CRESP
Consortium For Risk Evaluation with Stakeholder Participation

Consortium Universities: **Vanderbilt University**, Georgia Tech, Howard University, New York University, Oregon State University, Rutgers University, University of Arizona, University of Wisconsin - Madison

METHODOLOGY FOR THE HANFORD SITE-WIDE RISK REVIEW PROJECT

Revision A

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Acknowledgements and Disclaimer

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Executive Summary

The Consortium for Risk Evaluation with Stakeholder Participation (CRESP) was requested in January 2014 by the Department of Energy (DOE) to conduct an independent Hanford site-wide evaluation of human health, nuclear safety, environmental and cultural resource risks (hereinafter referred to as the "Risk Review Project"). The goal of the Risk Review Project is to identify and characterize risks to the public, workers, groundwater and the Columbia River, and ecological and cultural resources (collectively referred to as "receptors").

Cleanup at Hanford Site has proven to be more costly, has taken longer, and is more technically challenging than expected when cleanup at the Site began in 1989. As an example, it is anticipated that more than $100 billion will be expended on cleanup during the next 50 years. Yet, while earlier studies have evaluated portions of the Hanford Site, a comprehensive, site-wide review of the risks to human health and resources from contamination, waste management and cleanup activities has never occurred. So, the results of the Risk Review Project should provide the DOE regulators and the public with a better of understanding of the risks to receptors and should help inform decisions made on sequencing of future cleanup activities, including which areas should be focused on earlier for additional characterization and analysis. This document describes the methodology developed to execute the Risk Review Project. The methodology consists of the following elements:

1. The remaining cleanup sites at Hanford as of October 1, 2015 have been divided into approximately 60 evaluation units (EU), which have been organized into five categories composed of geographically co-located sites to the extent possible with consideration given to commonality among source types and overlapping of receptor types. The five groupings are: legacy source sites, such as past practice liquid waste disposal and buried solid waste sites; tank waste, tank farms, and associated contamination sources; groundwater plumes; inactive facilities undergoing decommissioning and demolition; and operating facilities.
2. Each of the EUs within the five categories will be described in detail using existing information, including regulatory documents, maps, and studies. Information gathered on each EU includes the unit description and history; an inventory of waste and contamination history; selected or the potential range of cleanup approaches; and the ratings of risks to receptors, by providing rough order of magnitude relative groupings or binning of risks to each different type of receptor. The primary categories for the groupings are: very high, high, medium, low, or not discernible.
3. The groupings or binning categories for each type of receptor will be determined from the specific methodology developed for that receptor based on recognized thresholds if they exist as well as other factors. Receptors being evaluated for risks are: workers, public, groundwater and the Columbia River, ecological resources, and cultural resources. This approach is intended to provide relative risk ratings *within* receptor categories (i.e., relative binning of risks to the Columbia River, groundwater, ecology, etc.). Although the integration across receptor categories is considered inherently individually value driven, the Risk Review Project (once it has evaluated a more complete set of EUs) will provide examples that illustrate how groupings or binning that integrates the ratings across receptor categories (e.g., integrated risk binning that combines risks to human health with risks to ecology and groundwater) could be carried out.
4. Risks will be evaluated considering distinct evaluation periods. They are: active cleanup period, including the current status prior to cleanup and during active cleanup (or until 2064); near-term

post-cleanup (until 2164, which is the assumed duration for institutional controls associated with land areas transferred from federal control); and long-term post cleanup (or until 3064).

5. The likelihood of initiating events occurring during the evaluation periods, such as fire, volcanic eruptions, and plane crashes are described to establish a consistent basis for identifying and categorizing phenomena that may remove or degrade barriers placing receptors at risk from contaminants. Nuclear safety is considered in the context of potential initiating events and risks to receptors.

It is also important to be clear what the Risk Review Project is not. The Risk Review Project is neither intended to be a substitute for nor preempt any requirement imposed under applicable federal or state environmental laws. As important, the Risk Review Project is not intended to make or replace any decision made under the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) and/or 2010 Consent Order.

The Risk Review Project focuses on risk characterization, which is a necessary predecessor to risk management, but does not focus on risk management decisions. In addition to contaminants, such as radionuclides or chromium, cleanup actions can pose risks to receptors. However, the Risk Review Project will not provide any analysis regarding which cleanup options should be selected or execution of cleanup specific cleanup activities. Rather, the Risk Review Project is limited to considering a plausible range of cleanup actions for different types of contaminant sources to provide a better understanding of the range of potential risks and impacts that may be caused by future cleanup actions

The Risk Review Project is led by a team of CRESP researchers with the cooperation and participation of senior management from DOE, Environmental Protection Agency (EPA), and the State of Washington Departments of Ecology and Health through a Core Team that provides advice and guidance on the development and execution of the Risk Review Project. The Pacific Northwest National Laboratory (PNNL) is providing research, analytical, and other assistance to CRESP.

CRESP is a multi-disciplinary consortium of universities with a mission to advance environmental cleanup by finding ways to improve the scientific and technical basis for management decisions, and to engage stakeholders and the public in that search. CRESP has completed risk informed characterization projects involving complex issues at DOE Office of Environmental Management (EM) sites around the country.

The purpose of this document is to present the Risk Review Project methodology that has been developed to carry out the project. The focus is on methodology, rather than outcomes. This means the general approach to be followed is described in detail, as are example applications from pilot case sites that were analyzed to test the efficacy of the developed approach. Final ratings and potential conclusions from example applications are not provided in this document to avoid a premature focus on ratings of individual pilot case site risks or impacts to receptors, prior to completion of a large enough set of cases that will provide a useful basis for comparison.

This document is intended to serve as the basis for obtaining written comments on the approaches described for conducting the Risk Review Project. Input received will be incorporated into further refinements of the methodology as it is being applied to carry out the Risk Review Project. Project results will be discussed in both an Interim Progress Report, which will be completed during the first quarter of 2015, and a Final Report submitted at the end of 2015.

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Abbreviations and Acronyms

ca.	'approximate'
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CH-TRU	contact-handled transuranic waste
CLUP	Comprehensive Land Use Plan
COPC	Contaminant of Potential Concern
CR	Columbia River
CRESP	Consortium for Risk Evaluation with Stakeholder Participation
CSB	Canister Storage Building
CWC	Central Waste Complex
D&D	Deactivation and Decommissioning
DFHLW	Direct Feed High-Level Waste treatment (to WTP vitrification facility)
DFLAW	Direct Feed Low Activity Waste treatment (to WTP vitrification facility)
DOE	Department of Energy
DSA	Documented Safety Analysis
DWS	Drinking Water Standard
e.g.	'for example'
EIS	Environmental Impact Statement
EM	Office of Environmental Management (DOE)
EPA	Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
EU	Evaluation Unit
FFTF	Fast Flux Test Facility
GW	Groundwater
HA	Hazard Analysis
HAMMER	Volpentest Hazardous Materials Management and Emergency Response Federal Training Center
i.e.	'that is' (used to explain, clarify or rephrase a statement rather than listing options)
IDF	Integrated Disposal Facility
IMUSTS	Inactive Miscellaneous Underground Storage Tanks
IS	Insufficient Information
LAW	Low activity waste
LERF	Liquid Effluent Retention Facility
LLW	Low level waste
MCL	Maximum Contaminant Level (drinking water standard)
MLLW	Mixed low level (radioactive) waste
NA	Not Applicable
NDA	nondestructive assay
NDE	nondestructive examination
NE	Not Estimated
NEPA	National Environmental Protection Act
NRC	Nuclear Regulatory Commission
NRDWL	Non-Radioactive Dangerous Waste Landfill
OSWER	Office of Solid Waste and Energy Response (EPA)
PC	Primary Contaminant
PCB	Polychlorinated Biphenyls

PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
PT	Pretreatment plant (at WTP)
PUREX	Plutonium and Uranium Recovery by Extraction
RCRA	Resource Conservation and Recovery Act
REDOX	Reduction-oxidation
RI/FS	Remedial Investigation / Feasibility Study
ROD	Record of Decision
ROM	Rough Order-of-Magnitude
SALDS	State Approved Land Disposal Site
SARAH	Safety Analysis and Risk Assessment Handbook
SWL	Solid waste landfill
SWOC	Solid Waste Operations Complex
SZ	Saturated zone
TBD	To Be Determined
TC&WM	Tank Closure and Waste Management (environmental impact statement)
TEDF	Treated Effluent Disposal Facility
TRU	Transuranic
TRUM	transuranic mixed
TSCA	Toxic Substances Control Act
TSD	Treatment, Storage and Disposal
VZ	Vadose Zone
WAC	Washington State Administrative Code
WE	Water Extractable
WESF	Waste Encapsulation and Storage Facility
WIPP	Waste Isolation Plant
WRAP	Waste Receiving and Processing Facility
WTP	Waste Treatment Plant

Probability, Consequence, and Risk Ratings

A	Anticipated
BEU	Beyond Extremely Unlikely
EU	Extremely Unlikely
H	High
L	Low
M	Medium
ND	Not Discernible
U	Unlikely
VH	Very High

Terminology and Definitions

The primary objective of the Risk Review Project is to characterize risks to human health (both workers and public), ecological resources, cultural resources, groundwater and the Columbia River. These terms are collectively referred to as "receptors." For the purposes of this document, the following definitions apply:

Completed Pathway – the transport (transfer or movement) of a contaminant from an environmental source or matrix (facilities (including those from materials and waste processing and disposal), tanks, air, water, soil,) to any receptor through a specific set of mechanisms or transport paths. If the transfer is currently occurring, the pathway is referred to as "complete." If transfer may occur in the future, the pathway may become complete. Other potential pathways may never become "complete" if there is cleanup or interdiction (barriers) or if receptors are kept out of harm's way, for example, by future land use restrictions or institutional controls.

Conceptual Site Model – a comprehensive (usually graphic) delineation of sources, potential initiating events, and completed or potential pathways, that may result in (or prevent) exposure, risks and/or impacts to receptors and resources, as well as barriers that interdict the exposure or mitigate the impacts.

Contaminant Sources (or Sources) – chemical and/or radiological contaminants or waste present in a specific form and geographic location. Example sources include contaminated soils, vadose zone, groundwater, buildings, tanks and drums, as well as historic, current and future waste disposal areas, waste storage and processing facilities.

Evaluation Period – the timeframe considered over which risks or impacts may occur. This Risk Review Project considers three time intervals: , (i) active cleanup, including current status prior to cleanup and risk during potential cleanup actions, (ii) near-term post-cleanup and (iii) long-term post-cleanup .

Evaluation Unit Summary Template (or Evaluation Template) – a standardized format used to summarize information and risk ratings for each evaluation unit.

Evaluation Units (EUs) – groupings of sources, aggregated for evaluation as part of this Risk Review Project. Sources may be aggregated into an EU based on potential impacts to a common set of receptors or receptor geographic area, common past waste management practices, or integration in the waste management process. The grouping of sources to form specific evaluation units is discussed in Part 2.

Iconic Contaminants – a set of contaminants that have been of central focus and importance in the historic evaluation of human health and environmental impacts at the Hanford Site.

Impacts – the damage or consequences (death, illness, reduced reproduction, resource impairment, or access limitation) from current or post-remediation residual contamination, or from cleanup, including degradation of resources (including ecosystems, cultural resources, economic assets, groundwater, and surface water above defined thresholds).

Initiating Events – natural or anthropogenic events or processes that may result in the release of or accelerated movement of contaminants from a source. Examples include water infiltration, earthquakes, fires, cleanup activities, volcanic eruptions, sudden structural collapses or failures etc. Initiating events relevant to this Risk Review Project are discussed in Part 2.

Insufficient Information (IS) – when adequate data or other forms of information are not available to complete the indicated part of the Evaluation Template .

Key Sources – the set of contaminated areas, wastes and facilities within an evaluation unit that pose the primary risks from the evaluation unit. Key sources would not include minor contributors to the overall risks.

Legacy Source Sites – contaminant releases to the ground surface or subsurface resulting from prior actions, including waste disposal actions that are no longer being carried out at a particular location and are potentially subject to cleanup.

Not Applicable (NA) – the indicated part of the Evaluation Template is not applicable to the specific EU or evaluation period being considered.

Not Discernible (ND) – the indicated risk or potential impact is not distinguishable from surrounding conditions.

Novel Remediation Approach – a remedial approach that is unprecedented or contains components that are unprecedented.

Operable Units – regulatory groupings of sites. Sites typically are aggregated for regulatory purposes either by function, type of contaminated media (i.e., near surface soils, groundwater, etc.), cleanup requirements (i.e., facility decommissioning), and/or geographic area.

Primary Contaminants – contaminants that are considered either risk drivers from specific contaminant sources or site-wide iconic contaminants (e.g., uranium, plutonium, technetium, etc.) for the Hanford Site. The terminology "primary contaminants" is used to differentiate the usage in this Risk Review Project from the regulatory usage of the terminology of "contaminants of potential concern."

Primary Sources – the origin for a potential or known release of contaminants to the environment (e.g., tanks, buildings, burial grounds, lagoons, cribs).

Rough Order of Magnitude Relative Rating – binning to provide distinction amongst major differences in a risk to a specific receptor (i.e., human health, ecology, etc.) between multiple EUs by way of assigning values of very high, high, medium, low or not discernible (i.e., relative risks posed when comparing amongst EUs).

Receptors – human populations (both workers and public), biota and ecological systems, environmental resources (ground and surface water), and cultural resources (both tribal and historical) that may be exposed to contaminants via one or more contaminant transport and uptake pathways or otherwise adversely impacted by the contamination or cleanup actions and are valued in ways that make them worthy of protection – either because they are legally protected or are of concern to stakeholders.

Resources – Entities that have inherent worth based on societal values (i.e., intact ecosystems, cultural artifacts, aesthetic values, as well as groundwater, surface water, economic assets, etc.).

Risk – the potential (likelihood and magnitude) for adverse consequences to receptors. For human health, risks originate from exposure to contaminants or trauma associated with the presence of contaminants and/or cleanup of contaminant sources. For other receptors, such as groundwater, ecological and cultural resources, risks reflect the potential for damages or losses of the resource.

Risk Characterization – a review of available information, including identification of key information gaps, to provide a comparative qualitative and semi-quantitative (order of magnitude) evaluation of relative risks to a set of receptors posed by a wide range of existing contamination of environmental media and sources of potential future additional environmental contamination. Risk characterization is in contrast to a regulatory risk assessment which provides quantitative estimates of human health risks.

Sites – individual contaminated areas within the Hanford Site, usually within a circumscribed area.

Secondary Sources – locations in the environment that have received material from a primary source such they can also act as sources (e.g., soil, groundwater, sediments).

Worker (remediation or facility worker) – facility worker that is a remediation worker or support staff located within 100 m from a postulated event that may cause them harm.

Worker (co-located) – Co-located workers are remediation workers located more than 100 m from a postulated event that may cause harm.

PART 1. OBJECTIVES AND APPROACH OVERVIEW

CHAPTER 1. RISK REVIEW PROJECT SCOPE AND EXECUTION

1.1. GOAL, OBJECTIVES AND SCOPE

In January 2014, the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) was requested by the Deputy Under Secretary of the Department of Energy (DOE) to conduct a Hanford site-wide evaluation of human health, nuclear safety, environmental, and cultural resource risks (See Appendix A); hereinafter referred to as the "Risk Review Project." The goal of the Risk Review Project is to identify and characterize potential risks to the public, workers, groundwater and the Columbia River, and ecological and cultural resources (collectively referred to as" receptors") at the Hanford Site. The Risk Review Project's results are expected to provide DOE and regulators with a common understanding of the risks contaminants and cleanup (including mitigation measure that offset or reduce risk with cleanup) may have on human health and the environment and also help inform the efficient use of DOE Office of Environmental Management (EM) resources. Specific objectives of the Risk Review Project are:

1. To review sources of contamination site-wide and determine the potential for contaminants and cleanup actions to cause risks to receptors;
2. To provide relative ratings of risks to receptors from sources, in order to better enable the Tri-Parties (DOE, U.S. Environmental Protection Agency (EPA), and Washington Department of Ecology) to make decisions on the sequencing of Hanford cleanup activities, and
3. To place the risks posed by the contamination and the cleanup at the Hanford site into context with the risks, remediation, and land uses at other places and sites in the region and the significance of Hanford's unique geography.

To meet the above listed objectives, risk characterization is designed to assemble and evaluate existing information to group or bin risks to each type of receptor into one of five categories: very high, high, medium, low, or not discernible. This approach is intended to provide relative risk ratings *within* receptor categories (i.e., relative binning of risks to the Columbia River, groundwater, ecology, etc.) and also to provide several examples that illustrate how grouping or binning that integrates the ratings across receptor categories (e.g., integrated risk binning that combines risks to human health with risks to ecology and groundwater) could be carried out. Integration across receptor categories is considered inherently driven by individual and collective values, and thus, multiple outcomes are possible. This is because of the wide range of individual and collective values that are naturally present within the Hanford community. The Risk Review Project intends (once it has completed a more complete set of EU analyses) to develop an algorithm that transparently exhibits several ways to integrate the various receptor ratings into the overall EU binning.

It is also important to be clear what the Risk Review Project is not:

1. The Risk Review Project is neither intended to substitute for, nor preempt any requirement imposed under applicable federal and state environmental laws. As important, the Risk Review Project is not intended to make or replace any decision made under the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) and/or 2010 Consent Order.
2. The Risk Review Project is focused on risk characterization, which is a necessary predecessor to risk management, but does not focus on risk management decisions. Nonetheless, cleanup actions can cause risks to receptors, which are a part of risk management decisions. The Risk Review Project, however, will not analyze which cleanup option should be selected or the timing of cleanup. Instead, the Risk Review Project considers a plausible range of cleanup actions for

different types of contaminant sources to better understand the range of potential risks that may be caused by future cleanup actions.

3. The Risk Review is focused only on portions of the Hanford Site where cleanup or waste management activities are ongoing and will continue past October 1, 2015 or where cleanup or waste management activities will occur beginning October 1, 2015 or later. Cleanup actions considered completed by the Tri-Parties are not part of the Risk Review Project and therefore will not be evaluated. Specific areas of the Hanford Site that are included as well those that are excluded from the Risk Review Project are described in Part 2 of this document.

The Risk Review Project is being carried out with the cooperation and participation of senior management from DOE, U.S. Environmental Protection Agency (EPA), and the State of Washington Departments of Ecology and Health through a Core Team that provides advice and guidance on the development and execution of the Risk Review Project. The Pacific Northwest National Laboratory (PNNL) provides analytical and research assistance, which includes gathering existing information on each unit being evaluated.

The Risk Review Project is led by CRESP and CRESP is responsible for its execution, results, conclusions, and recommendations. CRESP consists of a consortium of universities and is supported by DOE through a cooperative agreement[7]. The CRESP mission is to advance environmental cleanup by finding ways to improve the scientific and technical basis for management decisions while at the same time fostering opportunities for public participation. CRESP has completed risk-informed characterization projects involve complex issues at both large and small DOE EM sites.

The Risk Review Project is being carried out in multiple stages, which are:

1. Development of the risk characterization methodology and testing the developed methodology on pilot case sites representing the primary sources of contamination at Hanford (e.g., operating facilities and tank waste and tank farms). The methodology has been adapted from prior risk characterization approaches used at Hanford and elsewhere and suitably tailored to fit Hanford Site's unique cleanup and waste management activities, diversity of information, and also the goal and objectives of the Risk Review Project. The methodology is the subject of this document.
2. Completion of an Interim Progress Report that will provide risk characterization of approximately half of the contaminant sources at the Hanford Site.
3. Completion of a Final Report that will include risk characterization of the full set of contaminant sources at the Hanford Site included within the Risk Review Project.

Cleanup at Hanford has proven to be a much more lengthy, complex, technically challenging, and expensive undertaking than was envisaged in 1989 when Hanford's mission shifted from production of weapons material to waste management and cleanup. In fact, the Hanford Site is the most complex and costly cleanup project in the United States. Overall cleanup has been projected to cost over the next 50 years more than $100 billion. While earlier studies have evaluated portions of the Hanford Site, a comprehensive, site-wide review of the risks to human health and resources from the Hanford contamination, waste management, and cleanup activities has never been carried out. For all these reasons, then, it is appropriate for the DOE to have requested a comprehensive site-wide review of risks to receptors that also would provide opportunities for input at key points from individuals, organizations, agencies, elected officials, and tribal nations.

[7] CRESP is supported by the U. S. Department of Energy, under Cooperative Agreement Number DE-FC01-06EW07053 entitled 'The Consortium for Risk Evaluation with Stakeholder Participation III awarded to Vanderbilt University.

1.2. EXTERNAL REVIEW

To ensure that the methodology ultimately used to conduct the Risk Review Project is credible and of the highest quality, it is important that a broad spectrum of stakeholders, the public, tribes, and government agencies have an opportunity to provide written comments. In early September 2014, this document will be posted on a CRESP web page (www.cresp.org/hanford), which is dedicated to the Risk Review Project, and available for written comment. In addition, either before the Risk Review Project methodology is released for public comment or shortly thereafter, team members will meet with the Hanford Advisory Board (public invited), tribal representatives, affected government agencies, and local elected officials to explain the methodology and encourage feedback on this document. Finally Core Team members and their staff have been asked to review the methodology, and it is anticipated this document also will be sent to a peer-review group of experts for comment.

Written comment will be solicited from a broad spectrum of stakeholders, the public, tribes, and government entities at two other key points during the Risk Review Project. Those points are: during the first quarter (calendar year) of 2015 on the Interim Progress Report and during the fourth quarter of 2015 on the draft Final Report prepared on the Risk Review Project.

All written input received on this document will be acknowledged, considered, and form the basis for improving the methodology that will be used to execute the entire Risk Review Project. A summary of comments received either will be included as part of a separate report or included as one of the Appendices to the Interim Progress Report.

1.3. THE PURPOSE OF THIS DOCUMENT

The purpose of this Methodology for the Hanford Site-Wide Risk Review Project document is to present the scope and methodology developed to carry out the Project, including specific methodology for qualitative and order-of-magnitude relative rating and binning of risks to multiple receptors. The focus is on the elements of the methodology itself, rather than on outcomes of the ratings or binning of receptors for the pilot case sites. This document also contains the evaluation unit (EU) summaries, which were prepared on three pilot cases to test the applicability and efficacy of the methodology and evaluation templates. However, final ratings and potential conclusions from example pilot cases are not included as part of this document to avoid premature focus on ratings of individual sources and risks, prior to completion of a large enough set of cases, such as will be included in the interim report, to provide a useful basis for comparison.

In addition to the above and as noted earlier, this document serves as the document that stakeholders, the public tribes, and government entities will be asked to provide comment. Input received will be used to further refine the methodology as it is being applied during the remainder of the Risk Review Project.

CHAPTER 2. AN OVERVIEW OF THE RISK CHARACTERIZATION METHODOLOGY

2.1. THE RISK CHARACTERIZATION METHODOLOGY

The Risk Review Project Methodology or paradigm includes characterization of evaluation units (EUs), characterization of the risks to receptors, and a rating of the risks to the receptors for each EU. To accomplish this task, the Risk Review Project needed to define receptors, group and define EUs, determine assessment periods, and define initiating events. The key components of the methodology paradigm itself include characterization of the EUs (sources, contaminants, land use, pathways) and determination of the risk to receptors. The general risk characterization paradigm that is being used to evaluate risks to human health and other receptors includes the following steps:

1. Grouping of individual sources into EUs for the purposes of the Risk Review Project. Types of individual sources are:
    a. legacy sources sites (including prior intentional and unintentional liquid waste infiltration, near surface disposal sites (subject to cleanup) and related contamination in the vadose zone);
    b. tank waste and farms (including ancillary equipment, near-surface, and vadose zone contamination from prior tank leaks and geographically associated legacy source sites);
    c. groundwater plumes[8];
    d. inactive facilities for decommissioning; and
    e. operating facilities used for waste storage, treatment and disposal.

    The Hanford Site has been divided into more than 2500 individual contaminated areas and facilities for regulatory purposes. Individual sources have been grouped into approximately 60 EUs as part of this Risk Review Project to help make the review process tractable. Thus, there are five major source types (a-e above), and the Risk Review Project evaluates 60+ EUs that may have one or more sources within their geographical boundaries. Further descriptions of the sources and grouping methodology into EUs is provided in Part 2.
2. Defining assessment time periods and contaminants (radionuclides and other contaminants) to be considered (discussed below). The evaluation periods considered are (i) Active Cleanup Period (until 2064), which includes current conditions, and (ii) Near-Term, Post-Cleanup Period (until 2164), and (iii) Long-Term, Post-Cleanup Period (until 3064). Section 2.3 provides additional assumptions relative to each time frame.
3. Selecting a set of potential initiating events for each source type that may result in the release of contaminants from a source or physical disruption (including disruption from a range of possible cleanup approaches) that can result in risks to humans and other receptors (Part 2). Nuclear safety is considered in the context of initiating events the extent that may cause risks to human receptors. Furthermore, contaminants in environmental media (e.g., soils, vadose zone, groundwater) will flow, move, diffuse, and disperse under long-term prevailing conditions without the presence of specific episodic initiating events.
4. Characterizing potential receptors that may be at risk. Receptors, considered as part of the Risk Review Project and described in later chapters, are the public[9] (Chapter 5), workers (Chapter 6,

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[8] Groundwater is considered both a receptor (as a protected resource by the State of Washington) and, when contaminated, as a source in the context of potential contamination of the Columbia River.

including direct workers, such as remediation and/or facility workers, and co-located workers), groundwater and the Columbia River (Chapter 7), ecological resources (Chapter 8), and cultural resources (Chapter 9). Non-human receptors are referred to as resources. Economic assets are described briefly at the end of this chapter, but identified economic assets are not evaluated individually in detail in this document.

5. Using a standardized summary report structure, referred to as an Evaluation Template, that presents information about individual EUs and provides the basis for rating potential risks to each receptor category. The Evaluation Template is completed for an individual EU based on publically available information such as prior source-specific characterizations, environmental impact statements, CERCLA remedial investigations, preliminary documented safety analyses, etc.
6. Using a methodology to rate risks for each receptor (also referred to as a binning) for a given time frame Each EU will receive a rating for each applicable receptor during the active cleanup period (including as a result of cleanup actions where applicable) and the near-term post-cleanup period. The long-term, post-cleanup period will be considered for the remaining contaminant inventory and physical/chemical form, engineered and natural containment barriers to contaminant release and potential risk pathways. However, a rating for specific receptors will not be assigned to the long-term, post-cleanup period. Methodologies to be used to evaluate risks to each category of receptor, as well as the basis for each evaluation time frame, are provided in later chapters of this document.

Each step in the methodology is further described below in the following sections. The overall methodology is in Figure 2-1 below and the key components (Evaluation Template and characterization of EUs, and risk to receptors) are described in Sections 2.6 and 2.7 of this Chapter.

[9] Currently, public access is primarily restricted to activities associated with the mission of the Hanford Site. The definition of the potentially impacted public will evolve as the site is cleanup up and changes occur in land uses. This is discussed further in Chapter 5.

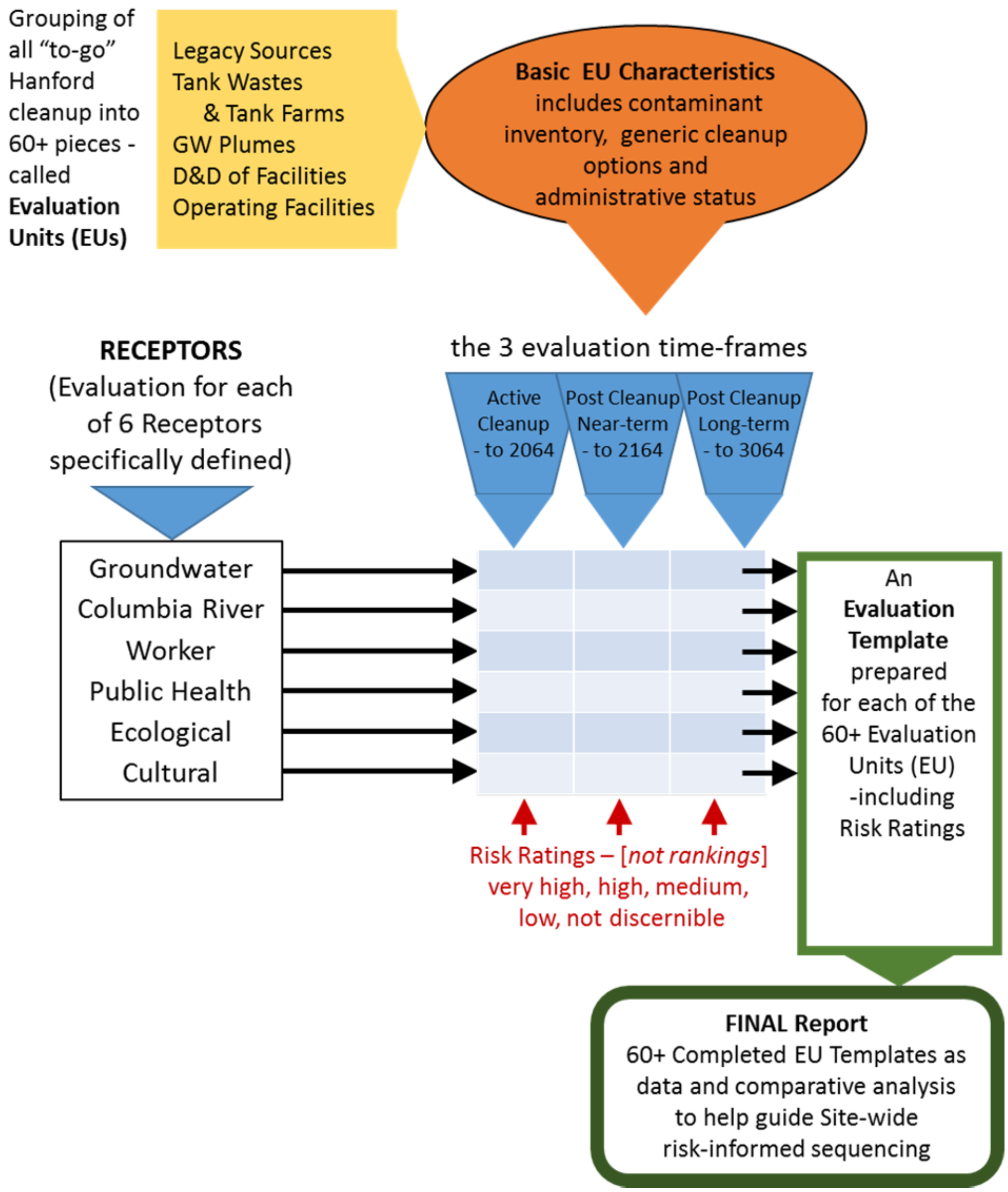

Figure 2-1. Basic methodology for the Hanford Site-Wide Risk Review Project.

As noted, there are six receptors and 60+ EUs. Each receptor (resource) type is discussed in a separate Chapter that includes an overall description of the resource, those factors affecting the receptor's health and well-being, and the methodology developed to evaluate risks. Each EU is described in an Evaluation Template that summarizes relevant information and includes the rating of risk for each receptor.

2.2. RADIONUCLIDES AND OTHER CONTAMINANTS CONSIDERED

The Risk Review Project focuses on radionuclides and contaminants that are either iconic for the Hanford Site (i.e., have been of large site-wide significance and public concern) or are the major contributors to receptor risks at specific EUs (i.e., risk drivers)[10]. Collectively, the set of radionuclides and contaminants being considered may differ for specific EUs (because of either presence or absence of iconic radionuclides and contaminants and different risk and impact drivers), but are collectively referred to as primary contaminants. In most cases, the list of primary contaminants for each EU will be a more limited list than the regulatory list of contaminants of potential concern (COPCs). The radionuclides and other contaminants that are considered iconic or Hanford-specific are as follows:

Radionuclides – cesium-137, iodine-129, plutonium, strontium-90, technetium-99, tritium

Other contaminants – carbon tetrachloride, trichloroethylene, chromium, total uranium, nitrate

One example of an additional risk driver in a specific EU is cyanide, which is present in the B-Complex groundwater within the Central Plateau.

2.3. ASSESSMENT TIME PERIODS

Three evaluation periods are considered for each evaluation unit in this Risk Review Project:

- Active Cleanup (50 years or until 2064), including the current status and cleanup actions,
- Near-term Post-Cleanup (2064 to 2164), and
- Long-term Post-Cleanup (2164 to 3064).

The rationale and description for each of these evaluation periods are provided below.

ACTIVE CLEANUP

The active cleanup period for Hanford is defined as 50 years (i.e., until the year 2064). During this period, all currently planned cleanup is assumed to be completed, except completion of groundwater cleanup, natural attenuation processes when selected as a remedy (for vadose zone and groundwater), and final disposition of entombed reactors and facilities along the Columbia River Corridor. The current designated actions for the entombed reactors is to evaluate the final timeline and removal of these facilities to the Central Plateau in the future with ca. 75 years for reactor entombment to allow for radioactive decay and therefore increased safety associated with future actions.[11]

One objective of this Risk Review Project is to help inform decisions that DOE and regulators will make concerning future sequencing of cleanup activities, including which areas should be focused on earlier for additional characterization and analysis. Thus, the Risk Review Project does not assume a fixed sub-interval in time for cleanup of any specific source or EU. Rather, each source (or EU) is evaluated as if cleanup were not to occur for 50 years to provide insights into the risks that may be incurred through delay.

Cleanup activities at Hanford are ongoing and not static. Since the Risk Review Project is being completed in a short time frame, this means that 1) changes in risk to resources may occur as a result of changing contamination distributions, 2) changes in risk to resources may occur as a result of nearby cleanup activities, and 3) currently undetermined cleanup methods or timing may affect risk in EUs or

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[10] The terminology of "iconic contaminants," "risk drivers", and "primary contaminants" is specific to the Hanford Risk Review Project, with the specific radionuclides and contaminants included in each category developed based on Hanford history, prior evaluations, and with input from the Core Team.

[11] The EIS (DOE/EIS-0119D. 1989) and its Addendum (DOE/EIS-0222-F. 1992) for the disposition of eight surplus Hanford reactors.

adjacent EUs. Although initial assessment will include the risks posed by the current and projected contamination, significant changes in the risk profile for each EU's sources may also occur during, or as a result of cleanup activities. Changes in the risk profile that may occur include increases in risks to workers, accidental or consequential dispersion of contaminants, disruption of biota and ecosystems, disruptions to or exposure of cultural resources, and impacts to nearby operating facilities. The final approach and timing selected for cleanup of each source area where there has not been a regulatory decision is typically, and by definition, not known at this time. Therefore, for EUs where regulatory determinations have not been made, a range of cleanup approaches is examined for each generic type of source when considering risks and impacts from cleanup.

The primary distinctions amongst different cleanup approaches is the amount of contaminant inventory remaining, barriers that prevent dispersion of residual contamination, and the type of activities required to achieve cleanup (potentially impacting worker safety and surrounding ecology and cultural resources). The range of possible cleanup approaches for any evaluation unit will emerge from information on the sources and risks/impacts at that unit. Hence, any list of probable cleanup approaches reflects how the sources might be addressed. The list below provides several examples of the types of different remedial options for the major contaminant sources:

Legacy Source Sites

- Removal (excavation), transport, and on-site disposal;
- *In-situ* immobilization (e.g., grouting or injections to form low solubility minerals);
- *In-situ* treatment resulting in contaminant removal (e.g., in-situ biodegradation or natural attenuation);
- *In-situ* phytoremediation; and
- Capping and restoration.

Tank Waste and Farms

- Retrieval of waste and
- Grouting of tanks and ancillary equipment.

Groundwater and Deep Vadose Contamination

- Natural attenuation (e.g., by radioactive decay or biodegradation processes);
- *In-situ* immobilization (e.g., grouting, desiccation, or injections to form low solubility minerals);
- Capping (i.e., to limit infiltration and recharge); and
- Groundwater recovery with or without active flushing ("pump and treat").

D&D of Inactive Facilities

- Decommissioning and demolition, including in-situ D&D;
- Full or partial permanent entombment; and
- Interim entombment followed by further decommissioning and demolition (i.e., allowance for radioactive decay to reduce worker risks and potential impacts).

In addition, off-site disposition of materials and wastes to an off-site federal or commercial disposal site or a national geologic repository is the disposition pathway for several sources of contamination (e.g., high-level waste).

For those sources where the cleanup plan has been determined by a final remedial action record of decision (EPA 2013), such as for the 300 Area (EPA 2013), or environmental impact statement (DOE/EIS-0391 2012), such as for the tank farms, the selected remedy will be considered the baseline cleanup scenario in the Risk Review Project risk ratings.

Since the EU's "sources" may be diverse and multiple, evaluation of current status and potential initiating events that cause or exacerbate risk is also diverse. Initiating events can result in movement or migration of contaminants. But, it is possible to describe and predict the major aspects of different scenarios for key sources. For example, a critical initiating event for transport of contaminants from several source types (near-surface soils, the vadose zone, and groundwater) is the rate of infiltration or recharge. During the active cleanup period, two infiltration rates are assumed for infiltration and recharge[12] (see Attachment 2.1): (i) 5 mm/per year to reflect covered and vegetated areas, and (ii) 50 mm/year to reflect unvegetated, disrupted surficial soils. Higher recharge rates (e.g., 100 mm/yr) will be considered for those areas covered with gravel. Lower recharge rates will also be considered when barriers are in place. Hence, for these source types, an evaluation will be carried out to determine (i) the risks and impacts if cleanup were not to occur for up to 50 years, assuming two rates of infiltration and recharge, and (ii) the risks and impacts during and as a result of the potential range of cleanup actions. To the greatest extent possible, available characterization and monitoring data will provide the basis for understanding the current rate of contaminant migration in the vadose zone and groundwater. Contaminant migration once present in the groundwater is assumed to move under prevailing regional flow conditions.

NEAR-TERM POST-CLEANUP

The near-term post-cleanup period is for 100 years after cleanup is completed (until the year 2164). This period was selected because it is the interval over which institutional controls are assumed to be in effect for land areas no longer maintained under federal control. During this period, maintenance activities also are assumed to occur as necessary to maintain the integrity of the remaining engineered systems (e.g., landfill caps, liners, entombment, etc.), along with active monitoring to detect any new releases and confirm the efficacy of remaining remedial activities (e.g., natural attenuation, groundwater containment, etc.).

Post-cleanup does not mean that all contamination has been removed from Hanford. Thus, there will be a diversity of states that constitute "completion" at the EUs. The following are examples that illustrate the range of end-states for units of characteristic "sources" to be achieved at the completion of the Active Cleanup, which is also the beginning of the Near-term Post-Cleanup period.

> Legacy Source Sites: Cleanup to unrestricted use; Cleanup to industrial use standards; Cleanup consistent with other land use designations;
>
> Tank Waste and Farms: Removal of 99% of the waste contained in tanks followed by grouting of tanks and ancillary equipment and capping of the tank farm;
>
> Groundwater and Deep Vadose Zone Contamination: Natural attenuation (e.g., by radioactive decay or biodegradation processes); Removal or immobilization of to a certain percent of the initial inventory; capping (i.e., to limit infiltration and recharge); and
>
> D&D of Inactive Facilities: Decommissioning and Demolition completed; final permanent entombment achieved.

The presence of residual contaminants in remediated areas and engineered disposal facilities typically is evaluated through performance assessments. As discussed earlier, critical initiating events for the transport of remaining contaminants from closed facilities, the vadose zone, and groundwater is the rate of infiltration or recharge. During the near-term post-cleanup period, three recharge rates are assumed for infiltration and recharge: (i) 0.5 mm/year to reflect areas capped with impermeable closure

[12] Recharge and infiltration rates are assumed equal for this Review.

caps (i.e., closure of permitted and engineered landfills) (ii) 5 mm/per year to reflect covered and vegetated areas, and (iii) 50 mm/year to reflect unvegetated, disrupted surficial soils[13].

LONG-TERM POST-CLEANUP

The long-term post-cleanup period is assumed to extend for 900 years after the near-term post-cleanup period (until the year 3064) for a total post closure assessment period of 1000 years. This interval was selected to be consistent with current DOE Order 435.1 for performance assessments, evolving Nuclear Regulatory Commission (NRC) recommendations for evaluation of closure of near-surface low activity waste disposal (ACRS Letter 2014), and the basis of prior contaminant transport modeling information. The same end-states associated with the end of the active cleanup period are assumed to be applicable until the year 3064, where reasonable. Associated uncertainties and uncertainty ranges will be clearly identified, where possible.

For many remaining sources, the only reasonable assessment for EUs will be (i) the remaining contaminant inventory along with the physical state and location, (ii) the degradation, prevailing natural processes (e.g., contaminant transport and dispersion associated with recharge and groundwater flow, etc.) or failure modes that can result in dispersal or migration of contaminants from the remaining engineered systems or subsurface contamination, and (iii) the probability of significant initiating events. The assumed set of infiltration and recharge rates for the long-term post-cleanup period will be the same as for the near-term, post-cleanup period.

2.4. A PRESUMPTIVE SET OF POTENTIAL CONTAMINANT RELEASE, RISKS, AND IMPACT PATHWAYS

Despite the diversity of sources and receptors/resources, there is a limited set of potential contaminant release mechanisms and pathways from source areas that constitute the focus of the Risk Review Project. Examination of the full list below for each EU will identify the range of contaminant release and impact pathways of primary importance. Hence, the following may be considered a "check list" for each EU:

Pathways

Risks from Contaminated Near-Surface Soils – the primary pathways are (i) direct human exposure through land use, (ii) transport to the subsurface and groundwater through infiltration, (iii) contaminant transport through erosion, biotic processes or atmospheric dispersion, (iv) biota exposure and biotic transport, and (v) exposure to cultural resources.

Risks from Vadose Zone Contamination – infiltration-induced transport through the subsurface to groundwater and the Columbia River.

Risks from Engineered Waste Management Facilities – initiating events that cause loss of waste/contaminant containment followed by either (i) direct human exposure, (ii) atmospheric dispersion, (iii) near-surface soil contamination, (iv) impairing or precluding use of other resources and facilities, (v) damaged biota or ecosystems, and (vi) damaging/destroying cultural resources.

Risks from Facility Decommissioning - occur primarily from unanticipated facility conditions and accidents during cleanup and maintenance activities. Accidents or other initiating events prior

[13] Higher recharge rates (e.g., 100 mm/yr) will be considered for those areas covered with gravel.

to completion of decommissioning may cause loss of waste/contaminant containment followed by combinations of (i) direct human exposure; (ii) atmospheric dispersion; (iii) near-surface soil contamination; (iv) impaired or precluded use of other resources and facilities; or (v) damage biota, ecosystems, or cultural resources.

Risks from Groundwater Contamination – only may occur when there is active or projected use and/or consumption of contaminated groundwater, or as a consequence of contaminant discharge to the Columbia River.

Receptors

Worker Health Risks – occur primarily from unanticipated circumstances and accidents during cleanup and maintenance activities. Occupational health exposures and traumas may occur as a consequence of existing conditions, maintenance, monitoring, or cleanup activities.

Public Health Risks – occur from exposures to through contaminants in air, water, near-surface soils or consumption of food grown or harvested from contaminated soils. Potential exposure due to routine excavation or other activities is considered to a depth of 5 m. Groundwater contamination is evaluated separately from other pathways.

Risks to Groundwater – either from waste currently in engineered facilities, near-surface contaminated soils, vadose zone contamination, or through the movement, diffusion and dispersion of contaminants already present in groundwater. Sources currently in engineered facilities require an initiating event (e.g., cover or liner failure, corrosion or other induced leakage, infrastructure failure causing large water release, large precipitation event, earthquake, accident) to release contaminants to the soil surface or subsurface. Contaminants in near surface soils and the vadose zone are transported to the groundwater as a function of prior moisture conditions and infiltration rate (location and surface condition dependent), individual contaminant sorption/transport characteristics (subsurface stratigraphy and contaminant dependent), and the distance to groundwater (location dependent). Further spreading of contaminants in the groundwater is dependent on contaminant concentration, groundwater flow rate and dispersion, and the individual contaminant sorption/transport characteristics.

Risks to the Columbia River – either from current or projected contaminated groundwater discharge through the river bed or seeps, direct waste discharges, or overland flow and erosion that discharges to surface water. Human health risks associated from contaminated surface water are considered in the context of Columbia River use.

Risks to Biota and Ecosystems – from physical disruption of an ecosystem, contaminant dispersion and uptake, fragmentation of habitats, or introduction of invasive species resulting from contaminant releases or cleanup activities (either in proximity to sensitive ecosystems or as a result of transit pathways to/from remediation activities). Physical disruption, such as soil compaction, introduction of barriers (e.g., roads), and soil removal, have major impacts on species distribution and ecosystems.

Risks to Cultural Resources – from physical disruption, destruction, exposure, impaired access or precluded access resulting from contaminant releases or cleanup activities, from contaminated food, water, medicinal plants, or fibers, or from destruction of the religious/cultural and aesthetic values (e.g., viewshed).

There are also potential risks to economic assets as a consequence of cleanup activities, but they are limited to EUs where either the presence of contamination or cleanup activities may directly impact other DOE or non-DOE facilities. Thus, the consideration of economic assets will be constrained to (i) the intersection of specific EUs with specific facilities, and (ii) a description of the general economic context of the Hanford Site.

The unit of evaluation for the Risk Review Project is the Evaluation Unit, but individual EUs may contain multiple source types (Chapter 3). Not every source type will require an exhaustive assessment for risks to every receptor, for every evaluation period considered. Similarly, some EUs will not have risk ratings for every receptor (e.g., heavily industrial sites may not have ecological or cultural resources on site, or adjacent to the EU). In addition, many EUs may have multiple sources that are aggregated to provide a clearer picture of the risks associated with a geographic area.

Evaluations of risks to certain receptors lend themselves to consideration in the context of individual EUs. These include risks to human health, impacts to groundwater, and risks to the Columbia River. In contrast, risks to remaining receptors are better characterized from two perspectives: 1) a site-wide perspective and 2) the potential risk or impact based on the geographic location of the EU and surrounding areas. These broadly geographically defined receptors include sensitive biota and ecosystems, cultural resources, and economic assets.

2.5. LAND USE AND GROUNDWATER USE

For the purposes of the Risk Review Project, it is assumed that all reasonably available land uses at Hanford will have been realized when the near-term post-cleanup period begins or by 2064. This means that land use will be a factor to be considered as part of the evaluation for each EU for two time periods: near-term post cleanup (until 2164) and long-term post cleanup (until 3064). Additionally, in this Risk Review Project, the human health risks associated with land use have been separated between (i) surface (i.e., facilities, soils and waste disposal sites) and near-surface exposures associated with the land use scenario, and (ii) use of groundwater. This separate consideration is important because (i) cleanup of facilities, surface and near-surface contamination is most frequently a separate effort from groundwater remediation, and (ii) treatment or alternate forms of water supply can be provided to facilitate desired land use when the groundwater within the unit being evaluated is not suitable.

The primary land use selected as the basis for assessment of each EU is the EU's land use as defined in the preferred land use alternative under the Comprehensive Land Use Plan (CLUP) (DOE/EIS-0222-F 1999). See Figure 2-2 and Table 2-1 below for more specific information on each designation. However, specific exposure scenarios that correspond with the CLUP land use categories have not been developed through past Tri-party[14] efforts. The State of Washington currently recognizes only "unrestricted use" and "industrial use" as standard land use designations with established exposure scenarios.

The Core Team has requested one other designation called "unrestricted use," which also has been referred to as "residential land use" to serve as a second basis for assessment along with the primary designation from the CLUP whenever the primary future land use designation would conflict with the "unrestricted use" designation or is not designated for industrial use. The alternative land use designation or "unrestricted use" does not apply to EUs located within the Central Plateau. However, it should be noted that the T Plant (2221 T Process Building) has been specifically identified as one of the buildings to be protected under federal legislation that would establish a Manhattan Project National Historical Park (see Chapter 9, Table 9-3). The EPA has recognized the following land uses as available following completion of remedial actions: any combination of unrestricted uses, restricted uses, and use for long-term waste management (OSWER Directive No.9355.7-04, p. 2).

[14] Tri-party refers to The State of Washington, DOE and EPA.

A limited set of additional alternative land use scenarios may be considered in response to input received from Tribes and/or the broader set of stakeholders.

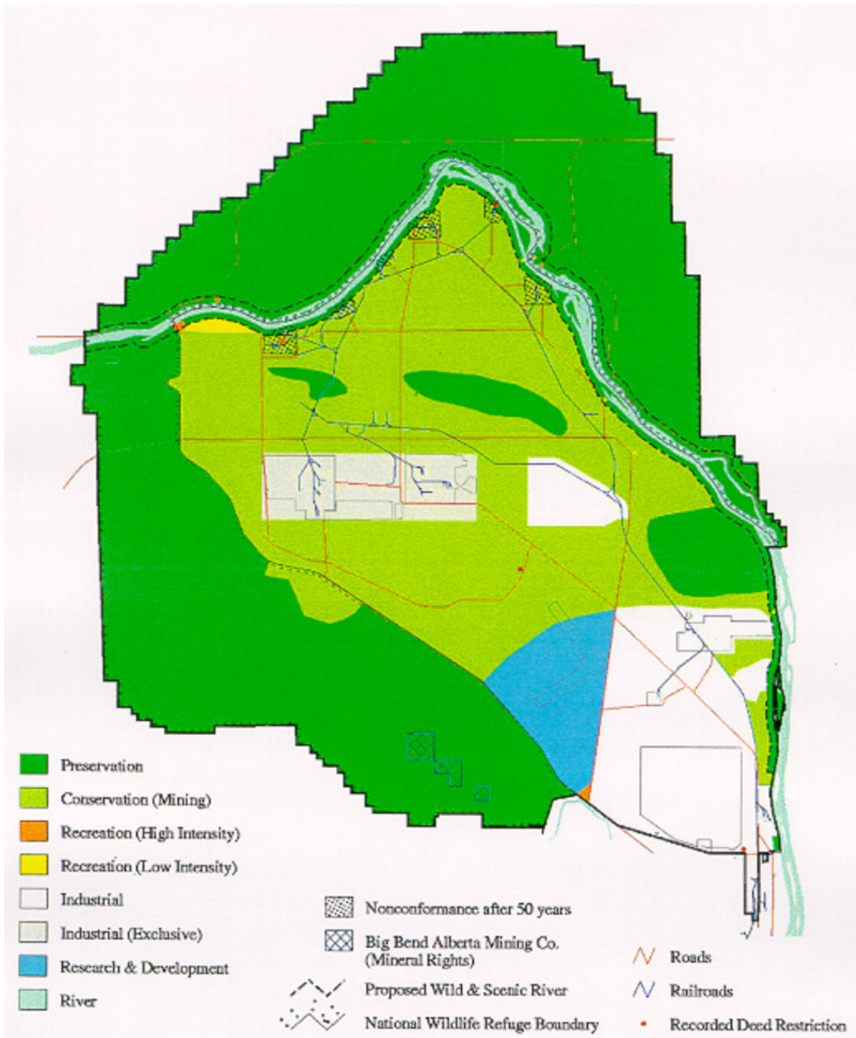

Figure 2-2. Future land use designations from the CLUP (DOE/EIS-0222-F, Figure 3.3).

Table 2-1. Definitions of land use designations in the CLUP (DOE/EIS-0222-F).

Industrial Exclusive	An area suitable and desirable for treatment, storage, and disposal of hazardous, dangerous, radioactive, and nonradioactive wastes. Includes related activities consistent with Industrial-Exclusive uses.
Industrial	An area suitable and desirable for activities, such as reactor operations, rail, barge transport facilities, mining, manufacturing, food processing, assembly, warehouse, and distribution operations. Includes related activities consistent with Industrial uses.
Research and Development	An area designated for conducting basic or applied research that requires the use of a large-scale or isolated facility, or smaller scale time-limited research conducted in the field or within facilities that consume limited resources. Includes scientific, engineering, technology development, technology transfer, and technology deployment activities to meet regional and national needs. Includes related activities consistent with Research and Development.
High-Intensity Recreation	An area allocated for high-intensity, visitor-serving activities and facilities (commercial and governmental), such as golf courses, recreational vehicle parks, boat launching facilities, Tribal fishing facilities, destination resorts, cultural centers, and museums. Includes related activities consistent with High-Intensity Recreation.
Low-Intensity Recreation	An area allocated for low-intensity, visitor-serving activities and facilities, such as improved recreational trails, primitive boat launching facilities, and permitted campgrounds. Includes related activities consistent with Low-Intensity Recreation.
Conservation (Mining)	An area reserved for the management and protection of archeological, cultural, ecological, and natural resources. Limited and managed mining (e.g., quarrying for sand, gravel, basalt, and topsoil for governmental purposes) could occur as a special use (i.e., a permit would be required) within appropriate areas. Limited public access would be consistent with resource conservation. Includes activities related to Conservation (Mining), consistent with the protection of archeological, cultural, ecological, and natural resources.
Preservation	An area managed for the preservation of archeological, cultural, ecological, and natural resources. No new consumptive uses (i.e., mining or extraction of non-renewable resources) would be allowed within this area. Limited public access would be consistent with resource preservation. Includes activities related to Preservation uses.

2.6. EVALUATION TEMPLATE AND THE EFFORT TO STANDARDIZE EVALUATION METRICS

The Risk Review Project initially considered developing Evaluation Templates for each type of source, but since EUs have multiple sources, the key information germane to all the source types have been identified and consolidated into a single template to be used with each EU. Each Evaluation Template provides a consistent, cohesive and useful portrayal of the multiple source types within each EU considered (Appendix B). The Evaluation Template contains the following sections:

Part I – Executive Summary provides an overview of the EU and its risk evaluations, in three pages or less;

Part II – Administrative Information that allows cross-walking of EUs used in this Risk Review with regulatory operable units;

Part III – Summary Description includes the types and history of sources present;

Part IV – Unit Description and History;

Part V – Waste and Contamination Inventory is a summary of the inventory, physical form and mobility of contaminants present, as well as figures that provide the geographic location of the evaluation unit within the overall Hanford site, and more a more detailed layout of source areas within the evaluation unit;

Part VI – Potential Risk Pathways and Events provides a summary of initiating events and pathways that can result in risks to receptors;

Part VII – Risk Ratings, A description and qualitative categorization of risks to receptors for each evaluation period and condition described above. Categories of risks from individual sources or grouping of types of sources within an evaluation unit will be derived by comparing the likelihood, magnitude and anticipated timeframe against tables (termed matrices) that provide the basis for categorization with respect to each potentially affected receptor; and,

Part VIII – Supplemental Information and Considerations may include co-location of facilities, sequencing considerations, linkages to other required facilities or unique skills, loss of facility integrity, etc.

The overall methodology, as well as the specific risk rating methodology for each receptor, was tested with several pilot cases. Lessons learned from the pilot cases resulted in redefining and grouping EUs. This means there is not complete alignment between the pilot case evaluations and final EU designations. Slight modifications were made in the methodology as a result, mainly to incorporate differences in EUs and receptors, as well as the nature of available EU-specific information. Completed Evaluation Templates without the final risk ratings are provided in draft form as Appendices for the following EUs:

Appendix C - 618-11 Solid Waste Burial Ground

Appendix D - Central Waste Complex

Appendix E - T Tank Farm (CP-TF-1)

The rationale for omitting the risk ratings is to help ensure that the focus is on the evaluation methodology rather than the outcomes.

2.7. METRICS FOR ASSESSING DEGREE OF RECEPTOR OR RESOURCE RISK

A categorization system for considering the magnitude, likelihood and timeframe of risks to receptors identified earlier forms the basis for binning of the risk ratings across EUs. However, risks to receptors will not be integrated across different receptor types. A final listing of the risk ratings for each of the receptor groups will be provided with the final Risk Review Project Report. For example, a final set of tables will provide the risk rating for each of the 60+ EUs for of the 6 receptors. However, there is no scientifically-accepted method of integrating and normalizing ratings between and among receptors. That is, high risk may mean different things for human health, ecological health, groundwater, and cultural resources. The final risk ratings will include an explanation of the meaning of the risk rating designation with respect to each receptor.

The balancing and relative importance of risks to different receptors are driven by individual and collective values, which vary considerably, and, which therefore make integration across different receptor types the domain of DOE and its regulators with input from their constituencies. However, the Risk Review Project (once it has evaluated a more complete set of EUs) will provide examples that illustrate how groupings or binning that integrates the ratings across receptor categories (e.g., integrated risk binning that combines risks to human health with risks to ecology and groundwater) could be carried out.

The receptors to be evaluated are: public, worker, groundwater and the Columbia River, and ecological and cultural resources. These were selected as the main receptors at risk from the activities at Hanford. For each receptor there are two major components:

1) Description of the receptors – What is at risk, what is the quality, what is the extent?
2) Description of a methodology to evaluate whether the receptor is at risk, currently, during active remediation, and in the 100 years post-remediation (until 2164).

The methodologies for evaluating risk to receptors are described in separate chapters in this document. Descriptions or characterization of the receptors vary somewhat depending upon the receptor. For example, ecological receptors are examined both in terms of species and ecosystems of value, cultural receptors include several key time periods (Native American habitation, pre-DOE (historical Hanford area), and the Manhattan Project), and the Columbia River is described with groundwater because it is the groundwater that has the potential to discharge radionuclides and other contaminants to the river. The characterization of resources at risk forms an important basis for developing the methodology for each resource, as well as the basis for determining the risk rating.

The methodology for evaluating each receptor varies because the nature of the receptor varies (e.g., groundwater vs workers), but the overall factors considered and metrics are similar. For example, worker and public includes only people, while ecological includes thousands of species and many different kinds of ecosystems, and cultural includes many kinds of cultural resources (e.g., Tribal, aesthetics, and historic buildings). Further, the Risk Review Project recognizes that risk to any person is important, while for ecosystems the important level is the population of a given species (except in the case of federally or state-listed species). The over-riding assumption, however, is that a risk rating can be developed for each receptor that includes evaluation of the resource, effects of different remediation options, and likelihood of harm to the receptor. And, the risk ratings can be determined for each EU, for each time period.

For each type of receptor, metrics are defined to serve as the basis for binning or rating risks (see Chapters 5 through 9 focusing on each type of receptor). Risks and potential impacts will be categorized into at most 5 ratings: not-discernible, low, medium, high or very high. Further, for many receptors, the risk rating for an equivalent impact during the active cleanup period is higher than in the near-term post-cleanup time period. This rating reduction is considered appropriate for most cases because of the additional response time available before preventative action would be required, and therefore addressing the risk or potential impact is less urgent. In addition, within similar types of EUs, the risk ratings are expected to differ. Risks that are rated higher, therefore, should suggest that remediation must proceed more quickly.

Figure 2-3 provides an example of the matrices that will be used to determine risk ratings for resources. As discussed above, certain resources consider fewer levels (e.g., six levels for ecological resources that range from endangered species as five and non-native plants and animals as Level 0) for that resource, but the remediation types or options and time periods evaluated are the same. For certain receptors, the highest resource level has a legal basis (e.g., Endangered Species Act for listed species, National Historic Preservation Act and other federal laws relative to cultural resources). Ratings of risks to resources during remediation are examined as a function of major remediation types because for many EUs the preferred alternative is undetermined. The remediation types have different degrees of physical disruption, spatially, temporally, and in terms of equipment/vehicular needs.

The last table in Figure 2-3 provides a summary of risk ratings for receptors (public health, workers, groundwater and Columbia River, ecological and cultural). Assigned values for receptors are not intended to be compared across receptor types, but rather within a receptor type. Thus, it is possible to consider all EUs rated as having "high" ecological risk to be in more imminent danger with respect to individual species or habitat than those ecological receptors with a "low" rating. As noted, however, a "high" risk rating for eco-receptors has a different meaning than a "high" risk rating for groundwater.

Matrix for Evaluation

Remediation Option	Level 1	Level 2	Level 3	Level 4	Level 5
Natural Attenuation					
In Situ Containment					
Pump and Treat					
In Situ Treatment					
Decommissioning & Demolition					
Excavation					

For each receptor (N=6) To be used for each evaluation unit (EU)

Risk Impact

Remediation Option	Current	During	100 yrs past
Natural Attenuation			
In Situ Containment			
Pump and Treat			
In Situ Treatment			
Decommissioning & Demolition			
Excavation			

For each receptor for each EU

Overall Evaluation

EU: xxxxx - Risk or Impact Rating				
Population or Resource		Evaluation Time Periods		
		Active Cleanup (to 2064)		Near-Term Post Cleanup (to 2164)
		Current Condition/ Operations	From Cleanup Actions	
Human	Worker ** (remediation & facility worker)			
	Worker (co-located)			
	Public			
Environmental	Groundwater			
	Surface water			
	Ecological Resources			
Social	Cultural Resources			
	Economic Resources			

For each EU For before, during, and after

Figure 2-3. Example evaluation tables for risk ratings.

2.8. ECONOMIC ASSETS

The Hanford Site and it vicinity include a range of economic assets that may be impacted by cleanup activities at the Hanford Site. DOE economic assets include the Hanford Site infrastructure. Commercial activities on the Hanford Site include the US Ecology low level waste disposal facility, Energy Northwest nuclear power generation, and multiple PNNL research laboratories. Furthermore, the regional economy may be impacted by public perceptions of cleanup activities at the Hanford Site.

The Risk Review Project will indicate when the current status, delay or cleanup activities may have direct impact on DOE and non-DOE economic assets. In addition, the Risk Review Project will provide a regional context for the relationships between the Hanford Site cleanup and the regional economy.

2.9. CONTEXT WITHIN THE REGION AND OTHER LARGE REMEDIATION EFFORTS

The Hanford Site needs to be viewed in the context of the regional economy, important on-site or adjacent economic assets, and the multiple relevant sources of human health risks and impacts to resources in the vicinity of the Hanford Site. Examples include the Energy Northwest nuclear generating station and PNNL facilities in the Hanford 300 Area, the U.S. Ecology waste disposal site in the 100 Area, and discharges from non-Hanford sources to the Columbia River of contaminants found on the Hanford Site. The Risk Review Project will also seek to put the Hanford risks, potential impacts and cleanup in context with other large cleanup efforts in the region.

2.10. REFERENCES

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ATTACHMENT 2.1. SUMMARY OF RECOMMENDED RECHARGE RATES AT HANFORD

According to Hoitink et al. (2005), the average annual precipitation from 1946 through 2004 at the Hanford Site is 173 mm/yr, with a range of 76 mm/yr in 1976 to 313 mm/yr in 1996, with about 52% of the precipitation falling from November to February. Most of the water available for recharge occurs during the winter months when evaporation is low and snowmelt occurs. Recharge rates depend on soil conditions and plant communities. In general, rates are higher for coarse-textured than fine-textured soil, for sparse plant communities rather than dense communities, and for shallow-rooted rather than deep-rooted plants (Fayer and Keller 2007). For a given soil and vegetation condition, the recharge also varies significantly from year to year depending on the precipitation and other weather conditions.

The following is a summary of recharge rates for different soil and plant conditions observed or estimated at the Hanford site. The reader is referred to the individual citations for additional information regarding assumptions, uncertainties and biases associated with each value provided. At the upper level, rounded estimates of recharge are provided, followed by more specific data provided in the Hanford literature. Tracer techniques, lysimeters and modeling are approaches that have been used to estimate recharge rates at Hanford.

1. **Surface barrier – 0.5 mm/yr beneath the barrier**
   a. For a Hanford protective barrier, the designed maximum recharge is 0.5 mm/yr (DOE 1999). The monitoring results at the Field Facility Test Facility (Fayer and Gee 2006) and at the Prototype Hanford Barrier (Ward et al. 2011) have indicated that the recharge through a Hanford barrier is less than 0.5 mm/yr. Based on the monitoring results from 1995 to 2009, the average recharge rate through the riprap or the gravel side slopes was 24 mm/yr (Ward et al. 2011).
   b. At the integrated disposal facility (IDF), 0.1 mm/yr for the surface barrier is estimated for a silt loam soil. Beneath the side slope, the recharge rate was estimated at 22.3 mm/yr for the first 16 years and 4.2 mm/yr thereafter, assuming the development of shrub-steppe community (Fayer and Szecody 2004).
2. **Undisturbed plant communities – 5 mm/yr**
   a. Sagebrush community: 5.0 mm/yr (Rockhold et al. 1995)
   b. Cheatgrass: 25.4 mm/yr (Rockhold et al. 1995)
   c. Integrated disposal facility (IDF)
      i. Undisturbed Rupert sand with a shrub-steppe plant community: 0.9 mm/yr (Fayer et al. 1999)
      ii. Undisturbed Burbank loamy sand with a shrub-steppe plant community: 4.2 mm/yr is recommended for an (Fayer et al. 1999)
   d. Vegetated Rupert sand (the most prevalent soil type in both the 200 Areas as well as to the south of the 200 Area): 1.7 mm/yr (Fayer and Keller 2007)
   e. Vegetated Burbank sand (the second most prevalent soil type in both the 200 Areas as well as to the north of the 200 Area): 1.9 mm/yr (Fayer and Keller 2007)
   f. Ephrata sandy loam (northern part of the 200 East Area and not present in the 200 West Area, and common north of the 200 Areas): 2.8 mm/yr . (Fayer and Keller 2007)

   g. Hezel sand (southwest corner of the 200 West Area): 0.1 mm/yr with shrubs and 8.7 mm/yr without shrubs (Fayer and Keller 2007)
   h. Tank farm modeling: 3.5 mm/yr (e.g., Freedman et al. 2005, Zhang et al. 2004)

3. **Disturbed soil – 50 mm/yr**
   a. Unvegetated Hanford formation: 55.4 mm/yr (Fayer et al. 1999)
   b. Rupert sand without vegetation: 45 mm/yr (Fayer and Keller 2007)
   c. Coarse sand (Hanford formation) without vegetation: 63 mm/yr (Last et al., Gee et al. 2005, Fayer and Keller 2007).
   d. Solid waste landfill: 51.1 mm/yr (Fayer and Keller 2007)
4. **Gravel surface (e.g., tank farms) - 100 mm/yr**
   a. Last et al. (2006) estimated 92 mm/yr using measured drainage from two lysimeters and precipitation received during the measurement period and scaling the measured drainage linearly to the long-term average precipitation of 173 mm/yr.

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PART 2. CONTAMINATION SOURCES

CHAPTER 3. METHODOLOGY FOR GROUPING CONTAMINANT SOURCES FOR EVALUATION

ABSTRACT

The risk and impact methodology developed for this effort will be applied to groups of cleanup sites defined as "evaluation units." The cleanup sites under consideration include solid and liquid waste sites, surplus facilities and infrastructure, and various operating facilities, including treatment, storage and disposal facilities. A primary goal of the grouping methodology will be to assemble evaluation units that not only illuminate distinctions between the various evaluation units, but also provide insight into the contributions to risks and impacts from discrete sources within a single evaluation unit.

Evaluation units will be composed of geographically collocated sites to the extent possible, with additional consideration given to commonality amongst the types of sources and the potential for geographically overlapping impacts and risks to receptors (e.g., ecological resources, groundwater, etc.). Such a construct will allow for the grouping of sites that have had common waste management operational practices and similar contaminant sources. A total of approximately 60 evaluation units have been defined for this effort binned into legacy waste, decontamination and decommissioning (D&D), tank wastes and farms, groundwater plumes, and operating facility categories.

3.1. OBJECTIVE

In order to perform a comprehensive, meaningful and efficient risk review it is necessary to group the various cleanup sites (i.e., solid and liquid waste sites, surplus facilities and infrastructure, and various operating facilities, including treatment, storage and disposal facilities) into a manageable collection of evaluation units. The term "evaluation units" will be used for describing these groupings. The risk and impact methodology developed for this effort will then be applied (as appropriate) to each resulting evaluation unit (Chapter 2). A primary goal of the grouping methodology will be to assemble evaluation units that not only illuminate distinctions between the various evaluation units, but also provide insight into the contributions to risks and impacts from discrete sources within a single evaluation unit.

3.2. GROUPING CONSTRUCT

In order to describe the human health risks and impacts to resources, under current conditions, during active cleanup operations, and during various post-cleanup time frames, a sound organizing construct is needed. Historically, waste disposal has been geographically located near their associated major operation facilities (e.g. 100 B/C Reactors; T Plant). Waste disposal was generally segregated by media and waste stream (e.g., high-level liquid waste associated with T Plant went to underground storage tanks (e.g., 241-T tank farm), intermediate-level liquid wastes went to underground infiltration facilities (collectively termed cribs, e.g., 216-T-5 & -6 cribs), low-level liquid wastes went to ditches and ponds (e.g., 216-T-4 pond), and solid waste went to landfills (termed burial grounds, e.g., 218-W-3A). Evaluation units will be composed of geographically collocated sites to the extent possible, with additional consideration given to commonality amongst the types of sources and the potential for geographically overlapping impacts and risks to receptors (e.g., ecological resources, groundwater, etc.). Such a construct will allow for the grouping of sites that have had common waste management operational practices and similar contaminant sources. For example, geographically collocated sources (such as a tank farm, proximate and underlying legacy sources, contaminated soils, vadose zone and groundwater) that may have overlapping impacts to groundwater may be grouped together into a single evaluation unit. This will also allow for the integration and the evaluation of possible interactions of contaminant sources as various initiating events, contaminant exposure pathways and common receptors are considered as part of this risk review. In addition, close geographic proximity will likely be an important consideration in the selection and timing of potential remedial and closure actions, since physical cleanup actions at one site could impact adjacent sites. As evaluation units are identified and described a cross-walk to the existing regulatory basis (Operable Units, TSD designation, etc.) will also be provided.

Sources, or cleanup elements, that will form the evaluation units will be grouped into the following major categories: legacy source units, groundwater plumes, tank waste and farms, operating facilities, decommissioning and demolition (D&D) of inactive facilities. The approach taken for assembling the evaluation units in each of these categories is provided below (Figure 3-1).

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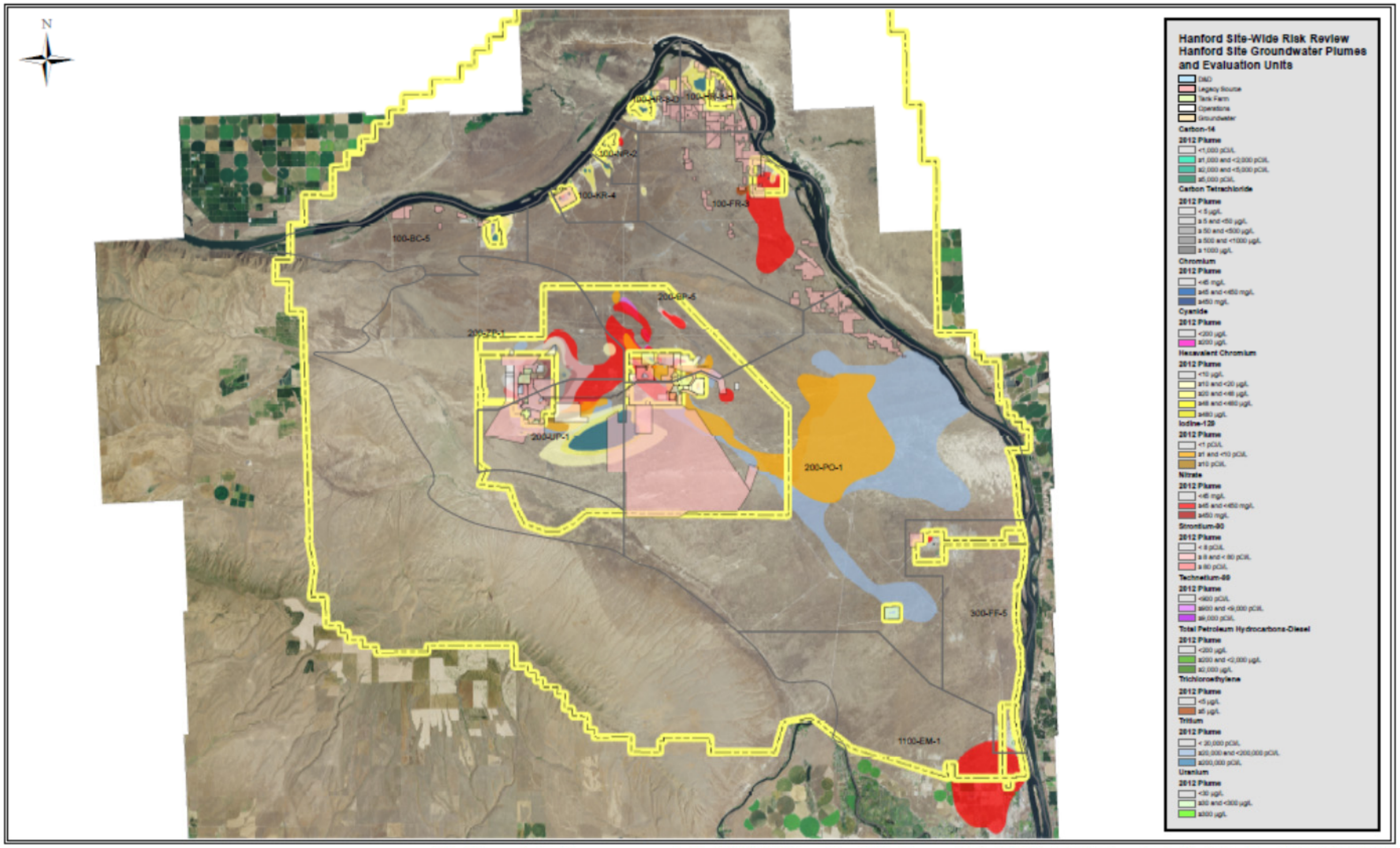

1 inch = 17,000 feet

Note: All groundwater plumes were generated by CH2MHILL Plateau Remediation Company for the 2012 Hanford Site Groundwater Monitoring Report (DOE/RL-2013-22).

Figure 3-1. Overall evaluation unit map, including groundwater plumes.

3.3. LEGACY SOURCE SITES

Legacy source sites will include all past practice liquid waste disposal sites (e.g., cribs, ponds, and ditches), buried solid waste sites (including retrievably stored transuranic waste sites), unplanned releases, and associated underground piping and infrastructure. This also includes associated near surface and vadose zone contaminated sediments associated with these sites. The evaluation of these sites will include, to the extent that information is available and clearly identifies uncertainties, a summary of the amount and physical-chemical-radiological nature of contamination and all relevant pathways (including the potential to impact groundwater resources) using a conceptual site model for the combined inventories within the evaluation unit. In evaluating potential impact to groundwater, important distinctions will be; whether the evaluation unit is currently releasing contaminants (and the type and nature of the contaminants) to the groundwater, has a potential to impact groundwater in the future (and when), and whether the evaluation unit is likely to contribute to new or expanded areas of groundwater impact. Risk to human health, impacts to ecological and cultural resources from the evaluation units during maintenance and cleanup operations will be a function of the ongoing operations, range of potential remedies, potential initiating events and pathways to receptors (e.g., direct exposure, atmospheric dispersion, physical disruption, etc.).

3.4. TANK WASTE AND FARMS

The tank waste and farms units include all underground single-shell and double-shell high-level waste tanks and associated infrastructure. The tank evaluation units also include related legacy waste sites (such as cribs, trenches, and unplanned releases) as well as any associated near surface and vadose zone contaminated sediments associated with these sites. Similar to the legacy source units, the evaluation of these sites will include, to the extent that information is available and clearly identifies uncertainties, a summary of the amount and physical-chemical-radiological nature of contamination and all relevant pathways (including the potential to impact groundwater resources) using a conceptual site model for the combined inventories within the evaluation unit. In evaluating potential impact to groundwater, important distinctions will be made regarding whether the evaluation unit is currently releasing contaminants (and the type and nature of the contaminants) to the groundwater, has a potential to impact groundwater in the future (and when), and whether the evaluation unit is likely to contribute to new or expanded areas of groundwater impact. Risk to human health, impacts to ecological and cultural resources from the evaluation units during maintenance and cleanup operations will be a function of the ongoing operations, range of potential remedies, potential initiating events and pathways to receptors (e.g., direct exposure, atmospheric dispersion, physical disruption, etc.).

3.5. GROUNDWATER PLUMES

Groundwater plume evaluation units will be based on areas of the site where there are existing groundwater plumes (with one or more contaminants above MCL's). In many of these cases interim or final remedial actions are underway. A description of the nature and extent of contamination, ongoing and potentially contributing contamination sources (e.g., are plumes growing or likely to grow?), and current remedial actions underway will provide the foundational information for the risk review. The description and risk evaluation for potential contributing sources will be included as part of other evaluation units (e.g., Legacy Sources, Tank Wastes and Farms, etc.) and will be referenced in the development of the risk review for the specific groundwater plumes. These units will include the operation of above ground pump and treat systems, including reinjection / hydraulic control schemes for treated water. An illustration of the principal Hanford Site groundwater contamination plumes is provided below (Figure 3-2). It is envisioned that the evaluation units would closely align to the existing groundwater operable units.

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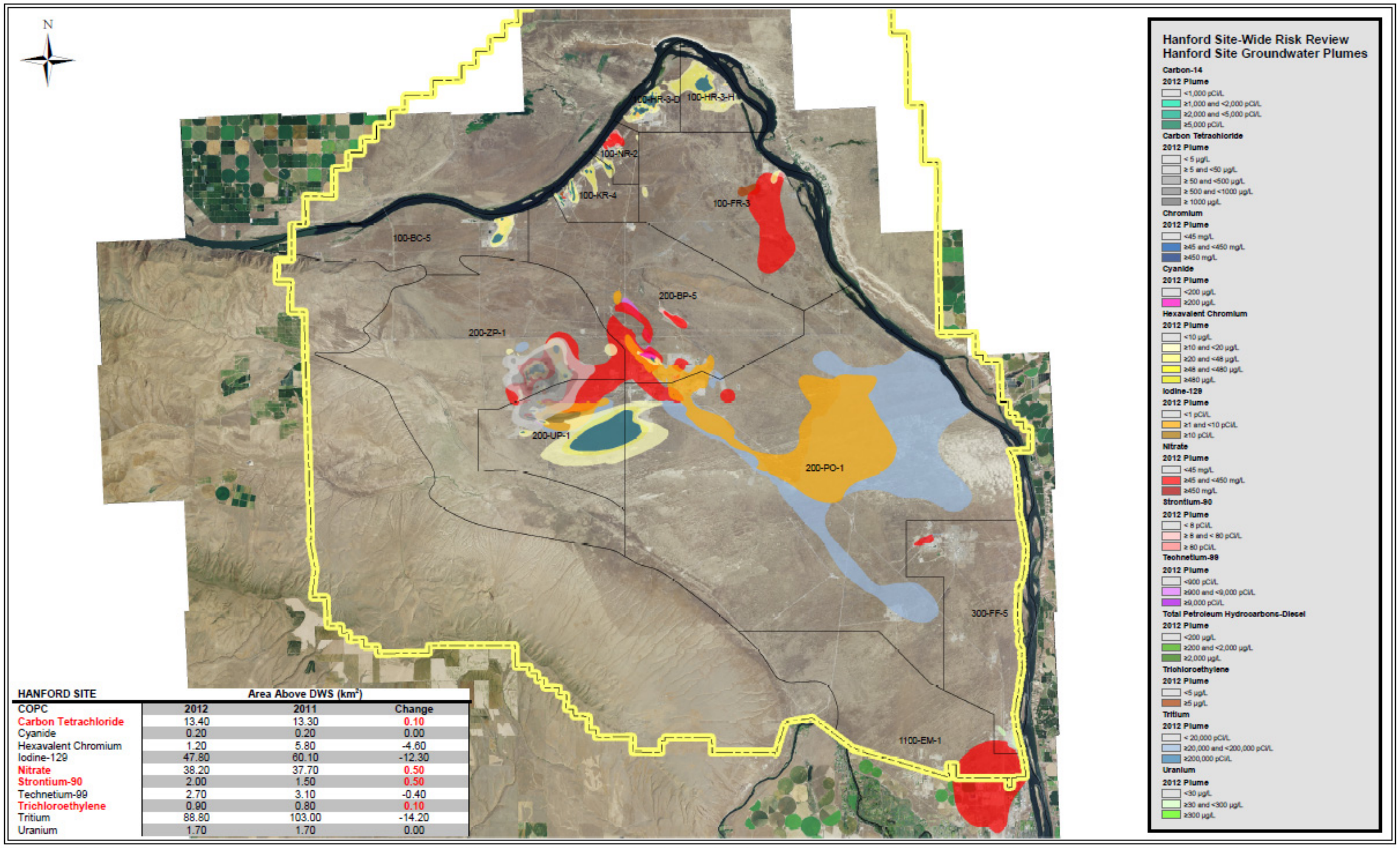

HANFORD SITE	Area Above DWS (km^2)		
COPC	2012	2011	Change
Carbon Tetrachloride	13.40	13.30	0.10
Cyanide	0.20	0.20	0.00
Hexavalent Chromium	1.20	5.80	-4.60
Iodine-129	47.80	60.10	-12.30
Nitrate	38.20	37.70	0.50
Strontium-90	2.00	1.50	0.50
Technetium-99	2.70	3.10	-0.40
Trichloroethylene	0.90	0.80	0.10
Tritium	88.80	103.00	-14.20
Uranium	1.70	1.70	0.00

1 inch = 17,000 feet

Note: All groundwater plumes were generated by CH2MHILL Plateau Remediation Company for the 2012 Hanford Site Groundwater Monitoring Report (DOE/RL-2013-22).

Figure 3-2. The Hanford Site groundwater plume map (source: PNNL).

3.6. D&D OF INACTIVE FACILITIES

A set of inactive facilities evaluation units will be assembled based on major processing complexes or facilities with a common history of operations and close geographic proximity. Examples of evaluation units would be the Plutonium Finishing Plant (PFP) complex, 324 building, the Fast Flux Test Facility, 100-K basins, the reactors along the river, and the 5 processing canyons. T Plant is the only canyon facility at Hanford that remains in operation. The historical mission of chemical separation at the Hanford Site was terminated in the late 1980's. Currently, the mission of T Plant is to support decontamination; headspace sampling; repackaging, remediation, and verification of containerized waste as noted below. The B Plant, REDOX (S Plant), U Plant, and PUREX (A Plant) are the other four canyon facilities at Hanford which have long been shut down. However, as also discussed below the WESF facility (adjacent to B Plant) is an operational facility used for underwater storage of Sr and Cs capsules. The current capsule storage operations and the possible move to dry cask capsule storage may be considered in the operating facility evaluation unit's portion of the risk review. In addition, contaminated soils as a result of facility operations or unplanned releases underneath or in the immediate vicinity of the facility (such as Building 324) will be included within the specified evaluation unit.

3.7. OPERATING FACILITIES

The operating facilities evaluation units will be organized around three principal operating functions: 1) solid waste treatment, storage and disposal; 2) liquid waste processing and disposal; and 3) supporting infrastructure facilities. Considerations of the operating functions, interactions of waste processing functions, and geographic proximity will be used in assembling the evaluation units for the operating facilities. A brief description of the overall process flow for each of these functional areas will be provided as context for the roles these facilities play in the cleanup efforts and to provide insight into the hazards present. In addition, a description of the off-site facilities that are important elements of the Hanford Site cleanup will be referenced as part of the overall cleanup context. They include such facilities as the Waste Isolation Pilot Plant (WIPP) where transuranic (TRU) waste is disposed, various commercial waste treatment and disposal facilities, and the yet to be established geologic repository.

SOLID WASTE TREATMENT, STORAGE AND DISPOSAL

The Solid Waste Operations Complex (SWOC) facilities are permitted treatment, storage and/or disposal units that manage low-level radioactive waste (LLW), mixed low-level waste (MLLW), TRU, transuranic mixed (TRUM) and Toxic Substances Control Act (TSCA) polychlorinated biphenyls (PCB) waste at Hanford as illustrated in the process flow diagram provided below (Figure 3-3).

1. **Store, package, certify, and ship transuranic, hazardous, and mixed wastes**. The SWOC consists of 4 facilities: the Central Waste Complex, two RCRA permitted disposal trenches, T Plant and WRAP. Collectively, these 4 facilities enable the storage, packaging, and certification of transuranic, mixed and hazardous waste. This waste results from the retrieval of stored waste and from transuranic-contaminated materials that are newly generated as a result of cleanup operations. The CWC accepts LLW/MLLW with no identifiable disposition path and the TRU and TRUM that has to be certified for shipment to the Waste Isolation Pilot Plant (WIPP) in New Mexico throughout cleanup. Once generated, the transuranic waste is stored in the Central Waste Complex (CWC). In addition, LLW, MLLW, hazardous waste, and other materials are also

stored at CWC awaiting treatment or final disposition. Trench 31 and 34 are permitted disposal units for certain MLLW and LLW and also certain types of TSCA PCB waste.

Transuranic waste is packaged and certified for shipment in the Waste Receiving and Processing Facility (WRAP) adjacent to the CWC. It is a multipurpose facility for processing and treating LLW and TRU waste including mixed and TSCA PCB waste. It can also perform nondestructive assay (NDA) and nondestructive examination (NDE) of waste containers. Some mixed waste is shipped off site for treatment at commercial facilities and returned to the site for disposal. WRAP is being maintained in an operational status, even though it has been several years since transuranic waste was sent to WIPP. The CWC and WRAP facilities, both located in the 200-W area, will be maintained and operated until site cleanup operations are completed, at which time all inventory will be removed and the facilities closed.

T Plant Complex is currently used by SWOC for storage, repackaging, treatment and decontamination of radioactive waste. T Plant can accept LLW and TRU waste including mixed and TSCA PCB waste. T Plant can also perform NDA/NDE analysis including the sampling of gases trapped inside drums of waste. Radioactive and mixed wastes are processed and packaged to meet state and federal regulations as well as criteria associated with transporting waste to certain specific waste disposal facilities. The T Plant Complex is also being evaluated for receiving, storing, and treating the radioactive sludge that has been containerized within the K-West Basin. T Plant has been identified as a potential historic site as part of the Manhattan Historic District National Park proposed legislation, and as such, for the purpose of risk review, T Plant operations will need to be partitioned from any potential D&D activities (including possible preservation as a historic landmark).

2. **Safely store used fuel and nuclear materials**. Hanford will continue to operate the Canister Storage Building (CSB) and the adjacent interim storage area for management of used fuel and nuclear materials that will eventually be removed to off-site locations. In addition, nearly 2,000 cesium and strontium capsules are currently stored under water inside the Waste Encapsulation and Storage Facility (WESF) adjoining the B Plant canyon facility. For the purpose of the risk review the disposition of the capsules will need to be partitioned from the D&D of the B Plant canyon, yet their schedules are linked. Some of these materials are yet to be generated, e.g., immobilized high-level waste from Hanford's tanks and to date, the final disposition pathway, schedule and location for off-site disposal is uncertain. Therefore, safe management of these materials (for interim storage and preparation for shipment) may be required for decades in new facilities similar to the CSB.
3. **Operate solid low-level waste and mixed low-level waste disposal facilities**. Waste disposal facilities including solid waste burial grounds (two mixed waste trenches in the 200W area), the Integrated Disposal Facility, and the Environmental Restoration Disposal Facility (ERDF) will continue to operate and receive inventory well into the future and when no longer needed will be closed. The ERDF facility receives bulk low-level radioactive, hazardous, and mixed wastes generated during environmental remediation and building demolition activities. The mixed waste trenches received containerized mixed-waste generated during various cleanup operations. The Integrated Disposal Facility (IDF) is designed to hold the immobilized low-activity waste and other low-level and mixed wastes generated during the tank waste processing mission. Strictly hazardous wastes and municipal solid wastes are packaged and shipped off-site for disposal at commercial facilities.

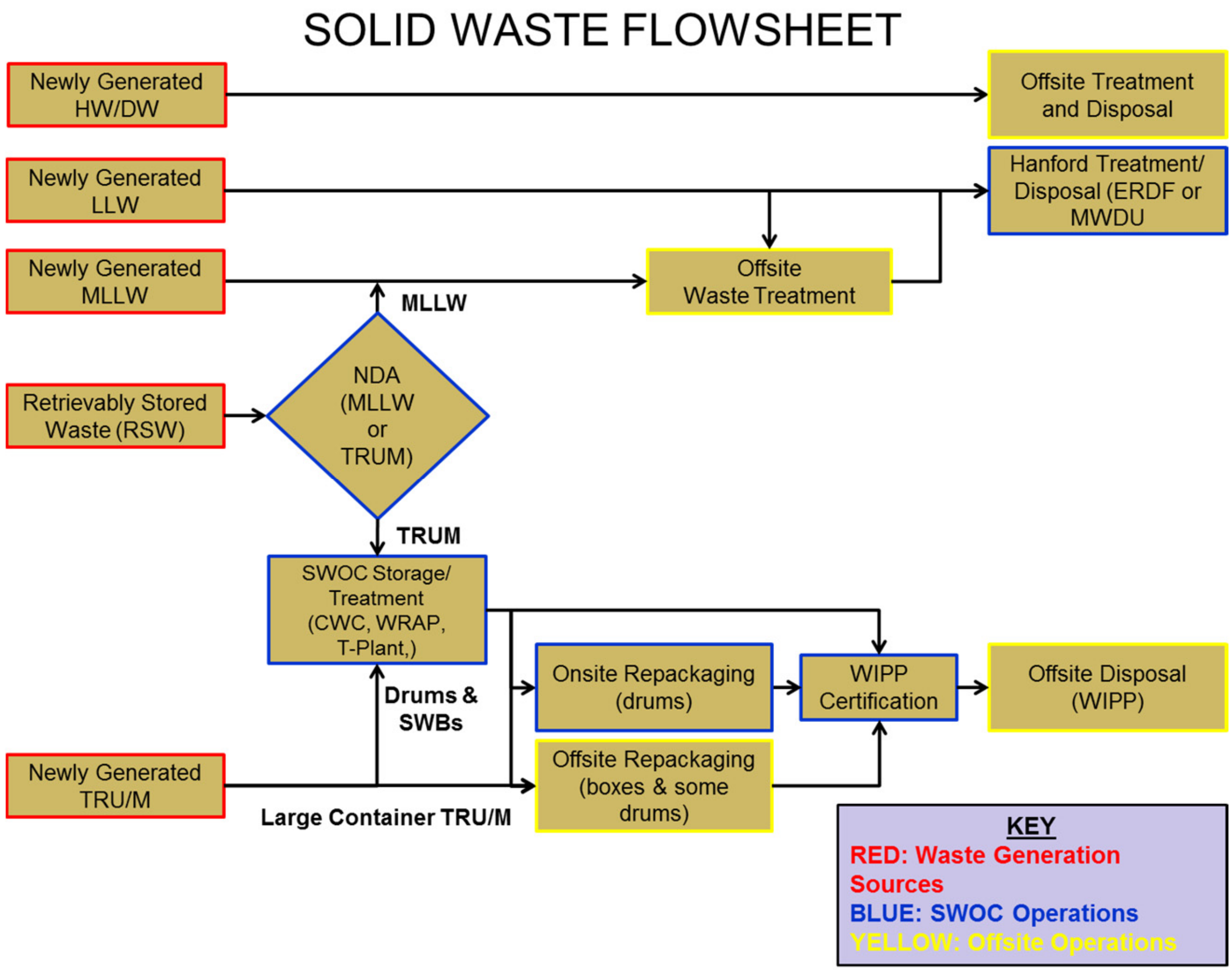

Figure 3-3. Hanford solid waste operations flow sheet.

LIQUID WASTE TREATMENT AND DISPOSAL FACILITIES

Liquid effluents are generated by numerous processes and facilities at Hanford. Treatment of these effluents is provided by the Evaporators, the Effluent Treatment Facility and the Liquid Effluent Retention Facility. Discharge of treated effluents is to the State Approved Land Disposal Site in the 200-E area. Modifications to facilities, permits, or operational conditions may be required to support future operation of the Waste Treatment Plant (WTP). The tank waste treatment flow diagram (Figure 3-4) illustrates both the existing and future liquid and solid waste processing and disposal facilities.

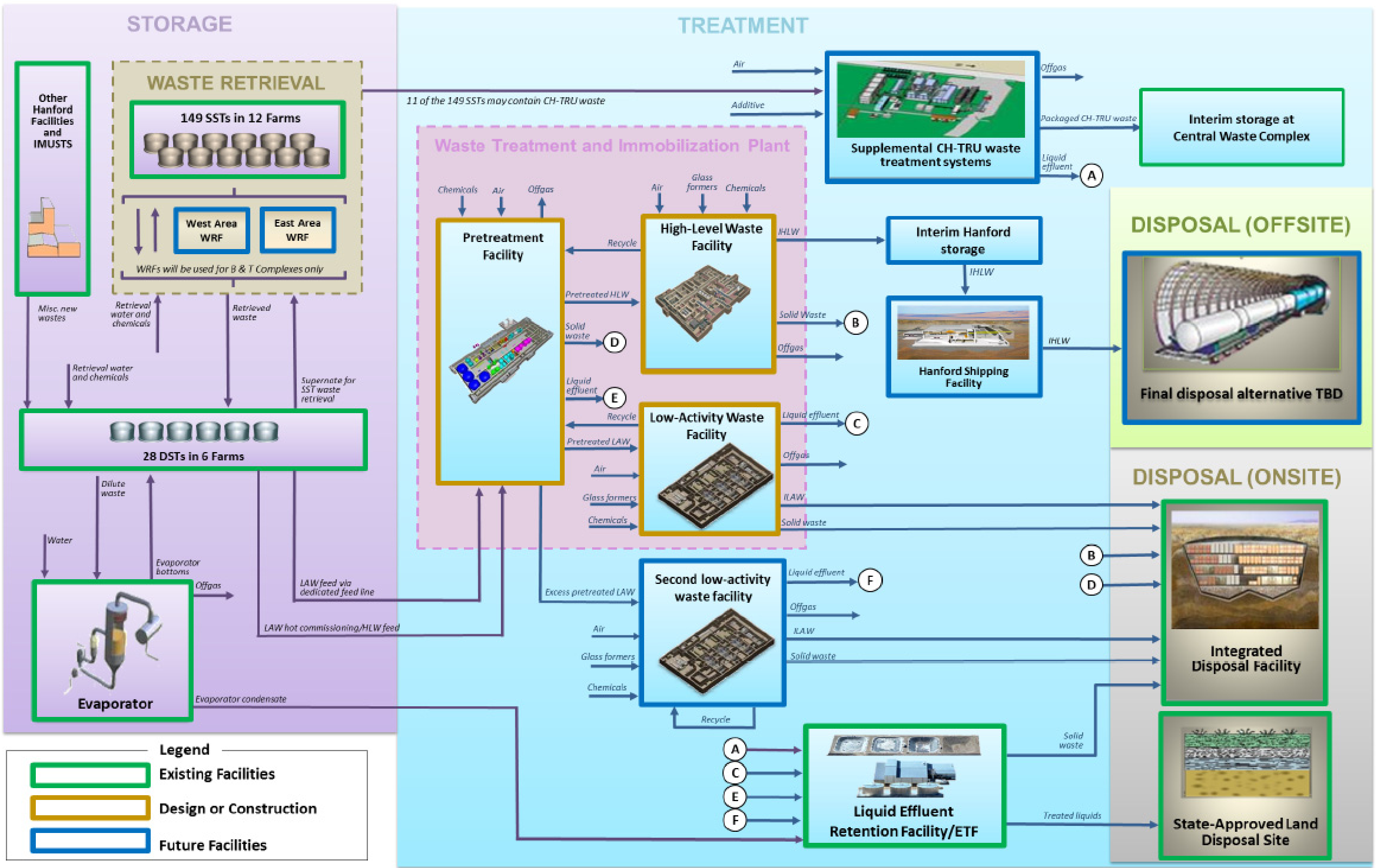

Figure 3-4. Tank waste treatment flow diagram (from ORP-11242, Rev. 6 2011).

The WTP consists of five facilities/complexes: (1) the Analytical Laboratory (LAB), (2) Balance of Facilities (BOF), (3) LAW Vitrification Facility, (4) HLW Vitrification Facility, and (5) PT Facility. The WTP is being designed to process the tank farm waste during a roughly 40-year period. The current design requires waste to be processed through the PT Facility, where it will be separated into a low-activity waste stream to be vitrified in the LAW Facility and a high-level waste stream to be vitrified in the HLW Facility. The LAB and BOF support these vitrification activities. In September 2013, the DOE published the Hanford Tank Waste Retrieval, Treatment, and Disposition Framework that indicated a phased approach designed to accomplish the following objectives:

- Begin immobilization of the tank waste as soon as practicable through Direct Feed to LAW (DFLAW).
- Process transuranic (TRU) tank wastes for disposal at the Waste Isolation Pilot Plant (WIPP), should those wastes be properly classified as TRU and be permitted for disposal at WIPP.
- Resolve technical issues for the PT and HLW Facilities, including determining how to adequately mix and sample the waste prior to processing, to enable design completion, and the safe completion of construction, startup and operations of these facilities.

The specific phases of the program (indicated in Figure 3-5), envision sequential completion and startup of the individual WTP facilities. Phase 1 key activities include:

- Current Activities
    - Completion, commissioning, and startup of BOF and the LAB
    - Completion of the ongoing C Farm retrievals
- DFLAW Activities
    - Completion of the tank farm infrastructure and an interim pretreatment capability (for removal of cesium and miscellaneous solids) needed to directly feed the LAW Facility
    - Completion, commissioning, and startup of the LAW Facility
    - Final permitting of the onsite Integrated Disposal Facility (IDF) for low-activity waste
- Contact Handled TRU (CH-TRU) Activities
    - Retrieval and shipment of any CH-TRU waste from the SSTs to WIPP, pending the proper and legal classification of the waste as TRU and obtaining the necessary permits
- Direct Feed HLW (DFHLW) Activities
    - Initiation of a tank waste characterization and staging capability in the tank farms to support HLW
- Technical Issue Resolution
    - Completion of full-scale vessel testing and resolution of technical issues in the PT and HLW Facilities.

Phase 2 key activities include:

- DFHLW Activities
    - Completion of HLW Facility
- Completion of a tank waste characterization and staging capability
- Completion and commissioning of the Interim Hanford Storage Facility.
- PT Facility
    - Continue construction of the PT Facility

Phase 3 key activities include:

- Full WTP Completion
- Pretreatment Facility commissioning

- Initiating integrated WTP operations
- Possible additional preconditioning capability for the harder to process waste

This phased approach—with individual but integrated paths for each of the three primary waste streams—is intended to provide optionality, flexibility, and redundancy for completing the tank waste cleanup mission.

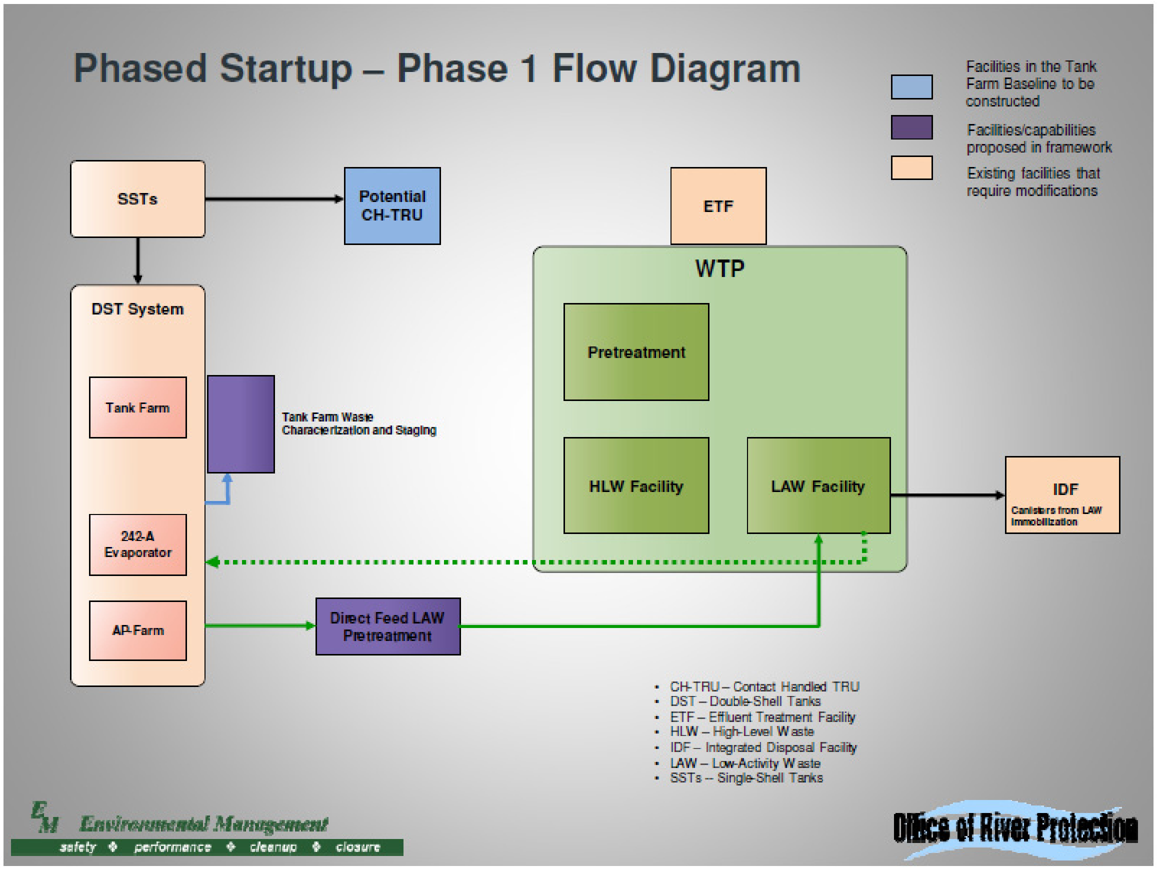

Figure 3-5. Direct-feed low-activity waste – interim pretreatment system facility flow diagram.

3.8. INFRASTRUCTURE FACILITIES SUPPORTING CLEANUP ACTIVITIES

Cleanup support facilities include: analytical laboratories (such as the 222-S Laboratory and the WTP analytical laboratory); maintenance shops and equipment storage facilities; office complexes (including mobile offices); meteorology station and towers; fire houses and security complexes; training and testing facilities (such as HAMMER and the Cold Test Facility); and various water, energy (gas and electric) and telecommunications infrastructure. As these facilities complete their missions, some will undergo final remediation through RCRA treatment, storage, and disposal unit closure, or deactivation/decommissioning per DOE or CERCLA requirements. It is likely that some of these infrastructure support facilities will be needed to support the long-term stewardship mission following the completion of cleanup. For completeness, a separate discussion describing the operations and issues associated with the infrastructure will be included in the document, but will not undergo the risk ranking. For those facilities (such as 222-S Laboratory) where a significant D&D effort following operations is likely, due to radiological and chemical inventories, a separate evaluation unit will be proposed.

3.9. NON-DOE-EM HANFORD SITE FACILITIES

Activities on the Hanford Site that are not part of the Environmental Management Cleanup mission will not be included in the Risk Review Project as evaluation units. Rather they will be considered in a site-wide context with the other Hanford site sources and activities and be included as potential receptors/impacted resources. These include the US Ecology commercial low-level waste burial ground, the Energy Northwest Columbia Generating Station, and the Laser Interferometer Gravitational Wave Observatory. In addition, the Pacific Northwest National Laboratory, stewarded by DOE's Office of Science will not be included as evaluation units. This includes the four facilities maintained by PNNL in the 300 Area (Buildings 318, 325, 331, and 350) as well as the rest of the PNNL campus located in north Richland. However, the presence of these facilities, and their associated workforces, will be included as potential receptors and potential accident initiators.

3.10. LISTING OF EVALUTION UNITS

Table 3-1 below provides a listing of the proposed evaluation units for this effort. The table is organized into two parts, the River Corridor and surrounding 600 Area and the Central Plateau. Where the evaluation unit ID is colored light brown, those units were part of the initial pilot assessment. The next round of units selected to be assessed as part of the interim report are colored light blue. The remaining sites would be included in the final report. Note that the operable unit cross-walk, related EU's, and preliminary key data source document fields are still evolving.

Following Table 3-1 are example maps (Figure 3-6, Figure 3-7, Figure 3-8) illustrating the location of the evaluation units. Similar maps are being developed for all of the major Areas across the Hanford Site. Attachment E-1 is an example evaluation unit data package - listing the waste sites and associated facilities within the geographic boundaries of the evaluation unit.

Table 3-1. Listing of evaluation units.

Evaluation Unit (EU) ID	Group	Evaluation Unit Name	Description & Comments	Operable Unit Cross-Walk	Related EU's
River Corridor					
RC-DD-1	D&D	324 Building	324 Building and associated soil contamination under the building.	300-FF-2	RC-GW-1
RC-DD-2	D&D	KE/KW Reactors	KE/KW Reactors, basin, ancillary buildings, sludge, associated soil contamination	TBD, 100-KR-1, 100-KR-2	RC-LS-2, RC-GW-3
RC-DD-3	D&D	Final Reactor Disposition	C, D, DR, F, H, KE, KW, and N Reactors.	TBD	
RC-DD-4	D&D	FFTF	Fast Flux Test Facility (FFTF) and ancillary buildings and structures.	NA	
RC-LS-1	Legacy Source	618-11 Burial Ground	618-11 Burial Ground.	300-FF-2	CP-GW-1
RC-LS-2	Legacy Source	K Area Waste Sites	Legacy waste sites within the fence at 100-K, where remediation is post 2015.	100-KR-1, 100-KR-2	RC-DD-2
RC-LS-3	Legacy Source	Orchard Lands	Pre-Hanford Orchard Lands.	100-OL-1	
RC-GW-1	GW	300 Area GW Plumes	300 Area Uranium and associated contaminant plumes.	300-FF-5	RC-DD-1
RC-GW-2	GW	100-N GW Plume	100-N Strontium and associated contaminant plumes.	100-NR-2	
RC-GW-3	GW	100-B/D/H/F/K Area GW Plumes	100-B/D/H/F/K Area Chromium and associated contaminant plumes, includes pump and treat systems.	100-BC-5, 100-KR-4, 100-HR-3, 100-FR-3	

Notes for River Corridor: Include Energy Northwest as a comparator – but not an EU. Include Infrastructure Discussion as context, but not as an EU. Need to decide how best to include context discussion around adjacent elements or on-site leased facilities (PNNL, WSU, AREVA, PermaFix, Energy Northwest, HAMMER, LIGO, Cold Test Facility, etc.). Source remediation and D&D (RTD) being completed in FY15 is not included. Remaining historic sites in the River Corridor that are being considered for the Manhattan Project National Park will be described but not evaluated (e.g., B Reactor, Bruggemann's Agricultural Complex, etc.). Remaining sites on the Hanford Reach National Monument will be described but not evaluated (e.g., Nike Missile site).

Evaluation Unit (EU) ID	Group	Evaluation Unit Name	Description & Comments	Operable Unit Cross-Walk	Related EU's
			Central Plateau		
CP-DD-1	D&D	PUREX	PUREX Canyon, tunnels, ancillary buildings, structures, and associated near-surface contaminated soils.	200-CP-1	CP-LS-9
CP-DD-2	D&D	B Plant	B Plant Canyon, ancillary buildings (e.g., 224-B), structures, and associated near-surface contaminated soils. Includes the D&D of WESF after the Capsules are moved into dry storage.	200-CB-1	CP-LS-8
CP-DD-3	D&D	U Plant	U Plant Canyon, ancillary buildings, structures, and associated near-surface contaminated soils.	200-CU-1	CP-LS-3
CP-DD-4	D&D	REDOX	REDOX Canyon (S Plant), ancillary buildings, except 222-S laboratory, structures, and associated near-surface contaminated soils.	200-CR-1	CP-LS-4
CP-DD-5	D&D	PFP	Plutonium Finishing Plant PFP ancillary buildings, structures, and associated near-surface contaminated soils.	200-WA-1	CP-LS-2
CP-LS-1	Legacy Source	BC Cribs and Trenches	Cribs, trenches and tank located to the south of the 200-E Area.	200-BC-1	CP-LS-17, CP-GW-1
CP-LS-2	Legacy Source	Plutonium Contaminated Waste Sites	Plutonium (Pu) contaminated cribs and trenches associated with PFP in central part of 200-W Area.	200-PW-1,3,6 200-CW-5	CP-DD-5, CP-GW-2
CP-LS-3	Legacy Source	U Plant Cribs and Ditches	Liquid waste discharges in the central part of 200-W Area associated with U Plant operations.	200-DV-1, 200-WA-1	CP-LS-7, CP-DD-3, CP-GW-2
CP-LS-4	Legacy Source	REDOX Cribs and Ditches	Liquid waste discharges in the southern part of 200-W Area associated with REDOX (S Plant) operations.	200-WA-1, 200-DV-1	CP-DD-4, CP-GW-2

Evaluation Unit (EU) ID	Group	Evaluation Unit Name	Description & Comments	Operable Unit Cross-Walk	Related EU's
CP-LS-5	Legacy Source	U and S pond	Liquid waste discharges in the southern part of 200-W and outside the fence of 200 West associate with U and S ponds and closely related trenches, ditches, and cribs.	200-CW-1, 200-OA-1	CP-GW-2
CP-LS-6	Legacy Source	T Plant Cribs and Ditches	Liquid waste sites on the northern end of 200-W area (associated with T Plant operations).	200-WA-1, 200-DV-1	CP-GW-2
CP-LS-7	Legacy Source	200 Area HLW Transfer Pipeline	HLW Pipelines outside of Tank Farms evaluation units. Includes 200 East-West transfer lines, IMUSTS, catch tanks, diversion boxes, etc.	200-IS-1	CP-TF-1 through -9
CP-LS-8	Legacy Source	B plant Cribs and Trenches	Liquid waste sites on the west side of 200-East (associated with B Plant operations).	200-EA-1, 200-DV-1, 200-OA-1	CP-DD-2, CP-GW-1
CP-LS-9	Legacy Source	PUREX Cribs and Trenches (inside 200-East)	Liquid waste sites on the east side of 200-East (associated with PUREX Operations and immediately surrounding PUREX).	200-EA-1, 200-PW-3	CP-DD-1, CP-GW-1
CP-LS-10	Legacy Source	PUREX and Tank Farm Cribs and Trenches (outside 200-East)	Liquid waste sites on the east side of 200-East (associated with PUREX and Tank Farm operations, but outside the 200-East area fence).	200-EA-1	CP-GW-1
CP-LS-11	Legacy Source	B Pond	B pond and associated ditches, where liquid wastes were discharged in the northern and western part of 200-East and outside the fence of 200-East.	200-EA-1, 200-CW-1, 200-OA-1, 200-IS-1	CP-LS-7, CP-GW-1
CP-LS-12	Legacy Source	200-West Burial Grounds	Past practice radioactive waste burial grounds, including retrievable stored TRU trenches.	200-SW-2	

Evaluation Unit (EU) ID	Group	Evaluation Unit Name	Description & Comments	Operable Unit Cross-Walk	Related EU's
CP-LS-13	Legacy Source	200-West Miscellaneous Waste Sites	Waste sites, buildings, and structures associated with maintenance operations, laundry, and coal power plant in the west/central portion of 200-West.	200-QA-1, 200-WA-1, 200-IS-1	CP-LS-7
CP-LS-14	Legacy Source	200-East Burial Grounds	Past practice radioactive waste burial grounds.	200-SW-2	
CP-LS-15	Legacy Source	200-East Miscellaneous Waste Sites	Waste sites, buildings, and structures associated with maintenance operations and coal power plant in the southern portion of 200-East.	200-OA-1, 200-EA-1	
CP-LS-16	Legacy Source	Grout Vaults	Grout vaults located east of WTP.	NA	
CP-LS-17	Legacy Source	BC Control Zone	Surface contamination area to the south of 200-East (excluding the BC Cribs and Trenches).	200-OA-1	CP-LS-1
CP-LS-18	Legacy Source	Outer Area Sites	Outer area solid waste disposal sites (e.g., NRDWL, SWL, etc.) and other outer area waste sites, miscellaneous buildings, and structures.	200-CW-1, 200-CW-3, 200-OA-1, 200-SW-1	
CP-TF-1	TF	T Tank Farm	T tank farm, ancillary structures, associated liquid waste sites, and soils contamination.	200-DV-1, WMA T, 200-WA-1	CP-LS-7, CP-GW-2
CP-TF-2	TF	S-SX Tank Farms	S-SX tank farms, ancillary structures, associated liquid waste sites, and soils contamination. Includes 242-S Evaporator.	WMA S/SX, 200-DV-1, 200-WA-1	CP-LS-7, CP-TF-9, CP-GW-2
CP-TF-3	TF	TX-TY Tank Farms	TX-TY tank farms, ancillary structures, associated liquid waste sites, and soils contamination. Includes 242-T Evaporator.	WMA TX/TY, 200-DV-1, 200-WA-1	CP-LS-7, CP-GW-2

Evaluation Unit (EU) ID	Group	Evaluation Unit Name	Description & Comments	Operable Unit Cross-Walk	Related EU's
CP-TF-4	TF	U Tank Farm	U tank farm, ancillary structures, associated liquid waste sites, and soils contamination.	WMA U, 200-WA-1	CP-LS-7, CP-GW-2
CP-TF-5	TF	A-AX Tank Farms	A-AX Tank farms, ancillary structures, associated liquid waste sites, and soils contamination.	WMA A/AX, 200-EA-1, 200-PW-3	CP-LS-7, CP-TF-8, CP-GW-1
CP-TF-6	TF	B-BX-BY Tank Farms	B-BX-BY tank farms, ancillary structures, associated liquid waste sites, and soils contamination.	WMA B/BX/BY, 200-DV-1, 200-EA-1	CP-LS-7, CP-GW-1
CP-TF-7	TF	C Tank Farms	C Tank farm, ancillary structures, associated liquid waste sites, and soils contamination.	WMA C	CP-LS-7, CP-GW-1
CP-TF-8	TF	200-East DSTs	AN, AP, AW, AY, AZ tank farms, ancillary structures, associated liquid waste sites, and soils contamination.	NA	CP-LS-7, CP-TF-5
CP-TF-9	TF	200-West DSTs	SY tank farm, ancillary structures, associated liquid waste sites, and soils contamination.	WMA S/SX	CP-LS-7, CP-TF-2
CP-GW-1	GW	200-East Groundwater	Existing groundwater plumes emanating from 200-East area.	200-BP-5, 200-PO-1	CP-LS-1, -8, -9, -10, -11, CP-TF-5, -6, -7
CP-GW-2	GW	200-West Groundwater	Existing groundwater plumes emanating from 200-West Area. Includes pump and treatment systems.	200-ZP-1, 200-UP-1	CP-LS-2 through -6, CP-TF-1 through 4
CP-OP-1	Ops	CWC	Central Waste Complex operations, closure, and D&D.	NA	

Evaluation Unit (EU) ID	Group	Evaluation Unit Name	Description & Comments	Operable Unit Cross-Walk	Related EU's
CP-OP-2	Ops	T Plant	T Plant Canyon, ancillary buildings, structures. Evaluate through operations, then will be preserved as a historical site or undergo D&D.	NA	
CP-OP-3	Ops	WESF (only Cs/Sr capsules)	Waste Encapsulation and Storage Facility (WESF) – Evaluate for the storage and removal of Cs/Sr Capsules. D&D included with B Plant EU.	NA	CP-DD-2
CP-OP-4	Ops	WRAP	Waste Repackaging and Processing (WRAP) facility operations, closure, and D&D.	NA	
CP-OP-5	Ops	CSB	Canister Storage Building (CSB) operations and closure (including adjacent spent fuel dry storage pad).		
CP-OP-6	Ops	ERDF	Environmental Restoration Disposal Facility operations and closure.	NA	
CP-OP-7	Ops	IDF	Integrated Disposal Facility operations and closure.	NA	
CP-OP-8	Ops	Mixed waste trenches	Mixed waste trenches (Trench 31 and 34, next to WRAP) operations and closure.	200-SW-2	CP-LS-14
CP-OP-9	Ops	Naval Reactors Trench	Naval Reactors disposal trench operations and closure.	200-SW-2	CP-LS-14
CP-OP-10	Ops	242-A Evaporator	Operations and D&D of the 242-A evaporator.	NA	CP-TF-5
CP-OP-11	Ops	LERF	Operations and closure of the Liquid Effluent Retention Facility (LERF).	NA	
CP-OP-12	Ops	TEDF	Operations and closure of the Treated Effluent Disposal Facility (TEDF).	NA	

Evaluation Unit (EU) ID	Group	Evaluation Unit Name	Description & Comments	Operable Unit Cross-Walk	Related EU's
CP-OP-13	Ops	SALDS	Operations and closure of the State Approved Land Disposal Sites (SALDS).	NA	
CP-OP-14	Ops	WTP	Waste Treatment Plant Operations and D&D. Includes new tanks (if needed), preconditioning, 4 major facilities, and interim storage elements.	NA	
CP-OP-15	Ops	222-S Laboratory	Operations and D&D of the 222-S Laboratory.	NA	

Notes for Central Plateau: Include US Ecology as a comparator – but not an EU. Include infrastructure discussion as context, but not as an EU. Need to list all those facilities included in the infrastructure discussion. T Plant is an Operating Facility and an historic site that is being considered for the Manhattan Project National Park.

DRAFT

Figure 3-6. Interim Report Evaluation Units - River Corridor, 100 K Area.

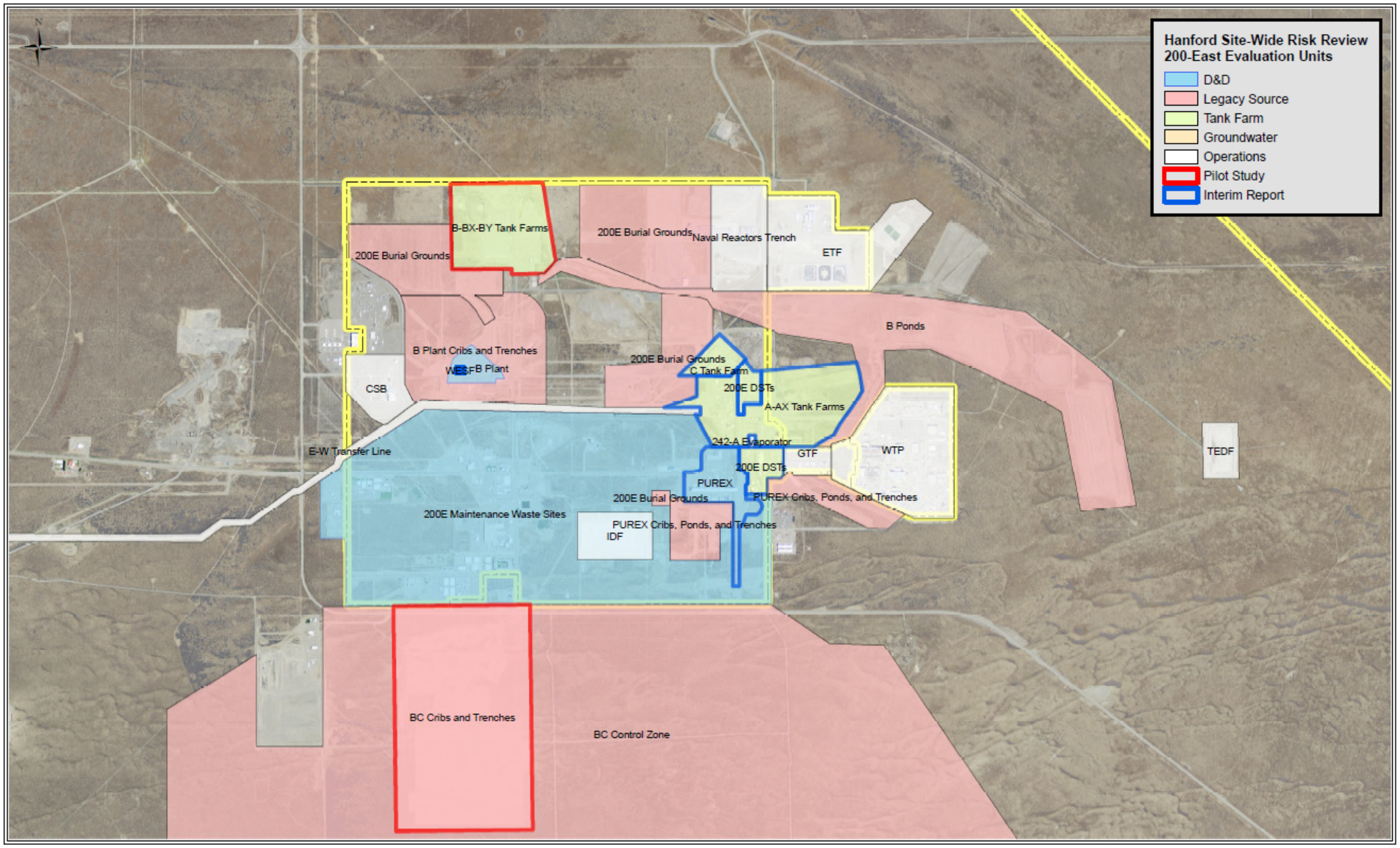

Figure 3-7. Interim Report Evaluation Units – Central Plateau 200 E Area.

Figure 3-8. Hanford site-wide risk review 200 West evaluation units.

3.11. REFERENCES

ORP-11242, Rev. 6 2011, 'River Protection Project System Plan,' ORP-11242, Rev. 6, U.S. Department of Energy, Office of River Protection, Richland, WA.

CHAPTER 4. METHODOLOGY FOR INITIATING EVENTS USED FOR EVALUATIONS

ABSTRACT

As part of the review methodology it is important to establish a consistent basis for identifying and categorizing phenomena that may remove or degrade barriers to completed pathways. The term "Initiating Events" will be used for these phenomena. The initiating event methodology provides a basis for assigning the likelihood of loss or degradation of barriers and guidance for assigning impacts (consequences) due to the loss of barrier based on the event being considered. The risk and impact methodology developed for this effort will be applied as appropriate to each category of evaluation unit, utilizing this basis.

4.1. OBJECTIVE

In order to perform a meaningful and efficient risk review it is necessary to establish a consistent basis for identifying and categorizing phenomena that may remove or degrade barriers to completed pathways. The term "Initiating Events" will be used for these phenomena. The primary goal of the Initiating Event Methodology will be to provide a basis for assigning the likelihood of loss or degradation of barriers and guidance for assigning impacts (consequences) due to the loss of barrier based on the event being considered. The risk and impact methodology developed for this effort will be applied as appropriate to each evaluation unit, utilizing this basis. Initiating Events are episodic events that may occur over short or long time frames (less than a day to years) and are considered in addition to natural prevailing processes (i.e., groundwater flow) that may result either by themselves or in combination with initiating events, in risks to receptors from contaminants already in environmental media (e.g., soils, vadose zone, groundwater).

4.2. GENERAL CONSTRUCT

In the context of this risk assessment initiating events will be grouped into anthropogenic and natural events. Anthropogenic events will include events directly attributed to human initiators (e.g., human error leading to accidents, loss of institutional control), failure of engineered systems, and external events from man-made sources (aircraft impacts, events at other evaluation units). Natural events will include natural hazards phenomena (earthquake, high winds, volcanic ashfall, and wildfires) consistent with guidance in DOE-STD-1020, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*. This includes natural processes such a structural decay of barriers and facilities (e.g., landfill covers, storage tanks, buildings, etc.) exposed to the environs, changes in water table, and drought/climate change.

4.3. INITIATING EVENT LIKELIHOOD DESIGNATIONS

Each Initiating Event will be associated with an event likelihood or likelihood range. The likelihood ranges are generally expressed as a function of estimated annual likelihood of occurrence (event/yr) (DOE-STD-3009), but may also be assigned based on qualitative estimate (e.g., the likelihood of experiencing structural decay for barriers exposed to the environment during the long-term post-cleanup phase). Table 4-1 identifies the quantitative likelihood ranges and descriptions for use in the evaluation of initiating events. The frequencies associated with anthropogenic events (human and system failures) are based on facility lifespans and are judged to be applicable to the active cleanup evaluation period (50 years, through 2064) without additional modification. For the post cleanup evaluation periods, additional consideration of the overall exposure time may be warranted. These initiating frequencies should only be considered in a relative sense and not considered as an absolute value. See Table 4-2 through Table 4-3.

Table 4-1. Likelihood estimates for initiating events (from DOE-STD-3009).

Likelihood Designation		Quantitative Range /yr	Qualitative Descriptions
Anticipated	(A)	$> 10^{-2}$ [(a)]	Events which are expected to happen in the evaluation period (e.g., life time of a facility for operational facilities). Typically includes human errors and failure of active systems, short term loss of power.
Unlikely	(U)	$10^{-2} – 10^{-4}$ [(b)]	Events that are not anticipated to occur during the evaluation period. Natural phenomena events in this range include: Uniform Building Code-level earthquake, 100-year flood, maximum wind gust, etc. Typically includes failure of passive systems, extended loss of power.
Extremely Unlikely	(EU)	$10^{-4} – 10^{-6}$ [(c)]	Events that will probably not occur during the evaluation period. This typically includes (severe NPH and rare external events, e.g., aircraft crashes, dam failures.)
Beyond Extremely Unlikely	(BEU)	$< 10^{-6}$ [(d)]	Events that are not expected to occur. Usually events requiring multiple independent failures or very rare phenomena (asteroid impacting the Hanford Site).

a. An event that has a likelihood of occurrence during the life of the project of about 1% per year or between 0.01 and 1 (10^{-2} to 1).
b. An event that has a likelihood of occurrence between 0.01 and 0.0001 (10^{-4} and 10^{-2}).
c. An event that has a likelihood of occurrence between 0.0001 and 0.000001 (10^{-6} to 10^{-4}).
d. An event that had a likelihood of occurrence of less than 1 in a million ($< 10^{-6}$).

4.4. EVENT DAMAGE/CONSEQUENCE ASSESSMENT

Events also must be related to the damage to a barrier it is expected to cause. The following guidance is provided to assist the analysts in assigning damage estimates/consequences for the initiating events. For consequence determinations within hazard analyses and documented safety analyses, the hazardous material exposures are usually limited to short durations (e.g., less than 8 hours) and do not include food or water pathways. In contrast, for the Risk Review Project, longer-term consequences and the additional receptors identified earlier also are considered.

(Low) Localized Impacts

Events are associated with damage to individual barriers (release of material) which may result in release of material and immediately impact the nearby worker but are not expected to have impacts outside the facility/area boundary (HNF-8739). Environmental impacts would be expected to be limited and able to be mitigated and remediated. For determining radiological impacts, these are events associated with less than Hazard Category 3 (DOE-STD-1027, CN1) quantities of material.

Examples Include:

- Container retrieval, handling, and storage events impacting one to a few drums or containers.
- Liquid waste handling events (leaks, spills, overflows) resulting in the release of a few gallons of material.
- Uncontained Inadvertent Criticality Events (single pulse).

Within a Documented Safety Analysis or Hazards Analysis these events are identified as having High consequences to the Facility Worker and Low consequences to the Co-located Worker (see Terminology) and Public.

(MODERATE) FACILITY IMPACTS

Events are associated with damage to many barriers or entire facility/systems (e.g., an entire tank farm or operating plant) which may result in release of material and have immediate impact to receptors outside the evaluation site or facility/area boundary but not the overall Hanford Site boundary (HNF-8739). Environmental impacts would be expected to be limited to the Hanford site boundary but could include potential impacts to groundwater.

Examples Include:

- Container retrieval, handling, and storage, events driven by mechanical failures (e.g., crane drops) impacting several pallets or row of storage containers.
- Liquid waste handling events (large leaks, miss-transfers) resulting in the release of a hundreds gallons of material.
- Low pressure spray leaks of high activity waste material.
- Deflagrations or explosions within a single waste tank.
- Contained inadvertent criticality events (multiple pulses).

Within the Documented Safety Analysis or Hazards Analysis these events are identified as having high consequences to the facility worker, moderate or high consequences to the co-located workers and low consequences to the public. However, in the context of the Risk Review Project, they may also have consequences to other receptors outside the facility/area boundary (i.e., groundwater, ecological and cultural resources).

(HIGH) OFFSITE IMPACTS

Events are associated with damage to multiple facilities/systems which may result in release of material and have immediate impact on receptors outside the Hanford Site Boundary (HNF-8739). Environmental impacts would be expected to be seen offsite and could include potential impacts to groundwater and surface water (Columbia River).

Examples Include:

- Facility wide events, such as fire or building collapse, impacting the entire inventory of stored (in-process) containers.
- Liquid waste handling events (Large leaks, miss-transfers) resulting in the release of a hundreds gallons of material. High pressure sprays leaks of high activity waste material.

- Deflagrations or explosions within multiple waste tanks resulting in airborne contamination reaching beyond Hanford boundary.

Within the Documented Safety Analysis or Hazards Analysis these events are identified as having High consequences to the Facility and Co-located Workers and Moderate or High consequences to the Public.

4.5. EVENT LIKELIHOOD AND CONSEQUENCES

Table 4-2 through Table 4-3 identify typical initiating events classes expected to be relevant to the Risk Review Project for each evaluation group type and for the three evaluation time periods being considered. Additional initiating events may be added for individual EUs based on review of the hazards assessments and documented safety analyses. The tables identify the quantitative likelihood range of the events (see Table 4-1) and a qualitative estimate of the expected consequences (Low, Moderate, High) from releases due to those initiators using a structure based on SARAH, which are then integrated to form an overall risk rating to at receptor from ND to Very High. The analysts can use these to aid in binning evaluation unit specific events in frequency and consequences. In the case of the longer post-cleanup evaluation periods the likelihood range and applicability of the initiating events have been adjusted as necessary based on the longer time frames and the nature of activities expected on site.

Key assumptions applied to the specific evaluation unit groupings (i.e., Legacy Source Sites, Tank Wastes and Farms, Groundwater Plumes, D&D of Inactive Facilities, Operating Facilities) for each evaluation period area are identified below:

Active Cleanup (Active): Defined as 50 years (i.e., until 2064):

- During Active Cleanup all groupings are assumed to include human activities and various types of engineered systems, administrative controls, (e.g., Health and Safety Plans) and maintenance efforts.
- For facilities in D&D (or transferring to D&D) during the Surveillance and Maintenance Phase – no active operations. Human activities limited to monitoring and maintenance to ensure necessary systems remain functional.

Near-Term Post-Cleanup (Near): Lasts 100 years after cleanup is completed (i.e., until 2164).

- No active-engineered systems are required to maintain integrity of barriers.
- Passive barriers including canyons and engineered covers are addressed as “Structures” versus “Systems.”
- Institutional controls are in place.
- Loss of monitoring and support infrastructure does not lead to the failure of a barrier.
- For groundwater and surface water it will be necessary to address consequences of released water or failure of barrier (intrusion into groundwater or river). Impacts to the groundwater from the vadose zone are addressed as appropriate to the individual evaluation groups.

Long-Term Post-Cleanup (Long): Extends for 1000 years after cleanup is complete (i.e., until 3064).

- No Institutional controls are in place although federal control may extend beyond the year 2164 in some areas of the Hanford.
- Loss of monitoring and support infrastructure does not lead to the failure of a barrier.

In Table 4-2 through Table 4-3 (see Table 4-1 for likelihood): A=anticipated, U=Unlikely, EU=extremely unlikely. Events with likelihood “beyond extremely unlikely” are not evaluated. Consequences, currently qualitatively assigned as L=Low; M=Moderate; or H=High, will be formalized within the specific Evaluation Units analyses and then the combination of likelihood and consequences will be assigned a risk rating with respect to each receptor.

The combination of likelihood and consequence determinations allows completion of a simple 3 by 3 matrix which can be used for ranking the risk of events as shown in Table 4-2.

I= Combinations that identify situations posing major concerns (High Risk)

II= Combinations that identify situations of concern (Moderate Risk)

III= Combinations that identify situations of low concern (Low Risk)

Table 4-2. A three by three likelihood and consequence rating matrix associated with Initiating Events.

Likelihood	Consequence or Impact (Risk Rating)		
	Low	**Moderate**	**High**
Anticipated	III (ND to Low)	I (High to Very High)	I (High to Very High)
Unlikely	III (ND to Low)	II (Medium to High)	I (High to Very High)
Extremely Unlikely	III (ND to Low)	III (ND to Low)	II (Medium to High)

Table 4-3. Typical initiating events and consequences for Legacy Source Sites.

EVENT [(reference)]	Likelihood/Impact			Discussion
	Active[(a)]	Near[(b)]	Long[(c)]	
Human errors	A/L	NA	NA	Includes events involving mechanical movements of contaminated material. Exposure to "unknown material."
	U/M	NA	NA	Typically these errors would be associated with failure of formal Regulatory or Safety Management Program (e.g., Criticality Safety Program).
Fires	A/L	NA	NA	Local fires prior to initiation of suppression. Range Fires impacting isolated units (e.g., exposed waste containers or contaminated areas).
Failures of industrial grade active systems	A/M	NA	NA	Loss of motive force ventilation. Drum Over-pressurizations (non-vented).
Loss of Power	A/L	NA	NA	(Short duration). Active failures (breaker trips, offsite power). Can initiate loss of multiple active systems (Normal operating systems). Loss of monitoring not assumed to lead to failure of barrier.
	U/L, M, H	NA	NA	(Long duration). Failure in switchgear substations, regional loss of power events (blackouts). May challenge robust engineered systems even with backup power available. Loss of monitoring not assumed to lead to failure of barrier.
Explosions	A/L	U/L	U/L	Accumulation in unvented container (Drum, inactive system). Unlikely that accumulation (flammable mixture) would occur in stabilized waste.
Loss of Institutional Controls	EU/L	U/L	A/L	For Long Term Post-cleanup period assumes no control.
Loss of Engineered Systems	U/L	NA	NA	For Post-cleanup period see Structural Decay.
Significant Dam Failure (flooding) [(d)]	EU/ L	EU/L	U/L	Impacts to Barriers near Columbia River (100 Area, 300 Area). Significant widespread flooding through Columbia River Basin. Assumes River Corridor has only residual contamination after Active Clean-up period. For other flooding see River Flood.

EVENT [reference]	Likelihood/Impact			Discussion
	Active[a]	Near[b]	Long[c]	
Plane Crash	EU/M	EU/L	EU/L	EU (light aviation). Significant damage to single System.
	BEU/H	EU/L	EU/L	(Commercial carriers). Significant damage to Facility/ multiple Systems.
Structural Decay	U/L	A/L	A/M	Failure of barrier exposed to environs assumes human intervention (maintenance & repair) during Active Cleanup phase and no/minimal human intervention in the Post Cleanup Phases.
Earthquake[e]	A/M	U/M	U/M	Failure of normal ("non-safety") Structures/Systems exposed to seismic loads.
	U/M H	NA	NA	Failure of robust ("safety") Structures/Systems during active remediation. Offsite impact would require multiple failures.
Winds[e]	A/M	A/L	A/L	Failure of normal ("non-safety") Structures/Systems exposed to 91 mph peak, 115 mph ultimate- peak wind speeds. For Post-Cleanup – assumes erosion resulting in loss of barrier with water infiltration).
	U/L	NA	NA	Failure of robust ("safety") Structures/Systems exposed to 100 mph peak, 129 mph ultimate-peak wind speeds during active remediation.
Tornado[e]	EU/H	NA	NA	Failure of Facilities and Exposed structures. Loss of Power. Not included in Hanford Site Design Criteria.
Snow Load/Icing[e]	U/M	NA	NA	Failure of barriers from structural loading >15 lbs/ft^2.
Ash Fall (Volcanic)[e]	U/M EU/H	NA	NA	Failure of barriers from structural loading (12-23 lbs/ft^2) and from airborne concentration leading to plugging, electrical shorting, loss of power (1325 -2650 mg/m^3). Offsite impact would require multiple failures.
Flood (Local Storm-rainfall) [e]	A/L	A/L	A/L	Failure of barriers due to potential intrusion/accumulation for 100-yr (2 inches) rainfall.
	U/L	U/L	U/L	Failure of barriers due to potential intrusion/accumulation for 1000-yr (2.7 inches) rainfall.
River Flood[e]	U/L	NA	NA	100 Area Elevations <426 ft 200 Area (southwestern) Cold Creek Drainage area, for Elevations <640 ft. 300 Area Elevations <380 ft

EVENT [reference]	**Likelihood/Impact**			**Discussion**
	Active[a]	**Near**[b]	**Long**[c]	
Land Slide[e]	U/M	NA	NA	To be evaluated on specific site basis – typically associated with steep slopes/ water saturation.
Severe drought/ precipitation	A/L	A/L	A/L	Migration of contamination in soil or groundwater.

a. Active Cleanup Period (until 2064)
b. Near-Term, Post-Cleanup Period (until 2164)
c. Long-Term, Post-Cleanup Period (until 3064)
d. RLO-76-4, Evaluation of impact of Potential Flooding Criteria on the Hanford Project. ERDA, 1976
e. HNF-SD-GN-ER-501, Natural Phenomena Hazards, Hanford Site, Washington Rev. 2

Table 4-4. Typical initiating events and consequences for Tank Waste and Farms.

EVENT [(reference)]	Likelihood/Impact			Discussion
	Active[(a)]	Near[(b)]	Long[(c)]	
Human errors	A/L	NA	NA	Includes events involving mechanical movements- drops or impacts onto a waste tank system. Misroutes of material (feed) resulting in spills overflows.
	U/M	NA	NA	Typically these errors would be associated with failure of formal Regulatory or Safety Management Program (e.g., Criticality Safety Program).
Fires	A/L	U/L	A/L	Local fires prior to initiation of suppression. Range Fires may impact barriers but would most likely only result in infiltration issues.
	U/M	NA	NA	Building/Infrastructure Fires (with failure of suppression).
Failures of industrial grade active systems	A/M	NA	NA	Loss of motive force (pumps, compressed air, ventilation). Usually restricted to 1 shift. Pressure boundary (gaskets, pumps) failure.
Loss of Power	A/L	NA	NA	(Short duration). Active failures (breaker trips, offsite power). Can initiate loss of multiple active systems (Normal operating systems). Loss of monitoring not assumed to lead to failure of barrier.
	U/L, M, H	NA	NA	(Long duration). Failure in switchgear substations, regional loss of power events (blackouts). May challenge robust engineered systems even with backup power available.
Explosions	A/L	EU/L	U/L	Accumulation in unvented container (diversion box, inactive piping system). Post Cleanup it is unlikely that accumulation (flammable mixture) would occur.
	U/M	NA	NA	Accumulation in actively vented tank system with active mitigation.
Failures of Robust system	A/L	NA	NA	Pressure Boundary failures resulting in leaks and spills for non-maintained systems.
	U/L, M	NA	NA	Failure of active redundant (safety) systems. Pressure Boundary failures resulting in leaks and spills for maintained systems or catastrophic failure of systems.

EVENT [reference]	Likelihood/Impact			Discussion
	Active[a]	Near[b]	Long[c]	
Loss of Institutional Controls	EU/L	U/L	A/L	For Long Term Post-cleanup period assumes no control.
Loss of Engineering Controls	U/L	U/L	EU/M	For Post-cleanup period see Structural Decay.
Dam Failure (flooding)[d]	NA	NA	NA	Tanks above maximum flood level.
Plane Crash[f]	EU/M	EU/L	EU/L	EU (light aviation). Significant damage to single System.
	BEU/H	EU/L	EU/L	(Commercial carriers). Significant damage to Facility/ multiple Systems.
Structural Decay	U/L	A/L	A/M	Failure of barrier exposed to environs assumes human intervention (maintenance & repair) during Active Cleanup phase and no/minimal human intervention in the Post Cleanup Phases.
Earthquake[e]	A/M	U/M	U/M	Failure of normal ("non-safety") Structures/Systems exposed to seismic loads.
	U/M H	U/M	U/M	Failure of robust ("safety") Structures/Systems exposed to seismic loads. Offsite impact would require multiple failures.
Winds[e]	A/M	A/L	A/L	Failure of normal ("non-safety") Structures/Systems exposed to 91 mph peak, 115 mph ultimate- peak wind speeds. For Post-Cleanup – assumes erosion resulting in loss of barrier with water infiltration).
	U/M	NA	NA	Failure of robust ("safety") Structures/Systems exposed to 100 mph peak, 129 mph ultimate-peak wind speeds. Offsite impact would require multiple failures.
Tornado[e]	EU/H	NA	NA	Failure of Facilities and Exposed structures. Loss of Power. Not included in Hanford Site Design Criteria.
Snow Load/Icing[e]	U/M	NA	NA	Failure of barriers from structural loading >15 lbs/ft^2
Ash Fall (Volcanic)[e]	U-EU/M, H	NA	NA	Failure of barriers from structural loading (12-23 lbs/ft^2) and from airborne concentration leading to plugging, electrical shorting, loss of power (1325 -2650 mg/m^3). Offsite impact would require multiple failures.

EVENT [reference]	Likelihood/Impact			Discussion
	Active[a]	Near[b]	Long[c]	
Flood (Local Storm-rainfall)[e]	A/L	A/L	A/L	Failure of barriers due to potential intrusion/accumulation for 100-yr (2 inches) rainfall.
	U/L	U/L	U/L	Failure of barriers due to potential intrusion/accumulation for 1000-yr (2.7 inches) rainfall
River Flood[e]	U/L	NA	NA	200 Area (southwestern) Cold Creek Drainage area, for Elevations < 640 ft.

a. Active Cleanup Period (to 2064)
b. Near-Term, Post-Cleanup Period (to 2164)
c. Long-Term, Post-Cleanup Period (to 3064)
d. RLO-76-4, Evaluation of impact of Potential Flooding Criteria on the Hanford Project. ERDA, 1976
e. HNF-SD-GN-ER-501, Natural Phenomena Hazards, Hanford Site, Washington Rev. 2
f. RPP-11736, Assessment of Aircraft Crash Frequency for the Hanford Site 200 Area Tank Farms, Rev 0

Table 4-5. Typical initiating events and consequences for Groundwater Plumes.

EVENT [(reference)]	Likelihood/Impact			Discussion
	Active[(a)]	Near[(b)]	Long[(c)]	
Human errors	A/L	NA	NA	Includes operations of Pump and Treat. Includes events involving mechanical movements- drops or impacts during resin loading/disposal. Misroutes of material (feed) resulting in spills overflows to bermed areas.
	U/L	NA	NA	Typically these errors would be associated with failure of formal Regulatory or Safety Management Program (e.g., Criticality Safety Program).
Fires	A/L	NA	NA	Local fires prior to initiation of suppression. Range Fires impacting isolated units (e.g., exposed waste containers or contaminated areas). Moderate Impacts based on multiple events occurring over the evaluation lifetime.
	U/L	NA	NA	Building Fires (with failure of suppression)
Failures of industrial grade active systems	A/L	NA	NA	Loss of motive force (pumps, compressed air, ventilation). Usually restricted to 1 shift. Pressure boundary (gaskets, pumps) failures. Drum Over-pressurizations (non-vented).
Loss of Power	A/L	NA	NA	(Short duration). Active failures (breaker trips, offsite power). Can initiate loss of multiple active systems (Normal operating systems). Loss of monitoring not assumed to lead to failure of barrier.
	U/L	NA	NA	(Long duration). Failure in switchgear substations, regional loss of power events (blackouts). May challenge robust engineered systems even with backup power available. Loss of monitoring not assumed to lead to failure of barrier.
Explosions	A/L	NA	NA	Accumulation in unvented container (Drum, inactive system). Unlikely that accumulation (flammable mixture) would occur in stabilized waste.
	U/L	NA	NA	Accumulation in vented container or in a system with active mitigation.

EVENT [reference]	Likelihood/Impact			Discussion
	Active[a]	Near[b]	Long[c]	
Failures of Robust system	A/L	NA	NA	Pressure Boundary failures resulting in leaks and spills for non-maintained systems.
	U/L	NA	NA	Failure of active redundant (safety) systems Pressure Boundary failures resulting in leaks and spills for maintained systems or catastrophic failure of systems
Loss of Institutional Controls	EU/L	U/L	A/L	For Long Term Post-cleanup period assumes no control.
Loss of Engineering Controls	U/L	NA	NA	For Post-cleanup period see Structural Decay.
Significant Dam Failure (flooding)[d]	EU/L	NA	NA	Impacts to Barriers near Columbia River (100 Area, 300 Area). Significant widespread flooding through Columbia River Basin. Assumes River Corridor has only residual contamination after Active Clean-up period. For other flooding see River Flood.
Plane Crash	EU/L	NA	NA	EU (light aviation) Significant damage to single System.
	BEU/L	NA	NA	(Commercial carriers). Significant damage to Facility/ multiple Systems.
Structural Decay	U/L	NA	NA	Failure of barrier exposed to environs assumes human intervention (maintenance & repair) during Active Cleanup phase and no/minimal human intervention in the Post Cleanup Phases.
Earthquake[e]	A/L	NA	NA	Failure of normal ("non-safety") Structures/Systems exposed to seismic loads.
	U/L	NA	NA	Failure of robust ("safety") Structures/Systems exposed to seismic loads. Offsite impact would require multiple failures.
Winds[e]	A/L	NA	NA	Failure of normal ("non-safety") Structures/Systems exposed to 91 mph peak, 115 mph ultimate- peak wind speeds. For Post-Cleanup – assumes erosion resulting in loss of barrier with water infiltration)
	U/L	NA	NA	Failure of robust ("safety") Structures/Systems exposed to 100 mph peak, 129 mph ultimate-peak wind speeds. Offsite impact would require multiple failures.
Tornado[e]	EU/L	NA	NA	Failure of Facilities and Exposed structures. Loss of Power. Not included in Hanford Site Design Criteria.

EVENT [reference]	Likelihood/Impact			Discussion
	Active[a]	Near[b]	Long[c]	
Snow Load/Icing[e]	U/L	NA	NA	Failure of barriers from structural loading >15 lbs/ft^2.
Ash Fall (Volcanic) [e]	U-EU/L	NA	NA	Failure of barriers from structural loading (12-23 lbs/ft^2) and from airborne concentration leading to plugging, electrical shorting, loss of power (1325 -2650 mg/m^3). Offsite impact would require multiple failures.
Flood (Local Storm-rainfall) [e]	A/L	NA	NA	Failure of barriers due to potential intrusion/accumulation for 100-yr (2 inches) rainfall.
	U/L	NA	NA	Failure of barriers due to potential intrusion/accumulation for 1000-yr (2.7 inches) rainfall.
River Flood[e]	U/L	NA	NA	100 Area Elevations <426 ft. 200 Area (southwestern) Cold Creek Drainage area, for Elevations <640 ft. 300 Area Elevations <380 ft.
Land Slide[e]	U/L	NA	NA	To be evaluated on specific site basis – typically associated with steep slopes/ water saturation.
Land Movement: Subsidence/ uplift[e]	A/L	NA	NA	To be evaluated on specific site basis – typically associated with groundwater removal/injection.
Severe drought/ precipitation	A/**L**	A/**L**	A/**L**	Migration of contamination in soil or groundwater.

a. Active Cleanup Period (to 2064)
b. Near-Term, Post-Cleanup Period (to 2164)
c. Long-Term, Post-Cleanup Period (to 3064)
d. RLO-76-4, Evaluation of impact of Potential Flooding Criteria on the Hanford Project. ERDA, 1976
e. HNF-SD-GN-ER-501, Natural Phenomena Hazards, Hanford Site, Washington Rev. 2

Table 4-6. Typical initiating events and consequences for D&D of Inactive Facilities.

EVENT [(reference)]	Likelihood/Impact			Discussion
	Active[(a)]	Near[(b)]	Long[(c)]	
Human errors	A/L	NA	NA	Includes events involving mechanical movements of contaminated material. Exposure to "unknown material."
	U/M	NA	NA	Typically these errors would be associated with failure of formal Regulatory or Safety Management Program (e.g., Criticality Safety Program).
Fires	A/L	A/L	A/M	Local fires prior to initiation of suppression. During Surveillance and Maintenance Phase – no active systems. Range Fires impacting isolated units (e.g., exposed waste containers or contaminated areas) Moderate Impacts based on multiple events occurring over the evaluation lifetime.
	U/M	NA	NA	Building Fires (with failure of suppression)
Failures of industrial grade active systems	A/M	NA	NA	Loss of motive force (pumps, compressed air, ventilation). Usually restricted to 1 shift. Pressure boundary (gaskets, pumps) failures. Drum Over-pressurizations (non-vented).
Loss of Power	A/L	NA	NA	(Short duration). Active failures (breaker trips, offsite power). Can initiate loss of multiple active systems (Normal operating systems). Loss of monitoring not assumed to lead to failure of barrier.
	U/L, M, H	NA	NA	(Long duration). Failure in switchgear substations, regional loss of power events (blackouts). May challenge robust engineered systems even with backup power available. Loss of monitoring not assumed to lead to failure of barrier.
Explosions	A/L	EU/L	U/L	Accumulation in unvented container (Drum, inactive system). Unlikely that accumulation (flammable mixture) would occur in stabilized waste.
	U/M	NA	NA	Accumulation in vented container or in a system with active mitigation.

EVENT [reference]	Likelihood/Impact			Discussion
	Active[a]	Near[b]	Long[c]	
Failures of Robust system	A/L	NA	NA	Pressure Boundary failures resulting in leaks and spills for non-maintained systems.
	U/L, M	NA	NA	Failure of active redundant (safety) systems. Pressure Boundary failures resulting in leaks and spills for maintained systems or catastrophic failure of systems.
Loss of Institutional Controls	EU/L	U/L	A/L	For Long Term Post-cleanup period assumes no control.
Loss of Engineered Systems	U/L	NA	NA	For Post-cleanup period see Structural Decay.
Significant Dam Failure (flooding)[d]	EU/M	EU/L	U/L	Impacts to Barriers near Columbia River (100 Area, 300 Area). Significant widespread flooding through Columbia River Basin. Assumes River Corridor has only residual contamination after Active Clean-up period. For other flooding see River Flood.
Plane Crash[f]	EU/M	EU/L	EU/L	EU (light aviation): Significant damage to single System.
	BEU/H	EU/L	EU/L	(Commercial carriers). Significant damage to Facility/ multiple Systems.
Structural Decay	U/L	A/L	A/M	Failure of barrier exposed to environs assumes human intervention (maintenance & repair) during Active Cleanup phase and no/minimal human intervention in the Post Cleanup Phases.
Earthquake[e]	A/M	U/M	U/M	Failure of normal (“non-safety”) Structures/Systems exposed to seismic loads.
	U/M H	U/M	U/M	Failure of robust (“safety”) Structures/Systems exposed to seismic loads. Offsite impact would require multiple failures.
Winds[e]	A/M	A/L	A/L	Failure of normal (“non-safety”) Structures/Systems exposed to 91 mph peak, 115 mph ultimate- peak wind speeds. For Post-Cleanup – assumes erosion resulting in loss of barrier with water infiltration).
	U/M	NA	NA	Failure of robust (“safety”) Structures/Systems exposed to 100 mph peak, 129 mph ultimate-peak wind speeds. Offsite impact would require multiple failures.
Tornado[e]	EU/H	NA	NA	Failure of Facilities and Exposed structures. Loss of Power. Not included in Hanford Site Design Criteria.

EVENT [reference]	**Likelihood/Impact**			**Discussion**
	Active[a]	**Near**[b]	**Long**[c]	
Snow Load/Icing[e]	U/M	NA	NA	Failure of barriers from structural loading >15 lbs/ft^2
Ash Fall (Volcanic)[e]	U/M EU/H	NA	NA	Failure of barriers from structural loading (12-23 lbs/ft^2) and from airborne concentration (1325 -2650 mg/m^3) leading to plugging, electrical shorting, loss of power. Offsite impact would require multiple failures.
Flood (Local Storm-rainfall)[e]	A/L	A/L	A/L	Failure of barriers due to potential intrusion/accumulation for 100-yr (2 inches) rainfall
	U/L	U/L	U/L	Failure of barriers due to potential intrusion/accumulation for 1000-yr (2.7 inches) rainfall
River Flood[e]	U/L	NA	NA	100 Area Elevations <426 ft 200 Area (southwestern) Cold Creek Drainage area, for Elevations < 640 ft. 300 Area Elevations <380 ft

a. Active Cleanup Period (to 2064)
b. Near-Term, Post-Cleanup Period (to 2164)
c. Long-Term, Post-Cleanup Period (to 3064)
d. RLO-76-4, Evaluation of impact of Potential Flooding Criteria on the Hanford Project. ERDA, 1976
e. HNF-SD-GN-ER-501, Natural Phenomena Hazards, Hanford Site, Washington Rev. 2
f. PRC-STP-00815, Aircraft Crash Evaluation for 105-KW Basin/ECRTS Modified Annex Operations Revision 1

Table 4-7. Typical initiating events and consequences for Operating Facilities.

EVENT [(reference)]	Likelihood/Impact			Discussion
	Active[(a)]	Near[(b)]	Long[(c)]	
Human errors	A/L	NA	NA	Includes events involving mechanical movements- drops or impacts to a single or a few drums, waste boxes. Misroutes of material (feed) resulting in spills overflows.
	U/M	NA	NA	Loss of Institutional Control addressed separately. Typically these errors would be associated with failure of formal Regulatory or Safety Management Program (e.g., Criticality Safety Program).
Fires	A/L	A/L	A/M	Local fires prior to initiation of suppression. Range Fires impacting isolated units (e.g., exposed waste containers or contaminated areas). Moderate Impacts based on multiple events occurring over the evaluation lifetime.
	U/M	NA	NA	Building Fires (with failure of suppression).
Failures of industrial grade active systems	A/M	NA	NA	Loss of motive force (pumps, compressed air, ventilation). Usually restricted to 1 shift. Pressure boundary (gaskets, pumps) failures. Drum Over-pressurizations (non-vented).
Loss of Power	A/L	NA	NA	(Short duration). Active failures (breaker trips, offsite power). Can initiate loss of multiple active systems (Normal operating systems). Loss of monitoring not assumed to lead to failure of barrier.
	U/L, M, H	NA	NA	(Long duration). Failure in switchgear substations, regional loss of power events (blackouts). May challenge robust engineered systems even with backup power available. Loss of monitoring not assumed to lead to failure of barrier.
Explosions	A/L	EU/L	U/L	Accumulation in unvented container (Drum, inactive system). Unlikely that accumulation (flammable mixture) would occur in stabilized waste.
	U/M	NA	NA	Accumulation in vented container or in a system with active mitigation.

EVENT [reference]	Likelihood/Impact			Discussion
	Active[a]	Near[b]	Long[c]	
Failures of Robust system	A/L	NA	NA	Pressure Boundary failures resulting in leaks and spills for non-maintained systems.
	U/L, M	NA	NA	Failure of active redundant (safety) systems. Pressure Boundary failures resulting in leaks and spills for maintained systems or catastrophic failure of systems.
Loss of Institutional Controls	EU/L	U/L	A/L	For Long Term Post-cleanup period assumes no control.
Loss of Engineered Systems	U/L	NA	NA	For Post-cleanup period see Structural Decay.
Significant Dam Failure (flooding)[d]	EU/M	EU/L	U/L	Impacts to Barriers near Columbia River (100 Area, 300 Area). Significant widespread flooding through Columbia River Basin. Assumes River Corridor has only residual contamination after Active Clean-up period. For other flooding see River Flood.
Plane Crash[f]	EU/M	EU/L	EU/L	EU (light aviation). Significant damage to single System.
	BEU/H	EU/L	EU/L	(Commercial carriers). Significant damage to Facility/ multiple Systems.
Structural Decay	U/L	A/L	A/M	Failure of barrier exposed to environs assumes human intervention (maintenance & repair) during Active Cleanup phase and no/minimal human intervention in the Post Cleanup Phases.
Earthquake[e]	A/M	U/M	U/M	Failure of normal ("non-safety") Structures/Systems exposed to seismic loads.
	U/M H	U/M	U/M	Failure of robust ("safety") Structures/Systems exposed to seismic loads. Offsite impact would require multiple failures.
Winds[e]	A/M	A/L	A/L	Failure of normal ("non-safety") Structures/Systems exposed to 91 mph peak, 115 mph ultimate- peak wind speeds. For Post-Cleanup – assumes erosion resulting in loss of barrier with water infiltration).
	U/M	NA	NA	Failure of robust ("safety") Structures/Systems exposed to 100 mph peak, 129 mph ultimate-peak wind speeds. Offsite impact would require multiple failures.
Tornado[e]	EU/H	NA	NA	Failure of Facilities and Exposed structures. Loss of Power. Not included in Hanford Site Design Criteria.

EVENT [reference]	Likelihood/Impact			Discussion
	Active[a]	Near[b]	Long[c]	
Snow Load/Icing[e]	U/M	NA	NA	Failure of barriers from structural loading >15 lbs/ft^2.
Ash Fall (Volcanic)[e]	U-EU/M, H	NA	NA	Failure of barriers from structural loading (12-23 lbs/ft^2) and from airborne concentration leading to plugging, electrical shorting, loss of power (1325 -2650 mg/m^3). Offsite impact would require multiple failures.
Flood (Local Storm-rainfall)[e]	A/L	A/L	A/L	Failure of barriers due to potential intrusion/accumulation for 100-yr (2 inches) rainfall
	U/L	U/L	U/L	Failure of barriers due to potential intrusion/accumulation for 1000-yr (2.7 inches) rainfall
River Flood[e]	U/L	NA	NA	100 Area Elevations <426 ft 200 Area (southwestern) Cold Creek Drainage area, for Elevations <640 ft. 300 Area Elevations <380 ft

a. Active Cleanup Period (to 2064)
b. Near-Term, Post-Cleanup Period (to 2164)
c. Long-Term, Post-Cleanup Period (to 3064)
d. RLO-76-4, Evaluation of impact of Potential Flooding Criteria on the Hanford Project. ERDA, 1976
e. HNF-SD-GN-ER-501, Natural Phenomena Hazards, Hanford Site, Washington Rev. 2
f. PRC-STP-00815, Aircraft Crash Evaluation for 105-KW Basin/ECRTS Modified Annex Operations Revision 1

4.6. REFERENCES

DOE-STD-1020, Natural Phenomena Hazards Design and Evaluation Criteria For Department Of Energy Facilities, U.S. DOE

DOE-STD-1027, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports Change Notice 1, U.S. DOE

DOE-STD-3009, Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses, U.S. DOE

HNF-8739, 2012. *Hanford Safety Analysis and Risk Assessment Handbook (SARAH,)* Revision 2. CH2M HILL Plateau Remediation Company, Richland WA

HNF-SD-GN-ER-501, 2012. *Natural Phenomena Hazards, Hanford Site, Washington* Rev. 2. Washington River Protection Solutions LLC, Richland WA

PRC-STP-00815, 2013. *Aircraft Crash Evaluation for 105-KW Basin/ECRTS Modified Annex Operations*, Revision 1, CH2M HILL Plateau Remediation Company, Richland WA

RLO-76-4, Evaluation of impact of Potential Flooding Criteria on the Hanford Project. ERDA, 1976

RPP-11736, 2003. Assessment of Aircraft Crash Frequency for the Hanford Site 200 Area Tank Farms, Rev 0. CH2M HILL Hanford Group Inc., Richland WA

PART 3. HANFORD CONTEXT AND METHODOLOGIES FOR EVALUTING RISKS TO HUMAN HEALTH AND RESOURCES

CHAPTER 5. RISKS TO PUBLIC HEALTH ON THE HANFORD SITE

ABSTRACT

This chapter provides an overview of public health risks that may occur from the Hanford Site and methodology for relative rating of risks to the public from the Evaluation Units, currently (before remediation), during active cleanup, and near-term post-cleanup, when land has been released by DOE for agreed upon future land uses. Public health risk scenarios developed by US EPA and Washington Dept. of Ecology provide the basis for anticipated soil cleanup requirements to achieve specific land use definitions. Use of groundwater is not included in the risk evaluation because (i) there exists potential for provision of alternate or treated water supply commensurate with the anticipated uses when groundwater quality is inadequate to meet relevant water quality standards, and (ii) risks and impacts to groundwater resources are considered independently of designated land uses because it is considered a protected natural resource by the State of Washington. Before and during remediation legitimate public access to high hazard areas of Hanford is restricted and escorted, while post-remediation public activity should be consistent with proposed land uses. There is a direct linkage between future land use options and cleanup levels. If unrestricted land use is planned, cleanup objectives and residual contaminant levels must be sufficiently low to allow the full range of potential uses without health risk. Conversely, if such low levels cannot be achieved safely, with existing technology or with existing resources, higher amounts of residual contamination would allow only more restrictive land uses (e.g., industrial use). Public health risks also need to consider the low probability but potential for failure of institutional controls and the potential for a stealth intruder before, during and after cleanup activities.

5.1. OVERVIEW OF PUBLIC HEALTH CONSIDERATIONS

People who work on or visit contaminated sites or formerly contaminated sites or live nearby have the potential for being exposed to a variety of site-specific hazards: chemical, radiologic, biologic, and physical. Hazards may be in the form of contaminants in air or water, or in soil or food, and may include direct radiation exposure. Contaminants may enter the body through inhalation, ingestion, dermal absorption, or direct radiation penetration. This chapter considers the "public" that may visit or use facilities or land within an EU, as opposed to remediation workers. The "public" includes people who may be exposed to current or residual contamination on or from the Hanford Site as casual visitors, recreational users, employees of current and future non-DOE industries, as well as potential residents, farmers, and Tribal members. The Risk Review Project considers current exposures (and their associated risks/impacts) prior to remediation, during remediation, and after completion of remediation, when an EU may be released for either a designated land use with associated institutional controls or for unrestricted land use.

The Risk Review Project is not completing a quantitative risk assessment, but rather a rough order-of-magnitude rating or binning of potential risks to the public at the Hanford Site. The DOE has determined that the Hanford Site does not have any Hazard Category 1 nuclear risks that have the potential for significant offsite public exposure, even in a disaster (HNF-8739, 2012). EPA has developed risk assessment guidelines, based on experiences with CERCLA sites on the National Priorities List. EPA's Risk Assessment Guideline documents (EPA 2000, 2003) describe the methods that agencies and companies should use to evaluate risk and inform decisions about remediation and allowable land uses. In the case of most hazardous waste sites, risk assessments are performed for populations currently living on or adjacent to the contaminated site. Remedial investigations are carried out to characterize sites, identify contaminants of concern, measure concentrations, identify completed or potential exposure pathways, and estimate human health risks from current or lifetime exposure, with or without interdiction. These assessments guide decisions about occupancy versus evacuation, mitigation measures (e.g., providing alternate water supplies) and about remediation versus no action.

A different situation exists at the Hanford Site where public occupancy and current public exposure is minimal and public access is highly controlled, but where the mosaic of planned future land uses depends in part on existing contamination and foreseeable future exposures. These in turn depend on the extent of contamination of particular EUs, and the proposed remediation alternatives. Indeed, Hanford can be considered as two separate entities: large areas of uncontaminated or minimally contaminated landscape, and a mosaic of former industrial lands and disposal areas subject to cleanup.

There is a reflexive relationship between land use and cleanup. Where unrestricted land use is desired, cleanup levels must be set to very low values to prevent future impacts on health or other resources. If these low cleanup levels cannot be achieved safely by current technologies and available resources, then future land use must be restricted. Thus, a primary current impact of near surface contamination is the restriction or preclusion of desired future land uses, rather than current public health risk. For the purposes of the Risk Review Project, near surface contamination is restricted to the uppermost 5 m below the ground surface or the depth of the constructed facility if it is deeper than 5 m. The restoration of groundwater to "highest beneficial uses" (HAB 2007), such as drinking water and irrigation, is considered separately (Chapter 7).

Large areas of uncontaminated landscape at Hanford can or will be released for public use under control of U.S Fish and Wildlife Service, without extensive remediation requirements. Release of other areas from federal control may occur after cleanup, and residual contamination may limit future land use options as "Brownfields" and may require future risk assessments to deal with uncertainties in current modelling (Scott et al. 2005).

This chapter presents methodology to be used for binning risks to the public under various current and future scenarios, considering likelihood and consequence. An overriding theme of this chapter is that if a person or a population is not exposed to a hazard, then it is not at risk. Further, for risks to public health, the level or magnitude of exposure and duration are the critical factors that leads directly to a risk rating ranging from not-discernible to very high. Thus exposure is discussed in detail, including likelihood of exposure and consequences. A scenario with no current completed exposure pathways and with all future potential pathways effectively interdicted will have a rating of "low", compared to scenarios with current completed or unblocked future pathways (potentially a rating up to "very high").

5.2. DEFINITION OF PUBLIC

"Public" encompasses several categories of people. Currently and prior to release of remediated sites, public access to most of the Hanford site is controlled. Public highways traverse uncontaminated portions of the site with no warning or keep out signs. However, access to the former industrial sites behind entrance barricades is strictly controlled, and signage and fencing limits access within these areas. Nonetheless some unauthorized and intrusion may occur exposing people to hazards. The Nuclear Regulatory Commission distinguishes deliberate intrusion (so-called stealth visitors or trespassers) who knowingly violate access controls, from inadvertent or lost intruders. However in some circumstances the likelihood and consequences may be the same. The consequences will vary by the time period (before, during remediation, and future land users). Table 5-1 illustrates the potential types of people who might come on site, both during and after remediation. The risk rating uses a worst case approach, by focusing on the stealth intruder and stealth farmer to represent reasonably maximally exposed individuals (Antonio et al. 2002). A stealth intruder might include a thrill-seeker, an anti-anything demonstrator, a saboteur or a hypothetical stealth farmer family (Antonio et al. 2002). A stealth farmer as used by EPA is a family of four that climbs a fence or by passes access controls, sets up a residence, farms and consumes crops, and potentially spends 365 days a year on the restricted site. The potential for a stealth farmer is precluded by site security controls during the active cleanup period.

Table 5-1. Categories of the public being considered as part of the human health risk characterization.

	Public Category				
Time Period ↓	**Employees** (not DOE mission affiliated)	**Visitors**	**Recreational users**	**Trespasser**	**Residential**
Active Cleanup	Employees of Energy Northwest, and other on-site activities	Official, guided	Limited access from along the Columbia River	Stealth visitor	NA[(a)]
Near-Term, Post-Cleanup	Employees commercial entities located on-site	Recreational visitor (low frequency, no extraction[(b)])	Broader recreational access with extraction	Camping or living on industrial land	Resident or Stealth Farmer (no use of groundwater)

a. NA means Not Applicable.

b. "no extraction" indicates that there will be no consumption of fish, wildlife, herbs and plants from the designated area.

5.3. TIME PERIODS FOR EVALUATION

In this chapter the following time periods are discussed: 1) Active Cleanup (until 2064), including sub-categories of the current status (pre-remediation) and during remediation, and 2) Near-term Post-cleanup (until 2164). Currently, there is very little opportunity for public exposure except under circumstances such as escorted official visitors, site run tours, Native Americans visiting cultural sites with DOE approval, and personnel of the Energy Northwest nuclear power generation facility, as well as visitors and employees at the Arid Lands Ecology preserve, the U.S. Ecology disposal facility and other non-DOE enclaves on Hanford.

Prior to or during remediation, the public including escorted visitors, tourists and others, are kept at a safe distance from unremediated areas with active hazard conditions, such as burial grounds or contaminated facilities to be decommissioned. For example, for the single shell high-level waste tank farms, The *Safety Analysis and Risk Assessment Handbook* for Hanford (SARAH) (HNF-8739, 2012) estimates no significant exposure resulting in safety and health consequences to the offsite public during active cleanup even during site "accidents", but it is not clear that this includes visitors or intruders. "Stealth" (unauthorized) or inadvertent intruders may enter areas where they are exposed to radiologic, chemical, or structural hazards. For example, a visitor on a guided tour might wander away from the group to take photographs (our tour escorts were on the lookout for such wandering).

The primary basis for near-term, post-cleanup land uses considered as part of the Risk Review Project are described in the Comprehensive Land-use Plan for Hanford (CLUP DOE/EIS-0222-F, 1999). The Core Team has requested that an "unrestricted release" scenario, also known as "residential land use," be considered as an alternate assessment scenario for areas outside of the Central Plateau and parts of the 100 and 300 areas, even though it is not included in the CLUP. Additional land uses have been described elsewhere (for example, DOE CRCIA 1998) but are not currently being considered as part of the Risk Review Project. A limited set of additional alternative land use scenarios may be considered in response to input from the Tribes and the broader set of stakeholders as part of public comment on this document. Post-cleanup, public exposure to contaminants may occur if engineered or institutional controls fail resulting in unplanned contaminant dispersion or human exposures or if higher-level land use (e.g., residential occupancy of industrial-designed land) occurs. Human health risk is discussed below under each of the Hanford designated land uses, including both the large portions of uncontaminated land designated for conservation or preservation (CLUP 1999) as well as for remediated sites (CLUP, DOE/EIS-0222-F, 1999).

5.4. LIKELIHOOD OF EXPOSURE AND CONSEQUENCES

Public exposures to radiologic or chemical hazards can occur either as sudden acute events or as intermittent/or chronic exposures. Acute exposure (lasting a few seconds to days) can occur as a result of a fire, explosion, or other sudden release, or from intrusion into a hazardous area. Chronic or intermittent exposure (ranging from days to years) can occur through completed exposure pathways to air, water, soil, or food. Hazard assessments (HAs) and more elaborate documented safety analyses (DSAs) primarily evaluate acute events and exposures. The chronic/intermittent exposures are evaluated in documents such as remedial investigation/feasibility studies and risk assessments performed for various parts of the Hanford Site.

The *Safety Analysis and Risk Assessment Handbook* for Hanford (SARAH, HNF-8739, 2012) and other documents describe procedures for identifying and controlling primarily the first category risks under a wide variety of "what if" accident scenarios before and during active cleanup. DOE developed this guidance for sites to perform HAs and DSAs.

There is substantial variability in the definitions and categorization of both likelihood and consequences across the DOE complex (CTSC 2003). The DOE at Hanford mainly used four categories of likelihood and three categories of consequences as defined in the SARAH for Hanford (HNF-8739, 2012). The Risk Review Project uses the same likelihood bins from "anticipated" (i.e., probable within the lifespan of an EU; (Table 4-1) to "beyond extremely unlikely", and four consequence bins: not discernible, low, medium, high.

The likelihood estimates are coupled with the consequence estimates to arrive at a combined risk rating. This approach is used to identify and control acute events such as natural or anthropogenic disasters which may impact workers (Chapters 4 and 6). It can also be used to rate risks to the public, before and during remediation, where likelihood refers to the probability that a stealth trespasser or inadvertent visitor will enter a contaminated area where they may encounter significant radiologic, chemical, or physical hazards. Each of these risks to a specific EU are considered Unlikely. Consequence estimates range from not discernible from every day background to high (meaning serious injury to multiple persons or a fatality) and are integrated into overall risk ratings for public health in (Table 5-2).

Table 5-2. Composite risk rating matrix combining likelihood estimates and consequence estimates as applied to public health for acute events, disasters, or intrusion, in death, injury, or illness, acute reversible symptoms, or no discernible effect (modified from HNF-8739, 2012).

	Beyond extremely unlikely (BEU) Less than 1 in a million	Extremely unlikely (EU) 1/10,000 to 1 in a million	Unlikely (U) 1/100 to 1/10,000	Anticipated (A) >1/100
Not discernible	*These events are beyond the scope of this analysis*	None	None	none
Low impact		Very Low	Very Low	Low
Medium impact		Very Low	Low	Moderate
High impact		Low	Moderate	High

5.5. PUBLIC HEALTH EXPOSURE SCENARIOS

General Approaches

Because exposure is central to determining risk/impacts to the public from on-site contamination, remediation, and after completion of remediation, it is discussed in detail before the Risk Review Project methodology is presented. A generalized exposure matrix that can be used to determine whether there are completed or potential exposure pathways is shown in Table 5-3. It can be applied to the land uses designated for individual EUs as part of the Risk Review Project. Each cell in the matrix represents a potential pathway. This general exposure scenario forms the basis for the risk characterization for each type of "public." When engineered barriers, natural barriers and, or institutional controls are successful there should no completed pathways to any members of the designated public, leading to a conclusion of "no exposure, and therefore no risk." However, in a huge, complex and dynamic site, the potential for pathway completion exists.

Table 5-3. Generalized exposure matrix: Each cell represents a potential exposure pathway that may occur during the different evaluation time periods. Some potential exposure pathways and some receptors are not applicable during specific evaluation time periods.

		CONTAMINATED ENVIRONMENTAL MEDIA			
		AIR	**WATER**	**SOIL**	**FOOD**
ROUTE OF UPTAKE	**INGESTION**	Fallout on soil and food stuffs	Drinking water is major pathway for GW or SW[a]	Toddlers[b], gardeners and some construction	Major route for home gardens, farms, fish and game
	INHALATION	Major pathway for airborne contaminants	Volatiles and aerosols during cooking and showering	Fine dusts generated during construction or transport Vapor intrusion	NA[c]
	DERMAL	NA	Some organics when showering or bathing	Some organics in muds and slurries	NA
	DIRECT	Direct radiation exposure from soil, containers, structures			

a. GW=groundwater, SW=surface water or Columbia River water.

b. The inadvertent or deliberate ingestion of soil by toddlers is often the main driver of residential or recreational (playground) risk assessments.

c. Not applicable.

EPA Land Use Scenarios

The U.S. EPA documents and memoranda for CERCLA sites, as well as the State of Washington, identify two main categories of future land use: residential and commercial/industrial, but there may be many site specific variations and additional land use categories. Many parts of the United States that have CERCLA sites are already urban industrial, relying on treated public water supplies. Various additional scenarios include the "Stealth Farmer", the "Avid Angler", and others that reflect use or avoidance of particular exposure pathways. At Hanford, tribal scenarios are sometimes considered. Potential recreational scenarios vary on the frequency of visitation and the intensity of resource use. In general, soil access can be interdicted by removal of contaminated near surface soil or hazardous materials followed by at least 15 feet of clean soil cover. This would preclude both residential and agricultural contact with residual contamination in the soil (very deep rooted plants may pose an exception). Residential use without groundwater access may be allowed, where external water sources can be provided. The Risk Review Project refers to this as the "suburban residential" scenario. This is consistent with local experiences, since part of the City of Richland, for example, relies on surface water for drinking.

There are also no access zones, sometimes disparagingly referred to as sacrifice zones, which include areas destined for long-term disposition of hazardous and radiologic waste, either too hazardous to remediate or aggregated at an on-site permanent disposal area monitored in perpetuity by the Federal Government (for example, ERDF at Hanford or the Rocky Flats core area). These disposal sites rely on a combination of engineered barriers (e.g., caps and liners), natural barriers (e.g., contaminant retention in the vadose zone) and institutional controls to prevent intrusion, contaminant dispersion and human exposure. The CLUP designation “Industrial: Exclusive” (DOE/EIS-0222-F 1999) is essentially a “no access” waste disposal and storage designation.

Commercial-industrial sites can be occupied by adults up to 40 hours per week over a 40 year working lifetime. Residual soil contamination precludes residential use, and it is assumed that there are no airborne contaminants that would require the future workers to use respiratory protection. Dust suppression, typically by paving (capping) or vegetative land cover, prevents access to soil contamination.

It is usually assumed that if groundwater is contaminated (as it is in most of the regions that have sites on the National Priorities List), use of groundwater for drinking will be restricted until all contaminant levels meet drinking water standards, even while the surface is released for use. The Risk Review Project risk rating methodology considers groundwater as a separate issue from other potential exposure pathways. Although future users and occupants of the site are most likely to rely on surface water for all uses, several exposure scenarios for future land use contemplate domestic reliance on groundwater for drinking water. Moreover, the Tribal scenarios assume that a failure of institutional controls may allow current use of contaminated groundwater prior to remediation (Ridolfi 2007; DOE 2010), although it is highly unlikely that groundwater could be accessed anywhere other than at seeps along the riverbank during low water periods.

Either industrial use or residential use scenarios may drive the near-surface soil cleanup levels. For residential use scenarios, soil contamination levels must be low enough to preclude significant exposure to a toddler or gardener. In other words, of the various possible pathways, it is usually the soil ingestion pathway that is most restrictive in determining risks and cleanup levels.

5.6. HANFORD LAND USE DESIGNATIONS AND FUTURE EXPOSURE SCENARIOS

The primary land uses defined by the Comprehensive Land Use Plan (CLUP) as modified in the EIS (1999) are described below and provided in Figure 2-2 (Chapter 2):

- **Industrial Exclusive** - this area is a core zone within the Central Plateau designated for long term waste management,
- **Industrial** - much of these areas had substantial surface and subsurface contamination from DOE activities. After remediation, future commercial and industrial uses as Brownfields would be allowed, based on a 40 hour work week and 40 year working lifetime.
- **Research & Development** - this land use is an economic designation that appears to correspond to an industrial use scenario.
- **Conservation (Mining)** - mainly a preservation area, but DOE can use some areas for surface mining in conjunction with its waste management activities (i.e., soil borrow pit areas for backfilling and capping remediated land areas). This designation may allow future public access.
- **Preservation** - land designated for protection of ecological and cultural resources. These areas will be open for public visitation under the auspices of the U.S. Fish and Wildlife Service.
- **High-intensity recreation** - areas along the Columbia River where extensive infrastructure development will attract tourism and various forms of recreation (e.g., swimming, boating, hiking, etc.). There currently is no explicit limit on visitation frequency or intensity of use.
- **Low intensity recreation** – Limited infrastructure development and support (i.e., picnic tables). There currently is no explicit limit on visitation frequency or intensity of use.

The CLUP designations provide broad land use categories and descriptions of potential associated activities but do not provide detailed exposure scenarios to serve as the basis for risk assessments. The industrial-exclusive, industrial, and research and development) are assumed here to correspond to the industrial use exposure scenario category. For public access areas, there is no specification in the CLUP of frequency or duration of allowable visitation nor for the conservation and preservation areas is there a statement of whether extractive uses (harvesting and consuming roots, fruits, fish and game would be specifically allowed or precluded. There has not been a follow on delineation by DOE of specific exposure scenarios to be used in risk assessments that provide a one-to-one correspondence with CLUP land use designations. However, there are several different exposure scenarios discussed in the other DOE, State, and EPA documents, and some of these are discussed below to illustrate the different assumptions and pathways.

The generalized exposure matrix (Table 5-3) is useful in considering specific public exposure scenarios with regard to potentially completed exposure pathways. Alternatively, The Columbia River Comprehensive Impact Assessment (DOE 1998), compared a dozen alternative land uses with assumptions of frequency and intensity of resource use.

5.7. EXPOSURE SCENARIOS FROM THE HANFORD 300 AREA RI/FS

In addition to the land use designations in the CLUP and CRCIA, CRESP reviewed scenarios from 300 Area River Corridor RI/FS (EPA 2013) including (in descending order of residual contamination): 1) Industrial, 2) Casual Recreational Visitor, 3) Residential Monument Worker, 4) Residential, and 5)Tribal. This document provides more useful hazard and exposure information than the CLUP. Each of these will be described briefly below.

INDUSTRIAL SCENARIO

For many parts of the Hanford Site, an industrial (or industrial/commercial) scenario is considered as a reasonably anticipated future land use (assuming cleanup and institutional controls are sufficient to achieve protectiveness of future onsite workers). The industrial scenario is also based on EPA Guidance (EPA RAGS 1989, 2003). Anticipated exposure to contaminants in soil includes direct contact radiation, dust and vapor inhalation, and incidental soil ingestion. A detailed description of the industrial exposure scenario is provided in *Calculation of Radiological Preliminary Remediation Goals in Soil for an Industrial Worker Exposure Scenario.* (ECF-HANFORD-11-0142). Table 5-4 indicates that although there are several potential exposure pathways, most, if not all pathways can be interdicted by layers of soil and capping, leading to very low exposure potential to any residual contamination (however, special controls may still be needed for construction/excavation activities).

An important distinction is made here and for the purposes of the Risk Review Project. Current and future employees of entities not affiliated with the DOE mission but located at the Hanford Site, are considered here as members of the public. Although all of the “public” covered in the industrial/worker scenarios are present as employees, they are considered “public” rather than part of the DOE worker scenarios because they are not remediation workers. This includes current employees of non-DOE facilities on Hanford, such as the Energy Northwest nuclear power generating station.

Whereas a residential scenario assumes that a homebound person may be on site 365 days a year for a 70 year lifetime, the industrial scenario is based on assumed on-site activities of 40 hours per week for a 25 year working lifetime. Moreover, whatever occupational hazards may be encountered in these future workplaces are presumed to be controlled with negligible impact and no additivity to any exposure to residual legacy radiologic or non-radiologic contaminants.

Table 5-4. Potential exposure pathways from future industrial/commercial activities under the Industrial Land Use scenario. Each cell in the exposure matrix represents a potential pathway.

EXPOSURE PATHWAY ↓	CONTAMINATED ENVIRONMENTAL MEDIA			
	AIR	**GROUNDWATER**	**SOIL** (minimized by capping or paving)	**FOOD**
INGESTION		Not allowed	Incidental ingestion	Not allowed
INHALATION	Vapors and dusts emanating from soil		Dust inhalation Vapor intrusion	
DERMAL			Direct contact or direct external exposure	

CASUAL RECREATIONAL VISITOR

The conservation/preservation land use areas will be open for "recreation" in the broadest sense (CLUP (DOE/EIS-0222-F, 1999). The casual recreational visitor is considered a "reasonably anticipated future land use" for areas along the river, excluding some restricted or otherwise categorized areas (e.g., the 300 Area industrial zone, burial ground, entombed reactors in parts of the 100 Area). These lands and activities would be under the jurisdiction of the U.S. Fish and Wildlife Service. Recreation covers a spectrum of potentially exposed activities. This could range from a single day use hiking and picnic visit to overnight camping (duration unspecified, typically for up to 14 days). Collection of plants (roots, berries) is typical of some Tribal visitation scenarios. Hunting and fishing with consumption represents a further exposure pathways for both avid non-Tribal as well as Tribal visitors. Truly casual visitors may be exposed to inhalation of airborne contaminants if present in near surface soil, but will have minimal contact with soil or and will not have consumption of groundwater. The exposure assessment in the RI/FS (DOE 2013) was limited to walking and picnicking along the river, entirely outdoors.

For soil, the exposure pathway included direct contact with surface soil (no digging), and inhalation of dust as well as vapors. Incidental ingestion, particularly for toddlers, would be an important pathway. Groundwater contamination is not considered since no groundwater use is envisioned in this scenario.

RESIDENT MONUMENT WORKER

"Future land use within the River Corridor's 100 and 600 Areas is predominantly conservation/preservation" (DOE RI/FS 2013). The Hanford Reach National Monument, managed by DOE in conjunction with the US Fish and Wildlife Service was created in 2000. Establishment of the monument specifically precluded future residential or commercial development. DOE noted that "For the purposes of the RI/FS, the resident Monument worker represents a reasonably anticipated future land use." Areas specifically excluded are the 300 Area industrial zone, as well as the 618-10 and 618-11 burial grounds.

The Resident Monument Worker scenario was originally designed to reflect an occupationally-exposed worker who was present on site for more than 40 hours per week, including living on-site on a remediated waste site and working outdoors (tour leader) in the river corridor for 40 hours /week. It is identified as an adult scenario (DOE 2007). As with a residential scenario, the Resident Monument Worker scenario includes domestic well water access to groundwater. It differs from the Residential scenario in that no food chain pathways are included in this exposure scenario.

The Resident Monument Worker scenario considers exposure to soil as well as inhalation and direct contact with the volatile materials in the vadose zone, as well as airborne vapors and dust. "Adults could potentially be exposed to site contaminants in shallow vadose zone material at their residence through direct external exposure to radiation, inhalation of intruding vapors, incidental ingestion, and dermal absorption. During working activities, these adults may also be potentially exposed to contaminants in shallow vadose zone material by direct external exposure, incidental ingestion, dermal absorption, and inhalation" (DOE RIFS 2013). Children are excluded from this scenario, hence surface soil ingestion by toddlers is not a pathway.

The Resident Monument Worker scenario represents a too narrowly defined group of people to be useful for the specific objectives of the Risk Review Project and will not be considered further.

RESIDENT

The residential scenario represents an unrestricted land use scenario including children and assumes 365 days/24 hours for some individuals with use of water and gardens. Table 5-5 is an exposure matrix for residential occupancy, which could include either surface or groundwater. With the exception of the on-site food consumption and soil ingestion by toddler, it applies to the resident monument worker as well. A separate tribal scenarios is given in Table 5-6. In many risk assessments the ingestion of contaminated surface soil by toddlers is the "driver" or predominant pathway of concern.

Table 5-5. Residential exposure matrix. All pathways are potentially complete for surface water or public water supply.

	CONTAMINATED ENVIRONMENTAL MEDIA			
	AIR	**GROUNDWATER**	**SOIL**	**FOOD**
INGESTION		Domestic wells	Incidental ingestion Contaminants leaching into GW	Homegrown produce and meat Fish (wild or in home ponds)
INHALATION	Vapors and dusts emanating from soil	Showering	Dust inhalation	
DERMAL		Bathing	Direct contact	
			Direct external exposure	

TRIBAL EXPOSURE SCENARIOS

Hanford differs from most sites on the National Priorities List and most DOE sites because of potential exposure scenarios of the Native Tribes that expect to use the Hanford site in the future for a variety of traditional activities. The DOE (2010) has summarized, in a simplified way, tribal exposure scenarios from the Yakama Nation (Ridolfi 2007) and the Confederated Tribes of the Umatilla (Harris & Harper 2004). Both the Yakama Nation (Ridolfi 2007) and Confederated Tribes of the Umatilla (Harris & Harper 2004) have performed independent risk assessments for various parts of the Hanford Site. These risk assessments use exposure assessment approaches that follow EPA guidance, but make extensive modifications to take into account a variety of activities regularly practiced by Native Americans. A major departure is in the frequent use of sweat lodges, for which Harris and Harper (2004) and Ridolfi (2007) developed detailed exposure estimates based on 1 to 2 hours per day for adults. The tribal risk assessments are driven by the groundwater consumption pathway. As noted earlier, groundwater usage is not being considered for the purposes of the Risk Review Project as part of the land use scenarios but rather is evaluated separately (Chapter 7).

UNRESTRICTED LAND USE

The Core Team has requested that the Risk Review Project consider "unrestricted land use" as an alternate evaluation basis for the 300 Area, exclusive of the 618-10 and 618-11 burial grounds, and the approximately 1 square mile industrial area in the southeast corner of the 300 Area, as well as other areas outside of the Central Plateau. For the purposes off the Risk Review Project, unrestricted land use will be considered equivalent to the resident scenario, unless response to feedback on this document results in more stringent requirements than the resident scenario.

Table 5-6. Tribal exposure scenarios emphasize the daily use of sweat lodges and the use of groundwater for drinking and sweat lodges. (Harris and Harper 2004, Ridolfi 2007).

	CONTAMINATED ENVIRONMENTAL MEDIA			
	AIR	**WATER**	**SOIL**	**FOOD**
INGESTION		Inadvertent or deliberate drinking	Toddler ingestion	Groundwater used to water crops or livestock Collection and preparation of fruits, roots, vegetation
INHALATION	Contamination of ambient air by dust and volatiles	Steam and volatiles in sweat lodge		
DERMAL		Sweat lodge may allow organics to penetrate skin		

5.8. RISK REVIEW PROJECT METHODOLOGY FOR RATING RISKS TO THE PUBLIC

The generalized exposure scenario (route of exposure by media-type e.g., food, water, etc., Table 5-3), the Hanford site exposure types (Table 5-4), and the exposure/risk levels developed above (Table 5-7) were used to develop a methodology for rating risks and impacts to the public. The Risk Review Project methodology for evaluation of public health includes the following steps:

1. Determine the EU being evaluated and review the EU summary developed following the evaluation template.
2. Select the evaluation period to be considered (Active Cleanup Period, Near-Term Post Cleanup Period).
3. Review the likelihood and consequence categorizations for the EU-specific postulated acute events from an EU relevant HA or DSA[15] when available or from analogous documents or approaches. An HA or DSA may exist for a specific EU such as a building or for a grouping such as Tank Farms.
4. Evaluate the potential for on-site public or a stealth intruder to violate engineered or institutional controls during the selected evaluation period (Table 5-7).
5. Evaluate the likelihood and consequences of a scenario involving stealth intruder who enters the EU during remediation activities (Table 5-8).

[15]Hazard assessments and documented safety analyses typically are not developed for specific remediation activities until the early stages of work plan development.

6. Evaluate the likelihood and consequences of a "stealth" intrusion scenario before and after remediation based on the designated land use.
7. Identify the proposed alternative remediation options for the EU.
8. For post-remediation cleanup, refer to Table 5-9, as a starting point and modify risks according to site-specific conditions. This may be an iterative process as conditions or information change. Summarize the risk ratings.

The stealth scenarios can be assumed to actually occur as a worst case representing reasonably maximally exposed individuals, and are designated as a likelihood = 1. However, it is possible to develop a likelihood estimate for stealth intrusion into a particular EU considering the EU proximity to the public access highways and the Columbia River as well as barriers to intrusion (i.e., signage, fencing, secured areas). For example, by virtue of its proximity to the river (300 m) and public roads, an intruder could easily reach Building 324 in the 300 Area near the Columbia River (likelihood="anticipated", see Table 4-1) but access may be controlled by security measures (likelihood = "unlikely"). By contrast, undetected access to the 618-11 burial ground is "extremely unlikely" because of distance from a road (ca. 1 mile) and proximity to the nuclear power plant with 24 hour security (hence intrusion is "extremely unlikely"). Although access to the 200 Area is well-controlled, an authorized visitor once inside the gate, might wander away from or elude escorts to enter a high hazard area; this likelihood is "unlikely."

Table 5-7. Near-Term Post-Cleanup likelihood consequence and risk rating table for violation of engineered and institutional controls associated with the CLUP future land use designations. Refer to Table 5-2 for the likelihood x consequence risk rating.

CLUP Designation	Comments	Likelihood of occurrence	Consequence	Risk Rating
Industrial exclusive	Engineered and institutional controls will limit access to authorized personnel	Unlikely	Moderate	Low
Industrial	Institutional controls will limit hours on site to 40 hr/week	Anticipated	Low	Low
Research and Development	Institutional controls will probably limit hours on site to 40 hr/week	Anticipated	Low	Low
High-intensity[a,b] recreation	Frequent visitation with some resource extraction (i.e., fishing) to uncontaminated land	Anticipated[d]	Not Discernible	Not Discernible
Low-intensity recreation[a,c]	Infrequent visitation with no resource extraction from uncontaminated land	Anticipated[d]	Not Discernible	Not Discernible
Conservation/ mining	Public access may be allowed to most of this area.	Anticipated[d]	Not Discernible	Not Discernible
Preservation	Public access allowed for recreation.	Anticipated[d]	Not Discernible	Not Discernible

a. The CLUP designation refers to the extent of infrastructure, not the type of activities.
b. The Risk Review Project uses this terms to refer to frequent visitation with some resource extraction.
c. The Risk Review Project uses this term to refer to infrequent visitation with no resource extraction.
d. Prolonged camping and extractive/consumptive use.

Table 5-8. During the Active Cleanup Period, consequence to a stealth intruder who bypasses access controls and enters an active remediation area, perhaps deliberately approaching a work area where a particular remediation is in process. Several of these remediation types can be viewed as active construction sites with the main intruder risk related to hazards other than site-specific radiation or toxics. This table can be used for each potential remediation option for each EU, with consequences modified according to site-specific conditions. Likelihood of an intruder at any EU is influenced by the EU's distance from public roads and/or Columbia River and by signs, fences, other barriers, and patrolling.

Remediation Process or Activity	Consequence to Stealth Intruder During Remediation
Natural attenuation	Not discernible
In situ containment (capping)	Low to Moderate
Pump and treat	Not discernible to Low
In situ treatment (grouting, barriers)	Not discernible to Low
D & D	Moderate to High
Excavation, trucking, disposal	Moderate to High

Table 5-9. Risk-rating matrix for CLUP land use designations, for reasonably maximally exposed individuals such as a stealth farmer intrusion on land, after completion of remediation. For the purpose of this rating, assume farmer does not rely on groundwater. For worst case, assume the intrusions are actually occurring (i.e., Likelihood = 1).

Land Use Designation	**Post-remediation Intruder Risk Rating** (stealth farmer or resident on site, irrigates crops, hunts, fishes, but no groundwater use)
Industrial exclusive	Not applicable
Industrial	High
Research and Development	Insufficient information
High-intensity recreation	Not discernible
Low-intensity recreation	Not discernible
Conservation	Not discernible
Preservation	Not discernible
Unrestricted	Not discernible

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CHAPTER 6. WORKER SAFETY

ABSTRACT

People who work on contaminated sites have the potential for being exposed to a variety of hazards: radiologic, chemical, biologic, and physical, particularly if they work directly with the hazardous materials, as in the case of remediation or “cleanup” workers on Department of Energy nuclear legacy sites such as Hanford. For the purpose of this review, three categories of worker risk are distinguished. Worker exposure to site-specific radiologic or chemical hazards may be acute (Category 1) due to some initiating event (e.g., a natural disaster or an anthropogenic accident), or subacute (Category 2) due to proximity, inhalation, ingestion or contact exposure to some radioactive agent or toxic chemical. The latter may occur during investigation or remediation of an inadequately characterized site. Workers also incur a more general risk (Category 3) of accidents and injury unrelated to site-specific contamination (identified here as “industrial accidents”). Hazard Assessments and Documented Safety Analyses (DSAs) estimate the likelihood and consequence of Category 1 and some Category 2 events, but specifically exclude Category 3 from analysis. These documents also identify controls to prevent or mitigate consequences. A safety culture emphasizing radiation protection, industrial hygiene, and safety should reduce Category 2 and 3 events to a low level. DOE and its contractors have accident rates about 1/3 that of comparable non-DOE work. This section provides an overview of occupational health and safety and the specific methodology to be used in developing worker risk ratings for each evaluation unit. The resulting risk ratings are relative to worker ratings for other evaluation units and are neither absolute nor normalized with respect to other types of receptors.

6.1. OCCUPATIONAL HEALTH AND SAFETY

An underlying principle of occupational health and safety is that **all** work-related illness and injury is preventable. Industrial hygiene, radiation protection, and industrial safety are the professions that focus on the “anticipation, recognition, evaluation, and control” of workplace hazards (NSC 2012). This principle, derived in the context of the industrial factory with its fixed walls and defined processes, has proven more challenging in the context of hazardous materials management, stabilization, demolition, and remediation or “cleanup.” Nonetheless the prevention of illness or injury related to work, hinges on the identification of current or potential hazards, the anticipation of accidents, and the controls to prevent accidents or mitigate their consequences. The document *Safety Analysis and Risk Assessment Handbook* for Hanford (HNF-8739, 2012) provides a detailed methodology for considering the probability and consequence of accidental events and exposures (Category 1) and for designing and implementing controls.

The Department of Energy has been pro-active in defining worker safety as a priority of its environmental management activities. The Department of Energy and its prime contractors endorse a “safety culture” through numerous orders, standards, contracts, and training programs. For example 10CFR851 and DOE order 440.1 requires that the same safety standards be incorporated into all contractual activities for all tiers of contractors. As a result, the overall safety performance at DOE legacy environmental management sites, is superior to the performance of comparable tasks in the “private sector” in terms of lost time injuries and illnesses at about 1/3 of the comparable rates at non-DOE sites (Duncan 2005).

However, work that requires several tiers of subcontractors, performing highly specialized jobs, challenge the safety culture, requires close oversight, and creates opportunity for accidents and injury, particularly as the contractors encounter sites and facilities that are incompletely characterized with respect to sources and hazards (Gochfeld and Mohr 2007). The risk of exposure or industrial accident increases with the duration of the job, the number of workers involved, the nature of the hazards, and the complexity of the work, including the span of supervision overseeing performance and safety.

A program for evaluating risks to workers and preventing exposures and disease, needs to distinguish DOE employees, prime contractors, and remediation subcontractors who have the required training, expertise, and safety equipment and protocols, from co-located workers, in support capacities, with only general site safety training. The latter category may have no prior experience with the site and its hazards, and their work may be incidental to the hazards of a particular site. However, because of unfamiliarity, these co-located workers may be at greater risk through accidental intrusion or even by triggering an event (fire, explosion, release). Subcontractor employees are generally at greater risk than prime contractor workers or federal employees, and the more complex the subcontracting arrangements, the greater the opportunity for accidents (Gochfeld & Mohr 2007).

6.2. EVALUATION UNITS AND TIME PERIODS

The EUs addressed in the Risk Review Project risk-rating fall into the following general categories:

- Legacy Source Sites
- Tank Waste and Farms
- Groundwater Plumes
- D&D of Inactive Facilities
- Operating Facilities

For each evaluation unit the following temporal phases are considered with respect to worker risk (Chapter 2): Active Cleanup Period (including the current status and remediation activities) and Near-Term Post Cleanup Period. At different stages, the cadre of workers involved may be different. Worker safety issues are mainly considered before and during remediation, while public health considerations (Chapter 5) are primarily addressed after remediation is completed in the context of future land use activities.

Prior to remediation, work mainly involves characterization, surveillance and maintenance. If sites are unstable or have initiating events during the pre-remediation phase, there may be a range of conditions resulting in worker injury. The recognition of such vulnerable sites is factored into remediation sequencing. Once remediation is complete, there will be relatively few surveillance and maintenance workers, remaining at the site. If future land use includes industrial or commercial development, those employees are considered members of a future “public” rather than “workers” as discussed in this methodology report.

Therefore this section focuses attention on mainly on active remediation when most worker risk will occur (see Table 4-1).

6.3. METHODOLOGY FOR RATING WORKER RISK

This section describes an approach to linking the information contained in the evaluation templates and DOE hazard assessments to the binning of risk for workers, i.e., worker risk ratings. For each evaluation unit, an evaluation template is completed (Chapter 2 and Appendices B to E) that includes description of the hazards, sources, and conditions of the site, its current status, and proposed or a range of potential remediation option(s). Specifically for workers, the evaluation steps include: 1) identifying site-specific worker hazards, 2) identifying worker risk issues found in remediation options, and 3) reviewing final or draft hazard assessments or documented safety analysis if available.[16] For EUs where cleanup planning is at early stages and hazard assessments do not yet exist for anticipated cleanup activities, hazard assessments or documented safety analysis from one or more analogous facility or cleanup activity will be used in carrying out the evaluation.

The Risk Review Project considers three categories of worker risk:

> **Category 1:** Acute events or upset conditions (i.e., from explosions, fires, earthquakes, structural failures) resulting in blast injuries, fires, collapses, and sudden radiation and chemical releases. These are low probability, high consequence events which may result in death, injury, or exposure of large numbers of facility workers, co-located workers (see Terminology) or potentially the public. These events or scenarios range greatly in probability (Table 4-1) and are captured in hazard assessments or documented safety analyses which should be available (at least in draft) for most of the EUs. The initiating events may be natural disasters or anthropogenic (including deliberate ones; see Chapter 4). Each acute event is assigned to a likelihood bin as defined in Table 4-1.

Category 2: Potential threats from subacute exposure (hours to days) to undetected or unsuspected site-specific radioactive or chemical hazards (intermediate probability and consequence). These will not occur under "normal" operating conditions, and they may be predicted in the course of hazard assessment and thereby prevented. Examples of potential Category 2 exposure pathways are given in the exposure matrix below. The 2014 events at a Tank Farm where workers repeatedly complain of irritating gas exposures, represents a Category 2 event which is captured in the air x inhalation pathway in

[16] A primary reference, where available for an evaluation unit is the *Documented Safety Analysis* (DSAs) implementing the requirement of 10 CFR 830 and described in the *Safety Analysis and Risk Assessment Handbook* (HNF-8739, 2012).

Table 6-1.

Category 3: Industrial accidents and injuries includes for example, transportation accidents, falls, struck by objects, crush injuries, machinery injuries, and heat stress. These are relatively frequent events, particularly in construction activities, that may result in death or injury, but usually to one or a few individuals, and can be considered higher probability and lower consequence events compared to Category 1 (above). Although risk for Category 3 events typically is measured as a function of worker-hours on the job (Brown 2008), it is not a simple function since contractor or worker experience with particular jobs or sites along with task complexity and environment, influences safety and safety behavior. DOE STD-3009 indicates that industrial accidents and injuries "for which standard industrial safety procedures, training, and equipment are in place", should be excluded from the hazard assessment, unless they serve as an initiator to the release of or exposure to "process hazards'" (radiological and hazardous material).

The three categories of worker risk must be considered individually to develop a risk rating, since the risks are not additive.

Table 6-1. An exposure matrix for Category 2 risks, identifying potential pathways by which a worker may be exposed to a radiologic or chemical hazard, over a period of hours or days, before the hazard is detected and identified.

EXPOSURE MATRIX for remediation worker with potential exposure to unsuspected hazard				
	Contaminated Matrix			
	Air	Water	Soil	Containers
Inhalation	Volatiles at tank farms Airborne radiation releases		Inadvertent ingestion of soil	Release during sampling
Ingestion				
Dermal				Surface contamination
Direct radiation			Direct radiation or vapor intrusion	Direct radiation during handling

6.4. RATING RISKS TO WORKERS

The methodology for a summary risk rating will employ the following approach:

1. Basic Assumption: worker risk only exists when work is actually occurring.
2. For active remediation projects and/or operating facilities that have hazards assessments or documented safety analyses, rely on the likelihood vs. consequence matrix for Category 1 risks. The hazards assessment or documented safety analysis will also capture some Category 2 events. These documents also identify controls to prevent or mitigate the risks.
3. Utilize the qualitative ratings for likelihood of occurrence (anticipated, unlikely, highly unlikely, beyond highly unlikely, as defined in Table 4-1) and consequences (high, medium, low, no consequence). Next, combine the likelihood and consequence data into risk ratings using a risk-rating matrix. Then, identify the scenarios which produce a certain level of potential-impact (DOE documents use the symbols: I – High, II – Medium, III – Low, IV – no impact).
4. For projects that do not yet have a hazards assessment or documented safety analysis completed, a surrogate evaluation (such as a preliminary hazard assessment) will be based on analogous prior projects to determine:
    a. How many of the hazards normally analyzed will be present?
    b. Is there a novel remediation strategy projected?
    c. How extensive is the project (long in duration/broad in impact)?
5. Hanford remediation workers will face Category 3 of industrial-type injuries comparable in type to those experienced in non-DOE sites. A listing and analysis of the regular comparable health and safety industrial accident scenarios indicates that the reported accident rates are lower at

Hanford for remediation tasks than in similar work off-site. However, radiation and chemical hazards are higher at Hanford than off-site. In general, construction/excavation/ demolition hazards are similar at DOE sites as elsewhere (Gochfeld 2004). The potential risks from these hazards must be considered for DOE remediation projects. The larger the scope of the project, the greater the contractual and oversight complexity, and/or longer duration, the greater the likelihood that an accident of this category will occur.[17]

Table 6-2. Combined risk rating matrix based on likelihood and consequences as applied to worker risk for acute events or subacute exposure resulting in death, injury, or illness (modified from SARAH-HNF-8739, 2012).

	Likelihood			
Consequences↓	Beyond extremely unlikely (BEU) Less than 1 in a million	Extremely unlikely (EU) 1/10,000 to 1 in a million	Unlikely (U) 1/100 to 1/10,000	Anticipated (A) >1/100
Low impact	*These events are beyond the scope of this analysis*	Low	Low	Low
Medium impact		Low	Low	Moderate
High impact		Low	Moderate	High

6.5. SCORING OF HAZARDS FOR CATEGORY 2 AND CATEGORY 3

The following approach supplements the information that may be obtained from hazard assessment documents for each E.U. Sites with large amounts or concentrations of radioactive or chemical materials, particularly in vulnerable containers, or in geologically vulnerable or physically vulnerable situations, will have higher likelihoods of acute releases with high consequence ratings (Category 1). Inadequately characterized sites may result in higher subacute to chronic exposure to radiation or chemicals. The likelihood of an industrial accident/injury depends on the numbers of workers, the duration of the job(s), and the nature of the workforce (high injury rates in some construction trades and truck operations). Moreover, some types of work, (e.g., demolition) offer greater opportunities for industrial-type accidents (Chapter 4).

The methodology for obtaining a relative rating of hazards and exposure potential depending on the source inventory, situations, the type and size of workforce, and their activities is provided as follows. For each of the four columns in Table 6-3 there will be a number from 0 to 3 with 0 indicating low hazard or few workers and 3 indicating high hazard or many workers at risk. Intermediate values (1 and 2) would be used, recognizing that the numbers are ordinal, but are not ratios. In other words, 2 is greater than 1 but 2 is not necessarily twice 1, and when uncertain the higher number should be used.

[17] Risk scenarios in this category may or may not differentiate among remediation projects. Furthermore, DOE safety analyses assume that standard safety training, procedures, and equipment should prevent such events.

Although the three categories of risk are rated separately, there may be some cases that could be assigned to more than one category. For example, a worker falling to death through a defective roof would be a Category 1 event, while a worker falling off a roof due to a misstep (without wearing safety harness) would be a Category 3 event.

For each evaluation unit the EU Template will provide information on the inventory or potential sources of exposure, and on the condition of the trenches, containers, tanks, buildings with regard to integrity.

Information on the workforce may be limited prior to availability of a work plan, remedial investigation/feasibility study and other documents detailing the activities, types of work, duration of work, and hazard assessment.

- For sources, 0=negligible quantities relevant to workers (such as groundwater plume) and 3=large amounts of highly radioactive or toxic chemicals (such as subsurface at Building 324).
- Situations range from 0=accessible sites with well-contained contaminants, preferably with adequate documentation of the inventory, to 3= vulnerable hazards in deteriorating containers, in unstable buildings, or inaccessible locations.
- Workforce involvement ranges from 1 for few workers involved in surveillance and maintenance to 3=for large numbers of workers, equipment operators, or construction workers involved in large scale excavations on operating facilities.
- Activities range from low hazard with only indirect exposure potential, for example, 0=Prior to remediation and after remediation, worker involvement may be limited to surveillance and maintenance to 3 for direct hands on involvement with contaminated soil, containers, structures.

Table 6-3. Factors influencing the likelihood of three types of risks, associated with sources, situations, workforce and activities. For each cell: 0 indicates very low worker risk, 3=high potential for worker risk.

	Sources	**Situations**	**Workforce**	**Activities**	**Score**
Category 1 **Acute impacts or exposures**	The likelihood and consequence of these events should be obtainable directly from a DSA or HA if available.				
Category 2 **Subacute exposures**	0=Small amounts 3=Large amounts	3=Many hidden containers or areas	1=Monitoring 3=Laborers and other construction	0=Prior characterization by rad and IH 3= No characterization	
Category 3 **Industrial accidents/ injuries**	1=Low hazard 3=Highly hazardous	0=Simple, flat, open area 3=Complex site environment (old buildings)	0=Short duration/ few workers 3=Years and many workers	0=Excellent safety program 3=Complex subcontracting	

This scoring system will be used as a supplement to the hazard assessment to compare remediation options or schedules within evaluation units or among evaluation units with regard to worker risks. The injury categories include vehicular accidents, electrocution, struck by objects, falls, heat stress. These are all preventable in principle and are dealt with by standard industrial safety approaches. The nature and integrity of sources, the elevation and structural integrity of facilities, the types of heavy equipment and vehicles, all allow safety analysts to detect potential hazards and institute controls. Injuries may occur during normal operations or during upset conditions. Miscommunication among contractors is a common proximate factor. Daily safety briefings including multiple contract workforces, are a common intervention.

In summary, information derived from the EU templates and the corresponding hazard assessment, documented safety analysis, or other documents, will be used to rate worker risk with respect to Category 1 (Acute event) and Category 2 (Subacute exposures), while Category 3 (Industrial accidents) will be inferred from the nature and scope of particular remediation approaches.

Table 6-4. Risks to workers for Category 1, 2 and 3 injuries related to the remediation option. Note that the Category 1 and 2 risks relate to hazards that are site specific, while Category 3 events are related to the type and duration of work (worker hours).

Remediation Activity	Types of workers	Category 1 Acute (high radiation dose or explosion from upset conditions including criticality)	Category 2 Subacute radiation or chemical exposure	Category 3 Industrial accidents Slips/trips/falls Struck by
Natural Attenuation	Well digging and sampling	Not discernible	Low	Low
Pump and Treat	Well digging, sampling, treatment operators	Not discernible	Low	Low
In Situ Containment	Construction involved in digging and capping	Low	Low	Moderate
In-Situ Treatment	Construction workers chemical workers	Low	Moderate	Moderate
Excavation	Construction workers (excavation), truckers, sampling and characterization and disposal site	Moderate	Moderate	High
Decommissioning and Demolition	Construction workers, site preparation, demolition, transportation, disposal	Moderate	Moderate	High

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CHAPTER 7. THE COLUMBIA RIVER AND GROUNDWATER AT THE HANFORD SITE

ABSTRACT

Many of the EUs being considered involve discharges of contaminants into the environment that either have resulted in current groundwater contamination or may in the future impact groundwater or the Columbia River. This chapter focuses on the methodology for evaluating primary contaminants that either are currently present in the vadose zone or groundwater or have the potential to be released to the subsurface and subsequently impact groundwater, the Columbia River, or other receptors. The approach described is to be used in the context of the highly variable degrees of uncertainty and information gaps in contaminant distributions and subsurface contaminant transport at the many contamination sources within the Hanford Site. Thus, this methodology focuses on groundwater evaluation metrics that may lead to rough-order of magnitude (ROM) differences and thereby allow relative binning of risks from EUs. This focus is in contrast to the information needed for a performance assessment, baseline risk assessment, or the basis for remedial process selection and design.

The major steps of the process are identifying EUs that have potential groundwater issues; compiling relevant information concerning the source, vadose zone, and saturated zone for each EU; and comparing the evaluation metrics. Information gaps, uncertainties, and data gaps will be described for each EU. The methodology considers the three assessment time frames defined for the Risk Review Project: Active Cleanup (50 years), Near-term Post-Cleanup (100 years), and Long-term Post-Cleanup (1000 years). Three possible recharge rates (i.e., surface barrier (0.5 mm/y), undisturbed plant communities (5 mm/y), and disturbed soil (50 mm/y)) are considered to reflect uncertainties and a range of potential local site conditions over the indicated time frames as a result of ground cover, closure covers, climate variation, and localized surface hydrologic effects.

The selected evaluation metrics for risks to groundwater from near surface or vadose zone sources are:

1. Time until groundwater would be *impacted* by a primary contaminant without a current plume over the three evaluation periods (i.e., Active Cleanup (50 years), Near-term Post-Cleanup (100 years), and Long-term Post-Cleanup (1000 years)). Groundwater is considered *impacted* when a primary contaminant concentration exceeds a threshold value, e.g., a drinking water standard or maximum contaminant level.
2. The amount of groundwater (e.g., areal extent or volume) currently *impacted* by those primary contaminants with existing plumes.
3. The amount of additional *impacted* groundwater over the three evaluation periods.

The selected evaluation metrics for risks to the Columbia River from near surface, vadose zone, and groundwater contamination sources are:

4. Time until the Columbia River is *impacted* over the three evaluation periods. The Columbia River is considered *impacted* when a primary contaminant concentration exceeds a benthic or free-flowing threshold value.
5. Primary contaminant discharge concentration and spatial extent (i.e., length of river potentially impacted) relative to benthic thresholds over the three evaluation periods.
6. Primary contaminant discharge flux and *impact* to the Columbia River relative to the free-flowing concentration thresholds over the three evaluation periods.

A demonstration example is presented using the B Complex groundwater plume in the 200-East Area.

7.1. AN OVERVIEW OF THE COLUMBIA RIVER, VADOSE ZONE AND GROUNDWATER CONDITIONS AT THE HANFORD SITE

THE COLUMBIA RIVER

The Columbia River is part of a large dynamic watershed that dominates the Pacific Northwest, and also is an important part of Native American culture. Many Native American tribes, including the Nez Perce, Umatilla, Wanapum, and Yakama, have depended upon the Columbia River for over 10,000 years (Landeen and Pinkham 1999). The River supports commercial and recreational fishing, hydroelectric power, industry, agricultural, and residential communities. It also supports a diverse and important ecosystem. Although there are 40+ species of fish in the river, salmon are the keystone species in the river ecosystem. The fall run Chinook (*Oncorhynchus tshawytscha*) is probably of greatest importance to the Hanford Reach within the Columbia Basin. A significant portion of the fall-spawning Chinook salmon construct their nests (redds) in the Hanford Reach, with a significant concentration near Locke Island and thus alongside reactor areas 100D through F. The salmon are important bioindicators of river health because of their tribal, cultural, and economic importance to the Pacific Northwest (NRC 1996, Landeen and Pinkham 1999, Williams 2006, Dauble 2009, Burger et al. 2013, CRITFC 2013).

The length and width of the River and its tributaries, and the size of the Columbia River basin watershed, have resulted in its use by people for thousands of years (Landeen and Pinkham 1999), and consequently it has experienced intense development, including factories, towns, agriculture and construction of hydroelectric dams along its banks. One widely-held conclusion among technical analysts and tribal observers alike is that the Columbia River should be returned to conditions of natural water flows, habitats, and biotic and human communities (Williams et al. 1999). However, Hobbs et al. (2013) caution that given global and demographic changes, it is unrealistic to assume that any ecosystem, much less one experiencing ongoing energy, agricultural, and industrial impacts, can be restored to pristine conditions. Natural water flow and native habitats, however, can be restored without returning to historic “natural conditions”, including maintaining healthy salmon populations (NRC 1996).

Over geologic time, the Columbia River has shifted its course and deepened its gorges, but its current course and water quality is controlled by anthropogenic forces. Water is withdrawn or added, nutrients, chemicals, and radionuclides were either dumped or flowed into the river, and in some cases water temperatures were changed because the water was used for cooling purposes. The species that live in the Columbia River are a function of the geographic, physical, and chemical conditions, which in turn are a result of natural and anthropogenic forces. The amount of water flowing in the river, as well as flow rate and water level, are a function of natural conditions (headwaters, snow melt, runoff from rainfall) and anthropogenic factors, such as withdrawal for agricultural, industrial, and residential uses, and control by hydroelectric dams (Figure 7-1). For example, some runs of Pacific salmon on the Columbia River have been severely impacted by dams without adult fishways which block access to historic spawning areas (Raymond 1988, Dauble et al.2003). Other impacts on adult passage near mainstem hydroelectric dams include fallback and delay, mammalian predators, elevated temperatures, and excess concentrations of dissolved gasses (Duable and Mueller 1993, Boggs et al. 2004). Likewise juvenile salmonids migrating downriver can be injured or killed when passing though turbines or spillways. The primary mechanisms include barotrauma, turbulence, shear, strike and elevated dissolved gasses (Ferguson et al. 2005, Neitzel et al. 2004, Richmond et al. 2014). Thus, habitat quality has been affected by altering water levels, water quality, and current characteristics.

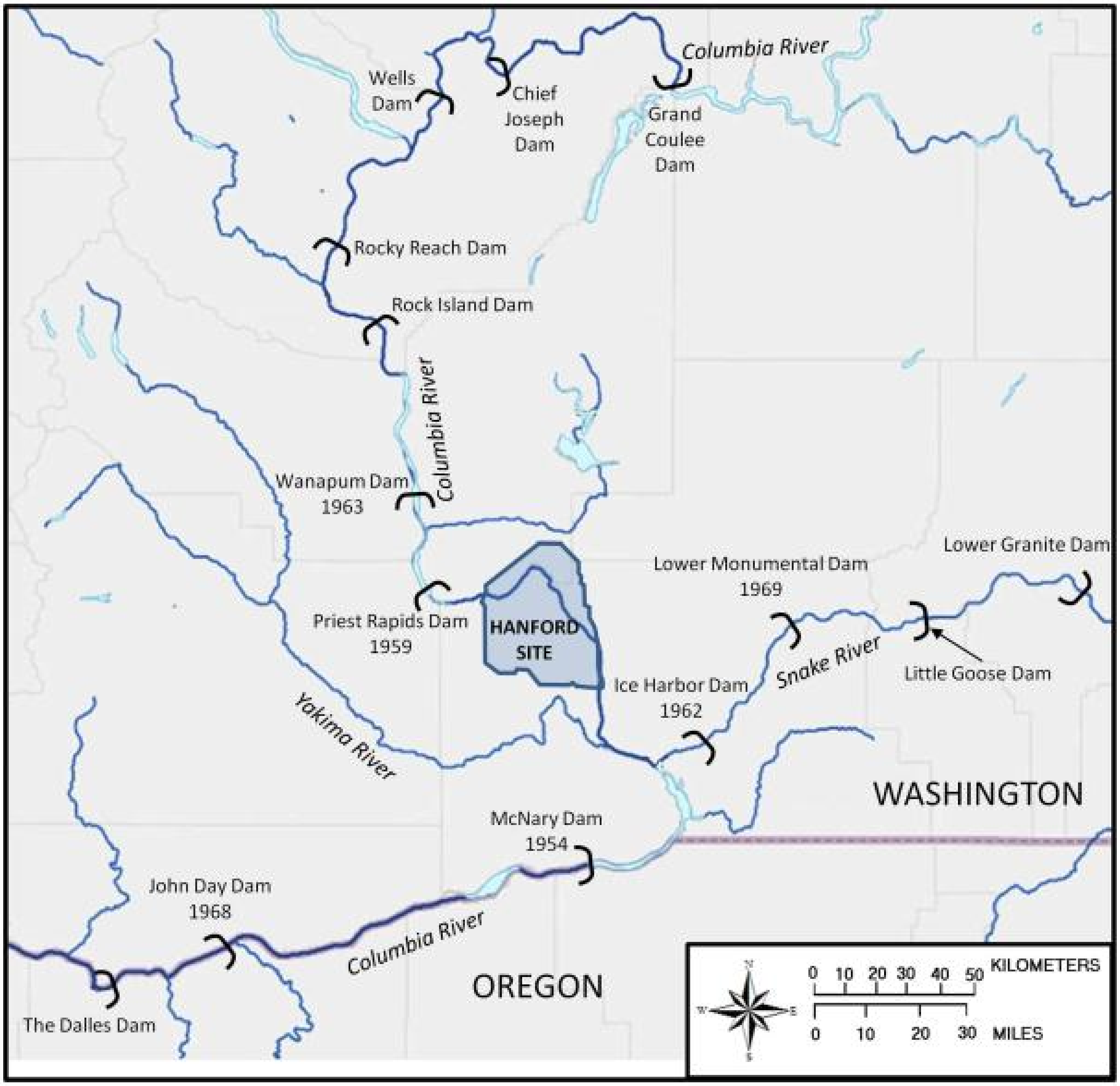


Figure 7-1. Map of the Columbia and Snake River showing dams. The dates of the major dams affecting the Hanford Reach and the confluence of the two rivers are also shown.

The Hanford Reach is one of only two sections of the Columbia River that is free-flowing. Although the Hanford Reach was affected by past activities on the Hanford Site, at present it is subject to surface runoff and incursions of water from seeps and upwellings on the riverbed. There is a direct pathway from the Hanford Site to the river through run-off and potentially future deliberate releases[18] – and some tribal observers note that run-off could be increased by remediation (such as massive digging to remove contaminated soil, R. Jim, pers. comm.). Since the geology of the river is ever changing, the exact locations of seeps and upwellings can shift over time. Upwellings and seeps can be contaminated

[18] Deliberate releases refer to surface water discharges permitted by the State of Washington as part of a federal surface water quality protection program. As of the writing of this document, no permitted or intentional discharges directly to the Columbia River remain from the Hanford Site operations. One permitted discharge to the Columbia River is from the PNNL Aquatic Research Laboratory.

by groundwater contaminant plumes originating from the Hanford Site. The very high quantity and speed of water flow in the river relative to groundwater discharge results in rapid dilution. Potential problems occur for organisms that live in the sediment and gravel of the river bed (e.g., salmon eggs), when upwelling water moves through the gravel to meet the fast-flowing river water. However, salmon biologists believe that "pollutants … generally are not considered a major factor in salmon declines, nor are they particularly problematic for recovery" (Stanford 2006, p. 211).

In summary, the Columbia River is a large watershed that is subject to a complex matrix of natural and anthropogenic factors. Its banks have been occupied by people for over 9,000 years, and since the arrival of westerners has seen massive agricultural, industrial, and residential development. It has experienced large scale disruption and pollution from a variety of sources. The river section flowing through the Hanford Site has experienced far less physical disruption than the rest of the Columbia River but is still potentially subject to contamination from groundwater contaminant plumes that discharge into the river.

Vadose Zone and Groundwater

Groundwater underlying the Hanford Site is of importance because it is both a valued natural resource subject to protection by the State of Washington and is a pathway for contaminant transport to the Columbia River. Most potential sources of contamination at Hanford currently are present either near or above ground surface (i.e., processing facilities, waste storage tanks, legacy disposal sites), or, in the vadose zone (a complex assemblage of unsaturated geologic layers and formations between the ground surface and underlying groundwater) as a result of past intentional or unintentional releases. After near surface releases, contaminants pass through the vadose zone, where contaminants are subject to complex physical-chemical transport, retention, and attenuation processes prior to entry into the groundwater. Additional contamination currently is present in the groundwater, delineated as groundwater contamination plumes. Once in the groundwater, contaminants are subject to a further set of complex physical-chemical transport, retention, and attenuation processes as they are transported along with the groundwater through multiple geologic formations. Contaminants entering an aquifer may (and in most cases do) in part flow or diffuse into less permeable parts of the aquifer, remaining there for long periods of time, and feed contaminants into flowing groundwater in more permeable surrounding materials. These low permeability materials within an aquifer thus form sources for the same aquifer and serve as long-term reservoirs of contamination during remediation. Contaminants in the groundwater ultimately in part discharge to the Columbia River.

Hydrogeologic conditions beneath the Hanford Site are controlled by the basalt bedrock (Columbia River Basalt Group), the consolidated to semi-consolidated sediments of the Ringold Formation and Cold Creek unit, and the unconsolidated sediments of the Hanford formation (Figure 7-2). The site is capped by a discontinuous veneer of Holocene alluvium, colluvium, and/or eolian sediment. Groundwater lies at a depth of up to 100 m beneath the Central Plateau (200 West and 200 East areas).

Past waste disposal practices (e.g., direct liquid waste disposal to the ground via engineered facilities) and unplanned releases (e.g., spills and tank leaks) contaminated hundreds of discrete waste areas across the Hanford Site, impacting the vadose zone and creating large contaminant plumes within the uppermost aquifer system.

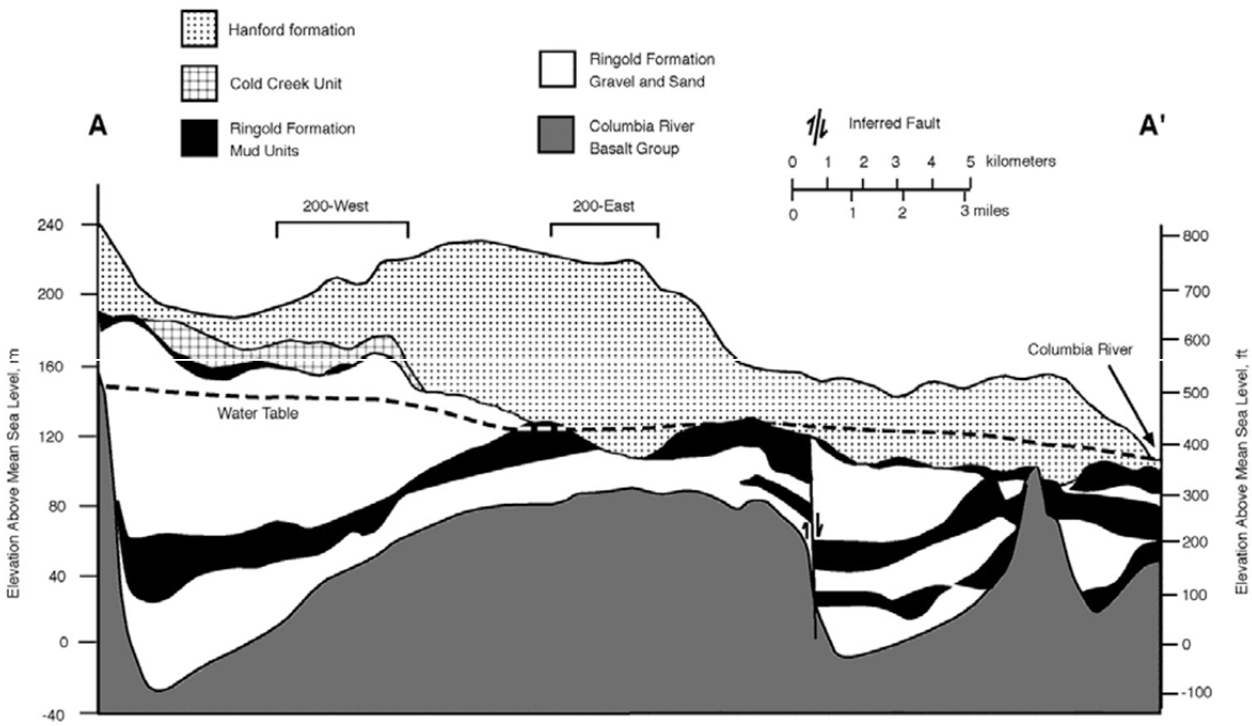


Figure 7-2. Generalized west-to-east geologic cross section through the Hanford Site (Last et al. 2006).

Vadose Zone Stratigraphy

The vadose zone beneath the Hanford Site ranges in thickness from less than 1 m along the Columbia River to more than 100 m on the Central Plateau. The geologic framework of the vadose zone is very complex. It is dominated by Holocene and Hanford formation sediments and to a lesser extent the Cold Creek unit and upper Ringold Formation. The sediments impart high heterogeneity and anisotropy in the physical, hydrologic, and geochemical properties of the vadose zone (Last et al. 2006).

The complex hydrogeochemical framework, together with wastewater and meteoric water fluxes, has led to complex three-dimensional movement of moisture and contaminants through the vadose zone. Flow within the vadose zone is dynamic and characterized by periods of unsaturated flow punctuated by episodes of preferential, saturated flow in response to hydrologic events or releases of liquids (Wilson et al. 1995).

Many parts of the vadose zone still contain residual wastewater and associated contamination sources that may continue to drain into the groundwater. Perched water table conditions are still present in parts of the 200 East and 200 West areas (Hartman 2000; Truex et al. 2013; Oostrom et al. 2013).

Unconfined Aquifer System

The unconfined aquifer system is contained in the unconsolidated Hanford formation and semi-consolidated to consolidated Ringold Formation, overlying the basalt bedrock (Figure 7-2). Coarse-grained facies of the Hanford formation make up the most permeable zones of the unconfined aquifer system. Hydraulic conductivities of these Hanford formation sediments are 10 to 100 times greater than that of coarse-grained facies of the Ringold Formation (Hartman 2000). In some areas, low permeability mud layers within the Ringold Formation form aquitards that create local confined hydraulic conditions in the underlying sediment. Collectively, the aquifers within the suprabasalt sediment are referred to as the Hanford/Ringold aquifer system (Hartman 2000). Saturated thickness of the Hanford/Ringold aquifer system exceeds 180 m in areas near the center of the Hanford Site and north of the Gable Mountain-Gable Butte anticline, but pinches out along the flanks of the basalt ridges (Hartman 2000). Groundwater in the unconfined aquifer system generally flows eastward from points of natural recharge along the Hanford Site's western boundary to points of discharge along the Columbia River (Figure 7-3).

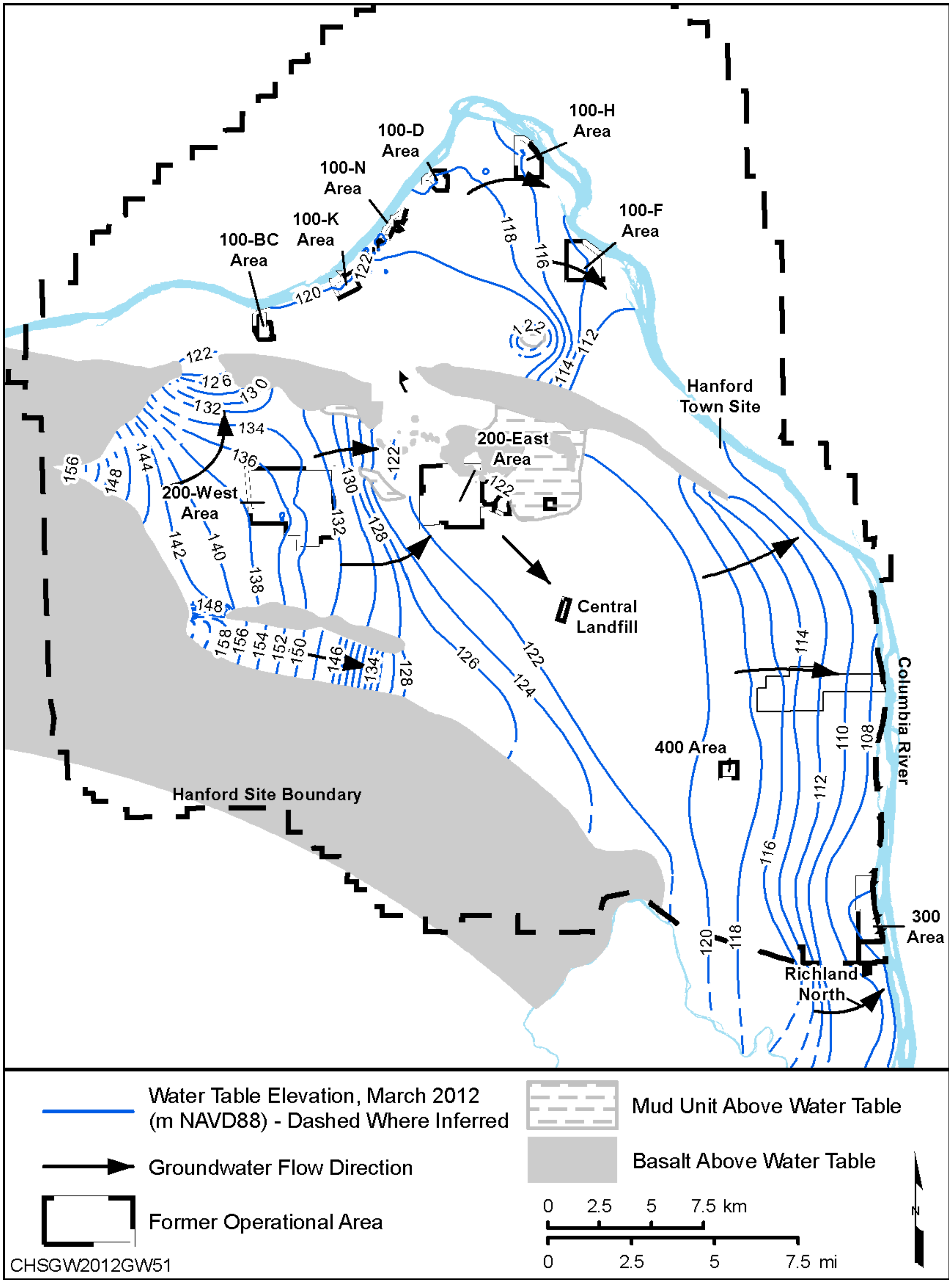


Figure 7-3. Water table map of the Hanford Site, March 2012 (from CHPRC 2013).

Recharge from precipitation is highly variable, both spatially and temporally, across the Hanford Site. It ranges from near zero to greater than 100 mm per year, depending on climate, vegetation, and soil texture (Gee et al. 1992; Fayer and Walters 1995)[19]. Recharge from precipitation is highest in coarse-textured soil with little or no vegetation, which is the case for most industrial areas on the Hanford Site.

Artificial recharge from wastewater disposal operations has dramatically affected the Hanford/Ringold aquifer system. Since the start of Hanford Site operations in the mid-1940s, estimated wastewater discharges have exceeded the estimated recharge from natural sources by several times (Hartman 2000). This has caused groundwater mounds to form beneath major wastewater disposal facilities and increased water table elevations over much of the Hanford Site. The largest of these groundwater mounds developed beneath the 216-U-10 Pond in the 200 West Area, where water levels increased by at least 22 m (Hartman 2000). In 1988, production activities on the Hanford Site began to close, resulting in dramatic decreases in wastewater disposal and subsequent decreases in water table elevation over much of the site.

Groundwater flow is generally to the east and southeast across the Hanford Site to the Columbia River, with groundwater travel times estimated at a few decades from 200 East Area to perhaps a century or more from the 200 West Area (Gephart 2003). Groundwater flow has been locally interrupted by residual groundwater mounds and pump-and-treat systems. Water levels have changed over time due to variations in the volume and location of wastewater discharges or pump-and-treat systems, and so too has the movement of groundwater and its associated constituents.

Groundwater in the unconfined aquifer system primarily discharges to the Columbia River through springs and areas of upwelling. These points of discharge are the primary exposure pathways for contaminants to reach human, environmental, and ecological receptors. Discharge along the Columbia River varies both spatially and temporally—strongly controlled by variations in river stage and bank storage.

Wastewater discharges (including unplanned releases) have resulted in both chemical and radioactive contamination of the uppermost aquifer system (the Hanford/Ringold aquifer system), with an estimated 152 km^2 exceeding drinking water standards (CHPRC 2013). The most noteworthy contaminants (and their estimated aerial extent exceeding drinking water standards) include tritium (88.8 km^2), iodine-129 (47.8 km^2), nitrate (38.2 km^2), carbon tetrachloride (13.4 km^2), technetium-99 (2.7 km^2), strontium-90 (2.0 km^2), uranium (1.7 km^2), hexavalent chromium (1.2 km^2), trichloroethene (0.9 km^2), and cyanide (0.2 km^2). Figure 7-4 and Figure 7-5 illustrate the distributions of groundwater contaminants in the River Corridor and 300 Area, as well as those emanating from the Central Plateau, respectively.

[19] Higher recharge rates (up to 100 mm/yr) will be considered for those areas with known gravel cover.

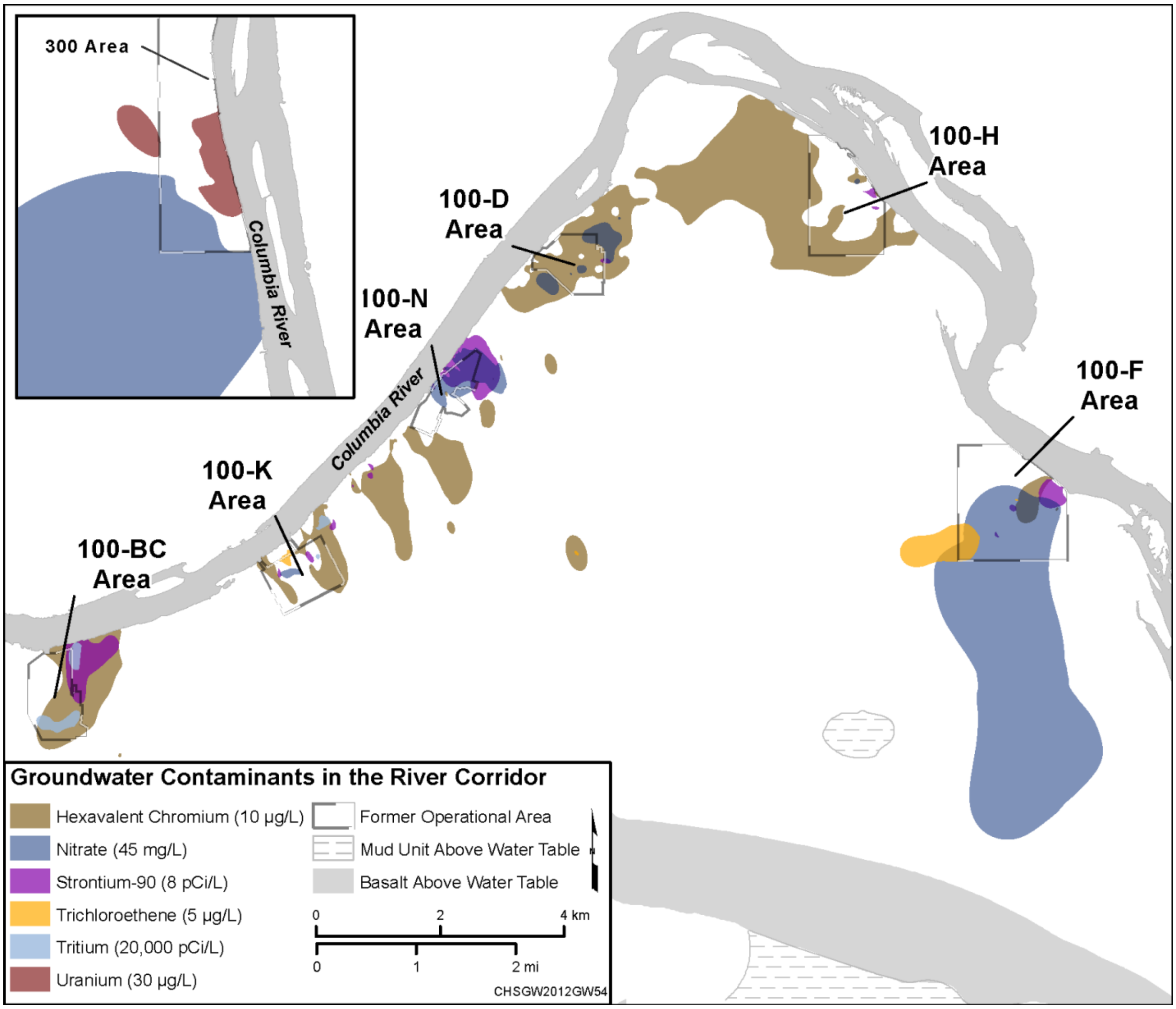


Figure 7-4. Groundwater contaminants in the River Corridor (from CHPRC 2013).

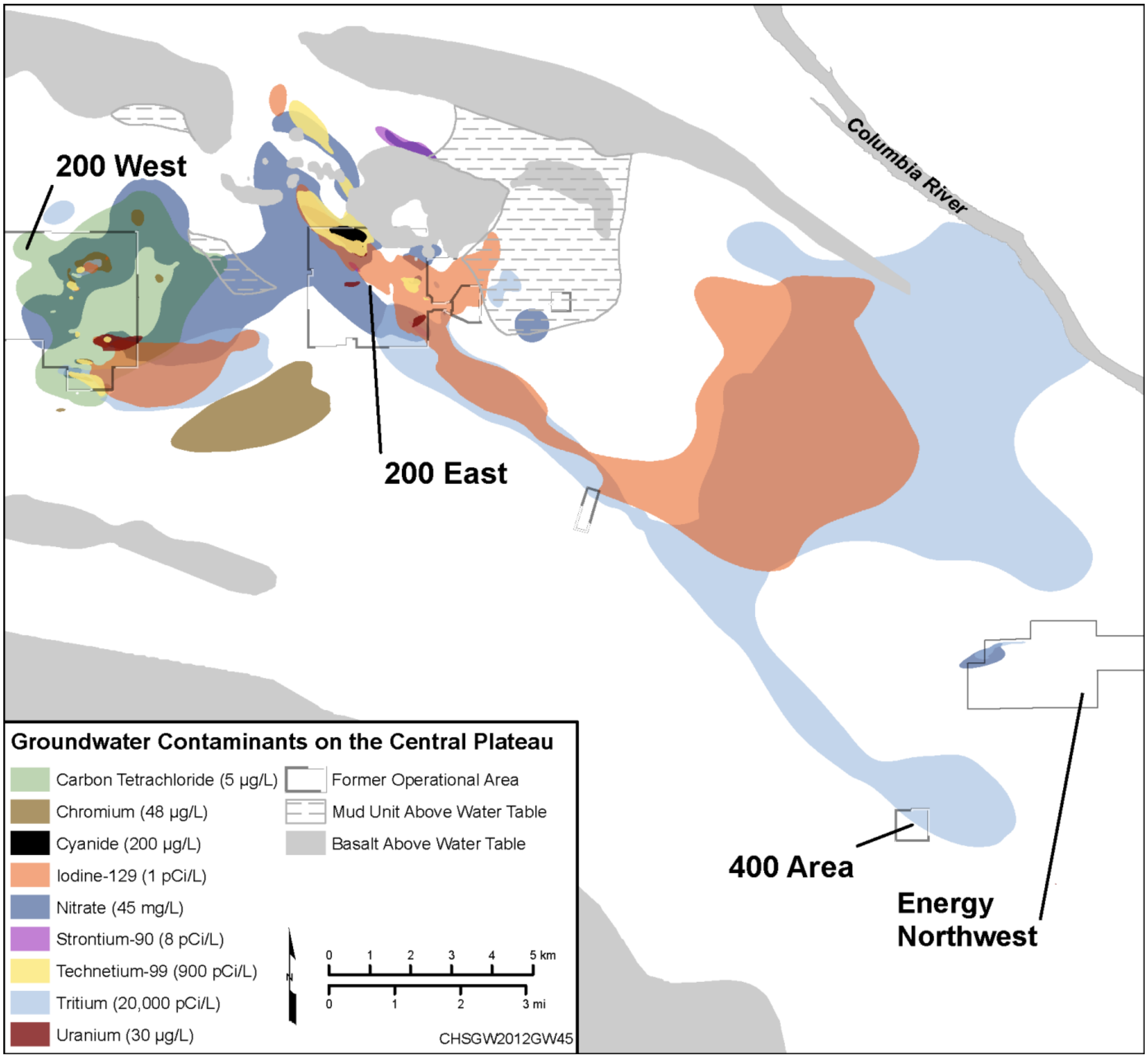


Figure 7-5. Central Plateau groundwater contaminants (from CHPRC 2013).

Since the curtailment of production activities, the U.S. Department of Energy has been working to remediate soil and groundwater contamination (CHPRC 2013). Current interim groundwater remedial actions in the River Corridor vary from active pump-and-treat systems for the 100-K Area (100-KR-4) and the 100-D and 100-H Areas (100-HR-3) to removal of hexavalent chromium through excavation (Figure 7-6). *In situ* treatment of strontium-90 is underway at 100-N Area (100-NR-2), using apatite sequestration as an interim action. In the 300 Area, a persistent uranium plume in the groundwater originates from sediments in the vadose zone, as well as in the aquifer. Passive management strategies considered are institutional controls and monitored natural attenuation, whereas active technologies are selective excavation to the water table and stabilization via application of polyphosphate. In the Central Plateau, a final action pump-and-treat system is being expanded for the 200-ZP-1 Operable Unit (in the northern 200 West Area) to remove and treat carbon tetrachloride and nitrate contamination. An interim action pump-and-treat system is also underway to remove technetium-99, carbon tetrachloride, chromium, trichloroethylene, and nitrate from a smaller area near the 241-T, 241-TX, and 241-TY tank farms (waste management areas [WMAs] T and TX-TY). In the southern 200 West Area, another interim action pump-and-treat system is operating for the 200-UP-1 Operable Unit near the 241-S and 241-SX tank farms (WMA S-SX) to recover and treat technetium-99, nitrate, and chromium.

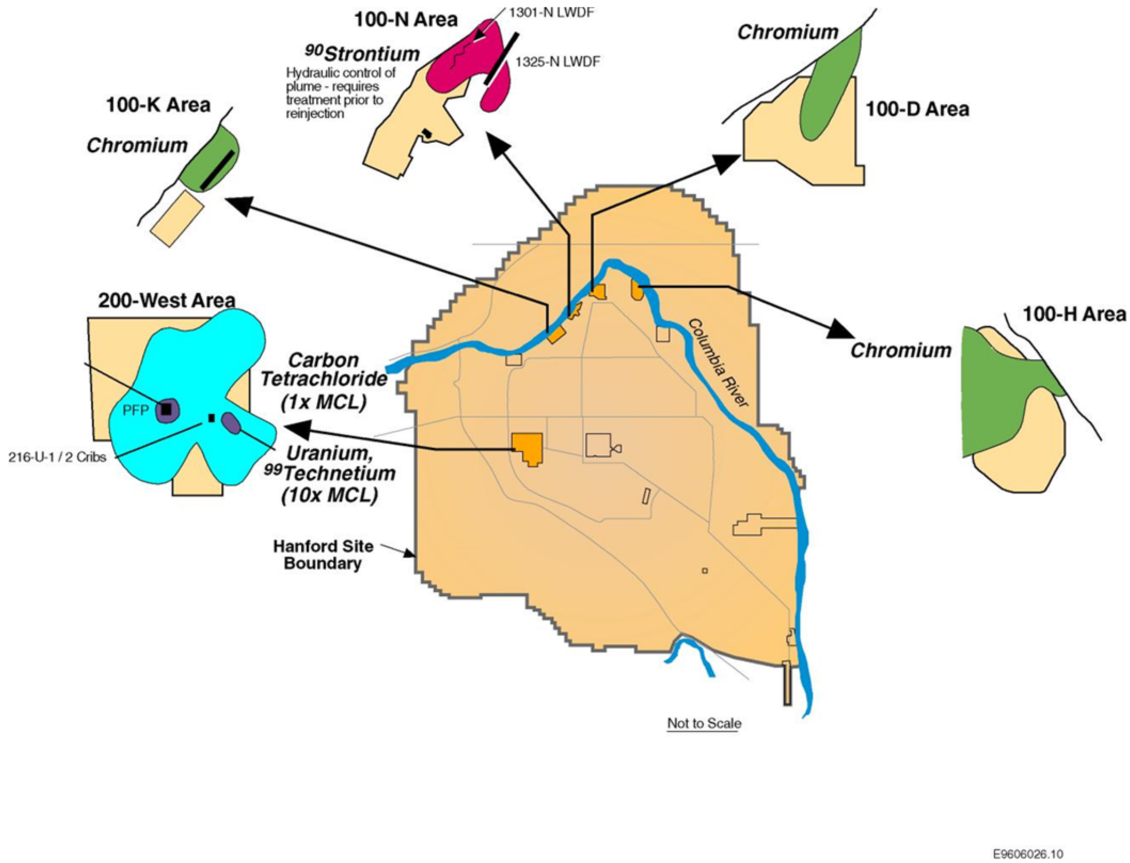


Figure 7-6. Contaminant plumes with active pump and treat remedial systems at the Hanford Site (PNNL 2013).

Confined Aquifer System

A sequence of 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. Groundwater in the basalt-confined aquifers generally flows from elevated regions at the edge of the Pasco Basin toward the Columbia River (Hartman 2000). No significant contamination has been detected in the basalt-confined aquifer system, except in the northwestern 200 East Area, where poor well construction and temporary drilling effects allowed local migration of groundwater from the overlying unconfined aquifer (CHPRC 2013).

7.2. METHODOLOGY FOR EVALUATING IMPACTS TO AND BY GROUNDWATER AND TO THE COLUMBIA RIVER

A General Framework for Evaluation

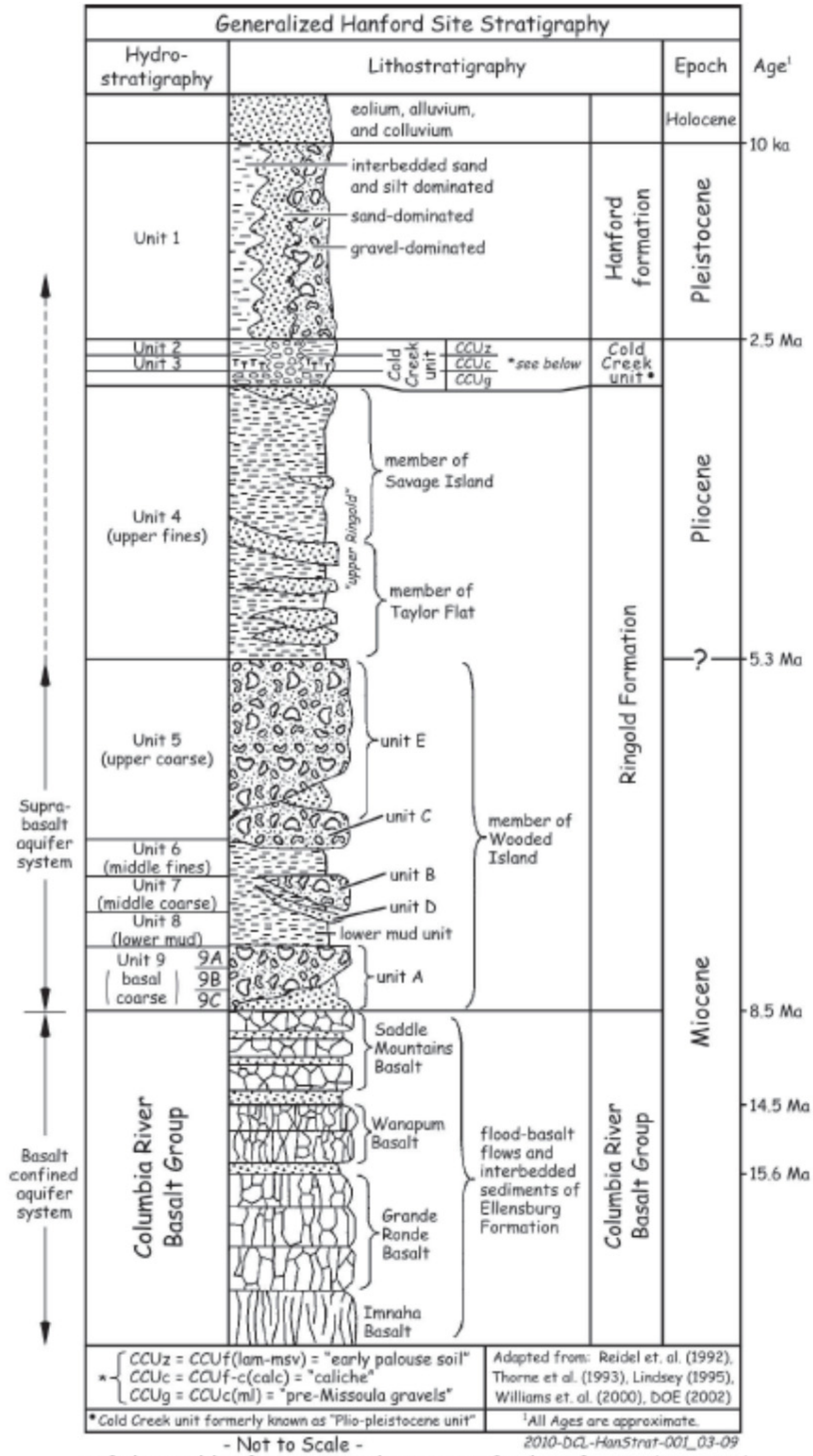
Many of the EUs to be considered involve past, current, and potential future intentional or unintentional discharges of primary contaminants into the subsurface. A framework is presented for determining and comparing evaluation metrics to estimate rough-order of magnitude differences in potential impacts from primary contaminants on groundwater at Hanford and discharge to the Columbia River.

The Hanford subsurface is a highly complex formation and contains both significant vadose (unsaturated) and saturated zones of varying thicknesses and characteristics at different geographic locations within Hanford (Figure 7-7). Significant effort has been applied over many decades to characterize the subsurface and the location and movement of primary contaminants, although substantial data gaps and uncertainties remain. This effort has produced a large amount of information pertinent to the Hanford Site, including borehole and well data and subsurface zone property estimates. Models also have been developed in varying detail describing the fate and transport of primary contaminants in the Hanford subsurface. It is recognized that the information available is not perfect, contains varying levels of sometimes high uncertainty, and is not available in the same level of detail across the EUs and related subsurface and receptor areas. The underlying complexity and uncertainty necessitates that analyses be tailored to the objectives of and intended use of the specific evaluation.

Analysis of the Hanford subsurface is also complex. In addition to the hydrogeological complexity of a very heterogeneous subsurface, biogeochemical interactions add additional layers of complexity. To make the analysis tractable for this Risk Review Project, prior work will be leveraged in a well-defined framework that provides an analysis to a rough-order of magnitude sufficient to compare risks to groundwater and the Columbia River related to the different EUs. Development of new primary data is beyond the scope of this review.

The specific objectives of the methodology described here are to:

1. Provide a basis for characterizing and binning current and potential future risks (over the three evaluation periods) of primary contaminants to groundwater resources,
2. Provide information necessary for characterizing the impacts of groundwater contamination on risks to the Columbia River over the three evaluation periods, and
3. Provide information needed for estimating risks to human health and potential impacts to other resources as described in other chapters of this document.



Hanford Site Guidelines for Preparation and Presentations of Geologic Information (PNNL-18819)

Figure 7-7. A generalized representation of subsurface stratigraphy for the Hanford Site showing nomenclature (DOE/RL-2010-11, Rev. 1, p. 3.0-12).

A process has been developed as a general framework for binning EUs according to evaluation metrics. The focus on these evaluation metrics will allow differentiation between potential groundwater-related risks from the EUs. This process does not concern itself directly with highly uncertain point estimates of risks and impacts often used for other analyses (e.g., performance or baseline risk assessments). The uncertainties associated with the analyses related to EUs become more tractable when evaluation metrics are considered in relative rather than absolute terms. It is understood, nonetheless, that sufficient information may not be available for certain EUs to meet the objectives of this evaluation and that additional characterization and modeling would be required; the likelihood of these information gaps and uncertainties has been accounted for in developing the framework presented here.

An analysis that allows comparison of available evaluation metrics for EUs, provides a rating of the EUs evaluated, and informs decision making, including the sequence of addressing specific sources and plumes as well as the needs for additional subsurface characterization, must necessarily consider:

1. the inherent complexity of the Hanford subsurface;
2. the difficulty and time required to determine accurate, point estimates out to a specified time horizon;
3. the lack of equivalent information across all EUs; and,
4. the large uncertainties that are necessarily associated with much of the extant information.

The overall approach to characterizing and comparing Evaluation Units is presented in Figure 7-8. Since this framework can be applied across EUs in a well-defined manner, it provides a straightforward process to compare EUs on a relative basis.

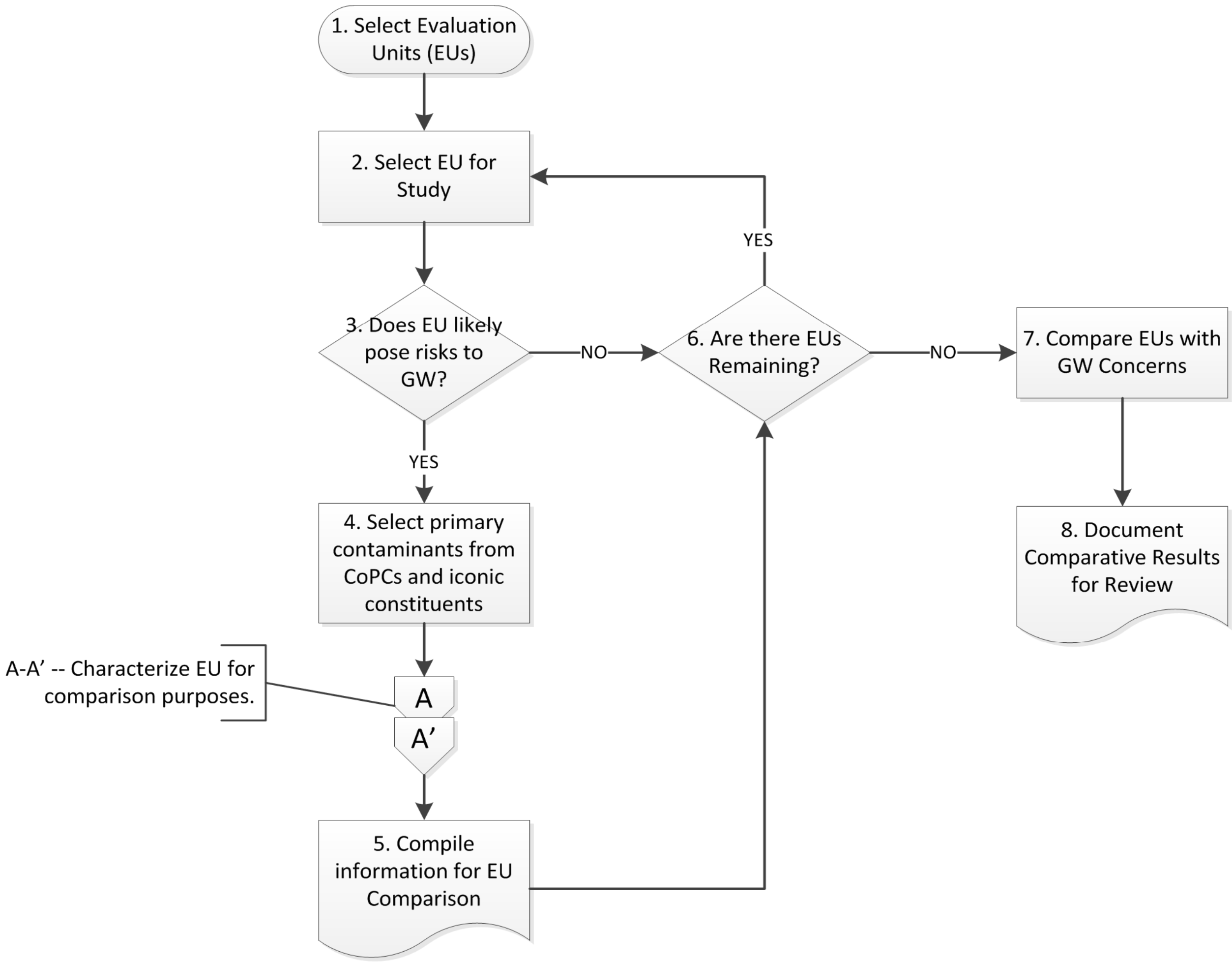


Figure 7-8. Overall process steps for evaluating potential groundwater-related risks.

After selecting units for evaluation (Steps 1-2) as described in Chapter 3, the first question (Step 3) is to determine whether or not each Evaluation Unit (EU) has existing or likely potential groundwater impacts based on prior evaluations (e.g., NEPA, Records of Decision, risk or performance assessments) and the presence, form, and amounts of contaminants present. If the EU does not pose potential groundwater impacts, then the next EU is selected (Step 2) if any remain to be evaluated (Step 6). If there is potential for groundwater impacts based on previous evaluations, a list of primary contaminants to be evaluated is selected (Step 4) from the contaminants of potential concern (COPCs) and iconic contaminants (from previous evaluations). The reason for retaining the constituent as a primary contaminant (e.g., iconic or EU specific risk-driver) as well as the source and reliability of the information used is documented as part of the selection process. The EU will then be characterized following the steps shown in Figure 7-9 (indicated by A-A') and the resulting groundwater and Columbia River metrics compiled (Step 5) for subsequent comparison (Steps 7-8).

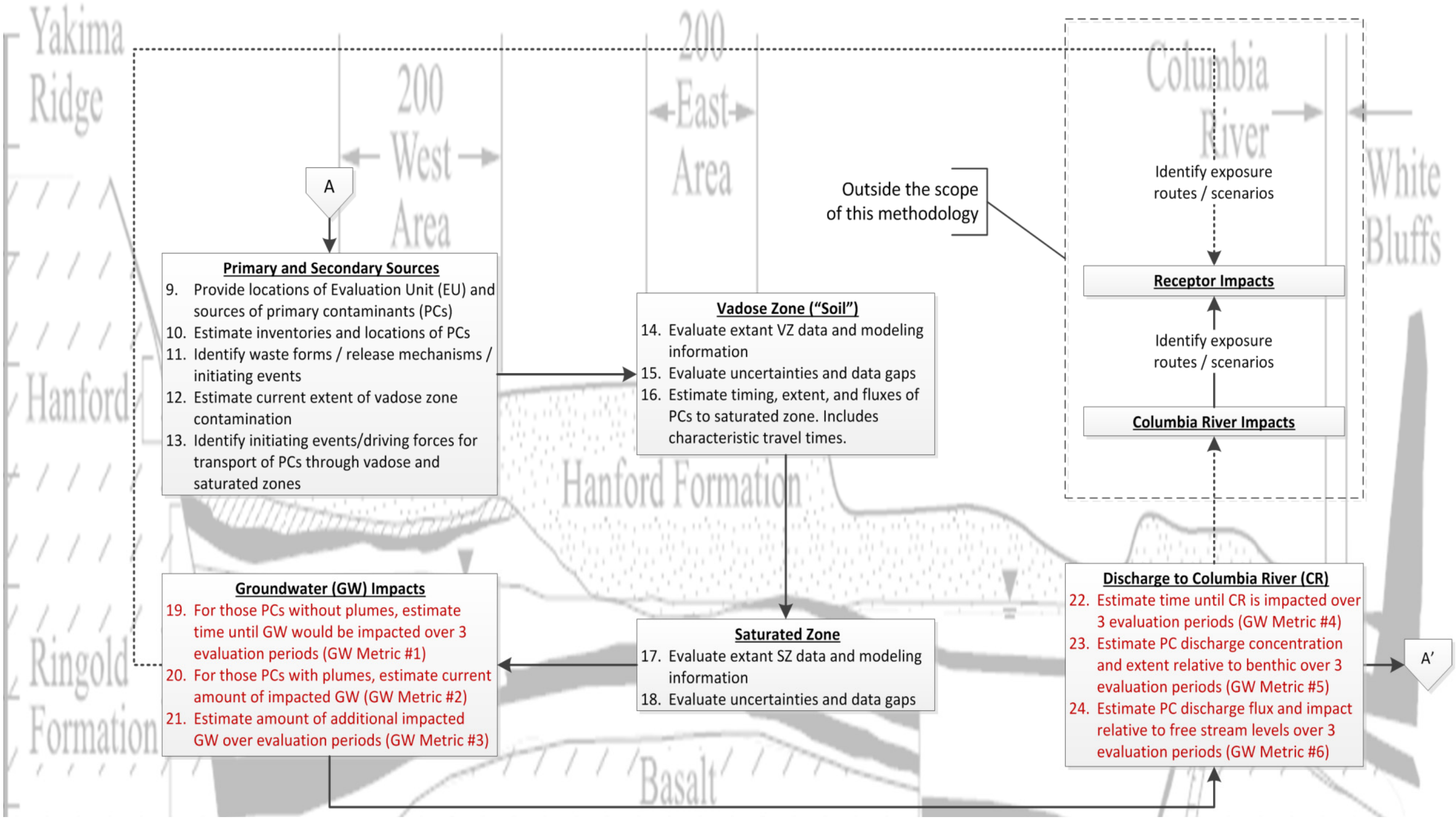


Figure 7-9. Proposed framework steps for characterizing an evaluation unit.

The EU characterization in Figure 7-9 can also be captured as a series of questions that can be grouped related to contaminant sources and release, vadose zone, and saturated zone questions. Questions related to exposure media and receptors are covered in Chapters 5 - 9. Some of the following questions may not be applicable for every specific EU being characterized. However, answering the applicable questions provides the critical characterization information needed to subsequently compare EUs based on potential for groundwater impacts.

Contaminant Sources and Release (Steps 9-13 in Figure 7-9)

The purpose of this set of questions is to characterize the sources of contamination related to the EU where primary contaminants have previously been or may in the future be discharged (intentionally or unintentionally) into the environment and are moving through the vadose zone and the groundwater. The minimum output from the contaminant sources and release part of the characterization is the list, inventory, and current physical-chemical form of primary contaminants for current contamination and the initiating events that may result in release and transport of the contaminants.

9. What is the location of the Evaluation Unit (EU) and its sources?
10. What are the inventories and locations of the radioactive and non-radioactive primary contaminants? The inventory information is key for comparative purposes.
11. What are the relevant wasteforms, release mechanisms (considering the list of potential initiating events, Chapter 4), and physical states related to the primary contaminants? An example set of wasteforms is activated metals, dry active wastes, resins, filter media, contaminated soils, and stabilized wastes. An example release mechanism is the loss of containment followed by leakage or leaching. A wasteform may release constituents by more than one mechanism. Are there initiating events that can result in a new release to the surface/subsurface? If so, how probable are these events.
12. What is the current extent of contamination for primary contaminants (e.g., from PHOENIX at http://phoenix.pnnl.gov/ or the Annual Groundwater Report at http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports) in the vadose zone?
13. What initiating events (e.g., excavation, container failure) and/or driving forces (e.g., recharge, discharge, infiltrating water, barometric) impact transport of primary contaminants through the vadose and saturated zones? These events are considered here because they related directly to sources of primary contaminants (Chapter 4).

Vadose Zone (Steps 14-16 in Figure 7-9)

The purpose of these questions is to evaluate and use existing information to estimate the concentrations and fluxes of primary contaminants from the vadose zone to the saturated zone over each assessment period. The desired information also includes the time frame over which the transport of primary contaminants from their current position in the vadose zone to the groundwater may occur under different assumed recharge rates. The minimum output from the vadose zone part of the characterization is the estimate of the time frame, footprint, and flux of primary contaminants to the saturated zone over the assessment period, considering the estimated maximum areal extent of impact or specific metric value over the 100-year interval during the long-term post-cleanup period.

14. What information (e.g., well data, model predictions) exists to estimate temporal and spatial fluxes of primary contaminants from the vadose zone to the saturated zone? What is the source and reliability of the information available to estimate the fluxes?

15. What are the uncertainties and data gaps in available information and how will they be managed as part of this evaluation?
16. What are the time frames, footprint and fluxes of primary contaminants to the saturated zone over the assessment period considering the three potential recharge rates? What is the characteristic travel time of primary contaminants through the vadose zone to the groundwater given the current location of the primary contaminants?

Saturated Zone (Steps 17-24 in Figure 7-9)

The purpose of the saturated zone questions is to evaluate and use existing information to estimate potential impacts to groundwater and fluxes to the Columbia River over the three evaluation periods. The minimum output from the saturated zone part of the characterization is 1) the time until the saturated zone would be impacted for those primary contaminants without current plumes (GW Metric #1), 2) the current amount (e.g., areal extent or volume) of impacted groundwater for those primary contaminants with plumes (GW Metric #2), 3) the additional amount of impacted groundwater over the three evaluation periods (GW Metric #3). For the Columbia River impacts, the minimum outputs are 1) the time until the Columbia River would be impacted (i.e., a primary contaminant exceeds a benthic or free-flowing threshold value) (GW Metric #4), 2) the primary contaminant discharge concentration and extent relative to benthic thresholds over the three evaluation periods (GW Metric #5), and 3) the primary contaminant discharge flux and *impact* to the Columbia River relative to the free-flowing concentration thresholds over the three evaluation periods (GW Metric #6).

17. What information (e.g., well data, model predictions) exists to estimate the current amount of contaminated groundwater (i.e., above a threshold value) for each primary contaminant, the change in the amount of contaminated groundwater over the assessment period, and the temporal and spatial fluxes of primary contaminants from the saturated zone to the Columbia River? What is the source and reliability of the information available to estimate this information? There may be different sources of information needed to answer these questions.
18. What uncertainties and gaps are in the available information and how will they be managed as part of this evaluation?
19. For those primary contaminants without current plumes, what is the estimated time until groundwater would be impacted (i.e., exceed a drinking water standard for a primary contaminant) over the three evaluation periods (GW Metric #1)?
20. For those primary contaminants with current plumes, what is the amount (e.g., areal extent or volume) of groundwater currently impacted (i.e., exceeds a threshold value for a primary contaminant) (GW Metric #2)?
21. What is the estimated amount (e.g., areal extent or volume) of additional impacted groundwater over the assessment period (GW Metric #3)?
22. What is the estimated time until the Columbia River is impacted (I.e., a primary contaminant exceeds a benthic or free-flowing threshold value) (GW Metric #4)?
23. What is the primary contaminant discharge concentration and extent relative to benthic thresholds over the three evaluation periods (GW Metric #5)?
24. What is the primary contaminant discharge flux and *impact* to the Columbia River relative to the free-flowing concentration thresholds over the three evaluation periods (GW Metric #6)?

When the information has been compiled for all Evaluation Units under consideration (Steps 1-6, Figure 7-8), the ROM risk factors will be compared (Step 7) among the Evaluation Units and then assembled (Step 8) into a final document for review.

Sources of Groundwater and Columbia River Thresholds

In this review, groundwater or the Columbia River is considered *impacted* when a primary contaminant concentration exceeds a given threshold value. For groundwater, the threshold for a primary contaminant is the corresponding US EPA drinking water standard (e.g., 900 pCi/L for Tc-99). The thresholds for the free-flowing parts of the Columbia River are the Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A WAC). With the thresholds for radiological contaminants will follow guidelines recommended by National Council on Radiation Protection and Measurements (NCRP 1991). The corresponding thresholds for chemical contaminants with respect to benthic organisms in the Columbia River are to be determined[20].

Primary Contaminant Groups

The primary contaminants under consideration are shown in Table 7-1, which categorizes them according to their mobility and persistence in the Hanford environment. The categorization was done on a relative basis between the primary contaminants. Mobility relates to the relative ability of the primary contaminant to be transported in the subsurface environment and is mainly a function of the contaminant's chemistry and sorption with the Hanford subsurface geology that affect its holdup in the subsurface. For the radioactive contaminants, the persistence relates to their half-lives. The persistence of the organic and inorganic contaminants relates to their degradation. Chromium, being non-degrading and not radioactive, is classified as having a high persistence in the subsurface. For the purposes of this Site-wide Review, the primary contaminants were divided into four groups based on their persistence and mobility. Group A contains technetium-99, iodine-129, and carbon tetrachloride. Group B contains cesium-137, strontium-90, trichloroethylene, uranium, chromium, and cyanide. Group C contains tritium and nitrate. Group D contains plutonium. The groups are ranked relative to each other with Group A being the highest and Group D being the lowest for the purpose of this study.

[20] The Tank Waste EIS includes a method and thresholds for benthic organisms but the necessary supporting citations and documentation were not available at the time of the writing of this document and will need to be evaluated further for applicability to the Risk Review Project.

Table 7-1. Primary component groups.

		Mobility		
		Low	Medium	High
Persistence	Low			$^{3}H_2O$, NO_3
	Medium		Cs-137, Sr-90, TCE	Cyanide
	High	Pu	U, Cr	Tc-99, I-129, Carbon Tetrachloride

Group A Primary Contaminants

Group B Primary Contaminants

Group C Primary Contaminants

Group D Primary Contaminants

Evaluation of Groundwater

Each primary contaminant from each source within each EU will be evaluated to determine a rating for that source for its potential impact to groundwater. The highest rating for individual primary contaminants from a source will be used as the overall rating for the source. The highest rating of an individual source for multiple sources in a given EU will then be used to provide an overall rating for the EU. The primary contaminants and sources driving the ratings will be indicated.

The steps for determining a risk rating basis for impact to groundwater are outlined in the flowchart in Figure 7-10. The ratings are looked up in Table 7-2 (Group A primary contaminants), Table 7-3 (Group B primary contaminants), or Table 7-4 (Group C primary contaminants) based on the information collected. The specific ratings provided in Tables 7-2 through 7-4 were developed based on evaluation of the distribution of current plume sizes (to provide plume area distinctions between > 1 km^2, 0.1 – 1 km^2, < 1 km^2), distinctions based on contaminant transport and attenuation characteristics (Table 7-1), and bias towards considering contamination of currently uncontaminated groundwater to be greater risk (thus providing sequencing urgency towards preventing currently unimpacted resources from becoming degraded).

Several risk rating metrics are determined for each primary contaminant from each source in the EU being evaluated in the characterization steps (steps A-A' in Figure 7-8 and steps 19-21 in Figure 7-9). The evaluation begins by looking at each of the evaluation periods: Current, Active Cleanup (50 years), Near-term Post-Cleanup (100 years), and Long-term Post-Cleanup (1000 years). The initial question is whether the primary contaminant under consideration currently does, or likely will before the end of an evaluation period, impact the Hanford groundwater. The ratings are generally lower for impacts that occur in later evaluation periods. The risk rating metrics will be provided for impacts that occur during the Long-term Post-Cleanup evaluation period but no rating will be assigned for that evaluation period because of the extremely high degree of uncertainty associated with such long time intervals. If the primary contaminant does not impact the groundwater during the Long-term Post-Cleanup evaluation period, the not-discernible (ND) rating will be assigned.

If the primary contaminant is determined to impact groundwater currently or within either of the first two evaluation periods (Active Cleanup and Near-term Post-Cleanup), the spatial extent of impact will be estimated. Spatial extent is defined as the areal extent of groundwater that has a concentration of the primary contaminant above the drinking water standard for that primary contaminant. The spatial extents were divided into three ranges based on an evaluation of the spatial extents of currently known groundwater plumes. The ranges are greater than 1 km^2, between 0.1 and 1 km^2, and less than 0.1 km^2.

Three cases have been identified that are used to further discriminate the assigned rating. Case I is where no prior contamination of the groundwater impacted by the primary contaminant under consideration has yet occurred. This case produces the highest rating for the primary contaminant because it is considered fresh contamination of previously uncontaminated groundwater. Case II is where the primary contaminant under consideration impacts groundwater that is already impacted by an existing plume of a primary contaminant from the same or higher group (Group A is highest and Group D is lowest). The rating for this primary contaminant from the source generally will be lower than the equivalent impact for Case I because this is not an impact to uncontaminated groundwater. Case III is where the primary contaminant under consideration impacts groundwater already impacted by an existing plume of a primary contaminant in a lower contaminant group. The rating for Case III will generally be the same as for Case I because this represents an additional new significant increase in contamination of the groundwater. No Case III for Group C is known to exist. Therefore, this case is listed as not applicable. If this case is found to exist, appropriate ratings will be assigned.

Once the evaluation period where impact occurs is determined, the Case I, II, or III selected, and the spatial extent determined, the rating for the primary contaminant for a source in an EU can be looked up in Table 7-2, Table 7-3, or Table 7-4.

Evaluation of Surface Water

The evaluation of risks to surface waters follows a similar process to the evaluation process used for risks to groundwater. Each primary contaminant from each source within each EU will be evaluated to determine a rating for that source for its risk to the Columbia River. The highest individual ratings for each primary contaminant from a source will be used as an overall rating for the source. The highest rating for multiple sources in a given EU will then be used as an overall rating for the EU. The primary contaminants and sources driving the ratings will be indicated.

The steps for calculating a risk rating basis for impact to the Columbia River are outlined in the flowchart in Figure 7-11. The ratings are looked up in Table 7-5.

For each primary contaminant from each source in the EU being evaluated in the characterization (steps A-A' in Figure 7-8 and steps 22-24 in Figure 7-9) of the overall process for evaluating potential surface water-related impacts, several risk rating metrics are determined. The evaluation begins by looking at each of the evaluation periods: Current, Active Cleanup (50 years), Near-term Post-Cleanup (100 years), and Long-term Post-Cleanup (1000 years). The question is whether the primary contaminant under consideration currently does, or before the end of an evaluation period, likely will impact the Columbia River. The risk ratings are generally lower for impacts that occur in later evaluation periods. The risk rating metrics will be provided for impacts that occur during the Long-term Post-Cleanup evaluation period but no risk rating will be assigned because of the extremely high degree of uncertainty associated with the very long timeframe. If the primary contaminant does not impact the Columbia River during the Long-term Post-Cleanup evaluation period, the not-discernible (ND) rating will be assigned.

If the primary contaminant is determined to impact the Columbia River currently or within either of the first two evaluation periods (Active Cleanup and Near-term Post-Cleanup), the spatial extent of impact will be determined. Spatial extent is defined for impacts to the Columbia River to be the reach along the river that receives a discharge of the primary contaminant above the benthic threshold for that primary contaminant. If the discharge concentration to the Columbia River is less than the benthic threshold for that primary contaminant, the ND rating will be assigned. The spatial extent of impact to the Columbia River has been divided into two ranges: greater than 100 meters of reach along the river and less than 100 meters of reach along the river.

If the primary contaminant is above the benthic threshold for some discharge to the Columbia River, the rating depends first upon which primary contaminant is being considered and then the relative loads of the specific contaminant to the river. For the purposes of this Hanford Site-wide Review, the primary contaminants Cs-137, Sr-90, Tc-99, I-129 are given the highest ratings because they originate only from Hanford EU sources. For the other primary contaminants, which have other natural or offsite sources, lower risk ratings are given if the load from the EU source is less than 1% of the total load to the Columbia River from all sources. If the load from the EU source is greater than 1% of the total load to the Columbia River from all sources, all other primary contaminants are treated the same as Cs-137, Sr-90, Tc-99, I-129. The risk ratings for impacts to the Columbia River are looked up in Table 7-5.

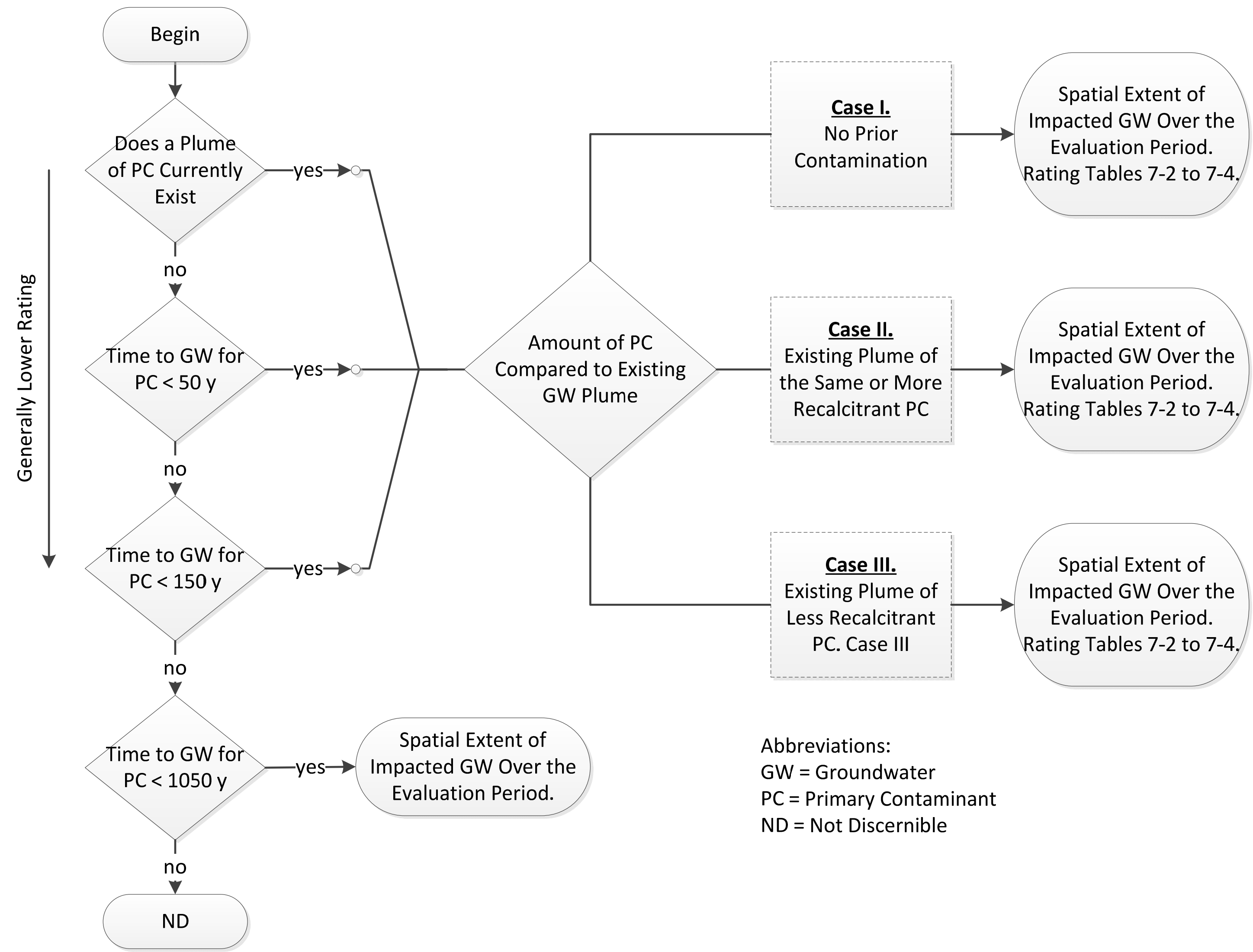


Figure 7-10. Risk rating basis for impact of a primary contaminant from surface and vadose zone sources to groundwater.

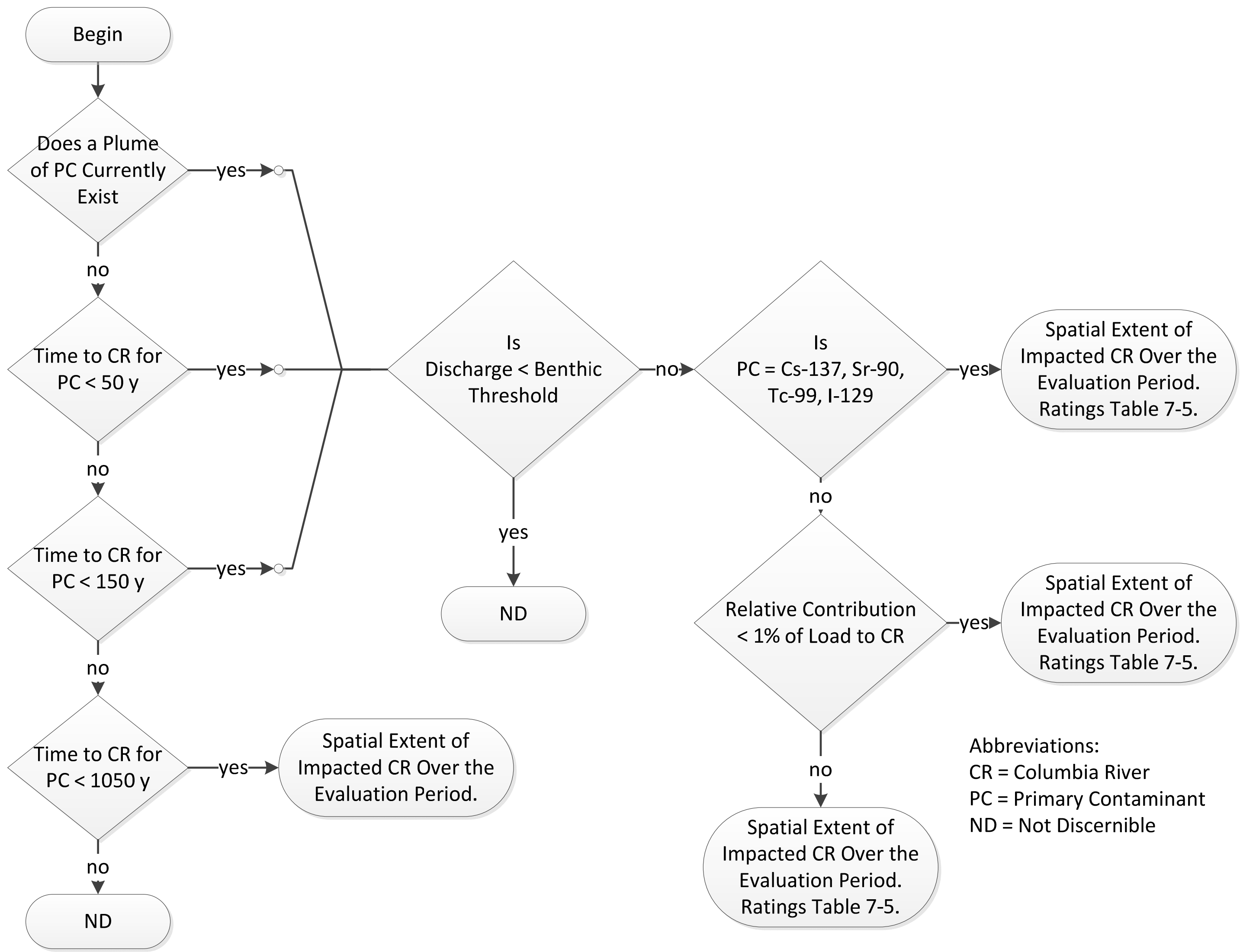


Figure 7-11. Risk rating basis for impact of primary contaminant to the Columbia River

Table 7-2. Rating impacts to groundwater: Group A. Evaluation of Tc-99, I-129, carbon tetrachloride (most recalcitrant and mobile).

	Estimated spatial extent of impact to						
	Case I. previously unimpacted groundwater (fresh plume)			**Case II.** existing plume of Group A (impact area within existing plume)		**Case III.** existing less recalcitrant plume (Group B or C; impact area within existing plume)	
Evaluation Period	>1 km^2	0.1 – 1 km^2	<0.1 km^2	0.1 – 1 km^2	<0.1 km^2	0.1 – 1 km^2	<0.1 km^2
Existing Plume	VH	VH	H	H	M	VH	H
<50 y	VH	H	M	M	L	H	M
50 – 150 y	H	M	L	L	L	M	L

VH = Very High, H = High, M = Medium, L = Low, NA = Not Applicable

Table 7-3. Rating impacts to groundwater: Group B. Evaluation of Cr, Cs-137, Sr-90, Total U, TCE (ca. 30 y half-life, less mobile than Group A). Note – U is evaluated as total uranium rather than a radionuclide.

	Estimated spatial extent of impact to						
	Case I. previously unimpacted groundwater (fresh plume)			**Case II.** existing same or more recalcitrant plume (Group A or B; impact area within existing plume)		**Case III.** existing less recalcitrant plume (Group C; impact area within existing plume)	
Evaluation Period	>1 km^2	0.1 – 1 km^2	<0.1 km^2	0.1 – 1 km^2	<0.1 km^2	0.1 – 1 km^2	<0.1 km^2
Existing Plume	H	H	M	M	L	H	M
<50 y	H	M	L	L	L	M	L
50 – 150 y	M	M	L	L	L	M	L

VH = Very High, H = High, M = Medium, L = Low, NA = Not Applicable

Table 7-4. Rating impacts to groundwater: Group C. Evaluation of tritium and nitrate (ca. 12 y half-life, high natural attenuation, high mobility).

	Estimated spatial extent of impact to						
	Case I. previously unimpacted groundwater (fresh plume)			**Case II.** existing same or more recalcitrant plume (Group A, B or C; impact area within existing plume)		**Case III.** existing less recalcitrant plume (not applicable)	
Evaluation Period	>1 km^2	0.1 – 1 km^2	<0.1 km^2	0.1 – 1 km^2	<0.1 km^2	0.1 – 1 km^2	<0.1 km^2
Existing Plume	M	M	L	L	L	NA	NA
<50 y	M	L	L	L	L	NA	NA
50 – 150 y	L	L	L	L	L	NA	NA

VH = Very High, H = High, M = Medium, L = Low, NA = Not Applicable

Table 7-5. Rating impacts to surface water.

Evaluation Period	Primary Contaminant					
	Cs-137, Sr-90, Tc-99, I-129		Other			
			> 1% of Load to Columbia River		< 1% of Load to Columbia River	
	>100 m	<100 m	>100 m	<100 m	>100 m	<100 m
Existing Plume	VH	H	VH	H	H	M
<50 y	H	M	H	M	M	L
50 – 150 y	M	L	M	L	L	L

VH = Very High, H = High, M = Medium, L = Low, NA = Not Applicable

DEMONSTRATION OF THE GROUNDWATER EVALUATION FRAMEWORK

The capability of the framework is demonstrated in this section by characterizing one pilot study site using the framework.

The pilot study site in the Central Plateau selected for characterization (corresponding to Steps 1-2 in Figure 7-8) is the B Complex that includes the B-BX-BY Tank Farms and Waste Management Area and B-BY cribs in North-Central 200-East Area (see Figure 7-12 for the location relative to other potential Evaluation Units).

Truex and Carroll (2013) analyzed a suite of contaminants in the 200-East Area based on a comparison of predicted groundwater concentrations and recent groundwater plume data to the respective MCLs. Their results indicate that the selected site has contaminants whose concentrations exceed MCLs and thus present potential impacts to groundwater (Step 3 in Figure 7-8). Thus the EU characterization process outlined in Figure 7-9 (A-A' and Steps 9-24) would be conducted for the selected pilot study site.

For this demonstration, two radioactive primary contaminants (technetium-99 and total uranium) will be evaluated (Step 4 in Figure 7-8) based on the results by Truex and Carroll (2013). A full evaluation would include all radioactive and non-radioactive primary contaminants.

Part of the evaluation for the 200-East Area B Complex is based on detailed information that is currently not available for the other pilot evaluation units, e.g., for the 241-Tank Farm in the 200-West Area. Information to an equivalent level of detail is currently being sought. The framework is also being evaluated to address the impacts of differing levels of information availability for different EUs.

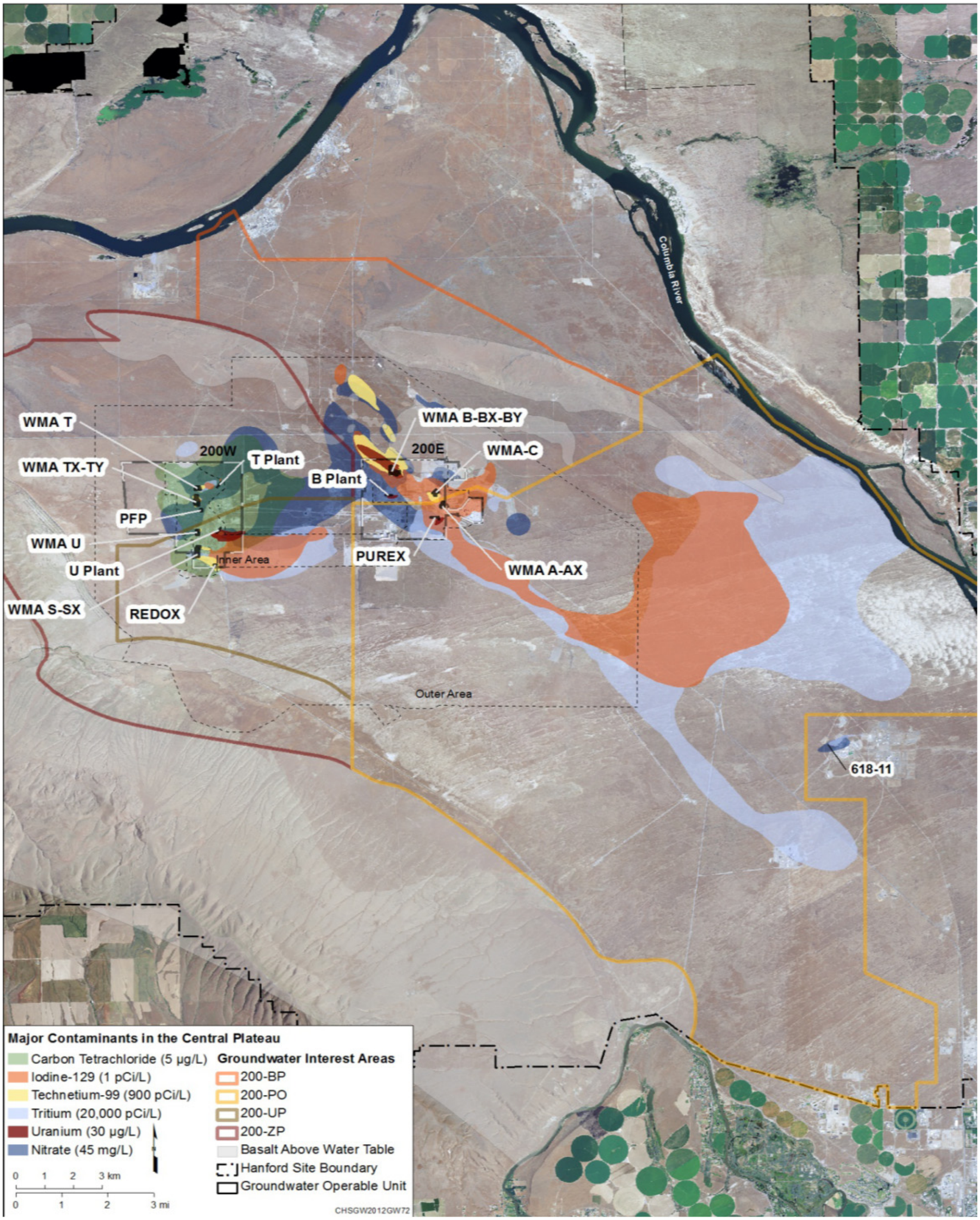


Figure 7-12. Central Plateau major facilities and groundwater contaminants (DOE/RL-2013-22, Rev. 0, p. CP-4).

Primary Contaminant Selection (Step 4 in Figure 7-8)

Truex and Carroll (2013) analyzed a suite of contaminants in the 200-East Area (and other relevant Hanford Areas) based on a comparison of predicted groundwater concentrations and recent groundwater plume data to respective MCLs. Their results suggest that the highest priority contaminants (i.e., estimated concentrations > 10X the MCL) likely to be controlling the risk rating for impact to groundwater over the first 2,100 years for the 200-East Area (B Complex) would be total uranium, technetium-99, and iodine-129 (*B, BX, BY tank farms & vicinity*) (Table 7-6). Contaminants that were deemed not to lead to groundwater concentrations above the MCL within 12,000 years were not listed.

Table 7-6. Categorization of vadose zone sites based on potential impact to groundwater (Truex and Carroll, 2013, p. 30).

Site Name	Site_ID	DWS Factor	Contamination Issue and Time
High Potential Impact Sites (Estimated Concentrations Greater than 10X of the Drinking Water Standard)			
REDOX cribs and trenches	216-S-7 216-S-1/2	82(37)/30/11 14	I All Times I3
S/SX tank farms & vicinity	241-SX-108 241-SX-107 241-SX-115 241-SX-104 241-S-104	70(56)/43/53 42(56)/14/17 25(56)/13/17 12 22	Tc1/Tc2/I2 Tc1/Tc2/I2 Tc1/Tc2/I 2 Tc2 Tc1
T tank farm & vicinity	241-T-106	64(125)/104/57	Tc1/Tc2/I2
U tank farm	241-U-104	23	Tc1
Solid Waste - 200-ZP-1	218-W-4B 218-W-5	17 12	I3 Tc3
BC cribs/trenches	multiple	10 - 17	Tc2
TX/TY tank farms	241-TX-107	23/11	I1/I2
B, BX, BY tank farms & vicinity	BX-102	115/4/34	U1/I1/Tc1
B, BX, BY tank farms & vicinity	BY-cribs	14/2	Tc1/I1
U cribs	216-U-1/2	12/46/3	U1/Tc1/I1
B cribs	216-B-12	10	U1

Note: Contaminant issue is shown as I (I-129), Tc (Tc-99), and U (uranium) for time intervals 1 (up to 2100), 2 (up to 3100), and 3 (up to 12000). Red text shows information added based on recent groundwater plume data.

Based on the analysis by Truex and Carroll (2013), for the 1,000-year time horizon of interest here, the evaluation here focuses on total uranium and technetium-99 for the B-complex.

Contaminant Sources and Release

These steps are used to characterize the sources of contamination related to the EU (A-A' in Figure 7-8 and Steps 9-13 in Figure 7-9 and indicated in parentheses below):

(9) The location of the B Complex is North-Central 200-East Area (Figure 7-12)

(10) The TC&WM EIS lists the following information for the B-BX-BY Tank Farms (where Tc-99 decayed to 2002 values):

HLW Tanks:	Tc-99	3100 Ci	Total Uranium	2×10^5 kg
Ancillary Equipment:	Tc-99	18 Ci	Total Uranium	1.5×10^3 kg
Leaks:	Tc-99	29 Ci	Total Uranium	1.5×10^4 kg
B-BX-BY Cribs & Trenches:	Tc-99	140 Ci	Total Uranium	2×10^3 kg

(11) The B-BX-BY tanks contain sludge, saltcake, and supernatant phases. Tank waste contaminants have been discharged to the environment and some have moved through the vadose zone to the saturated zone beneath the B-BX-BY Tank Farms. The primary driver for contaminant transport is infiltrating water.

(12) Some tank waste constituents have moved through the vadose zone to the saturated zone. This information will be presented in more detail below.

(13) The primary driver for contaminant transport is infiltrating water.

Vadose Zone (A-A' in Figure 7-8 and Steps 14-16 in Figure 7-9)

Existing information will be used to estimate the concentrations and fluxes of primary contaminants from the vadose zone to the saturated zone over each assessment period. Travel times through the vadose zone will also be estimated.

(14) The B Complex has been studied in detail (Truex and Carroll 2013).

(15) Because of the nature of subsurface fate and transport, there are uncertainties associated with field measurements (from boreholes and wells); however, there are much larger uncertainties associated with predictions of the fate and transport of primary contaminants through the subsurface. The B Complex area has been studied in more detail than most other areas within the Hanford Site and thus the information is considered complete relative to the needs of this characterization. This level of detail may not exist for the other Evaluation Units and is being sought for the other Evaluation Units for the sake of consistency.

(16) In the 200 East Area, the Hanford formation comprises nearly the entire thickness of the vadose zone. The Hanford formation is the most permeable material for potential continued contaminant migration. (DOE/RL-2007-56, Rev. 0, p. 2-6/7) Travel time (T_t) of water and unretarded species through the subsurface can often be related directly to the recharge rate, *r*. For the 200 East Area, approximations of T_t are (where data are from Table N-52 from the TC&WM EIS) (T_t for the 200-West 241-T tanks is shown for comparison):

$$T_t = 3850r^{-0.895}$$ 200-East (B Complex) 7-1

$$T_t = 4006r^{-0.899}$$ 200-West (241-T Tanks) 7-2

(see Figure 7-13).

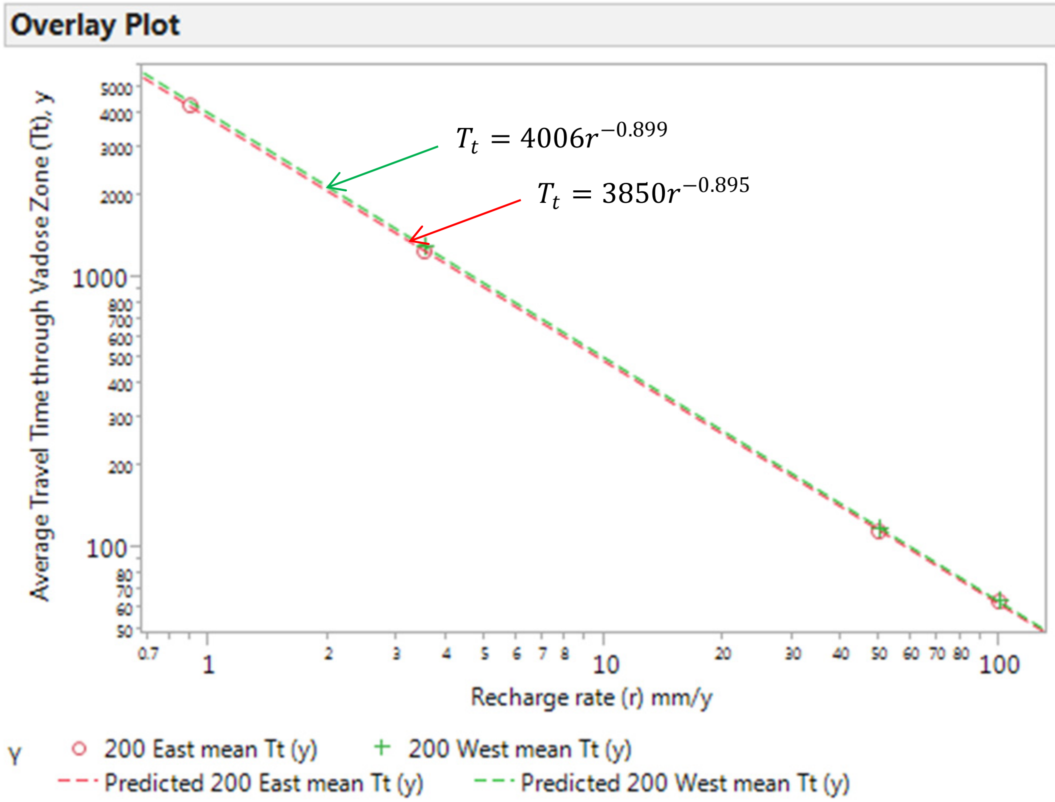


Figure 7-13. Average travel time (Tt) from the 200 Areas through the vadose zone as a function of the recharge rate (r) (from TC&WM EIS Table N-52).

For recharge values of 0.5, 5, and 50 mm/y for surface barrier, undisturbed plant communities, and disturbed soil, respectively[21], travel times of approximately 7,200; 910; and 120 years, respectively, are obtained. The vadose zone thickness is approximately 100 m in the 200-East Area (PNNL-14702, Rev. 1, p. 2.2).

Recommended K_d values (Table 7-7) for the B Complex are provided for high and intermediate impact zones for different sediment types[22] (PNNL-17154). Tc-99 can be taken as a non-retarded species because its K_d approaches zero for the various conditions considered. *Best* recommended K_d values for uranium range from 0.1 (high impact sand) to 2.5 mL/g (for intermediate impact silt). However, these K_d's for uranium are still relatively low, and the uranium may be relatively unretarded in the vadose zone compared to other contaminants (e.g., Pu). This difference in retardation likely partially explains the reason that some contaminants (e.g., Tc-99) are observed in Hanford groundwater wells but not others (e.g., Pu).

[21] Personal communication from Vicky Freedman entitled "Summary of Recommended Recharge Rates at Hanford" included as Attachment 2-1.

[22] *High impact* – zone where organic or salt concentration or pH in the fluid may have significantly affected the K_d. *Intermediate impact* – zone where the acidic or basic nature of the wastes was expected to have been largely neutralized by reaction with the natural sediment (PNNL-17154, p. 2.3).

Table 7-7. K_d values for impacted sediments at WMA B-BX-BY (units are mL/g) (PNNL-17154, p. 3.31).

	Sand-Size Sediments						Silt-Size Sediments					
	High Impact			Intermediate Impact			High Impact			Intermediate Impact		
	Best	Min	Max	Best	Min	Max	Best	Min	Max	Best	Min	Max
Chemicals												
F^-	0	0	0	0	0	1	0	0	0	0.05	0	1
Cr(VI)	0.05	0	3	0	0	3	0.1	0	3	0	0	10
Hg(II)	0	0	0	0	0	0	0	0	0	0	0	0
NO_3^-, NO_2^-	0	0	0	0	0	0.1	0	0	0	0	0	0.1
Pb	3	0	10	10	3	100	0	0	30	30	10	300
U(VI) – all isotopes	0.1	0	2	0.2	0.2	0.4	0.3	0	3	2.5	0.6	15
Radionuclides												
^{241}Am(III)	3	0	50	600	200	2000	10	0	150	600	200	2000
^{14}C(IV)	5	0	50	1	0	100	5	0	50	1	0	100
^{60}Co(II,III)	0	0	10	0	0	10	0	0	30	0	0	30
^{137}Cs	1	0	10	100	10	1000	1	0	30	100	30	3000
Eu – all isotopes	1	0	10	10	3	100	3	0	30	30	10	300
^{3}H	0	0	0	0	0	0	0	0	0	0	0	0
^{129}I	0	0	0.2	0.2	0	2	0	0	0	0.2	0	2
^{63}Ni	0	0	10	3	1	20	0	0	30	10	3	60
^{237}Np(V)	0	0	5	10	2	30	0	0	15	10	2	50
Pu – all isotopes	3	0	50	600	200	2000	5	0	150	600	200	2000
^{226}Ra	1	0.2	20	10	5	20	3	0.6	60	10	5	60
^{79}Se(VI,IV)	0	0	3	0.1	0	3	0	0	3	0.3	0	10
^{126}Sn(IV)	0	0	10	0.5	0	20	0	0	30	1.5	0	60
^{90}Sr	1	0.2	20	10	5	20	3	0.6	60	10	5	100
^{99}Tc(VII)	0	0	0.2	0	0	1	0	0	0.2	0	0	5

For gravel-size sediments, modify sand-size K_d values using Equations (2.3) and (2.4) in Section 2.4.
See Appendix A for references and selection rationale.

Technetium-99. Tc-99 is not solubility limited so delivery amounts (i.e., fluxes) to the water table depend largely on disposal amounts and on water flux. The calculated peak concentrations delivered to the water table appear strongly dependent on recharge rate. Results presented by Ward et al. (2004, p. 5.12) using a one-dimensional steady flow model (Figure 7-14) indicate a power law relationship:

$$c_{peak} = 1.138x10^4 r^{1.055} \qquad 7\text{-}3$$

The results represented by Eq. 7-3, which are appropriate for screening-level estimates, are considered somewhat conservative because they do not account for stratification and its corresponding dimensionality effects (Ward et al. 2004, p. 5.12). For their do-nothing alternative, Ward et al. (2004) used a recharge rate of 25 mm/y that gives an estimated peak concentration of 33,900 pCi/L. Using the above power law and recharge rates of 0.5, 5, and 50 mm/y, peak concentration delivered to the water table were calculated and are shown in Table 7-8. Using the default EPA value for the dilution-attenuation factor (DAF) of 20 to account for natural processes that reduce contaminant concentrations in the subsurface (EPA/540/R95/128, p. 46), the peak groundwater concentrations were calculated and are shown in Table 7-8. In fall 2008, peak concentrations measured in groundwater (below the BY cribs) were approximately 35,000 to 45,000 pCi/L (PNNL-19277, p 5.16) suggesting that the calculated numbers are not unreasonable. The MCL for Tc-99 is 900 pCi/L (DOE/RL-2013-22, Rev. 0).

The recharge rate affects the flux of primary contaminants from the vadose zone to the groundwater, while regional groundwater flow controls the dispersion and transport of primary contaminants once they are in the groundwater and is assumed to remain the same as current conditions.

Table 7-8. Peak concentrations as a function of recharge rate.

	Recharge		
	0.5 mm/y	**5 mm/y**	**50 mm/y**
Peak concentration delivered to the water table [pCi/L]	5500	62,000	710,000
Maximum technetium-99 flux to saturated zone [$g/m^2/y$][(a)]	0.5	6	70
Peak groundwater concentration [pCi/L][(b)]	270	3,100	35,000

a Calculated from the peak groundwater concentration for Tc-99 assuming the same area of influx to the groundwater as uranium, which was derived from the data shown in Table 7-9.

b Using the default EPA value for the dilution-attenuation factor (DAF) of 20 to account for natural processes that reduce contaminant concentrations in the subsurface (EPA/540/R95/128, p. 46).

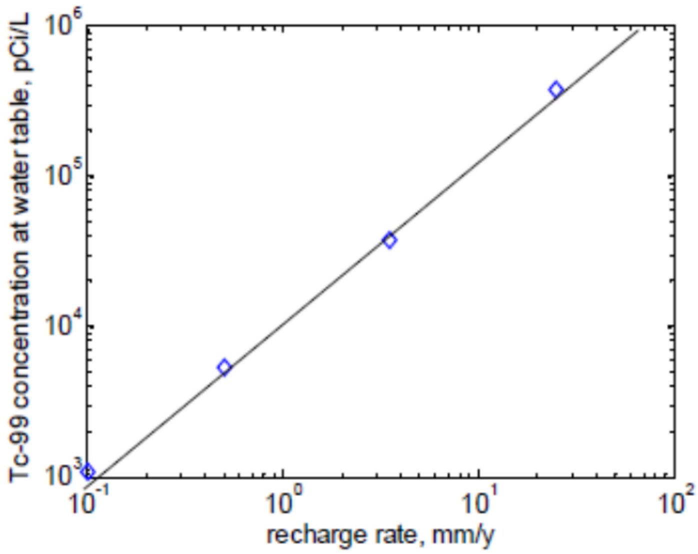


Figure 7-14. Tc-99 Concentration at water table from 200 Areas as a function of recharge rate. (Data from PNNL-14907, p. 5.12).

Uranium. The chemistry of uranium at the Hanford site is very complex (e.g., Zachara et al. 2007); an evaluation methodology that takes into account the level of complexity need to fully represent uranium chemistry at the Hanford Site is not tenable for this site-wide evaluation. Thus a simpler analysis is used here.

For uranium, the inventory in the vadose zone is very large relative to what has reached the groundwater and will be assumed infinite over the three evaluation periods (i.e., up to 1,000 years) considered in the Hanford Site-wide Review.

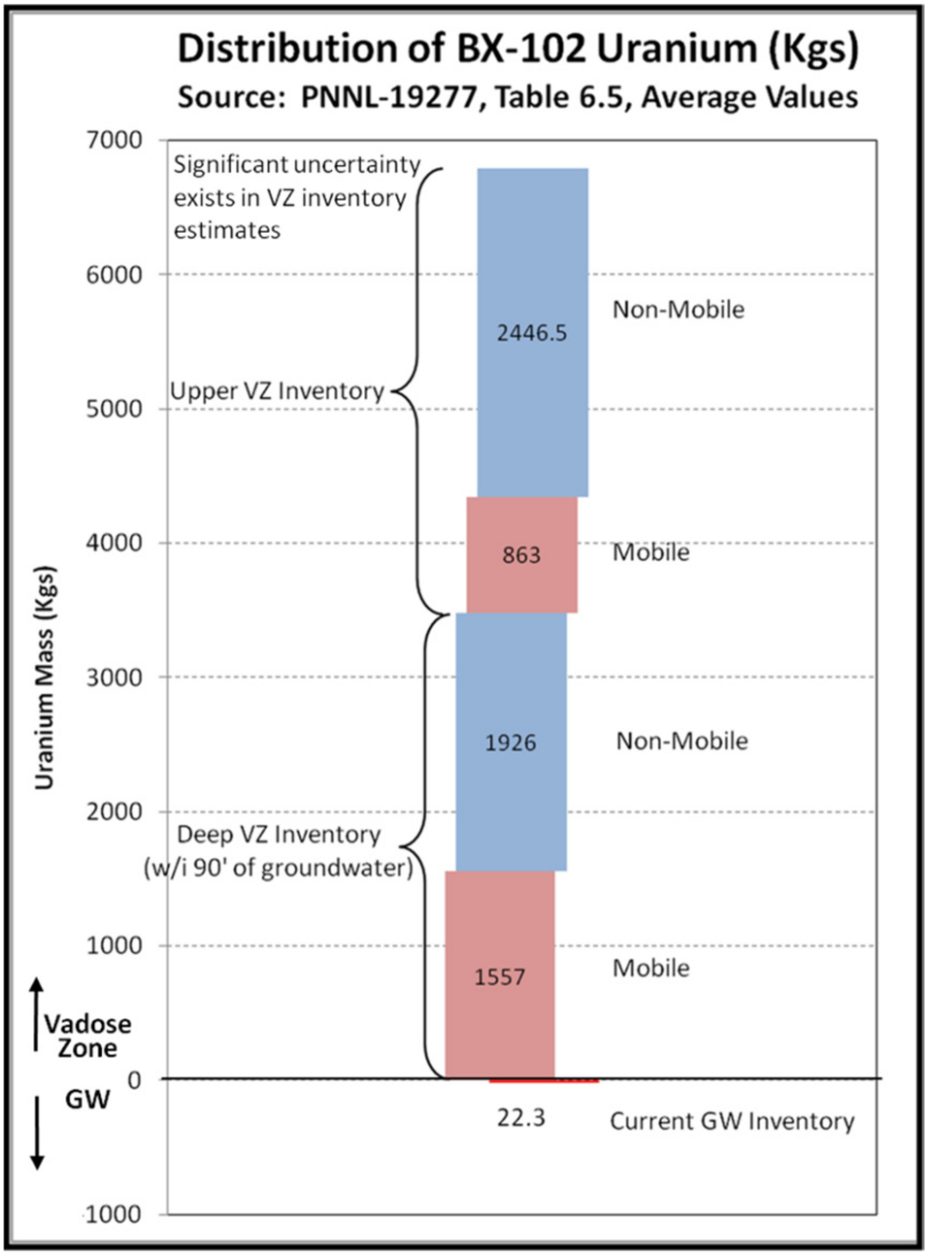


Figure 7-15. Depiction of the estimated uranium inventory in the vadose zone at the BX-102 site (Truex and Carroll, 2013; p. 34).

The water extractable (WE) uranium is assumed to be sorbed and infiltrating water will be in equilibrium with this sorbed uranium[23]. *Best* K_d values for uranium range from 0.1 to 2.5 mL/g (PNNL-17154, p. 3.31). Furthermore, the amount of water extractable uranium below the tank overflow is between approximately 0.1 and 100 µg/g (Table 3.16 in PNNL-19277, p. 3.94). Using

[23] The amount of water extractable uranium is most likely related to the distribution oxidation states of the uranium present, with uranium substantially more soluble (and therefore more water extractable) when oxidized. It therefore can be postulated that the amount of water extractable uranium is in equilibrium between the rate of transport and the rate of oxidation under the prevailing conditions. However, this assumption is considered when the source of water extractable uranium is assumed infinite for the purposes of this evaluation.

these values gives an aqueous concentration of 0.04 to 1000 mg/L for various combinations of sorbed mineral concentrations and K_d's.

Using a travel length of 100 m for the 200-East Area through the vadose zone and a maximum aqueous concentration of 1000 mg/L, travel times and fluxes of primary contaminants were calculated and are shown in Table 7-9 for recharge values of 0.5, 5, and 50 mm/y (from Step 16). Assuming that the amount of contaminant that reaches the saturated zone distributes through a 2 m deep aquifer during the year, the groundwater concentrations were calculated and are shown in Table 7-9. All calculated groundwater concentrations were above the 30 µg/L MCL (DOE/RL-2013-22, Rev. 0).

Table 7-9. Uranium impact to saturated zone as a function of recharge rate.

	Recharge		
	0.5 mm/y	5 mm/y	50 mm/y
Travel time through the vadose zone (assuming 100 m thickness) [y]	7200	910	120
Maximum uranium flux to saturated zone [$g/m^2/y$]	14	110	830
Groundwater concentration (assuming a 2 meter aquifer) thickness) [µg/L]	7000	55,000	420,000

Saturated Zone (A-A' in Figure 7-8 and Steps 17-24 in Figure 7-9)

The purpose of the saturated zone questions is to evaluate and use existing information to estimate potential impacts to groundwater and fluxes to the Columbia River over the three evaluation periods.

(17) The B Complex has been studied in detail (Truex and Carroll 2013).

(18) Because of the nature of subsurface fate and transport, there are uncertainties associated with field measurements (from boreholes and wells). However, there are much larger uncertainties associated with predictions of the fate and transport of primary contaminants through the subsurface, especially over the long distances to the Columbia River. The B Complex area has been studied in more detail than most other areas within the Hanford Site and thus the information is considered complete relative to the needs of this characterization.

(19) There are plumes associated with the selected primary contaminants (DOE/RL-2013-22, Rev. 0) so the time to impact does not need to be estimated since groundwater is already impacted (exceeds the MCL) by both uranium (Figure 7-16) and Tc-99 (Figure 7-17) (GW Metric #1).

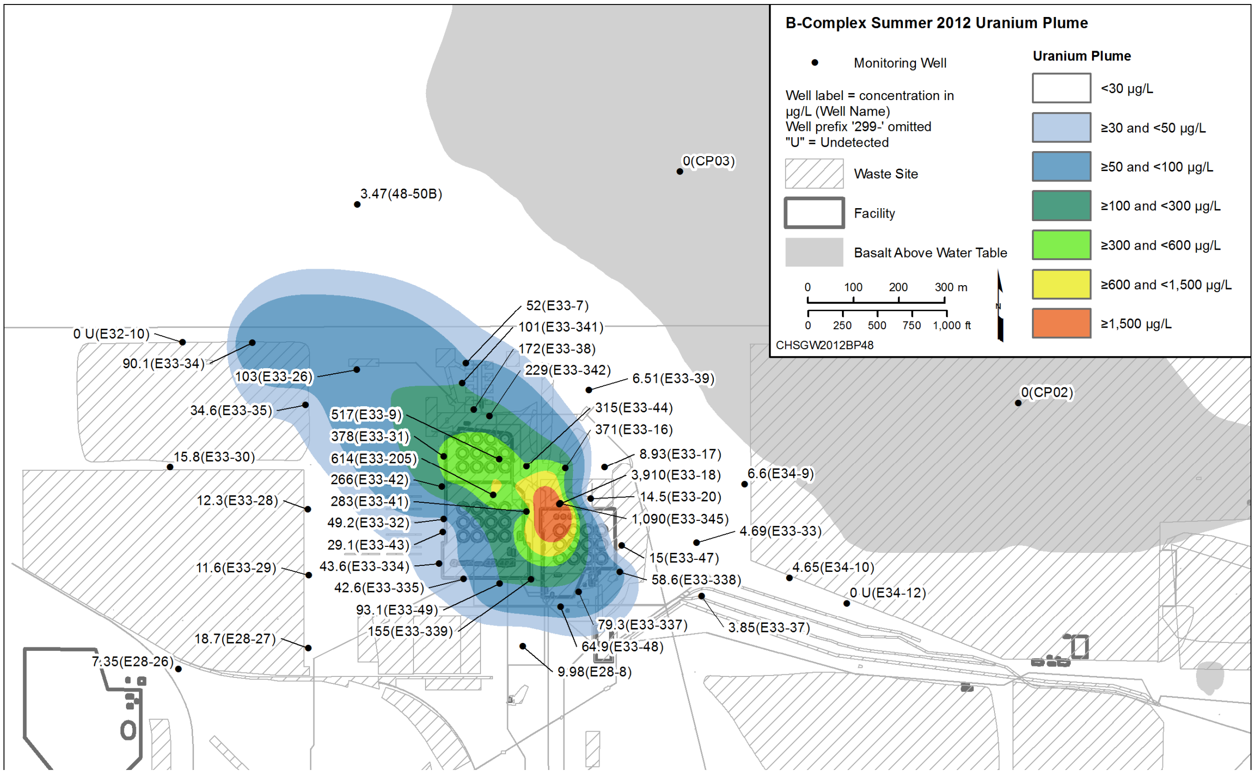


Figure 7-16. B Complex uranium plume (DOE/RL-2013-22, Rev. 0).

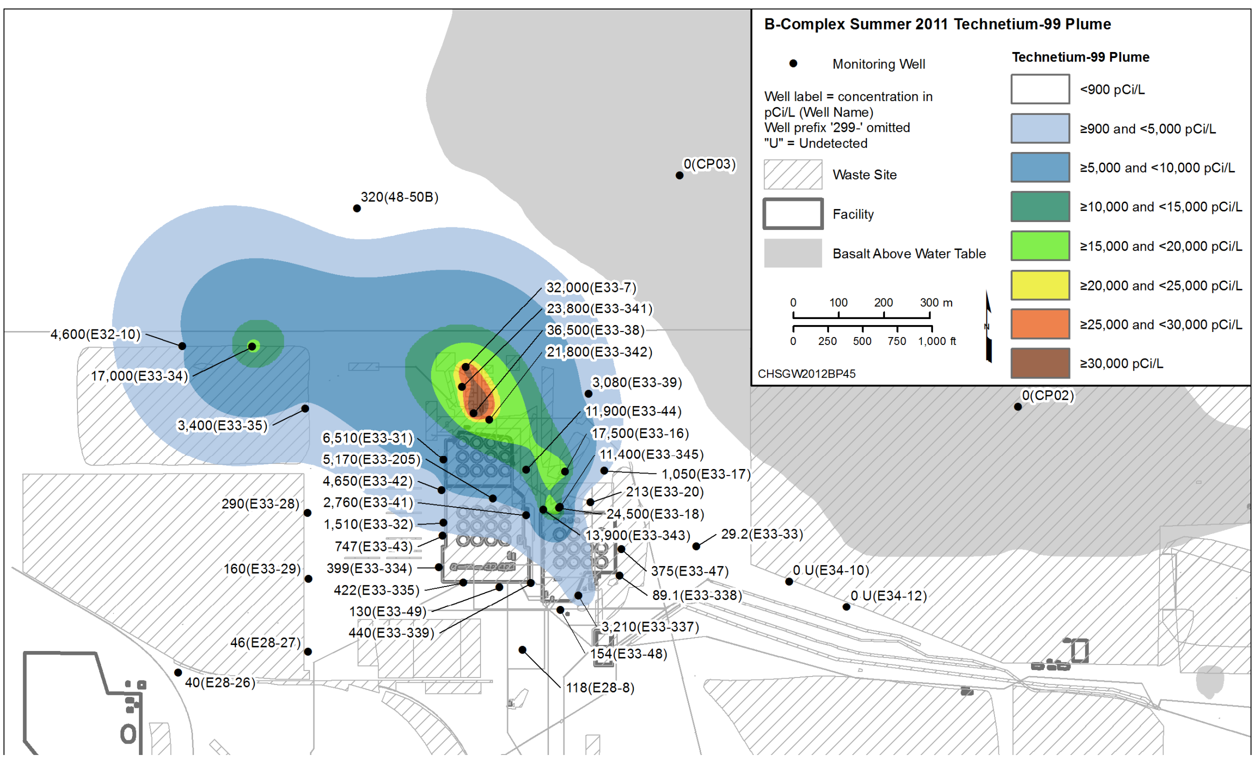


Figure 7-17. B Complex Tc-99 plume (DOE/RL-2013-22, Rev. 0).

(20) As illustrated in Figure 7-16 and Figure 7-17, groundwater concentrations exceed MCLs (also the drinking water standards) for both uranium and Tc-99 (DOE/RL-2013-22, Rev. 0).

Table 7-10. Operable Unit 200-BP-5 summary (DOE/RL-2013-22, Rev. 0).

B Plant Operations:	**1945–1952 (Plutonium separation) 1967–1985 (Strontium and Cesium recovery)**		
2012 Groundwater Monitoring			
Contaminant	**Drinking Water Standard**	**Maximum Concentration[a]**	**Plume Area[b] (km^2)**
Nitrate	45 mg/L	1,570 mg/L (299-E33-15)	7.8
Iodine-129	1 pCi/L	7.45 pCi/L (299-W27-12)	3.9
Technetium-99	900 pCi/L	35,100 pCi/L (299-E33-18)	2.3
Uranium	30 µg/L	4,470 µg/L (299-E33-18)	0.6
Strontium-90	8 pCi/L	2,400 pCi/L (299-E28-25)	0.6
Cyanide	200 µg/L	1,100 µg/L (299-E33-15)	0.2
Tritium	20,000 pCi/L	35,000 pCi/L (699-42-40A)	0.2
Remediation			
B Complex perched aquifer pump-and-treat (treatability test): • Being performed by the 200-DV-1 Operable Unit • Test successful; ~ 324,000 liters pumped in 2012 Final action 200-BP-5 record of decision scheduled for 2016.			

a. Maximum concentration within the regional unconfined aquifer (i.e., excludes the perched aquifer beneath the B Complex).
b. Estimated area above listed drinking water standard.

(21) Operable Unit 200-BP-5 corresponds to the areas surrounding the B Complex with groundwater contamination. The amount of additional groundwater impacted is estimated (GW Metric #3).

Technetium-99. When comparing plume maps for Tc-99 in Figure 7-18 (from PNNL-19277, p. 5.24 and 5.27), the 900 pCi/L contour (representing the MCL) appears to have moved about 250 m to the northwest between 2000 and 2009. These results suggest a groundwater average linear velocity of about 0.08 m/day (0.03 km/y) over this period. The plume length (900 pCi/L contour) in 2000 was about 2000 m and the width was about 400 m. Taking these as major and minor axes (*a* and *b*) of an ellipse, the area of the plume is:

$$A = \frac{\pi}{4} ab \qquad \text{7-4}$$

or approximately 0.6 km^2. If the aspect ratio of the ellipse is assumed to remain constant,

$$A = \left(\frac{\pi}{4}\right) a \left(\frac{400a}{2000}\right) = \pi a \left(\frac{a}{20}\right) \qquad \text{7-5}$$

a change in plume area with time can be estimated using

$$\frac{dA}{dt} = \frac{\pi a}{20} \frac{da}{dt} \qquad \text{7-6}$$

For the conditions between 2000 and 2009 (using an average linear velocity of 0.08 m/day or 0.03 km/yr), this indicates a rate of increase in the area of the plume of about 0.01 km^2/y. This result would be a presumptive estimate for the change in future plume areas if peak concentrations at the origin of the plume remain at about 35,000 pCi/L.

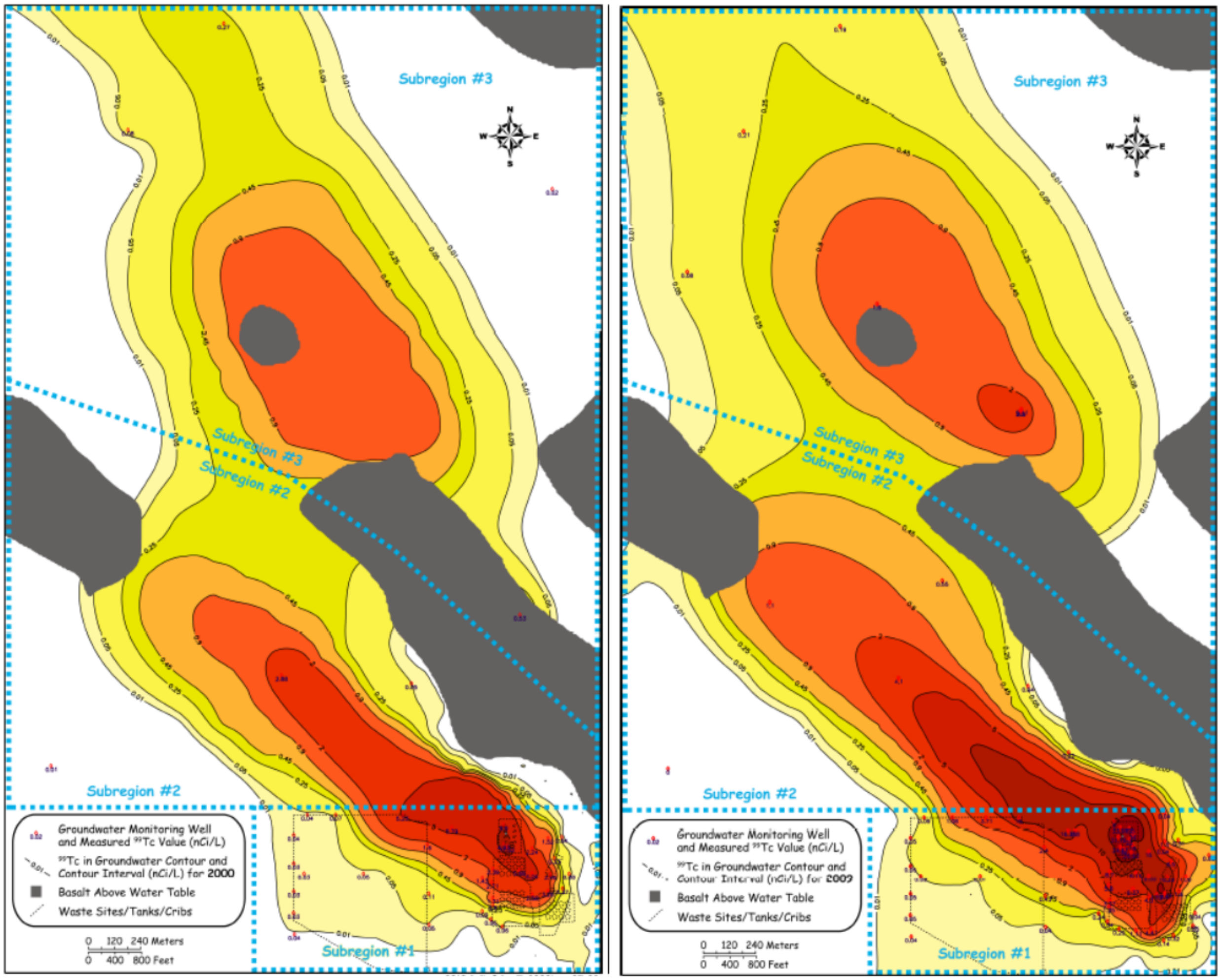


Figure 7-18. Technetium-99 (nCi/L) groundwater plume for 2000 (left) and 2009 (right) (PNNL-19277, p. 5.24 and 5.27).

Uranium. When comparing plume maps for uranium in Figure 7-19 and Figure 7-20 (from PNNL-19277, p. 5.60 and 5.63, respectively), the 30 µg/L contour (representing the MCL) appears to have moved about 680 m to the northwest between 2000 and 2009. These results suggest a groundwater average linear velocity of about 0.2 m/day (0.07 km/y) over this period. The plume length (30 µg/L contour) in 2000 was about 820 m and the width was about 165 m. Taking these as major and minor axes (*a* and *b*) of an ellipse, the area of the plume is:

$$A = \frac{\pi}{4} ab \qquad 7\text{-}7$$

or approximately 0.1 km^2. If the aspect ratio of the ellipse is assumed to remain constant,

$$A = \left(\frac{\pi}{4}\right) a \left(\frac{165a}{820}\right) = \pi a \left(\frac{a}{20}\right) \qquad 7\text{-}8$$

a change in plume area with time can be estimated using

$$\frac{dA}{dt} = \frac{\pi a}{20} \frac{da}{dt} \qquad 7\text{-}9$$

For the conditions between 2000 and 2009 (using an average linear velocity of 0.2 m/day or 0.07 km/yr), this indicates a rate of increase in the area of the plume of about 0.01 km^2/y.[24] This result would be a presumptive estimate for the change in future plume areas if peak concentrations at the origin of the plume remain at about 420,000 µg/L.

[24] Note that the projected area increase for both U and Tc-99 is approximately the same although the average linear velocity for U is higher than that for Tc-99. These results are consistent with the groundwater measurements in the Hanford Annual Groundwater Reports (http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports).

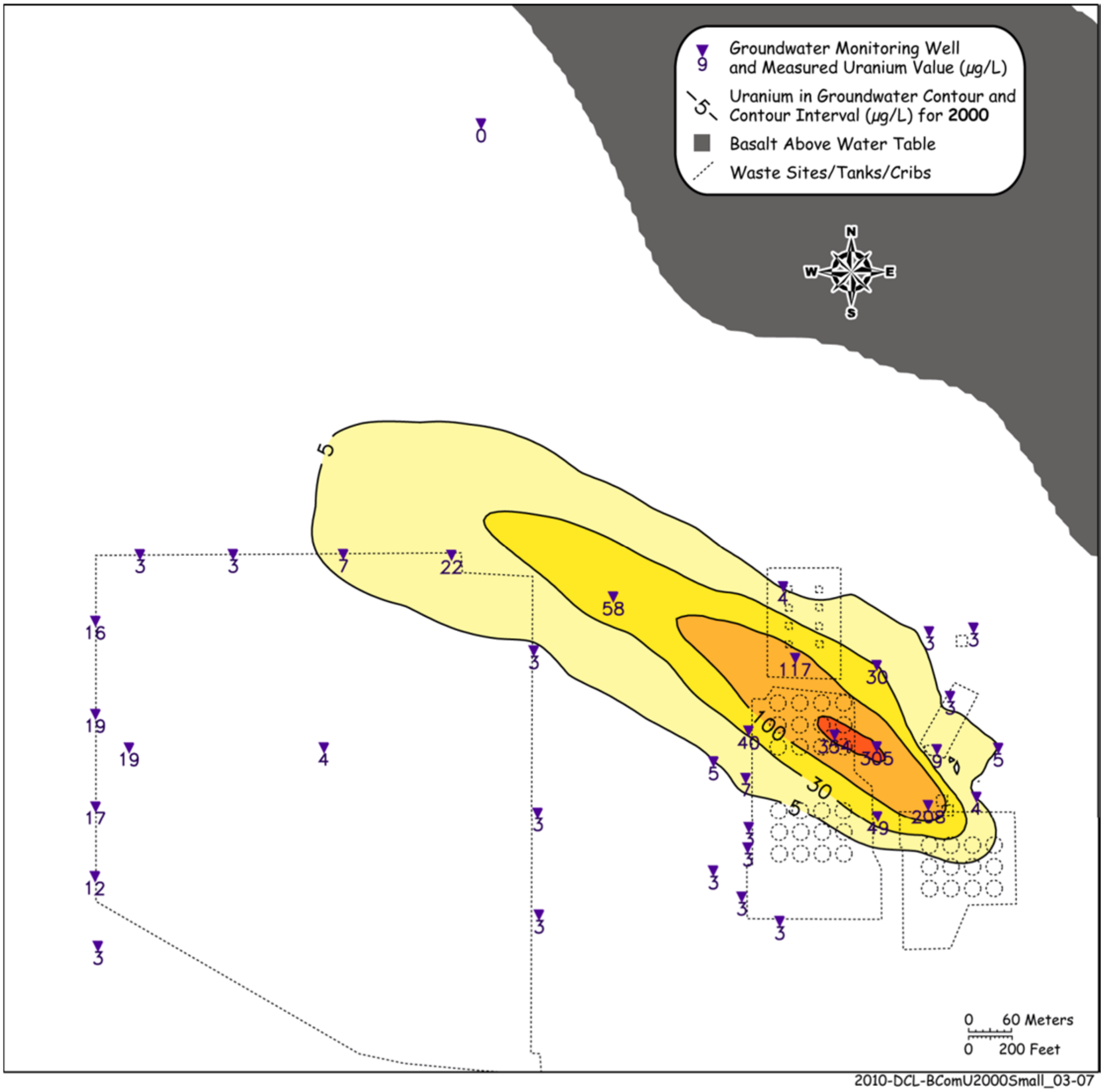


Figure 7-19. Groundwater uranium (µg/L) plume map for year 2000 (PNNL-19277, p. 5.60).

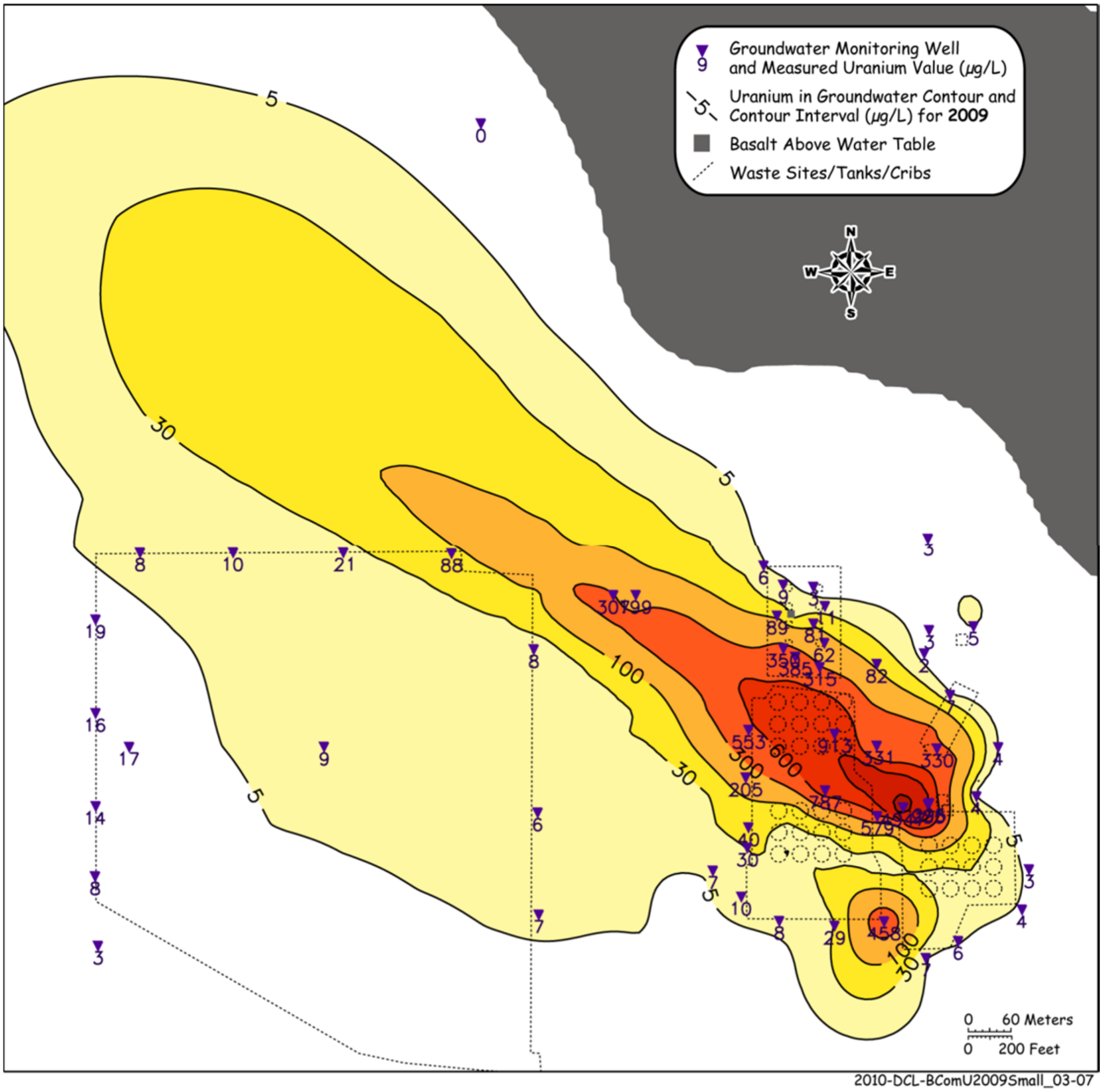


Figure 7-20. Groundwater uranium (µg/L) plume map for year 2009 (PNNL-19277, p. 5.63).

(22) The estimated time until the Columbia River is impacted (GW Metric #4) is assumed to be the time it requires for water to travel from 200-East to the Columbia River. The relatively long residence times in the Hanford saturated zone are consistent with recharge conditions for a semi-arid site; however, there is variation in expected residence times (PNNL-6415 Rev. 18, p. 4-72). Groundwater travel time from the 200 East Area to the Columbia River is currently relatively fast, ~10 to 30 years because of 1) the large recharge volume from wastewater disposed in the 200 Areas between 1944 and mid-1990s and 2) the relatively high permeability of Hanford formation sediments (that are below the water table). Travel time from the 200 West Area is longer because of the lower permeability of Ringold Formation sediments. Groundwater from the 200 West Area has moved about 6 km (3.7 mi) during the past 50 years. Travel times from the 200 Areas to the Columbia River are expected to decrease because of the reduced hydraulic gradient from the discontinued wastewater recharge in the 200 Areas.

(23-24) Discharge into the Columbia River, at a concentration above the MCL, does not occur until the MCL contour of the plumes reach the river. To arrive at a rough order of magnitude estimate (greater or less than 100 m), the spatial extent of impact to the Columbia River was evaluated by expanding the ellipse used to approximate the groundwater plumes (Equations 7-5 and 7-6, for Tc-99, and 7-8 and 7-9, for U) and noting whether the length of the intersection of the Columbia River and the expanded ellipse was greater or less than 100 m during each of the evaluation periods.

Summary of Metrics Example Case

Based on the information gathered for this demonstration, metrics were calculated and are presented in Table 7-11 and Table 7-12. The results in this section and summarized in Table 7-11 and Table 7-12 are intended to present an example of how an Evaluation Unit will be evaluated, however, the example here does not represent a full analysis of a complete evaluation unit.

Table 7-11. Summary of groundwater metrics for technetium-99, 200-East Area. [(a)]

	Current	Evaluation Periods						
		Active Cleanup (50 years, to 2064)	Near-term Post-Cleanup (100 years, to 2164)			Long-term Post-Cleanup (1000 years, to 3064)		
	50 mm/y[(b)]	50 mm/y [a]	0.5 mm/y	5 mm/y	50 mm/y	0.5 mm/y	5 mm/y	50 mm/y
Metric 1. Time to Groundwater Impact [y]	0[(c)]	0	0	0	0	0	0	0
Maximum technetium-99 flux to saturated zone [g/m^2/y].	70	70	0.5	6	70	0.5	6	70
Metric 2 and 3[(d)]. Plume Area [km^2]	0.8	>1.0	>1.0	>1.0	>1.0	>10.0	>10.0	>10.0
Metric 4. Time to Columbia River Impact [y]	300[(e)] to impact							
Metric 5a. Discharge concentration at the Columbia River [pCi/L].	0	0	0			900		
Metric 5b. Spatial extent at the Columbia River [m].	<100	<100	<100			>100		
Metric 6. Discharge flux [pCi/m^2/y] to the Columbia River.	NE	NE	NE			3[(f)]		

a. See notes on Table 7-11 in the text.
b. The current conditions are a gravel or disturbed soil cover tank farm.
c. Based on existence of a Tc-99 plume (Figure 7-17).
d. Based on Equation 7-5.
e. A distance to the Columbia River of 9 km (from the current plume location) and a plume linear expansion rate of 0.03 km/y are assumed. Time until the 900 pCi/L plume to reach the Columbia River.
f. Flux is calculated as the flow at 0.03 km/y at 900 pCi/L, the MCL of technetium-99.

Table 7-12. Summary of groundwater metrics for uranium, 200-East Area. [(a)]

	Current	Evaluation Periods						
		Active Cleanup (50 years)	Near-term Post-Cleanup (100 years)			Long-term Post-Cleanup (1000 years)		
	50 mm/y[(b)]	50 mm/y[(a)]	0.5 mm/y	5 mm/y	50 mm/y	0.5 mm/y	5 mm/y	50 mm/y
Metric 1. Time to Impact [y]	0[(c)]	0	0	0	0	0	0	0
Maximum uranium flux to saturated zone [g/m^2/y].	830	830	14	110	830	14	110	830
Metric 2 and 3[(d)]. Plume Area [km^2]	0.4	>1.0	>1.0	>1.0	>1.0	>10.0	>10.0	>10.0
Metric 4. Time to Columbia River Impact [y]	130[(e)] to impact							
Metric 5a. Discharge concentration at the Columbia River [µg/L].	0	0	30			30		
Metric 5b. Spatial extent at the Columbia River [m].	<100	<100	>100			>100		
Metric 6. Discharge flux [µg/m^2/y] to the Columbia River.	NE	NE	NE			2[(f)]		

a. See notes on Table 7-12 in the text.

a. The current conditions are a gravel or disturbed soil cover tank farm.

b. Based on existence of a uranium plume (Figure 7-16).

c. Based on Equation 7-8.

d. A distance to the Columbia River of 9 km (from the current plume location) and a plume linear expansion rate of 0.03 km/y are assumed. Time until the 30 µg/L plume to reach the Columbia River.

e. Flux is calculated as the flow at 0.07 km/y at the 30 µg/L, the MCL of uranium.

Notes for Table 7-11 and Table 7-12

Metric 1. Both technetium-99 and uranium have been detected in the groundwater (DOE/RL-2013-22, Rev. 0). Thus, the time to groundwater impact is 0 for all evaluation periods. The flux into the groundwater was calculated as described above.

Metrics 2 and 3. The amount of groundwater impacted, as an aerial extent, was determined from Equations 7-5 and 7-6, for Tc-99, and 7-8 and 7-9, for U. This assumes 1) regional groundwater flow controls the transport and dispersion of primary contaminants in the groundwater; 2) the groundwater flow remains the same as current conditions over all evaluations periods; 3) a linear expansion rate for the Tc-99 and U plume MCL contours; and 4) peak concentration levels of 35,000 pCi/L and 420,000 µg/L, for Tc-99 and U, respectively, over all evaluation periods.

Metric 4. For the calculation of the time to impacting the Columbia River the same assumptions as for Metrics 2 and 3 were used. Measurements of the shortest distance from the leading edge of the MCL contour of the groundwater plume to the Columbia River were made using PHOENIX (http://phoenix.pnnl.gov/, accessed on September 2, 2014) and were determined to be 9 km, for both the Tc-99 and U plumes from the B Complex. The linear velocity of the plume MCL contours, 0.03 and 0.07 km/y for Tc-99 and U, respectively, were determined above. The impact to the Columbia River was determined to occur during the Long-term Post-Cleanup evaluation period for Tc-99 and the Near-term Post-Cleanup evaluation period for U. Of note is that the U plume MCL contour has a greater estimated linear velocity than the Tc-99 plume, although Tc-99 is assumed to move with the groundwater flow and U has some degree of physical/chemical retention. For the period considered, these estimates agree with the groundwater measurements in the Hanford Annual Groundwater Report (DOE/RL-2013-22, Rev. 0). Also, while the groundwater flow has been measured to be on the order of 10 to 30 years from the B Complex to the river, this analysis shows that the plume MCL contours will take up to an order of magnitude longer.

Metric 5. Discharge into the Columbia River, at a concentration above the MCL, does not occur until the MCL contour of the plumes reach the river, as was determined for Metric 4. To arrive at a rough order of magnitude estimate, the spatial extent of impact to the Columbia River was evaluated by expanding the ellipse used to approximate the groundwater plumes (Equations 7-5 and 7-6, for Tc-99, and 7-8 and 7-9, for U) and noting whether the length of the intersection of the Columbia River and the expanded ellipse was greater or less than 100 m during each of the evaluation periods.

Metric 6. The flux into the Columbia River was calculated as the MCL of Tc-99 and U times the average linear velocity of the respective plumes. The flux was not estimated (NE) until the plume's MCL contour

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CHAPTER 8. EVALUATING RISKS TO ECOLOGICAL RESOURCES

ABSTRACT

The Risk Review Project evaluation of ecological resources on the Hanford Site is an independent evaluation that encompasses evaluations of site resources in comparison to the Columbia Basin Ecoregion and evaluations made by DOE, the State of Washington, the State of Oregon, Nature Conservancy, and Tribes (where available). It is a combination of using the Level of Resource Values designed by DOE (DOE/RL-96-32 2013) in conjunction with information from State of Washington, Tribes, and others, modified by landscape features (patch size, patch shape, connectivity), and exotic/alien species (% occurrence).

The risk that ecological resources experience is a function of remediation types, functional remediation parameters (e.g., number of cars, trucks, heavy equipment), and scales (temporal, spatial). Ecological resources are at risk not only from on-site activities but from the activities on nearby sites. That is people, cars and trucks moving through a non-target site to reach the target remediation site have an effect on adjacent, not-target sites. These effects can be direct (e.g., traffic and habitat disruption) and indirect (e.g., disturbance to animals, dispersal of seeds).

8.1. INTRODUCTION

Environmental assessment and management involve preserving, protecting, and enhancing ecological, human, and cultural health and well-being. Assuring well-being for ecological resources requires understanding the diversity and condition of natural resources, which range from populations of individuals of a single species to whole ecosystems. Some species are protected by law to prevent further declines and increase current population levels. The U.S. Endangered Species Act (ESA, 1973) provides legal protection and recovery efforts for plant and animal species listed as threatened or endangered. States also have lists of threatened and endangered species. Both entities list candidate species (those being considered for listing) and species of special concern (those that could become listed in the future due to their small population numbers or vulnerability). Thus, at a basic level, understanding potential impacts to endangered, threatened, and species of special concern is paramount when determining ecological risks.

At the other end of biological organization is an identifiable, vulnerable, or unique habitat or ecosystem (i.e., shrub-steppe, vernal pond, talus slope) critical to species health and well-being. While being on the Endangered Species List results in legal protection of the species, the Act also affords some protection for the habitat of listed species. In addition, there is considerable concern for sensitive or unique ecosystems (Downs et al. 1993). These are habitats most at risk, limited in quantity or extent, and often contain one or more endangered species, endemic species (species that occur only in those areas), or threatened species assemblages (e.g., migrant songbirds, breeding frogs, hibernating snakes). Unique habitats are those that are rare locally (e.g., Hanford Site) and regionally (e.g., Washington State, the Pacific Northwest). Such habitats are limited and often fragmented, and any decreases in quantity or declines in quality[1] have severe consequences.

This chapter describes key ecological aspects for the Hanford Site and the Review Project, including: 1) Major habitat types for the Hanford Site and the Columbia Basin Ecoregion; 2) Endangered and Threatened Species and species of special concern; 3) DOE's evaluation of rare, unique, and irreplaceable resources (DOE/RL-96-32 2013); 4) How remediation types affect ecological resources; and 5) The Risk Review Project's approach to evaluating potential impacts and risks to ecological resources in evaluation units[2]. The first three provide an overview of what ecological receptors are at risk in different evaluation units at Hanford, and the latter two describe Risk Review Project's approach to evaluation for these units. Habitats are described first because they are more straight-forward in that their occurrence is site-specific and can be mapped for the Hanford Site. Examination of habitat maps can identify general habitats and habitats of special or unique concern, but this must be followed by field examinations. In addition, the section below describes critical issues to consider in evaluating relative risk to ecological resources. It is important to distinguish between environmental and ecological resources. Ecological resources refer to the living component of the ecosystem. Environmental is a broader category that includes living resources, geology (soils, physiognomy), and, often, chemical plumes and levels. A facilities and land use area map is shown in Figure 8-1.

[1]Declines in quality are referred to as degradation.

[2] Evaluation units are the groupings of contaminant sources that serve as the basis for evaluation as part of this Risk Review (see Methodology for Grouping Contaminant Sources for Evaluation).

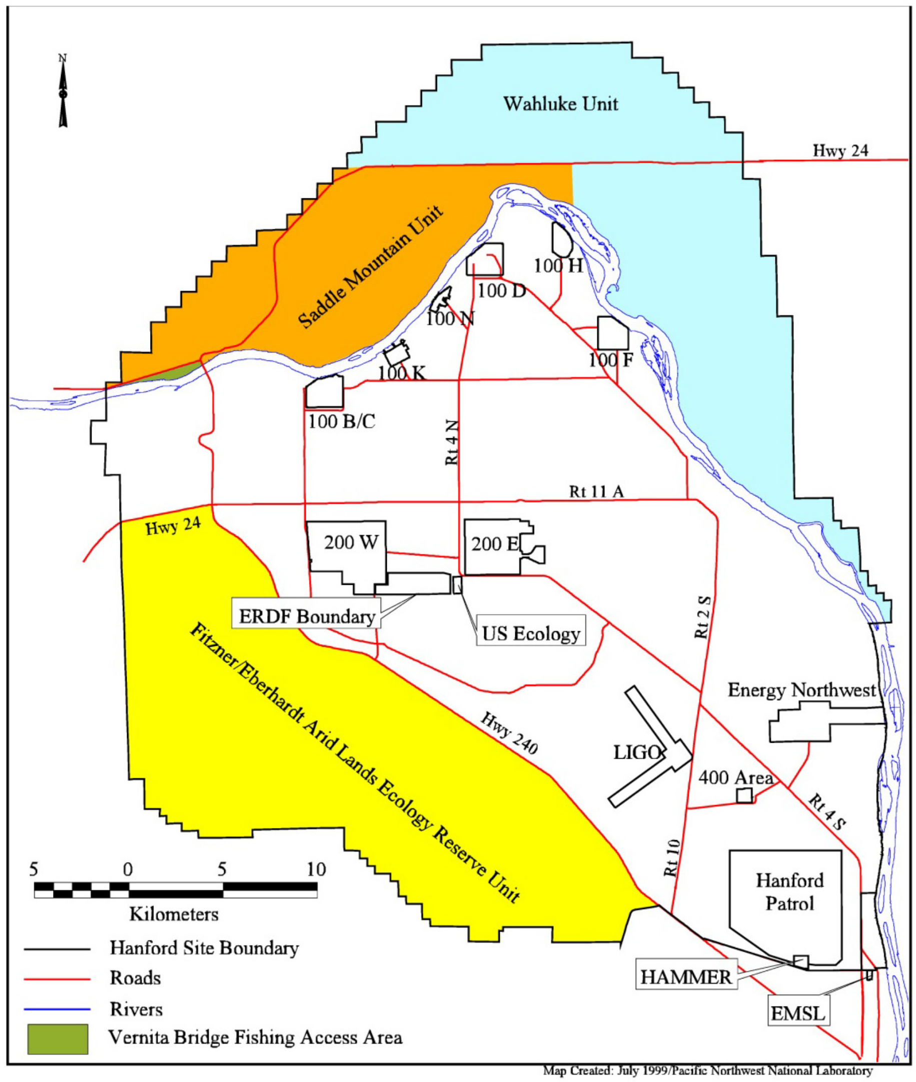

Figure D.2 Hanford Site Facilities and Land Use Areas (ERDF = Environmental Restoration Disposal Facility, LIGO = Laser Interferometer Gravitational-Wave Observatory, HAMMER = Hazardous Materials Management and Emergency Response Training Center, EMSL = Environmental Molecular Sciences Laboratory; *Energy Northwest formerly was the Washington Public Power Supply System)

Figure 8-1. Hanford Site facilities map (from DOE/RL 96-32 2001b, Appendix D).

The main factors affecting habitats on Hanford (in addition to climate and geology) are fire, exotic/alien species, human development and disturbance, and succession. Succession is the natural progression of change of vegetation types from early stages (e.g., after a fire or other perturbation) to climax vegetation (the community that occurs under the prevailing geologic and climatic conditions). Fire is one of the primary factors that sets back habitats to early successional stages. Fires on Hanford Site have burned as many as 800 km^2 (1984), and during 2000, a fire burned most of the shrub-steppe habitat on the Fitzner-Eberhardt Arid Lands Ecology Reserve (Poston & Sackschewsky 2007). Post-fire revegetation on Hanford is an important process aimed at reducing sand movement and decreasing invasion of noxious weeds (Roose et al. 2009).

8.2. RELATIVE RISK ISSUES AND UNCERTAINTIES WITH ECOLOGICAL RESOURCES

Species and ecosystems are not static, which can result in difficulties in rating vulnerabilities. Some of the issues to consider include:

1. Ascribing ecological resources to a finite, discrete location (or waste unit) is difficult because of mobility and seasonality of species (e.g., monitoring immediately before remediation is critical).
2. Some species move within habitats depending upon season (e.g., snakes and bats move to hibernation sites in the winter).
3. Species can have different life stages, requiring different habitats or locations (e.g., salmon).
4. Habitats change with ecological succession, as well as with fire, human disturbance, and human activities (e.g., early successional stages may involve grassland, while later stages may have shrubs).
5. Habitats become degraded by alien/exotic species, which can replace native ones.
6. Edge effects can be important. The value of equal acreages varies by configurations (e.g., round habitats [smaller edge to area ratio] have higher value than long thin ones).
7. The value of equal acreages varies by the number of barriers (e.g., roads, ditches, or dikes through an area) that disrupt animal movements and ecological functions.
8. Ecological risk is dependent upon the stressors (e.g., natural, man-made), especially the extent and type of remediation.
9. Ecological risk is dependent upon timing and varies before, during, and after remediation, as well as different periods in the "after remediation" phase.
10. Ecological risk can be affected by dispersal of contaminants by plants/animals (e.g., birds and mammals can carry contaminants over land, fish move contaminants in aquatic habitats, tumbleweed can carry contaminants).
11. Ecological resources are vulnerable to off-site effects from nearby remediation (e.g., building roads to get to a remediation site introduces exotic/alien species, widening a road or increasing traffic can serve as a barrier to wildlife movement).
12. Impacts to resources can be evaluated, but risk depends on the stressors and the frequency and duration of those stressors (e.g., frequent fires have a greater effect than infrequent ones, increased road traffic disrupts population movement).
13. Monitoring data on species occurrences, species abundances, and spatial patterns of habitat are not available for most species or habitats on the Hanford Site.
14. Monitoring data on alien/exotic species site-wide are not available (e.g., exotic/alien species, such as Cheatgrass (*Bromus tectorum)* and thistles).
15. Mitigation of ecological risks is part of required planning and execution of cleanup activities but the actual success of mitigation and restoration plans often is unclear for long time periods.

Thus, there are issues that relate to the nature of species and habitats (e.g., seasonal movements, population variations), those that relate to lack of data on species and habitats (e.g., lack of consistent monitoring, variations in species examined or methods of monitoring), and those that relate to impacts (e.g., nature, extent, quality and quantity of stressors; type of stressor). These factors need to be considered when doing any risk evaluation of any specific site.

In addition, plants and animals can disburse contaminant/radionuclides, ranging from food chain uptake to transference between environmental media. For example, contaminants can move from soil to plants, to atmospheric dispersion by fire or wind. At Hanford, radionuclides have been dispersed by blowing Russian thistle (*Salsola tragus*). In addition, birds and animals can transport contaminants in seeds that have attached to their fur/feathers or are deposited in their droppings. Burrowing animals can move contaminants through the soil, both horizontally and vertically, as well as introduce them to ground or surface water. In addition, contaminants can obviously adversely affect plants and animals directly, as individuals and as populations.

The following sections describe why landscape features are critical in evaluating ecological resources in any given site. The value of the "whole" is greater than the individual parts. And conversely, while losing one small habitat patch may not cause severe degradation, losing several may do so. The critical landscape features that need to be considered include patch size, patch shape, patch isolation, and connectivity among patches (Fahrig 2002; Fischer & Lindenmayer 2007). These can be defined as:

> **Patch size**: How big is the habitat? Some species require interior space far from edges to survive and reproduce (e.g., predatory mammals and secretive birds and other species may require large patches.
>
> **Patch shape**: Is the patch circular, rectangular, or long and thin? A long, thin patch has a significant amount of edge for the amount of interior habitats.
>
> **Patch isolation**: How far is the habitat type from other similar habitats and what is it surrounded by? Similarly-sized patches have different values, depending upon whether they are surrounded by urban development or another natural habitat.
>
> **Connectivity**: Are patches connected and how are they connected? Isolated patches are less valuable than similar-sized patches that are connected. Two patches of the same size that are NOT connected are less valuable that two patches of the same size that are. The latter allows animals to move between the patches. The size of the connecting corridor is important.

In addition, exotic/alien species have the potential to degrade habitats, and the degree of degradation should enter any evaluation of the value of a given habitat type. This is discussed further below.

8.3. HABITAT/ECOSYSTEMS ON THE HANFORD SITE IN A REGIONAL CONTEXT

Hanford's biological resources can be examined as part of the Columbia Basin Ecoregion. Ecoregions are regions of the United States that are defined on the basis of geology, soils, physiography, climate, vegetation, wildlife, and land use (Omernik 1987, 2004). The Columbia Basin Ecoregion occupies the area south of the Columbia River between the Cascade mountain range and the Blue Mountains in Oregon and includes about two thirds of the area east of the Cascades in Washington State (DOE/RL 96-32 2001a). Thus, ecotypes on Hanford are compared to those in the state of Washington (DOE/RL-96-32 2013) and to the state's priority habitats and species in Figure 8-2 (Azerrad et al. 2011; Rodrick & Milner 1991). Ecological resources at U.S. Department of Energy sites around the country were examined in detail in 1996 (McAllister et al. 1996). They also described both sensitive habitats and wildlife and plants species of concern (including endangered and threatened species). Yearly ecological monitoring reports for Hanford continue to describe critical resources and important/emerging issues (US Department of Energy 2013, and previous environmental monitoring reports).

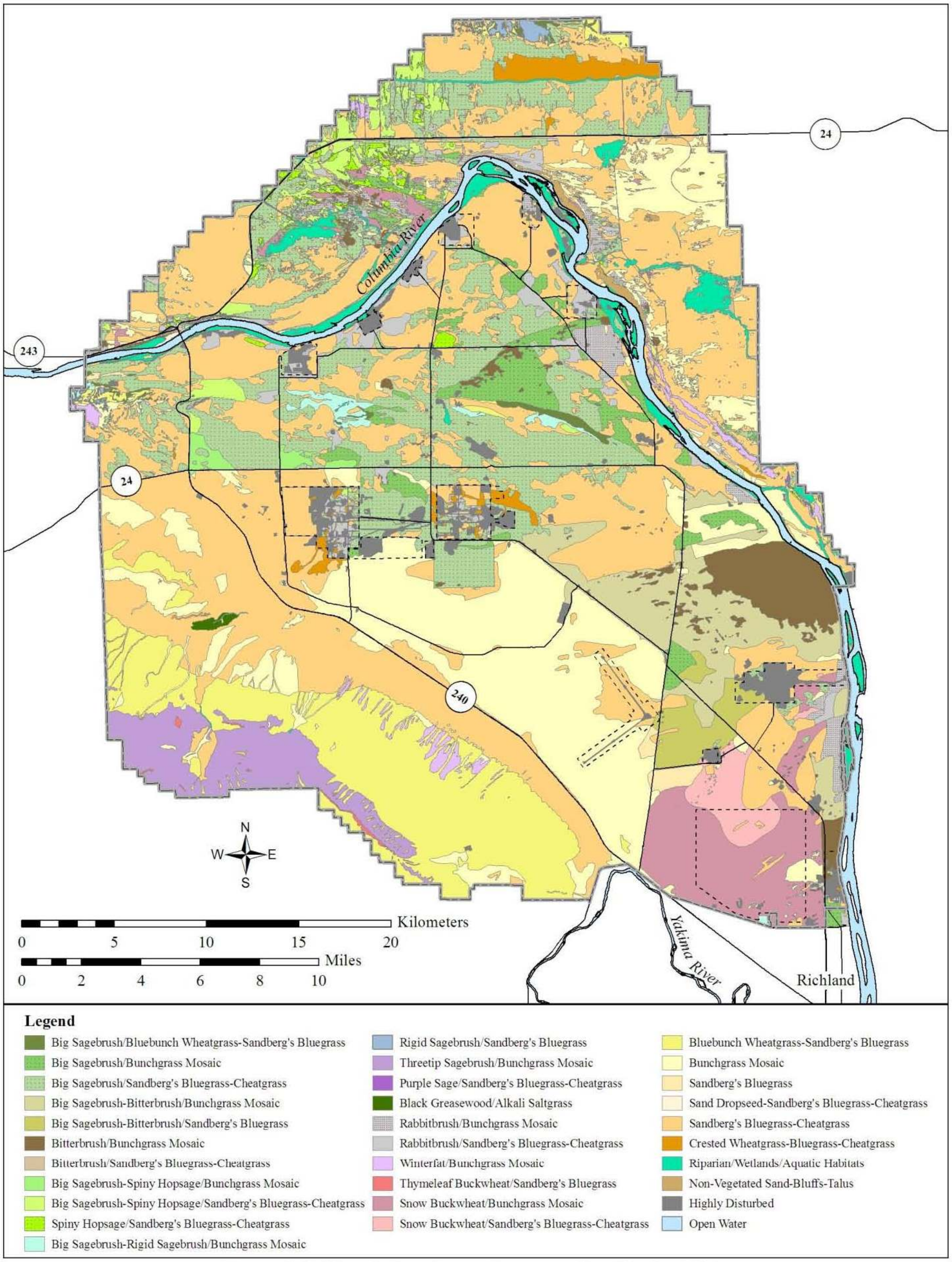

Figure 8-2. Vegetation cover types on the Hanford Site (from DOE/RL-96-32 2013, Figure 4.6, page 4.10).

The Hanford Site is in the middle of the Columbia Basin Ecoregion (DOE/RL-96-32 2013), allowing for comparisons of the habitats of the Hanford Site with the surrounding Ecoregion. Examining the relationship of current to historic habitats provides insights into what has been lost on the site, and comparisons with the Ecoregion provide information on both the relative importance of current habitats on Hanford and of those most at risk in the Ecoregion generally (Table 8-1). Those habitats indicated in red are those for which the Hanford Site has a significant proportion of regional resources, and/or they have decreased less proportionately on the Hanford Site compared to the Ecoregion.

Table 8-1. Changes in habitat types from historical records to 2001 for the Hanford Site and the Columbia Basin ecoregion. Given are habitat or cover types in the region and at Hanford, and the percent change in each over this time period. Data adapted from Appendix C of Hanford Environmental Report (DOE/RL 96-32 2001a, Table C.3 and C.4). Some of the habitat types (e.g., threetip sagebrush) were not examined (recorded) in 2001, and a direct comparison cannot be made. Rows in red indicate habitat that is particularly significant on the Hanford Site, especially in relationship to the ecoregion. Historical data were based on potential vegetation predicted to be at the end of the plant succession in the absence of human induced change.

Cover Type	Historic Ecoregion Area (ha)	Current Ecoregion Area (ha)	Historic Hanford Site Area (ha)	Current Hanford Area (ha)	% Change in Ecoregion	% Change in Hanford Site
Bluebunch wheatgrass steppe	1,028,900	431,400	612	1602	-58.1%	161.8%
Idaho fescue steppe	436,700	122,200	0	0	-72.0%	No change
Bitterbrush steppe	118,600	78,100	915	904	-34.1%	-1.2%
Big sagebrush steppe	4,096,900	1,662,400	148,902	137,834	-59.4%	-7.4%
Juniper/sagebrush	110,300	109,100	508	508	-1.1%	No change
Threetip sagebrush	746,000	0	16	0[(a)]	-100%	-100%
Black greasewood	134,900	0	503	0[(a)]	-100%	-100%
Conifers/Idaho fescue	225,000	0	0	0	-100%	-100%
Ponderosa pine	302,900	335,100	102	102	10.6	10.6%
Water	71,100	71,100	25	25	No change	No change
Other	205,500	4,667,400	0	10,612	2,171%	
Total	7,476,800	7,476,800	151,583	151,587		

a. This disappearance is likely due to not being documented in later years. 100 % decrease means it went from some amount to none (or it was not measured). The change in Bitterbrush steppe is likely non-significant because fire does not affect its presence and it currently occurs mainly on the Hanford National Monument.

The table provides an indication of the relative change on the Hanford Site compared to the region. It is also possible to look at differences that have occurred on the Hanford Site itself, which partly indicates the declining habitats on site. It is not the whole ecological picture, as percent occurrence does not indicate critical ecological features such as patch size, patch shape, interspersion of patches (including isolation and fragmentation), connectivity, and habitat corridors. For example, the same size patch (in ha) provides more protection for sensitive species if it is round rather than if it is long and thin because the latter has more edge where predators, alien/exotic species, and people/vehicles can enter and has less interior than the former. While PNNL regularly conducts surveys of alien/exotic species on their building site (Becker & Chamness 2012), these are not conducted site-wide.

In general, habitats are most at risk that are in short supply (both at Hanford Site and in the region) and habitats that have been declining most rapidly on site or in the Ecoregion (Table 8-2). Bluebunch Wheatgrass is a unique habitat that increased on Hanford but decreased markedly in the Ecoregion. Big Sagebrush steppe is also of concern because Hanford has a significant component of this habitat in the Ecoregion, and it has decreased both at Hanford and the Ecoregion (although it is still the dominant and largest habitat on the Hanford Site). Big sagebrush habitats are considered at risk even though they form a common habitat on the Hanford Site. This is a priority habitat in Washington State.

The categories listed in Table 8-1, however, are actually a mixture of different habitats – it is the major vegetation type that has defined them. Thus, much finer gradations are possible, and it is these more detailed vegetation cover types that reveal the sensitive habitats on the Hanford Site. For example, Bluebunch Wheatgrass is a native grass habitat that can be infiltrated with Cheatgrass (an exotic species), which reduces the quality of the Wheatgrass. Cheatgrass often invades from roadways, as construction allows these species to move in by disrupting the natural vegetation, soil ecosystem, and drainage (see the Hanford Site evaluation below). Shrub-steppe communities at the lowest elevation on the Hanford Site and on the Hanford National Monument are at the greatest risk of invasion of non-native plants. The Bluebunch Wheatgrass steppe communities above 800 ft are more resilient to invasion than are Big Sagebrush/Needlegrass communities.

Aquatic habitats embedded within the terrestrial environment at the Hanford Site are critical because they are so limited in space (see Table 8-1) and act as habitat islands for many species. That is, some species are limited to these regions, and the dry steppe habitat serves as a barrier to movement. In addition, many species are sedentary or have few movement options. For example, Tiger Salamander (*Ambystoma tigrinum*) will not move over very dry areas to reach another water source if its habitat is destroyed.

In addition, sections of Hanford can be considered alone, especially those managed separately, such as the Hanford Reach National Monument (US Fish and Wildlife Service 2008a). Comprehensive conservation plans have been developed for the Monument (US Fish and Wildlife Service 2008a), describing rare habitats and species.

8.4. SPECIES AND SPECIES GROUPS ON THE HANFORD SITE

Species that are listed on federal and state Endangered Species Lists and other listed species (species of special concern, candidate species) are those that must be considered in any ecological evaluation of Hanford Site resources. Of the 25 DOE sites slated for remediation/restoration as of 2007, Burger et al. (2007) reported that the Hanford Site had 8 federally endangered/threatened species compared to 7 or less for the other sites, and Hanford had 18 state-listed species (Fermi Lab had 22, all others had fewer than Hanford). This is an indication of the importance of the resources on the Hanford Site compared to other DOE sites. Although the number of habitats and number of endangered species were significantly correlated with total acreage of these DOE sites, the correlations are only 0.57 and 0.48 respectively (Burger et al. 2004). Thus, habitat and total acreage is not the whole answer to the importance of ecological resources on Hanford or any other DOE site.

The number of species on both the federal and state Endangered Species lists, however, shifts. Some species are removed and others are added (Table 8-2). This makes characterization of ecological resources more complex.

Table 8-2. Summary of number of species with listing status from 1996 to 2013 for listings of federal and the state of Washington. Given are endangered, threatened, candidate species, and species of concern (called monitored for Washington State). References are given in Table 8-13 at the end of this chapter, which is a full listing of species.

Species Group	Total #	1996 Federal	2001 Federal	2005 Federal	2013 Federal	1996 Wash.	2001 Wash.	2005 Wash.	2013 Wash
Plants	60	4	4	6	6	12	48	53	52
Invertebrates	20	2	4	2	2	0	15	19	17
Fish	10	2	4	5	5	0	6	9	10
Amphibians and reptiles	9	1	1	1	2	0	5	6	8
Birds	47	11	14	8	8	12	42	41	40
Mammals	19	7	6	1	4	1	11	11	11
TOTAL	165	27	33	23	27	25	127	139	138

Table 8-2 clearly indicates that both federal and state agencies are continually monitoring the status of species and that the list is dynamic. In some years, several species were being monitored, considered species of concern, or are federal candidate species. In the following years, species status may be clarified, and the numbers of species on the protected list declines. The full list of species with their changing status over the years is given in Table 8-13. A fuller description of federally-listed plants can be found in Sackschewsky & Downs (2001). However, the number of species that are currently federally listed at present or are listed by Washington as threatened or endangered is relatively small (Table 8-3).

The federally-endangered fish are Spring Chinook Salmon (spring run), and threatened fish are Steelhead and Bull Trout. Although Bull Trout have been reported on the Hanford Reach, its natural habitat is mountain streams (US Fish and Wildlife Service 2014). Bull Trout is also listed on the Oregon list as threatened (McAllister et al. 1996). The Peregrine Falcon, which is occasionally seen on the Hanford Site during migration, is no longer listed as a state or federal endangered species, and the Bald Eagle was considered a federally threatened species in Oregon but has "recovered" and has been removed from the Endangered Species List (US Fish and Wildlife Service 2014). The Oregon Biodiversity Information Center developed a list of rare, threatened and endangered species of Oregon (Oregon Biodiversity Information Center 2013). Table 8-3, in conjunction with the Table 8-2, indicates that although many species are being monitored or are of special concern, few are actually listed as endangered or threatened by federal US Fish and Wildlife Service or Washington State at any one time.

Table 8-3. Current (2013 data) on the number of threatened and endangered species on the Hanford Site (for a full listing, see Table 8-13 at the end of this chapter).

GROUP	Federally Listed as Endangered or Threatened	Listed as Endangered or Threatened by State of Washington	Threatened and Endangered Species in 2013
Invertebrates	0	0	
Fish	3	0	Spring Chinook Salmon, Steelhead, Bull Trout
Amphibians and reptiles	0	0	
Birds	0	4	Ferruginous Hawk, Sage Grouse, Sandhill Crane, American White Pelican
Mammals	0	0	
Plants	0	12	Great Basin Gilia, Grand Redstem, Geyer's Milkvetch, Rosy Pussypaws, Desert Dodder, White Eatonella, Awned Halfchaff Sedge, Loeflingia, Whitebluffs Bladderpod, Columbia Yellowcress, Lowland Toothcup

Exotic/alien species are considered the second largest threat to vegetation integrity at Hanford, second only to wildfires (DOE/EA-1728-F 2012), and presumably, they are important threats in the Ecoregion overall (after development). Exotic species gain a foot-hold when native vegetation (and soil) is disturbed, especially by vehicular traffic or other disruptive activities. Noxious weed seeds can lay dormant in soil for decades, and are often transported by wind, animals, vehicles, and clothing. Introduction and off-project transport of exotic plants can be minimized by inspecting vehicles and clothing, and covering trucks carrying soil. The impacts of vehicular traffic or other disruptive activities that can result in introduction of exotic species adjacent to remediation sites indicate the importance of considering the total footprint of remediation activities (not just the specific remediation site). Even remediation on industrial areas (e.g., tank farms) can have secondary effects both within the site itself and on adjacent lands (including from the development of roads to provide access), due to disruption of vegetation and soils, with increases in exotics and other noxious weed species (e.g., DOE/EIS-0391 2012).

In addition to development, fire, and exotic species, habitat fragmentation often results in the isolation of habitat patches (an important barrier to biodiversity). Connectivity of terrestrial habitats is a feature that promotes biological diversity and integrity (DOE/EA-1728-F 2012), and isolation of habitat patches should always be considered when rating risks. Physical disruptions not only affect connectivity, but also reproductive success of ground-nesting species or burrowing species (e.g., Burrowing Owls).

8.5. CURRENT HANFORD SITE ECOLOGICAL EVALUATION

Ranking of Ecological Resources by DOE

Hanford Site has been concerned about ecological resources for some time, including describing and evaluating sensitive ecosystems, as well as monitoring species of concern (Downs et al. 1993; Duncan et al. 2007). Ecological resources at selected U.S. Department of Energy sites were examined in detail in 1996 (McAllister et al. 1996). They described both sensitive habitats and wildlife and plants species of concern (including endangered and threatened species). Yearly ecological monitoring reports for Hanford continue to describe critical resources and important/emerging issues (e.g., US Department of Energy 2013). "Species of concern" includes threatened and endangered, as well as those that are vulnerable. The DOE's evaluation included detailed information from the state of Washington's significant habitat delineations (DOE/RL-96-32 2013, see section below). A detailed evaluation of species and habitats was conducted by DOE (DOE/RL-96-32 2013). Significant or rare habitats on site included desert streams, non-riverine wetlands, vernal ponds, sloughs, river islands, and open water, as well as physical features such as dunes, cliffs (White Bluffs), basalt, and outcrops (e.g., Figure 4.8 in DOE/RL-96-32 2013). Many aquatic habitats are significant because they are rare, and some species are limited to these areas or to the habitat immediately fringing these habitats.

DOE developed habitat criteria, with associated levels of concern (DOE/RL 96-32 2013, pages 5.6-5.9). While these categories are useful for planning, field research is essential to confirm or determine distribution and abundance prior to any cleanup-related activities. And, as this review and discussion points out, landscape features and exotic/alien species aspects need to be added as an overlay. The categories can be summarized as follows:

Levels of Ecological Resources (DOE/RL-96-32, 2013)

Level 5 = Irreplaceable habitat or federal threatened and endangered species (including proposed species, and species that are new to science or unique to Washington state).

Level 4 = Essential habitat for important species.

Level 3 = Important habitat.

Level 2 = Habitat with high potential for restoration[25].

Level 1 = Industrial or developed.

Level 0 = Non-native plants and animals.

The implication of this characterization is that Level 0 and 1 are of little concern, although it is imperative to take into account two factors: 1) off-site effects can occur from remediation or actions within an industrial site (e.g., through roads or exposure to exotic/alien species or fire) and 2) use of buildings by native animal species (e.g., bats can occupy buildings, posing a potential risk from demolition). Buildings, including underground facilities, can serve as roosting places for bats, including maternity colonies of *Myotis* (Lucas 2011). The presence of a maternity colony of Yuma Myotis in the 183 clearwell halted the demolition of building 183-F (Lucas 2011). Further, snakes can form dens or hibernate in buildings.

Level 1 resources are in habitats where DOE is not required to complete habitat replacement, but habitat could be restored there. There may be common native plants and animals, as well as stands of

[25] Restoration is used here in the biological sense and does not relate to the CERCLA process.

non-native plants or abandoned agricultural fields. There may be small patches of shrub-steppe surrounded by industrial areas (DOE/RL-96-32, 2013).

Level 2 resources include migratory birds and state monitored plants and animals, as well as upland stands of shrub over-story, non-native plants, and some steppe stands that co-occur with non-native plants (DOE/RL-96-32, 2031). Maps of Level 1 and Level 2 follow (Figure 8-3 and Figure 8-4). Note that in all cases, the original DOE figure number is given at the bottom to facilitate location in the original document.

Level 3 (Figure 8-5) resources are state sensitive or candidate plants and animals that may have cultural importance. There is shrub-steppe with native climax shrub overstory with native grasses below. It also includes some wetlands and riparian habitat and conservation corridors.

Level 4 (Figure 8-6) resources include state threatened or endangered species, federal candidates, upland stands with native climax shrub overstory and native grass understory, and wetlands and riparian habitats. They are designated for preservation, with avoidance/minimization of disturbance. They require habitat replacement (DOE/RL-96-32 2013). The other levels of concern are either designated as conservation (Levels 3, 2) or mission support (Levels 1, 0). Conservation areas can have habitat replacement at a less stringent level and may be areas to perform mitigation actions.

Resource Level 5 (Figure 8-7) includes not only federally-listed species, but sensitive habitats. Irreplaceable habitats included cliffs, lithosols, dune fields, ephemeral streams and vernal ponds, as well as Fall Chinook Salmon and Steelhead spawning areas (DOE/RL-96-32 2013). Rare Habitats on the Hanford Site are shown in Figure 8-8 below. Although the Hanford Site evaluation included only these as Level 5 resources, largely because they are exceedingly rare on the site, Bluebunch Wheatgrass habitats are also considered critical and unique because they are both rare on Hanford, decreasing at a more rapid rate in the Ecoregion, and are very vulnerable to Cheatgrass invasion. Shrub-steppe communities at the lowest elevation on the Hanford Site and the Hanford National Monument are at greater risk from the invasion of exotic species than are those at higher elevations. Bluebunch Wheatgrass steppe communities above 800 feet elevation are less at risk because they are more resistant to invasion by exotic species. The management goal is preservation, *with an avoidance of management actions.* Monitoring effort is high. Level 5 resources are shown in the next figure. The corridor along highway 240 is not considered a Level 5 (or 4) resource because, although the habitat climax is similar to adjacent habitat, it has Cheatgrass.

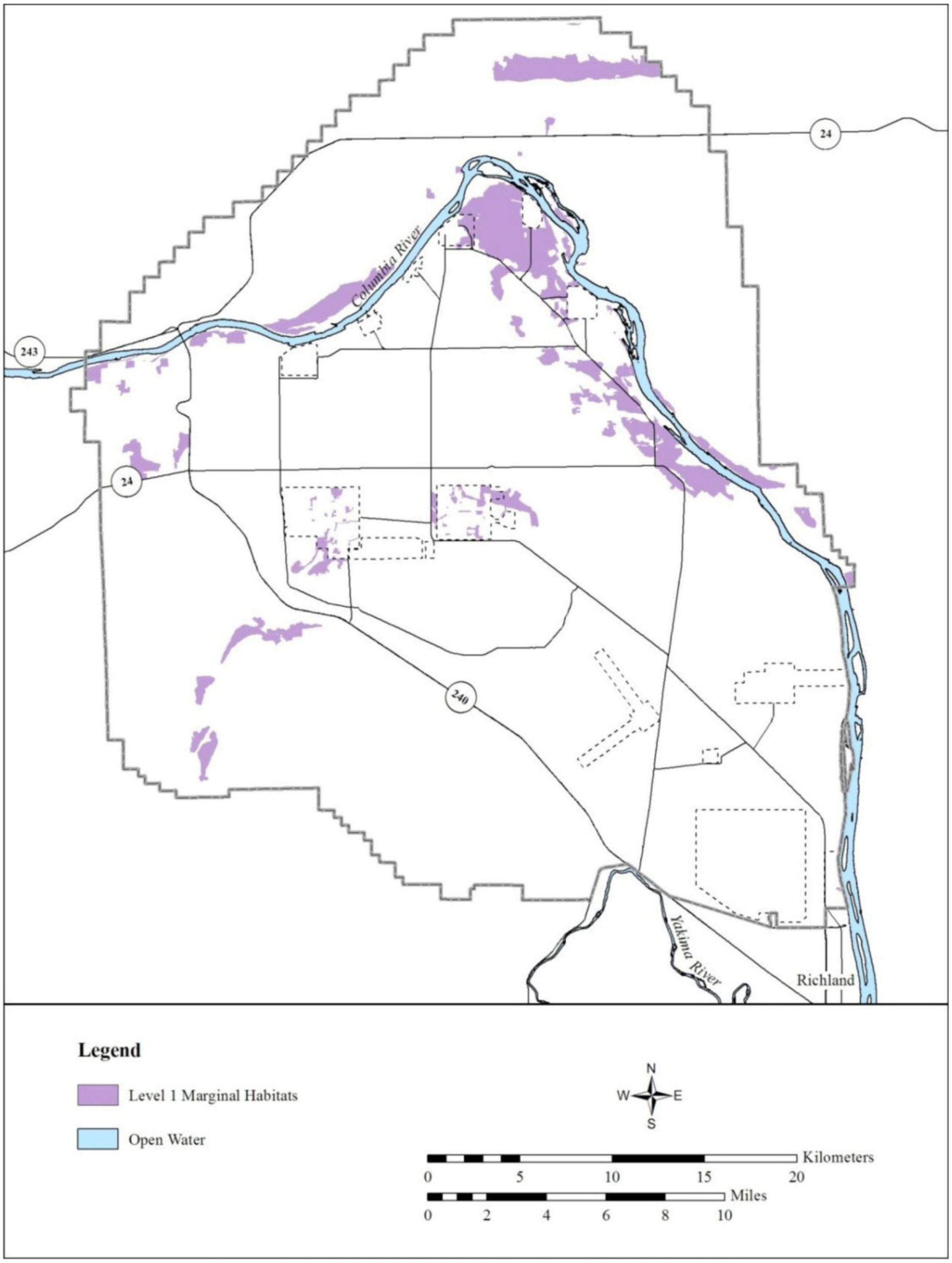

Figure 8-3. Map of Level 1 habitat types on the Hanford Site (from DOE/RL-96-32 2013, Figure 5.6, page 5.17).

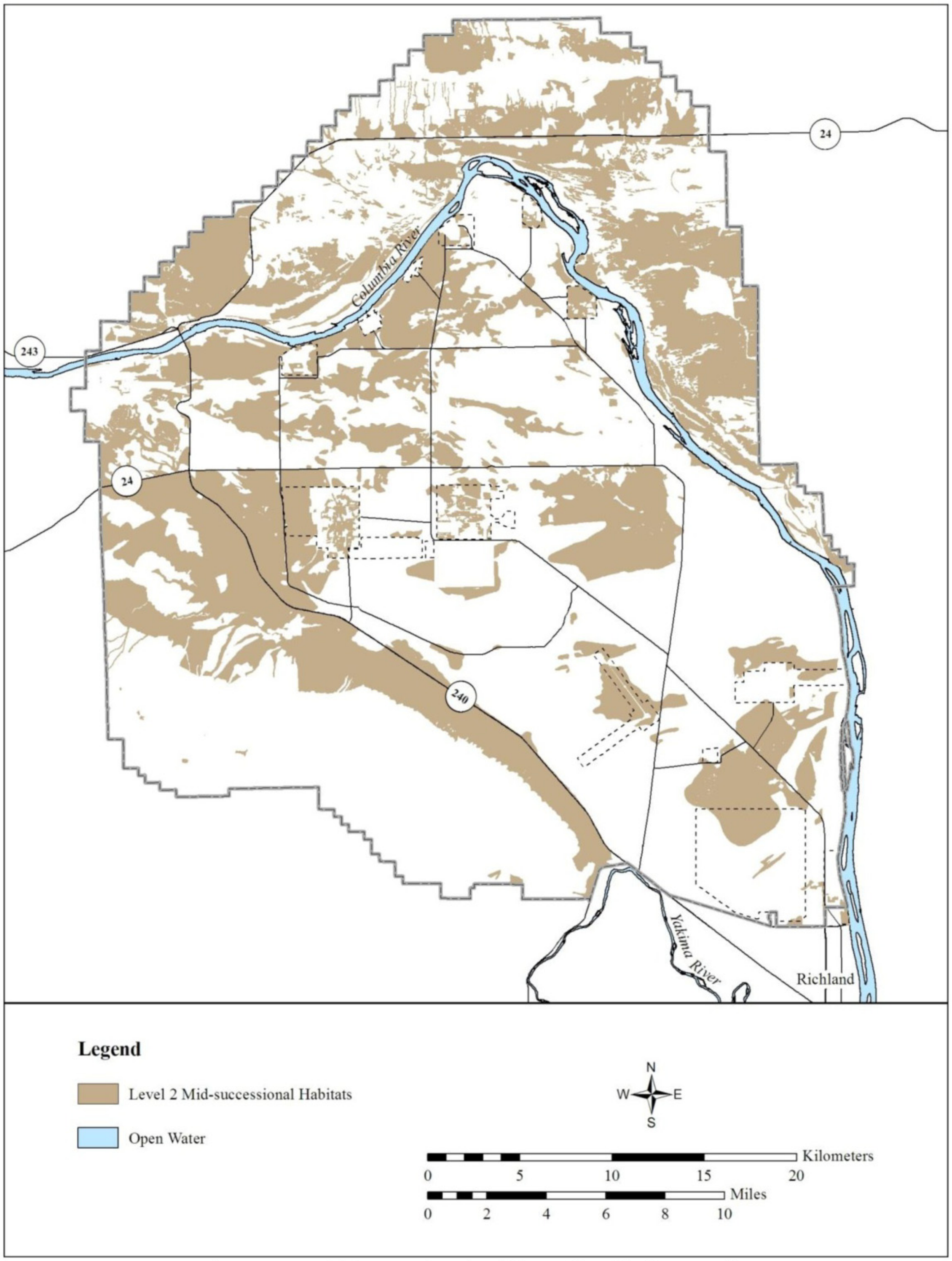

Figure 8-4. Map of mid-successional habitats classified as Level 2 (from DOE/RL-96-32 2013, Figure 5.5, page 5.16).

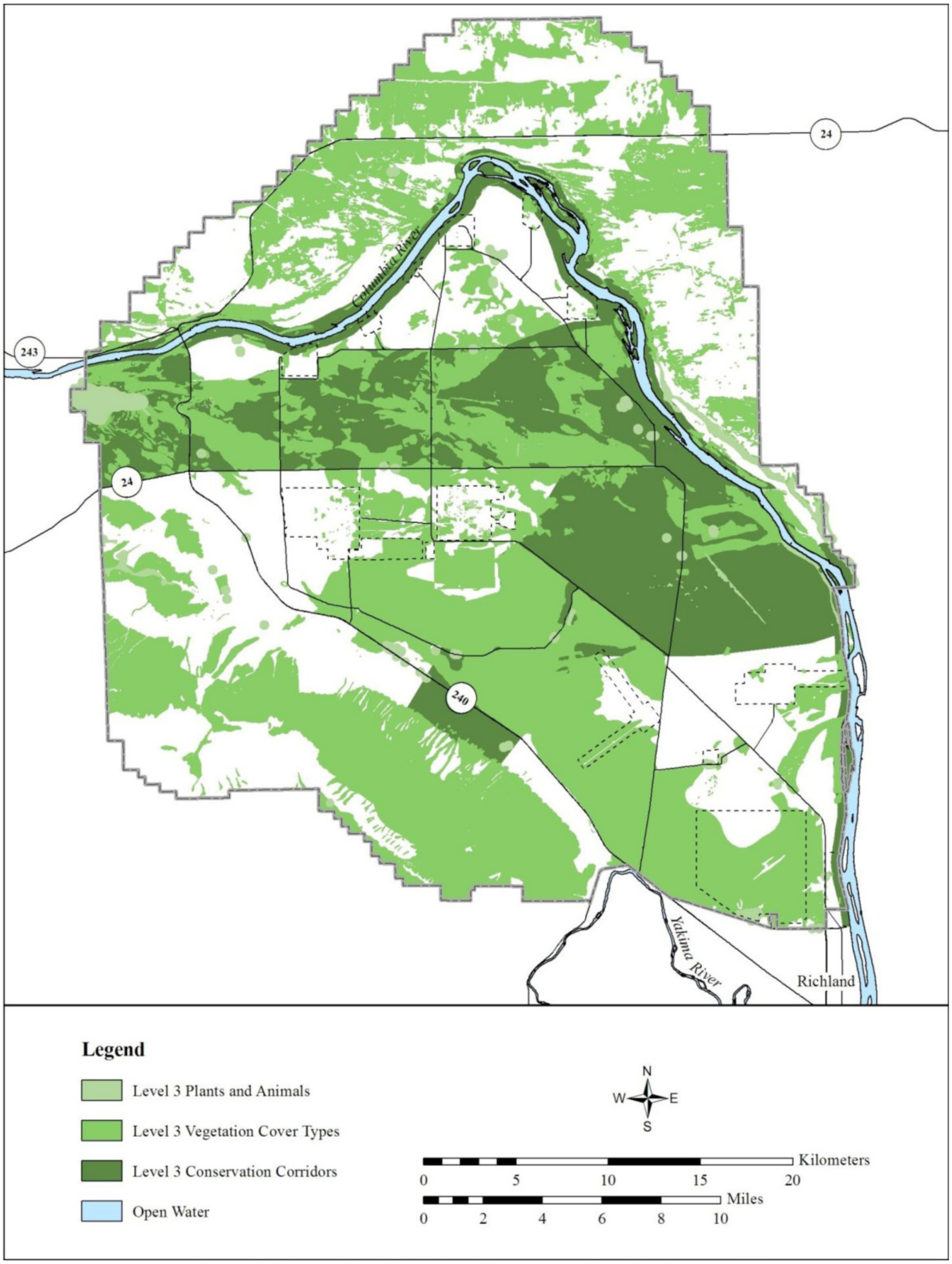

Figure 8-5. Map of important biological resources classified as Level 3 (from DOE/RL-96-32 2013 Figure 5.4, page 5.15).

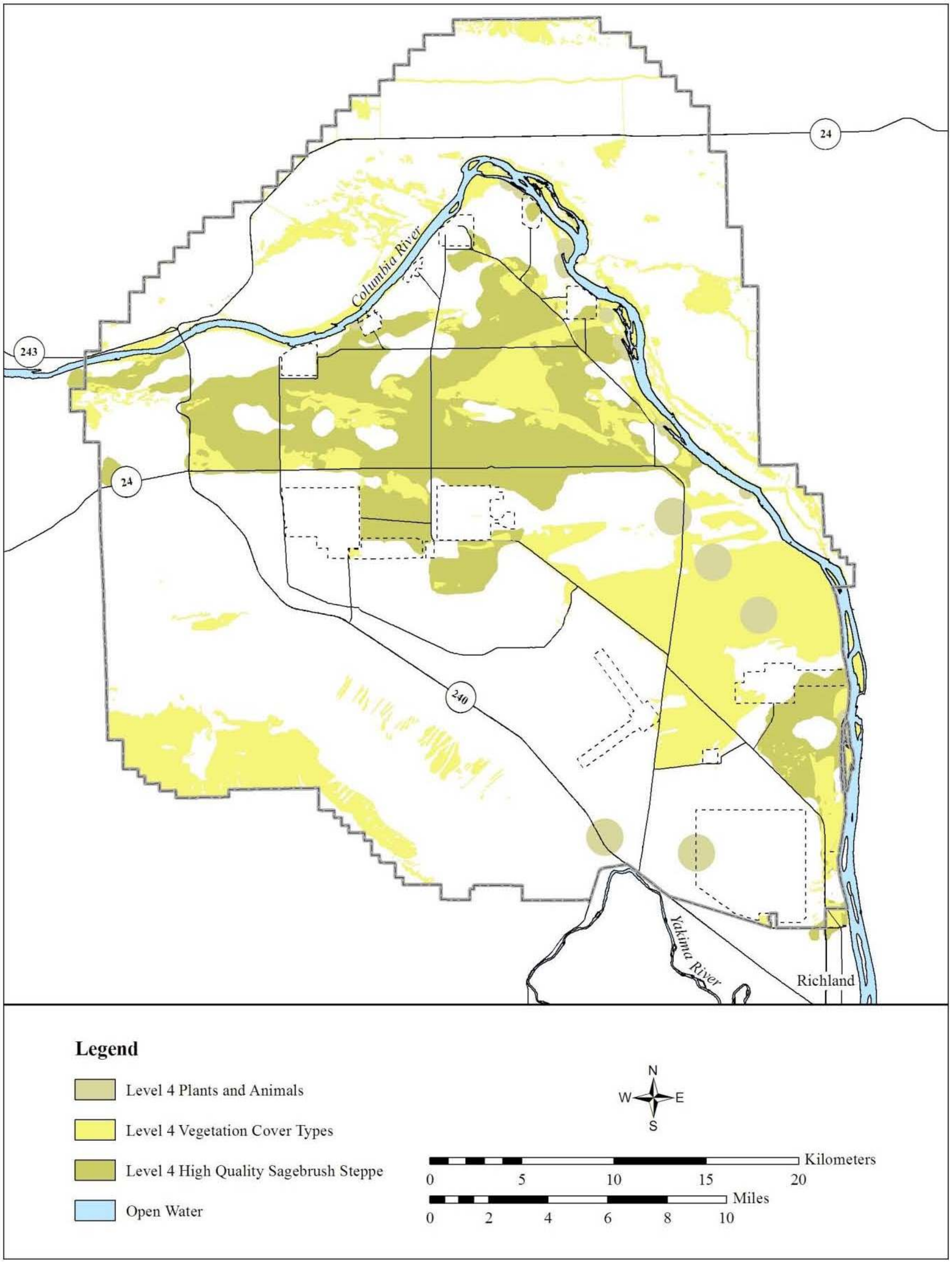

Figure 8-6. Map of DOE's (2013) evaluation of Level 4 species and unique or rare habitats (from DOE/RL-96-32 2013, Figure 5.3, page 5.14).

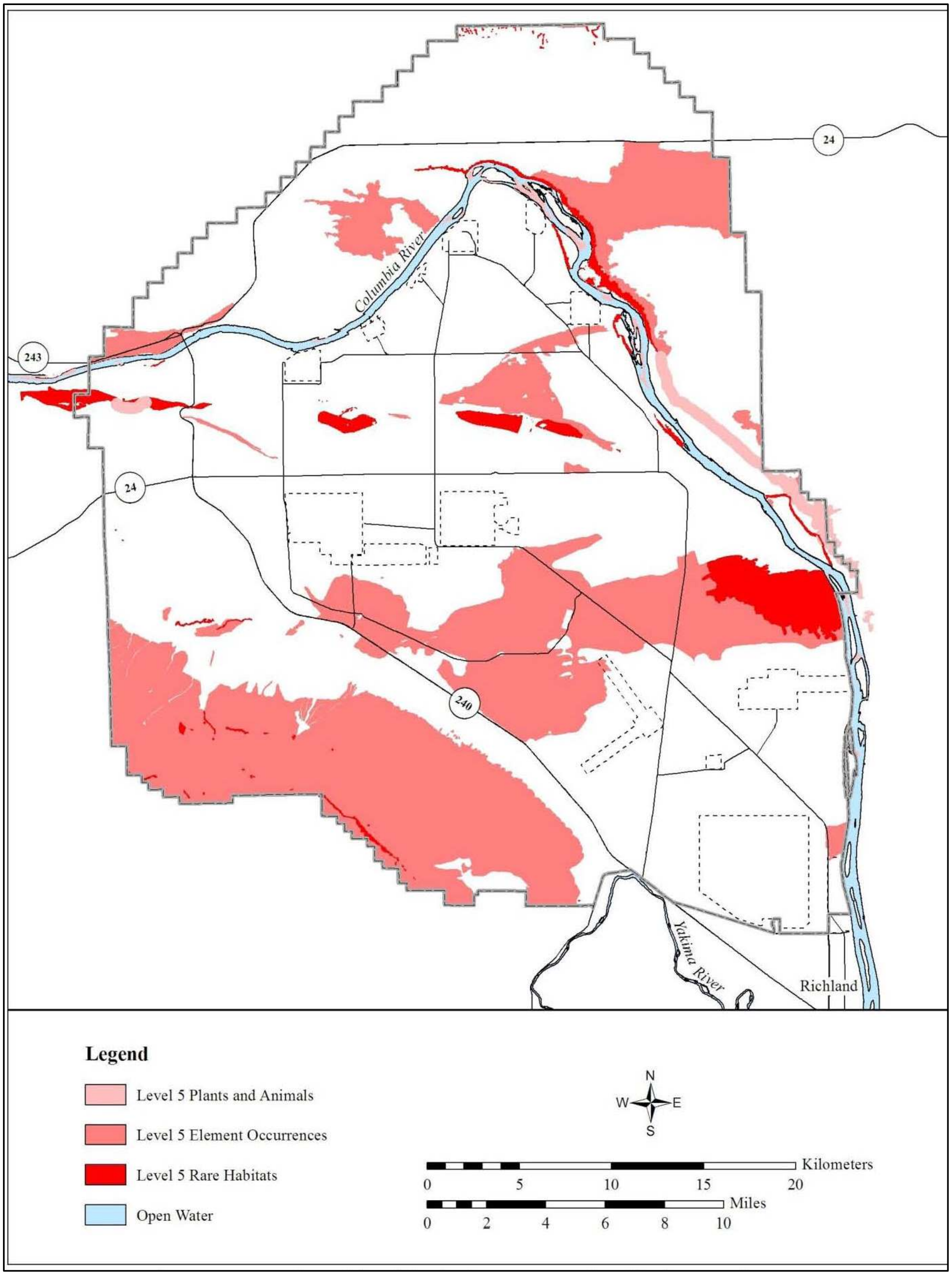

Figure 8-7. Map of resources classified as Level 5 (from DOE/RL-96-32 2013, Figure 5.2, page 5.13).

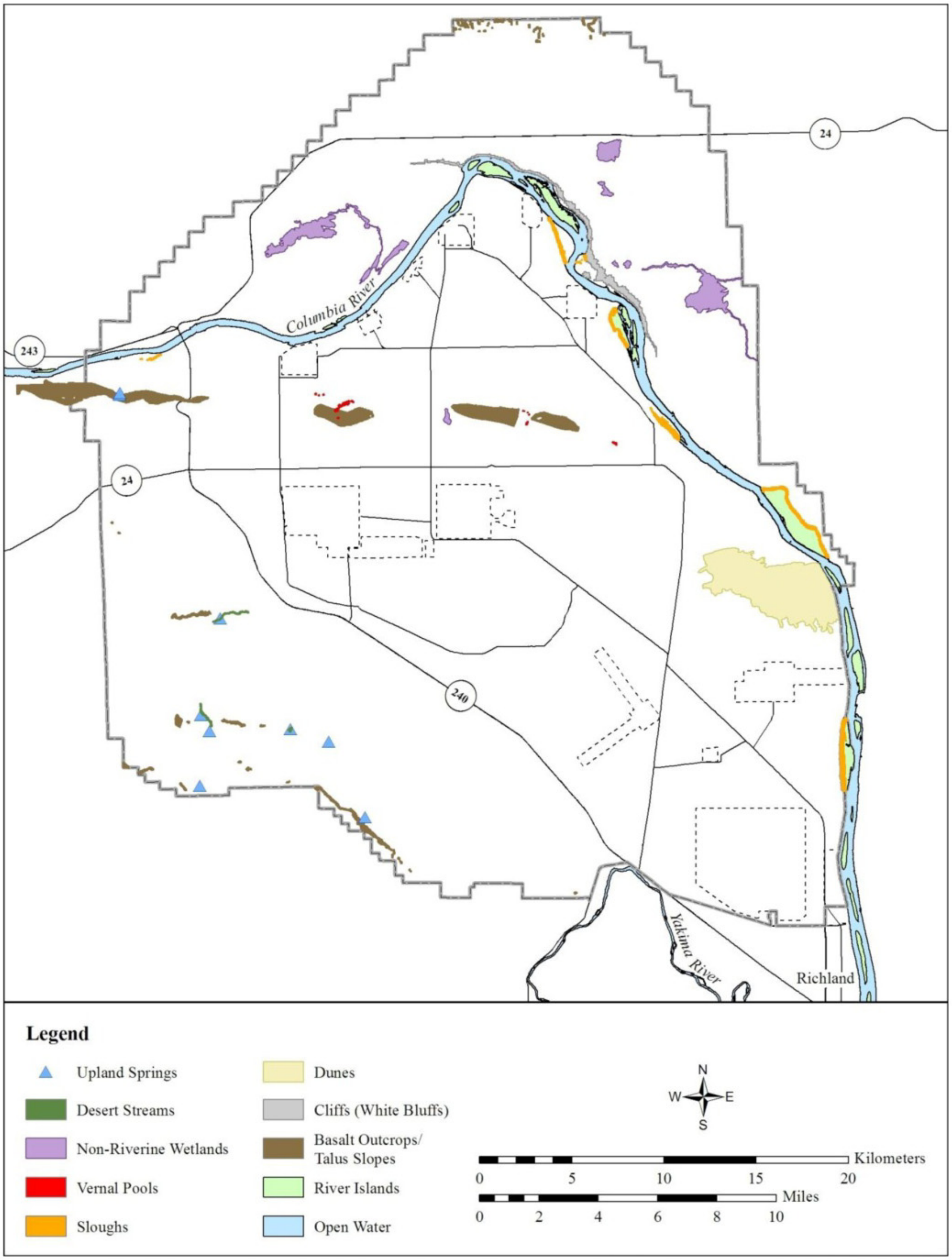

Figure 8-8. Significant or rare habitats on the Hanford Site (from DOE/RL-96-32 2013, Figure 4.8, page 4.14).

Key resources are those that were evaluated as Level 4 (essential, Figure 5.3 of DOE/RL-96-32 2013 report) and as Level 5 (irreplaceable, Figure 5.2 of DOE/RL-96-32 2013). These provide information on resources as risk and take into account the quality of the resources, not just the presence. In the case of vegetation, one of the primary degradation features is the presence (and extensive presence) of exotic species (e.g., Cheatgrass).

For the purposes of the evaluation as part of the Risk Review Project, it is the Level 4 and 5 resources that are of greatest concern because they reflect both species of high concern/value and ecosystems of high concern/value. In both cases, such endpoints are both rare and vulnerable. It is important to remember, however, that Level 3 resources are also important for preservation because they contain important shrub/steppe habitat. During the rating for all levels, additional landscape features need to be considered, including patch size and shape, and connectivity, as well as exotic and alien species.

EVALUATIONS BY OTHER ENTITIES OF ECOLOGICAL RESOURCES ON THE HANFORD SITE

The state of Washington also has established priority habitats and species (Washington Department of Fish and Wildlife 2008; DOE/RL 96-32 2001b). These are defined as those "habitat types or elements with unique or significant value to a diverse assemblage of species" (DOE/RL 96-32 2001b, page D.17). The state ecosystem evaluations are slightly different from DOE's, but they are basically similar. To be classified as high priority, habitats must have one or more of the following:

- Comparatively high fish and wildlife density
- Comparatively high fish and wildlife species diversity
- Important fish and wildlife breeding habitat
- Important fish and wildlife seasonal ranges
- Important fish and wildlife movement corridors
- Limited availability
- High vulnerability to habitat alteration
- Unique or dependent species

They used these categories to create a Hanford Site map of habitats of concern (Figure 8-9 and Figure 8-10), which is similar, although more inclusive, than Hanford's Level 4 and 5 maps. Further, the state maps were taken into account when determining DOE's Levels of Concern (DOE/RL-96-32 2013, pages 5.6-5.9). Areas of Concern as designated by Washington, and DOE's areas with Level 4 and 5 resources can be used in conjunction with a Site Facilities Map to assess which resources are at risk (Figure 8-1).

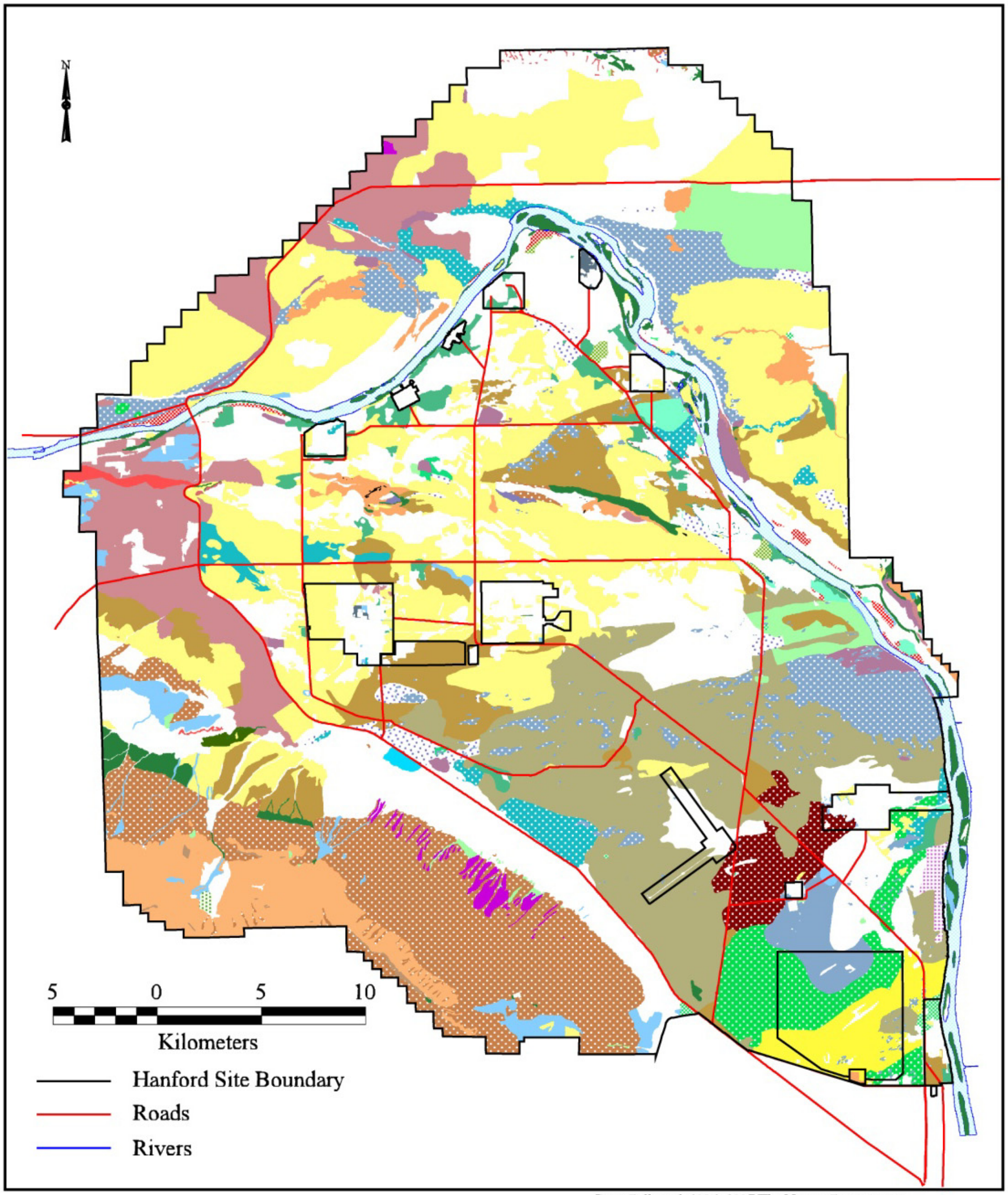

Figure 8-9. Habitats of concern for the Hanford Site, based on the state of Washington's evaluation (OE/RL 96-32 2001b, page D.18).

Figure D.12 Habitats of Concern for the Hanford Site (Legend)

Figure 8-10. Legend for Figure 8-9 (DOE/RL 96-32 2001b, page D.19).

Other evaluations of ecological resources should be considered, including those of the Nature Conservancy, the four Tribes, and recreational or commercial users of resources. Nature Conservancy has conducted a number of evaluations at Hanford, mainly concentrating on biodiversity (Soll et al. 1999; Evans et al. 2003), but they also described rare communities, as well as plants and wildlife at risk. Nature Conservancy and DOE are in the process of creating a new vegetation map for Hanford which may require new rating for Level 1-5 resources.

The four main Tribes with interests in the Hanford Site have both species of concern and habitats/locations of interest, even though these may not be formally catalogued or published. Further, ecological resources of high value (e.g., Level 4 and 5 resources) have additional cultural value to Native Americans since ecological resources are often important components of Native traditional/cultural places (Burger et al., 2008). While many of these do not explicitly involve ecological resources, several require them either for goods and services (food, herbs, medicines, or fiber) or for aesthetic/religious purposes (e.g., view-sheds, specific geological features). Although not the main subject of this section, it should be noted that ecological resources intersect cultural resource evaluations (US Fish and Wildlife Service 2008b), especially for tribal members. Ecological and cultural resources of Tribes have both spatial and temporal patterns, and tribal members recognize use of specific ecological resources in all 12 months (Bohnee et al. 2011). Further, it is often a combination of habitats, over a large spatial area, that provide for important view-sheds, cultural places, or religious places.

Finally, there are species that are of especial interest *recreationally and commercially*. A list is shown below (Table 8-4). Recreational uses include hunting (game birds, wild game) and fishing. Salmon are an iconic and important species in the Columbia River tribally, commercially, and recreationally. Chinook Salmon and steelhead are an integral part of tribal culture. The economic value of these ecological resources is not examined here, but these species are also of interest to tribal members. This list, as well as those species of interest to the Tribes, qualifies as cultural resources that are dependent upon ecological resources, and are described more fully in the Chapter 9.

8.6. METHODOLOGY FOR EVALUATING ECOLOGICAL RESOURCES

Developing the Risk Review Project methodology includes considering potential effects of remediation, conducting additional field work to assess current ecological resource levels, and formulating an overall paradigm that makes use of DOE's resource level designations (DOE/RL-96-32, 2013), and field assessments.

POTENTIAL EFFECTS ON ECOLOGICAL RESOURCES FROM REMEDIATION

Previous sections described the ecological resources on the Hanford Site, both regionally and internally. This section examines the potential effects of remediation, and functional aspects of remediation on ecological resources. Contaminants (radionuclides or other contaminants of concern) can affect aquatic and terrestrial ecosystems. Very high levels of direct radiation exposure can sterilize an area, while lower levels may have inhibitory or stimulatory effects on plant growth. Exposure to radiologic or chemical contaminants may occur through root uptake from water or surface deposition prior to, during or after remediation, and may cause adverse effects on some plant and animal individuals, populations, and associated ecosystems. Given the relatively low levels of surface contamination over most of the site, the long period of recovery from potentially high exposures during the Manhattan Project, and the natural recovery (resiliency) of biota, plant and animal communities on Hanford appear to show relatively little documentable effects from contaminants (particularly on most of the non-industrial sites). Remediation, however, may result in increased exposure to contaminants due to disruption of soil or water. Further, the risk to people who consume plants or animals from the site needs to be considered. Such risk assessments should be conducted periodically.

Table 8-4. Species of recreational and commercial interest found on or near the Hanford Site (DOE/RL 96-32 2001b, page D.86).

SPECIES	HABITAT
Chukar	Upper elevations
Ring-necked Pheasant	Riparian
White-tailed Jackrabbit	Upper elevations of ALE
Mink	Riparian and Columbia River
Rocky Mountain Elk	ALE
Rocky Mountain Mule Deer	Entire site
White Sturgeon	Deep pools and main channel, Columbia River
Channel Catfish	Slack areas near McNary Pool
Fall Chinook Salmon	Life-stage dependent, Columbia River
Coho Salmon	Main channel of Columbia River
Rainbow Trout/steelhead	Main channel of Columbia River
Sockeye Salmon	Main channel of Columbia River
Largemouth Bass	Sloughs of Hanford Reach
Smallmouth Bass	Sloughs of the Hanford Reach
Walleye	Main channel of Columbia River

Remediation includes types of remediation practices occurring on Hanford. Functional aspects of remediation are defined here as the salient features that affect ecological resources (e.g., people, cars, trucks, heavy equipment). These entities can be common to many different types of remediation, and can be combined differently as a function of remediation type. Also discussed are temporal aspects (during and after remediation), and the relationship to future land use. Remediation activities are a specific class of human activities that can affect the health and well-being of ecological resources. These must be considered in evaluating risk to ecological resources, since in essence, without remediation (or other on-site human activities), ecological resources generally are not at risk from anthropogenic activities. It should be noted that normally when a site is slated for remediation, both ecologists and cultural personnel are involved in the planning and execution.

Resources can be categorized as a function of importance and rarity on a scale from 1-5, where Level 5 are unique habitats and federal endangered/threatened species (after DOE/RL-96-32 2013). These levels of resources, with maps for their distribution on the Hanford Site, are described in the previous section. The main method of rating potential impacts to ecological resources for the purpose of this Risk Review includes a combination of Table 8-5 and the modifications that follow.

Table 8-5. Ecological risk by remediation type during clean-up and remediation. Levels refer to an evaluation of ecological resources, including unique/sensitive habitats and endangered/threatened species at Level 5, and few resources at Level 1. The matrix considers the quality of the resources currently present, and the activities associated with the remediation action. Quality includes integrity measures such as exotic/alien species, patch size and shape, and isolation and connectivity, and must be part of the evaluation when determining the level of risk rating that will be ascribed for each cleanup type.

REMEDIATION TYPE	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
Natural Attenuation	ND	ND	Low	Low	Medium
In-Situ Containment (Capping)	ND	ND-Medium	Low-Medium	Medium	High
Pump and Treat	ND	Low	Low	Medium	High
In-Situ Treatment (grouting, permeable barriers)	Low	Low	Medium	High	High
D & D (Take down building)	Low	Medium	High	High	Very High
Excavation	Low- Medium	High	Very High	Very High	Very High

Note: The ecological impact to resources at the borrow pits is not included in these evaluations. Restoration of the evaluation unit is assumed to be part of the remediation action, particularly for excavation sites.

KEY TO RISK RATING:

ND = not discernible from the surrounding conditions; no additional risk

Low = Little risk to disrupt or impact ecological resources.

Medium = Potential to disrupt or impair ecological resources, but the remedial action is not expected to disrupt communities permanently.

High – Likely to disrupt and impair ecological resources of high value (e.g., Level 3-5) or resources that have restoration potential, and can cause permanent disruption.

Very High – Very high probability of impairing (or destroying) ecological resources of high value that have typical (and healthy) shrub-steppe species, low percent of exotic species, and may have federally listed species. Likely results in permanent destruction or degradation of habitat.

These risks ratings are thus based on the degree of physical disruption (and potential additional exposure to contaminants) as a result of remediation options. Increase in personnel, vehicles, heavy equipment, and hoses causes injury or death to resident plants and animals. In addition, creation of lay-down areas for equipment, storage, and transfer can have major effects. Some of these areas, newly created for remediation, can be quite large and usually occur on adjacent places not slated for remediation. Where Level 4 and 5 resources are concerned, these disruptions can cause long-term or permanent effects.

Quality of a specific patch of habitat should be assessed with two additional factors: 1) presence or amount of exotic/alien species, and 2) landscape features (patch size, patch shape, connectivity). Thus, a low quality Level 5 resources may be equivalent to a high quality Level 4 resource. This might happen if a patch of Level 5 resource has a high amount of exotic/alien species and is small, while a patch of Level 4 resource is large, with no exotic/alien species, and is connected to other Level 4 or 5 resource habitats.

While the above designations shown in Table 8-5 are useful, in reality, each type of remediation varies by both the intensity and extent of activity. Any of them can involve few vehicles or people on site, or a great number of people and vehicles on site, for a long or short period of time. Further, these activities need to be evaluated both on the remediation site and on adjacent lands as the latter may be more pristine and thus more at risk in terms of ecological resource value. The following table (Table 8-6) examines and describes ecological effects as a result of functional remediation activities. Ecological damages are a function of both direct (i.e., destruction or degradation of plants or animals) or indirect (i.e., inadvertent introduction of seeds) effects. Further, they involve cascading effects (where an effect on one species has further effects on species that depend on it). For example, if the population of particular predator (A) decreases rapidly, another predator (B) may increase because the overall prey population is higher (due to a decline in predator A). Further, prey populations released from the predator pressure from A, may increase relative to other prey populations, and so on. Thus, resources can be rated initially based on the resource level maps, followed by field examination to determine if the resources should be upgraded or downgrades depending upon current conditions, the landscape features, and percent exotic/alien species.

Further, although there are recognized remediation types, functional remediation activities can be described. These include the actual agents that can cause damage to ecological resources, such as people, trucks, drill rigs, heavy equipment, and large hoses. These can be combined at any one remediation site, both in quantity and spatial activity. Further, while not a functional remediation type, the potential for increased exposure to radionuclides or other contaminants during remediation needs to be considered (and is thus added to the table).

Table 8-6. Potential effects of functional remediation/clean-up activities and risk to ecological resources (during Active Cleanup, until 2064). This list is arranged from lowest to highest risks. This list is arranged from lowest to highest risks. Note that movement of seeds includes both native and non-native exotic/alien species. To some extent the effects increase down the list.

TYPE OF DISTURBANCE FROM REMEDIATION	ECOLOGICAL EFFECTS
Personnel traffic through non-target area	Carry seeds or propagules (pieces of vegetation or other biological parts that can grow and/or reproduce) on person (boots, clothes, equipment); injure vegetation or small invertebrates or small animals (e.g., insects, snakes); make paths or compact soil.
Personnel traffic through target (remediation) area	All of the above, but to a greater extent
Car traffic adjacent to the site	Carry seeds or propagules on tires, injure or kill vegetation or animals, make paths, greater compaction of soil, scare or displace animals.
Car traffic through remediation site	All of the above, but of greater extent. Also can create permanent or long-term trails and compaction; can impact animal behavior or reproductive success.
Truck traffic on roads through non-target area	Carry seeds or propagules on tires, injure or kill vegetation or animals, make paths, greater compaction of soil, scare or displace animals. Also seeds and propagules from soil from truck or blowing from filled dump trunks. Affect animals dispersion and habitat use (e.g., some birds avoid nesting near roads because of song masking). Traffic is usually on established roads.
Truck traffic on roads through remediation site	Carry seeds or propagules on tires, injure or kill vegetation or animals, make paths, greater compaction of soil, scare or displace animals. Also seeds and propagules from soil from truck or blowing from filled dump trunks. Disruption and displacement of animals from near roads due to increased noise or other disturbances. Often permanent or long-term compaction of roads or trails, disruption and destruction of areas where trucks turn or engage in other activities; some destruction of soil invertebrates.
Heavy Equipment	Carry seeds or propagules on tires, injure or kill vegetation or animals, make paths, greater compaction of soil, displace animals and disrupt behavior/reproductive success. Also seeds and propagules dispersed from soil from truck or blowing from heavy equipment. Often permanent or long-term compaction, destruction of soil invertebrates. May destroy permanently areas of the site with intense activity.
Heavy, wide hoses	Carry seeds, disrupt soil, remove or crush vegetation, kill vegetation. May have semi-permanent effects from compaction or vegetation removal. Effects continue if hoses remain or are moved over time.

TYPE OF DISTURBANCE FROM REMEDIATION	ECOLOGICAL EFFECTS
Drill Rigs	Carry seeds or propagules on tires, injure or kill vegetation or animals, make paths, greater compaction of soil, displace animals and disrupt behavior/reproductive success. Also seeds and propagules dispersed from soil from truck or blowing from heavy equipment. Often permanent or long-term compaction. Destruction of soil invertebrates at greater depths. Potential bringing up of dormant seeds from deeper soil layers. Disruption of ground-living small mammals and hibernation sites of snakes and other animals. Effects additive with other traffic types.
Construction buildings	All of the above. Permanent destruction of plants and animals, and of the on-site ecosystem larger than the footprint of the building. Effects will radiate from the building, and post-remediation effects depend on the degree of use (e.g., personnel and truck traffic, type of truck traffic and heavy equipment activity).
Caps, Other containment	During construction: Carry seeds or propagules on tires, injure or kill vegetation or animals, make paths, greater compaction of soil, displace animals and disrupt behavior/reproductive success. Also seeds and propagules dispersed from soil or tailings from truck or blowing from heavy equipment. Often permanent or long-term compaction of soil from car, truck and heavy equipment on roads or paths. Destruction of soil invertebrates at depths of pits. Potential bringing up of dormant seeds from soil layers. Disruption of ground-living small mammals and hibernation sites of snakes and other animals on site of containment. Often disrupts local aquatic environment and drainage; often non-native plants used on caps (which can become exotic/alien adjacent to the containment site).
Soil Removal	Complete destruction of existing ecosystem, all of the above effects on adjacent sites, but these effects are potentially more severe because of blowing soil (and seeds); potential for exposure of dormant seeds.
Contamination	During remediation, radionuclides or other contaminants could be released or spilled on the surface, and depending upon the type and quantity, could have adverse effects on the plants and animals on site.

The above Table 8-6 provides examples of effects that occur during remediation. But these effects can remain for many years before ecosystems recover. There is natural recovery of ecosystems, providing the stressor (remediation activity) does not continue, and that remnants of the system (e.g., seeds, plants, nearby animals) remain. The following table examines potential effects during the near-term post-cleanup period (over the 100 years after remediation; Table 8-7).

Table 8-7. Potential ecological effects from remediation in the 100 years post remediation (2164).

TYPE OF DISTURBANCE FROM REMEDIATION	ECOLOGICAL EFFECTS
Personnel traffic through non-target area	Likely no longer present
Personnel traffic through target (remediation) area	Likely no longer present, except for invasive species if they became established
Car traffic on adjacent site	Likely no longer present, unless heavy traffic caused ruts.
Car traffic on remediation site	Likely no longer present, unless heavy traffic caused ruts, except for alien/exotic species if they became established.
Truck traffic on roads through non-target area	Likely effects only adjacent to roadway (may involve exotic/alien species, but less likely to affect animal populations)
Truck traffic on roads through remediation site	Likely effects only adjacent to roadway (may involve alien/exotic species, but less likely to affect animal populations)
Heavy Equipment	Permanent effects likely in areas of heavy equipment use; effects likely to include exotic/alien species, differences in native species structure, soil invertebrate changes in areas of high activity (compaction).
Drill Rigs	Permanent effects in the area of drill rig construction. Possible permanent effects in area surrounding rigs, depending upon traffic and current activities.
Construction buildings	Permanent effects in the area of building site. Permanent effects in area surrounding building, depending upon traffic and current activities.
Caps, Other containment	Permanent effects in the area of cap site. Permanent effects in area surrounding cap or containment, depending upon traffic and current activities. Periodic monitoring will involve effects due to personnel, car and truck traffic (see previous table).
Soil Removal	Permanent effects in the area of soil removal. Degree of effect depends upon restoration activities, and whether restoration included vegetation and animal restoration (e.g., native vegetation, insects, pollinators, and other essential ecosystem components). Permanent effects in area surrounding soil removal, depending upon traffic and current activities. Periodic monitoring will involve effects due to personnel, car, and truck traffic, as well as level of activities.
Contamination	During remediation, radionuclides or other contaminants released or spilled on the surface could have long-term effects if the contamination remained, and plants did not recolonize or thrive. Such disruptions could affect the associated animal community.

For an ecologist, it is impossible to evaluate the resources at risk 1000 years hence or any time period greater than 100 years after cleanup has been completed. Ecosystems change, both naturally, and in response to anthropogenic factors. Climate change is expected to have dramatic effects over the next 100 years, and any changes in mean temperature or rainfall could have major effects on the ecosystems at Hanford. Increased temperatures and decreased rainfall would result in changes in the climax vegetation on the site, with concurrent changes in the animals on site. Similar climate changes would affect the depth, flow, and seasonal patterns of water in the Columbia River, which would in turn affect the fish and other animals living within the river. While not the subject of this section, climate change should be borne in mind when considering any future resources at risk on the Hanford Site.

Ecosystems on Hanford, as on other sites, are subject to initiating events that could affect their health and well-being. Some of these include failure of institutional and engineered controls, and others involve natural catastrophes, such as fires or earthquakes. A more complete list can be found in the chapter on Initiating events. All of these can affect ecological resources, even natural, undisturbed ones. It should be noted that areas that at first appear undisturbed, in actuality may have been disturbed by human land use 100 – 200 years ago, or more. However, valuable ecological resources on remediated/restored lands can be affected by the interaction of initiating events with remediation itself. Some of these are described below (Table 8-8).

Table 8-8. Initiating events that could impact the integrity and health of ecological resources. Some of the effects are similar to those of functional remediation (see Table 8-6). Loss of institutional controls refers to loss of active controls.

EVENT	IMMEDIATE EFFECTS	SYNERGISMS WITH REMEDIATION
Loss of Institutional Controls	Increased human activities, same effects as personnel on site	No interaction
Loss of Engineered Controls	Immediate exposure to contaminants the engineered controls managed.	Increased human activities; same effects as those listed in previous table, depending on level of functional impacts of remediation
Structural Decay	Immediate exposure to contaminants the structure contained; immediate exposure to building materials.	Increased human activities; same effects as those listed in previous table, depending on level of functional impacts of remediation or constructed needed to either repair or remediation the building
Fire	Habitat destruction, and possible re-setting of succession to early successional phase.	Increased human activity related to fire-fighting, and to remediation needed to repair any engineering controls or structures on site. Effects can vary depending upon degree of human activity.

EVENT	IMMEDIATE EFFECTS	SYNERGISMS WITH REMEDIATION
Earthquake	Little effect	Increased human activity related to dealing with any damage to engineered controls and buildings, and to remediation needed to repair any engineering controls or structures on site. Effects can vary depending upon degree of human activity.
Dam Failure (flooding)	Can wash away or kill plants and associated animals (from soil invertebrates to birds or mammals unable to escape quickly.	Long term effects resulting in re-setting succession, erosion of habitats, and potential loss of species diversity. Potential increases of human activity related to dealing with any damage to engineered controls and buildings, and to remediation needed to repair any engineering controls or structures on site. Effects can vary depending upon degree of human activity.
Ash Fall (Volcanic)	Depending upon depth of ash, can degrade or destroy ecosystems, and associated plants and animals	Long term effects resulting in re-setting succession, erosion of habitats, and potential loss of species diversity. Deep ash will prevent photosynthesis of covered plants, potentially eliminating some species. Potential increases of human activity related to dealing with any damage to engineered controls and buildings, and to remediation needed to repair any engineering controls or structures on site. Effects vary depending upon degree of human activity.
Drought	Shift in species diversity, selecting for drought-tolerant species	Little expected effects.
Plane Crash	Limited destruction to site of crash.	Long term effects resulting in re-setting succession, erosion of habitats, and potential loss of species diversity in immediate vicinity of crash. Potential increases of human activity resulting from immediate rescue and human safety activities, as well as those dealing with any damage to engineered controls and buildings, and to remediation needed to repair any engineering controls or structures on site. Effects vary depending upon degree of human activity both immediately, and over a longer period.
Climate change	Potential shifts in biodiversity and abundance of specific plants or animals. Could result in on-site movement of animals to other habitats.	Long-term shifts in biodiversity and major habitat types.

EVENT	IMMEDIATE EFFECTS	SYNERGISMS WITH REMEDIATION
Water table changes	Changes in plant composition, abundance and diversity.	Increased human activity as a result of increased need for engineered controls or remediation of existing facilities.

Finally, future land use designations have an effect on the health and well-being of ecological resources on Hanford. Land Use designations considered are those in the CLUP (DOE/EIS-0222-F, 1999; HCP EIS 2000), as well as the designation called "unrestricted." To consider risk of ecological resources as a function of future land use (what would occur following the designated remediation), two evaluations of risk can be made: 1) Are there resources that are at risk? If not, the ecological risk is low, and 2) Are the resources that are there (no matter how few or limited) at risk? Table 8-9 addresses the post-remediation period (2064 to 2164).

Table 8-9. Ecological risk as a function of land use designations. Given are scenarios involving Levels 4 and 5 resources (most critical, sensitive, unique habitats, with federal endangered/threatened species). Land use designations from the CLUP (DOE/EIS-0222-F, 1999, Final HCP EIS, 2000). The right two columns summarize the likelihood of Level 4 and 5 resources occurring, and whether these resources would be at risk from the current land use designations. This table addresses the period after 2064 (when cleanup is complete).

LAND USE	LEVEL 4 and 5 RESOURCES: PRESENCE AND POTENTIAL MANAGEMENT ACTIONS	Likelihood of presence	Risk to Resources
Industrial-exclusive (hazardous wastes)	Few Level 4 or 5 resources collocated with the Industrial-exclusive land use designation.	Few	Low
Industrial	Few present.	Few	Low
Research and Development	May occur in patches, or in larger sections that could be protected and connected.	Moderate	Moderate
High-intensity recreation	May occur in patches, or in larger sections that could be protected and connected. Need to limit high intensity recreation in patches that have high biological integrity (few exotic/alien species, few trails).	Moderate	High
Low-intensity recreation	Likely present in larger sections that could be protected and connected to provide high quality habitat.	Likely Present	High
Conservation (mining)	Likely present in large sections that could be protected and connected to provide high quality habitat.	Likely Present	Moderate to high
Preservation	Present in patches and large sections that should be protected from human activities (especially Level 4 and 5 resource areas of high quality).	Present	Low

LAND USE	LEVEL 4 and 5 RESOURCES: PRESENCE AND POTENTIAL MANAGEMENT ACTIONS	Likelihood of presence	Risk to Resources
Unrestricted	Resources present before this use, impact depending upon presence and level of resource.	Present	High

The likelihood of occurrence reflects whether unique habitats and threatened/endangered/species of concern may be in areas with these land use designations. That is, are there any ecological resources, and what level are they? The risk to those resources is a result of the degree of human activity that resources would be exposed to. Thus, industrial areas have little risk because there are few resources, and conservation areas have low risk because, although there are Level 4 and 5 resources on site, the human disturbance is expected to be very low and future land management agencies may restrict or prohibit human activity to help ensure a low level of disturbance. Thus, absent any further remediation activities, or other human activities, the resources are not at risk.

FIELD ASSESSMENT AND RESOURCE LEVEL UPDATE

The overall objective is to evaluate ecological resources on and around the Evaluation Units with the intent of providing additional possible “impact” information to managers that can inform sequencing and provide information to reduce impacts to ecological resources. This information must include the possible lay-down areas adjacent to the site (which may be 1-3 times the size of the evaluation unit). The field assessment includes:

1. Assessment of “Evaluation unit” and adjacent habitat
2. Assessment of current habitat resource level (using DOE/RL-96-32 2013)
3. Field assessment of exotic/alien species (% cover and types).
4. Field assessment of presence of federal and state endangered and threatened species, or unique species or assemblages.
5. Field assessment of landscape features (patch size and shape, connectivity).

The field methodology was developed in collaboration with M. R. Sackchewsky, M.A. Chamness, K. B. Larson and J. L. Downs. Field maps showing the evaluation unit itself and expected impact area, along with a buffer area 1X the evaluation unit were developed by W. Johnson, and were used by the field crews. An ecological evaluation of species, populations and habitats is an important part of the Risk Review Project evaluation. The evaluation includes using the DOE (DOE/RL-96-32 2013) evaluation of ecological resources. These levels include:

Level 5 = Irreplaceable habitat or federal threatened and endangered species (including proposed species.

Level 4 = Essential habitat for important species

Level 3 = Important habitat

Level 2 = Habitat with high potential for restoration[25]

Level 1 = Industrial or developed

Level 0 = Non-native plants and animals

Overall field methods include examining the current level resource maps (DOE/RL-96-32 2013), and field investigations of current vegetation, percent and type of exotic/alien species, landscape features, and presence of listed species. The evaluation includes both the “evaluation unit” and adjacent habitat. All aspects are critical.

To insure consistency within and among “evaluation units”, field data sheets are used (shown below, Table 8-10 and Table 8-11). The sheets will be initially filled out by PNNL plant ecologists, followed by a site visit by Burger and PNNL plant ecologists and other relevant people. Each field visit of an evaluation unit may take 2-8 hours (depending upon size and complexity). The field visit will require walking transects through the relevant habitat on or adjacent to the evaluation unit to collect the appropriate data. Work sheets will also be used to evaluate landscape features (Worksheet 8.1 and 8.2). Evaluations will not include paved, industrial sites, or those where access is prohibited.

The field methodology and tables that follow are ideal for areas with high level resources. Modifications will be made in the field depending upon conditions (e.g., inability for security reasons to have access, condition of the vegetation). Further modifications may be made for pump and treat remediation and groundwater plumes that have larger spatial scales.

Definitions follow:

1. Percent estimates - field estimates of each characteristic (e.g., pavement, gravel, vegetation, native grasses, etc.), For many sites it will be necessary to either use transects or quadrats to estimate these, obtaining a mean value for each.
2. Exotic/alien species – a list of exotic/alien species found, with approximate % occurrence (by quadrat) or % cover.
3. Resource Level – a field assessment of the current resource Level (1-5), which may have changed since the previous evaluation, or may not have actually been done during the previous evaluation.
4. Size of the patch – either acres or dimensions (with map)
5. Shape of patch – round, square, oblong (with approximate dimensions)(ratio of length to width)
6. Connectivity – is the habitat patch continuous with, or connected to similar (or higher/lower quality habitat). If connected, how wide is the corridor?
7. # roads – roads through the area (# lanes, traffic indication [heavy trucks, cars, etc.])
8. Lay-down – Is the lay-down (area used for equipment, supplies) on the site, or on or planned for adjacent habitat, and how large is it. Past experience suggests it is 1-3 X the size of the remediation site.

The field assessment will include a new resource level. Additional information to be recorded includes:

1. Comments about Animals: any observations of animals on the site.
2. General comments: anything noted of special interest
3. Suggestions for reducing remediation impacts or places/areas to be particularly careful of: Be creative in thinking about what minor changes in remediation practices could preserve ecological integrity.

Table 8-10. Field data sheet for each EU. A similar worksheet should be filled out for each site, and for each of the directions from the site. If any direction is paved or industrial (e.g., no ecological), this should be noted and no transects are needed.

SITE NAME:	Transect									
PARAMETER	1	2	3	4	5	6	7	8	9	10
% Gravel or pavement										
% Vegetated										
% Native Grasses										
% Native Forbs										
% Climax brush										
% Sub-climax brush										
% Exotic/alien species										
% Gravel or pavement										
% Vegetated										
% Native Grasses										
% Native Forbs										
% Climax brush										
% Sub-climax brush										
% Exotic/alien species										
% Gravel or pavement										
% Vegetated										
% Native Grasses										
% Native Forbs										
% Climax brush										
% Sub-climax brush										
% Exotic/alien species										

Number of transects, and number of sampling points depends on the size of habitat. In some cases % of all plant species may be recorded. Repeatability among field personnel will be examined, and is expected to be high based on previous work at Hanford and the PNNL personnel involved.

Table 8-11. Summary from field visit.

SITE LOCATION____ DATE_____________

OBSERVER______________________ RESOURCE LEVEL BY 2001 MAPS_____________________________

PARAMETER	SITE	N of SITE	E of SITE	S of SITE	W of SITE
% Gravel or pavement					
% Vegetated					
% Native Grasses					
% Climax brush[a]					
% Sub-climax brush[b]					
% Exotic/alien species					
% native forbs					
Exotic/alien species					
New Resource Level					
Size of Patch					
Shape of Patch					
Connectivity					
# roads					
Location Lay-by					
NEW RESOURCE LEVEL					

NOTE: The site is the "evaluation unit", and N, S, E, and W of the site should be an area 1X the size of the site.

a. Climax brush includes Sagebrush, bitterbrush, spiny hop sage.
b. Sub-climax includes smaller, earlier successional stages.

PRESENCE OF ANY THREATENED/ENDANGERED SPECIES (Federal and Washington State)

COMMENTS ABOUT ANIMALS:

GENERAL COMMENTS:

SUGGESTIONS FOR REDUCING REMEDIATION EFFECTS (including spatial and temporal).

Worksheet 8.1. Worksheet for evaluating landscape features is to be completed after resource level evaluation.

PATCH SIZE

1. What % of area on site is vegetated? ____
2. Is the vegetated area on site surrounded by industrial/non vegetated sites? __________
   If so, what is the size of the vegetated site? _______________________________________
3. Does the area 3X the size of the site surrounding it have any native habitat? __________
4. Is the habitat on the site similar (e.g., same resource level) to that in the area surrounding it (3 X)? ____
   yes_____ no_____
   a. If NO, is the habitat on site surrounded by higher or lower resource level habitat?
      i. If lower, is similar or higher quality habitat to site nearby? ___________
         Where (direction)? ____
      ii. If higher, how much is there___________ direction from site _________
   b. If Yes, Is the resource level the same in all directions? ______________________
   c. If yes, In which direction (s) is the resource level higher? ____________________
   d. If yes, are there significant, high quality level plants _________________________
      i. List plants ____

EVALUATION: High value: large patch size of high resource value, with nearby high quality; low quality is small patch size of low quality

SHAPE OF PATCH

1. Is habitat patch on site (circle one) round, square, oblong other ____________________
2. If thin, how thin? ____
3. Length: width ratio ____

EVALUATION High value is square or round with less edge to interior (L/W ratio close to 1); low quality is very thin patch with high amount of edge (L/W ratio high)

CONNECTIVITY

1. Does patch size on site extend into surround 3X area (how much) ___________________
2. If patch size extends from site to surrounding area, does shape change _______________

EVALUATION High value is high quality habitat that has connection to other quality habitat; low quality is no connections of habitat (e.g., separated by pavement or industrial).

NOTE: The applicability of this information will depend upon the site. Industrial sites will require less field work.

Worksheet 8.2. Final evaluation from the field visit. Main point that may change the resource level evaluation. That is, patch size, shape and connectivity can elevate or reduce the resource level.

Past resource level (from DOE/RL-96-32 2013): ____

New resource level (from summary data sheet): ____

Resource level modification (from landscape sheet): ____________________________________

____

Comments to reduce impacts: ____

____

Hypothetical example of field risk evaluation is given below. This would then be used to complete the ecological risk rating for the EU templates.

Past resource level (from DOE/RL-96-32 2013): 3

New resource level (from summary data sheet): 4
(now has high quality plants, including native grasses and forbes, dense stands)

Resource level modification (from landscape sheet): 5

(large patch, connected to nearby areas)

Comments to reduce impacts: Reduce impact to natural habitat on evaluation site and adjacent resource Level 4 on North side; can put lay-down on south side where habitat quality is 2. Reduce truck traffic on high quality habitat, use caution during windy days to prevent seed dispersal.

This information will then be used with the evaluation matrix (Table 8-5). An example of the field evaluation is found in Attachment 8.1

Following the field evaluation, evaluators and field personnel will meet to discuss specific evaluation units. In some cases additional field visits will be necessary. Past resource level evaluations, field evaluations, and landscape features will be integrated to arrive at the current resource level, and the potential for impact/risk to ecological resources during remediation. Where potential remediation options are available, these will be considered in the ratings.

An example of a field assessment can be found in Attachment 8.1 for three EUs.

8.7. OVERALL METHODOLOGY FOR EVALUATING ECOLOGICAL RESOURCES

The proposed Risk Review Project approach for evaluating the ecological resources with respect to specific cleanup evaluation units includes the following:

1. Describe and analyze ecological resources at three levels
    a. Regional context (comparison with Columbia Basin Ecoregion)
    b. Hanford context
    c. Site-specific resources
2. Evaluate relative importance of habitat using the above three-part context.
3. Evaluate importance using Level of Resources (0-5, where 5 is most valuable resources, DOE/RL-96-32-2013), incorporating quality component (e.g., modifiers, such as degradation by exotic/alien species). Must also include a description of the rationale for the evaluation outcome (i.e., rating).
4. Collect on-site ecological information (field data), including
    a. Current resource level from maps (DOE/RL-96-32-2013)
    b. Landscape scale issues
    c. Exotic, alien or other exotic/alien species
5. Describe potential damage to ecological resources from specific remediation actions, using remediation matrices developed above.
6. Bin potential risks from remediation actions, after field visit
7. Binning must be completed for resources at risk currently, during the active cleanup period (until 2064) and in the 100 years post clean-up (until 2164).

This methodology is designed to make use of available, GIS-based, information on ecological resources on the Hanford Site. The information relates both to individual species (which are at risk), and key unique habitats or ecosystems that could be at risk. The methodology was developed so that it could be applied to different "evaluation units", and could be applied by personnel with basic ecological knowledge. While landscape features can be determined from maps, they must be checked in the field, and other necessary field work includes the determination of the percent of alien/exotic species present on the site. The proposed Risk Review methodology is diagramed below (Figure 8-11).

This Risk Review approach makes use of the resource levels developed by DOE (2013), as modified by exotic/alien species and landscape features (patch size, patch shape, connectivity). The resource levels developed by DOE were refined over many years (as indicated by DOE yearly environmental reports), and included the State of Washington's resource evaluations, as well as those of others. It includes federally listed species as its highest level (in addition to unique habitats), which is based on the US Endangered Species Act. Inclusion on this list involves a long, involved process that considers many different ecological factors, and has legal standing.

Since Level 4 resources include State of Washington's listed species, as well as critical habitat, the two levels are firmly based in law and involve both a national and regional perspective. Level 4 and Level 5 resources are of the highest value, although their relative value can be compromised by the degree of exotic/alien species (an indication of degradation) and landscape features (patch size and shape, connectivity).

The level of resources present will be ascertained from the resource maps provided (Figure 8-3 to 8-7), the degree the site is compromised by landscape features can be ascertained from these maps as well, but the current resource level determined from field work, landscape features, amount and significance of exotic/alien species needs to be determined on each site. This indicates the importance of an initial exotic/alien species evaluation (particularly plants), an on-going program to track exotic/alien species, and regular up-dating of exotic/exotic/alien species maps. Exotic/alien plants will be most important because plants are at the base of the food chain, many have toxic chemicals that prevent native plant species from continued growth and colonization, and affect the animal communities inhabiting them.

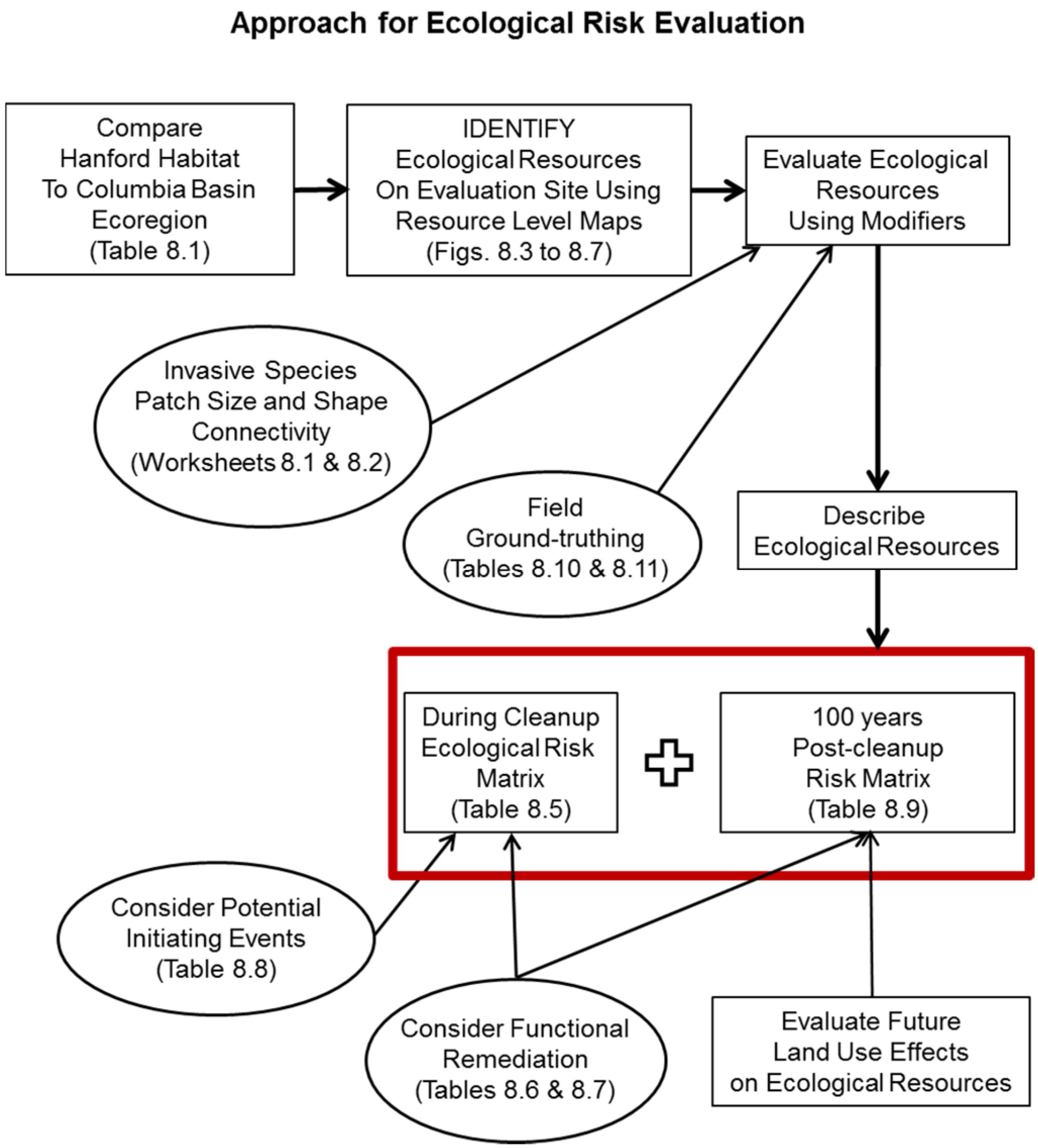

Figure 8-11. Schematic of the risk review approach to evaluating ecological resources on the Hanford Site, using the DOE's levels of resources (DOE/RL-96-32, 2013).

In summary, the methodology for evaluation risk to ecological resources includes:

1. Examine importance of resources to Columbia River Basin (Table 8-1). This is descriptive, not evaluative.
2. Use resource maps to arrive at resource level (Figures 8-3 through 8-7) to refine resource level and incorporate landscape features and exotic species.
3. Conduct field evaluations (see appropriate section above).
4. Consider remediation (and functional remediation, Table 8-6) and initiating events (Table 8-8).
5. Complete ecological risk matrix (Table 8-5).
6. Fill out Final Risk Evaluation Form (Table 8-12).
7. Table 8-12 is the final step in the risk rating evaluation, and provides information to be used for the EU templates for ecological resources

Table 8-12. Evaluations of potential impact to ecological resources on the Hanford Site.

Evaluation Unit:

Comparison to Columbia River Basin Ecoregion (Table 8-1) ________________________________

Initial Resource Level (Figure 8-3 through Figure 8-7) _____________________________________

Initial Risk Rating from Resource Level (Table 8-5) ____

Field evaluations:

Presence of endangered species (list species) ______________________________________

Modified resource level from Worksheet for landscape features ____________________

Final Resource Level from field evaluation ____

Reasons for differences from initial evaluation ____

Surrounding Area

Comparison to Columbia River Basin Ecoregion (Table 8-1) ________________________________

Initial Resource Level (Figure 8-3 through Figure 8-7) _____________________________________

Initial Risk Rating from Resource Level (Table 8-5) ____

Field evaluations:

Presence of endangered species (list species) ______________________________________

Modified resource level from Worksheet for landscape features ____________________

FINAL RISK RATING (Table 8-5)

CURRENT: EU _________________ Surrounding ____

DURING REMEDIATION: EU __________ Surrounding ____________________________________

POST-REMEDIATION: EU ___________ Surrounding ____________________________________

WAYS TO REDUCE IMPACT TO ECOLOGICAL RESOURCES

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8.8. REFERENCES

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Table 8-13. List of federal and state listed species on the Hanford Site. Data from McAllister et al. 1996; DOE 2001 appendix D; DOE 2006; DOE 2013 appendix A.

Abbreviations are as follows: SoC = Species of concern; Can = Candidate; End = Endangered; Sens = Sensitive; F. Can = Former Candidate; Watch = Watch; Mon = Monitor; R1 = Review Group 1 (insufficient data to support listing); R2 = Review Group 2 (unresolved taxonomic questions); P. Thre = Proposed Threatened; P. Can = Proposed Candidate

Plants **Scientific Name**	**Common Name**	**1996 FED** [a]	**2001 FED** [b]	**2005 FED** [c]	**2013 FED** [d]	**1996 STA** [a]	**2001 STA** [b]	**2005 STA** [c]	**2013 STA** [d]
Aliciella (= Gilia) leptomeria	Great Basin gilia						R 1	Thre	Thre
Allium robinsonii	Robinson's onion						Watch	Watch	Watch
Allium scillioides	Squill onion						Watch	Watch	Watch
Ammannia robusts	Grand redstem						R 1	Thre	Thre
Anagallis (= Centunculus) minima, (Centunculus minimus)	Chaffweed						R 1	R 1	Sens
Arenaria franklinii var. thompsonii	Thompson's sandwort						R 2	R 2	
Artemisia campestris borealis var. wormskioldii	Northern wormwood	Can	F. Can			End	End, (1)		
Artemisia lindleyana	Columbia River mugwort						Watch	Watch	Watch
Astragalus arrectus	Palouse milkvetch						Sens, (3)		
Astragalus columbianus	Columbia milkvetch	Can	F. Can	SoC	SoC	Thre	Thre, (2)	Sens	Sens
Astragalus conjunctus var rickardii	Basalt milkvetch						R 1	Watch	Watch
Astragalus geyeri	Geyer's milkvetch						Sens, (3)	Thre	Thre

Plants Scientific Name	Common Name	1996 FED [a]	2001 FED [b]	2005 FED [c]	2013 FED [d]	1996 STA [a]	2001 STA [b]	2005 STA [c]	2013 STA [d]
Astragalus sclerocarpus	Stalked-pod milkvetch						Watch	Watch	Watch
Astragalus speirocarpus	Medick milkvetch						Watch	Watch	Watch
Astragalus succumbens	Crouching milkvetch						Watch	Watch	Watch
Balsamorhiza rosea	Rosy balsamroot						Watch	Watch	Watch
Camissonia (= Oenothera) minor	Smallflower evening-primrose						R 1	Sens	Sens
Camissonia (=Oenothera) pygmaea	Dwarf evening-primrose						Thre, (2)	Sens	Sens
Carex densa	Dense sedge					Sens	Sens, (3)		
Carex hystericina	Porcupine sedge							Watch	Watch
Castilleja exilis	Smallflower annual paintbrush						R 1	Watch	Watch
Cirsium brevifolium	Palouse thistle						R 1		
Cistanthe (= Calyptridium) rosea	Rosy pussypaws						Sens	Thre	Thre
Collinsia sparsiflora var. bruceae	Few-flowered collinsia						Sens, (3)		
Crassula aquatica	Pigmy-weed							Watch	Watch
Cryptantha leucophaea	Gray cryptantha			SoC	SoC	Sens	Sens, (3)	Sens	Sens
Cryptantha scoparia	Miner's candle						R 1	Sens	Sens
Cryptantha spiculifera (= C. interrupta)	Snake River cryptantha					Sens	Sens	Sens	Sens

Plants **Scientific Name**	**Common Name**	**1996 FED [a]**	**2001 FED [b]**	**2005 FED [c]**	**2013 FED [d]**	**1996 STA [a]**	**2001 STA [b]**	**2005 STA [c]**	**2013 STA [d]**
Cuscuta denticulata	Desert dodder						Sens	Thre	Thre
Cyperus bipartitus (=C. rivularis)	Shining flatsedge					Sens	Sens, (3)	Watch	Watch
Delphinium multiplex	Kittitas larkspur							Watch	Watch
Eatonella nivea	White eatonella						Thre, (2)	Thre	Thre
Eleocharis rostellata	Beaked spike-rush							Sens	Sens
Epilobium pymaeum	Smooth willowherb								R 1
Epipactis gigantea	Giant helleborine							Watch	Watch
Erigeron piperianus	Piper's daisy					Sens	Sens, (3)	Sens	Sens
Eriogonum codium	Umtanum desert buckwheat			Can	P. Thre		End	End	End
Gilia inconspicua	Shy gily-flower								R 1
Hierchloe odorata (= Anthoxanthum hirtum)	Vanilla grass							R1	R 1
Hypericum majus	Canadian St. John's-wort						Sens	Sens	Sens
Lesquerella tuplashensis	White Bluffs bladderpod			Can			End	Thre	
Limosella acaulis	Southern mudwort					Sens	Sens, (3)	Watch	Watch
Lindernia dubia var. anagallidea	False pimpernel					Sens	R 2	Watch	Watch
Lipocarpha (= Hemicarpha) aristulata	Awned halfchaff sedge						R 1	Thre	Thre
Loeflingia squarrosa var squarrosa	Loeflingia						Thre	Thre	Thre

Plants **Scientific Name**	**Common Name**	**1996 FED** [a]	**2001 FED** [b]	**2005 FED** [c]	**2013 FED** [d]	**1996 STA** [a]	**2001 STA** [b]	**2005 STA** [c]	**2013 STA** [d]
Lomatium tuberosum	Hoover's desert parsley	Can	F. Can	SoC	SoC	Thre	Thre, (2)	Sens	Sens
Mimulus suksdorfii	Suksdorf's monkey-flower						Sens, (3)	Sens	Sens
Minuartia pusilla var. pusilla	Annual sandwort							R 1	R 1
Myosurus clavicaulis	Mousetail							Sens	
Nama densum var. parviflorum	Small-flowered nama						R 1	Watch	Watch
Nicotiana attenuata	Coyote tobacco						Sens, (3)	Sens	Sens
Oenothera caespitosa	Desert evening-primrose					Sens	Sens, (3)	Sens	Sens
Opuntia fragilis	Brittle prickly pear							R 1	
Pectocarya linearis var. penicillata	Winged combseed						R 1	Watch	Watch
Pectocarya setosa	Bristly combseed						Sens, (3)	Watch	Watch
Pediocactus nigrispinus (=P. simpsonii var. robustior)	Hedgehog cactus							R 1	Sens
Pellaea glabella var. slimpex	Smooth cliffbrake						Watch	Watch	Watch
Penstemon eriantherus var. whitedii	Fuzzytongue penstemon						Mon. 3	Sens	Sens
Physaria (= Lesquerella) tuplashensis	White Bluffs bladderpod				P. Thre				Thre
Rorippa columbiae	Columbia yellowcress	Can	F. Can	SoC	SoC	End	End, (1)	End	End

Plants **Scientific Name**	**Common Name**	**1996 FED** [a]	**2001 FED** [b]	**2005 FED** [c]	**2013 FED** [d]	**1996 STA** [a]	**2001 STA** [b]	**2005 STA** [c]	**2013 STA** [d]
Rotala ramosior	Lowland toothcup						R 1	Thre	Thre

Animal Type	**Invertebrates** **Scientific Name**	**Common Name**	**1996 FED** [a]	**2001 FED** [b]	**2005 FED** [c]	**2013 FED** [d]	**1996 STA** [a]	**2001 STA** [b]	**2005 STA** [c]	**2013 STA** [d]
Insects	*Boloria selene atrocostalis*	Silver-bordered fritillary						Cand	Cand	Cand
Insects	*Callophrys sheridanii neoperplexa*	Canyon green hairstreak						Mon	Mon	
Insects	*Chlosyne palla palla*	Northern checkerspot							Mon	
Insects	*Cicindela columbica*	Columbia River tiger beetle						Cand	Cand	Cand
Insects	*Erynnis persius*	Persius' duskywing							Mon	*Mon*
Insects	*Harkenclenus titus immaculosus*	Coral hairstreak						Mon	Mon	
Insects	*Hesperia juba*	Juba Skipper						Mon	Mon	*Mon*
Insects	*Hesperia nevada*	Nevada skipper						Mon	Mon	*Mon*
Insects	*Limenitis archippus lahontani*	Nevada viceroy		F. Cand				Mon	Mon	*Mon*

Animal Type	**Invertebrates** **Scientific Name**	**Common Name**	**1996 FED** [a]	**2001 FED** [b]	**2005 FED** [c]	**2013 FED** [d]	**1996 STA** [a]	**2001 STA** [b]	**2005 STA** [c]	**2013 STA** [d]
Insects	*Lycaena helloides*	Purplish copper						Mon	Mon	*Mon*
Insects	*Lycaena rubida perkinsorum*	Ruddy copper						Mon	Mon	*Mon*
Insects	*Mitoura siva*	Juniper hairstreak						Cand		
Insects	*Ochlodes sylvanoides bonnevilla*	Bonneville skipper						Mon	Mon	*Mon*
Insects	*Phyciodes tharos pascoensis*	Pasco pearl						Mon	Mon	*Mon*
Mollusks	*Anodonta californiensis*	California floater	Cand	F. Cand	SoC	SoC		Cand	Cand	Cand
Mollusks	*Anodonta kennerlyi*	Western floater							Mon	*Mon*
Mollusks	*Anodonta oregonensis*	Oregon floater							Mon	*Mon*
Mollusks	*Fisherola nuttalli*	Shortface lanx		F. Cand				Cand	Cand	Cand
Mollusks	*Fluminicola columbiana*	Great Columbia River spire snail	Cand	F. Cand	SoC	SoC		Cand	Cand	Cand
Mollusks	*Margaritifera falcata*	Western pearlshell							Mon	*Mon*

Fish **Scientific Name**	**Common Name**	**1996 FED** [a]	**2001 FED** [b]	**2005 FED** [c]	**2013 FED** [d]	**1996 STA** [a]	**2001 STA** [b]	**2005 STA** [c]	**2013 STA** [d]
Catostomus platyrhynchus	Mountain sucker						Mon	Cand	Cand
Cottus beldingi	Piute sculpin						Mon	*Mon*	*Mon*
Cottus perplexus	Reticulate sculpin						Mon	Mon	*Mon*
Lampetra ayresi	River lamprey	Cand	F. Can	SoC	SoC			Cand	Cand
Lampetra tridentata	Pacific lamprey			SoC	Con				*Mon*
Oncorhynchus mykiss	Steelhead		End	End	Thre		Cand	Cand	Cand
Oncorhynchus tshawytscha	Chinook Salmon		End	End	End		Cand	Cand	Cand
Percopsis transmontana	Sand roller						Mon	Mon	*Mon*
Rhinichthys falcatus	Leopard dace							Cand	Cand
Salvelinus confluentus	Bull trout	Cand	Cand	Thre	Thre			Cand	Cand

Reptiles and Amphibians **Scientific Name**	**Common Name**	**1996 FED** [a]	**2001 FED** [b]	**2005 FED** [c]	**2013 FED** [d]	**1996 STA** [a]	**2001 STA** [b]	**2005 STA** [c]	**2013 STA** [d]
Ambystoma tigrinum	Tiger salamander							Mon	Mon
Anaxyrus boreas	Western toad				SoC			Can	Can
Anaxyrus woodhousii	Woodhouse's toad						Mon	Mon	Mon
Coluber constrictor	Racer								Mon

Reptiles and Amphibians **Scientific Name**	**Common Name**	**1996 FED** [a]	**2001 FED** [b]	**2005 FED** [c]	**2013 FED** [d]	**1996 STA** [a]	**2001 STA** [b]	**2005 STA** [c]	**2013 STA** [d]
Hypsiglena torquata	Night snake						Mon	Mon	Mon
Masticophis taeniatus	Striped whipsnake						Can	Can	Can
Phrynosoma douglasii	Short-horned lizard								Mon
Pituophis melanoleucus	Pacific gopher snake						Mon		
Sceloporus graciosus	Sagebrush lizard	Can	F. Can	SoC	SoC		Mon	Can	Can

Birds ***Scientific Name***	**Common Name**	**1996 FED** [a]	**2001 FED** [b]	**2005 FED** [c]	**2013 FED** [d]	**1996 STA** [a]	**2001 STA** [b]	**2005 STA** [c]	**2013 STA** [d]
Accipter gentilis	Northern Goshawk	Can	F. Can	SoC	SoC		Can	Can	Can
Aechmophorus clarkii	Clark's Grebe						Mon	Mon	Can
Aechmophorus occidentalis	Western Grebe						Mon	Can	Can
Ammodramus savannarum	Grasshopper Sparrow						Mon	Mon	Mon
Amphispiza belli	Sage Sparrow					Can	Can	Can	Can
Aquila chrysaetos	Golden Eagle					Can	Can	Can	Can
Ardea alba	Great Egret						Mon	Mon	Mon
Ardea herodias	Great Blue Heron						Mon	Mon	Mon
Athene cunicularia	Burrowing Owl	Can	F. Can	SoC	SoC		Can	Can	Can

Birds ***Scientific Name***	**Common Name**	**1996 FED [a]**	**2001 FED [b]**	**2005 FED [c]**	**2013 FED [d]**	**1996 STA [a]**	**2001 STA [b]**	**2005 STA [c]**	**2013 STA [d]**
Branta hutchinsii leucopareia	Aleutian Canada Goose	Thre	Thre			End	End		
Buteo regalis	Ferruginous Hawk	Can	F. Can	SoC	SoC	Thre	Thre	Thre	Thre
Buteo swainsoni	Swainson's Hawk		F. Can			Can	Mon	Mon	Mon
Cathartes aura	Turkey Vulture						Mon	Mon	Mon
Centrocercus urophasianus	Sage Grouse	Can	F. Can	Can	Can		Can	Thre	Thre
Chlidonias niger	Black Tern	Can	F. Can				Mon	Mon	Mon
Contopus cooperi	Oliv8-sided Flycatcher		F. Can	SoC	SoC				
Dolichonyx oryzivorus	Bobolink							Mon	Mon
Empidonax traillii	Willow Flycatcher		F. Can						
Empidonax wrightii	Gray Flycatcher							Mon	Mon
Falco columbarius	Merlin						Can	Can	
Falco mexicanus	Prairie Falcon						Mon	Mon	Mon
Falco peregrinus	Peregrine Falcon	End	End	SoC	SoC	End	End	Sens	Sens
Falco rusticolus	Gyrfalcon						Mon	Mon	Mon
Gavia immer	Common Loon					Can	Can	Sens	Sens
Grus canadensis	Sandhill Crane	End					End	End	End
Haliaeetus leucocephalus	Bald Eagle	Thre	Thre	Thre	SoC	Thre	Thre	Thre	Sens
Himantopus mexicanus	Black-necked Stilt						Mon	Mon	Mon
Lanius ludovicianus	Loggerhead Shrike	P. Can	F. Can	SoC	SoC		Can	Can	Can
Melanerpes lewisii	Lewis' Woodpecker					Can	Can	Can	Can

Birds ***Scientific Name***	**Common Name**	**1996 FED [a]**	**2001 FED [b]**	**2005 FED [c]**	**2013 FED [d]**	**1996 STA [a]**	**2001 STA [b]**	**2005 STA [c]**	**2013 STA [d]**
Myiarchus cinerascens	Ash-throated Flycatcher						Mon	Mon	Mon
Numenius americanus	Long-billed Curlew	Can	F. Can				Mon	Mon	Mon
Nyctea scandiaca	Snowy Owl						Mon	Mon	Mon
Nycticorax nycticorax	Black-crowned Night Heron						Mon	Mon	Mon
Oreoscoptes montanus	Sage Thrasher					Can	Can	Can	Can
Otus flammeolus	Flammulated Owl					Can	Can	Can	Can
Pandion haliaetus	Osprey						Mon	Mon	Mon
Pelecanus erythrorhynchos	American White Pelican					End	End	End	End
Podiceps auritus	Horned Grebe						Mon	Mon	Mon
Podiceps grisegena	Red-necked Grebe						Mon	Mon	Mon
Pooecetes gramineus affinins	Oregon Vesper Sparrow						Mon		
Sialia mexicana	Western Bluebird						Mon	Mon	Mon
Spinus psaltria	Lesser Goldfinch							Mon	Mon
Sterna caspia	Caspian Tern						Mon	Mon	Mon
Sterna forsteri	Forster's Tern						Mon	Mon	Mon
Sterna paradisaea	Arctic Tern						Mon	Mon	Mon
Strix varia	Barred Owl						Mon		
Tympanuchus phasianellus	Sharp-tailed Grouse		F. Can				Mon		

Mammals **Scientific Name**	**Common Name**	**1996 FED** [a]	**2001 FED** [b]	**2005 FED** [c]	**2013 FED** [d]	**1996 STA** [a]	**2001 STA** [b]	**2005 STA** [c]	**2013 STA** [d]
Antrozous pallidus	Pallid bat						Mon	Mon	Mon
Brachylagus idahoensis	Pygmy rabbit	Cand	F. Cand			End	End		
Corynorhinus townsendii	Pale Townsend's big-eared bat	Cand							
Dipodomys ordii	Ord's Kangaroo rat						Mon		
Lemmiscus curtatus	Sagebrush vole						Mon	Mon	Mon
Lepus californicus	Black-tailed jackrabbit							Cand	Cand
Lepus townsendii	White-tailed jackrabbit							Cand	Cand
Myotis ciliolabrum	Small-footed myotis	Cand	F. Cand		Con		Mon	Mon	Mon
Myotis evotis	Long-eared myotis						Mon		
Myotis thysanodes	Fringed myotis	Cand	F. Cand				Mon		
Myotis volans	Long-legged myotis	Cand	F. Cand		Con		Mon	Mon	Mon
Myotis yumanensis	Yuma myotis	Cand	F. Cand						
Onychomys leucogaster	Northern grasshopper mouse						Mon	Mon	Mon
Parastrellus hesperus	Western Pipistrelle							Mon	Mon
Plecotus townsendii pallescens	Pale Townsend's big-eared bat		F. Cand						
Sorex merriami	Merriam's shrew						Cand	Cand	Cand
Spermophilus townsendii	Townsend's ground squirrel				SoC			Cand	Cand
Spermophilus washingtoni	Washington ground squirrel	Cand		Cand	Cand		Mon	Cand	
Taxidea taxus	Badger								Mon

ATTACHMENT 8.1. ECOLOGICAL EVALUATION OF THREE PILOT SITES ON THE U.S. DEPARTMENT OF ENERGY HANFORD SITE

KB Larson, JL Downs, MR Sackschewsky, MA Chamness

Introduction

As part of waste site remediation and evaluation, the assessment of species, populations and habitats is important in determining potential ecological impacts. As part of this evaluation process, field assessments must be performed to document current vegetation, percent and type of invasive species, landscape features, and presence of listed species. Procedures for performing field assessments were developed by Consortium for Risk Evaluation with Stakeholder Participation (CRESP) members and implemented by PNNL ecologists at three pilot sites in July 2014. The following describes the preliminary results of these field assessments.

Methods

The Risk Review Project approach evaluates potential ecological impacts of waste site remediation at two scales. The evaluation process makes use of existing resource level maps (DOE/RL-96-32 2013) and field surveys of current vegetation conditions to evaluate potential ecological impacts associated with cleanup activities at the waste sites. The footprint for cleanup and remediation for each site or designated area is also evaluated in the context of habitat conditions in the immediate surrounding landscape. Additional information used in the Risk Review Project approach includes the current Endangered and Threatened Species (Federal and State) distribution data; available imagery and Hanford Site waste site and infrastructure spatial data; and available information about species of concern distribution and habitat use in the vicinity of the evaluation sites.

This report discusses three pilot waste site areas that were surveyed and evaluated with respect to potential ecological impacts of remediation. For each target waste site, a polygon was defined to represent the estimated boundary or extent of habitat removal and direct disturbance due to remediation before surveys were attempted. This estimated polygon is referred to as the evaluation site. A second outer polygon buffering the remediation area was defined based on the assumed size of the remediation disturbance to evaluate indirect effects and assess the remediation in relation to adjacent landscape features. (Figure 8-12).

Field Surveys

As part of the evaluation, field measurements of current vegetation conditions were made to characterize the habitat and species existing within the area to be remediated, as feasible. PNNL ecologists surveyed the three sites described in this report on 16 July, 2014 to characterize habitats surrounding the pilot waste sites and quantify vegetation cover by species. Collection of field data to describe the current habitat conditions was limited by the timing of the pilot evaluation with respect to both the season and time constraints to provide data and evaluations within a very short time frame. Much of the vegetation in shrub-steppe habitats is senescent or dormant during the summer. In addition, the timing of the current assessments was not favorable for observing wildlife.

To address this limitation, previously collected information from the PNNL/DOE-RL Ecological Compliance and Assessment Program (ECAP) were used to supplement site wildlife and vegetation evaluations where possible. The ECAP field surveys included information describing observed plant and animal presence in defined polygons adjacent to the target waste sites. ECAP building survey data were also reviewed for past presence of nesting birds that may be protected under the Migratory Bird Treaty Act (MBTA). Observations of fauna were made during the field surveys, however, more extensive surveys should be conducted to adequately describe fauna diversity and habitats at the sites. These surveys should consider types of species potentially present and time of year and day these species are most likely to be detected.

For the July 2014 effort, field measurement of vegetation composition and habitat structural characteristics was limited to selected habitat patches that contained climax shrubs within the boundary of the evaluation site. Because time for field investigation was limited, pedestrian surveys were made of adjacent habitat types, without climax shrubs, to visually assess habitat structure and composition. Additional observational data gathered during previous ECAP surveys were used to further characterize particular areas within the evaluation site boundary.

Vegetation metrics measured by PNNL in the field included estimates of percent canopy cover by species and surface cover of bare soils, microbiotic crust, native and invasive grasses, and native shrubs. Ocular estimates of surface cover of non-vegetation characteristics (e.g., pavement, gravel) were also recorded. In selected habitat patches, percent canopy cover of herbaceous species and percent surface cover (e.g., bare, litter, crust, and gravel) were measured using four to six, 0.5-m^2 quadrats placed randomly within the patch. Line-intercept methods were used to measure shrub cover in habitat patches > 1 acre in size containing climax shrubs.

PNNL used field data collection sheets to organize information for inclusion in the evaluation (Appendix A). Summary field data sheets were provided by CRESP to PNNL ecologists to guide data collection and ensure consistency among sites. These summary data sheets can be used to synthesize the species level cover information into functional groups.

Landscape Context Evaluation

Sites were evaluated in relation to landscape features using available imagery of the Hanford Site (1-ft resolution imagery taken in 2012), Hanford Site resource level spatial data, historical ECAP field data, and field reconnaissance data. The primary landscape features evaluated include the amount of higher quality shrub-steppe habitat (resource Level 3 or higher) present within the site and within a circular area radiating from the geometric center of the site with a radius equal to the maximum width of the evaluation site. The removal of habitat that would occur during cleanup activities at the evaluation site was put into context of surrounding habitat conditions by quantifying changes in the amount of higher-quality habitat within the circular area. For this analysis it was assumed that the habitat conditions of the evaluation site after cleanup would be consistent with Level 0 biological resources. This method for examining landscape context was chosen because it is repeatable, relatively easy to understand, and provides context at a scale that is relevant to the size of the evaluation site (i.e., larger context area is needed as site area increases). Landscape context analyses were performed in a Geographic Information System (GIS).

Resource Classification

To the extent possible, efforts were made to evaluate current habitat conditions and determine the need for reclassifying biological resource levels within the evaluation site. Resource reclassification was done based on field observations, vegetation measurements, and analysis of aerial imagery. With the exception of industrial or heavily disturbed areas that were clearly visible in aerial imagery, habitats outside of the evaluation site boundaries were not reclassified due to the limited time available and level of effort needed to adequately characterize these larger areas. In addition, DOE intends to reevaluate resource levels for the entire Hanford Site in the near future. Therefore, although the evaluation of landscape features around the waste area and evaluation site can provide some context for ranking habitat loss within the evaluation site proper, the results presented herein should be interpreted cautiously with the understanding that future habitat mapping may alter the resource classifications for habitats adjacent to the evaluation site that are used in landscape analyses.

Site Evaluation

Results

Six Hanford Site waste sites were initially selected for piloting the Risk Review Project methodology (Figure 8-12). Of these six sites, the 324 Building (300 Area), 618-11 Burial Grounds (Energy Northwest), and BC Cribs and Trenches (600 Area) were selected for this assessment. Results of site evaluations for each of these sites are described in the following sections.

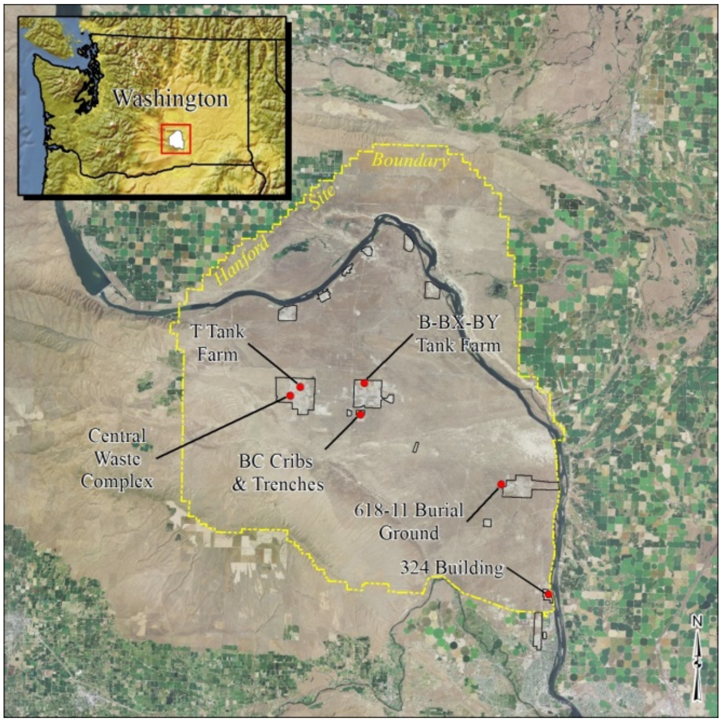

Figure 8-12. Location of Risk Review Project pilot sites on the U.S. Department of Energy Hanford Site in Washington State.

324 Building

Reconnaissance of the 324 Building evaluation site indicated the site consists entirely of non-vegetated areas, industrial sites, paved and compacted gravel areas (i.e., Level 0 resources; Figure 2). Therefore, no field measurements of vegetation were taken during the July 2014 survey. The amount of each category of biological resources within the 324 Building evaluation site and within a circular area radiating 231 m from the geometric center of the site (equivalent to 41.5 acres) was also evaluated to provide additional landscape context. The evaluation site and buffer area north, south, and east of the site was previously classified as Level 3 because it is within 0.25 miles of the Columbia River. These areas were reclassified for this assessment to Level 0 to reflect current vegetation conditions. Because the site consists entirely of Level 0 resources, there would be no net change in the amount of Level 3 or higher resources within a 231 m radius of the site

Historical ECAP building survey data were reviewed to determine past presence of nesting birds on the 324 Building and associated structures. European starling (*Sturnus vulgaris*), which is not protected by the MBTA, has been observed nesting on the building as recently as 2009.

Table 8-14. Summary of biological resource classification areas at the 324 Building.

	Resource Level						Total
	0	**1**	**2**	**3**	**4**	**5**	
Evaluation Site	6.2	0	0	0	0	0	6.2
Buffer Area Excluding Evaluation Site	35.3	0	0	0	0	0	35.3
Total Area	41.5	0	0	0	0	0	41.5
% Total Area Pre-Cleanup	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
% Total Area Post-Cleanup	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
% Change	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	

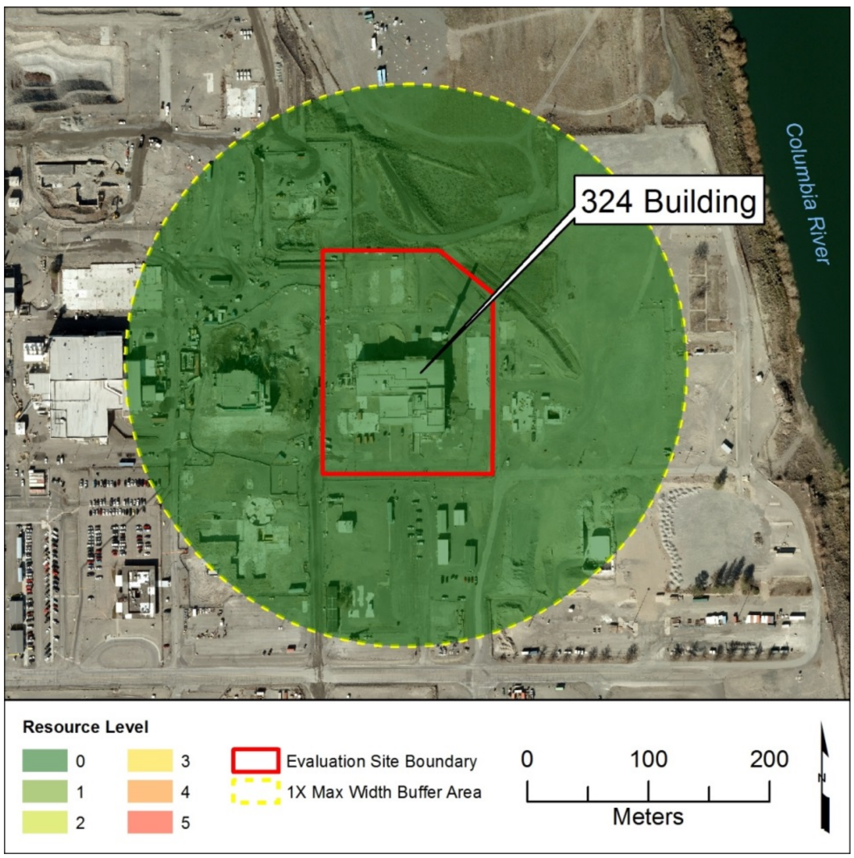

Figure 8-13. Map of biological resource level classifications for the 324 Building evaluation site (red) and landscape metrics buffer area (yellow).

618-11 Burial Grounds

Vegetation on the 618-11 Burial Ground site was visually estimated to be composed of approximately 30% to 40% crested wheatgrass (*Agropyron cristatum*), an introduced perennial bunchgrass planted for erosion control. Russian thistle was also prevalent on the burial ground—approximately 10% to 20%.

Vegetation was measured in habitat patches to the north, west, and south of the burial ground. A summary of these data are provided in Table 8-15.

Table 8-15. Percentage canopy cover and surface cover measured for the 618-11 Burial Ground.

Vegetation/Surface Cover	618-11 South	618-11 West	618-11 North	Borrow/ Laydown Area
BARE	3	30.5	19.3	22.8
CRUST	2.5	4.5	17.6	5.5
Introduced Forb	20	14.8	3.7	6.3
Introduced Grass	17.8	15	16.1	27.5
LITTER	40	29.3	32.4	28.5
Native Forb	2.8	3.8	1.1	
Native Grass	14	2.3	9.7	11.5
Climax Shrubs			9.6	
Successional Shrubs	<1	< 1	.3	

To the authors' knowledge, the 618-11 Burial Ground evaluation site has not been surveyed for nesting birds. Species (or their sign) observed during the 16 July 2014 survey include horned lark (*Eremophila alpestris*), loggerhead shrike (*Lanius ludovicianus*), western meadowlark (*Sturnella neglecta*), common raven (*Corvus corax*), unknown hawk (*Buteo* spp.), northern pocket gopher (*Thomomys talpoides*), coyote (*Canis latrans*), and American badger (*Taxidea taxus*).

The amount of each category of biological resources was evaluated within the 618-11 Burial Grounds evaluation site and within a circular area radiating 1164 m from the geometric center of the site (equivalent to 1052 acres; Figure 3). The evaluation site was previously characterized as having Levels 0, 2, and 4 biological resources in the existing resource level map (DOE/RL-96-32 2013). However, portions of the evaluation site that were classified as Level 4 were reclassified in this assessment as Levels 0 and 2 based on observations and field data collected during the field visit. Resource levels outside the evaluation site and within the circular buffer area were not re-classified for this assessment, although preliminary field observations suggest resource levels in this area may need to be reevaluated.

Approximately 56 percent of the 618-11 total landscape area (evaluation site and associated buffer area) is classified as Level 3 or higher biological resource in the existing resource map. None of the evaluation site is classified above Level 2 (Table 3). Thus, the removal of vegetation within the proposed spatial footprint of 618-11 cleanup activities would result in no net change in the amount of Level 3 or higher resources within a 1.1 km radius.

Table 8-16. Summary of biological resource classification areas for the 618-11 Burial Ground.

	Resource Level						Total
	0	**1**	**2**	**3**	**4**	**5**	
Evaluation Site	62	0	74.8	0	0	0	136.8
Buffer Area Excluding Evaluation Site	197.9	0	130.6	33.3	553.6	0	915.4
Total Area	259.9	0	205.4	33.3	553.6	0	1052.2
% Total Area Pre-Cleanup	24.7%	0.0%	19.5%	3.2%	52.6%	0.0%	100.0%
% Total Area Post-Cleanup	31.8%	0.0%	12.4%	3.2%	52.6%	0.0%	100.0%
% Change	7.1%	0.0%	-7.1%	0.0%	0.0%	0.0%	

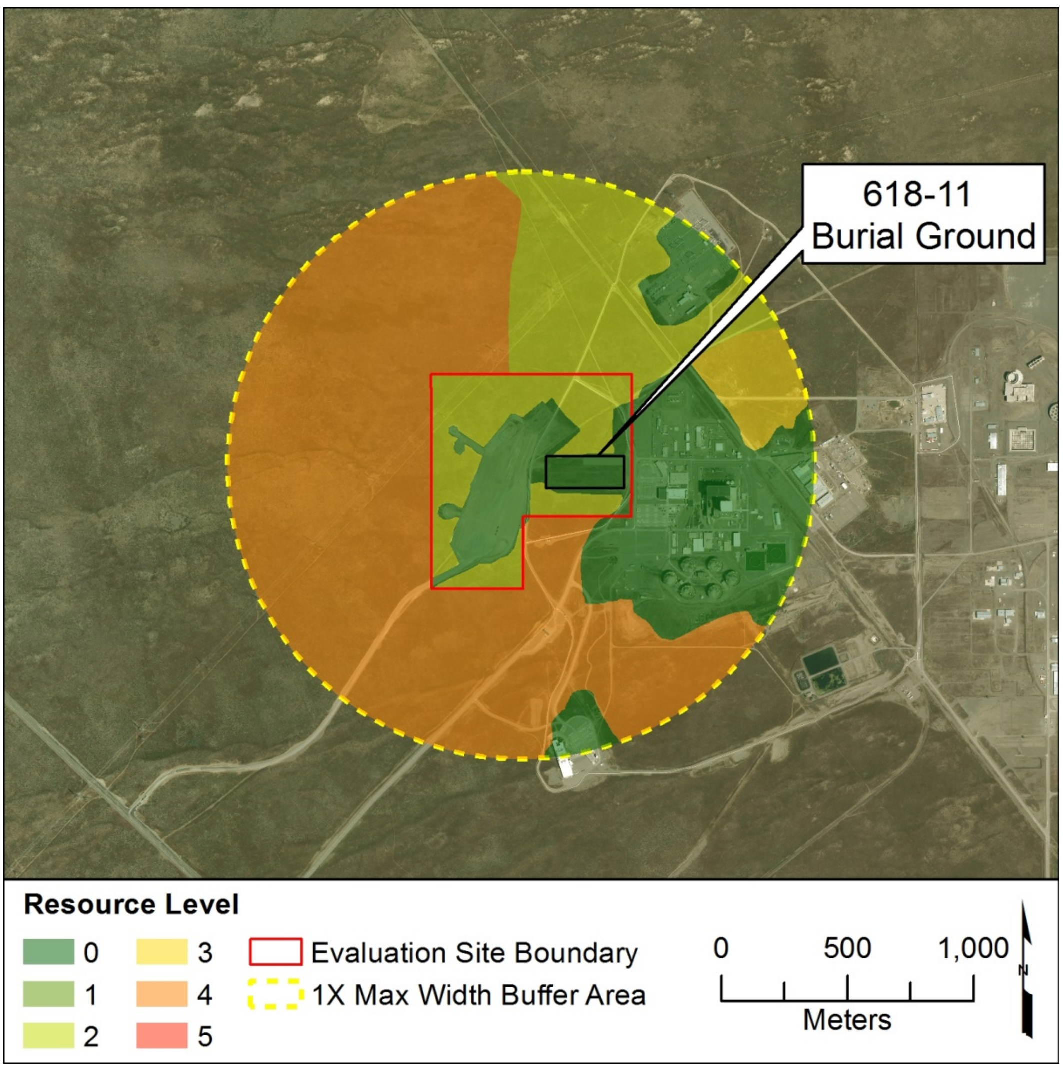

Figure 8-14. Map of biological resource level classifications for the 618-11 Burial Ground evaluation site (red) and landscape metrics buffer area (yellow).

BC Cribs and Trenches

Reconnaissance of the BC Cribs and Trenches evaluation site indicated that most of site currently consists of non-vegetated areas, heavily disturbed or revegetated areas, and compacted gravel areas (i.e., Level 0 resources; Table 4). A portion of this area that was previously classified as Level 3 and 4 (approximately 153 acres) was reclassified as Level 0 for this assessment to reflect current vegetation conditions (Figure 4). Areas of Level 3 and 4 resources still exist around the perimeter of the evaluation site and surrounding landscape, but these areas could not be accessed for field measurements due to radiological contamination restrictions. (Because this waste site and evaluation area lie within a radiological control area, no pedestrial surveys, or field survey of quadrats, or transects were attempted.)

Figure 8-15. Photograph of disturbed/revegetated area within the BC Cribs and Trenches evaluation area.

The amount of each category of biological resources at the BC Cribs and Trenches site was examined within a circular area radiating 1830 m from the geometric center of the site (equivalent to 2598 acres) to provide additional landscape context (Figure 5). Approximately 71 percent of the total site area (evaluation site and associated buffer area) is classified as Level 3 or higher biological resources in the existing resource level map. However, most of this area lies to outside of the evaluation site boundary (Figure 4). The removal of vegetation within the proposed spatial footprint of BC Cribs and Trenches cleanup activities would result in a 4.3 percent reduction in the amount of Level 3 or higher resources within a 1.8 km radius of the site.

Table 8-17. Summary of biological resource classification areas for the BC Cribs and Trenches.

	Resource Level						Total
	0	**1**	**2**	**3**	**4**	**5**	
Evaluation Site	255.9	0	0	41.5	69.6	0	367
Buffer Area Excluding Evaluation Site	294.7	52.1	163.2	429	1292.5	0	2231.5
Total Area	550.6	52.1	163.2	470.5	1362.1	0	2598.5
% Total Area Pre-Cleanup	21.2%	2.0%	6.3%	18.1%	52.4%	0.0%	100.0%
% Total Area Post-Cleanup	25.5%	2.0%	6.3%	16.5%	49.7%	0.0%	100.0%
% Change	4.3%	0.0%	0.0%	-1.6%	-2.7%	0.0%	

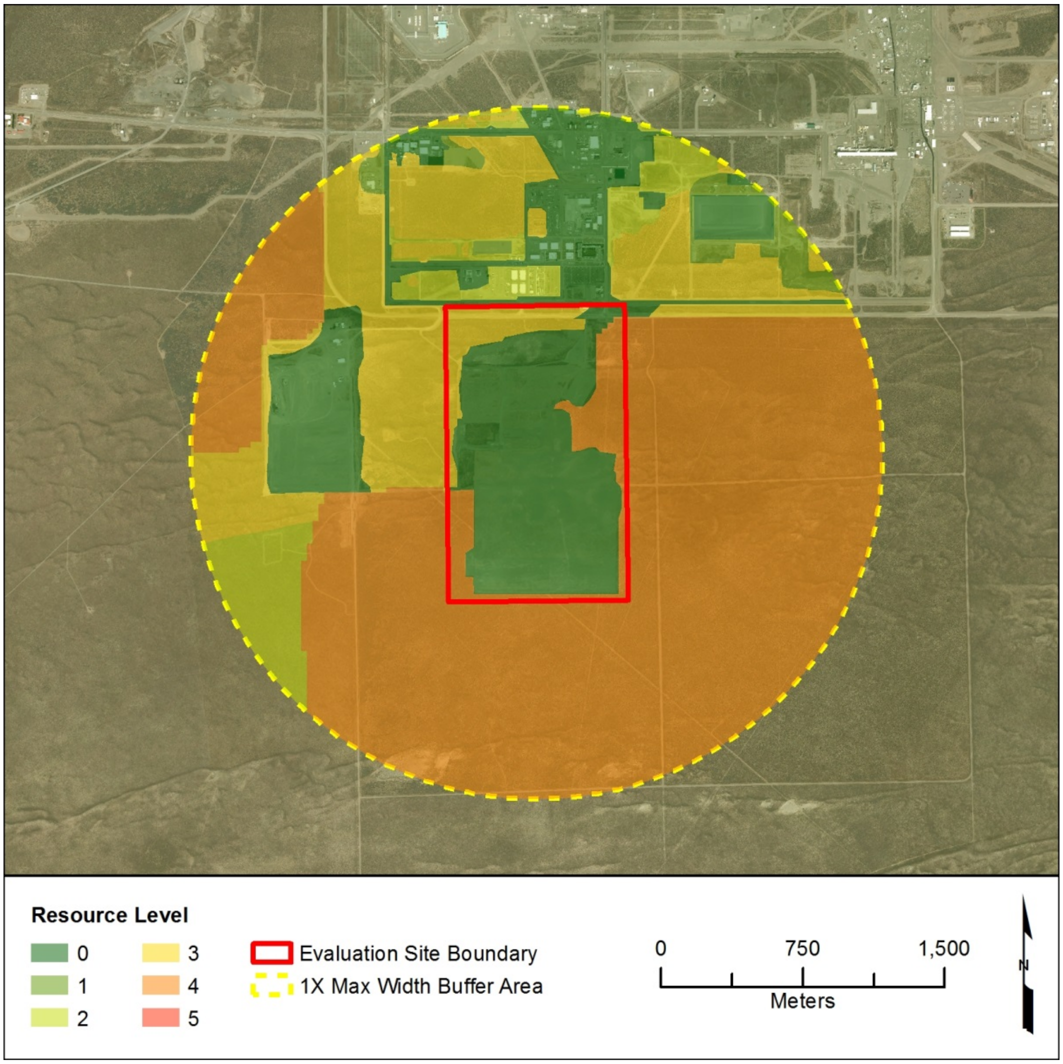

Figure 8-16. Map of biological resource level classifications at the BC Cribs and Trenches evaluation site (red) and landscape metrics buffer area (yellow).

Field Data Sheets

Table 8-18. Field data sheet utilized by PNNL staff to record vegetation composition and cover.

Field data sheet utilized by PNNL staff to record vegetation composition and cover.

Site												
Species	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**

Notes

CHAPTER 9. CULTURAL RESOURCES

ABSTRACT

This chapter describes the cultural resources at risk during two of the time periods being evaluated under the Risk Review Project. In this document, the definition of the term "cultural resources" which will be used throughout is identical to the one contained in the Hanford Cultural and Historic Resources Management Plan (DOE/EIS/RL-98-10, Rev 0 2003). The Plan states:

> "…cultural resources is a collective term applicable to: 1)prehistoric-and historic-archaeological sites and artifacts designating past Native American utilization of the Hanford Site; 2) historic-archaeological sites and artifacts indicating post Euro-American activities relating to the pre-Hanford period; 3)Hanford Site Manhattan Project and Cold War era buildings, structures, and artifacts; 4) landscapes, sites, and plants and animals of cultural value to the Native American community; and 5) landscapes, sites, and materials of traditional cultural value to non-Native Americans (DOE/EIS/RL-98-10, Rev 0 Appendix A 2003). "

The time periods evaluated for risks to cultural resources are active cleanup (50 years or 2064) and near-term post-cleanup (100 years after cleanup or until 2164). Cultural resource risks cannot be estimated mathematically in the same way that risks to groundwater can be characterized. However, the magnitude of risk can be provided in broad categories from not discernible to very high based first, on the value and importance of cultural resources within the evaluation unit (EU) and second, on the likelihood that remediation or future use of the EU may place the resource at risk. This means that the analysis for both periods will be qualitative. The third time period for evaluation – long-term post-cleanup - is not being evaluated for risks to cultural resources. This is because of the difficulty in predicting both the presence of cultural resources for a time period so remote and whether resources having value today and in the near future will have the same value hundreds of years from now.

Risks to cultural resources evaluated as part of the Risk Review Project are derived from the Hanford Cultural and Historic Resources Management Plan, other, relevant planning and regulatory documents, and applicable federal laws, cited in the References Section below. As is evident from these source documents, the primary risk factors associated with cultural resources will emerge during **active remediation** or during the time period referred to as active cleanup (50 years). Thus, the risk evaluation centers on remediation options that may take place during the period.

As all land use designations for Hanford should be in place by 2064 or when the near-term post-cleanup period begins, cultural resource risks for the near-term post-cleanup period are described using the DOE identified land use designations (DOE-EIS-0222-F 2008) as well as a land-use designation called "unrestricted." This term is designed to be consistent with an anticipated future land use designation that the US Environmental Protection Agency most recently identified in the Record of Decision for part of the Hanford 300 area (DOE/RL and EPA/Region 10 Hanford Site 300 Area 2013). So, after remediation has been completed, or stated another way, beginning in 2064, analysis of risk focuses on potential frequency of human use of the unit being evaluated within the context of the land use designation for that unit. Additionally, certain uses may cause an adverse effect on the resource itself, on sensitive receptors, or on tribal members or others using the resource.

Cultural Resources also are at risk during both time periods being evaluated from initiating events, such as loss of institutional controls or fire. Therefore, the analysis includes discussion of how the unit being evaluated may be impacted from remediation activities taking place after the actual occurrence of such an event.

9.1. OVERVIEW OF CULTURAL RESOURCES

BACKGROUND

The Hanford Site contains an extensive record of human occupation stretching over a period of more than 10,000 years. Archaeological remains and written accounts, together with the oral histories that are associated with the practices and beliefs of Native American tribes document how people lived and used the Hanford Site. As part of its responsibility for managing the Site's archeological, cultural, and historic properties and resources under federal law, the Department of Energy (DOE) has identified the following overlapping cultural landscapes (DOE/RL-98-10, Revision 0 2003). They are:

- **Native American (Pre-Contact): Approximately 10,000 Years Before the Present to the Present** - Encompasses 720 archaeological sites, prehistoric artifacts and features; traditional cultural places, such as cemeteries and objects of significance to Native Americans. Native Americans continue to hold religious and cultural affinities for the Hanford Site.
- **Historic Pre-Hanford: 1805 to 1943** – Encompasses evidence of explorers, traders, travelers, and settlers; farmsteads, homesteads, and ranches; transportation; town sites; irrigation.
- **Manhattan Project and Cold War Era: 1943 to 1990** – Encompasses Manhattan Construction Camp; Manhattan Project; Cold War and associated buildings, structures, and artifacts.[26]

As of 2004, about 25 percent of the Site had been surveyed for cultural resources. Those surveys conducted between 1926 and 2004 documented 1,447 cultural resource sites and isolated finds and 531 buildings. See Figure 9-1 below (Neitzel, D. A., ed. 2004).

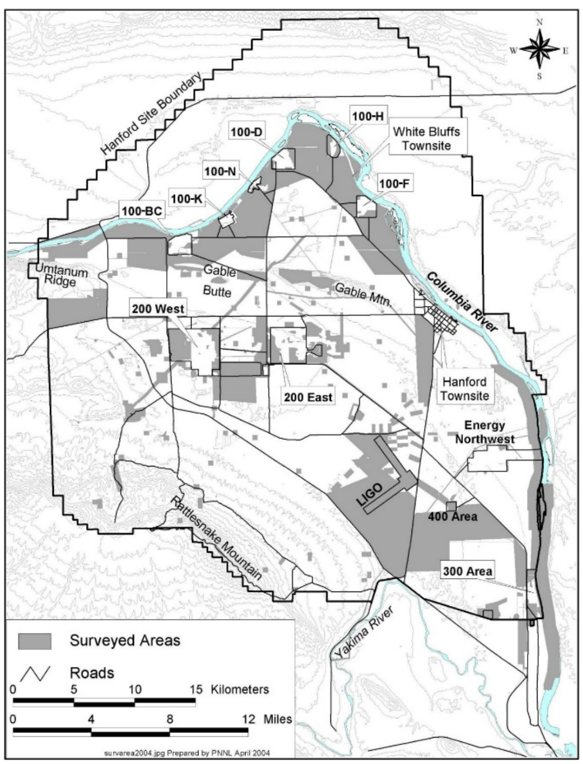

Figure 9-1. Areas surveyed for cultural resources on the Hanford Site.

[26] Structures and other items erected or installed and used after 1990 to support the cleanup effort are not included as part of the evaluation.

Of the 127 sites evaluated for listing in the National Register of Historic Places, 49 were listed. The Register contains the nation's official listing of cultural resources deemed worthy of preserving. The B Reactor is the only listing from the Manhattan Project and Cold War Era. All other listed sites relate to the landscape associated with Native Americans. Sites eligible for listing in the National Register, but not formally listed, are dispersed throughout Hanford Site. DOE treats these sites the same as if they had been listed in the Register. See Table 9-1 and Table 9-2 below, which identify the properties listed in the National Register and properties eligible for listing (together with Pacific Northwest National Laboratory (PNNL) comments on the status of the properties (2014)).

Table 9-1. Historic buildings, archaeological sites, and districts listed in the National Register of Historic Places (from Hanford Cultural Resources Management Plan, 1998).

Property Name	General Location	Landscape Association	Comment (PNNL)
Districts			
Hanford North Archaeological District	Vicinity of 100 F	Native American	No current activities, future activities require Section 106 and Tribal consultation
Locke Island Archaeological District	Vicinity of 100 H	Native American	Current and future activities require Section 106 and Tribal consultation
Ryegrass Archaeological District	Vicinity of 100 K	Native American	Same as above
Savage Island Archaeological District	North of Energy Northwest	Native American	No current or future activities planned
Snively Canyon Archaeological District	Rattlesnake Hills	Native American	Same as above
Wooded Island Archaeological District	North of 300 Area	Native American	Same as above
Sites			
Hanford Island Archaeological District (45BN121)	Vicinity of Hanford townsite	Native American	No current or future activities planned
Paris Archaeological Site (45GR317)	Vicinity of Vernita Bridge	Native American	Same as above
Rattlesnake Springs Sites (2) (45BN170, 45BN171)	Base of Rattlesnake Mountain	Native American	Same as above
Building			
105-B Reactor	100 B/C Area	Manhattan Project	Planned transfer to NPS

Table 9-2. Archaeological sites and historic districts determined eligible for listing in the National Register (from Hanford Cultural Resources Management Plan).

Property Name	General Location	Comment
Native American		
Gable Mountain Cultural District (TCP)	600 Area, North of 200 East	No change
45BN423 45BN434 45BN446 45BN606 (HT-95-186) 45-BN-888 (HT-2001-007)	100-K Area 100-K Area 100-B/C Area 100-F Area 100-D Area	Characterization ongoing in 100-K. Remediation scheduled to finish in FY15 for 100-B/C, -F and –D. Future activities require Section 106 and Tribal consultation.
Early Settlers		
McGee Ranch/Cold Creek Valley District	600 Area (Along HW24)	Remediation of Riverland Railroad Wash Pit, Delisted from NPL, no further changes planned
HT-95-050 (Fry and Conforth Farm) H3-121 (White Bluffs Road)	600 Area, East of 100-B/C Area 600 Area, 200 West Area	No current activities; future activities require Section 106 consultation
HT-95-231 (White Bluffs Bank) HT-98-039 (Bruggemann's Warehouse) Hanford Electrical Substation-Switching Station Hanford High School Coyote Rapids Hydroelectric Pumping Plant	600 Area, West of 100-B/C 600 Area, West of 100-B/C 600 Area 600 Area 600 Area	No current activities; unsure of any preservation mitigation actions; future activities require Section 106 consultation
Manhattan Project/Cold War		
Hanford Site Manhattan Project and Cold War Era Historic District	100, 200 E and W, 300, 400, 600, and 700 Areas	Only 6 sites for Manhattan Historic Park are to be preserved. Remainder of buildings are/will be evaluated as listed in DOE/RL-97-56
HT-94-028 (Anti-Aircraft Artillery Site)	600 Area, Vicinity of 200 E/W	Unclear on disposition
HT-94-029 (Anti-Aircraft Artillery Site)	600 Area, Vicinity of 200 E/W	Same as above
HT-94-030 (Anti-Aircraft Artillery Site)	600 Area, Vicinity of 200 E/W	Same as above
HT-94-031 (Anti-Aircraft Artillery Site)	600 Area, Vicinity of 200 E/W	Same as above
HT-94-032 (Anti-Aircraft Artillery Site)	600 Area, Vicinity of 200 E/W	Same as above
HT-99-007 (Hanford Atmospheric Dispersion Test Facility)	600 Area, Vicinity of 200 W	Same as above

In 2000, President Clinton issued a Presidential Proclamation establishing the Hanford Reach National Monument to protect wildlife, rare plants, and cultural resources (Presidential Proclamation 73019 2000). The Monument includes about 51 miles of the Columbia River. The Proclamation states in part: "As the Department of Energy and the U.S. Fish and Wildlife Service determine that lands within the monument managed by the Department of Energy become suitable for management by the U.S. Fish and Wildlife Service, the U.S. Fish and Wildlife Service will assume management by agreement with the Department of Energy" (Presidential Proclamation 73019 2000). Currently, approximately 65,000 acres of the Monument managed by the FWS are accessible to the public.

In 2013, identical bills were introduced in the Congress authorizing the establishment of the Manhattan Project National Historical Park at Hanford, Oak Ridge and Los Alamos as a unit of the National Park system within one year of enactment. The bills require coordination, planning, and cooperation between the National Park Service and the DOE to ensure that access to park locations would be safe and secure. Neither bill has passed the Congress (H.R. 1208 2013), but the exact language of these bills is included as a section of the Department of Defense authorization bill for fiscal year 2015. That bill passed the House of Representatives on May 22, 2014 and is pending in the Senate (H.R.4435, Section 2867 2014). (See Table 9-3 and Figure 9-2 below)

Table 9-3. Manhattan Project National Historical Park Hanford structures (explicitly identified in all legislation referred to above).

PROPERTY NAME	GENERAL LOCATION
105 B Reactor	100 B/C Area
Hanford High School in the town of Hanford and Hanford Construction Camp Historic District	600 Area
White Bluffs Bank building in the White Bluffs Historic District	600 Area, West of 100-B/C
Warehouse at the Bruggeman's Agricultural Complex	600 Area, West of 100-B/C
Hanford Irrigation District Pump House	600 Area
T Plant (221-T Process Building)	200 Area

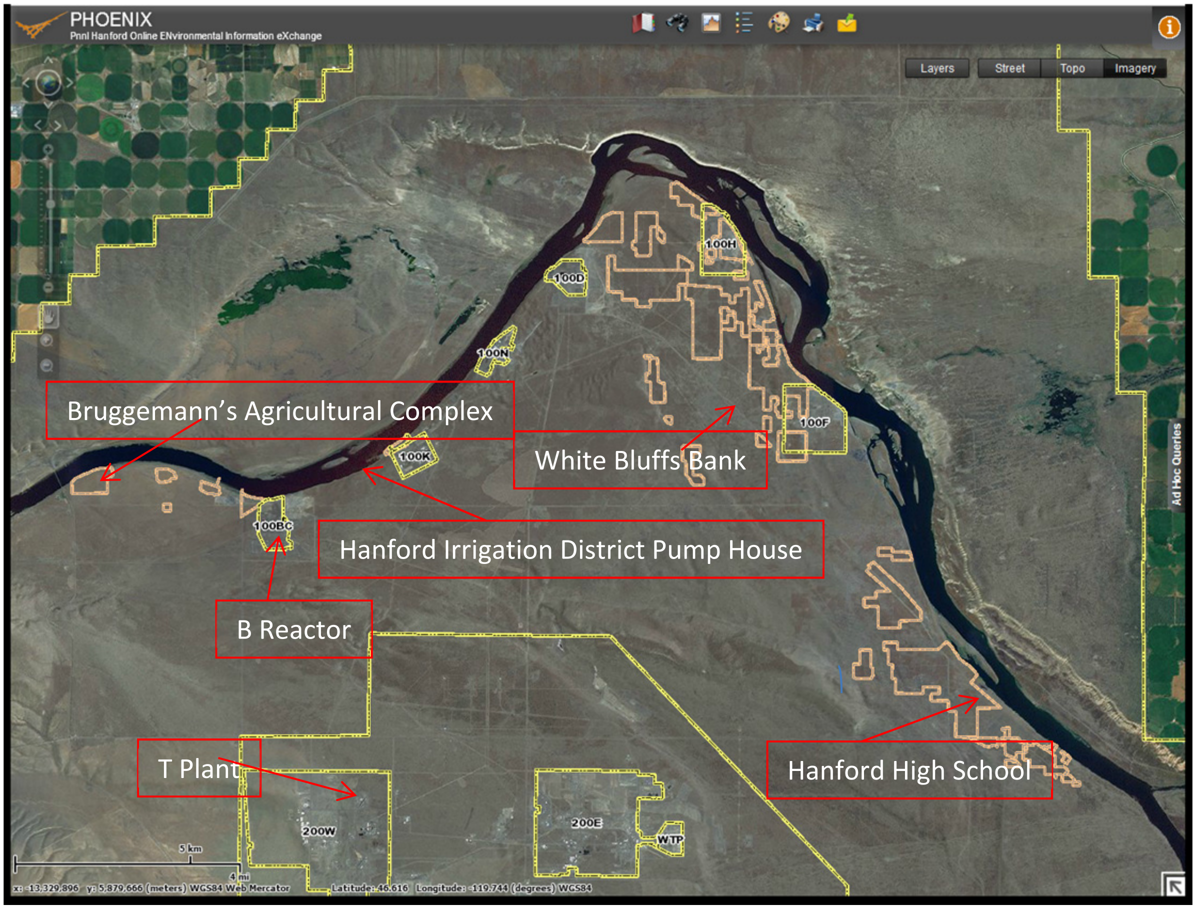

Figure 9-2. Location of properties included in legislation (prepared by PNNL, 2014).

CULTURAL RESOURCES PROGRAM OVERVIEW

In 1987, DOE-RL established the Hanford Cultural and Historic Resources program (program) to manage the Site's cultural resources (DOE/RL-98-10, Revision 1 1998). The primary objectives of the program have been to achieve regulatory compliance under federal law, meet DOE stewardship responsibilities, promote outreach with Native Americans and former residents at the Site, and protect the site's resources consistent with the 1999 Department of the Interior's National Strategy for Federal Archaeology (DOE/RL-98-10, Revision 1 1998).

During the first decade of the program's existence, a management plan was developed and procedures were implemented to ensure that all DOE undertakings (activities or projects) will receive a cultural resource clearance in accord with federal law before the activity or project proceeds. These cultural resource reviews are conducted project-by-project. Additionally, significant efforts were made to better understand the extent of the historic properties and cultural resources located at the Site and their historic, cultural, archaeological, and architectural importance or value (DOE/RL-98-10, Revision 1 1998).

To better understand the Manhattan Project and Cold War period built environment, the program completed a comprehensive inventory of the buildings and structures from this period. About 2200 were identified (DOE/RL-97-56, Revision 1 1998). Additionally, a programmatic agreement was negotiated with Washington's State Historic Preservation Officer to provide "a streamlined framework that will direct the management of all Manhattan Project and Cold War Era properties on Hanford and will guarantee that preservation efforts are expedited while ensuring that cleanup activities are not delayed" (DOE/RL-96-77, Revision 0 1996). Standards for evaluating the built environment were developed as were appropriate mitigation measures. Mitigation may include such actions as: documentation through drawings, photographs, and historical research; preservation in place; salvage of information; restoration; and collection of artifacts.

More recently, the program has focused on repatriating human remains from collections, developing a database; and developing a long term monitoring program to ensure the preservation of significant resources (DOE/RL-98-10, Revision 0 2003). DOE maintains extensive records on the history of Hanford Site, including the artifacts removed from areas at Hanford and oversees this collection of artifacts. Access to certain documents and the collection is restricted.

DOE currently consults with four tribes (Nez Perce, Umatilla, Yakama, and Wanapum) about their historical, religious and/or cultural importance that each of these tribes has attached to areas at Hanford (DOE/RL-98-10, Revision 0 2003). DOE accepts information provided orally and has agreed to keep certain information confidential, such as the exact location of a sensitive cultural resource. DOE involves tribes in cultural clearances[27] (16 U.S.C. 470 et seq; DOE/RL-98-10, Revision 0 2003) and tribal representatives have actively participated, particularly on those cultural reviews where proposed undertakings are in areas, such as the river corridor, considered to be culturally sensitive. A programmatic agreement between the DOE and each of the tribes regarding cultural resources important to that tribe has not been negotiated.

[27] Cultural Resource reviews are required to be conducted in advance of a project or activity under section 106 of the National Historic Preservation Act. The Program DOE has implemented offers three primary outcomes for proposed projects and activities. They are: no potential to cause effect (decision made internally with no consultation); no field work or mitigation required (may include site work and/or monitoring and tribes, SHPO, and interested parties may comment); and fieldwork or mitigation required (may include surveys, site avoidance, and/or data recovery and above listed groups may comment). Mitigation may dictate that a memorandum of agreement or programmatic agreement with tribes and the SHPO be negotiated and executed. If monitoring or field activities are required, tribes are offered the opportunity to participate.

9.2. METHODOLOGY FOR EVALUATING CULTURAL RESOURCES

Risks During Active Cleanup (50 Years or Until 2064)

Valuing cultural resources is predicated on several assumptions. They are: 1) cultural resources include the two time periods discussed above; 2) cultural resources include structures, geologic features, landscapes, and living resources (such as plants); 3) many cultural resources rely heavily on intact, functioning ecosystems for cultural and religious integrity; 4) extensive inventories have been conducted to identify and document the historical importance of all buildings and structures at Hanford and from these inventories, to determine which of the buildings and structures will remain after active remediation ends; and 5) not all cultural resources, particularly those that are subsurface, are mapped or identified. As such, it is important to understand the influence that preservation of Level 5 (and many Level 4) ecological resources has on cultural resources. (See Chapter 8 on Ecological Resources for definitions of Level 4 and Level 5 ecological resources)

In addition to the above, it should be emphasized that while the built environment at Hanford is well understood and documented and mitigation actions have been identified to limit or compensate for the damage the planned remediation activity will cause to the building or structure, archaeological artifacts and other cultural resources continue to be discovered at the Hanford Site. Indeed, as of 2004, seventy five (75) percent of the entire Hanford Site had not been surveyed for the existence of cultural resources (Neitzel, D. A., ed. 2004). This means both the DOE and tribes likely are unaware of the extent to which many EUs undergoing remediation contain archaeological and/or other sensitive artifacts or resources. And, as important, even when a cultural review has been completed for a structure or building, mitigation has occurred, and the risk to cultural resources is considered low, the remediation still may inadvertently expose, affect, disturb, or destroy one or more cultural resources.

Table 9-4 below follows a format that recognizes that the primary risks to cultural resources are during active remediation at Hanford. Therefore, the value of the cultural resources must be considered within the framework of different types of remediation.

Assigning a cultural resource risk rating to the EU involves following three steps. They are: determine the cultural resource level; determine the remediation option; and apply the rating.

STEP 1: Determine the Cultural Resource Level. A qualitative analysis of each EU must be made using the key and definitions below to determine the highest level of cultural resource present within the unit. This should include reviewing documentation on the unit, as well as having discussions with tribes about their views of the cultural importance of the EU. The Levels below range from resources deemed the most worthy of protection and preservation, such as Native American Burial Sites (or Level 4 Resource) to presence of resource is possible or likely (or Level 1 Resource).

The Key to levels of Cultural Resources (listed from highest to lowest within the EU) is below and is followed by a more detailed definition for each level.

> **Level 4 =** (A) Contains a Native American burial site or burial Item and/or (B) Contains property listed or eligible for listing in the National Register of Historic Places (except as described in Level 1 B)
>
> **Level 3 =** Is a location that has been specifically identified as having tribal historic, religious and cultural importance
>
> **Level 2 =** (A) Contains a place for usual and customary subsistence or consumptive practices or exercising other tribal rights by Native Americans; and/or (B) Is a place for recreation and/or is considered a view shed of a scenic place or is scenic place

Level 1 = Uncertain, But Presence Is Possible or Likely and/or (B) Contains Manhattan Project and Cold War Era building or structure(within the Historic District and eligible for listing in the National Register, but a determination has been made that the building or structure does not qualify for adaptive reuse

DEFINITIONS OF LEVELS OF CULTURAL RESOURCES

(FROM HIGHEST IN VALUE TO LOWEST IN VALUE):

LEVEL 4:

A. Native American Burial Site or Burial Item: A location is identified within the unit being evaluated that either is above or below the surface into which individual human remains are deposited. The identity can be reasonably traced historically or prehistorically between a present-day Indian tribe and an identifiable earlier group. "Burial item" means human remains and objects that, as part of the death rite or ceremony, are believed to have been placed with the individual human remains either at the time of death or later (25 U.S.C. 3001 et seq).

B. Property Present Listed or Eligible for Listing in the National Register of Historic Places (Except as described in Level 1(B)):[28] Within the unit being evaluated, there is at least one property that has been listed or is eligible for listing in the National Register of Historic Places. Buildings or structures described below in Level 1(B) are excluded.

LEVEL 3

Location Has Been specifically Identified as Having Tribal Historic Religious and Cultural Importance: (DOE/RL-98-10 1998) The EU or a location within the unit has historic religious and cultural importance to a tribe, which is defined as "… a place that is associated with cultural practices or beliefs of a living community that 1) are rooted in that community's history, and 2) are important in maintaining the continuing cultural identity of that community" (DOE/RL-98-10, Appendix A 1998). As an example, the unit being evaluated contains a place or is a landscape that has spiritual meaning to tribes, such as a butte or mountain.

LEVEL 2:

A. Contains a Place for Usual and Customary Subsistence or Consumptive Ppractices or Exercising Other Tribal Rights by Native Americans: A tribe has divulged that the unit being evaluated contains a place or is the place where historically Native Americans exercised their tribe's treaty (made with the United States) rights, such as engaging in practices as gathering or collecting food and/or medicinal plants, including berries, roots, seeds, nuts, and herbs. Alternatively, the EU contains a place or is the place where historically Native Americans exercised other treaty rights, such as fishing or hunting. However, the tribe or tribes may not have divulged the precise or exact location.

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[28]Under federal law, property means any prehistoric or historic district, site, building, structure, or objects significant in American history, architecture, archaeology, engineering, and culture on, or eligible for inclusion on the National Register including artifacts, records, and material remains related to such a property or resource. The National Register of Historic Places is the official listing of cultural resources worthy of preservation. National Historic Preservation Act, 16 U.S.C. 470a(a)(1)(A); 36 CFR Part 800 (2004). Section 800.4(a)(4) states: "Review existing information on historic properties within the area of potential effects, including any data concerning possible historic properties not yet identified." This includes "those located off tribal lands, which may be of religious and cultural significance to them and may be eligible for the National Register recognizing that an Indian Tribe… may be reluctant to divulge specific information regarding the location, nature, and activities associated with such areas." 36 CFR 800.5(a)(2). See Archeological and Historic Preservation Act of 1974, 16 U.S.C. 461-469c-1, which imposes additional requirements on an agency if the project will affect historic properties having archeological value.

B. Place for Recreation and/or Is Considered a View Shed of a Scenic Place or is a Scenic Place: The unit being evaluated has recreation value (e.g., fishing, boating, camping). The unit contains a place or is a landscape that is considered scenic or has scenic value, such as a butte or mountain. A view shed is the visual corridor that allows for unobstructed examination or observation of the scenic place.

LEVEL 1:

A. Uncertain, but Presence Possible or Likely: A survey of the unit being evaluated has not been conducted to determine whether any cultural resource in fact exists or is present. However, the existing information (records and literature) has been reviewed within the EU and indicates that a cultural resource may be present (e.g., adjacent unit surveyed and contains cultural resources). Tribes have not divulged or may be reluctant to divulge whether the unit being evaluated contains resource(s) of cultural value to Native Americans. Tribes have asserted that the entire Hanford site is of value to the Tribes from a cultural resource perspective.

B. Contains Manhattan Project and Cold War Era building or structure within the historic district eligible for listing in the National Register, but a determination has been made that the building or structure does not qualify for adaptive reuse: The unit being evaluated contains a building or structure that has been described in the site-wide treatment plan for Manhattan Project and Cold War Era buildings and structures (DOE/RL-97-56, Revision 1 1998). The building or structure was considered to be a contributing or non-contributing element to the National Historic Register eligibility of the historic district. However, a determination has been made the building or structure does not qualify for adaptive reuse as an interpretive center, museum, industrial or manufacturing facility (DOE/RL-97-56, Revision 1 1998).

STEP 2: Determine the Remediation Option. DOE uses a range of cleanup approaches for each type of source at Hanford and those remediation options are listed in Table 9-4 below. The remediation option for the EU will be obtained from the Table. There may be more than one remediation option being considered. If that is the situation, then, each option should be identified and the value for each provided (or a range of values).

STEP 3: Apply the Rating. The Risk Review Project has identified risk ratings of not discernible, low, medium, high, and very high. As noted, while much is known about the Hanford Site, a significant portion has yet to be surveyed. Further, surveys will not necessarily identify all the resources that are present with an EU, particularly those located below the surface (e.g., burial items and artifacts). This means that at best, it may be possible to provide only a qualitative assessment of risk to cultural resources at a particular EU as it undergoes remediation.

The assigned ratings in Table 9-4 are a function of the likelihood of a cultural resource being present based on the Level of Resource assignation made in Step 1 and the extent to which the subsurface or near surface may be disturbed during a specified type of cleanup. So, cleanup options where subsurface disturbance is minimal are rated lower than those options where disturbance is a certainty. As an example, remediation involving excavation most certainly will include digging and is assigned a higher rating for each level of resource than the remediation option of natural attenuation, where minimal disturbance will occur.

Additionally, the rating takes into consideration the potential that the remediation type and its scale will cause an indirect or visual effect, such as to a view shed of a cultural resource (36 CFR 800.16(d)). All remediation options (except natural attenuation) could cause an indirect or visual effect on Level 3 and 4 resources and are rated either high or very high.

Once the remediation option is known, then, the risk to Cultural Resource is determined by finding the rating attached to the Level of Resource for the Remediation Option. As an example, a Native American burial site is considered a Level 3 Resource and when pump and treat is the remediation option for the unit being evaluated containing the burial site, the Risk Rating to be assigned is "High." If more than one remediation option is being considered, then, the entire range of appropriate ratings is indicated. The remediation options below are general categories only and, so, the rating may need to be adjusted up or down depending on whether the planned remediation within that option will result in greater or lesser subsurface disturbance than the disturbance normally expected for the remediation option.

Table 9-4. Risks to Cultural Resources (by Cultural Resource Level) from Active Cleanup.

REMEDIATION OPTIONS	Level 1 Resource	Level 2 Resource	Level 3 Resource	Level 4 Resource
Natural Attenuation	Not Discernible	Low	Low	Low
In Situ Containment, excluding Impacts to Borrow Areas (e.g., Capping (may involve modest subsurface work)	Low	Medium	High	High
Pump and Treat (disturbance may only be around location of recovery well)	Low	Medium	High	High
In-Situ Treatment (e.g., permeable barriers; grouting (may include agents injected in subsurface and mixed)	Low	Low to Medium	Medium to High	High
Decommissioning and Demolition	Medium	High	High	Very High
Excavation	Medium	High to Very High	High to Very High	Very High

Activities supporting remediation vary in intensity and level and, as such may vary in how they would impact cultural resources, particularly those that would not be exposed until the remediation. Table 9-5 below is arranged from lowest (unlikely) to highest (permanent) effects/impacts to a unit being evaluated. Table 9-5 is provided as a guide so that activities supporting remediation are considered along with the cleanup itself. Ratings are qualitative considering the likelihood that the identified activity involves or may involve subsurface disturbance, which would expose the cultural resource to damage or otherwise cause an adverse effect. As an example, activities associated with soil removal are rated permanent for cultural resources because of the likelihood that removal will expose a resource and cause it to be adversely affected.

Table 9-5. Effects/impacts to Cultural Resources from associated activities during Active Cleanup.

TYPE OF DISTURBANCE FROM REMEDIATION	EFFECTS/IMPACTS TO CULTURAL RESOURCE (Unlikely, Likely, Permanent)
Personnel traffic through non-target area	Unlikely Effects unless resource is close to surface and can be inadvertently exposed
Personnel traffic through target (remediation) area	Unlikely Effects (see above); may be disruptive if trails are made that decrease view shed value
Car traffic on adjacent site	Unlikely Effects (see above)
Car traffic on remediation site	Depends upon level of traffic and whether permanent roads are made or invasive species decrease presence of native plants used for medicinal or tribal religious purposes
Car traffic on remediation site	Depends upon level of traffic and whether permanent roads are made or invasive species decrease presence of native plants used for medicinal or religious purposes
Truck traffic on roads through non-target area	Unlikely Effects (see above)
Truck traffic on roads through remediation site	Unlikely Effects (see above); Depends upon level of traffic, and whether permanent roads are made, or invasive species decrease presence of native plants used for medicinal or religious purposes
Heavy Equipment	Likely Effects possible but depends on whether resource may be exposed by work
Drilling Rigs	Likely Effects possible but depends on whether "undiscovered" resource may be exposed by work; Heavy equipment could result in introduction of invasive species that displace native species used for medicines, food, or cultural purposes; may result in permanent compaction, changing the aspect of the landscape and view shed
Construction of buildings	Permanent Effects; act of construction may destroy resource
Caps, Other containment	Permanent Effects; Containment act may destroy resource; if resource is not destroyed, containment may disturb or adversely affect resource
Soil Removal	Permanent Effects; act of removal may destroy resource; if resource not destroyed, soil removal may disturb or adversely affect resource; Complete destruction of view shed, plants and animals used for food, medicines, or cultural purposes; Possible introduction of invasive species that preclude restoration

Risks During Near Term Post-Cleanup (100 Years or Until 2164)

After remediation has been completed and while institutional controls are assumed to be functioning (until 2164), the primary risk to cultural resources is associated with human use or intrusion. To help characterize that risk, the identified land use designation (See Part 1 of this document) is determined for the unit being evaluated. After that determination is made, then, risk is evaluated in two steps. First, a qualitative determination is made of the likelihood of a Level 3 cultural resource being present in the unit, based on the extent to which documentation, including cultural resource reviews conducted for active remediation, and discussions with tribes indicate any Level 3 or 4 cultural resources are present or may be present within the EU. Second, the rating is applied assuming that a Level 3 or 4 cultural resource is present. Determining the rating is based on the expected frequency of human use within the EU that can be predicted in a qualitative way from the description of the land use. Likelihood of presence of the resource is expressed as follows: Unlikely Present, Potentially Present, Likely Present, or Present.

Source documents cited in the Reference section reveal that cultural resources are more likely to be present within land use areas designated as conservation and preservation, particularly along the Columbia River. At the same time, it is also likely that cultural resources actually present within these two land use designations can be protected from human activities that may lead to their exposure or cause an adverse effect or even destruction.

For purposes of the rating described in Table 9-6 below during the Near-term Post Cleanup time period, it is presumed properties either listed or eligible for listing in the National Register of Historic Places that still remain at the Hanford Site will continue to be maintained during the entire period. It also is presumed that certain land use designations mean the land management entities will have authority to protect the resource from human activities.

Table 9-6. Risks to Level 3 Cultural Resources from land use designation during Near-Term Post-Cleanup Period (100 years or until 2164).

LAND USE	LIKELIHOOD OF PRESENCE OF LEVEL 3 CULTURAL RESOURCE LEVEL 4: A) Contains a Native American burial site or burial Item; and/or (B) Contains property listed or eligible for listing in the National Register of Historic Places (except as described in Level 1 B) LEVEL 3: Is a location that has tribal historic, religious and cultural importance	RISK WHEN LEVEL 3 and/or LEVEL 4 CULTURAL RESOURCE IS ACTUALLY PRESENT
Industrial-Exclusive (hazardous wastes)	Unlikely Present	Very High
Industrial – transport, mining, manufacturing, warehouses	Potentially Present, but presently unknown as any such resources are located below surface. Inadvertent discovery may be difficult to avoid.	Very High
Research and Development	Potentially Present in areas, but it is possible to protect resources from intrusive human activity.	High
High-Intensity Recreation (mostly along river corridor)	Likely Present in concentrated areas that may be protected by law or regulation. Need to limit high intensity recreation in areas where Level 3 resources are currently known to be present.	Medium
Low-Intensity Recreation (mostly along river corridor)	Likely Present in concentrated areas that may be protected by law or regulation. Need to limit certain forms of recreation in areas where Level 3 resources are currently known to be present.	Low
Conservation (mining)	Present in most areas, but it is possible to limit mining related activities.	Very Low
Preservation	Present in many areas that either should be protected from human activities or closely monitored, particularly if the resource is important to Native Americans. As an example, tribes may object that certain activities such as walks in sensitive areas, as the activity may decrease the value of the resource and impact the ecology and/or a tribal treaty right.	Very Low
Unrestricted	Present in many areas that either should be protected from human activities or closely monitored, particularly if the resource is important to Native Americans. If residential is one of the uses, protection may be difficult.	Very High

Table 9-7 addresses residual effects from associated cleanup activities (See Table 9-5 for list) that may still be present during the 100-year period following active remediation. Table 9-7 is provided as a guide or resource only.

Table 9-7. Residual effects to Cultural Resources from associated cleanup activities during Near-Term Post Cleanup (residual effects after cleanup is complete).

TYPE OF DISTURBANCE FROM REMEDIATION	CULTURAL RESOURCE EFFECTS
Personnel traffic through non-target area	Effects no longer present assuming resource not disturbed during remediation
Personnel traffic through target (remediation) area	Effects no longer present assuming resource not disturbed during remediation
Car traffic on adjacent site	Effects no longer present assuming resource not disturbed during remediation
Car traffic on remediation site	Effects no longer present assuming resource not disturbed during remediation; Could cause permanent paths in vegetation, some invasive species, changes in plants used for food, medicines or cultural purposes
Truck traffic on roads through non-target area	Effects no longer present assuming resource not disturbed during remediation
Truck traffic on roads through remediation site	Effects no longer present assuming resource not disturbed during remediation; Similar to car traffic
Heavy Equipment	Permanent effects possible in areas of heavy equipment use
Drill Rigs	Permanent effects in the area of drill rig construction. Possible permanent effects in area surrounding rigs, depending upon traffic and current activities.
Caps, Other Containment	Permanent effects in the area of cap site, if resource was exposed thereby creating a possibility that other resources around the cap may be exposed depending on traffic and current activities. Periodic monitoring of cap will involve effects due to personnel, car and truck traffic.
Soil Removal	Permanent effects in the area of soil removal, if resource was exposed thereby creating a possibility that other resources are near/adjacent to the area where soil was removed depending on traffic and current activities. Periodic monitoring of cap will involve effects due to personnel, car and truck traffic (see previous table). Degree of effect depends also upon restoration activities (potential for further exposure of resources).

Initiating Events

Human or natural caused initiating events could strike the Hanford area at any time although certain events such as fire are more likely than others (e.g., plane crash; see Chapter 4). And, any of the events could destroy a cultural resource, including a property listed or eligible for listing in the National Register of Historic Places. A more complete description of the range of impacts or effects these hazard events could have on a cultural resource follows. Those impacts/effects described are: disturbed, but no adverse effect; denied consumptive use; denied access; adverse effective; and destruction. After the event, remediation may occur, which may further jeopardize cultural resources not already destroyed by the event. The impacts or effects from remediation are described below in Table 9-8.

A description of the range of impacts/ effects follows.

Disturbed, but no adverse effect: The event directly or indirectly either has caused or will cause the resource to be harmed or otherwise disturbed, but the disturbance has no adverse effect on the cultural resource or the potential for having an adverse effect (36 CFR 800.3, 5 2004). For purposes of this discussion, an "adverse effect" occurs when any of the characteristics of the resource may be altered, directly, or indirectly in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. Adverse effects may include reasonably foreseeable effects caused by the proposed activity. Examples include: alteration of the cultural resource, removal of the cultural resource from its historic location, change of the character of the cultural resource's use or of physical features, introduction of visual, atmospheric or audible elements that diminish the cultural resource's significant historic features, transfer, lease or sale of cultural resource out of federal ownership or control without adequate restrictions/conditions (36 CFR 80.5 2004). Adverse effect also may occur when the property, resource or place is or has been subjected to fire. Adverse effect does not include the potential to eradicate, obliterate, demolish, or otherwise destroy part or all of the resource within the unit being evaluated.

Denied Consumptive Use: Within the area of the initiating event (which would include the EU), individuals are not currently or will not prospectively be authorized to engage in religious, cultural, or usual and customary subsistence or consumptive practices, such as collecting food and/or medicinal plants, including seeds, nuts and herbs) or to exercise rights reserved under a treaty such as fishing or hunting. Individuals may be denied access to hunting, fishing or engaging in recreation activities.

Denied Access: Individuals are not currently or will not prospectively be authorized to enter the area of the initiating event for the purpose of performing ceremonial use of religious sites (DOE/RL-98-10 1998), usual and customary subsistence or consumptive use practices, such as collecting food and/or medicinal plants, including seeds, nuts and herbs or to exercise rights reserved under a treaty such as fishing or hunting.

Adverse Effect: The event does have an adverse effect on the resource or has the potential for having an adverse effect. An "adverse effect" occurs when any of the characteristics of the property/resource may be altered, directly, or indirectly in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. Adverse effects may include reasonably foreseeable effects caused by the proposed activity. Examples include: alteration of the property, removal of the property from its historic location, change of the character of the property's use or of physical features, introduction of visual, atmospheric or audible elements that diminish the property's significant historic features, transfer, lease or sale of property out of federal ownership or control without adequate restrictions/conditions (36 CFR 800.5). Adverse effect also may occur when the property, resource, or place is or has been subjected to fire. Adverse effect does not include the potential to eradicate, obliterate, demolish, or otherwise destroy part or all of the cultural resource within the unit being evaluated.

Destruction: The initiating event has the potential to eradicate, obliterate, demolish, or otherwise destroy part or all of the cultural resource within the unit being evaluated.

Table 9-8. Types of cleanup impacts/effects after an Initiating Event.

INITIATING EVENT	SYNERGISMS WITH REMEDIATION
Loss of Institutional Controls	Increased human activities (same effects as those listed in previous table), depending on whether resource is present. Use of/access to resource by Native Americans may be precluded.
Loss of Engineered Controls	Increased human activities (same effects as those listed in previous table), depending on whether resource is present. Use of/access to resource by Native Americans may be precluded.
Structural Decay	Increased human activities (same effects as those listed in previous table), depending on whether resource is present. Use of/access to resource by Native Americans may be precluded.
Fire	Increased human activity related to fire-fighting, and to remediation needed to repair any engineering controls or structures on site. Effects can vary depending on degree of human activity. Use of/access to resource by Native Americans may be precluded.
Earthquake	Increased human activity related to dealing with any damage to engineered controls and buildings, and to remediation needed to repair any engineering controls or structures on site. Effects can vary depending on degree of human activity. Use of/access to resource by Native Americans may be precluded.
Dam Failure (flooding)	Potential increases of human activity related to dealing with any damage to engineered controls and buildings, and to remediation needed to repair any engineering controls or structures on site. Effects can vary depending on degree of human activity. Use of/access to resource by Native Americans may be precluded.
Ash Fall (Volcanic)	Potential increases of human activity related to dealing with any damage to engineered controls and buildings, and to remediation needed to repair any engineering controls or structures on site. Effects vary depending on degree of human activity. Potential loss of resource that Native Americans value.
Climate Change	Long-term shifts in use of resource that Native Americans value that cannot be restored.
Drought	Long term: potential loss of resource that Native Americans value that cannot be restored.
Water Table Decreases	Increased human activity as a result of increased need for engineered controls or remediation of existing facilities. Long term: potential loss of resource that Native Americans value that cannot be restored.
Plane Crash	Potential increases of human activity resulting from immediate rescue and human safety activities, as well as those dealing with any damage to engineered controls and building s and to remediation needed to repair any engineered controls or structures on site. Effects may vary depending on degree of human activity both immediately and over longer period. Use of/access to by Native Americans may be precluded.

9.3. REFERENCES

DOE/EIS-0222-F 1999, Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement, Richland, Wash. :U.S. Department of Energy, Richland Operations Office, Richland, Wash.

DOE/EIS-0222-SA-01 (2008) Supplemental Analysis, Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement, Richland, Wash. :U.S. Department of Energy, Richland Operations Office, Richland, Wash.

DOE/RL-98-10, Revision 0 (issued to public 2003), Hanford Cultural and Historic Resources Management Plan, Richland, Wash. :U.S. Department of Energy, Richland Operations Office, Richland, Wash.

DOE/RL and EPA/Region 10 Hanford Site 300 Area, Record of Decision for 300-FF-2 and 300FF-5, and Record of Decision Amendment for 300 FF-1 (2013), U.S. Department of Energy, Richland Operations Office, Richland, Wash.

DOE/RL-RIMS-EM-PD (2010) Hanford Cultural and Historical Resources, Richland, Wash. :U.S. Department of Energy, Richland Operations Office, Richland, Wash.

DOE/RL-96-77, Revision 0 (1996), Programmatic Agreement Among the U.S. Department of Energy, Richland Operations Office, the Advisory Council on Historic Preservation , and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site, Washington, Richland, Wash. :U.S. Department of Energy, Richland Operations Office, Richland, Wash.

DOE/RL-97-56, Revision 1 (1998), Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan, Richland, Wash.: U.S. Department of Energy, Richland Operations Office, Richland, Wash.

Neitzel, D. A., ed. 2004. Hanford Site National Environmental Policy Act (NEPA) Characterization. PNL-6415, Rev. 16. Pacific Northwest National Laboratory, Richland, Washington.

Statutes and Regulations

Archaeological Resources Protection Act of 1979, 16 U.S.C. 470aa et seq.

Archeological and Historic Preservation Act of 1974, 16 U.S.C. 461 et seq.

American Indian Religious Freedom Act, 42 U.S.C. 1996 et seq.

National Historic Preservation Act of 1966, 16 U.S.C. 470 et seq.

Native American Graves Protection and Repatriation Act, 25 U.S.C. 3001 et seq,

36 CFR 800 (2004), Protection of Historic Properties, U.S. Department of the Interior, Code of Federal Regulations

Executive Orders, Proclamations and Legislation

Executive Order 13007, Indian Sacred Sites, 61 FR 26771-26772 (1996)

Presidential Proclamation 73019, Establishment of the Hanford Reach National Monument

(June 9, 2000), 3 CFR Vol. 1 2001-01-01

H.R. 4435, Section 2867, 113 Cong., 2d Sess. (2014)

H.R. 1208, 113 Cong. 1st Sess. (2013)

S.507, 113 Cong. 1st Sess. (2013)

APPENDIX A

HANFORD SITE-WIDE RISK REVIEW PROJECT DIRECTION MEMORANDUM

Department of Energy
Washington, DC 20585
January 16, 2014

MEMORANDUM FOR DAVID G. HUIZENGA
SENIOR ADVISOR
FOR ENVIRONMENTAL MANAGEMENT

DAVID S. KOSSON
PRINCIPAL INVESTIGATOR, CONSORTIUM FOR RISK EVALUATION WITH STAKEHOLDER PARTICIPATION

FROM: DAVID M. KLAUS
DEPUTY UNDER SECRETARY
FOR MANAGEMENT AND PERFORMANCE

SUBJECT: Hanford Site-Wide Risk Review Project

The purpose of this memo is to request the conduct of a Hanford site-wide evaluation of human health, nuclear safety, environmental and cultural resource risks (Risk Review Project). The goal of the Risk Review Project is to identify and characterize potential risks and impacts to the public, workers, and the environment at the Hanford Site and to inform the efficient use of Department of Energy (DOE) Environmental Management (EM) resources. The project shall be independently led by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) and shall involve the active cooperation and participation of senior management at DOE-EM, DOE-Office of River Protection (ORP) and DOE-Richland (RL) as well as by U.S. Environmental Protection Agency (EPA) and the State of Washington Departments of Ecology and Health as participants in a Core Team to be established as part of the execution of the project. Additionally, the Pacific Northwest National Laboratory will provide assistance in a supporting role to CRESP during the Project.

The purpose of the Risk Review Project is to review existing information and to develop a summary level catalogue of risks and impacts to the environment and to rate or bin those risks and impacts according to the magnitude of potential risks to the members of the public, workers, and to the environment. The Risk Review Project should take into consideration: current and potential future impacts to human health (public and workers), land and river ecology, nuclear safety, natural resources, and cultural resources. This effort is to focus on risks associated with cleanup work that is currently on-going and remaining at the Hanford Site, and therefore recommendations should be prospective in nature. On-going and future cleanup work to be considered includes tank waste treatment and tank closure; soils, vadose zone and groundwater remediation; facility decommissioning; on-site near-surface disposal; and on-site risks from transuranic and high level wastes projected for off-site disposition for which formal regulatory completion of the remedy or corrective action has not been achieved. The review should place Hanford environmental and nuclear safety hazards and risks in context with currently designated future uses of the Hanford site and nearby land uses and activities that have a potential to impact risks, natural resources, and cultural resources. Additional context should be provided on impacts to on-site and nearby economic resources.

The participation of EPA Region 10 and EPA Headquarters and Washington Department of Ecology (Ecology) and Washington Department of Health (Health) is an important component of the Risk Review Project. Toward that end, please ensure that EPA, Ecology and Health are provided the opportunity to have representation on the Core Team, which will be established to oversee the development of risk characterization metrics and templates for determining risk ratings, the analysis and integration of rating results and to develop conclusions and recommendations regarding the risks and impacts evaluated. Additionally, please consult with appropriate tribal nations and give other stakeholders and agencies an opportunity to provide input during the execution of the Risk Review Project.

To help ensure efficient completion of the Project, I am directing the following:

1. EM, ORP, and RL will make the necessary staff and resources available to assist CRESP in conducting the review in a timely manner. This includes active senior management participation on the Core Team; and
2. EM, ORP, and RL will provide CRESP with all appropriate written reports, investigations, reviews, maps, charts, surveys, summaries or other communications or documents and access to electronic databases that CRESP may request as needed for the Risk Review Project. Documentation and electronic data may include mapping or other geographic information system data and overlays.

CRESP is responsible for scheduling meetings and/or teleconferences as needed, with cooperation from RL, ORP and EM. CRESP is to carry out the Risk Review Project based on the following schedule:

1. Within 2 months, initiate Core Team meetings to be held in Richland, WA;
2. Within 9 months, provide for review a set of approximately half of the draft summaries and specific evaluations to be completed and an interim progress report; and
3. Within 18 months, provide a draft final report.

A more detailed schedule is to be developed and updated quarterly. Quarterly progress summaries are to be provided by CRESP as well as progress briefings, as requested.

APPENDIX B

SAMPLE
EVALUATION UNIT SUMMARY TEMPLATE

Table of Contents

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EU Designation:
["EU" refers to Evaluation Unit.][1]

Part I. Executive Summary

[Part I needs to be strictly limited to less than 3 pages.}

EU Location:

[This would be the general Hanford Area, i.e., 200 West, 200 East, 100-K Area, etc.]

Related EUs:

[This is a list of evaluation units that are closely related (i.e., near surface contamination that overlies groundwater plumes, etc.).]

Primary Contaminants, Contaminated Media and Wastes:

[This should be a listing of the primary contaminants that are risk drivers, associated wastes and their physical/chemical form. Note that the terminology "primary contaminants" is used to differentiate from a regulatory list of "contaminants of potential concern." For this Risk Review Project, a shorter list of primary contaminants is used to focus on the risk drivers in each EU as well as contaminants that are considered iconic for the Hanford Site (e.g., uranium, plutonium, technetium, etc.). This is a brief summary of the key contaminants, media, wastes and forms (should be as a comma delimited list).]

Brief Narrative Description:

[This section should be limited to 1 paragraph.]

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[1] Instructions for completing the template appear in blue text.

Add EU Designation here
REVIEW DRAFT, add date here

Summary Table of Risks and Potential Impacts to Receptors:

[The potential set of ratings are: NA (not applicable), IS (insufficient information available to rate), ND (not discernible from natural conditions), Low, Medium, High, Very High.]

EU: xxxxx - Risk or Impact Rating				
Population or Resource		**Evaluation Time Periods**		
		Active Cleanup (to 2064)		Near-Term Post Cleanup (to 2164)
		Current Condition/ Operations	From Cleanup Actions	
Human	Worker ** (remediation & facility worker)			
	Worker (co-located)			
	Public			
Environmental	Groundwater			
	Surface water			
	Ecological Resources			
Social	Cultural Resources			
	Economic Resources			

[**Worker risks are as a consequence of maintenance, operations, cleanup activities, and post-cleanup maintenance and monitoring (where applicable).]

Support for Risk and Impact Ratings for each Time Period

[The following subsections should be brief notes that highlight the key risks and potential impacts. For EUs with multiple sources, the relative importance or risk/impacting source areas should be identified. This should also identify the primary mechanisms/pathways that present the most important risks and potential impacts.]

Current Condition:

Risks and Potential Impacts from Selected or Potential Cleanup Approaches:

Risks and Potential Impacts if Cleanup is Delayed:

[This is a discussion of the concerns if remediation is deferred until late in the cleanup time period. For example, for D&D cases it may point to the loss of the building envelope integrity, resulting in more complex D&D and increased worker risk.   For HLW tanks, this may point towards future leakage from specific tanks that may be important. In some cases, delay may be beneficial because of radioactive decay. For Operating Facilities, this section may be not be applicable and should just be indicated as “NA”.]

Near-Term, Post-Cleanup Risks and Potential Impacts:

Long-Term, Post-Cleanup Conditions:

[This section should focus on the remaining inventory (order of magnitude of the remaining source) or contamination/facilities, the physical state, and important pathways that may lead to risks or impacts. We are not "rating" long-term, post-cleanup risks.]

Part II. Administrative Information

OU and/or TSDF Designation(s): [This should provide the cross-walk to regulatory identifications.]

Common name(s) for EU:

Key Words:

[A common list of key words will be developed and then supplied for inclusion where applicable. An initial list should include: soils, vadose zone, groundwater, HLW Tanks,… The purpose here is to provide a basis for sorting.]

Regulatory Status

Regulatory basis: [CERCLA, RCRA, WA MOTCA?]

Applicable regulatory documentation: [i.e., baseline risk assessment, RI/FS, NEPA EIS, records of decision, etc.]

Applicable Consent Decree or TPA milestones: [indicate applicable milestone and date]

Risk Review Evaluation Information

Completed:

Evaluated by: [This should indicate the team members that completed the evaluation. Use first initial and last name, without affiliation.]

Reviewed by: [This should indicate who reviewed the evaluation prior to completion. Reviewers should be indicated by first initial and last name.]

Part III. Summary Description

Current land use: [This should be a simple statement of the current land use. For most cases, it will just be "DOE Hanford Site".]

Designated future land use:

[This should be the land use designation from the Comprehensive Land Use EIS.]

Primary EU Source Components

[These next subsections should be a listing/brief identification/description of the major components within the EU by source component types. The nomenclature has been made consistent with that used in the section "Methodology for Grouping Contaminant Source for Evaluation"]

Legacy Source Sites: [Includes soils, cribs, trenches, vertical pipe units, buried TRU, vadose zone contamination, etc.]

High-Level Waste Tanks and Ancillary Equipment:

Groundwater Plumes:

D&D of Inactive Facilities:

Operating Facilities:

Location and Layout Maps

[A map/figure illustrating the location of the EU within the Hanford site and one or more "zoom in" that illustrates the layout of sources within the EU]

Part IV. Unit Description and History

[Part III - only use the subsections that are applicable to the EU being considered. For example, if the unit being evaluated does not include any buildings or structure, include the section heading but place a hyphen following the subsection heading and state " – Not Applicable". Remaining parts of the subsection should be deleted.
This section, in combination with the inventory in Part IV should provide all of the information needed to carry out the risk ratings with respect to each type of receptor.
For Groundwater, the range of concentrations within the plume or plume maps are appropriate, as well as the estimated rate of expansion/contraction of impacted groundwater. For surface soils and vadose zone, travel times and concentrations needed to describe impacts to groundwater should be included.]

EU Former/Current Use(s)

Legacy Source Sites

[Includes soils, cribs, trenches, vertical pipe units, buried TRU, etc]

What is the origin and history of the contamination (e.g., accidental release, intentional discharge, multiple discharges)?

What are the primary contaminants (risk drivers)?

Are there co-contaminants that will affect mobility of the primary contaminants?

What is the depth of contamination and soil type/stratigraphy associated with the contamination? Is the soil profile primarily natural or heavily disrupted?

What is the physical state of the primary contaminants (i.e., adsorbed in contaminated soil, as debris, in subsurface piping)?

Is information available indicating the partition coefficients and other important transport parameters for the primary contaminants with the type of soil (if yes, provide table)?

What is the source and reliability of the information available to describe the contaminants (risk drivers) and materials present?

High-Level Waste Tanks

Which processes produced the waste contained in the tanks within the farm?

How is the waste contained in the tanks classified (e.g., HLW, CH-TRU, RH-TRU)?

What nuclear safety concerns exist for the tanks/tank farm? (e.g., adequate dispersal of hydrogen)

What types of tanks (i.e., tank construction/configuration) are located in the tank farm?

What is the origin of the contamination (e.g., spills, intentional discharges, disposal areas)?

Does the tank farm have known or suspected leaks from specific tanks? If yes, describe the extent and time period of known or suspected leakage.

What are additional sources of contamination in the tank farm (e.g., spills, intentional discharges, disposal areas)? Describe the extent and time period of intentional and unintentional discharges.

What is the current assessment of the integrity of each tank?

What ancillary infrastructure is contained within the tank farm (i.e., transfer pits, transfer piping, etc.)?

What is the depth of contamination and sediment types/stratigraphy associated with the contamination associated with past releases or leakage?

When is the waste in the tank farm scheduled for retrieval?

What measures have been taken to reduce migration of past contamination?

Is information available indicating the partition coefficients for the primary contaminants (risk drivers) with the type of soil? (If yes, provide table.)

Groundwater Plumes

What is the source and reliability of the information available to describe the contaminants (risk drivers) and materials present?

What is the origin of the contamination (e.g., spills, intentional discharges, disposal areas)?

What are the primary contaminants (risk drivers)?

Are there co-contaminants that will affect mobility of the primary contaminants?

What is the depth of the groundwater table from the ground surface? Has the depth to groundwater changed significantly since the contamination was emplaced? How is the depth to groundwater expected to change over the period of evaluation?

What is the depth of contamination and sediment types/stratigraphy associated with the contamination?

What is the physical state of the primary contaminants (e.g., adsorbed in contaminated sediments, dissolved in groundwater, present in or as non-aqueous phase fluids)?

Are perched water or contaminated hydrologic lenses present?

Are there continuing contaminant sources that are currently adding to the extent of contamination or may in do so in the future over the evaluation period? (Can the source concentrations be defined for the primary contaminants?)

Is information available indicating the partition coefficients and other important transport parameters for the primary contaminants in the site hydrologic materials? (If yes, provide table.)

Is there information on the site contamination and hydrology with respect to interpreting current and future plume migration (e.g., temporal history of plume to estimate rate of spread)?

D&D of Inactive Facilities

What is the footprint and size of the facility?

What are the physical components and their sizes?

What is the current status of components?

What are the forms of the residual contamination (i.e., in process piping and tanks, on facility walls and surfaces, contained in hot cells or glove boxes, etc.)?

What is the primary construction of the facility (i.e., concrete, steel shell, etc.)? Does it contain asbestos or PCBs?

Are there particular elements of the facility that are considered to have high radionuclide inventory relative to the rest of the facility or risk drivers?

What is the integrity of the building and structural containment envelope (i.e., is the building fully intact, in a state of decay such that leakage into or out of the building is occurring or imminent, are safety systems such as ventilation and fire suppression fully functional)?

What is the proposed end-state for the building (i.e., demolition, entombment, other)?

Are there tanks currently containing wastes associated with the facility? If yes, what is the nature and volume of the waste, the construction of the tank and the tank integrity?

Is the surrounding area or area under the facility adequately characterized with respect to contamination, contaminants, and contaminant transport processes?

Operating Facilities

What processes produced the radioactive material and waste contained in the facility?

What are the primary radioactive and non-radioactive constituents that are considered risk drivers?

What types of containers or storage measures are used for radioactive materials at the facility?

How is the radioactive material and waste contained or stored within the facility classified?

What nuclear and non-nuclear safety accident scenarios dominate risk at the facility?

What are the average and maximum occupational radiation doses incurred at the facility?

What processes and operations are conducted within the facility?

What is the process flow of material into and out of the facility?

What effect do potential delays have on the processes, operations, and radioactive materials in the facility?

What other facilities or processes are involved in the flow of radioactive material into and out of the facility?

Is shipping of material involved and if so, how often and by what means?

What infrastructure is considered a part of the facility?

Ecological Resources Setting

[Provide a brief description of the ecological setting of the EU and the resources at risk within or adjacent to the EU. Keep in mind that this will be in context with the earlier report chapter that provides a detailed description of the Hanford site ecological resources.]

Cultural Resources Setting

[Provide a brief description of the cultural resource setting of the EU and the resources at risk within or adjacent to the EU. Keep in mind that this will be in context with the earlier report chapter that provides a detailed description of the Hanford site cultural resources.]

Economic Assets

[Identify any unique or unusual economic assets that may be associated with or proximate to this EU. For example, the 618-11 Pilot Site is within the confines of the Energy Northwest generating station. The 324 building is in close proximity to the PNNL operating facilities. ERDF is proximate to the US Ecology LLW disposal site.]

Part V. Waste and Contamination Inventory

[This section is intended to be a summary of contaminants and contaminated media. Results in this section may be best described in table or narrative form and figures (such as relative inventories of specific radionuclides for individual sources as developed for the Tank Farm pilot) may be applicable here. The discussion should be broken out by the type of sources and specific units (e.g., tanks, ancillary piping, near-surface soils, vadose zone, etc.) where applicable.]

Brief description of contaminated media and materials

What are the primary contaminants (risk drivers)?

What is the physical state of the primary contaminants (e.g., adsorbed in contaminated soil, as debris, in subsurface piping)?

Contamination within Primary EU Source Components

Legacy Source Sites:

[Near-surface contaminated soils and disposed wastes (e.g., buried, packaged TRU)]

High Level Waste Tanks and Ancillary Equipment:

[Includes breakout of primary tanks (by tank) and ancillary equipment/facilities). Cribs and trenches should be part of Legacy Source Sites. Past leaks and tank leakage should also be part of Legacy Source Site, but under a category of past leaks and unintentional releases.]

Vadose Zone Contamination:

[This is broken out here because of multiple potential sources (i.e., legacy sites, tank leakage, etc.)]

Groundwater Plumes:

Facilities for D&D:

Operating Facilities:

Part VI. Potential Risk/Impact Pathways and Events

Current Conceptual Model

[This section should provide a narrative description of the pathways and barriers to receptors and conditions/events that can lead to completed pathways or specific forms of risks or impacts. The barriers discussion should include 1. Description of institutional, natural and engineered barriers (including material characteristics) that currently mitigate or prevent risk or impacts, 2. Time scale from loss of each barrier to realization of risk or impacts. Each major source type needs to be considered and discussed (hence, subsections for each applicable source type). For EUs with multiple types of sources, these questions need to be answered for each source type. The questions are to be repeated in the narrative and should serve as the basis for the response. Subsections that are not applicable should be deleted.]

Narrative description of pathways and barriers to receptors and conditions/events that can lead to completed pathways

Pathways and Barriers: (1. description of institutional, natural and engineered barriers (including material characteristics) that currently mitigate or prevent risk or impacts, 2. Time scale from loss of each barrier to realization of risk or impacts)

Briefly describe the current institutional, engineered and natural barriers that prevent release or dispersion of contamination, risk to human health and impacts to resources:

1. What are the current barriers to release or dispersion of contamination from the primary facility? What is the integrity of each of these barriers? Are there completed pathways to receptors or are such pathways likely to be completed during the evaluation period?
2. What forms of initiating events may lead to degradation or failure of each of the barriers?
3. What are the primary pathways and populations or resources at risk from this source?
4. What is the time frame from each of the initiating events to human exposure or impacts to resources?
5. Are there current on-going releases to the environment or receptors?

Table of relevant initiating events and potential impacts

[To be drawn from the report section Initiating Events methodology]

Populations and Resources Currently at Risk or Potentially Impacted

[In the following sections, please briefly describe the receptors that may be impacted or at risk. Be quantitative/descriptive to the extent possible but do not be repetitive with earlier information. This is considering a 50-year timeframe and remaining under DOE control until at least cleanup of the EU is complete. Indicate “not applicable” where appropriate (the 50- year time frame assumes that cleanup of an individual EU will not be completed for 50 years to establish a comparison for risks and potential impacts, and thus provide input for sequencing of cleanup). For example, if a groundwater plume is not capable of reaching the Columbia River from the Central Plateau, then indicate “not applicable”. Similarly, if the public does not have access, the result would be “not applicable” for many/most evaluation units. Institutional controls are assumed to be effective for the purposes of this review.]

Workers (directly involved):

Workers (co-located):

Public:

[Is there currently a "public" that can be impacted by current contamination of soil, ground water, surface water, fish or game (i.e. salmon, deer)? Incudes tribes, offsite recreation, onsite recreation where allowed.
Is there currently a "public" that can be impacted by an upset condition such as fire, quake, or explosion? NOTE: The SARAH process did not identify any such circumstances, and DOE has concluded that Hanford does not have any CLASS 1 Nuclear Facilities.]

Groundwater:

Columbia River:

Ecological Resources:

Cultural Resources:

Economic Resources:

Cleanup Approaches and End-State Conceptual Model

Selected or Potential Cleanup Approaches:

What are the selected cleanup actions or the range of potential remedial actions?

[If a particular cleanup or end-state has been selected (e.g., through an EIS or CERCLA ROD) then this should be the assumed baseline cleanup approach and/or end state. If not, then the range of potential cleanup actions should be considered.
For each type of source, the Overall Methodology section of the report will define a range of potential cleanup approaches and their general impacts (i.e., degree of disturbance of the area, change in contamination inventory, etc.).
For buildings, decontamination, entombment, demolition; for soils, excavation, capping or in-situ immobilization, indicate estimated time frame and quantity of effort to achieve assumed remediation.]

What is the sequence of activities and duration of each phase?

What is the magnitude of each activity (i.e., cubic yards of excavation, etc.)?

Contaminant Inventory Remaining at the Conclusion of Planned Active Cleanup Period:

Risks and Potential Impacts Associated with Cleanup:

Can any (or all) of the potential remedial actions serve as initiating events for risks or impacts (i.e., to workers, to natural resources, etc.)?

Populations and Resources at Risk or Potentially Impacted During or as a Consequence of Cleanup Actions

[In the following sections, please briefly describe the receptors that may be impacted or at risk. Be quantitative/descriptive to the extent possible but do not be repetitive with earlier information. This is considering a 50-year timeframe and remaining under DOE control until at least cleanup of the EU is complete. Indicate "not applicable" where appropriate (the 50- year time frame assumes that cleanup of an individual EU will not be completed for 50 years to establish a comparison for risks and potential impacts, and thus provide input for sequencing of cleanup). For example, if a groundwater plume is not capable of reaching the Columbia River from the Central Plateau, then indicate "not applicable". Similarly, if the public does not have access, the result would be "not applicable" for many/most evaluation units. Institutional controls are assumed to be effective for the purposes of this review.]

Workers (directly involved):

Workers (co-located):

Public:

[Remediation activities: could, in theory, have offsite impacts (i.e. to nearby communities or farms) either through dust, surface water, traffic, or transportation accidents. As remediation continues over the course of 50 years, some portions of the Hanford Site may be released for public access.]

Groundwater:

Columbia River:

Ecological Resources:

Cultural Resources:

Economic Resources:

Additional Risks and Potential Impacts if Cleanup is Delayed

[This section should be used to describe any additional risks or impacts if the cleanup is delayed, such as increased D&D complexity if the building envelope is compromised and would result in increased D&D complexity, cost and worker risk. Note, that for the purposes of sequencing, we are assuming that all of the cleanup actions occur at the end of the 50-year cleanup period.]

Near-Term, Post-Cleanup Status, Risks and Potential Impacts

[In general, risks and potential impacts after cleanup will likely be from residual contamination in closed sites (entombed, capped, vadose zone) where intrusion or disruption/degradation of the closure system occurs (requiring maintenance), or from groundwater where either on-going pump and treat or passive decontamination is occurring (minor operational risks).]

A narrative description specific to the EU.

Populations and Resources at Risk or Potentially Impacted After Cleanup Actions (from residual contaminant inventory or long-term activities)

[In the following sections, please briefly describe the receptors that may be impacted or at risk. Be quantitative/descriptive to the extent possible but do not be repetitive with earlier information. This is considering a 50-year timeframe and remaining under DOE control until at least cleanup of the EU is complete. Indicate "not applicable" where appropriate (the 50- year time frame assumes that cleanup of an individual EU will not be completed for 50 years to establish a comparison for risks and potential impacts, and thus provide input for sequencing of cleanup). For example, if a groundwater plume is not capable of reaching the Columbia River from the Central Plateau, then indicate "not applicable". Similarly, if the public does not have access, the result would be "not applicable" for many/most evaluation units. Institutional controls are assumed to be effective for the purposes of this review.]

Workers (directly involved):

Workers (co-located):

Public:

Groundwater:

Columbia River:

Ecological Resources:

Cultural Resources:

Long-Term, Post-Cleanup Status – Inventories and Risks and Potential Impact Pathways

[This will need to be a narrative description of the remaining contamination/wastes, the physical form, and potential initiating events and pathways that may result in exposure or disruption. This information will be used to paint a picture of the site and its surroundings relative to long-term legacy.]

A narrative description specific to the EU.

Part VII. Risk and Potential Impacts Ratings

Current Risks and Potential Impacts – Ratings

[Using the consequence matrices (separate tables) the risk to each potential receptor population and impact to each resource is rated against each relevant initiating event in the previous table. For each population or resource, this may result in multiple risk or impact ratings because of multiple possible events. However, only the highest risk or impact rating for each receptor is recorded below. Furthermore, the risks from different sub-units within the Evaluation Unit may be different and warrant separate ratings or at least explanatory notes.]

Population or Resource	**Risk or Impact Rating (based on risk matrix)**	**Comments**
Worker (remediation & facility worker)		
Worker (co-located)		
Public		
Groundwater		
Surface water		
Ecological Resources		
Cultural Resources		
Economic Resources		

Risks During and as a Consequence of Cleanup Actions - Ratings

Population or Resource	**Risk or Impact Rating (based on risk matrix)**	**Comments**
Worker (remediation & facility worker)		
Worker (co-located)		
Public		
Soils		
Groundwater		
Surface water		
Ecological Resources		
Cultural Resources		
Economic Resources		

Near-Term, Post-Cleanup Risks and Potential Impacts

Population or Resource	**Risk or Impact Rating (based on risk matrix)**	**Comments**
Worker (remediation & facility worker)		
Worker (co-located)		
Public		
Soils		
Groundwater		
Surface water		
Ecological Resources		
Cultural Resources		
Economic Resources		

Part VII. Supplemental Information and Considerations

I.e., need to remain under DOE control to maintain safety buffer; interim actions that may mitigate deteriorating conditions, etc.

References

Appendix C

Hanford Site-Wide Risk Review Project
Evaluation Unit Summary Template

618-11 Solid Waste Burial Ground

Table of Contents

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EU Designation: 618-11 Solid Waste Burial Ground

Part I. Executive Summary

EU Location: 600 Area

Related EUs: 618-10, 618-4 and 618-5

Primary Contaminants, Contaminated Media and Wastes:

The burial ground received low to high-activity dry waste, fission products, plutonium, and other transuranic constituents in a variety of waste forms from research operations associated with the 300 Area. The inventory in the waste is varied, and includes:

- Radioactive constituents including kg quantities of plutonium, TRU wastes, Tc oxide, thousands of curies (TBq) of mixed fission products including ^{90}Sr (4200 Ci), ^{137}Cs(5300 Ci), ^{147}Pm, ^{244}Cm ^{103}Ru, ^{144}Ce, and others. TRU nuclides include ^{241}Am (226 Ci), ^{238}Pu, ^{240}Pu, ^{237}Np, 132 Ci Pu-239, 639 Ci Pu-241. There is also N-Reactor fuel, enriched to 0.95 to 1.25% ^{235}U.
- Hazardous constituents include 330 kg Beryllium, lead shielding, ignitable metal turnings, Th oxide, salt cycle residues, and lithium aluminate targets with tritium.

Brief Narrative Description:

From (HNF-EP-0649 Rev. 0, 1997) pages i and ii: The 618-11 burial ground received transuranic and mixed fission waste from 9 March 1962 until 31 December 1967. Waste came from all of the 300 Area radioactive material handling facilities. The inventory is varied, and includes kg quantities of plutonium and other TRU wastes in three trenches. There are discrepancies in both inventory and structures within this site. Thousands of curies (TBq) of mixed fission products were disposed in trenches, caissons, and drum storage units. The burial ground consists of three trenches, approximately 900 feet long, 25 feet deep and 50 feet wide, laid out in an east-west direction. The trenches comprise 75% of the site area. There are 50 drum storage units that consist of five, 55-gallon steel drums welded together and placed vertically in the soil. There are also approximately five, eight-foot diameter caissons situated at the west end of the drum storage units. There is some discrepancy in the number of caissons at the site. In addition to the radiological waste, this site contains hazardous chemical constituents. In 1992, USEPA and the Washington Department of Ecology requested an analysis of alternatives for the 618-11 Burial ground. Proximity of the waste to the water table and the potential for migration of contaminants were a concern based on the limited information about the waste inventory. A removal action was eliminated as an immediate need based on the absence of data to identify a threat to human health and the environment and the lack of facilities to receive, process, and/or dispose of the excavated high-activity transuranic material. However, remediation of this site is currently slated for completion by 2018, page 30). A tritium plume underlies the site and extends beyond its boundaries. Tritium was not identified in the waste inventory but its presence has been attributed to the disposal of targets. Remediation of the site is problematic due to the potential for fire and explosion from waste constituents.

Summary Table of Risks and Potential Impacts to Receptors:

EU: 618-11 Solid Waste Burial Ground **- Risk or Impact Rating**				
Population or Resource		**Evaluation Time Periods**		
		Active Cleanup (to 2064)		Near-Term Post Cleanup (to 2164)
		Current Condition/ Operations	From Cleanup Actions	
Human	Worker (remediation & facility worker)			
	Worker (co-located)			
	Public			
Environmental	Groundwater			
	Surface water			
	Ecological Resources			
Social	Cultural Resources			
	Economic Resources			

TO BE COMPLETED IN FINAL TEMPLATE

Support for Risk and Impact Ratings for each Time Period

Current Condition:

The site is closed, covered with soil, and vegetated. The waste site is currently embedded with unconsolidated sands and gravels of the Hanford Formation and covered with eolian silts characteristic of this region that have been vegetated with crested wheatgrass. The vegetated silt acts as hydraulic barrier that limits percolation of meteoric water into the waste to minute amounts (1-3 mm per year).

A plume containing tritium and nitrate that exceeds drinking water standards is beneath the site. However, the groundwater is not utilized, and concentrations are diminishing due to natural dilution, dispersion, and decay such that the tritium concentration is not expected to exceed drinking water standards when the plume reaches the Columbia River. Surface water is ranked as not discernible as the plume has not reached the Columbia River. That is, natural attenuation processes appear to be managing the plume effectively.

The U.S. Department of Energy Richland Operations Office and the Washington State Historic Preservation Office designated the Manhattan Project and Cold War facilities of the Hanford Site a historic district eligible for listing in the National Register of Historic Places (NRHP) in 1996. The railroad is a contributing element to the NRHP eligibility of the historic district. The Hanford Site Plant Railroad System has been mitigated as described in the *Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan* (DOE/RL-97-56). The Hanford Site Plant Railroad System was determined to be a contributing property to the historic district with documentation required under the treatment plan. A Historic Properties Inventory Form was completed to meet this documentation requirement. This information is based on data received as of the date of the document and may change as new information becomes available or is provided.

Risks and Potential Impacts from Selected or Potential Cleanup Approaches: Remediation of this site is currently slated for completion by 2018 (DOE/RL-2011-47, 2013, page 30) with industrial exposure criteria set as the cleanup level. Buried wastes and associated hard infrastructure (caissons, VPUs) will be removed and disposed in ERDF. During remediation the primary pathways of concern are potential air releases from energetic events (the site has a mixture of potentially explosive and or pyrophoric constituents). This pathway probably would have limited distance from the area. Several activities related to <u>**characterization**</u> of the site (**not remediation**) have anticipated frequencies of occurrence in the 10^{-2} per year, estimated maximum worker hazard from characterization is categorized as moderate ($\geq$25 rem TEDE, 0.25 Sv). Ongoing remediation of a similar site (618-10), which contains lower inventories, has already experienced small fires during excavation (see Washington Closure Hanford, LLC, Report from the Department of Energy Voluntary Protection Program Onsite Review June 11-14, 2012 – pages 14 and 15). The hazard categorization for the 618-10 burial ground (a similar, but less hazardous site) has been revised three times since 2012, making categorization of hazards from 618-11 removal activities uncertain (see Washington Closure Hanford, LLC, Report from the Department of Energy Voluntary Protection Program Onsite Review June 11-14, 2012 – pages 14 and 15).

Risks and Potential Impacts if Cleanup is Delayed:

The inventory is covered with 2 m of clean soil, which precludes accidental intrusion if institutional controls are maintained. However, the constituents of the waste site pose an extreme hazard to inadvertent intruders due to large inventories of gamma emitters and potentially pyrophoric and explosive constituents. Delay of cleanup for several decades will allow reduction in activity of the moderate lived radionuclides present at the site (e.g., 90Sr and 137Cs). Delay of cleanup by 30 years will reduce the dose rate from gamma emitters such as 137Cs to 50%; at 60 years the dose rate will drop to 25% of the original intensity. If remediation is delayed for 150 years the 137Cs activity will be 3% of its current intensity. While this will substantially lower the dose rate from gamma emitting wastes, it is unlikely to impact the hazardous constituents. If un-remediated in the long term, erosion may compromise the surficial soils, allowing exposure of the waste and ingress of meteoric water.

Impacts to groundwater are expected to diminish as radiological decay, dispersion, and attenuation reduce the concentration of tritium in the plume. Impacts to the river are anticipated to be low, with tritium concentrations below drinking water standards following contact of the groundwater plume with the river.

Near-Term, Post-Cleanup Risks and Potential Impacts:

This site is slated to be cleaned to industrial exposure criteria. Following cleanup activities there may be some potential for enhanced infiltration of rainwater into the site until the soil covering is sufficiently vegetated and stabilized. The existing tritium plume is expected to diminish as radiological decay, dispersion, and attenuation reduce the concentration of tritium in the plume. Impacts to the river are anticipated to be low, with tritium concentrations below drinking water standards following contact of the groundwater plume with the river.

EU Designation: 618-11 Solid Waste Burial Ground

DRAFT for Methodology Illustration

Long-Term, Post-Cleanup Conditions:

The cleanup standard selected for this site is industrial exposure criteria. The proposed retrieval mechanisms may leave heterogeneous spots of distributed activity, which will be more prone to migration. Radiological impacts are expected to be low, and the site considered for industrial exclusive use.

EU Designation: 618-11 Solid Waste Burial Ground

DRAFT for Methodology Illustration

Part II. Administrative Information

OU and/or TSDF Designation(s): This site is part of the 300 FF-2 Operable Unit[1]

Common name(s) for EU: The site is 618-11 Solid Waste Burial Ground, also known as the Wye or 318-11 Burial ground

Key Words:

Regulatory Status

Regulatory basis: CERCLA

Applicable regulatory documentation: Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1. U.S. Environmental Protection Agency, Region 10 U.S. Department of Energy, Richland Operations Office November 2013

Applicable Consent Decree or TPA milestones: The Tri-Party Agreement Milestone M-16-00B indicates that completion of all 300 Area remedial actions are expected by 9/30/2018 (which includes 618-10/11 Burial Grounds).[2]

Risk Review Evaluation Information

Completed: August 7, 2014

Evaluated by: Kathryn A. Higley, Craig H. Benson

Reviewed by: C.W. Powers, D.S. Kosson

Part III. Summary Description

Current land use: DOE Hanford Site

Designated future land use: Industrial with institutional controls

Primary EU Source Components

Legacy Source Sites: The 618-11 burial site is a closed near surface disposal site containing radioactive and hazardous solid wastes from the 300 Area. The site consists of trenches, vertical pipe units and caissons. There is a tritium and nitrate plume underlying and extending beyond the boundary of the waste site. For closure the site was capped with clean soil and vegetated.

High-Level Waste Tanks and Ancillary Equipment: NA

Groundwater Plumes: The 618-11 site sits over a groundwater plume originating from two sources: 200 –East and one originating from waste within the site itself.

D&D of Inactive Facilities: NA

Operating Facilities: NA

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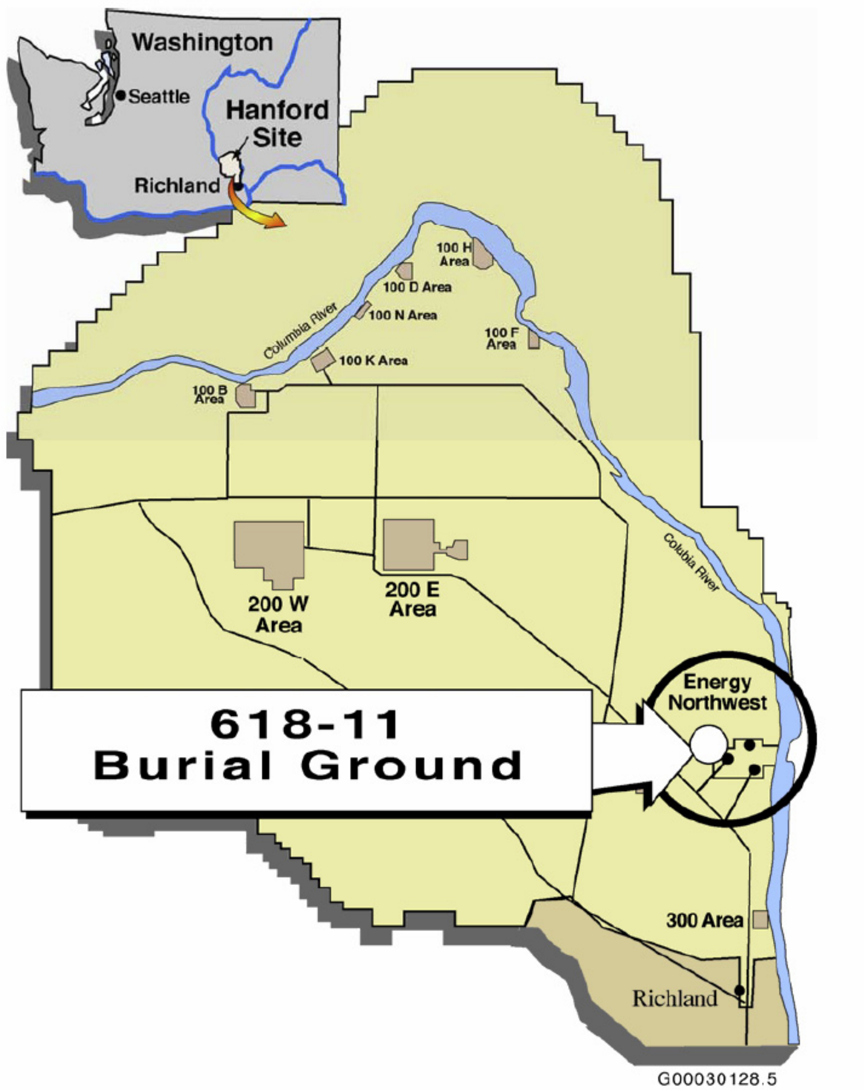
[1]Page ii, Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1. U.S. Environmental Protection Agency, Region 10 U.S. Department of Energy, Richland Operations Office November 2013.

[2]From the 618-10-11 Project Status to EMHQ on 3-18-2014 by Matt McCormick Manager, DOE-RL. Power point presentation. Page 8.

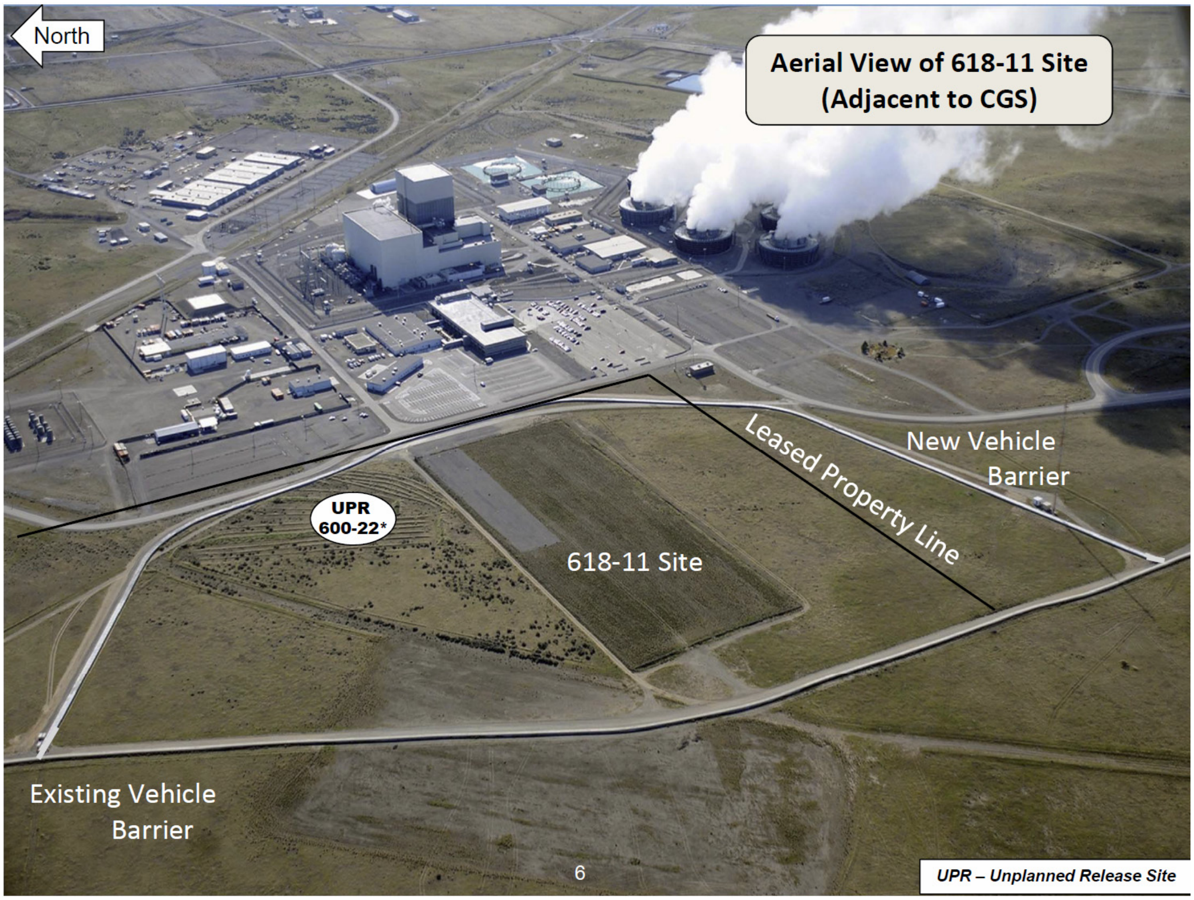
Location and Layout Maps



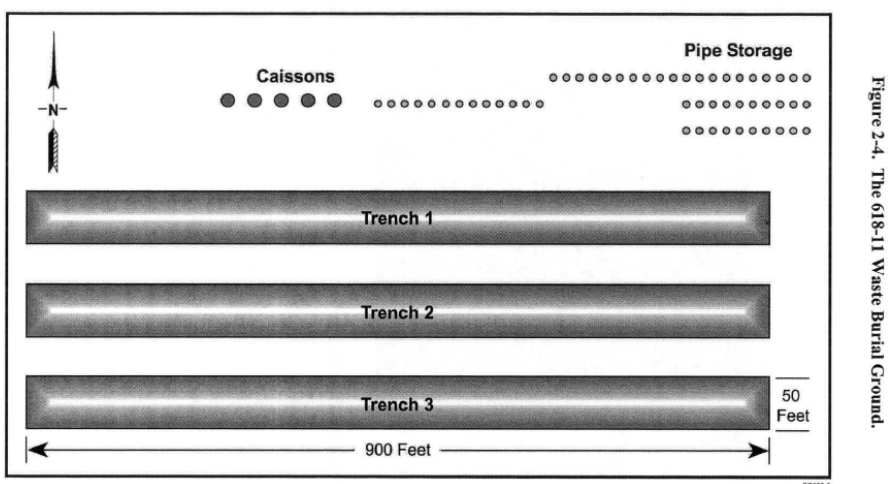
Location of 618-11 Solid Waste Burial Ground on Hanford Site.

EU Designation: 618-11 Solid Waste Burial Ground

DRAFT for Methodology Illustration



Aerial photograph of 618-11 Solid Waste Burial Ground (rectangular area directly west of plant) adjacent to Energy Northwest plant.



Aerial schematic of 618-11 Solid Waste Burial Ground showing trenches, pipe storage units, and caissons.

Part IV. Unit Description and History

EU Former/Current Use(s)

Legacy Source Sites

What is the origin and history of the contamination (e.g., accidental release, intentional discharge, multiple discharges)?

The 618-11 burial ground was used for disposal of transuranic and mixed fission waste from 9 March 1962 through 2 October 1962. The burial ground was temporarily closed, additional burial facilities added, and re-opened on 16 September 1963. Waste was received until 31 December 1967. Waste disposed in 618-11 was from all of the 300 Area radioactive material handling facilities.

What are the primary contaminants (risk drivers)?

The inventory in the waste is varied, and includes kg quantities of plutonium and other TRU wastes in three trenches. There are discrepancies in both inventory and structures within this site. Thousands of curies (TBq) of mixed fission products including ^{90}Sr, ^{137}Cs, ^{147}Pm, ^{244}Cm ^{103}Ru, ^{144}Ce and others were disposed in trenches, caissons, and drum storage units. The TRU nuclides include ^{241}Am, ^{238}Pu, ^{240}Pu, ^{237}Np. Also included in the inventory is N-Reactor fuel, enriched to 0.95 to 1.25% ^{235}U. Tritium has not been listed as a primary contaminant, but has been detected in groundwater beneath the site. The tritium presence is attributed to disposal of lithium aluminate targets used in the production of tritium.

Are there co-contaminants that will affect mobility of the primary contaminants?

Unknown.

What is the depth of contamination and soil type/stratigraphy associated with the contamination? Is the soil profile primarily natural or heavily disrupted?

The site contains 50 vertical pipe units (11% of site), approximately 4 (actual number not confirmed) caissons, and 3 trenches (75- 88% of site) that are 900 feet long, 25 feet deep, and 50 feet wide; (see location maps in Part III). Schematics of the pipe units are shown in Figure C-1 and the caissons in Figure C-2. The trenches are shown in Figure C-3. At closure in 1967, the entire area was backfilled and covered with four feet of silt loam soil that is now vegetated with local species (HNF-EP-0649 Rev. 0, 1997). An additional two feet of clean soil was added in 1982 (HNF-EP-0649 Rev. 0, 1997, pg. 2-27). Thickness of the soil cover varies based on what is covered (trench, caisson, vertical pipe units), but is at least 2 m. The waste site is currently embedded in unconsolidated sands and gravels of the Hanford Formation and covered with silt loam of eolian origin that is characteristic of this region. The silt loam is vegetated with crested wheatgrass. The vegetated silt acts as hydraulic barrier that limits percolation of meteoric water into the waste to minute amounts (1-3 mm per year).

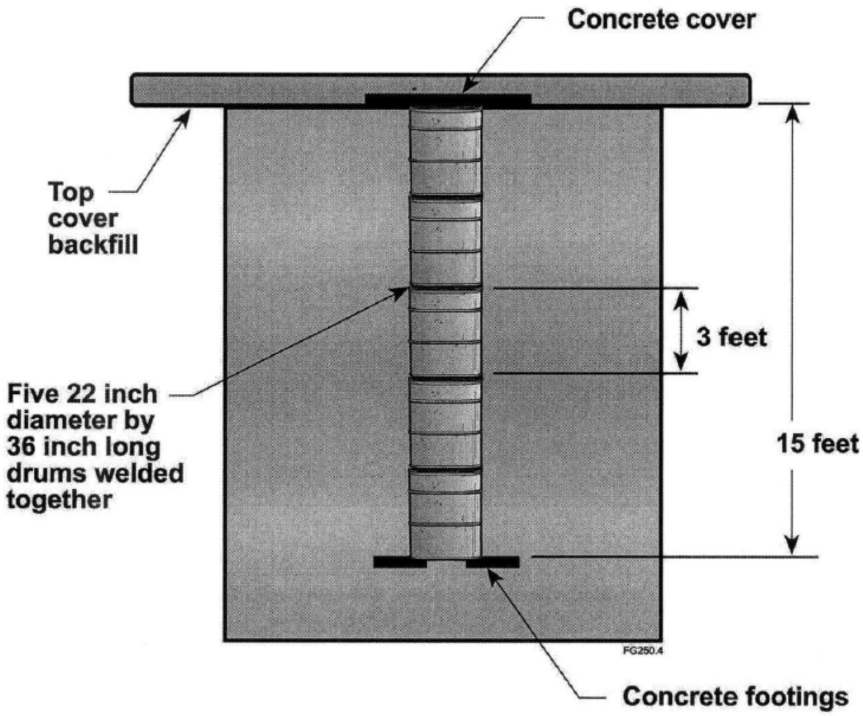


Figure C-1. Schematic of vertical pipe unit from CH-14592, Rev 0, 2003.

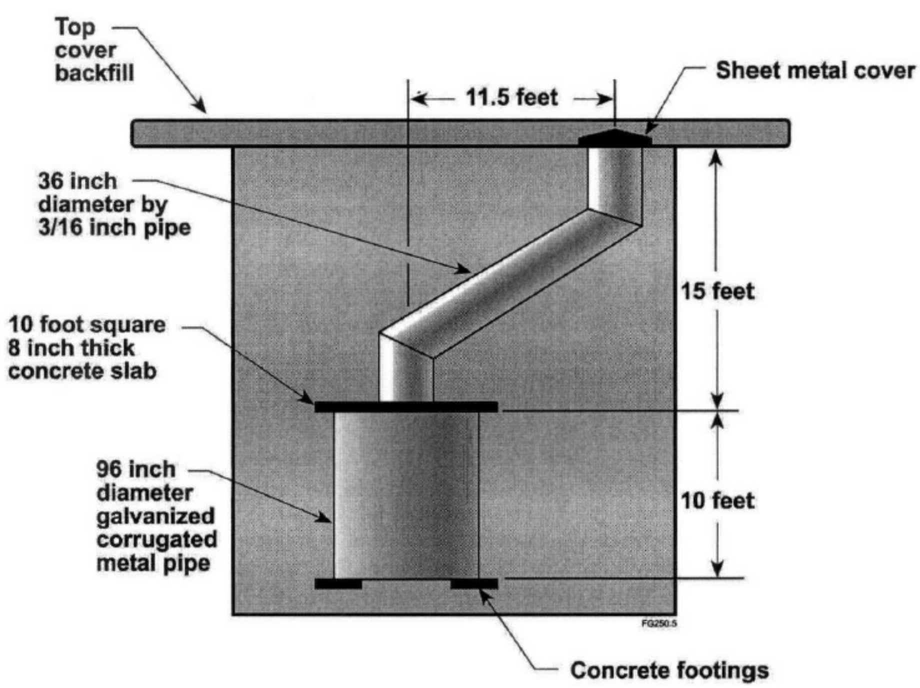


Figure C-2. Caisson in 618-11 area as depicted in CH-14592 Rev. 0, 2003.

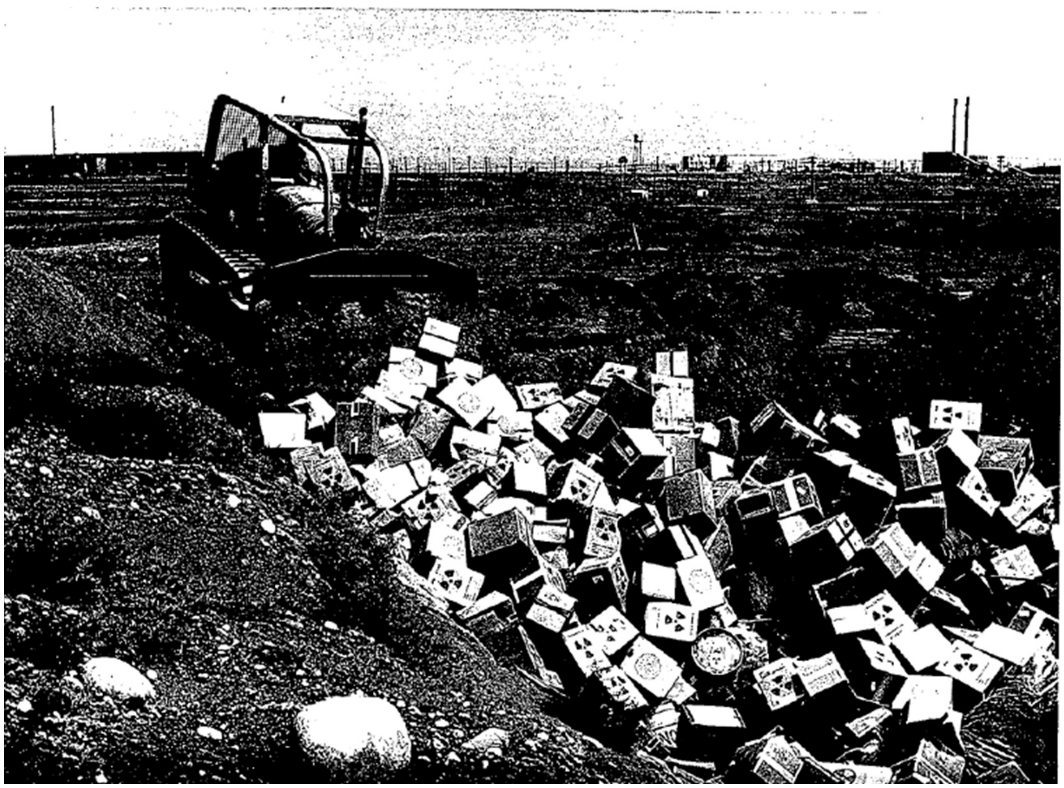


Figure C-3. Covering boxes with radioactive contents with soil in trenches at 618-11, from HNF-EP-0649 Rev. 0, 1997.

What is the physical state of the primary contaminants (i.e., adsorbed in contaminated soil, as debris, in subsurface piping)?

PNNL 13765 (page 1) states the following: "The burial ground received low to high-activity dry waste, fission products, plutonium, and other transuranic constituents in a variety of waste forms from research operations associated with the 300 Area." Most of the primary contaminants are likely associated with the solid wastes and adjacent soils in the trenches, VPUs, and caissons. Some over excavation of adjacent soils will probably be necessary during the remediation.

A plume containing tritium and nitrate is beneath the site. Concentrations are diminishing due to natural dilution, dispersion, and decay such that the tritium concentration is not expected to exceed drinking water standards when the plume reaches the Columbia River. That is, natural attenuation processes are managing the plume effectively.

Is information available indicating the partition coefficients and other important transport parameters for the primary contaminants with the type of soil (if yes, provide table)?

None identified to date.

What is the source and reliability of the information available to describe the contaminants (risk drivers) and materials present?

The site is reasonably well characterized, although there remain some inconsistencies in the number of subsurface caissons, and the radionuclide inventory is incomplete.

The burial ground consists of three trenches, approximately 900 feet long, 25 feet deep, and 50 feet wide, laid out in an east-west direction. The trenches comprise 75% of the site area. There are 50 drum storage units that consist of five, 55-gallon steel drums welded together end-to-end and placed vertically in the soil. These are buried in three rows in the northeast corner of the site. There are also approximately five, eight-foot diameter caissons situated at the west end of the center row of the drum storage units. There is some discrepancy in the number of caissons at the site. Geophysical surveys have identified five anomalies that are presumed to be caissons (but not confirmed).

In addition to the radiological waste, the site contains chemical constituents that may be designated as hazardous waste per RCRA Subtitle C. Thus, the waste extracted during remediation most likely will be a mixed waste requiring disposal in accordance with both DOE 435.1 and RCRA Subtitle C.

In 1992, USEPA and the Washington Department of Ecology (henceforth “Ecology”) requested an analysis of alternatives for the 618-11 Burial ground. Proximity of the waste to the water table and the potential for migration of contaminants were a concern based on the limited information about the waste inventory. A removal action was eliminated as an immediate need based on the absence of data to identify a threat to human health and the environment and the lack of facilities to receive, process, and/or dispose of the excavated high-activity transuranic material (see page 2.7 of HNF-EP-0649).

Tritium was not listed as a waste, and therefore was not a waste analyte.

High-Level Waste Tanks – NA

Groundwater Plumes

What is the source and reliability of the information available to describe the contaminants (risk drivers) and materials present?

There are multiple sources of information regarding the plume under the 618-11 site. Two recent publications by PNNL specifically address the presence and distribution of ^{3}H under the 618-11 site. These are (PNNL-13675, 2001) and (PNNL-15293, 2005).

What is the origin of the contamination (e.g., spills, intentional discharges, disposal areas)?

Tritium within the Hanford formation is the only contaminant currently reported in groundwater that can be attributed to 618-11 (Figure C-4 and Figure C-5). DOE/RL-2013-22, rev 0, page ES-13 states: *“Groundwater associated with the 618-11 Burial Ground contains a high-concentration tritium plume, likely originating from irradiated material in the burial ground. Concentrations at a well adjacent to the burial ground have decreased from the peak values, and the plume has maintained its basic shape since its discovery in 1999. Relatively constant tritium concentrations immediately adjacent to the site suggest that buried materials are providing an ongoing source of tritium to groundwater. At wells farther from the burial ground, toward the river, concentration trends reflect the plume’s migration. The conceptual model for the plume, including a simulation of plume evolution over time, indicates that tritium concentrations will be below the drinking water standard when the plume reaches the Columbia River.” In addition,* DOE/RL-2013-22, rev 0 (pg. FF-16 of the 300 FF) indicates that the source of the plume is tritium gas released from buried radiological solid wastes.

PNNL conducted core drillings near the site in 1978 and gross alpha, beta, and other natural radionuclides were listed as within background (PNNL-15293, 2005, pg. 2.6). However, a contaminated groundwater plume extends from the 200 Area adjacent to 618-11, as shown in Figure C-6. Cover soils placed over the wastes in the 618-11 area will control percolation of meteoric water into the 618-11 wastes and eliminate additional tritium addition to groundwater.

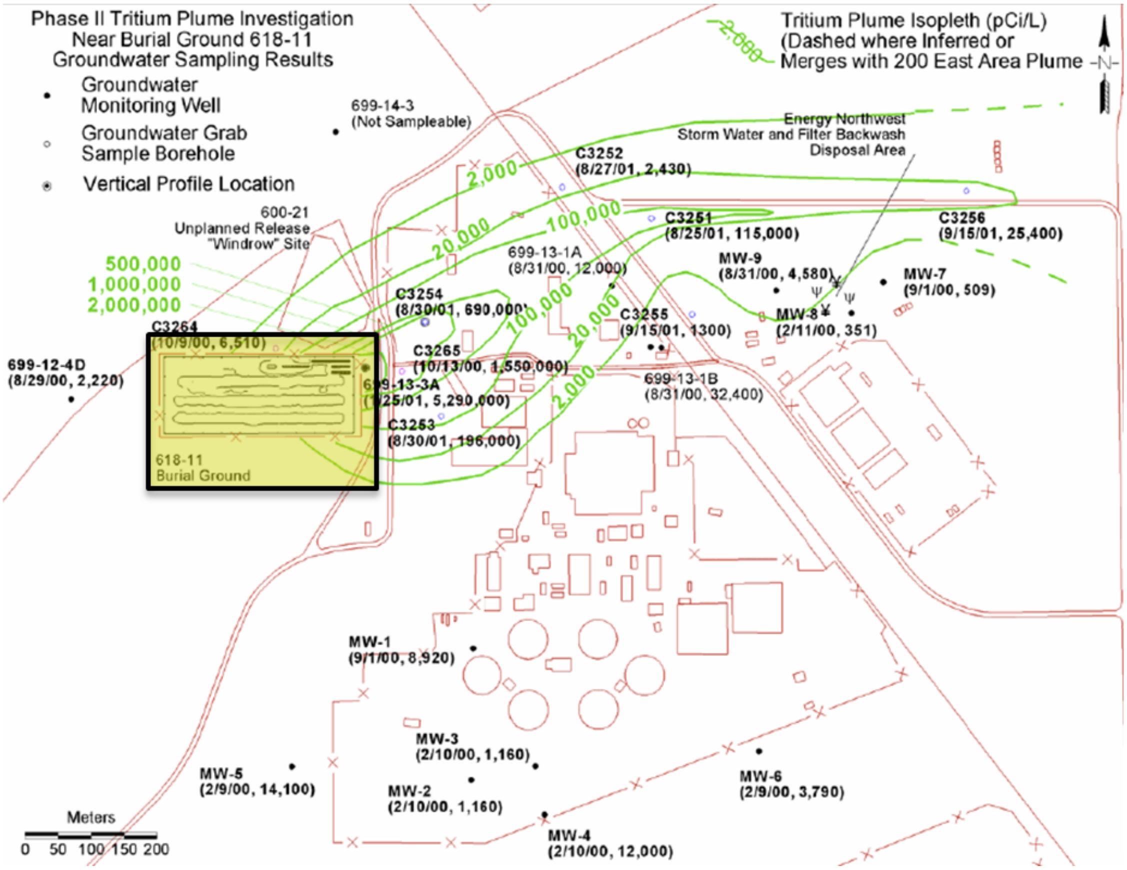


Figure C-4. Tritium isochors associated with the 618-11 site (yellow box), from page 2.9 of PNNL 15293.

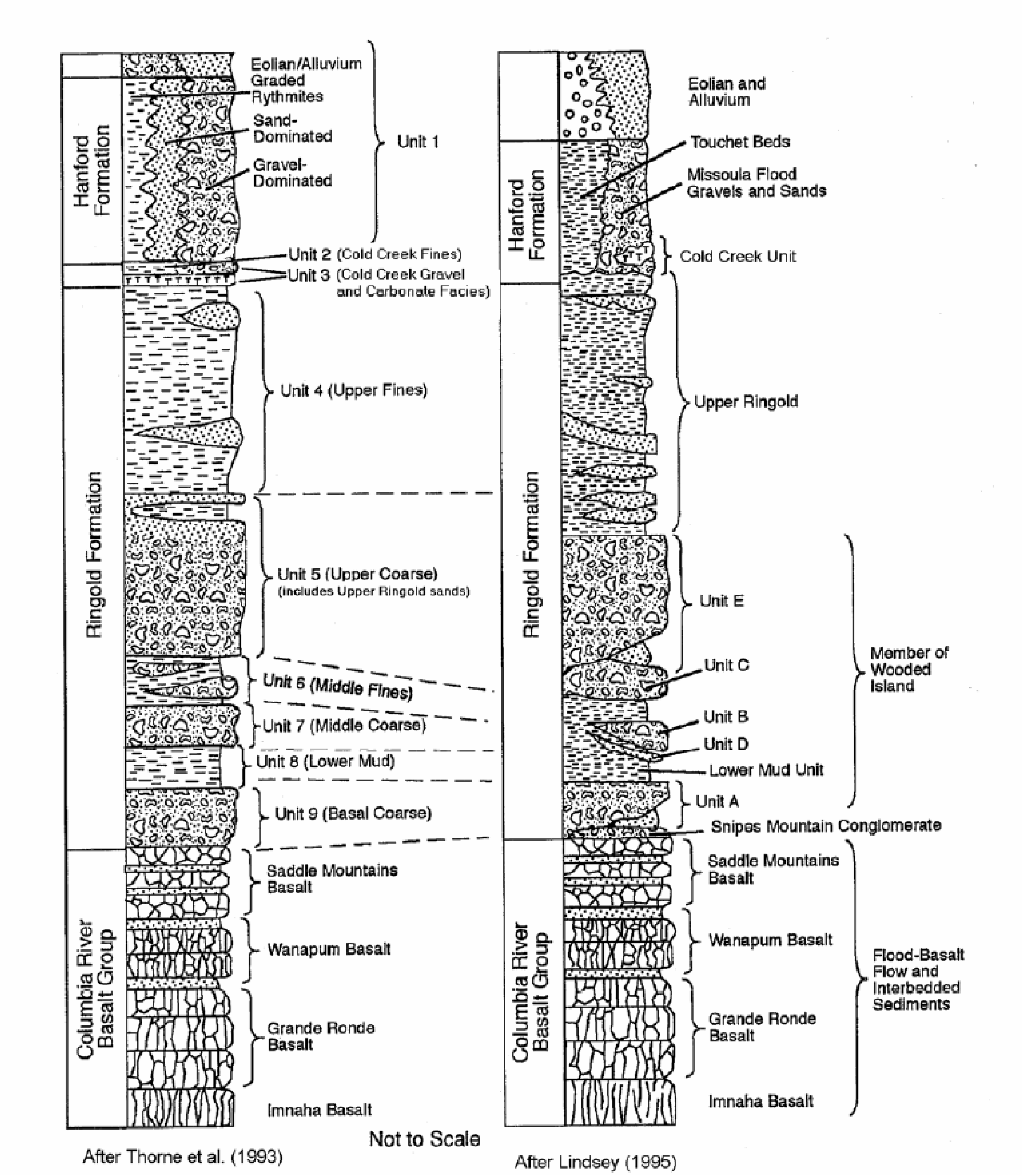


Figure C-5. Geological cross-section at 618-11 site

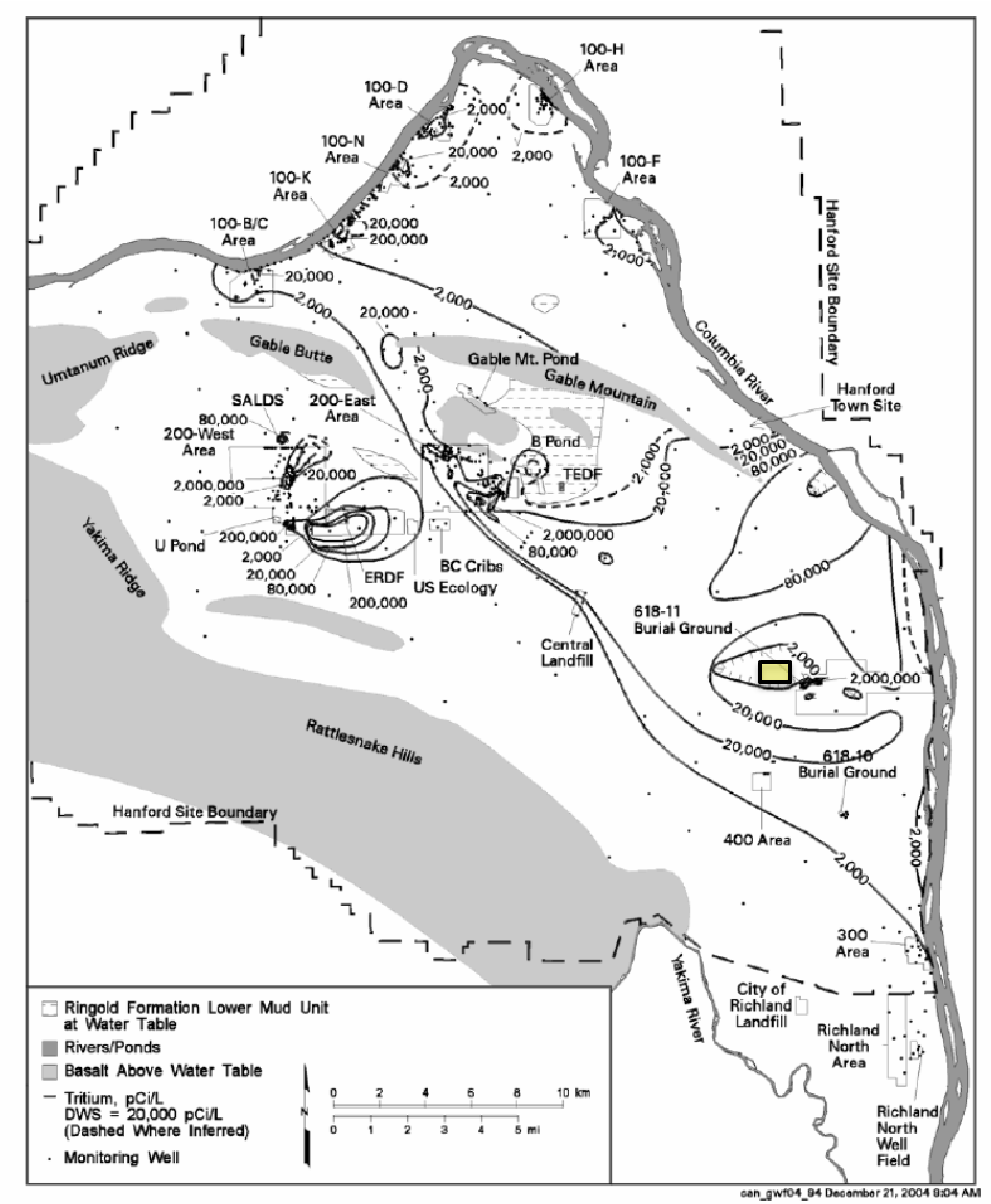


Figure C-6. Location of 618-11 (yellow box) and isochors of tritium concentration in Hanford formation from other sources

What are the primary contaminants (risk drivers)?

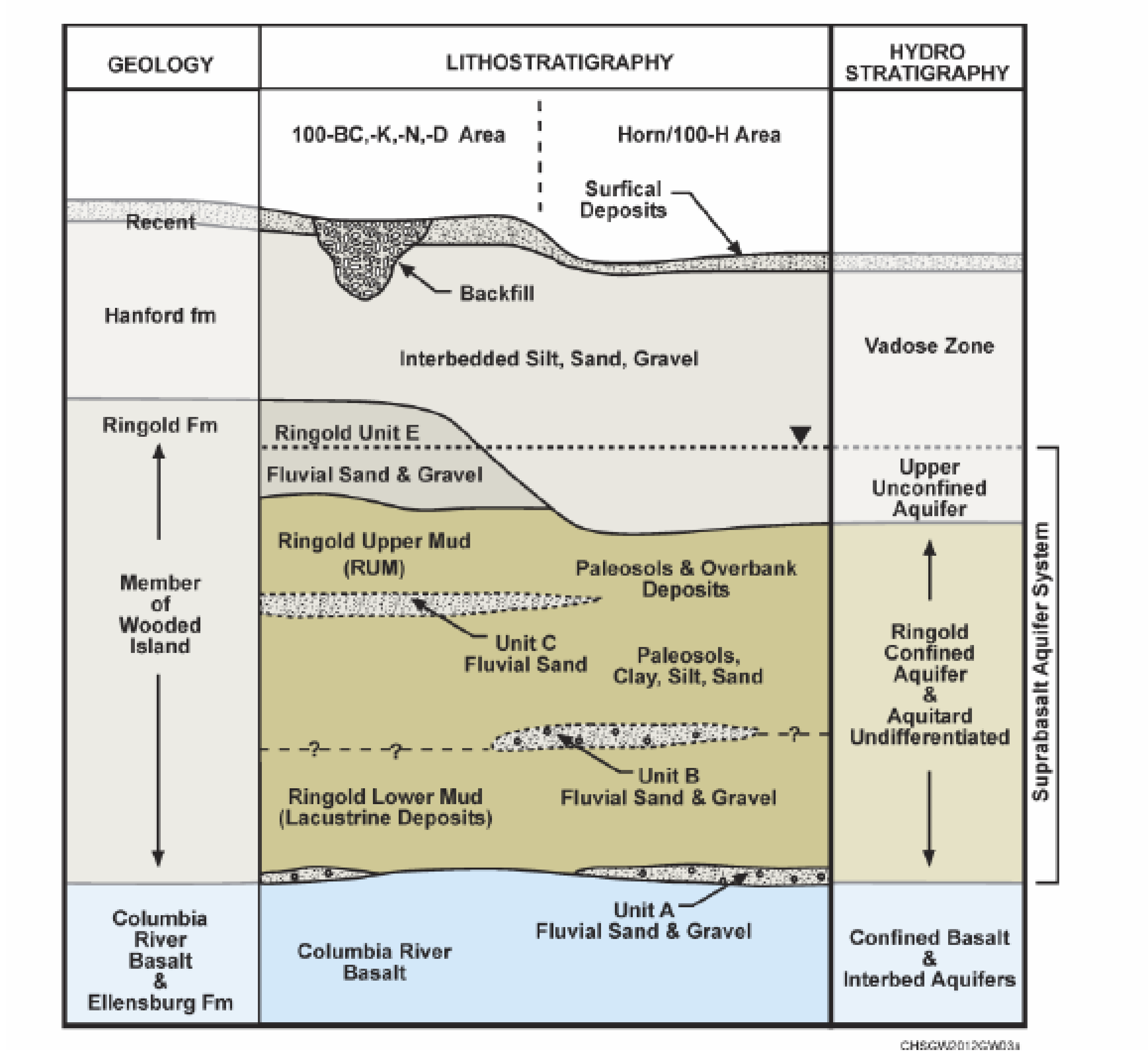
As noted in PNNL 15293: "*The mechanisms controlling tritium release from the 618-11 Burial Ground are not well understood or have not been well characterized; thus, developing a detailed conceptual model* *of historic releases from the site is not possible*"(PNNL-15293, 2005). DOE/RL-2013-22, rev 0, page ES-13 indicates that the *tritium "likely originating from irradiated material in the burial ground." Concentrations at a well adjacent to the burial ground have decreased from the peak values, River"*

Are there co-contaminants that will affect mobility of the primary contaminants?

The primary driver of tritium migration will be dictated by surface recharge. While this is generally low across the site (5 – 10 mm / year) there is the possibility of episodic events that may result in pulses of water through the surface.(PNNL-15293, 2005)

What is the depth of the groundwater table from the ground surface? Has the depth to groundwater changed significantly since the contamination was emplaced? How is the depth to groundwater expected to change over the period of evaluation?

From (PNNL-15293, 2005): Approximately 19 m (DOE/RL-2011-47, 2013). The current water table surrounding the 618-11 Burial Ground is elevated compared to pre-Hanford conditions. At a maximum, the water table was elevated more than 4.6 m (15 ft) from pre-Hanford conditions due to infiltration of a large volume of artificial recharge to the aquifer in the 200 Areas west of the site. Water level measurements more representative of pre- Hanford conditions are available from wells drilled in the 1950s. These older water level measurements suggest that the pre-Hanford water table near the 618-11 Burial Ground was close to where the Ringold Formation contacts the overlying Hanford/Pre-Missoula gravel and sand sequences. This regionally stable water table condition likely existed because the water table could not be sustained in the high hydraulic conductivity Hanford formation sediments above this contact under the low natural recharge conditions. See the following figure from DOE/Rl-2013-22.



What is the depth of contamination and sediment types/stratigraphy associated with the contamination?

From (PNNL-15293, 2005):

"The 618-11 Burial Ground and the Energy Northwest nuclear power plant complex are constructed on suprabasalt sediments of Miocene to Pleistocene age [Figure C-5]. The stratigraphic column includes, in ascending order from oldest to most recent, the Columbia River Basalt Group, Ringold Formation coarse-grained facies of the Cold Creek unit, and Hanford formation. In addition, a thin, regionally discontinuous veneer of Holocene alluvium and eolian sediment overlies the principal geologic units."

"The suprabasalt sediments are the most significant hydrogeological units in terms of contaminant transport beneath the area because they form the uppermost aquifer system. This aquifer system is the primary groundwater contaminant pathway to the Columbia River. The upper aquifer system consists of an upper unconfined aquifer and deeper zones that have confined to semi-confined aquifer conditions. The Elephant Mountain Member basalt forms the bottom of this uppermost aquifer system more than 150 m (500 ft) beneath the surface. Confined aquifer conditions exist beneath the Elephant Mountain Member basalt. The confined aquifer system is used for water supply at WNP-1 (two wells) and for emergency supply at WNP-2 (one well). Information obtained from well drilling records, and recent water level measurements confirm that the basalt-confined aquifers have a higher water level (potentiometric surface) than the uppermost unconfined aquifer, resulting in upward flow if any leakage occurs between the two aquifers. This condition significantly reduces the possibility of a downward movement of tritium into the lower, deeper confined aquifer."

"The water table may be found within the Hanford formation, the Cold Creek gravel unit, or the Ringold Formation in the vicinity of the 618-11 Burial Ground because of structural features created at the top of the Ringold Formation by cataclysmic flooding, fluvial reworking, and erosion by the Columbia River. Areas where saturated Hanford formation sediments are thin or absent are expected to provide barriers to flow or to significantly decrease groundwater velocity. Ringold Formation sediments are interpreted to exist above the water table beneath the 618-11 Burial Ground and in some areas east (i.e., no saturated Hanford sediments are present ".

What is the physical state of the primary contaminants (e.g., adsorbed in contaminated sediments, dissolved in groundwater, present in or as non-aqueous phase fluids)?

Dissolved

Are perched water or contaminated hydrologic lenses present?

Unlikely.

Are there continuing contaminant sources that are currently adding to the extent of contamination or may in do so in the future over the evaluation period? (Can the source concentrations be defined for the primary contaminants?)

Not certain, but unlikely.

Is information available indicating the partition coefficients and other important transport parameters for the primary contaminants in the site hydrologic materials? (If yes, provide table.)

See PNNL-15293, 2005.

Is there information on the site contamination and hydrology with respect to interpreting current and future plume migration (e.g., temporal history of plume to estimate rate of spread)?

Yes. Quoting from (PNNL-15293, 2005) or Section 4.4.5 of (DOE/RL-2010-99):

- Tritium concentrations near the 618-11 Burial Ground show a decreasing trend since peak concentrations occurred during 2000. Current levels (up to approx. 2 M pCi/L) still exceed the drinking water standard.
- The narrow tritium plume extends for 1.2 km to the east downgradient from the 618-11 Burial Ground. The plume passes just to the north of the Energy Northwest Columbia Generating Station (Map FF.5). The plume appears to be contained within the saturated Hanford formation gravels portion of the unconfined aquifer. The tritium concentrations attributed to the 618-11 Burial Ground lie within the larger, lower concentration tritium plume that is part of 200-PO-1
- Tritium concentrations near the 618-11 Burial Ground have declined from the maximum values observed in 1999 and 2000 (Figure C-7, below, from DOE/RL-2013-22, rev 0) and are continuing to decline or to level out.

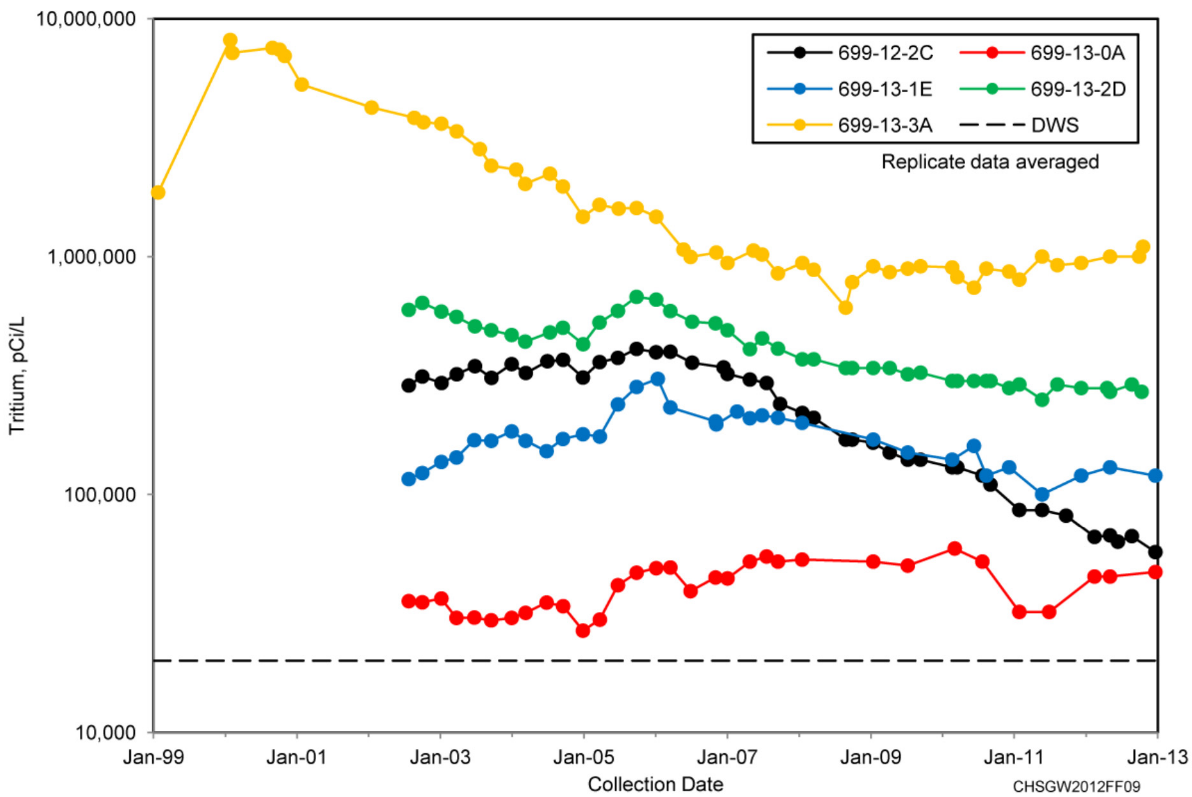


Figure C-7. 300-FF Tritium Data for wells 699-12-2C, 699-13-0A, 699-13-1E, 699-13-2D, and 699-13-3A (DOE/RL-2013-22, rev 0, p. FF-15)

- The general shape of the tritium plume has remained nearly constant since the first maps were drawn in 2000.
- The conceptual model for the plume, including a simulation of plume evolution over time, indicates that tritium concentrations will be below the drinking water standard when the plume reaches the Columbia River (Section 5.1 of PNNL-15293). Groundwater wells monitored by Energy Northwest do not show evidence of this plume, nor is tritium detected in Energy Northwest water supply wells."
- The decrease in concentration close to the source cannot be entirely accounted for by radioactive decay, indicating that transport processes are impacting tritium concentrations and suggesting dispersal of a "pulse" release that was first identified in 1999-2000.

D&D of Inactive Facilities - NA

Operating Facilities - NA

Ecological Resources Setting

The 618-11 waste site is part of the terrestrial ecosystem that is generally characterized as a shrub-steppe, which generally includes a shrub overstory and a grass overstory. However, 618-11 is a highly disturbed area. There are no above ground structures or buildings at 618-11. The entire area was backfilled and covered with four feet of fine-textured silt loam in 1967 (HNF-EP-0649 Rev. 0, 1997). An additional two feet of clean fine-textured silt loam was added in 1982 (page 2-27, (HNF-EP-0649 Rev. 0, 1997). The site is covered with topsoil and vegetated.

Cultural Resources Setting

The U.S. Department of Energy Richland Operations Office and the Washington State Historic Preservation Office designated the Manhattan Project and Cold War facilities of the Hanford Site a historic district eligible for listing in the National Register of Historic Places (NRHP) in 1996. The railroad is a contributing element to the NRHP eligibility of the historic district. The Hanford Site Plant Railroad System has been mitigated as described in the *Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan* (DOE/RL-97-56). The Hanford Site Plant Railroad System was determined to be a contributing property to the historic district with documentation required under the treatment plan. A Historic Properties Inventory Form was completed to meet this documentation requirement. This information is based on data received as of the date of the document and may change as new information becomes available or is provided.

Economic Assets

The 618-11 Pilot Site is adjacent to the Columbia Generating Station, the Northwest's only commercial nuclear energy facility, which is owned and operated by Energy Northwest. CGS produces about 10 % of the electricity generated in Washington State.

Part V. Waste and Contamination Inventory

Contamination within Primary EU Source Components

Legacy Source Sites:

Brief description of contaminated media and materials

This site was a near surface waste disposal facility that received waste from the 300 Area. The waste was primarily solid waste in a variety of forms.

From (Landon and Nolan, 2007):

> "The waste material was generated during laboratory examinations and studies, including analyses of fuel reactor samples, characterization of the chemical and physical properties of immobilized forms of plutonium, and analysis of ruptured reactor fuel. … These analyses, performed in glove boxes, fume hoods and hot cells, used a wide variety of electrochemical, spectrophotometric, and physical tests that generated primarily inorganic (e.g., aluminum- and iron-based metal, glass, ceramics, and asbestos) and organic debris (e.g., plastic, rubber, paper, cloth, wood) waste materials. Specific waste items may include wipes, towels, protective clothing, cardboard, metal cans, High Efficiency Particulate Air (HEPA) filters, stainless steel tubing, plastic pipe, lead (brick s and sheeting), polyethylene bottles, failed machinery, used lab WM'07 Conference, February 25 – March 1, 2007, Tucson, AZ ware (beakers, pipettes, vial s, and tubing), gloves, lab equipment (balances, drying ovens, heating mantles, pumps and reaction vessels), thermometers, concrete, soil, plumbing fixtures, and tools (screw drivers, wrenches, and shears). …. Some drums disposed in trenches contain oil. Also included are sample residues from fuel pellets, ruptured fuel elements, ceramics and grouted plutonium in cans. … The radiological inventory includes uranium oxides, fission products, and plutonium. In most cases, plutonium will be found with various fission products, but in some of the generating facilities, separation of various isotopes took place, creating isolated streams of plutonium, promethium, cesium, curium, strontium, and americium…"

EU Designation: 618-11 Solid Waste Burial Ground

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What are the primary contaminants (risk drivers)?

Estimated Inventory for 618-11 Site

- 4,200 Ci Sr-90
- 5,300 Ci Cs-137
- 226 Ci Am-241
- 132 Ci Pu-239
- 639 Ci Pu-241
- 330 kg Beryllium

The time of estimated activity for the radioactive constituents needs to be confirmed. The waste constituents are classified as "principal threat waste" because of TRU (DOE/RL-2011-47, 2013, pg. 24).

What is the physical state of the primary contaminants (e.g., adsorbed in contaminated soil, as debris, in subsurface piping)?

Surficial contamination was noted (1980) after the site was initially closed and covered with soil. The entire site was subsequently re-graded, backfilled with an additional two feet of soil, and seeded with crested wheatgrass. The seed was irrigated for six weeks to establish the vegetation (HNF-EP-0649 Rev. 0, 1997, pg. 2-27).

After a marked increase in tritium concentration (January 2000) was detected in monitoring well 699-13-3A down gradient of the site, a detailed investigation was launched (PNNL-15293, 2005) to determine the source. Although tritium was not listed as one of the radioactive constituents of the waste inventory for 618-11, operation of the burial ground coincided with development of lithium aluminate targets used for the production of tritium (PNNL-13675, 2001). Waste from the tritium target activities may have been disposed in 618-11 and be the source of the tritium.

According to DOE/RL-2011-47 (Revision 0, page 33), "tritium concentrations would decline to below the DWS by 2031 under all alternatives, assuming no additional tritium input to groundwater." This statement, however, does not address additional tritium releases that might occur. However, provided the site remains covered with a vegetated soil layer, additional releases of tritium are unlikely due to the very low percolation rates at the near surface in the region.

Other contaminants associated with the inventory likely are bound within the existing solid waste as sorbed material or as part of a complex (e.g., salt) based on their original disposition. With limited infiltration and deep percolation of meteoric water, most of the contaminants likely are in their original or near original state.

High Level Waste Tanks and Ancillary Equipment: NA

Vadose Zone Contamination:

As part of the effort to determine the source of ^{3}H contamination near 618-11, helium-3/helium-4 ratios were measured in soil gas samples collected near the burial ground and along downgradient transects oriented both longitudinally and transverse to the direction of groundwater flow. Results from this investigation indicated that the source of the tritium was the 618-11 Burial Ground, as evidenced by the high helium-3/helium-4 ratio soil gas results in the vadose zone, high tritium in groundwater grab samples, and low tritium values from upgradient wells (PNNL-13675, 2001, PNNL-15293, 2005)

Groundwater Plumes:

Specific inventory of ^{3}H in groundwater attributed to the 618-11 burial site has not been found.

From (DOE/RL-2011-47, 2013) " Tritium in groundwater that exceeds the 20,000 picocurie per liter (pCi/L) DWS occurs in five wells downgradient from the 618-11 Burial Ground. Tritium concentrations from the 618-11 Burial Ground do not, and are not predicted to, affect the Columbia River above the DWS (Section 5.7.4 of the 300 Area RI/FS report [DOE/RL-2010-99])."

From (DOE/RL-2011-47, 2013): "Nitrate concentrations also exceed the DWS at four wells downgradient from the 618-11 Burial Ground. The extent of the nitrate plume is similar to the extent of the tritium plume shown on Figure 4-73 in the 300 Area RI/FS report (DOE/RL-2010-99)."

Facilities for D&D: NA

Operating Facilities: NA

Part VI. Potential Risk Pathways and Events

Current Conceptual Model

Narrative description of pathways and barriers to receptors and conditions/events that can lead to completed pathways

Pathways and Barriers: (1. description of institutional, natural and engineered barriers (including material characteristics) that currently) mitigate or prevent risk or impacts, 2. Time scale from loss of each barrier to realization of risk or impacts)

Briefly describe the current institutional, engineered and natural barriers that prevent release or dispersion of contamination, risk to human health and impacts to resources:

From (DOE/RL-2011-47, 2013) page 27, "The current human exposure scenario is industrial. Exposure to contamination in the 300 Area is currently controlled by DOE's site controls to prevent unacceptable exposure to humans. Risks to current workers are managed through health and safety programs." This also applies to 618-11, which is part of the 300 FF operable unit for which industrial use is identified explicitly as the cleanup level (see Section 4.4.5, DOE/RL-2010-99)

1. *What are the current barriers to release or dispersion of contamination from the primary facility? What is the integrity of each of these barriers? Are there completed pathways to receptors or are such pathways likely to be completed during the evaluation period?*

   The current barriers to release include an intact and vegetated soil cover over the waste site. The waste site is currently embedded with unconsolidated sands and gravels of the Hanford Formation and covered with eolian silts characteristic of this region that have been vegetated with crested wheatgrass. The vegetated silt acts as hydraulic barrier that limits percolation of meteoric water into the waste to minute amounts (1-3 mm per year).

   The depth of clean soil varies based on what is covered (trench, caisson, vertical pipe units), but the cover is at least 2 m of clean soil. In addition, specific waste disposal units such as the vertical pipe units and caissons hold the higher activity wastes in a constrained fashion. Boxes containing low level wastes that were disposed in the trenches probably have degraded.

   The tritium and nitrate plumes that have extended beyond the site boundaries indicate that some wastes may have reduced physical integrity. However, as noted in (DOE/RL-2011-47, 2013): "A fate and transport model was constructed for tritium in the groundwater that exceeds the federal DWS beneath the 618-11 Burial Ground. This analysis determined that the tritium concentrations would decline to below the DWS by 2031 under all alternatives, assuming no additional tritium input to groundwater."

2. *What forms of initiating events may lead to degradation or failure of each of the barriers?*

   This site is scheduled for remediation within the next five years. Deep erosion of the cover soils or structural failure of any buried components (e.g., caissons) is unlikely, and therefore release due to degradation is unlikely. However, an atmospheric release of radioactivity is likely during characterization and remediation of the site (risk > 10^{-2}).

3. *What are the primary pathways and populations or resources at risk from this source?*

   This site is situated adjacent to the Columbia Generating Station. The principal pathways of release are through fire and /or explosion of reactive contents of the site, triggered by remediation activities. The primary population at risk is the onsite worker conducting the remediation. Secondary populations include workers at the adjacent nuclear plant, or members of the public in the vicinity of the site.

4. *What is the time frame from each of the initiating events to human exposure or impacts to resources?*

   Seconds.

5. *Are there current on-going releases to the environment or receptors?*

   There is a tritium and nitrate plume extending from underneath the site. The tritium plume is possibly a pulsed release historically, and very slow and low-flux release currently due to percolation of meteoric water.

Table of relevant initiating events and potential impacts

Risk posed by 681-11 waste site (primary facility)			
Population or Resource	**At risk?** (Yes or No)	**If yes, identify & estimate quantity where applicable**	**Brief description**
Remediation worker	Yes	See (CP-14592 Rev. 0, 2003) Table 3-4 and 3-5	Several activities related to characterization of the site (not remediation) have anticipated frequencies of occurrence in the 10^{-2} per year, maximum worker risk is categorized as moderate (≥25 rem TEDE (0.25 Sv)
On-site, non-remediation worker	Yes		Several activities related to characterization of the site (not remediation) have anticipated frequencies of occurrence in the 10^{-2} per year, maximum onsite worker risk is categorized as low

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Risk posed by 681-11 waste site (primary facility)			
Population or Resource	**At risk?** (Yes or No)	**If yes, identify & estimate quantity where applicable**	**Brief description**
On-site, non-worker	Yes		Several activities related to characterization of the site (not remediation) have anticipated frequencies of occurrence in the 10^{-2} per year, maximum public risk is categorized as low
Off-site population	Not likely		Not applicable
Soils	Yes		May become contaminated as wastes are removed.
Vadose zone (below 5 m depth)	Yes	Already contaminated	Additional releases possible, but unlikely, when cover soils are removed to access wastes for removal.
Groundwater	Yes	Principally tritium	From past releases. Additional releases possible, but unlikely, when cover soils are removed to access wastes for removal.
Surface water	Yes	Note PNNL's modeling suggest concentrations will not exceed DWS	Additional releases possible, but unlikely, when cover soils are removed to access wastes for removal.
Specific protected biota or ecosystem	No		
Cultural Resources	No		
Economic Resources	No		

Populations and Resources Currently at Risk or Potentially Impacted

Workers (directly involved): None except for those associated with groundwater monitoring. They are exposed to low risk.

Workers (co-located): None.

Public: NA

Groundwater: There is no or low potential impact to a public entity in the current condition because there are no receptors in direct contact with groundwater contaminated with tritium from the 618-11 site. The tritium concentrations will be below drinking water standards by the time the reach a public receptor.

Columbia River: Tritium concentrations will be below drinking water standards by the time the reach a public receptor.

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Ecological Resources: NA

Cultural Resources: NA

Economic Resources: None.

Cleanup Approaches and End-State Conceptual Model

Selected or Potential Cleanup Approaches:

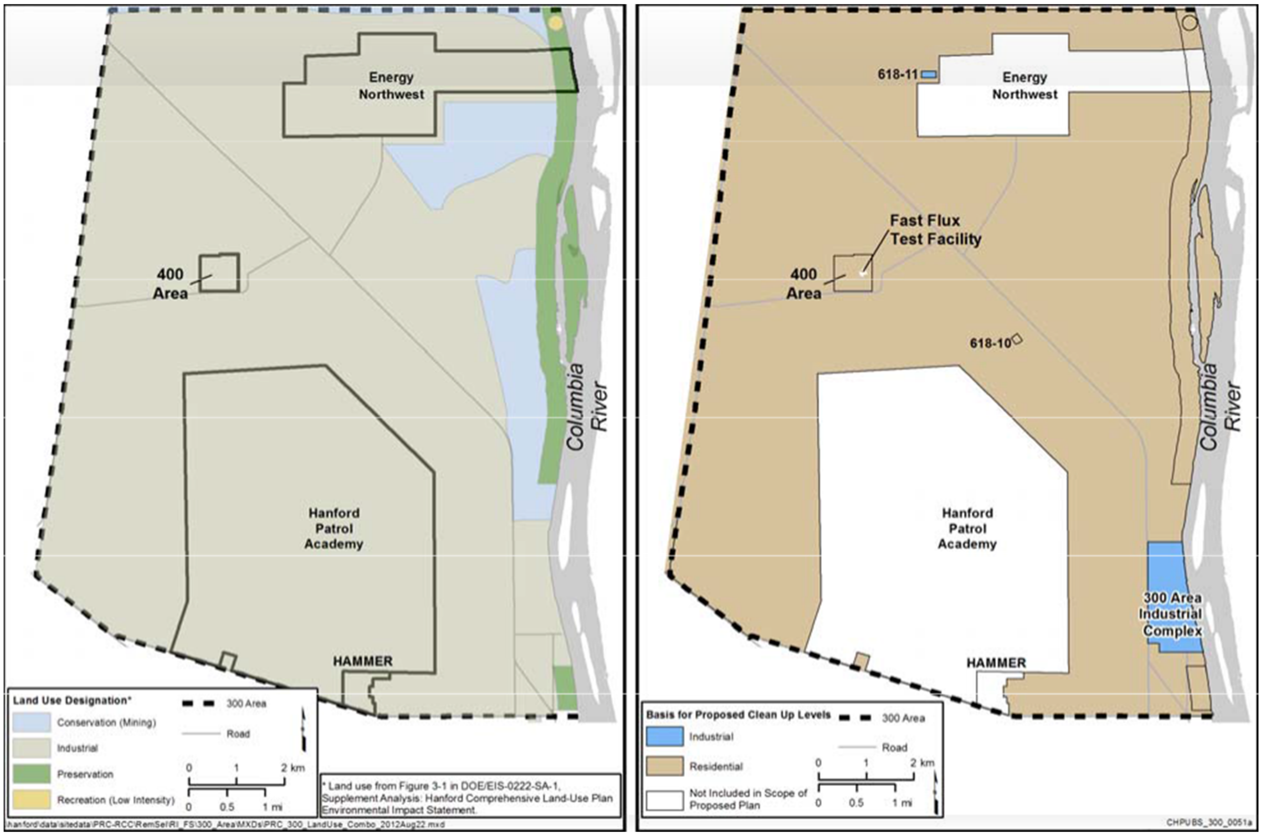
What are the selected cleanup actions or the range of potential remedial actions?

The major components of the selected remedy for 618-11 under the 300-FF-2 OU are[3]*:*

- *Remove, treat, and dispose (RTD) at waste sites*
- *Temporary surface barriers and pipeline void filling*
- *Enhanced attenuation of uranium using sequestration in the vadose zone, periodically rewetted zone (PRZ) and top of the aquifer, and*
- *Institutional Controls (ICs), including the requirement that DOE prevent the development and use of property that does not meet residential CULs at 618-11 for other than industrial uses, including use of property for residential housing, elementary and secondary schools, childcare facilities and playgrounds.*

From Figure C-8 (DOE/RL-2011-47, 2013), the proposed industrial level cleanup for 618-11:

[3] Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1 U.S. Environmental Protection Agency, Region 10 U.S. Department of Energy, Richland Operations Office November 2013.



Source: DOE/EIS-0222-SA-01, *Supplement Analysis: Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (left figure).

Figure C-8. Land Use Plan in DOE's NEPA Document (on left), and Exposure Basis for the Proposed Cleanup Levels (on right) (from DOE/RL-2011-47, 2013, p. 28)

The proposed remediation goals for 618-11 are shown in Table C-1 (DOE/RL-2011-47, 2013).

Table C-1. Preliminary Remediation Goals for Protection of Human Health and for Groundwater and Surface Water Protection (DOE/RL-2011-47, 2013, pp. 67-69)

Contaminant	Hanford Site Background Concentration[d]	PRGs[a,b] Based on the Residential Scenario for Areas Outside Both the 300 Area Industrial Complex and the 618-11 Burial Ground		PRGs[b,c] for Areas Inside the 300 Area Industrial Complex and the 618-11 Burial Ground	
		Proposed Shallow PRGs for Protection of Human Health (<= 4.6 m [15 ft] bgs)	Proposed Vadose Zone PRGs (Irrigation) for Groundwater and Surface Water Protection[f]	Proposed Shallow PRGs for Protection of Human Health (<= 4.6 m [15 ft] bgs)	Proposed Vadose Zone PRGs for Groundwater and Surface Water Protection[e]
Radionuclides (pCi/g)					
Americium-241	--	32	--[g]	210	--[g]
Cesium-137	1.1	4.4	--[g]	18	--[g]
Cobalt-60	0.0084	1.4	--[g]	5.2	--[g]
Europium-152	--	3.3	--[g]	12	--[g]
Europium-154	0.033	3.0	--[g]	11	--[g]
Europium-155	0.054	125	--[g]	518	--[g]
Iodine-129	--	0.076	12.8	1,940	37.1
Plutonium-238	0.0038	39	--[g]	155	--[g]
Plutonium-239/240	0.025	35	--[g]	245	--[g]
Plutonium-241	--	854	--[g]	12,900	--[g]
Technetium-99	--	1.5	272	166,000	420
Total beta radiostrontium (Strontium-90)	0.18	2.3	227,000	1,970	--[g]
Tritium	--	459	9,180	1,980	12,200
Uranium-233/234	1.1	27.2	--[h]	167	--[h]
Uranium-235	0.11	2.7	--[h]	16	--[h]
Uranium-238	1.1	26.2	--[h]	167	--[h]
Total uranium isotopes (summed)	--	56.1	--[h]	350	--[h]
Chemicals (mg/kg)					
Antimony	0.13	32	252	1,400	760
Arsenic	6.5	20[i]	20[i]	20[i]	--[g]
Barium	132	16,000	--[g]	700,000	--[g]
Beryllium	1.5	160	--[g]	7,000	--[g]
Cadmium	0.56	80	176	3,500	--[g]
Chromium (total)	18.5	120,000	--[g]	>1,000,000	--[g]
Chromium (hexavalent)	--	2.1	2.0[j]	10,500	2.0[j]
Cobalt	15.7	24	--[g]	1,050	--[g]
Copper	22	3,200	3,400	140,000	--[g]
Lead	10.2	250	1,480	1,000	--[g]

Contaminant	Hanford Site Background Concentration[d]	PRGs[a,b] Based on the Residential Scenario for Areas Outside Both the 300 Area Industrial Complex and the 618-11 Burial Ground		PRGs[b,c] for Areas Inside the 300 Area Industrial Complex and the 618-11 Burial Ground	
		Proposed Shallow PRGs for Protection of Human Health (<= 4.6 m [15 ft] bgs)	Proposed Vadose Zone PRGs (Irrigation) for Groundwater and Surface Water Protection[f]	Proposed Shallow PRGs for Protection of Human Health (<= 4.6 m [15 ft] bgs)	Proposed Vadose Zone PRGs for Groundwater and Surface Water Protection[e]
Lithium	13.3	160	--[g]	7,000	--[g]
Manganese	512	11,200	--[g]	490,000	--[g]
Mercury	0.013	24	8.5	1,050	--[g]
Nickel	19.1	1,600	--[g]	70,000	--[g]
Selenium	0.78	400	302	17,500	912
Silver	0.17	400	--[g]	17,500	--[g]
Strontium	--	48,000	--[g]	>1,000,000	--[g]
Thallium	0.19	--	--[g]	--	--[g]
Tin	--	48,000	--[g]	>1,000,000	--[g]
Uranium	3.2	81	102	505	157
Vanadium	85.1	400	--[g]	17,500	--[g]
Zinc	68	24,000	64,100	>1,000,000	--[g]
Asbestos	--	--[k]	--[k]	--[k]	--[k]
Cyanide	--	48	636	42	1,960
Fluoride	2.8	4,800	--[g]	210,000	--[g]
Nitrate	52	568,000	13,600	>1,000,000	21,000
Aroclor 1016	--	5.6	--[g]	245	--[g]
Aroclor 1221	--	0.50	0.017	66	0.026
Aroclor 1232	--	0.50	0.017	66	0.026
Aroclor 1242	--	0.50	0.14	66	--[g]
Aroclor 1248	--	0.50	0.13	66	--[g]
Aroclor 1254	--	0.50	--[g]	66	--[g]
Aroclor 1260	--	0.50	--[g]	66	--[g]
1,1,1-Trichloroethane	--	3,660	361	8,000	686
1,2-Dichloroethene (total)	--	720	55	31,500	89
Methyl ethyl ketone (2-butanone)	--	28,400	1,670	62,200	2,590
Methyl isobutyl ketone (hexone) (4-methyl-2-pentanone)	--	6,400	285	28,700	445
Benzene	--	0.57	0.82	5.7	1.4

Contaminant	Hanford Site Background Concentration[d]	PRGs[a,b] Based on the Residential Scenario for Areas Outside Both the 300 Area Industrial Complex and the 618-11 Burial Ground		PRGs[b,c] for Areas Inside the 300 Area Industrial Complex and the 618-11 Burial Ground	
		Proposed Shallow PRGs for Protection of Human Health (<= 4.6 m [15 ft] bgs)	Proposed Vadose Zone PRGs (Irrigation) for Groundwater and Surface Water Protection[f]	Proposed Shallow PRGs for Protection of Human Health (<= 4.6 m [15 ft] bgs)	Proposed Vadose Zone PRGs for Groundwater and Surface Water Protection[e]
cis-1,2-Dichloroethylene	--	160	11	7,000	18
Carbon tetrachloride	--	0.61	0.44	6.1	0.86
Chloroform	--	0.24	1.3	2.4	2.1
Ethyl acetate	--	72,000	--	>1,000,000	--
Ethylene glycol	--	160,000	5,030	>1,000,000	7,770
Hexachlorobutadiene	--	13	--[g]	1,680	--[g]
Hexachloroethane	--	2.5	23	25	72
Tetrachloroethene	--	20	2.4	82	6.0
Toluene	--	4,770	1,150	10,400	2,190
Trichloroethene	--	1.1	1.3	3.5	2.4
Vinyl chloride	--	0.53	0.013	5.2	0.021
Xylenes (total)	--	103	4,700	227	11,090
Benzo(a)pyrene	--	0.14	--[g]	18	--[g]
Chrysene	--	14	--[g]	1,800	--[g]
Phenanthrene	--	--	--	--	--
Tributyl phosphate	--	111	217	14,600	658
Normal paraffin hydrocarbon (kerosene)	--	2,000	2,000	2,000	2,000
Total petroleum hydrocarbons- diesel	--	2,000	2,000	2,000	2,000
Total petroleum hydrocarbons- motor oil	--	2,000	2,000	2,000	2,000

Note: The contaminants provided in this table are consistent with the contaminants of potential concern identified in the *300 Area Remedial Investigation/Feasibility Study Work Plan for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units* (DOE/RL-2009-30). The soil COCs (Table 1 in this Proposed Plan) represent the primary risk-driver contaminants for the majority of the waste sites but are not comprehensive for all sites such as the 618-10 and 618-11 Burial Grounds. For these waste sites, the additional COCs will be identified in the remedial design report/remedial action work plan.

a. Vadose zone PRGs are based on the residential exposure scenario represented using the State's "*Model Toxics Control Act*—Cleanup" (WAC 173-340) unrestricted use for chemicals and a residential exposure scenario for radionuclides.

b. Vadose zone PRGs for the protection of groundwater and surface water were calculated based on site-specific data and specific parameters using the STOMP code with a one-dimensional model for all contaminants except uranium. For uranium, the STOMP code was used with a two-dimensional model that includes the effects of uranium's more complex sorption behavior.

For highly mobile contaminants (K_d <2), the model assumes the entire vadose zone from ground surface to groundwater is contaminated. For less mobile contaminants (K_d ≥2), the model assumes the top 70 percent is contaminated and the bottom 30 percent is not contaminated. For the 300 Area Industrial Complex and 618-11 Burial Ground, a groundwater recharge rate of 25 mm/year was used for the long term, representing a permanently disturbed soil with cheatgrass vegetative cover. For the residential scenario, a groundwater recharge rate of approximately 72 mm/year was used, representing an irrigated condition. Model details are contained in the 300 Area RI/FS report (Section 5.7 and Table 5.4 of DOE/RL-2010-99).

EU Designation: 618-11 Solid Waste Burial Ground

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What is the sequence of activities and duration of each phase?

From (DOE/RL-2011-47, 2013) page 38, monitored natural attenuation is the proposed strategy for the groundwater contaminated by releases from 618-11. Model predictions show that tritium concentrations will be below DWS by 2031. The waste within 618-11 will be removed by RTD. Groundwater monitoring will be performed to evaluate the effectiveness of the alternative.

What is the magnitude of each activity (i.e., cubic yards of excavation, etc.)?

The following are estimates of the volume of material associated with remediation of the trenches, pipe units and caissons at the 618-11 area:

Contaminated Facility Components	Primary Contaminants	Amt. with low levels of contamination (m^3, linear m or number as appropriate)	Amt. with high levels of contamination (m^3, linear m or number as appropriate)	Total Amt. Media	Total amt. of each primary contaminant
Within trenches, pipe units, and caissons	TRU, ^{3}H, U, Be, solid metallic sodium, lead shielding, Tc oxide, ignitable metal turnings, Th oxide, wide range fission products, salt cycle residues	96,000 m^3 in trenches	56 m^3 in caissons, 220 m^3 in VPUs. VPUs likely contain lower levels.	96,300 m^3	4,200 Ci Sr-90 5,300 Ci Cs-137 226 Ci Am-241 132 Ci Pu-239 639 Ci Pu-241 330 kg Be
Structural materials (i.e., concrete and steel)	Same as above	None	Steel pipe: 24 m @ 1 m d, 120 m @ 2.4 m diam, 229 m @ 0.5 m Concrete: 40 m^3	Will likely be grouted. Volume will depend on grouting method.	Not available.

Contaminant Inventory Remaining at the Conclusion of Planned Active Cleanup Period:

When remediation is completed, contaminant levels will be below industrial clean up standards. Over time, tritium in ground water will diminish below drinking water standards due to natural attenuation.

EU Designation: 618-11 Solid Waste Burial Ground

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Risks and Potential Impacts Associated with Cleanup:

Can any (or all) of the potential remedial actions serve as initiating events for risks or impacts (i.e., to workers, to natural resources, etc.)?

The remediation activity is primary risk driver at the 618-11 site in the near term. The remediation activities associated with removal of wastes from the pipe units and caissons can serve as initiating events for airborne releases with high risk to remediation workers and any worker outside the Energy Northwest plant that are in the vicinity of the 618-11 site.

Populations and Resources at Risk or Potentially Impacted During or as a Consequence of Cleanup Actions

Workers (directly involved): Remediation workers have medium to high risk when involved in removal and blending of existing wastes and transport to ERDF. Workers involved in post-remediation monitoring will have low risk.

Workers (co-located): Workers at Energy Northwest facility will have low risk except when wastes are exhumed from the pipe units and caissons. These workers may have high risk if outside the Energy Northwest facility and near the 618-11 area when waste is exhumed from the pipe units and caissons.

Public: NA

Groundwater: There is no risk to a public entity via groundwater during remediation because there are no receptors in direct contact with groundwater contaminated with tritium from the 618-11 area. The tritium concentrations will be below drinking water standards by the time the tritium reaches a public receptor. Moreover, if a release occurred during remediation, the time elapsed before a receptor was affected would be much longer than the time period associated with the remediation.

Columbia River: Not at risk during remediation unless hydrologic events allow significant infiltration into the interred waste when the cover soil is removed for remediation. In such cases, contaminant releases could occur that could ultimate reach the Columbia River. However, there is essentially no risk imposed to the Columbia River during the remedial action.

Ecological Resources: NA

Cultural Resources: NA

Economic Resources: The Energy Northwest facility could be adversely affected by an airborne release during remediation, potentially affecting its operation.

Additional Risks and Potential Impacts if Cleanup is Delayed

None.

Near-Term, Post-Cleanup Status, Risks and Potential Impacts

Populations and Resources at Risk or Potentially Impacted After Cleanup Actions (from residual contaminant inventory or long-term activities)

Workers (directly involved): Workers involved in post-remediation monitoring (e.g., ground water monitoring) will have low risk. No other workers will be present.

Workers (co-located): None

Public: NA

Groundwater: Low to none unless an unexpected release occurs during remediation (e.g., hydrologic events allowing significant infiltration into the interred waste during remediation). The remediation will eliminate the source of potential contaminants, thereby eliminating risks to groundwater. There are no receptors in direct contact with groundwater contaminated with tritium from the 618-11 area currently, and the tritium concentrations currently in groundwater that are associated with 618-11 will drop below drinking water standards over time.

Columbia River: Not at risk after remediation unless an unexpected release occurs during remediation.

Ecological Resources: NA

Cultural Resources: NA

Economic Resources: None.

Long-Term, Post-Cleanup Status – Inventories and Risks and Potential Impact Pathways

Workers (directly involved): Workers involved in post-remediation monitoring will have low risk. There will be no risk to other workers.

Workers (co-located): None.

Public: NA

Groundwater: Low to none unless an unexpected release occurs during remediation. The remediation will eliminate the source of potential contaminants, thereby eliminating risks to groundwater.

Columbia River: Low to none unless an unexpected release occurs during remediation. The remediation will eliminate the source of potential contaminants, thereby eliminating risks to groundwater and the Columbia River.

Ecological Resources: NA

Cultural Resources: NA

Economic Resources: None

Part VIII. Risk and Potential Impacts Ratings

Current Risks and Potential Impacts – Ratings

Population or Resource	Risk or Impact Rating (based on risk matrix)	Comments
Worker (remediation & facility worker)		Worker exposure limited to activities associated with collecting ground water samples.
Worker (co-located)		
Public		There is no direct impact on public from this site in current state.
Groundwater		Existing cover soils provide good hydrologic containment, thereby eliminating source of groundwater contaminants.
Surface water		Tritium in groundwater from historic releases from site will be below drinking water standards before reaching the Columbia River.
Ecological Resources		
Cultural Resources		
Economic Resources		

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EU Designation: 618-11 Solid Waste Burial Ground

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Risks During and as a Consequence of Cleanup Actions - Ratings

Population or Resource	Risk or Impact Rating (based on risk matrix)	Comments
Worker (remediation & facility worker)		Releases during remediation put remediation workers at risk while waste is being exhumed, blended, and then transported to ERDF.
Worker (co-located)		Atmospheric release during waste removal could affect nearby remediation workers.
Public		There will be no direct impact on public from this site during remediation.
Soils		Contamination to be below industrial use when remediation is complete.
Groundwater		Unexpected release during waste removal could introduce new contaminants to groundwater, but highly unlikely.
Surface water		Tritium in groundwater from historic releases from site will be below drinking water standards before reaching the Columbia River. Unexpected release during waste removal could introduce new contaminants to groundwater, but highly unlikely.
Ecological Resources		
Cultural Resources		
Economic Resources		Atmospheric release during waste removal could affect operation of Energy Northwest plant.

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EU Designation: 618-11 Solid Waste Burial Ground

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Near-Term, Post-Cleanup Risks and Potential Impacts

Population or Resource	Risk or Impact Rating (based on risk matrix)	Comments
Worker (remediation & facility worker)		Worker exposure limited to activities associated with collecting ground water samples for long-term monitoring.
Worker (co-located)		No co-located workers will be present.
Public		There is no direct impact on public from this site in post-remediation state.
Soils		Site to be remediated to below industrial clean up standards, and all residual contamination will be at least 2 m below surface.
Groundwater	TO BE COMPLETED IN FINAL TEMPLATE	Source of groundwater contaminants will be eliminated.
Surface water		Tritium in groundwater from historic releases from site will be below drinking water standards before reaching the Columbia River.
Ecological Resources		
Cultural Resources		
Economic Resources		

Part IX. Supplemental Information and Considerations

I.e., need to remain under DOE control to maintain safety buffer; interim actions that may mitigate deteriorating conditions, etc.

References

CP-14592 REV. 0 2003. 618-10 and 618-11 Waste Burial Grounds Basis for Interim Operation. In: HANFORD, F. (ed.). Richland, Wash.: Richland, Wash. : U.S. Dept. of Energy, Richland Operations Office.

DOE/RL-2011-47, R. 2013. Proposed Plan for Remediation of the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units. Richland, Wash.: Richland, Wash. : U.S. Department of Energy, Richland Operations Office.

DOE/RL-97-56, Revision 1 (1998), Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan, Richland, Wash.: U.S. Department of Energy, Richland Operations Office, Richland, Wash.

HNF-EP-0649 REV. 0 1997. Characterization of the 618-11 Solid Waste Burial Ground, Disposed Waste, and Description of the Waste-Generating Facilities. Richland, Wash: Richland, Wash. : U.S. Department of Energy, Richland Operations Office.

LANDON, S. & NOLAN, L. Characterization modeling to support the hanford 618-10 and 618-11 burial grounds remediation design solution: two differing approaches with similar results. 2007. WM Symposia, 1628 E. Southern Avenue, Suite 9-332, Tempe, AZ 85282 (United States).

PNNL-13675 2001. Measurement of helium-3/helium-4 ratios in soil gas at the 618-11 burial ground. Richland, Wash.: Richland, Wash. : Pacific Northwest National Laboratory.

PNNL-15293 2005. Evaluation of the Fate and Transport of Tritium Contaminated Groundwater from the 618-11 Burial Ground. Richland, Wash.: Richland, Wash. : Pacific Northwest National Laboratory.

Appendix D

Hanford Site-Wide Risk Review Project
Evaluation Unit Summary Template

Central Waste Complex

Table of Contents

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EU Designation: Operating Unit Group 6 - Authorized dangerous waste management units[1]

Part I. Executive Summary

EU Location: Hanford 200 West Area

Related EUs: WRAP, Low Level Burial Grounds, T Plant

Primary Contaminants, Contaminated Media and Wastes:

In the Master Documented Safety Analysis for Solid Waste Operations Complex (HNF-14741), the bounding drum and array analysis assumptions of the Hanford Safety Analysis and Risk Assessment Handbook (SARAH, HNF-8739) are used. In that bounding drum, the radionuclides are assumed to be Pu-238, Pu-239 (more than 80% by activity), Pu-240, Pu-241 and Pu-242, along with the Pu decay product Am-241. Debris from D&D and operational wastes, notably from PNNL and Tank Farms, can also contain fission products (Cs-137, Sr-90). However, majority of presently stored waste is classified as TRU.

Contaminated Media, Nuclear Material	Primary Hazardous Materials Contributing to Risk	Amt. in Standard LLW or TRU Waste Packages[1]	Retrieved Large Boxes in Outdoor Storage	Total Containers	Total Volume	Est. amt. of each primary contaminant
Within facility						
Major Mission materials	Containerized waste being stored prior to final treatment.					
Waste Stored		~8,600	~175	~8,800	10,788 m3[2]	
Facility contamination (piping, gloveboxes, etc.)	Minor leaks and rainwater intrusion do occur. Regular RCRA inspection and radiological monitoring to identify problems, which are remediated.					
Facility Vicinity						
Known plumes	Facility is built over/adjacent two a known CCl_4 plume from the Plutonium Finishing Plant (PFP) that is under remediation via pump-and-treat with some wells within the CWC perimeter.					
Waste stored outside facility	There are several outside storage pads. The waste on these pads are managed and monitored similar to waste stored inside of the buildings but the pads do not have double containment.					
Subsurface infrastructure (i.e., piping, etc.)	Sumps in some storage buildings; electricity and fire suppression water lines in most buildings,					

[1] Permit WA7890008967, Part III, OU Group 6, Central Waste Complex, CWC Facility Description: Page 3
[2] Total from a recent output of SWITS (Solid Waste Information Tracking System).

EU Designation: Central Waste Complex

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Brief Narrative Description:

The CWC provides storage, inspection (as required), limited processing, and staging for waste containers that are awaiting waste processing operations or disposal at other waste management facilities. The CWC receives waste from both onsite and offsite generators. Four types of waste are processed or stored at the CWC: low-level radioactive waste (LLW); mixed, low-level radioactive waste (MLLW), transuranic waste (TRU); and mixed TRU (TRUM) waste. The CWC can receive, as necessary, unvented containers from retrieval operations for staging prior to venting (for example, at T-Plant).

Summary Table of Risks and Potential Impacts to Receptors:

EU: OU-6 - Risk or Impact Rating				
Population or Resource		Evaluation Time Periods		
		Active Cleanup (to 2064)		Near-Term Post Cleanup (to 2164)
		Current Condition/ Operations	From Cleanup Actions	
Human	Worker (remediation & co-located)		D&D of this facility is not yet planned.	D&D of this facility is not yet planned.
	Worker (not co-located)		D&D of this facility is not yet planned.	D&D of this facility is not yet planned.
	Public		D&D of this facility is not yet planned.	D&D of this facility is not yet planned.
Environmental	Near Surface Soils		D&D of this facility is not yet planned.	D&D of this facility is not yet planned.
	Groundwater		D&D of this facility is not yet planned.	D&D of this facility is not yet planned.
	Surface water		D&D of this facility is not yet planned.	D&D of this facility is not yet planned.
	Ecological Resources		D&D of this facility is not yet planned.	D&D of this facility is not yet planned.
Social	Cultural Resources		D&D of this facility is not yet planned.	D&D of this facility is not yet planned.
	Economic Resources		D&D of this facility is not yet planned.	D&D of this facility is not yet planned.

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Support for Risk and Impact Ratings for each Time Period:

Current Condition:

The consequent categories and frequency estimates discussed in this section are consistent with the estimates made in HNF-15589, *Consolidated Hazard Analysis for the Master Documented Safety Analysis* (MDSA, Rev. 8). In the CHA, 91 total scenarios were evaluated for the CWC.

- There were sixteen (16) analyzed accident scenarios that produced consequences evaluated as "Moderate" for facility workers at CWC which had an estimated frequency of occurrence of "Anticipated"; these included eight (8) fire/energetic reaction scenarios and eight (8) radiological spills. Also, three (3) accident scenarios evaluated as "High" consequences with a frequency of "Low"; two fires and seismic building collapse.
- For on-site other workers, there were two accident scenarios that produced "High" consequences, but had an "Unlikely" estimated frequency of occurrence (Transportation-related fire & seismic building collapse); also, one fire was rated to have "Moderate" consequences with an estimate frequency of "Anticipated."
- There were no accidents evaluated to other than "Low" consequences to the maximum exposed off-site individual.
- Twenty (20) accidents evaluated, all "Unlikely" or less frequent, were deemed to have the potential to produce E3 consequences, that is: "off-site discharge to discharge to the groundwater." Discharges to the surface soil are assumed herein to be similar, as the primary dispersal pathway is airborne.
- Impacts to Cultural resources were evaluated by the appropriate CRESP teams and inserted.
- Impacts to Economic resources were evaluated by the appropriate CRESP teams and inserted.

Risks and Potential Impacts from Selected or Potential Cleanup Approaches: NA

Addendum H of the RCRA Permit for CWC outlines closure activities as follows: (1) remove waste inventory; (2) decontaminate structural surfaces and equipment; (3) analyze decontamination waste to determine proper methods of treatment/disposal; and (4) dispose of decontamination waste based on results of waste analysis. The total duration of the cleanup phase is expected to be 180 days.[3]

Present information in the DSA indicates simply that SWOC facilities in general "have not identified any D&D activities that are unique, facility specific, or important to preventing or mitigating radiation exposure with respect to the D&D program."

Risks and Potential Impacts if Cleanup is Delayed: NA

Near-Term, Post-Cleanup Risks and Potential Impacts: Depend on D&D methodologies, yet to be planned.

Long-Term, Post-Cleanup: Depend on D&D methodologies, yet to be planned.

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[3] Permit WA7890008967, Part III, OU Group 6, Central Waste Complex, Closure Plan: Page 6.

Part II. Administrative Information

OU and/or TSDF Designation(s): Operating Unit Group 6 - Authorized dangerous waste management units[4]

Common name(s) for EU: Central Waste Complex (CWC)

Key Words: radioactive waste, waste storage, mixed waste, transuranic waste (TRU)

Regulatory Status

Regulatory Basis: CWC is a Hazard Category 2 nuclear facility, as categorized by DOE-STD-1027. It is also categorized as Dangerous Waste Storage and Treatment Facility by Washington State Department of Ecology.

Applicable regulatory documentation: In accordance with 10CFR830, Nuclear Safety Management, a documented safety analysis (HNF-14741) has been completed, with required safety controls. The State of Washington has issued a RCRA permit (WA7890008967, Part III, OU Group 6, Central Waste Complex) for CWC operations.

Applicable Consent Decree or TPA milestones: M-091-Series Milestones (as applicable)

Risk Review Evaluation Information:

Completed: 7/19/14

Evaluated by: S. Krahn, A. Croff, L. Fyffe

Reviewed by: D. Kosson, C.W. Powers

Part III. Summary Description

Current land use: DOE Hanford Site[5]

Designated future land use: Industrial Exclusive[6]

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[4] Permit WA7890008967, Part III, OU Group 6, Central Waste Complex, CWC Facility Description: Page 3

[5] The current land use is Industrial, for Waste Storage, Treatment and Management. The CWC Operating Unit Group Dangerous Waste Management Units are designed for storage but can also perform operations such as: opening, sorting, treating (e.g., segregation, sorting for assignment to treatment), repackaging, sampling, physically/chemically screening to characterize retrieved waste, and to verify the characterization of containers of mixed waste. The facility can perform nondestructive examination (NDE) on an as needed basis using portable equipment. Limited treatment of mixed waste is permitted in the 2401-W, 2402-W, and 2403-W series dangerous waste management units. Sampling and verification may be done at the CWC Operating Unit Group. However, receiving, evaluating the integrity of packaging, repackaging when necessary and storing wastes for final disposition are the primary activities at the CWC; other operations mentioned above, while authorized by the RCRA permit and analyzed in the Documented Safety Analysis (DSA), are performed infrequently.

[6] CWC is projected to be operated as long as the waste management mission requires. Thereafter, the Central Plateau is designated for Industrial-Exclusive use. This designation is defined as an area suitable and desirable for treatment, storage, and disposal of hazardous, dangerous, radioactive, and nonradioactive wastes. It includes related activities consistent with Industrial-Exclusive uses. This designation would allow for continued Waste Management operations within the Central Plateau geographic area.

EU Designation: Central Waste Complex

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Primary EU Source Components:

Legacy Source Sites: N/A

High-Level Waste Tanks: N/A

Groundwater Plumes: Facility rests on top of known Carbon Tetrachloride plume which is under active pump and treat remediation.

D&D of Inactive Facilities: N/A

Operating Facilities: Containerized LLW, MLLW, TRU, MTRU

Narrative Summary:

Personnel receive and inspect waste packages at the Waste Receiving and Staging Area. In accordance with all applicable procedures, transport offloading operations are performed using handtrucks, forklifts, or cranes operated by qualified personnel. Packages are transferred from the offloading area to the appropriate CWC storage building or other storage area. Alternatively, waste packages may be received, inspected, and unloaded at the specific CWC building or storage area where the waste would be stored. Typical stored waste packages include 208-liter (55-gallon) drums; 322-liter (85-gallon) overpacks; and fiberglass-reinforced plywood, plywood, or metal boxes. Atypical packages include, but are not limited to, radioisotopic thermoelectric generators, vault tank filter assemblies, blanked-off gloveboxes, overpacks, and pipe overpacks in 208-liter (55-gallon) drums.[7]

The CWC main structures include the 2402 series (excluding 2402-W and 2402-WC), 2403 series, and 2404 series buildings. Other CWC facilities include the Low Flash Point Storage Modules (FS-1 to FS-3, FS-5 to FS-7, FS-9 to FS-12, and FS-14 to FS-27), Alkali Metal Waste Modules (AMW-1 to AMW-4) the Waste Receiving and Staging Area, the Mixed Waste Storage Pad, and the 2420-W Cask Storage Pad.

Planned activities at the CWC include performing headspace gas sampling (HSGS) on containers; NDEs and NDAs using portable units to characterize container contents; intrusive sampling operations to characterize or verify contents; minimal waste treatment (encapsulating, absorbing, stabilizing, neutralizing, and venting); and packaging and repackaging (adding shielding inside containers, filling voids, removing noncompliant items, and decontaminating shipping container interiors).8 Treatment will consist of absorption of free liquids, absorption to accomplish deactivation, neutralization of corrosive materials. Further, CWC has contracted with off-site radioactive waste treatment vendors that provide additional capacity and capabilities. The CWC Operating Unit Group provides storage for dangerous and/or mixed waste from Hanford onsite generating locations including waste from the Waste Retrieval Project (WRP), and off-site generators.[9]

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[7] EIS 0391 (2012), Appendix E: Page 236-237

[8] EIS 0391 (2012), Appendix E: Page 237

[9] Permit WA7890008967, Part III, OU Group 6, Central Waste Complex, Addendum C: Page 4

EU Designation: Central Waste Complex

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Location and Layout Maps

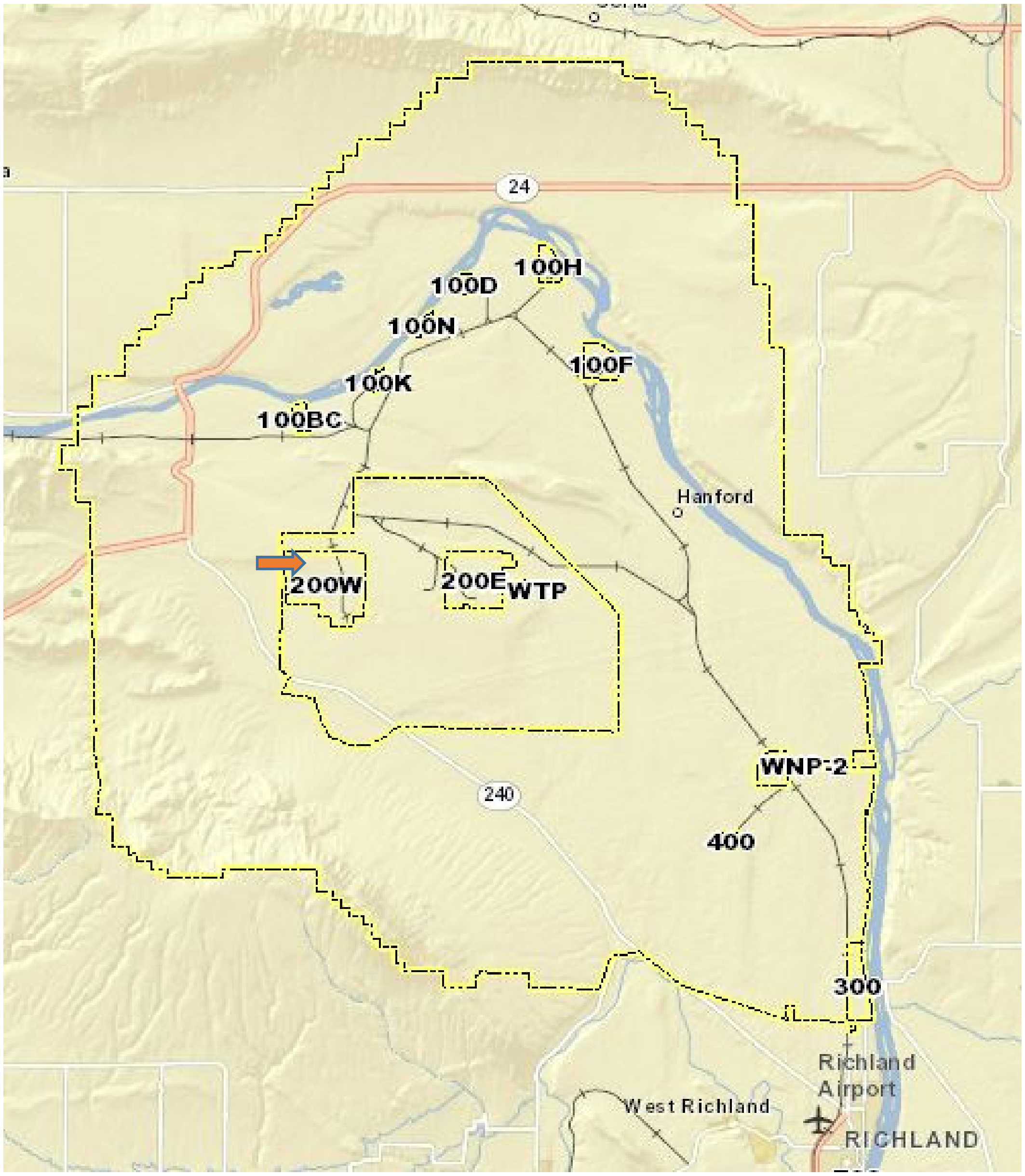

Figure D-1. Overall view of the Hanford Site with the 200W Area Highlighted[10]

This image illustrates the location of the 200 West (200W) Area in reference to the Hanford site and surrounding areas. The orange arrow indicates the location of the CWC. An important feature of this map is Highway 240, which is the closest public point to the CWC, and thus the location of the Maximum Exposed Individual.

[10] This image from the PNNL PHOENIX System (http://phoenix.pnnl.gov/).

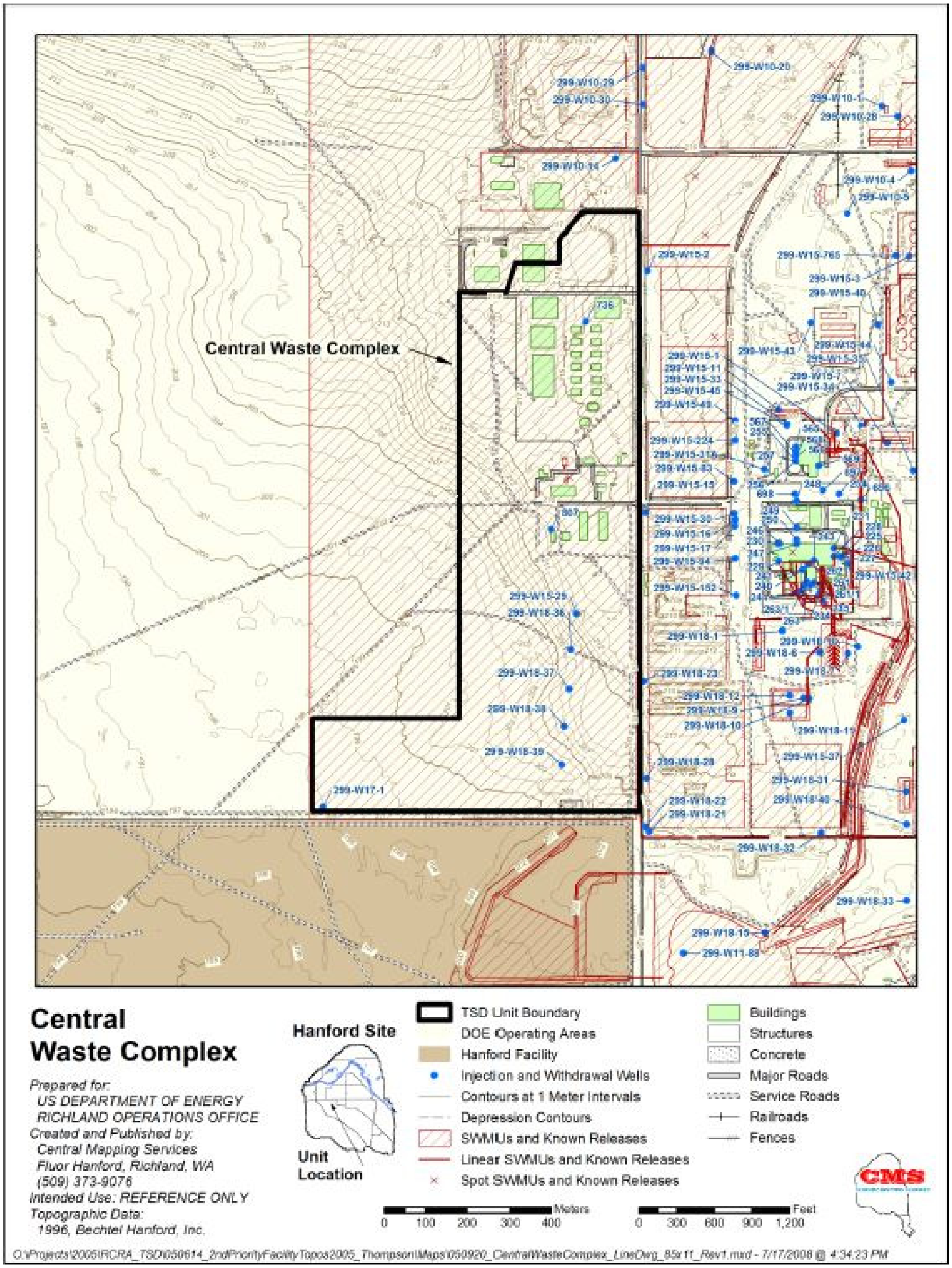

Figure D-2. Map of CWC within the SWOC[11]

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[11] Permit WA7890008967, Part III, OU Group 6, Central Waste Complex, Addendum A Part A: Page 29

Part IV. Unit Description and History

Legacy Source Sites: NA

High-Level Waste Tanks: NA

Groundwater Plumes: NA

D&D of Inactive Facilities: NA

Operating Facilities

What processes produced the radioactive material contained in the facility?

The radioactive material contained at the CWC includes MLLW, LLW, TRU and mixed TRU from both Hanford and offsite. In its current status, the majority of the waste in the CWC is retrievably stored TRU retrieved from the old burial grounds[12].

What types of containers or storage measures are used for radioactive materials at the facility?

The waste containers at the CWC are for the most part 55 gallon drums, composed of a noncombustible material with coatings or liners sufficient to maintain the integrity of the containment system from corrosion over the anticipated storage life of the waste; in some cases an overpack will be used and sorbent where necessary. There are some (175, or about 2% of all containers) legacy, large containers that are 'strong, tight packages,' most frequently wood boxes with fiberglass reinforcement; these containers have been provided additional weather protection. Further, waste packages will not exceed 1 mSv/hr 20 cm away from the surface or 2 mSV/hr on the surface.[13]

How is the radioactive material and waste contained or stored within the facility classified?

There are four distinct classes of material stored at the CWC including LLW, MLLW, TRU and Mixed TRU. The waste generator must determine the physical and chemical characteristics of the waste. This information can come from the following sources: A representative sample, test data from a nonradioactive surrogate sample, MSDS, mass balance data from the waste generation process, interview information, log books, procurement records, and others[14]. Upon reaching the CWC, a small sample of the waste will be assayed to determine the accuracy of the information provided by the generator.

What nuclear and non-nuclear safety accident scenarios dominate risk at the facility[15]?

There were sixteen (16) analyzed accident scenarios that produced consequences evaluated as "Moderate" for facility workers at CWC which had an estimated frequency of occurrence of "Anticipated"; these included eight (8) fire/energetic reaction scenarios and eight (8) radiological spills.

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[12] WA7 89000 8967, Part III, Operating Unit 6- (2009), Page 1

[13] HNF-EP-0063-Rev. 18- (2011), Page 4-4.

[14] HNF-EP-0063-Rev. 18- (2011), Page 2-2.

[15] HNF 15589-8 (2012), Appendix A.

Also, three (3) accident scenarios evaluated as "High" consequences with a frequency of "Low"; two fires and seismic building collapse.

For on-site other workers, there were two accident scenarios that produced "High" consequences, but had an "Unlikely" estimated frequency of occurrence (Transportation-related fire & seismic building collapse); also, one fire was rated to have "Moderate" consequences with an estimate frequency of "Anticipated."

There were no accidents evaluated to other than "Low" consequences to the maximum exposed off-site individual.

Twenty (20) accidents evaluated, all "Unlikely" or less frequent, were deemed to have the potential to produce E3 consequences, that is: "off-site discharge to discharge to the groundwater."

What are the average and maximum occupational radiation doses incurred at the facility?

The average dose (TED) is 36.5 mrem; the cumulative dose for 2013 is 2630 mrem; the maximum individual dose is 217 mrem; the low quoted contract radiation readings (discussed above), along with this data would, indicate low overall risk from chronic, occupational radiation exposure for CWC workers.[16]

What processes and operations are conducted within the facility?

The primary actions at the CWC are shipping and receiving, waste container handling and waste storage.

However, permitted activities at the CWC for all types of wastes packages include the following[17]:

- Shipping and receiving
- Waste container handling
- Waste staging and storage
- Nonintrusive survey and inspection (including non-destructive examination and non-destructive assay)
- Waste loading/transfers
- Container venting
- Waste treatment
- Decontamination
- Packaging and repackaging (overpacking)
- Waste Verification
- Headspace gas sampling

[16] Collins, Mike e-mail communication (2014).

[17] HNF 14741-10 (2013). Pages 2-21 and 2-22

What is the process flow of material into and out of the facility?

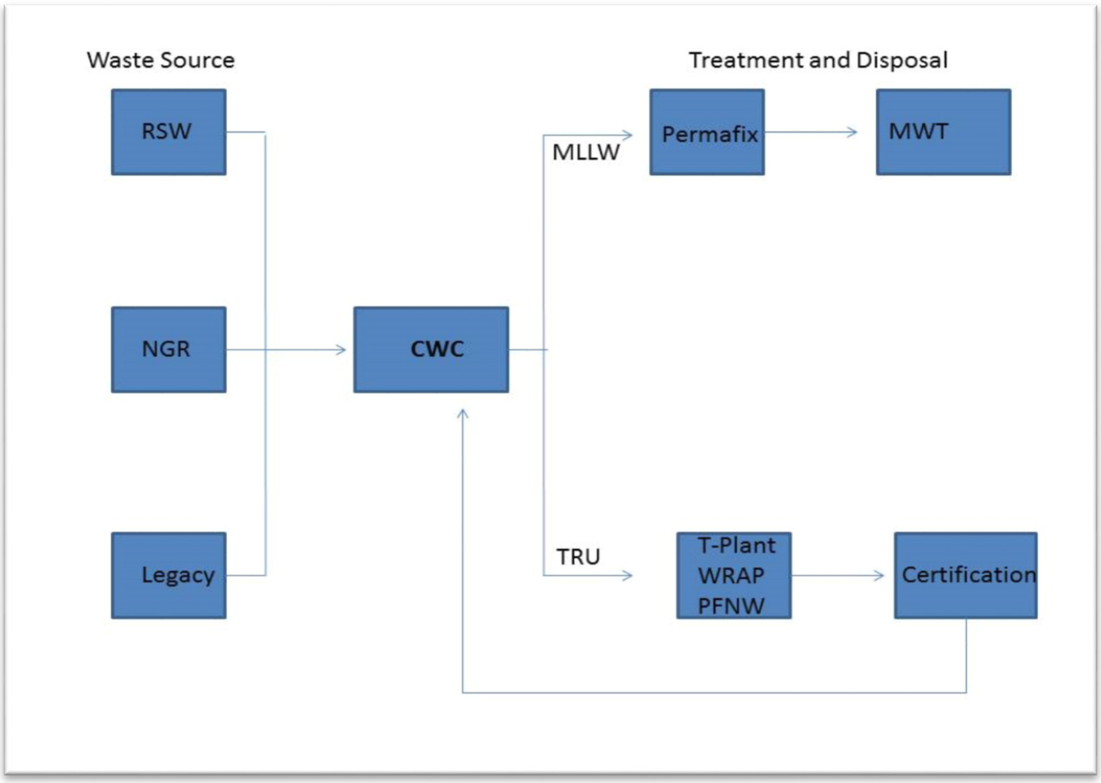

Figure D-3. The Flow of Waste into and out of the CWC[18]

What effect do potential delays have on the processes, operations, and radioactive materials in the facility?

For the CWC there are 2 foreseeable delays: (1) overall delays for which the impact would be that the risks and hazards of the operating facility would continue as they are, without moving into a cleanup phase; (2) problems with WIPP or other long term storage would require the CWC to remain available to store TRU for an extended period of time for which the impact would also be the continuation of operating risks and hazards.

What other facilities or processes are involved in the flow of radioactive material into and out of the facility?

The CWC is a part of the Solid Waste Operating Group which also includes T-Plant and WRAP. The following process flow diagram illustrates the solid waste flow into and out of the facilities in the SWOC.

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[18] This diagram was created by Mike Collins during a group tour of the CWC.

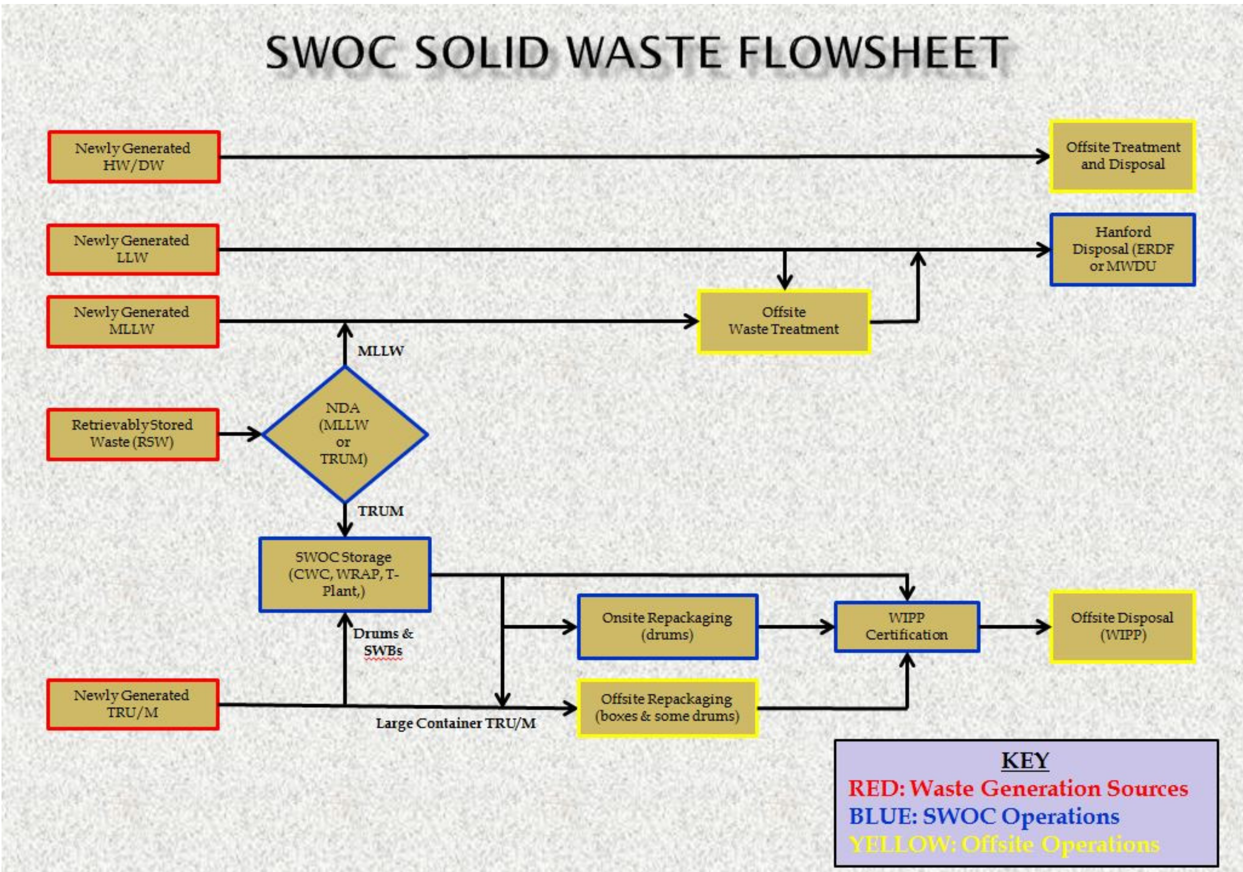

Figure D-4. SWOC Solid Waste Flow Sheet[19]

Is shipping of material involved and if so, how often and by what means?

Waste transportation involves shipments from offsite and onsite waste generators to CWC facilities. Onsite shipments must comply with the Transportation Safety Document (TSD), required under DOE O 460.1C, Packaging and Transportation Safety. The TSD is the approved documented safety analysis for onsite transportation and packaging activities. Offsite shipments (arriving or leaving) must comply with the requirements of 49 CFR 171, “Hazardous Materials Regulations” unless exceptions are made, usually with attendant special provisions like temporary closure of public roads for transportation to Permafix NW. Offsite shipments may be made by truck, railroad, or other transportation conveyance. The railroad tracks are located outside of the boundaries of the CWC facilities with the exception of T Plant, which has taken measures to preclude entry of a train without positive actions by Operations.[20]

What infrastructure is considered a part of the facility?

The following units are considered a part of the CWC: 2403WA, 2403WB, 2403WC, 2403WD, 2404WA (permitted under WRAP but operated as a part of CWC), as well as the Flammable and Alkali Metal

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[19] This flowsheet was provided after our site visit via Sharepoint. It was loaded by Mike Collins, but the author may be a different party.

[20] HNF 14741-10 (2013). Page 2-89

Waste Storage Modules, the 2401-W Building, the 2402-W Series of 12 buildings and outside storage areas A-F.

Ecological Resources Setting

The area surrounding the CWC in the 200 West area is classified as containing Level III biological resources[21]. This area is home to the plant community of concern of big sagebrush- bunchgrasses-cheatgrass[22]. The area is also in the proximity of burrowing owl nest sites and loggerhead shrike nest sites.[23] Areas within the facility are contained within purpose-built storage facilities, asphalt covered or graded with gravel. More information about the ecological resources of the 200 West area can be found in the Ecological Cross Cutting Issues Analysis.

Cultural Resources Setting

The U.S. Department of Energy Richland Operations Office and the Washington State Historic Preservation Office designated the Manhattan Project and Cold War facilities of the Hanford Site a historic district eligible for listing in the National Register of Historic Places (NRHP) in 1996. The 272-WA, 213-W, 2120-WA, 2120-WB, 2336W, 2401-W, 2402-W, 2403-WA, 2403-WB, 2403-WC, 2403-WD, 2404-WA, 2404-WB, 2404-WC, MO 251, MO 280, MO 434, MO 437, MO 535, MO 720, MO 721, MO 743, and MO 288 buildings are were determined to be non-contributing/exempt properties requiring no mitigation under the *Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan*[24]. Although, the 275-WA building is not listed in the *Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan*[24], it is likely also a non-contributing exempt property (personal communication, Tom Marceau August 5, 2014). This information is based on data received as of the date of the document and may change as new information becomes available or is provided.

Economic Assets

Nearby economic assets include Highway 240, which is approximately 5 km away from the CWC.

Part V. Waste and Contamination Inventory

Brief description of contaminated media and materials

The predominant waste type at the CWC is containerized TRU. There are no known spills or contaminated media.

What is the origin of the nuclear materials/wastes?

The CWC provides storage and staging for waste containers that are awaiting processing or shipment to other waste facilities. LLW, MLLW, TRU and mixed-TRU waste is shipped from remediation projects elsewhere on the Hanford Site. Material is also received back from off-site treatment contractors (e.g., Perma-Fix Northwest) and prepared for shipment to final disposal sites, such as the Waste Isolation Pilot Plant (WIPP) for TRU waste; TRU is the predominant waste type at CWC.

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[21] DOE/EIS-0222-F, (1999) Page 4-87
[22] DOE/EIS-0222-F, (1999) Page 4-75
[23] DOE/EIS-0222-F, (1999) Page 4-59
[24] DOE/RL-97-56, Revision 1 (1998)

What are the primary radionuclides/contaminants?

In the Master Documented Safety Analysis for Solid Waste Operations Complex (HNF-14741), the bounding drum and array analysis assumptions of the SARAH are used. In that bounding drum, the radionuclides are assumed to be Pu-238, Pu-239 (more than 80% by activity), Pu-240, Pu-241 and Pu-242, along with the Pu decay product Am-241. Debris from D&D and operational wastes, notably from PNNL and Tank Farms, can also contain fission products (Cs-137, Sr-90). However, majority of presently stored waste is classified as TRU.

What is the physical state of the materials, facility(ies), stored waste, and area surrounding the facility?

Waste received that the CWC is containerized LLW, MLLW, TRU, and mixed-TRU in 55-gallon drums; less-frequently in larger packages (85-gallon over-packs), along strong, tight LLW containers such as wood and metal boxes[25]. The material condition is verified by the shipper as being satisfactory prior to shipment. Containers received in the CWC are either in good condition or are over-packed[26]. Shipping documentation is reviewed by CWC personnel upon receipt and a sample of containers are opened and visually inspected for adequate material condition and waste verification prior to entering the facility inventory[27].

Contamination within Primary EU Source Components:

Legacy Source Sites: NA

High Level Waste Tanks: NA

Vadose Zone Contamination: NA

Groundwater Plumes: Carbon Tetrachloride plume exists below the CWC which is under active pump and treat remediation.

Facilities for D&D: NA

Operating Facilities: Stored radioactive material is normally contained within its engineered containers. Exceptions to this are remediated.

Part VI. Potential Risk/Impact Pathways and Events

Current Conceptual Model

Narrative description of pathways and barriers to receptors and conditions/events that can lead to completed pathways

Pathways and Barriers: (1. description of institutional, natural and engineered barriers (including material characteristics) that currently mitigate or prevent risk or impacts, 2. Time scale from loss of each barrier to realization of risk or impacts)

Briefly describe the current institutional, engineered and natural barriers that prevent release or dispersion of contamination, risk to human health and impacts to resources:

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[25] EIS 0391 (2012), Section E.3.1.2.
[26] Permit WA7890008967, Part III, OU Group 6, Central Waste Complex, Section C.2.1.1
[27] Permit WA7890008967, Part III, OU Group 6, Central Waste Complex, Addendum B

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1. *What are the current barriers to release or dispersion of contamination from the primary facility? What is the integrity of each of these barriers? Are there completed pathways to receptors?*

There are three major types of barriers to release of contamination from the primary facility: (1) Engineered systems including the waste container, and secondary containment systems (buildings, berms, sumps, etc.); (2) Operating Procedures such as Waste Acceptance Criteria, Venting Programs, RCRA and radiological inspections, and others; and (3) Safety Management Systems such as nuclear criticality safety and transportation safety. These are further defined in Appendix 1.

There is one identified completed pathway to receptors, which is the ionizing radiation associated with these packages. People in the vicinity of the packages do accumulate occupational exposure, but it is monitored to ensure it stays well below regulatory levels of concern.

2. *What forms of initiating events may lead to degradation or failure of each of the barriers?*

The initiating events that may lead to degradation or failure of the barriers include: worker accidents, loss of institutional controls, loss of engineering controls, structural decay or failure, wild fire or facility fire, earthquake, dam failure, ash fall and plane crash; these are evaluated in the DSA (HNF-14741).

3. *What are the primary pathways and populations or resources at risk from this source?*

The primary pathway of concern is airborne dispersion of material from containerized waste; the populations at risk from this source include workers (on site and non-collocated).

4. *What is the time frame from each of the initiating events to human exposure or impacts to resources?*

For all initiating events, because the primary pathway to the receptors is airborne, the time frame to human exposure or impacts will be very short, on the order of hours, days or weeks.

5. *Are there current on-going releases to the environment or receptors?*

At the time of this study, we are unaware of on-going releases to the environment or receptors, but as mentioned previously, we do have one completed pathway to workers of an occupational radiation dose.

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Highest risks from various initiating Events to various receptors[28]

(use High, Medium, Low, etc.; footnote bounding accident(s))

Population or Resource	Worker Accident[29, 30]	Loss of Institutional controls[31]	Loss of engineering controls[32]	Structural decay or failure[33]	Wild fire or Facility fire[34, 35]	Earthquake[36]	Dam Failure[37]	Ash Fall[38]	Plane crash[39]
Operations Personnel[40]	TO BE COMPLETED IN FINAL TEMPLATE								
Other on-site worker[45]									
On-site, non-worker									

[28] All information obtained from summary document: HNF-15589, Consolidated Hazards Analysis for the Master Documented Safety Analysis, Rev. 8 (September 2012) but it has not been validated in whole or in part from underlying source documents that constitute an information need. Legend: H(igh): SARAH I or Environmental E3; M(edium): SARAH II or Environmental E2; L(ow): SARAH III or Environmental E1; V(ery) L(ow): SARAH IV or Environmental E0.

[29] Interpreted as an accident caused by a worker leading to the release of hazardous materials: package drop from forklift, puncturing a drum, etc.

[30] The risk to the involved worker is blank for a number of events for which there is clearly an involved worker, e.g., vehicle impacts

[31] Interpreted as failure of administrative controls in an operating facility

[32] Interpreted to mean accidents involving failure of structures, equipment, piping, etc. not directly initiated by workers that leads to releases

[33] Includes failure of waste packages resulting in releases

[34] Fires in and around facility are Included under worker accidents. This is for wildfire only.

[35] Range fire CWC-EE-04: Rupture of packages stored outside leading to release of contents

[36] Earthquake CWC-NP-03: Building collapse and release of contents due to earthquake

[37] Interpreted as flood event CWC-NP-006: Flood releases content of building and packages

[38] Event CWC-NP-04: Building collapse due to ash from volcano or snowfall

[39] Plane crash event CWC-EE-01: plane crashes into building

[40] Equated to an involved worker

[41] Spill CWC-03-05: waste package release after contact with electrical service

[42] A number of events involving gas deflagration or chemical reaction or incompatible materials

[43] Events CWC-24-01 and CWC-24-02: rupture of water line leading to criticality and CWC-02-03 fuel tank rupture leading to fire

[44] Events CWC-06-02 and CWC-05-02: both involve container breach due to corrosion and subsequent releases

[45] Equated to a co-located worker

[46] Fire CWC-05-06: Vehicle impact breaching a drum leading to a fire

[47] Fire CWC-03-02: Gas deflagration or chemical reaction caused by incompatible materials leading to fire

[48] Event CWC-02-03: Fuel tank rupture leading to fire and releases

[49] Events CWC-06-02 and CWC-05-02: both involve container breach due to corrosion and subsequent releases

[50] Unknown: Information on the number and frequency of non-worker presence is not available

Population or Resource	Worker Accident[29, 30]	Loss of Institutional controls[31]	Loss of engineering controls[32]	Structural decay or failure[33]	Wild fire or Facility fire[34, 35]	Earthquake[36]	Dam Failure[37]	Ash Fall[38]	Plane crash[39]
Off-site population									
Soils[54]									
Groundwater[59]									
Surface water[60]				TO BE COMPLETED IN FINAL TEMPLATE					
Specific protected biota or ecosystem									
Cultural Resources									
Economic Resources									

The rate at which CWC has been able to ship its inventory to disposal sites – especially for TRU waste – has been curtailed in recent years because of higher budget priorities elsewhere. The slow rate of shipping wastes for disposal has been exacerbated by the curtailment of operations at WIPP. As a consequence, the TRU waste inventory at CWC (the material at risk in accident scenarios) and, thus, the inventory available for release (material at risk) during certain accidents, has and will continue to increase until the facility inventory can be reduced.

Populations and Resources Currently at Risk or Potentially Impacted

Workers: Workers are the resource impacted by the only current completed pathway of occupational radiation exposure. In the instance of the initiating events described above, any exposure would likely be airborne dispersion of containerized waste and exposure via inhalation or external radiation due to proximity to contamination.

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51 A number of events involving gas deflagration or chemical reaction or incompatible materials
52 Three events at this level, two are VL
53 Events CWC-06-02 and CWC-05-02: both involve container breach due to corrosion and subsequent releases
54 Available information only addresses composite environmental risk
55 Fire CWC-03-03: Fire and release of vehicle contents due to fuel tank rupture via accident
56 A number of events involving gas deflagration or chemical reaction or incompatible materials
57 Events CWC-EE-03: Loss of site power and CWC-02-03: fuel tank rupture and fire
58 Event CWC-05-02: container breach due to corrosion and subsequent releases
59 Included in soils
60 Included in soils
61 Information from another CRESP Review Team Report on Ecological Resources inserted here for convenience.
62 Information from another CRESP Review Team Report on Cultural Resources inserted here for convenience.
63 Information from another CRESP Review Team Report on Economic Resources inserted here for convenience.

Public: The low level public is at risk due to airborne exposure of containerized waste in an event scenario.

Groundwater: Threats to groundwater could emerge from container degradation and subsequent leaks into the subsurface.

Columbia River: The Columbia River will not be impacted by the CWC due to the 13 km distance between the facility and the river.

Ecological Resources: There are several events described in the Consolidated Hazard Analysis which are labeled as a level E3 effect on the environment and these could have an impact on ecological resources if they occurred. These include: seismic events, spills and energetic reactions, which could disperse presently contained radioactive materials.

Cultural Resources: There are some cultural resources, such as the White Bluffs Road, which are in the proximity of the CWC and thus could be impacted under accident conditions.[64]

Economic Resources: Potential economic resources affected include Highway 240 which is roughly 5 km away from the CWC

Cleanup Approaches and End-State Conceptual Model

Potential Cleanup Approaches:

Addendum H of the RCRA Permit for CWC outlines closure activities as follows: (1) remove waste inventory; (2) decontaminate structural surfaces and equipment; (3) analyze decontamination waste to determine proper methods of treatment/disposal; and (4) dispose of decontamination waste based on results of waste analysis. The total duration of the cleanup phase is expected to be 180 days.[65]

The DSA states that D&D and cleanup activities have yet to be planned.

Contaminant Inventory Remaining at the Conclusion of Active Cleanup Period: N/A

Risks and Potential Impacts Associated with Cleanup:

The DSA states that D&D and cleanup activities have yet to be planned.

Additional Risks and Potential Impacts if Cleanup is Delayed

None, continued operations and maintenance of the facility. Potential for increased container maintenance due to normal degradation mechanisms (e.g., corrosion).

Near-Term, Post-Cleanup Status, Risks and Potential Impacts

Dependent on D&D methods chosen.

Long-Term, Post-Cleanup Status – Inventories and Risks and Potential Impact Pathways

Dependent on D&D methods chosen.

[64] DOE-RL-98-10, (2003) Page 3-30.
[65] Permit WA7890008967, Part III, OU Group 6, Central Waste Complex, Closure Plan: Page 6.

Part VIII. Risk and Potential Impacts Ratings

Current Risks and Potential Impacts – Ratings

Population or Resource	Risk or Impact Rating (based on risk matrix)	Comments
Worker (remediation)		Ratings determined from the CWC portion of the SWOC DSA.
Worker (co-located)		See above.
Public		See above.
Groundwater		See above.
Surface water		
Ecological Resources		From CRESP Team rating.
Cultural Resources		From CRESP Team rating.
Economic Resources		From CRESP Team rating.

TO BE COMPLETED IN FINAL TEMPLATE

Risks During and as a Consequence of Cleanup Actions – Ratings- No Separate Analysis Done

Near-Term, Post-Cleanup Risks and Potential Impacts- No Separate Analysis Done

Part IX. Supplemental Information and Considerations

Current conditions that impair or preclude planned future land use: (narrative description or listing)

The CWC is an active radioactive waste storage facility. Several large and number of smaller steel-framed structures are built on concrete pads for waste storage. In addition, several outdoor storage areas exist, the largest of which is compacted gravel, and others are concrete or asphalt pads. Most other structures associated with CWC are mobile/modular in construction and are re-locatable.

Other uses would await post D&D condition assessment; however, CWC is located on the Central Plateau, an area presently scheduled for continued federal custody.

Remedial processes and impacts

There is a potential future impact from the carbon tetrachloride plume. The following figure illustrates the plume and its proximity to the CWC within the 200 West Area.

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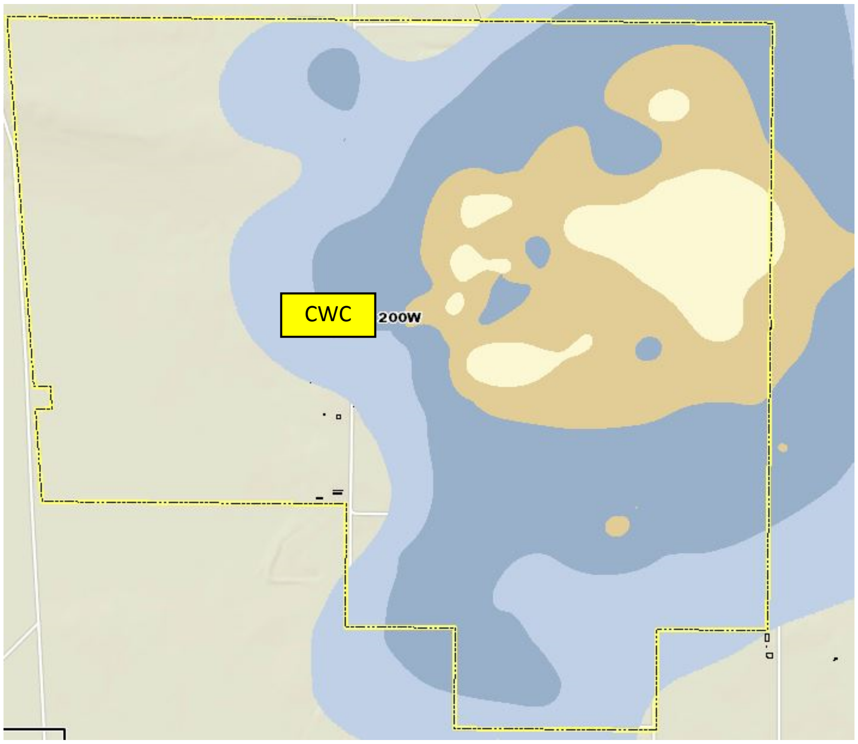

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22. DOE-RL-98-10- 2003. *Hanford Cultural Resources Management Plan*. U.S. Dept. of Energy Office of Environmental Management, Richland, Washington.
23. Collins, Mike- 2014. *RE: CRESP- CWC Information Request*. E-mail Communication received 29 July, 2014.
24. DOE/RL-97-56, Revision 1 (1998), Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan, Richland, Wash.: U.S. Department of Energy, Richland Operations Office, Richland, Wash.

Attachment D-1: Description of Barriers

There are several barriers in place to prevent risk or impacts as follows:

Engineered Systems:

- The waste container and/or overpack
- Secondary Containment
    - CWC automatic fire suppression systems[66]
        - Fire suppression for buildings 2402-W through -WL is provided by a single dry pipe automatic sprinkler system in each building. Piping is sized in accordance with National Fire Protection Association (NFPA) 13, *Standard for the Installation of Sprinkler Systems* (ordinary hazard pipe schedule or better). These buildings have two fire pull boxes located near personnel exit doors.
        - The 2401-W, 2402-W and 2402-WC buildings have been categorized as <HC-3 facilities. The fire suppression systems for these buildings are not a credited safety-significant (SS) structure, system or component (SSC).
        - Fire suppression for Buildings 2403-WA through -WD is provided by two dry pipe automatic sprinkler systems in each building. Each half of the structure is protected by a separate system, one located in each of two small heated rooms outside each building. Piping for the dry pipe sprinkler systems is sized in accordance with NFPA 13Fire pull boxes are located near exit doors.
        - The 2404-WA through WC buildings fire suppression systems (FSSs) were hydraulically designed with a density of 0.30 gpm/ft2 over 3,000 ft2 with high temperature heads. Adjustments made to the design basis of the sprinkler systems to allow storage of NFPA containers, resulted in a revised design specification of 0.25 gpm/ft2 over 3,900 ft2.
    - Fire Protection
        - 2403 buildings contain manual dry chemical, 20-lb, Type ABC fire extinguishers at strategic locations throughout each building.
        - In 2404-WA, fire protection water lines comply with applicable
        - Fire protection orders and standards. Each building has a manual fire extinguisher.
        - The LFMW storage modules are supplied with portable fire extinguishers in accordance with NFPA 10, Standard for Portable Fire Extinguishers. The LFWM modules have Class ABC (approximately 10 lbs agent weight) stored pressure dry chemical extinguishers. The AMW modules, including Module FS-19, have Class D portable fire extinguishers. A 14 kg, Type D fire extinguisher is mounted on the exterior of each module. All extinguishing equipment is hand operated.
    - Building specific features for the CWC Dangerous Waste Management Units[67]:

Flammable and Alkali Metal Waste Storage Modules

- Vented catch sump under the storage floor provides spill containment

[66] HNF 14741-10 (2013). Page 2-139

[67] Permit WA7890008967, Part III, OU Group 6, Central Waste Complex, Addendum C: Pages 5-9.

- Dedicated secondary containment system

2401 – W Building

- Perimeter concrete curb 15.2 cm above grade with ramps for loading and unloading operations
- Floors coated with an epoxy resin floor surfacing system compatible with the waste

2402 – W Series Buildings

- Perimeter concrete curb 15.2 cm above grade with ramps for loading and unloading operations

2403 – W Series Buildings

- Floors are divided into quadrants by concrete curbs 12.7 cm high
- Floors are coated with an epoxy resin floor surfacing system compatible with the waste
- Adjacent areas to the buildings are stabilized and graded to slope away from the buildings

CWC Outside Storage Area A (gravel)

- Storage area graded and leveled with gravel
- No double containment

CWC Outside Storage Area B (gravel)

- Storage area graded and leveled with gravel
- No double containment

CWC Outside Storage Area C (gravel)

- Storage area graded and leveled with gravel
- No double containment

CWC Outside Storage Area D (epoxy coated concrete pad)

- Curbed with concrete and provided with epoxy coating to prevent contaminants from entering the concrete with access ramps
- Rainwater collection and removal system

CWC Outside Storage Area E (asphalt pad)

- No double containment

CWC Outside Storage Area F (asphalt pad)

- No double containment

Operating Procedures and Processes:

- Waste Acceptance Criteria and Waste Characterization
  - Waste screening and documentation occurs as required by HNF-EP-0063, Hanford Site Solid Waste Acceptance Criteria, before waste is shipped to CWC.
- Generators must receive advance approval to ship a waste package and must certify before shipment that the waste meets the SWOC waste acceptance criteria.
- The Hanford Site can accept only waste from offsite generators that have been approved by DOE. Offsite generators must submit information to DOE, Richland Operations Office, which forwards the information for evaluation.

- The information necessary to verify that the waste meets acceptance requirements (HNF-EP-0063) must be provided before the waste can be shipped to CWC. The information must address the following seven elements (as well as any other pertinent information necessary to ensure proper management of the waste):
  − Identification number (must be the corresponding waste specification record number)
  − Waste generating process description
  − Physical characterization
  − Radioactive characterization
  − Chemical characterization
  − Segregation
  − Packaging
    - Analytical data or process knowledge documentation must be included with the waste information. Once waste is shipped to CWC, it is checked to ensure that each container matches the information approved during initial information review. Waste containers are inspected to determine if they meet acceptance criteria. Those meeting the criteria are accepted, offloaded, and stored. Noncompliant containers are isolated and evaluated, and either returned to the generator for resolution or remedied at SWOC using approved methods for handling the nonconforming condition safely.
- Venting Waste Containers[68]
    - There is a potential for hydrogen generation within specific waste containers, based on their contents. The amount of hydrogen generated is dependent on the radionuclide activity, organic or hydrogenous waste matrix, and distribution of the radionuclides in the organic or hydrogenous material matrix. Venting is performed to reduce the potential for flammable gas accumulations within waste containers.
    - Several different drum venting systems currently are available for use although other systems are also acceptable if they meet the safety functions specified in HNF-EP-0063. The venting systems facilitate installation of WIPP-certified filters in waste drums. These filters are designed to allow hydrogen and other flammable gases to diffuse from the drum while retaining radioactive materials.
    - While these capabilities exist in CWC, SWOC operations has decided that venting will normally be performed at T Plant.
- Container Management Program – limits source term (i.e., release fraction) for certain accidents
    - Container Management (Technical Safety Requirement-Specific Administrative Control (TSR-SAC)): The SAC elements of this program establish credited controls to ensure safe container staging and storage as follows. This control ensures that container handling, staging, and storing are conducted in a safe manner by providing controls on container acceptance, handling damaged containers, waste acceptance, and characterization. The SAC elements under this program that are credited as important controls are the following:[69]
        - Bulged Container Exam
        - Intrusive Operations

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[68] HNF 14741-10 (2013). Page 2-102

[69] HNF 14741-10 (2013). Page 3-155

    - Bulged Container Venting
    - Container Integrity
    - Venting/Staging Requirements
- Abnormal Container Management Program[70]
  - This control ensures that containers are inspected for potential damage prior to being handled (readily visible container surface areas), thus minimizing a potential accident that could lead to loss of containment and release of radioactive material during handling activities. The inspection allows early warning and taking a protective posture for identified hazardous conditions (e.g., bulging containers, unvented containers at inappropriate locations).

Safety Management Systems:

- Nuclear Criticality Safety – spacing of high-SNM content containers, physical barriers
  - Criticality Safety Program at the Hanford Site (HNF-7098, CHPRC Criticality Safety Program) implements key requirements including the following[71]:
    - Fissionable material controls at locations where significant amounts of these materials might be present
    - Criticality safety training
    - CSERs
    - Criticality prevention specifications (CPS)
    - Criticality safety postings
    - Fissionable material labeling
    - Fissionable material storage
    - Criticality safety configuration control
    - Fissionable material packaging and transportation
    - Criticality safety for firefighting
    - Criticality safety inspections and assessments
    - Criticality safety nonconformance response
    - Emergency procedures following a criticality or potential criticality accidents
- Transportation Safety – for onsite and off-site shipments
  - Waste transportation involves shipments from offsite and onsite waste generators to CWC facilities. Onsite shipments must comply with the Transportation Safety Document (TSD), required under DOE O 460.1C, Packaging and Transportation Safety. The TSD is the approved documented safety analysis for onsite transportation and packaging activities. Offsite shipments (arriving or leaving) must comply with the requirements of 49 CFR 171, "Hazardous Materials Regulations" unless exceptions are made, usually with attendant special provisions like temporary closure of public roads for transportation to PermafixNW. Offsite shipments may be made by truck, railroad, or other transportation conveyance. The railroad tracks are located outside of the boundaries of the CWC facilities with the exception of T Plant, which has taken measures to preclude entry of a train without positive actions by Operations.[72]

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[70] HNF 14741-10 (2013). Page 3-157

[71] HNF 14741-10 (2013). Page 3-360

[72] HNF 14741-10 (2013). Page 2-89

Appendix E

Hanford Site-Wide Risk Review Project

Evaluation Unit Summary Template

T Tank Farm (CP-TF-1)

Table of Contents

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EU Designation: CP-TF-1 – T Tank Farm

Part I. Executive Summary

EU Location: North-Central part of 200-West (200W) on the Hanford Reservation

Related EUs: S-SX Tank Farm (CP-TF-2), TX-TY Tank Farms (CP-TF-3), U Tank Farm (CP-TF-4), A-AX Tank Farms (CP-TF-5), B-BX-BY Tank Farms (CP-TF-6), C Tank Farm (CP-TF-7), 200-East DSTs (CP-TF-8), 200-West DSTs (CP-TF-9), 200-W Groundwater (CP-GW-2), and 200 Area HLW Transfer Pipeline (CP-LS-7)

Primary Contaminants, Contaminated Media and Wastes:

The TC&WM EIS describes tank wastes as including radioactive (tritium or H-3, C-14, Sr-90, Tc-99, I-129, Cs-137, U-233, U-234, U-235, U-238, Np-237, Pu-239, and Pu-240) and non-radioactive contaminants (chromium, mercury, nitrate, lead, total uranium, and PCBs) of potential concern (TC&WM EIS, Appendix D). The tank wastes contain saltcake, sludge, and supernatant phases. Contaminated media related to the T Tank Farm include ancillary equipment and surrounding vadose zone (including cribs and trenches) down to the saturated zone (for some mobile contaminants) from past and current discharges. The Record of Decision for the 200-ZP-1 Operable Unit (EPA 2008) identifies Tc-99, I-129, chromium, and nitrate as tank waste constituents that must be addressed in cleanup.

After evaluating the contaminants associated with T Tank Farm tanks, ancillary equipment, legacy sources, and contaminated vadose zone, the primary contaminants that drive human health risk to groundwater for the T Tank Farm Evaluation Unit are: Tc-99, I-129, chromium, and nitrate. Those primary contaminants that drive risk from groundwater discharge to the Columbia River are nitrate and chromium. Cs-137 and Sr-90 are important from a safety standpoint and uranium isotopes, plutonium isotopes, and tritium are iconic constituents; these contaminants are included in the inventory summary even though they are not considered risk drivers for impacts to or from groundwater in this review.

Brief Narrative Description:

Waste Management Area T (WMA-T) occupies approximately 32,000 m^2 (7.9 acres) and contains 16 underground single-shell tanks (SSTs) constructed in 1943 and 1944 (Horton 2006, p. 2.1) that constitute the T Tank Farm. The Tank Farm contains 12 carbon steel tanks with capacities of 2×10^6 liters (530 kGal) and four smaller carbon steel tanks with capacities of 2×10^5 liters (55 kGal) in additional to ancillary equipment (e.g., diversion boxes, pumps, valves, and pipes). The SSTs in WMA-T began receiving waste in 1944 and were in use until 1980 when the tanks were removed from service. The tanks received primarily high-level metal and first cycle waste from chemical processing (bismuth phosphate process) of uranium-bearing spent fuel rods. When there was a shortage of tank capacity, supernatant from tanks was sent to cribs. Waste management operations created a complex intermingling of tank wastes; natural processes resulted in settling, stratification, and segregation of waste components. Initial corrective actions (including berms, ditches, water line testing and sealing, and a partial cover) have been implemented at WMA-T (Horton 2006, p. 2.2; Zhang, et al. 2009).

Summary Table of Risks and Potential Impacts to Receptors:

EU: CP-TF-1 - Risk or Impact Rating				
		Evaluation Time Periods		
		Active Cleanup (to 2064)		Near-Term Post Cleanup (to 2164)
Population or Resource		Current Condition/ Operations	From Cleanup Actions	
Human	Worker (remediation & facility worker)			
	Worker (co-located)			
	Public			
Environmental	Groundwater			
	Surface water			
	Ecological Resources			
Social	Cultural Resources			
	Economic Resources			

TO BE COMPLETED IN FINAL TEMPLATE

Support for Risk and Impact Ratings for each Time Period

Current Condition:

Workers – Both direct and co-located workers are at risk from wastes (including vapors and direct radiation exposure) and activities related to on-going operations at the T Tank Farm EU. Active controls have been implemented to limit radiological and toxicological risks to workers.

Public – The T Tank Farm EU, which is in a secure and controlled area that prevents intentional and inadvertent intruders, is several miles interior to the Hanford Site boundary so any potential impact via the air pathway to the general public would be minimal. Hanford groundwater use is restricted so there is no significant pathway to the public.

Groundwater – There are existing plumes that represent impacts to the saturated zone (receptor) from T Tank Farm EU PCs (i.e., chromium, Tc-99, I-129, and nitrate). Using the basis provided in Chapter 7, the ratings for Tc-99 and I-129 are *very high*, that for chromium is *high*, and that for nitrate is *medium*. Thus the overall rating is *very high*.

Surface Water – T Tank Farm EU primary contaminants have migrated through the vadose zone and into the saturated zone but have not reached the nearshore or surface water portions of the Columbia River in measureable concentrations.

EU Designation: T Tank Farm (CP-TF-1)

DRAFT for Methodology Illustration

Ecological – Ecological risk from T Tank Farm EU groundwater contamination (200-ZP-1 OU) is not anticipated because of the lack of direct or indirect exposure to groundwater by ecological receptors now or in the future. Ecological receptors could be low risk from direct radiation exposure from tank wastes and other pathways (e.g., uptake) from legacy source sites.

Cultural – Much of the 200 West Area is considered of low archaeological potential with the exception of intact portions of the White Bluffs Road corridor that runs through the 200 West Area. No archaeological sites have been recorded within the T Tank Farm EU.

Economic – No unique or unusual economic assets were identified associated with the T Tank Farm Evaluation Unit.

Risks and Potential Impacts from Selected or Potential Cleanup Approaches:

Workers – Direct and co-located workers will be at risk from exposure to direct radiation and waste contaminants during SST retrieval and closure operations. Some anticipated events can have moderate impacts to these workers

Public – The T Tank Farm, which is in a secure and controlled area that prevents intentional and inadvertent intruders, is several miles interior to the Hanford Site boundary so the air pathway to the general public is considered minimal even during closure activities. Hanford groundwater use will be restricted during this period so there is no significant pathway to the public.

Groundwater – There will be a continuing impact during this period to the saturated zone (receptor) from those mobile T Tank Farm EU primary contaminants (i.e., chromium, Tc-99, I-129, and nitrate) that currently exceed MCLs. The Tc-99 and I-129 plumes are predicted to be smaller (i.e., remain <<0.1 km^2) and the chromium and nitrate plumes are predicted to increase to >>10 km^2 during Active Cleanup operations. It is possible that tank waste sluicing operations may result in additional supernatant leaks from tanks, which could result in greater vadose zone and perhaps saturated zone contamination; however, the 200-West Area pump-and-treat system is also assumed to be operational during this evaluation period. Using the basis provided in Chapter 7, the ratings for Tc-99 and I-129 (Group A) are *medium*, that for chromium (Group B) is *medium*, and that for nitrate (Group C) is *low*.

Surface Water – The ecological PCs (nitrate and chromium) may be discharged into the Columbia River in concentrations above threshold values before the end of the Active Cleanup period. The basis for ratings is provided in Chapter 7. The ecological PCs are not Cs-137, Sr-90, Tc-99, or I-129, thus an estimate must be made of the relative contribution of the PCs to the river. The T Tank Farm EU PC contribution from all SST sources is significant; thus it will be assumed for this review that the contribution of PCs to the load to the river would be greater than 1%. The rating for both chromium and nitrate is *medium* because all groundwater is assumed to discharge into a 40-meter near shore zone.

Ecological Resources – Ecological risk from T Tank Farm EU groundwater contamination is not anticipated because of the lack of direct or indirect exposure to groundwater by ecological receptors during this period. There is no risk to ecological receptors from contaminated groundwater because there is no complete groundwater pathway. Ecological receptors may be at low risk from direct radiation exposure from tank wastes and other pathways (e.g., uptake) from legacy source sites. Thus the risk to ecological receptors is considered low during Cleanup Actions.

Cultural Resources – Much of the 200 West Area can be considered of low archaeological potential with the exception of intact portions of the White Bluffs Road corridor that runs through the 200 West Area.

It is considered unlikely that additional archaeological sites will be discovered during T Tank Farm closure activities based on past experience. Thus the impact to cultural resources is considered low.

Economic Resources – No unique or unusual economic assets were identified associated with the T Tank Farm Evaluation Unit. Thus there would be no discernible impact on economic resources.

Risks and Potential Impacts if Cleanup is Delayed:

There is potential for additional tank degradation and further leaks and contaminant transport through the vadose and saturated zones if tank closure activities are delayed. There is also potential risk from direct radiation and tank waste contaminants to ecological receptors and workers from routine tank farm operations.

Near-Term, Post-Cleanup Risks and Potential Impacts:

Direct Workers – Risks to direct workers from residual wastes are considered low after the cap has been emplaced. Regular workers performing monitoring and maintenance activities will be at some degree of risk, albeit considered low. The area will remain secure during the Institutional Control period.

Co-located Workers – Since the tank farm area will be capped, the risk to co-located workers is considered not be discernible from residual T Tank Farm EU contamination.

Public – The T Tank Farm, which will be in a secure and controlled area that prevents intentional and inadvertent intruders during this period, is several miles interior to the Hanford Site boundary. Since the tank farm area will be capped and the use of groundwater will be precluded during this evaluation period, there should be no discernible risk to the public.

Groundwater – There will be a continuing impact during this period to the saturated zone (receptor) from T Tank Farm EU PCs (i.e., chromium, Tc-99, I-129, and nitrate). The Tc-99 and I-129 plumes are predicted to be very small (i.e., remain $\ll 0.1$ km^2) and the chromium and nitrate plumes are predicted to increase to $\gg 10$ km^2. The 200-West Area pump-and-treat system is assumed to be operational during this evaluation period. Using the basis provided in Chapter 7, the ratings for Tc-99 and I-129 (Group A) are *medium*, that for chromium (Group B) is *medium*, and that for nitrate (Group C) is *low*.

Surface Water – The ecological PCs (nitrate and chromium) are predicted to be discharged into the river at concentrations above threshold values before this period begins. Using the basis for ratings provided in Chapter 7 and assuming the contribution of PCs to the river load to be greater than 1%, the rating for both chromium and nitrate remains *medium*.

Ecological Resources – Since the tank farm area will be capped, ecological receptors should not be at low risk from residual T Tank Farm EU primary contaminants in tank, ancillary equipment, and legacy sources. Ecological risk from T Tank Farm EU groundwater contamination is not anticipated because of the lack of direct or indirect exposure to groundwater by ecological receptors during this evaluation period. There will be a continuing potential low risk from nitrate and chromium being discharged to the river.

Cultural Resources – Any cultural concerns are assumed to have been addressed during cleanup and closure operations (e.g., excavation of contaminated soil and capping). Thus no discernible impacts are considered likely to cultural resources after cleanup operations have concluded.

Long-Term, Post-Cleanup Conditions:

After closure, the T Tank Farm EU will have HLW tanks and ancillary equipment grouted in place with residual contamination in tanks, ancillary equipment, and legacy source sites (cribs, trenches, and soil).

EU Designation: T Tank Farm (CP-TF-1)

DRAFT for Methodology Illustration

Mobile primary contaminants have migrated from the T Tank Farm sources through the vadose zone to the saturated zone and will continue to move through the groundwater. A cap will be placed over the tank farm site to reduce infiltrating water and contaminant migration for the time that the cap performs according to specifications. Upon cap failure, the infiltration rate will likely increase significantly and thus so will the primary driver for contaminant transport. However, waste retrieval operations and grouting activities will help reduce the potential for release from residual waste source terms.

Because of the closure activities (including waste retrieval and capping), worker and public impacts are expected to remain low during the Long-Term, Post-Cleanup period. Expected primary contaminant migration through the saturated zone and discharges to the Columbia are expected to result in medium impacts to these important environmental media. The discharges to the river also translate into low risks to ecological receptors over this evaluation period. Any impacts to cultural resources are expected before this period and thus no additional discernible impacts to cultural resources are anticipated.

Part II. Administrative Information

OU and/or TSDF Designation(s): *CP-TF-1 – T Tank Farm*, consists of 16 high-level waste (HLW) tanks, ancillary structures, associated liquid waste sites, and soils contamination; much of this EU is contained within Waste Management Area T (WMA-T). The Tank Farm contains 16 HLW tanks (T-101 through T-112 and T-201 through T-204). Other components in the EU are listed below in the *Primary EU Source Components* section.

Common name(s) for EU: The EU is comprised of elements from other waste management units including Waste Management Area T (WMA T) that includes the 241-T (or T) Tank Farm. The tanks often are designated as 241-T-101 through 241-T-112 and 241-T-201 through 241-T-204 or 241-T-TK-101 through 241-T-TK-112 and 241-T-TK-201 through 241-T-TK-204.

Key Words: T Tank Farm, 241-T Tank Farm, high-level waste, HLW tanks, tank farm, Waste Management Area T, WMA-T

Regulatory Status

Regulatory basis: DOE is the responsible agency for the closure of all single-shell tank (SST) waste management areas (WMAs) through post closure, in close coordination with other closure and cleanup activities of the Hanford Central Plateau. Washington State has a program that is authorized under RCRA and implemented through the HWMA and its associated regulations; Ecology is the lead regulatory agency responsible for the closure of the SST system. Specifically, WMA-T (of which the T Tank Farm EU is part) is regulated under RCRA as modified in 40 CFR Part 265, Subpart F and Washington State's Hazardous Waste Management Act (HWMA, RCW 70.105 and its implementing requirements in the Washington State dangerous waste regulations [WAC 173-303-400]). EPA is the support regulatory agency providing oversight of the state's authorized program. The 200 Areas of the Hanford Site have been placed by EPA on the National Priorities List (NPL). The completion of remediation of the 200 Areas overall will eventually be finalized via CERCLA decisions made by the EPA, and permitting decisions made by Ecology.

Applicable regulatory documentation: The relationship among the tank waste retrieval work plans (TWRWP) and the overall single-shell tank (SST) waste retrieval and closure process is described in Appendix I of the Hanford Federal Facility Agreement and Consent Order (HFFACO), along with requirements for the content of TWRWPs. In 1993 WMA-T was placed in assessment monitoring because of elevated specific conductance, which is a RCRA indicator parameter, in a downgradient well (Horton 2006). A groundwater quality assessment plan was written (Caggiano & Chou 1993; Hodges & Chou 2001) describing the monitoring activities used in deciding whether WMA-T has affected groundwater.

Applicable Consent Decree or TPA milestones: M-045-00 *Complete the closure of all Single Shell Tank Farms by 01/31/2043* Lead Agency: Ecology

Risk Review Evaluation Information

Completed: August 14, 2014

Evaluated by: K.G. Brown (Vanderbilt University-CRESP), K. Jones (Howard University-CRESP), L.H. Turner (CRESP), R. Peterson (PNNL), and P. Lowery (PNNL)

Reviewed by: D.S. Kosson (Vanderbilt University-CRESP)

Part III. Summary Description

Current land use: *DOE Hanford Site for industrial use*. All current land-use activities in the 200-West Area are *industrial* in nature (Hanford 200-Area ROD[1]).

Designated future land use: *Industrial-Exclusive*. All four land-use scenarios listed in the Comprehensive Land Use Plan (CLUP) indicate that the 200-West Area (of which T Tank Farm EU is a part) is denoted *Industrial-Exclusive* (DOE/EIS-0222-F). An industrial-exclusive area is "suitable and desirable for treatment, storage, and disposal of hazardous, dangerous, radioactive, and nonradioactive wastes" (DOE/EIS-0222-F).

Primary EU Source Components

Legacy Source Sites: The legacy source sites associated with the T Tank Farm EU (Attachment E-1) are enumerated in Table E-1.

Table E-1. Legacy Source Sites included in the T Tank Farm Evaluation Unit (EU) (Attachment E-1)

WIDS Code	Description
200-W-126	Tank Farm Vertical Storage Units – West of T Tank Farm
200-W-127	Surface Stabilized Area East of UPR-200-W-29/UPR-200-W-97 (UN-216-W-5)
200-W-52	216-T-7 Crib; 241-T-3 Crib
200-W-53	Unplanned release; UN-216-W-31; UPR-200-W-166
200-W-93	Contaminated Soil at 241-T Tank Farm
216-T-14	241-T-1 Trench; 216-T-1 Grave
216-T-15	216-T-15 Crib; 241-T-2 Grave; 241-T-2 Trench
216-T-16	216-T-16 Crib; 241-T-3 Grave; 241-T-3 Trench
216-T-17	216-T-4 Grave; 241-T-4 Trench
216-T-32	216-T-6; 241-T #1 & 2 Cribs
216-T-36	216-T-36 Crib
216-T-5	216-T-5 Grave; 216-T-5 Trench; 241-T-5 Trench
216-T-7	216-T-7 Tile Field; 216-T-7TF; 241-T-3 Tile Field
UPR-200-W-147	241-T-103 Leak
UPR-200-W-148	241-T-106 Leak
UPR-200-W-166	Contamination Migration from 241-T Tank Farm; UN-216-W-31

[1] http://www.epa.gov/region10/pdf/sites/hanford/200/hanford_200_rod.pdf

High-Level Waste Tanks and Ancillary Equipment: The 16 HLW tanks in the T Tank Farm EU are:

- (241-)T-101 (241-T-TK-101)
- (241-)T-102 (241-T-TK-102)
- (241-)T-103 (241-T-TK-103)
- (241-)T-104 (241-T-TK-104)
- (241-)T-105 (241-T-TK-105)
- (241-)T-106 (241-T-TK-106)
- (241-)T-107 (241-T-TK-107)
- (241-)T-108 (241-T-TK-108)
- (241-)T-109 (241-T-TK-109)
- (241-)T-110 (241-T-TK-110)
- (241-)T-111 (241-T-TK-111)
- (241-)T-112 (241-T-TK-112)
- (241-)T-201 (241-T-TK-201)
- (241-)T-202 (241-T-TK-202)
- (241-)T-203 (241-T-TK-203)
- (241-)T-204 (241-T-TK-204)

The ancillary equipment included in the T Tank Farm EU is (Attachment E-1):

- 200-W-129-PL (Encased Pipeline from 241-T-151 and 241-T-152 to 241-TX-155 Diversion Box; Lines V399, V405 and V411)
- 200-W-130-PL (Pipelines from 241-T-151 and 241-T-152 Diversion Boxes to 241-U-151 Diversion Box)
- 200-W-132-PL (Pipelines from 221-T to 241-T-151 and 241-T-152)
- 200-W-165-PL (Pipeline from Tank 241-TX-112 to 207-T Retention Basin)
- 200-W-175-PL; (Pipeline to Route Waste from 241-T-112 to 216-TY-201 Flush Tank and 216-T-26, 216-T-27 and 216-T-28 Cribs)
- 200-W-78-PL (Pipeline Between 241-TX/TY and 241-T Tank Farms)
- 200-W-79-PL (216-T-36 Crib Pipeline)
- 241-T-151 (241-T-151 Diversion Box)
- 241-T-152 (241-T-152 Diversion Box)
- 241-T-153 (241-T-153 Diversion Box)
- 241-T-252 (241-T-252 Diversion Box)
- 241-T-301B (241-T-301-B; IMUST; Inactive Miscellaneous Underground Storage Tank; Lines V664 and V727; 241-T-0301; 241-T-301 Catch Tank)
- 241-T-302 (241-T-302 Catch Tank)
- 241-TR-152 (241-TR-152 Diversion Box)
- 241-TR-153 (241-TR-153 Booster Pump Pit; 241-TR-153 Diversion Box)

Groundwater Plumes: The current 200-ZP-1 Operable Unit (OU) plumes that exceed final cleanup and/or drinking water standards associated with the T Tank Farm EU are chromium, I-129, Tc-99, tritium, and nitrate (DOE/RL-2013-22, Rev. 0). There are other contaminants of concern (i.e., carbon tetrachloride and trichloroethene) associated with the 200-ZP-1 OU that exceed final cleanup levels (EPA 2008); however, these contaminants do not result from sources in the T Tank Farm EU. Only the nitrate plume is not contained within the current footprint of the carbon tetrachloride plume. A pump-and-treat system has been operating in the 200-West Area since 2007.

D&D of Inactive Facilities: Not Applicable.

Operating Facilities: The SSTs (including the 16 HLW tanks in the T Tank Farm) were declared a non-compliant treatment, storage, and disposal (TSD) facility under RCRA. Furthermore, there was a

Congressional mandate that prohibited waste additions to Hanford SSTs after January 1, 1981[2]. Because of concerns with risks resulting from SSTs, the tank waste retrieval process currently planned at Hanford consists of two general phases: 1) retrieving wastes from SSTs to double-shell tanks (that are RCRA-compliant) for staging and subsequent tank closure and 2) mixing of the retrieved and staged SST waste for delivery to treatment facilities at the WTP. Because of the prohibition on waste additions to the Hanford SSTs, the T Tank Farm EU components are not considered Operating Facilities for this review.

Location and Layout Maps

A series of maps are used to illustrate the location of the components within the EU and the T Tank Farm EU relative to the Hanford Site. Figure E-1 shows the relationship between the 200-W (200 West) Area (where the T Tank Farm is located) and the Hanford Site. Figure E-2 shows the relationship between the tanks in the T Tank Farm and the other areas within the 200W Area. Figure E-3 illustrates the T Tank Farm boundary. Figure E-4 shows a detailed view of the high-level waste tanks, ancillary equipment, legacy source units in the T Tank Farm EU. Figure E-5, Figure E-6, Figure E-7, and Figure E-8 show selected groundwater plumes (i.e., chromium, I-129, Tc-99, and nitrate, respectively) associated with the T Tank Farm and liquid waste disposal facilities.

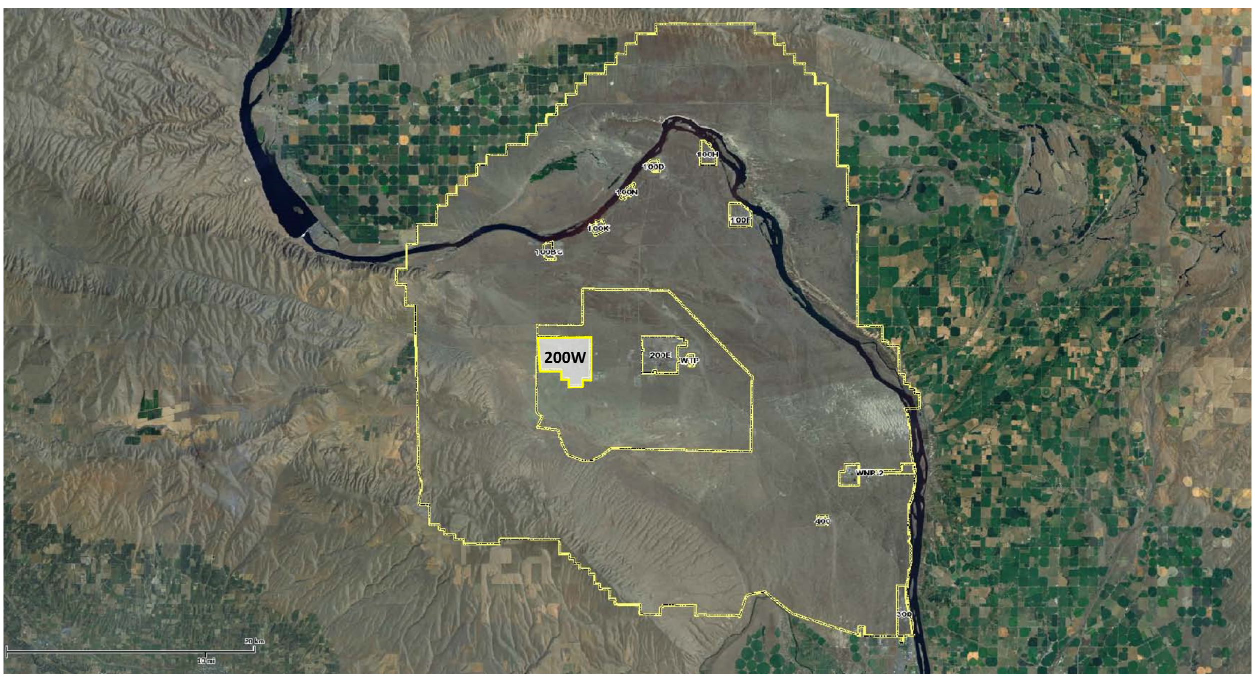

Figure E-1. Hanford Site Boundary showing 200-W Area. The T Tank Farm and Waste Management Area T (WMA-T) are located in the 200-W Area (http://phoenix.pnnl.gov/).

[2] Berman presentation on July 29, 2009, entitled "Hanford Single-Shell Tank Integrity Program." Available at www.em.doe.gov.

Figure E-2. Hanford 200W Area. The 241-T Tank Farm and Waste Management Area T (WMA-T) are located in the upper left-hand area of the diagram (http://phoenix.pnnl.gov/).

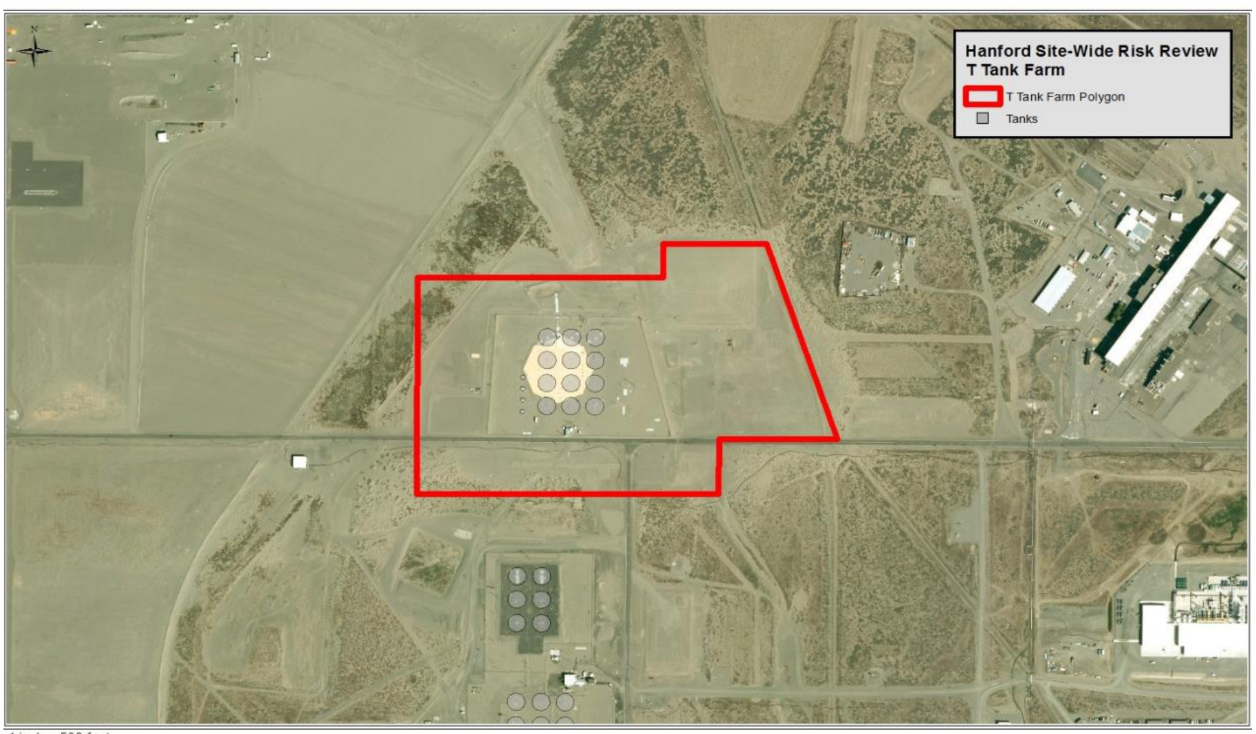

Figure E-3. Polygon representing the boundary of the T Tank Farm Evaluation Unit (Attachment E-1).

EU Designation: T Tank Farm (CP-TF-1)

DRAFT for Methodology Illustration

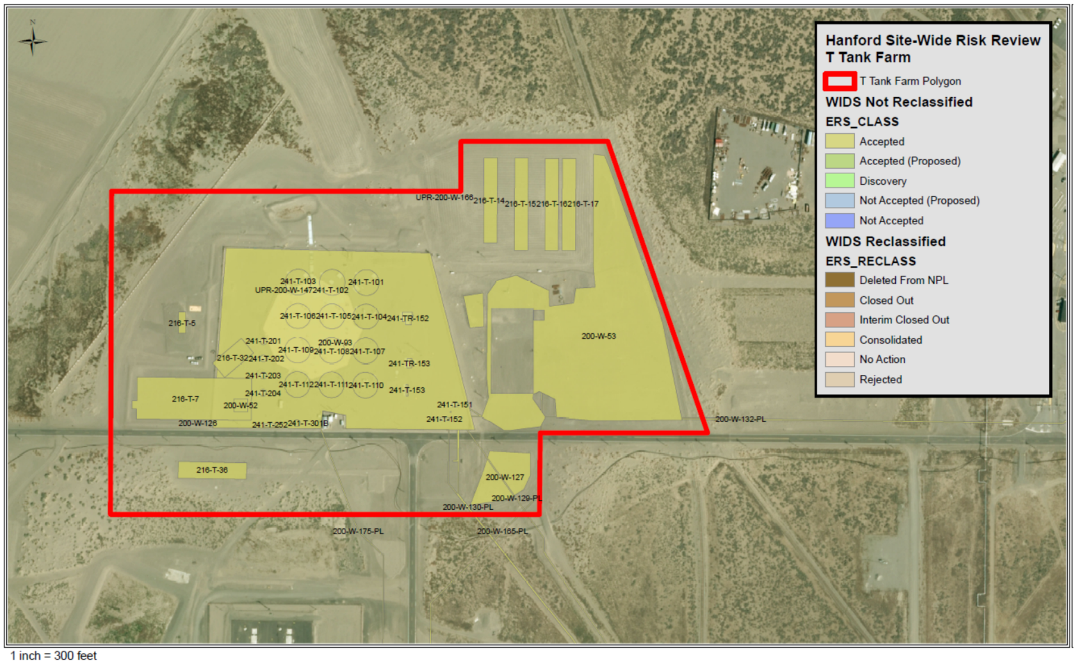

Figure E-4. Hanford T Tank Farm Evaluation Unit including tanks, legacy source units, and ancillary equipment (Attachment E-1).

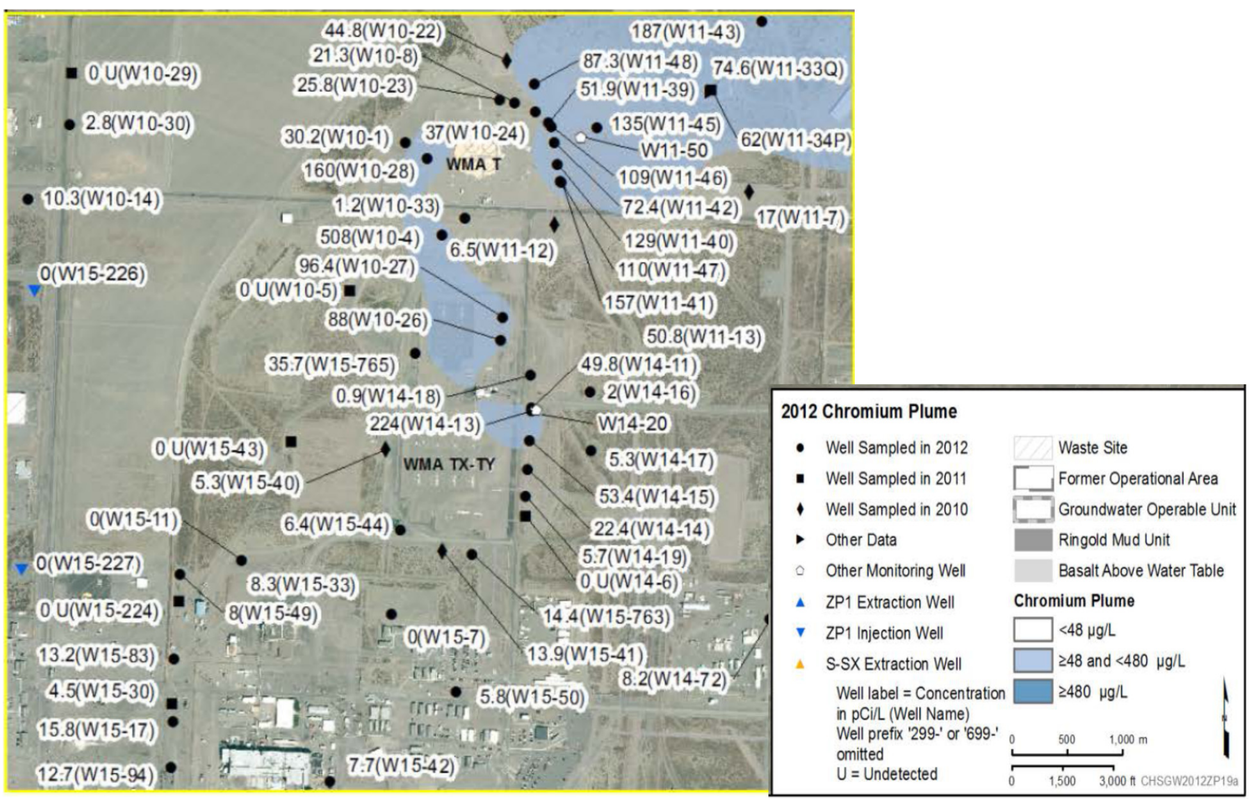

Figure E-5. 2012 Chromium Plumes near Waste Management Area T (DOE/RL-2013-22, Rev. 0).

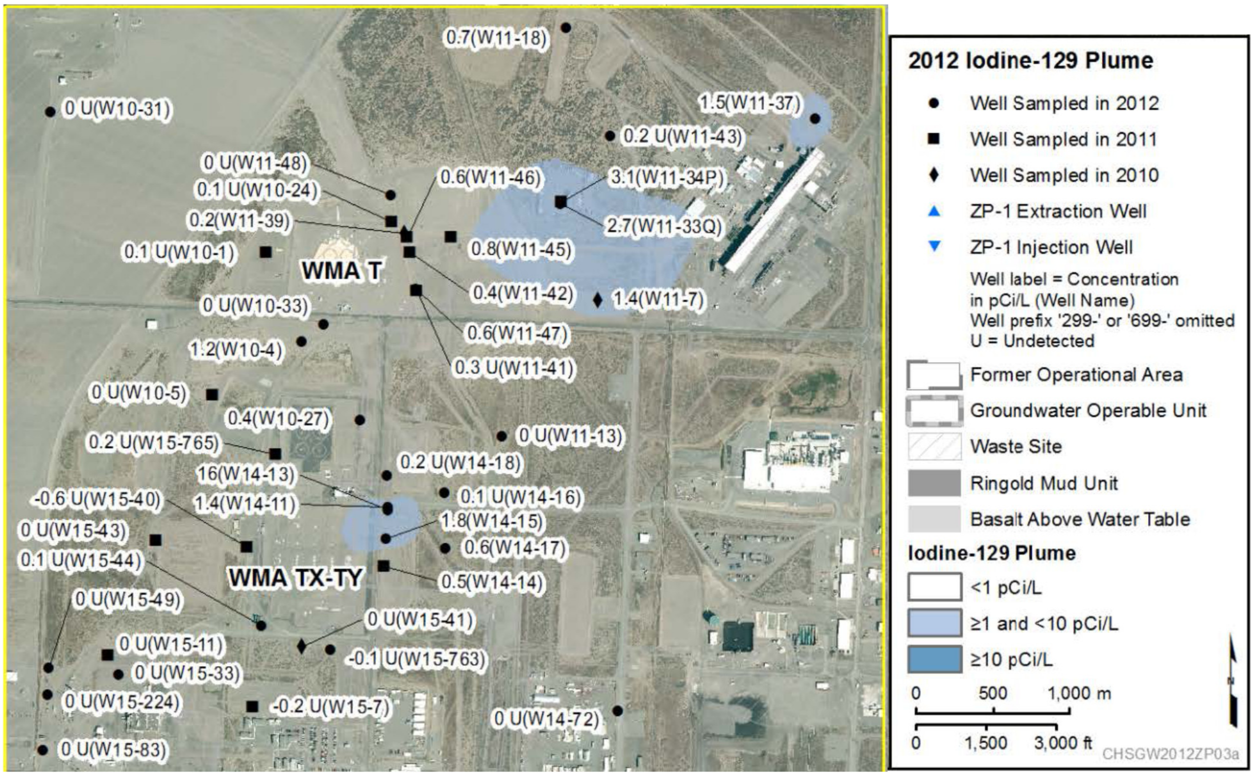

Figure E-6. 2012 Iodine-129 Plumes near Waste Management Area T (DOE/RL-2013-22, Rev. 0).

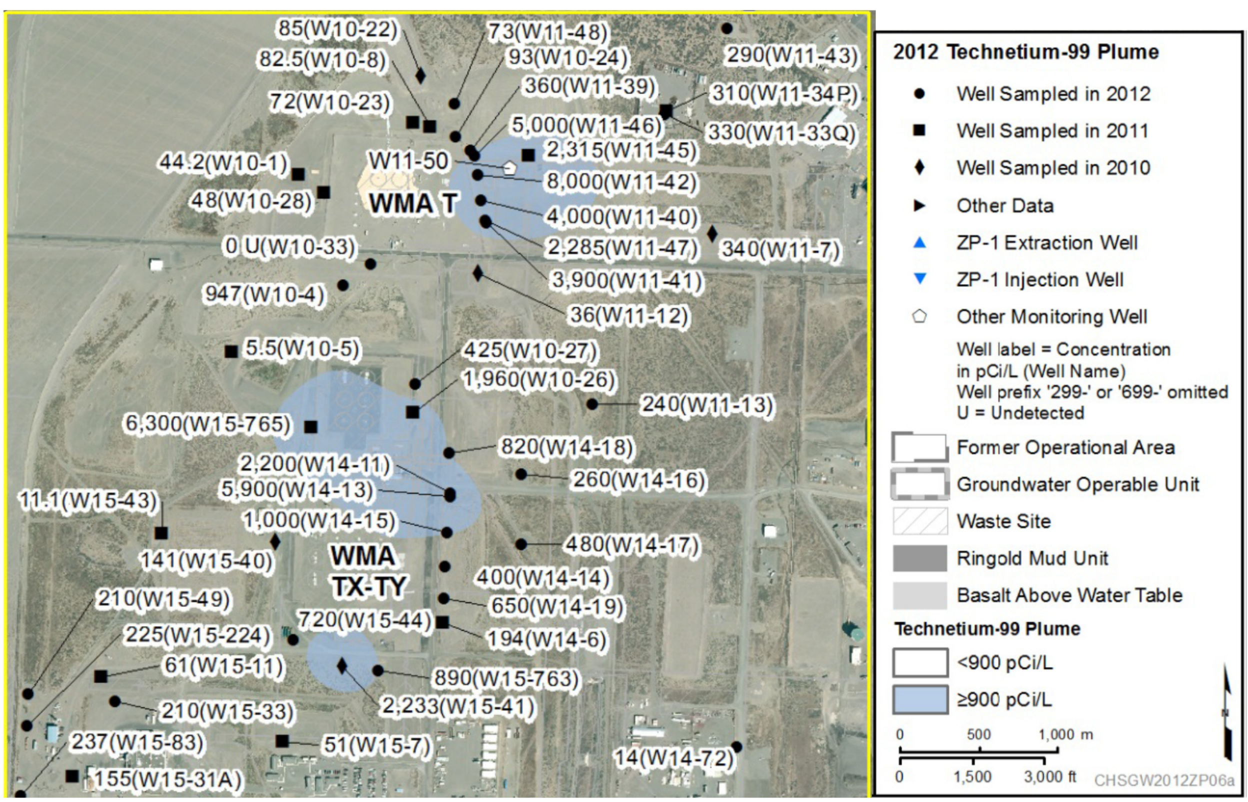

Figure E-7. 2012 Technetium-99 Plumes near Waste Management Area T (DOE/RL-2013-22, Rev. 0).

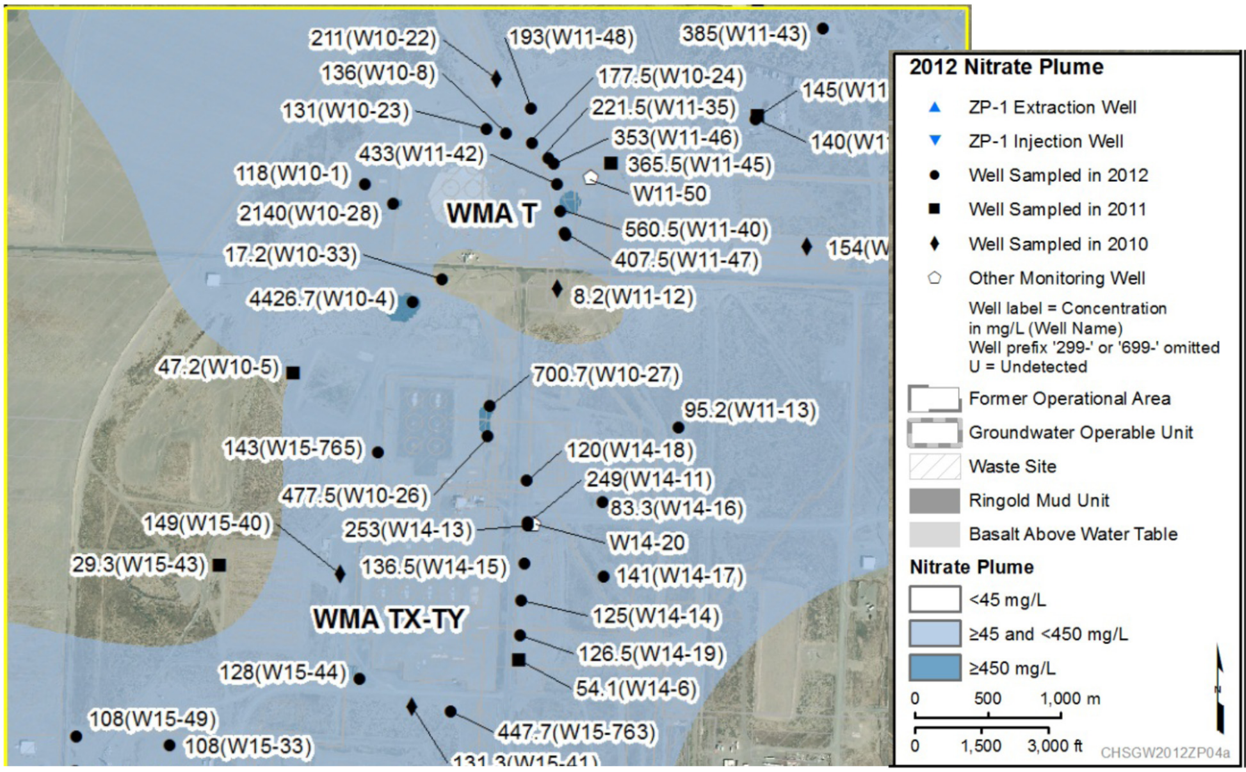

Figure E-8. 2012 Nitrate Plume near Waste Management Area T (DOE/RL-2013-22, Rev. 0). An illustration showing the complete nitrate plume is provided in Chapter 7 (Figure 7-5).

Part IV. Unit Description and History

EU Former/Current Use(s)

The T Tank Farm Evaluation Unit includes legacy source sites (e.g., cribs, trenches, and near-tank soils), high-level waste tanks and ancillary equipment (e.g., vaults, pits, and transfer piping), and groundwater plumes.

Legacy Source Sites

What is the origin and history of the contamination (e.g., accidental release, intentional discharge, multiple discharges)?

The contamination in the legacy source sites (cribs, trenches, and near-tank soil) associated with the T Tank Farm Evaluation Unit (EU) comes from intentional and unintentional discharges of T Tank Farm wastes. From historic monitoring activities, there are seven "assumed" (i.e., known or suspected leakers)[3] (T-101, T-103, T-106, T-107, T-108, T-109, and T-111) in the T Tank Farm. Tanks have been classified into four groups based "quality" of leak information and how the leak, if suspected or known,

[3] Tanks that are either known or suspected of leaking at any time (including the present) are denoted "assumed leakers" (Rodgers 2014).

was trending (RPP-23405, Rev. 1, p. 1-4). Estimates of the inventories for intentional and unintentional releases for the T Tank Farm are summarized in Table E-2.

Table E-2. Estimated Waste Release Inventories in the T Tank Farm (Field & Fort 2013, p. 4-2)

Tank/UPR	Waste Release Volume, gal	^{60}Co, Ci	^{137}Cs, Ci	^{99}Tc, Ci	Basis
241-T-101	264,000	24	1,300	0.4	^{137}Cs distribution in drywells and CWR2 waste type concentration estimate.
241-T-102 (T-102)	50 to 500	<0.04	20 to 200	<4E-4	^{137}Cs in drywell 52-02-05, 1974 sample from tank T-102 and CWP2 waste type concentration estimates.
241-T-103	1,300	0.1	600	0.7	ARH-2874, *241-T-106 Tank Leak Investigation* volume estimate, 1974 sample from tank T-102, and CSR waste type concentration estimates.
241-T-106 (T-106)	115,000	10	20,000	63	Ru-106 data, samples (RHO-ST-14, *High-Level Waste Leakage from the 241-T-106 Tank at Hanford*) and CSR waste type concentration estimates and drywells.
241-T-107 (T-107)					Drywell activity near tank T-107 included in tank T-106 leak estimates.
241-T-108 (T-108)					Drywell activity near tank T-108 included in tank T-106 leak estimates.
241-T-109 (T-109)					Drywell activity near tank T-109 included in tank T-106 leak estimates.
241-T-111 (T-111)	2,100	7E-7	0.9	0.08	Leak volume estimated in RPP-RPT-54964, *Evaluation of Tank 241-T-111 Level Data and In-Tank Video Inspection* constituents from the tank T-111 Best-Basis Inventory. Drywells not logged since 1998 (except for two in 2008 for interim surface barrier baseline).
Near-Surface UPRs in 241-T Tank Farm	Thousands to millions	Not detected	<28 Ci	Not detected	Drywell ^{137}Cs detected in spectral gamma logging system measurements from 0 to 10 ft bgs. Volume and inventories vary depending on waste type released.
Other UPRs	Estimate not available. <2,000 gal for UPRs 200-W-29 and 200-W-97	0.006	1.9	0.001	RPP-26744, *Hanford Soil Inventory Model, Rev. 1* includes estimates for UPR-200-W-29 and 200-W-97 only. See Table 5-2. These and other significant releases identified in this table should be included as source terms in 241-T Tank Farm performance assessments.
Intentional Releases to Cribs and Trenches near 241-T Tank Farm	~40 million gal to cribs and trenches Over 10 billion gal cooling water to 207-T and 216-T-4 ponds and ditches	< 2	2,200	<1	Inventories provided are mean values from RPP-26744 for cribs and trenches in 241-T Tank Farm (see Section 6.0). No inventory for 207-T and 216-T-4 ponds and ditches. Significant releases identified in this Section should be included as source terms for 241-T Tank Farm performance assessments.

[1] Cesium-137, ^{60}Co, and ^{99}Tc values are approximations decayed to January 1, 2001.

CSR = supernate from which the cesium has been removed by ion exchange (1967-1976)
CWP2 = Plutonium Uranium Extraction (Plant) cladding waste, aluminum clad fuel (1961-1972)
CWR2 = Reduction-Oxidation (S Plant) cladding waste, aluminum clad fuel (1961-1966)
UPR = unplanned release

EU Designation: T Tank Farm (CP-TF-1)

DRAFT for Methodology Illustration

What are the primary contaminants (risk drivers)?

A screening analysis was used to evaluate the 46 radionuclides and 24 chemical constituents currently maintained in the best-basis inventory (BBI) (TC&WM EIS, Appendix D, p. D-4). For radionuclides, groundwater (drinking water pathway) and direct intrusion (soil ingestion and inhalation pathways) scenarios were evaluated. Based on the results of the screening analysis, ten radionuclides and ten chemicals were selected for detailed analysis. The relative contributions for each of the 20 analytes from the T Tank Farm EU sources to the total over all 12 SST Tank Farms are shown in Table E-3.

Table E-3. Relative Contributions of T Tank Farm Evaluation Unit Sources to Corresponding Inventory over All Hanford Single-Shell Tank Farm Sources (TC&WM EIS, Appendix D) (T Tank Farm EU contributions exceeding equal distribution, 8.3%, are shown in red.)

	Analyte	Current Plume[c]	HLW Tanks[d]	Ancillary Equipment[e]	Soil (Leaks)[f]	Unplanned Releases[g]	Cribs[h]	Trenches[i]
Radionuclides	Hydrogen-3 (tritium)	√	0.38%	0.91%	17.53%	--	0.002%	93.64%
	Carbon-14		0.57%	1.38%	27.59%	--	2.62%	3.91%
	Strontium-90[a]		1.08%	1.51%	19.13%	--	4.14%	3.56%
	Technetium-99	√	1.05%	2.33%	26.12%	--	0.14%	0.66%
	Iodine-129	√	0.38%	0.88%	26.92%	--	0.01%	3.51%
	Cesium-137[a]		1.02%	2.04%	6.38%	--	3.09%	12.21%
	Uranium isotopes (U-233, -234, -235, -238)		2.96%	3.47%	2.37%	--	3.95%	2.17%
	Neptunium-237		0.47%	0.99%	23.92%	--	7.69%	1.82%
	Plutonium isotopes (Pu-239, -240)		2.14%	3.25%	19.57%	--	47.31%	2.47%
	Americium-241[b]		--	--	--	--	--	--
Chemicals	Chromium	√	2.44%	5.24%	11.65%	--	36.22%	3.23%
	Mercury		1.18%	1.48%	10.68%	--	--	18.41%
	Nitrate	√	1.44%	3.21%	11.87%	--	27.16%	3.25%
	Lead		6.06%	7.90%	11.69%	--	--	19.78%
	Uranium (total)		6.86%	9.63%	2.12%	--	9.31%	5.13%
	Acetonitrile		--	--	--	--	--	--
	Benzene		--	--	--	--	--	--
	Butanol (n-butyl alcohol)		--	--	33.45%	--	--	--
	Polychlorinated biphenyls (PCBs)		5.77%	10.73%	--	--	--	--
	2,4,6-Trichlorophenol		--	--	--	--	--	--

a. Daughters for Sr-90 and Cs-137 (Y-90 and Ba-137m) are not included; respective dose contributions are either incorporated into dose estimates for the parent radionuclide or estimated to be minor.
b. Applies to intruder analysis scenarios only through inhalation pathway.
c. From 200-ZP Operable Unit Description (DOE/RL-2013-22, Rev. 0).
d. Percent of inventory contained in all single-shell tank farms
e. Percent of inventory contained in all ancillary equipment in all single-shell tank farms
f. Percent of inventory released in all leaks from all single-shell tank farms
g. There were no unplanned releases (at or near ground level) from the T tank Farm EU. These releases are considered distinct from underground leaks into the soil.
h. Percent of inventory released to all cribs in all single-shell tank farms
i. Percent of inventory released to all trenches in all single-shell tank farms

Assuming inventories of analytes within each source type (tanks, ancillary equipment, leaks, cribs, or trenches) are equally distributed over the 12 single shell tank farms, the relative contribution from each source type would be 8.3% from the T Tank Farm EU. The T Tank Farm tank wastes and ancillary equipment sources generally represent less than 8.3% of the corresponding total SST sources; whereas, the percentage of SST leaks is generally much higher than 8.3% of all SST leaks. The T Tank Farm EU crib and trench legacy sources represent significant contributions (> 8.3% of all corresponding SST sources) for tritium, Cs-137, plutonium isotopes, chromium, mercury, nitrate, lead, and total uranium, including almost all the tritium and one-half the plutonium isotopes. The T Tank Farm EU *soil* legacy source site contaminated by leaks represents a relative contribution of much greater than 8.3% for most of the analytes tracked in the TC&WM EIS, including tritium, C-14, Sr-90, Tc-99, I-129, Np-237, Pu isotopes, chromium, mercury, nitrate, lead, and butanol.

However, the large relative source contributions shown in Table E-3 may represent small amounts of analytes that may not pose significant, future human health or ecological risks. The TC&WM EIS included a human health screening analysis (TC&WM EIS, Appendix O) that compares predicted groundwater concentrations[4] to benchmark values (Table E-4) at Tank Farm boundaries, Columbia River Nearshore, and the Columbia River (surface water) from all sources for various tank closure alternatives. However, the groundwater screening analysis (TC&WM EIS, Appendix O) is not separated by individual sources and thus the analysis here is necessarily qualitative.

The peak estimated concentrations for the legacy source sites (cribs and trenches) exceeded benchmark values for tritium, I-129, nitrate, and chromium (TC&WM EIS, Appendix O, p. O-60); however, exceedances were in the past (late 1960s to mid-1970s). However, recent groundwater data (Table E-4) indicate that the measured values for these contaminants exceed both benchmark values and MCLs. The estimated peak concentration (in 2023) for Tc-99 from past tank leaks is expected to exceed the corresponding benchmark value (TC&WM EIS, Appendix O, p. O-60), and groundwater results (Table E-4) confirm that the Tc-99 concentration in groundwater currently exceeds the MCL. The screening analysis indicates that no other contaminant *from all legacy sources* (cribs, trenches, and soil contaminated by leaks) is expected to exceed benchmark values or MCLs at the T Barrier boundary in the future. Further analysis of all sources (including tank wastes and ancillary equipment) suggest that no additional contaminant is expected to exceed benchmark values (or MCLs) at the T Barrier boundary in the future. Because the T Tank Farm EU provides significant contributions to all sources (Table E-3), it appears reasonable to also ascribe these results to the T Tank Farm EU.

As indicated in the TC&WM EIS groundwater screening analysis, T Tank Farm EU legacy sites including cribs, trenches, and soil contaminated by leaks are significant sources for the primary radiological (tritium, Tc-99, and I-129) and chemical (chromium and nitrate) risk drivers at the T Barrier boundary, where natural radioactive decay will reduce tritium concentrations to below the cleanup level before the tritium leaves the land-use area (DOE/RL-2013-22, Rev. 0). Thus four primary contaminants, Tc-99, I-129, chromium, and nitrate, are selected for the T Tank Farm legacy source sites related to human health impacts from groundwater[5].

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[4] Drinking water well and other risks and hazards were estimated in the TC&WM EIS even for times and areas (within the Hanford Site) when there will be no use of Hanford drinking water.

[5] These risk drivers agree with the contaminants of concern identified in the Hanford 200 Area 200-ZP-1 Superfund Site Record of Decision (EPA 2008) that have sources in the T Tank Farm EU.

Table E-4. Groundwater Threshold Values related to Selected T Tank Farm EU Constituents

	200-ZP-1 Operable Unit (EPA 2008, p. 19)			TC&WM EIS
Contaminant of Concern	**90th Percentile Concentration**	**Federal/ State MCL[(a)]**	**Final Cleanup Level**	**Benchmark Concentration**
Carbon tetrachloride, ug/L	2,900	5	3.4	5[(c)]
Chromium (total), ug/L	130	100	100	100[(c)]
Hexavalent chromium, ug/L	203	N/A[(b)]	48	--
Nitrate, ug/L	81,050	10,000	10,000	45,000[(c)]
Trichloroethylene (TCE), ug/L	10.9	5	1	5[(c)]
Iodine-129, pCi/L	1.2	1	1	1[(d)]
Technetium-99, pCi/L	1,442	900	900	900[(d)]
Tritium, pCi/L	36,200	20,000	20,000	20,000[(d)]
Strontium-90, pCi/L	--	--	--	8[(d)]
Cesium-137, pCi/L	--	--	--	200[(d)]
U-233, -234, -235, -238, pCi/L	--	--	--	15[(c)]
Pu-239 -240, pCi/L	--	--	--	15[(c)]

a. Federal MCL values from 40 CFR 141, with I-129 and Tc-99 values from EPA's Implementation Guidance for Radionuclides (EPA 816-F-00-002). State MCL values from WAC 246-290.
b. There is no MCL specific to hexavalent chromium.
c. I *National Primary Drinking Water Regulations*, 2009.
d. *EPA Implementation Guidance for Radionuclides*, EPA 816-F-00-002, 2002.

An ecological screening analysis was also performed in the TC&WM EIS (Appendix P) to evaluate the potential long-term impacts of radioactive and chemical contaminants (from *all sources*) discharged with groundwater on aquatic and riparian receptors at the Columbia River. The screening results indicate that exposure to radioactive contaminants from groundwater discharge under all tank closure alternatives for all sources was below benchmarks (0.1-rad-per-day for wildlife receptors and 1-rad-per-day for benthic invertebrates and aquatic biota, including salmonids) (TC&WM EIS, Appendix P, p. P-52), indicating there should be no expected adverse effects[6].

The corresponding evaluation for potential impacts of chemical contaminants discharged with groundwater indicate that chromium and nitrate have expected Hazard Quotients exceeding unity for aquatic and riparian receptors. However, the benchmark value used for chromium (hexavalent) was the sensitive-species-test-effect concentration that affects 20 percent of a test population (EC_{20}) despite the fact that the less toxic trivalent form of chromium is more like to be present in oxygenated, aquatic environs (TC&WM EIS, Appendix P, pp. P-52 to P-53). Furthermore, the potential impact of increased nitrate levels depends on other factors (e.g., phosphorus). Given conservative assumptions and benchmarks, the discharge of chemical contaminants in groundwater from all sources may not pose unacceptable risks to aquatic and sediment-dwelling biota in the Columbia River (TC&WM EIS, Appendix P, p. P-53). However, since the predicted Hazard Quotients exceed unity for chromium and nitrate and the T Tank Farm EU legacy source sites appear to contribute a significant amount of these contaminants

[6] Because these expected impacts are likely to be small, the potential indirect impacts on the ecosystem ae assumed to be correspondingly minor (TC&WM EIS, Appendix P, p. P-52).

to the subsurface, the chromium and nitrate are considered primary contaminants for ecological receptors.

From the screening evaluations in the TC&WM EIS, Tc-99 and I-129 are selected as primary contaminants related to potential human health impacts and chromium and nitrate are selected as primary contaminants for both potential human health and ecological impacts. However, because of their iconic nature, inventory information for other contaminants, namely, Cs-137, Sr-90, Pu isotopes, U isotopes, and tritium, will be provided for information.

Are there co-contaminants that will affect mobility of the primary contaminants?

No information was found on co-contaminants (i.e., from tank wastes) affecting contaminant mobility; however, there are processes that can affect mobility. For example, "[t]he bicarbonate content of aqueous media strongly influences the rate of exchange, with relatively higher content enhancing mobility" [PNNL-17034, p. v]. Furthermore, pH and redox will strongly influence the mobility of some primary contaminants (e.g., Tc-99).

What is the depth of contamination and soil type/stratigraphy associated with the contamination? Is the soil profile primarily natural or heavily disrupted?

Figure E-9 shows the locations of the wells and boreholes in the vicinity of the 241-T Tank Farm that were used for geologic interpretation. The vadose zone beneath the T Tank Farm EU is approximately 68 - 74 meters thick consisting of the Hanford formation, Cold Creek unit, the Taylor Flats member of the Ringold Formation, and the upper part of unit E of the Wooded Island member of the Ringold Formation (Horton 2006, p. 2-8). The area below where the tanks and ancillary equipment were installed is largely undisrupted. The water table is at about 136.5 meters elevation, and the unconfined aquifer beneath the EU is approximately 53 meters thick.

The generalized stratigraphic cross-sections (A-A' and B-B') under the T Tank Farm are provided in Figure E-10 and Figure E-11 (where locations were provided in Figure E-9). The geology consists of basalt basement overlain by nine sedimentary sequences distinguished by texture (particle size), mineralogy, responses to natural gamma logs, and position (Horton 2006, p. 2-8).

An understanding of the nature and extent of subsurface contamination in the T Tank Farm EU area is challenging because of the long time these tanks were in service (since the 1940s), the complex nature of the wastes that have been stored in the tanks, and the extensive discharges (both intentional and unintentional) from these tanks. Field investigations have been performed including drilling boreholes near tank T-106; borehole samples were taken from and analyzed for chemical and radionuclide content as well as hydrogeological characteristics (RPP-23752, p. 3-16).

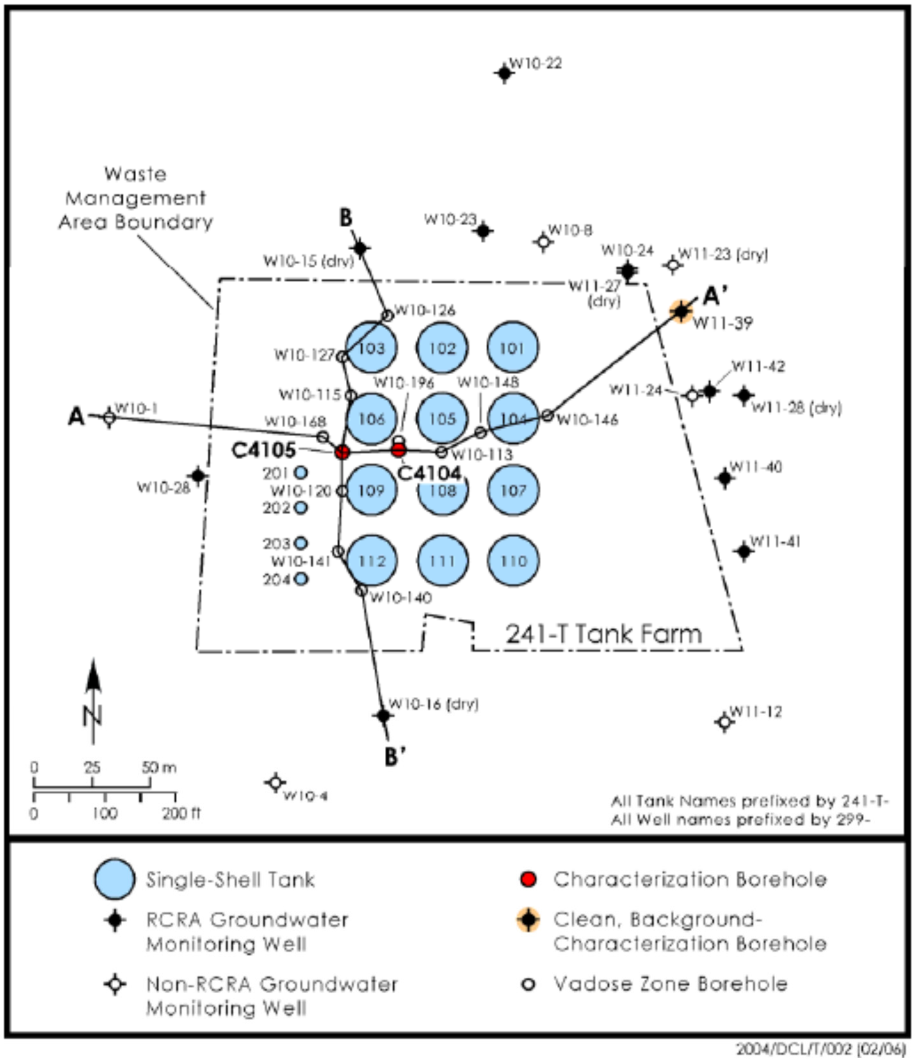

Figure E-9. Boreholes and cross-sections for T Tank Farm (Serne, et al. 2008, p. 2-10)

For example, elevated levels of several constituents (Tc-99, nitrate, and sodium) were found in Borehole C4105 (Figure E-12) that can be attributed to Tank T-106. Elevated levels of water-extractable Tc-99 (~6 to 1650 pCi/L) and nitrate (>9 to 1610 µg/g) extend from 70 ft to the bottom of the borehole (130 ft bgs) where peak concentrations were measured near the top of the contaminated zone (85-94 ft bgs) (RPP-23752, p. 3-28). Other anionic tank waste constituents (chloride, sulfate, and nitrite) were also observed in the borehole where water-extractable chloride was the most widespread and generally found at depths (86-130 ft bgs) much like water-extractable nitrate and Tc-99. Elevated water-extractable concentrations of sulfate and nitrite were found at shallower intervals (~86-110 and ~86-116 ft bgs, respectively). Clear zones of elevated water-extractable divalent cations (e.g., calcium, magnesium, barium, and natural strontium) were not discovered (RPP-23752, p. 3-16).

EU Designation: T Tank Farm (CP-TF-1)

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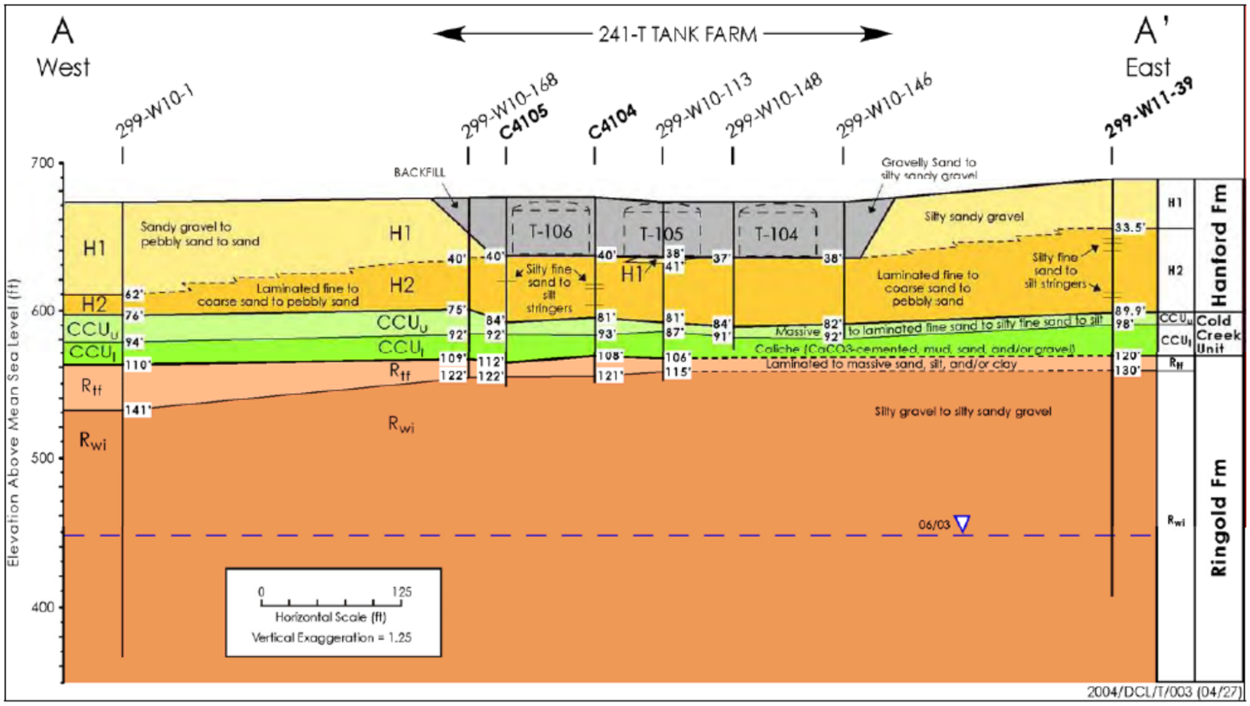

Figure E-10. East-West Hydrogeologic Cross Section (A-A') Across the T Tank Farm (Serne, et al. 2008, p. 2-11)

Co-60 and Eu-154 were detected in Borehole C4105. Co-60 is present over a large depth interval (48-122 ft bgs); whereas, Eu-154 is found in a much smaller depth interval (48-67 ft bgs). Finally, water-extractable chromium, molybdenum, and ruthenium were found elevated between 87 and 110 ft bgs; the molybdenum and ruthenium are likely stable fission daughter products of short-lived radionuclides originally in the tank waste (RPP-23752, p. 3-16).

Some tank waste constituents have migrated to the saturated zone under the T Tank Farm EU. Figure E-13 shows the concentrations of Tc-99 and nitrate with depth in the aquifer. The Tc-99 concentration near the water table is relatively low (238 pCi/L) but rapidly increases to a maximum of 181,600 pCi/L at 10 meters below the water table. The Tc-99 concentration decreases below the 10-m depth but remains elevated at 20,000-50,000 pCi/L to the total depth of the well. Maximum nitrate concentrations also are found at the 10-m depth. The concentrations of nitrate and Tc-99 appear to track each other with depth in the aquifer. Other tank waste constituents (e.g., chromium and manganese) were also found in the aquifer.

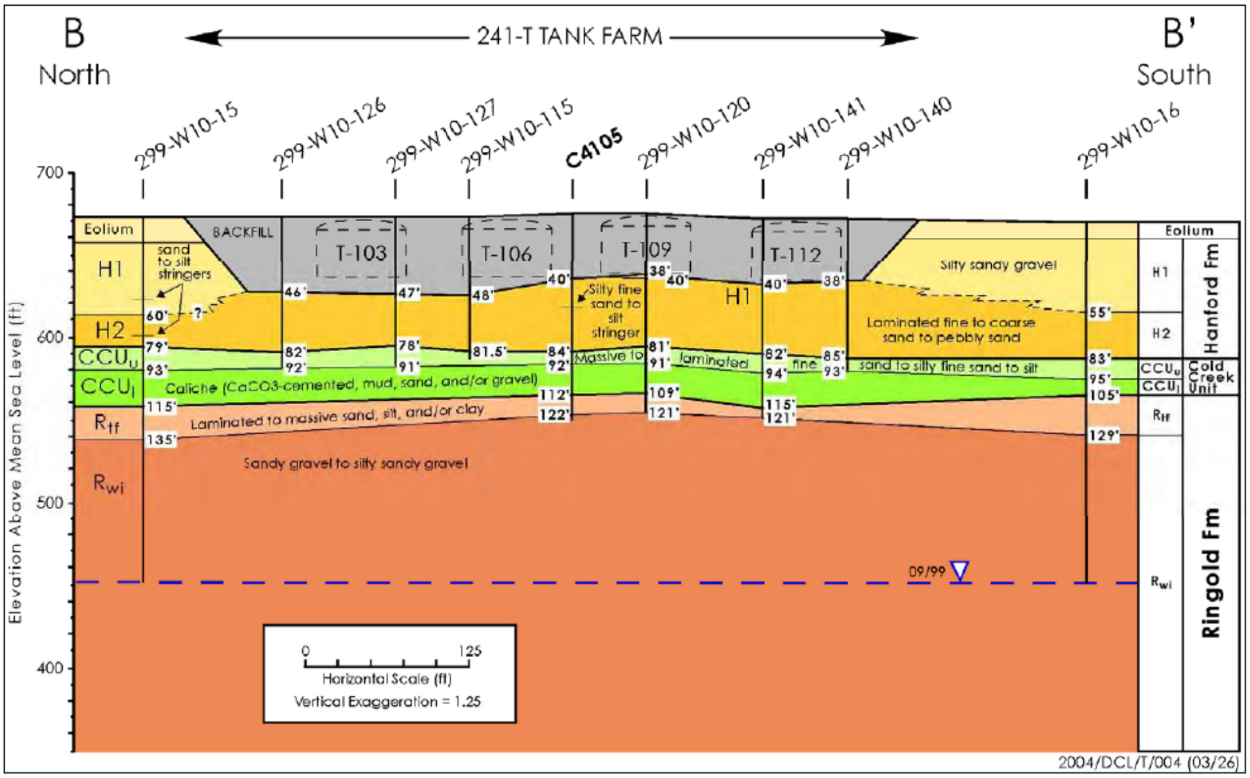

Figure E-11. North-South Hydrogeologic Cross Section (B-B') Across the T Tank Farm (Serne, et al. 2008, p. 2-12)

What is the physical state of the primary contaminants (i.e., adsorbed in contaminated soil, as debris)?

Primary contaminants were intentionally and unintentionally discharged into the environment (including cribs, trenches, and soil). The primary contaminants (Tc-99, I-129, chromium, and nitrate) for the T Tank Farm legacy sites (cribs, trenches, and soil) have moved through the vadose zone into the saturated zone; some of these contaminants have also been retained in pore spaces in the vadose zone, which constitutes a secondary source for future contamination.

Is information available indicating the partition coefficients and other important transport parameters for the primary contaminants with the type of soil (if yes, provide table)?

A comprehensive partition coefficient database for the Hanford Site is available (PNNL-13895); however, this report does not lend itself to a summary table. PNNL-17154 does provide a summary table (Table E-5) of selected partition coefficients applicable to the Waste Management Areas T and TX-TY.

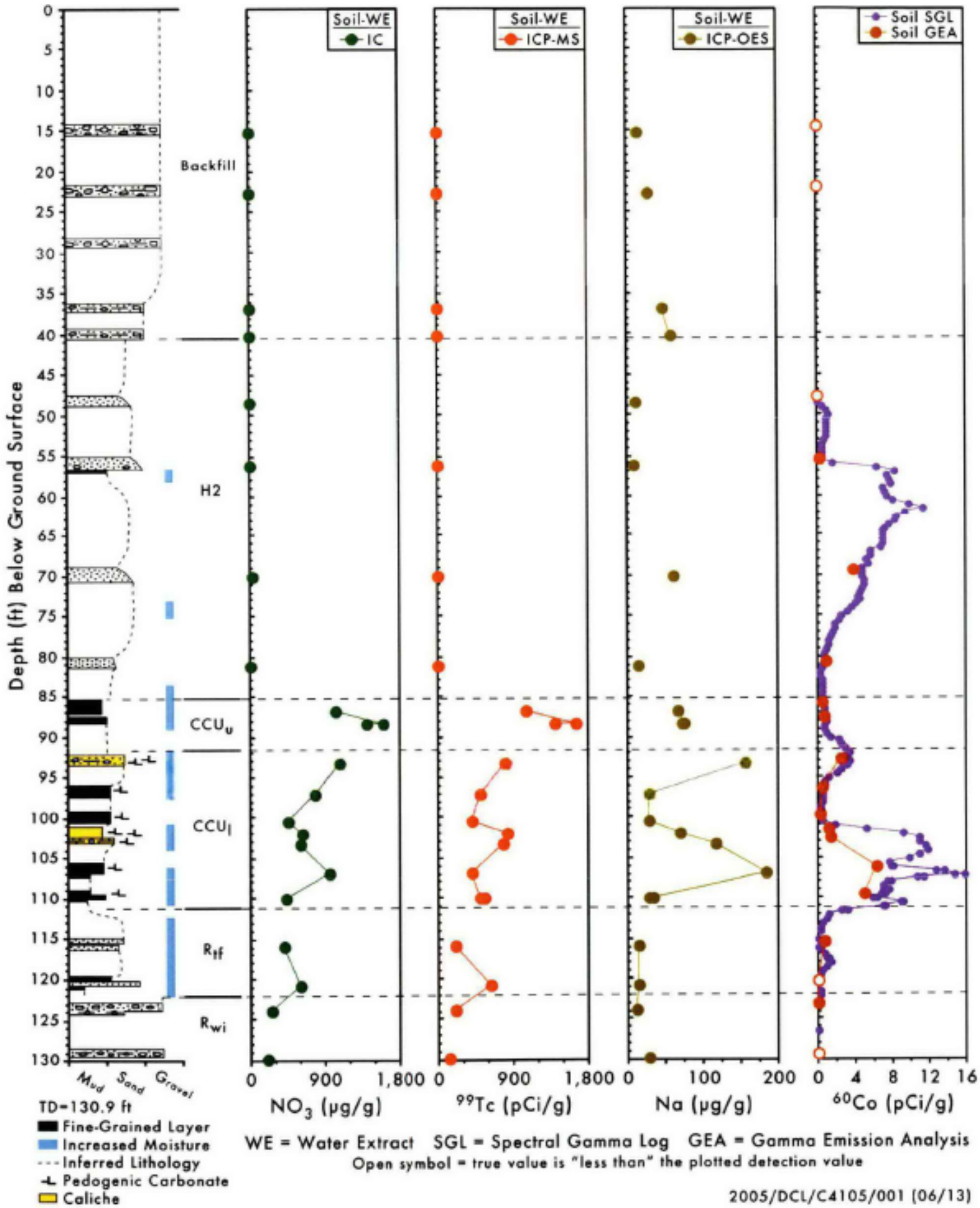

Figure E-12. Distribution of Major Tank Waste Constituents in Borehole C4105 (RPP-23752, Rev. 0, p. 3-29)

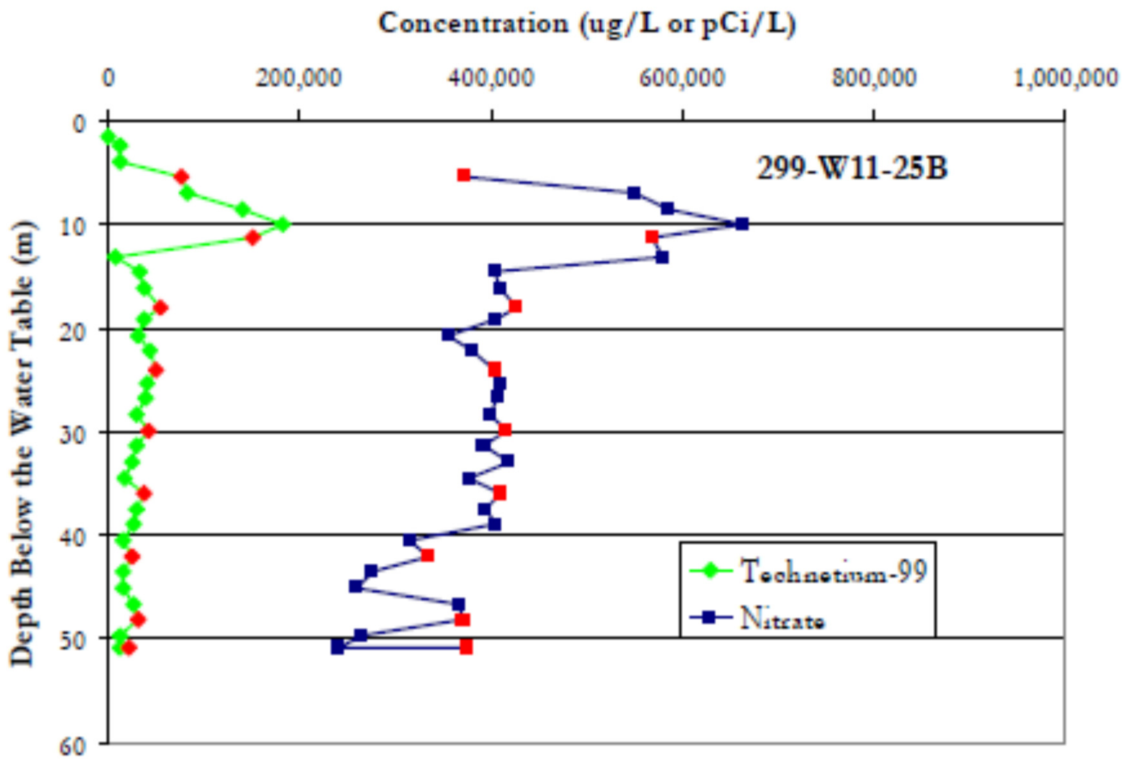

Figure E-13. Concentrations of Tc-99 and Nitrate versus Depth below the Water Table (Well 299-W11-25B). Red dots are pumped samples; others are air lifted samples (Horton 2006, p. 2.34)

Table E-5. Selected K_d Values (mL/g) for Sediments at WMA T and TX-TY (from PNNL-17154, p. 3.87)

Sediment→	Sand-Size						Silt-Size						Carbonate Dominated					
Impact→	High			Intermediate			High			Intermediate			High			Intermediate		
Analyte↓	Best	Min	Max	Best	Min	Max	Best	Min	Max	Best	Min	Max	Best	Min	Max	Best	Min	Max
Cr(VI)	0.2	0	3	0	0	8	0.4	0	8	0	0	10	0.2	0	3	0	0	8
NO3	0	0	0	0	0	0.1	0	0	0	0	0	0.1	0	0	0.1	0	0	0.1
I-129	0	0	0.2	0.2	0	2	0	0	0	0.2	0	2	0	0	0	0.2	0	2
Tc-99(VII)	0	0	1	0	0	1	0	0	1	0	0	0.3	0	0	1	0	0	1
Cs-137	1	0	10	100	10	1000	1	0	30	100	30	3000	1	0	10	100	10	1000
Sr-90	1	0.2	20	10	5	20	3	0.6	60	10	5	100	3	0.6	60	10	5	100
Pu – all isotopes	3	0	50	600	200	2000	5	0	150	600	200	2000	3	0	50	600	200	2000
U(VI) – all isotopes	0.2	0.06	0.6	0.8	0.2	17	0.3	0	3	2.5	0.6	15	0.3	0	30	2.5	0.6	30
H-3 (tritium)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

What is the source and reliability of the information available to describe the primary contaminants (risk drivers) and materials present?

The primary source used to identify and describe the primary contaminants is the TC&WM EIS, which relies on the best-basis inventory (BBI) for tank waste inventories. The BBI utilizes sample data, process knowledge, surveillance data, and waste stream composition information from the Hanford Defined Waste model (Agnew, et al. 1997) to estimate tank inventories. The tank waste inventory estimates contain large uncertainty based the number and quality of the available measurements (with uncertainties due to limited samples, complex tank contents, and impacts of the waste management process) and the estimation procedures (e.g., based on process knowledge) that were used in the absence of measurements. For example, the estimated relative standard deviations for the Tc-99 and I-129 primary contaminants at the levels in the tank wastes range from 70-231% and 44-231%, respectively (TC&WM EIS, Appendix D, p. D-12).

Thus the information regarding the input (e.g., radioisotopes related to the separations processes) to the Hanford tank farms appears reliable; however, the current locations of the primary tank waste contaminants that are the result of the various tank transfers (including discharges to the environment) and over the several decades are highly uncertain. This uncertainty is compounded by the highly complex nature of the Hanford subsurface and increases dramatically over time and space. It is thus likely that inventory estimates for individual tanks and tank farms will have larger relative uncertainties than total inventory estimates.

High-Level Waste Tanks and Ancillary Equipment

Which processes produced the waste contained in the tanks within the farm?

Source descriptions for the wastes in the T Tank Farm are provided in the Hanford Defined Waste (HDW) Model (Agnew, et al. 1997). The HDW descriptions for the T Tank Farm waste origin descriptions are summarized in Table E-6 (adapted from Horton 2006, p. 2-6). Note that much of the waste in the T Tank Farm resulted from the bismuth phosphate separation process that may have unique chemical hazards associated with it.

Table E-6. T Tank Farm Waste Summary (adapted from Horton 2006, p. 2.6)

Tank	$BiPO_4$ metal waste	First cycle decon waste from $BiPO_4$ process	Second cycle decon waste from $BiPO_4$ process	LaF finishing waste	Tributyl phosphate waste	Cladding waste (including from $BiPO_4$)	Cladding waste from REDOX	B Plant HLW	IX from cesium recovery	Evaporator bottoms/feed	REDOX IX	REDOX HLW	B Plant LLW	Decon waste	Battelle NW/Hanford Lab waste	224 waste (LaF finishing waste)	Non-complexed waste	IX waste (including B Plant LL IX)
T-101	√				√	√	√	√	√	√	√	√	√	√	√	√	√	
T-102	√					√				√	√	√	√				√	√
T-103	√					√			√	√	√	√	√				√	
T-104		√															√	
T-105		√	√			√	√		√				√	√	√		√	√
T-106		√	√			√			√				√	√			√	
T-107		√			√	√			√	√			√				√	
T-108		√			√				√	√					√		√	√
T-109		√			√				√	√			√		√		√	
T-110			√	√													√	
T-111			√	√													√	
T-112			√	√		√		√		√			√	√			√	
T-201				√						√							√	
T-202				√													√	
T-203				√						√							√	
T-204				√													√	

What are the primary contaminants (risk drivers)?

The risks associated with the tank waste in the T Tank Farm EU result from the radioactive and chemical constituents in the waste and contaminated ancillary equipment. As described in the previous section entitled Legacy Source Sites, a screening analysis was used to reduce the 46 radionuclides and 24 chemical constituents maintained in the BBI to ten radionuclides and ten chemicals for detailed analysis. The relative contributions for each of the resulting 20 analytes from the T Tank Farm EU sources to the total over all 12 SST Tank Farms are shown in Table E-3.

The T Tank Farm EU tank wastes and ancillary equipment represent a relatively small fraction of the corresponding SST totals (Table E-3). The potential accidents evaluated in the Documented Safety Analysis (DSA) include flammable gas accidents leading to fire / explosion; nuclear criticality resulting in a localized high-energy event; waste transfer leak or air blow accident leading to a spill, leak, or aerosolized spray; release from contaminated facility; excessive loads resulting in partial or total tank (dome) failure; mixing of incompatible materials resulting in unwanted chemical reactions; tank bump leading thermally-induced release; and filter failures leading to unfiltered releases of contaminants (RPP-13033 Rev. 5-D). Furthermore, the DSA indicates that the flammable gas accident, waste transfer leak, air blow accident, and release from a contaminated facility are anticipated without controls. With controls, only the air blow accident remains anticipated during waste transfer (resulting in waste release from a hose-in-hose transfer line primary hose assembly and connected waste transfer primary piping system), however, with low consequences to workers (< 5 rem total effective dose) and the offsite public (RPP-13033 Rev. 5-D, p. T3.3.2.4.5-3). The hazards associated with potential likely accidents with significant consequences relate to the tank waste constituents.

Using the DSA air blow accident analysis as an example, concentrations of Cs-137 and Sr-90 are assumed to be 7.0×10^{10} and 3.0×10^{12} Bq/L (2 and 80 Ci/L), respectively, where the bounding value for the SST unit-liter dose was also used. The estimated activities of Cs-137 and Sr-90 in the T Tank Farm are 1.65×10^{5} and 3.72×10^{5} Ci, respectively (TC&WM EIS, Appendix D, p. D-6). The current volume of sludge (Sr-90) in the T Tank Farm is 6.4×10^{6} L and that of saltcake and supernatant (Cs-137) is 6.1×10^{5} L (DOE/ORP-2003-02, Rev. 0, p. 6-8). Thus approximate Sr-90 and Cs-137 concentrations across the T Tank Farm are 0.6 and 0.03 Ci/L, or approximately two orders of magnitude less than the assumed concentrations used in the air blow accident analysis. Some T Tank Farm tanks will have higher or lower concentrations of Sr-90 and Cs-137 than others. However, because of the low likelihood/consequence of the other accidents when controls are in place, only Cs-137 and Sr-90 are considered safety-related contaminants of concern for the T Tank Farm HLW tanks and ancillary equipment. These contaminants are described in the inventory analysis provided later.

The air blow accident (for Cs-137 and Sr-90) and most other accidents evaluated in the DSA only pertain during the Active Cleanup period (to 2064). After closure, the T Tank Farm will have 99% of the waste retrieved and the tanks filled with grout and covered with a cap that would mitigate the primary initiating events related to the T Tank Farm EU; these events involve fire and natural events that degrade barriers and increase infiltration of water (Chapter 4, *Methodology for Evaluating Initiating Events used for Evaluations*). Because of the distribution of contaminants (especially those from past tank leaks as illustrated in Table E-3 relative to residual tank contamination), increased infiltration is more likely to impact vadose zone contaminant transport from the T Tank Farm EU to the saturated zone than events related to the HLW tanks and ancillary equipment.

EU Designation: T Tank Farm (CP-TF-1)

DRAFT for Methodology Illustration

How is the waste contained in the tanks classified (e.g., HLW, CH-TRU, RH-TRU)?

All Hanford double-shell and single-shell tanks currently contain high-level waste. However, there may be as many as 11 potential Hanford contact-handled TRU waste (CH-TRU) waste tanks (Tingley, et al. 2004). It has been estimated that processing these 11 tanks for disposal at WIPP could shorten WTP operation by 1 year and save as many as 100 canisters of HLW glass. Seven of the 11 Hanford SSTs that are candidates for designation as CH-TRU waste include the four T-200 series tanks (T-201, T-202,T-203, and T-204) and three of the T-100 series tanks (T-104, T-110, and T-111) in the T Tank Farm EU (Figure E-14). The tanks are undergoing a classification analysis to determine whether the waste may be properly and legally classified as CH-TRU. To change the classification from HLW to TRU, DOE would have to follow the appropriate steps in DOE 435.1.

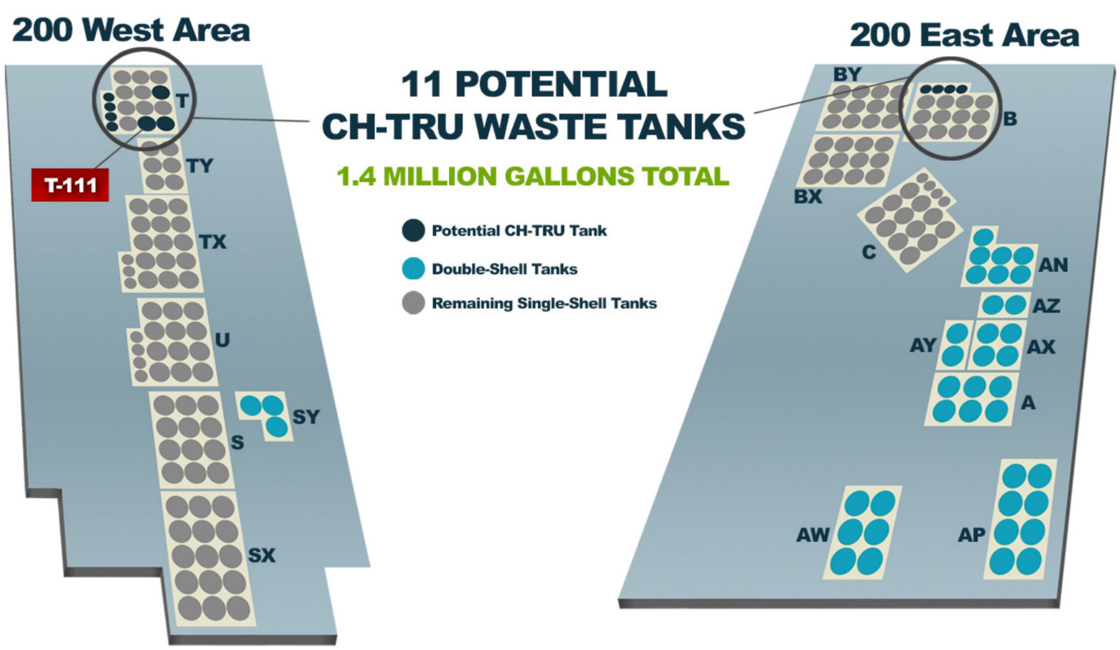

Figure E-14. Location of Potential CH-TRU Tanks in the 200 East and 200 West Area Tank Farms[7]

What nuclear safety concerns exist for the tanks/tank farm?

According to the Tank Farm Documented Safety Analysis (DSA) (RPP-13033 Rev. 5-D), there are four accidents designated as *anticipated* for the waste tanks *if no controls were in place*:

- Flammable gas accidents – This accident involves flammable gas deflagrations in waste storage vessels/containers (including SSTs) where the bounding event is a flammable gas deflagration from the steady-state generation and accumulation or a gas release event in a DST/SST.
- Waste transfer leaks – This accident involves a wide spectrum of waste leaks where the bounding event is a fine spray leak using a high head waste transfer pump.
- Releases from a contaminated facility – This accident involves various release mechanisms (i.e.,

[7] http://energy.gov/sites/prod/files/2013/09/f3/DOE%20Hanford%20Framework%20FINAL.pdf

flammable gas deflagrations, fires, load handling accidents, or compressed gas system failures) in contaminated facilities.

- Air blow accidents – This accident involves a waste release from a contaminated hose-in-hose transfer line (HIHTL) primary hose assembly and connected waste transfer piping system pressurized by compressed air where the bounding event is a small crack leak below the waste surface[8].

A nuclear criticality accident is considered *beyond extremely unlikely* (BEU) (or frequency of less than or equal to once in a million operating years) (RPP-13033 Rev. 5-D). The flammable gas accident (specifically a detonation in a DST/SST) and waste transfer leaks (specifically a fine spray when using a high head pump) were selected as bounding accidents.

For the four anticipated accidents listed above, only the waste transfer leak had an onsite radiological total effective dose (consequence) > 100 rem. None of the design basis accidents had an offsite dose greater than the 25-rem Evaluation Standard. For onsite toxicological consequences, both the waste transfer leak and air blow accidents are < Protective Action Criteria[9] (PAC) 3, and all accidents had off-site toxicological consequences of < PAC-2. Qualitatively, only the air blow accident *was not* judged to represent a significant impact to a facility worker (i.e., result in "prompt death, serious injury, or significant radiological or chemical exposure to the facility worker") (RPP-13033 Rev. 5-D).

Other representative accidents have consequences that are less than onsite worker guidelines and do not pose significant facility worker hazards. However, defense-in-depth features have been selected for these accidents (RPP-13033 Rev. 5-D):

- SST failure may be caused by excessive concentrated loads or excessive uniform loads, excessive vacuum, load drops, or seismic events and failures of other tanks; dome loading requirements are selected as the defense-in-depth protection feature.
- SST failure could result from chemical reactions resulting from mixing incompatible materials; paperwork must be verified to ensure that the correct chemical is being delivered has been selected as a defense-in-depth feature.
- Contaminated soils may be released (from a crib, ditch, pond) from unplanned excavations or drilling into contaminated soils or ruptures of underground pressurized lines in contaminated soils; environmental air permitting requirements and the excavation permitting process are selected as defense-in-depth features.
- A thermally induced upset (e.g., steam bump in an SST liner gap) could cause a failure in an SST.

There are other representative accidents (aboveground tank or structure failure, transportation-related waste sample handling accidents, filtration failures, organic solvent fires, etc.) with consequences less

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[8] An anticipated event has frequency greater than once in 100 operating years (RPP-13033 Rev. 5-D). In other words, these accidents are "anticipated" because they have occurred at least once before. External and natural events are not treated separately since they lead to the same accident types.

[9] Protective Action Criteria (PAC) may be used "to evaluate the severity of the event, to identify potential outcomes, and to decide what protective actions should be taken" and may be used "to estimate the severity of consequences of an uncontrolled release and to plan for an effective emergency response". There are benchmark values (i.e., PAC-1, -2, and -3) for each chemical. Each successive benchmark represents an increasingly severe effect involving a higher exposure level: 1) mild, transient health effects, 2) irreversible or other serious health effects that could impair the ability to take protective action, and 3) life-threatening health effects. http://orise.orau.gov/emi/scapa/chem-pacs-teels/.

than the guidelines for an onsite worker, do not pose significant facility worker hazards, and have no defense-in-depth features.

Based on the results of hazard and accident analyses, safety-significant structures, systems, and components (SSC); technical safety requirements (TSR), including Specific Administrative Controls (SAC) and Key Elements of Administrative Controls; and defense-in-depth features have been identified for protection of the public, onsite workers, and facility workers (RPP-13033 Rev. 5-D). The SSC associated with the SSTs is the *Waste Transfer Primary Piping System*, which is designated Safety Significant for the four *anticipated* types of accidents listed above:

- For flammable gas accidents related to SSTs, a SST Steady-State Flammable Gas Control (TSR/SAC) is defined as well as supporting administrative controls for DST and SST Time to Lower Flammability Limit, Ignition Controls, and Waste Characteristics Controls.
- For waste transfer leaks and releases from contaminated facilities, additional SSCs are defined including HIHTL Primary Hose Assemblies, and Isolation Valves. A series of TSR/SAC are defined including Double Valve Isolation, Waste Transfer System Overpressure and Flow Transient Protection, Waste Transfer System Valve Closure Controls, and Waste Transfer System Freeze Protection.

No TSRs were required for the air blow accident.

From a review of hazardous conditions and safety basis controls, additional design and operational features were identified to help prevent or minimize the potential for large releases of SST wastes that could cause significant environmental impacts (RPP-13033 Rev. 5-D):

- HEPA filters (including testing requirements)
- Ventilation stack continuous air monitoring (CAM) systems
- Tank integrity program
- Protection of buried piping encasements
- Design and operational features for in-tank operations (e.g., push mode core sampling, equipment handling) to prevent penetration of the tank
- Spill prevention and response
- Restrictions or requirements on water/waste additions to limit additional leakage from SSTs during SST retrieval activity (e.g., restrictions on water/waste additions above agreed-upon waste levels in the for “assumed leakers”)
- Allowable SST vapor space pressures (i.e., vacuum limits) to prevent tank failure
- The primary purpose of the SSTs is to contain the tank wastes until they can be retrieved and treated. There are certain features of the tanks that help further minimize the interaction of tanks wastes with the environment (RPP-13033 Rev. 5-D):
- For example, passive ventilation is used for SSTs (all the 241-T waste tanks) with the vapor coming out of the tank passing through a HEPA filter to remove contamination. Active ventilation (in the form of portable exhausters) may be used to support SST activities (e.g., equipment installation and removal, retrieval).
- Liquid-level monitoring is a primary tool for maintaining accountability of radioactive and

chemical waste solutions in the waste tanks and can be a first indication of a significant liquid leak or intrusion to a tank.

- For SSTs and transfer-associated structures, external leak detection equipment (e.g., electrical and thermal conductivity probes, weight factor instrumentation, gamma detectors, and neutron moisture gauges) is used in dry wells to monitor for liquid intrusion to the soils surrounding and supporting the underground tanks.
- In some SSTs, thermocouples are installed to provide information about the waste temperature and to identify "hot spots" (e.g., solids accumulation).
- Interlocks have been installed on some tank farm equipment (e.g., waste transfer pumps) to provide an automatic response to abnormal conditions and to protect personnel, equipment, and the environment.
- The Tank Farm Monitoring and Control System (TFMCS) allows waste transfer equipment to be selected for individual transfers and monitoring critical instruments on the route (e.g., transfer system leak detectors). If a transfer system leak detector alarms or fails, the transfer pump interlock must be opened manually to shut down the pump.

There are no safety limits for tank farm facilities and thus there are also no limiting control settings for tank farm facilities (RPP-13033 Rev. 5-D).

What types of tanks (i.e., tank construction/configuration) are located in the tank farm?

There are five Hanford tank farms containing 530,000-gallon Series 100 tanks (RPP-10435, Rev. 0). Four of the five tank farms (i.e., B, C, T, and U) have tanks constructed from the same drawings. The B, C, T, and U farm tanks were constructed from 1943 through 1944. The 530,000-gallon tanks (Figure E-15) are geometrically the same and have the same material properties with minor differences in reinforcing steel arrangements and liner construction.

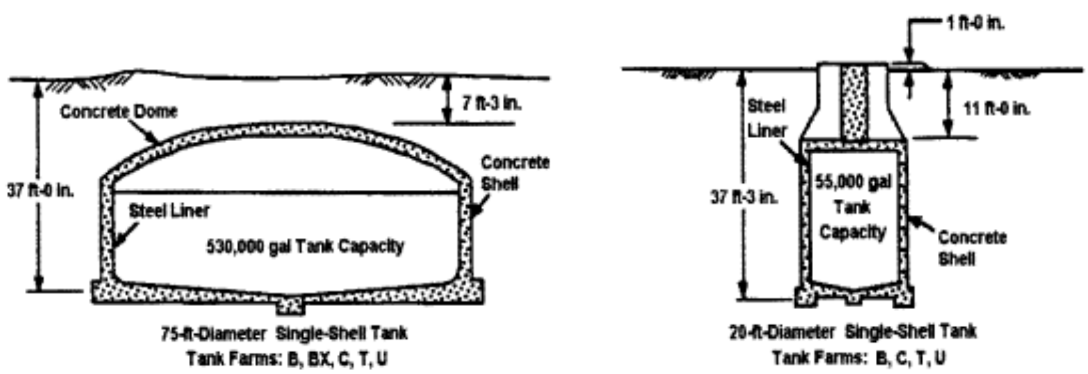

Figure E-15. Hanford Single-Shell Tank Configurations (Rodgers 2013, p. A-1)

Construction drawings for Hanford single-shell tanks were organized around a "key drawing" that can be used to identify the original drawings[10]. Sufficient drawings are listed to adequately describe each SST group design details for use in current structural integrity assessments. General schematics illustrating

[10] The key drawing for the 75-ft diameter tanks is W-72742 (RPP-10435, Rev. 0, p. A-8) and that for the 20-ft diameter tanks is W-72742 (RPP-10435, Rev. 0, p. A-22).

the configurations of the WMA-T tanks are provided in Figure E-15. Table E-7 summarizes the design specifications (RPP-10435, Rev. 0, Appendix A).

Table E-7. B, C, T, U, and BX Tank Farm Reinforced Concrete Tank Design Standards (from RPP-10435, Rev. 0, pp. A-26 and A-27)

Base Slab[a]	Tank Sidewall	Tank Dome
Thickness		
6 in.	1 ft - 0 in.	1 ft - 3 in.[b]
Inside Radius		
570 ft	37 ft - 3 in.	95 ft - 0 in.
Knuckle Radius		
--	4 ft - 5/16 in.	Varies
Height		
--	17 ft - 0 in.	31 ft - 0 in.
Design Codes		
PCA ST-57, PCA ST-55 Recommended Practice and Standard Specifications for Concrete and Reinforced Concrete (ASTM 1940)	PCA ST-57, PCA ST-55 Recommended Practice and Standard Specifications for Concrete and Reinforced Concrete (ASTM 1940)	PCA ST-57, PCA ST-55 Recommended Practice and Standard Specifications for Concrete and Reinforced Concrete (ASTM 1940)
Construction Specifications		
Spec. No. 1946 BPF73550-RPG-1451112	Spec. No. 1946 BPF73550-RPG-1451112	Spec. No. 1946 BPF73550-RPG-1451112
Concrete Compressive Strength		
3,000 psi	3,000 psi	3,000 psi
Maximum Concrete Aggregate Size		
1 ½ in.	1 ½ in.	1 ½ in.
Reinforcing Steel		
ASTM A15-39 Intermediate Grade Fy=40ksi	ASTM A15-39 Intermediate Grade Fy=40ksi	ASTM A15-39 Intermediate Grade Fy=40ksi
Internal Corrosion Protection		
--	--	Magnesium Zinc Fluorosilicate 3 Coats (min.)
External Waterproofing		
--	--	3-Ply Asphaltic Fabric Coating Asphalt- ASTM D449-37T Fabric Fed. Spec. HHC-58I

a. Inverted dome.

b. On the tank centerline.

What is the origin and history of the contamination (e.g., spills, intentional discharges, disposal areas)?
This information was previously described in the *Legacy Source Sites* section. See Table E-6.

Does the tank farm have known or suspected leaks from specific tanks? If yes, describe the extent and time period of known or suspected leakage.
From historic monitoring activities, there are seven assumed leakers[11] (T-101, T-103, T-106, T-107, T-108, T-109, and T-111) in the T Tank Farm (Rodgers 2014). Tanks have been classified into four groups based “quality” of leak information and how the leak, if suspected or known, was trending (RPP-23405, Rev. 1, p. 1-4). Estimates of the inventories for planned and unplanned releases for the T Tank Farm tanks are summarized in Table E-2. A summary for each of the suspected leaking tanks is provided (from Field & Fort 2013, Chapter 4):

- **T-101** – This tank was removed from service in 1979 and declared an “assumed leaker” in October 1992 with an estimated leak volume of 7,500 gal based on a liquid level decrease of 2.6 in (where an evaluation determined was likely due to instrument error). Tank T-101 was filled with coating waste (535,000 gal) in 1963, which was stored until early 1969. Process data indicated that the tank was filled above the cascade/spare inlet level between 1964 and 1969. An unplanned release of REDOX coating waste supernatant occurred in early 1969 when the tank was overfilled (539,000 gal) and waste overflowed to the soil through the spare fill line. After the overflow, most of the waste was transferred. The tank did not receive additional waste until 1972 when the tank received waste from the SX and BX Tank Farms.
- **T-103** – This tank is the third tank in a three-tank cascade that includes tanks T-101 and T-102 and began receiving metal waste from the cascade overflow line connected to tank T-102 in November 1945 and was full by February 1946. In March 1974, this tank was classified as having “questionable integrity” based on a 0.3-in. liquid level decrease, which took place from November 1973 to February 1974. Subsequent investigations indicated the leak resulted from a failed grout seal in a fill entry line resulting in the release of approximately 5 m^3 of CSR (i.e., supernatant from which cesium was removed by ion exchange).
- **T-106** – This tank, which was placed in service in June 1947, is the third of the three-tank cascade including tanks T-104 and T-105. This tank recorded a level decrease of 42 in. over a period of 49 days between April and June 1973 (for an estimated leak volume of 115,000 gal.[12]). As assessment indicated that the liner failed near the tank bottom, and REDOX coating waste with small amounts of 221-B Plant low-level waste and ion exchange waste leaked into the soil. The tank was pumped to a minimum heel in June 1973 and then further pumped down to a residual layer of less than 6 in. by July 1974. The tank was primary stabilized in January 1979. The tank was interim stabilized, and intrusion prevention was completed in August 1981. The tank remains categorized as an “assumed leaker.” All of the drywells located adjacent to the tank show significant levels of activity; however, the majority of the radionuclides in the plume appear to have not migrated through the formation sediments since 1974.
- **T-107** – This tank is the first in a three-tank cascade including tanks T-108 and T-109. Tank T-107 first entered service receiving 1C waste from T Plant in February 1945. This tank was designated

[11] Tanks that are either known or suspected of leaking at any time including the present are denoted “assumed leakers” (Rodgers 2014).

[12] The T-106 tank leak (115,000 gal) is the largest known tank leak at the Hanford Site (RPP-23405, Rev. 1, p. 3-5).

as having "questionable integrity" in 1976 based on measured increases in gamma activity in drywell 50-07-07 showing radionuclide activity at a depth of 44 ft. Historical records indicate that the tank was filled above the cascade outlet on at least two occasions (1953 and 1966). Possible sources for the increased activity measured in drywells include a leak near the base of the tank or a spare inlet overflow. The waste that may have been leaked is undetermined.

- **T-108** – This tank is the second tank in a three-tank cascade including T-107 and T-109. Waste was first added to tank T-108 in September 1945 with the cascade of 1C1 waste from tank T-107, which continued until the first quarter of 1946. This tank was removed from service and classified as having "questionable integrity" in 1974 based on an unexplained decrease in liquid level of 0.3-in. between June 1973 and April 1974. It has been suggested that there may be a possible instrument malfunction; furthermore, interpretation of the results are complicated by the plume from tank T-106. The liquid level data appear inconclusive, and no inventory has been estimated for leaks from T-108.
- **T-109** – This tank is the third of the three-tank cascade including T-107 and T-108. Waste was initially added to tank T-109 in the fourth quarter of 1945 with the cascade of 1C waste from tank T-108. This tank was identified as being of "questionable integrity" in June 1974 based on increases in drywell radiation readings between February 1974 and June 1974. The radioactivity contour plots indicate the source of contamination detected likely originated from the tank T-106 leak (May 1973). Therefore, it is unlikely that a leak developed in tank T-109, and no leak inventory has been estimated for T-109. However, it appears that tank was overfilled to near the spare inlet ports between 1965 and 1970 and that supernatant may have been released to the surrounding soil. A tank integrity assessment has been recommended for this tank.
- **T-111**[13] – This tank is the second tank in a three-tank cascade including T-110 and T-112. This tank was brought into service during the fourth quarter of 1945 with a cascade from tank T-110 of second cycle decontamination (2C) waste. This tank was categorized as having questionable integrity after an unexplained liquid level decrease of 0.30 in. in 1974. In 1994, Tank T-111 was classified as an "assumed re-leaker" after additional unexplained liquid-level decreases were observed. The supernatant released is classified in the BBI as interstitial liquid from 224 and 2C sludge. Interstitial liquid and surface levels peaked in late 2006 and have decreased since December 2007. Tank conditions were evaluated in April 2013, and it was determined that the interstitial liquid level drop is likely due to leaking. Additional investigations were performed (Washenfelder 2013) indicating 1) the tank began to leak somewhere between 2002 and 2009, most likely around 2002; 2) the leak rate as of April 1, 2013 is 2.0 - 3.1 gal/day, with the most likely rate ~2.8 gal/day; and 3) the post-1994 leak volume is probably between 1,000 - 3,900 gal, with the most likely volume ~2,100 gal. Note that Tank T-111 is also considered to have had an intrusion based upon a video inspection in December 2013 (Rodgers 2014).

Many of the assumed leakers described above were overfilled and some tanks show activity in nearby drywells that have been attributed to operations spills, line leaks, or leaks from another tank. Other T tanks are classified as *sound* (Rodgers 2014). However, Table E-2 indicates a 50-500 gallon release from Tank T-102 (currently classified as "sound") based on Cs-137 detected in drywell 52-02-05 in 1974 (Field

[13] Note that tank T-111 has 10 times the total organic carbon in the waste compared to other T Farm tanks. High organic carbon has been linked to the formation of gas (Washenfelder 2013, p. 36).

& Fort 2013, p. ii). A tank integrity assessment is in progress to determine the reason for the increased Cs-137 activity and to identify the release source.

What are additional sources of contamination in the tank farm (e.g., spills, intentional discharges, disposal areas)? Describe the extent and time period of intentional and unintentional discharges.

The known sources of contamination related to the T Tank Farm EU include the HLW tanks and ancillary equipment, legacy source sites (e.g., cribs, trenches, vadose zone) contaminated by intentional and unintentional discharges to the environment, and groundwater contamination. No additional sources of contamination are known in the T Tank Farm EU; however, there are additional sources of contamination from other EUs (e.g., WMA TX-TY) that have contaminated the vadose near the T Tank Farm EU and have resulted in plumes (e.g., carbon tetrachloride, TCE, and nitrate) in the saturated zone under the T Tank Farm EU.

What is the current assessment of the integrity of each tank?

Seven T Tank Farm tanks (i.e., T-101, T-103, T-106, T-107, T-108, T-109, and T-111) are currently designated as *assumed leakers* where the remaining tanks are designated as *sound* (Table E-8) (Rodgers 2014). Tank T-102 is being assessed as a possible source of Cs-137. The leak of 115,000 gal associated with Tank T-106 in 1973 is the largest known tank leak at the Hanford Site (RPP-23405, Rev. 1, p. 3-5). Tank T-111 was declared an *assumed re-leaker* in 1994 (Rodgers 2014) and is considered likely to be the only active leaker in the T Tank Farm. As much of the liquid waste in the SSTs including those in the T Tank Farm was transferred to DSTs as possible, i.e., the tanks were interim stabilized.

Table E-8. Inventory and Status by Tanks –T Tank Farm Evaluation Unit (Rodgers 2014)

			Waste Volumes (26)					
Tank Number	Tank Integrity	Tank Status	Total Waste (kgal)	Supernatant Liquid (kgal)	Drainable Interstitial Liquid (kgal)	Sludge (kgal)	Saltcake (kgal)	Solids Volume Update
241-T TANK FARM STATUS								
T-101	ASMD LKR	IS	99	0	16	37	62	06/30/04
T-102	SOUND	IS/IP	32	13	3	19	0	08/31/84
T-103	ASMD LKR	IS/IP	27	4	4	23	0	10/01/04
T-104	SOUND	IS	317	0	31	317	0	11/30/99
T-105	SOUND	IS/IP	98	0	5	98	0	05/29/87
T-106	ASMD LKR	IS/IP	22	0	0	22	0	01/01/01
T-107	ASMD LKR	IS	173	0	34	173	0	05/31/96
T-108	ASMD LKR	IS/IP	16	0	4	5	11	01/01/01
T-109	ASMD LKR	IS/IP	62	0	11	0	62	01/01/02
T-110	SOUND	IS	370	1	48	369	0	03/31/02
T-111	ASMD LKR	IS	447	0	38	447	0	01/01/02
T-112	SOUND	IS/IP	67	7	4	60	0	04/28/82
T-201	SOUND	IS/IP	30	2	4	28	0	07/01/04
T-202	SOUND	IS/IP	20	0	3	20	0	07/01/04
T-203	SOUND	IS/IP	36	0	5	36	0	07/01/04
T-204	SOUND	IS/IP	36	0	5	36	0	07/01/04
16 TANKS - TOTAL			1852	27		1690	135	

IP – Intrusion Prevention
IS – Interim Stabilized

EU Designation: T Tank Farm (CP-TF-1)

DRAFT for Methodology Illustration

The *structural integrity* of the Hanford SSTs and DSTs is being evaluated per a Tri-Party Agreement to "determine the SST system integrity, and whether or not the SST tank system is adequately designed and has sufficient structural strength and compatibility with the waste to be stored or treated to ensure that it will not collapse, rupture, or fail" (RPP-10435, Rev. 0). Based on the SST integrity assessment (RPP-10435, Rev. 0), the reinforced concrete SST structures were concluded to have an adequate collapse margin so that continued safe storage of interim-stabilized waste could continue. "However, given the tank leak history and current condition of the tank liners, long-term leak integrity, for the liquids remaining in the tanks, cannot be proven for any of the SSTs" (RPP-10435, Rev. 0).

To ensure adequate margin against dome collapse through closure, potential reinforced concrete degradation mechanisms were reviewed including the primary potential degradation mechanisms for the SSTs (RPP-10435, Rev. 0):

- Corrosion of reinforcing bars,
- Degradation of concrete mechanical properties from high temperature exposure, and
- Exposure of the concrete to caustic waste in leaking tanks and resulting damage.

Based on the structural integrity assessment and evaluations of possible degradation mechanisms, the SSTs were declared structurally adequate (RPP-10435, Rev. 0). Because of the relatively benign operating environment and reduced liquid waste volumes, future degradation is assumed to be small and the dome collapse margin will remain adequate through closure.

The most significant structural uncertainty pertains to the condition of the concrete basemat and footing, which cannot be inspected. However, dome surveillance indicates no current evidence of significant distress in the dome. Periodic monitoring of the SST domes is needed to maintain sufficient confidence in the SST structural integrity for future operations through closure (RPP-10435, Rev. 0.

What ancillary infrastructure is contained within the tank farm (i.e., transfer pits, transfer piping, etc.)?

A listing of the ancillary equipment included in the T Tank Farm EU is provided in Table E-1 (Attachment E-1). Judging the structural integrity of ancillary equipment is based on evaluating system design, waste characteristics, corrosion protection measures, and age (RPP-10435, Rev. 0). Two examples will be described here. Pits provide secondary containment for transfer components (e.g., jumpers and pumps). Pit design requirements and performance history were evaluated. It was concluded that the pits are sound and compatible with the waste transfers (RPP-10435, Rev. 0); these results were confirmed by visual and remote inspection of the interior of pit structures. There are also many transfer lines in and connecting the Hanford tank farms; only 18 are in use and none related to the T Tank Farm EU (RPP-10435, Rev. 0). Because transfer lines are buried, the material condition of the piping is largely unknown; test pipe lines are pressure-tested to determine if they are fit for use.

What is the depth of contamination and sediment types/stratigraphy associated with the contamination associated with past releases or leakage?

This information was previously provided under the corresponding *Legacy Source Sites* section.

When is the waste in the tank farm scheduled for retrieval?

The most recent System Plan (Certa, et al. 2011) suggests that several tanks in T Tank Farm would be retrieved between 2020 and 2025 if the waste in them is reclassified as TRU; the remaining (HLW) tanks would be retrieved in the 2030-2035 timeframe. This timing is illustrated in Figure E-16.

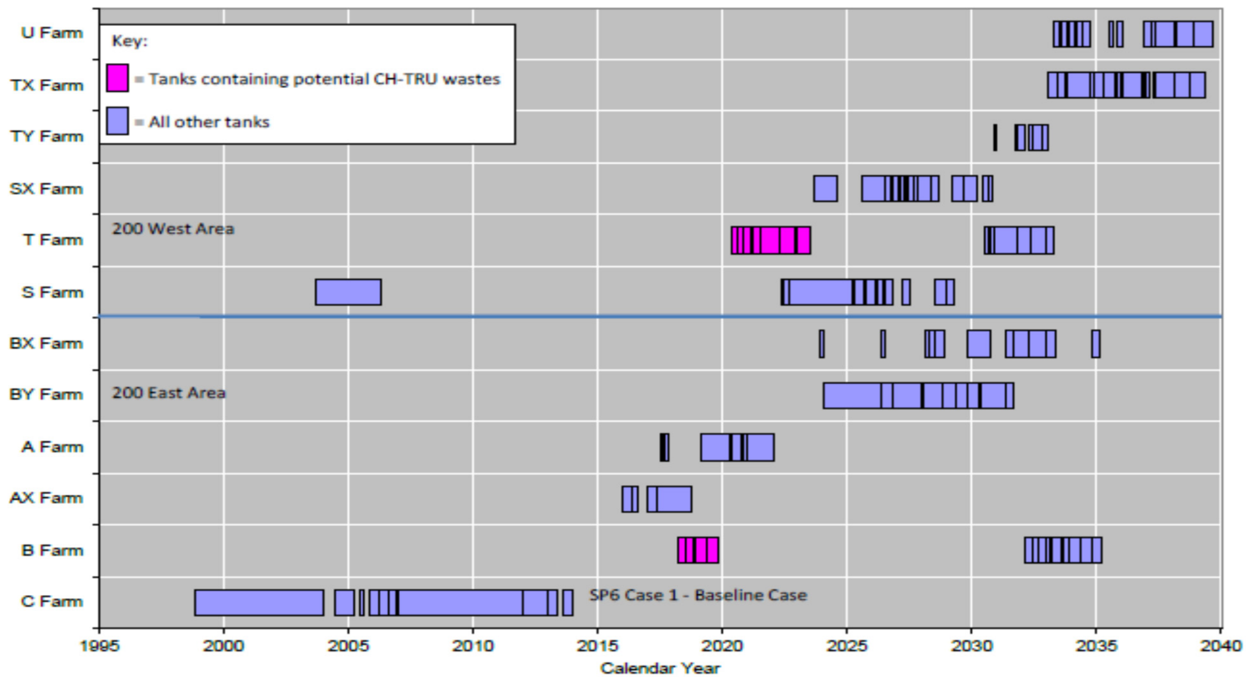

Figure E-16. General Timing of Single-Shell Tank Retrieval by Tank Farm (Certa, et al. 2011, p. 5-8)

The waste in the T/TX/TY tank farm grouping, except that managed as CH-TRU (decision pending)[14], would be retrieved and transferred via hose-in-hose transfer lines (HIHTLs) to new diversion boxes (RPP-PLAN-40145, Rev 4, p. D-2). Waste will be transferred from the new diversion boxes via new double-encased HIHTLs or stainless steel lines to a waste receipt facility located nearby. Supernatant used for solids mobilization will preferably be generated at the T/TX/TY complex by dissolution of saltcake with water. Retrieval of SST wastes, except that managed as CH-TRU, will be to a waste receipt facility tank.

What measures have been taken to reduce migration of past contamination?

Interim measures were completed to minimize contaminant infiltration from artificial water sources such as waterline leaks or surface run-on. These interim measures include (RPP-23752, Rev. 0, p. xvi):

- Emplacing upgradient surface water run-on control measures (barriers and diversions).
- Performing leak tests of the waterlines to T, TX, and TY tank farms. No leaks in the tank farm area were detected at the time of the survey. The raw water line serving TX and TY tank farms was cut and capped in 2001.
- Verifying that the sanitary waterline to T Tank Farm had been cut and capped.
- Capping existing drywells to prevent water intrusion.
- Decommissioning pre-1980 monitoring wells at T Tank Farm.

An interim action pump-and-treat (P&T) system has been in operation since 2007 to remove carbon tetrachloride and Tc-99 contamination near WMAs T and TX-TY. Since 2007, the P&T system has

[14] Waste in the T Tank Farm tanks that will be handled as CH-TRU waste will be transferred directly from the SST to the CH-TRU treatment plant located nearby (RPP-PLAN-40145, Rev 4, p. D-2).

extracted 82 grams (1.4 Curies) of Tc-99, 193 kilograms of carbon tetrachloride, 14.5 kilograms of chromium, 732 grams of trichloroethene, and 85,000 kilograms of nitrate from the aquifer (DOE/RL-2013-22, Rev. 0).

A major interim measure consisting of an interim barrier of polyurea has been installed over the subsurface plume from Tank T-106 that extends to 40 meters (bgs) (Zhang, et al. 2011, p. vi). The interim barrier, designed for 30 years, will allow waste retrieval while preventing additional moisture from entering the soil in the area over the plume. The interim barrier was installed in 2008, and monitoring results indicate that it has performed as expected by intercepting meteoric water from infiltrating into the soil; the soil has become gradually drier (Zhang, et al. 2011, p. vii).

Is information available indicating the partition coefficients for the primary contaminants (risk drivers) with the type of soil? (If yes, provide table.)

A comprehensive partition coefficient database for the Hanford Site is available (PNNL-13895); however, this report does not lend itself to a summary table. PNNL-17154 does provide a summary table (Table E-5) of partition coefficients for the primary coefficients (Sr-90 and Cs-137) applicable to the Waste Management Areas T and TX-TY.

Groundwater Plumes

As described in the *Summary Description s*ection, the current plumes that exceed final cleanup and/or MCLs associated with the T Tank Farm EU are (DOE/RL-2013-22, Rev. 0) include chromium, I-129, Tc-99, tritium, and nitrate. There are other contaminants of concern (i.e., carbon tetrachloride and trichloroethene) associated with the 200-ZP-1 Operable Unit (OU) that exceed final cleanup levels (and MCLs) (EPA 2008); however, these contaminants do not result from sources related to the T Tank Farm EU. Only the nitrate plume is not contained within the current carbon tetrachloride plume.

The methodology for assessing potential related to groundwater for an EU is described in Chapter 7, Section 7.2 entitled *Methodology for Evaluating Impacts to and by Groundwater and to the Columba River* (denoted here as the *GW/SW framework*). Once it has been established that the EU has potential to impact groundwater or surface water, the evaluation proceeds to characterizing the EU for three metrics related to groundwater as a resource:

1. Time until groundwater would be *impacted* by a primary contaminant without a current plume over the three evaluation periods. Groundwater is considered *impacted* when a primary contaminant concentration exceeds a threshold value, e.g., a drinking water standard or MCL.
2. The amount of groundwater (e.g., areal extent or volume) currently *impacted* by those primary contaminants with existing plumes.
3. The amount of additional *impacted* groundwater over the three evaluation periods.

and three metrics related to near surface, vadose zone, and groundwater contamination with respect to potential impacts to the Columbia River:

4. Time until the Columbia River is *impacted* over the three evaluation periods. The Columbia River is considered *impacted* when a primary contaminant concentration exceeds a benthic or free-flowing threshold value.
5. Primary contaminant discharge concentration and spatial extent (i.e., length of river potentially impacted) relative to benthic thresholds over the three evaluation periods.

6. Primary contaminant discharge flux and *impact* to the Columbia River relative to the free-flowing concentration thresholds over the three evaluation periods.

Because there are current plumes associated with the T Tank Farm EU that exceed MCLs (DOE/RL-2013-22, Rev. 0), *the EU does pose risks* to groundwater and potentially the Columbia River (*GW/SW framework* Step 3).

What is the origin of the contamination (e.g., spills, intentional discharges, disposal areas)?

The source of the saturated zone plumes related to the T Tank Farm EU is vadose zone contamination and ultimately the wastes from intentional and unintentional discharges of tank and other wastes (Table E-2). A significant component of these discharges are from the SSTs in the 200-East and 200-West areas; the T Tank Farm EU is located in 200-West. As indicated in Table E-2, approximately 40×10^6 gallons were discharged into cribs and trenches (e.g., representing <2 Ci of Co-60, 2,200 Ci of Cs-137, and <1 Ci of Tc-99 decayed to 2001). Furthermore, in addition to other leaks, the 115,000-gallon leak from Tank T-106 (in the T Tank Farm EU) is the largest known tank leak at the Hanford Site (RPP-23405, Rev. 1, p. 3-5) and represented impacts to the environment of 10 Ci of Co-60, 20,000 Ci of Cs-137, and 63 Ci of Tc-99 (decayed to 2001 per Table E-2).

The current plumes that exceed final cleanup and/or drinking water standards (Table E-4) associated with sources related to the T Tank Farm EU are (DOE/RL-2013-22, Rev. 0):

- *200-ZP Chromium* – Sources include past leaks from SSTs containing metal and liquid waste from chemical processing of uranium-bearing, irradiated reactor fuel rods, the bismuth phosphate process, uranium-recovery process, and plant operations in 200-East Area.
- *200-ZP Iodine-129* – Sources include past leaks from SSTs containing metal and liquid waste and from chemical processing and plant.
- *200-ZP Technetium-99* – Sources include releases from past leaks in SSTs and pipelines in WMA T and WMA TX-TY and liquid waste disposal from plutonium processing operations to cribs and trenches adjacent to the WMAs.
- *200-ZP Tritium* – Sources include past leaks from SSTs and other plant operations. Since there is no cost-effective groundwater treatment for tritium and because of its short half-life, natural radioactive decay will reduce concentrations to below the cleanup level.
- *200-ZP Nitrate* – Primary sources for nitrate include liquid waste disposal from other site operations (e.g., Plutonium Finishing Plant); the T Tank Farm appears to be a minor contributor to the nitrate plumes in 200-West Area.

There are other contaminants of concern (i.e., carbon tetrachloride and trichloroethene) associated with the 200-ZP-1 OU that exceed final cleanup levels and MCLs (EPA 2008); however, these contaminants do not result from sources in the T Tank Farm EU.

What are the primary contaminants (risk drivers) related to groundwater?

After establishing that the T Tank Farm EU poses a risk to groundwater, the next step (Step 4 in the *GW/SW framework*) is to select primary contaminants (PCs). From the TC&WM EIS, the saturated zone contaminants of concern related to the T Tank Farm EU include both radioactive (e.g., tritium, Tc-99, I-129, and U-238) and non-radioactive (e.g., chromium, nitrate, and total uranium) analytes. The 2012 Hanford Annual Groundwater Report (DOE/RL-2013-22, Rev. 0) shows plume maps (from CERCLA monitoring) for carbon tetrachloride, chromium, I-129, nitrate, Tc-99, and trichloroethene.

A plume map is not provided in the Annual Groundwater Report for tritium because the half-life of tritium is sufficiently short that it will likely decay below the final cleanup standard (and MCL) before it leaves the industrial land-use zone. Thus tritium is not considered a PC for potential groundwater impact. Uranium is not considered a contaminant of concern for the 200-ZP-1 OU in the Record of Decision (EPA 2008); groundwater monitoring data suggest that there have been no measured uranium concentrations above cleanup levels or MCLs (DOE/RL-2013-22, Rev. 0, p. ZP-3). Furthermore, the TC&WM EIS human health screening evaluation (TC&WM EIS, Appendix O) indicates that uranium would not likely impact the saturated zone through the Long-Term Post-Cleanup Period (1150 years). Therefore, uranium is also not considered a groundwater PC for the T Tank Farm EU. Finally, carbon tetrachloride and trichloroethene do not result from tank farm operations, and thus these contaminants are not considered PCs. This process of elimination results in four primary contaminants: chromium (Figure E-5), I-129 (Figure E-6), Tc-99 (Figure E-7), and nitrate (Figure E-8), i.e., the same set of groundwater PCs as the more detailed analysis conducted (above) for the legacy source sites. The PCs (i.e., chromium and nitrate) that were identified from the ecological screening analysis (TC&WM EIS, Appendix P) resulted from potential impacts from groundwater discharges on Columbia River benthic and aquatic receptors.

Are there co-contaminants that will affect mobility of the primary contaminants?

This information was presented in the corresponding *Legacy Source Sites* section.

What is the depth of the groundwater table from the ground surface? Has the depth to groundwater changed significantly since the contamination was emplaced? How is the depth to groundwater expected to change over the period of evaluation?

Depths from land surface to the water table range from 50-80 m in the 200-West Area (where the T Tank Farm EU is located). Within the Central Plateau region, recharge to the unconfined aquifer comes from the Cold Creek and Dry Creek Valleys, Rattlesnake Hills, and infiltrating precipitation (DOE/RL-2013-22, Rev. 0). Groundwater in this region generally flows from west to east, although some of the flow from the 200-West Area and/or north of the 200-West Area moves north through Gable Gap (DOE/RL-2011-01).

The Hanford Site water table has changed significantly since operations began in the 1940s (Hartman 2000). Since then, artificial recharge from wastewater disposal has often been several times greater than natural recharge, which caused an increase in water-table elevation over much of the Site between 1944 and 1979 and the formation of groundwater mounds beneath major wastewater disposal facilities. Mounds formed in the 100, 200, and 300 Areas with the two most prominent mounds formed near the U Pond (22 meters) in the 200-West Area and near B Pond (10 meters) in the 200-East Area. The mounds altered natural flow patterns in the aquifer system.

Beginning in 1988, production activities on the Hanford Site were ceased resulting in a decrease of wastewater disposal and corresponding decreases in water-table elevation across the Hanford Site with the greatest decline near the U Pond (200 West). As the Site's mission has changed from production to environmental cleanup and restoration, the volume of wastewater discharged to the soil column has been greatly reduced and many discharge sites have been eliminated. Water levels in the 200 Areas have continued to decline since 1995 and would be expected to decline further as the groundwater mounding relaxes over time.

EU Designation: T Tank Farm (CP-TF-1)

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What is the depth of contamination and sediment types/stratigraphy associated with the contamination?

This information was provided in the corresponding *Legacy Source Sites* section.

What is the physical state of the primary contaminants (e.g., adsorbed in contaminated sediments, dissolved in groundwater, present in or as non-aqueous phase fluids)?

This information was presented in the corresponding *Legacy Source Sites* section.

Are perched water or contaminated hydrologic lenses present?

Perched water has been encountered in sediment above the Hanford/Ringold aquifer system in the 200-West Area i.e., where the T Tank Farm EU is located) and in irrigated areas east of the Columbia River (Hartman 2000).

Are there continuing contaminant sources that are currently adding to the extent of contamination or may in do so in the future over the evaluation period? (Can the source concentrations be defined for the primary contaminants?)

The EU characterization process (i.e., denoted A-A' in the *GW/SW framework*) begins (Step 9) with the location of the EU and sources related to the EU (i.e., see Figure E-1 through Figure E-4). Inventory estimates (Step 10) for the various T Tank Farm sources (tanks and ancillary equipment, past leaks, and intentional discharges to legacy source sites) are provided in Appendix D and N of the TC&WM EIS and summarized in Table E-13 and Figure E-19 through Figure E-21 (Part V, below). Primary (tank wastes via leaking) and secondary sources (vadose zone contamination including that in pore spaces from past discharges) are currently releasing contaminants (Step 11 and Step 13) into the Hanford subsurface including the vadose and saturated zones. The primary driver for contaminant transport is percolating water (vadose zone) and recharge rate to saturated zone influencing contaminant movement toward the Columbia River.

Since the T Tank Farm EU PCs are already in the saturated zone, the drivers for contaminant movement through the subsurface are captured by considering three recharge rates: surface barrier (0.5 mm/yr), undisturbed plant communities (5 mm/yr), and disturbed soil (50 mm/yr) to reflect a range of potential local site conditions as a result of ground cover, closure covers, climate variation, and localized surface hydrologic effects (Chapter 7). The extent of vadose zone contamination (Step 12) was indicated above in the corresponding *Legacy Source Site* section (e.g., Figure E-9).

What is the source and reliability of the information available to describe the contaminants (risk drivers) and materials present?

Primary sources of information used to evaluate potential groundwater and surface water impacts related to the T Tank Farm EU (Steps 14 and 17 in the *GW/SW framework*) are the 2012 Hanford Annual Groundwater Report (DOE/RL-2013-22, Rev. 0) and the TC&WM EIS. The data source for PHOENIX and the 2012 Annual Groundwater Report is the Hanford Environmental Information System (HEIS) database, which is the official repository of data from soil, biota, atmospheric, miscellaneous material, surface water, and groundwater samples at the Hanford Site. The information that pertains to WMA-T (and the T Tank Farm EU) and WMA-TX/TY is denoted the 200-ZP-1 Operable Unit (OU) where maximum contaminant levels (MCLs) and final cleanup levels are provided in Table E-4. Model predictions from the TC&WM EIS are also used to assess potential groundwater and surface water impacts. There are significant sources of uncertainties and gaps in the information used for the analysis (Steps 15 and 18);

however, the information used has been released for public comment and appears reasonable for the rough-order-of-magnitude analysis performed here.

Is information available indicating the partition coefficients and other important transport parameters for the primary contaminants in the site hydrologic materials? (If yes, provide table.)

As indicated in previous sections, mobile primary contaminants have already migrated (Step 16) from the T Tank Farm EU to the saturated zone. Furthermore, based on the No Action Alternative analysis in the TC&WM EIS (Appendix O) as described in the *Legacy Source Sites* section, no additional contaminants (from any or all sources including the T Tank Farm EU) are predicted to exceed benchmark values or MCLs at the T barrier boundary in the future.

In the 200 West Area (where the T Tank Farm EU is located), the vadose zone includes the Hanford formation, Cold Creek unit, and Ringold Formation (DOE/RL-2007-56, Rev. 0, p. 2-6&7). The Cold Creek unit is comprised of finer grained and semi-consolidated layers that impact the flow and retention of pore fluids and contaminants. The Hanford formation and Ringold Formation are the most permeable materials for potential continued contaminant migration. Travel time (T_t) of water and unretarded species through the subsurface can often be related to the recharge rate, r. For the 200 West Area, T_t can be estimated using (data from Table N-52 from the TC&WM EIS):

$$T_t = 4006r^{-0.899} \qquad \text{200-West (T Tank Farm EU)}$$

For recharge values of 0.5, 5, and 50 mm/y for surface barrier, undisturbed plant communities, and disturbed soil, respectively, travel times of approximately 7000, 900, 100 years, respectively, are obtained. Using a vadose zone thickness of approximately 50 m (where the thickness is 50-80 m in the 200-West Area), average linear velocities of approximately 0.007, 0.05, and 0.4 m/y are obtained. As indicated above, screening results from the No Action Alternative in the TC&WM EIS (Appendix O) indicate that no additional PCs would likely impact the saturated zone in the future.

Table E-9. Important Vadose Zone (VZ) Parameters Estimated for the 200-West Area

	Recharge rate (r), mm/yr		
Parameter	**0.5**	**5**	**50**
Average water travel time through vadose zone (VZ), years	7,000	900	100
Average linear water velocity (assuming 50 m VZ), m/year	0.007	0.05	0.4

Relevant partition coefficients are provided in the *Legacy Source Sites* section (Table E-5).

Is there information on the site contamination and hydrology with respect to interpreting current and future plume migration (e.g., temporal history of plume to estimate rate of spread)?

As indicated above, screening results from the No Action Alternative analysis in the TC&WM EIS (Appendix O) and described in the *Legacy Source Sites* section, indicate that no additional contaminants (PCs) are expected to impact groundwater (i.e., exceed MCLs) at the T Barrier boundary *from all sources* over the next 1150 years corresponding to the Long-Term Post-Cleanup Period; therefore, there are no (additional) PCs related to the T Tank Farm EU that do not currently have plumes. Therefore, the time until GW would be impacted by those groundwater PCs without existing plumes, for each evaluation period, is identically zero (Step 19 and GW Metric #1). These results are independent of recharge rate.

The Hanford Annual Groundwater Reports[15] provide estimates of the areal extents of selected contaminant plumes over time (Figure E-17 and Table E-10) including for the four PCs related to T Tank Farm EU groundwater: chromium, I-129, Tc-99, and nitrate. The extents represented in Figure E-17 and Table E-10 may sources and plumes from other EUs. The plume maps were extracted from the Annual Groundwater Reports and the relative area for each WMA (T-TX-TY) in the 200-ZP Operable Unit (OU) was estimated using a graphics program. The resulting relative areas were reasonably straightforward to estimate for Tc-99 where there appeared to be plumes that could be associated with each WMA. These estimates became progressively more difficult for other primary contaminants. For example, because of the large plume area for nitrate and the multiple sources outside the 200-ZP OU, it was decided that the nitrate plume area was equally distributed among three WMAs, T, TX, and TY as indicated in Table E-10 (Step 20 and GW Metric #2).

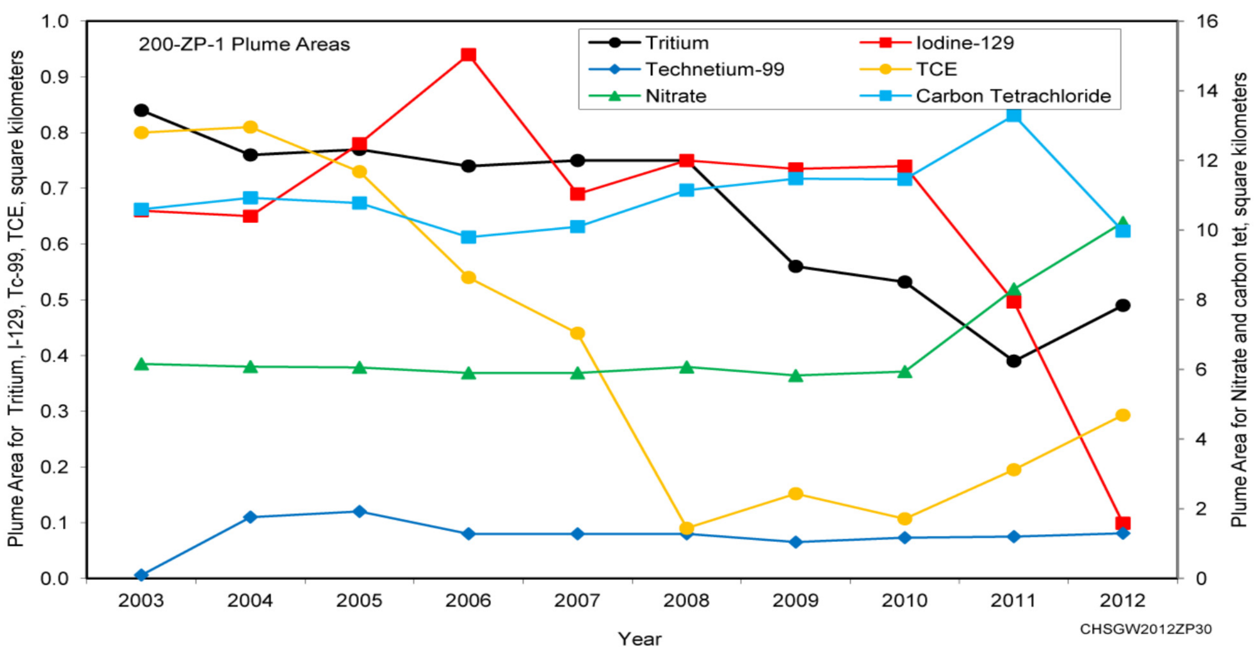

Figure E-17. Estimates of Plume Areas related to the 200-ZP Operable Unit

[15] See http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports. The 2012 Hanford Annual Groundwater Report provides an animation of the changes in groundwater plumes by year from the mid-1990s to 2012.

Table E-10. Estimated Plume Areas based on Hanford Annual Groundwater Monitoring Reports

Contaminant (Fed/State MCL)		Plume Area (km^2) [c] Total area (top) and Area attributed to T Tank Farm EU (below)									
		2012	2011	2010	2009	2008	2007	2006	2005	2004	2003
Tc-99	Total	0.11	0.08	0.07	0.06	0.08	0.08	0.08	0.12	0.11	0.01
(900 pCi/L)	T Tank Farm	0.04	0.01	0.03	0.02	0.04	0.05	0.05	0.11	0.11	0.004
I-129	Total	0.10	0.50	0.74	0.74	0.75	0.69	0.94	0.78	0.65	0.66
(1 pCi/L)	T Tank Farm	0.08	0.47	0.67	0.66	0.69	0.62	0.89	0.7	0.59	0.56
Chromium	Total	0.14	0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
(100 ug/L) [a]	T Tank Farm	0.11	0.19	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.04
Nitrate	Total	10.	8.3	5.8	5.4	6.1	5.9	5.9	6.1	6.1	6.2
(10,000 ug/L) [b]	T Tank Farm	3.4	2.7	1.9	1.8	2.0	2.0	2.0	2.0	2.0	2.0

a. 100 µg/L federal drinking water standard for total chromium.

b. Nitrate as nitrate; 10 mg/L nitrate as nitrogen.

c. Estimated area above listed Maximum Contaminant Level (MCL) based on Hanford Annual Groundwater Monitoring Report for that year. The authors have attempted to distinguish among the sources using graphics software to estimate relative areas of plumes. The ability to distinguish is relatively straightforward for the multiple Tc-99 plumes and is progressively more difficult for other contaminants. For example, because of the large nitrate plume (with significant sources outside the 200-ZP OU), it was decided that the plume area given in the corresponding Hanford Annual Groundwater Monitoring was equally distributed among the three WMAs (T-TX-TY).

The temporal variations in groundwater primary contaminant (PC) plume areas that were attributed to the T Tank Farm EU (Table E-10) are illustrated in Figure E-18. Operation of the pump-and-treat system since 2007 does appear to have impacted plume areas in the 200-ZP OU. Any temporal trends in the PC plume areas in either Figure E-18 (or Figure E-17) appear weak statistically[16]; however, it does appear that the Tc-99 and I-129 plume areas are generally decreasing and those for chromium and nitrate are generally increasing. The rough order estimates of these changes are provided by fitting the post-2005 plume areas (Figure E-18); the plume areas change by the following amount relative to the 2006 area given in Table E-10 (where ΔT is the difference in years relative to 2006):

Tc-99: $\exp(-0.1\Delta T)$ km^2/yr   I-129: $\exp(-0.3\Delta T)$ km^2/yr

Chromium: $\exp(0.2\Delta T)$ km^2/yr   Nitrate: $\exp(0.08\Delta T)$ km^2/yr

The above estimates have very high uncertainties associated with them and should be used with care when projecting plume areas into the future because they are based on several assumptions (including pump-and-treat system operation, sufficient source, stable subsurface conditions), that may not hold in the future. For example, the Tc-99 and I-129 plume areas, at the current recharge that represents disturbed soil, would be essentially zero (<< 0.1 km^2) by the end of 50-year Active Cleanup evaluation period (and thus also the longer term evaluation periods). Lower recharge rates would likely make these areas smaller more rapidly. Therefore, there would likely be no *additional* groundwater impacted over all evaluation periods; however, less groundwater may be impacted by the Tc-99 and I-129 from pump-and-treat system operation and changes in the Hanford water table. There are existing plumes (e.g.,

[16] Time series analyses were conducted in JMP that illustrated the weakness of temporal trends in plume areas.

nitrate) that would likely also cover those areas expected to be unimpacted in the future; therefore, these areas are considered to remain impacted in the future (Step 21 and GW Metric #3).

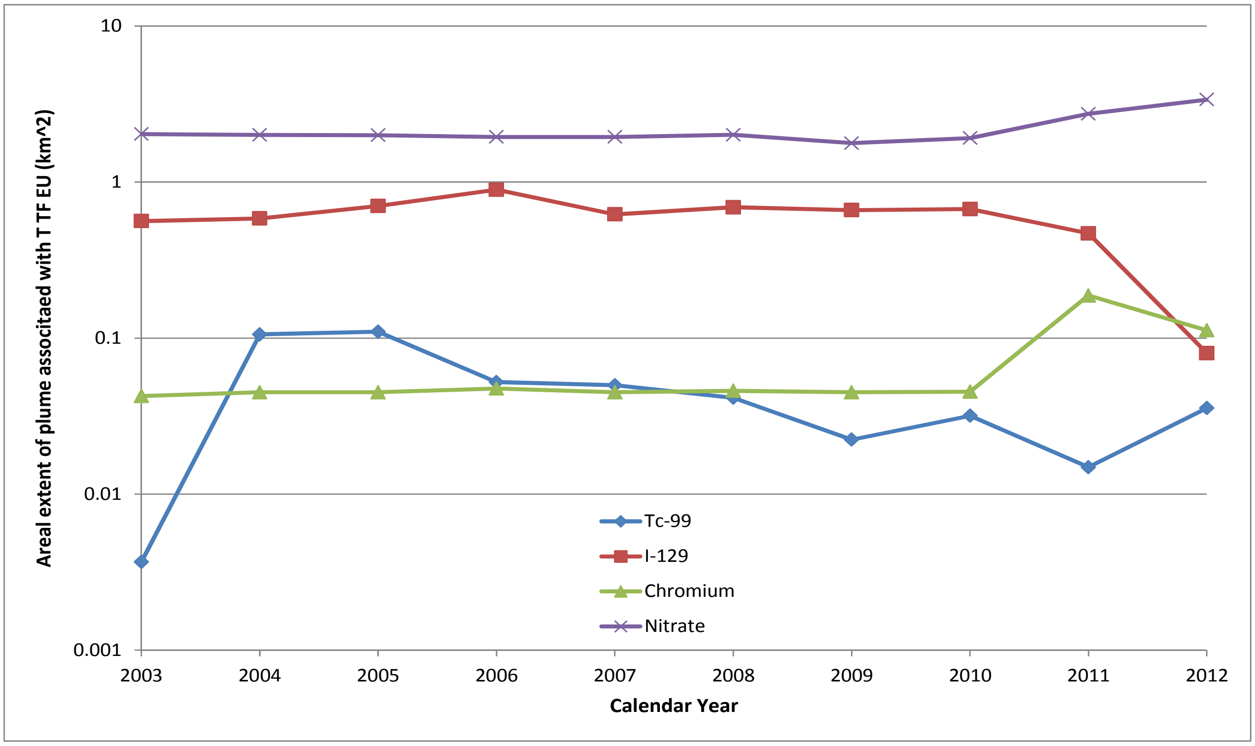

Figure E-18. Estimated areal extents of primary contaminant plumes associated with the T Tank Farm Evaluation Unit

Based on current recharge (assuming 50 mm/yr for a tank farm) and subsurface conditions, the chromium plume is predicted to expand and cover a very large area (>> 10 km^2) before the end of the 50-year Active Cleanup evaluation period (Step 21 and GW Metric #3). The chromium plume area is predicted to reach 10 km^2 by 2036, and thus if the recharge rate is assumed to be that of a surface barrier (0.5 mm/yr), then it is possible that the plume area might not exceed 10 km^2 by the end of any of the three evaluation periods (Step 21 and GW Metric #3).

The nitrate plume already covers a large area (3.4 km^2) and is predicted to expand and cover a much larger area (>> 10 km^2) well before the end of the Active Cleanup period. The nitrate plume area is predicted to reach 10 km^2 by 2028, and thus even if the recharge rate is assumed to be that of a surface barrier (or 0.5 mm/yr), then it appears unlikely (because the nitrate plume is already so large and has been spreading) that the plume area would be less than 10 km^2 by the end of the Active Cleanup and thus all evaluation periods (Step 21 and GW Metric #3). More detailed statistical analysis of the data may be warranted in the future. The T Tank Farm EU results for the first three GW Metrics are summarized in Table E-11.

Table E-11. Summary of T Tank Farm Evaluation Unit Results for GW Metrics 1-3

		Active Cleanup (to 2064)		**Post-Cleanup Periods**					
	Primary Contaminant	**Currently at risk[(a)]**	**Active Cleanup**	**Near-Term Post-Cleanup (to 2164)**			**Long-term Post-Cleanup (to 3064)**		
Recharge rate (mm/y) →		50	50	0.5	5	50	0.5	5	50
Metric #1 Time (yr)	No additional PCs	--	0	0	0	0	0	0	0
Metrics#2&3 (area in km^2)	Tc-99	0.04	<<0.1	<<0.1	<<0.1	<<0.1	<<0.1	<<0.1	<< 0.1
	I-129	0.08	<<0.1	<<0.1	<<0.1	<<0.1	<<0.1	<<0.1	<< 0.1
	Chromium	0.11	>> 10	0.1< area <10	>> 10	>> 10	0.1< area <10	>> 10	>> 10
	Nitrate	3.4	>>10	>10	>10	>>10	>10	>10	>>10

(a) 2012 T Tank Farm results from Table E-10.

An ecological screening analysis was performed in the TC&WM EIS (Appendix P) to evaluate potential long-term impacts of radioactive and chemical contaminants (from all sources) discharged with groundwater on aquatic and riparian receptors at the Columbia River. From the evaluation summarized in the *Legacy Source Sites* section, chromium and nitrate are selected as ecological PCs.

The evaluation for potential impacts of chemical contaminants discharged with groundwater indicate that chromium and nitrate have expected Hazard Quotients exceeding unity for aquatic and riparian receptors for all tank closure alternatives during the 10,000-year assessment period used in the TC&WM EIS. However, the time to ecological impacts is not provided in the TC&WM EIS. An estimate of the distance the plume travels toward the Columbia River will be used to provide a rough estimate of the time that the contaminant plume might reach the river in sufficient concentration.

From the plume maps in the Hanford Annual Groundwater reports, the plumes appear to be roughly ellipsoidal and the largest of the aspect ratios (ratio of long axis, *a*, to short axis, *b*, of the plumes is approximately 6:1; a value of 10:1 will be used here. The area of an ellipse is:

$$A = \left(\frac{\pi}{4}\right) \mathrm{ab} \approx \left(\frac{\pi}{4}\right) \mathrm{a} \left(\frac{\mathrm{a}}{10}\right) = \left(\frac{\pi}{40}\right) \mathrm{a}^2$$

Thus the long axis of the plume is given by:

$$a \approx \sqrt{\frac{40A}{\pi}}$$

The difference in the long axis (and thus the longest distance that could be travelled toward the river) between time T_1 and T_2 is

$$\Delta a = \sqrt{\frac{40A(T_2)}{\pi}} - \sqrt{\frac{40A(T_1)}{\pi}}$$

The difference in plume areas, ΔA, as a function of time, ΔT, after 2006 was previously estimated using

$$\Delta A = \exp(\alpha \Delta \mathrm{T})$$

or

$$\Delta a = \sqrt{\frac{40exp[\alpha(T_2 - 2006)]}{\pi}} - \sqrt{\frac{40exp[\alpha(T_1 - 2006)]}{\pi}}$$

where T_1 is 2014. Using the plume growth parameters estimates for chromium and nitrate, α = 0.2 and 0.08, respectively, in the *Groundwater Plumes* section, the approximate times that chromium and nitrate plumes will reach the Columbia River are 2029 and 2062, respectively, using a distance of ~8-km from the T Tank Farm EU vicinity to the river. Because the chromium plume is predicted to discharge into the river at a high enough concentration well before the end of the Active Cleanup period, the arrival time is considered independent of the future recharge rate. However, it is possible for nitrate at lower future recharge rates that the plume may not discharge a significant flux to the river until after the Active Cleanup period; however, it is assumed that the nitrate flux will be sufficiently high during the longer evaluation periods.

The Hazard Quotient for aquatic biota exposed to chemical contaminants in nearshore surface water is given by (TC&WM EIS, Appendix P, p. P-47):

$$HQ = \frac{C_w}{TRV}$$

where both the nearshore surface-water concentration, C_w, and the toxicity reference value, *TRV*, are in milligrams per liter. The product (HQ•TRV) thus gives the nearshore concentration. The *TRV* for hexavalent chromium is 0.000266 mg/L (Suter 1996) and for nitrate is assumed to be 13 mg/L[17]. Thus the nearshore surface water concentration when the Hazard Quotient is unity (i.e., the Columbia River is first impacted) is the same as the *TRV*. The maximum Hazard Quotients for chromium and nitrate were 43.2 and 1.37, respectively, producing maximum predicted surface water concentrations of approximately 1.1×10^{-2} and 18 mg/L. It is assumed that the maximum nearshore surface water concentrations will approach these maximum values during the Long-Term Post-Cleanup period regardless of recharge rate. For the Near-Term Post-Cleanup period, it is assumed that the high recharge rate would result in the nearshore surface water concentration approaching the maximum estimated value. For lower recharge rates, it is assumed that the concentration may be closer to those when the river is first impacted.

[17] This value is the only one found in the Risk Assessment Information System (RAIS) at http://rais.ornl.gov/.

Table E-12. Summary of T Tank Farm Evaluation Unit Results for GW Metrics 4-6

		Active Cleanup (to 2064)		Post-Cleanup Periods					
	Primary Contaminant	Currently at risk	Active Cleanup	Near-Term Post-Cleanup (to 2164)			Long-term Post-Cleanup (to 3064)		
Recharge rate (mm/y)→		50	50	0.5	5	50	0.5	5	50
Metric #4 Time (yr)	Chromium	--	2029	<<2164	<<2164	<<2164	<<3064	<<3064	<<3064
	Nitrate	--	2062	~2064<time <2164	~2064<time <2164	<<2164	<<3064	<<3064	<<3064
Metric #5&6 C_w (mg/L)[a]	Chromium	--	3×10^{-4}	$\sim3\times10^{-4}<C_w<1.1\times10^{-2}$	$\sim3\times10^{-4}<C_w<1.1\times10^{-2}$	$<1.1\times10^{-2}$	$<1.1\times10^{-2}$	$<1.1\times10^{-2}$	$<1.1\times10^{-2}$
	Nitrate	--	13	$\sim13<C_w<18$	$\sim13<C_w<18$	<18	<18	<18	<18

(a) All groundwater discharge is assumed to occur in the 40-meter nearshore zone.

D&D of Inactive Facilities – Not applicable

Operating Facilities – Not applicable.

The Hanford single-shell tanks (SSTs) were declared a non-compliant treatment, storage, and disposal (TSD) facility under RCRA. Furthermore, Congress mandated a prohibition on waste additions to Hanford SSTs after January 1, 1981[18]. Because of the prohibition on waste additions to the Hanford SSTs, the T Tank Farm EU components are not considered Operating Facilities for this review.

Ecological Resources Setting

There are potential risks to ecological receptors from residual wastes in tanks after treatment and wastes in unlined trenches and contaminated vadose zone. Ecological risk from 200-ZP-1 OU (groundwater) contaminants is not anticipated because of the lack of direct or indirect exposure to groundwater by ecological receptors now or in the future (EPA 2008). However, there is risk to benthic and aquatic receptors from contaminated groundwater being discharged to the Columbia River.

Cultural Resources Setting

Being disturbed by the presence of the tanks and cribs, the T Tank Farm area itself has not been surveyed for archaeological resources. The ground surrounding T Tank Farm was addressed in a cultural resources report entitled *Archaeological Survey of the 200 East and 200 West Areas, Hanford Site* (Chatters and Cadoret 1990). The focus of this archaeological survey was on inventorying all undisturbed portions of the 200 East and 200 West Areas. This report concluded that much of the 200 East and 200 West Areas can be considered areas of low archaeological potential with the exception of intact portions of the White Bluffs Road corridor which runs through the 200 West Area. A non-

[18] Berman presentation on July 29, 2009, entitled "Hanford Single-Shell Tank Integrity Program." Available at www.em.doe.gov.

contributing and un-intact portion of the White Bluffs Road runs just to the north and west of the T Tank Farm Area. No archaeological sites have been recorded within the T Tank Farm Area.

The U.S. Department of Energy Richland Operations Office and the Washington State Historic Preservation Office designated the Manhattan Project and Cold War facilities of the Hanford Site a historic district eligible for listing in the National Register of Historic Places (NRHP) in 1996. The Hanford Site Plant Railroad System is located within close proximity to the T Tank Farm area. The railroad is a contributing element to the NRHP eligibility of the historic district. The Hanford Site Plant Railroad System has been mitigated as described in the *Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan* (DOE/RL-97-56). The Hanford Site Plant Railroad System was determined to be a contributing property to the historic district with documentation required under the treatment plan. A Historic Properties Inventory Form was completed to meet this documentation requirement. This information is based on data received as of the date of the document and may change as new information becomes available or is provided.

Economic Assets

No unique or unusual economic assets were identified associated with the T Tank Farm Evaluation Unit.

Infrastructure

The T Tank Farm EU is dependent on site utilities and facility access via the Hanford road network.

Part V. Waste and Contamination Inventory

Brief description of contaminated media and materials

What are the primary contaminants (risk drivers)?
This information was provided in the corresponding *Legacy Source*, *High-Level Waste Tanks and Ancillary Equipment*, and *Groundwater Plume* sections. The primary contaminants related to the Legacy Source and Groundwater units are chromium, Tc-99, I-129, and nitrate. Contaminants considered for the HLW Tanks and Ancillary Equipment are Cs-137 and Sr-90. The inventories for tritium, Pu isotopes, and U isotopes are provided because of their iconic status.

What is the physical state of the primary contaminants (e.g., adsorbed in contaminated soil, as debris, in subsurface piping)?
This information was provided in the corresponding *Legacy Source*, *High-Level Waste Tanks and Ancillary Equipment*, and *Groundwater Plume* sections.

Contamination within Primary EU Source Components

Table E-13 provides inventory estimates of the various source components associated with the T Tank Farm EU (TC&WM EIS, Appendices D and N). This information is further summarized in Figure E-19 (Tc-99 and I-129 as groundwater PCs), Figure E-20 (chromium and nitrate as groundwater and ecological PCs), and Figure E-21 (Sr-90 and Cs-137 as iconic contaminants) before and after planned 99% retrieval, respectively. For Tc-99 and I-129, the major sources before retrieval are the T Tank Farm tanks and leaks from these tanks. After retrieval, leaks dominate the sources for Tc-99 and I-129. For chromium and nitrate, both cribs and trenches and the T Tank Farm tanks are major sources before retrieval. After retrieval, the cribs and trenches dominate the source of these PCs. For Sr-90 and Cs-137, the tanks dominate the current inventory; after retrieval, the leaks dominate the remaining inventory.

Legacy Source Sites:

The estimated inventory for the Legacy Source Sites (cribs and trenches and soil contaminated by tank leaks) is provided in Table E-13 for those rows describing the vadose zone and saturated zone contamination related to intentional discharges to cribs and trenches. This information is further summarized in Figure E-19, Figure E-20, and Figure E-21 before and after planned 99% retrieval, respectively.

High Level Waste Tanks and Ancillary Equipment:

The estimated total inventory for all the T Tank Farm High Level Waste Tanks and Ancillary Equipment is provided in Table E-13 for those rows describing tank wastes and ancillary equipment. The tank-by-tank inventories are provided in Table E-14. This information is further summarized in Figure E-19, Figure E-20, and Figure E-21 before and after planned 99% retrieval, respectively.

Vadose Zone Contamination:

The estimated inventory for the vadose and saturated zone contamination is found in Table E-13 under the corresponding heading and includes both intentional discharges to cribs and trenches and leak estimates.

Groundwater Plumes:

The estimated inventory for the vadose and saturated zone contamination is provided in Table E-13 under the corresponding heading and includes both discharges to cribs and trenches and leak estimates. Figure E-5, Figure E-6, Figure E-7, and Figure E-8 show selected groundwater plumes (i.e., chromium, I-129, Tc-99, and nitrate, respectively) associated with the T Tank Farm and liquid waste disposal facilities.

Facilities for D&D:

Not applicable.

Operating Facilities:

Not applicable.

Table E-13. Summary Table of Infrastructure and Subsurface Contamination Inventory for the T Tank Farm Evaluation Unit

Contaminated Media	Primary Contaminants	90% Retrieval Scenario	99% Retrieval Scenario	Total amt. of each Contaminant before retrieval
Infrastructure (Tanks and Ancillary Equipment)				
Tank Wastes	Saltcake, Sludge, and Supernatant phases[h]	Waste 702 m^3 Saltcake 51.1 m^3 Sludge 641 m^3 Supernatant 10.1 m^3	Waste 70.2 m^3 Saltcake 5.11 m^3 Sludge 64.1 m^3 Supernatant 1.01 m^3	Total Waste 7,024 m^3 Saltcake 511 m^3 Sludge 6,412 m^3 Supernatant 101 m^3
Tank Waste (Radioactive, 2002)[a]	Tritium (H-3) Sr-90 Tc-99 I-129 Cs-137 U-233,-234,-235,-238 (∑U) Pu-239, -240 (∑Pu)	H-3 3.42 Ci Sr-90 3.72×10^{4} Ci Tc-99 1.63×10^{1} Ci I-129 1.14×10^{-2} Ci Cs-137 1.65×10^{4} Ci ∑U 2.59 Ci ∑Pu 1.43×10^{2} Ci	H-3 3.42×10^{-1} Ci Sr-90 3.72×10^{3} Ci Tc-99 1.63 Ci I-129 1.14×10^{-3} Ci Cs-137 1.65×10^{3} Ci ∑U 2.59×10^{-1} Ci ∑Pu $1.43\times10^{+1}$ Ci	H-3 3.42×10^{1} Ci Sr-90 3.72×10^{5} Ci Tc-99 1.63×10^{2} Ci I-129 1.14×10^{-1} Ci Cs-137 1.65×10^{5} Ci ∑U 2.59×10^{1} Ci ∑Pu 1.43×10^{3} Ci
Tank Waste (Non-radioactive)[a]	Chromium (Cr) Nitrate (NO3) Uranium (U)	Cr 1.21×10^{3} kg NO3 7.47×10^{4} kg U 3.72×10^{3} kg	Cr 1.21×10^{2} kg NO3 7.47×10^{3} kg U 3.72×10^{2} kg	Cr 1.21×10^{4} kg NO3 7.47×10^{5} kg U 3.72×10^{4} kg
Ancillary Equipment (Radioactive, 2002)[b]	Tritium (H-3) Sr-90 Tc-99 I-129 Cs-137 U-233,-234,-235,-238 (∑U) Pu-239, -240 (∑Pu)	H-3 4.58×10^{-1} Ci Sr-90 4.98×10^{3} Ci Tc-99 2.18 Ci I-129 1.52×10^{-3} Ci Cs-137 2.20×10^{3} Ci ∑U 3.47×10^{-1} Ci ∑Pu 1.92×10^{1} Ci	H-3 4.58×10^{-1} Ci Sr-90 4.98×10^{3} Ci Tc-99 2.18 Ci I-129 1.52×10^{-3} Ci Cs-137 2.20×10^{3} Ci ∑U 3.47×10^{-1} Ci ∑Pu 1.92×10^{1} Ci	H-3 4.58×10^{-1} Ci Sr-90 4.98×10^{3} Ci Tc-99 2.18 Ci I-129 1.52×10^{-3} Ci Cs-137 2.20×10^{3} Ci ∑U 3.47×10^{-1} Ci ∑Pu 1.92×10^{1} Ci
Ancillary Equipment (Non-radioactive)[b]	Chromium (Cr) Nitrate (NO3) Uranium (U)	Cr 1.62×10^{-1} kg NO3 9.98 kg U 4.97×10^{-1} kg	Cr 1.62×10^{-1} kg NO3 9.98 kg U 4.97×10^{-1} kg	Cr 1.62×10^{-1} kg NO3 9.98 kg U 4.97×10^{-1} kg

EU Designation: T Tank Farm (CP-TF-1)

DRAFT for Methodology Illustration

Contaminated Media	Primary Contaminants	90% Retrieval Scenario	99% Retrieval Scenario	Total amt. of each Contaminant before retrieval
Vadose Zone Source (Leaks and Intentional Discharges into Cribs and Trenches)				
Leaks from T Tank Farm Waste Tanks (Radioactive, 2002)(c)	Tritium (H-3) Sr-90 Tc-99 I-129 Cs-137 U-233,-234,-235,-238 (∑U) Pu-239, -240 (∑Pu)	H-3 5.33×10^{1} Ci Sr-90 2.43×10^{4} Ci Tc-99 6.74×10^{1} Ci I-129 1.30×10^{-1} Ci Cs-137 2.49×10^{4} Ci ∑U 3.49×10^{-1} Ci ∑Pu 1.28×10^{1} Ci	H-3 5.33×10^{1} Ci Sr-90 2.43×10^{4} Ci Tc-99 6.74×10^{1} Ci I-129 1.30×10^{-1} Ci Cs-137 2.49×10^{4} Ci ∑U 3.49×10^{-1} Ci ∑Pu 1.28×10^{1} Ci	H-3 5.33×10^{1} Ci Sr-90 2.43×10^{4} Ci Tc-99 6.74×10^{1} Ci I-129 1.30×10^{-1} Ci Cs-137 2.49×10^{4} Ci ∑U 3.49×10^{-1} Ci ∑Pu 1.28×10^{1} Ci
Leaks from T Tank Farm Waste Tanks (Non-radioactive)(c)	Chromium (Cr) Nitrate (NO3) Uranium (U)	Cr 1.10×10^{3} kg NO3 6.74×10^{4} kg U 3.82×10^{2} kg	Cr 1.10×10^{3} kg NO3 6.74×10^{4} kg U 3.82×10^{2} kg	Cr 1.10×10^{3} kg NO3 6.74×10^{4} kg U 3.82×10^{2} kg
Intentional Discharges into Cribs (Radioactive, 2002)(d)	Tritium (H-3) Sr-90 Tc-99 I-129 Cs-137 U-233,-234,-235,-238 (∑U) Pu-239, -240 (∑Pu)	H-3 1.00×10^{-1} Ci Sr-90 3.96×10^{2} Ci Tc-99 2.05×10^{-1} Ci I-129 1.49×10^{-5} Ci Cs-137 4.60×10^{2} Ci ∑U 2.45×10^{-1} Ci ∑Pu 2.81×10^{2} Ci	H-3 1.00×10^{-1} Ci Sr-90 3.96×10^{2} Ci Tc-99 2.05×10^{-1} Ci I-129 1.49×10^{-5} Ci Cs-137 4.60×10^{2} Ci ∑U 2.45×10^{-1} Ci ∑Pu 2.81×10^{2} Ci	H-3 1.00×10^{-1} Ci Sr-90 3.96×10^{2} Ci Tc-99 2.05×10^{-1} Ci I-129 1.49×10^{-5} Ci Cs-137 4.60×10^{2} Ci ∑U 2.45×10^{-1} Ci ∑Pu 2.81×10^{2} Ci
Intentional Discharges into Cribs (Non-radioactive)(d)	Chromium (Cr) Nitrate (NO3) Uranium (U)	Cr 2.93×10^{4} kg NO3 6.79×10^{6} kg U 3.63×10^{2} kg	Cr 2.93×10^{4} kg NO3 6.79×10^{6} kg U 3.63×10^{2} kg	Cr 2.93×10^{4} kg NO3 6.79×10^{6} kg U 3.63×10^{2} kg
Intentional Discharges into Trenches (Radioactive, 2002)(d)	Tritium (H-3) Sr-90 Tc-99 I-129 Cs-137 U-233,-234,-235,-238 (∑U) Pu-239, -240 (∑Pu)	H-3 5.15×10^{3} Ci Sr-90 3.41×10^{2} Ci Tc-99 9.41×10^{-1} Ci I-129 8.28×10^{-3} Ci Cs-137 1.82×10^{3} Ci ∑U 1.35×10^{-1} Ci ∑Pu 1.47×10^{1} Ci	H-3 5.15×10^{3} Ci Sr-90 3.41×10^{2} Ci Tc-99 9.41×10^{-1} Ci I-129 8.28×10^{-3} Ci Cs-137 1.82×10^{3} Ci ∑U 1.35×10^{-1} Ci ∑Pu 1.47×10^{1} Ci	H-3 5.15×10^{3} Ci Sr-90 3.41×10^{2} Ci Tc-99 9.41×10^{-1} Ci I-129 8.28×10^{-3} Ci Cs-137 1.82×10^{3} Ci ∑U 1.35×10^{-1} Ci ∑Pu 1.47×10^{1} Ci
Intentional Discharges into Trenches (Non-radioactive)(d)	Chromium (Cr) Nitrate (NO3) Uranium (U)	Cr 2.61×10^{3} kg NO3 8.13×10^{5} kg U 2.00×10^{2} kg	Cr 2.61×10^{3} kg NO3 8.13×10^{5} kg U 2.00×10^{2} kg	Cr 2.61×10^{3} kg NO3 8.13×10^{5} kg U 2.00×10^{2} kg

EU Designation: T Tank Farm (CP-TF-1)

DRAFT for Methodology Illustration

Contaminated Media	Primary Contaminants	90% Retrieval Scenario	99% Retrieval Scenario	Total amt. of each Contaminant before retrieval
Saturated Zone (from Vadose Zone Sources)				
Leaks from T Tank Farm Waste Tanks (Radioactive, 2002)[e]	Tritium (H-3) Tc-99 I-129 U-238	H-3 6.30 Ci Tc-99 6.74×10^{1} Ci I-129 1.30×10^{-1} Ci U-238 3.10×10^{-2} Ci	H-3 6.30 Ci Tc-99 6.74×10^{1} Ci I-129 1.30×10^{-1} Ci U-238 3.10×10^{-2} Ci	H-3 6.30 Ci Tc-99 6.74×10^{1} Ci I-129 1.30×10^{-1} Ci U-238 3.10×10^{-2} Ci
Leaks from T Tank Farm Waste Tanks (Non-radioactive)[e]	Chromium (Cr) Nitrate (NO3) Uranium (U)	Cr 1.10×10^{3} kg NO3 6.75×10^{4} kg U 3.52×10^{1} kg	Cr 1.10×10^{3} kg NO3 6.75×10^{4} kg U 3.52×10^{1} kg	Cr 1.10×10^{3} kg NO3 6.75×10^{4} kg U 3.52×10^{1} kg
Discharges to T Cribs and Trenches (Radioactive, 2002)[f]	Tritium (H-3) Tc-99 I-129 U-238	H-3 3.04×10^{4} Ci Tc-99 1.17 Ci I-129 8.39×10^{-3} Ci U-238 2.13×10^{-2} Ci	H-3 3.04×10^{4} Ci Tc-99 1.17 Ci I-129 8.39×10^{-3} Ci U-238 2.13×10^{-2} Ci	H-3 3.04×10^{4} Ci Tc-99 1.17 Ci I-129 8.39×10^{-3} Ci U-238 2.13×10^{-2} Ci
Discharges to T Cribs and Trenches (Non-radioactive)[f]	Chromium (Cr) Nitrate (NO3) Uranium (U)	Cr 4.54×10^{4} kg NO3 1.08×10^{7} kg U 3.21×10^{1} kg	Cr 4.54×10^{4} kg NO3 1.08×10^{7} kg U 3.21×10^{1} kg	Cr 4.54×10^{4} kg NO3 1.08×10^{7} kg U 3.21×10^{1} kg
Other Sources (Radioactive, 2002)[g]	Tc-99 I-129 U-238	Tc-99 1.60×10^{2} Ci I-129 1.13×10^{-1} Ci U-238 5.50×10^{-1} Ci	Tc-99 1.60×10^{2} Ci I-129 1.13×10^{-1} Ci U-238 5.50×10^{-1} Ci	Tc-99 1.60×10^{2} Ci I-129 1.13×10^{-1} Ci U-238 5.50×10^{-1} Ci
Other Sources (Non-radioactive)[g]	Chromium (Cr) Nitrate (NO3) Uranium (U)	Cr 1.20×10^{4} kg NO3 7.34×10^{5} kg U 7.92×10^{2} kg	Cr 1.20×10^{4} kg NO3 7.34×10^{5} kg U 7.92×10^{2} kg	Cr 1.20×10^{4} kg NO3 7.34×10^{5} kg U 7.92×10^{2} kg

a. TC&WM EIS, p. D-6 for radioactive (Rad) and D-8 for non-radioactive (Non-rad) constituents in tank wastes (decayed to 2002).

b. TC&WM EIS, p. D-17 for radioactive (Rad) and non-radioactive (Non-rad) constituents in ancillary equipment.

c. TC&WM EIS, p. D-28 for radioactive (Rad) and non-radioactive (Non-rad) constituents associated with waste tank leaks.

d. TC&WM EIS, p. D-31 for radioactive (Rad) and non-radioactive (Non-rad) constituents intentionally discharged into cribs and trenches.

e. TC&WM EIS, p. N-27 for radioactive (Rad) and non-radioactive (Non-rad) constituents associated with waste tank leaks. No action alternative.

f. TC&WM EIS, p. N-48 for radioactive (Rad) and non-radioactive (Non-rad) constituents associated with discharges to cribs and trenches. No action alternative.

g. TC&WM EIS, p. N-59 for radioactive (Rad) and non-radioactive (Non-rad) constituents associated with other tank farm sources (e.g.,). No action alternative.

h. The T Tank Farm tanks were estimated to have 0 m^3 of retained gas (DOE/ORP-2003-02, Rev. 0, p. 6-8).

Table E-14. Current Primary Contaminant Inventory and Steady State Flammability Results (by Tank) for the T Tank Farm

			Inventory (kGal) [(a)]				Days to 25% LFL	Days to 25% LFL	**Inventory** [(b)]					
Tank ID	Tank Type	Capacity (kGal)	Sludge	Salt-cake	Super-natant	HGR[(c)] (ft^3/d)	barom[(d)]	zero vent[(e)]	Cs-137 (Ci)	I-129 (Ci)	Sr-90 (Ci)	Tc-99 (Ci)	Cr (kg)	Nitrate (kg)
T-101	SST	530	37	62	0	0.41	NA	>1826	3.58E+04	3.55E-02	3.50E+02	3.44E+01	5.73E+02	1.20E+05
T-102	SST	530	19	0	13	0.84	NA	1226	4.19E+03	1.94E-02	1.51E+04	7.13E+00	1.48E+02	8.16E+03
T-103	SST	530	23	0	4	0.33	NA	>1826	3.65E+02	1.37E-02	6.31E+02	2.28E+00	6.76E+01	4.48E+03
T-104	SST	530	317	0	0	0.50	NA	1369	2.19E+02	5.10E-04	2.85E+03	9.74E-01	1.39E+03	8.97E+04
T-105	SST	530	98	0	0	0.44	NA	>1826	4.56E+03	2.07E-05	2.55E+04	3.50E+01	8.75E+02	1.25E+04
T-106	SST	530	22	0	0	0.32	NA	>1826	1.82E+03	7.73E-05	5.94E+02	2.85E+00	1.18E+02	1.61E+04
T-107	SST	530	173	0	0	0.59	NA	1436	1.37E+04	5.94E-03	9.33E+04	4.83E+01	4.24E+02	7.21E+04
T-108	SST	530	5	11	0	0.32	NA	>1826	5.73E+02	1.21E-04	1.49E+02	7.72E-01	2.95E+01	2.60E+04
T-109	SST	530	0	62	0	0.34	NA	>1826	7.51E+02	4.20E-04	9.20E+01	3.02E-01	3.13E+01	1.33E+04
T-110	SST	530	369	0	1	1.2	NA	475	2.37E+01	2.58E-07	4.33E+01	1.22E-03	1.96E+03	1.05E+05
T-111[(f)]	SST	530	447	0	0	0.60	NA	844	1.95E+02	1.47E-07	7.77E+03	1.66E+01	3.51E+03	1.22E+05
T-112	SST	530	60	0	7	0.35	NA	>1826	1.90E+02	1.25E-03	3.15E+01	2.12E+00	6.29E+02	5.64E+03
T-201	SST	55	28	0	2	0.21	304	166	2.83E+00	7.77E-10	8.57E+00	1.75E-06	5.90E+02	6.50E+03
T-202	SST	55	20	0	0	0.063	NA	748	5.61E-01	0.00E+00	1.85E-01	1.65E-06	2.93E+02	5.60E+03
T-203	SST	55	36	0	0	0.094	NA	294	1.01E+00	0.00E+00	3.34E-01	2.96E-06	5.88E+02	9.73E+03
T-204	SST	55	36	0	0	0.094	NA	294	1.00E+00	0.00E+00	5.88E-01	3.00E-06	7.39E+02	9.08E+03

a. Volumes from the most recent liquid waste system plan (Certa, et al. 2011).
b. From Best Basis Inventory (BBI) Summary (March 24, 2014) provided in spreadsheet form by Mark Triplett.
c. Hydrogen generation rate (ft^3/d) (RPP-5926 Rev. 14, p. 25). Note in 2001 all 24 tanks were removed from the flammable gas watch list (including T-110 in the T Tank Farm EU) (Johnson, et al. 2001, p. iii).
d. Time (in days) to 25% of the Lower Flammability Limit (LFL) under a barometric (barom) breathing scenario (RPP-5926, Rev. 14, p. 19). "NA" indicates that the headspace will not reach specified flammability level.
e. Time (in days) to 25% of the LFL under a zero ventilation scenario (RPP-5926, Rev. 14, p. 22).
f. Tank T-111 has 10 times the total organic carbon in the waste compared to other T Farm tanks. High organic carbon has been linked to the formation of gas (Washenfelder 2013, p. 36).

EU Designation: T Tank Farm (CP-TF-1)

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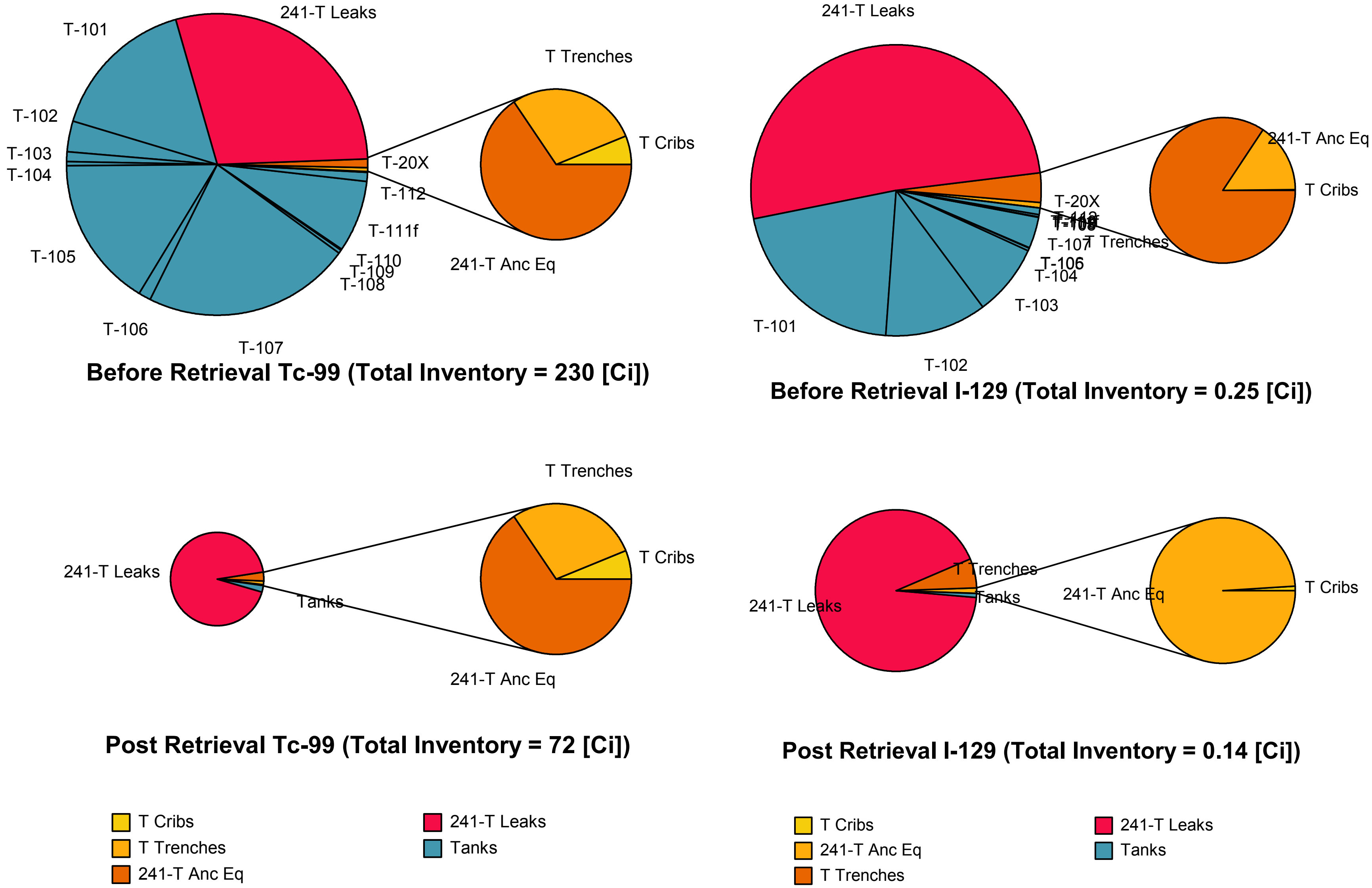

Figure E-19. T Tank Farm Evaluation Unit Inventory Estimates for Tc-99 and I-129 Before and After 99% Retrieval

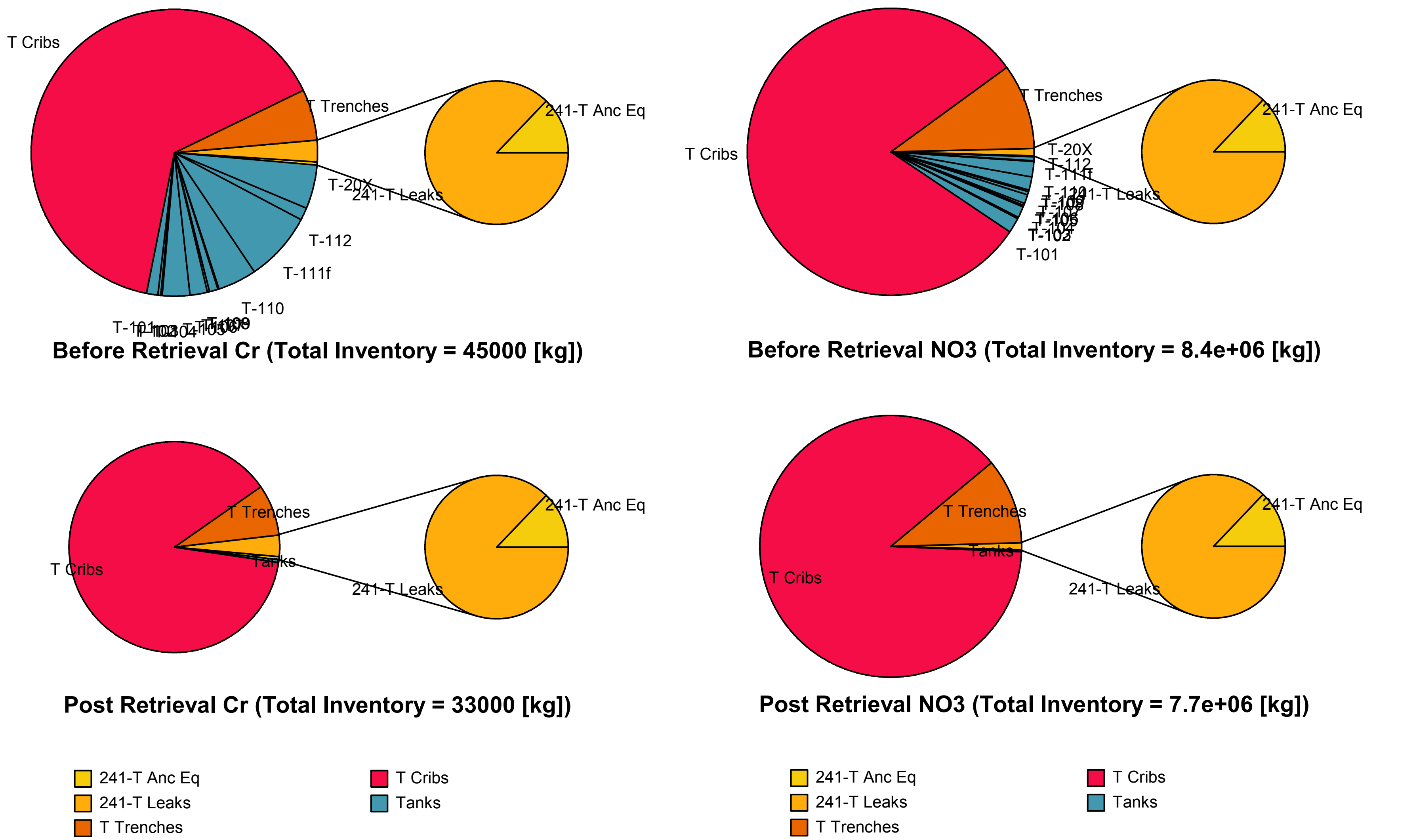

Figure E-20. T Tank Farm Evaluation Unit Inventory Estimates for Chromium and Nitrate Before and After 99% Retrieval

EU Designation: T Tank Farm (CP-TF-1)

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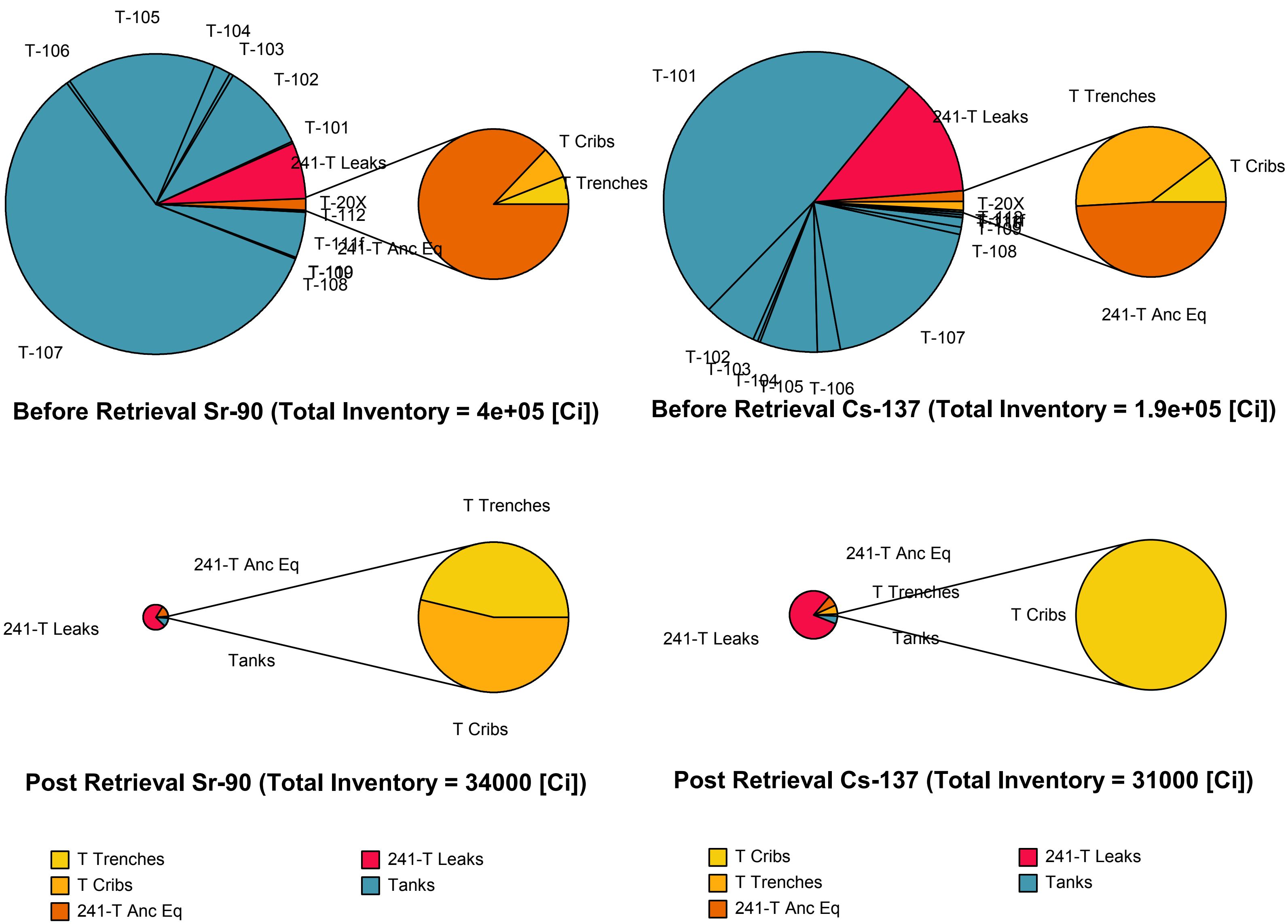

Figure E-21. T Tank Farm Evaluation Unit Inventory Estimates for Sr-90 and Cs-137 Before and After 99% Retrieval

Part VI. Potential Risk/Impact Pathways and Events

Current Conceptual Model

Narrative description of pathways and barriers to receptors and conditions/events that can lead to completed pathways

Pathways and Barriers: (1. description of institutional, natural and engineered barriers (including material characteristics) that currently mitigate or prevent risk or impacts, 2. Time scale from loss of each barrier to realization of risk or impacts)

Briefly describe the current institutional, engineered and natural barriers that prevent release or dispersion of contamination, risk to human health and impacts to resources:

What are the current barriers to release or dispersion of contamination from the primary facility? What is the integrity of each of these barriers? Are there completed pathways to receptors or are such pathways likely to be completed during the evaluation period?

In general, the Tank Farm Vadose Zone Program implemented several interim measures to mitigate impacts from past tank farm leaks and discharges (i.e., limiting contaminant mobility by controlling the amount of water introduced into the shallow vadose zone): (DOE/ORP-2008-01, p. 11-1)

- Installation of well caps on dry wells
- Decommissioned monitoring wells and drywells
- Tested and decommissioned waterlines
- Construction of surface water control measures (berms and gutters)
- Construction of surface barriers.

The T Tank Farm tanks themselves are the primary barriers to the further spread of tank waste contaminants to the environment (albeit waste has leaked in the past). The barriers represented by the tanks are then coupled with the large vadose zone (~64-71 meters (Hartman 2000, p. 4.12)) and travel through the saturated zone to off-site areas (e.g., Columbia River) where receptors could be exposed. Restrictions on use of site groundwater also represent a barrier to exposure. Because of relatively long travel times, natural attenuation of the radionuclides with relatively short half-lives (when compared to travel times) is also a barrier. Furthermore, the large flow in the Columbia River tends to dilute the concentration of any contaminants to which receptors might be exposed via the surface water pathway.

There are several assumed leakers in the T Tank Farm that may represent incomplete barriers (e.g., T-111) to additional liquid phase contaminant release into the shallow vadose zone around the tanks. However, much of the liquid waste has been transferred from the T Tank Farm to DSTs. Past waste management practices have also reduced the effectiveness of the tanks as barriers. Over 450×10^6 liters of liquid waste that cascaded through underground storage tanks (including all 200-West tanks) and 65,000 curies (decayed through December 1989) were discharged to the vadose zone via cribs, trenches, and french drains (Waite 1991). Because of the large liquid volume discharged, the entire soil column beneath many disposal sites in the 200 Areas became saturated (Hartman 2000) resulting in the breakthrough of mobile contaminants (e.g., chromium, I-129, nitrate, and Tc-99) from the soil column to groundwater. The cascade practice was discontinued 30+ years ago; however, the residual contaminated liquid retained in soil pore spaces (from past discharges) continues to be a long-term, secondary source of groundwater contamination (Hartman 2000). Contaminant transport would be exacerbated if a significant moisture source is present in the future (e.g., enhanced infiltration from unfavorable topography, removal of vegetation, or leaking water line) (Hartman 2000).

Infiltrating water is the major driving force transporting contaminants through the vadose zone to groundwater. Because Hanford tank farms are located in depressions (allowing gravity to carry waste from separation plants to tank farms), water has often collected over the tank farms. Berms and gutters were installed to divert water away from the tank farms and reduce infiltration. Water lines have also been tested for integrity for use, and those not needed have been capped outside of the tank farms.

A major interim measure consisting of an interim barrier of polyurea has been installed over the subsurface plume from Tank T-106 (Zhang, et al. 2011, p. vi), which is the largest known tank leak at the Hanford Site. The interim barrier, designed for 30 years, will allow waste retrieval while preventing additional moisture from entering the soil in the area over the plume. The interim barrier was installed in 2008, and monitoring results indicate that it has performed as expected by intercepting meteoric water from infiltrating into the soil; the soil has become gradually drier (Zhang, et al. 2011, p. vii).

The rapid appearance and increase of Tc-99 concentrations near the WMAs T and TX-TY caused DOE (with regulator concurrence) to begin extracting groundwater from wells in September 2007, which has contained the plume to a localized region. The measured concentration declined after pumping began (Figure E-22) because the high concentration portion of the groundwater is mixed with relatively uncontaminated groundwater lower in the screened interval. Since 2007, the interim P&T system has extracted 82 grams (1.4 Ci) of Tc-99, 193 kilograms of carbon tetrachloride, 14.5 kilograms of chromium, 732 grams of trichloroethene, and 85,000 kilograms of nitrate from the saturated zone near WMAs T and TX-TY (DOE/RL-2013-22, Rev. 0). The P&T system has room for additional extraction and treatment capacity and may be used to treat uranium plumes in the future.

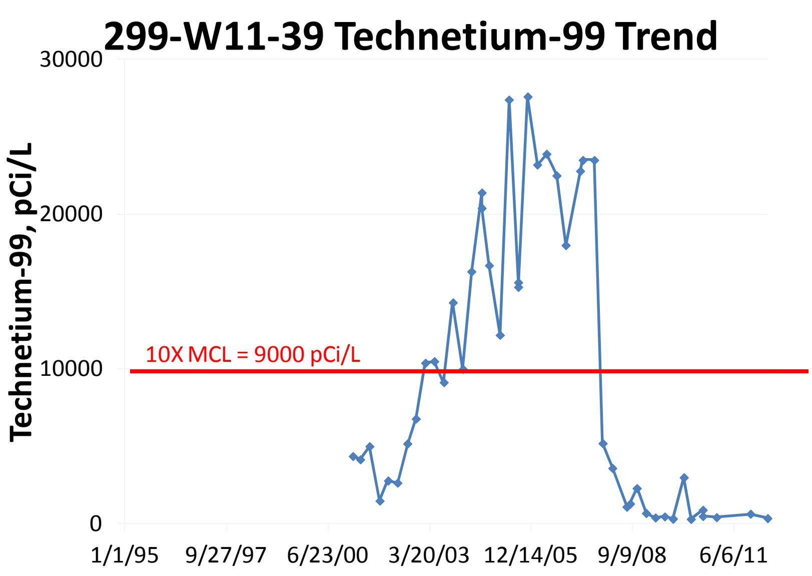

Figure E-22. Tc-99 Trend before and after P&T system operation[19]

[19] Personal communication from Triplett.

There are complete pathways to regular and co-located workers to vapors from the T Tank Farm and external radiation exposure. The vadose zone pathway from T Tank Farm sources to the saturated zone (receptor) is complete for primary contaminants (chromium, Tc-99, I-129, and nitrate). Nitrate and chromium may reach the Columbia River (receptor) during any of the evaluation periods in concentrations that may impact aquatic receptors (Table E-12).

What forms of initiating events may lead to degradation or failure of each of the barriers?
The various barriers and potential degradation and/or failure modes for the T Tank Farm EU include:

- *Tanks as primary barriers* – The HLW tanks, that represent the primary barriers to significant tank waste release, were originally built for limited operations. Past practices including the intentional discharge of tank waste liquids (at least some of which is retained in vadose zone pore spaces) may present a larger and much more uncertain source than leaks and even current tank waste for some constituents. However, there is an increased likelihood that there could be additional or increased leaking for those T Tank Farm tanks storing liquids as the tanks age. Both accidents and degradation/aging processes could lead to eventual tank failure. For example, a series of possible accidents involving SSTs were evaluated in the DSA (RPP-13033 Rev. 5-D). There may also be unplanned excavation or drilling in the areas near the tank farm that could disturb contaminated soil. The DSA indicates that the flammable gas accident, waste transfer leak, air blow accident, and release from a contaminated facility would be anticipated without controls. With controls, only an air blow accident would be anticipated during waste transfer (resulting in tank waste release from a HIHTL primary hose assembly and connected waste transfer primary piping system) (RPP-13033 Rev. 5-D). A specific analysis of the structural integrity of 241-C-106 (SST) was also made for *in situ* load conditions (WHC-SD-W320-ANAL-0001, Rev. 0). In this study, tank failure modes fell into two categories: local (concrete cracking and spallation, shear failures, and crushing and rebar bond and splice failures) and global (structural instability associated with either collapse or buckling). However, based on the structural integrity assessment and evaluations of possible degradation mechanisms, the SSTs have been declared structurally adequate (RPP-10435, Rev. 0).

- *Vadose zone/saturated zone* – The thick vadose zone under the T Tank Farm EU and generally arid climate result in natural infiltration rates of between less than detection to more than 100 mm/yr (RPP-13033 Rev. 5-D). Present conditions (e.g., bare ground and coarse sand and gravel surfaces) in and around the tank farms are conducive to higher infiltration rates than would be expected on undisturbed ground within the 200 Areas. Thus the vadose zone is currently acting as both a barrier and, in some areas, a secondary source for tank waste contaminants. Episodic groundwater recharge may occur following periods of high precipitation, especially if combined with topographic depressions, highly permeable surface deposits such as gravel, and where the land is denuded of vegetation (RPP-13033 Rev. 5-D), which would also increase infiltration through the vadose zone. The vadose and saturated zones have been contaminated from the T Tank Farm EU wastes; however, the travel times from the waste tanks to potential receptors has been sufficiently long that no off-site receptors are known to have been exposed.

- *Berms and gutters* – The berms and gutters are currently intact. The berms and gutters could be impacted by human errors (e.g., vehicular traffic) or changes in surface drainage patterns and resulting erosion of the berms and filling of the gutters with soil.

- *Water lines* – None expected.

- *Interim barrier* – The interim barrier of polyurea in 241-T Tank Farm has a 30-yr design life. However, this barrier has needed periodic maintenance since installation and is difficult to install and repair.

What are the primary pathways and populations or resources at risk from this source?

The primary pathway represented is release from the T Tank Farm EU HLW tanks and ancillary equipment (primary sources) and legacy source sites including cribs, trenches, and contaminated vadose zone (exposure medium and secondary source) through the vadose zone (medium) to the saturated zone (medium and receptor) to the Columbia River (medium and receptor) to various biological and human receptors (receptors) that can be potentially exposed by external radiation and dermal, inhalation (vapors), or ingestion routes. There are current restrictions on Hanford groundwater use so this path is not currently complete and considered to remain under federal control in perpetuity.

There are complete pathways for the exposure of ecological receptors to vadose zone contaminants in the legacy source areas around the T Tank Farm EU. Mitigation efforts (e.g., pump-and-treat, surface water control, interim capping) are underway to reduce contaminant migration and potential exposure to ecological receptors. There will also be other possible pathways (ingestion, external radiation and dermal, inhalation) from residual wastes to human and ecological receptors after institutional controls are lifted.

What is the time frame from each of the initiating events to human exposure or impacts to resources?
The primary (tank wastes via leaking) and secondary sources (vadose zone pore spaces from legacy sources) are releasing contaminants into the Hanford subsurface environment. However, the tanks still represent a major barrier to additional large-scale contaminant release and there are interim measures (e.g., pump-and-treat, surface water control, interim capping) underway to mitigate additional transport of materials. The typical initiating events including likelihood and impacts related to HLW tanks are provided in Table E-15 (from Chapter 4, Table 4-4). The four events (i.e., flammable gas accident, waste transfer leak, air blow accident, and release from a contaminated facility) from the DSA (RPP-13033 Rev. 5-D) that would be anticipated without controls and the iconic nuclear criticality accident are appended to Table E-15.

The relatively long residence times in the Hanford saturated zone are consistent with recharge conditions for a semi-arid site; however, there is variation in expected residence times (PNNL-6415 Rev. 18, p. 4-72). Groundwater travel time from the 200 East Area to the Columbia River is relatively fast, ~10-30 years because of 1) the large recharge volume from wastewater disposed in the 200 Areas between 1944 and mid-1990s and 2) the relatively high permeability of Hanford formation sediments (that are below the water table). Travel time from the 200 West Area is longer because of the lower permeability of Ringold Formation sediments. Groundwater from the 200 West Area has moved about 6 km (3.7 mi) during the past 50 years (or approximately 0.1 km/yr). Travel times from the 200 Areas to the Columbia River are expected to decrease because of the reduced hydraulic gradient from the discontinued wastewater recharge in the 200 Areas.

Are there current on-going releases to the environment or receptors?
Seven of the 16 T Tank Farm tanks are assumed leakers and thus there may be on-going releases to the vadose zone from the HLW tanks. There are also on-going releases from secondary sources (cribs, trenches, and soil contaminated by tank leaks) to the vadose and saturated zones.

Table E-15. Typical Initiating Events and Consequences for High-Level Waste Tanks (adapted from *Chapter 4, Table 4-4* and *SST Documented Safety Analysis (RPP-13033 Rev. 5-D)*)

	Likelihood[e]/Impact[f]			
EVENT [reference]	**Active**	**Near**	**Long**	**Discussion**
Human errors	A/L	NA	NA	Includes events involving mechanical movements - drops or impacts onto a waste tank system. Misroutes of material (feed) resulting in spills overflows.
	U/M	NA	NA	Typically these errors would be associated with failure of formal Regulatory or Safety Management Program (e.g., Criticality Safety Program).
Fires	A/L	U/L	A/L	Local fires prior to initiation of suppression. Range Fires may impact barriers but would most likely only result in infiltration issues.
	U/M	NA	NA	Building/Infrastructure Fires (with failure of suppression)
Failures of industrial grade active systems	A/M	NA	NA	Loss of motive force (pumps, compressed air, ventilation). Usually restricted to 1 shift. Pressure boundary (gaskets, pumps) failure
Loss of Power	A/L	NA	NA	(Short duration) Active failures (breaker trips, offsite power). Can initiate loss of multiple active systems (Normal operating systems). Loss of monitoring not assumed to lead to failure of barrier.
	U/ L, M, H	NA	NA	(Long duration) Failure in switchgear substations, regional loss of power events (blackouts). May challenge robust engineered systems even with backup power available.
Explosions	A/L	EU/L	U/L	Accumulation in unvented container (diversion box, inactive piping system). Post Cleanup it is unlikely that accumulation (flammable mixture) would occur.
	U/M	NA	NA	Accumulation in actively vented tank system with active mitigation
Failures of Robust system	A/L	NA	NA	Pressure Boundary failures resulting in leaks and spills for non-maintained systems
	U/L, M	NA	NA	Failure of active redundant (safety) systems Pressure Boundary failures resulting in leaks and spills for maintained systems or catastrophic failure of systems
Loss of Institutional Controls	EU/L	U/L	A/L	For Long Term Post-cleanup period assumes no control.
Loss of Engineering Controls	U/L	U/L	EU/M	For Post-cleanup period see Structural Decay.
Dam Failure (flooding) [a]	NA	NA	NA	Tanks above maximum flood level.
Plane Crash[c]	EU/M	EU/L	EU/L	EU (light aviation) Significant damage to single System.
	BEU/H	EU/L	EU/L	(Commercial carriers). Significant damage to Facility/ multiple Systems.
Structural Decay	U/L	A/L	A/M	Failure of barrier exposed to environs assumes human intervention (maintenance & repair) during Active Cleanup phase and no/minimal human intervention in the Post Cleanup Phases.

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EVENT (reference)	Likelihood(e)/Impact(f) Active	Near	Long	Discussion
Earthquake (b)	A/M	U/M	U/M	Failure of normal ("non-safety") Structures/Systems exposed to seismic loads.
	U/M, H	U/M	U/M	Failure of robust ("safety") Structures/Systems exposed to seismic loads. Offsite impact would require multiple failures.
Winds(b)	A/M	A/L	A/L	Failure of normal ("non-safety") Structures/Systems exposed to 91 mph peak, 115 mph ultimate- peak wind speeds. For Post-Cleanup – assumes erosion resulting in loss of barrier with water infiltration)
	U/M	NA	NA	Failure of robust ("safety") Structures/Systems exposed to 100 mph peak, 129 mph ultimate-peak wind speeds. Offsite impact would require multiple failures.
Tornado(b)	EU/H	NA	NA	Failure of Facilities and Exposed structures. Loss of Power. Not included in Hanford Site Design Criteria.
Snow Load/ Icing(b)	U/M	NA	NA	Failure of barriers from structural loading >15 lbs/ft^2
Ash Fall (Volcanic) (b)	U-EU/ M, H	NA	NA	Failure of barriers from structural loading (12-23 lbs/ft^2) and from airborne concentration leading to plugging, electrical shorting, loss of power (1325 - 2650 mg/m^3). Offsite impact would require multiple failures.
Flood (Local Storm-rainfall)(b)	A/L	A/L	A/L	Failure of barriers due to potential intrusion/accumulation for 100-yr (2 inches) rainfall
	U/L	U/L	U/L	Failure of barriers due to potential intrusion/accumulation for 1000-yr (2.7 inches) rainfall
River Flood(b)	U/L	NA	NA	200 Area (southwestern) Cold Creek Drainage area, for Elevations < 640 ft.
Flammable Gas Accident(d)	A/M EU/M	NA NA	NA NA	Flammable gas deflagration in waste storage vessels/containers (ranging from DSTs to SSTs to waste packaging drums).
Nuclear Criticality(d)	BEU/M BEU/M	NA NA	NA NA	Nuclear criticality in waste tanks/vessels. Near- and long-term assessments based on 99% retrieval of tank wastes assuming < critical mass remaining.
Waste Transfer Leak(d)	A/H EU/L	NA NA	NA NA	Involves a broad spectrum of waste leaks. The bounding event is a fine spray leak using a high head waste transfer pump.
Release from Contaminated Facility(d)	A/M EU/M	NA NA	NA NA	Involves release mechanisms (i.e., flammable gas deflagrations, fires, load handling accidents, or compressed gas system failures) in contaminated facilities. Bounding event is a flammable gas deflagration in a waste transfer-associated structure.
Air Blow Accident(d)	A/M A/L	NA NA	NA NA	Involves a waste release from a contaminated HIHTL primary hose assembly and connected waste transfer primary piping system that is pressurized by compressed air.

a. RLO-76-4, Evaluation of impact of Potential Flooding Criteria on the Hanford Project. ERDA, 1976

b. HNF-SD-GN-ER-501, Natural Phenomena Hazards, Hanford Site, Washington Rev. 2

c. RPP-11736, Assessment of Aircraft Crash Frequency for the Hanford Site 200 Area Tank Farms, Rev 0

d. RPP-13033, Rev. 5-D, Tank Farms Documented Safety Analysis (DSA). Only the representative accidents (without controls) are considered; however, the likelihood/impact is assessed both without controls (top pair) and with controls (bottom pair).

e. Likelihoods: A – Anticipated (> 10E-2/yr); U – Unlikely (10E-2 – 10E-4/yr); Extremely Unlikely (10E-4 – 10E-6/yr); and BEU – Beyond Extremely Unlikely (< 10E-6 /yr). NA – Not anticipated.

f. Impacts: L – Low (Single barrier with localized impacts); M – Moderate (Single facility or system with on-site impacts); and H – High (Multiple facilities or systems with potential off-site impacts). NA – Not anticipated. For the accidents analyzed in the DSA (4), impacts are: L – Low (<5 rem TED co-located worker or <0.1 rem TED offsite public); M – Moderate (5 to 100 rem TED co-located worked or 0.1 to 5 rem TED offsite public); and H – High (≥ 100 rem TED co-located worker or ≥ 5 rem TED offsite public).

Active Cleanup Period (to 2064)

Currently at Risk – Populations and Resources

Workers (directly involved):

Low. Both regular and construction workers are at risk from wastes (including vapors and direct radiation exposure) and activities related to on-going operations at the T Tank Farm EU. Active controls have been implemented to limit radiological and toxicological risks to workers so the potential impact is considered low.

Workers (co-located):

Low. Co-located workers may be at risk from wastes (including vapors and direct radiation exposure) during surveillance and maintenance activities related to the T Tank Farm EU. Active controls have been implemented to limit radiological and toxicological risks to workers so the potential impact is considered low.

Public:

Low. The T Tank Farm EU, which is in a secure and controlled area that prevents intentional and inadvertent intruders, is several miles interior to the Hanford Site boundary so any potential impact via the air pathway to the general public would be minimal. Hanford groundwater use is restricted so there is no significant pathway to the public. Thus the potential current impact from the T Tank Farm EU to the public is considered low.

Groundwater:

Very high. There are existing plumes that represent impacts to the saturated zone (receptor) from T Tank Farm EU PCs (i.e., chromium, Tc-99, I-129, and nitrate). Using the scheme provided in Chapter 7, Table 7-1, Tc-99 and I-129 are denoted Group A, chromium Group B, and nitrate Group C. Using the basis provided in Chapter 7, Figure 7-10 and Table 7-2, the ratings for Tc-99 and I-129 are *very high*, that for chromium is *high*, and that for nitrate is *medium*. Thus the overall rating is *very high*.

Columbia River:

Not discernible. T Tank Farm EU primary contaminants have migrated through the vadose zone and into the saturated zone but have not reached the nearshore or surface water portions of the Columbia River in measureable concentrations. Thus there should be no discernible risk to the Columbia River.

Ecological Resources:

Low. Ecological risk from T Tank Farm EU groundwater contamination (200-ZP-1 OU) is not anticipated because of the lack of direct or indirect exposure to groundwater by ecological receptors now or in the future. There is no discernible risk to ecological receptors from contaminated groundwater because there is no complete pathway. Ecological receptors could be low risk from direct radiation exposure from tank wastes and other pathways (e.g., uptake) from legacy source sites. Thus the current risk to ecological receptors is considered low.

Cultural Resources:

Low. Much of the 200 West Area is considered of low archaeological potential with the exception of intact portions of the White Bluffs Road corridor that runs through the 200 West Area. No archaeological sites have been recorded within the T Tank Farm EU, and thus there is no discernible impact to these resources. Thus the potential impact to cultural resources is considered low (archaeological potential).

Economic Resources:

Not discernible. No unique or unusual economic assets were identified associated with the T Tank Farm Evaluation Unit. Thus there would be no discernible impact on economic resources.

Cleanup Approaches and End-State Conceptual Model

Selected or Potential Cleanup Approaches:

What are the selected cleanup actions or the range of potential remedial actions?

A series of interim measures were completed to minimize contaminant transport:

- Emplacing upgradient surface water run-on control measures (barriers and diversions).
- Performing leak tests of the waterlines to T, TX, and TY tank farms. The raw water line serving TX and TY tank farms was cut and capped in 2001.
- Verifying that the sanitary waterline to T Tank Farm had been cut and capped.
- Capping existing drywells to prevent water intrusion.
- Decommissioning pre-1980 monitoring wells at T Tank Farm.
- Pump-and-treat (P&T) system has been in operation since 2007 to remove carbon tetrachloride and Tc-99 groundwater contamination near WMAs T and TX-TY.
- An interim barrier was installed over the subsurface plume from Tank T-106 in 2008.

The preferred HLW tank closure alternative includes 99 percent retrieval of waste (by volume) from the SSTs for staging in DSTs and treatment elsewhere onsite; operations and necessary maintenance, waste transfers and associated operations, and upgrades to existing tanks or construction of waste receipt facilities (TC&WM EIS). SST closure operations include filling the tanks and ancillary equipment with grout to immobilize residual waste. Disposal of contaminated equipment and soil would occur on site.

Decisions on the extent of soil removal or treatment would be made on a tank farm or waste management area basis through the RCRA closure permitting process. The tanks would be stabilized with grout, and an engineered modified RCRA Subtitle C barrier put in place followed by post-closure care. The other tank closure alternatives evaluated in the TC&WM EIS (other than No Action) tended to be a variation on the above theme.

What is the sequence of activities and duration of each phase?

The sequence of activities is provided in the previous section. The proposed duration of each phase is illustrated in Figure E-23.

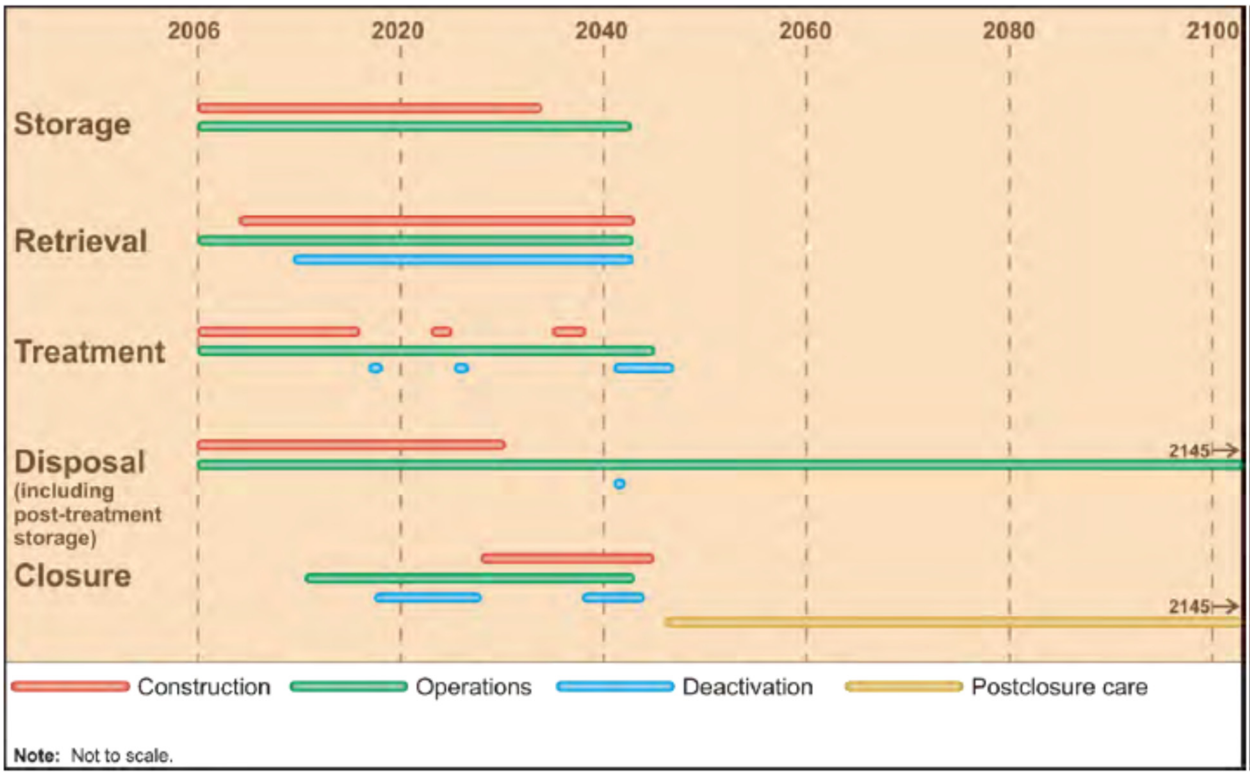

Figure E-23. Preferred Tank Closure Alternative Proposed Schedule (TC&WM EIS, p. 2-73)

What is the magnitude of each activity (i.e., cubic yards of excavation, etc.)?

The estimated amount of each tank waste phase that is planned to be retrieved is provided in Table E-13. The impact of the planned retrieval on the remaining, residual inventories is indicated in Figure E-19, Figure E-20, and Figure E-21.

Contaminant Inventory Remaining at the Conclusion of Planned Active Cleanup Period:

The projected inventories remaining after planned retrieval activities are provided in Table E-13 and illustrated relative to the other sources in Figure E-19, Figure E-20, and Figure E-21.

Risks and Potential Impacts Associated with Cleanup:

Can any (or all) of the potential remedial actions serve as initiating events for risks or impacts (i.e., to workers, to natural resources, etc.)?

Tank closure activities specific to the T Tank Farm EU include retrieval of SST waste for treatment elsewhere onsite; operations and necessary maintenance, waste transfers and associated operations, and upgrades to existing tanks or construction of waste receipt facilities; filling the tanks and ancillary equipment with grout; disposal of contaminated equipment and soil; and installing an engineered modified RCRA Subtitle C barrier followed by post-closure maintenance. The information in Table E-15 suggests that there are anticipated events (e.g., failures of industrial grade active systems) associated with T Tank Farm EU closure operations that may have moderate impacts. Controls have been put in place to address events with known significant risks (RPP-13033, Rev. 5-D).

During or as a Consequence of Cleanup Actions – Populations and Resources at Risk

Workers (directly involved):

Moderate. Regular and construction workers will be at risk from exposure to direct radiation and waste contaminants during SST retrieval and closure operations. Some anticipated events can have moderate impacts to these workers (Table E-15).

Workers (co-located):

Moderate. Co-located workers will be at risk from exposure to direct radiation and waste contaminants during SST retrieval and closure operations. Some anticipated events can have moderate impacts to co-located workers (Table E-15).

Public:

Low. The T Tank Farm, which is in a secure and controlled area that prevents intentional and inadvertent intruders, is several miles interior to the Hanford Site boundary so the air pathway to the general public is considered minimal even during closure activities. Hanford groundwater use will be restricted during this period so there is no significant pathway to the public. Thus risks to the public during cleanup operations are considered low.

Groundwater:

Medium. There will be a continuing impact during this period to the saturated zone (receptor) from those mobile T Tank Farm EU primary contaminants (i.e., chromium, Tc-99, I-129, and nitrate) that currently exceed MCLs. The Tc-99 and I-129 plumes are predicted to be smaller (i.e., remain <<0.1 km^2) and the chromium and nitrate plumes are predicted to increase to >>10 km^2 during Active Cleanup operations. It is possible that tank waste sluicing operations may result in additional supernatant leaks from tanks, which could result in greater vadose zone and perhaps saturated zone contamination; however, the 200-West Area pump-and-treat system is also assumed to be operational during this evaluation period. Using the basis provided in Chapter 7, Figure 7-10 and

Table 7-2, the ratings for Tc-99 and I-129 (Group A) are *medium*, that for chromium (Group B) is *medium*, and that for nitrate (Group C) is *low*. Thus the overall rating is *medium*.

Columbia River:

Medium. The ecological PCs (nitrate and chromium) may be discharged into the Columbia River in concentrations above threshold values before the end of the Active Cleanup period (Table E-12). The basis for ratings is provided in Chapter 7, Figure 7-11 and Table 7-4. The ecological PCs are not Cs-137, Sr-90, Tc-99, or I-129, thus an estimate must be made of the relative contribution of the PCs to the river. According to Table E-3, the T Tank Farm EU PC contribution from all SST sources is significant; thus it will be assumed for this review that the contribution of PCs to the load to the river would be greater than 1%. The rating from Table 7-4 for both chromium and nitrate is *medium* because all groundwater is assumed to discharge into a 40-meter nearshore zone (TC&WM EIS, Appendix P, p. P-53). Thus the overall rating is *medium*.

Ecological Resources:

Low. Ecological risk from T Tank Farm EU groundwater contamination is not anticipated because of the lack of direct or indirect exposure to groundwater by ecological receptors during this period. There is no risk to ecological receptors from contaminated groundwater because there is no complete groundwater pathway. Ecological receptors may be at low risk from direct radiation exposure from tank wastes and other pathways (e.g., uptake) from legacy source sites. Thus the risk to ecological receptors is considered low during Cleanup Actions.

Cultural Resources:

Low. Much of the 200 West Area can be considered of low archaeological potential with the exception of intact portions of the White Bluffs Road corridor that runs through the 200 West Area. It is considered unlikely that additional archaeological sites will be discovered during T Tank Farm closure activities based on past experience. Thus the impact to cultural resources is considered low.

Economic Resources:

Not discernible. No unique or unusual economic assets were identified associated with the T Tank Farm Evaluation Unit. Thus there would be no discernible impact on economic resources.

Additional Risks and Potential Impacts if Cleanup is Delayed

There is potential for additional tank degradation and further leaks and contaminant transport through the vadose and saturated zones if tank closure activities are delayed. There is also potential risk from direct radiation and tank waste contaminants to ecological receptors and workers from routine tank farm operations.

Near-Term, Post-Cleanup Status, Risks and Potential Impacts

After closure T Tank Farm will have HLW tanks and ancillary equipment grouted in place as well as residual contamination in tanks, ancillary equipment, and legacy source sites (cribs, trenches, and soil). A cap will be subsequently emplaced over the SSTs including T Tank Farm. Mobile tank waste contaminants have migrated from legacy source sites (cribs, trenches, and contaminated soils) through the vadose zone to the saturated zone. Use of groundwater is precluded at the Hanford Site during the 100-year institutional control period.

Near-Term Post-Cleanup (to 2164) - Populations and Resources at Risk or Potentially Impacted After Cleanup Actions (from residual contaminant inventory or long-term activities)

Workers (directly involved):

Low. Risks to workers from residual wastes are considered low after the cap has been emplaced. Regular workers performing monitoring and maintenance activities will be at some degree of risk, albeit considered low. The area will remain secure during the Institutional Control period.

Workers (co-located):

Not discernible. Since the tank farm area will be capped, the risk to co-located workers is considered not be discernible from residual T Tank Farm EU contamination.

Public:

Not discernible. The T Tank Farm, which will be in a secure and controlled area that prevents intentional and inadvertent intruders during this period, is several miles interior to the Hanford Site boundary. Since the tank farm area will be capped and the use of groundwater will be precluded during this evaluation period, there should be no discernible risk to the public.

Groundwater:

Medium. There will be a continuing impact during this period to the saturated zone (receptor) from T Tank Farm EU PCs (i.e., chromium, Tc-99, I-129, and nitrate). The Tc-99 and I-129 plumes are predicted to be very small (i.e., remain <<0.1 km^2) and the chromium and nitrate plumes are predicted to increase to >>10 km^2. The 200-West Area pump-and-treat system is assumed to be operational during this evaluation period. Using the basis provided in Chapter 7, Figure 7-10 and Table 7-2, the ratings for Tc-99 and I-129 (Group A) are *medium*, that for chromium (Group B) is *medium*, and that for nitrate (Group C) is *low*. Thus the overall rating is *medium*.

Columbia River:

Medium. The ecological PCs (nitrate and chromium) are predicted to be discharged into the river at concentrations above threshold values before this period begins (Table E-12). Using the basis for ratings provided in Chapter 7, Figure 7-11 and Table 7-4 and assuming the contribution of PCs to the river load to be greater than 1%, the rating for both chromium and nitrate remains *medium*. Thus the overall rating is *medium* because all groundwater is assumed to discharge into a 40-meter nearshore zone (TC&WM EIS, Appendix P, p. P-53).

Ecological Resources:

Low. Since the tank farm area will be capped, ecological receptors should not be at low risk from residual T Tank Farm EU primary contaminants in tank, ancillary equipment, and legacy sources. Ecological risk from T Tank Farm EU groundwater contamination is not anticipated because of the lack of direct or indirect exposure to groundwater by ecological receptors during this evaluation period. There will be a continuing potential low risk from nitrate and chromium being discharged to the river. Thus the rating is considered *low*.

Cultural Resources:

Not discernible. Any cultural concerns are assumed to have been addressed during cleanup and closure operations (e.g., excavation of contaminated soil and capping). Thus no discernible impacts are considered likely to cultural resources after cleanup operations have concluded.

Long-Term, Post-Cleanup Status (to 3064) – Inventories and Risks and Potential Impact Pathways

After closure, the T Tank Farm EU will have HLW tanks and ancillary equipment grouted in place with residual contamination in tanks, ancillary equipment, and legacy source sites (cribs, trenches, and soil). Mobile primary contaminants have migrated from the T Tank Farm sources through the vadose zone to the saturated zone and will continue to move through the groundwater. A cap will be placed over the tank farm site to reduce infiltrating water and contaminant migration for the time that the cap performs according to specifications. Upon cap failure, the infiltration rate will likely increase significantly and thus so will the primary driver for contaminant transport. However, waste retrieval operations (Figure E-19, Figure E-20, and Figure E-21) and grouting activities will help reduce the potential for release from residual waste source terms.

Because of the closure activities (including waste retrieval and capping), worker and public impacts are expected to remain low during the Long-Term, Post-Cleanup period. Expected primary contaminant migration through the saturated zone and discharges to the Columbia are expected to result in medium impacts to these important environmental media. The discharges to the river also translate into low risks to ecological receptors over this evaluation period. Any impacts to cultural resources are expected before this period and thus no additional discernible impacts to cultural resources are anticipated.

Part VIII. Risk and Potential Impacts Ratings

Current Risks and Potential Impacts – Ratings

Population or Resource	Risk or Impact Rating (based on risk matrix)	Comments
Worker (facility worker)		Workers exposed to direct radiation and possibly waste constituents and vapors during routine maintenance and construction activities.
Worker (co-located)		Workers exposed to direct radiation and possibly waste constituents and vapors during routine maintenance and construction activities.
Public		The T Tank Farm EU is in a secure and controlled area that prevents intentional and inadvertent intruders. No groundwater pathway and minimal air pathway.
Groundwater	TO BE COMPLETED IN FINAL TEMPLATE	Primary contaminants (PCs): Cr, Tc-99, I-129, NO3 Group A: Tc-99 & I-129; B: Cr; and C: NO3 All PCs exceed MCLs → existing GW plumes Tc-99 (A) → Case I (Area ≈ 0.11 km^2) → Very High I-129 (A) → Case I (Area ≈ 0.10 km^2) → Very High Cr (B) → Case I (Area ≈ 0.14 km^2) → High NO3 (C) → Case I (Area ≈ 10.24 km^2) → Medium
Surface water		PCs: Cr and NO3 PC concentrations << river thresholds
Ecological Resources		No groundwater pathway. Low risk from legacy sources.
Cultural Resources		Area has low archaeological potential.
Economic Resources		No unique or unusual economic assets were identified.

Risks During and as a Consequence of Cleanup Actions - Ratings

Population or Resource	**Risk or Impact Rating (based on risk matrix)**	**Comments**
Worker (remedial & facility worker)		Workers will be at increased risk from exposure to direct radiation and waste contaminants during SST retrieval and closure operations.
Worker (co-located)		Workers will be at increased risk from exposure to direct radiation and waste contaminants during SST retrieval and closure operations.
Public		The T Tank Farm EU is in a secure and controlled area that prevents intentional and inadvertent intruders. No groundwater pathway and low from air pathway.
Groundwater		Existing GW plumes Tc-99 & I-129 (A) → Areas << 0.1 km^2 → Medium Cr (B) → Area >>10 km^2 → Medium NO3 (C) → Area >>10 km^2 → Low
Surface water		PCs: Cr and NO3 (not Cs-137, Sr-90, Tc-99, I-129) PCs discharged >thresholds and >1% load and <100m zone → Medium
Ecological Resources		No groundwater pathway. Low impact from legacy sources.
Cultural Resources		Area has low archaeological potential.
Economic Resources		No unique or unusual economic assets were identified.

TO BE COMPLETED IN FINAL TEMPLATE

Near-Term, Post-Cleanup Risks and Potential Impacts

Population or Resource	Risk or Impact Rating (based on risk matrix)	Comments
Worker (remediation & facility worker)	TO BE COMPLETED IN FINAL TEMPLATE	Workers will be low risk from exposure to direct radiation and waste contaminants after waste retrieval, grouting, and capping.
Worker (co-located)		Workers will be no discernible risk from exposure to direct radiation and waste contaminants after waste retrieval, grouting, and capping.
Public		The T Tank Farm EU is in a secure and controlled area that prevents intentional and inadvertent intruders. No groundwater pathway and low from air pathway (post-closure).
Groundwater		Existing GW plumes Tc-99 & I-129 (A) → Areas << 0.1 km^2 → Medium Cr (B) → Area >>10 km^2 → Medium NO3 (C) → Area >>10 km^2 → Low
Surface water		PCs: Cr and NO3 (not Cs-137, Sr-90, Tc-99, I-129) PCs discharged >thresholds and >1% load and <100m zone → Medium
Ecological Resources		No groundwater pathway. Low impact from legacy sources.
Cultural Resources		Addressed during previous period.

Part IX. Supplemental Information and Considerations

The primary risk drivers related to the T Tank Farm Evaluation Unit will be contaminated groundwater and residual contamination that could lead to additional groundwater contamination. There is a restriction on groundwater use in the 200 Areas, except for treatment and monitoring (Ranade 2009). Furthermore, appropriate use restrictions (including that on groundwater use) will be attached to any real estate transaction if DOE transfer property to other entities. The restriction on groundwater use needs to remain in place in perpetuity to maintain the safety margins considered in this review.

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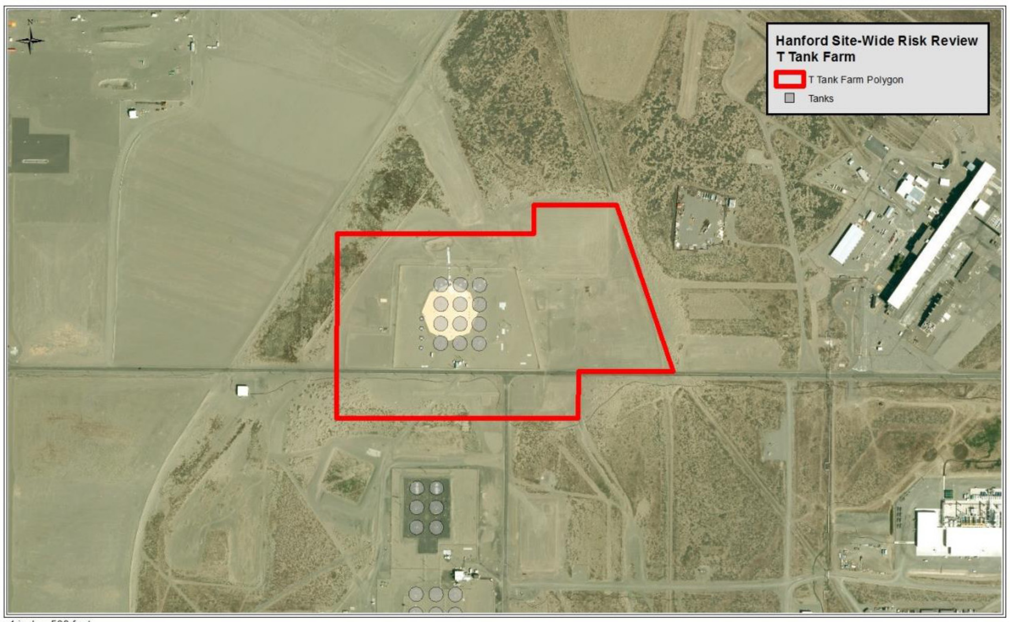
Attachment E-1 – T Tank Farm Evaluation Unit WIDS Review

Hanford Site-Wide Risk Review

Evaluation Unit:	T Tank Farm
ID:	CP-21
Group:	TF
Operable Unit Cross-Walk:	
Related EU:	
Sites & Facilities:	T Tank Farm
	Ancillary structures
	Associated liquid waste sites
	Associated soils contamination
Key Data Sources Docs:	



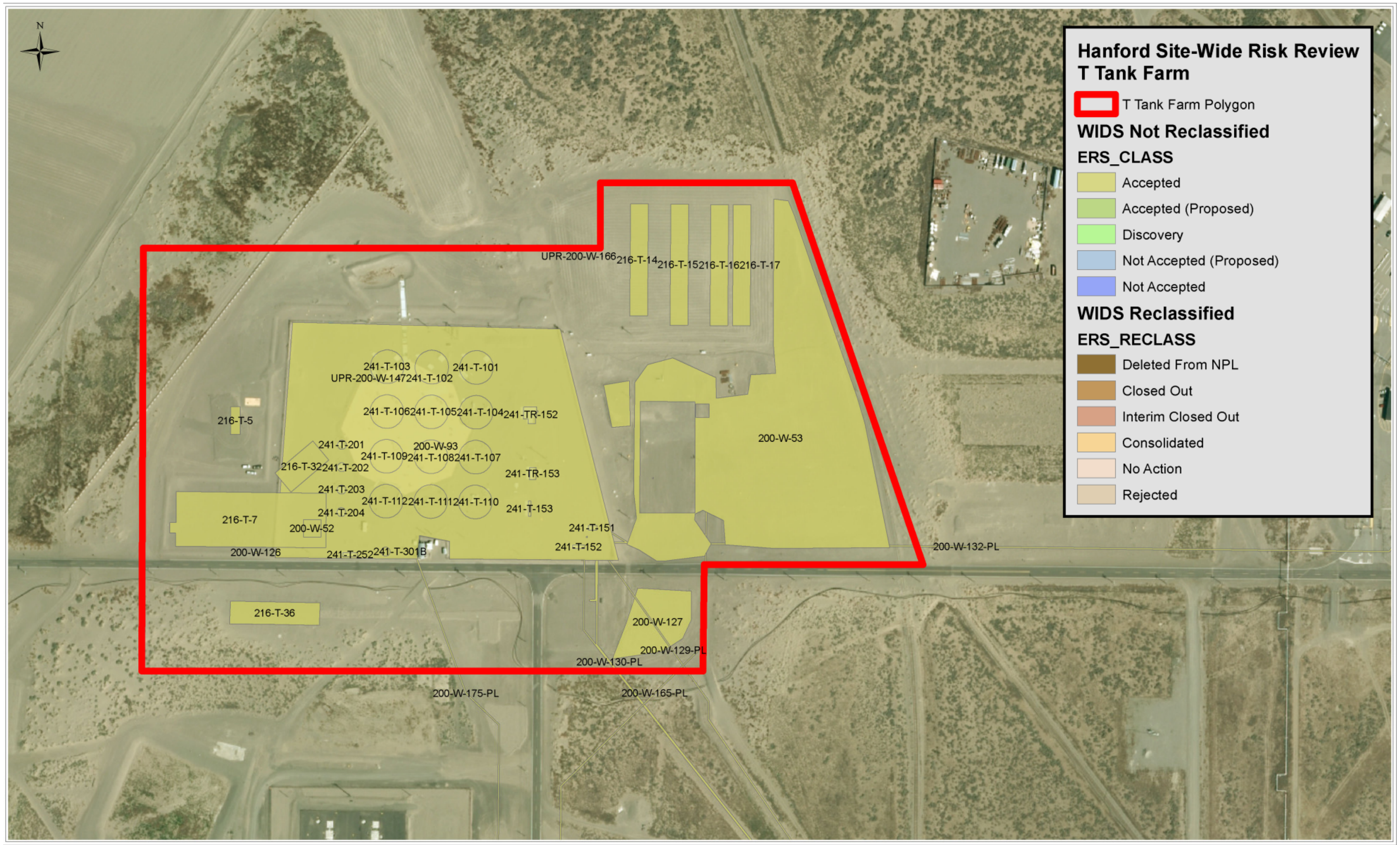
Hanford Site-Wide Risk Review

Waste Sites Associated with T Tank Farm	Waste Sites Not Associated with T Tank Farm
200-W-126 (Tank Farm Vertical Storage Units; Vertical Storage Units West of 241-T Tank Farm)	200-W-163-PL (T Plant Process Sewer)
200-W-127 (Surface Stabilized Area East of UPR-200-W-29/UPR-200-W-97 (UN-216-W-5))	200-W-164-PL (Pipeline from 207-T Retention Basin to the 216-T-4 Ditch)
200-W-129-PL (Encased Pipeline from 241-T-151 and 241-T-152 to 241-TX-155 Diversion Box; Lines V399, V405 and V411)	200-W-166-PL (Pipeline from 242-T Evaporator Building to the 207-T Retention Basin)
200-W-130-PL (Pipelines from 241-T-151 and 241-T-152 Diversion Boxes to 241-U-151 Diversion Box)	200-W-167-PL (Pipeline from 242-T Evaporator to 207-T Retention Basin)
200-W-132-PL (Pipelines from 221-T to 241-T-151 and 241-T-152)	200-W-226-PL (Pipeline from 224-T (Plutonium Concentration Facility) to 241-T-361 Settling Tank and 216-T-3 Reverse Well)
200-W-165-PL (Pipeline from Tank 241-TX-112 to 207-T Retention Basin)	200-W-231 (Temporary Facilities Construction Trailer Septic Tank and Tile Field)
200-W-175-PL; (Pipeline to Route Waste from 241-T-112 to 216-TY-201 Flush Tank and 216-T-26, 216-T-27 and 216-T-28 Cribs)	200-W-88-PL (221-T Process Sewer)
200-W-52 (216-T-7 Crib; 241-T-3 Crib)	207-T (T Plant Retention Basin)
200-W-53 (UN-216-W-31; UPR-200-W-166)	200-W-90 (Underground Radioactive Material Areas Posted Along 23rd Street in 200 West Area)
200-W-78-PL (Pipeline Between 241-TX/TY and 241-T Tank Farms)	216-T-12 (207-T Sludge Grave)
200-W-79-PL (216-T-36 Crib Pipeline)	UPR-200-W-29 (23rd and Camden Line Break; Transfer Line Leak; UN-200-W-27; UN-200-W-29; UN-216-W-5; UPR-200-W-27)
200-W-93 (Contaminated Soil at 241-T Tank Farm)	UPR-200-W-63 (Road Contamination Along the South Shoulder of 23rd Street; UN-200-W-63)
216-T-14 (241-T-1 Trench; 216-T-1 Grave)	UPR-200-W-64 (Road Contamination at 23rd and Camden; UN-200-W-64)
216-T-15 (216-T-15 Crib; 241-T-2 Grave; 241-T-2 Trench)	UPR-200-W-97 (Transfer Line Leak; UN-200-W-97; UN-216-W-5)
216-T-16 (216-T-16 Crib; 241-T-3 Grave; 241-T-3 Trench)	
216-T-17 (216-T-4 Grave; 241-T-4 Trench)	
216-T-32 (216-T-6; 241-T #1 & 2 Cribs)	
216-T-36 (216-T-36 Crib)	
216-T-5 (216-T-5 Grave; 216-T-5 Trench; 241-T-5 Trench)	
216-T-7 (216-T-7 Tile Field; 216-T-7TF; 241-T-3 Tile Field)	
241-T-101 (241-T-TK-101)	
241-T-102 (241-T-TK-102)	
241-T-103 (241-T-TK-103)	

241-T-104 (241-T-TK-104)	
241-T-105 (241-T-TK-105)	
241-T-106 (241-T-TK-106)	
241-T-107 (241-T-TK-107)	
241-T-108 (241-T-TK-108)	
241-T-109 (241-T-TK-109)	
241-T-110 (241-T-TK-110)	
241-T-111 (241-T-TK-111)	
241-T-112 (241-T-TK-112)	
241-T-151 (241-T-151 Diversion Box)	
241-T-152 (241-T-152 Diversion Box)	
241-T-153 (241-T-153 Diversion Box)	
241-T-201 (241-T-TK-201)	
241-T-202 (241-T-TK-202)	
241-T-203 (241-T-TK-203)	
241-T-204 (241-T-TK-204)	
241-T-252 (241-T-252 Diversion Box)	
241-T-301B (241-T-301-B; IMUST; Inactive Miscellaneous Underground Storage Tank; Lines V664 and V727; 241-T-0301; 241-T-301 Catch Tank)	
241-T-302 (241-T-302 Catch Tank)	
241-TR-152 (241-TR-152 Diversion Box)	
241-TR-153 (241-TR-153 Booster Pump Pit; 241-TR-153 Diversion Box)	
UPR-200-W-147 (241-T-103 Leak)	
UPR-200-W-148 (241-T-106 Leak)	
UPR-200-W-166 (Contamination Migration from 241-T Tank Farm; UN-216-W-31)	
UPR-200-W-7 (Contamination Spread from the 241-T-151 and 241-T-152 Diversion Boxes; UN-200-W-7)	

EU Designation: T Tank Farm (CP-TF-1)

DRAFT for Methodology Illustration



1 inch = 300 feet

Hanford Site-Wide Risk Review
T Tank Farm
WIDS Export from PHOENIX

No.	Name	Site Code	Site ID	Class Status	Reclass Status	Site Status	Site Type	Hanford Area	Operable Unit
1	200-W-126; Tank Farm Vertical Storage Units; Vertical Storage Units West of 241 T Tank Farm	200 W 126	2939	Accepted	None	Inactive	Storage	200W	TBD
2	200-W-127; Surface Stabilized Area East of UPR-200-W-29/UPR-200-W-97 (UN-216-W-5)	200-W-127	2940	Accepted	None	Inactive	Unplanned Release	200W	TBD
3	200 W 129 PL; Encased Pipeline from 241 T 151 and 241 T-152 to 241-TX-155 Diversion Box; Lines V399, V405 and V411	200-W-129-PL	2938	Accepted	None	Inactive	Encased Tank Farm Pipeline	200W	TBD
4	200-W-130-PL; Lines V445, V663. V601 and V416 and Spare Lines V662, V663, V682 and V683; Pipelines from 241-T-151 and 241-T-152 Diversion Boxes to 241-U-151 Diversion Box	200-W-130-PL	2935	Accepted	None	Inactive	Direct Buried Tank Farm Pipeline	200W	TBD
5	200-W-132-PL; Pipelines from 221-T to 241-T-151 and 241-T-152; V653, V654, V667, V668, V669. V706, and V707	200 W 132 PL	2937	Accepted	None	Inactive	Direct Buried Tank Farm Pipeline	200W	TBD
6	200-W-163-PL; T Plant Process Sewer; 18-Inch 221-T Process Sewer Pipeline	200-W-163-PL	2893	Accepted	None	Inactive	Radioactive Process Sewer	200W	TBD
7	200-W-164-PL; Pipeline from 207-T Retention Basin to the 216-T-4 Ditch	200 W 164 PL	2901	Accepted	None	Inactive	Radioactive Process Sewer	200W	TBD
8	200-W-165-PL; Pipeline from Tank 241-TX-112 to 207-T Retention Basin	200 W 165 PL	2898	Accepted	None	Inactive	Radioactive Process Sewer	200W	TBD
9	200-W-166-PL; Pipeline from 242-T Evaporator Building to the 207-T Retention Basin	200-W-166-PL	2899	Accepted	None	Inactive	Radioactive Process Sewer	200W	TBD
10	200-W-167-PL; Pipeline from 242-T Evaporator to 207-T Retention Basin	200 W 167 PL	2900	Accepted	None	Inactive	Radioactive Process Sewer	200W	TBD
11	200 W 175 PL; Line V681; Pipeline to Route Waste from 241 T 112 to 216 TY 201 Flush Tank and 216 T 26, 216 T 27 and 216-T-28 Cribs	200 W 175 PL	2964	Accepted	None	Inactive	Radioactive Process Sewer	200W	TBD
12	200 W 226 PL; Lines V326, V671 and V706; Pipeline from 224 T (Plutonium Concentration Facility) to 241 T 361 Settling Tank and 216 T 3 Reverse Well	200 W 226 PL	2975	Accepted	None	Inactive	Radioactive Process Sewer	200W	TBD
13	200-W-231; Temporary Facilities Construction Trailer Septic Tank and Tile Field	200 W 231	3013	Accepted	None	Inactive	Septic Tank	200W	TBD
14	200-W-52; 216-T-7 Crib; 241-T-3 Crib	200-W-52	3202	Accepted	None	Inactive	Crib	200W	WMA T
15	200 W 53; UN 216 W 31; UPR 200 W 166	200 W 53	3203	Accepted	None	Inactive	Unplanned Release	200W	200 WA 1
16	200-W-78-PL: 6025; 7624 and 7630; Lines 6012; Pipeline Between 241-TX/TY and 241-T Tank Farms	200 W 78 PL	3236	Accepted	None	Inactive	Encased Tank Farm Pipeline	200W	TBD
17	200 W 79 PL; 216 T 36 Crib Pipeline; V663	200 W 79 PL	3237	Accepted	None	Inactive	Radioactive Process Sewer	200W	TBD
18	200-W-88-PL: 221-T Process Sewer; 24 Inch Process Sewer; T Plant Process Sewer Pipeline; 200-W-88	200 W 88 PL	3241	Accepted	None	Inactive	Radioactive Process Sewer	200W	TBD
19	200 W 90; Underground Radioactive Material Areas Posted Along 23rd Street in 200 West Area	200 W 90	2931	Accepted	None	Inactive	Unplanned Release	200W	200 WA 1
20	200-W-93; Contaminated Soil at 241-T Tank Farm	200-W-93	2930	Accepted	None	Inactive	Unplanned Release	200W	WMA T
21	207-T; 207-T Retention Basin; T Plant Retention Basin	207-T	622	Accepted	None	Inactive	Retention Basin	200W	200-WA-1
22	216 T 12; 207 T Sludge Grave; 207 T Sludge Pit; 216 T 11	216 T 12	607	Accepted	None	Inactive	Trench	200W	200 WA 1

Hanford Site-Wide Risk Review
T Tank Farm
WIDS Export from PHOENIX

No.	Name	Site Code	Site ID	Class Status	Reclass Status	Site Status	Site Type	Hanford Area	Operable Unit
23	216-T-14; 241-T-1 Trench; 216-T-1 Grave; 216-T-13	216-T-14	601	Accepted	None	Inactive	Trench	200W	200-DV-1
24	216 T 15; 216 T 15 Crib; 241 T 2 Grave; 241 T 2 Trench; 216-T-14	216-T-15	602	Accepted	None	Inactive	Trench	200W	200-DV-1
25	216-T-16; 216-T-16 Crib; 241-T-3 Grave; 241-T-3 Trench; 216-T-15	216 T 16	603	Accepted	None	Inactive	Trench	200W	200 DV 1
26	216 T 17; 216 T 4 Grave; 241 T 4 Trench; 216 T 16	216 T 17	623	Accepted	None	Inactive	Trench	200W	200 DV 1
27	216 T 32; 216 T 6; 241 T #1 & 2 Cribs	216 T 32	648	Accepted	None	Inactive	Crib	200W	200 DV 1
28	216 T 36; 216 T 36 Crib	216 T 36	630	Accepted	None	Inactive	Crib	200W	200 WA 1
29	216-T-5; 216-T-5 Grave; 216-T-5 Trench; 241-T-5 Trench; 216 T 12	216-T-5	600	Accepted	None	Inactive	Trench	200W	200-DV-1
30	216-T-7; 216-T-7 Tile Field; 216-T-7TF; 241-T-3 Tile Field	216-T-7	594	Accepted	None	Inactive	Drain/Tile Field	200W	200-DV-1
31	241-T-101; 241-T-TK-101	241-T-101	631	Accepted	None	Inactive	Single-Shell Tank	200W	WMA T
32	241-T-102; 241-T-TK-102	241-T-102	632	Accepted	None	Inactive	Single-Shell Tank	200W	WMA T
33	241-T-103; 241-T-TK-103	241-T-103	633	Accepted	None	Inactive	Single-Shell Tank	200W	WMA T
34	241-T-104; 241-T-TK-104	241-T-104	1897	Accepted	None	Inactive	Single-Shell Tank	200W	WMA T
35	241-T-105; 241-T-TK-105	241-T-105	3161	Accepted	None	Inactive	Single-Shell Tank	200W	WMA T
36	241 T 106; 241 T TK 106	241 T 106	3162	Accepted	None	Inactive	Single Shell Tank	200W	WMA T
37	241-T-107; 241-T-TK-107	241-T-107	3163	Accepted	None	Inactive	Single-Shell Tank	200W	WMA T
38	241 T 108; 241 T TK 108	241 T 108	3160	Accepted	None	Inactive	Single Shell Tank	200W	WMA T
39	241 T 109; 241 T TK 109	241 T 109	3157	Accepted	None	Inactive	Single Shell Tank	200W	WMA T
40	241 T 110; 241 T TK 110	241 T 110	3158	Accepted	None	Inactive	Single Shell Tank	200W	WMA T
41	241 T 111; 241 T TK 111	241 T 111	3159	Accepted	None	Inactive	Single Shell Tank	200W	WMA T
42	241 T 112; 241 T TK 112	241 T 112	3168	Accepted	None	Inactive	Single Shell Tank	200W	WMA T
43	241 T 151; 241 T 151 Diversion Box	241 T 151	3169	Accepted	None	Inactive	Diversion Box	200W	WMA T
44	241-T-152; 241-T-152 Diversion Box	241-T-152	3170	Accepted	None	Inactive	Diversion Box	200W	WMA T
45	241 T 153; 241 T 153 Diversion Box	241 T 153	3167	Accepted	None	Inactive	Diversion Box	200W	WMA T
46	241-T-201; 241-T-TK-201	241-T-201	3164	Accepted	None	Inactive	Single-Shell Tank	200W	WMA T
47	241-T-202; 241-T-TK-202	241-T-202	3165	Accepted	None	Inactive	Single-Shell Tank	200W	WMA T
48	241-T-203; 241-T-TK-203	241-T-203	3166	Accepted	None	Inactive	Single-Shell Tank	200W	WMA T
49	241-T-204; 241-T-TK-204	241-T-204	3156	Accepted	None	Inactive	Single-Shell Tank	200W	WMA T
50	241-T-252; 241-T-252 Diversion Box	241-T-252	3146	Accepted	None	Inactive	Diversion Box	200W	WMA T
51	241-T-301B; 241-T-301-B; IMUST; Inactive Miscellaneous Underground Storage Tank; Lines V664 and V727; 241-T-0301; 241 T 301 Catch Tank	241-T-301B	3147	Accepted	None	Inactive	Catch Tank	200W	WMA T
52	241-T-302; 241-T-302 Catch Tank	241-T-302	3148	Accepted	Rejected	Inactive	Catch Tank	200W	Not Applic
53	241 TR 152; 241 TR 152 Diversion Box; Line 6053	241 TR 152	3154	Accepted	None	Inactive	Diversion Box	200W	WMA T
54	241-TR-153; 241-TR-153 Booster Pump Pit; 241-TR-153 Diversion Box; Line 6172	241-TR-153	3155	Accepted	None	Inactive	Diversion Box	200W	WMA T
55	UPR 200 W 147; 241 T 103 Leak	UPR 200 W 147	2563	Accepted	Consolidated	Inactive	Unplanned Release	200W	Not Applic
56	UPR-200-W-148; 241-T-106 Leak	UPR-200-W-148	2560	Accepted	Consolidated	Inactive	Unplanned Release	200W	Not Applic
57	UPR-200-W-166; Contamination Migration from 241-T Tank Farm; UN 216 W 31	UPR-200-W-166	2603	Accepted	None	Inactive	Unplanned Release	200W	200-WA-1

Hanford Site-Wide Risk Review
T Tank Farm
WIDS Export from PHOENIX

No.	Name	Site Code	Site ID	Class Status	Reclass Status	Site Status	Site Type	Hanford Area	Operable Unit
58	UPR-200-W-29: 23rd and Camden Line Break; Transfer Line Leak; UN-200-W-27; UN-200-W-29; UN-216-W-5; UPR-200 W 27	UPR-200-W-29	2487	Accepted	None	Inactive	Unplanned Release	200W	200-IS-1
59	UPR-200-W-63; Road Contamination Along the South Shoulder of 23rd Street; UN-200-W-63	UPR 200 W 63	2397	Accepted	None	Inactive	Unplanned Release	200W	200 WA 1
60	UPR-200-W-64; Road Contamination at 23rd and Camden; UN-200-W-64	UPR-200-W-64	2394	Accepted	None	Inactive	Unplanned Release	200W	200-IS-1
61	UPR-200-W-7; Contamination Spread from the 241-T-151 and 241-T-152 Diversion Boxes; UN-200-W-7	UPR-200-W-7	2434	Accepted	Consolidated	Inactive	Unplanned Release	200W	Not Applic
62	UPR-200-W-97; Transfer Line Leak; UN-200-W-97; UN-216-W 5	UPR-200-W-97	2427	Accepted	None	Inactive	Unplanned Release	200W	200-IS-1

EU Designation: T Tank Farm (CP-TF-1)

DRAFT for Methodology Illustration

Hanford Site-Wide Risk Review
T Tank Farm
WIDS Export from PHOENIX

No.	Name	Contractor	Responsible Project	Unit Category	Photos	Map Authority
1	200-W-126; Tank Farm Vertical Storage Units; Vertical Storage Units West of 241-T Tank Farm	Washington River Protection Solutions	Not Specified	Waste Management Area (WMA) Related	Yes	CHPRC
2	200-W-127; Surface Stabilized Area East of UPR-200-W-29/UPR-200-W-97 (UN-216-W-5)	CH2M HILL Plateau Remediation Company	Central Plateau Surveillance and Maintenance	To Be Determined (TBD)	Yes	CHPRC
3	200 W 129 PL; Encased Pipeline from 241 T 151 and 241 T 152 to 241 TX 155 Diversion Box; Lines V399, V405 and V411	CH2M HILL Plateau Remediation Company	Not Specified	Treatment, Storage and Disposal (TSD)	0	CHPRC
4	200-W-130-PL; Lines V445, V663, V601 and V416 and Spare Lines V662, V663, V682 and V683; Pipelines from 241-T 151 and 241 T 152 Diversion Boxes to 241 U 151 Diversion Box	CH2M HILL Plateau Remediation Company	Not Specified	Treatment, Storage and Disposal (TSD)	0	CHPRC
5	200 W 132 PL; Pipelines from 221 T to 241 T 151 and 241 T 152; V653, V654, V667, V668, V669, V706, and V707	CH2M HILL Plateau Remediation Company	Not Specified	Treatment, Storage and Disposal (TSD)	0	CHPRC
6	200 W 163 PL; T Plant Process Sewer; 18 Inch 221 T Process Sewer Pipeline	None	Not Specified	To Be Determined (TBD)	0	CHPRC
7	200 W 164 PL; Pipeline from 207 T Retention Basin to the 216-T-4 Ditch	None	Not Specified	To Be Determined (TBD)	0	CHPRC
8	200-W-165-PL; Pipeline from Tank 241-TX-112 to 207-T Retention Basin	None	Not Specified	To Be Determined (TBD)	0	CHPRC
9	200-W-166-PL; Pipeline from 242-T Evaporator Building to the 207-T Retention Basin	None	Not Specified	To Be Determined (TBD)	0	CHPRC
10	200-W-167-PL; Pipeline from 242-T Evaporator to 207-T Retention Basin	None	Not Specified	Treatment, Storage and Disposal (TSD)	0	CHPRC
11	200 W 175 PL; Line V681; Pipeline to Route Waste from 241-T-112 to 216-TY-201 Flush Tank and 216-T-26, 216-T-27 and 216-T-28 Cribs	None	Not Specified	To Be Determined (TBD)	0	CHPRC
12	200-W-226-PL; Lines V326, V671 and V706; Pipeline from 224-T (Plutonium Concentration Facility) to 241-T-361 Settling Tank and 216-T-3 Reverse Well	None	Not Specified	To Be Determined (TBD)	0	CHPRC
13	200 W 231; Temporary Facilities Construction Trailer Septic Tank and Tile Field	None	Not Specified	To Be Determined (TBD)	0	CHPRC
14	200-W-52; 216-T-7 Crib; 241-T-3 Crib	Washington River Protection Solutions	Not Specified	RCRA Past Practice (RPP)	Yes	CHPRC
15	200-W-53; UN-216-W-31; UPR-200-W-166	CH2M HILL Plateau Remediation Company	Not Specified	CERCLA Past Practice (CPP)	Yes	CHPRC
16	200-W-78-PL; 6025; 7624 and 7630; Lines 6012; Pipeline Between 241-TX/TY and 241-T Tank Farms	CH2M HILL Plateau Remediation Company	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
17	200 W 79 PL; 216 T 36 Crib Pipeline; V663	CH2M HILL Plateau Remediation Company	Central Plateau Surveillance and Maintenance	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
18	200-W-88-PL; 221-T Process Sewer; 24 Inch Process Sewer; T Plant Process Sewer Pipeline; 200-W-88	CH2M HILL Plateau Remediation Company	Central Plateau - Surveillance and Maintenance	To Be Determined (TBD)	Yes	CHPRC
19	200-W-90; Underground Radioactive Material Areas Posted Along 23rd Street in 200 West Area	CH2M HILL Plateau Remediation Company	Central Plateau - Surveillance and Maintenance	CERCLA Past Practice (CPP)	Yes	CHPRC
20	200 W 93; Contaminated Soil at 241 T Tank Farm	Washington River Protection Solutions	Not Specified	Waste Management Area (WMA) Related	Yes	CHPRC
21	207-T; 207-T Retention Basin; T Plant Retention Basin	CH2M HILL Plateau Remediation Company	Central Plateau - Surveillance and Maintenance	CERCLA Past Practice (CPP)	Yes	CHPRC
22	216-T-12; 207-T Sludge Grave; 207-T Sludge Pit; 216-T-11	CH2M HILL Plateau Remediation Company	Central Plateau - Surveillance and Maintenance	CERCLA Past Practice (CPP)	0	CHPRC

EU Designation: T Tank Farm (CP-TF-1)

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Hanford Site-Wide Risk Review
T Tank Farm
WIDS Export from PHOENIX

No.	Name	Contractor	Responsible Project	Unit Category	Photos	Map Authority
23	216-T-14; 241-T-1 Trench; 216-T-1 Grave; 216-T-13	CH2M HILL Plateau Remediation Company	Central Plateau - Surveillance and Maintenance	RCRA-CERCLA Past Practice (R-CPP)	Yes	CHPRC
24	216 T 15; 216 T 15 Crib; 241 T 2 Grave; 241 T 2 Trench; 216-T-14	CH2M HILL Plateau Remediation Company	Central Plateau - Surveillance and Maintenance	RCRA-CERCLA Past Practice (R-CPP)	0	CHPRC
25	216-T-16; 216-T-16 Crib; 241-T-3 Grave; 241-T-3 Trench; 216-T-15	CH2M HILL Plateau Remediation Company	Central Plateau Surveillance and Maintenance	RCRA CERCLA Past Practice (R CPP)	0	CHPRC
26	216 T 17; 216 T 4 Grave; 241 T 4 Trench; 216 T 16	CH2M HILL Plateau Remediation Company	Central Plateau Surveillance and Maintenance	RCRA CERCLA Past Practice (R CPP)	0	CHPRC
27	216 T 32; 216 T 6; 241 T #1 & 2 Cribs	CH2M HILL Plateau Remediation Company	Not Specified	RCRA CERCLA Past Practice (R CPP)	Yes	CHPRC
28	216 T 36; 216 T 36 Crib	CH2M HILL Plateau Remediation Company	Central Plateau Surveillance and Maintenance	CERCLA Past Practice (CPP)	0	CHPRC
29	216-T-5; 216-T-5 Grave; 216-T-5 Trench; 241-T-5 Trench; 216 T 12	CH2M HILL Plateau Remediation Company	Central Plateau - Surveillance and Maintenance	RCRA-CERCLA Past Practice (R-CPP)	Yes	CHPRC
30	216-T-7; 216-T-7 Tile Field; 216-T-7TF; 241-T-3 Tile Field	CH2M HILL Plateau Remediation Company	Central Plateau - Surveillance and Maintenance	RCRA-CERCLA Past Practice (R-CPP)	Yes	CHPRC
31	241-T-101; 241-T-TK-101	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
32	241-T-102; 241-T-TK-102	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
33	241-T-103; 241-T-TK-103	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
34	241-T-104; 241-T-TK-104	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
35	241-T-105; 241-T-TK-105	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
36	241 T 106; 241 T TK 106	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
37	241-T-107; 241-T-TK-107	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
38	241 T 108; 241 T TK 108	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
39	241 T 109; 241 T TK 109	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
40	241 T 110; 241 T TK 110	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
41	241 T 111; 241 T TK 111	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
42	241 T 112; 241 T TK 112	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
43	241 T 151; 241 T 151 Diversion Box	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
44	241-T-152; 241-T-152 Diversion Box	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
45	241 T 153; 241 T 153 Diversion Box	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
46	241-T-201; 241-T-TK-201	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
47	241-T-202; 241-T-TK-202	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
48	241-T-203; 241-T-TK-203	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
49	241-T-204; 241-T-TK-204	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
50	241-T-252; 241-T-252 Diversion Box	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
51	241-T-301B; 241-T-301-B; IMUST; Inactive Miscellaneous Underground Storage Tank; Lines V664 and V727; 241-T-0301; 241 T 301 Catch Tank	Washington River Protection Solutions	Not Specified	Waste Management Area (WMA) Related	Yes	CHPRC
52	241-T-302; 241-T-302 Catch Tank	Washington River Protection Solutions	Not Specified	To Be Determined (TBD)	0	CHPRC
53	241 TR 152; 241 TR 152 Diversion Box; Line 6053	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
54	241-TR-153; 241-TR-153 Booster Pump Pit; 241-TR-153 Diversion Box; Line 6172	Washington River Protection Solutions	Not Specified	Treatment, Storage and Disposal (TSD)	Yes	CHPRC
55	UPR 200 W 147; 241 T 103 Leak	Washington River Protection Solutions	Not Specified	To Be Determined (TBD)	Yes	CHPRC
56	UPR-200-W-148; 241-T-106 Leak	Washington River Protection Solutions	Not Specified	To Be Determined (TBD)	0	CHPRC
57	UPR-200-W-166; Contamination Migration from 241-T Tank Farm; UN 216 W 31	CH2M HILL Plateau Remediation Company	Central Plateau - Surveillance and Maintenance	CERCLA Past Practice (CPP)	Yes	CHPRC

EU Designation: T Tank Farm (CP-TF-1)

DRAFT for Methodology Illustration

Hanford Site-Wide Risk Review
T Tank Farm
WIDS Export from PHOENIX

No.	Name	Contractor	Responsible Project	Unit Category	Photos	Map Authority
58	UPR-200-W-29; 23rd and Camden Line Break; Transfer Line Leak; UN-200-W-27; UN-200-W-29; UN-216-W-5; UPR-200-W-27	CH2M HILL Plateau Remediation Company	Not Specified	RCRA-CERCLA Past Practice (R-CPP)	Yes	CHPRC
59	UPR-200-W-63; Road Contamination Along the South Shoulder of 23rd Street; UN-200-W-63	CH2M HILL Plateau Remediation Company	Central Plateau - Surveillance and Maintenance	CERCLA Past Practice (CPP)	0	CHPRC
60	UPR-200-W-64; Road Contamination at 23rd and Camden; UN-200-W-64	CH2M HILL Plateau Remediation Company	Not Specified	RCRA-CERCLA Past Practice (R-CPP)	Yes	CHPRC
61	UPR-200-W-7; Contamination Spread from the 241-T-151 and 241-T-152 Diversion Boxes; UN-200-W-7	Washington River Protection Solutions	Not Specified	To Be Determined (TBD)	0	CHPRC
62	UPR-200-W-97; Transfer Line Leak; UN-200-W-97; UN-216-W-5	CH2M HILL Plateau Remediation Company	Not Specified	RCRA-CERCLA Past Practice (R-CPP)	Yes	CHPRC

Hanford Site-Wide Risk Review
T Tank Farm
WIDS Export from PHOENIX

No.	Name	ERS_OP_DES	SWMUFLAG
1	200-W-126; Tank Farm Vertical Storage Units; Vertical Storage Units West of 241-T Tank Farm	0	Yes
2	200-W-127; Surface Stabilized Area East of UPR-200-W-29/UPR-200-W-97 (UN-216-W-5)	0	No
3	200 W 129 PL; Encased Pipeline from 241 T 151 and 241 T 152 to 241 TX 155 Diversion Box; Lines V399, V405 and V411	0	Yes
4	200-W-130-PL; Lines V445, V663, V601 and V416 and Spare Lines V662, V663, V682 and V683; Pipelines from 241-T 151 and 241 T 152 Diversion Boxes to 241 U 151 Diversion Box	0	Yes
5	200 W 132 PL; Pipelines from 221 T to 241 T 151 and 241 T 152; V653, V654, V667, V668, V669, V706, and V707	0	Yes
6	200 W 163 PL; T Plant Process Sewer; 18 Inch 221 T Process Sewer Pipeline	0	Yes
7	200 W 164 PL; Pipeline from 207 T Retention Basin to the 216-T-4 Ditch	0	Yes
8	200-W-165-PL; Pipeline from Tank 241-TX-112 to 207-T Retention Basin	0	Yes
9	200-W-166-PL; Pipeline from 242-T Evaporator Building to the 207-T Retention Basin	0	Yes
10	200-W-167-PL; Pipeline from 242-T Evaporator to 207-T Retention Basin	0	Yes
11	200 W 175 PL; Line V681; Pipeline to Route Waste from 241-T-112 to 216-TY-201 Flush Tank and 216-T-26, 216-T-27 and 216-T-28 Cribs	0	Yes
12	200-W-226-PL; Lines V326, V671 and V706; Pipeline from 224-T (Plutonium Concentration Facility) to 241-T-361 Settling Tank and 216-T-3 Reverse Well	0	Yes
13	200 W 231; Temporary Facilities Construction Trailer Septic Tank and Tile Field	0	Yes
14	200-W-52; 216-T-7 Crib; 241-T-3 Crib	0	Yes
15	200-W-53; UN-216-W-31; UPR-200-W-166	0	No
16	200-W-78-PL; 6025; 7624 and 7630; Lines 6012; Pipeline Between 241-TX/TY and 241-T Tank Farms	0	Yes
17	200 W 79 PL; 216 T 36 Crib Pipeline; V663	0	Yes
18	200-W-88-PL; 221-T Process Sewer; 24 Inch Process Sewer; T Plant Process Sewer Pipeline; 200-W-88	0	No
19	200-W-90; Underground Radioactive Material Areas Posted Along 23rd Street in 200 West Area	0	No
20	200 W 93; Contaminated Soil at 241 T Tank Farm	0	No
21	207-T; 207-T Retention Basin; T Plant Retention Basin	0	Yes
22	216-T-12; 207-T Sludge Grave; 207-T Sludge Pit; 216-T-11	0	Yes

Hanford Site-Wide Risk Review
T Tank Farm
WIDS Export from PHOENIX

No.	Name	ERS_OP_DES	SWMUFLAG
23	216-T-14; 241-T-1 Trench; 216-T-1 Grave; 216-T-13	0	Yes
24	216 T 15; 216 T 15 Crib; 241 T 2 Grave; 241 T 2 Trench; 216-T-14	0	Yes
25	216-T-16; 216-T-16 Crib; 241-T-3 Grave; 241-T-3 Trench; 216-T-15	0	Yes
26	216 T 17; 216 T 4 Grave; 241 T 4 Trench; 216 T 16	0	Yes
27	216 T 32; 216 T 6; 241 T #1 & 2 Cribs	0	Yes
28	216 T 36; 216 T 36 Crib	0	Yes
29	216-T-5; 216-T-5 Grave; 216-T-5 Trench; 241-T-5 Trench; 216 T 12	0	Yes
30	216-T-7; 216-T-7 Tile Field; 216-T-7TF; 241-T-3 Tile Field	0	Yes
31	241-T-101; 241-T-TK-101	0	Yes
32	241-T-102; 241-T-TK-102	0	Yes
33	241-T-103; 241-T-TK-103	0	Yes
34	241-T-104; 241-T-TK-104	0	Yes
35	241-T-105; 241-T-TK-105	0	Yes
36	241 T 106; 241 T TK 106	0	Yes
37	241-T-107; 241-T-TK-107	0	Yes
38	241 T 108; 241 T TK 108	0	Yes
39	241 T 109; 241 T TK 109	0	Yes
40	241 T 110; 241 T TK 110	0	Yes
41	241 T 111; 241 T TK 111	0	Yes
42	241 T 112; 241 T TK 112	0	Yes
43	241 T 151; 241 T 151 Diversion Box	0	Yes
44	241-T-152; 241-T-152 Diversion Box	0	Yes
45	241 T 153; 241 T 153 Diversion Box	0	Yes
46	241-T-201; 241-T-TK-201	0	Yes
47	241-T-202; 241-T-TK-202	0	Yes
48	241-T-203; 241-T-TK-203	0	Yes
49	241-T-204; 241-T-TK-204	0	Yes
50	241-T-252; 241-T-252 Diversion Box	0	Yes
51	241-T-301B; 241-T-301-B; IMUST; Inactive Miscellaneous Underground Storage Tank; Lines V664 and V727; 241-T-0301; 241 T 301 Catch Tank	0	Yes
52	241-T-302; 241-T-302 Catch Tank	0	Yes
53	241 TR 152; 241 TR 152 Diversion Box; Line 6053	0	Yes
54	241-TR-153; 241-TR-153 Booster Pump Pit; 241-TR-153 Diversion Box; Line 6172	0	Yes
55	UPR 200 W 147; 241 T 103 Leak	0	No
56	UPR-200-W-148; 241-T-106 Leak	0	No
57	UPR-200-W-166; Contamination Migration from 241-T Tank Farm; UN 216 W 31	0	No

Hanford Site-Wide Risk Review
T Tank Farm
WIDS Export from PHOENIX

No.	Name	ERS_OP_DES	SWMUFLAG
58	UPR-200-W-29: 23rd and Camden Line Break; Transfer Line Leak; UN-200-W-27; UN-200-W-29; UN-216-W-5; UPR-200 W 27	Infrastructure	No
59	UPR-200-W-63; Road Contamination Along the South Shoulder of 23rd Street; UN-200-W-63	0	No
60	UPR-200-W-64; Road Contamination at 23rd and Camden; UN-200-W-64	Infrastructure	No
61	UPR-200-W-7; Contamination Spread from the 241-T-151 and 241-T-152 Diversion Boxes; UN-200-W-7	0	No
62	UPR-200-W-97; Transfer Line Leak; UN-200-W-97; UN-216-W 5	Infrastructure	No

APPENDIX F

SHORT BIOGRAPHIES OF

CRESP and PNNL PARTICIPANTS

Table of Contents

*CRESP Management Board member

1. CRESP Leadership

David S. Kosson*

David Kosson, PhD (CRESP Principal Investigator) is Cornelius Vanderbilt Professor of Engineering at Vanderbilt University, where he has appointments as Professor of Civil and Environmental Engineering, Chemical Engineering, and Earth and Environmental Sciences. Professor Kosson also is the Principal Investigator for the multi-university Consortium for Risk Evaluation with Stakeholder Participation (www.CRESP.org), supported by the Department of Energy to improve the risk-informed basis for remediation and management of nuclear waste from former defense materials production and nuclear energy. Professor Kosson's research focuses on management of nuclear, energy production and industrial wastes, including process development and contaminant mass transfer applied to groundwater, soil, sediment, waste and cementitious materials systems. Dr. Kosson in collaboration with other Vanderbilt researchers, U.S. EPA and the Energy Research Centre of The Netherlands has developed the Leaching Environmental Assessment Framework (LEAF) for understanding the release of contaminants from wastes and construction materials under a wide range of use and disposal scenarios (www.vanderbilt.edu/Leaching). Dr. Kosson leads the Cementitious Barriers Partnership (www.CementBarriers.org) which is a multi-institution initiative focused on developing advanced tools for predicting the long-term performance of cementitious materials in nuclear applications. Professor Kosson has participated in or led many external technical reviews on nuclear waste processing for the Department of Energy including for tank wastes and a range of technology approaches at Hanford, Savannah River and Idaho sites. Dr. Kosson served as a member of U.S. DOE Secretary Chu's team to address design challenges associated with the Hanford Waste Treatment Plant. Professor Kosson also has provided expertise and leadership for the National Academies, and as advisory to the Department of Defense, for two decades on demilitarization of chemical weapons in the United States and abroad. Professor Kosson has authored more than 100 peer-reviewed professional journal articles, book, book chapters and other archival publications. He received his Ph.D. in Chemical and Biochemical Engineering from Rutgers University, where he subsequently was Professor of Chemical and Biochemical Engineering.

Charles W. Powers*

Charles W. Powers, PhD (CRESP Co-Principal Investigator) is Professor of Environmental Engineering at Vanderbilt where he is co-PI (with David Kosson) of the multi-university Consortium for Risk Evaluation with Stakeholder Participation (CRESP) that he co-founded in 1995. This many-discipline consortium exists to advance cost-effective, risk-informed cleanup and disposition of nuclear waste by carrying out independent scientific evaluation and fostering decisions based on the informed consent of affected publics.

Dr. Powers early academic career was spent at Yale University where, as associate professor of social ethics, he led the University's multi-disciplinary graduate program in ethics. He has been an environmental officer in the private sector (Cummins Engine Company), the founding chair or CEO of eight environmental institutions and consortia including the Health Effects Institute, Clean Sites, the NY/NJ Harbor Consortium, and he was the custodial trustee of the nation's then #5 Superfund site (Industri-plex). In addition to Yale and Vanderbilt, he has been on the faculties of Robert Wood Johnson Medical School, Tufts, Harvard, Princeton, and Haverford. He is an author of some 85 peer reviewed articles on diverse scientific and policy issues and an author of The Ethical Investor: Universities and Corporate Responsibility (New Haven) and The Great Experiment: Brownfields Pilots Catalyze Revitalization (New Brunswick).. Dr. Powers received his B.A. with honors from Haverford College, and holds graduate degrees from Oxford University, Union Theological Seminary and two from Yale University including his Ph.D.

*CRESP Management Board member

Jennifer A. Salisbury

After graduating from the University of New Mexico School of Law, Jennifer A. Salisbury, JD, spent the first part of her career working in the United States Congress, including as Director of Legislation for a Senator. Then, she served as a trial lawyer in such positions as Assistant United States Attorney and General Counsel of a state agency. Later, her career shifted away from legal jobs and toward executive management positions in government, such as at the Department of the Interior, where she provided management oversight as Deputy Assistant Secretary of such federal agencies as the Minerals Management Service and National Park Service. This was followed by a seven year stint as the Cabinet Secretary of New Mexico's natural resources agency. While Secretary, Salisbury coordinated the state's efforts to ensure New Mexico's radioactive waste transportation safety program had been completely implemented by the time shipments of transuranic waste to the Waste Isolation Pilot Plant began in March 1999.

Since leaving government, Salisbury has served as a consultant on such issues as environmental cleanup, nuclear waste transportation, and natural resource development on public lands. Salisbury also mediates legal disputes. She recently ended ten years of service as a member of the Department of Energy's Environmental Management Advisory Board and currently serves as board chair of a non-profit that fosters collaborative processes to develop concrete recommendations for tackling important state policy concerns.

2. CRESP

Craig H. Benson*

Craig H. Benson, PhD, PE, DGE is Wisconsin Distinguished Professor and Chair of Geological Engineering at the University of Wisconsin-Madison. He also serves as Director of the Recycled Materials Resource Center (RMRC), a federally funded research center focused on sustainable construction of transportation infrastructure, and the Bioreactor Partnership, a industry-academic partnership on sustainable solid waste management. He is a member of the Management Board of the Consortium for Risk Evaluation with Stakeholder Participation (CRESP). Dr. Benson has a BS from Lehigh University and MSE and PhD degrees from the University of Texas at Austin. Dr. Benson has been conducting experimental and analytical research in geoenvironmental engineering for 27 yr, with the primary focus in environmental containment, beneficial use of industrial byproducts, and sustainable infrastructure. His research has included laboratory studies, large-scale field experiments, and computer modeling. Dr. Benson has received several awards for his work, including the Huber Research Prize, the Alfred Nobel Prize, and the Croes (twice), Middlebrooks, Collingwood, and Casagrande Awards from the American Society of Civil Engineers. Dr. Benson is a member of the ASCE Geo-Institute (GI) and is former Editor-in-Chief of the ASCE/GI Journal of Geotechnical and Geoenvironmental Engineering. He currently serves as Treasurer for the ASCE/GI Board of Governors and is a member of the Executive Committee of ASTM Committee D18 on Soil and Rock. Dr. Benson is a member of the University of Texas Academy of Distinguished Alumni.

Kevin G. Brown

Kevin Brown, PhD, is Senior Research Scientist in the Department of Civil and Environmental Engineering at Vanderbilt University. His research has been supported by the multi-university Consortium for Risk Evaluation with Stakeholder Evaluation (CRESP). Dr. Brown's current research focuses on life-cycle risk evaluation, model integration, and waste management issues related to proposed advanced nuclear fuel cycles and cementitious materials and barriers for nuclear applications. Between 1986 and 2002 at the Savannah River Laboratory, he was recognized as a DOE Complex-wide authority in process and product control for high-level waste vitrification. Dr. Brown spent 2002-2003 at the International Institute for Applied Systems Analysis in Laxenburg, Austria where he estimated potential transboundary radiation doses resulting from hypothetical accidents at Russian Pacific Fleet sites. Dr. Brown led the CRESP evaluation of life-cycle risks for the DOE Idaho Site Subsurface Disposal Area where wastes contaminated with radioactive and hazardous materials were buried in pits, trenches, and soil vaults before

1970. The Idaho results were presented to the Idaho Site Citizens Advisory Board, who strongly endorsed the clarity of the approach and the results. In 2009 Dr. Brown was a member of the External Technical Review Team chartered by DOE-HQ to evaluate the system-level modeling and simulation tools in support of Savannah River Site and Office of River Protection liquid waste processing and disposal. In 2010 and 2011 Dr. Brown participated on the Tank Waste Subcommittee of the DOE Environmental Management Advisory Board charted to provide independent technical reviews of liquid waste capital and operations projects related to DOE-EM's tank waste cleanup program at major DOE Sites. He participated in Construction Project Reviews for the Hanford Tank Waste Treatment and Immobilization Plant in 2011 and 2013 and the Savannah River Salt Waste Processing Facility in 2011, 2012, and 2013. In 2011 and 2012, Dr. Brown applied the prioritization model developed by CRESP to prioritize remediation and associated projects at DOE sites to Melton Valley, Experimental Molten Salt Reactor Experiment, East Tennessee Technology Park, and Bear Creek Burial Grounds at the Oak Ridge National Laboratory. He holds a BE in Chemical Engineering, an MS in Environmental and Water Resources Engineering, and a PhD in Environmental Engineering all from Vanderbilt University.

Joanna Burger *

Joanna Burger, PhD, is a Distinguished Professor of Biology at Rutgers University and a professor in the School of Public Health, where she teaches ecology, behavior, and ecological risk to undergraduate and graduate students. Her primary research has been in ecotoxicology, risk assessment, behavioral ecology, biomonitoring and stakeholder involvement, especially at Department of Energy Sites, including Savannah River Site, Oak Ridge, Brookhaven, Idaho National Laboratory, Los Alamos, Amchitka Island, and Hanford. She has studied the interactions of ecosystems and people for over 30 years, including monitoring levels of radionuclides, mercury and other contaminants on environmental health. Additional research involves public perceptions and attitudes, inclusion of stakeholders in solving environmental problems, and the efficacy of conducting stakeholder-driven and stakeholder-collaborative research. Professor Burger has participated in reviews for the Department of Energy, as well as the educational program of the Nuclear Regulatory Commission. She has edited a book on Science and Stakeholders, aimed at understanding the role of a full range of stakeholders in energy-related decisions, focusing on several case studies of Department of Energy sites. She is on the Editorial Board for Journal of Nuclear Energy and Power Generation Technologies, Environmental Research, Science for the Total Environment, Environmental Monitoring and Assessment, and Journal of Toxicology and Environmental Health. Professor Burger has participated on many National Academy of Sciences committees, including serving on the Board of Environmental Science and Toxicology and Board of Biology, as well as several committees for the US Environmental Protection Agency (most recently on unique exposures for environmental justice communities). Professor Burger has authored more than 400 peer-reviewed professional journal articles, books, and book chapters. She received the Lifetime Distinguished Achievement Award from the Society of Risk Analysis, as well as being a Fellow of several societies. She received her B. S. in Biology from the State University of New York at Albany, her M. S. in Zoology and Science Education from Cornell University, her Ph.D. in Ecology from the University of Minnesota in Minneapolis, Minnesota, and an Honorary PhD from the University of Alaska at Fairbanks.

James H. Clarke*

Jim Clarke, PhD, is Professor of the Practice of Civil and Environmental Engineering and Professor of Earth and Environmental Sciences at Vanderbilt University. Prior to joining the faculty of Vanderbilt University in the Fall of 2000, he was Chairman, President and CEO of Eckenfelder, Inc., an environmental engineering and consulting firm focusing on services to the private sector in the areas of hazardous waste management, contaminated site investigation and remediation and wastewater treatment. Jim's experience includes the investigation, risk assessment, technology evaluation and remediation of over 30 Superfund sites. His research at Vanderbilt focuses on the investigation, remediation and long-term management of legacy hazardous chemical and radioactive waste sites and the energy – environment interface.

Jim was a member of the former Nuclear Regulatory Commission (NRC) Advisory Committee on Nuclear Waste and Materials and advised the Commission and the Office of Nuclear Materials Safety and Safeguards on issues concerning the Yucca Mountain project, risk-informed performance-based approaches to site decommissioning and remediation (lead Committee member) and the overall nuclear waste regulatory program He is a consultant to the NRC Advisory Committee for Reactor Safeguards and its subcommittee on Radiation Protection and Nuclear Materials. Jim is a member of the American Academy of Environmental Engineers and Scientists and has served on committees of the National Academies (the Committee on Remediation of Buried and Tank Waste). He is a peer reviewer for the National Academy, the U.S. Environmental Protection Agency, the Department of Energy and several journals and book publishers.

Dr. Clarke received his Ph.D. in theoretical physical chemistry from The Johns Hopkins University and a B.A. in chemistry with honors from Rockford College.

Allen G. Croff

Allen G. Croff has a BS in chemical engineering from Michigan State University, a Nuclear Engineer Degree from the Massachusetts Institute of Technology, and a MBA from the University of Tennessee. He worked at Oak Ridge National Laboratory (ORNL) for 29 ½ years and retired in 2003. While employed at ORNL, Mr. Croff was involved in technical studies and program development focused on waste management and nuclear fuel cycles, including development of the ORIGEN2 computer code and study of actinide partitioning-transmutation. Mr. Croff chaired a committee of the National Council on Radiation Protection and Measurements that produced the 2002 report titled "Risk-Based Classification of Radioactive and Hazardous Chemical Wastes" and the Nuclear Energy Agency's Nuclear Development Committee from 1992 to 2002. He was also vice-chairman of the U.S. Nuclear Regulatory Commission's Advisory Committee on Nuclear Waste and Materials from 2004 until its merger with the Advisory Committee on Reactor Safeguards in 2008. Mr. Croff was a member of the DOE Nuclear Energy Research Advisory Committee from 1998 to 2005 and seven previous committees of the National Academies. He is currently a member of the National Council on Radiation Protection and Measurements, the National Academies' Nuclear and Radiation Studies Board, and a National Academies committee on a development of a DOE cleanup technology roadmap.

Lyndsey Fern Fyffe

Lyndsey Fyffe is a graduate research assistant with CRESP and Ph.D. Candidate in Environmental Engineering at Vanderbilt University in Nashville Tennessee. Her research area is nuclear and chemical safety, with a dissertation focused on analyzing trends (qualitative and quantitative) from accidents in both the nuclear industry and the chemical industry to improve safety and efficiency of operations at nuclear chemical facilities. Ms. Fyffe has a M.S. in Environmental Engineering from Vanderbilt and a B.S. in Civil and Environmental Engineering from Duke University.

Michael Gochfeld

Michael Gochfeld, MD, PhD, is an environmental toxicologist and occupational physician who is Professor in the Department of Environmental and Occupational Medicine at Rutgers-Robert Wood Johnson Medical School in the Environmental and Occupational Health Sciences Institute (Piscataway, New Jersey). He is one of the founding members of the Consortium for Risk Evaluation with Stakeholder Participation (CRESP), which provides a variety of research endeavors supporting the Department of Energy's management of nuclear and chemical contamination from the manufacture and testing of nuclear weapons. His research has focused on ecological and human health consequences of occupational and environmental exposure to heavy metals, particularly mercury. From 1999 to 2001 he chaired New Jersey's Mercury Task Force. His work on mercury included investigating cultural practices resulting in exposure to elemental mercury as well as mercury risks from fish consumption.

He has been active in exploring unique environmental exposure pathways, and environmental justice. He has also chaired the international Cadmium Working Group for the Scientific Group on Methodology for Safety Evaluation of Chemicals, part of the International Scientific Committee on Problems of the Environment. He is also a clinician seeing patients exposed to heavy metals and other contaminants in their home, community, or workplace environments, one aspect of which is evaluation of high-end fish consumers exposed to methylmercury. He received the Health Achievement Award from the American College of Occupational and Environmental Medicine. He is author of over 200 peer-reviewed papers on environmental and occupational health and has contributed book chapters on toxicology and risk assessment.

Michael Greenberg*

Michael Greenberg, PhD, studies environmental health and risk analysis. He is distinguished professor and associate dean of the faculty of the Edward J. Bloustein School of Planning and Public Policy, Rutgers University. He has written 30 books and more than 300 articles. His two most recent books are *The Environmental Impact Statement After Two Generations: Managing Environmental Power*, New York: Routledge (2011), and *Nuclear Waste Management, Nuclear Power and Energy Choices: Public Preferences, Perceptions, and Trust,* London: Springer (2012). Currently, professor Greenberg is writing *Protecting Seniors Against Environmental Disasters: From Hazards and Vulnerability to Prevention and Resilience*. He has been a member of National Research Council Committees that focus on the destruction of the U.S. chemical weapons stockpile and nuclear weapons; chemical waste management; and the degradation of the U.S. government physical infrastructure. Dr. Greenberg has received awards from the United States Environmental Protection Agency, the Society for Professional Journalists, the Public Health Association, the Association of American Geographers, and Society for Risk Analysis. He served as area editor for social sciences and then editor-in-chief of *Risk Analysis: An International Journal* during the period 2002-2103, and continues as associate editor for environmental health for the *American Journal of Public Health*

Kathryn A. Higley*

Kathryn Higley, PhD, is a Professor in the Department of Nuclear Engineering. She holds a B.A. in Chemistry (1978) from Reed College; an M.S. in Radiological Health Sciences (1992) and a Ph.D. in Radiological Health Sciences (1994) from Colorado State University. Her fields of interest include environmental transport and fate of radionuclides; radiochemistry; radiation dose assessment; neutron activation analysis; nuclear emergency response; and environmental regulations.

She has held both Reactor Operator and Senior Reactor Operator's licenses, and is a former Reactor Supervisor for the Reed College TRIGA reactor. She has held research positions at three research reactors including Reed College, Washington State University (Pullman), and Oregon State University. She has fourteen years with Battelle, Pacific Northwest Laboratories as an environmental health physicist at the Hanford Nuclear Reservation, and three years experience in environmental radiation monitoring at the Trojan Nuclear Power Plant in Oregon. She is a consultant to the U.S. Department of Energy's Office of Air, Water and Radiation Protection. She is a member of the Health Physics Society and a certified Health Physicist. Dr Higley has been at Oregon State University since 1994 teaching undergraduate and graduate classes on radioecology, dosimetry, radiation protection, radiochemistry, societal aspects of nuclear technology, and radiation biology.

George M. Hornberger

George Hornberger, PhD, is Distinguished University Professor at Vanderbilt University where he holds appointments as the Craig E. Philip Professor of Civil & Environmental Engineering and Professor of Earth & Environmental Sciences. Professor Hornberger is the Director of the Vanderbilt Institute for Energy and Environment which fosters research, teaching and outreach on social, economic, legal, and technical aspects of critical issues at the energy-environment intersection. He previously for many years was a member of the faculty at the University of Virginia, where he held the Ernest H. Ern Chair in Environmental Sciences. He received a Ph.D. in Hydrology from Stanford University in 1970. In addition to interdisciplinary research underway through VIEE, he continues his longstanding research on the transport of dissolved and suspended constituents through soils, groundwater, and catchments. Hornberger is a Fellow of the American Geophysical Union, of the Association for Women in Science, and of the Geological Society of America. He is a recipient of the Robert E. Horton Award of the Hydrology Section of AGU, the Biennial Medal for Natural Systems of the Modelling and Simulation Society of Australia, the John Wesley Powell Award for Citizen's Achievement from the USGS, the Excellence in Geophysical Education Award from AGU, and the William Kauala Award from AGU. He was the 2002 Langbein Lecturer of the

American Geophysical Union. He was selected as Outstanding Scientist in Virginia in 2007. He is a member of the U.S. National Academy of Engineering.

Kimberly L. Jones*

Kimberly L. Jones, PhD, is a professor of Environmental Engineering and Chair of the Department of Civil and Environmental Engineering at Howard University in Washington, DC. She holds a B.S in Civil Engineering from Howard University, a M.S. in Civil and Environmental Engineering from the University of Illinois in Champaign, IL and a Ph.D. in Environmental Engineering from The Johns Hopkins University. Dr. Jones' research interests include developing membrane processes for environmental applications, physical-chemical processes for water and wastewater treatment, remediation of emerging contaminants, and environmental nanotechnology.

Dr. Jones currently serves on the Chartered Science Advisory Board of the US Environmental Protection Agency, and as chair of the Drinking Water Committee of the Science Advisory Board. She has served on the Water Science and Technology Board of the National Academy of Sciences, and the Board of Association of Environmental Engineering and Science Professors, where she was Secretary of the Board. She has served on several committees of the National Academy of Science and the Institute of Medicine. She served as the Deputy Director of the Keck Center for Nanoscale Materials for Molecular Recognition, one of the first centers to bring nanotechnology research to Howard University. She also serves on the Center Steering Committee of the Center for the Environmental Implications of Nanotechnology (CEINT), a National Environmental Nanotechnology Center. Dr. Jones has received a Top Women in Science Award from the National Technical Association, the Outstanding Young Civil Engineer award from University of Illinois Department of Civil and Environmental Engineering, a NSF CAREER Award, an Outstanding Leadership and Service award from the College of Engineering, Architecture and Computer Sciences at Howard, Outstanding Faculty Mentor award from the American Society of Civil Engineers HU Student Chapter and Top Women Achievers award from Essence Magazine. She also served as an associate editor of the Journal of Environmental Engineering (ASCE).

Steven L. Krahn*

Steven Krahn, PhD, is Professor of the Practice of Nuclear Environmental Engineering in the Department of Civil and Environmental Engineering at Vanderbilt University. Immediately prior to coming to Vanderbilt, he served in U. S. Department of Energy (DOE) as the Deputy Assistant Secretary for Safety & Security in the Office of Environmental Management (EM). He is performs research as part of the Consortium for Risk Evaluation and Stakeholder Participation (CRESP) in the areas of nuclear and environmental risk assessment and risk management and the insertion of advanced technology into nuclear facilities. While at DOE, Dr. Krahn: served as the Deputy Chair of the Nuclear Safety Research and Development Committee which provided oversight and direction to safety-related research; directed the technology development program for the nuclear waste processing; chaired the EM Technical Authority Board, charged with providing final technical approval of new facilities and major modifications to nuclear facilities; and was selected by the Deputy Secretary to serve on the Risk Assessment Working Group, DOE's technical leadership team for overseeing the development of improved quantitative risk analysis in the department. He has led or served on more than dozens technical reviews of nuclear facilities and radioactive waste processing systems for DOE sites including Savannah River, Hanford, Idaho, Oak Ridge and others. He has also provided nuclear/environmental engineering and risk assessment consultation to the U.S. nuclear industry for more than a dozen years and to NASA for five years. He received his Doctorate in Public Administration from the University of Southern California and holds an M.S. in Materials Science from the University of Virginia. He previously taught systems engineering at The George Washington University and the University of Maryland.

Eugene J. LeBoeuf

Eugene J. LeBoeuf, PhD, PE, is an Associate Professor of Civil and Environmental Engineering at Vanderbilt University. He also serves as the Associate Chair for the Department of Civil and Environmental Engineering and Director of Undergraduate Studies. His teaching and research interests include water resources engineering, surface and groundwater hydrology, and physicochemical processes of environmental systems, including fate and transport of contaminants in the environment.

Dr. LeBoeuf received his B.S. in civil engineering from Rose-Hulman Institute of Technology in 1985, M.S. in industrial engineering and management science from Northwestern University in 1986, M.S. in civil engineering from Stanford University in 1993, and a Ph.D. in environmental engineering from The University of Michigan in 1998. He has over 40 archival peer-reviewed publications and one U.S. patent. He is a registered professional engineer in the states of Tennessee and Missouri, and a member of the American Academy of Environmental Engineers and Scientists as a Board Certified Environmental Engineer. Dr. LeBoeuf also serves as a Colonel in the U.S. Army Reserve, having served in a number of Army and joint military positions both on active duty and in the Reserve. He is currently serving as Chief of Staff, 416th Theater Engineer Command, Dairen, Illinois.

Henry J. Mayer

Henry J. Mayer, Ph.D., is Executive Director of the Environmental Analysis & Communications Group , Director of the Bloustein-CAIT Ports Program and a Faculty Fellow at the E.J. Bloustein School of Planning & Public Policy, Rutgers University. Dr. Mayer has extensive experience in the corporate, academic, and government arenas, with a focus over the past fifteen years on the large and complex environmental, infrastructure, and capital financing issues associated with the redevelopment of many of the country's older cities and towns. His recent work has included examining the policies, programs and decisions that have influenced the development and life-cycle costs of the U.S. Department of Energy's environmental management cleanup efforts at the nation's former nuclear weapons sites over the past fifteen years. He recently completed a Background Forensics Analysis of the Portsmouth and Paducah Gaseous Diffusion Facilities Decontamination and Demolition (D&D).

Jane B. Stewart

Jane B. Stewart, JD, is an environmental lawyer with over 30 years experience in the private and nonprofit sectors. She founded and directs the International Environmental Legal Assistance Program of New York University School of Law's Frank J. Guarini Center on Environmental and Land Use Law. Formerly a lawyer with Paul, Weiss, Rifkind, Wharton and Garrison and a senior staff attorney with the Natural Resources Defense Council, she has since 1996 provided environmental law and policy advice and consultation on a wide variety of issues to governments, international organizations, academic institutions, law firms and nongovernmental organizations. She is also one of the key personnel of the Consortium for Risk Evaluation with Stakeholder Participation (CRESP), where her research focuses on the history and evolution of nuclear waste law and policy in the U.S. and options for the future, including lessons learned from the WIPP and Yucca Mountain repositories, options for interim storage of SNF and HLW, and options for managing GTCC nuclear wastes. Ms. Stewart is co-author, with her husband, NYU Professor Richard B. Stewart, of the forthcoming book, Fuel Cycle to Nowhere, to be published by Vanderbilt University Press in 2011. She received her A.B. from Brown University and her J.D. from NYU School of Law.

Richard B. Stewart*

Richard B. Stewart, LL.B., is a world-recognized scholar in environmental, administrative and regulatory law, having published over 10 books and nearly 100 articles in these fields. He is University Professor, John E. Sexton Professor of Law, New York University. He is Director of the Frank T. Gurini Center on Environmental and Land Use Law, and of the Hauser Global law School program at NYU. His recent work has included a major forthcoming book, with Jane Stewart that provides the first comprehensive history and account of U.S. nuclear waste law and regulatory policy, several articles on nuclear waste policy, and a co-authored book that sets forth a general program for reform of U.S. environmental law. Before joining NYU in 1992, Stewart was Byrne Professor of Administrative Law at Harvard Law School and, from 1989-91, Assistant Attorney General in charge of the Environment and Natural Resource Division of the U.S. Department of Justice, where he formulated the U.S. government's position on the Rio Climate Convention, prosecuted Exxon for the Exxon Valdez oil spill, and was responsible for legal issues relating to DOE's defense facilities and wastes, including representing the U.S. is Nevada's unsuccessful litigation challenge to the constitutionality of the Nuclear Waste Policy Act. Stewart is Advisory Trustee and former

Chairman, Environmental Defense Fund. Stewart is a graduate of Yale University, Harvard Law School and Oxford University, where he was a Rhodes Scholar. He is a member of the American Academy of Arts and Sciences and the American Law Institute. He holds honorary degrees from the University of Rome “La Sapienza” and Erasmus University, Rotterdam.

Hamp Turner

Dr. Hamp Turner has more than 25 years' experience in software development, data management, and engineering process modeling. He is the owner of Turner Technology, LLC (Nashville, TN), a software and engineering consulting company founded in 2001. He previously worked for OLI Systems, Inc. (Morris Plains, NJ).

Interests include the development of systems and interfaces that provide a bridge between complex modeling and software technology and the skill sets of less sophisticated computer users. This includes the integration of engineering computer models with internet interfaces and with Microsoft Excel and the management and presentation of complex data sets.

Dr. Turner has a PhD in chemical engineering from Rutgers University.

3. PNNL

Wayne Johnson
PNNL Lead and Core Team Liaison

Mr. Johnson, P.E., is the Director of the Earth Systems Science Division within Pacific Northwest National Laboratory's Energy and Environment Directorate, overseeing six technical groups and approximately 250 staff. ESSD conducts a wide range of environment-related research in support of waste cleanup, natural resource management and energy production. Mr. Johnson possesses more than 29 years of management experience in the fields of nuclear engineering and radiological science; environment and earth sciences; and energy systems. Specific areas of expertise include complex project planning and strategic analysis, systems engineering, radiological controls, threat detection, environmental remediation and waste management. This includes serving as an Officer in the U.S. Navy at Naval Reactors, management responsibilities for environmental restoration and technology deployment projects at the Hanford Site, and project management and consulting support to multiple radiological facilities at various DOE and International sites, including the development and implementation of reactor accident cleanup and stabilization plans at the Chernobyl Site in the Ukraine. He currently has the assignment to be PNNL's lead in providing support to Japan in response to the Fukushima disaster. He is a registered Professional Engineer, Nuclear in the State of Washington. Mr. Johnson holds an M.S. in Engineering Management from Washington State University (1995) and a B.S. in Nuclear Engineering from Oregon State University (1983). Mr. Johnson is a member of the American Nuclear Society (since 1981).

Robert Bryce

Mr. Bryce (Project Manager Environmental Assessment Group) has thirty four years of experience managing or performing applied environmental research. He has managed environmental programs and major ground-water monitoring and hydrologic characterization and risk assessment projects for U.S. Department of Energy (DOE) contractors. He has also assisted DOE, regulators and contractors with the development of groundwater protection and risk assessment strategies for Hanford and was the contractor lead for developing the Hanford End State Vision in 2005. In addition to his experience with Hanford site monitoring and risk assessment he has participated in the geochemical and hydrologic characterization of regional ground-water flow systems.

Mr. Bryce was also member of the leadership team for the Hanford Site Groundwater Vadose Zone integration project and led the development of the System Assessment Capability. The System Assessment Capability was designed to assess the impact of Hanford waste on human health, ecological health, cultures and the regional economy. The capability represented Hanford waste inventory, simulated the transport of contaminants through the environment and estimated the resulting impact. The capability was developed through an open process with regulator, stakeholder, and Tribal Nation participation.

Mr. Bryce currently manages the Hanford Probabilistic Seismic Hazard Analysis (PSHA) project. The objective of the project is to assess future hazard to Hanford facilities from seismic events. The products of a PSHA include seismic hazard curves, uniform hazard spectra, and other products that serve as the input to ground motion site response analyses at a particular facility. The PSHA team is made up of international experts in seismic hazard analysis. The effort is performed with oversight from a participatory peer review panel.

Mr. Bryce also currently supports the Nuclear Regulatory Commission in performing environmental reviews of applications for new nuclear power plants. He has led the review team for several new applications and performed the review of groundwater and surface water aspects for a number of plant sites.

Amoret Bunn

Amoret Bunn, PhD, (Scientist, Environmental Assessment Group) has twenty years of experience as an environmental engineer performing applied environmental research. Her experience ranges from remediation activities for contaminated soil and groundwater, to development of ecological risk assessment software, to working with groups of people with various technical training and cultural backgrounds on environmental impact assessments. In addition, she has extensive experience in preparing and leading field surveys for hazard assessments of metal and organic contaminants in terrestrial and aquatic environments. Dr. Bunn has reviewed and prepared environmental compliance documentation for CERCLA, RCRA and NEPA, and participated in all phases of CERCLA RI/FS process. Her research areas of interest include pharmacokinetic studies of aquatic organisms, health assessments for nanomaterials, and ecological risk assessments of radionuclides and hazardous chemicals. Many of these assessments have focused on fate and transport in hyporheic systems using large-scale mesocosms.

John Cary

John Cary joined PNNL in 2012 as an Risk and Decision Analyst. John currently supports DOE/EM's Richland Operations Office Life-Cycle Model (LCM). LCM is a database-driven, object-oriented computer model which loads, links, and displays the detailed project baselines. John works with DOE/EM's Richland Operations Office to support life-cycle what-if analyses, budget re-planning activities, and, uses LCM's underlying simulation capabilities to estimate the impact of scope/schedule changes to project inventories across the Hanford site.

In addition, John also support project risk analysis for DOE's Global Threat Reduction Initiative (GTRI), a program design to convert research reactors research reactors and isotope production facilities from the use of highly enriched uranium (HEU) to low enriched uranium (LEU). John works to identifying risks that have an impact on the successful completion of the project by systematically challenging the assumptions and logic of the project, and examining the identified uncertainties. Moreover, he uses Monte Carlo simulations and qualitative risk prioritization methods to estimate the impact of risk on cost and completion milestones and determine mitigation strategies.

Prior to joining PNNL, John worked as an environmental economist in private industry specializing in survey design and environmental valuation. This mainly comprised the development of studies in support of several Natural Resource Damage Assessments with regard to human use services. This includes developing questionnaires, facilitating focus groups, testing survey formats through cogitative interviewing, forming technical approaches, leading field collection efforts, managing large databases, building and running econometric models. He holds a B.S in Environmental Economics and a Masters in Applied Economics from Washington State University.

Mickie Chamness

Ms. Chamness (Scientist Ecology Group) has worked at the Hanford Site for most of the past 34 years. For the first 15 years she worked on projects related to hydrogeologic characterization of sites for storage, monitoring and cleanup of radioactive and mixed waste sites. After a brief hiatus, she returned to PNNL to work on wide range of environmental projects including environmental monitoring, ecological surveys at Hanford and around the country, and compilation of data on biological receptors at the Hanford Site. Work on ecological surveys gives her the opportunity to work with cultural resource experts.

Currently, Ms. Chamness is working on geologic energy storage and energy and water conservation projects. She holds a Bachelor of Science degree in Geology from Washington State University.

Vicki Freedman

Vicki Freedman's, PhD, (Scientist Hydrology Group) research activities have included theoretical and numerical studies of coupled hydrodynamics, contaminant transport, and geochemistry in environmental systems since joining PNNL in 2000. She has been involved in both forward prediction and inverse modeling of tank farm wastes at the Hanford Site, and has been a major contributor to the vadose zone modeling for field investigations of past leaks, as well as tank closure performance assessments (PA) investigating potential leak scenarios. She is currently providing technical oversight to the baseline risk assessment PA being performed for Waste Management Area C. Dr. Freedman has also led the demonstration of a new high performance computing capability currently under development by ASCEM (Advanced Simulation Capability for Environmental Management). This demonstration included using supercomputers to model subsurface discharges and evaluate potential remediation technologies in the deep vadose zone at Hanford.

Jeannette Hyatt

Ms. Hyatt has 23 years of experience at DOE sites in leadership, management and technical direction of diverse organizations. In her current position she is responsible for project management of deployment of innovative technical approaches to complex operational conditions involving multiple organizations and facilities. As the Director of Regulatory Integration and Environmental Services at the Savannah River Site, she was responsible for ensuring proper environmental risk assessment, operational compliance, and successful decommissioning and demolition. During the execution of the American Recovery and Reinvestment Act project she implemented innovative approaches to environmental risk reduction, effective deployment of new programs and data rich reporting systems. Her area of expertise ranges between development of rapid deployment analytical techniques & mobile laboratories, Radioanalytical Laboratory Operations, Quality Assurance, Client Services, Business Management and delivery of Environmental Services to Nuclear Operations, Environmental Remediation, and Federal Emergency Management Act project direction. Projects requiring extensive negotiation and facilitation between parties of diverse technical and socio-economic interests are her area of special interest. Ms. Hyatt holds a BS in Chemistry (Montana State University, 1990), an MBA in Engineering & Technology (City University-Bellevue, 1995), and maintains professional certification as a Project Management Professional. She is a member of the Savannah River Site Leadership Association and is the past VP of Programs for the local PMI Chapter.

George Last

Mr. Last has 38 years of experience in applied geology and hydrogeologic research, project management, and line management. He joined the Pacific Northwest National Laboratory (PNNL) in February 1984, where he managed the Site Characterization Group from 1988 to 1993, and the Hanford Cultural Resources Program from 1993 to 1994. He has managed many environmental projects for the U. S. Department of Energy (and its contractors), the Bonneville Power Administration, the U.S. Army, U.S. Air Force, U.S. Nuclear Regulatory Commission, and the private sector. He has lead or participated in a broad range of geology, hydrogeology, and environmental studies supporting facility siting, hazardous waste site investigations, vadose zone research, and groundwater hydrology. His experience includes project scoping and management, drilling and sampling, geophysics, geologic mapping, field and laboratory experimentation, and data analysis. He has authored or coauthored over 130 technical reports and journal articles. He is a licensed geologist and hydrogeologist in the State of Washington. Mr. Last holds an M.S. in Environmental Sciences (Hydrogeology) from Washington State University (1997) and a B.S. in Geology from Washington State University (1976). Mr. Last is a member of a number of professional organizations including the Geological Society of America, American Geophysical Union, American Association of Petroleum Geologists, and the Northwest Scientific Association (Board of Directors).

Peter Lowry

Peter Lowry (Senior Engineer, Risk & Decision Sciences) is a safety engineer with over 20 years of experience in supporting nuclear licensing, hazard and accident analyses and safety control development, system engineering, and project management.

Mr. Lowry has performed and supported hazards and safety analysis for several Hanford Facilities and projects including, the Plutonium Finishing Plant (PFP), PUREX Deactivation, Spent Nuclear Fuels Project Canister Storage Building and Sludge Treatment Project, Tank Waste Remediation System (Tank Farms), and the Waste Treatment Plant (Nuclear Safety Lead for Low-Activity Waste (LAW), High Level Waste (HLW) Vitrification and Pre-Treatment facilities). Mr. Lowry supported the Hanford Tank Operations Contractor (TOC)/Waste Treatment Plant (WTP) - One System Team in the comparative evaluation of documented safety analyses performed on TOC and WTP facilities. In addition, he has conducted and supported hazards and safety analysis at nuclear power plants, U.S. Department of Energy nuclear and non-nuclear facilities at the Pacific Northwest National Laboratory, Savannah River Site, Idaho National Laboratory, and Rocky Flats Site, and for Petróleos Mexicanos (PEMEX) petroleum pump and transfer systems.

Mr. Lowry currently supports the Nuclear Regulatory Commission as part of the PNNL team to review the Risk Informed Fire Protection Amendment Requests for existing U.S Light Water Reactor Nuclear Power Plants and has supported DOE NE and NRC in the evaluation of aging of passive components in nuclear power plants.

Mr. Lowry serves on the writing groups for both ANS 53.1 Nuclear Safety Criteria and Safety Design Process for Modular Helium-Cooled Reactor Plants and ASME/ANS, Standard for Probabilistic Risk Assessment for Advanced Non-Light Water Reactor Nuclear Power Plants.

Michelle Niemeyer

Michelle Niemeyer (Scientist, Appliance & Commercial Equipment Standards Energy and Environment Directorate) joined PNNL in January of 2008 as an Energy and Research Economist. She has conducted regional economic impact analyses including input-output modeling analysis, job creation impacts and socioeconomic analysis. She has worked on such projects as the economic impact of Pacific Northwest National Laboratory on the State of Washington. Her work included gathering data, input-output modeling in IMPLAN and document preparation and review.

Ms. Niemeyer also supports the Nuclear Regulatory Commission in performing environmental reviews of applications for new nuclear reactors as a subject matter expert in the evaluation of matters related to socioeconomics, environmental justice, land-use, benefit-cost analyses, and need for power assessments. Other work activities include life-cycle cost analysis, national impact analysis, and environmental analysis for appliance and equipment energy conservation standards for the U.S. Department of Energy.

Prior to joining PNNL, Ms. Niemeyer worked for the Texas AgriLife Extension Service as a program specialist in fiscal and economic impact analysis. Her responsibilities primarily included economic modeling and data analysis support for outreach programs and applied research designed to improve public-sector, community, and business decision-making. She holds a Bachelor of Science and Master of Science in Agricultural Economics from Texas A&M University.

Mary Peterson

Since joining Battelle in 1982, Ms. Peterson has held positions as a deputy sector manager, line manager of 60 technical people, key client account manager, program manager and project manager for projects totaling over $20 M, technical contributor, and principal investigator. The focus of her activities has been on strategy development, sales/business growth with government and industrial clients, building and managing relationships, lab-wide capability development and program/project execution.

She is currently working with multiple sectors including Environmental Management and Homeland Security to establish new business opportunities and develop business and capability strategies. In addition, she is engaged in a breadth of programmatic activities and client relationships associated with sector management.

Reid Peterson

Reid Peterson, PhD, has worked largely in the field of waste processing for treatment of High Level Waste. Dr. Peterson has extensive background in managing large research programs. In addition, Dr. Peterson has experience in taking projects from inception to pilot scale proof of concept. Through his experiences at PNNL, WTP and SRNL, Dr. Peterson has developed working relationships with key staff across the National Lab complex including ANL, INEL, LANL, and SRNL as well as the site contractors for waste processing at both SRS and Hanford. Past activities include: Leading research teams in the areas of separation processes for nuclear applications. Current focus areas include dissolution reaction, cesium removal technologies and solid/liquid separation techniques; Organized and led team to identify, select and demonstrate back-up ion exchange resin for cesium separation; Supervised research programs that timely mitigated all key technology risks associated with separation processing for the WTP; and Led preparation.

Christine Ross

Christine Ross joined Battelle Memorial Institute in 1995 and transferred to Pacific Northwest National Laboratory in March of 2009. She has extensive experience in knowledge management activities and has led this effort for several projects both internal and external to the laboratory. In addition, Ms. Ross manages a SharePoint Support team which provides ongoing maintenance and support for a wide-range of projects.

Ms. Ross also supports the Nuclear Regulatory Commission (NRC) in their combined license and license renewal programs as the Knowledge Management Task Lead. Other work activities include Database Administrator and Lead for the NRC's Comment-Response Database hosted by PNNL, Knowledge Management Lead and Non-Spatial Database Manager for projects that support the U.S. Department of Energy (DOE) and Deputy Project Manager supporting NRC's Office of Federal and State Materials and Environmental Program.

Mark Triplett

Mark Triplett is a Senior Advisor at the Pacific Northwest National Laboratory. He has more than 30 years of experience at PNNL in waste management systems analysis, decision analysis for environmental restoration, and risk communication. Mr. Triplett has worked on many aspects of the Hanford site cleanup, including soil, groundwater and tank waste cleanup, and has expertise in planning and prioritizing cleanup activities. During 2013, he participated in a two month assignment with Japan's Ministry of Environment sponsored by the US State Department's Embassy Science Fellowship program. In that assignment, he reviewed Japan's environmental remediation activities for offsite Fukushima cleanup.

Michael Truex

Mr. Truex (Program Manager, Environmental Systems Group) has twenty-one years of experience at Pacific Northwest National Laboratory (PNNL) in subsurface remediation research and field applications. His experience includes providing clients with technical support for remediation decisions through technology assessments, applications of numerical fate and transport modeling, and feasibility and treatability assessments. He specializes in evaluation and application of in situ remediation and attenuation-based remedies. Field experience includes work at Department of Energy, Department of Defense, and private remediation sites.

At the Department of Energy Hanford Site, Mr. Truex was a technical liaison between PNNL and the Environmental Restoration Contractor (1997-2005) and River Corridor Closure Contractor (2005-2007). Mr. Truex provided technical and programmatic support for assessing and implementing improved remediation and characterization technologies. Mr. Truex has also been a principle investigator for several treatability tests and has provided input to feasibility studies at the Hanford site. Currently, he is a leading contributor to PNNL's effort for development and testing of technologies addressing deep vadose zone contamination and for development of analyses and approaches to support selection and implementation of remediation strategies for the Hanford Site and other sites with complex subsurface contaminant plumes.