Appendix K

Nonoperational Area Evaluation

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Terms

BCAA	BC Control Area
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DOE	U.S. Department of Energy
GPS	global positioning system
HEDR	Hanford Environmental Dose Reconstruction (Project)
LiDAR	light detection and ranging
NPE	nonoperational property evaluation
NPL	National Priorities List
OSE	orphan sites evaluation
OU	operable unit
RARA	Radiation Area Remedial Action (Program)
RI/FS	remedial investigation/feasibility study
ROD	record of decision
SESP	Surface Environmental Surveillance Program
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
WIDS	Waste Information Data System

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K1 Introduction

This appendix presents information supporting the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial investigation/feasibility study (RI/FS) conducted for 100-D/H Areas. Most of the waste sites in the 100 Area (including those in the 100-DR and 100-HR Operable Units [OU]) are located near decommissioned reactors. Large land areas exist (beyond the reactors and their associated facilities and waste sites) that have little or no subsurface infrastructure or indication of past or present releases of hazardous constituents; this land is referred to as nonoperational property. This appendix presents an evaluation of the nonoperational property evaluation (NPE) specific to 100-D/H.

K1.1 Scope of the Nonoperational Property Evaluation

The NPE was performed to verify that the portions of 100-D/H, where Hanford Site operations did not occur, do not contain any additional waste sites beyond those addressed in the RI/FS. While the NPE was not directly a part of the RI/FS process, it confirms that waste sites were not omitted when conducting the nature and extent evaluation presented in Chapter 4 of the RI/FS report. Two important outputs from the NPE are (1) evidence that effort has been taken to identify where waste may be present outside of operational areas; and (2) where appropriate, the inclusion of NPE waste sites that may warrant further consideration as part of the RI/FS. The NPE also documents nonoperational conditions for use in risk communication and for informing stakeholders.

Fate and transport mechanisms could potentially distribute contaminants to nonoperational areas. The most credible are human disposal, windblown dust dispersion, air emissions from stacks during active operations, overland flow, and biological vectors (i.e., intrusion by plants and animals). Multiple lines of evidence have been developed to assess these fate and transport mechanisms and the potential for contamination to exist outside of known operational areas. Areas of focus in developing the lines of evidence include the following:

- **Review of existing programs, data, and information with a nonoperational area focus—**Decades of environmental monitoring and surveillance have been conducted and reported at the Hanford Site. In addition to general (routine) monitoring that has included nonoperational areas, special studies have been commissioned and conducted that assess broad-area evidence of emissions and releases from facilities and waste sites.

- **Results of orphan sites evaluations (OSE)—**The OSE program has been designed primarily to support cleanup and long-term stewardship activities in the River Corridor. It provides a detailed understanding of disturbed areas (contaminated or not). Review of historical records and imagery, combined with on-the-ground walkdowns and field investigations, provide a comprehensive evaluation of current conditions in nonoperational areas.

- **Statistical analyses—**Two statistical analyses were conducted as adjuncts to environmental monitoring, data review, and field investigations. The first was developed and applied to enhance efforts to systematically and rigorously locate potential waste disposal sites. The second evaluated radionuclide distribution (based on available soil concentration data and aerial radiological surveys) in order to quantify and understand relationships with known waste sites and examine the potential for unidentified sites to exist outside operational areas.

K1.2 100-D and 100-H Areas Description

The 100-D and 100-H Areas are geographically separated by the horn area, where the southeasterly flow of the Columbia River is redirected to the northeast round the tip of the horn, then regains its southeasterly flow. The 100-D Area is located west and upstream of the horn and contains the 100-DR-1 and 100-DR-2 source OUs. The 100-H Area is located east and downstream from the horn and contains the 100-HR-1 and 100-HR-2 source OUs. The 100-HR-3 groundwater OU encompasses the groundwater beneath the entire region from 100-D to 100-H. The topography of 100-D/H lies on a flat semiarid bench of the Columbia River. The land surface slopes gradually toward the river, with a bank of up to 9 m (30 ft) at the edge of the river.

The upland environment within the boundaries of both the 100-D/H Areas contains graveled areas adjacent to buildings and facilities; however, significant portions of the 100-D Area are vegetated. In the eastern portion of the 100-D Area, cheatgrass and other exotic annuals compose the dominant vegetation cover. The upland habitats surrounding the 100-H Area dominated by cheatgrass and other exotic annuals are described in the vegetation mapping for the site as "abandoned old fields." Other vegetation found in 100-D/H includes Sandberg's bluegrass and gray rabbitbrush (*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* [DOE/RL-2008-46]; *Literature Review of Environmental Documents in Support of the 100 and 300 Area River Corridor Baseline Risk Assessment* [PNNL-SA-41467]).

K2 Nonoperational Property Evaluation Approach

River Corridor cleanup efforts have focused on known waste sites located within operational areas (often within perimeter fences) and on a limited number of known sites outside these boundaries. Where surveillance monitoring or focused investigative activities have identified previously unknown sites, the sites have been identified and evaluated for inclusion within the scope of the cleanup efforts. Operational areas comprise a small fraction of the total land surface in the River Corridor. Outside of the operational areas is the nonoperational property area. For purposes of this appendix, the nonoperational property area in the River Corridor is defined as that area beyond the boundaries of waste sites listed in the Waste Information Data System (WIDS) database. The nonoperational area is considered not to be directly associated with a Hanford Site process or operational activity known or suspected to contribute CERCLA hazardous constituents to the environment.

The approach to the NPE for the River Corridor is to develop a conceptual model of the fate and transport mechanisms that could distribute contaminants from Hanford operations that would warrant further evaluation in the nonoperational areas, and then apply multiple lines of evidence to examine the likelihood that such contamination is present. The lines of evidence include (1) results from long-term surveillance and monitoring programs and other studies, (2) results from a spatial model for predicting the location of man-made features (including waste sites) based on proximity to manmade and topographic features, (3) a spatial model for predicting where elevated radionuclide concentrations (specifically cesium-137) are present in soil based on aerial radiological survey results, and (4) results from the OSE.

Section K2.1 presents a brief description of potentially significant contaminant fate and transport pathways. Summary descriptions of the key surveillance and monitoring programs and other studies for the nonoperational area in the 100-D/H OUs are presented in Section K2.2. Brief descriptions of the statistical analyses are presented in Section K2.3. A brief description of the OSE program is presented in Section K2.4.

K2.1 Nonoperational Contaminant Transport Pathways

The nonoperational property area, having no history of releases of hazardous or radioactive substances, is presumed to have a low likelihood of contamination that would require a response action under CERCLA. The principal objective of this evaluation is to examine multiple lines of evidence to confirm that hazardous or radioactive substance releases are not present in the nonoperational property area. An outcome of this evaluation could be the identification of areas where releases or contaminant transport may have occurred.

A select set of contaminant release pathways are applicable when evaluating the potential for contaminant transport into nonoperational areas:

- **Anthropogenic contaminant sources—**Contaminants from facilities or known waste sites may have been physically transported by human actions to shallow soils outside of waste site boundaries. Several activities and programs at the Hanford Site identify waste sites that have resulted from these types of activities. Section K2.2 presents an overview of these activities and programs.

- **Transport via windblown dust—**Hazardous and radioactive substances in surface soils and materials can become suspended into the air, dispersed to downwind locations, and subsequently deposited onto the ground. Approximately 6 percent of the 1,518 km^2 (586 mi^2) Hanford Site (about 83 km^2 [32 mi^2], or 8,909 ha [20,000 ac]) has been actively disturbed or used. Potential fugitive dust emission sources are located in the five operational areas within this actively disturbed area: the 100 Area, 200 East and 200 West Areas, 300 Area, and 400 Area. The potential for fugitive dust emissions from these sources is generally conceived to occur subsequent to disturbance, erosion, or removal of soil covers over waste sites or through plant or animal biointrusion. These events can expose erodible material that contains contamination. Engineering controls (e.g., surface soil stabilization, dust suppression water, work cessation due to wind conditions) can be, and are, applied to mitigate or eliminate this transport pathway. However, contaminated areas are posted as Radiologically Controlled Areas or Soil Contamination Areas if these areas could contain erodible material that could produce fugitive emissions from resuspension of windblown dust (*Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2009* [DOE/RL-2010-17]). Figure K-1 depicts a conceptual model of windblown dust transport.

- **Emissions from facility stacks—**Hazardous and radioactive substances emitted into the air from former and currently operating facility stacks and vents can be dispersed to downwind locations and subsequently deposited to the ground. Three groups of sources of Hanford Site stack air emissions had the potential to impact the River Corridor by air deposition. Two of the groups, which represent by far the greatest potential contributors, are stack emissions that occurred during active operations between 1944 and 1972. The two groups are examined separately based on their physical location and type of contamination. The first group contains stack emissions from 200 Area operations that separated plutonium and uranium from irradiated reactor fuel. The second group contains stacks in the 100 Area that exhausted ventilation air from the working areas of the nine production reactor facilities. The 100 Area sources were minor emissions compared to the emissions from 200 Area facilities. The third group includes nonradionuclide emissions resulting from coal-fired power plants used to generate steam for heating and process operations. Two large power plants in the 200 Area operated until the mid-1990s: 284-E Power Plant in the 200 East Area, and 284-W Power Plant in the 200 West Area (*Facility Effluent Monitoring Plan for the 284-E and 284-W Power Plants* [WHC-EP-0472]). Nonradionuclide toxic air pollutants that could be emitted from coal-fired power plants are principally trace metals but also include traces of volatile organic compounds such as formaldehyde, and polycyclic organic matter. The polycyclic aromatic organic matter and certain trace metals (in particular, arsenic, cadmium, lead, and antimony) adhere to the fine particulate matter emitted from a power plant stack. Figure K-2 presents the conceptual model of transport from stack emissions.

- **Overland transport—**Hazardous and radioactive substances in surface materials can be transported away from facilities or known waste sites by surface runoff (overland flow). This could conceivably occur following precipitation events or, as has been documented, from releases (or "spillage") of process liquid waste that had been discharged to liquid waste disposal sites. Overland flow potentially results in the transport of contaminated sediments or water away from a waste site. Factors that affect overland flow include slope of the ground surface, soil texture, vegetative cover, and frequency of precipitation.

  The Hanford Site is in a semiarid region, and precipitation is more than balanced by evaporation and transpiration, therefore substantial overland flow from precipitation is an unlikely occurrence. A more likely source for overland flow is spills or releases from liquid waste disposal facilities during historical active operations. In general, these leaks were infrequent and documented through written and photographic records. Most resulted in localized contamination in and around the disposal sites. A number of these sites have been remediated under the interim action records of decision (RODs).

- **Biointrusion—**Hazardous and radioactive substances in shallow soil can be transported to plants at ground surface through their roots, or disturbed and transported to the soil surface by burrowing animals or insects. Plants extend roots into the soil to extract nutrients and water. Most of the mass of plant roots is concentrated within the shallow soil; however, some deep-rooted plant species are found at the Hanford Site. Unless actively managed and controlled, deep-rooted vegetation (e.g., tumbleweeds and sagebrush) growing over underground sources of contamination may selectively uptake contaminants, particularly radionuclides, into their tissues. When radionuclides are transported from roots to aerial portions of the plant, surface contamination may result. Desert animals and insects burrow for shelter from the heat, cold, or predators; reproduction; feeding; and water conservation. Most wildlife burrow no more than a few feet in depth; however, some macroinvertebrates (harvester ants) have been reported to burrow to depths of up to 2.4 m (8 ft) in soil at the Hanford Site. Animals that burrow into contaminated soil could unearth contaminants and disperse them on the soil surface. The conceptual model of biointrusion is depicted on Figures K-3 and K-4.

K2.2 Surveillance and Monitoring Programs

Several programs at the Hanford Site collect environmental surveillance and monitoring data. Many of these programs collect data to address regulatory requirements for emissions, effluent discharges, or U.S. Department of Energy DOE orders regarding radiological control. Other programs perform environmental monitoring of soil, water, air, or vegetation. Most of these programs are summarized in the annual environmental reports for the Hanford Site (e.g., *Hanford Site Environmental Report for Calendar Year 2009* [PNNL-19455]).

Table K-1 lists the 15 Hanford Site programs that identify waste sites and/or collect environmental monitoring and surveillance data. Table K-1 also identifies five other sources of information and data applicable to an NPE. Information and data from these programs were evaluated to identify trends in how hazardous substances or radionuclides may have been transported from operational areas or waste sites to nonoperational areas within the River Corridor. Information from the programs involved with soil, air, or vegetation monitoring, or with radiological control, were of most use in the NPE. Section K3.1 summarizes the evaluation of the results from these programs as they pertain to 100-D/H.

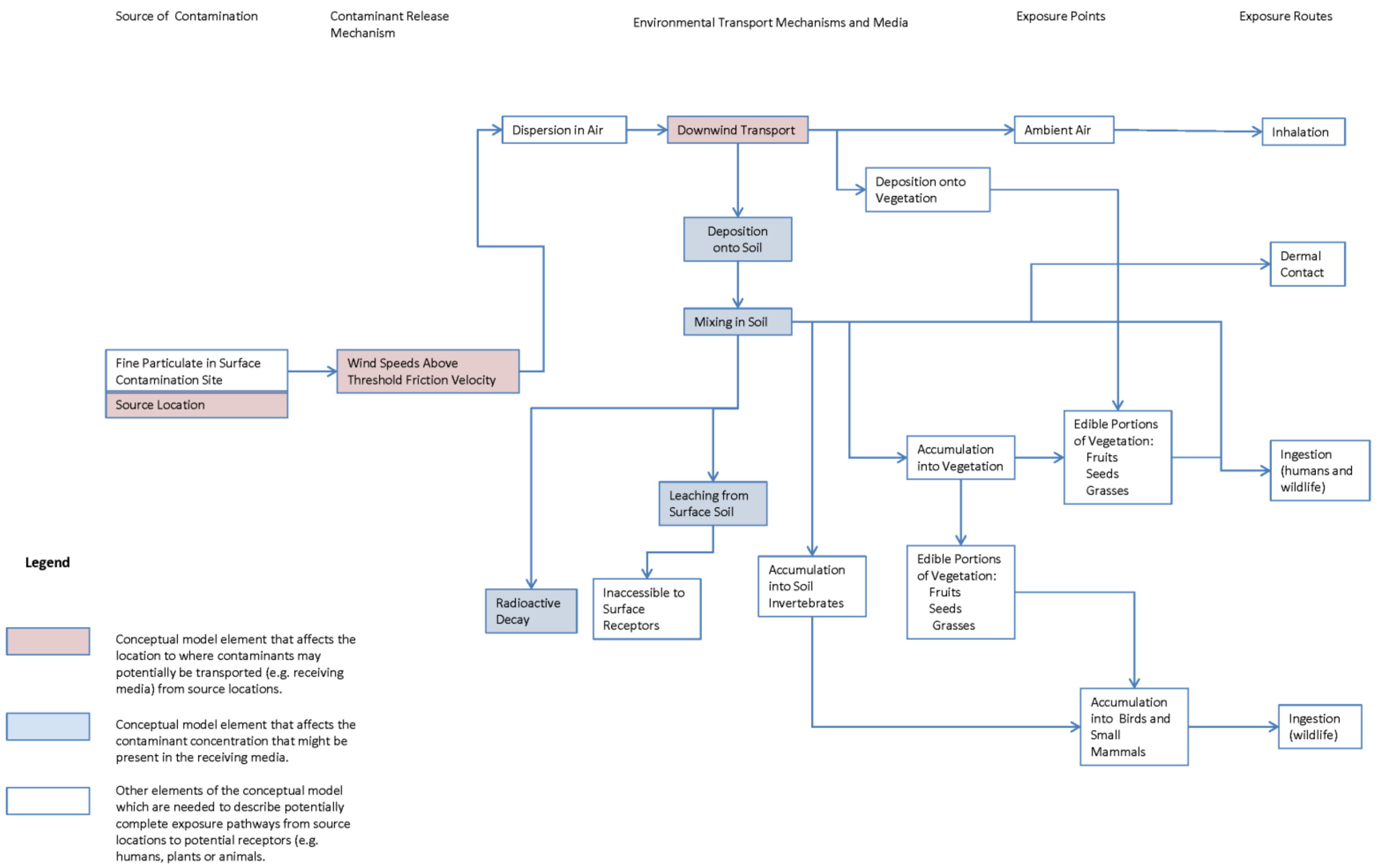

Figure K-1. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport of Windblown Dust

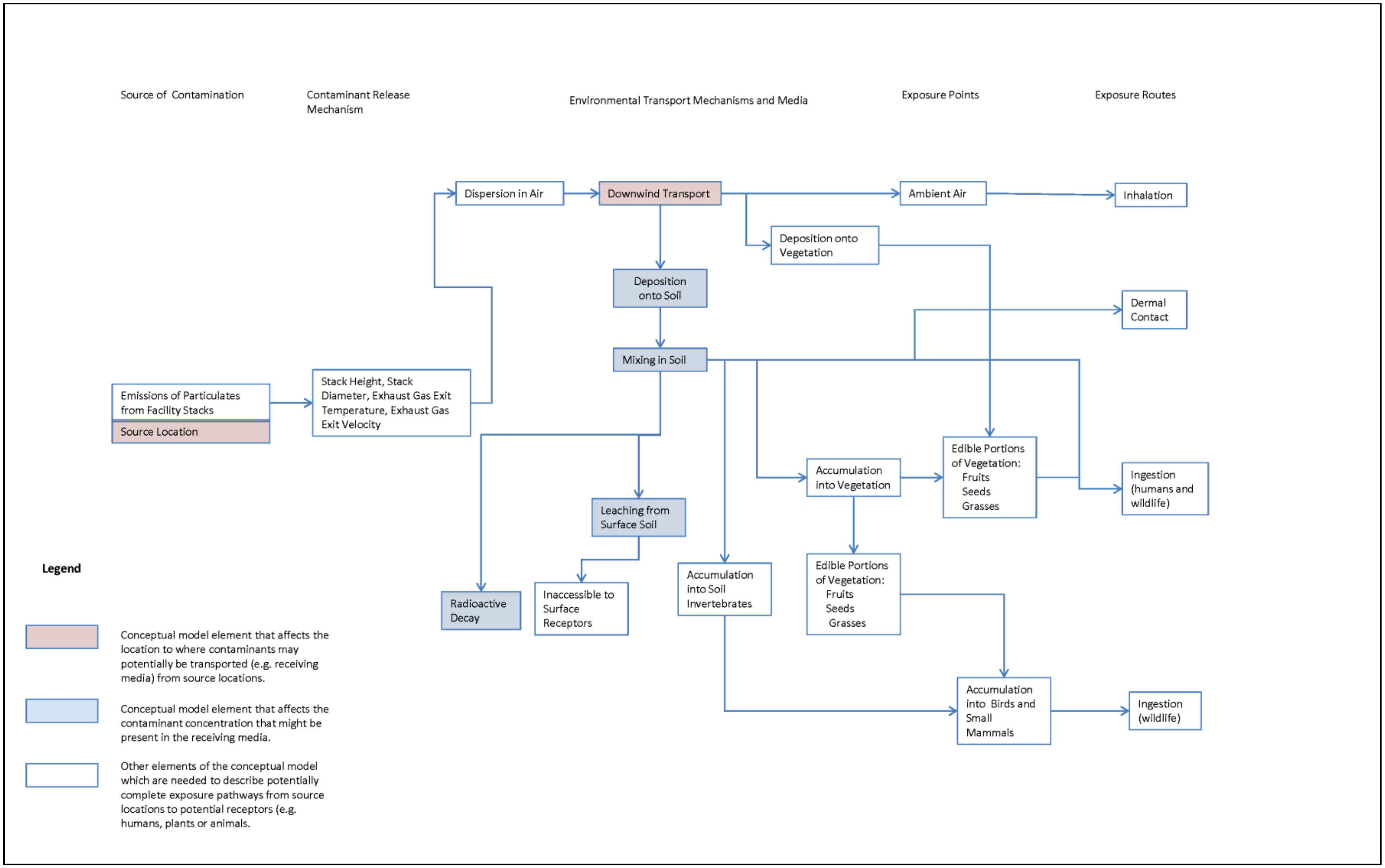

Figure K-2. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Emissions from Facility Stacks

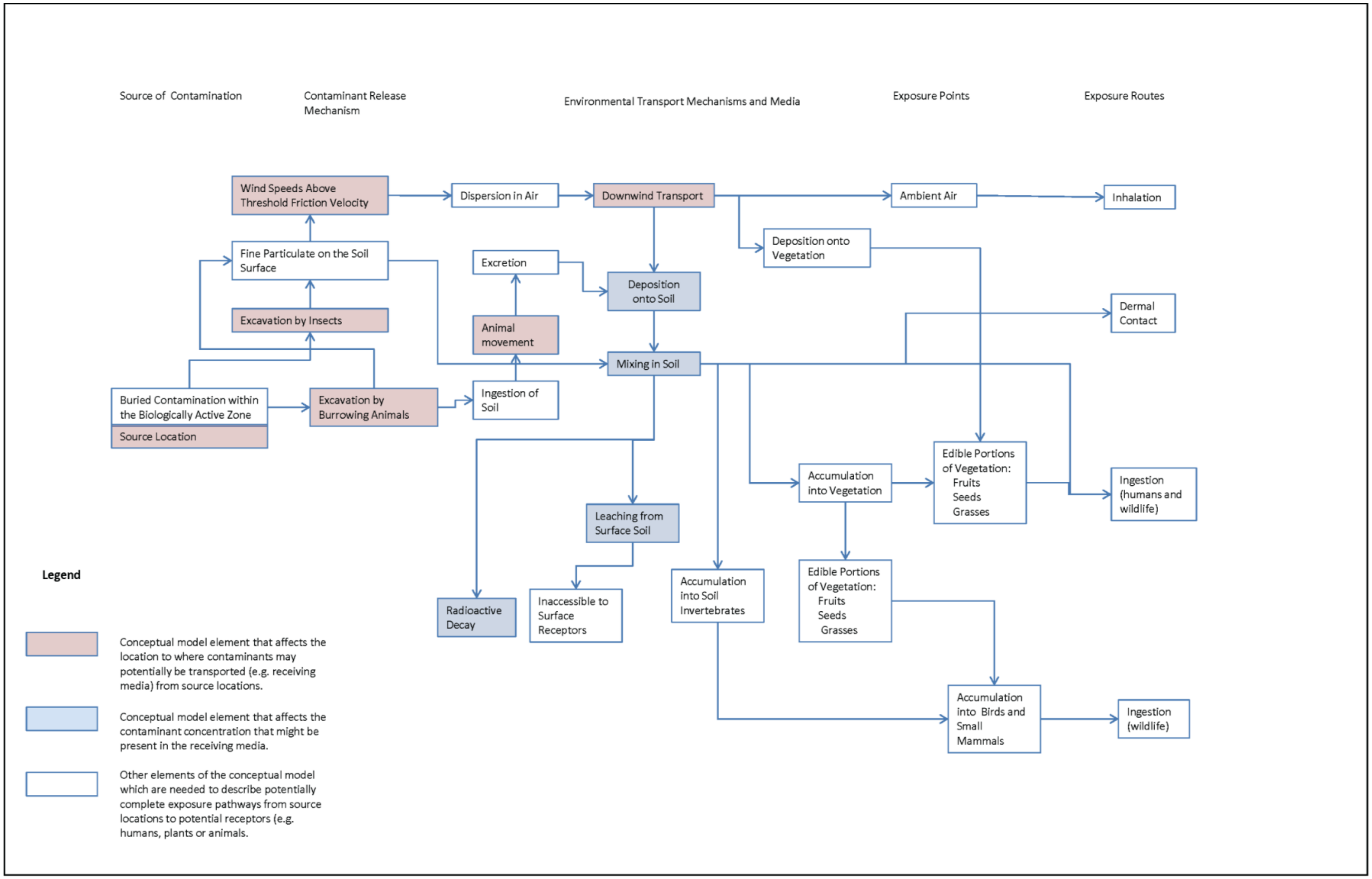

Figure K-3. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Animal Intrusion of Buried Contaminants

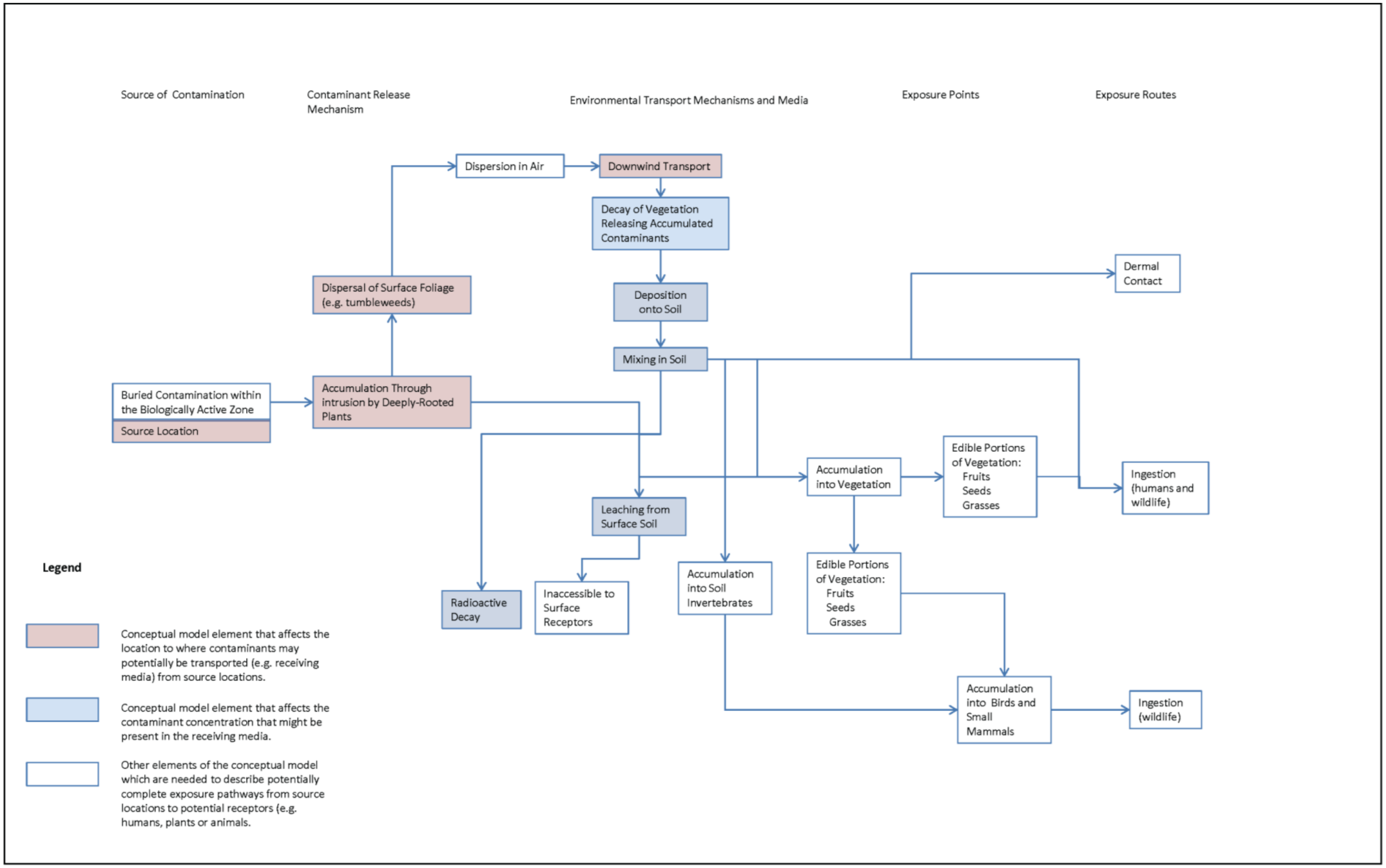

Figure K-4. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Intrusion of Deep-Rooted Plants

Table K-1. Existing Hanford Site Programs Related to Environmental Data and Monitoring

Ongoing Hanford Site Programs	
Air Emissions Monitoring	Liquid Effluent Monitoring
Ambient Air Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Ambient Air Monitoring
Soil Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Soil Monitoring
Vegetation Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Vegetation Monitoring
Radiological Dose Measurement Near Hanford Site Facilities and Operations	Radiological Surface Surveys Near Hanford Site Facilities and Operations
Groundwater Monitoring	Radiation Area Remedial Action Project
Waste Information Data System	Spill and Release Reporting
Vegetation Control Activities	
Additional Information and Data Sources	
Aerial radiological surveys	*River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment* (DOE/RL-2007-21)
Aerial photography (includes LiDAR)	Emissions estimation and dose assessments conducted as part of the HEDR Project.
Hanford Site background studies	

HEDR = Hanford Environmental Dose Reconstruction (Project)
LiDAR = light detection and ranging

K2.3 Statistical Analyses

The statistical analyses focused on the following:

- Developing and applying a predictive model for waste site locations
- Establishing an association between cesium-137 measured directly in soil and high-resolution aerial survey results
- Developing a Sitewide model of soil cesium-137 using lower resolution Sitewide aerial surveys

The results of these analyses were used to model the likelihood of finding previously undiscovered waste sites in the nonoperational areas as a function of manmade and topographic features, and to model the potential for radionuclide concentrations (specifically, cesium-137) in surface soil to be higher than selected threshold concentrations. These lines of investigation are described below. Section K3.2 discusses the results from these analyses.

K2.3.1 Predictive Modeling of Waste Site Locations

The predictive model is based on the conceptual model that waste sites are located in proximity to anthropogenic features such as roads or existing operational areas or flat or low-lying topography. The distributions of these geographic variables, measured at WIDS sites, were compared with the distribution of the same variables calculated at an unbiased set of locations systematically distributed across the Hanford Site. A quantitative model was developed to show the probability of a waste site being located at any unsampled location within the Hanford Site as a function of these geographic measures. Factors considered in developing geographic variables for known waste sites and sources included distance to operational areas; distance to roads, railroad grades, utility rights of way (e.g., power lines) and roads; and topography, including slope aspect elevation, and curvature. These models were used to rank areas based on the relative probability that a previously undiscovered waste site might exist.

K2.3.2 Aerial Surveys and Soil Radionuclides

Measurements of the presence of radionuclides were available from direct soil measurements, as well as from laterally extensive aerial radiological surveys. Soil measurements were expressed as activities per unit mass (pCi/g), suitable for estimation of exposure for risk assessment, whereas data obtained from aerial surveys were expressed as gross counts for gamma-emitting radionuclides. Aerial survey data could be used to estimate exposure if it could be calibrated with soil cesium-137 activity data. Predictive models and maps of the probability that cesium-137 levels would be expected to exceed screening levels could be prepared based on the statistical relationship between soil activity measurements and aerial survey gross counts.

A detailed investigation in the BC Control Area (BCCA), which included collecting high-resolution aerial survey data and relatively high-density soil sampling, provided data to perform a detailed geostatistical analysis. The analysis of the BCCA data supported development of a Sitewide model based on less resolved, but more laterally extensive, aerial surveys of all of the Hanford Site. The results of the Sitewide model were used to draw conclusions specific to the River Corridor. The results of both analyses support the utility of aerial radiological surveys for estimating concentrations in soil for unsampled areas.

K2.4 Orphan Sites Evaluation

The OSE is a systematic approach to evaluate land parcels in the River Corridor to ensure that all waste sites or releases requiring characterization and cleanup have been identified. Information collected through these evaluations also supports elements of the CERCLA Section 120(h)(4) ("Federal Property Real Disposal Process") requirements for review and identification of uncontaminated property at federal facilities. The OSE supplemented past systematic efforts that identified source waste sites, including the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) procedure TPA-MP-14 (*Tri-Party Agreement Handbook Management Procedures* [RL-TPA-90-0001]) discovery process for identifying known and potential waste sites and the CERCLA hazard ranking conducted in 1985 and 1986 to place the Hanford Site on the National Priorities List (NPL).

Two key elements of OSE include a historical review and a field investigation. Review of historical information was conducted to identify potential orphan sites and to target areas for further evaluation during the associated field investigation. Historical research focused on identifying specific items or features typically associated with a waste site. The most common features associated with a waste site in reactor areas include drains, cribs, drywells/French drains, burial grounds, pipelines, aboveground and belowground storage tanks, septic systems, drain fields, burn pits, trenches, ditches, pits, spills, sumps, vaults, ash pits, disposal areas, pumps, and buildings and facilities that contain chemicals and radiological contaminants. Information obtained and used in the historical review included the following resource types:

- Maps
- Construction and operations drawings
- Technical and operations documents
- Construction and operations photographs
- Aerial photographs
- Geophysical survey results
- Cleanup verification packages
- Sampling logbooks
- Personnel interviews

Field investigation activities were used to provide another level of assurance through conducting systematic walking surveys to document potential orphan sites and to follow up on potential orphan sites identified from historical review. Three primary tools provided the media to record the information observed in the field including hand-held Trimble GeoXT™ global positioning system (GPS) units, digital cameras, and field logbooks. Geophysical survey instrumentation was used to supplement these tools in selected areas of suspect subsurface features identified during the historical review or field investigation.

To ensure a systematic approach for area coverage, standardized 30 × 30 m (98.4 ft × 98.4 ft) conceptual grids were established over the investigation areas. The grid and existing known features in the areas were loaded onto the GeoXT GPS units, which were used in the field to monitor progress and record information. Walking surveys were typically performed in pairs with approximately 15 m (49.2 ft) spacing between individuals. Features encountered during this investigation were recorded using the GPS unit, digital camera, and field logbook.

Field investigation for regions of the River Corridor used a graded approach. High-resolution, four-band (red, green, blue, and near-infrared) orthophotography imagery and LiDAR topography data were collected for approximately 57,468 ha (142,000 ac) of the River Corridor in April 2008. The data were collected in the early spring when foliage and undergrowth obscuring the ground surface were at a minimum. The orthophotography and LiDAR data were used to conduct "virtual walkdowns" of the areas. Based on results of these "virtual walkdowns," areas were selected to conduct walking surveys (30 × 30 m [98.4 ft × 98.4 ft] reference grid system). Vehicle surveys along accessible roads and utility easements were also part of the field investigation. In addition, standard walking surveys were conducted throughout the River Corridor along the Columbia River, based on the level of interest in the shoreline area and its inclusion as part of the Hanford Reach National Monument (Establishment of the Hanford Reach National Monument" [65 FR 37253]).

The 100-D Area was addressed by the *100-D Area Orphan Sites Evaluation Report* (OSR-2006-0001), while 100-H was addressed by the *100-H Area Orphan Sites Evaluation Report* (OSR-2008-0002). Within 100-D/H, 46 orphan sites (new discovery sites) were identified through the OSEs and are addressed in the 100-D/H RI/FS report. The results from this evaluation are discussed in Section K3.3.

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K3 Evaluation Results

This section summarizes the results of the NPE in the 100-D/H Areas of the River Corridor based on the approach presented in Section K2. The NPE is based on multiple lines of evidence, including (1) the results from surveillance and monitoring programs, and other studies conducted in the River Corridor; (2) the results from statistical analyses performed to identify the potential presence of waste sites and to evaluate the spatial distribution of selected radionuclides in soil; and (3) the results from the OSE.

K3.1 Results from Surveillance and Monitoring Programs

Hanford Site programs, which provided information characterizing conditions in the nonoperational areas in and around the 100-DR and 100-HR OUs, included soil, air, and vegetation sampling conducted as part of the Near-Facility Monitoring Program and the Surface Environmental Surveillance Program (SESP). The radiological control program (with emphasis on radiological surveys and activities for identifying and controlling biological vectors [biointrusion from plants and animals], and external radiation monitoring) was conducted as part of the SESP.

Other activities that contribute to characterizing conditions in the nonoperational areas include the waste site discovery process under TPA-MP-14, which results in identified waste sites being inventoried in WIDS and, as discussed in Section K3.3, the OSE. Historically, interim actions conducted under the Radiation Area Remedial Action (RARA) program contributed to stabilizing and controlling releases from waste sites. The results from these programs have been discussed using the framework of the conceptual model described in Section K2.1.

K3.1.1 Anthropogenic Disposal Activities

Past and present investigation activities provide confidence that waste site locations within the River Corridor are known. Waste site identification activities in the River Corridor fall into two categories: systematic and observational. Various systematic programs have been conducted at different times since the beginning of Hanford Site transition from production to cleanup in the 1980s, with the most recent being the OSE program that was initiated in 2004 (Section K3.3). An inventory of known and potential waste sites has been maintained in the WIDS database since the early 1980s and is continually maintained through the TPA-MP-14 discovery process. Between 1985 and 1988, preliminary assessment/site inspection activities were completed to identify waste sites and prioritize the relative hazards. Waste disposal information was collected through exhaustive reviews of literature and maps, employee interviews, and visual inspection of all sites and unplanned releases. Results were organized, and sites were ranked with respect to potential environmental impacts in accordance with a slightly modified version of the CERCLA hazard ranking system. The results from this process provided information to support addition of the 100 and 300 Areas to the NPL and the subsequent listing of waste sites in Appendix C of the Tri-Party Agreement (Ecology et al., 1989).

A variety of characterization activities conducted as part of the RI/FS process has further characterized potential release and disposal activities in the 100 Area. These historical activities are summarized in DOE/RL-2008-46.

K3.1.2 Windblown Dust Emissions

Emission sources, which could release contaminants through windblown dust, are described variously as “fugitive,” “diffuse,” or “nonpoint” emissions sources (DOE/RL-2010-17). The Hanford Site consists of 1,518 km^2 (586 mi^2) of semiarid shrub-steppe land, of which approximately 6 percent (about 83 km^2 [32 mi^2], or 8,909 ha [20,000 ac]) has been actively disturbed or actively used. This 6 percent of land is distributed into large operational and support areas where almost all fugitive emissions sources are located: the 100 Area, 200 Area (which includes the 200 East and 200 West Areas), 300 Area, and 400 Area.

The potential for fugitive dust emissions from waste sites (prior to their cleanup) is generally characterized as occurring subsequent to erosion of soil covers or plant or animal biointrusion, which may expose erodible material containing concentrations of radionuclides. Contaminated areas posted as "Radiologically Controlled Areas" or "Soil Contamination Areas" also could contain erodible material that is radiologically contaminated and that could produce fugitive emissions from resuspension of windblown dust (DOE/RL-2010-17).

The RARA program is responsible for the interim stabilization, surveillance, and maintenance of the inactive waste sites at the Hanford Site. Interim stabilization measures to control fugitive dust have historically been performed on inactive waste sites prior to their cleanup. Stabilization measures included consolidation of surface contamination within the waste site from which it originated, then covering the waste with a layer of soil or other material (e.g., cobbles). Waste sites were then revegetated or treated as needed with a nonselective herbicide. Quarterly surveillance, annual radiological surveys, annual herbicide applications, removal of deep-rooted vegetation, and occasional corrective action for small areas of surface contamination that appeared continued following stabilization. Interim stabilization reduced sources of windblown dust potentially originating from contaminated soils.

The potential magnitude of windblown dust transport can be evaluated from the frequency of restrictions to visibility and ambient air monitoring for particulate matter and radionuclides in air. Dust, blowing dust, and smoke from field burning are described as phenomena causing restrictions to visibility (i.e., visibility less than or equal to 9.6 km [6 mi]). Reportedly, there are few such days at the Hanford Site (*Hanford Site National Environmental Policy Act (NEPA) Characterization* [PNNL-6145]). Particulate air monitoring shows that annual average PM_{10} (particulate matter finer than 10 cm in diameter) concentrations at the Hanford Meteorological Station are similar to PM_{10} concentrations at the Benton Clean Air Authority station in Kennewick, Washington.

K3.1.3 Stack Emissions

Radionuclide emissions formerly from stacks in the 100 and 200 Areas had the potential to impact the River Corridor through deposition from the air. Based on studies conducted as part of the HEDR Project, most of the emissions occurred between 1944 and 1972 from facilities in the 200 Area that separated plutonium and uranium from irradiated reactor fuel (*Radionuclide Releases to the Atmosphere from Hanford Operations* [PNWD-2222 HEDR, 1994]). The largest releases from these facilities occurred in 1945, before effective collection devices were installed ahead of the stacks to prevent the discharge of volatile and particulate radionuclides. Most of the inventory emitted consisted of gaseous and/or short-lived radionuclides, which would be unlikely to result in measurable concentrations in soil in Hanford Site nonoperational areas. The nine production nuclear reactors in the 100 Area had stacks to exhaust ventilation air from the working areas of the reactor facilities, which were minor sources of emissions compared to the 200 Area facilities. No significant stack releases from 300 Area operations were reported in the documents that evaluated soil sampling and monitoring. The 300 Area primarily supported fuel fabrication processes and research activities that were not expected to have contributed to radioactive airborne emissions released on the Hanford Site (*RCBRA Stack Air Emissions Deposition Scoping Document* [DOE/RL-2005-49]).

Releases of long-lived radionuclides (including americium-241, cesium-137, iodine-129, strontium-90, plutonium-238, plutonium-239/240, and plutonium-241) from the 200 East and 200 West Areas major stacks were a very small fraction of the total inventory emitted into the air. A review of dose reconstruction information indicates that most of the total releases of long-lived radionuclides consist of cesium-137 and strontium-90, with a minor contribution of the other radionuclides.

Potential long-term impacts from these emissions within the Hanford Site have been assessed through air and soil sampling conducted as part of the Near-Facility Monitoring and SESP programs (PNNL-19455). Air sampling is performed at a sampling station located south of the fence line of the 100-D operational area. Particulate sampling for gross alpha and beta radiation conducted at this station since 1991 shows either a flat or a declining trend in concentrations. Direct gamma dose measurements at this station (with a thermoluminescent detector) since 1970 have shown background levels of radioactivity, with the exception of an elevated level measured in 2005. The annual environmental reports describe the general trends in radionuclide concentrations measured in soil. While concentrations at some near-facility sampling locations are higher than offsite locations, average concentrations are low and show no changes in trends over several years (PNNL-19455). In general, concentrations of sampled radionuclides (including cesium-137, strontium-90, plutonium-239/240, uraniuim-235, and uranium-238) resemble Hanford Site background concentrations in soil.

K3.1.4 Overland Flow

The Hanford Site is in a semiarid region and, therefore, experiences many dry periods. January, March, and December are the only months that have always received measurable precipitation, as reported from 1946 through 2004. Normal annual precipitation at the Hanford Site is 17.7 cm (6.98 in.) (*Hanford Site Climatological Summary 2004 with Historical Data* [PNNL-15160]). In the Hanford semiarid climate; precipitation is balanced by evaporation, transpiration, and vegetative uptake, therefore substantial overland flow from precipitation is an unlikely occurrence.

A more likely source for overland flow is historical spills or releases from liquid waste disposal facilities during active operational periods. Liquid effluents generated as a direct result of reactor operations consisted primarily of reactor cooling water, fuel storage basin water, and decontamination solutions.

Cooling water was transferred from the reactor buildings, through effluent lines, and then to the retention basins for cooling and decay of short-lived radionuclides. From the retention basins, the water was transferred through large pipes to the outfall structures, then into pipes that discharged to the Columbia River. Overflow from the outfall structures also could discharge directly to the river shoreline through nearby spillways (for example, see *100-K Area Technical Baseline Report* [WHC-SD-EN-TI-239]). During 1975, sampling was performed at all of the retired radioactive liquid waste disposal sites, retention basin systems, and associated diversion trenches in the 100 Area. Sampling was performed for the contaminated fill inside the basins, along and in effluent lines and junction boxes, and through the basin floors. Most importantly for understanding overland flow, samples were taken along the outside of the retention basin walls (*Radiological Characterization of the Retired 100 Areas* [UNI-946]).

Leaks from liquid waste disposal sites in the 100 Area that resulted in overland flow are described in the report of the 1975 sampling event (UNI-946). In general, these leaks were infrequent, well-documented, and resulted in localized contamination around the periphery of the disposal sites. The leaks have been characterized historically or as part of the current RI/FS process. The majority of the leaks have been cleaned up and interim closed out in accordance with the interim action RODs. The identification of leaks or spills from waste sites is also incorporated into the procedure for maintaining WIDS in accordance with procedure TPA-MP-14. Based on available information, overland flows from liquid waste disposal facilities are limited in lateral extent, and unplanned liquid release sites are identified through existing programs such as WIDS. The factors considered in this evaluation indicate that contamination in nonoperational areas through overland transport is unlikely to occur.

K3.1.5 Biointrusion

Biointrusion episodes in 100-D/H have not been described in radiological survey reports for the past 3 years. Radiological surveillance monitoring or vegetation sampling conducted as part of the Near-Facility Monitoring Program (PNNL-19455) has not identified contaminated vegetation episodes around 100-D/H.

K3.2 Statistical Evaluations

Statistical evaluations provide estimates of the likelihood of finding previously undiscovered waste sites in the nonoperational property areas and the potential for exposure to cesium-137 exceeding selected threshold concentrations in surface soils.

K3.2.1 Relative Probability of Missing an Existing Waste Site

Known waste sites have largely been located in proximity to anthropogenic features and relatively particular topographic conditions. For example, most waste sites found to date tended to be close to roads, in low lying areas such as ditches or ponds, or proximate to operational areas. The spatial distributions of these geographic variables, measured at known WIDS sites, were compared with the distribution of the same variables calculated at an unbiased set of locations systematically distributed across the Hanford Site. A statistical relationship was established to rank the likelihood that an available location might contain a previously unknown waste site. Logistic regression was used to develop the statistical relationship between waste site locations and geographic variables.

Factors considered in developing geographic variables expected to predict locations of known waste sites and sources included distance to operational areas; distance to roads, railroad grades, lakes, streams, utility rights-of-way (e.g., power lines); and topography.

The geographic characteristics of the known waste sites were investigated to determine if their locations exhibited predictable spatial patterns. The purpose of this analysis was to develop a quantitative predictive model describing relationships so areas within the River Corridor could be prioritized based on the relative probability that a previously unidentified waste site might be present. This analysis does not provide an absolute probability that a waste site exists, but rather provides a relative probability that allows locations to be ranked to identify the more likely location for a waste site (because there may be no additional waste sites in the River Corridor that have not been found). The predictive model provides direction to the most likely places for a waste site to occur, if indeed one exists.

The predictive model was developed based on a set of known waste site locations obtained from WIDS (referred to as a “training set”). The results of this model were used to predict the relative probability of encountering a potential waste site at areas that might not have been investigated in the field. This provided a ranking of locations within the nonoperational property that could then be investigated in the field, compared with previous field or desktop investigation results to determine the potential that additional previously undetected waste sites may remain within the nonoperational property. In the River Corridor area, the modeled predictions were compared with information generated from the OSE. The modeled predictions were compared with miscellaneous remediation points and waste site points based on observations of aerial photography and LIDAR imagery, field walkdowns and vehicular road surveys conducted as part of the OSE. These comparisons provided independent validation of the predictive model.

K3.2.2 Spatial Analysis of Soil Radionuclides and Aerial Surveys

Measurements of the presence of radionuclides were available from direct soil measurements, as well as from laterally extensive radiological aerial surveys. Soil measurements were expressed as activities per unit mass (pCi/g), suitable for estimation of exposure for risk assessment, but provide only limited understanding of the spatial distribution of concentrations. Data obtained from aerial surveys interrogates much larger areas but are expressed as gross counts for gamma-emitting radionuclides. The aerial survey data were not directly applicable to estimation of potential exposure without calibration to directly measured soil concentrations.

For purposes of the NPE, aerial survey data were calibrated against measured soil cesium-137 activity data. Geostatistical methods were used in a preliminary study to develop a spatially explicit relationship between soil activity measurements and aerial survey gross counts within the BCCA. Detailed geostatistical analysis was conducted within the BCCA because high-resolution aerial survey data and relatively high-density soil sampling were available for this area. The preliminary analysis of the BCCA data was used as a pilot study to support determination to proceed with development of a more extensive Sitewide model based on less resolved, but more laterally extensive, aerial surveys of all of the Hanford Site. The results of the Sitewide model were used to draw conclusions regarding the distribution of cesium-137 (a contaminant of potential concern related to Hanford Site operations) specific to the nonoperational area.

Aerial surveys conducted in 1996 (*An Aerial Radiological Survey of the Hanford Reservation Richland Washington: Date of Survey: February 29 to March 21, 1996* [DOE-0335]) and 2009 (*An Aerial Radiological Survey of the Hanford BC Controlled Area and West Lake Area Survey Data Survey Data – September 22 to 30, 2009* [SGW-45563]) were combined with ground radiological surveys and soil sampling and analytical data for cesium-137 in the BCCA to establish a relationship to the aerial survey results and measured concentrations in soil. A statistical model of the probability that soil cesium-137 levels exceed selected threshold levels (1.05, 1.5, 3.1, and 6.2 pCi/g) was developed as a function of gross counts of gamma-emitting radionuclides using sitewide aerial survey results. The statistical model was validated against a set of waste sites in the 200-MG-1 OU, where radiological surveys and soil sampling and analysis had been conducted as part of interim remedial actions.

The logistic regression models provide estimates of the probability of exceeding threshold levels, which can be interpreted as estimates of the proportion of an area that would be expected to exceed those levels if the area were sampled. Figure K-5 provides a map corresponding to the fitted probability model for the 1.05 pCi/g threshold level for the entire Hanford Site. It can be seen that probabilities reflect the gross patterns of variation seen in aerial survey gross counts. The highest probabilities are clearly in proximity to known radiological sources. Figure K-6 shows the spatial distribution of the probability of exceeding 6.2 pCi/g threshold level, with the same color scale as that used for the 1.05 pCi/g threshold level, and it can be seen that nearly all of the nonoperational area has less than 2.5 percent probability of exceeding the 6.2 pCi/g threshold level. The nearly uniformly dark color of the map shows the much lower probability that surface soil samples are expected to exceed 6.2 pCi/g, compared to the probability of exceeding 1.05 pCi/g shown on Figure K-5. This illustrates the high degree of sensitivity to the selection of threshold levels regarding the area of the site that might be expected to exceed the levels. Note that in both cases, there are no areas identified with cesium-137 concentrations in soil that are above either 1.05 or 6.2 pCi/g.

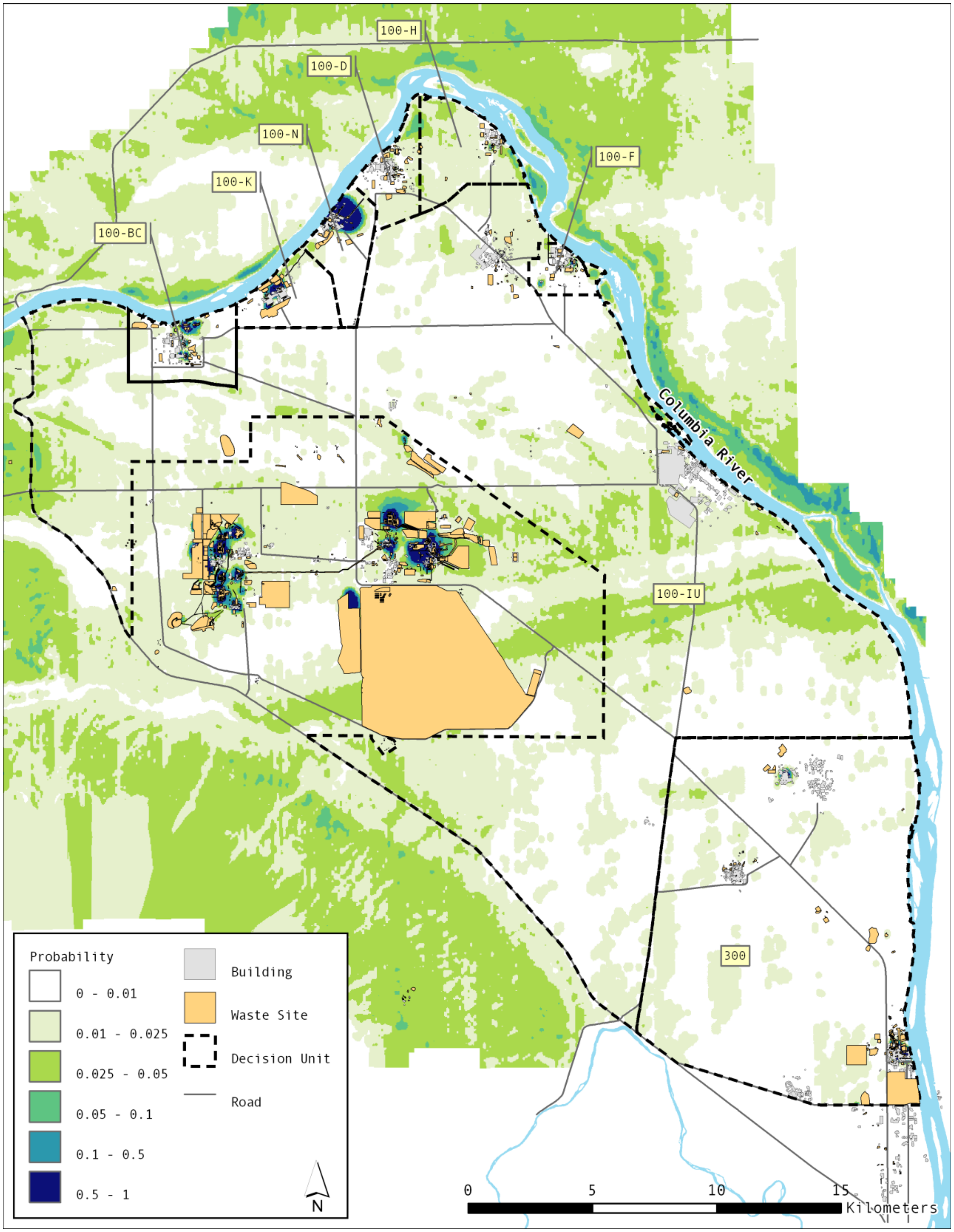

Figure K-5. Modeled Probability that Soil Cesium-137 Exceeds 1.05 pCi/g at the Hanford Site

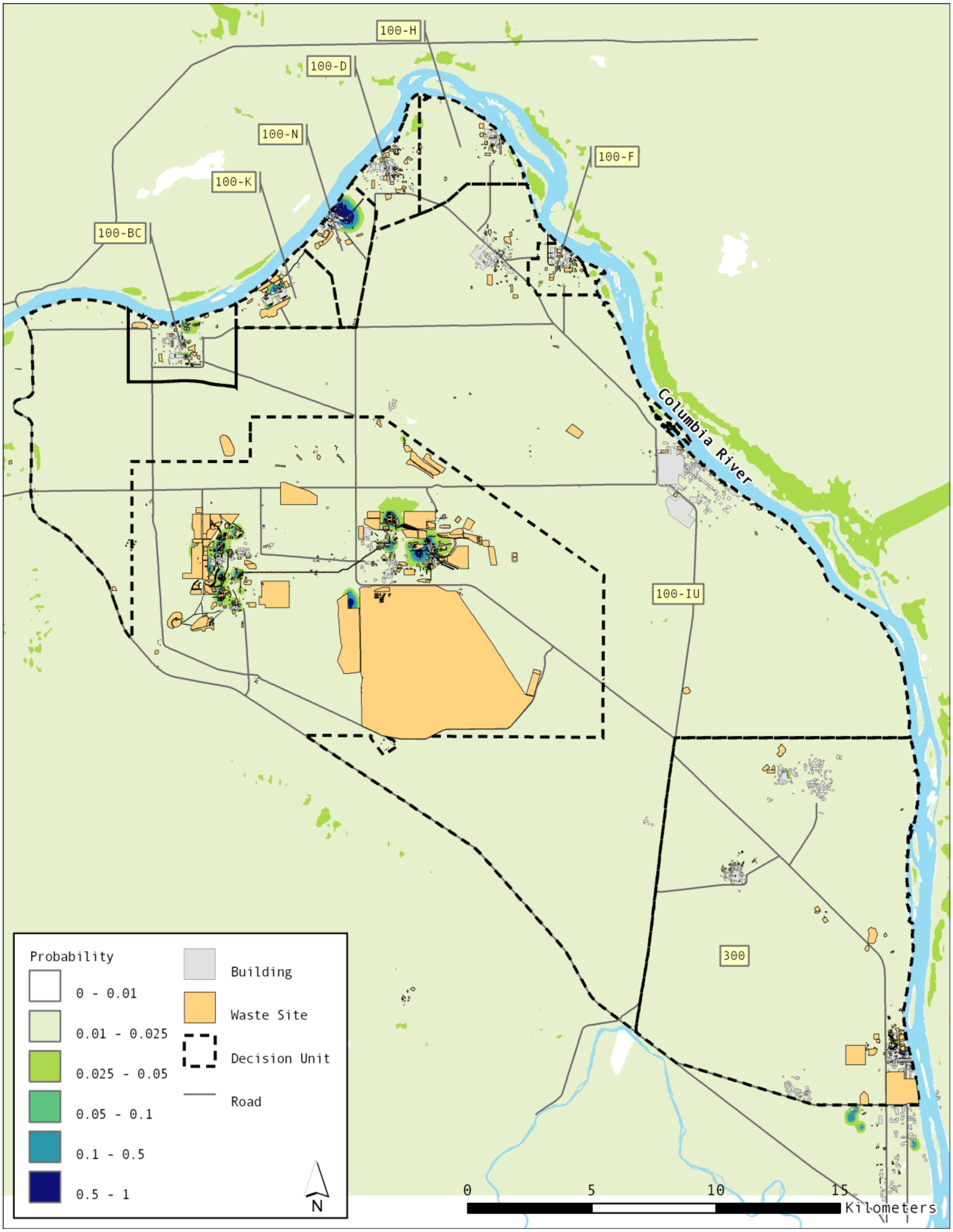

Figure K-6. Modeled Probability that Soil Cesium-137 Exceeds 6.2 pCi/g at the Hanford Site

K3.3 Orphan Sites Evaluation

The results from historical research, field walkdowns, geographic information system mapping and geophysical surveys for 100-D are summarized in *100-D Area Orphan Sites Evaluation Report* (OSR-2006-0001). A field walkdown was conducted over 275 ha (680 ac) of the 100-D Area, where a total of 30 orphan sites were identified through the OSE. Each of these sites were accepted into WIDS and incorporated into the River Corridor Closure Contract scope. A total of 32 locations had non-CERCLA debris consistent with the miscellaneous restoration criteria.

The results for 100-H are summarized in *100-H Area Orphan Sites Evaluation Report* (OSR-2008-0002). A field walkdown was conducted over 300 ha (742 ac) of the 100-H Area, and a total of 16 orphan sites were identified through the OSE. Each of these sites were accepted into WIDS and incorporated into the River Corridor Closure Contract scope. A total of 13 locations had non-CERCLA debris consistent with the miscellaneous restoration criteria.

K4 Conclusions

Multiple lines of evidence were reviewed to evaluate conditions in the 100-D/H nonoperational area (and the River Corridor, more generally) based on potential release and transport mechanisms. Surveillance and monitoring programs, in combination with the OSE, have comprehensively identified all waste sites within 100-D/H. In addition, the surveillance and monitoring programs, in combination with studies conducted as part of the HEDR Program, have demonstrated that emissions to the air, either from windblown dust or stack emissions, have not impacted nonoperational area soils with radionuclides. The surveillance and monitoring programs also have verified that biointrusion has not resulted in a spread of contamination into the nonoperational areas.

Statistical analysis of the geographical distribution of waste sites based on manmade features and topography describes the likely locations of waste sites near the 100-D/H nonoperational area. The results from this analysis reinforce the findings from the OSE, which has systematically identified the remaining waste sites within the 100-D/H nonoperational area. Statistical analysis of the distribution of radionuclide concentrations observable from aerial surveys has confirmed that the probability of detecting elevated radionuclide concentrations in nonoperational area soils is very small.

Based on the evaluation of these multiple lines of evidence, the probability of identifying waste sites or contaminant dispersal from Hanford Site operations in the 100-D/H nonoperational areas is considered negligible.

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