that are necessary to address identified corrective actions. Active facility systems are limited to the fire suppression system, the exhauster ventilation system, and general utilities.

Based on the process knowledge and the radiological data from the 209-E facility, a determination of the radionuclides of concern was made. This determination addressed the waste generated at the facility. The results were documented in a May 14, 2001.[1] From this letter, the radionuclides of concern and their relative ratios are presented in Table 4.15.

Table 4.15. 209-E Radionuclide Percentages

Radionuclide	Radionuclide Percent (by curies)
^{238}Pu	0.0145
^{239}Pu	0.1394
^{240}Pu	0.0355
^{241}Pu	0.7665
^{241}Am	0.0440

The 209-E facility has no defined date scheduled for demolition and will remain in surveillance and maintenance mode until such time as the deactivation and demolition paths are defined. Closure of 209-E is part of the semi-works zone (also known as the hot semiworks).

200-North Facilities. The facilities that comprise the 200-North Area include the 212-N, 212-P, and 212-R Buildings and associated above-grade structures. The historical information regarding the inventory of the 212-N, 212-P, and 212-R Buildings is sparse and enigmatic. Existing records were used to define potential inventories of the containerized waste in the transfer areas of the 212-N and 212-R Buildings. The storage basins in each of the three buildings are suspected to contain minor levels of residual contamination. Visual inspections, field survey data, and the fact that the related cooling water waste sites contain relatively low levels of radiological contamination are indicative of the relatively minor radiological source term associated with the storage basins.

Routine surveillance is required to determine if further deterioration or damage occurs to the 212-N, 212-P, and 212-R Buildings. Contingency response (if further damage or deterioration should occur) is provided to maintain the building in the interim.

The residual wastes of the 200-North Area are contained within a single operable unit, 200-NO-1 (WHC 1992). This document addresses only the 212-N, 212-P, and 212-R Buildings and associated

[1] Letter report KAS-01-1425, from KA Smith (Duratek Federal Services, Richland, Washington) to JE Hodgson (Fluor Hanford, Inc.), *209E Characterization*, dated May 14, 2001.

above-grade structures. The waste sites that are associated with these buildings are excluded from the scope of this document, and any discussions regarding these sites are included only for information purposes. Final disposition of the buildings and waste sites is not yet scheduled, pending decisions by DOE and external regulators. The 212-N, 212-P, and 212-R Buildings are of identical design and construction. The buildings consist of three general areas: a transfer area, a storage basin, and a heater room (see Section 2.2, Kerr and Adam 2000). The 212-N, 212-R, and 212-P Buildings are managed in their entirety by Fluor Hanford, Inc. Associated above-grade structures include two well-house structures located east of the 212-R Building.

Evaluation of legacy inventories of hazardous substances in retired facilities found that the 212-N Building potentially contains significant quantities of hazardous and radioactive materials (BHI 1998c). Hazards with the potential to cause release of these materials to the environment or cause exposure to individuals are evaluated to verify the controls necessary to manage the hazards. The documented radiological inventory (Tables 4.16 and 4.17) was found to exceed the threshold that defines a preliminary hazard classification of "Nuclear" (BHI 1997b).

Table 4.16. Summary of 212-N Radiological Inventory

Isotope	Inventory (Ci)
Plutonium-239[(a)]	2.00E+01
Strontium-90[(b)]	6.00E+01
Americium-241[(b)]	6.67E+00

(a) Reported in RHO (1982) as plutonium, assumed to be plutonium-239.
(b) Reported in RHO (1982) as beta, assumed to be strontium-90. Americium-241 assumed based on review of PNL (1991, 1996) assuming 25 to 30 years in-growth of 6% fuel.

Table 4.17. Summary of 212-R Radiological Inventory

Isotope	Inventory
Strontium-90	1.08E-01
Cesium-137	2.22E-03

Investigation and evaluation of the 212-N, 212-P, and 212-R Buildings during 1998 and 2000 concluded that the roof structure has deteriorated and that the facilities are inadequate to withstand natural loading forces, as required by DOE. Additionally, the 212-N Building and its configuration of wooden boxes containing suspect transuranic waste were found to be inconsistent with onsite storage practices. Conclusions about the suspect transuranic waste and noted deficiencies are the drivers for the preparation of this basis of interim operation.

Removal and disposal of the suspect transuranic waste from the 212-N Building to the Central Waste Complex in the 200-West Area is recommended to achieve compliant and safe storage. Removal of the waste will reduce operational risk (e.g., radiological release from building collapse) involved during surveillance and maintenance and will remove the inventory of contamination that resulted in the facility's hazard classification. After the waste containers that are stored in the 212-N Building are removed, the facility may be re-classified with a facility hazard classification of "Radiological." The 200-North facilities are not currently scheduled for demolition and will remain in surveillance and maintenance mode until such time as the decontamination and decommissioning is complete.

4.2.3 Tank Farms

Scope and History. Since 1944, radioactive waste generated from the reprocessing of irradiated uranium fuel has been stored in large underground storage tanks (Anderson 1990) located in the 200 Areas (Figure 1.1). These tanks are arranged in "tank farms" that initially received waste from specific processing facilities. In 1943, construction was begun on four tank farms (B, C, T, and U) that were to support four facilities recovering plutonium from irradiated uranium fuel using the bismuth phosphate separations process. Only three of these facilities were constructed (B, T, and U) and only two (B and T) were used for plutonium recovery. Each of these four tank farms consisted of twelve 2,006,268-liters (530,000-gallon) and four 55,000 single-shell tanks. These tanks are shown schematically in Figure 4.26. The so-called single-shell tanks consist of a reinforced concrete shell with a low-carbon steel liner. The concrete provides structural stability and the steel liner provides liquid containment.

When the decision was made to continue the operation of the Hanford Site after the end of World War II, additional single-shell tanks were constructed to support operations of the two bismuth phosphate plants. The BX farm (12 tanks) and TX farm (18 tanks) were constructed during 1947 to 1948. The TX farm tanks have a 2,869,342-liter (758,000-gallon) storage capacity. During 1950 to 1951 the BY farm was constructed of 12 tanks with a capacity of 2,869,342 liters (758,000 gallons). In 1951 to 1952, the TY farm (six tanks) was constructed. The TY tanks have a 2,869,342-liter (758,000-gallon) storage capacity.

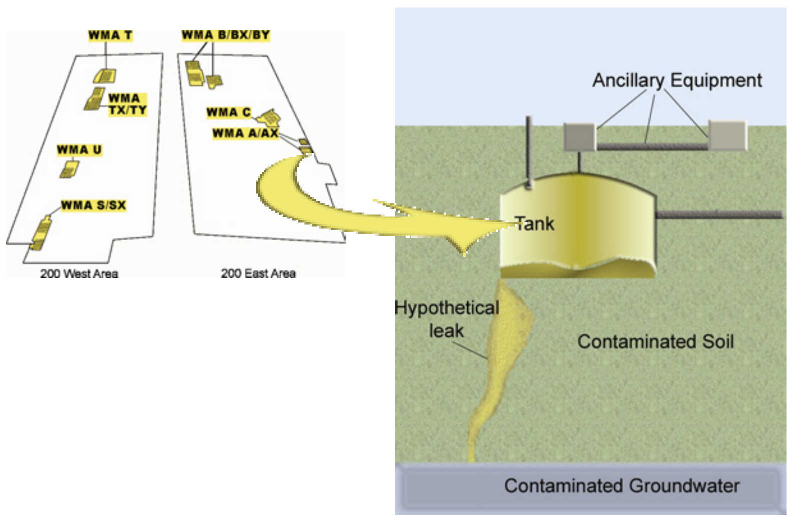


Figure 4.26. Conceptual Drawing of the Single-Shell Tank Components

In 1952, a more efficient solvent-extraction-based plutonium recovery process was implemented. It is known as the reduction/ oxidation process. Two new tank farms were constructed to support the REDOX process. In 1950 to 1951, the S farm was constructed of 12 tanks that could hold 2,869,342 liters (758,000 gallons). In 1953 to 1954, the SX farm (15 tanks) was constructed; the SX tanks can store 3,785,412 liters (1 million gallons). In 1956, an even more efficient solvent extraction-based plutonium recovery process was implemented, known as the plutonium/uranium extraction (PUREX) process. Two tank farms were constructed to support the PUREX plant operations. The A farm was constructed in 1954-55 and had six tanks with 3,785,412 liters (1 million gallons) capacity. The four tank AX farm was constructed in 1965-66.

Thus, between 1943 and 1966, a total of 149 single-shell tanks were constructed in 12 tank farms. Operation of these tank farms required an extensive array of ancillary equipment and piping systems. There are multiple junction boxes in most farms allowing movement of waste between tanks. A number of tank farms contain process vaults. Most of the waste transfer piping and much of the ancillary equipment are underground for shielding purposes. Some waste transfer piping is above ground or slightly underground and is shielded by above ground shielding devices.

Two approaches were used in an attempt to assure integrity of the single-shell tanks. Measurements were routinely made of the liquid level inside the tanks, and a series of shallow (18 to 46 meters [60 to 150 feet]) wells were installed around all of the 100-series (i.e., 23-meter [75-foot] diameter) single-shell tanks to allow monitoring for gamma-ray activity. Most tanks in the SX farm and all tanks in the A farm had laterals placed 3 meters (10 feet) below the base of these tanks to allow for routine gamma-ray monitoring. The AX tanks were constructed with a drain system and gamma-ray monitoring wells to facilitate leak detection. None of the approaches used for leak detection in single-shell tanks proved to be optimal.

In the mid-1950s, the single-shell tanks began to leak. The increasing number of tanks listed as leaking was exacerbated by the storage of high-temperature waste produced from the more efficient plutonium recovery plants. Problems with failure of the single-shell tanks led to two major decisions in the mid-1960s. First, the decision was made to convert the high-salt liquids into solids as rapidly as possible; the second decision was to begin construction of double-shell tanks for storage of liquid waste. By 1980, the use of single-shell tanks for the active storage of liquid waste had been terminated. Between 1971 and 1986, twenty-eight 3,785,412-liter (1-million-gallon) double-shell tanks were constructed. The double-shell tanks have positive leak detection systems installed between the two steel tanks and no leaks have been detected in any of the double-shell tanks. Currently, 67 of the 149 single-shell tanks are confirmed or suspected to have leaked.

Tank inventories shown in Table 4.18 are based on the best basis inventory (DOE 2003).

Table 4.18. Existing and Projected Inventories (Post Retrieval)

	Existing	Post Retrieval
Radionuclides (Ci)		
All single-shell tanks	1.03E+08	1 to 5 E+06
Chemicals (kg)		
All single-shell tanks	1.10E+08	9.82E+05
Quantity of Material in Single-Shell Tanks		
	121,630,000 liters (32.1 million gallons)	1,370,000 liters (361,886 gallons

- Post-retrieval volume estimates are based on 133 single-shell tanks 100-series and 16 200-series tanks each containing 2,694 and 224 gallons, respectively.
- Based on the HFFACO, this is the minimum goal to be reached for retrieval. Retrieval efficiencies were based on the "Selected Phase Retention Approach" defined in Section 6.6 of the above reference.
- Double-shell tanks (28) contain an additional 22.5 million gallons and 9.1E+07 curies. Post-retrieval estimates have not been made for double-shell tanks, but one could assume they would be equivalent or more complete than for single-shell tanks.

Concepts of risk management have always played dominant roles in critical decisions related to waste management in the tank farms. Expedited actions are found throughout the history of tank farm operations and include: liquid removal from leaking tanks in the early 1950s, resolution of potential explosivity issues associated with ferrocyanides added during reprocessing operations, and resolution of intermittent "burping" tank problems due to hydrogen gas production. Risk-based decisions continue up to the present day with the expedited retrieval of C-106 tank contents to the double-shell tank farms. And finally, decisions to remove free liquids from tanks were based on the management of impact to the environment. This "salt well" pumping process was expedited through the consent decree process; interim stabilization of all tanks included in the 1999 decree is expected to be accomplished in 2004.

Risk-based management continues to play an important role in tank selection for tank waste retrieval and closure. Tank selection criteria emphasize maximizing risk reduction while feeding the vitrification plant and maintaining double-shell tank space. Closure of the farms will be required to meet both groundwater and intruder performance objectives, which are again risk based.

Description of the Hazard Area. Figure 4.27 presents a generalized schematic of the hazard area associated with a single-shell tank farm. Waste is contained in steel-lined concrete tanks buried up to 15 meters (50 feet) in the soil with a minimum of 1.5 to 2.1 meters (5 to 7 feet) of earthen shielding above the crown of the tank dome. The primary non-industrial hazard from storage of waste in tanks is associated with loss of containment through leaks into the soil or gaseous emissions through both active and passive ventilation systems. Tank leaks are observed to migrate through the 61 meters (200 feet) or more of soil to the groundwater and potentially will reach the surface waters of the Columbia River. Gaseous emissions disperse quickly after release. Access to the Hanford Site is currently controlled, which limits exposure to air emissions and direct contact to soil contaminated with tank waste by workers and ecological receptors through the food web.

Identification of the Primary and Secondary Sources of Contamination. The primary source of contamination in a tank farm is the waste contained in the tanks themselves, ancillary piping systems, vaults and junction boxes. Secondary sources of contamination include shallow and deeply contaminated soil, groundwater and, to a much more limited extent, surface waters connected through the groundwater transport pathway. Another secondary source of contamination includes gaseous emissions and depositions trough the air pathway.

Identification of the Current Potential Future Release, Transport and Exposure Mechanisms. Release, transport and exposure mechanisms are described in the following list:

1. Release mechanisms

- Current release mechanisms primarily involve loss of containment from the tanks through corrosion or mechanical failure of pumps, valves, or junctions during the retrieval process.

- Future release mechanisms from the stabilized tank waste residuals is projected to be leaching and dispersive processes. Other failure mechanisms associated with the potential failure of the waste form are believed to include failure of the surface barrier, eventual loss of the tank structure, and desiccation and fracturing of the waste form.

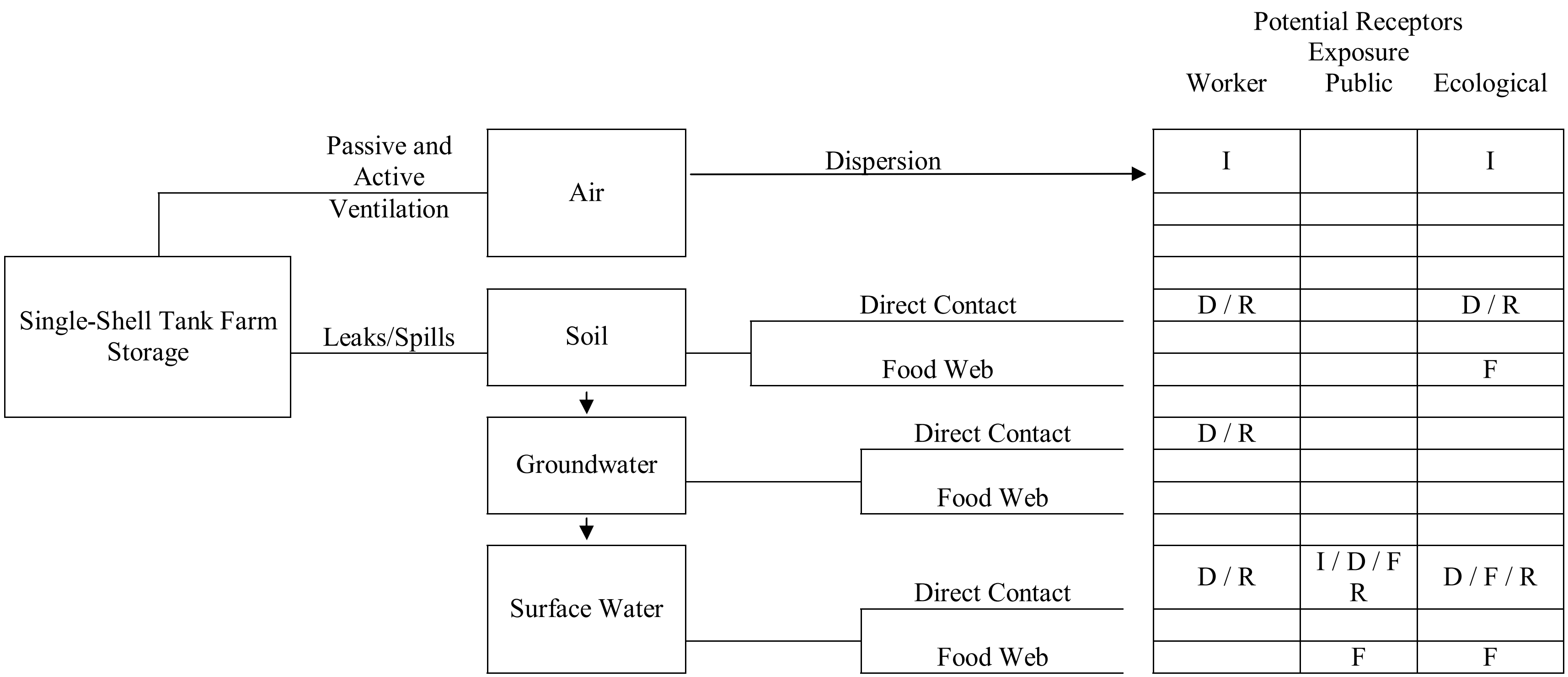


Figure 4.27. Generalized Tank Farm Human Health and Environmental Hazard, Current State

2. Transport mechanisms

- Transport mechanisms for both the present and future condition conceptually are similar. The quantity of material and thus the importance of the mechanism does change. These mechanism include advective and dispersive transport through the air, soil, and water of the area

3. Exposure Mechanism

- Current exposure mechanisms primarily includes inhalation and dermal contact for the workers and limited biota exposure through contact and ingestion.

- Future exposure mechanisms are postulated to include inhalation, ingestion through contact with the waste form resulting from an inadvertent intruder and post intruder scenario. Inhalation, ingestion, and dermal contact with groundwater resulting from leaching of the waste form over time is also considered possible.

Temporary Barriers or Controls. Figure 4.28 depicts a generalized vision of barriers currently planned to be in place at the closed tank farms. These barriers are a combination of engineering and administrative controls that interdict the exposure pathways through the mediums of air, water, and soil. Potential future barriers and controls include the following items:

- Retrieval of the waste to the extent practicable
- Use of a cementitious grout form to bind the waste retrieval
- Use of a multi-layer grout form with a high strength cap to help prevent intrusion
- Use of the steel and concreter shell for containment
- Use of “getters,” as necessary
- Deployment of a surface barrier to infiltration expected to perform over 500 years
- Drainage controls in the barrier design
- Biological inhibitors in the barrier design
- Intruder warnings in the barrier design
- Resistance to wind erosion in the barrier design
- Administrative controls to restrict entry for a minimum of 150 years and probably into perpetuity
- Potentially groundwater and vadose monitoring systems
- Annual inspections of the engineered and administrative systems
- Potential deed restrictions
- Restricted access to groundwater and if necessary local seeps into the river

Current controls and barriers used to limit exposure include the following items:

- Engineering and administrative controls to perpetuate the safe storage of the waste
- Physical barriers to prevent animal and inadvertent human intrusion
- Pesticides to minimize biological contact and as a barrier to entry in the food chain
- Herbicides and gravel to prevent plant intrusion
- Inspections to maintain that administrative and engineering controls are in place and functioning

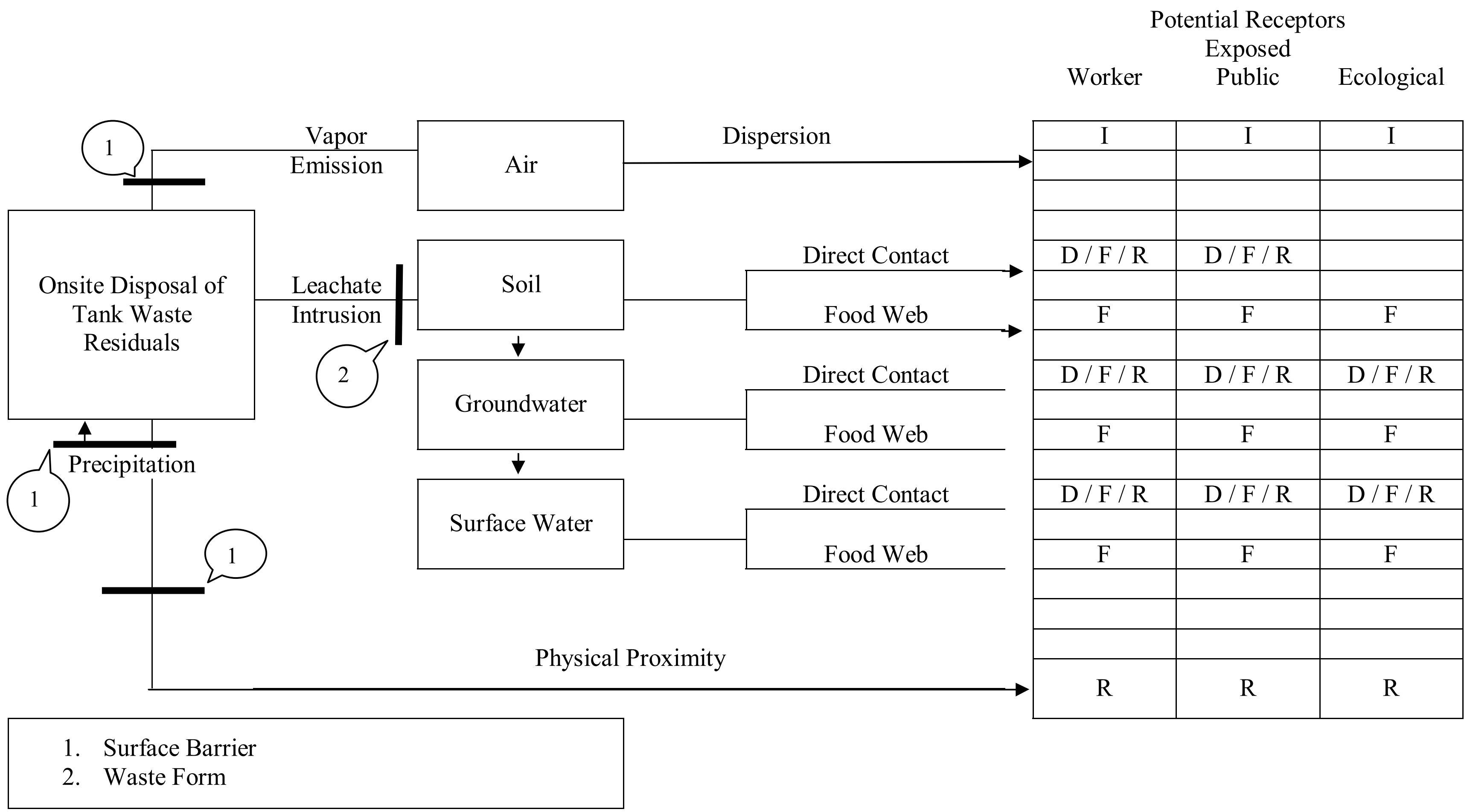


Figure 4.28. Generalized Tank Farm Human Health and Environmental Hazard, End State

Additional Information. The development of a RBES for tank farms will be guided by the resolution of two central issues. The first is to establish the level of retrieval necessary to protect human health and the environment. The second issue is the development of detailed exposure scenarios to calculate ecological and environmental risk. At Hanford, exposure scenarios have been developed for informational purposes. Selection and implementation of exposure scenarios for risk evaluation is not completed.

Regulatory Basis for Tank Retrievals. According to Tri-Party Agreement Milestone M-45-00, waste shall be retrieved from single-shell tanks to the limits of the technology (or technologies) selected. As much waste as technically possible will be retrieved, with remaining residuals of no more than 10.2 cubic meters (360 cubic feet) for 100-series tanks and 0.85 cubic meter (30 cubic feet) for 200-series tanks. If the retrieval goal is not met for a specific tank, DOE will request an exception to the criteria in the manner specified in Appendix H of the Tri-Party Agreement. A risk assessment will be performed on any remaining residuals to determine their contribution to risks to human health and the environment using acceptable methods.

Potential Exposure Scenarios. Table 4.19 summarizes the exposure pathways for the typical performance assessment scenarios. There are nine scenarios presented in Table 4.19. The first four are the waste intruder cases, namely, the well driller and the post-intrusion residents. The next four are individuals exposed to a contaminated water source, either a well to groundwater or the Columbia River. The final scenario considers the collective effect on the population residing down river from Hanford.

The intruder scenarios (the Well Driller, Suburban Garden, Rural Pasture, and Commercial Farm) consider only the impact of radionuclides. For the Well Driller, the total effective dose equivalent is calculated based on a unit concentration averaged over all the material removed from the well hole. For the other post-intrusion cases, the total effective dose equivalent is calculated during the first year after the well is drilled. The dose is based on a unit quantity of activity removed from the well and spread on the ground in a garden, a cow pasture, or an agricultural field. Lifetime cancer risk and hazard quotients cannot be calculated for the Well Driller due to the short exposure to a healthy worker. The performance objectives for the post-intrusion scenarios are annual radionuclide doses; therefore, the lifetime risk and hazard quotient calculations were not carried out.

The next two exposure scenarios have individuals who are users of contaminated water. The contaminated water may be obtained from either a well or the Columbia River. When the Columbia River is the source of contaminated water, the risk calculations include the fish pathway and exposure to shoreline sediment. Otherwise, they are identical. This situation occurs far in the future, when the hazardous materials have migrated into the groundwater and the Columbia River. The two individuals are the All Pathways Farmer and the Native American. The All Pathways Farmer is a representative average individual who grows much of his own food. His intake of food and water, for example, are population averages. The Native American represents a bounding individual, particularly with regard to fish consumption. The risk from hazardous chemicals is included in these calculations. For the All Pathways Farmer, the averaging time is 30 years, based on population relocation frequencies. The averaging time for the Native American is 70 years.

The collective exposure to millions of individuals living near the Columbia River is evaluated in the Columbia River Population scenario. This situation occurs far in the future, when the hazardous materials

Table 4.19. Exposure Pathway Summary for Standard Performance Assessment Scenarios

	Exposure Scenarios →	Standard Performance Assessment Exposure Scenarios								
		Waste Intruders				All Pathways Farmer		Native American		Columbia River Population
	Exposure Pathways	Driller	Suburban Garden	Rural Pasture	Commercial Farm	GW	River	GW	River	
Water	Ingestion					●	●	●	●	●
	Vapor Inhalation					●	●	●	●	●
	Shower, dermal					●	●	●	●	●
	Swimming, dermal								●	●
	Sweat Lodge, inhalation							●	●	
Shore Sediment	Ingestion						●		●	●
	Inhalation									
	Dermal Contact						●		●	●
	External Radiation Dose						●		●	●
Soil	Ingestion	●	●	●	●	●	●	●	●	●
	Inhalation	●	●	●	●	●	●	●	●	●
	Dermal Contact					●	●	●	●	●
	External Radiation Dose	●	●	●	●	●	●	●	●	●
	Tritium Vapor Inhalation		●			●	●	●	●	●
Food Chain	Garden Produce		●			●	●	●	●	●
	Grains									
	Beef and Milk			milk only		●	●	●	●	●
	Poultry and Egg					●	●	●	●	●
	Fish						●		●	●
	Wild Game								●	

The annual dose equivalent (in mrem) is calculated for all of the exposure scenarios shown on this table. This is the only risk quantifier for the waste intruders. The other exposure scenarios also have incremental cancer risk from a lifetime exposure for both radionuclides and chemicals, and hazard index for chemicals.

have migrated with the groundwater to the Columbia River. There are no performance objectives for total population dose, but it is a general indicator of collective harm under the linear, no-threshold theory of health effects. In this theory, any amount of exposure to a hazardous material carries some detriment. Even small doses among large numbers of people can sum to a significant detriment.

Table 4.20 summarizes the exposure pathways for the Hanford Site Risk Assessment Methodology scenarios (DOE 1995) used to assess human health risks associated with specific waste disposal options. The scenarios are consistent with EPA guidance and the Tri-Party Agreement (Ecology et al. 1998). For these scenarios, the annual radiation dose is not calculated. Only the lifetime average cancer risk and hazard index are of interest. The final two columns in Table 4.20 show the exposure pathways used for the State of Washington groundwater and surface water cleanup calculations (WAC 173-340, Part VII). Method B is a residential setting, while Method C uses an occupational setting.

The hazard index for chemicals and the incremental cancer risk for both chemicals and radionuclides are calculated for each scenario in Table 4.20, and all of the irrigation scenarios in Table 4.19. The lifetime radiation dose (in mrem) resulting from the first year of exposure is calculated for all of the exposure scenarios shown in Table 4.19. This dose is primarily received during the year of exposure. For radionuclides that are retained in the body for many years (e.g., strontium-90 and plutonium-239), a portion of the dose is received in following years. This is how radiation doses are calculated under the system of dose limitation developed by the International Commission on Radiological Protection. The internal dose is referred to as the effective dose equivalent. Because the dose factors include external dose received during the year of exposure, it is also known as a total effective dose equivalent.

Table 4.20. Exposure Pathway Summary for Hanford Site Risk Assessment Methodology and Model Toxic Control Act Scenarios

	Exposure Scenarios ➞	Hanford Site Risk Assessment Methodology							WAC 173-340	
		Industrial	Recreational		Residential		Agricultural		MTCA B and C	
	Exposure Pathways		GW	River	GW	River	GW	River	GW	River
Water	Ingestion	●	●	●	●	●	●	●	●	●
	Vapor Inhalation	●	●	●	●	●	●	●		
	Shower, dermal	●	●	●	●	●	●	●		
	Swimming, dermal			●		●		●		
	Sweat Lodge, inhalation									
Shore Sediment	Ingestion			●		●		●		
	Inhalation									
	Dermal Contact			●		●		●		
	External Radiation Dose			●		●		●		
Soil	Ingestion	●	●	●	●	●	●	●		
	Inhalation	●	●	●	●	●	●	●		
	Dermal Contact	●	●	●	●	●	●	●		
	External Radiation Dose	●	●	●	●	●	●	●		
	Tritium Vapor Inhalation	●	●	●	●	●	●	●		
Food Chain	Garden Produce				●	●	●	●		
	Grains									
	Beef and Milk						●	●		
	Poultry and Egg									
	Fish			●		●		●		●
	Wild Game			●				●		

The annual dose equivalent (in mrem) is not calculated for the exposure scenarios shown on this table. The risk quantifiers for these scenarios are incremental cancer risk from a lifetime exposure for both radionuclides and chemicals, and hazard index for chemicals.

There is one difference between radiological and chemical exposure pathways that is not apparent from Tables 4.19 and 4.20. The radiological exposures do not include dermal pathways. Radioactive materials generally are found as inorganic compounds that tend to have lower dermal absorption. The dermal exposures are small compared to the ingestion dose and therefore can be neglected. The only exception in the list of radionuclides being analyzed is tritium, which is assumed to be in the form of tritiated water. Dermal absorption of tritiated water is included in all the inhalation calculations for tritium.

4.2.4 200 Area Groundwater

Groundwater beneath the 200-East and 200-West Areas has been subdivided into four operable units that correspond to the primary contaminant plumes in the subsurface.

Groundwater beneath the southeastern portion of 200-East Area is designated as the 200-PO-1 Operable Unit. This operable unit resulted primarily from liquid waste discharges from the PUREX Plant. The primary contaminants in the 200-PO-1 Operable Unit groundwater are tritium, nitrate, and iodine-129. These plumes extend from 200-East Area to the shoreline of the Columbia River where this groundwater discharges into the river.

The 200-BP-5 Operable Unit is comprised of small isolated plumes within the northwestern portion of 200-East Area. These plumes are due primarily to discharges of highly concentrated tank and process wastes to the soil. The primary contaminants include the mobile contaminants technetium-99 and nitrate as well as strontium-90, cesium-137, and plutonium that are far less mobile contaminants.

The 200-West Area has also been divided into two operable units based on the nature and extent of groundwater contamination. The 200-UP-1 Operable Unit that is comprised of groundwater plumes resulting from REDOX and U Plant liquid discharges. In the area near the REDOX Plant, a plume containing tritium, nitrate, and iodine-129 is located. Just to the north and east of REDOX near U Plant, a second plume containing elevated concentrations of uranium, technetium-99, and nitrate is located.

The 200-ZP-1 Operable Unit is contaminated primarily by carbon tetrachloride discharged from the Plutonium Finishing Plant. These releases of carbon tetrachloride to the soil column have spread well beyond the area surrounding Plutonium Finishing Plant and contaminate much of the groundwater beneath the 200-West Area.

In each case, these plumes represent long-term cleanup challenges to groundwater quality in and around the 200-West Area due to the large inventory of these contaminants released and that remain throughout the deep vadose zone that provide a continuing source of contamination to the groundwater.

The strategy to complete cleanup of the Central Plateau and transition to long-term stewardship focuses on completing actions on land within the Core Zone that contains high-risk waste sites with significant potential to contaminate groundwater and to remediate those lower risk sites that are located outside the Core Zone of the Central Plateau (i.e., shrinking the contaminated area). The four parcels selected as high-risk sites and slated for early action do not include tank farms and those high-risk sites immediately adjacent to tank farms (Maps 10 and 11). Schedules for completion of those high-risk sites and the adjacent tank farms depend on the timing and strategy for retrieval of tank waste and closure of the tank farms.

Similar to the approach in the 100 Areas, where actions were taken to complete each individual reactor area, each of the parcels selected for early action in the Central Plateau require a group of actions to move to long-term stewardship. Unlike the 100 Areas where the cleanup goals established were predicated on unrestricted future use, the 200 Area cleanup goals would be based on restricted future use, appropriate institutional controls, and effective containment actions to protect human health and the environment. These activities also will be closely coordinated with the decontamination and decommissioning of facilities within the Central Plateau to ensure consistency and that an equivalent degree of protection for human health and the environment is ultimately achieved.

For the areas outside the Core Zone, a much more limited group of actions is envisioned than for waste sites and facilities within the 200-East and 200-West Areas. All of the 200 Area waste sites outside the Core Zone including the 200-North Gable/B Pond complex and the Central Landfill parcels represent only marginal risk to groundwater. Early actions in these areas are expected to preserve the existing groundwater quality and support a final remedy of monitored natural attenuation for much of the 200-PO-1 and 200-BP-5 Operable Units potentially returning much of the aquifer between 200-East Area and the Columbia River to future beneficial use. In and around the 200-West Area, the persistence of carbon tetrachloride contamination is likely to be the primary contaminant in limiting the future beneficial use of groundwater.

The long-range plan for continued operation of the 200 Areas, coupled with the existing inventory of hazardous and radioactive contamination, make it unlikely that the Core Zone of the Central Plateau will be deleted from the NPL. Efforts to pursue partial deletion of lands outside the Core Zone may be possible, but must be made in the context of continuing operations.

4.3 300 Area

The 300 Area is one of the four NPL areas at Hanford and encompasses approximately 1.35 square kilometers (0.52 square mile), is adjacent to the Columbia River and approximately 1.6 kilometers (1 mile) north of the Richland city limits.

4.3.1 Summary of Operations

Scope and History. The 300 Area began operations in 1943 as a fuels fabrication complex for the nuclear reactors located in the 100 Areas. Most of the facilities in the area were involved in the fabrication of nuclear reactor fuel elements. In addition to the fuel manufacturing processes, technical support, service support, and research and development related to fuels fabrication also occurred within the 300 Area. In the early 1950s, the Hanford Laboratories were constructed for research and development. As the Hanford Site production reactors were shut down, fuel fabrication in the 300 Area ceased. Research and development activities have expanded over the years. The 300 Area contains a number of support facilities and other facilities necessary for research and development, environmental restoration, decontamination, and decommissioning. Approximately 150 buildings and structures are scheduled for decontamination and decommissioning by 2018. At the present time, DOE plans to use a number of facilities with ongoing missions beyond the 2018 date.

Operations in the 300 Area created both liquid and solid wastes. Prior to 1994, liquid waste was discharged to a series of unlined ponds and process trenches just north of the 300 Area. Prior to 1973, a series of burial grounds were used for solid waste and debris generated by 300 Area operations. These burial grounds were located just north and west of the 300 Area complex. In 1989, the 300 Area was placed on the NPL because of soil and groundwater contamination that resulted from past operations. The primary contaminant in the 300 Area is uranium from the fuel fabrication processes. However, numerous other potential contaminants exist for individual waste sites based on the history of their use and operation.

Contaminant plumes from 200 Area waste sites have migrated southeast toward the 300 Area. These plumes were driven east and southeast by the natural groundwater gradient across the Hanford Site and the large volume discharges of cooling water to ponds and ditches in the Central Plateau. Contaminant concentrations reaching the 300 Area are well below drinking water standards as a result of natural attenuation of the plumes through radioactive decay and dispersion. Groundwater concentrations above regulatory standards are not expected to reach the 300 Area from 200 Areas sources in the future due to planned remediations in the 200 Areas and this natural attenuation.

Like each of the NPL sites at the Hanford Site, the 300 Area was divided into operable units, which are groupings of individual sites based primarily on geographic area and common waste sources. The 300 Area consists of three operable units. The 300-FF-1 and the 300-FF-2 Operable Units address contamination at burial grounds and soil waste sites. The 300-FF-5 Operable Unit addresses groundwater contamination beneath the 300-FF-1 and 300-FF-2 burial grounds and soil waste sites.

300-FF-1 Source Operable Unit. The 300-FF-1 Operable Unit is a final source control action that includes the major 300 Area liquid/process waste disposal sites, the 618-4 burial ground, and three small landfills. The 300-FF-1 Operable Unit liquid and process waste sites were unlined trenches and ponds that routinely received discharges of millions of gallons of contaminated wastewater from 300 Area operations between 1943 and 1994. These sites are suspected to be the primary source of uranium contamination in 300-FF-5 Operable Unit groundwater.

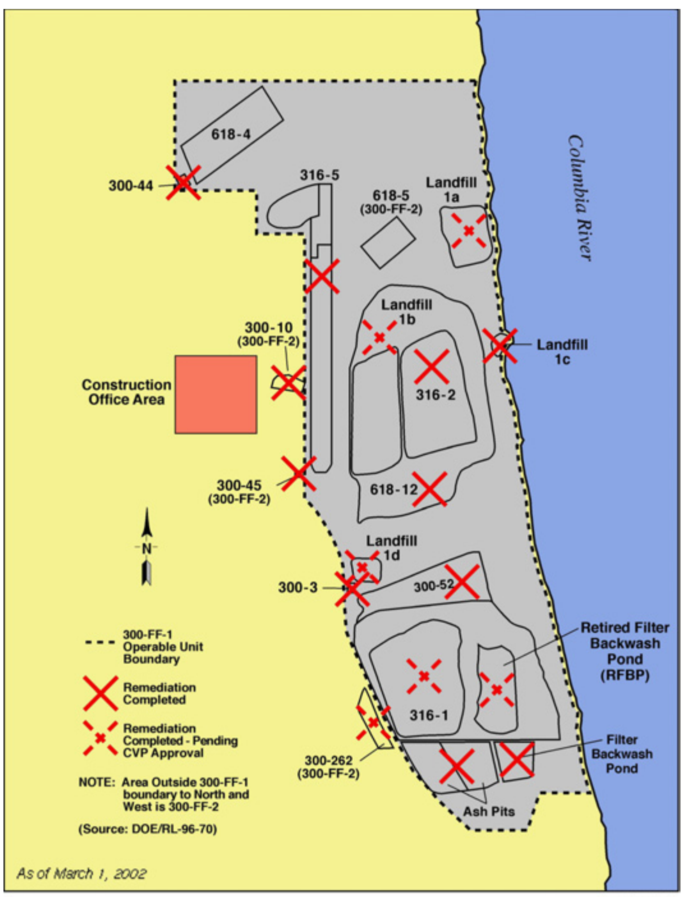


Figure 4.29. Summary of Completed 300 Area Remedial Actions

Full-scale remediation of the 300-FF-1 Operable Unit began in July 1997 in accordance with the 1996 *Declaration of the Record of Decision for the 300-FF-1 and 300-FF-5 Operable Units* (EPA 1996). Cleanup objectives for the 300-FF-1 Operable Unit are based on an industrial land-use scenario. Remedial action operations at for the 300-FF-1 Operable Unit waste sites were complete in August 2003. More than 553,382 metric tons (610,000 tons) of contaminated soil and debris were excavated from the 300-FF-1 Operable Unit waste sites and transported to the Environmental Restoration Disposal Facility for disposal. With the exception of the 618-4 burial ground, all 300-FF-1 sites have been closed out with approved cleanup verification packages and associated waste site reclassification forms as depicted in Figure 4.29. In addition, several 300-FF-2

Operable Unit waste sites (300-10, 300-45, and 300-262) were addressed by 300-FF-1 Operable Unit remedial actions due to their proximity to other 300-FF-1 Operable Unit waste sites.

300-FF-2 Source Operable Unit. The 300-FF-2 Operable Unit is the third and final unit associated with cleanup of the 300 Area NPL site. It is an interim source control action for 56 waste sites that have been identified in the 300-FF-2 record of decision (EPA 2001). Like the 300-FF-1 Operable Unit, cleanup objectives for the 300-FF-2 Operable Unit are based on an industrial land-use scenario. The action sites are subdivided into four groups based on site type, waste content, and/or relative location:

- 300 Area Complex source sites (40)
- Outlying source sites (7)
- General content burial grounds (7)
- Transuranic-contaminated burial grounds (2)

In addition to the 56 waste sites that require remedial action, 24 waste sites were identified as candidate sites for remedial action. The candidate sites require additional characterization to determine if remedial actions are warranted. Pursuant to the results of additional sampling, these sites may be added to the scope of the 300-FF-2 Operable Unit at a later time. If remediation is not warranted, the sites will be closed through appropriate procedures and with approval of the Tri-Parties.

Most of the 300-FF-2 Operable Unit source sites (40 of 47) are located within the 300 Area complex, which is currently an active industrial area. These sites are frequently found beneath existing facilities and/or covered areas that are directly impacted by active industrial operations in the area and/or future economic development plans. For administrative purposes, buildings and associated above-ground structures within the 300 Area are not included in the 300-FF-2 Operable Unit scope. The decontamination and decommissioning activities will be evaluated in EE/CA documents and authorized in CERCLA Action Memoranda (i.e., CERCLA removal authority). The 300-FF-2 Operable Unit remedial action scope includes surface or subsurface contamination remaining at a building site after decontamination and decommissioning is completed. Consequently, cleanup activities for waste sites within the 300 Area Complex will be conducted after decontamination and decommissioning of structures above and adjacent to the waste sites.

Excavation operations and waste transportation/disposal actions at the 618-5 burial ground, the first major waste site addressed in the 300-FF-2 Operable Unit record of decision (EPA 2001), were initiated in October 2002 and completed in August 2003. Closeout of the waste site is anticipated in 2004. The remaining 300-FF-2 Operable Unit waste sites are to be addressed by 2018 in accordance with the applicable Tri-Party Agreement milestones.

4.3.2 300 Area Waste Sites

Table 4.21 summarizes the remedial action objectives established for the 300 Area in the 300-FF-2 Operable Unit record of decision (EPA 2001).

DOE has initiated three efforts aimed at developing and applying methodologies to assess risk/ protectiveness at the Hanford Site. These are the 100-B/C pilot risk assessment, River Corridor risk assessment, and the 200 Area ecological evaluation. Draft plans for these efforts use various substantive elements of the terrestrial ecological evaluation procedures found in WAC 173-340-7490, along with

EPA guidance to evaluate risk. The River Corridor risk assessment will be a baseline risk assessment to help determine cleanup levels and be used as a basis for final remedy decisions for the 100 and 300 Areas.

Table 4.21. Summary of 300 Area Remedial Action Objectives

RAO 1. Prevent or reduce risk to human health, ecological receptors, and natural resources associated with exposure to wastes or soil contaminated above applicable or relevant and appropriate requirements (ARARs) or risk-based criteria. For radionuclides, this RAO means prevention or reduction of risks from exposure to waste or contaminated soil that exceed the CERCLA cumulative excess cancer risk range of 10^{-4} to 10^{-6}. For chemicals, this RAO means prevention or reduction of risk from direct contact with waste or contaminated soil that exceed the *Washington Administrative Code* (WAC) 173-340 cumulative excess cancer risk goal of 10^{-5} and/or a hazard index of 1. This RAO will be met by (1) removal of contaminated media above contaminant-specific cleanup levels identified in the 300-FF-2 record of decision (EPA 2001), (2) demonstration that residual contamination meets the cumulative risk and hazard index standards for a period of 1,000 years, and (3) demonstration that closeout sample results pass the WAC 173-340 three-part test for chemical contaminants. The Tri-Parties have chosen an operational guideline of 15 mrem/year above background over a period of 1,000 years after final remediation for a maximally exposed individual to address this RAO. Meeting this guideline will also be protective of ecological receptors based on criteria specifying that dose rates shall not exceed 0.1 rad/day for terrestrial organisms and 1.0 rad/day for aquatic organisms and terrestrial plants. Levels may have to be adjusted further to be protective of terrestrial plants and animals depending on the location of the individual waste site and the nature of the surrounding habitat.
RAO 2. Prevent migration of contaminants through the soil column to groundwater and the Columbia River such that concentrations reaching groundwater and the river do not exceed maximum contaminant levels under the Federal Safe Drinking Water Act (40 *Code of Federal Regulations* [CFR] 141) and/or State of Washington drinking water standards (*Washington Administrative Code* [WAC] 246-290), ambient water quality criteria for protection of freshwater aquatic organisms under the Federal Clean Water Act (40 CFR 131) and/or State of Washington surface water quality standards (WAC 173-201A), and the WAC 173-340 groundwater cleanup standards (WAC 173-340-720). This RAO will be met by removal of contaminated media above contaminant-specific cleanup levels identified in the 300-FF-2 ROD (EPA 2001) and demonstration that residual contamination will not exceed the groundwater and river water quality standards for a period of 1,000 years.
RAO 3. Prevent or reduce occupational health risks to workers performing remedial action. This RAO will be achieved by compliance with procedures and plans for subsurface excavation and waste management on the Hanford Site. Hazard analyses are conducted for remedial activities in accordance with the work control process. Hazard analysis data and proposed activities are examined, and controls for hazards that may pose a threat to workers, the public, or the environment are developed.
RAO 4. Minimize disruption of cultural resources and wildlife habitat, and prevent adverse impacts to cultural resources and threatened or endangered species. This RAO will be achieved through the implementation of resource review activities and a cultural resource mitigation plan prior to remediation of a waste site. Known cultural resources and traditional-use areas will be avoided whenever possible. If cultural resources were encountered during excavation, the State Historic Preservation Office and Native American Tribes will be consulted about minimizing impacts and taking appropriate actions for resource documentation or recovery.
RAO 5. Ensure that appropriate institutional controls and monitoring requirements are in place to protect future users at a remediated site. Institutional control and monitoring requirements will be achieved through the implementation of the requirements identified in the 300-FF-2 record of decision (EPA 2001) and the *Site-Wide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE 2002c). The monitoring requirements of this RAO will also be met by compliance with the activities defined in the *Operation and Maintenance Plan for the 300-FF-5 Operable Unit* (DOE 2001).

Future Land Use. In 1999, the DOE published the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement (*DOE 1999a) and record of decision (64 FR 61615). The environmental impact statement and record of decision evaluated "the potential environmental impacts associated with implementing a comprehensive land-use plan for the Hanford Site for at least the next 50 years."

The land-use alternative chosen for the majority of the Hanford Site was Conservation (Mining) (DOE 1999a). Land uses for specific area includes Preservation for a 0.4-kilometer (0.25-mile) buffer zone along the Columbia River and the river islands to protect cultural and ecological resources. High-intensity recreation is designated at four sites for visitor-serving activities and facilities development. These four sites are the B Reactor (proposed to be converted into a museum), a boat ramp near the Vernita Bridge, and two Wahluke Slope areas designated for potential exclusive tribal fishing sites. Also part of the chosen land use alternative is low-intensity recreation west of the B Reactor, a boat launch at White Bluffs, and visitor facilities near the old Hanford High School.

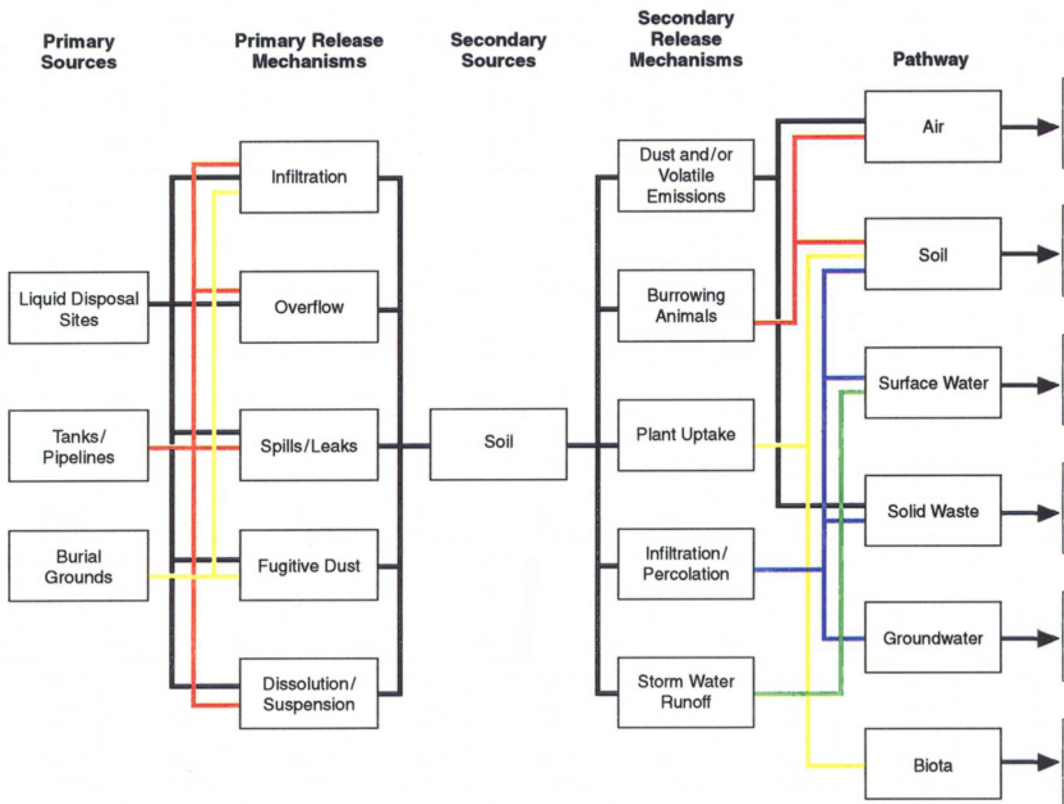
Conceptual Model. The 300 Area industrial land-use conceptual model is shown in Figure 4.30. For radionuclides, the 300 Area industrial land-use scenario assumes that the exposure pathways for residual contamination will be (1) direct exposure to radiation, (2) ingestion of soil containing residual contamination, and (3) inhalation of particles in the air from residual contamination. It is assumed that drinking water is not obtained from groundwater sources and food products are not grown on the site. Although groundwater is not considered a potential exposure pathway in the qualitative risk assessment that supports the basis for remedial action, groundwater is considered to be a potential future drinking water source that must be restored to drinking water standards in a reasonable time frame as established in the 300-FF-5 Operable Unit record of decision (EPA 1996). Major assumptions used for the 300 Area industrial-use scenario include the following (Figure 4.31):

- **Direct Exposure Route**. The industrial land-use scenario assumes an adult worker is located in the area of residual contamination for approximately 1,500 hours per year inside a building and 500 hours per year outdoors for a period of 30 years (these correspond to a typical work year for an adult worker). When the worker is outdoors, it is assumed that clean fill does not provide shielding from residual contamination. Furthermore, it is assumed that indoor exposure to external radiation is 70% of the outdoor levels (based on the shielding provided by the building from direct exposure to radiation from residual contaminants in the soil).

- **Soil Ingestion Route**. The scenario assumes that a worker ingests 25 grams (0.88 ounces) of contaminated soil each year.

- **Inhalation Route**. The scenario assumes that the air contamination inside a building is 40% of the outside air particle concentration (which is assumed to be 0.0002 grams per cubic meter from residual soil contamination).

Cleanup levels for chemicals in the 300 Area industrial land-use scenario are based on WAC 173-340, which assumes that the exposure pathway for residual contamination will be from ingestion of contaminated soil. Soil cleanup levels are calculated using the equations provided by WAC 173-340 Method C (WAC 173-340-745), for carcinogens and for non-carcinogens. For both carcinogens and non-carcinogens, the calculations assume that a person weighing 70 kilograms (154 pounds) ingests soil at a rate of 50 milligrams (0.0017 ounces) per day, with a frequency of contact of 40% and a gastrointestinal



Pathway	Potential Exposure Routes	Potential Receptors – Humans: Industrial Land Use	Ecological[1]: Terrestrial	Ecological[1]: Aquatic
Air	External Radiation	INC	INC	INC
	Ingestion	INC	INC	INC
	Inhalation	S	S	S
Soil	External Radiation	●	●	●
	Ingestion	S	S	S
	Inhalation	S	S	S
Surface Water	External Radiation	INC	INC	INC
	Ingestion	INC	S	S
	Inhalation	INC	INC	INC
Solid Waste	External Radiation	●	●	●
	Ingestion	S	S	S
	Inhalation	INC	INC	INC
Groundwater	External Radiation	INC	INC	INC
	Ingestion	S	INC	INC
	Inhalation	INC	INC	INC
Biota	External Radiation	INC	INC	INC
	Ingestion	INC	S	S
	Inhalation	INC	INC	INC

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● Primary exposure pathway
S Secondary exposure pathway
INC Incomplete or inconsequential exposure pathway
1 Includes both Terrestrial and Aquatic Plants and Animals

Figure 4.30. Conceptual Site Model for the 300-FF-1 Operable Unit, Current Status

absorption rate of 100. For carcinogens, the calculation is based on achieving a lifetime cancer risk goal of 1 in 100,000 (1×10^{-5}) for an exposure duration of 20 years and a lifetime of 75 years. For non-carcinogens, the calculation is based on achieving a hazard quotient of 1.

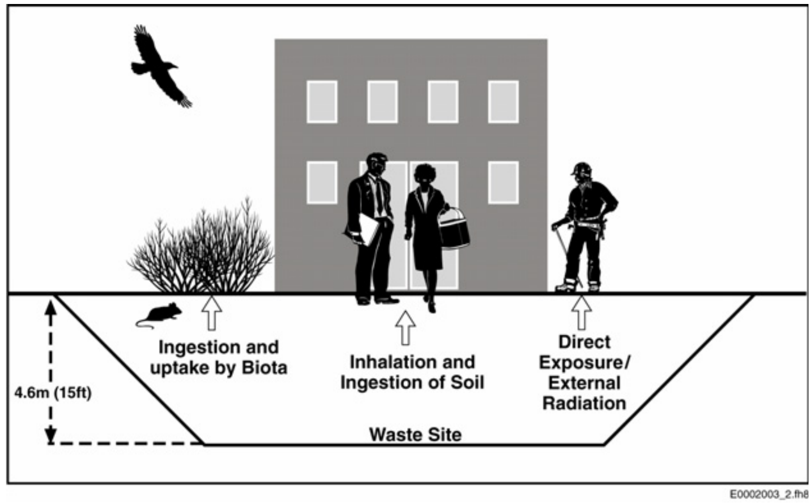

Figure 4.31. Conceptual Site Model Primary and Secondary Exposure Pathways

The 300-FF-2 record of decision (EPA 2001) also requires that the soil cleanup level used not cause contamination of groundwater above drinking water standards or WAC 173-340 Method B cleanup levels (even though groundwater ingestion is not an applicable exposure pathway in the industrial land-use scenario). The key modeling parameters that affect the analysis of groundwater protection are (1) the hydraulic parameters of the aquifer and contaminant characteristics (e.g., distribution coefficient [K_d] values and leach rates), (2) the evapotranspiration rate (i.e., evaporation and plant uptake of precipitation), and (3) the amount of water applied for irrigation purposes. The key assumptions in the 300 Area industrial land-use scenario that affect the groundwater protection determination are (1) vegetation not requiring irrigation will be grown on the waste site after the cleanup is complete or the waste site will be resurfaced to reduce water infiltration (thus allowing for a higher, 0.91, evapotranspiration coefficient to be used), and (2) no water will be applied to former waste site locations for irrigation purposes. These assumptions can only be modified if it can be demonstrated that there will be no negative impact on groundwater quality from residual contamination at former waste site locations, which requires EPA approval in advance.

Finally, it is assumed that (1) no sensitive human subpopulations (e.g., children) are permitted to come into contact with residual soil or debris contamination from waste sites (i.e., the cleanup levels are based on exposures to adults), (2) the period of analysis for evaluation of site risks and groundwater protection is 1,000 years, and (3) direct exposure of onsite workers to residual contamination to a depth of 4.6 meters (15 feet) may occur (this represents a reasonable estimate of the depth of soil that could be excavated and distributed at the soil surface as a result of site development activities).

4.4 400 Area

Being developed.

4.5 600 Area

Being developed.

4.6 1100 Area

The 1100 Area served primarily as the vehicle maintenance and transportation area for the Hanford Site. The primary contaminants in these areas were hazardous substances associated with vehicle maintenance including asbestos, lead batteries, and sulfuric acid, steam cleaning liquids containing trichloroethene, and spent antifreeze. Also included within the 1100 Area, are a number of spills, disposal areas, electrical transformers, and several tanks used to store fuel and chemical solvents spread across ALE, which has recently been incorporated into the Hanford National Monument. Contaminants in these outlying areas are primarily herbicides and other common chemicals. The 1100 Area did not house any radioactive operations.

Groundwater beneath the 1100 Area was found to contain trichloroethene in the region surrounding the Horn Rapids landfill.

A record of decision for cleanup of the entire 1100 Area was issued in September 1993 (EPA 1993). This decision required all of the area to be cleaned to an unrestricted use status with the exception of the Horn Rapids Landfill. The landfill was closed with contaminants in-place consistent with the requirements for sites that contain PCBs and asbestos. This decision also invoked the use of monitored natural attenuation for the trichloroethene in the groundwater beneath the landfill. After 5 years, the trichloroethene in the groundwater has declined to near drinking water standard and is expected to continue this decline.

Remedial actions were deemed complete in July 1996 with the approval of the final closeout report and was followed shortly thereafter in September 1996 with its deletion from the NPL. It is expected that the entire 1100 Area has achieved a safe and protective condition with no further actions beyond the land-use restriction at the Horn Rapids Landfill needed to meet the required end state.

5.0 Variance Discussion

The purpose of this section is to describe how existing Hanford-specific cleanup decisions documented in the Tri-Party Agreement (Ecology et al. 1998) may vary from the new DOE Risk-Based End States Policy (455.1). Existing cleanup decision documents were examined to determine if they are consistent with end states described in Chapter 3. DOE recognizes that a management plan for the Hanford Reach National Monument is being developed by the U.S. Fish and Wildlife Service. In addition, various tribal scenarios along the River Corridor are being developed to support a River Corridor Area Risk Assessment. When these plans and risk exposure scenarios are developed, this variance assessment will need to be re-evaluated. However, identification of a variance does not in itself require that the cleanup decision documents be renegotiated. DOE will further examine the variance and weigh the pros-and-cons of proposing changes to cleanup agreements. Any changes proposed by DOE will be through the procedures defined in the Tri-Party Agreement.

The building blocks for developing a RBES vision for the Hanford site have been accumulating since the cleanup mission was initiated. Key pieces include the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999a) which identifies land uses following site cleanup, the creation of *Development of a Risk-Based Approach to Hanford Site Cleanup* (Hesser et al. 1995) and more recently the development by DOE, EPA, and Ecology of the Central Plateau Risk Framework in October 2001. The consideration of risk in planning the cleanup of Hanford goes back to the development of the Tri-Party Agreement among DOE, EPA, and Ecology.

The following sections present several areas where a variance has been identified between the baseline plans and the cleanup that would result if driven by clearly defined risk-based end states consistent with current land-use planning.

5.1 Background

EPA provides guidance about the role of land-use decisions in the CERCLA remedy selection process. The guidance is part of the CERCLA process and is embodied in two directives:

- *Land Use in the CERCLA Remedy Selection Process* (the Superfund Land Use Directive, OSWER 9355.7-04, EPA 1995b)
- *Reuse Assessments: A Tool To Implement The Superfund Land Use Directive* (OSWER 9355.7-06P, EPA 1995c)

Additional discussions on how land-use decisions are used in the CERCLA process appear in a variety of EPA guidance documents. Published guidance recognizes that the reasonably anticipated land use is important under CERCLA to determine the types and frequency of exposures that could occur from any residual contamination, thereby indicating the degree of cleanup necessary through risk assessments. Cleanup decisions must also use applicable or relevant and appropriate requirements that may not be totally risk-based.

Published regulatory guidance and DOE Policy 455.1 recognizes that the regulatory agencies do not establish future land use at CERCLA sites; the agencies are to use appropriate determinations by established land-use authorities. Authority to make future use plans at DOE facilities was assigned to the Secretary of Energy by Congress in Public Law 104-201, requiring the Secretary of Energy to develop a future use plan for Hanford.

The EPA land-use guidance states that, to the extent possible**,** EPA is to use readily available information to assess future land use. At sites where land-use decisions have already been determined and documented, a simple review to confirm the information may be all that is necessary. The Hanford CLUP documented in DOE (1999a) serves as the basis of Hanford's land use planning. This Congressionally mandated land-use plan was formally developed using the process established by the National Environmental Policy Act (NEPA).

Early input from a public forum on the range of foreseeable land uses was received from the ad hoc Future Site Uses Working Group, which preceded the Hanford Advisory Board. The 1992 report *The Future for Hanford: Uses and Cleanup – The Final Report of the Hanford Future Site Uses Working Group* (DOE 1992b) has no legal status for land-use planning. However, it does provide public input on the spectrum of land uses envisioned by Northwest stakeholders. More current advice from the Hanford Advisory Board has been consistent with advice from this group (see Appendix B). Additional input was received from (among other stakeholder groups) the Hanford Tank Waste Task Force and the Hanford Advisory Board.

Consistent with EPA CERCLA guidance regarding the importance of community involvement in making land-use decisions, development of the Hanford land-use plan (DOE 1999a) included an extensive public participation effort involving the general public in addition to nine cooperating agencies (including local city and county planning entities) and consulting tribal governments. Over 400 comment documents were received by DOE on the revised draft of the land-use plan, along with over 200 pages of transcripts from four public hearings. Based on EPA and CERCLA guidance and DOE Policy 455.1, the CLUP should be used in developing assumptions about future land use. Draft Hanford land-use plans by local (city and county) authorities – although not legally enforceable – were generally consistent with the decision made in the Hanford plan through the NEPA process. Notably, none of the future land-use plans at the time called for future residential use of Hanford lands.

EPA guidance states that alternative land-use scenarios are not necessary in cases where the future land use is relatively certain. Several factors indicate that future land use at Hanford is relatively certain, at least on a broader scale. These factors include the issuance of the CLUP (DOE 1999a), consistency between the DOE determination and city and county planning efforts, the Presidential proclamation establishing portions of the Hanford Site as a National Monument (65 FR 37253), and the ongoing use of certain areas of the Hanford Site for waste management. Details associated with the likely exposure scenarios remain (e.g., exposure time frames and scenarios associated with a preservation/ conservation land use); however, alternative scenarios involving residential land use are outside the realm of what would be considered reasonable in the CERCLA context given the fairly high level of certainty about future land use at Hanford.

In accordance with Congressional direction, the Hanford land-use planning window is for a *minimum* of 50 years. The plan establishes a living document with provisions for periodic reassessments and adjustments. In contrast with the 50-year-minimum time frame covered by the Hanford land-use plan (DOE 1999a), a 20-year time horizon is frequently used by community land-use planning authorities. For example, the state of Washington's Growth Management Act (Revised Code of Washington [RCW] 36.70A) establishes a 20-year planning period for cities and county planning. The 20-year standard land-use planning period is acknowledged and accepted as a basis for future land use determinations in EPA and CERCLA guidance. *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents* (EPA 1999b) issued by EPA identifies "20-year development plans" as an example of documents that can be used as a basis for future land-use assumptions.

It is vitally important to consider regional and local values in cleanup decisions. These values have been articulated by the Future Site Uses Working Group, the Hanford Advisory Board, tribal nations, local land-use authorities, and the general public and were considered in the development of the CLUP under NEPA. Much of the cleanup work currently performed at Hanford is being performed under the authority and requirements of interim action records of decision that were developed in the period between 1994 to 1996, prior to the completion of Hanford land-use plans and the presidential declaration of the Hanford Reach National Monument. In general, these interim action records of decision provide for a level of protectiveness that would allow for unlimited surface use of Hanford lands adjacent to the Columbia River in the 100 and 1100 NPL sites. The interim action records of decision for the 300 Area would provide for a level of protectiveness that would allow for industrial use scenarios of Hanford lands adjacent to the Columbia River in the 300 NPL site.

Although no records of decision exist for the 200 Area soil sites, it is anticipated that such cleanup would support industrial use scenarios for the lands not used for waste disposal activities within the 200 Area Core Zone. Lands currently used as a "buffer zone" for safety purposes may eventually shrink as cleanup progresses. However, Hanford operational requirements may define the long-term safety buffer. It is anticipated that cleanup would support an eventual unrestricted surface use for the waste sites within the buffer zone outside the 200 Area Core Zone.

The primary pathway for Hanford contaminants to reach the current accessible environment is through the groundwater pathway. Existing groundwater plumes have been examined by DOE, EPA, and Ecology for risk to the environment and to the public. Interim measures, generally pump-and-treat systems, have been applied to groundwater plumes that were thought capable of migrating from the Central Plateau or thought to pose a risk at the Columbia River. These decisions are documented in interim action records of decision. Groundwater interim action records of decision in the 100 Area are designed for containment of existing plumes. For instance, chromium pump-and-treat systems were put in place partly to meet requirements to protect aquatic resources such as important potential salmon nesting habitat. Groundwater interim action records of decision in the 200 Area are designed to reduce the mass of contaminant in the aquifer and to contain plumes of carbon tetrachloride, uranium, and technetium-99. There are no groundwater interim action records of decision designed to cleanup Hanford groundwater for consumptive uses. It is anticipated that protection of the Columbia River environmental resources and its users will remain as the foremost priority that will drive Hanford groundwater cleanup decisions. A secondary anticipated groundwater remediation goal will be containment of existing groundwater plumes within the Central Plateau where practicable. CERCLA processes will be initiated to determine the final groundwater cleanup requirements.

The overall negotiated cleanup strategy for Hanford has been to first and foremost, protect the Columbia River for unlimited use scenarios. Secondly, the strategy has been to consolidate contaminated soil and debris from waste sites along the Columbia River, to the extent practicable in the Central Plateau and to protect human health and the environment under unlimited use scenarios in the 100 and 1100 NPL sites and under industrial use scenarios in the 300 Area. These strategies were developed through intense negotiations with the EPA and Ecology throughout the cleanup effort under the Tri-Party Agreement (Ecology et al. 1998). Extensive public interaction has occurred throughout this process including the Future Site Uses Working Group and the Hanford Advisory Board. In addition, there has been extensive consultation with tribal, regional and local governments including the state of Oregon. Stakeholder and tribal values have been given consideration in the existing interim action records of decision. Extensive advice has been documented concerning future land use, appropriate cleanup levels, and acceptable scenarios to be used in risk assessments.

5.2 100 Area Descriptions of Variance

Cleanup actions in the 100 Areas (excavation and removal of contaminated soil and debris) could be more than the minimum required to support land uses envisioned in the Hanford Comprehensive Land Use Plan (DOE 1999a) and the Presidential proclamation of the Hanford Reach National Monument (65 FR 37253).

Description of the 100 Area Variance Impacts. Cleanup actions in the 100 Area are designed to protect human health and the environment in unlimited surface use scenarios. This is consistent with the uncertainties in the Hanford comprehensive land use plan (DOE 1999a) and Hanford Reach National Monument (65 FR 37253); however it is unclear at this time just how much excavation would be required to meet the envisioned land use. For example, excavation to approximately 4.6 meters (15 feet) might be needed to support certain tribal scenarios. In supporting these unrestricted surface use scenarios, current cleanup actions, which were put in place prior to the Hanford CLUP (DOE 1999a), would also support (1) residential use as long as no groundwater is used in support of the residences, and (2) irrigated agriculture as long as the source of the irrigation water was the Columbia River. Neither unrestricted use nor unrestricted crop irrigation is the objective of the interim action records of decision nor are they envisioned in current land-use planning.

Nonetheless, depending on precisely how the land is eventually used under the general scenarios in current land-use planning, current cleanup actions could prove to be excessive. The interim action records of decision require excavation of contaminated soil and debris to 4.6 meters (15 feet) below ground surface to protect human health and the environment in unlimited surface use scenarios and to protect groundwater from further degradation. No exposure scenarios included consumptive use of groundwater, recognizing that it is impractical to cleanup groundwater to drinking water standards in the near-term. Current land-use plans do not envision residential development of the 100 Area. The interim action records of decision were developed prior to the Hanford comprehensive land use plan (DOE 1999a) and the Presidential proclamation of the Hanford Reach National Monument (65 FR 37253).

It is difficult to quantify the scope, cost and schedule impacts of the variance at this time. A new River Corridor risk assessment on protection of human health and the environment will help determine these impacts. It is anticipated that area tribes will be able to perform traditional fishing activities under the conservation and preservation land use. A RBES should be protective of these activities. In addition to the human health scenario, an ecological risk assessment needs to be performed for the River Corridor. Until these risk assessments are completed, it will be difficult to determine the impact of the variance.

Barriers to Achieving RBES. The primary barrier to the RBES vision is the absence of a final record of decision for the 100 Area NPL site. The preferred pathway to RBES is using the CERCLA process to achieve a final record of decision.

Recommendation/Next Steps. DOE-RL does not recommend modification of the planned 100 Area cleanup activities due to the uncertainties in the amount of excavation necessary to protect human health and the environment under planned future uses in the 100 Area, the potential costs for characterization and the potential for future natural resources damage liabilities associated with alternatives that leave waste in place.

The River Corridor has developed a close-out strategy. Figure 5.1 shows the close out process for the River Corridor. The process shows a River Corridor risk assessment to support final remedy decisions for the 100 and 300 Areas. Once the final remedy decisions are in place, the process follows CERCLA protocols to achieve close out.

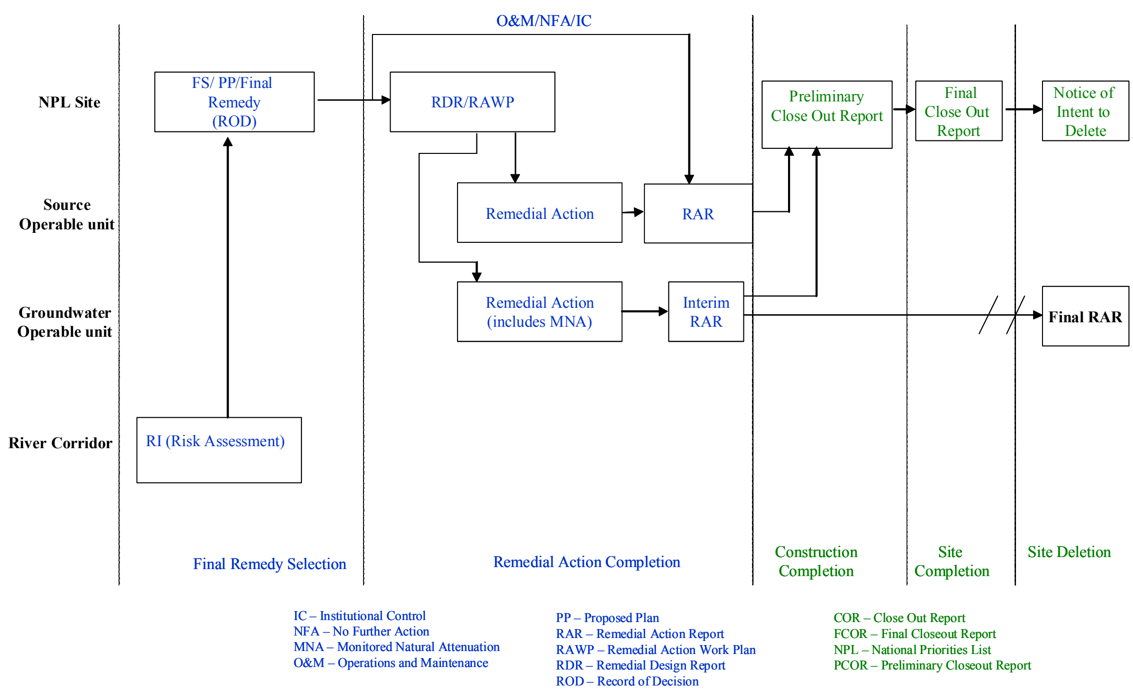

Figure 5.1. River Corridor NPL Close Out Process

Key to the close-out strategy is the River Corridor Area Risk Assessment. A detailed schedule is still in development; however, it is anticipated that the scoping process and a work plan will be completed in FY 2004. In addition, the data quality analysis to determine what additional data is required will start in FY 2004. Final remedies could be in place by FY 2008.

Prior to completing the final remedy decisions in the 100 and 300 Areas, the interim action records of decision will continue to be implemented. Cleanup actions in the 100 Area are designed to protect human and ecological health under unlimited surface use scenarios while much of this region has been designated a national monument. As a national monument many land uses that lead to higher exposures (such as residential land use) will likely not be allowed. The U.S. Fish and Wildlife Service is developing a comprehensive conservation plan that will further define potential land uses for the national monument.

Cleanup plans will most likely not be modified to leave more contamination in place. One of the foremost reasons is that a large percentage of the cleanup in the 100 Areas is already complete. Cleanup of approximately 75% of the 100 Area liquid waste discharge sites has been completed at this time and cleanup is underway at other waste sites.

The interim action records of decision also reflect long-standing negotiated agreements with the regulators that are integral to existing and future groundwater and 200 Area cleanup agreements. Revisiting these decisions to reduce the level of cleanup planned may stall the cleanup process as all agreements will be opened to question. Renegotiation of the existing interim action records of decision will likely negatively affect other existing and future cleanup agreements. In addition, the interim action records of decision reflect tribal and stakeholder values.

It can be argued that the requirement to remove the contents of the solid waste burial grounds and the excavation depth requirements of the interim action records of decision are excessive in light of the Hanford Reach National Monument designation and the CLUP record of decision (64 FR 61615). However, there are mitigating factors that must be considered when the interim action record of decision requirements are reassessed.

The interim action records of decision assumed that extensive characterization of the solid waste burial grounds would be necessary to provide sufficient data to perform risk assessments that would allow DOE to leave the burial grounds in place adjacent to the Columbia River. Engineering evaluations indicated that the larger burial grounds would cost more to characterize than to exhume and transport to the 200 Area for permanent disposal. Recent discoveries of unexpected burial ground contents in the 300 Area confirm the need for extensive characterization to support leave-in-place decisions. Removal and consolidation of 45 separate and dispersed 100 Area solid waste burial grounds to the Environmental Restoration Disposal Facility will allow for more effective and efficient management of these wastes under long-term stewardship.

5.3 Central Plateau Decisions

The remedial decision-making process is in its early stages for the 200 Area waste sites, and there are no interim action records of decision except for interim groundwater decisions. In the 200 West Area, containment and mass reduction interim actions are underway to limit future degradation of groundwater outside the boundaries of the Central Plateau due to uranium and technetium-99 from the 200-UP-1 Operable Unit and from carbon tetrachloride contamination from the 200-ZP-1 Operable Unit. Actions were initiated in these locations due to elevated concentrations of these contaminants in the groundwater and the massive inventory of these substances that remain unaccounted for in the vadose zone. While some source control actions have been initiated (e.g., the retrieval and shipment of transuranic material to the waste isolation pilot plant, the packaging of plutonium for long-term storage, and carbon tetrachloride removal), many future source control measures are some years out. In the meantime, measures have been taken, such as capping leaking water lines, decommissioning unused wells, and controlling runoff to stop the future migration of contaminants in the vadose zone to the groundwater. Once source control is completed, and the impact on groundwater can be evaluated, final groundwater decisions can be made.

Single-Shell Tanks. As presented in Chapter 4, Tri-Party Agreement Milestone M-45-00 indicates that waste shall be retrieved from single-shell tanks to the limits of the technology (or technologies) selected. As much waste as is technically possible will be retrieved, with remaining residuals of no more than 10.2 cubic meters (360 cubic feet) for 100-series tanks and 0.85 cubic meters (30 cubic feet) for 200-series tanks. If the retrieval goal is not met for a specific tank, DOE will request an exception to the criteria in the manner specified in Appendix H of the Tri-Party Agreement (Ecology et al. 1998) based on retrieval performance, cost, and risk. No variance between the RBES policy and the selection, retrieval, and closure of single-shell tanks exists at the present time.

5.4 300 Area Description of Variance

Cleanup actions for liquid waste disposal sites and solid waste burial grounds for the 300 Area NPL sites are continuing under the authority of records of decision. The records of decision (both final and interim) are written to protect industrial use scenarios consistent with the CLUP (DOE 1999a).

One variance identified in the 300 Area is the cleanup of eight isolated waste sites outside the 300 Area core industrial zone to an unrestricted surface use scenario. DOE committed to stakeholders requests to evaluate the incremental cost to cleaning up these sites to a more restrictive scenario. When the increase in cost came out small, DOE-RL decided to initiate discussions with the regulators to change the record of decision for these eight burial grounds.

Description of Variance Impacts. It has been estimated that there will be an extra $750,000 (or less than 1%) additional cost for remediation of the eight burial grounds to stricter standards. Approximately $500,000 of the extra cost comes from one burial ground. This additional cost is balanced by the reduction of incremental long-term stewardship costs in this area and the reduction of trustee settlement liabilities.

Recommendations/Next Steps. DOE-RL plans to continue to consider changes to the record of decision to cleanup the eight waste sites outside the 300 Area core industrial zone to an unrestricted surface use scenario. There is a small cost difference and there will be intangible benefits for this additional cleanup.

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Appendix A

200 Area Alternatives Considered

Appendix A

200 Area Alternatives Considered

Alternative 1 - Engineered Surface Barriers With or Without Vertical Barriers

Alternative 1 consists of engineered surface barriers that would be designed to remediate different types of waste. Alternative 1 would provide a permanent cover over the affected area. The cover would accomplish the following: minimize the migration of precipitation into the affected soil and contaminant leaching; minimize the potential for biotic intrusion; reduce the migration of windblown dust that originated from contaminated surface soils; reduce the potential for direct exposure to contamination; and reduce the volatilization of volatile organic compounds (VOCs) to the atmosphere. If vertical barriers were included, they would limit the amount of lateral migration of contaminants and limit the horizontal movement of moisture beneath the surface barrier. An option for dynamic compaction is also included in this alternative for application at solid waste landfills prior to surface barrier construction to reduce settlements and subsidence that may impact the integrity of a surface barrier. This alternative would not reduce the volume or toxicity of the contaminants, and periodic inspections, maintenance, and monitoring would be required for an indefinite period.

Alternative 2 - Excavation and Disposal With or Without Ex Situ Treatment

Radioactive and hazardous soil or solid debris would be excavated using conventional techniques, with special precautions to minimize fugitive dust generation. If needed, several treatment options could be selected from physical, chemical, and thermal ex situ treatment process options. For example, thermal desorption with offgas treatment could be used if organic compounds are present; soil washing or mechanical separation could be used to separate contaminated fine-grained soil particles; and stabilization/solidification could be used to immobilize radionuclides and heavy metals or to satisfy the treatment option for land disposal restricted wastes. The treated soil would be backfilled into the original excavation or landfilled. Soil treatment by-products may require additional processing or treatment.

Both onsite and offsite landfill disposal options are included in the alternative depending on the nature of the waste. The Environmental Restoration Disposal Facility located adjacent to the 200 Areas is the preferred disposal facility because it has been specifically constructed to handle low level radioactive and/or hazardous waste from environmental remediation activities on the Hanford Site. The offsite disposal option is identified as a contingency for waste forms or contaminants prohibited at the Environmental Restoration Disposal Facility.

Alternative 2 would be effective in treating a full range of contamination, depending on the type of treatment processes selected. Attainment of remedial action objectives would depend on the depth to which the material was excavated. If near surface soil or buried waste was treated, airborne contamination, direct exposure to contaminated soil, and bio-mobilization of contamination would be minimized. Because of practical limits on deep excavation, deep contamination may not be removed and would be subject to migration into groundwater. If further degradation of the groundwater were a concern, additional treatment of deep contamination would be needed. For example, Alternative 2 could be used in conjunction with Alternative 4 (in situ grouting or stabilization of soil) to stabilize deep contaminants.

Alternative 3 - Excavation, Ex Situ Treatment, and Geologic Disposal of Material With Transuranic Radionuclides

Certain waste sites in the 200 Areas may contain isolated zones where the concentration of transuranic radionuclides exceeds 100 nCi/g. For Alternative 3, the soil or solids from those isolated zones would be excavated, stabilized or treated, and shipped to an offsite geologic disposal site.

This alternative would use many excavation and treatment technologies that have been only partly demonstrated at industrial sites. Extensive treatability testing would be required for the transuranic-containing soil to develop optimum methods for treating or stabilizing the transuranic radionuclides. Additional treatability studies might be required to support the aboveground treatment of the non-transuranic soil. The use of remotely controlled excavation and material handling equipment may be needed.

Alternative 4 - In Situ Grouting or Stabilization of Soil

Radioactive and hazardous soil would be grouted using in situ injection methods. The end product is monolithic block of contaminated material encapsulated in grout which would significantly reduce the leachability of hazardous contaminants, radionuclides, and/or semivolatile organic compounds from the affected soil. Grouting may also be used to fill voids, such as in timbered cribs, thereby reducing subsidence. Another variation of this alternative would be to stabilize the soil using in situ mixing of soil with stabilizing compounds such as fly ash.

Alternative 4 would provide a combination of immobilization and containment of heavy metal, radionuclide, inorganic, and semivolatile organic compound contamination. Thus, this alternative would reduce migration of precipitation into the affected soil, reduce the migration of windblown dust that originated from contaminated surface soils, reduce the potential for direct exposure to contaminated soils, and possibly reduce the volatilization of VOCs. Because this alternative would not remove the contaminants from the soil, it is likely that institutional controls would be required.

Alternative 5 - In Situ Vitrification of Soil

The contaminated soil in a subject site would be immobilized by in situ vitrification. High-power electrodes would be used to vitrify the contaminated soil under the site to a depth below where contamination is present. Fences and warning signs may be placed around the vitrified monolith to minimize disturbance and potential exposure.

In situ vitrification would be effective in treating radionuclides, heavy metals, and inorganic contamination, and can also destroy organic contaminants. This would reduce the potential for exposures by leaching to groundwater, windblown dust, and direct dermal contact. However, this alternative would not remove metals or radionuclides from the soil and would likely require additional institutional controls. In situ vitrification may be limited to depths of less than about 6 meters (20 feet), which may not be adequate to immobilize deep contamination.

Alternative 6 - In Situ Soil Vapor Extraction for Volatile Organic Compounds

Soil vapor is drawn from wells that are screened in permeable soil zones that contain high organic vapor concentrations. The vented air would be treated to remove water vapor, the organic vapor of concern, particulate radionuclides that might be entrained in the air stream, and volatile radionuclides.

Alternative 6 utilizes proven technologies to remove the volatilized vapors from the vadose zone soil. No additional treatability testing is expected to be needed for this process because it has been successfully implemented in the 200 Areas near Z Plant. Soil vapor extraction would reduce downward and lateral migration of the VOC vapors through the vadose zone, and thereby reduce potential cross-media migration into the groundwater. Soil vapor extraction would reduce upward migration of VOC through the soil column into the atmosphere, and thereby minimize inhalation exposures to the contaminants. In some cases where radionuclides were discharged to the disposal sites with VOCs (e.g., carbon tetrachloride), the removal of VOCs could reduce the mobility of the radionuclides, and thereby reduce the potential for downward migration of the radionuclides. Finally, soil vapor extraction would enhance partitioning of the VOC off of the soil and into the vented air stream, resulting in the permanent removal of the VOC. Alternative 6 may be used in conjunction with other alternatives if contaminants other than VOCs are present.

Alternative 7 - Monitored Natural Attenuation

This alternative includes a variety of contaminant-specific physical, chemical, or biological processes to reduce the mass, activity, toxicity, mobility, volume, or concentration of contaminants in soil or solid debris. The alternative would include sampling and environmental monitoring, consistent with EPA guidance (EPA 1997), to verify that contaminants are attenuating as expected and to ensure that contaminants remain isolated (i.e., will not lead to further degradation of groundwater). As part of the site-specific detailed analysis of this alternative, the hazards and mobility of the possible transformation or daughter products must be addressed.

Sampling activities would include:

- Sampling contaminated materials and the soils below the sites to verify the nature and extent of contamination
- Verify the hydrogeologic, geochemical and/or biological properties of the vadose zone important to the attenuating processes
- Serve as a monitoring baseline
- Support predictive modeling, if needed.

Environmental monitoring (e.g., vadose zone and/or groundwater) would be conducted to ensure waste containment is achieved and no further degradation of groundwater occurs. The existing network of groundwater monitoring wells in the 200 Areas should be adequate for monitoring most sites. Vadose zone monitoring may be appropriate to verify the effectiveness of attenuating processes and as an indicator of potential future groundwater impacts.

Monitored natural attenuation may be used as a complete remedial alternative, in conjunction with other remedial alternatives, or as a follow-up activity to remedial measures already completed. As a standalone option, monitored natural attenuation is considered most applicable to low-mobility contaminants with limited persistence, where the source is controlled, contaminant plumes that are stable or shrinking, and where potential surface exposure is minimal. If the ability of natural attenuation to meet site-specific RAOs is uncertain, contingency measures (e.g., defaulting to another alternative) should be identified. In any case, institutional controls will likely be necessary to ensure long-term protectiveness.

The preliminary remedial action alternatives identified previously for use in the 200 Areas comprise the complete list of alternatives. However, not all alternatives are applicable to all waste groups. For example, in situ vapor extraction would not be applicable for waste groups that do not have volatile organic soil contamination. Criteria used to evaluate the applicability of alternatives to specific waste groups include:

- Installing engineered surface barriers with or without vertical barriers (Alternative 1) could be used on sites where contaminants may be leached or mobilized by the infiltration of precipitation.
- Excavation and disposal with or without soil treatment (Alternative 2) could be used at most waste sites that contain shallow contamination including; radionuclides, heavy metals, other inorganics compounds, semivolatile organic compounds, and VOCs.
- Excavation, treatment, and geologic disposal of transuranic-containing soils (Alternative 3) could be used only on those sites that contain transuranic radionuclides. Since a geologic repository is likely to accept only transuranic radioactive soils or transuranic/mixed waste, the non-transuranic radioactive soils will not be remediated using this alternative.
- In situ grouting or stabilization (Alternative 4) could be used on waste sites that contains heavy metals, radionuclides, and/or other inorganic compounds. In situ grouting could also be effective in filling voids for subsidence control.
- In situ vitrification (Alternative 5) could be used at most waste sites although this alternative is considered to be most applicable to sites that contain high concentrations of contamination in a small area. Vapor extraction may be needed when VOCs are present. In situ vitrification would not be effective at sites where deep contamination or combustible solid debris is present.
- In situ soil vapor extraction (Alternative 6) could be used on any sites that contain VOCs.
- Natural attenuation (Alternative 7) is applicable at any waste site.

Using these criteria, Table A.1 shows preliminary remedial action alternatives that could be used to remediate specific waste groups. A single alternative may not be sufficient to remediate all contamination within a single group. For example, it may be more feasible to place engineered surface barriers at certain waste sites within a group while at other sites excavation and disposal may be more appropriate.

Furthermore, some waste sites may require a combination of alternatives. For example, soil vapor extraction to remove organic contaminants could precede in situ vitrification. Detailed feasibility studies will be required to refine and more fully evaluate alternatives as they relate to the specific waste sites.

To date, no final remedial actions have been taken on the 200 Area waste sites. Numerous stabilization actions have been taken to prevent movement of contamination from waste sites, such as applying 46 to 61 centimeters (18 to 24 inches) or more of clean soil over waste sites and controlling animal and plant intrusion. These interim stabilizations provide some protection to human and ecological receptors, but do not necessarily provide a final solution.

Maps A.1 and A.2 show the surface barriers sites in the 200-East and 200-West Areas.

Table A.1. Remedial Action Alternatives

Waste Group	Alternative 1 - Engineered Surface Barrier	Alternative 2 - Excavation and Disposal	Alternative 3 - Excavation, Ex Situ Treatment, and Geologic Disposal of Transuranic Soil	Alternative 4 - In Situ Grouting or Stabilization	Alternative 5 - In Situ Vitrification of Soil	Alternative 6 - In Situ Soil Vapor Extraction	Alternative 7 - Monitored Natural Attenuation
Process Condensate and Process Waste Category	•	•	•	•	•	•	•
Steam Condensate, Cooling Water, and Chemical Sewer Category	•	•	•	•	•		•
Chemical Laboratory Waste Category	•	•	•	•	•	•	•
Miscellaneous Waste Category	•	•		•	•		•
Tank and Scavenged Waste Category	•	•	•	•	•		•
Tanks/Lines/Pits/Boxes Category		•	•	•	•		•
Unplanned Releases Category	•	•	•	•	•		•
Septic Tank and Drain Fields Category		•					•
Landfills and Dumps Category	•	•	•	•			•

Appendix B

Hanford Advisory Board Advice for Risk-Based End States

To: Mike Thompson

From: Todd Martin

Date: 18 October 2003

Re: HAB advice pertaining to Risk Based End States

Mike, below are some select passages from HAB advice that bear on the RBES discussion. This quick summary comes with a couple of caveats.

First, it is always a bit dicey to take any individual comment out of the context of its original piece of advice. As a result, these are reference points for you on how the Board might lean on any particular issue as opposed to hard, fast stances.

Second, this doesn't represent an exhaustive review of HAB advice and adopted products (such as the Future Site Uses Working Group Final Report). Rather, this is a quick review of input the Board has provided over the last couple years on these topics.

I hope this is useful and don't hesitate to contact me if you have questions (250/362-5629 or toddmartin@telus.net).

Advice #125:

> "Groundwater remains of foremost concern to the Board. The Board encourages the agencies to maintain ongoing successful groundwater remediation actions and pursue more aggressive technology development and treatment activities."
>
> Board advised that 300 Area cleanup should be comprehensive (e.g. include all facilities and waste sites).
>
> "The Board also recommends DOE's approach to cleanup priorities in the 300 Area be based on risks to workers, the public and the environment with appropriate consideration to infrastructure and mortgage reduction issues."
>
> "Consistent with past Board advice, the cleanup goal 'outside the 300 Area fence' should be unrestricted use." The Tri-Party Agreement agencies response to this was essentially, 'it will remain industrial.' This is an example of where the RBES process may bring the 300 Area cleanup closer to HAB values.

Advice #128:

> "The Board advises that a comprehensive risk assessment, including quantitative analyses be developed to guide cleanup decisions."

Advice #129:

> "Any decision to relax current standards to accelerate cleanup and reduce costs must be supported by credible risk assessments, for example, leaving waste in tanks, reclassifying wastes, and possible increases in soil disposal."

Advice #131:

"Currently the Board defines compliance with the Tri Party Agreement (TPA) and its processes as the blueprint for responsible cleanup."

This advice also identified a sort of variance analysis saying that the PMP should, "identify acceleration proposals not in compliance with current orders, rules and laws, or in keeping with the TPA."

Advice #132:

"The Board acknowledges that some waste will remain in the core zone when this cleanup effort is complete. However, the core zone should be as small as possible and should not include contaminated areas outside the 200 Area fences. The waste within the core zone should be stored and managed to make it inaccessible to inadvertent intruding humans and animals."

"A continued human presence in the core zone would provide an ongoing, active institutional interest vested in future management of the risks posed by Hanford waste. One way to ensure this continuous human presence is to maximize the potential for any beneficial use of the accessible areas of the core zone, rather than rely only on long-term government control of these areas."

"Groundwater is a valuable resource with beneficial future uses that must not be restricted outside of the individual waste management unit points of compliance within the core zone."

"For the Central Plateau, the Board advises the agencies to analyze a range of potential human health and ecological risks, including the reasonable maximum risk expected over time. The stakeholder community will use this analysis to advise the agencies on appropriate cleanup decisions. The risk analysis should include: a reasonable maximum exposure to a resident and/or Native American, including groundwater use, in what is currently labeled the buffer zone and in areas freed up for use as the core zone shrinks. For the waste management areas within the core zone, exposure scenarios should include a reasonable maximum exposure to a worker/day user, to possible Native American users, and to intruders."

Advice #135:

"Consistent with its previous advice on risk assessment and exposure scenarios, the Board recommends that a spectrum of analyses and scenarios be run to include tribal use, recreational and rural residential uses in the river corridor. The agencies should consider tribal and recreational use scenarios for all lands within at least one-quarter mile from the river shoreline. In the upland areas of the river corridor, tribal, recreational and rural residential scenarios should be used. Results of risk analyses and exposure scenarios need to be communicated with the public prior to making any decisions based on these efforts."

"Groundwater in the river corridor should be remediated to meet drinking water and ambient water quality standards by the time DOE petitions the EPA to remove the river corridor from the National Priorities List."

Advice #145:

> "Activities must do no further harm to groundwater and groundwater should be cleaned up to its highest beneficial use. The Department of Energy's Hanford site Groundwater Strategy and Groundwater Implementation Plan, and all DOE plans, strategies and actions should reflect that goal."