START 9613389.0773

0042614

DOE/RL-95-13
Revision 0

Limited Field Investigation for the 200-UP-2 Operable Unit

United States
Department of Energy
Richland, Washington

DEC 1995
RECEIVED
EDMC

Approved for Public Release

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy. Available in paper copy and microfiche.

Available to the U.S. Department of Energy
and its contractors from
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831
(615) 576-8401

Available to the public from the U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

Printed in the United States of America

DISCLM-5.CHP (8-91)

9613589.0774

DOE/RL-95-13
Rev. 0

Limited Field Investigation for the 200-UP-2 Operable Unit

Date Published
November 1995

United States
Department of Energy
P.O. Box 550
Richland, Washington 99352

Approved for Public Release

EXECUTIVE SUMMARY

The 200-UP-2 Operable Unit is a source operable unit located in the 200 West Area at the Hanford Site. A limited field investigation (LFI) of high-priority waste units was conducted from August 1993 through August 1994. This report summarizes the data collection and analysis activities conducted during the LFI and presents the associated qualitative risk assessment (QRA). In addition, included in this report in Appendix A is the information necessary for completing an equivalent Resource Conservation and Recovery Act (RCRA) Closure/Postclosure for the 216-U-12 Crib through the use of 200-UP-2 Operable Unit Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) documents.

The investigation of the 200-UP-2 Operable Unit utilized a tiered approach, starting with the *U Plant Aggregate Area Management Study Report* (AAMSR) (DOE-RL 1992) as the uppermost tier. The next tier down is the 200-UP-2 Operable Unit work plan (DOE-RL 1993a). The final tier consists of the descriptions of work (DOW) that direct the investigation. The DOWs present the specific information needed to carry out the field data-gathering activities of each task.

The high-priority waste sites located in the 200-UP-2 Operable Unit were evaluated by location and function in the U Plant AAMSR (DOE-RL 1992). These sites were then grouped into analogue units selected to represent a larger group of similar waste sites based on the following:

- Generally similar waste water discharge depths and underlying stratigraphy
- Similar depth to groundwater
- Similar discharge chemistry and discharge volumes
- Similar waste inventories.

The following analogue units were investigated in this LFI:

- The 216-U-1/2 Cribs system, consisting of the 216-U-1/2 Crib structure, ancillary equipment (such as the 241-U-361 Settling Tank and influent stainless steel pipeline), the adjacent 2607-W5 Septic Tank and Drain Field, and the 216-U-16 Crib

- The 216-U-4 Reverse Well/4a French Drain system, consisting of the 216-U-4 Reverse Well and the adjacent 216-U-4a French Drain

- The 216-U-8 Crib system, consisting of the 216-U-8 Crib and 216-U-12 Crib structures and the vitrified clay effluent pipeline from the 222-U and 224-U facilities

- The 216-U-10 Pond system, consisting of the 216-U-10 Pond which was the central collection area, the inlet ditches (Z-Ditches and 216-U-14 Ditch) which fed the 216-U-10 Pond, and the 216-U-11 Trench and 216-U-9 Ditch which received overflow from the pond.

This LFI report describes the following LFI tasks:

- Vadose zone investigation, including borings and test pits
- Cone penetrometer investigation
- Surface soil investigation
- Vitrified clay pipeline investigation
- Stainless steel pipeline investigation

- Ecological investigation
- Air investigation.

These tasks are described in more detail in the LFI and the supporting documents. In addition to these investigative tasks, the LFI report also includes the QRA for the operable unit.

The pathways evaluated for the industrial scenario in the 200-UP-2 Operable Unit QRA are:

- Soil ingestion
- Fugitive dust inhalation
- External radiation exposure from soil.

The total lifetime incremental cancer risk (ICR) for each waste site is qualitatively discussed with respect to the following levels based on agreements by the signatories to the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1994) on May 26, 1993:

- "High" (ICR > 1E-02)
- "Medium" (1E-02 < ICR < 1E-04)
- "Low" (1E-04 < ICR < 1E-06)
- "Very Low" (ICR < 1E-06).

For the 216-U-1/2 Cribs system, the total estimated lifetime ICR to humans is "medium" (5E-03) for radionuclide exposure in the industrial scenario. The external radiation exposure is the primary pathway contributing to radionuclide ICR. Cesium-137 is the greatest contributor to human health risk. No ICR to humans from exposure to inorganics or organics is expected as all of these analytes were eliminated in the screening process.

For the 216-U-4 Reverse Well/4a French Drain system, the total estimated lifetime ICR to humans is "medium" (2E-03) for radionuclide exposure in the industrial scenario. The external radiation exposure is the primary pathway contributing to radionuclide ICR. Cesium-137 is the greatest contributor to human health risk. No ICR to humans from exposure to inorganics or organics is expected as all of these analytes were eliminated in the screening process.

For the 216-U-8 Crib area, the total estimated lifetime ICR to humans is "high" (> 1E-02) for radionuclide exposure in the industrial scenario. The external radiation exposure is the primary pathway contributing to radionuclide ICR. Cesium-137 is the greatest contributor to human health risk. The total estimated life time ICR to humans for exposure to inorganics is "low" (8E-06). The soil ingestion pathway is the primary pathway and arsenic the greatest contributor to ICR. No ICR to humans from exposure to organic analytes is expected as all of these analytes were eliminated in the screening process.

For the U Pond system, the total estimated lifetime ICR to humans is "high" (> 1E-02) for radionuclide exposure in the industrial scenario. The external radiation exposure is the primary pathway contributing to radionuclide ICR. Cobalt-60, cesium-137, and europium-154 are the greatest contributors to human health risk. The total ICR to humans from exposure to organics is "medium" (1E-04). Aroclor-1260 is the greatest contributor to human health risk and the primary pathway is soil ingestion. The total ICR to humans from exposure to inorganics is "low" (1E-05). Chromium is the greatest contributor to risk and the primary pathway is fugitive dust inhalation. The maximum concentrations of contaminants of potential concern contributing to risk from radionuclide exposure risk are found in the 216-U-10 Pond.

The relative ecological risk to each system is assigned according to the EHQ determined for the respective system. Risks are designated as follows:

- "High" (EHQ ≥ 100)
- "Medium" (10 > EHQ > 100)
- "Low" (EHQ ≤ 10).

Relative ecological risks associated with the four systems range from "low" to "medium-high." The 216-U-1/2 Cribs system was designated as having a low level of ecological risks as did the 216-U-4 Reverse Well/4a French Drain system. Overall, the 216-U-8 Crib area was rated as having a "medium-high" ecological risk. The risks ranged from "low" (216-U-12 Crib) to "medium-high" (216-U-8 Crib). Within the U Pond system, which overall was rated "medium," the 216-U-10 Pond had a rating of "medium" while the 216-U-14 Ditch rated "low." These risks are associated with both chemical constituents (metals) and radionuclides (primarily cesium-137). The Z Ditches had a "low" to "medium" ecological risk. For many areas, current management practices restrict vegetative growth directly over waste sites, thereby reducing ecological exposure pathways. This waste site management practice, however, may not be continued in the future; therefore, a conservative approach was taken in the evaluation of potential ecological risks within the 200-UP-2 Operable Unit.

The basic idea behind the analogous unit concept is to investigate a site that is representative of the worst-case condition of other waste management units similar in waste disposal history and location. The conclusions drawn from this analogue site can than be applied to those similar waste management units. For the 200-UP-2 LFI, this approach was applied to four waste systems: the 216-U-1/2 Cribs system, the 216-U-4 Reverse Well/4a French Drain system, the 216-U-8 Crib system, and the 216-U-10 Pond system. The following recommendations are based on these groupings.

The 216-U-1/2 Cribs system is recommended to continue as a candidate for an IRM. Qualitative risk assessment data suggest that a medium human health risk exists under an industrial exposure scenario with a moderate level of uncertainty and a low risk from an ecological standpoint.

The 216-U-4 Reverse Well/4a French Drain system is recommended to continue as a candidate for an IRM. The QRA findings indicate a medium human health risk level for external exposure with a moderate level of uncertainty.

The 216-U-8 Crib system is recommended to continue as a candidate for an IRM. The QRA data suggest that human health risk under an industrial exposure scenario is high and the uncertainty associated with this risk is moderate. The ecological risk evaluation also indicates potential health hazards (medium-high risk) to the Great Basin pocket mouse from both chemical (metals) and radiological standpoints.

The 216-U-10 Pond system is recommended to continue as a candidate for an IRM. The QRA data suggest that human health risk under an industrial exposure scenario is high and the uncertainty associated with this risk is moderate. The ecological risk assessment also indicates that much of the 216-U-10 Pond system presents a medium risk to the Great Basin pocket mouse from a chemical ingestion standpoint, with radionuclide concentrations in mice from this system being higher than those measured in mice from reference locations.

CONTENTS

1.0 INTRODUCTION 1-1
1.1 FRAMEWORK FOR RCRA CLOSURE COORDINATION 1-2
1.2 ORGANIZATION OF THE LFI REPORT 1-2

2.0 INVESTIGATIVE APPROACH 2-1
2.1 APPROACH 2-1
2.1.1 Physical Conceptual Model Summary 2-1
2.1.2 Analogue Units Strategy 2-2
2.2 200-UP-2 OPERABLE UNIT FIELD ACTIVITIES 2-4
2.2.1 Vadose Zone Borehole Drilling, Test Pit Excavation, and Sampling 2-5
2.2.2 Cone Penetrometer Investigation 2-5
2.2.3 Surface Soil Sampling 2-6
2.2.4 Effluent Pipeline Investigations 2-6
2.2.5 Air Monitoring 2-6
2.2.6 Ecological Investigation 2-6

3.0 INVESTIGATION RESULTS AND CONCLUSIONS 3-1
3.1 200-UP-2 ECOLOGICAL INVESTIGATION RESULTS 3-1
3.1.1 216-U-1/2 Cribs System 3-2
3.1.2 216-U-4 Reverse Well/4a French Drain System 3-2
3.1.3 216-U-8 Crib System 3-2
3.1.4 216-U-10 Pond System 3-2
3.2 216-U-1/2 CRIBS SYSTEM 3-3
3.2.1 Surface Radiological Survey Results 3-3
3.2.2 Surface Soil Sampling Results 3-3
3.2.3 Stainless Steel Pipeline Camera Investigation Results 3-4
3.2.4 Borehole Sediment Sampling and Gamma Logging Results 3-4
3.2.5 216-U-1/2 Cribs System Data Results Summary 3-5
3.3 216-U-4 REVERSE WELL/4a FRENCH DRAIN SYSTEM FIELD INVESTIGATION RESULTS 3-6
3.3.1 Surface Radiological Survey Results 3-6
3.3.2 Surface Soil and Vegetation Sampling Results 3-6
3.3.3 Borehole Sediment Sampling and Gamma Logging Results 3-6
3.3.4 216-U-4 Reverse Well/4A French Drain System Data Results Summary 3-7
3.4 216-U-8 CRIB SYSTEM FIELD INVESTIGATION RESULTS 3-7
3.4.1 Surface Radiological Survey Results 3-7
3.4.2 VCP Pipeline Camera Investigation Results 3-7
3.4.3 Surface Soil and Vegetation Sampling Results 3-8
3.4.4 Borehole Sediment Sampling and Gamma Logging Results 3-8
3.4.5 216-U-8 Crib System Data Results Summary 3-9
3.5 216-U-10 POND SYSTEM FIELD INVESTIGATION RESULTS 3-10
3.5.1 Surface Radiological Survey Results 3-10
3.5.2 Surface Soil and Vegetation Sampling Results 3-10
3.5.3 Cone Penetrometer Results 3-11

CONTENTS (cont.)

3.5.4 Test Pit Results 3-11
3.5.5 Borehole Sediment Sampling and Gamma Logging Results 3-12
3.5.6 216-U-10 Pond System Data Results Summary 3-12
3.6 IMPACT TO GROUNDWATER ASSESSMENT 3-12
3.6.1 Responses to Effluent Disposal 3-13
3.6.2 200-UP-2 Vadose Zone Model 3-13
3.6.3 Vadose Zone Sediment Types 3-14
3.6.4 Flow and Transport Modeling 3-14
3.6.5 Conclusions 3-17

4.0 QUALITATIVE RISK ASSESSMENT SUMMARY AND CONCLUSIONS 4-1
4.1 QUALITATIVE RISK EVALUATION OVERVIEW 4-1
4.2 HUMAN HEALTH EVALUATION 4-1
4.2.1 Human Health Risk Evaluation Process 4-1
4.2.2 Results of the Human Health Evaluation 4-6
4.3 ECOLOGICAL EVALUATION 4-9
4.3.1 Ecological Risk Evaluation Process 4-9
4.3.2 Results of the Ecological Evaluation 4-13

5.0 RECOMMENDATIONS 5-1
5.1 IRM CANDIDATE EVALUATION CRITERIA 5-1
5.1.1 Qualitative Risk Assessment 5-1
5.1.2 Conceptual Model 5-1
5.1.3 Current Impact on Groundwater 5-2
5.1.4 Potential for Natural Attenuation 5-2
5.2 SITE RECOMMENDATIONS 5-2
5.2.1 216-U-1/2 Cribs System 5-2
5.2.2 216-U-4 Reverse Well/4a French Drain System 5-2
5.2.3 216-U-8 Crib System 5-3
5.2.4 216-U-10 Pond System 5-3

6.0 REFERENCES 6-1

APPENDICES:

A REGULATORY ROADMAP A-1
B ELECTRONIC FILE SCREENING TABLES FOR HUMAN HEALTH AND ECOLOGICAL RISK B-1

FIGURES:

1-1 200-UP-2 Operable Unit 1F-1
2-1 216-U-1/2 Cribs System 2F-1
2-2 216-U-4 Reverse Well/4a French Drain System 2F-2
2-3 216-U-8 Crib System 2F-3

CONTENTS (cont.)

FIGURES (cont.):

2-4 216-U-10 Pond System 2F-4
3-1 Water Table Maps of 200 West Area from 1944 to 1987 . . . . . 3F-1
3-2 Discharge Data and Hydrographs of the Perched Zone and Groundwater Illustrating the Relationship Between Effluent Discharge and Changes in Water Table Elevation 3F-2
3-3 Discharge Data and Plots of Changes in Uranium-238 and Gross Alpha Contamination at the Water Table 3F-3
4-1 Conceptual Model for Human Exposure Assessment at 200-UP-2 Operable Unit 4F-1
4-2 Conceptual Ecological Model 4F-2

TABLES:

2-1 Key Supporting Documents 2T-1
2-2 Limited Field Investigation Activities by Analogous Unit 2T-2
3-1 216-U-1/2 Cribs Soil Sample Radiological Analysis Results 3T-1
3-2 216-U-1/2 Cribs Summary of RLS and Sediment Radiochemistry Data 3T-2
3-3 216-U-4 Reverse Well/4a French Drain Summary of RLS and Sediment Radiochemistry Data 3T-3
3-4 216-U-8 Crib Surface and Near-Surface Soil and Vegetation Sample Radiological Results 3T-4a
3-5 216-U-8 Crib Surface and Near-Surface Soil and Vegetation Sample Metal Results 3T-5
3-6 216-U-8 Crib Summary of RLS and Sediment Radiochemistry Data 3T-6
3-7 216-U-12 Crib Summary of RLS and Sediment Radiochemistry Data 3T-7
3-8 216-U-10 Pond Soil Sample Chemical and Radiological Results 3T-8
3-9 216-U-10 Pond Summary of RLS and Sediment Radiochemistry Chemistry Data 3T-9
3-10 Sediment Types and Unsaturated Hydraulic Conductivity and Moisture Retention Curve Matches 3T-10a
3-11 Layers used in the 216-U-1 and 216-U-2 Crib Model 3T-11
3-12a Discharge and Infiltration for the 216-U-1/2 Cribs 3T-12a
3-12b Soil Column Data for the 216-U-1/2 Cribs 3T-12b
3-12c Unit Gradient Analysis for the 216-U-1/2 Cribs 3T-12c
3-13 Layers Used in the 216-U-8 Crib Model 3T-13
3-14a Discharge and Infiltration for the 216-U-8 Crib 3T-14a
3-14b Soil Column Data for the 216-U-8 Crib 3T-14b
3-14c Unit Gradient Analysis for the 216-U-8 Crib 3T-14c
3-15 Layers Used in the 216-U-12 Crib Model 3T-15
3-16a Discharge and Infiltration for the 216-U-12 Crib 3T-16a
3-16b Soil Column Data for the 216-U-12 Crib 3T-16b
3-16c Unit Gradient Analysis for the 216-U-12 Crib 3T-16c

CONTENTS (cont.)

TABLES (cont.):

4-1 Summary of Systemic Toxicity Information for Contaminants of Potential Concern at the 200-UP-2 Operable Unit 4T-1
4-2 Summary of Carcinogenic (Radioactive) Toxicity Information for Contaminants of Potential Concern at the 200-UP-2 Operable Unit 4T-2
4-3 Summary of Carcinogenic (Nonradioactive) Toxicity Information for Contaminants of Potential Concern at the 200-UP-2 Operable Unit 4T-3
4-4a Summary of Contaminant Identification and Exposure Assessment Uncertainties for Radionuclides at the 200-UP-2 Operable Unit Waste Sites 4T-4a
4-4b Summary of Contaminant Identification and Exposure Assessment Uncertainties for Organic and Inorganic Analytes at the 200-UP-2 Operable Unit Waste Sites 4T-4b
4-5 Human Health Risk Characterization for the 216-U-1/2 Cribs System 4T-5
4-6 Human Health Risk Characterization for the 216-U-4 French Drain and 216-U-4a Reverse Well System 4T-6
4-7 Human Health Risk Characterization for the 216-U-8 Crib System (Inorganics) 4T-7
4-8 Human Health Risk Characterization for the 216-U-8 Crib System (Radiological) 4T-8
4-9 Human Health Risk Characterization for the 216-U-10 Pond System (Organics) 4T-9
4-10 Human Health Risk Characterization for the 216-U-10 Pond System (Inorganics) 4T-10
4-11 Human Health Risk Characterization for the 216-U-10 Pond System (Radiological) 4T-11
4-12 Summary of the Human Health Qualitative Risk Assessment for the 200-UP-2 Source Operable Unit 4T-12
4-13 Radionuclide Activity Concentrations in 200-UP-2 Area Plants 4T-13
4-14 Metal Concentrations in 200-UP-2 Area Plants and Mammals 4T-14
4-15 Radionuclide Activity Concentrations in 200-UP-2 Area Small Mammals 4T-15
4-16 Relative Ecological Risks at the 200-UP-2 Operable Unit 4T-16
5-1 Conceptual Model for 200-UP-2 High-Priority Waste Systems 5T-1

ACRONYMS

AAMSR	Aggregate Area Management Study Report
ARAR	applicable or relevant and appropriate requirements
bgs	below ground surface
BHI	Bechtel Hanford, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMS	corrective measures study
COPC	contaminants of potential concern
COPEC	contaminants of potential ecological concern
CPT	cone penetrometer
DOE	U.S. Department of Energy
Ecology	Washington Department of Ecology
EHQ	environmental hazard quotient
EPA	U.S. Environmental Protection Agency
HEIS	Hanford Environmental Information System
HI	hazard index
HPPS	Hanford Past-Practice Strategy
HQ	hazard quotient
HSRAM	Hanford Site Risk Assessment Methodology
ICR	incremental cancer risk
IROD	interim record of decision
IRM	interim remedial measure
LFI	limited field investigation
MSCM II	Mobil Surface Contamination Monitor
MTCA	Model Toxics Control Act
NOEL	no observed effect level
PCB	polychlorinated biphenyl
PEF	particulate emission factor
QRA	qualitative risk assessment
RCRA	Resource Conservation and Recovery Act
RESRAD	residual radioactive material guidelines and software model
RFI	RCRA facility investigation
RL	Richland Operations Office
RLS	radionuclide logging system
ROD	record of decision
SCA	surface contamination area
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
USRADS	ultrasonic ranging and data system
UTL	upper threshold limit
VCP	vitrified clay pipeline
WAC	Washington Administrative Code

THIS PAGE
INTENTIONALLY LEFT BLANK

1.0 INTRODUCTION

Since signing the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) in 1989 (Ecology et al. 1994), the parties to the agreement have recognized the need to modify the approach to conducting investigations, studies, and remedial actions at Hanford with a goal of maximizing efficiency, optimizing use of limited resources, and achieving cleanup in the earliest possible time frame. To implement this approach, the parties have jointly developed the *Hanford Past-Practice Strategy* (HPPS) (DOE-RL 1991). The principles of the strategy make use of interim remedial measures (IRM) and expedited response actions (ERA) to either remove threats to human health or the environment or to reduce risk by reducing the toxicity, mobility, or volume of contaminants.

The HPPS defines the limited field investigation (LFI) as a collection of limited additional site data that are sufficient to support a decision on conducting ERAs or IRMs. The 200-UP-2 Operable Unit (Figure 1-1) is a source operable unit located in the 200 West Area at the Hanford Site. An LFI of high-priority waste units was conducted from August 1993 through August 1994. This LFI was conducted in accordance with the *Resource Conservation and Recovery Act (RCRA) Facility Investigation/Corrective Measures Study (RFI/CMS) Work Plan for the 200-UP-2 Operable Unit* (DOE-RL 1993a). As agreed upon in the work plan by the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Washington Department of Ecology (Ecology), although titled as a RFI/CMS, the work plan provides direction for conducting an LFI in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) process. The *U Plant Source Aggregate Area Management Study Report* (AAMSR) (DOE-RL 1992) was conducted to compile information about operable units in the aggregate area and to recommend followup investigations at the waste management units.

The primary purpose of this LFI report is to provide recommendations for continuation on the IRM pathway for four waste unit groups: the 216-U-1/2 Cribs system, the 216-U-4 Reverse Well/4a French Drain system, the 216-U-8 Crib system, and the 216-U-10 Pond system. An IRM is a management or engineering practice designed to minimize short-term risk to human health or the environment. An IRM is defined in broad terms and is not restricted to limited or near-term actions. It allows for interim action with the final goal of achieving final action levels. If an IRM path is not recommended, the waste unit would continue on the final remedy path as defined in the HPPS.

This report summarizes the data collection and analysis activities conducted during the 200-UP-2 Operable Unit LFI and presents the associated qualitative risk assessment (QRA). In addition, included in this report in Appendix A is the information necessary for completing an equivalent RCRA Closure/Postclosure for the 216-U-12 Crib through the use of 200-UP-2 Operable Unit CERCLA documents.

The data collection and analysis activities were conducted in accordance with the work plan and implemented through approved descriptions of work (DOW). The QRA was performed in accordance with *the Hanford Site Risk Assessment Methodology* (HSRAM) (DOE-RL 1994a). Recommendations incorporate the strategies of the HPPS (DOE-RL 1991), which specifies an LFI when additional data are required to support an IRM decision. The QRA is used only to assess risk for IRM determination and is not intended to define quantitative baseline risk. The proposed IRM for the operable unit will be documented in the IRM proposed plan. The final decision to conduct an IRM will be presented in the interim record of decision (IROD) and will be based on many factors, including the QRA, applicable or relevant and appropriate requirements (ARAR), future land use, and the potential threat to human health or the environment, including any potential threat to the groundwater.

Chapter 1.0 of this report discusses the background for the LFI, the framework for coordination of a RCRA closure for the 216-U-12 Crib, and the organization of the report.

1.1 FRAMEWORK FOR RCRA CLOSURE COORDINATION

The AAMSR recommended that the RCRA closure of the 216-U-12 Crib be conducted in coordination with planned CERCLA activities within the operable unit. A coordinated closure approach was included as part of the work plan and formed the basis for negotiation of the required change request to the Tri-Party Agreement (Ecology et al. 1994). The CERCLA/RCRA coordination was agreed to by the parties to the Tri-Party Agreement with Proposed Change Request M-15-94-03, dated September 15, 1994 (Ecology et al. 1994). The change request specifies inclusion of a matrix in the LFI report showing the 200-UP-2 Operable Unit documents where the RCRA closure plan requirements would be found. This report meets the requirements of the Tri-Party Agreement Milestone M-15-15B for the LFI submittal and Milestone M-20-37 for the closure plan submittal. The intention of the change request was to have a proposed selected remedy that has been coordinated with the RCRA and CERCLA processes. The closure plan will be considered complete with the submittal of the final IRM proposed plan.

1.2 ORGANIZATION OF THE LFI REPORT

This report is made up of six sections, including this introduction. Chapter 2.0 provides a summary of the investigative approach, defines the systems investigated, and references documents that contain specific information regarding site investigation activities done in the 200-UP-2 Operable Unit.

Chapter 3.0 summarizes the key results of applicable field activities conducted at the waste units during the LFI that directly support an IRM recommendation. It draws general conclusions regarding the distribution of contaminants to refine the physical conceptual model and presents a qualitative assessment of the potential impact to groundwater for selected waste units.

Chapter 4.0 presents the rationale and results of the human health and ecological QRA.

Chapter 5.0 provides recommendations for each waste unit discussed in this report regarding continuation on the IRM path.

Chapter 6.0 lists references.

Appendix A contains the "roadmap" for RCRA/CERCLA coordination. This roadmap discusses where the RCRA closure/postclosure requirements will be met in current or future documents. There are two attachments to the appendix. Attachment 1 of the appendix contains information for the introduction and the first sections of the 216-U-12 Crib closure plan. Attachment 2 of the appendix is the RCRA Part A, Form 3 for the 216-U-12 Crib.

Appendix B contains contaminant screening tables for the human health and ecological QRA and is provided as electronic files on the enclosed diskette.

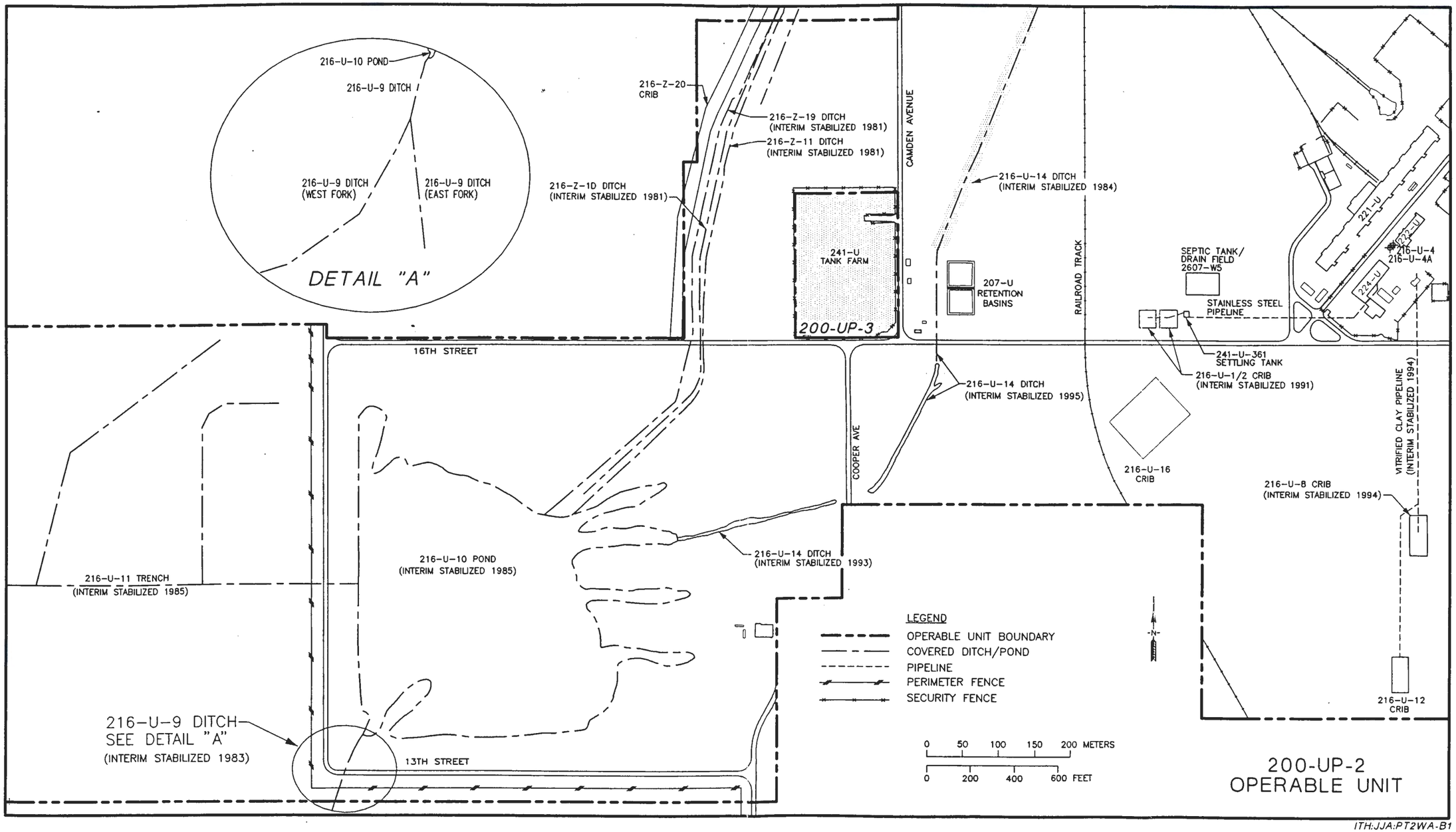


Figure 1-1. 200-UP-2 Operable Unit.

2.0 INVESTIGATIVE APPROACH

This chapter provides a summary of the investigative approach and defines the systems investigated.

Several documents contain specific information regarding site investigative activities done in the 200-UP-2 Operable Unit. The documents were generated either in direct support of 200-UP-2 LFI activities, support of the Hanford Site Effluent Disposal Study, support of sitewide environmental monitoring programs, or support of a specific task. These documents will be referenced rather than restated. Table 2-1 lists these documents by title and document number and provides a summary of key information discussed in each.

2.1 APPROACH

The investigation of the 200-UP-2 Operable Unit utilized a tiered approach, starting with the U Plant AAMSR (DOE-RL 1992) as the uppermost tier. The U Plant AAMSR is a scoping-level study that provides the operable unit background, the basis for initiating investigative activities, and recommendations for an LFI at high-priority units. The next tier down is the 200-UP-2 Operable Unit work plan (DOE-RL 1993a). The work plan identifies specific investigative areas (the analogue units), develops the physical conceptual model of contaminant distribution, presents the rationale for proposed field activities, and establishes the general investigative approach for each area. The final tier consists of the DOWs that direct the investigation. The DOWs present the specific information needed to carry out the field data-gathering activities of each task. The DOWs were living documents that were revised as necessary based on changes in field conditions. This approach permitted flexibility in the investigation while maintaining the work scope outlined in the general task description.

The following sections summarize the physical conceptual model of the operable unit and the process for selecting waste management units for investigation.

2.1.1 Physical Conceptual Model Summary

The physical conceptual model represents the major types of waste units associated with the 200-UP-2 Operable Unit and includes cribs, a reverse well/French drain, and a pond. In general, the basic physical conceptual model for contaminant movement and distribution beneath the 216-U-1/2, 216-U-8, and 216-U-12 Cribs is similar and can be summarized as follows.

- The vadose zone beneath the operable unit is 60 to 70 m (197 to 230 ft) thick. The most significant aquitard within the vadose zone is the caliche layer within the Plio-Pliestocene unit. This layer inhibits the downward flow of water. The caliche layer is thought to be continuous across the operable unit with a gently undulating upper surface. The surface tends to slope to the south; perched water would likely flow in this direction.

- The unconfined aquifer is within the unit E and unit A gravels of the Ringold Formation.

- Initial contaminants of potential concern (COPC) are listed in Table 5-9 of DOE-RL (1993a).

- The majority of contaminants are held in the vadose zone immediately beneath the point of release. The highest total activities for radionuclides will be immediately beneath the waste unit, and less mobile contaminants will be restricted to this area.

- Some lateral migration of contamination may occur due to fine-grained stratigraphic horizons present beneath the waste unit.

- The majority of liquid travels downward through the vadose zone carrying the more mobile contaminants, such as technetium-99 and nitrates.

- Contaminants may concentrate at the caliche layer as the flow of water is retarded; perched water may occur. The concentrations in these areas would be much lower than those that occur immediately below the point of release.

The conceptual model for the 216-U-1/2 Cribs has an added dimension because of the influence of liquid discharges from adjacent active units that may remobilize contaminants in the underlying vadose zone. In 1984, large volumes of cooling water were discharged to the 216-U-16 Crib, forming a perched groundwater zone above the caliche layer. This perched water spread beneath the 216-U-1/2 Cribs. Acid wastes discharged to the cribs reacted with uranium complexes to form compounds that were soluble and relatively nonsorbing in the sediments. The uranium was transported through the caliche layer, possibly conducted by inusfficiently sealed boreholes, to the unconfined aquifer (Delegard et al. 1986, DOE-RL 1992). At the start of this LFI, potential perched water formation below the 2607-W5 Septic Tank and Drain Field was thought to have a potential to remobilize contaminants.

The model for the 216-U-4 Reverse Well and 216-U-4a French Drain is slightly different than the crib model. The reverse well discharged water into the deeper vadose zone and eventually became plugged. The French drain was then installed in the upper vadose zone next to the reverse well and operated for a longer period of time. It was expected that two separate contaminant plumes developed, one lower in the vadose zone associated with the reverse well discharge and the other in the upper vadose zone associated with the French drain.

The conceptual model of contaminant movement and distribution beneath the 216-U-10 Pond is similar to the one described for cribs. Again, the majority of contaminants are held in the soils immediately beneath the pond bottom. Localized, low contaminant concentrations may occur in deeper fine-grained stratigraphic horizons. The caliche layer beneath the 216-U-10 Pond acts as a physical barrier where perched water may occur. Water does percolate through the layer to the unconfined aquifer.

The drilling program at the 216-U-1/2, 216-U-8, and 216-U-12 Cribs, 216-U-4/Reverse Well/4a French Drain, and the 216-U-10 Pond was designed to account for these expected contaminant distributions. To encounter the most contaminated sediments, boreholes were generally placed as close as possible to the liquid waste discharge points. Sampling was focused directly below discharge points because this is where the contaminants were expected to be concentrated. Boreholes were extended to the caliche layer where perched water was likely to occur.

2.1.2 Analogue Units Strategy

The high-priority waste sites located in the 200-UP-2 Operable Unit were evaluated by location and function in the U Plant AAMSR (DOE-RL 1992). As described in Section 1.0 of the 200-UP-2 work

plan (DOE-RL 1993a), the LFI was accomplished using a limited number of analogue units selected to represent a larger group of similar waste sites. The types of units chosen for the investigation include the following:

- Cribs
- Reverse wells and French drains
- Ponds and ditches.

A series of criteria was developed to make these comparisons and to ensure that each unit not involved in the LFI had a representative analogue unit. These criteria are discussed in detail in Section 4.2.1.3 of the 200-UP-2 Operable Unit work plan (DOE-RL 1993a) and include the following:

- Generally similar waste water discharge depths and underlying stratigraphy
- Similar depth to groundwater
- Similar discharge chemistry and discharge volumes
- Similar waste inventories.

Based on these criteria, a set of similar units has been identified and the worst-case units from that set selected for investigation (Table 4-4 in Section 4 of the 200-UP-2 work plan [DOE-RL 1993a]). The worst-case units were those where one would expect the highest contaminant concentrations, the largest contaminant inventories, and the greatest likelihood for contaminant migration to groundwater. More than one crib was selected to be investigated. The 216-U-8 Crib is the analogue for the cribs in the operable unit; however, the 216-U-1/2 Cribs were also selected since they were associated with a significant release of uranium to groundwater in 1984-1985. It is also necessary to determine the potential impact from discharges to the adjacent 2607-W5 Septic Tank and Drain Field. Additional field work was conducted at the 216-U-12 Crib because it is a RCRA facility with an interim permit that requires closure. The 216-U-4 Reverse Well was selected as the only reverse well in the operable unit. In addition, its proximity to the 216-U-4a French Drain allowed investigation of two units with a single borehole. The 216-U-10 Pond and associated ditches comprise the only pond/ditch system within the operable unit and are therefore selected for study.

In this report the analogue units selected are discussed as part of the four groups or systems investigated. The systems are discussed in Sections 2.1.2.1, 2.1.2.2, 2.1.2.3, and 2.1.2.4. This approach provides an overview of the investigation activities and minimizes repetition within the report.

Evaluation of the analogue unit concept will become part of the analysis contained in the 200-UP-2 Focused Feasibility Study. The focused feasibility study uses the results of this LFI and the supporting documents in Table 2-1 to evaluate the feasibility of IRMs for the units directly investigated and their associated analogues.

2.1.2.1 216-U-1/2 Cribs System. The 216-U-1/2 Cribs system, shown in Figure 2-1, consists of the 216-U-1/2 Cribs structure, ancillary equipment (such as the 241-U-361 Settling Tank and influent stainless steel pipeline), the adjacent 2607-W5 Septic Tank and Drain Field, and the 216-U-16 Crib. These units were investigated primarily to determine the current state of the vadose zone as a result of a 1984 release of uranium from the 216-U-1/2 Cribs vadose zone into the groundwater. In early 1985, results of the January 1985 groundwater monitoring of wells in the vicinity of 216-U-1/2 Cribs showed an abrupt increase of the concentration of uranium. Investigations determined that a confining layer in the vadose zone caused the 216-U-16 Crib effluent to migrate laterally, mobilizing contaminants beneath the 216-U-1/2 Cribs. The contaminants were transported to the groundwater

(Delegard et al. 1986, DOE-RL 1992). The LFI investigation strategy was designed to determine the lateral extent of vadose zone contaminants north and south of the 216-U-1/2 Cribs and the impact, if any, of the present operation of the adjacent 2607-W5 Septic Tank and Drain Field. Information collected on the stainless steel pipeline would support decisions for this unit and provide a qualitative assessment of stainless steel waste disposal lines in general.

2.1.2.2 216-U-4 Reverse Well/4a French Drain System. The 216-U-4 Reverse Well/4a French Drain system is shown in Figure 2-2. The system consists of the 216-U-4 Reverse Well and the adjacent 216-U-4a French Drain. The investigation strategy focused on these structures primarily due to their proximity to each other, which presented the opportunity to evaluate their performance with a single borehole. The impact to groundwater (subsurface distribution of contaminants) could be evaluated and the potential for drawing conclusions for similar units assessed.

2.1.2.3 216-U-8 Crib System. The 216-U-8 Crib system, shown in Figure 2-3, consists of the 216-U-8 Crib and 216-U-12 Crib structures and the vitrified clay effluent pipeline from the 222-U and 224-U facilities. The investigation strategy was designed to determine the extent of vadose zone contamination associated with the 216-U-8 Crib. The 216-U-12 Crib was investigated to provide additional information on that specific unit to support its closure under RCRA. Information collected on the vitrified clay portion of the effluent pipeline would support decisions for this unit and provide a qualitative assessment of vitrified clay disposal lines in general.

2.1.2.4 216-U-10 Pond System. The 216-U-10 Pond system, shown in Figure 2-4, consists of the 216-U-10 Pond which was the central collection area, the inlet ditches (Z-Ditches and 216-U-14 Ditch) which fed the 216-U-10 Pond, and the 216-U-11 Trench and 216-U-9 Ditch which received overflow from the pond. The 216-U-10 Pond and Z-Ditches were studied in detail before their interim stabilization in the early 1980's. The lateral distributions and concentrations of the primary radionuclide COPC were mapped during these earlier studies (Last et al. 1994). The 200-UP-2 investigation strategy was designed to determine the vertical and lateral extent of vadose zone contamination associated with the interim stabilized 216-U-10 Pond.

2.2 200-UP-2 OPERABLE UNIT FIELD ACTIVITIES

The 200-UP-2 LFI was generally implemented through the use of DOWs. The DOWs discussed in detail the strategy to be used for each intrusive investigation. The DOWs were approved by DOE-Richland Operations Office (RL) and lead regulatory groups prior to initiating field work. The following DOWs were written to conduct intrusive field activities:

- Vadose Zone Boreholes (Kelty 1993a)
- Cone Penetrometers (Kelty 1993b)
- Test Pits (Kelty 1993c)
- Surface Soil Sampling (Mitchell 1994)
- Vitrified Clay Pipeline Investigation (Rowley 1994b)
- Stainless Steel Pipeline Investigation (Rowley 1994a).

In addition to these activities conducted through DOWs, surface radiation surveys were conducted through an internal memo within Westinghouse Hanford Company to the Health Physics organization for this nonintrusive investigation (WHC 1993a). Other nonintrusive investigations included air monitoring (Webb 1994), both ongoing and project specific, and an ecological investigation (Mitchell and Weiss 1995).

Table 2-2 identifies the field activities conducted at each of the systems investigated for this LFI. Surface radiation surveys utilized ultrasonic ranging and data system (USRADS) and the mobile surface contamination monitor (MSCM-II). The USRADS uses a sodium iodide detector to report gamma and a microRoentgen meter to report dose rate information. The MSCM-II reports beta and gamma detections in counts per second and calculated activity in picocuries. Both these systems are described in greater detail in Wendling (1994). Results of these activities are also contained in Wendling (1994) and Wasemiller et al. (1994).

2.2.1 Vadose Zone Borehole Drilling, Test Pit Excavation, and Sampling

As part of the 200-UP-2 LFI vadose zone characterization activities, seven new vadose wells were constructed: three on or adjacent to the 216-U-1/2 Cribs (Figure 2-1), one between the 216-U-4 Reverse Well and the 216-U-4a French Drain (Figure 2-2), one at the 216-U-8 Crib (Figure 2-3), one adjacent to the 216-U-12 Crib, and one at the 216-U-10 Pond (Figure 2-4). In addition to the boreholes, one test pit was excavated at 216-U-10 Pond (Figure 2-4).

Soil sediment samples were collected from the vadose zone boreholes and test pit. Samples were collected to refine stratigraphic relationships, determine the nature and extent of contamination, and assess the physical properties of the sediments. Specific sampling intervals were designated in the DOWs for the required activity. The general sampling strategy was to sample at the expected areas of maximum contamination as determined by field screening and observation of changes in lithology. Samples collected for chemical and physical analysis were analyzed for the constituents as specified in each DOW covering sampling activities.

Each vadose zone borehole was also characterized using the radionuclide logging system (RLS). The RLS is used to quantitatively identify the presence of man-made gamma-emitting radionuclides and their relative activity in the borehole. The RLS borehole survey also records natural gamma-emitting radionuclide activity. Nineteen boreholes (seven new and twelve existing) were surveyed with the RLS in support of the 200-UP-2 vadose zone investigation. A detailed description of characterization activities appears in Kelty et al. (1995).

Following characterization and logging using the RLS, the new boreholes were abandoned by removing the casing and backfilling.

2.2.2 Cone Penetrometer Investigation

A cone penetrometer (CPT) demonstration was conducted at the interim stabilized 216-U-10 Pond. It was designed to evaluate the use of gamma logging of installed CPT rods to determine the extent of contamination in the vadose zone. A series of 10 CPT rods were installed across the pond to an average depth of 21.8 m (71.4 ft). One line of seven CPT rods was installed across the site in a northwest direction, towards the influent region of the pond, intersecting test pit #2. The second line of three CPT rods extended in a northeast direction and was perpendicular to the first line. The pattern was chosen to characterize the lateral and horizontal extent of contamination in the 216-U-10 Pond based on the detection of the man-made gamma-emitting radionuclides with a gamma scintillation detector. A detailed description of the demonstration and the results is in Kelty et al. (1995).

2.2.3 Surface Soil Sampling

As part of the LFI, data on the extent of contamination in the surface soils associated with the 216-U-1/2 Cribs, the 216-U-4/4a Reverse Well/French Drain, the 216-U-8 Crib, and the 216-U-10 Pond systems were collected. The activity was accomplished in two steps:

(1) A surface radiation survey was completed over the areal extent of each system.

(2) Sampling sites were selected such that they would represent the areas of highest radiological concentration for each system as determined by the surface surveys.

A complete discussion of radiological survey methods and results is included in *200-UP-2 Operable Unit Radiological Surveys* (Wendling 1994). The discussion of sample site selection and sampling activities, including a summary of data results, is included in *Surface and Near Surface Field Investigation Data Summary Report for the 200-UP-2 Operable Unit* (Wasemiller et al. 1994).

2.2.4 Effluent Pipeline Investigations

The pipelines investigated were the vitrified clay pipeline (VCP) in the 216-U-8 system and the stainless steel pipeline in the 216-U-1/2 system. The investigation included remote camera surveys in both pipelines and surface and subsurface soil sampling at the 216-U-8 VCP.

A full discussion of sample site selection and sampling activities, including a summary of data results, is included in Wasemiller et al. (1994).

2.2.5 Air Monitoring

Ambient air at Hanford is routinely monitored and evaluated through Westinghouse Hanford Company's Near-Field Environmental Surveillance and Pacific Northwest Laboratory's Environmental Surveillance programs. The *200-UP-2 Air Monitoring Report* (Webb 1994) evaluated data in their most recent annual reports for air monitoring stations related to the 200-UP-2 Operable Unit. Additional information was included from special air samples collected during the LFI activities.

2.2.6 Ecological Investigation

Ecological surveys were performed by visual field observations of plant communities and habitats within the 200-UP-2 Operable Unit. Dominant plant and animal species were identified and listed. Particular attention was focused on evidence of animal and insect intrusion at each site. Vegetative and soil samples were collected from the 216-U-11 Trench during an ecological sampling effort for the 200 Areas. Results of the sampling effort are reported in Mitchell and Weiss (1995).

Document reviews of Hanford related biological investigations and surveys were performed to assess the 200 West Area communities. These findings are further addressed in the Ecological Risk Assessment (Section 4.3).

Figure 2-1. 216-U-1/2 Cribs System.

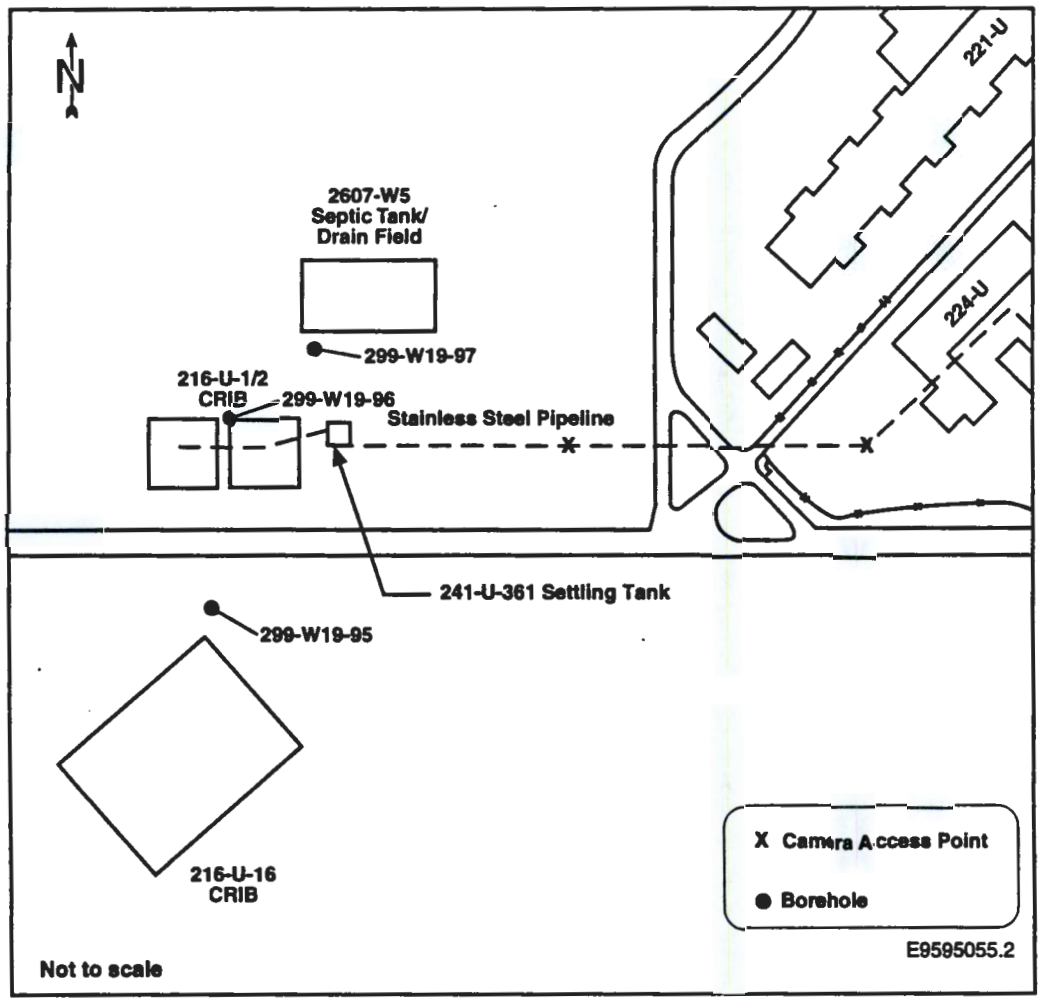


Figure 2-2. 216-U-4 Reverse Well/4a French Drain System.

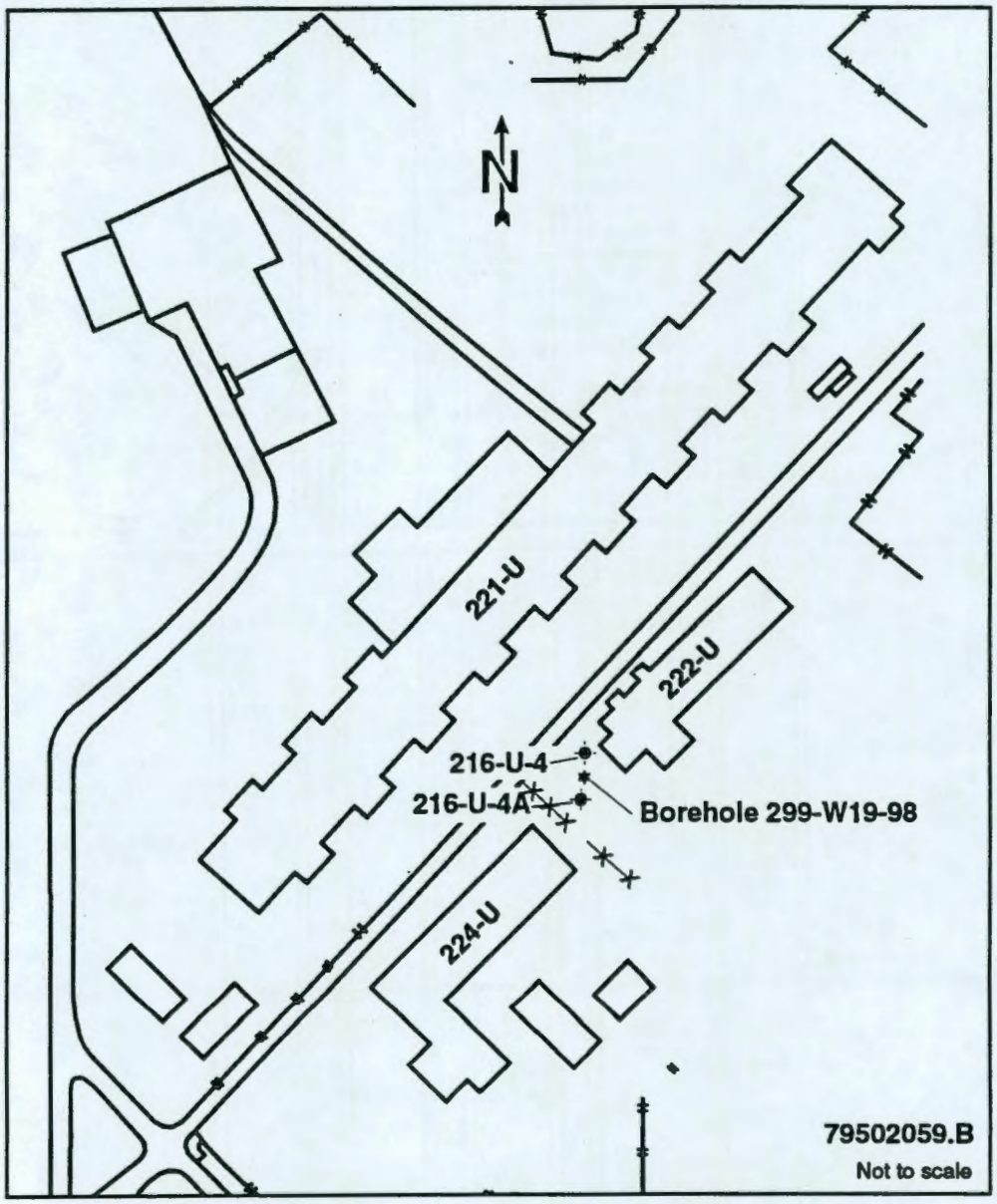
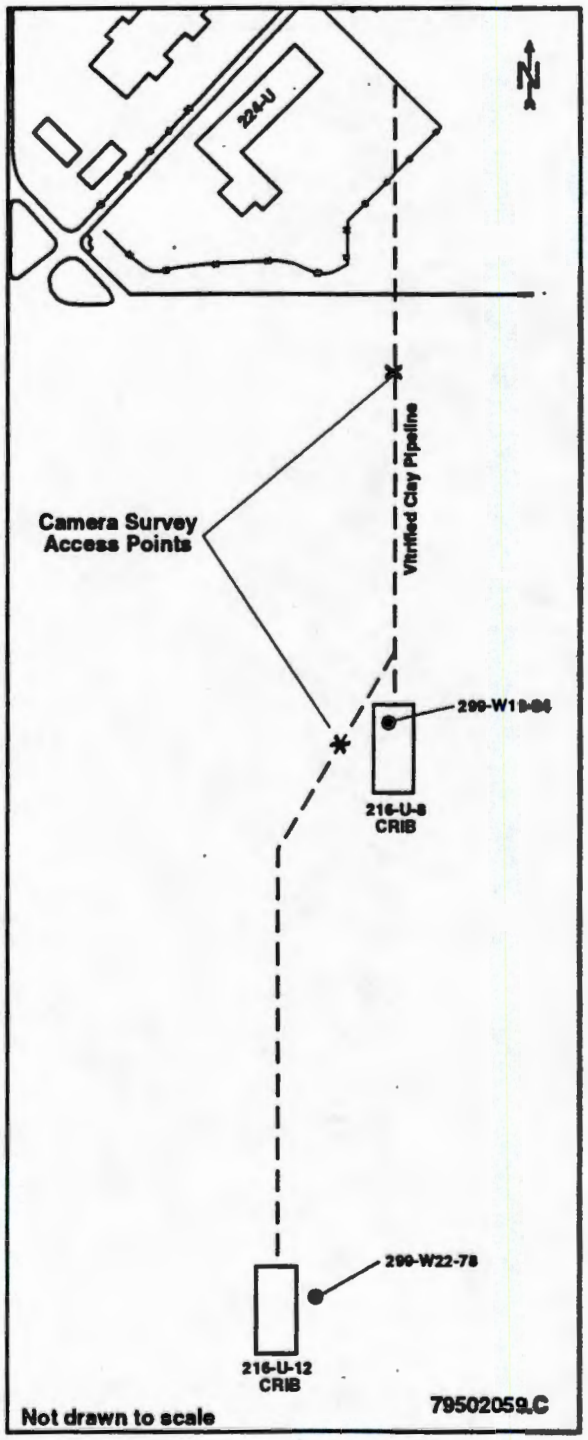


Figure 2-3. 216-U-8 Crib System.



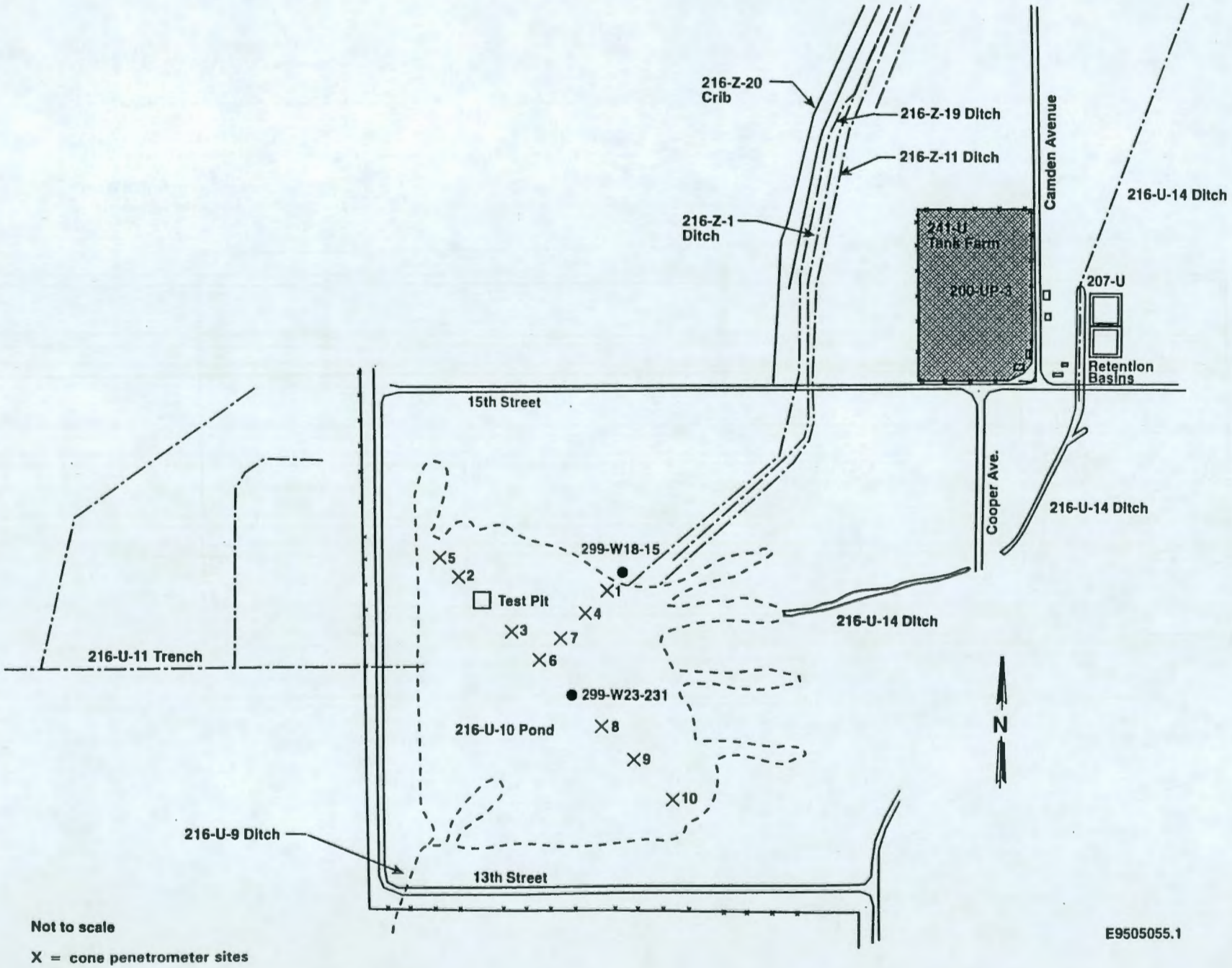


Figure 2-4. 216-U-10 Pond System.

Table 2-1. Key Supporting Documents.

Title	Document #	Release Date	Key Items Discussed
WORK PLAN-DRIVEN DOCUMENTS SUMMARIZING FIELD INVESTIGATION ACTIVITIES			
Surface and Near Surface Field Investigation Data Summary Report for the 200-UP-2 Operable Unit	BHI-00033, Rev. 00	September 1994	Surface sampling of waste management units Inline Camera Surveys (VCP and Stainless Steel) Collection of Subsurface samples - VCP
Borehole Summary Report for the 200-UP-2 Operable Unit, 200 West Area	BHI-00034, Rev. 01	March 1995	7 Vadose Zone boreholes 1 Test Pit (U-Pond) Cone Penetrometer Test (U-Pond)
200-UP-2 Ambient Air Monitoring Report	BHI-00035, Rev. 00	September 1994	200-UP-2 Operable Unit Ambient Air Monitoring Report
200-UP-2 Operable Unit Radiological Surveys	WHC-SD-EN-RPT-009	May 1994	Surface radiological survey summaries and graphical presentations. MSCM II - (U-Pond System) USRADS - (216-U-8 Crib, 216-U-1/2 Crib, 207-U Retention Basins) Manual - (216-U-9 Ditch, 216-U-4/4a)
HANFORD SITE EFFLUENT DISPOSAL STUDY DOCUMENTS			
Groundwater Impact Assessment Report 216-U-14 Ditch	WHC-EP-0698	January 1994	Effluent disposal study at 216-U-14 ditch 6 Test Pits excavated 2 Vadose Zone Boreholes drilled 3 Groundwater Monitoring Wells installed
Groundwater Impact Assessment Report 216-Z-20 Crib, 200 West Area	WHC-EP-0674	October 1993	Effluent Disposal Study of Z-20 Crib Nonintrusive investigation of site, summary of existing historical data.
MISCELLANEOUS DOCUMENTS			
216-U-10 Pond and 216-Z-19 Ditch Characterization Report	WHC-EP-0707	February 1994	1980 investigation to support U-Pond decommissioning activities.
Ecological Sampling at Four Wastes in the 200 Areas	BHI-00032, Rev. 00	September 1994	Biotic Analogue Summary of 200 Area 216-U-11 Trench is included.

VCP = vitrified clay effluent pipeline
MSCM II = Mobile Surface Contamination Monitor
USRADS = ultrasonic ranging and data system

Table 2-2. Limited Field Investigation Activities by Analogous Unit.

System	Waste Management Unit	Limited Field Investigation Activities								
		Surface Radiation Survey[a]	In-Line Camera	Test Pit	CPT	RLS	Sampling			
							Vadose Borehole	Surface	Near Surface	Vegetation
U-10 Pond	216-U-10	M		X	X	X	X	X		X
	216-U-14	M						X		
	216-U-11	M						X		X
	Z Ditches	M						X		
	207-U	U						X		
	216-U-9	H								
U-1/2 Crib	216-U-1/2	U				X	X			
	241-U-361	U						X		
	Stainless Steel Pipeline		X							
	2607-W5	U						X		
U-8 Crib	216-U-8	U				X	X			X
	216-U-12	U				X	X			
	VCP	U	X					X	X	X
U-4/4a	216-U-4	H				X	X			
	216-U-4a	H				X	X			

[a]M = Mobile Surface Contamination Monitor II
U = USRADS
H = Hand
CPT = Cone penetrometer
RLS = Radionuclide logging system

3.0 INVESTIGATION RESULTS AND CONCLUSIONS

The results of applicable field activities conducted at each of the analogue units during the LFI are summarized in this chapter. Basic conclusions to assist in determining the need for each system to remain on an IRM path or to be deferred to the final remedy path are made. The conceptual model for the 200-UP-2 Operable Unit identified five radionuclides in the U Plant disposal system that were of particular interest: americium-241, cesium-137, plutonium-239/240, strontium-90, and uranium isotopes. This discussion focuses on these constituents and those identified during the QRA human health screening process as COPC (see Appendix B - QRA contaminant screening tables and the QRA tables in Chapter 4.0). This screening process eliminated almost all chemical analytes except for Arochlor 1254, Arochlor 1260, and some heavy metals. Because the radionuclides represent the greatest potential risk and are the most widespread, the focus of this discussion falls on radionuclide contamination. A more extensive presentation of all analytical results for surface soils is contained in Wasemiller et al. (1994) and, for vadose zone soils, in Kelty et al. (1995). Data presented in tables in this section are summarized from the Hanford Environmental Information System (HEIS) (DOE-RL 1993b).

This section provides a summary of each system's investigation from the surface to the groundwater, including ecological investigations. Surface soil sampling activities are discussed for those units where samples were collected followed by a discussion of those systems (216-U-8 Crib, 216-U-1/2 Cribs, and 216-U-10 Pond) where shallow contamination is also part of the conceptual model. Vadose zone sediment and gamma logging results from the RLS are presented along with a comparison of the RLS data and vadose zone analytical data. Impacts to groundwater for the 216-U-1/2 Cribs, the 216-U-8 Crib, and the 216-U-12 Crib are addressed by a unit gradient method to estimate travel times through the vadose zone to the water table for each site. The impact to groundwater and unit gradient analyses are discussed in Section 3.6.

3.1 200-UP-2 ECOLOGICAL INVESTIGATION RESULTS

No natural surface water bodies exist within the 200-UP-2 Operable Unit. During the LFI activities, the only artificial surface water source was a small stretch of the 216-U-14 Ditch south of 16th Avenue and the 200 West Powerhouse Pond located over the historical head end of the 216-U-14 Ditch.

All of the high-priority waste sites investigated within the 200-UP-2 ecological QRA have either been (1) stabilized with wheatgrass (Siberian and Thickspike wheatgrass mixture) and managed with broadleaf-specific herbicides to control deep-rooted Russian thistle and perennial brush species or (2) covered with uncontaminated soil and/or gravel and treated with nonselective herbicides. In addition, all of the waste sites have infrequent (two or more times per year) surveys for harvester ant or mammal burrowing activity and treatment with insecticide or rodenticide products as needed. Additionally, most of the waste sites investigated are bordered with mechanically disturbed areas dominated by cheatgrass and some rabbitbrush communities in general. Areas having different species surrounding the site are noted in specific system ecology descriptions.

3.1.1 216-U-1/2 Cribs System

The ecology of the 216-U-1/2 Cribs system consisted of very disturbed areas dominated by cheatgrass. The 216-U-1/2 Cribs was restabilized with clean backfill and reseeded with a wheatgrass mixture in 1994. The area will receive selective broadleaf herbicide applications annually under the Radiation Area Remedial Action project. The 241-U-361 Settling Tank previously received an application of a long-lived (30 years or more) herbicide product (trifluralin) bonded onto a geotextile to prevent the establishment of Russian thistle. In addition, 4 in. of shotcrete was placed over the geotextile to prevent ultra-violet degradation of the herbicide. Contaminated Russian thistle often blows from adjacent areas and leaves contaminated vegetative foliar portions on the surface soil, which must be removed.

The 2607-W5 Septic Tank and Drain Field have a dominant cover of cheatgrass. In November 1994, a small surface contamination zone was posted near the eastern border of the drain field. The area is treated four times per year with broadleaf-specific herbicides.

The 216-U-16 Crib cover currently consists of established wheatgrass surrounded by mechanically disturbed sandy soils with a dominant establishment of Indian ricegrass. The 216-U-16 Crib currently receives quarterly applications of broadleaf-specific herbicides.

3.1.2 216-U-4 Reverse Well/4a French Drain System

The 216-U-4 Reverse Well and 216-U-4a French Drain are presently covered with soil and gravel and void of vegetation. These sites receive yearly applications of nonselective herbicide.

3.1.3 216-U-8 Crib System

The 216-U-8 Crib and the portion of the VCP from 16th Street south to the crib were stabilized with 0.6 m (2 ft) of surface soil in late 1994 and will be revegetated with wheatgrass as part of the Radiation Area Remedial Action program. They will be treated with broadleaf-selective herbicides. Presently the vegetation on 216-U-12 and the nearby surrounding area can be described as a disturbed cheatgrass community.

3.1.4 216-U-10 Pond System

Most of 216-U-10 Pond system waste sites have been stabilized with at least 0.6 m (2 ft) of clean backfill and revegetated. The exceptions are the 207-U Retention Basins and portions of the 216-U-14 Ditch. The most common revegetation species is Siberian wheatgrass with infrequent thickspike wheatgrass. These sites have frequent (four times per year) applications of broadleaf-specific herbicides applied by a variety of means to control establishment of deep-rooted Russian thistle and perennial shrub species. In general, all of these sites have spotty and infrequent establishment of wheatgrass species and sometimes a monoculture of cheatgrass.

The formerly active portion of the 216-U-14 Ditch was dominated by willows and bulrushes that had infrequent applications of a nonselective herbicide product for herbicide control in open water areas when the vegetation becomes taller than the ditch side berm. In early 1995, this section of the ditch was backfilled and interim stabilizied. The remaining active portion of the 216-U-14 Ditch extends

from Cooper Avenue to the 216-U-10 Pond. It has been filled in with 0.6 m (2 ft) of large river rock and is treated with nonselective herbicide to control all vegetative growth.

The 200 West Powerhouse Pond was formerly a portion of the 216-U-14 Ditch. It receives effluent from the 200 West Powerhouse. The 216-U-14 Ditch runs from northeast to southwest across 1 mile of the 200 West Area. The 216-U-14 Ditch is backfilled and stabilized from the 200 West Powerhouse Pond to the 207-U Retention Basin.

The Z Ditch complex has been surface stabilized with clean soil and revegetated. The 216-Z-20 Crib surface has a soil and gravel cover that is treated with nonselective herbicides to control all vegetative growth.

The 207-U Retention Basins consist of two open, concrete-lined basins. Currently, they have no significant vegetative growth or visible animal intrusion. The area directly north of the basins is a surface contamination area (SCA) containing cheatgrass and rabbitbrush with numerous Russian thistles. The source for this SCA is speculated to be windblown contamination from the adjacent 241-U Tank Farm. No contaminated vegetation has been identified in the SCA. Since no subsurface contamination source has been identified, the area is not included on the herbicide spray schedule.

3.2 216-U-1/2 CRIBS SYSTEM

3.2.1 Surface Radiological Survey Results

At the time of the LFI activities, an SCA surrounded the cribs and an underground radioactive material zone was posted around the 241-U-361 Settling Tank. The 2607-W5 Septic Tank and Drain Field are located in a depression roughly 15 m (50 ft) northeast of the 216-U-1/2 Cribs. This unit had no radiological posting at the time of the initial survey. The survey area is almost entirely void of vegetation due to management practices used to control plant growth.

This area was surveyed entirely with the USRADS due to a potential collapse condition at the 216-U-1/2 Cribs and a potential for damage to the 2607-W5 Drain Field, prohibiting the use of heavy equipment (i.e., MSCM II). Due to borehole drilling activities at the 216-U-1/2 Cribs, a portion of the crib surface had been stabilized with gravel and could not be surveyed. Roughly 25,000 m^2 of surface area associated with the 216-U-1/2 system was surveyed. Of the area surveyed, the highest concentration of data points above established background were in the northwest and northeast corners of the survey area. Other areas of high concentration were identified along the eastern border of the 2607-W5 Septic Tank and Drain Field, in the accessible area of the 216-U-1/2 Cribs, and in the vicinity of the 241-U-361 Settling Tank. A detailed presentation of the data is contained in Wendling (1994).

3.2.2 Surface Soil Sampling Results

As a result of the surface radiation survey of the 216-U-1/2 Cribs system, five soil samples were collected from this unit (not counting quality control samples). No vegetation samples were collected because the site is mostly void of vegetation. Surface soil samples were collected from areas with the highest readings recorded during the surface radiological surveys. These areas were located east of the 2607-W5 Septic Tank and Drain Field (Wasemiller et al. 1994, Figure 4). The radiological

constituents that represent the greatest risk for this system are cesium-137, plutonium-239/240, strontium-90, and uranium. Sample results for these constituents are shown in Table 3-1.

3.2.3 Stainless Steel Pipeline Camera Investigation Results

As part of the LFI, the integrity of the 216-U-1/2 effluent pipeline was evaluated. The pipeline is a 7.6-cm (3-in.) stainless steel line that transferred liquid waste from U Plant and its support facilities to the 216-U-1/2 Cribs system. The existing conceptual model assumed that the integrity of the pipeline was good; the investigation was designed based on this assumption. An in-line camera survey was done to visually examine 120 to 150 m (400 to 500 ft) of the pipeline's interior. When the pipeline was cut to gain access for the camera survey, wipe samples of the pipeline interior showed up to 30,000 cpm, but the exterior of the pipe and the surrounding soils showed no activity.

The camera survey showed the following.

- Minor amounts of liquid remained at low spots along the line.
- The final 6 to 9 m (20 to 30 ft) prior to entering the 241-U-361 Settling Tank was totally filled with liquid.
- Some areas of the system contained a slag/crusty material.
- Two tie-ins from other pipelines were verified with the camera survey (one from the 276-U Solvent Handling Facility and the other from U Plant).

The DOW for this investigation provided for pressure testing if the in-line camera survey did not provide sufficient data on the pipeline integrity; however, the pressure test was considered unnecessary (Rowley 1994b, Wasemiller et al. 1994). The field data gathered from this investigation supported the conceptual model of pipeline integrity. A detailed discussion of the full investigation is found in Wasemiller et al. (1994).

3.2.4 Borehole Sediment Sample Gamma Logging Results

Three boreholes were drilled in the 216-U-1/2 system for this LFI to focus on the effects of a lateral migration of effluent from the 216-U-16 Crib along an impermeable caliche layer, northward to beneath the 216-U-1/2 Cribs (Delegard et al. 1986, DOE-RL 1992). The discharge of large volumes of cooling water to the crib in 1984-1985 resulted in the mobilization of contaminants from the vadose zone beneath the 216-U-1/2 Cribs to groundwater. All boreholes were drilled into or through the caliche layer.

Also of interest were the effects of the active use of the 2607-W5 Septic Tank and Drain Field, which lies roughly 15 m (50 ft) northeast of the 216-U-1/2 Cribs. This system receives roughly 12,000 L/day (3,200 gal/day) of sanitary waste and sewage discharge. The conceptual model for this system speculates that water discharged to drain fields as a potential reason for continued uranium contamination of groundwater.

Along with the collection of sediment samples, radionuclide logging using RLS was done in each borehole. Contaminants detected with RLS generally correlate well with data from sediment samples

analyzed in the laboratory. Discrepancies in results between the two analysis techniques are likely due to differences in the methods used. Samples collected for laboratory analysis are typically high graded (e.g., large particle sizes are removed from the sample resulting in a concentrated sample). Chemical sampling is not always representative of the entire borehole since a limited number of samples are collected in comparison with RLS, which monitors continuously. Results from RLS are biased as inputs to the detector are averaged values 0.6 m (2 ft) above and below the tool. This represents an interval generally larger than the sediment sample interval.

Sediment samples from borehole 299-W19-96 drilled at the northern edge of the crib subsurface timber structure showed two areas high in contamination. The first area is located below the crib bottom, generally 6 to 12 m (20 to 40 ft) below ground surface (bgs). The highest concentrations of constituents are located here. The maximum concentrations of americium-241 (33 pCi/g), cobalt-60 (10.6 pCi/g), cesium-137 (1.7E6 pCi/g), strontium-90 (2.4E6 pCi/g), uranium-233/234 (1,400 pCi/g), and uranium-238 (1,500 pCi/g) occur either at the bottom of the crib (6.25 m [20.5 ft] bgs) or at the bottom of this first contamination zone (12.3 m [40.5 ft] bgs). The next area high in contamination is the top of the caliche layer (at roughly 52 m [170 ft] of depth) where uranium isotopes were seen to increase in concentration when compared to the vadose zone above this layer. The uranium-233/234 concentration at the caliche layer was 32 pCi/g, the uranium-235 concentration was 2.2 pCi/g, and the uranium-238 concentration was 32 pCi/g. Between the zone directly beneath the crib and the top of the caliche layer, constituents are present, but at levels generally at or near background (DOE-RL 1994b).

Boreholes 299-W19-95 and 299-W19-97 were drilled north and south of the 216-U-1/2 Cribs to investigate lateral migration of any contaminants along the caliche layer found at roughly 52 m (170 ft) of depth. Sediment samples from these boreholes show maximum concentrations for uranium isotopes (uranium-238 at 1.3 pCi/g and uranium-233/234 at 2.4 pCi/g) in these boreholes at the caliche layer.

Radionuclide logging system data show six man-made radionuclides (cesium-137, cobalt-60, europium-152, europium-154, and uranium-235, -238) identified in borehole 299-W19-96, which was drilled through the crib unit as part of the LFI. The two boreholes drilled adjacent to the 216-U-1 and 216-U-16 Cribs (299-W19-95 and 299-W19-97) to evaluate lateral migration in the vadose zone revealed detectable amounts of only cesium-137; this contaminant was found in the top 2.3 m (7.5 ft) of the vadose zone. The logging results for the three boreholes investigated are shown in Table 3-2. Data from sediment samples analyzed in the laboratory from the same zone are included in Table 3-2 for comparison of results.

3.2.5 216-U-1/2 Cribs System Data Results Summary

Surface soil investigations point to movement of contamination from the 216-U-1/2 Cribs surface or the surrounding area. This surface contamination is found around the 241-U-361 Settling Tank and the 2607-W5 Septic Tank and Drain Field. Since strontium and cesium are seen in the surface samples collected, it is suspected that some of the surface contamination in this area may have resulted from upward migration of contaminants through vegetation. Since the surface of the 216-U-1/2 Cribs is chemically controlled to prevent growth of vegetation, the cribs are a less likely source of this. Underground contamination is documented associated with the 241-U-361 Settling Tank, but this area is also chemically controlled as described in Section 3.1.1. Contamination from windblown vegetation from surrounding areas (the U-Tank farms being the most likely source) deposited in this area is suspected.

The stainless steel pipeline integrity investigation found no loss of integrity in the line. The line still contained fluid; the exterior of the pipe as well as the surrounding soil showed no radiological activity.

The evaluation of lateral spreading of contaminants in the vadose zone due to a confining layer was a key part of this system's vadose zone conceptual model. Soil sediment data and RLS data showed little to no lateral spread of contamination. Sediment and RLS data do point to constituents remaining in the soil column directly beneath the 216-U-1/2 Cribs. These concentrations decreased as the investigation moved away from the crib, yet contamination is present at reduced levels (generally near background) throughout the expanse of the borehole. As the investigation approached the caliche layer, located at roughly 52 m (170 ft) bgs, an increase in uranium isotopes was seen in both sediment and RLS data.

3.3 216-U-4 REVERSE WELL/4a FRENCH DRAIN SYSTEM FIELD INVESTIGATION RESULTS

3.3.1 Surface Radiological Survey Results

At the beginning of LFI activities for this system, no radiological postings were associated with it. The surface area of the system is relatively small, roughly 3 m by 3 m (10 ft by 10 ft). The area is void of vegetation and consists of compacted earth and gravel.

Because of this space limitation, hand excavation of the site was undertaken to locate the two waste facilities and any utilities in the area. During this hand excavation, the site was hand surveyed for radiological concerns. The first field indication of contamination was found at a depth of 1.4 m (4.5 ft), which is approximately 0.15 m (0.5 ft) above the top of the French drain. For the entire survey area, elevated readings of up to 100 dpm alpha and 15,000 dpm beta were recorded. As a result of this excavation work, an SCA was established around the two waste sites. After LFI activities ceased, the area was returned to its original condition and released from the SCA posting. Since the radiological survey was done after drilling had begun for the vadose zone borehole, no surface soils were collected from this system.

3.3.2 Surface Soil and Vegetation Sampling Results

No surface soil or vegetation samples were collected.

3.3.3 Borehole Sediment Sampling and Gamma Logging Results

Sediment samples from this investigation showed two distinct areas of contamination. The first is associated with the 216-U-4a French Drain and extends to a depth of 5 m (16 ft). In this zone, americium-241 (200 pCi/g) and cesium-137 (420 pCi/g) are at their maximum concentrations. Between 5 m and 11 m (16 ft and 37 ft) of depth, activity levels are near or below background. At the 11 m (37 ft) depth, activity levels once again increased, extending to a depth of roughly 30 m (100 ft) with maximum concentrations located at or near the top of the 216-U-4 screening interval (roughly 20 m [60 ft] bgs). Within this zone the maximum concentrations of americium-241 (190 pCi/g), cesium-137 (1,980 pCi/g), europium-152 (0.6 pCi/g), neptunium-237 (0.85 pCi/g),

uranium-234 (5.8 pCi/g), and uranium-238 (7.8 pCi/g) are seen. From the rough bottom of the reverse well at 30 m (100 ft), to the top of the caliche layer (located at roughly 53 m [175 ft] of depth), very little activity above background levels is seen. At the caliche layer, americium-241 (0.8 pCi/g), europium-152 (0.2 pCi/g), uranium-234 (1.8 pCi/g), uranium-235 (0.08 pCi/g), and uranium-238 (1.6 pCi/g) are once again found above background levels.

Three man-made radionuclides (cesium-137, cobalt-60, europium-154) were identified in the 216-U-4 Reverse Well/4a French Drain area with RLS. The data were obtained from borehole 299-W19-98, drilled between the 216-U-4 Reverse Well and 216-U-4a French Drain as part of the LFI. The range of contamination is shown in Table 3-3. Data from sediment samples analyzed in the laboratory from the same zone are included in Table 3-3 for comparison of results.

3.3.4 216-U-4 Reverse Well/4A French Drain System Data Results Summary

Soil sediment data from investigations at the 216-U-4 Reverse Well/4A French Drain system show constituents mainly in two zones. Each zone is tied to one of the disposal facilities. All significant contamination is detected within the upper 30 m (100 ft) of the vadose zone, which coincides with the depth of the 216-U-4 Reverse Well. Constituents are detected below this depth but at greatly reduced levels, generally at or below background until the caliche layer is reached at 53 m (175 ft) of depth, where a few constituents are seen to increase activity above background levels.

3.4 216-U-8 CRIB SYSTEM FIELD INVESTIGATION RESULTS

3.4.1 Surface Radiological Survey Results

At the time of LFI activities, an SCA surrounded the 216-U-8 Crib and extended north to 16th Avenue along the route of the VCP. The 216-U-12 Crib was designated as an underground radioactive material zone. The area surveyed consisted of the SCA associated with 216-U-8 Crib. Roughly 20,000 m^2 of the area was surveyed with USRADS. The area with the highest activity level was directly over and along the VCP with additional elevated readings found scattered throughout the remainder of the survey area. These findings fit with the conceptual model of this area. A detailed presentation of the survey data is found in Wendling (1994).

3.4.2 VCP Pipeline Camera Investigation Results

As part of the LFI for this system, an in-line camera survey of the VCP was conducted. The intention of this survey was to document the condition of the pipe material and the joints along the pipeline. This was also done to help evaluate any correlation that might exist between surface contamination and the condition of the pipeline. The pipeline was entered from two excavations in order to view as much of the line as possible and to view both the sections that lead to the 216-U-8 Crib and the 216-U-12 Crib. The survey revealed the following.

In the section that was used by both the 216-U-8 and 216-U-12 Cribs:

- Many of the joints were dislodged
- The degree of dislodgement varied from minor to very serious
- A silty/sandy material remained in portions of the pipeline.

In the section that was exclusive to the 216-U-12 Crib:

- The pipe was in excellent condition; the joints were sound
- The same silty/sandy material was found.

The lack of integrity in the VCP, as verified by the camera survey and surface radiation survey, fit the conceptual model for this pipeline. A complete discussion of the camera survey can be found in Wasemiller et al. (1994).

3.4.3 Surface Soil and Vegetation Sampling Results

As a result of the surface radiation survey and the camera survey of this system, 4 surface soil samples and 4 vegetation samples were collected to characterize the SCA, while 14 surface/subsurface soil samples and 4 vegetation samples were collected to characterize the VCP soils. Sample results for maximum concentrations are shown in Tables 3-4 and 3-5. Generally, the maximum concentrations for all analytes can be found in the soils closest to the VCP except for strontium-90, which is found at its maximum concentration in vegetation samples. Lateral spreading of contaminants was also investigated at one location. This location showed minimal lateral movement of contaminants. A graphical presentation of surface and subsurface analytical data and a detailed discussion of sample site selection and sample collection are contained in Wasemiller et al. (1994).

3.4.4 Borehole Sediment Sampling and Gamma Logging Results

3.4.4.1 216-U-8 Crib. One borehole (299-W19-94) was drilled in the 216-U-8 Crib as part of the LFI. Contaminants are generally present in the area directly beneath the crib bottom located 9 m (31 ft) below ground surface, roughly to a depth of 13 m (42 ft). Between 13 m and 34 m (42 ft and 112 ft), radiological contamination is only slightly above background levels. From 34 m (112 ft) through the remainder of the borehole, activity levels rose and remained elevated to the bottom of the boring located at 61 m (199 ft).

Four radionuclides (cesium-137, europium-154, uranium-235, uranium-238) were detected with RLS in boreholes drilled through the 218-U-8 Crib system. Three of the boreholes, 299-W19-70, 299-W19-71, and 299-W19-2, are existing wells and comprise part of the crib monitoring system. The fourth borehole, 299-W19-94, was drilled and abandoned as part of this LFI. The range of radioactivity detected is shown in Table 3-6. Data from sediment samples analyzed in the laboratory for radionuclides contamination are also included in the table for comparison of results.

3.4.4.2 216-U-12 Crib. One borehole was drilled as part of the LFI to characterize the 216-U-12 Crib. Borehole 299-W22-78 was drilled (and abandoned) adjacent to the 216-U-12 Crib as part of this LFI. Three man-made radionuclides (cesium-137, uranium-235, and uranium-238) were identified at the 216-U-12 Crib with the RLS. Contaminants were detected in existing crib monitoring borehole 299-W22-75, which was drilled through the crib, and 299-W22-78, which was drilled adjacent to the crib. Contaminants detected in each borehole are shown in Table 3-7. Results from sediment

samples analyzed in the laboratory from 299-W22-78 are also included in the table to provide a comparison of data.

Cesium-137 was detected to a depth of 8 m (59 ft) bgs in borehole 299-W22-75 with the RLS. Cesium-137 activity saturated (>5,000 pCi/g) the RLS 6 to 7.6 m (20 to 25 ft) bgs and also 13 to 17.7 m (43 to 58 ft) bgs. The maximum activity was an estimated 16,100 pCi/g at 7 m (23 ft) bgs. Cesium-137 was also detected in borehole 299-W22-78, 0.15 m (0.5 ft) bgs at activities <1 pCi/g. Cesium-137 was not detected in sediment samples analyzed in the laboratory.

Uranium-235 was detected in borehole 299-W22-75 with the RLS between 22 and 24 m (73 and 80 ft) bgs. The maximum activity in this zone is estimated at 20 pCi/g. Uranium-235 was also detected in borehole 299-W22-78 at depths of 3.8 m and 5.8 m (12.5 and 19 ft) bgs with the RLS. Activities were 4.5 and 2.4 pCi/g, respectively. Uranium-235 was detected in sediment samples analyzed in the laboratory at depths of 6.4 and 11.6 m (21 and 38 ft) bgs. Activities were <1 pCi/g.

Uranium-238 was detected in borehole 299-W22-75 with the RLS, between 5 and 24 m (17 and 80 ft) bgs. The maximum activity in this zone was 500 pCi/g at 23 m (76 ft). Uranium-238 was also detected in borehole 299-W22-78 with the RLS between 5.5 and 7 m (18 and 23 ft) bgs. Activities ranged from 11 to 66 pCi/g. Uranium-238 was detected in sediment samples analyzed in the laboratory to a depth of 70 m (230 ft). Activities were typically <1 pCi/g; however, a maximum of 2.2 pCi/g was detected 11.6 m (38 ft) bgs. The zones of maximum contamination correlate well with the crib discharge pipe located at 17 to 20 ft bgs.

3.4.5 216-U-8 Crib System Data Results Summary

This system is broken into two subsystems, the effluent line (VCP) and the cribs (216-U-8 and 216-U-12). Surface soil samples in the entire system tended to show background levels of activity for analyzed constituents. Vegetation samples showed high activity levels for cesium-137 and strontium-90. These two constituents were also found in surface soils, most likely due to plant decay. Subsurface soils also had high levels of cesium-137 and strontium-90 near the depth of the VCP. This was the case for almost all of the constituents of concern based on the VCP sampling results. Many constituents were found distributed throughout the entire sample region for the VCP (surface to roughly 3.3 m [11 ft]) with the higher concentrations being found at the depth of the VCP. Minor lateral spreading (no more than 0.9 to 1.5 m [3 to 5 ft]) of constituents is suspected at the VCP as indicated by the one attempt at quantification. Correlations between surface conditions and pipeline conditions is apparent in cesium-137 and strontium-90 results. Vegetation samples located above and near elevated subsurface samples show high concentrations of these constituents. Graphic presentations of surface analytical data for cesium-137, plutonium-239/240, strontium-90, and uranium can be found in Wasemiller et al. (1994).

Vadose zone sampling at the cribs indicated constituents were located near the bottom of the 216-U-8 Crib; concentrations generally decreased with depth similar to the 216-U-1/2 investigation. Sampling at the 216-U-12 Crib did not show any constituents at levels above background. This may be due to the location of the borehole adjacent to the crib rather than through it. Radionuclide logging system data gathered in the 216-U-12 Crib monitoring borehole show estimated activity levels for cesium-137, uranium-235, and uranium-238 at levels much higher than in the borehole adjacent to the crib. This would point to limited horizontal migration of contaminants in the vadose zone as has been noted in other investigations in the operable unit.

3.5 216-U-10 POND SYSTEM FIELD INVESTIGATION RESULTS

3.5.1 Surface Radiological Survey Results

The U Pond system consists of an interim stabilized pond, inlet ditches, and overflow ditches. They are classified as areas of underground contamination. The interim stabilization consisted of placing clean fill over the waste management unit. Ditches were generally filled to grade and then covered with 0.6 to 1.2 m (2 to 4 ft) of clean fill. U Pond was covered with approximately 1.8 to 3 m (6 to 10 ft) of clean material.

Four areas of the system were radiologically surveyed using the MSCM-II tractor. They included the 216-U-10 Pond, 216-U-11 Trench, 216-U-14 Ditch, and the Z Ditch complex (216-Z-1, 216-Z-11, 216-Z-19, and 216-Z-20 Ditches). The area around the 207-U Retention Basins was surveyed with USRADS. The surveys showed localized activity in almost all components of the system.

- Activity above background in U Pond was generally associated with the perimeter areas.
- Activity above background in the 216-U-11 Trench was highest along the main trench closest to the outflow from U Pond.
- Activity above background in the Z Ditches was highest in the delta region associated with U Pond.
- Activity above background in the 216-U-14 Ditch was highest north of the 207-U Retention Basins.
- Activity above background around the 207-U Retention Basins was also highest closest to the 216-U-14 Ditch.

These data fit well with the conceptual model that contaminants would be located in the perimeter region of the pond. Since the perimeter of U Pond would have received the least amount of fill material, this area would be the most likely to have upward migration of contaminants. This was seen in the vegetation samples collected in the southwest corner of the pond and in the presence of pond bottom material found on the surface near burrowing mammal holes.

3.5.2 Surface Soil and Vegetation Sampling Results

As a result of the surface radiation survey, the areas determined to have the highest levels of detectable contamination became candidate soil and vegetation sample sites. From these, a total of 12 soil samples and 2 vegetation samples were collected as follows (Wasemiller et al. 1994, Figure 3):

- Five soil and two vegetation samples in the 216-U-10 Pond; soil samples were collected throughout the pond and vegetation samples were taken in the southwest corner
- Two soil samples in the 216-U-11 Trench, one near each of the two outlet lines
- Three soil samples from the 216-U-14 Ditch, two of these from the 207-U Retention Basins Area, the other from the ditch north of the basins

- Two soil samples from the Z Ditches were collected near the pond end of the ditches
- No samples were collected from the 216-U-9 Ditch because contamination was not identified during surface surveys.

As stated previously, during the sample collection process, a peat-like material was found scattered on the surface of U Pond near the perimeter. When surveyed with field instruments, this material was active, more so when broken apart. It appeared to be similar to the material found in the test pit excavation in the northwest corner of U Pond.

Both vegetation sample collection sites were located in the southwest corner of U Pond. Both sites showed strontium-90 at roughly 400 pCi/g. In addition, surface soils in U Pond tended to only have concentrations of concern for strontium-90. The section of the 216-U-14 Ditch closely associated with the 207-U Retention Basins was high for several analytes. These results were generally higher than for the same analytes in the 216-U-10 Pond. The southern portion of the Z Ditches, closely associated with the delta region of U Pond where they and 216-U-14 entered, also showed elevated activity for several constituents, especially plutonium-239/240. A summary of maximum concentrations and locations is given in Table 3-8. Graphical presentations of surface analytical data for cesium-137, plutonium-239/240, strontium-90, and uranium can be found in Wasemiller et al. (1994).

3.5.3 Cone Penetrometer Results

The CPT was used to evaluate the potential for contamination at depth in U Pond. The conceptual model for U Pond stated that uranium could possibly be found at depth. This was concluded from previous investigations (DOE-RL 1992). Evaluation of the CPT scintillator data indicated the area of greatest concentration of radiological contamination to be approximately 1.9 m (6.5 ft) bgs of the 216-U-10 stabilized surface. CPT holes CP-8 and CP-10, located in the southeast corner of the pond (Figure 2-4), showed activity at depth. These results helped lead to the decision to not excavate a second test pit as originally planned for the delta region of the pond at the start of LFI activities.

3.5.4 Test Pit Results

The 200-UP-2 work plan (DOE-RL 1993a) called for two test pits to be excavated to refine the conceptual model for the 216-U-10 Pond. Test pit 1 (TP-1) was to be excavated in the delta region of the pond since it was here that the greatest inventory of contaminants was expected. Test pit 2 (TP-2) was to be excavated in the deepest part of the pond. Test pit-2 was excavated first to evaluate procedures for dust control, radiation exposure control, and sample collection techniques. It was assumed that the depth of clean fill material at the TP-2 location was around 3 m (10 ft). Upon excavation of TP-2, the depth of fill material was found to be only 1.9 m (6.5 ft). Decayed organic matter (black in color and peat-like in appearance) was encountered at this depth. Field screening also showed the greatest level of activity at this depth. Maximum concentrations for contaminants from TP-2 are found in Table 3-8, and a discussion of test pit data can be found in Kelty et al. (1995).

3.5.5 Borehole Sediment Sampling and Gamma Logging Results

One vadose zone borehole was drilled in the U Pond system as part of LFI activities. This borehole was not part of the original investigation strategy for U Pond. As stated in Section 3.5.3, CPT data indicated contamination at depth in the southeast area of the pond. This became the location of the U-Pond borehole. Uranium, which was the suspected U Pond vadose zone contaminant (DOE-RL 1992), was not detected by the RLS and was typically <3 pCi/g in sediment samples. The only man-made radionuclide detected with RLS at 216-U-10 Pond was cesium-137. It was detected from 0 to 3 m (0 to 10 ft) bgs at 440 pCi/g. Sediment samples analyzed in the laboratory showed cesium-137 values to be <1 pCi/g over the entire length of the borehole except for two samples collected in the backfill at the 0.6- and 1.2-m (2- and 4-ft) depths (1,150 and 66.1 pCi/g, respectively). This depth matched with sediment data. The range of cesium-137 contamination is shown in Table 3-9 with data from sediment samples analyzed in the laboratory for comparison of results.

3.5.6 216-U-10 Pond System Data Results Summary

In the 216-U-10 Pond system, surface soils and vegetation contain the highest activity levels for strontium-90 and cesium-137. The fact that the surface soils contain elevated levels of these constituents points to plant decay as a primary source. A secondary source would be burrowing animals bringing contaminated soil up from the pond bottom.

The pond bottom is a second area of constituent concentration. In the 216-U-10 Pond test pit, the location of the pond bottom is 1.9 m (6.5 ft) bgs. It is at this location that elevated readings are seen for many radionuclides, heavy metals, and two polychlorinated bihphenyls (PCBs). The borehole drilled in this system showed minimal elevated readings for its entire length, below the 1.9-m (6.5-ft) depth.

Other areas within the U-Pond system that showed high activity levels included the 216-U-14 Ditch, the delta region of the pond where the 216-U-14 Ditch and the Z-Ditches enter, and the area around the 207-U Retention Basins. Soil sediment data from test pits and boreholes used in conjunction with the Hanford Site Liquid Effluent Study showed elevated readings for constituents in the vadose zone immediately below the bottom of the ditches. Although there was no intrusive investigation of the delta region of the 216-U-10 Pond, this area has been looked at in the past, especially as part of U-Pond decommissioning support activities. In *216-U-10 Pond and 216-Z-Ditch Characterization Studies* (Last et al. 1994), this area has historically and consistently shown elevated activity levels for several constituents. This LFI, sitewide environmental monitoring efforts, and other investigations of the U-Pond system show that surface soils in this area contained the highest concentration of plutonium-239/240.

3.6 IMPACT TO GROUNDWATER ASSESSMENT

This section provides a summary of observed hydrologic and contaminant impacts resulting from effluent discharge to the soil column in the 200-UP-2 Operable Unit. Models of contaminant flow and transport have been developed. Section 3.6.1 focuses on the 216-U-10 Pond Disposal System. Simplistic models of contaminant and transport are presented in Sections 3.6.2 through 3.6.5 for the 216-U-1/2, 216-U-8, and 216-U-12 Cribs. The description of lithology used in this report is, at best, a generalization of geologic conditions beneath these cribs. In addition, the usefulness of physical

property data is dependant upon sampling technique and lithology (Reynolds and Lindsey 1994). Therefore, the modeled results are approximations of what may occur under the above conditions. These models suggest relatively short travel times to groundwater during the operation of the facilities.

3.6.1 Responses to Effluent Disposal

Hydrologic responses to effluent discharge have been observed at the water table throughout the 200 West Area. Discharge data, depth to water measurements, and groundwater chemistry data have been assimilated from many years of monitoring this system. The data indicate that waste water and contaminants can move rapidly through the vadose zone to the water table under saturated or near-saturated conditions. Additionally, water table maps are used to depict the influence of effluent disposal on groundwater morphology. Figure 3-1 illustrates the generation of a groundwater mound beneath 216-U-10 Pond as a result of local discharge. Development of the mound eastward reflects periods of decreased discharge to 216-U-10 Pond and the continuing influence of facilities discharging to other areas of the soil column after the interim stabilization of 216-U-10 Pond in 1985. The relationship between discharge and changes in water table elevation at the 216-U-14 Ditch has been evaluated by comparing water table elevations versus time (hydrographs) and plots of discharge versus time (Figure 3-2). Contaminant concentration responses to effluent discharge have also been documented at the 216-U-14 Ditch (Figure 3-3). Observations of these responses indicate that relatively short travel times to groundwater take place under saturated or near-saturated conditions and that breakthrough has occurred. A detailed discussion of impact to groundwater at the 216-U-14 Ditch is presented in Singleton and Lindsey (1994).

3.6.2 200-UP-2 Vadose Zone Model

In an effort to assess vadose zone contaminant flow and transport conditions in the 200-UP-2 Operable Unit, subsurface stratigraphy was examined at three cribs: 216-U-1/2, 216-U-8, and 216-U-12. Saturated flow conditions and the presence of a highly mobile contaminant, technetium-99, were assumed in order to provide the most conservative assessment. The vadose zone stratigraphy beneath each crib was interpreted from borehole geologic, geophysical (gross gamma), and physical characteristics data. These data were supplemented by information and interpretations gained from the study of surficial exposures of analogous strata. From these data sets, the nature and extent of the main sediment types underlying each crib, from ground surface to the top of the unconfined aquifer, were determined.

The first part of this discussion centers on describing the main sediment types that typically comprise the vadose zone at the Hanford Site. This is followed by sections that address site-specific descriptions of the stratigraphic units underlying each crib. These sections also include assessment of the probable influence the different stratigraphic units have on flow rate and transport within the vadose zone as moisture content approaches saturation. A unit gradient transport analysis was applied to each crib in an effort to ascertain saturated flow conditions as part of these assessments. The unit gradient method is one-dimensional and based on steady-state flow conditions in the vadose zone and a unit hydraulic gradient. It is used to estimate the rate of moisture and contaminant movement vertically through the soil column. Since the method does not consider lateral spreading, it is regarded as more conservative (faster) than actual contaminant migration (Singleton and Lindsey 1994). The final section discusses the implications these interpretations have under decreased moisture content.

3.6.3 Vadose Zone Sediment Types

Detailed descriptions of Hanford Site suprabasalt sediments and stratigraphy are found in several reports (Myers et al. 1979; Tallman et al. 1979, 1981; PSPL 1982; Bjornstad 1984; DOE 1988; Lindsey 1989, 1992; Baker et al. 1991; Lindsey et al. 1991, 1992, 1994; Reidel et al. 1992). These reports clearly indicate that the suprabasalt sediments consist of a variety of gravel, sand, silt, and carbonate-rich facies. For this report, the suprabasalt sediments are categorized on the basis of formational units (e.g., Hanford formation, Plio-Pleistocene unit, and Ringold Formation) and sediment types within each formation (Table 3-10). For example, one sediment type is Hanford formation sand with minor interbedded silt. Use of the formation name differentiates this sediment type from sediments found in other formations that may have similar names but different physical properties.

Clastic dikes are common features within the 200-UP-2 Operable Unit, occurring as vertical or near-vertical structures filled with sand, silt, and/or minor coarser sediments. These sediments are unconsolidated and may form layers that are laminated parallel to the dike walls, cross laminated, or massive. As dikes, these features cross cut and locally disrupt bedding. They can also bend and become sills. The cross-cutting nature and bedding forms of clastic dikes suggest that they will influence moisture movement in near-surface sediments. The characteristics and the probable influence on vadose zone flow and transport these geologic features have are discussed in Kelty et al. (1995).

3.6.4 Flow and Transport Modeling

Unsaturated hydraulic conductivity and moisture retention curves acquired for a variety of sediment types throughout the 200 Areas were matched to the sediment types determined to be present beneath the 216-U-1/2, 216-U-8, and 216-U-12 Cribs. Using Table 3-10, one can match appropriate curves to different sediment types at any given site. The data curves used for the unit gradient analyses performed for this report where chosen to best represent potential vadose zone flow conditions in each of the interpreted stratigraphic units.

Unit gradient analyses of water flow from the cribs to groundwater were run for each crib. Saturated flow conditions were assumed throughout the stratigraphic section underlying each site. Variables such as area, discharge volume, curves, and saturated conductivities are listed in tables applicable to each of the three cribs. The most rapid transport times for contaminants will be essentially the same as the model results for saturated conditions for contaminants with retardation factors at or near 1 (such as technetium-99). Qualitative estimates of flow rates under various unsaturated conditions can be made for each of these sites using the models generated. However, these estimates were not performed in this exercise.

3.6.4.1 216-U-1/2 System. A 12-layer model is defined for the 216-U-1/2 Cribs (Tables 11, 12a, 12b, and 12c). Layers 1, 2a, 2b, 3, 4, 6, 6a, and 6b correspond to the Hanford formation from 7.3 to 46 m (24 to 162 ft). Layers 7 and 8 correspond to the Plio-Pleistocene unit from 46 to 52.4 m (162 to 172 ft), while Ringold strata are represented by layers 9 and 10 from 52.4 to 70 m (172 to 230 ft). The uppermost 7.3 m (24 ft) at this site consists of backfill and is not modeled. Modeled transport time to groundwater under saturated conditions is 1.89 years (Table 3-12c). This interpretation is supported by observed transport times of uranium and technetium-99 at the 216-U-1/2 Cribs under saturated conditions (Delegard et al. 1986).

Layer 1, extending from 7.3 to 10.4 m (24 to 34 ft), consists of Hanford formation sandy pebble-cobble gravel with interbedded sand. These strata are typically well stratified, and the total silt-clay content usually is less than 5% by weight. An open-framework texture is at least locally present. Silt interbeds are rare and probably very discontinuous. Therefore, perched water and lateral spreading is probably limited. Curve C is used for this layer because it is thought to better represent conditions than the saturated conductivity data (resulting in curves CC, Y, and Z estimating saturated flow conditions) from the 216-U-17 Crib report (Reidel et al. 1993). The 216-U-17 Crib is located southeast of U Plant at the intersection of 16th Street and Beloit. Use of Curve C allows variable moisture conditions to be modeled, which cannot be done with the 216-U-17 data.

Interstratified sand and silt is typical of the remainder of the Hanford formation and includes layers 2a at 10.4 to 11.8 m (34 to 39 ft), 2b at 11.8 to 12.8 m (39 to 42 ft), 3 at 12.8 to 15.8 m (42 to 52 ft), 4 at 15.8 to 17.7 m (52 to 58 ft), 6a at 30 to 48 m (100 to 158 ft), and 6b at 48 to 49.4 m (158 to 162 ft). Layer 5, at 17.7 to 30 m (58 to 100 ft), is excluded because it consists of gravel and coarse-grained sand.

Lateral spreading will most likely occur in the silt-rich layers 2a, 6a, and 6b. However, the lack of lateral continuity of individual silt beds and the presence of clastic dikes, which are common in the area (Singleton and Lindsey 1994), suggest lateral spreading is probably less than a few tens of meters. Curve R, a Ringold silt curve, was used for layer 2a because there is not a curve generated from Hanford strata having the appropriate lithology. Curves I, C, and K are used for the remainder of the Hanford strata with I corresponding to sands with interbedded silt, C to coarser deposits, and K to finer deposits.

Perched water may accumulate on the silt-rich and carbonate-rich Plio-Pleistocene unit (layer 7 at 49.4 to 50.9 m [162 to 167 ft] and layer 8 at 50.9 to 52.4 m [167 to 172 ft]) as it does in the Z Plant area (Rohay et al. 1994). However, clastic dikes have been observed penetrating this interval in borehole samples (299-W23-16) near the west end of the 216-U-14 Ditch where perched water does not appear to be laterally extensive (Singleton and Lindsey 1994). Examination of outcrops and core further indicate the Plio-Pleistocene carbonates are characterized by numerous pinchouts of cemented beds and fracturing in the carbonate. The combination of clastic dikes and fracturing indicate that the Plio-Pleistocene unit may only locally cause the formation of significant perched water. Curve P corresponds to silty sandy carbonate bearing strata while Curve O corresponds to more gravelly carbonate-rich deposits.

Layers 9 and 10 represent Ringold Formation lithologies. Layer 9 (52.4 to 53.6 m [172 to 176 ft]) corresponds to sand-rich strata of the upper unit (Curve S), and layer 10 (53.6 to 70.1 m [176 to 230 ft]) corresponds to the variably cemented, sandy pebble-cobble gravel of unit E (Curve FF). Upper Ringold sand typically is not cemented. Therefore, lateral spreading within this sediment type is probably limited. Cemented horizons are commonly found in the gravels of unit E, both in borehole samples and outcrops. These cemented horizons may form potential perched zones, although perched water is not commonly described in Ringold sediments. Absence of perched water in this sediment type may be in part due to the fact that the lateral continuity of cemented horizons appears to be limited.

3.6.4.2 216-U-8 System. Six layers are defined for the 216-U-8 Crib model (Tables 3-13, 3-14a, 3-14b, and 3-14c). Layers 1 and 2 correspond to the Hanford formation, layers 3 and 4 to the Plio-Pleistocene unit, layer 5 to the Ringold upper unit, and layer 6 to Ringold unit E. Modeled transport time to groundwater under saturated conditions is 1.15 years (Table 3-14c).

Beneath the 216-U-8 Crib, the Hanford formation is dominated by interbedded sand and silt. Gravel units are not present. The first unit, layer 1 (7.6 to 22.9 m [25 to 75 ft]), consists of medium- to coarse-grained sand with minor silt interbeds. Outcrops of this type of Hanford sediment are well stratified, although the lateral continuity of individual beds is limited. Curve F was chosen because of the coarseness of the sample. Curve H was generated from the remainder of the Hanford formation, represented by layer 2 (22.9 to 45.7 m [75 to 165 ft]), which consists of fine- to medium-grained sand with silt interbeds. Curve H is used because of decreased grain size and increased silt interbeds relative to layer 1. Clastic dikes generally are common in sandy and silty Hanford deposits. The limited continuity of individual beds and the presence of clastic dikes is expected to minimize the extent of lateral spreading and formation of perched water.

As is the case with the 216-U-1/2 Cribs, the Plio-Pleistocene unit at the 216-U-8 Crib is divided into two layers, an upper silt-rich layer (layer 3 at 45.7 to 56.7 m [165 to 186 ft]) and a lower carbonate-rich layer (layer 4 at 56.7 to 60 m [186 to 197 ft]). The silt-rich layer is characterized by massive to laminated slightly sandy silt that may be cut by clastic dikes. Curve M is used here because this horizon appears to be very silt rich. The carbonate-rich layer is silty at this location, but like other sites each carbonate bed probably is discontinuous and fractured. Because of the apparent lack of gravel in these strata, Curve P was used rather than Curve O, as is done at the 216-U-1/2 Cribs.

The upper Ringold unit beneath the 216-U-8 Crib is dominated by sandy silt and clay (layer 5 at 60 to 64.3 m [197 to 211 ft]), which is interpreted to be silt and clay-rich paleosols. Discrete sand beds are typically lacking in Ringold paleosol outcrops. Lateral continuity of paleosols at the base of the upper Ringold tends to be minimal. Therefore, lateral spreading is likely to be limited on this layer. Because of this, Curve S is used.

Ringold unit E (layer 6 at 64.3 to 72.5 m [211 to 237 ft]) is very similar to Ringold unit E at the other cribs. It consists of variably cemented, sandy pebble-cobble gravel. Cemented beds may be somewhat more fractured elsewhere than in this unit. In addition, there appears to be more silt at this location. Therefore, Curve T is used for layer 6.

Inadequate seals may need to be addressed for well 299-W19-2, which is located <30 m (100 ft) east of the 216-U-8 Crib. A surface seal is documented in this well to an undetermined depth. An annular seal is not documented below the surface seal. The absence of an annular seal becomes important if the well is situated within any of the spreading areas in the vadose zone as it may act as a vertical conduit through the stratigraphic layers. The extent of spreading zones has not been determined.

3.6.4.3 216-U-12 System. Fourteen layers comprise the model for the 216-U-12 Crib (Tables 15, 16a, 16b, and 16c). Layers 1, 2, 3, 4a, 4b, 5a, and 5b correspond to the Hanford formation. Plio-Pleistocene strata are represented by layers 6 and 7; the upper Ringold by layers 8, 9, 10, and 11; and Ringold unit E by layer 12. Modeled transport time to groundwater under saturated conditions is 1.83 years (Table 3-16c).

Medium- to coarse-grained sand-rich deposits comprise the first two Hanford formation layers (1 at 4.9 to 6 m [16 to 20 ft] and 2 at 6 to 11.5 m [20 to 38 ft]). These sand layers contain minor interbedded gravel. Silt appears to be lacking. Curves C and F were used for layers 1 and 2 respectively because they best matched apparent grain size distributions for these strata. Curve P, although used for Plio-Pleistocene strata, is chosen to represent layer 3 (11.5 to 12.1 m [38 to 39 ft] because of similarities in grain size and carbonate content. Layers 4a and 4b (12.1 to 27.4 m [39 to

90 ft] and 27.4 to 31.7 m [90 to 104 ft], respectively) consist predominantly of fine- to medium-grained sand with interbedded silt. The silt interbeds may promote lateral spreading. However, the lack of lateral continuity of individual beds typical of these deposits and the presence of clastic dikes will probably act to limit the lateral spreading of water. Curve F is chosen to best approximate the flow conditions in layers 4a and 4b. The lower part of the Hanford formation is more silt rich and consists of interbedded silt and sand deposits represented by layers 5a (31.7 to 45.1 m [104 to 148 ft]) and 5b (45.1 to 50 m [148 to 165 ft]). The increased incidence of silt beds in layers 5a and 5b lead to the use of Curve I for these layers. Here again the potential for extensive spreading caused by silt beds is at least partially offset by the lenticular bedding geometries and the presence of clastic dikes.

As at the other two sites, the Plio-Pleistocene unit here is represented by two curves corresponding to an upper silty zone (layer 6 at 50 to 50.3 m [165 to 176 ft]) and a lower carbonate-rich sandy silt (layer 7 at 50 to 55.5 m [176 to 182 ft]). Although Curve Q is used to represent Ringold Formation silts, it is used for layer 6 because of similarities in grain size. The sandy carbonates of layer 7 are matched to Curve P.

The upper Ringold unit beneath the 216-U-12 Crib consists of a variety of interbedded sand lithologies and silty paleosols (layer 8 at 55.5 to 58.9 m [182 to 192 ft], layer 9 at 58.9 to 60.4 m [192 to 198 ft], layer 10 at 60.4 to 65.2 m [198 to 214 ft], and layer 11 at 65.2 to 71 m [214 to 234 ft]). Given this variety, coupled with bedding trends typically seen in outcrops, it is unlikely that any of the various silt beds found at this location are laterally continuous. Layers 8, 9, 10, and 11 are matched to assorted curves (Table 3-15) that best represent the irregular flow conditions assumed to be present. The variably cemented sandy pebble-cobble gravel of unit E (layer 12 at 71 to 71.9 m [234 to 236 ft]) is similar to unit E deposits at the other two sites. In addition, the amount of unit E above the water table at the 216-U-12 site is so small (approximately 0.6 m [2 ft]) that the discontinuous cemented lithologies that may comprise it will have little or no impact on vadose flow. Curve FF was chosen for layer 12.

Inadequate well seals may also need to be addressed for the 216-U-12 Crib. Wells 299-W22-22 and 299-W22-23 are located within 30 m (100 ft) of the 216-U-12 Crib. A surface seal is documented in 299-W22-22 to an unknown depth. However, an annular seal is not documented below the surface seal. Well 299-W22-23 is constructed in a similar fashion. Surface and annular seals also are not documented for well 299-W22-24. This well is located about 60 m (200 ft) southeast of the 216-U-12 Crib and contains a cluster of six piezometers.

3.6.5 Conclusions

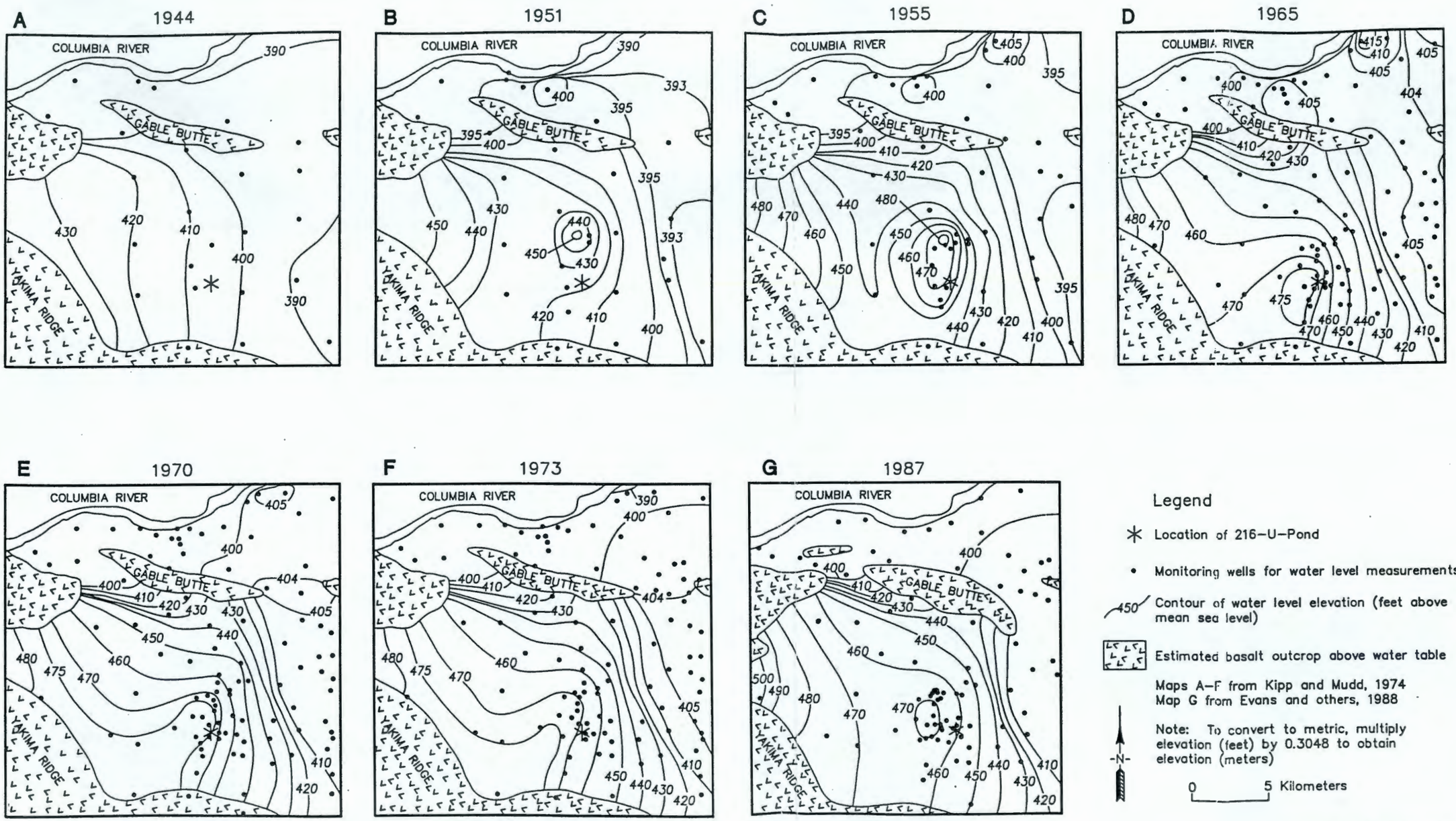
The geologic conceptualization discussed here, in conjunction with the unit gradient analysis, suggests that under saturated or near-saturated conditions, vertical flow and transport through the vadose zone is relatively rapid. In each case, the unit gradient model yielded results of less than two years from the bottom of the cribs to the groundwater. Direct observations of discharge and perched water mounding discussed in Reidel et al. (1992) and Singleton and Lindsey (1994) directly support this conclusion. This conclusion is not unreasonable in view of the geologic evidence gathered from outcrops and boreholes. These results also indicate that contaminants with low retardation factors, such as technetium-99, will have rapidly reached groundwater during crib operation.

Outcrop evidence clearly indicates that, although silt-rich beds that could act as perching horizons are common, they are of generally limited lateral extent, usually no more than several tens of meters. In addition, clastic dikes are common throughout the Hanford formation and Plio-Pleistocene unit,

cutting through fine-grained beds. Together, these two features probably act to limit the lateral spread of perched water on any given bed or horizon. It also seems probable that clastic dikes may, in many cases, act as vertical conduits that promote downward flow. The limited lateral extent of perched water that has been shown in subsurface investigations (Rohay et al. 1994, Singleton and Lindsey 1994) supports this conclusion.

Since the termination of discharge to the cribs, vadose zone water content will have decreased. Recent observations in the 200 West Area indicate it may take a period of several years for vadose zone sediments to return to approximate natural moisture conditions following the end of water disposal at a facility. Plume observations at the 216-U-12 Crib indicate water and contaminants held in the vadose zone may continue to contribute to groundwater plumes for several years after the termination of discharge (DOE-RL 1995). This would suggest that vadose sediments may act as a temporary reservoir for water and contaminants following the end of disposal. Under the influence of gravity, the reservoir would continue to release water and contamination to the groundwater for some period of time. All of the curves used to provide data for this investigation (Table 3-10) show orders of magnitude decrease in hydraulic conductivity with decrease in moisture content resulting in significantly increased transport times.

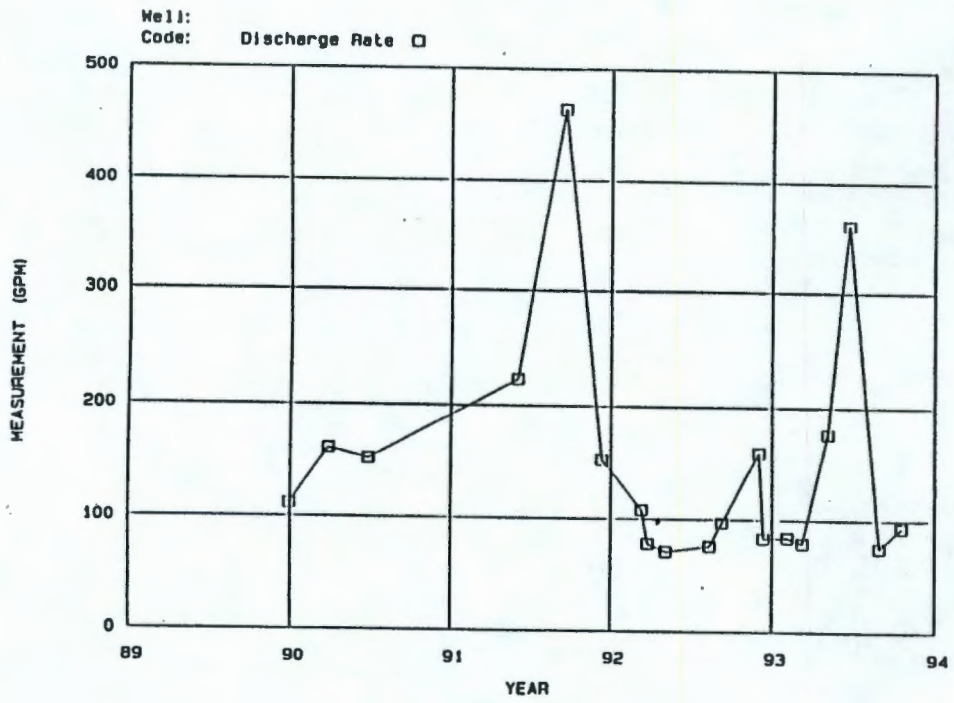
In conclusion, it seems clear that the lateral continuity of perched water is limited. However, the presence of perched zones cannot be discounted, and it may take some time for water held up on these to completely infiltrate through the vadose zone. The best way to minimize this flow rate is to reduce vadose moisture to near natural conditions. Since the main source of vadose zone moisture is facility effluents, it is logical to assume that if effluents are reduced or eliminated, vadose zone moisture will be reduced. This will lead to significant decreases in transport times from the ground surface to the water table, which is more than 67 m (220 ft) below the surface. Moisture reduction alone would likely curtail the impact of contaminants still in the vadose zone reaching the underlying groundwater.



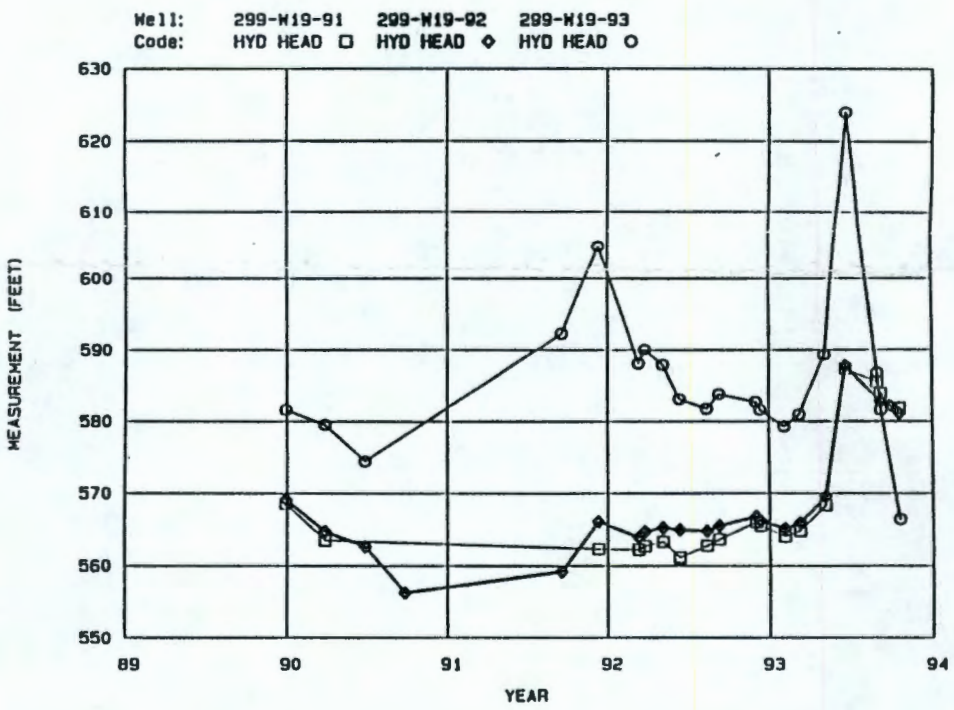
GEOSCI\010494-B

Figure 3-1. Water Table Maps of 200 West Area from 1944 to 1987.

Discharge into the Ditch.



Water Levels at the Perched Zone Beneath the Ditch.



Water Levels at the Water Table Beneath the Ditch.

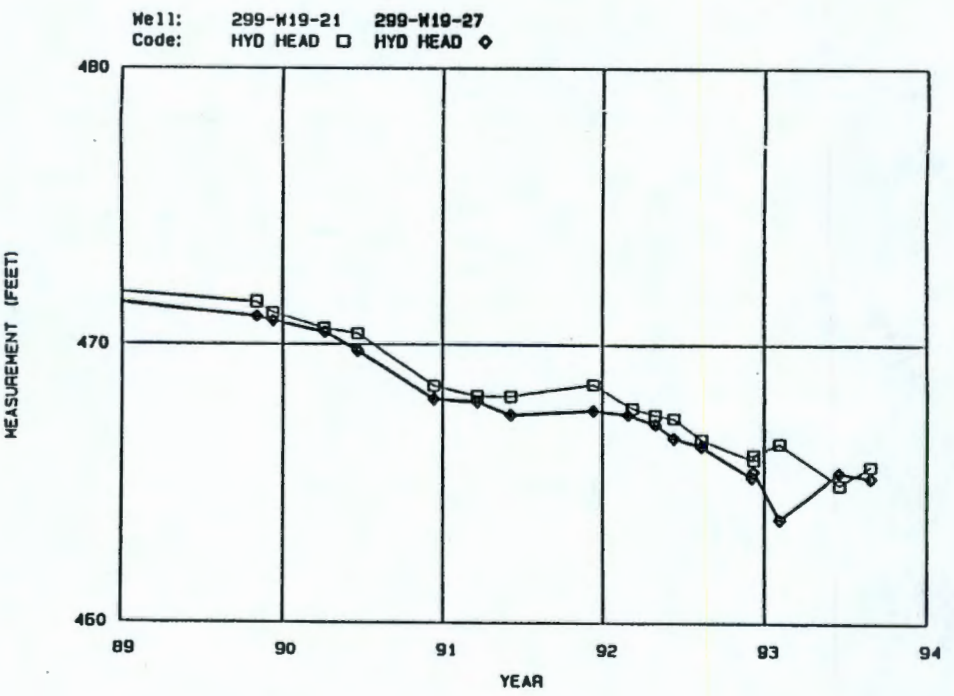
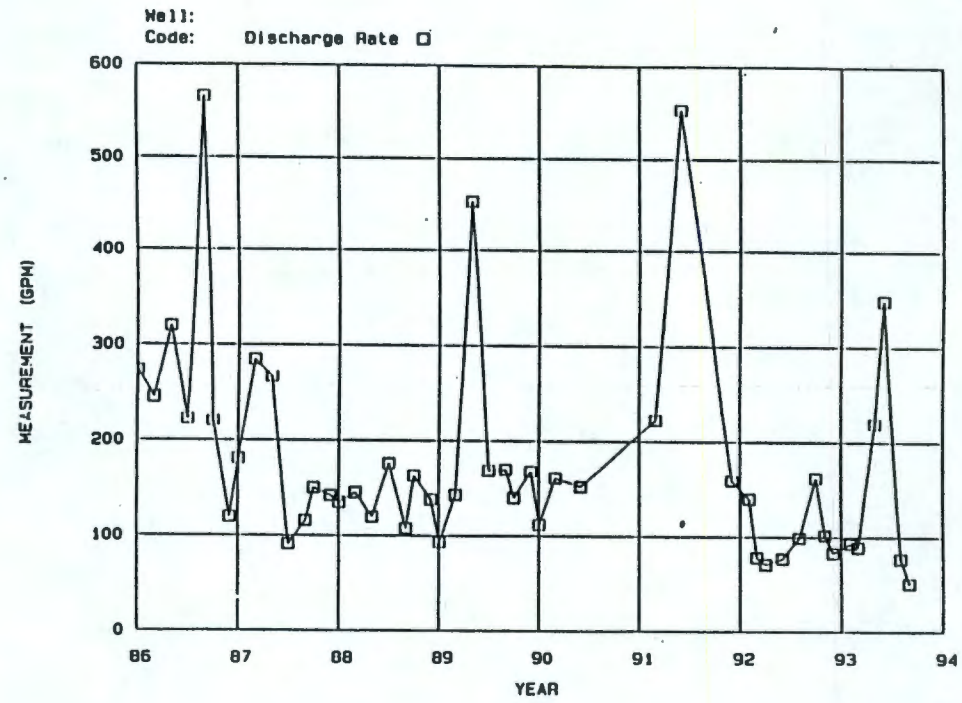


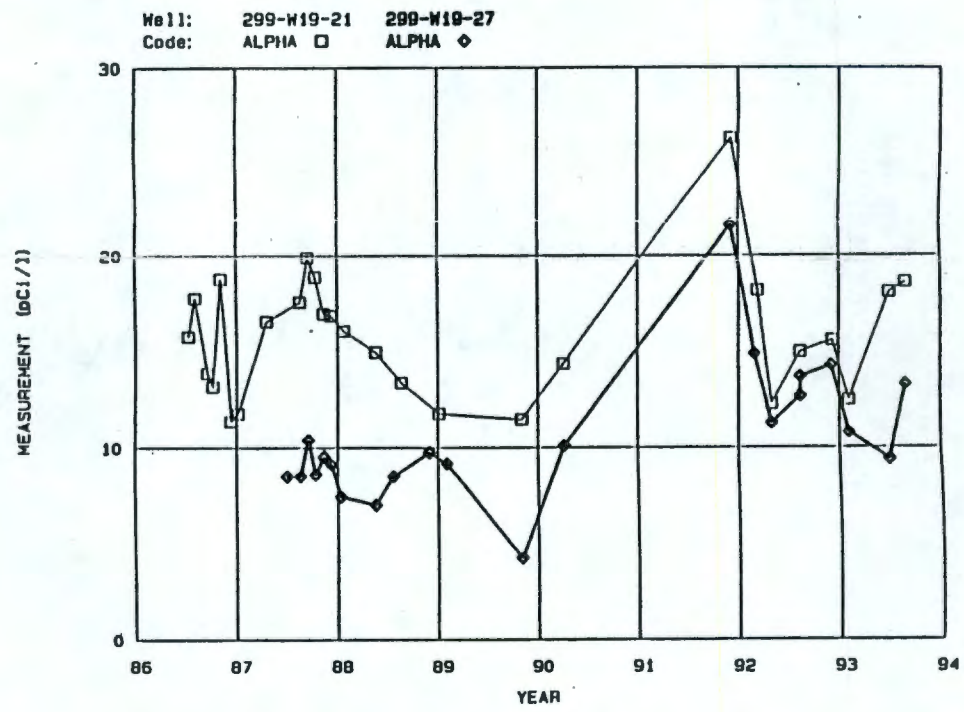
Figure 3-2. Discharge Data and Hydrographs of the Perched Zone and Groundwater Illustrating the Relationship Between Effluent Discharge and Changes in Water Table Elevation.

9613389.0798

Discharge to the Ditch.



Gross Alpha Contamination in the Groundwater.



Uranium-238 Contamination in the Groundwater.

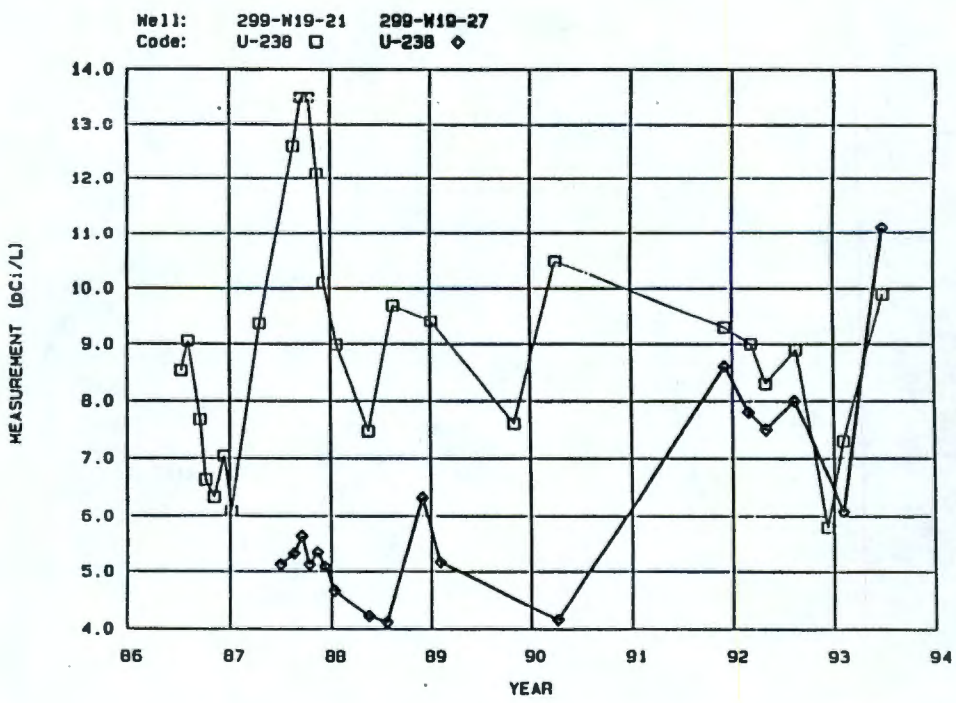


Figure 3-3. Discharge Data and Plots of Changes in Uranium-238 and Gross Alpha Contamination at the Water Table.

9613389.0799

Table 3-1. 216-U-1/2 Cribs Soil Sample Radiological Analysis Results.

Radionuclide	Soil Sample Activity Range (pCi/g)	Location of Maximum Activity
Cesium-137	13.5 to 83.4	Adjacent to 2607-W5 System
Plutonium-239/240	0.021 to 0.907	Adjacent to 2607-W5 System
Strontium-90	3.78 to 10.3	Adjacent to 2607-W5 System
Total Uranium	1.8 to 4.01	East edge of crib

Table 3-2. 216-U-1/2 Cribs Summary of RLS and Sediment Radiochemistry Data.

Contaminant	Depth (ft)	RLS Data[a] (pCi/g)	Sediment Data[b] (pCi/g)
Borehole 299-W19-96 (through crib)			
Cesium-137	0 to 6	7 to 4,000	320
	6 to 15	>5,000	1,132
	15 to 49[c]	>5,000	0-1.7E6[d]
Cobalt-60	0 to 6	UD	UD
	6 to 15	UD	<1
	15 to 43[c]	UD to 1.8	<1-10.6[d]
Europium-152	0 to 6	UD	UD
	6 to 15	UD	UD
	15 to 42.5[c]	UD to 1.9	UD
Europium-154	0 to 6	UD	UD
	6 to 15	UD	UD
	15 to 44[c]	UD to 951	UD[d]-2
Uranium-235	0 to 6	UD	UD
	6 to 15	UD	ND
	15 to 167[c]	UD to 246	<1[e]
Uranium-238	0 to 6	UD	<1
	6 to 15	UD	NA
	15 to 169[c]	UD to >5,000	1,500[e]
Boreholes 299-W19-95 and 299-W19-97			
Cesium-137	0 to 6	<1 to 20	NA
	6 to 7.5[c]	UD to 3.6	NA

[a] The RLS is saturated at 5,000 pCi/g.
[b] Sediment data are from borehole 299-W19-96.
[c] Maximum extent of detectable contamination in survey.
[d] Maximum extent of detectable contamination is 40 ft.
[e] Maximum extent of detectable contamination is 175 ft.
UD = Undetected
NA = Not analyzed
RLS = Radionuclide logging system

Table 3-3. 216-U-4 Reverse Well/4a French Drain Summary of RLS and Sediment Radiochemistry Data.

Contaminant	Depth (ft)	RLS Data[a] (pCi/g)	Sediment Data[b] (pCi/g)
Borehole 200-W-19-98			
Cesium-137	0 to 6	<1 to 185	420
	6 to 15	<1 to 294	5
	15 to 96[c]	UD to 1,460	UD[d] to 1,980
Cobalt-60	0 to 6	UD to <1	<1
	6 to 15	<1 to 1.2	<1
	15 to 96[c]	UD to 2.5	UD[d] to 2
Europium-154	0 to 6	<1	<1
	6 to 15	<1 to 1.1	UD
	15 to 55[c]	UD to 5.0	UD[e] to <1
	6 to 15	UD	UD

[a]The RLS is saturated at 5,000 pCi/g.
[b]Sediment data are from borehole 299-W19-98.
[c]Maximum extent of detectable contamination in survey.
[d]Maximum extent of detectable contamination in sediment samples is 60 ft.
[e]Maximum extent of detectable contamination in sediment samples is 47 ft.
UD = Undetected
RLS = Radionuclide logging system

Table 3-4. 216-U-8 Crib Surface and Near-Surface Soil and Vegetation Sample Radiological Results. (sheet 1 of 2)

Radionuclide	Sample Activity (max pCi/g)	Sample Type	Comments
Americium-241	426 UD UD	near surface soil vegetation surface soil	Sample with highest activity was at the VCP. This sample was more than 2 orders of magnitude higher than all other samples.
Cesium-134	<1 <1 UD	near surface soil vegetation surface soil	Only 2 soil and 1 vegetation sample contained cesium-134.
Cesium-137	9,990 <1 181	near surface soil vegetation surface soil	Highest activity noticed in surface soils. Surface soils not directly above pipeline contained high activity levels with one sample taken 2 ft below the surface with an activity of 525 pCi/g.
Europium-152	<1 <1 UD	near surface soil vegetation surface soil	Only activity was found at depth of VCP.
Europium-154	<1 <1 UD	near surface soil vegetation surface soil	Only activity was found at depth of VCP.
Neptunium-237	1.87 <1 UD	near surface soil vegetation surface soil	Majority of activity at the depth of the VCP.
Plutonium-238	<1 <1 UD	near surface soil vegetation surface soil	Minimal activity levels, majority at the depth of the VCP.
Plutonium-239/240	70.6 <1 1.01	near surface soil vegetation surface soil	Highest activity levels all located at the depth of the VCP.
Radium-226	<1 <1 UD	near surface soil vegetation surface soil	Minimal activity noticed throughout sample region.
Radium-228	1.4 <1 UD	near surface soil vegetation surface soil	Activity noticed throughout sample region.

Table 3-4. 216-U-8 Crib Surface and Near-Surface Soil and Vegetation Sample Radiological Results. (sheet 2 of 2)

Radionuclide	Sample Activity (max pCi/g)	Sample Type	Comments
Strontium-90	108 1,380 19.6	near surface soil vegetation surface soil	Activity generally increasing with depth with highest being at the depth of the pipeline with the exception that vegetation samples all had higher activity levels than the soil.
Thorium-232	1.46 <1 UD	near surface soil vegetation surface soil	Activity noticed throughout sample region.
Thorium-234	421 2.63 UD	near surface soil vegetation surface soil	Activity located at or near VCP.
Uranium-233/234	56 <1 (U-233) UD	near surface soil vegetation surface soil	Activity throughout sample region with higher levels in the region of the VCP. Vegetation was only analyzed for uranium-233.
Uranium-235	4.36 <1 UD	near surface soil vegetation surface soil	Activity throughout sample region with higher levels in the region of the VCP. Vegetation sample was located in the vicinity of the max near surface sample.
Uranium-238	53 <1 UD	near surface soil vegetation surface soil	Activity throughout sample region with higher levels in the region of the VCP.
Total Uranium	144 μg/g <1 μg/g 5.72 μg/g	near surface soil vegetation surface soil	Activity throughout sample region with higher levels in the region of the VCP.

UD = Undetected
VCP = Vitrified clay effluent pipeline

Table 3-5. 216-U-8 Crib Surface and Near-Surface Soil and Vegetation Sample Metal Results.

Metal	Sample Activity (maximum ppm)	Sample Type	Comments
Arsenic	19.1 < Bkg	Near-surface soil Surface soil	Samples above background located at the depth of the vitrified clay effluent pipeline
Chromium	33.1 < Bkg	Near-surface soil Surface soil	Only sample above background located at depth of vitrified clay effluent pipeline

Table 3-6. 216-U-8 Crib Summary of RLS and Sediment Radiochemistry Data.

Contaminant	Depth (ft)	RLS Data[a] (pCi/g)	Sediment Data[b] (pCi/g)
Boreholes 299-W-19-70, 299-W19-71, and 299-W19-94			
Cesium-137	0 to 6	<1 to 10	UD
	6 to 15	<2	NA
	15 to 100[c]	<2 to 5,000	0-91,190[d]
Europium-154	0 to 6	UD	UD
	6 to 15	UD	UD
	15 to 40[c]	~3	UD to 3.1[e]
Uranium-235	0 to 6	UD	UD
	6 to 15	UD	UD
	15 to 189[c]	<3 to 5	UD to 6.7[f]
Uranium-238	0 to 6	UD	0.55
	6 to 15	UD to 10.5	0.43
	15 to 189[c]	UD to 1,000	0.75 to 150[f]
Borehole 299-W19-2			
Cesium-137	0 to 6	<1	NA
	6 to 15	<1	NA
	15 to 115[c]	<1	NA

[a] The RLS is saturated at 5,000 pCi/g.
[b] Sediment data are from borehole 299-W19-94.
[c] Maximum extent of detectable contamination in survey.
[d] Maximum extent of detectable contamination is 90 ft.
[e] Maximum extent of detectable contamination is 38 ft.
[f] Maximum extent of detectable contamination is 187 ft.
UD = Undetected
NA = Not analyzed
RLS = Radiologic logging system

Table 3-7. 216-U-12 Crib Summary of RLS and Sediment Radiochemistry Data.

Contaminant	Depth (ft)	RLS Data[a] (pCi/g)	Sediment Data[b] (pCi/g)
Borehole 299-W22-78			
Cesium-137	0 to 6	UD to <1	UD
	6 to 15	UD	UD
	15 to TD	UD	UD
Uranium-235	0 to 6	UD	UD
	6 to 15	4.5	UD
	15 to 19[c]	2.4	UD to <1[d]
Uranium-238	0 to 6	UD	UD to <1
	6 to 15	UD	NA
	15 to 23[c]	UD-66	<2.2[e]

[a] The RLS is saturated at 5,000 pCi/g.
[b] Sediment data are from borehole 299-W22-78.
[c] Maximum extent of detectable contamination in survey.
[d] Maximum extent of detectable contamination is 38 ft.
[e] Maximum extent of detectable contamination is 187 ft.
UD = Undetected
NA = Not analyzed
TD = Total Depth
RLS = Radiologic logging system

Table 3-8. 216-U-10 Pond Soil Sample Chemical and Radiological Results.

Constituent	Maximum Concentration	Sample Type	Comments
Aroclor-1260	0.22 ppm	Subsurface soil	PCBs only analyzed in test pit samples
Barium	231 ppm	Subsurface soil	6.5-ft pond bottom
Chromium	33.4 ppm	Subsurface soil	6.5-ft pond bottom
Nickel	44 ppm	Subsurface soil	Adjacent to U-14
Americium-241	45 pCi/g	Subsurface soil	6.5-ft pond bottom
Cesium-137	2,740 pCi/g 4,800 pCi/g 3.43 pCi/g 1,230 pCi/g	Subsurface soil Subsurface soil Vegetation Surface soil	U-14 Ditch 6.5-ft pond bottom SW U-Pond U-14 Ditch at 207-U
Cobalt-60	290 pCi/g	Subsurface soil	U-14 Ditch
Plutonium-238	23 pCi/g	Subsurface soil	6.5-ft pond bottom
Plutonium-239/240	74.9 pCi/g	Surface soil	Z-Ditch delta
Radium-226	1.08 pCi/g	Subsurface soil	Generally throughout soil column
Radium-228	1.49 pCi/g	Subsurface soil	Generally throughout soil column
Strontium-90	190 pCi/g 415 pCi/g 32.7 pCi/g	Subsurface soil Vegetation Surface soil	6.5-ft pond bottom SW U-Pond U-14 Ditch at 207-U
Technetium-99	12 pCi/g	Surface soil	U-14 Ditch
Thorium-234	12.5 pCi/g	Subsurface	135 ft at U-Pond
Thorium-232	1.46 pCi/g	Subsurface	6.5-ft pond bottom
Uranium-233/234	85 pCi/g	Subsurface	6.5-ft pond bottom
Uranium-238	178 pCi/g 88 pCi/g 1.76 pCi/g	Subsurface Subsurface Subsurface	U-14 Ditch (4 ft) 6.5-ft pond bottom 135 ft
Total Uranium	31.8 μg/g	Surface soil	U-14 Ditch at 207-U

PCB = polychlorinated biphenyl

Table 3-9. 216-U-10 Pond Summary of RLS and Sediment Radiochemistry Chemistry Data.

Contaminant	Depth (ft)	RLS Data[a] (pCi/g)	Sediment Data[b] (pCi/g)
Cesium-137	0 to 6	<1 to 440	<1 to 1,150
	6 to 15	UD to <1[c]	UD
	15 to 135	UD	<1
Uranium-238	0 to 6	UD	<1
	6 to 15	UD	<1
	15 to 135	UD	1.76

[a] RLS is saturated at 5,000 pCi/g.
[b] Sediment data are from borehole 299-W23-231.
[c] Maximum extent of detectable contamination is 10 ft.
UD = Undetected
RLS = Radiologic logging system

Table 3-10. Sediment Types and Unsaturated Hydraulic Conductivity and Moisture Retention Curve Matches. (sheet 1 of 2)

Facies	Description	Data Source[a]	Curve
Hanford fm, SP/C - SC/B	Sandy, pebble-cobble to cobble-boulder gravel, open framework texture common, mud content generally low (<5%). Deposits are well stratified. Silt and sand interbeds may be common locally but generally difficult to identify on geologic logs. Interbeds tend to be lenticular.	W10-13 (80'), SP/C, CT, U-17 W15-16 (109.9'), SP/C, CT, U-17 W7-9 (10.2'), SP/C-GS, CT, U- 17	Y CC Z
Hanford fm, GS	Interbedded sand and gravel. In sand dominated intervals gravel exists as individual clasts and thin (<1 ft) beds. Will be well stratified.	W7-9 (10.2'), SP/C-GS, CT, U-17 35-69A (84.26-84.76'), GS, S, ERDF	Z A
Hanford fm, S	Sand facies without significant silt component. Ranges from fine- to coarse-grained (CS-FS) sand, generally low angle to planar stratified, with medium-grained (MS) as mean grain size. Mud limited to thin (<0.5 ft) laterally discontinuous interbeds that are very difficult to distinguish in borehole logs.	W18-33 (108-109), MS-FS, CT, U-14 W10-13 (60), S?, CT, U-17 36-63A (245.6-246.1), bedded CS-FS AR, ERDF 35-61A (250-252.2), MS, CT, ERDF W19-95 (30-32.5), MS, CT, UP-2 35-65A (207.8-208.3), FS-MS, CT, ERDF	C AA F D B E
Hanford fm, S w/ Z/C IB's	FS-CS with enough silt and clay to be noticeable during drilling. Essentially sand dominated deposits with common silt interbeds. Transitional between sand facies and Touchet Beds.	W23-17 (84.2-84.7), Z/C FS, CT, U-14 W19-95 (140-142.2), Z/CS, CT, UP-2	I H
Hanford fm, Z/C w/ IB sand	Silt facies, essentially Touchet Beds. Have interbedded silt and sand with silt dominant. Beds will be fairly continuous although pinchouts still common. Carbonate rich paleosols can be found in some.	W18-251 (97-97.5), SZ/C, CT, U-14 W18-33 (130.25-130.75), SZ/C, CT, U-14 W15-2 (101), SZ/C, CT, U-17 W19-95(151-153), SZ/C, CT, UP-2	L K BB J
Hanford fm, Z/C	Occasional silt beds greater than .3 m (1 ft) thick.	No curves specifically for this sediment type. Use either Hanford fm, Z/C w/ IB sand or Ringold upper, silty, depending on sand content	
Plio-Pleistocene, silt (early Palouse)	Most intact samples indicate is laminated to massive silt with minor very fine sand mixed in. Where significant sand content present, or sand interbeds found, should be assigned to Hanford fm.	W19-95 (165-167), silt, CT, UP-2	M
Plio-Pleistocene, sandy carbonate	Variable FS-CS with carbonate as nodules, disseminated cement, and layers. Basalt content variable. Can be muddy. Commonly contains a high amount of reworked upper Ringold material.	32-72B (162.4-163.9), Z/CS carb, AR, ERDF 38-68A (186-187), sandy carb., CT, ERDF	P N
Plio-Pleistocene, gravelly carbonate	Generally a muddy basaltic gravel with carbonate as disseminated cement, nodules, concretions, and layers. Gravels range from granules and pea gravel to mid-size pebbles. Ringold content usually low.	W18-251 (150.5), SP/C carb, CT, U-14 W7-9 (80), Z/C GS carb, CT, U-17 W7-9 (88), Z/C GS carb, CT, U-17	O DD DD

Table 3-10. Sediment Types and Unsaturated Hydraulic Conductivity and Moisture Retention Curve Matches. (sheet 2 of 2)

Facies	Description	Data Source[a]	Curve
Ringold upper, sandy	Dominantly FS-CS w/ minor intercalated silts, some paleosol development. Carbonate content variable, from none (common) to disseminated cement and small nodules. Sand is quartzo-feldspathic.	35-69A (239.5-240), Z/C FS, w/ carb, S, ERDF	S
Ringold upper, silty	Paleosol dominated sandy silt, clay content relatively low, laminated silt present. Sand interbeds may also be present, but of limited lateral extent. Carbonate content generally low.	W7-9 (142), SZ/C IB, CT, U-17 32-72B (202.5-204), Z/C PS, AR, ERDF 32-72B (212.4-213.9), Z/C PS, AR, ERDF	EE R Q
Ringold, sandy gravel	Sandy, pebble-cobble gravel. Displays variable mud content and cementation. Bedding geometry variable, lateral pinchouts common.	W18-33 (170-170.5), SP/C w/ Z/C, CT, U-14 35-69A (255-256), SP/C, S, ERDF 35-69A (241.8-242.3), SP/C, S, ERDF 35-61A (306.7-308), SP/C, CT, ERDF 35-61A (298.2-299.2), SP/C, CT, ERDF 35-65A (247.5-248.50, SP/C, AR, ERDF	T W X U V FF

[a]Lists: Borehole and depth of sample data derived from, type of sediment, sampling technique, and project data was collected for.

Types of Sediments: SP/C - sandy pebble-cobble gravel, GS - interstratified gravel and sand, CS - coarse-grained sand, MS - medium-grained sand, FS - fine-grained sand, Z/CS - silty-clayey sand, SZ/C - sandy silt-clay, Z/C - silt and clay, PS - paleosol, and carb - carbonate rich.

Sampling Technique: CT - cable tool/split spoon, AR - air rotary/split spoon, S - sonic/split spoon. Note: In gravel-dominated and/or cemented strata samples collected any of the split spoon techniques have a high probability of not being intact (Reynolds and Lindsey 1994). Consequently, analysis that require intact samples will not generate completely representative data from samples acquired using split spoon sampling techniques.

Project: U-17 (Reidel et al. 1993), U-14 (Singleton and Lindsey 1994), Weekes and Borghese (1994), Kelty et al. (1995)

ERDF = Environmental Restoration Disposal Facility

Table 3-11. Layers Used in the 216-U-1 and 216-U-2 Crib Model.

Layer	Depth (ft)	Sediment Type	Curve
1	24-34	Hanford formation, interbedded sandy pebble-cobble gravel and medium-coarse grained sand. Silt beds, if present, of limited lateral extent.	C
2a	34-39	Hanford formation, silt-clay with sand interbeds, interbeds probably lenticular, clastic dikes will be present.	R
2b	39-42	Hanford formation, medium- to coarse-grained sand with minor silt and clay interbeds. Interbeds generally of limited lateral extent. Clastic dikes probably common.	I
3	42-52	Hanford formation, sandy pebble-cobble gravel interbedded with medium-coarse grained sand. Silt-clay interbeds uncommon.	C
4	52-58	Hanford formation, medium-grained sand with minor silt interbeds. Interbeds of limited lateral extent and clastic dikes probably common.	I
5	58-100	Hanford formation, interbedded sandy pebble gravel and coarse- to medium-grained sand. Silt interbeds uncommon.	C
6a	100-158	Hanford formation, ranges from sand with thin interbedded silt to silt with thin interbedded sand. Generally, sandy strata and clastic dikes probably more common.	I
6b	158-162	Hanford formation, silt and clay with thin sand interbeds. Limited lateral continuity of individual beds and clastic dikes common.	K
7	162-167	Plio-Pleistocene, silt-dominated, massive to laminated silt with minor sand, clastic dikes may cross-cut.	P
8	167-172	Plio-Pleistocene, carbonate-rich gravelly sand, individual carbonate beds discontinuous and fractured and potentially cross-cut by clastic dikes.	O
9	172-176	Upper Ringold, sand-rich, medium to fine grained sand with minor silt and clay. If silt and clay present occur as lenticular interbeds less than 30 cm thick.	S
10	176-230	Ringold unit E, variably cemented, sandy pebble-cobble gravel. Cemented beds of limited lateral extent.	FF

Table 3-12a. Discharge and Infiltration for the 216-U-1/2 Cribs.

Year	Volume
1951	1.40E+05 liters
1952	2.35E+06 liters
1953	5.00E+06 liters
1954	4.21E+06 liters
1955	6.30E+05 liters
1956	6.00E+03 liters
1958	7.27E+05 liters
1959	1.21E+06 liters
1960	4.43E+05 liters
1966	5.30E+04 liters
1967	1.13E+06 liters
Sum of Volumes	1.59E+07 liters
Yearly Average	1.45E+06 l/yr
Yearly Average	4.58E+01 cm^3/s
Area of Crib Bottom	1.34E+01 m^2
Infiltration (f)	3.42E-04 cm/s

Table 3-12b. Soil Column Data for the 216-U-1/2 Cribs.

Layer #	Begin Depth(ft)	End Depth (ft)	L (cm)	Curve	K_s	θ_s
1	24	34	304.8	C	2.94E-05	0.3654
2a	34	39	152.4	R	1.70E-05	0.395
2b	39	42	91.44	I	6.27E-05	0.3692
3	42	52	304.8	C	2.94E-05	0.3654
4	52	58	182.88	I	6.27E-05	0.3692
5	58	100	1280.16	C	2.94E-05	0.3654
6a	100	158	1767.84	I	6.27E-05	0.3692
6b	158	162	121.92	K	3.82E-06	0.3968
7	162	167	152.4	P	2.00E-05	0.39
8	167	172	152.4	O	2.17E-04	0.0882
9	172	176	121.92	S	1.00E-05	0.28
10	176	230	1645.92	FF	3.00E-04	0.28

Unit Gradient Model Summary Table Key

L is the thickness of a soil unit
θ is the moisture content of a soil unit.
θ_s is the moisture content of a unit when it is saturated
K is the hydraulic conductivity of a soil unit
K_s is the hydraulic conductivity of a soil unit when it is saturated
f is the infiltration rate
q is the hydraulic conductivity of a unit defined by its current saturation condition.

In the **Condition** column, S indicates a unit is saturated and U indicates it is unsaturated

The **Curve** column gives the designation of the curve used to characterize a particular soil unit. The curves are contained in Table 3-10.

Table 3-12c. Unit Gradient Analysis for the 216-U-1/2 Cribs.

Layer	Curve	f (cm/s)	K_s (cm/s)	Condition	q (cm/s)	θ	L (cm)	T(sec)	T(day)	T(years)
1	C	3.42E-04	2.94E-05	S	2.94E-05	0.3654	304.8	3.79E+06	43.85	0.12
2a	R	3.42E-04	1.70E-05	S	1.70E-05	0.395	152.4	3.54E+06	40.98	0.11
2b	I	3.42E-04	6.27E-05	S	6.27E-05	0.3692	91.44	5.38E+05	6.23	0.02
3	C	3.42E-04	2.94E-05	S	2.94E-05	0.3654	304.8	3.79E+06	43.85	0.12
4	I	3.42E-04	6.27E-05	S	6.27E-05	0.3692	182.88	1.08E+06	12.46	0.03
5	C	3.42E-04	2.94E-05	S	2.94E-05	0.3654	1280.16	1.59E+07	184.15	0.50
6a	I	3.42E-04	6.27E-05	S	6.27E-05	0.3692	1767.84	1.04E+07	120.48	0.33
6b	K	3.42E-04	3.82E-06	S	3.82E-06	0.3968	121.92	1.27E+07	146.58	0.40
7	P	3.42E-04	2.00E-05	S	2.00E-05	0.39	152.4	2.97E+06	34.40	0.09
8	O	3.42E-04	2.17E-04	S	2.17E-04	0.0882	152.4	6.19E+04	0.72	0.00
9	S	3.42E-04	1.00E-05	S	1.00E-05	0.28	121.92	3.41E+06	39.51	0.11
10	FF	3.42E-04	3.00E-04	S	3.00E-04	0.28	1645.92	1.54E+06	17.78	0.05
									Travel Time	1.89

Unit Gradient Model Summary Table Key

L is the thickness of a soil unit
θ is the moisture content of a soil unit.
θ_s is the moisture content of a unit when it is saturated
K is the hydraulic conductivity of a soil unit
K_s is the hydraulic conductivity of a soil unit when it is saturated
f is the infiltration rate
q is the hydraulic conductivity of a unit defined by its current saturation condition.

In the **Condition** column, S indicates a unit is saturated and U indicates it is unsaturated

The **Curve** column gives the designation of the curve used to characterize a particular soil unit. The curves are contained in Table 3-10.

Table 3-13. Layers Used in the 216-U-8 Crib Model.

Layer	Depth (ft)	Sediment Type	Curve
1	25 to 75	Hanford formation, medium- to coarse-grained sand with minor silt interbeds. Silt interbeds are of limited lateral extent. Clastic dikes probably common.	F
2	75 to 165	Hanford formation, fine- to medium-grained sand with silt interbeds. Silt interbeds more abundant than in unit 1 but still of limited lateral extent. Clastic dikes probably common.	H
3	165 to 186	Plio-Pleistocene unit, silt-rich, massive to laminated silt cut by clastic dikes.	M
4	186 to 197	Plio-Pleistocene unit, carbonate-rich, silt-rich carbonates. Individual carbonate beds limited in extent, fractures common and clastic dikes may be present.	P
5	197-211	Ringold upper unit, silt and clay paleosol with minor intermixed sand. Sand beds not common although lateral extent of paleosol probably limited.	S
6	211 to 237	Ringold unit E, sandy pebble-cobble gravel with variable cemented ledges of limited lateral extent.	T

Table 3-14a. Discharge and Infiltration for the 216-U-8 Crib.

Year	Volume
1952	2.40E+07 liters
1953	8.50E+07 liters
1954	7.20E+07 liters
1955	7.35E+07 liters
1956	8.20E+07 liters
1957	2.00E+07 liters
1958	9.00E+06 liters
1959	1.00E+07 liters
1960	3.00E+06 liters
Sum of Volumes	3.79E+08 liters
Yearly Average	4.21E+07 l/yr
Yearly Average	1.33E+03 cm^3/s
Area of Crib Bottom	278.71 m^2
Infiltration (f)	4.78E-04 cm/s

Table 3-14b. Soil Column Data for the 216-U-8 Crib.

Layer #	Begin Depth(ft)	End Depth (ft)	L (cm)	Curve	K_s	θ_s
1	25	75	1524	F	9.00E-05	0.33
2	75	165	2743.2	H	1.00E-04	0.28
3	165	186	640.08	M	5.00E-05	0.44
4	186	197	335.28	P	2.00E-05	0.39
5	197	211	426.72	S	1.00E-05	0.28
6	211	237	792.48	T	3.13E-03	0.116

Unit Gradient Model Summary Table Key

L is the thickness of a soil unit
θ is the moisture content of a soil unit.
θ_s is the moisture content of a unit when it is saturated
K is the hydraulic conductivity of a soil unit
K_s is the hydraulic conductivity of a soil unit when it is saturated
f is the infiltration rate
q is the hydraulic conductivity of a unit defined by its current saturation condition.

In the **Condition** column, S indicates a unit is saturated and U indicates it is unsaturated

The **Curve** column gives the designation of the curve used to characterize a particular soil unit. The curves are contained in Table 3-10.

Table 3-14c. Unit Gradient Analysis for the 216-U-8 Crib.

			5.00E-05	S	9.0[illegible]	0.33	1524	5.59E+06	64.68	0.18
		4.78E-04	1.00E-04	S	1.00E[illegible]	0.28	2743.2	7.68E+06	88.90	0.24
3	M	4.78E-04	5.00E-05	S	5.00E-05	0.44	640.08	5.63E+06	65.19	0.18
4	P	4.78E-04	2.00E-05	S	2.00E-05	0.32	335.28	5.36E+06	62.09	0.17
5	S	4.78E-04	1.00E-05	S	1.00E-05	0.28	426.72	1.19E+07	138.29	0.38
6	T	4.78E-04	3.13E-03	U	4.78E-04	0.105	792.48	1.74E+05	2.01	0.01
									Total Travel Time:	1.15

Unit Gradient Model Summary Table Key

L is the thickness of a soil unit
θ is the moisture content of a soil unit.
θ_s is the moisture content of a unit when it is saturated
K is the hydraulic conductivity of a soil unit
K_s is the hydraulic conductivity of a soil unit when it is saturated
f is the infiltration rate
q is the hydraulic conductivity of a unit defined by its current saturation condition.

In the **Condition** column, **S** indicates a unit is saturated and **U** indicates it is unsaturated

The **Curve** column gives the designation of the curve used to characterize a particular soil unit. The curves are contained in Table 3-10.

9613589.0812

Table 3-15. Layers Used in the 216-U-12 Crib Model.

Layer	Depth (ft)	Sediment Type	Curve
1	16 to 20	Hanford formation, medium- to coarse-grained sand with minor gravel and few if any silt interbeds. Deposit well stratified, but beds are of limited lateral extent.	C
2	20 to 38	Hanford formation, fine- to coarse-grained sand with few silt interbeds. Deposit is well stratified, but beds are of limited lateral extent. Clastic dikes present.	F
3	38 to 39	Hanford formation, silt bed, unknown lateral extent. Clastic dikes present.	P
4a	39 to 90	Hanford formation, medium- to coarse-grained sand with silt interbeds. Deposit is well stratified, but interbeds probably are not laterally extensive. Clastic dikes present.	F
4b	90 to 104	Hanford formation, fine-grained sand with silt interbeds. Deposit is well stratified, and silt interbeds may be more extensive than overlying layer. Clastic dikes present.	F
5a and 5b	104 to 148 and 148 to 165 ft	Hanford formation, medium-grained sand with silt interbeds. Deposit is well stratified but interbeds probably of limited lateral extent. Clastic dikes present.	I
6	165 to 176 ft	Plio-Pleistocene unit, silt-rich interval consisting of massive to laminated slightly sandy silt. Clastic dikes present.	Q
7	176 to 182 ft	Plio-Pleistocene unit, carbonate-rich sandy silt, individual carbonate beds are discontinuous and fractured. Clastic dikes probably present.	P
8	182 to 192 ft	Ringold upper unit, silt-clay paleosol with discontinuous sand interbeds.	EE
9	192 to 198	Ringold upper unit, silt and clay paleosol, probably laterally discontinuous.	R
10	198 to 214	Ringold upper unit, similar to unit 8.	EE
11	214 to 234	Ringold upper unit, fine- to medium-grained, well stratified, uncemented sand. Silt content generally very low (<3% wt) and silt interbeds, if present, are very discontinuous.	S
12	234 to 236	Ringold unit E, variably cemented, sandy pebble-cobble gravel. Individual cemented horizons generally are discontinuous.	FF

Table 3-16a. Discharge and Infiltration for the 216-U-12 Crib.

Year	Volume
1960	9.00E+06 liters
1961	1.44E+07 liters
1962	1.41E+07 liters
1963	1.42E+07 liters
1964	1.74E+07 liters
1965	1.40E+07 liters
1966	1.07E+07 liters
1967	1.00E+07 liters
1968	8.90E+06 liters
1969	7.20E+06 liters
1970	3.10E+06 liters
1971	6.00E+06 liters
1972	3.81E+06 liters
1981	1.63E+04 liters
1982	1.89E+05 liters
1983	1.28E+06 liters
1984	5.48E+06 liters
1985	4.68E+06 liters
1986	3.92E+06 liters
1987	6.40E+05 liters
1988	1.07E+05 liters
Sum of Volumes	1.49E+08 liters
Yearly Average	7.10E+06 l/yr
Yearly Average	2.25E+02 cm^3/s
Area of Crib Bottom	107.64 m^2
Infiltration (f)	2.09E-04 cm/s

Table 3-16b. Soil Column Data for the 216-U-12 Crib.

Layer #	Begin Depth (ft)	End Depth (ft)	L (cm)	Curve	K_s	θ_s
1	16	20	121.92	C	2.94E-05	0.3654
2	20	38	548.64	F	9.00E-05	0.33
3	38	39	30.48	P	2.00E-05	0.39
4a	39	90	1554.48	F	9.00E-05	0.33
4b	90	104	426.72	F	9.00E-05	0.33
5a	104	148	1341.12	I	6.27E-05	0.3692
5b	148	165	518.16	I	6.27E-05	0.3692
6	165	176	335.28	Q	2.00E-04	0.41
7	176	182	182.88	P	2.00E-05	0.39
8	182	192	304.8	EE	3.40E-05	0.418
9	192	198	182.88	R	1.70E-05	0.395
10	198	214	487.68	EE	3.40E-05	0.418
11	214	234	609.6	S	1.00E-05	0.28
12	234	236	60.96	FF	3.00E-04	0.28

Unit Gradient Model Summary Table Key

L is the thickness of a soil unit
θ is the moisture content of a soil unit.
θ_s is the moisture content of a unit when it is saturated
K is the hydraulic conductivity of a soil unit
K_s is the hydraulic conductivity of a soil unit when it is saturated
f is the infiltration rate
q is the hydraulic conductivity of a unit defined by its current saturation condition.

In the **Condition** column, S indicates a unit is saturated and U indicates it is unsaturated

The **Curve** column gives the designation of the curve used to characterize a particular soil unit. The curves are contained in Table 3-10.

Table 3-16c. Unit Gradient Analysis for the 216-U-12 Crib.

		f (cm/s)	K_s (cm/s)	Condition	q (cm/s)	θ	L (cm)	T(sec)	T(day)	T (Years)
1	C	2.09E-04	2.94E-05	S	2.94E-05	0.3654	121.92	1.52E+06	17.54	0.05
2	F	2.09E-04	9.00E-05	S	9.00E-05	0.33	548.64	2.01E+06	23.28	0.06
3	P	2.09E-04	2.00E-05	S	2.00E-05	0.39	30.48	5.94E+05	6.88	0.02
4a	F	2.09E-04	9.00E-05	S	9.00E-05	0.33	1554.48	5.70E+06	65.97	0.18
4b	F	2.09E-04	9.00E-05	S	9.00E-05	0.33	426.72	1.56E+06	18.11	0.05
5a	I	2.09E-04	6.27E-05	S	6.27E-05	0.3692	1341.12	7.90E+06	91.40	0.25
5b	I	2.09E-04	6.27E-05	S	6.27E-05	0.3692	518.16	3.05E+06	35.31	0.10
6	Q	2.09E-04	2.00E-04	S	2.00E-04	0.41	335.28	6.87E+05	7.96	0.02
7	P	2.09E-04	2.00E-05	S	2.00E-05	0.39	182.88	3.57E+06	41.28	0.11
8	EE	2.09E-04	3.40E-05	S	3.40E-05	0.418	304.8	3.75E+06	43.37	0.12
9	R	2.09E-04	1.70E-05	S	1.70E-05	0.395	182.88	4.25E+06	49.18	0.13
10	EE	2.09E-04	3.40E-05	S	3.40E-05	0.418	487.68	6.00E+06	69.39	0.19
11	S	2.09E-04	1.00E-05	S	1.00E-05	0.28	609.6	1.71E+07	197.56	0.54
12	FF	2.09E-04	3.00E-04	U	2.09E-04	0.275	60.96	8.02E+04	0.93	0.00
									Travel Time	1.83

Unit Gradient Model Summary Table Key

L is the thickness of a soil unit
θ is the moisture content of a soil unit.
θ_s is the moisture content of a unit when it is saturated
K is the hydraulic conductivity of a soil unit
K_s is the hydraulic conductivity of a soil unit when it is saturated
f is the infiltration rate
q is the hydraulic conductivity of a unit defined by its current saturation condition.

In the **Condition** column, **S** indicates a unit is saturated and **U** indicates it is unsaturated

The **Curve** column gives the designation of the curve used to characterize a particular soil unit. The curves are contained in Table 3-10.

9613389.0815

4.0 QUALITATIVE RISK ASSESSMENT SUMMARY AND CONCLUSIONS

4.1 QUALITATIVE RISK EVALUATION OVERVIEW

The chapter discusses the process used for and the results obtained from the qualitative evaluation of human health and ecological risk. Discussions include the data evaluation, exposure assessment, toxicity assessment, risk characterization, and uncertainty analysis for the 216-U-1/2 Cribs, 216-U-4 Reverse Well/4a French Drain, 216-U-8 Crib, and 216-U-10 Pond systems at the 200-UP-2 Operable Unit. The QRA results will aid in determining the candidacy of a waste site for an IRM; the numerical risk and hazard estimates in the 200-UP-2 Operable Unit QRA can be used in comparisons with QRAs for other operable units evaluated using the same methodology (DOE-RL 1994a).

4.2 HUMAN HEALTH EVALUATION

4.2.1 Human Health Risk Evaluation Process

The purpose of the qualitative human health evaluation is to estimate the potential risks to a hypothetical, unprotected worker under an industrial exposure to contaminants in 200-UP-2 Operable Unit soils. The following sections include the identification of COPC, exposure assessment, toxicity assessment, risk characterization, and uncertainty associated with each of these assessments. Exposures and associated risks presented in the QRA are not actual risks but are estimates of potential risks under an industrial use scenario.

4.2.1.1 Identification of COPC. Data generated from LFI sampling activities were validated following EPA functional guidelines and specific EPA methods and were used in the process for identification of COPC at the 200-UP-2 Source Operable Unit. The LFI data have been reconsidered to include some estimated data (J qualifier) values in the QRA. The maximum concentration of each detected analyte from the LFI data set was selected for evaluation.

The analytes were considered for the human health QRA only if they were detected in the upper 4.6 m (15 ft) of soil. This depth was used because it provides a reasonable estimate of the depth of soil that could be excavated and distributed at the ground surface as a result of site development activities (e.g., laying a pipeline). Analytes below 4.6 m (15 ft) were evaluated in Section 3.6 based on their potential to impact groundwater.

The evaluation process discussed in Sections 2.2 and 3.1 of HSRAM (DOE-RL 1994a) is used to identify inorganic, radionuclide, and organic COPC for each waste site. If the maximum concentration of an inorganic analyte exceeds the 95% upper threshold limit (UTL) of the Hanford Site background distribution (DOE-RL 1994b), it is retained in the risk assessment. For the purpose of this report, several radionuclide analytes are screened using soil background concentrations published in the annual Hanford Site Environmental Report (Jaquish and Mitchell 1987; Jaquish and Bryce 1988, 1989; Woodruff et al. 1990, 1991, 1992). Measured 200-UP-2 radionuclide analytes not listed in the referenced reports are not screened against any background concentration. If the maximum concentration of an inorganic or radionuclide analyte also exceeds the preliminary risk-based screening concentration, it is retained for the human health evaluation. The risk-based screening concentrations correspond to a lifetime incremental cancer risk (ICR) of 1E-07 or to a hazard quotient (HQ) of 0.1, assuming exposure in a frequent-use scenario (DOE-RL 1994a).

Organic analytes are compared only to risk-based screening concentrations and not to background concentrations since the majority of organic chemicals found at Superfund sites are not naturally occurring. The risk-based screening is used only in the human health evaluation.

The COPC identification process is presented in screening tables for individual systems in Appendix B included as digital files on the attached diskette. They include the system designation, depth interval, and maximum detected concentrations of COPC for waste sites evaluated in the 200-UP-2 Operable Unit QRA.

4.2.1.2 Exposure Assessment. The exposure assessment methodology is presented in Section 3.2 and Appendix A of HSRAM (DOE-RL 1994a). The exposure assessment is conducted according to a conceptual site model (Figure 4-2) that includes the determination of exposure scenario, exposure pathways, and exposure parameters to human receptors.

Exposure to a hypothetical, unprotected worker receptor is assessed using industrial exposure parameters as defined in Appendix A of HSRAM (DOE-RL 1994a) and the maximum soil concentration within a depth of 4.6 m (15 ft) as the exposure point concentration.

Under current site conditions, exposure to identified contaminants is minimized by institutional controls that prevent access to waste sites or require use of protective devices in situations where exposure could occur.

The pathways evaluated for the industrial scenario in the 200-UP-2 Operable Unit QRA are:

- Soil ingestion
- Fugitive dust inhalation
- External radiation exposure from soil.

The radiation shielding provided by clean-fill soils covering 200-UP-2 Operable Unit waste sites can reduce external radiation exposure of human receptors. Analyses using the residual radioactive material guidelines and software model (RESRAD) computer program (Argonne 1992) have determined that radiation emitted by radionuclides located deeper than 2 m (6 ft) would be effectively shielded by the overlying soils (WHC 1993b). Therefore, the industrial-use scenario is also qualitatively evaluated using radionuclide exposure point concentrations derived from the maximum concentration detected in the upper 2 m (6 ft) of soil.

Air concentration data specific to individual waste sites were monitored during the investigation and determined to be at background levels or below. Therefore, to be conservative, the COPC airborne concentrations are estimated from their respective maximum soil concentrations. Fugitive dust concentrations are estimated using a particulate emission factor (PEF) of 2E+07 m^3/kg. This PEF conservatively assumes that the fugitive dust concentrations at each waste site are constantly equivalent to the National Primary Ambient Air Quality Standard for particulate matter of 50 $\mu g/m^3$ (EPA 1993).

Standard equations (EPA 1989, DOE-RL 1994a) are used as the basis for all intake calculations. Exposures of human receptors to chemical COPC are expressed as dose rate (e.g., mg of contaminant per kg of receptor bodyweight per day). Exposures to radionuclide COPC are expressed as total intake in pCi. Radionuclide concentrations were considered to remain at constant levels with no consideration for diminishing of concentrations through natural decay processes.

4.2.1.3 Toxicity Assessment. The general procedures for toxicity assessment are presented in HSRAM (DOE-RL 1994a). The toxicity assessment for the QRA identifies contaminant-specific systemic toxicity factors for nonradionuclide and carcinogenic toxicity factors for radionuclide and nonradionuclide analytes for the COPC at 200-UP-2 Operable Unit. The noncarcinogenic systemic toxicity factors are presented in Table 4-1.

The EPA classifies all radionuclides as Group A (known human) carcinogens. Radionuclide slope factors are calculated by EPA's Office of Radiation and Indoor Air to assist with risk-related evaluations and decision-making at various stages of the remedial process. Ingestion and inhalation slope factors are best estimates (i.e., median or 50th percentile values) of the age-averaged, lifetime excess cancer incidence (fatal and nonfatal cancer) risk per unit of activity inhaled or ingested, expressed as risk/pCi. External exposure slope factors are best estimates of the lifetime excess cancer incidence risk for each year of exposure to external radiation from photon-emitting radionuclides distributed uniformly in a thick layer of soil and are expressed as risk/yr per pCi/g soil (EPA 1993). Table 4-2 presents the carcinogenic toxicity factors for COPC at 200-UP-2 Operable Unit. The nonradionuclide carcinogenic toxicity factors are presented in Table 4-3.

4.2.1.4 Risk Characterization. The risk characterization for the QRA is conducted as presented in HSRAM (DOE-RL 1994a). The risk characterization methodology provides estimates of HQ for exposures to systemic toxicant COPC and lifetime ICR for exposures to carcinogenic COPC.

The total lifetime ICR and hazard index (HI) to human receptors at each site are determined by summing the individual COPC ICR and HQ contributions from all evaluated pathways. Because the risk characterization equation for carcinogens used in this QRA is only valid up to estimated risks of approximately 1E-02 (EPA 1989), lifetime ICR estimates that exceeded 1E-02 were reported as "> 1E-02."

The total lifetime ICR for each waste site is qualitatively discussed with respect to the following levels based on agreements by the signatories to the Tri-Party Agreement on May 26, 1993:

- "High" (ICR > 1E-02)
- "Medium" (1E-02 < ICR < 1E-04)
- "Low" (1E-04 < ICR < 1E-06)
- "Very Low" (ICR < 1E-06).

The major COPC and exposure pathways contributing to total risk are discussed individually for sites with total lifetime ICR exceeding 1E-06 and/or HI exceeding 1.0.

4.2.1.5 Uncertainty Associated With Human Health Risk Evaluation. The human health risks calculated in this QRA are estimates that reflect several assumptions and related uncertainties. Uncertainties inherent in these estimated risks reflect a combination of uncertainties in the data, exposure and toxicity assessments, and risk characterization calculations. The uncertainties associated with the human health risk evaluation at the 200-UP-2 Operable Unit are summarized in Tables 4-4a and 4-4b.

4.2.1.6 Uncertainty Associated with Data Evaluation. In order to assess the uncertainty regarding data, categories of high, medium or low quality are assigned to LFI and historical data. Uncertainty associated with the LFI data contributes to the overall uncertainties of human health risk estimates in this QRA. The uncertainty in the identification and quantification of contaminant concentrations in soil used in the exposure assessment is defined as follows.

- "Low": analytical data were obtained from media similar to the exposure pathway medium.
- "Moderate": analytical data were not obtained from media similar to the exposure pathway medium.
- "High": site-specific analytical data were not available. Waste sites characterized by comparison with analogous waste sites are considered to have "high" contaminant identification and contaminant concentration uncertainties.

Contaminant identification uncertainty is considered "low" for individual waste sites evaluated using LFI data. The COPC identified have established release histories at the 200-UP-2 Operable Unit. The uncertainty associated with the contaminant concentrations reported is also considered "low" because the systematic and/or random errors attributed to the analytical methods used are expected to be minimal relative to exposure assumptions of HSRAM (DOE-RL 1994a).

Although the use of LFI data would result in low contaminant identification uncertainty, the uncertainty associated with evaluation of each separate exposure pathway must also be considered. This evaluation may introduce a moderate or high uncertainty in contaminant identification.

The LFI data used in the ingestion pathway evaluations were obtained from media similar to the exposure pathway medium and are considered to have "low" uncertainty for the contaminants reported.

Uncertainty in data used to evaluate external radiation exposures was considered "moderate" because the evaluation used toxicity slope factors that extrapolate external radiation risks from radionuclide concentrations in soil. Because exposure via the external radiation pathway is shown to be a major contributor to risk at many waste sites, this "moderate" data uncertainty is expected to significantly impact this QRA.

Uncertainty in data used to evaluate the inhalation pathway exposures was also considered "moderate." The evaluation required extrapolation of airborne dust concentrations from soil analyte concentrations rather than direct measurement of analyte concentrations in airborne dust samples.

The contaminants and concentrations identified in the LFI data are not necessarily representative of all the soil within 4.6 m (15 ft) of the surface. The maximum COPC concentration used might be an under or over estimate of the actual concentration. Because of the limitations of the sampling methodology, the possibility also exists that contaminants may be present other than those identified. Further sampling or refinements in existing data cannot reduce uncertainties associated with the exposure assessment unless the effort changes the maximum concentration.

4.2.1.7 Exposure Assessment Uncertainties. The impact of the exposure assessment uncertainties can be grouped into the following qualitative categories (EPA 1989):

- "Low": uncertainty might affect estimates by less than one order of magnitude
- "Moderate": uncertainty might affect estimates by one to two orders of magnitude
- "High": uncertainty might affect estimates by more than two orders of magnitude.

The major contributions to exposure assessment uncertainties result from assumptions concerning exposure parameters, exposure pathways, and soil concentrations. Industrial use is considered to be the most likely future land use for the 200-UP-2 Operable Unit.

Contaminants of potential concern in subsurface soil were assumed to be accessible to the hypothetical receptor by all exposure pathways. Inhalation and ingestion exposures are generally limited to COPC concentrations located near the surface. This assumption results in over estimations of receptor exposures at sites known to be covered with clean fill.

The use of maximum soil concentrations of all COPC from the surface to a depth of 4.6 m (15 ft) introduces "high" uncertainty, with bias towards over estimation, into the exposure assessment. Further sampling or refinements in existing data cannot reduce uncertainties associated with the exposure assessment unless the effort changes the maximum concentration.

Spatial distributions of surface and subterranean COPC concentrations are not considered. Because the maximum observed concentration is assumed everywhere in the surface and subsurface soil, the potential human exposure is over estimated.

An assumption of "infinite source" geometry is used to evaluate individual external radiation exposures. This assumption is inherent in the EPA toxicity parameters used in this QRA (EPA 1993). Exposures calculated using this assumed geometry estimate that a hypothetical receptor would be exposed to radiation from an infinitely wide and deep soil column uniformly distributed with the maximum concentrations of all radionuclide COPC. Because this assumption ignores differences in radiation intensity provided from any other distribution of COPC in soil, "high" uncertainty, with bias towards over estimation, is introduced. At certain sites this uncertainty causes exposures to be over estimated, and the associated "high" risks to be dominated by the external exposure pathway.

4.2.1.8 Toxicity Assessment Uncertainties. The effects of toxicity assessment uncertainties may reflect either under or over estimations of site risks. Uncertainties associated with the various toxicity parameters result from:

- Using data from animal exposures to predict health effects in humans
- Using dose-response information from a homogeneous animal or human population to predict potential health effects that may occur in the more heterogeneous general population
- Using information on dose-response effects from high-dose exposures to predict effects at low doses
- Using short-term exposure data to estimate effects from chronic exposures or vice versa.

The EPA addresses these uncertainties by assigning degrees of confidence to the published toxicology studies for the compounds in question. An assignment of "low" confidence indicates that a change in the toxicity parameter is expected when additional chronic data become available (EPA 1989). An assignment of "low" confidence implies "high" uncertainty in the toxicity assessment for this QRA. Similarly, a "medium" confidence implies "medium" uncertainty; and "high" confidence implies "low" uncertainty.

Tables 4-4a and 4-4b include the toxicologic uncertainties associated with the COPC in this QRA. However, the methodology followed by the LFI, which focuses on areas expected to contain the maximum values, provides bias toward over estimation.

4.2.1.9 Uncertainty Evaluation Summary. The risk characterization process combines the results of the exposure assessment with the toxicity assessment into a measure of risks to human health at the evaluated waste site. Use of conservative assumptions usually results in over estimation of human health risk and increased uncertainty. This approach serves a useful purpose in this QRA by providing strict criteria for identifying the contaminants and exposure pathways of concern at the 200-UP-2 Operable Unit. Although these conservative assumptions serve to simplify the risk characterization process, the resulting numerical values do not represent the most realistic estimates of risks and hazards to human health.

4.2.2 Results of the Human Health Evaluation

4.2.2.1 216-U-1/2 Cribs System Human Health Risk Characterization. Surface sampling and borehole samples provide maximum soil analyte concentrations for the 216-U-1/2 Cribs system, which are summarized along with the sampling depth ranges in the screening tables for this system in Appendix B. Incremental cancer risk estimated for the industrial scenario at the 216-U-1/2 Cribs system is summarized in Table 4-5.

The human health risk characterization is based on LFI sampling data using maximum soil concentrations detected from a depth 0 to 4.6 m (0 to 15 ft). These data were obtained from surface and core sampling data.

The total HI for systemic toxicants does not exceed 1.0 for the industrial scenario at the 216-U-1/2 Cribs system. Several COPC represent estimated ICR > 1E-06 in the industrial scenario.

The following contaminants have soil concentrations that represent ICR > 1E-06 from the ingestion exposure pathway: cesium-137 and strontium-90

The following contaminant has soil concentrations that represent ICR > 1E-06 from the inhalation exposure pathway: strontium-90.

The following contaminants have soil concentrations that represent ICR > 1E-06 from the external exposure pathway: cesium-137, cobalt-60, radium-228, and thorium-228. For the 216-U-1/2 Cribs system the total estimated lifetime ICR to humans is "medium" (5E-03) for radionuclide exposure in the industrial scenario. The external radiation exposure is the primary pathway contributing to radionuclide ICR. Cesium-137 is the greatest contributor to human health risk. No ICR to humans from exposure to inorganics or organics is expected as all of these analytes were eliminated in the screening process.

4.2.2.2 216-U-4 Reverse Well/4a French Drain System Human Health Risk Characterization. Borehole samples provide maximum soil analyte concentrations for the 216-U-4 Reverse Well/4a French Drain system, which are summarized along with the sampling depth ranges in Apppendix B. Incremental cancer risk estimated for the industrial scenario at this area is summarized in Table 4-6.

The human health risk characterization is based on LFI sampling data using maximum soil concentrations detected from a depth 0 to 4.6 m (0 to 15 ft). These data were obtained from surface and core pit sampling data.

The total HI for systemic toxicants does not exceed 1.0 for the industrial scenario at the 216-U-4 Reverse Well/4a French Drain system. Several radionuclide COPC represent estimated ICR > 1E-06 in the industrial scenario.

The following contaminants have soil concentrations that represent ICR > 1E-06 from the ingestion exposure pathway: americium-241 and cesium-137.

The following contaminant has soil concentrations that represent ICR > 1E-06 from the inhalation exposure pathway: americium-241.

The following contaminants have soil concentrations that represent ICR > 1E-06 from the external exposure: americium-241, cobalt-60, cesium-137, europium-152, europium-154, radium-228, and thorium-228.

For the 216-U-4 Reverse Well/4a French Drain system the total estimated lifetime ICR to humans is medium (2E-03) for radionuclide exposure in the industrial scenario. The external radiation exposure is the primary pathway contributing to radionuclide ICR. Cesium-137 is the greatest contributor to human health risk. No ICR to humans from exposure to inorganics or organics is expected as all of these analytes were eliminated in the screening process.

4.2.2.3 216-U-8 Crib System Human Health Risk Characterization. Surface sampling and borehole samples provide maximum soil analyte concentrations for the 216-U-8 Crib system, which are summarized along with the sampling depth ranges in Appendix B - the screening tables for this system. Incremental cancer risk estimated for the industrial scenario at the 216-U-8 Crib system is summarized for inorganics in Table 4-7 and for radionuclides in Table 4-8.

The human health risk characterization is based on LFI sampling data using maximum soil concentrations detected from a depth 0 to 4.6 m (0 to 15 ft). These data were obtained from surface and core sampling data.

The total HI for systemic toxicants does not exceed 1.0 for the industrial scenario at the 216-U-8 Crib system. Several COPC represent estimated ICR > 1E-06 in the industrial scenario.

The following contaminants have soil concentrations that represent ICR > 1E-06 from the ingestion exposure pathway: arsenic, americium-241, cesium-137, and plutonium-239.

The following contaminants have soil concentrations that represent ICR > 1E-06 from the inhalation exposure pathway: chromium, americium-241, cesium-137, plutonium-239, uranium-234, and uranium-238.

The following contaminants have soil concentrations that represent ICR > 1E-06 from the external exposure pathway: americium-241, radium-226, cesium-137, radium-228, europium-152, thorium-228, europium-154, uranium-235, neptunium-237, and uranium-238.

For the 216-U-8 Crib area the total estimated lifetime ICR to humans is high (> 1E-02) for radionuclide exposure in the industrial scenario. The external radiation exposure is the primary pathway contributing to radionuclide ICR. Cesium-137 is the greatest contributor to human health risk. The total estimated life time ICR to humans for exposure to inorganics is low (8E-06). The soil ingestion pathway is the primary pathway and arsenic the greatest contributor to ICR. No ICR to

humans from exposure to organic analytes is expected as all of these analytes were eliminated in the screening process.

4.2.2.4 216-U-10 Pond System Human Health Risk Characterization. Surface sampling, borehole samples, and test pit samples provide maximum soil analyte concentrations for the 216-U-10 Pond system (which includes the associated ditches, trenches, etc.) and are summarized along with the sampling depth ranges in Appendix B, which includes the screening tables for this system. Incremental cancer risk estimated for the industrial scenario at the 216-U-10 Pond system are summarized in Table 4-9 for organics, Table 4-10 for inorganics, and Table 4-11 for radionuclides.

The human health risk characterization is based on LFI sampling data using maximum soil concentrations detected from a depth 0 to 4.6 m (0 to 15 ft). These data were obtained from surface, core, and test pit sampling data.

The total HI for systemic toxicants does not exceed 1.0 for the industrial scenario at the U-Pond system. Several COPC represent estimated ICR > 1E-06 in the industrial scenario.

The following contaminants have soil concentrations that represent ICR > 1E-06 from the ingestion exposure pathway: americium-241, cesium-137, plutonium-239, and Aroclor-1260.
The following contaminants have soil concentrations that represent ICR > 1E-06 from the inhalation exposure pathway: americium-241, plutonium-238, plutonium 239, uranium-234, uranium-238, and chromium.

The following contaminants have soil concentrations that represent ICR > 1E-06 from the external exposure pathway: cesium-137, radium-226, cobalt-60, radium-228, europium-152, europium-154, thorium-228, and uranium-238.

For the U-Pond system the total estimated lifetime ICR to humans is high (> 1E-02) for radionuclide exposure in the industrial scenario. The external radiation exposure is the primary pathway contributing to radionuclide ICR. Cobalt-60, cesium-137, and europium-154 are the greatest contributors to human health risk. The total ICR to humans from exposure to organics is medium (1E-04). Aroclor-1260 is the greatest contributor to human health risk, and the primary pathway is soil ingestion. The total ICR to humans from exposure to inorganics is low (1E-05). Chromium is the greatest contributor to risk, and the primary pathway is fugitive dust inhalation. The maximum concentrations of COPC contributing to risk from radionuclide exposure risk are found in the 216-U-10 Pond.

4.2.2.5 Summary of Results of Human Health Evaluation. The results of the human health QRA are summarized in Table 4-12. The total estimated lifetime ICR to humans from external radiation exposure is "high" at the 216-U-10 Pond system and the 216-U-8 Crib system in the industrial exposure scenario. At the 216-U-1/2 Cribs system and the 216-U-4 Reverse Well/4a French Drain system, the total estimated lifetime ICR to humans from external radiation exposure is "medium" in the industrial scenario. Cobalt-60, cesium-137, and europium-154 are the greatest contributors to human health risk. The total ICR to humans from exposure to organics is "medium" at the 216-U-10 Pond system. Aroclor-1260 is the greatest organic contributor to human health risk, and the primary pathway is soil ingestion.

4.2.2.6 Human Health Risk Characterization Uncertainty Analysis. General uncertainties attributed to the methodology used in this QRA are discussed in Section 4.2.1.5. Uncertainties

inherent in the quality of the data used in the human health risk characterization were discussed in Section 4.2.1.6.

Uncertainty in data used to evaluate external radiation exposures was considered moderate because the evaluation used toxicity slope factors that extrapolate external radiation risks from radionuclide concentrations in soil. Direct measurements of external radiation intensity were not available for this QRA. Exposure assessment uncertainty is high because of the general assumptions used to evaluate radionuclides as discussed in Section 4.2.1.7. General toxicity assessment uncertainties are discussed in Section 4.2.1.8 and is considered moderate to high for this site. Tables 4a and 4b summarize data and exposure uncertainty.

Uncertainty in the data used to evaluate organic and inorganic carcinogens was considered "low to moderate" because LFI data obtained from media similar to the exposure pathway medium were used. Moderate uncertainty is introduced from using the maximum COPC concentrations. Exposure assessment uncertainty is "moderate to high" because future land use has not yet been decided. High uncertainty is introduced because the maximum soil concentrations of all COPC from the surface to a depth of 4.6 m (15 ft) are used. Spatial distributions of surface and subterranean COPC concentrations are not considered. Because the maximum observed concentration is assumed everywhere in the surface and subsurface soil, the potential human exposure is over estimated.

4.3 ECOLOGICAL EVALUATION

4.3.1 Ecological Risk Evaluation Process

The purpose of the qualitative ecological evaluation is to estimate the potential ecological risks to a selected ecological receptor following exposure to contaminants within 200-UP-2 Operable Unit soils.

The qualitative ecological evaluation approach relies primarily on professional judgement and experience regarding waste site stressors, appropriate ecological receptors, and primary exposure pathways and uses existing or limited field data. The ecological evaluation is not an absolute measure of risk and does not warrant use of detailed conceptual models and pathway analyses. The operating assumption is that contaminants are present at the site and the evaluation estimates qualitative risk from these contaminants to an ecological receptor.

The objective of the ecological QRA is to assess potential risks to ecological receptors at the 200-UP-2 sites by (1) estimating potential risks to the Great Basin pocket mouse from exposure to contaminants within the 200-UP-2 waste sites through the use of exposure models and (2) evaluating biological monitoring data collected from the 200-UP-2 area. Potential risks were only evaluated for those sites with existing environmental data that were found to be in usable form (DOE-RL 1994a).

4.3.1.1 Problem Formulation. Issues relevant to qualitatively evaluating the ecological risks associated with the waste sites within the 200-UP-2 Operable Unit are the stressor characteristics (chemical and radiation), the ecosystems likely to be affected by these stressors, and the possible effects on the pocket mouse from exposure to chemical and physical stressors.

4.3.1.1.1 The Conceptual Model. Based on the descriptions of ecological resources present at or near the 200-UP-2 Operable Unit waste sites, and assuming a contaminant source limited to the soil, a conceptual ecological model is derived for the key ecological receptors as shown in Figure 4-2.

In general, uptake of contaminants from soil by vegetation serves as the primary source of contaminant entry into the food chain. Only major routes of exposure to contaminants are considered for the QRA. For contributions to dose rate, radionuclides are screened for those which may add significant external/internal ionizing radiation. Contributions to dose by inhalation and ingestion via preening or grooming contaminated fur are not documented and are assumed to be minimal for the QRA.

The approach taken in the QRA is to evaluate risk for the small herbivore component (Great Basin pocket mouse) based on a two-step accumulation model (e.g., soil-to-plant and plant-to-mouse). Equations relating to dose rate calculations for primary (plants) and secondary organisms (pocket mouse) are reported in HSRAM (DOE-RL 1994a). The accumulation model is utilized on a site-by-site basis. Because the home range of the mouse approximates the size of each of the waste sites (DOE-RL 1994a), the mouse is assumed to be exclusively exposed to contaminants within the specific waste site during all of its lifetime. This facilitates a comparison of risks between waste sites.

Animals occupying higher levels within a foodweb will be exposed to varying degrees of contamination because of larger home range sizes and because prey may be gathered from a combination of contaminated and uncontaminated locations. Greater exposure correlates with greater risk. In all cases, except for chemicals that may be biomagnified through the food chain (i.e., PCBs, methyl mercury, and chlorinated pesticides), the pocket mouse is expected to be representative of a high-risk species with regard to potential exposure to chemical and radiation stressors.

4.3.1.1.2 Stressor Characteristics. The stressors, contaminants of potential ecological concern (COPEC), are identified as those contaminants detected above background at depth intervals of 0 to 2 m (0 to 6 ft) and 2 to 4.6 m (6 to 15 ft).

The selection of COPEC differs from that used in the selection of COPC for human health. The difference is in the use of a human health risk-based screening criteria in the selection of chemicals of human health concern. For the ecological risk evaluation, all organic compounds that pass the laboratory/field blank screening criteria are considered COPEC. Inorganic analytes detected at concentrations (specifically the maximum value) in excess of the range of site-specific background concentrations were also considered as COPEC. Iron, sodium, potassium, and calcium are nutrients that are toxic only at very high concentrations. These elements were not evaluated as COPEC. Radionuclides that were found to exceed site-specific background concentrations and those for which no background data were available for comparison were considered to be COPEC. Because the selection of COPEC for ecological evaluation does not include comparison to risk-based screening values, analytes may be retained in the ecological risk evaluation that have not been included in the human health evaluation. All analytes exceeding background are included in Appendix B.

Nonradioactive chemicals can induce both localized and systemic effects. In addition, many chemicals have mutagenic and/or carcinogenic properties. Because ecological receptors generally do not live long enough to succumb to most cancers, only noncarcinogenic effects will be evaluated in the assessment of potential risks to biota within the 200-UP-2 area. Exposure to chemical agents are evaluated through food chain modeling and the use of biological monitoring data. Potential impacts on individual organisms are used as an indicator of stress at higher levels of ecological organization.

Radionuclides can induce ecological effects as a result of their presence in the abiotic environment (external dose rate) and by their incorporation into the body (e.g., internal dose rate from consumption of contaminated food). The total daily radiation dose rate to an organism can be

estimated as the sum of doses received from all radioactive elements ingested, residing in the body, and available in the organism's environment. The radiological dose rate an organism receives is usually expressed as rad/day. Because exposure to radiation can result from both external environmental radiation and internal radiation (DOE-RL 1994a), the radiation dose from each of these pathways will be summed to determine the total dose to the organism. Measured concentrations of radionuclides in 200-UP-2 collected biota will also be used to gauge ecological impacts in the 200-UP-2 Operable Unit.

4.3.1.1.3 Receptor Selection. Typically, in a QRA several trophic levels and several ecological receptors within the foodweb are selected for evaluation in order to encompass receptors of varying sensitivity, to assess different endpoints, and to assess contaminant transport through different pathways. For the qualitative ecological evaluation, the Great Basin pocket mouse is used as the receptor in the models for limited exposure scenarios and simple endpoints. Other biota are considered only as biological monitoring data are available.

4.3.1.1.3 Endpoint Selection. Endpoints are classified as either assessment endpoints or measurement endpoints. As stated in *Framework for Ecological Risk Assessment* (EPA 1992), "Assessment endpoints are explicit expressions of the actual environmental value that is protected. Measurement endpoints are measurable responses to a stressor that are related to the valued characteristics chosen as the assessment endpoints." The assessment and measurement endpoints are, respectively, the health and mortality of the Great Basin pocket mouse. This is consistent with the objective of the qualitative ecological evaluation. The dose rate to the pocket mouse was used to screen the level of risk at an individual waste site. For radionuclides, the dose rate to a mouse is compared to 1 rad/day (IAEA 1992, DOE Order 5400.5). For nonradiological contaminants, exposure is compared to toxicity based benchmark values.

4.3.1.2 Analysis Phase. The analysis phase of the qualitative ecological evaluation is a technical evaluation of the available data used to assess the potential of exposure of Great Basin pocket mouse and any other receptors to the stressors at each waste site.

4.3.1.2.1 Characterization of Exposure. This section focuses on the development of the exposure relationship between receptor and site contaminants. It is assumed that the chemicals and radionuclides are uniformly distributed over the site and are biologically available. In the modeling effort, receptors are exposed to the maximum contaminant concentrations obtained from the LFI sampling efforts or from historical studies.

4.3.1.2.2 Exposure Analysis. This analysis assumes that the receptor (the mouse) spends its entire life at the site, obtains all its food from the site, and consumes only contaminated food. Although standing water can be found, it is not a requirement for the pocket mouse, who obtains all its water needs from food. Therefore, drinking water is not considered a route of exposure. The ecological evaluation focuses on potential adverse effects on the Great Basin pocket mouse to constituents present in the 200-UP-2 Operable Unit waste sites. Terrestrial vegetation is represented as a generic plant species exposed to soil contaminants. The major route of exposure of plants to waste site COPEC was assumed to be direct uptake of contaminants from soil. Plants were assumed to be the sole source of food for the mouse. All contaminants are assumed to be biologically available. In general, for organisms whose home range is smaller than the operable unit, it is assumed that 100% of their diet consists of contaminated foodstuffs. The usage factor for the Great Basin pocket mouse by waste site is assumed to be one in this evaluation.

Exposure of the pocket mouse to soil contaminants and to contaminants in plants is estimated based on the methodology outlined in DOE-RL (1994a). The radiation dose rate to the mouse is based on receptor whole-body concentrations. Example calculations for radiological internal and external dose are given in DOE-RL (1994a).

4.3.1.2.3 Characterization of Ecological Effects. Toxic responses can be induced in mice exposed to chemicals and to ionizing radiation. In both cases, severity of the toxic response is directly related to the dose. This assessment analyzes the relationship between the stressor and assessment and measurement endpoints. Because site-specific toxicity data are not available, potential adverse effects of these agents on the mouse were predicted based on toxicity data in the literature.

Toxicity based benchmark screening values are used to evaluate potential adverse effects to the pocket mouse following exposure to the COPEC. These benchmark screening values are based on chronic no observed effect levels (NOEL) and are estimated for the pocket mouse using the methodology outlined in Opresko et al. (1993). As mentioned earlier, only noncarcinogenic effects were considered.

The only regulatory standard for radionuclides in the environment is contained in DOE Order 5400.5, which adapted IAEA (1992) recommendations to limit exposure to aquatic organisms to <1 rad/day. This recommended dose limitation was used as a default value to establish the environmental HQ for radionuclides for the mouse.

For both radionuclides and nonradioactive contaminants, concentrations measured in 200-UP-2 biota are compared to reference site data. This is done to evaluate whether exposure to biota occurs above "background" levels.

4.3.1.2.4 Environmental Risk Characterization. The risk characterization phase evaluates the likelihood of an adverse effect to the pocket mouse following exposure to the COPEC. The purpose of this section is to integrate the receptor dose or intake values for the COPC with expected biological responses and describe the significance of risk to the ecological receptors. The risk to the Great Basin pocket mouse was estimated by calculation of an environmental hazard quotient (EHQ). The EHQ was based on a comparison between identified benchmarks for the specific chemical or 1 rad/day for radionuclides and the calculated animal dose or intake. The EHQ is expressed as follows:

$$\text{EHQ} = \frac{\text{Estimated Dose}}{\text{Benchmark Value}}$$

The EHQ ratio is used to assess potential adverse effect to an individual animal. For example, an EHQ that approaches or exceeds unity would indicate a potential adverse effect to an individual.

4.3.1.2.5 Interpretation of Ecological Significance. The approach presented for the QRA at the 200-UP-2 Operable Unit waste sites screened the potential radiation dose to the mouse and chemical intakes against benchmark criteria. The screening, or qualitative, approach models COPEC uptake from soil-to-plant to the mouse. In addition, 200-UP-2 biological monitoring data were evaluated to validate the model and to add supplemental information on potential impacts to site biota. The ecological significance of the QRA is limited because few biological field data exist to support or refute predicted impacts on individuals. In addition, without field data it is difficult to ascertain impacts at the population or community level of organization.

4.3.1.2.6 Uncertainty Associated with Ecological Risk Evaluation. The uncertainty associated with the approach used in the qualitative ecological evaluation for the 200-UP-2 Operable Unit waste sites is significant because of the uncertainties associated with the ecological model and the limited amount of biological monitoring data. With respect to the modeling, chemicals used as a source term were assumed to be available for uptake by site vegetation. In addition, the waste sites are primarily covered with cobble or gravel, which limits the amount of vegetation available for use as an ecological foodstuff. Modeling from soil to the pocket mouse required a number of assumptions including soil-to-plant transfer factors or coefficients. Because of the limited amount of site-specific data in this area, nonspecific soil-to-plant transfer factors obtained from literature were used in the models. Other assumptions included estimating the time that a receptor spends feeding within the unit and that all foodstuff consumed is contaminated. The highest dose is used to assess qualitative risk, although in reality the dose is somewhere between these boundaries. With regard to radionuclides, radioactive decay was not considered after incorporation, and it was assumed that all radionuclides are uniformly distributed throughout the body of the mouse. In addition, uncertainties are associated with the benchmark screening values that were used to estimate potential risks to the mouse. Uncertainties associated with the actual concentrations measured in biota include the quality of the data, natural biological variability, variations in exposure, insufficient reference site data, and the absence of residue data for all COPEC at each of the 200-UP-2 sites. The screening assessment presented here only predicts potential impacts to individual animals. It does not describe adverse impacts to higher levels of ecological organization. Each of these uncertainties contributes to the overall degree of uncertainty associated with the ecological evaluation.

4.3.2 Results of Ecological Evaluation

Ecological risks associated with exposure of the Great Basin pocket mouse to chemical and radionuclide contaminants within the 200-UP-2 Operable Unit are evaluated based on biological monitoring data and modeling results. Relative risks are used to evaluate the sites. Risks are designated as low if biological monitoring data revealed limited contamination and modeling results produced EHQ < 10. Sites were designated as being of medium risk when biological monitoring data indicated contamination in biota and modeling results indicated EHQ values between 10 and 100. Sites were designated high risk if biological monitoring data indicated contaminated biota and EHQ values were > 100.

4.3.2.1 216-U-1/2 Cribs System Ecological Risk Characterization. The only biological monitoring data that exist for this site are radionuclide concentrations in plants (Table 4-12). Plants from the 216-U-1/2 Cribs system were found to contain activity concentrations of cesium-137, plutonium-239, and total uranium that were greater than those measured in plants from the reference locations.

Estimating the radiation dose to the mouse following the ingestion of plant matter from the 216-U-1/2 Cribs revealed that maximum activity concentrations measured in plants from the site resulted in an internal dose rate of < 1 rad/day (2.53×10^{-5} rad/day) to the mouse.

No nonradioactive chemicals of potential ecological concern in soil from this site were found to have EHQ values in excess of unity. Cyanide was not evaluated because insufficient information is available to estimate the potential for exposure of the mouse to the analyte.

Exposure of the mouse to radiation at the site (as modeled from measured soil concentrations) resulted in a predicted total dose of 3.68×10^{-5} rad/day for the 0 to 1.9 m (0 to 6 ft) and 1.28×10^{-4} rad/day for the > 1.9 to 4.5 m (6 to 15 ft) depth interval.

4.3.2.2 216-U-4 Reverse Well/4a French Drain Area Ecological Risk. No biological monitoring data were found for this site. Radioactive constituents were, however, measured in soil. Modeling results indicated a total radiation dose to the mouse of 4.81×10^{-5} rad/day for the depth interval 0 to 1.9 m (0 to 6 ft) and 8.88×10^{-7} rad/day for the depth interval >1.9 to 4.5 m (6 to 15 ft) following exposure to radionuclides in soil from the 216-U-4 Reverse Well.

4.2.3.3 216-U-8 Crib System Ecological Risk Characterization. Plants collected from the 216-U-8 Crib were analyzed for both radionuclides and metals (Tables 4-13 and 4-14). Concentrations of metals that were found to exceed either those measured in plants from a 200 Area reference location or those from plants from a 100 Area reference location were aluminum, antimony, barium, copper, manganese, and vanadium. Titanium concentrations were not measured in plants from the reference locations and therefore could not be compared with those detected in plants from the 216-U-8 Crib system.

Radionuclide concentrations in 216-U-8 Crib plants that exceeded those measured in plants from the reference locations were cesium-137, strontium-90, plutonium-239, and total uranium (Table 4-13).

Modeling actual concentrations of aluminum, antimony, barium, copper, manganese, titanium, and vanadium measured in 216-U-8 Crib plants into the mouse resulted in HQ >1 for aluminum (EHQ = 5,030), antimony (EHQ = 52.3), barium (EHQ = 7.66), copper (EHQ = 18.7), manganese (EHQ = 21.7), and vanadium (EHQ = 5.96). Sufficient toxicity data were not available to evaluate hazards to the mouse following exposure to titanium.

Estimating the radiation dose to the mouse following the ingestion of plant matter from 216-U-8 revealed that exposure to the maximum activity concentrations measured in plants from the site resulted in a total dose rate of 1.57 rad/day. Strontium-90 alone contributed approximately 99% to the total dose rate.

Modeling results indicated no chemicals of potential ecological concern detected in soils from this site as having an EHQ >1.

Exposure of the mouse to radionuclides in soil resulted in an estimated total dose at the 0 m to 1.9 m (0 ft to 6 ft) interval and at the >1.9 m to 4.5 m (6 ft to 15 ft) interval to be <1 rad/day (5.57×10^{-3} rad/day).

4.3.2.4 216-U-12 Crib Ecological Risk Characterization. The only biological monitoring data that exist for this site are radionuclide concentrations in plants (Table 4-13). Plants from site 216-U-12 were found to contain activity concentrations of cesium-137, strontium-90, and plutonium-239 that were greater than those measured in plants from the reference locations.

Estimating the radiation dose to the mouse following the ingestion of plant matter from 216-U-12 revealed that exposure to the maximum activity concentrations measured in plants from the site resulted in a total internal dose rate of <1 rad/day (4.18×10^{-4} rad/day).

No nonradioactive chemicals were found to be COPEC in soil from this site. The mouse is, therefore, not expected to be exposed to hazardous concentrations of nonradioactive chemicals at this site as determined through the evaluation of soil concentrations.

Exposure of the mouse to radionuclides of potential ecological concern in site 216-U-12 soil did not result in a radiation dose of >1 rad/day (1.69×10^{-7} rad/day).

4.3.2.5 216-U-10 Pond System Ecological Risk Characterization. Plants collected from 216-U-10 Pond were found to contain concentrations of copper, lead, zinc, cesium-137, strontium-90, and plutonium-239 that were greater than those detected in biota from 200 Area reference locations (Tables 4-13 and 4-14). Barium and vanadium were also detected in vegetation from this site (Table 4-14) at concentrations that exceeded those from 100 Area reference locations (Landeen et al. 1993).

With reference to concentrations detected in small mammals from the 216-U-10 site, cesium-137 and strontium-90 were detected at concentrations that exceeded those measured in small mammals from the 200 Area reference location (Table 4-15).

Modeling actual maximum concentrations of barium, copper, lead, vanadium, and zinc measured in 216-U-10 plants into the mouse resulted in HQ >1 for barium (EHQ = 7.13), copper (EHQ = 13.0), and vanadium (EHQ = 2.01). Estimating the radiation dose to the mouse following the ingestion of plant matter from 216-U-10 revealed that maximum activity concentrations measured in plants from the site resulted in a total internal dose rate to the mouse of <1 rad/day (0.63 rad/day).

Chemicals and radionuclides were modeled from soil to the ecological receptors to estimate potential impacts on 216-U-10 biota. Soil concentrations used for this site were a compilation of data from the 216-U-10 Pond and 216-U-11 Trench. No chemicals at a soil depth of 0 to 1.9 m (0 to 6 ft) were predicted to be potentially hazardous to the mouse. At the depth interval of 1.9 to 4.5 m (6 to 15 ft), barium (EHQ = 11.1), copper (EHQ = 99.9), and zinc (EHQ = 11.3) were found to have EHQ values >1, indicating potential hazards to the mouse from exposure to these chemicals. With reference to the radionuclides, no radionuclides were found to result in a dose of greater than 1 rad/day to the mouse (1.33×10^{-4} rad/day). This was true for both depth intervals and also for the total radiation dose received from a given site.

4.3.2.6 216-U-11 Trench Ecological Risk Characterization. Plants collected within 216-U-11 were found to contain above background concentrations of copper, cesium-137, strontium-90, plutonium-239, and total uranium. No other radionuclides or metals were detected at concentrations that exceeded those measured in plants from the reference locations (Tables 4-13 and 4-14).

With regard to nonradioactive constituents measured in small mammals from this site, copper and cyanide were detected in mice at concentrations greater than those measured in mice from the reference locations.

As with mice collected from 216-U-10, mice from 216-U-11 were found to contain radionuclide concentrations that were greater than those from animals collected at the reference sites (Table 4-15). Elevated activity concentrations of cesium-137, strontium-90, plutonium-239, and total uranium were measured in 216-U-11 mice.

Modeling the actual maximum concentration of copper measured in 216-U-11 plants into the mouse resulted in a HQ of >1 (EHQ = 21.2).

Estimating the radiation dose to the mouse following the ingestion of plant matter from 216-U-11 revealed that maximum activity concentrations measured in plants from the site resulted in an internal dose rate to the mouse of <1 rad/day (3.88×10^{-4} rad/day).

Estimated risks associated with exposure of the mouse to COPEC in soil at this site can be inferred from the modeling results from 216-U-10, which incorporated data from both 216-U-10 and 216-U-11.

Radionuclides specific to soil from 216-U-11 were used to estimate the external and internal dose to a mouse at the site. Using the concentrations from the 0 to 1.9 m (0 to 6 ft) interval, the total radiation dose to the mouse was estimated to be <1 rad/day (2.81×10^{-6} rad/day).

4.3.2.7 216-U-9 Ditch Ecological Risk Characterization. No LFI or historical data on nonradioactive or radioactive constituents in soil were found for this site. As a consequence, ecological risks associated with exposure to constituents in soil could not be evaluated. They can, however, be estimated by comparisons with analogous units within the 216-U-10 Pond system unit.

4.3.2.8 216-U-14 Ditch Ecological Risk Characterization. No biological monitoring data were found for this site. Radioactive constituents were, however, measured in soil. Modeling results indicated a total radiation dose to the mouse of less than 1 rad/day (2.74×10^{-4} rad/day) for the depth interval 0 to 1.9 m (0 to 6 ft) following exposure to radionuclides in soil from the 216-U-14 Ditch.

4.3.2.9 207-U Retention Basins Ecological Risk Characterization. The only biological monitoring data that exist for this site were radionuclide concentrations in plants. Maximum concentrations of cesium-137, strontium-90, plutonium-239, and total uranium were all found to exceed those measured in plants from reference locations (Table 4-13).

Estimating the radiation dose to the mouse following the ingestion of plant matter from the 207-U-Retention Basins revealed that exposure to the maximum activity concentrations measured in plants from the site resulted in a total internal dose rate of <1 rad/day (5.14×10^{-3} rad/day) to the mouse.

Modeling results indicate that among the COPEC detected in soils from this site, arsenic (EHQ = 1.1), barium (EHQ = 10.2), copper (EHQ = 43.7), manganese (EHQ = 55.8), and zinc (EHQ = 6.89) were predicted to have EHQ values of >1. It is possible that ecological receptors at this site may be exposed to hazardous concentrations of these elements as measured in soil samples of less than 1.9 m (6 ft).

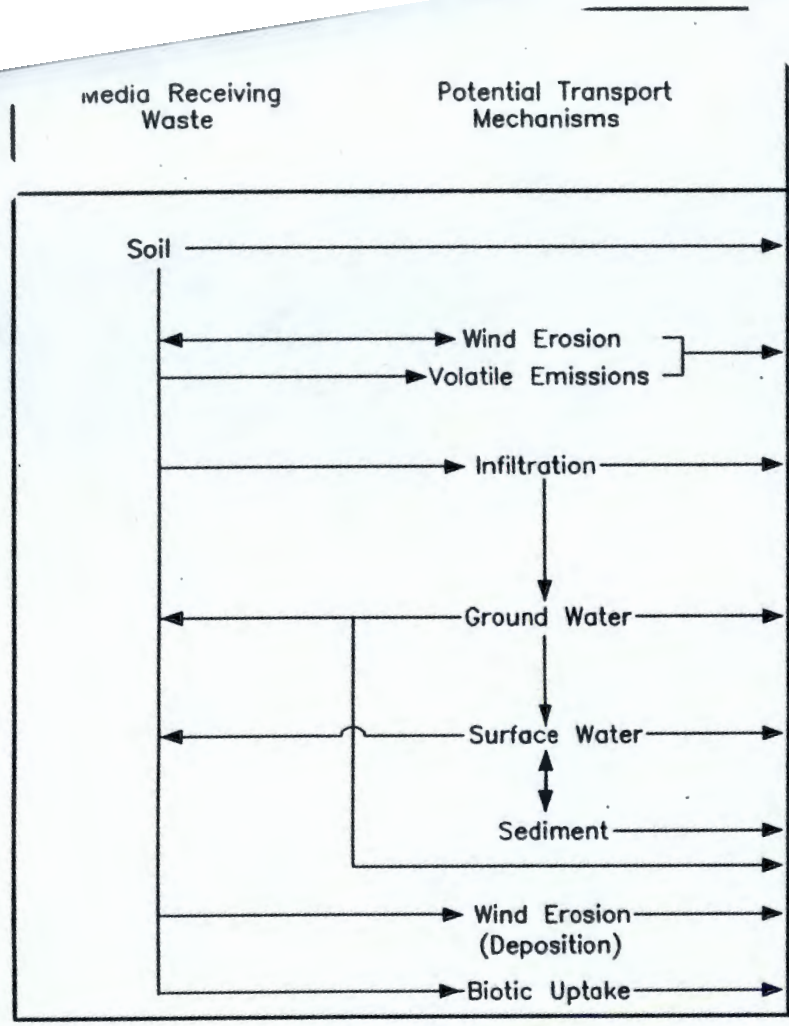
With reference to radionuclides of potential ecological concern in soil at this site, the estimated total radiation dose to the mouse was estimated to be <1 rad/day (1.46×10^{-4} rad/day) for soil from the 0 to 1.9 m (0 to 6 ft) depth interval.

4.3.2.10 Z Ditches Ecological Risk Characterization. Data from the Z Ditches are limited. The only available biological data from these areas were radionuclide concentrations in mice from 216-Z-19 (Table 4-15). The maximum strontium-90 concentration in the mice from this site was greater than that found in mice from the reference location. Because no data were found for cesium-137 concentrations in the gastrointestinal tracts of mice from a reference location, the concentrations detected in the gut of 216-Z-19 mice could not be evaluated. Plutonium-239 was also detected in mice from 216-Z-19; however, reference data were not available for comparison.

4.3.2.11 Summary of Results of Ecological Evaluation. As indicated in Table 4-16, relative ecological risks associated with the four systems range from low to medium-high. The 216-U-1/2 Cribs system was designated as having a low level of ecological risks as did the 216-U-4 Reverse Well/4a French Drain system. Overall, the 216-U-8 Crib area was rated as having a medium-high

ecological risk. The risks ranged from low (216-U-12 Crib) to medium-high (216-U-8 Crib). Within the U-Pond system, which overall was rated medium, the 216-U-10 Pond had a rating of medium while the 216-U-14 Ditch rated low. These risks are associated with both chemical (metals) and radionuclides (primarily cesium-137). The Z Ditches had a low to medium ecological risk. For many areas, current management practices restrict vegetative growth directly over waste sites, thereby reducing ecological exposure pathways. This waste site management practice, however, may not be continued in the future; therefore, a conservative approach was taken in the evaluation of potential ecological risks within the 200-UP-2 Operable Unit.

4.3.2.12 Summary of Key Uncertainties in the Ecological Evaluation. The major uncertainties associated with the evaluation of ecological risks at the 200-UP-2 Operable Unit are those related to the limited amount of biological and environmental monitoring data for the sites and to the estimation of exposure and risk to the receptor. Maximum concentrations in soil and biota were used to predict potential risks to biota. If the available data were not representative of the degree of contamination within a given site, risks to biota may be either over or under-estimated. Exposure calculations were performed to fill data gaps when necessary. Uncertainties associated with the models include the use of non-site-specific soil-to-plant transfer factors, one receptor species, estimated NOELs based on laboratory studies, and assumptions related to the diet, weight, home range size, and ingestion rate of the mouse. In most cases, assumptions were conservative in nature and may actually over-estimate potential impacts to the receptor. Finally, the limited amount of biological data and the modeling results were not sufficient to assess impacts at the population, community, or ecosystem level. The approach taken here was to utilize all available data to obtain the best estimate of potential adverse impacts on biota within the 200-UP-2 area.



Exposure		Human Receptors			
Media	Route	Residential	Industrial	Agricultural	Recreational
Soils	Ingestion	–	●	–	–
	Dermal	–	–	–	–
	External	–	●	–	–
Air (Dust/ Volatiles)	Inhalation	–	●	–	–
	External	–	–	–	–
Ground Water	Ingestion	–	–	–	–
	Inhalation	–	–	–	–
	Dermal	–	–	–	–
	External	–	–	–	–
Surface Water	Ingestion	–	–	–	–
	Inhalation	–	–	–	–
	Dermal	–	–	–	–
	External	–	–	–	–
Sediment	Ingestion	–	–	–	–
	Dermal	–	–	–	–
	External	–	–	–	–
Biota	Dairy	–	–	–	–
	Beef	–	–	–	–
	Game	–	–	–	–
	Fish	–	–	–	–
	Plant/Crop	–	–	–	–

● Primary Pathway

– Pathway Not Assessed

CH2:TLC:PTAAA–A1

Figure 4-1. Conceptual Model for Human Exposure Assessment at the 200-UP-2 Operable Unit.

9615389.0825

Figure 4-2. Conceptual Ecological Model.

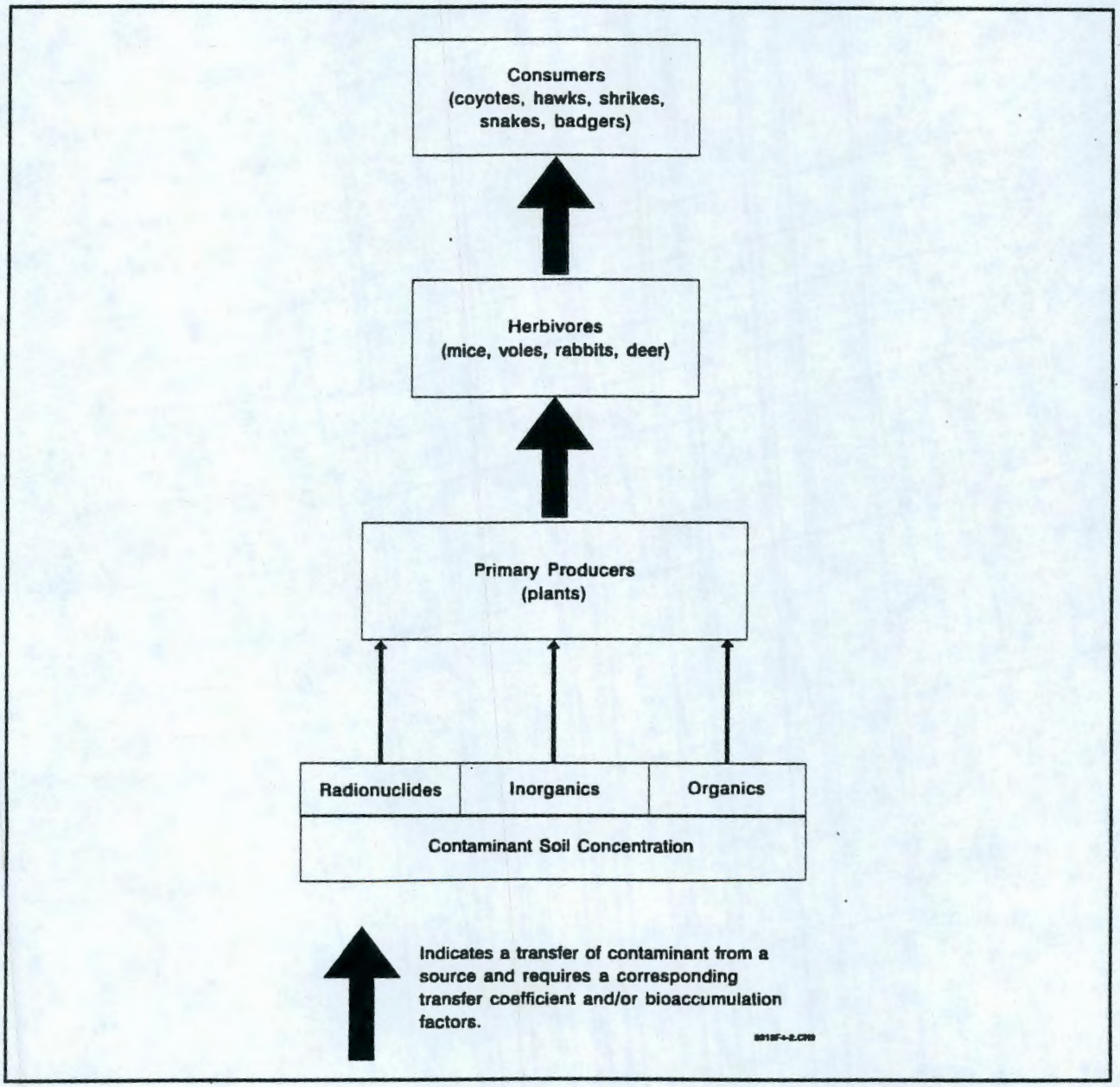


Table 4-1. Summary of Systemic Toxicity Information for Contaminants of Potential Concern at the 200-UP-2 Operable Unit.

Contaminant	Oral RfD[a] (mg/kg-d)	Inhalation RfD[b] (mg/kg-d)
Arsenic	0.0003	
Chromium	0.005	
Nickel	0.02	
1,4-Dichlorobenzene		0.2
4,4'-DDD	N/A	
Aroclor-1254	N/A	
Aroclor-1260	N/A	
Benzo(a)Pyrene	N/A	
Bis(2-Ethlhexyl)Phthalate	0.02	
Carbazole	N/A	
Chloroform	0.01	
Pentachlorophenol	0.03	
Tetrachloroethene	0.01	

[a] Integrated Risk Information System (IRIS) EPA (1993b).
[b] Health Effects Assessment Summary Tables (HEAST) (EPA 1993a).
N/A = Not available
RfD = Reference dose

Table 4-2. Summary of Carcinogenic (Radioactive) Toxicity Information for Contaminants of Potential Concern at the 200-UP-2 Operable Unit.

Radionuclide Analyte	Oral SF[a] $(pCi)^{-1}$	Inhalation SF[a] $(pCi)^{-1}$	External SF[a] $pCi\text{-}yr/g^{-1}$
Americium-241	2.4E-10	3.2E-08	4.9E-09
Americium-243	2.4E-10	3.2E-08	2.5E-07
Curium-244	1.6E-10	2.2E-08	3.0E-11
Cobalt-60	1.5E-11	1.5E-10	8.6E-06
Cesium-134	4.1E-11	2.8E-11	5.2E-06
Cesium-137	2.8E-11	1.9E-11	2.0E-06
Europium-155	4.5E-13	1.8E-11	5.9E-08
Europium-154	3.0E-12	1.4E-10	4.1E-06
Europium-152	2.1E-12	1.1E-10	3.6E-06
Iodine-129	1.9E-10	1.2E-10	4.1E-09
Neptunium-237	2.2E-10	2.9E-08	4.3E-07
Niobium-93m	1.5E-13	1.9E-11	5.3E-11
Plutonium-238	2.2E-10	3.9E-08	2.8E-11
Plutonium-239	2.3E-10	3.8E-08	1.7E-11
Potassium-40	1.1E-11	7.6E-12	5.4E-07
Radium-226	1.2E-10	3.0E-09	6.0E-06
Radium-228	1.0E-10	6.9E-10	2.9E-06
Sodium-22	6.8E-12	4.8E-12	7.2E-06
Strontium-90	3.6E-11	6.2E-11	0.0
Technetium-99	1.3E-12	8.3E-12	6.0E-13
Thorium-228	5.5E-11	7.8E-08	5.6E-06
Thorium-232	1.2E-11	2.8E-08	2.6E-11
Uranium-234	1.6E-11	2.6E-08	3.0E-11
Uranium-235	1.6E-11	2.5E-08	2.4E-07
Uranium-238	2.8E-11	5.2E-08	3.6E-08

[a] Health Effects Assessment Summary Tables (HEAST) (EPA 1993a).
SF = Slope Factor
NOTE: Radionuclide slope factors account for the contribution of radioactive daughter products, as indicated in EPA (1993a).

Table 4-3. Summary of Carcinogenic (Nonradioactive) Toxicity Information for Contaminants of Potential Concern at the 200-UP-2 Operable Unit.

Contaminant	Oral SF $(mg/kg\text{-}d)^{-1}$		Inhalation SF $(mg/kg\text{-}d)^{-1}$	
Arsenic	1.7	I	15	I
Chromium			42	I
Nickel			0.84	I
1,4-Dichlorobenzene	0.024	H		
4,4'-DDD	0.24			
Aroclor-1254	7.7	H		
Aroclor-1260	7.7	I		
Benzo(a)Pyrene	7.3	I		
Bis(2-Ethlhexyl)Phthalate	0.014	I		
Carbazole	0.02	H		
Chloroform	0.0061	I	0.081	J
Pentachlorophenol	0.12	I		
Tetrachloroethene	0.052	S	0.002	S

I = Integrated Risk Information System (IRIS) (EPA 1993b)
H = Health Effects Assessment Summary Tables (HEAST) (EPA 1993a)
S = Superfund Technical Support Center
SF = Slope factor

Table 4-4a. Summary of Contaminant Identification and Exposure Assessment Uncertainties for Radionuclides at the 200-UP-2 Operable Unit Waste Sites.

Waste Site	Data Uncertainty	Exposure Assessment Uncertainty (for external exposure)	Toxicity Assessment Uncertainty	Potential Impact of Uncertainties on the Risk Characterization[a]
U-Pond System	Moderate	High	Moderate to High	Over Estimation
216-U-8 Crib Area	Moderate	High	Moderate to High	Over Estimation
216-U-1 and U-2 Crib Area	Moderate	High	Moderate to High	Over Estimation
216-U-4 French Drain and U-4a Reverse Well Area	Moderate	High	Moderate to High	Over Estimation

[a]Based on currently available site data and information

Table 4-4b. Summary of Contaminant Identification and Exposure Assessment Uncertainties for Organic and Inorganic Analytes at the 200-UP-2 Operable Unit Waste Sites.

Waste Site	Data Uncertainty	Exposure Assessment Uncertainty (for ingestion exposure)	Toxicity Assessment Uncertainty	Potential Impact of Uncertainties on the Risk Characterization[a]
216-U-8 Crib Area	Low to Moderate	Moderate to High	Moderate to High	Over Estimation
U-Pond System	Low to Moderate	Moderate to High	Moderate to High	Over Estimation

[a]Based on currently available site data and information

Table 4-5. Human Health Risk Characterization for the 216-U-1/2 Cribs System.

Radionuclide COPC	Ingestion ICR	Inhalation ICR	External Exposure ICR	Total ICR
Industrial Use Scenario				
Americium-241	2.8E-08	1.3E-07	8.4E-09	2E-07
Cobalt-60	1.8E-09	6.1E-10	1.5E-05	2E-05
Cesium-137	4.6E-06	1.1E-07	4.8E-03	5E-03
Europium-152	2.7E-11	4.9E-11	6.8E-07	7E-07
Neptunium-237	4.8E-09	2.2E-08	1.4E-07	2E-07
Plutonium-239/240	1.5E-07	8.3E-07	1.6E-10	1E-06
Radium-228	1.5E-08	3.5E-09	6.2E-06	6E-06
Strontium-90	1.8E-04	1.0E-05	(a)	2E-04
Thorium-228	8.0E-09	3.9E-07	1.2E-05	1E-05
Uranium-234	3.2E-09	1.8E-07	8.8E-11	2E-07
Uranium-235	1.9E-10	9.9E-09	4.1E-08	5E-08
Uranium-238	4.9E-09	3.1E-07	9.3E-08	4E-07
Total	2E-04	1E-05	5E-03	
WASTE SITE TOTAL				5E-03

(a) No slope factor available to calculate human health risk
COPC = Contaminant of Potential Concern
ICR = Incremental Cancer Risk

Table 4-6. Human Health Risk Characterization for the 216-U-4 French Drain and 216-U-4a Reverse Well System.

Radionuclide COPC	Ingestion ICR	Inhalation ICR	External Exposure ICR	Total ICR
Industrial Use Scenario				
Americium-241	7.0E-06	3.2E-05	2.1E-06	4E-05
Cobalt-60	2.1E-09	7.2E-10	1.8E-05	2E-05
Cesium-137	1.7E-06	4.0E-08	1.8E-03	2E-03
Europium-152	3.4E-10	6.1E-10	8.4E-06	8E-06
Europium-154	2.8E-10	4.5E-10	5.6E-06	6E-06
Neptunium-237	6.7E-09	3.0E-08	1.9E-07	2E-07
Plutonium-238	1.8E-08	1.1E-07	3.3E-11	1E-07
Plutonium-239/240	2.0E-08	1.2E-07	2.2E-11	1E-07
Radium-228	2.3E-08	5.5E-09	9.9E-06	1E-05
Strontium-90	4.9E-07	2.9E-08	(a)	5E-07
Thorium-228	1.0E-08	5.1E-07	1.6E-05	2E-05
Thorium-232	2.8E-09	2.2E-07	8.9E-11	2E-07
Uranium-234	4.2E-09	2.3E-07	1.2E-10	2E-07
Uranium-235	4.2E-10	2.3E-08	9.2E-08	1E-07
Uranium-238	6.5E-09	4.2E-07	1.2E-07	5E-07
Total	9E-06	3E-05	2E-03	
WASTE SITE TOTAL				2E-03

(a) No slope factor available to calculate human health risk.
COPC = Contaminant of Potential Concern
ICR = Incremental Cancer Risk

Table 4-7. Human Health Risk Characterization for the 216-U-8 Crib System.

Inorganic COPC	Industrial Scenario					
	Pathway				Contaminant Totals	
	Soil Ingestion		Fugitive Dust Inhalation			
	HQ	ICR	HQ	ICR	HI	ICR
Arsenic	1.8E-02	2.7E-06	(a)	8.0E-07	2E-02	4E-06
Chromium(b)	1.9E-03	(a)	(a)	3.9E-06	2E-03	4E-06
Nickel	1.1E-03	(a)	(a)	1.8E-07	1E-03	2E-07
Total	2E-02	3E-06		5E-06		
WASTE SITE TOTAL					2E-02	8E-06

(a) No Rfd or SF available
(b) Evaluated as Chromium VI
RfD = Reference dose
SF = Slope factor
COPC = Contaminant of potential concern
HQ = Hazard quotient
ICR = Incremental cancer risk
HI = Hazard index

Table 4-8. Human Health Risk Characterization for the 216 U-8 Crib System.

Radionuclide COPC	Ingestion ICR	Inhalation ICR	External Exposure ICR	Total ICR
Industrial Use Scenario				
Americium-241	1.5E-05	6.8E-05	4.5E-06	9E-05
Cesium-134	2.0E-10	4.8E-12	3.8E-07	4E-07
Cesium-137	2.0E-04	4.7E-06	2.1E-01	>1E-02
Europium-152	4.5E-11	8.0E-11	1.1E-06	1E-06
Europium-154	2.2E-09	3.6E-09	4.5E-05	5E-05
Neptunium-237	6.0E-08	2.7E-07	1.7E-06	2E-06
Plutonium-238	9.6E-09	5.9E-08	1.8E-11	7E-08
Plutonium-239/240	2.4E-06	1.3E-05	2.6E-09	2E-05
Radium-226	3.5E-08	3.0E-08	2.6E-05	3E-05
Radium-228	2.2E-08	5.1E-09	9.2E-06	9E-06
Strontium-90	9.5E-07	5.6E-08	(a)	1E-06
Thorium-228	7.9E-09	3.8E-07	1.2E-05	1E-05
Thorium-232	2.6E-09	2.0E-07	8.1E-11	2E-07
Uranium-234	8.9E-08	4.9E-06	2.4E-09	5E-06
Uranium-235	7.7E-09	4.1E-07	1.7E-06	2E-06
Uranium-238	1.8E-07	1.1E-05	3.3E-06	1E-05
Total	2E-04	1E-04	>1E-02	
WASTE SITE TOTAL				>1E-02

(a) No slope factor available to calculate human health risk
COPC = Contaminant of potential concern
ICR = Incremental cancer risk

Table 4-9. Human Health Risk Characterization for the 216-U-10 Pond System.

Organic COPC	Industrial Scenario					
	Pathway				Contaminant Totals	
	Soil Ingestion		Fugitive Dust Inhalation			
	HQ	ICR	HQ	ICR	HI	ICR
Aroclor-1260	(a)	1.4E-04(b)	(a)	(a)		1E-04
Aroclor-1254	(a)	(a)	(a)	(a)		
Total		1E-04				
WASTE SITE TOTAL						1E-04

(a) No Rfd or SF available
(b) Concentration unit conversion from μg/kg to mg/kg to calculate risk.
COPC = Contaminant of potential concern
HQ = Hazard quotient
ICR = Incremental cancer risk
HI = Hazard index
RfD = Reference dose
SF = Slope factor

Table 4-10. Human Health Risk Characterization the 216-U-10 Pond System.

Inorganic COPC	Industrial Scenario					
	Pathway				Contaminant Totals	
	Soil Ingestion		Fugitive Dust Inhalation			
	HQ	ICR	HQ	ICR	HI	ICR
Arsenic	9.9E-03	1.4E-06	(a)	4.4E-07	1E-02	2E-06
Barium	1.4E-03	(a)	3.2E-02	(a)	3E-02	
Chromium(b)	4.7E-03	(a)	(a)	9.7E-06	6E-04	1E-05
Manganese(c)	3.2E-03	(a)	1.4E-01	(a)	1E-01	
Nickel	1.9E-03	(a)	(a)	3.1E-07	2E-03	3E-07
Total	2E-02	1E-06	2E-01	1E-05		
WASTE SITE TOTAL					2E-01	1E-05

(a) No Rfd or SF available
(b) Evaluated as Chromium VI
(c) Evaluated as concentration in food
COPC = Contaminant of potential concern
HQ = Hazard quotient
ICR = Incremental cancer risk
HR = Hazard index
Rfd = Reference dose
SF = Slope factor

Table 4-11. Human Health Risk Characterization for the 216-U-10 Pond System.

Radionuclide COPC	Ingestion ICR	Inhalation ICR	External Exposure ICR	Total ICR
Industrial Use Scenario				
Americium-241	1.6E-06	7.2E-06	4.7E-07	9E-06
Cobalt-60	9.8E-08	3.4E-08	8.2E-04	8E-04
Cesium-137	2.0E-05	4.6E-07	2.0E-02	>1E-02
Europium-152	2.0E-10	3.5E-10	4.9E-06	5E-06
Europium-154	1.0E-08	1.6E-08	2.0E-04	2E-04
Europium-155	3.6E-10	4.9E-10	6.8E-07	7E-07
Neptunium-237	9.0E-09	4.1E-08	2.6E-07	3E-07
Plutonium-238	7.4E-07	4.5E-06	1.4E-09	5E-06
Plutonium-239/240	2.5E-06	1.4E-05	2.7E-09	2E-05
Radium-226	1.9E-08	1.6E-08	1.4E-05	1E-05
Radium-228	3.8E-08	9.0E-09	1.6E-05	2E-05
Strontium-90	1.0E-06	5.9E-08	(a)	1E-06
Thorium-228	6.7E-09	3.2E-07	9.9E-06	1E-05
Thorium-232	4.6E-09	3.6E-07	1.4E-10	4E-07
Uranium-234	2.0E-07	1.1E-05	5.4E-09	1E-05
Uranium-235	3.1E-09	1.7E-07	6.9E-07	9E-07
Uranium-238	3.6E-07	2.3E-05	6.8E-06	3E-05
Total	3E-05	6E-05	>1E-02	
WASTE SITE TOTAL				>1E-02

(a) No slope factor available to calculate human health risk
COPC = Contaminant of potential concern
ICR = Incremental cancer risk

Table 4-12. Summary of the Human Health Qualitative Risk Assessment for the 200-UP-2 Source Operable Unit.

Waste Site Designation	Industrial Use Scenario		
	Qualitative Risk Classification[a,b]	Major Contaminant	Major Pathway
216-U-1 and U-2 Crib System	Medium	Cesium-137	External radiation exposure
216-U-10 Pond System	High (radionuclides)	Cobalt-60 Cesium-137 Europium-154 sodium-22	External radiation exposure
	Medium (organics) Low (inorganics)	Aroclor-1260 Chromium	Ingestion Fugitive dust inhalation
216-U-8 Crib System	High (radionuclides) Low (inorganics)	Cesium-137 Chromium	External radiation exposure Fugitive dust inhalation
216-U-4 French Drain and 216-U-4a Reverse Well System	Medium	Cesium-137	External radiation exposure

[a] Very Low = Very Low Qualitative Risk; Incremental Cancer Risk (ICR) < 1E-06
Low = Low Qualitative Risk; 1E-06 < ICR < 1E-04
Medium = Medium Qualitative Risk; 1E-04 < ICR < 1E-02
High = High Qualitative Risk; ICR > 1E-02

[b] Qualitative risk classification is based on the highest risk category for chemical contaminant of potential concern from waste sites characterized by analytical data.

Table 4-13. Radionuclide Activity Concentrations in 200-UP-2 Area Plants[a].

Site	Cesium-137 (pCi/g)	Strontium-90 (pCi/g)	Plutonium-239 (pCi/g)	Uranium (pCi/g)
207-U Retention Basin	ND - 1.8E+03	ND - 3.9E+00	ND - 5.0E-01	1.3E-02 - 8.5E-01
216-U-1/2 Cribs	3.2E-02	1.9E-02	7.2E-03	5.0E-02
216-U-8 Crib	7.8E-02 - 1.1E+01	8.3E-02 - 1.4E03	6.8E-03 - 1.3E-02	6.5E-02
216-U-10 Pond	ND - 2.2E+01	ND - 1.7E+02	ND - 7.4E+01	1.8E-02 - 3.0E-02
216-U-11 Trench	ND - 2.5E-01	ND - 3.0E-01	ND - 7.4E-02	2.4E-03 - 8.1E-02
216-U-12 Crib	ND - 1.1E+00	ND - 3.3E-01	ND - 2.3E-02	2.0E-02 - 2.2E-02
200 Area Control Site	2.7E-02 - 4.6E-02[b]	2.1E-02[b] - 7.2E-02[b]	ND	ND[c]
200 Area Vegetation PNL Offsite Average	2.6E-02	6.3E-02	3.0E-03	3.4E-02[d]

[a] Data from Johnson et al. (1994)
[b] Detection limit
[c] Detection limit was reported as a negative value
[d] Total Uranium
ND = Not Detected
PNL = Pacific Northwest Laboratory

Table 4-14. Metal Concentrations in 200-UP-2 Area Plants and Mammals [a,b]

Metals	216-U-8 for Plants (mg/kg dry wt.)	216-U-10 for Plants (mg/kg dry wt.)	216-U-11 for Plants (mg/kg dry wt.)	200 Area "Control" Site for Plants (mg/kg dry wt.)	100 Area "Control" Site for Plants (mg/kg dry wt.)	216-U-11 for Mammals (mg/kg dry wt.)	200 Area "Control" Site for Mammals (mg/kg dry wt.)
Aluminum	96.6 - 1870	124 - 142			767.67		
Antimony	9.3[c] - 15.8	5[c] - 11.1[c]			5.49		
Arsenic	0.41[d] - 0.44[d]	0.14[c] - 0.44[c]	0.43[d] - 1.46[c]	0.63 - 0.72[d]	1.53	0.12[d] - 0.15[d]	0.11[d] - 0.17[d]
Barium	4.4[c] - 34.4[e]	17.5[e] - 32.0[e]			24.26		
Beryllium	0.19[c] - 0.22[c]	0.06[c] - 0.22[c]			0.16		
Cadmium	0.93[c] - 1.1[c]	0.44[c] - 1.1[c]	1.08[c] - 3.35[c]	1.05[d] - 1.19[d]	0.47	0.31[c] - 0.38[c]	0.26[c] - 0.41[c]
Calcium	2630 - 28900	10300 - 20700			3854.17		
Chromium	1.9[c] - 2.5	0.84[c] - 2.2[c]	1.08[c] - 3.35[c]	1.26[d] - 1.43[d]	2.88	0.75[c] - 1.8[c]	0.38[c] - 1.0[c]
Cobalt	1.9[c] - 2.2[c]	0.84[c] - 2.2[c]	1.79[c] - 5.36[c]	1.47[d] - 1.67[d]	0.90	0.44[c] - 0.53[c]	0.37[c] - 0.58[c]
Copper	4.1[e] - 12.2	7.9 - 8.5	3.1[e] - 13.8[e]	3.5[d,e] - 3.7[d,e]	8.65	11.3[d] - 28.0[d]	1.3[d] - 7.4[d]
Cyanide			1.08[f] - 3.68[c]	1.06[c] - 1.20[c]		0.25[f] - 7.66[d]	0.21[f] - 0.69[d]
Iron	182 - 4150	285 - 359[d]			1336.75		
Lead	0.42[c] - 1.0	0.44[d] - 0.46[c]	0.43[c] - 1.46[d]	0.63[d] - 0.72[d]	2.04	0.12[d] - 0.15[d]	0.11[d] - 0.17[d]
Magnesium	1020 - 8160	4210 - 4320			2196.67		
Manganese	11.5 - 154	22.0 - 27.5			70.63		
Mercury	0.09[d] - 0.11[d]	0.05[d] - 0.11[c]	0.05[d] - 0.18[c]	0.05[c] - 0.06[c]	0.17	0.03[f] - 0.04[f]	0.03[d] - 0.04[d]
Nickel	3.7[c] - 4.5[c]	3.7[c] - 4.4[c]	3.14[c] - 9.39[c]	2.53[d] - 2.86[d]	2.72	0.87[c] - 1.1[c]	0.63[c] - 1.2[c]
Potassium	1130 - 8390	8790 - 11600[d]			14928.33		
Selenium	0.41[c] - 0.44[c]	0.36[d] - 0.44[d]	0.43[c] - 1.46[c]	0.42[d] - 0.48[c]	1.79	0.14[c] - 0.2[c]	0.16[c] - 0.29
Silver	0.93[c] - 1.1[c]	0.74[d] - 1.1[c]	1.29[c] - 4.02[c]	1.47[d] - 1.67[d]	1.01	0.44[d] - 0.53[d]	0.38[d] - 0.58[d]
Sodium	36.4[c] - 161[e]	85.2[e] - 245[e]			175.49		
Thallium	0.41[c] - 0.44[c]	0.14[d] - 0.44[c]			0.44		
Titanium	12.8 - 292	18.9 - 23.2					
Vanadium	1.9[c] - 9.2[e]	2.2[c] - 3.1[d,e]			2.60		
Zinc	6.9[c] - 34.0	18.5[d] - 36.0	12.8 - 30.8	10.2[d] - 11.5[d]	76.43	15.4[d] - 25.9[d]	6.4[d] - 33.7[d]

[a] 200 Area data from Johnson et al. (1994); 100 Area data from Landeen et al. (1993)
[b] Data are for herbaceous, nonaquatic plants
[c] Not detected
[d] Not detected; value is estimated
[e] Analyte found in associated blank
[f] Data designated unusable

Table 4-15. Radionuclide Activity Concentrations in 200-UP-2 Area Small Mammals[a].

Site	Cesium-137 (pCi/g)	Strontium-90 (pCi/g)	Plutonium-239 (pCi/g)	Uranium (pCi/g)	Cobalt-60 (pCi/g)
216-Z-19 Ditch	ND[b] - 1.6E+03[c]	3.7E+0[d]	9.8E-1 - 1.0E+02		
216-U-11 Trench	1.9E-02[f] - 1.1E-1[f]	1.4E-1[f] - 1.1E0		ND[g]	2.1E-02[f] - 5.5E-02[f]
216-U-10 Pond	ND - 5.0E+02[h]	9.7E-01 - 1.1E+01	ND - 1.6E+00	ND - 1.3E-01	
200 Area Control Site	ND[g] - 5.9E-02[f]	ND[g] - 7.1E-02[f]		ND[g] - 2.9E-01[f]	

[a] Data from Johnson et al. (1994)
[b] Not detected
[c] Gastro-intestinal tract
[d] Average value for fur/skin
[e] Average value
[f] Detection limit
[g] Detection limit was reported as a negative value
[h] Average value for kidney

Table 4-16. Relative Ecological Risks at the 200-UP-2 Operable Unit.

216-U-1/2 Cribs System	**low**
216-U-1/2 Cribs	low
Stainless Steel Effluent Pipe	low[a]
241-U-361 Settling Tank	low[b,c]
216-U-16 Crib	low
2607-W5 Septic Tank and Drain Field	low[c]
216-U-4 French Drain/U-4a Reverse Well System	**low**
216-U-8 Crib System	**medium-high**
216-U-8 Crib	medium-high
Vitrified Clay Pipeline	medium-high
216-U-12 Crib	low
216-U-10 Pond System	**medium**
216-U-10 Pond	medium
216-U-11 Trench	medium
216-U-9 Ditch	medium[c]
216-U-14 Ditch	low
207-U Retention Basins	medium
Z-Ditches	low-medium

[a] Based on in-line camera study
[b] Based on historical data
[c] Based on comparison with associated units

5.0 RECOMMENDATIONS

The primary purpose of this LFI report is to provide recommendations for continuation of waste units on the IRM pathway. Sites that are not recommended as candidates for the IRM path will be addressed in the final remedy selection process.

5.1 IRM CANDIDATE EVALUATION CRITERIA

The 200-UP-2 Operable Unit systems are evaluated to identify those systems that are to continue on an IRM path. The following set of criteria is used in this process:

- Results from the QRA
- Assessment of the waste site physical conceptual model
- Evaluation of site-specific contaminant impact to the groundwater
- Identification of sites where natural attenuation of contaminants may reduce risks and mitigate contamination.

5.1.1 Qualitative Risk Assessment

Evaluation of human health risks associated with exposure of individuals to chemical and radionuclide contaminants were evaluated. Risk levels were determined in the QRA by using the industrial use scenario. The qualitative risk estimations were grouped in "high" (ICR > 1E-02), "medium" (ICR > 1E-04 to 1E-02), "low" (ICR > 1E-06 to 1E-04), and "very low" (ICR < 1E-06) risk categories based on results presented in this report. Sites that pose "medium" to "high" risks to human health are recommended to continue as IRM candidates.

Evaluation of ecological risks associated with exposure of biota to chemical and radionuclide contaminants at 200-UP-2 were evaluated by examination of site-specific biological monitoring data and by the exposure of a specific ecological receptor, in this case the Great Basin pocket mouse, to contaminants in soil through modeling efforts. The assessment of ecological impacts associated with 200-UP-2 indicate medium to medium-high level impacts to biota within the 216-U-10 Pond system and 216-U-8 Crib system, and low level risks associated with exposure of biota to contaminants within the 216-U-1/2 system and 216-U-4 Reverse Well/4a French Drain system.

5.1.2 Conceptual Model

The conceptual model for a waste site includes the sources of contamination, the types of contaminants, the extent of contamination in each affected media, known and potential routes of migration, known or potential human and environmental receptors, and the general understanding of the site structure and process. A detailed physical conceptual model of the 200-UP-2 Operable Unit is in Chapter 4.0 of the U Plant AAMSR (DOE-RL 1992). A summary of the current version of the 200-UP-2 model based on data gathered during field investigation activities and subsequent data analysis is presented in Table 5-1 (extent of contamination is found for each system in Section 3).

The COPC identified in Table 5-1 are the major contributors to the risks associated with each system. As a result of the LFI, enough information exists on the physical conceptual model to make decisions on continued candidacy for an IRM.

5.1.3 Current Impact on Groundwater

The potential impact to groundwater is evaluated qualitatively for the 216-U-1/2 Cribs, the 216-U-8 Crib, and the 216-U-12 Crib. The selection of these systems was based on those units that had the highest level of contaminants distributed throughout the vadose zone or for which groundwater monitoring indicated a present potential impact. Groundwater impact assessments for the 216-U-10 Pond and 216-U-4 Reverse Well/4a French Drain systems were not conducted due to their relatively low concentrations of contaminants distributed throughout the vadose zone. For the 216-U-8, 216-U-12, and 216-U-1/2 Cribs, the groundwater impact conceptual model indicates very short travel times (<5 years) to groundwater under saturated conditions. When discharges to the system end and an unsaturated condition exists, travel times increase by 2 to 3 orders of magnitude. However, gravity drainage may continue for several years after discharges cease. Since all effluent disposal to these cribs has ceased, impact to groundwater would be unaffected by any IRM conducted in the near term (5 to 10 years).

5.1.4 Potential for Natural Attenuation

The potential for the contaminants at a site to be reduced by natural attenuation is not considered for these systems. Natural attenuation is not a consideration for sites contaminated by metals, by radionuclides with half-lives 30 years or greater, or where multiple pathways drive the risk.

5.2 SITE RECOMMENDATIONS

The basic idea behind the analogous unit concept is to investigate a site that is representative of the worst-case condition of other waste management units similar in waste disposal history and location. The conclusions drawn from this analogue site can than be applied to those similar waste management units. For the 200-UP-2 LFI, this approach was applied to four waste systems: the 216-U-1/2 Cribs system, the 216-U-4 Reverse Well/4a French Drain system, the 216-U-8 Crib system, and the 216-U-10 Pond system. The following recommendations are based on these groupings.

5.2.1 216-U-1/2 Cribs System

The 216-U-1/2 Cribs system is recommended to continue as a candidate for an IRM. Qualitative risk assessment data suggest that a medium human health risk exists under an industrial exposure scenario with a moderate level of uncertainty and a low risk from an ecological standpoint.

5.2.2 216-U-4 Reverse Well/4a French Drain System

The 216-U-4 Reverse Well/4a French Drain system is recommended to continue as a candidate for an IRM. The QRA findings indicate a medium human health risk level for external exposure with a moderate level of uncertainty.

5.2.3 216-U-8 Crib System

The 216-U-8 Crib system is recommended to continue as a candidate for an IRM. The QRA data suggest that human health risk under an industrial exposure scenario is high while the uncertainty associated with this risk is moderate. The ecological risk evaluation also indicates potential health hazards (medium-high risk) to the Great Basin pocket mouse from both chemical (metals) and radiological standpoints.

5.2.4 216-U-10 Pond System

The 216-U-10 Pond system is recommended to continue as a candidate for an IRM. The QRA data suggest that human health risk under an industrial exposure scenario is high while the uncertainty associated with this risk is moderate. The ecological risk assessment also indicates that much of the 216-U-10 Pond system presents a medium risk to the Great Basin pocket mouse from a chemical ingestion standpoint, with radionuclide concentrations in mice from this system being higher than those measured in mice from reference locations.

Table 5-1. Conceptual Model for 200-UP-2 High-Priority Waste Systems.

System	Waste Management Unit	Contaminant Source	Potential Contaminants of Concern
216-U-10 Pond	216-U-10 Pond	224-U, 224-Z, 221-U, 242-S Evaporator, 241-U-110 Condenser, 284-W Powerhouse, 207-U Retention Basins	Aroclor-1260 Cobalt-60 Cesium-137 Europium-154
	216-U-14 Ditch	224-U, 221-U, 242-S Evaporator, 241-U-110 Condenser, 284-W Powerhouse	
	216-U-11 Trench	216-U-10 Pond Overflow	
	Z Ditches	224-Z	
	207-U Retention Basins	224-U	
	216-U-9 Ditch	216-U-10 Pond Overflow	
216-U-1/2 Cribs	216-U-1/2 Cribs	224-U, 221-U, 276-U	Cesium-137 Strontium-90
	241-U-361 Settling Tank	224-U, 221-U, 276-U	
	2607-W5 Drain Field	221-U, 222-U, 224-U, 271-U	
	Stainless Steel Pipeline	224-U, 221-U, 276-U	
216-U-8 Crib	216-U-8 Crib	224-U	Cesium-137
	216-U-12 Crib	224-U	
	Vitrified Clay Pipeline	224-U	
216-U-4, -4a	216-U-4 French Drain	222-U	Cesium-137
	216-U-4a Reverse Well	222-U	

6.0 REFERENCES

Argonne, 1992, *RESRAD,* Version 4.3.5, Argonne National Laboratory, Argonne, Illinois.

Baker, V. R., B. N. Bjornstad, A. J. Busacca, K. R. Fecht, E. P. Kiver, U. L. Moody, J. G. Rigby, D. F. Stradling, and A. M. Tallman, 1991, "Quaternary Geology of the Columbia Plateau," in *Quaternary Nonglacial Geology; Conterminous United States*, R. B. Morrison (ed.), Geological Society of America, The Geology of North America, Boulder, Colorado, Vol. K-2, pp. 215-250.

Bjornstad, B. N., 1984, *Suprabasalt Stratigraphy Within and Adjacent to the Reference Repository Location*, SD-BWI-DP-039, Rockwell Hanford Operations, Richland, Washington.

Delelgard, C. H., R. T. Kimura, A. G. Law, R. C. Routson, and R. L. Weiss, 1986, *Characterization and Anion Exchange Removal of Uranium from Hanford Groundwater,* RHO-RE-SA-116P, Rockwell Hanford Operations, Richland, Washington.

DOE, 1988, *Consultation Draft Site Characterization Plan*, DOE/RW-0164, Vols. 1-9, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, Washington, D.C.

DOE-RL, 1991, *Hanford Past-Practice Strategy*, DOE/RL-91-40, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992, *U Plant Aggregate Area Management Study Report*, DOE/RL-91-52, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993a, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-UP-2 Operable Unit,* DOE/RL 91-19, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993b, *Hanford Environmental Information System (HEIS)*, DOE/RL-93-24, Vol. 1, June 1994, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1994a, *Hanford Site Risk Assessment Methodology,* DOE/RL-91-45, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1994b, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes,* DOE/RL-92-24, Rev. 2, Draft, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1995, *Annual Report for RCRA Groundwater Monitoring at the Hanford Site,* DOE/RL-94-136, Rev. 0, U.S. Department of Energy, Richland, Washington.

Ecology, EPA, and DOE-RL, 1994, *Hanford Federal Facility Agreement and Consent Order Proposed Change Packages*, September 29, 1994, Washington Department of Ecology, Olympia, Washington, U.S. Environmental Protection Agency, Region X, Seattle, Washington, and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

EPA, 1989, *Risk Assessment for Superfund: Volume, Human Health Evaluation Manual, Part A; Interim Final,* EPA/540/1-89/002, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1992, *Framework for Ecological Risk Assessment,* EPA/630/R-92/001, Risk Assessment Forum, U.S. Environmental Protection Agency, Washington D.C.

EPA, 1993a, *Health Effects Assessment Summary Tables: Annual FY-1993,* OHEAA/ECAO-CIN-909, March 1993, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA, 1993b, *Integrated Risk Information System (IRIS),* data file, U.S. Department of Health and Human Services, National Library of Medicine Toxicology Data Network (TOXNET), Bethesda, Maryland.

IAEA, 1992, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards,* Technical Reports Series Vol. 332, International Atomic Energy Agency, Vienna, Austria.

Jaquish, R. E. and R. W. Bryce (eds.), 1988, *Hanford Site Environmental Report for Calendar Year 1988,* PNL-6825, Pacific Northwest Laboratory, Richland, Washington.

Jaquish, R. E. and R. W. Bryce (eds.), 1989, *Hanford Site Environmental Report for Calendar Year 1989,* PNL-7346, Pacific Northwest Laboratory, Richland, Washington.

Jaquish, R. E. and P. J. Mitchell (eds.), 1987, *Environmental Monitoring at Hanford for 1978,* PNL-6464, Pacific Northwest Laboratory, Richland, Washington.

Johnson, A. R, B. M. Markes, J. W. Schmit, A. N. Shah, S. G. Weiss, and K. J. Wilson, 1994, *Historical Records of Radioactive Contamination in Biota at the 200 Areas of the Hanford Site,* WHC-MR-0418, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Kelty, G. G., 1993a, *Description of Work for Vadose Borings in Support of 200-UP-2 Operable Unit,* WHC-SD-EN-AP-147, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Kelty, G. G., 1993b, *Description of Work for 216-U Pond Cone Penetrometer Demonstration,* WHC-SD-EN-AP-142, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Kelty, G. G., 1993c, *Description of Work for 216-U Pond Test Pits,* WHC-SD-EN-AP-141, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Kelty, G. G., K. A. Lindsey, S. E. Kos, and R. K. Price, 1995, *Borehole Summary Report for the 200-UP-2 Operable Unit, 200 West Area,* BHI-00034, Rev. 1, Bechtel Hanford, Inc., Richland, Washington.

Landeen, D. S., M. R. Sackschewsky, and S. G. Weiss, 1993, *100 Areas CERCLA Ecological Investigations,* WHC-EP-0620, Westinghouse Hanford Company, Richland, Washington.

Last, G. V., D. W. Duncan, M. J. Graham, M. D. Hall, V. W. Hall, D. S. Landeen, J. G. Leitz, and R. M. Mitchell, 1994, *216-U-10 Pond and 216-Z-19 Ditch Characterization Studies,* WHC-EP 0707, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Lindsey, K. A., 1992, *Geology of the Northern Part of the Hanford Site: An Outline of Data Sources and the Geologic Setting of the 100 Areas*, WHC-SD-EN-TI-011, Westinghouse Hanford Company, Richland, Washington.

Lindsey, K. A. and D. R. Gaylord, 1989, *Sedimentology and Stratigraphy of the Miocene-Pliocene Ringold Formation, Hanford Site, South-Central Washington*, WHC-SA-0740-FP, Westinghouse Hanford Company, Richland, Washington.

Lindsey, K. A., M. P. Connelly, and B. N. Bjornstad, 1991, *Geologic Setting of the 200 West Area: An Update*, WHC-SD-EN-TI-008, Westinghouse Hanford Company, Richland, Washington.

Lindsey, K. A., B. N. Bjornstad, J. W. Lindberg, and K. M. Hoffman, 1992, *Geologic Settings of the 200 East Area: An Update*, WHC-SD-EN-TI-012, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Lindsey, K. A., S. P. Reidel, K. R. Fecht, J. L. Slate, A. G. Law, and A. M. Tallman, 1994, *Geohydrologic Setting of the Hanford Site, South-Central Washington,* Geologic Field Trips in the Pacific Northwest: 1994 Geological Society of America Annual Meeting.

Mitchell, R. M., 1994, *Surface Soil Sampling Plan for 200-UP-2 Operable Unit*, WHC-SD-EN-AP-157, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Mitchell, R. M. and S. G. Weiss, 1995, *Ecological Sampling at Four Waste Sites in the 200 Areas*, BHI-00032, Bechtel Hanford, Inc., Richland, Washington.

Myers, C. W., S. M. Price, J. A. Caggiano, M. P. Cochran, W. J. Czimer, N. J. Davidson, R. C. Edwards, K. R. Fecht, G. E. Holmes, M. G. Jones, J. R. Kunk, R. D. Landon, R. K. Ledgerwood, J. T. Lillie, P. E. Long, T. H. Mitchell, E. H. Price, S. P. Reidel, and A. M. Tallman, 1979, *Geologic Studies of the Columbia Plateau: A Status Report*, RHO-BWI-ST-4, Rockwell Hanford Operations, Richland, Washington.

Opresko, D. M., B. E. Sample, and G. W. Suter, II, 1993, *Toxicological Benchmarks for Wildlife,* ES/ER/TM-86, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

PSPL, 1982, *Skagit/Hanford Nuclear Project, Preliminary Safety Analysis Report*, Vol. 4, App. 2, Amendment 23, Puget Sound Power and Light Company, Bellevue, Washington.

Reidel, S. P., K. A. Lindsey, and K. R. Fecht, 1992, *Field Trip Guide to the Hanford Site*, WHC-MR-0391, Westinghouse Hanford Company, Richland, Washington.

Reidel, S. P., V. G. Johnson, N. W. Johnson, and N. W. Kline, 1993, *Groundwater Impact Assessment for the 216-U-17 Crib,* WHC-EP-0664, Westinghouse Hanford Company, Richland, Washington.

Reynolds, K. D. and K. A. Lindsey, 1994, *Instructions for Borehole Sampling*, WHC-SD-EN-AP-181, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Rohay, V. J., K. J. Swett, and G. V. Last, 1994, *1994 Conceptual Model of the Carbon Tetrachloride Contaminator in the 200 West Area at the Hanford Site,* WHC-SD-EN-TI-248, Westinghouse Hanford Company, Richland, Washington.

Rowley, C. A., 1994a, *Description of Work for 216-U-1 and 216-U-2 Stainless Steel Pipeline Integrity Testing*, WHC-SD-EN-AP-166, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Rowley, C. A., 1994b, *Field Characterization Plan for the 216-U-8 Vitrified Clay Pipeline*, WHC-SD-EN-AP-154, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Singleton, K. M. and K. A. Lindsey, 1994, *Groundwater Impact Assessment Report for the 216-U-14 Ditch,* WHC-EP-0698, Westinghouse Hanford Company, Richland Washington.

Tallman, A. M., K. R. Fecht, M. C. Marratt, and G. V. Last, 1979, *Geology of the Separations Areas, Hanford Site, South-Central Washington*, RHO-ST-23, Rockwell Hanford Operations, Richland, Washington.

Tallman, A. M., J. T. Lillie, and K. R. Fecht, 1981, "Suprabasalt Sediments of the Cold Creek Syncline Area," in *Subsurface Geology of the Cold Creek Syncline*, RHO-BWI-ST-14, C. W. Myers and S. M. Price (eds.), Rockwell Hanford Operations, Richland, Washington.

Wasemiller, M. A., C. A. Rowley, C. R. Webb, and R. M. Mitchell, 1994, *Surface and Near Surface Field Investigation Data Summary Report for 200-UP-2 Operable Unit,* BHI-00033, Bechtel Hanford, Inc., Richland, Washington.

Webb, C. R., 1994, *200-UP-2 Air Monitoring Report*, BHI-00035, Rev. 00, Bechtel Hanford, Inc., Richland, Washington.

Weekes, D. C. and J. V. Borghese, 1994, *Site Characterization Report for the Environment Restoration Disposal Facility,* WHC-SD-EN-ER-005, Westinghouse Hanford Company, Richland, Washington.

Wendling, M. A., 1994, *200-UP-2 Operable Unit Radiological Surveys*, WHC-SD-EN-RPT-009, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1993a, R. A. Carlson to C. D. Wade, "Surface Radiation Surveys for the 200-UP-2 Operable Unit," Internal Memo 81320-93-027, dated July 27, 1993, Westinghouse Hanford Company, Richland, Washington.

WHC, 1993b, *Data Validation Procedures for Chemical Analyses,* WHC-SD-EN-SPP-002, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

Woodruff, R. K., R. W. Hanf, and M. G. Hefty (eds.), 1990, *Hanford Site Environmental Report for Calendar Year 1990,* PNL-7930, Pacific Northwest Laboratory, Richland, Washington.

Woodruff, R. K., R. W. Hanf, and R. E. Lundgren (eds.), 1991, *Hanford Environmental Report for Calendar Year 1991*, PNL-8148, Pacific Northwest Laboratory, Richland, Washington.

Woodruff, R. K., R. W. Hanf, and R. E. Lundgren (eds.), 1992, *Hanford Site Environmental Report for Calendar Year 1992*, PNL-862, Pacific Northwest Laboratory, Richland, Washington.

APPENDIX A

REGULATORY ROADMAP

THIS PAGE
INTENTIONALLY LEFT BLANK

1.0 INTRODUCTION

This appendix is designed to support the coordination of the 200-UP-2 Operable Unit and the 216-U-12 Crib regulatory required documents as set forth in the Tri-Party Agreement Change Requests M-15-94-03 and M-20-94-05 and Milestone M-20-00 Modification (1994 ER Refocusing Negotiations). The goal of this roadmap is to address all regulated units, adequately reflect agreements to coordinate hazardous waste unit closure/postclosure activities with operable unit remediation, accurately reflect regulatory status or necessary coordination with developing transition efforts, and adequately reflect stakeholder values. This appendix contains the closure plan roadmap discussion: Attachment 1, which contains information not found in the referenced documents; and Attachment 2, which contains the Resource Conservation and Recovery Act (RCRA) Part A permit application, Form 3. Attachment 1 contains certain information found in a RCRA Closure Plan that is not normally addressed in a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) document. Attachment 2 is the RCRA Part A Permit Application on Form 3 that is required to be submitted and updated for an interim status treatment, storage, or disposal (TSD) unit under RCRA.

The closure plan roadmap identifies the location within the CERCLA documentation of information normally found in closure plan chapters. Each CERCLA document will be structured or referenced so that the RCRA closure/postclosure requirements for the 216-U-12 Crib can be readily identified for the review and approval process. Table A-1 is a matrix showing the general RCRA requirements and where those requirements are addressed in the referenced documentation. After the review process has been completed, the documentation associated with closure activities will be approved through the sitewide Part B permit modification process. Implementation of the closure activities will be through the record of decision (ROD).

2.0 CLOSURE PLAN ROADMAP DISCUSSION

The following discussion lists the typical chapters and divisions of a RCRA Closure/Postclosure Plan for an interim status TSD unit for the U.S. Department of Energy, Richland Operations Office (DOE-RL) and presents where the equivalent sections of the 216-U-12 Crib closure plan are located in the 200-UP-2 Operable Unit CERCLA documents and sections.

Outline of a Typical RCRA Closure/Postclosure Plan	Equivalent Sections in 200-UP-2 CERCLA Documentation
Chapter 1.0 is an introduction containing two divisions. The first division is an executive summary of the Closure/Postclosure Plan that summarizes the important points of the plan. The second division contains the history of the RCRA Part A Permit Application and a section relating the Part A, Form 3 to the closure plan.	
Division 1: Executive Summary	Attachment 1, Section 1 of this appendix
Division 2: History of the Part A, Form 3	Attachment 1, Section 1 of this appendix Attachment 2 of this appendix, Part A permit
Chapter 2.0 provides a Facility Description (3 divisions)	
Division 1: General description of the Hanford Site	Attachment 1, Section 1 of this appendix DOE-RL, 1992, *U Plant Aggregate Area Management Study Report* (U Plant Source AAMSR) DOE/RL-91-52, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Sections 2.1, 2.3, and 3.0. Also Figures 2-6 and 2-7 and Table 2-1
Division 2: Specific facility description	Attachment 1, Section 1 of this appendix U Plant Source AAMSR, Sections 2.1, 2.3, and 3.0. Also Figure 2-6 and Table 2-1
Division 3: Security information	Attachment 1, Section 2 of this appendix
Chapter 3.0 contains the process description.	
Process description	Attachment 1, Section 1.0 of this appendix U Plant Source AAMSR - Sections 2.0 through 2.4, Section 3.0 through 3.3, Sections 4.0 and 4.1, Figures 2-1, 2-6, 2-7, and 2-11. Tables 2-1, 2-7 through 2-10, and 4-1. DOE-RL, 1993a, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-UP-2 Operable Unit,* DOE/RL 91-19, U.S. Department of Energy, Richland Operations Office, Richland, Washington. (LFI Work Plan) - Sections 3.0 and 3.1, 4.0 through 4.2, and 5.0 through 5.3. Figures 5-11 through 5-13. Toebe, W.E., 1991, *Sources of Organic Contaminants in the UO_3 Process*, WHC-SD-CP-TI-160, Westinghouse Hanford Company, Richland, Washington - Sections 3 and 4

Chapter 4.0 provides information about waste characteristics	
1. Estimate of maximum inventory	U Plant Source AAMSR, Section 2.0, Table 2-3. Attachment 2 of this appendix, Part A permit. Toebe, W.E., D.C. Hedengren, and J.H.E. Rasmussen, 1990, *UO_3 Plant Process Condensate Stream-Specific Report*, WHC-EP-0342, Addendum 19, Westinghouse Hanford Company, Richland, Washington. Thompson, R.J. and S. Sontag, 1991, *Facility Effluent Monitoring Plan for the Uranium Trioxide Facility*, WHC-EP-0470, Westinghouse Hanford Company, Richland, Washington - Section 4, Table 4.2 Toebe 1991 - Section 6.0, Table 3
2. Waste types disposed at the 216-U-12 Crib	U Plant Source AAMSR - Section 2.0, Table 4-25 Toebe 1991
Chapter 5.0 describes Groundwater Monitoring - Contains information on the groundwater monitoring program.	Attachment 1, Section 3 of this appendix
Chapter 6.0 pertains to Closure Performance Standards (four divisions)	
Division 1: Closure strategy	U Plant Source AAMSR - Sections 2.6, 2.7, 4.0, 4.1, 5.0, 7.0, 7.1, and 9.3. Appendix B of this LFI report 200-UP-2 Focused Feasibility Study (FFS) (when prepared)
Division 2: Minimization of need for further maintenance	200-UP-2 FFS (when prepared)
Division 3: Protection of human health and the environment	200-UP-2 FFS (when prepared)
Division 4: Closure requirements	200-UP-2 FFS (when prepared)
Chapter 7.0 details Closure Activities (nine divisions)	
Division 1: Introduction	U Plant Source AAMSR - Sections 8.0 and 9.0.
Division 2: Removal of dangerous waste inventory	200-UP-2 Interim Remedial Measures (IRM) Proposed Plan (when prepared)

Division 3: Facility sampling	Toebe et al. 1990 Thompson and Sontag 1991 - Section 4, Table 4.2 Toebe 1991 - Section 6.0, Table 3 LFI Work Plan - Sections 1.0 through 5.0, Tables 5.1, 5.2, 5.8, and 6.0. LFI Work Plan - Section 1.5, Quality Assurance and Attachment 1 Borehole Summary Report for the 200-UP-2 Operable Unit Attachment 1, Section 1.3 of this appendix Appendix B of this LFI report
Division 4: Removal of contaminated material and waste residue	200-UP-2 IRM Proposed Plan (when prepared), if removal is the selected alternative
Division 5: Decontamination	200-UP-2 FFS (when prepared)
Division 6: Other required closure activities	200-UP-2 FFS (when prepared)
Division 7: Closure schedule	200-UP-2 FFS (when prepared)
Division 8: Amendment of Closure Plan	Attachment 1, Section 6 of this appendix 200-UP-2 IRM Record of Decision (ROD) (when prepared)
Division 9: Certification of closure and survey plat	Attachment 1, Section 5 of this appendix
Chapter 8.0 describes the Postclosure Plan (if required) (seven divisions)	
Division 1: Inspection plan	Attachment 1, Section 7 of this appendix 200-UP-2 FFS (when prepared)
Division 2: Monitoring plan	Attachment 1, Section 7.1 of this appendix
Division 3: Maintenance plan	Attachment 1, Section 7.2 of this appendix
Division 4: Personnel training	200-UP-2 IRM ROD (when prepared)
Division 5: Postclosure contact	200-UP-2 IRM ROD (when prepared)
Division 6: Amendment of postclosure plan	Attachment 1, Section 7.3 of this appendix Hanford Sitewide Permit
Division 7: Certification	Attachment 1, Section 7.4 of this appendix

Table A-1. CERCLA/RCRA Coordination Matrix. (sheet 1 of 2)

Objective	RCRA TSD State and Federal Requirement	RCRA Closure Plan Chapter	CERCLA Past Practice Documentation	200-UP-2 Integrated Document Title	Notes
Identify Investigate	Submit Part A to Regulators	216-U-12 Crib Part A, Form 3, Rev. 3	PA/SI	LFI Report, Appendix A, Attachment 2	Will be submitted with the LFI Report, June 1995
Characterization, nature, extent, and rate of release or site description	Facility Description and Process Information WAC 173-303-610; 40 CFR 265.112	Ch. 1 Introduction; Ch. 2.0 Facility Description and Location Information; Ch. 3.0 Process Information	RI	U Plant AAMS LFI Work Plan LFI Report, Appendix A	Submitted to Regulators in 10/15/92. Submitted to Regulators August 92. Will be submitted in June 95
Characterize contaminant constituents and concentrations or maximum amount of waste	Sampling Plan and waste inventory removal WAC 173-303-610(2) and (3)(a)(iii); 40 CFR 265.111 and .112(b)(3)	Ch. 4, Waste Characteristics Ch. 7, Div. 1 and 3	LFI and sampling strategy	U Plant AAMS RCRA Facility Investigation/ Corrective Measures Study Work Plan for the 200-UP-2 Operable Unit	Additional Info. Sample results are contained in Surface and Near Surface Field Investigation Data Summary Report for the 200-UP-2 Operable Unit (Wasemiller et al. 1994) Borehole Summary Report for the 200-UP-2 Operable Unit, (Kelty et al. 1995)
Report extent and risk of contamination	Detailed methods for removal of all hazardous waste WAC 173-303-610 (3)(a)(iv); 173-303-645	Ch. 7, Div. 8 and 9 Ch. 5, All	Field investigation & risk assessment report	LFI/QRA for the 200-UP-2 Operable Unit and Appendix A, Attachment 1	LFI Report - Appendix A, will contain the introduction and strategy for the RCRA/CERCLA coordination, Attachment 1 has specific closure plan requirements
Evaluate alternatives and identify preferred remedy	Detailed steps needed to remove waste WAC 173-303-610(2) and (3)(a)(v)	Ch. 6, Div. 4 and 3	FS Proposed IRM Plan	200-UP-2 FFS Report (12/96) 200-UP-2 Proposed IRM Plan	
Determine potential Federal, State, or local regulations and requirements	Prescribed under WAC 173-303-610 and 40 CFR 265.111	N/A	ARAR	All	ARARs will be finalized in the ROD
Evaluation of Selected Remedy	Closure Performance Standards WAC 173-303-610(2)(b)	Ch. 6, Div. 4	FFS or Final FFS	200-UP-2 FFS Report (12/96)	Closure performance standards will be included in the ROD
Expedite Cleanup of Contamination	WAC 173-303-610(3)(c)(iv)	N/A	ERA or IRM	N/A	
Interim Stabilization and/or Cleanup Contamination	Closure/ Postclosure Activities	Ch. 7, Div. 2 and 4 Ch. 8 (if required)	IRM	200-UP-2 IRM Proposed Plan (12/96)	
Proposed Method for Stabilization and/or Cleanup of Contamination	Closure/ Postclosure Activities	Ch. 7, Div. 5 and 6 Ch. 8 (if required)	Proposed IRM Plan	200-UP-2 IRM Proposed Plan (12/96)	

Table A-1. CERCLA/RCRA Coordination Matrix. (sheet 2 of 2)

Objective	RCRA TSD State and Federal Requirement	RCRA Closure Plan Chapter	CERCLA Past Practice Documentation	200-UP-2 Integrated Document Title	Notes
Approve Stabilization and/or Cleanup Method	NOD	All submittals	IRM ROD	TBD	
Design Approved Stabilization and/or Cleanup Method	Closure/ Postclosure Activities	Ch. 7 and Ch. 8 (if required)	IRM Design Report	TBD	
Realize Stabilization and/or Cleanup Method	Closure/ Postclosure Plan Approval	Closure/ Postclosure Plan Implementation	IRM Implementation	TBD	
Propose Final Remedy Selection	Draft RCRA Site Wide Permit Modification Postclosure Permit Application	Ch. 8 Div 4,5,6 and 7 (if required)	N/A		
Authorize Selected Remedy	Modify RCRA Site Wide Permit/Regulato r Plan Approval	Modify RCRA Site Wide Permit	N/A		
Design Chosen Remedy	Postclosure Permit Application; Closure Detail Design	Submittal to regulators	N/A		
Implement Remedy	Site, Clean Closure or Cap as Landfill	ACTION	N/A		
RCRA Certification of Closure	Certification of Closure	Signed by Independent PE	N/A	Registered Letter from the Owner/Operator to the Regulators	Will require certification by an independent registered PE. Required before final closure and modification to the Sitewide Part B permit application

AAMS - aggregate area management study
ARAR - applicable or relevant and appropriate requirement
CERCLA - Comprehensive Environmental Response, Compensation and Liability Act
CFR - Code of Federal Regulations
ERA - expedited response action
FFS - focused feasibility study
IRM - interim remedial measure
LFI - limited field investigation
N/A - not applicable
NOD - notice of deficiency
PA/SI - preliminary assessment/site investigation
QRA - qualitative risk assessment
RCRA - Resource Conservation and Recovery Act
RI - remedial investigation
TBD - to be determined
TSD - treatment, storage, and disposal
WAC - Washington Administrative Code

ATTACHMENT 1 - RCRA REQUIREMENTS

THIS PAGE
INTENTIONALLY LEFT BLANK

1.0 INTRODUCTION

This attachment describes those activities that are needed for closure of the 216-U-12 Crib under interim status (40 CFR 265.112) pursuant to the Washington Administrative Code (WAC) 173-303-610 and the RCRA site-wide Part B Permit for the Hanford Facility and that are not normally found in CERCLA documents. The 216-U-12 Crib Part A Permit Application, Form 3 was submitted because nitric acid was disposed to the soil column, i.e., corrosive characteristic with a pH <2. The 216-U-12 Crib is operated by the U.S. Department of Energy, Richland Operations Office (DOE-RL) and is co-operated by Bechtel Hanford, Inc. (BHI). Although the U.S. Government holds legal title to this unit, the U.S. Department of Energy, Richland Operations Office (DOE-RL) is considered the legal owner/operator of this unit under existing federal and WAC 173-303 regulations.

The 216-U-12 Crib consists of a 46-m- (150-ft) long, gravel-filled drain field. The 216-U-12 Crib was constructed in 1960 and measures 30 by 3 m (100 by 10 ft) at the base, has earthen sides with a 2:1 slope, and contains no internal structure. The bottom 1.5 m (5 ft) is filled with layers of sand and gravel that are covered with a polyethylene barrier.

The 216-U-12 Crib was constructed in 1960 when the 216-U-8 Crib began to subside. The 216-U-12 Crib received approximately 150,000,000 L (40,000,000 gal) of liquid waste during 28 years of use. The 216-U-12 Crib was used to dispose of Uranium-Oxide (UO_3) Plant corrosive process condensate. The 216-U-12 Crib, a percolation unit, was designed to receive mixed waste from the UO_3 Plant for approximately 5 minutes every hour, at the rate of 100 gal/min (379 L/min), and to dispose of the process condensate by percolation into the soil column. Effluent was received from the 291-U Stack Drainage system, the nitric acid (pH ≤ 1) in the UO_3 Process Condensate system, wastes from the C-5 and C-7 tanks, and storm drain wastes from the 224-U Building. Approximately 3.1 kg (6.9 lb) of thorium was received from the 241-WR Vault in October 1965. The 216-U-12 Crib was taken out of service in January 1988 as the 216-U-17 Crib was placed into service.

The 216-U-12 Crib was identified as a RCRA TSD unit because of the disposal of nitric acid. After January 1987, process condensate was administratively controlled to prevent the discharge of corrosive dangerous waste to 216-U-12 Crib. The unit continued to receive process condensate until the crib pipeline was cut and permanently capped on January 30, 1988. The 216-U-12 Crib is not active and is planned to be closed under WAC 173-303-610 in conjunction with the remediation of the 200-UP-2 Operable Unit. The associated pipeline will be closed as part of the operable unit through the CERCLA process.

1.1 PERMITTING HISTORY

As a result of past dangerous waste discharges to the 216-U-12 Crib, a RCRA Part A permit application (Part A), Form 3 (Rev. 0) was submitted to the Washington Department of Ecology (Ecology) in 1987. Revision 1 of the Part A, Form 3, was submitted in November 16, 1987. Certification of "Co-operator", Westinghouse Hanford Company, and a new photograph were added by Revision 1. Revision 2 was submitted in February 2, 1988, adding a statement that a neutralization unit began operation on January 14, 1988. Revision 2 changed the Process Code D85 (other) to D81 (landfill) per U.S. Environmental Protection Agency (EPA)/Ecology's direction. Revision 3 was submitted in June 30, 1994. (Revision 3 changed Co-operator from "President, Westinghouse Hanford Company" to "Bechtel Hanford, Inc".) This current Part A, Form 3, Revision 3 for the 216-U-12 Crib is included with this Appendix as Attachment 2. The Part A, Form 3, was submitted under the single Dangerous Waste Permit Identification Number, WA7890008967, issued to

the Hanford Site by EPA and Ecology. The Part A, Form 3, designates the 216-U-12 Crib as a landfill, subject to RCRA regulations for TSD units.

The 216-U-12 Crib closure is being initiated to meet the Tri-Party Agreement Milestones M-15-15B and M-20-37, "Submit 216-U-12 Crib Closure/Postclosure Plan to Ecology and EPA in coordination with the LFI Report for Operable Unit 200-UP-2." The date associated with this milestone is June 1995.

1.2 REGULATORY FRAMEWORK

A closure plan under WAC 173-303-610 was scheduled to be submitted to the regulators in November 1994 to meet the Tri-Party Agreement Milestone M-20-37, "Submit 216-U-12 Crib Closure/Postclosure Plan to Ecology and EPA" (Ecology et al. 1994). The M-15-94-03 change request was signed in September 1994 to coordinate the CERCLA remediation of the 200-UP-2 Source Operable Unit with the 216-U-12 Crib RCRA Closure. The Change Request M-15-94-03 also changed Milestone M-20-37 to incorporate a new direction for cleanup at Hanford. The milestone was changed to allow submittal of the Hazardous Waste Facility TSD Unit Closure/Postclosure Plan for 216-U-12 in coordination with operable unit work plans (and associated CERCLA documents) for 200-UP-2. The coordination is expected to optimize the efficiency of site characterization and cleanup activities and to result in cost and resource savings.

1.3 CLOSURE STRATEGY

The Hanford Site has been divided into operable units to facilitate cleanup under CERCLA, the State of Washington Hazardous Waste Management Act of 1976, and RCRA corrective action provisions. An operable unit is a grouping of individual waste management units based primarily on geographic area, common waste sources, and similar geohydrologic properties. The Hanford Site waste management units have been categorized into past-practice units and TSD units. A past-practice unit is a waste management unit where waste has been disposed of (intentionally or unintentionally) but is not subject to regulation as a TSD unit. The 216-U-12 Crib is located within the 200-UP-2 Operable Unit, a CERCLA past-practice unit. There are 34 waste management units and 19 unplanned releases located within this operable unit. None of the unplanned releases are associated with 216-U-12 Crib. The groundwater operable unit associated with the 216-U-12 Crib is the 200-UP-1 Groundwater Operable Unit. Any impacts to groundwater will be addressed through the 200-UP-1 Groundwater Operable Unit.

The 216-U-12 Crib received waste materials similar to other facilities in the vicinity (i.e., 216-U-8 Crib) that supported U Plant prior to 1980. The 216-U-12 Crib was designated a RCRA facility because it operated past the effective date of RCRA and received nitric acid wastes that had a pH of <2. This TSD is required to go through closure under WAC 173-303-610 and the Hanford Site-Wide Part B permit application. Investigation and remediation will be through the CERCLA process. The Model Toxics Control Act (MTCA) cleanup levels will be used to compare sampling results to show that no dangerous waste or contaminated soil, structures, or equipment remaining onsite pose a threat to human health or the environment.

Sampling and analysis for the 216-U-12 Crib is described in the U Plant Source AAMSR (DOE-RL 1992). The sampling plan is contained in the *Description of Work for Vadose Borings in Support of the 200-UP-2 Operable Unit* (Kelty 1993). Results are contained in the the *Borehole Summary Report for the 200-UP-2 Operable Unit* (Kelty et al. 1995). The analytes and values are summarized in the

LFI Report, Appendix B, QRA Screening Tables. The FFS will develop the closure strategy from the results of the analyses. A study was done in 1990 by UO_3 operations on organic contaminants in the UO_3 process stream. The results of this study were reported in *Sources of Organic Contaminants in the UO3 Process* (Toebe 1991); no organic contaminants were found that would designate the process condensate stream as a listed dangerous waste pursuant to WAC 173-303-081 and 082. An elementary neutralization unit (ENU) was put inline with the process condensate as the final element prior to being sent to the 216-U-17 Crib (replacement for 216-U-12). The 216-U-17 Crib was not required to be permitted as a TSD under WAC 173-303 with the addition of the ENU.

2.0 SECURITY

An effective security program is maintained at the Hanford Site because of the presence of several facilities that handle dangerous and radioactive materials and the continuing activities associated with these materials. Staffed barricades are maintained around the clock at checkpoints on vehicular access roads leading to the 216-U-12 Crib. All personnel accessing these and other Hanford Site areas must have a DOE-issued security identification badge indicating the appropriate authorization. Personnel may also be subject to a random search of items carried into or out of the Hanford Site.

Site personnel receive training on Hanford Site security regulations through required security education and on-the-job training. Procedures for ensuring personnel compliance with security requirements and provisions for security training are maintained at the Hanford Site. Periodic security-compliance audits and inspections ensure that these procedures are followed.

The 216-U-12 Crib boundaries are currently enclosed by a single-strand chain and post fence that has appropriate radiological warning signs. The 216-U-12 Crib is located inside the 200 West Area perimeter fence.

3.0 GROUNDWATER MONITORING

The 216-U-12 Crib groundwater monitoring program is carried out under the RCRA Groundwater Monitoring Program. The 200-UP-1 Groundwater Operable Unit is tasked with investigation and remediation of the groundwater for this unit. The 200-UP-2 Source Operable Unit is responsible for the vadose zone. The groundwater will continue to be monitored under the current WHC program until a 200-UP-1 ROD is issued. The groundwater monitoring is contained in quarterly and annual reports such as the *Quarterly Report of RCRA Groundwater Monitoring Data for the Period July 1 through September 30, 1994* (DOE-RL 1995a) and the *Annual Report for RCRA Groundwater Monitoring at the Hanford Site* (DOE-RL 1995b).

Results of groundwater monitoring, groundwater quality assessment, and the description of any contamination plumes are contained in the following documents:

- *Westinghouse Hanford Operational Groundwater Status for 1990 - 1992* (WHC 1993b)
- *Hanford Site Groundwater Monitoring for 1993* (PNL 1993)

- *Interim Status Groundwater Monitoring Plan for the 216-U-12 Crib* (WHC 1990)
- *Interim Status Groundwater Quality Assurance Plan for 216-U-12 Crib* (WHC 1993a)

Aquifer identification including area, location, specific geology, and hydrology is contained in the following documents:

- *200 West Groundwater Aggregate Area Management Study Report* (DOE-RL 1993b)
- *Remedial Investigation Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit* (DOE-RL 1993c).

4.0 LOCATION OF DOCUMENTS

Official copies of the documentation supporting a closure plan will be located at the following office:

U.S. Department of Energy,
Richland Operations Office
Federal Building
825 Jadwin Avenue
P.O. Box 550
Richland, Washington 99352

The DOE-RL office will be responsible for amending this closure plan, as deemed necessary, according to the amendment procedures in WAC 173-303-610 through the site-wide permit. The documentation will be kept at the DOE-RL office until closure is complete and certified.

5.0 CLOSURE PLAN AMENDMENT

In addition, as required by WAC 173-303-610(3)(b), the closure plan will be amended if, when conducting final closure activities, unexpected events require a modification of the approved closure plan. If an amendment to the approved closure plan is required, DOE-RL will submit a written request to Ecology to authorize a change to the approved plan through the site-wide permit modification. The written request will include a copy of the closure plan amendment to the site-wide permit for approval; a public review of the revision may be required.

6.0 CERTIFICATION OF CLOSURE

Within 60 days of closure of the TSD unit, the DOE-RL will submit to the Benton County Auditor and the lead regulatory agency a certification of closure and a duly certified survey plat. The certification of closure will be signed by both the DOE-RL and a registered independent professional engineer, stating that the unit has been closed in accordance with the approved closure plan. The

certification will be submitted by registered mail or an equivalent delivery service. Documentation supporting the independent registered professional engineer's certification will be supplied.

7.0 POSTCLOSURE PLAN

Final closure/postclosure of the 216-U-12 Crib (including the piping and radionuclides) will be coordinated with the 200-UP-2 Operable Unit activities. A final cover design, specific postclosure care requirements, and the postclosure permit application will be developed in accordance with procedures in the operable unit documentation.

7.1 GROUNDWATER MONITORING PROGRAM

The current groundwater monitoring program for 216-U-12 Crib is described in Section 3.0 above. Monitoring will continue in accordance with this program through closure of the TSD unit. If it is determined that postclosure care is required, the program will be modified, as necessary to meet the applicable requirements of WAC 173-303-645.

7.2 MAINTENANCE

Should postclosure maintenance be necessary, the facility will be visually inspected throughout the postclosure care period. Inspections will be conducted in accordance with an established schedule; observations will be recorded in a logbook that will be maintained throughout the postclosure care period. The information obtained during the inspections will be used to assess when maintenance activities are necessary. Inspection and maintenance activities will be assigned to personnel that are properly trained to conduct these activities.

The following will be checked during the scheduled inspections as appropriate:

- Condition of the security control devices
- Condition of vegetative cover
- Animal activity such as burrows
- Condition of groundwater monitoring wells including locks, guardposts, and pumps.

Following inspections, maintenance activities will be initiated to correct any problems noted during the inspection.

7.3 POSTCLOSURE PLAN AMENDMENT

The postclosure plan may be amended at any time during the active life of the facility or during the postclosure care period. The DOE-RL must submit a written request to authorize a change in the approved postclosure plan whenever changes in operating plans or facility design affect the approved postclosure plan or events that occur during the active life of the facility, including partial and final closure, affect the approved postclosure plan.

The approved postclosure plan will be amended by submitting a written request to Ecology and the EPA to authorize a change through the site-wide permit modification process, including a public review cycle if necessary, to the approved postclosure plan in the site-wide permit. The written request will include a copy of the amended postclosure plan for approval. The request will be submitted at least 60 days before the proposed change in facility design or operation or no later than 60 days after an unexpected event has occurred that has affected the postclosure plan.

7.4 CERTIFICATION

NOTICE TO LOCAL LAND AUTHORITY

The DOE-RL will submit to the Benton County Land Planning Department, Ecology, and the EPA a survey plat indicating the location and dimensions of the 216-U-12 Crib with respect to permanently surveyed benchmarks no later than the submission of the certification of closure. The survey plat submitted will (1) be prepared and certified by a professional land surveyor licenced to practice in the State of Washington and (2) contain a note, prominently displayed, that states DOE-RL obligation to restrict disturbance of the dangerous waste disposal unit in accordance with the requirements of WAC 173-303-610(a).

In addition, no later than 60 days after certification of closure, the DOE-RL will submit to the Benton County Land Planning Department a record of the type, location, and quantity of dangerous waste disposed within the facility.

NOTICE IN DEED

Within 60 days of the certification of closure, the DOE-RL will, in accordance with state regulations, sign, notarize, and file for recording, the following notice. The notice will be sent to the Auditor of Benton County, P.O. Box 470, Prosser, Washington, with instructions to record this notice in the General Index. This document normally is reviewed in property title searches.

TO WHOM IT MAY CONCERN

The United States Department of Energy-Richland Operations Office, an operations office of the United States Department of Energy, which is a department of the United States government, the undersigned, whose local address is the Federal Building, 825 Jadwin Avenue, Richland, Washington, hereby gives the following notice as required by 40 Code of Federal Regulations (CFR) 264.119(b) and WAC 173-303-610(10) (whichever is applicable):

(a) The United States of America is, and since April 1943, has been in possession in fee simple of the following described lands: (legal description of the 216-U-12 Crib).

(b) The United States Department of Energy-Richland Operations Office, by operation of the 216-U-12 Crib, has disposed of hazardous and/or dangerous waste as defined under the terms of regulations promulgated by the United States Environmental Protection Agency and the Washington Department of Ecology (whichever is applicable) at the above described land.

(c) The future use of the above described land must be consistent with the terms of 40 CFR 264.117(c) and WAC 173-303-610(7)(d) (whichever is applicable) which specify that land use should not interfere with cover integrity.

(d) Any and all future purchasers of this land should inform themselves of the requirements of the regulations and ascertain the amount and nature of waste disposed on the above described property.

(e) The United States Department of Energy-Richland Operations Office has filed a survey plat with the Benton County Planning Department and with the United States Environmental Protection Agency, Region X and the Washington Department of Ecology (whichever are applicable) showing the location and dimensions of site, and a record of the type, location, and quantity of waste disposed of within the unit.

CERTIFICATION OF POSTCLOSURE CARE

No later than 60 days after and furnished to Ecology upon request.

Owner/Operator Postclosure Certification--The DOE-RL will self-certify with the following document or a document similar to it:

> The undersigned, the owner and the operator of the 216-U-12 Crib, hereby certify that I have reviewed the approved 216-U-12 Crib Postclosure Plan and made visual inspection of the facility, and to the best of my information and belief, all postclosure activities were performed in accordance with the specifications identified in the approved postclosure plan. (Signature and date)

Professional Engineer Postclosure Certification--The DOE-RL will engage an independent professional engineer, registered in the state of Washington, to certify that postclosure care for the facility has been conducted in accordance with the approved postclosure plan. The DOE-RL will require the professional engineer to sign the following document or a document similar to it:

> The undersigned, an independent registered professional engineer, hereby certify that I have reviewed the approved 216-U-12 Crib Postclosure Plan and made visual inspection of the facility and to the best of my information and belief, all postclosure activities were performed in accordance with the specifications identified in the approved postclosure plan. (Signature, date, registered professional engineer license number, business address, and phone number).

8.0 REFERENCES

DOE-RL, 1992, *U Plant Aggregate Area Management Study Report*, DOE/RL-91-52, Rev. 0, U. S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993a, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-UP-2 Operable Unit,* DOE/RL 91-19, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993b, *200 West Groundwater Aggregate Area Management Study Report,* DOE/RL-92-16, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL 1993c, *Remedial Investigation Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit,* DOE/RL-92-76, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1995a, *Annual Report for RCRA Groundwater Monitoring at the Hanford Site*, DOE/RL-94-136, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1995b, *Quarterly Report of RCRA Groundwater Monitoring Data for the Period July 1 through September 30, 1994*, DOE/RL-94-036-3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE-RL, 1994, *Hanford Federal Facility Agreement and Consent Order Proposed Change Packages*, September 29, 1994, Washington Department of Ecology, Olympia, Washington, U.S. Environmental Protection Agency, Region X, Seattle, Washington, and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Kelty, G. G., 1993, *Description of Work for Vadose Borings in Support of 200-UP-2 Operable Unit*, WHC-SD-EN-AP-147, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Kelty, G. G., K. A. Lindsey, S. E. Kos, and R. K. Price, 1995, *Borehole Summary Report for the 200-UP-2 Operable Unit, 200 West Area,* BHI-00034, Rev. 1, Bechtel Hanford, Inc., Richland, Washington.

PNL, 1993, *Hanford Site Groundwater Monitoring for 1993,* PNL-10082, Pacific Northwest Laboratory, Richland Washington.

Toebe, W.E., 1991, *Sources of Organic Contaminants in the UO_3 Process*, WHC-SD-CP-TI-160, Westinghouse Hanford Company, Richland, Washington

Toebe, W.E., D.C. Hedengren, and J.H.E. Rasmussen, 1990, *UO_3 Plant Process Condensate Stream-Specific Report*, WHC-EP-0342, Addendum 19, Westinghouse Hanford Company, Richland, Washington.

Thompson, R.J. and S. Sontag, 1991, *Facility Effluent Monitoring Plan for the Uranium Trioxide Facility*, WHC-EP-0470, Westinghouse Hanford Company, Richland, Washington.

WHC, 1990, *Interim Status Groundwater Monitoring Plan for the 216-U-12 Crib*, WHC-SD-EN-AP-019, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1993a *Interim Status Groundwater Quality Assessment Plan for the 216-U-12 Crib*, WHC-SD-EN-AP-108, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1993b, *Westinghouse Hanford Operational Groundwater Status for 1990 - 1992*, WHC-EP-0595, Westinghouse Hanford Company, Richland, Washington.

ATTACHMENT 2 - PART A, FORM 3, 216-U-12 CRIB

THIS PAGE
INTENTIONALLY LEFT BLANK

Please print or type in the unshaded areas only
(fill-in areas are spaced for elite type, i.e., 12 character/inch).

FORM

DANGEROUS WASTE PERMIT APPLICATION

1. EPA/STATE I.D. NUMBER: W A 7 8 9 0 0 0 8 9 6 7

FOR OFFICIAL USE ONLY

APPLICATION APPROVED	DATE RECEIVED *(mo., day, & yr.)*	COMMENTS

II. FIRST OR REVISED APPLICATION

Place an "X" in the appropriate box in A or B below (mark one box only) to indicate whether this is the first application you are submitting for your facility or a revised application. If this is your first application and you already know your facility's EPA/STATE I.D. Number, or if this is a revised application, enter your facility's EPA/STATE I.D. Number in Section I above.

A. FIRST APPLICATION *(place an "X" below and provide the appropriate date)*

☐ 1. EXISTING FACILITY *(See instructions for definition of "existing" facility. Complete item below.)*

MO.	DAY	YR.
0 4		6 0

FOR EXISTING FACILITIES, PROVIDE THE DATE *(mo., day, & yr.)* OPERATION BEGAN OR THE DATE CONSTRUCTION COMMENCED *(use the boxes to the left)*

☐ 2. NEW FACILITY *(Complete item below)*

MO.	DAY	YR.

FOR NEW FACILITIES, PROVIDE THE DATE *(mo., day, & yr)* OPERATION BEGAN OR IS EXPECTED TO BEGIN

B. REVISED APPLICATION *(place an "X" below and complete Section I above)*

☒ 1. FACILITY HAS AN INTERIM STATUS PERMIT

☐ 2. FACILITY HAS A FINAL PERMIT

III. PROCESSES - CODES AND CAPACITIES

A. PROCESS CODE - Enter the code from the list of process codes below that best describes each process to be used at the facility. Ten lines are provided for entering codes. If more lines are needed, enter the code(s) in the space provided. If a process will be used that is not included in the list of codes below, then describe the process *(including its design capacity)* in the space provided on the *(Section III-C)*.

B. PROCESS DESIGN CAPACITY - For each code entered in column A enter the capacity of the process.

1. AMOUNT - Enter the amount.

2. UNIT OF MEASURE - For each amount entered in column B(1), enter the code from the list of unit measure codes below that describes the unit of measure used. Only the units of measure that are listed below should be used.

PROCESS	PROCESS CODE	APPROPRIATE UNITS OF MEASURE FOR PROCESS DESIGN CAPACITY
Storage:		
CONTAINER (barrel, drum, etc)	S01	GALLONS OR LITERS
TANK	S02	GALLONS OR LITERS
WASTE PILE	S03	CUBIC YARDS OR CUBIC METERS
SURFACE IMPOUNDMENT	S04	GALLONS OR LITERS
Disposal:		
INJECTION WELL	D80	GALLONS OR LITERS
LANDFILL	D81	ACRE-FEET *(the volume that would cover one acre to a depth of one foot)* OR HECTARE-METER
LAND APPLICATION	D82	*ACRES OR HECTARES*
OCEAN DISPOSAL	D83	GALLONS PER DAY OR LITERS PER DAY
SURFACE IMPOUNDMENT	D84	GALLONS OR LITERS

PROCESS	PROCESS CODE	APPROPRIATE UNITS OF MEASURE FOR PROCESS DESIGN CAPACITY
Treatment:		
TANK	T01	GALLONS PER DAY OR LITERS PER DAY
SURFACE IMPOUNDMENT	T02	GALLONS PER DAY OR LITERS PER DAY
INCINERATOR	T03	TONS PER HOUR OR METRIC TONS PER HOUR; GALLONS PER HOUR OR LITERS PER HOUR
OTHER (Use for physical, chemical, thermal or biological treatment processes not occurring in tanks, surface impoundments or incinerators. Describe the processes in the space provided; Section III-C.)	T04	GALLONS PER DAY OR LITERS PER DAY

UNIT OF MEASURE	UNIT OF MEASURE CODE
GALLONS	G
LITERS	L
CUBIC YARDS	Y
CUBIC METERS	C
GALLONS PER DAY	U
LITERS PER DAY	V
TONS PER HOUR	D
METRIC TONS PER HOUR	W
GALLONS PER HOUR	E
LITERS PER HOUR	H
ACRE-FEET	A
HECTARE-METER	F
ACRES	B
HECTARES	Q

EXAMPLE FOR COMPLETING SECTION III *(shown in line numbers X-1 and X-2 below): A facility has two storage tanks, one tank can hold 200 gallons and the other can hold 400 gallons.* The facility also has an incinerator that can burn up to 20 gallons per hour.

LINE NUMBER	A. PROCESS CODE *(from list above)*	B. PROCESS DESIGN CAPACITY 1. AMOUNT *(specify)*	B. 2. UNIT OF MEASURE *(enter code)*	FOR OFFICIAL USE ONLY	LINE NUMBER	A. PROCESS CODE *(from list above)*	B. PROCESS DESIGN CAPACITY 1. AMOUNT *(specify)*	B. 2. UNIT OF MEASURE *(enter code)*	FOR OFFICIAL USE ONLY
X-1	S 0 2	600	G		5				
X-2	T 0 3	20	E		6				
	D 8 1	50,000	U		7				
2					8				
3					9				
4					10				

Continued from the front.

III. PROCESSES (continued)

SPACE FOR ADDITIONAL PROCESS CODES OR FOR DESCRIBING OTHER PROCESS (code "T04"). FOR EACH PROCESS ENTERED HERE INCLUDE DESIGN CAPACITY

D81

The 216-U-12 Crib was used to dispose of UO_3 (uranium-oxide) Plant corrosive process condensate. The 216-U-12 Crib, a percolation unit, was designed to receive mixed waste from the UO_3 Plant for approximately 5 minutes every hour, 100 gallons (379 liters) per minute, and to dispose of the process condensate by percolation into the soil column.

Process condensate discharges were considered only a dangerous waste due to corrosivity caused by UO_3 Plant operations. After January 1987, process condensate was administratively controlled to prevent corrosive dangerous waste discharge to the 216-U-12 Crib. The unit continued to receive process condensate until the crib pipeline was cut and permanently capped on January 30, 1988. The 216-U-12 Crib will be closed under interim status.

IV. DESCRIPTION OF DANGEROUS WASTES

A. DANGEROUS WASTE NUMBER - Enter the four digit number from Chapter 173-303 WAC for each listed dangerous waste you will handle. If you handle dangerous wastes which are not listed in Chapter 173-303 WAC, enter the four digit number(s) that describes the characteristics and/or the toxic contaminants of those dangerous wastes.

B. ESTIMATED ANNUAL QUANTITY - For each listed waste entered in column A estimate the quantity of that waste that will be handled on an annual basis. For each characteristic or toxic contaminant entered in column A estimate the total annual quantity of all the non-listed waste(s) that will be handled which possess that characteristic or contaminant.

C. UNIT OF MEASURE - For each quantity entered in column B enter the unit of measure code. Units of measure which must be used and the appropriate codes are:

ENGLISH UNIT OF MEASURE	CODE	METRIC UNIT OF MEASURE	CODE
POUNDS	P	KILOGRAMS	K
TONS	T	METRIC TONS	M

If facility records use any other unit of measure for quantity, the units of measure must be converted into one of the required units of measure taking into account the appropriate density or specific gravity of the waste.

D. PROCESSES

1. PROCESS CODES:

For listed dangerous waste: For each listed dangerous waste entered in column A select the code(s) from the list of process codes contained in Section III to indicate how the waste will be stored, treated, and/or disposed of at the facility.

For non-listed dangerous wastes: For each characteristic or toxic contaminant entered in Column A, select the code(s) from the list of process codes contained in Section III to indicate all the processes that will be used to store, treat, and/or dispose of all the non-listed dangerous wastes that possess that characteristic or toxic contaminant.

Note: Four spaces are provided for entering process codes. If more are needed: (1) Enter the first three as described above; (2) Enter "000" in the extreme right box of Item IV-D(1); and (3) Enter in the space provided on page 4, the line number and the additional code(s).

2. PROCESS DESCRIPTION: If a code is not listed for a process that will be used, describe the process in the space provided on the form.

NOTE: DANGEROUS WASTES DESCRIBED BY MORE THAN ONE DANGEROUS WASTE NUMBER - Dangerous wastes that can be described by more than one Waste Number shall be described on the form as follows:

1. Select one of the Dangerous Waste Numbers and enter it in column A. On the same line complete columns B, C, and D by estimating the total annual quantity o the waste and describing all the processes to be used to treat, store, and/or dispose of the waste.
2. In column A of the next line enter the other Dangerous Waste Number that can be used to describe the waste. In column D(2) on that line enter "included with above" and make no other entries on that line.
3. Repeat step 2 for each other Dangerous Waste Number that can be used to describe the dangerous waste.

EXAMPLE FOR COMPLETING SECTION IV *(shown in line numbers X-1, X-2, X-3, and X-4 below)* - A facility will treat and dispose of an estimated 900 pounds per ye. of chrome shavings from leather tanning and finishing operation. In addition, the facility will treat and dispose of three non-listed wastes. Two wastes are corrosive only and there will be an estimated 200 pounds per year of each waste. The other waste is corrosive and ignitable and there will be an estimated 100 pounds per ye of that waste. Treatment will be in an incinerator and disposal will be in a landfill.

LINE NO.	A. DANGEROUS WASTE NO. *(enter code)*	B. ESTIMATED ANNUAL QUANTITY OF WASTE	C. UNIT OF MEASURE *(enter code)*	D. PROCESSES 1. PROCESS CODES *(enter)*	D. PROCESSES 2. PROCESS DESCRIPTION *(if a code is not entered in D(1))*
	K 0 5 4	900	P	T 0 3 D 8 0	
X-2	D 0 0 2	400	P	T 0 3 D 8 0	
X-3	D 0 0 1	100	P	T 0 3 D 8 0	
X-4	D 0 0 2			T 0 3 D 8 0	*included with above*

Continued from page 2.
NOTE: Photocopy this page before completing if you have more than 26 wastes to list.

I.D. NUMBER *(entered from page 1)*

\	7	8	9	0	0	0	8	9	6	7

DESCRIPTION OF DANGEROUS WASTES (continued)

LINE NO.	A. DANGEROUS WASTE NO. *(enter code)*	B. ESTIMATED ANNUAL QUANTITY OF WASTE	C. UNIT OF MEASURE *(enter code)*	D. PROCESSES 1. PROCESS CODES *(enter)*	D. PROCESSES 2. PROCESS DESCRIPTION *(if a code is not entered in D(1))*
1	D002	4,454,000	P	D81	Percolation
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					

Continued from the front.

DESCRIPTION OF DANGEROUS WASTES (continued)

USE THIS SPACE TO LIST ADDITIONAL PROCESS CODES FROM SECTION D(1) ON PAGE 3.

The 216-U-12 Crib was used to dispose of corrosive (D002) UO_3 Plant process condensate until January 1987, at which time administrative controls were implemented to neutralize the condensate before discharge. Waste consisted of process condensate off-gases from the production of UO_3 powder from uranium nitrate hexahydrate solutions. When the plant was operating, the pH of this waste ranged from 0.5 to 1.5.

When the UO_3 Plant was shut down for periods of time, the pH of the process condensate ranged from 2.0 to 4.0. The UO_3 Plant has been permanently shut down and no process condensate is being discharged to the 216-U-12 Crib. Past process rates show that approximately 1,700,000 gallons (6,440,000 liters) per year of process condensate were disposed in the 216-U-12 Crib.

V. FACILITY DRAWING

All existing facilities must include in the space provided on page 5 a scale drawing of the facility *(see instructions for more detail)*.

VI. PHOTOGRAPHS

All existing facilities must include photographs *(aerial or ground-level)* that clearly delineate all existing structures; existing storage, treatment and disposal areas; and sites of future storage, treatment or disposal areas *(see instructions for more detail)*.

VII. FACILITY GEOGRAPHIC LOCATION This information is provided on the attached drawings and photos.

LATITUDE *(degrees, minutes, & seconds)*	LONGITUDE *(degrees, minutes, & seconds)*

VIII. FACILITY OWNER

[x] A. If the facility owner is also the facility operator as listed in Section VII on Form 1, "General Information", place an "X" in the box to the left and skip to Section I below.

B. If the facility owner is not the facility operator as listed in Section VII on Form 1, complete the following items:

1. NAME OF FACILITY'S LEGAL OWNER	2. PHONE NO. *(area code & n*

3. STREET OR P.O. BOX	4. CITY OR TOWN	5. ST.	6. ZIP CODE

IX. OWNER CERTIFICATION

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this and all attached documents, and that based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

NAME *(print or type)*	SIGNATURE	DATE SIGNED
John D. Wagoner, Manager U.S. Department of Energy Richland Operations Office	John D. Wagoner	6/30/94

X. OPERATOR CERTIFICATION

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this and all attached documents, and that ba my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

NAME *(print or type)*	SIGNATURE	DATE SIGNED
SEE ATTACHMENT	Att2-6	

CONTINUE ON PAGE

X. OPERATOR CERTIFICATION

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this and all attached documents, and that based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

John D. Wagoner

Owner/Operator
John D. Wagoner, Manager
U.S. Department of Energy
Richland Operations Office

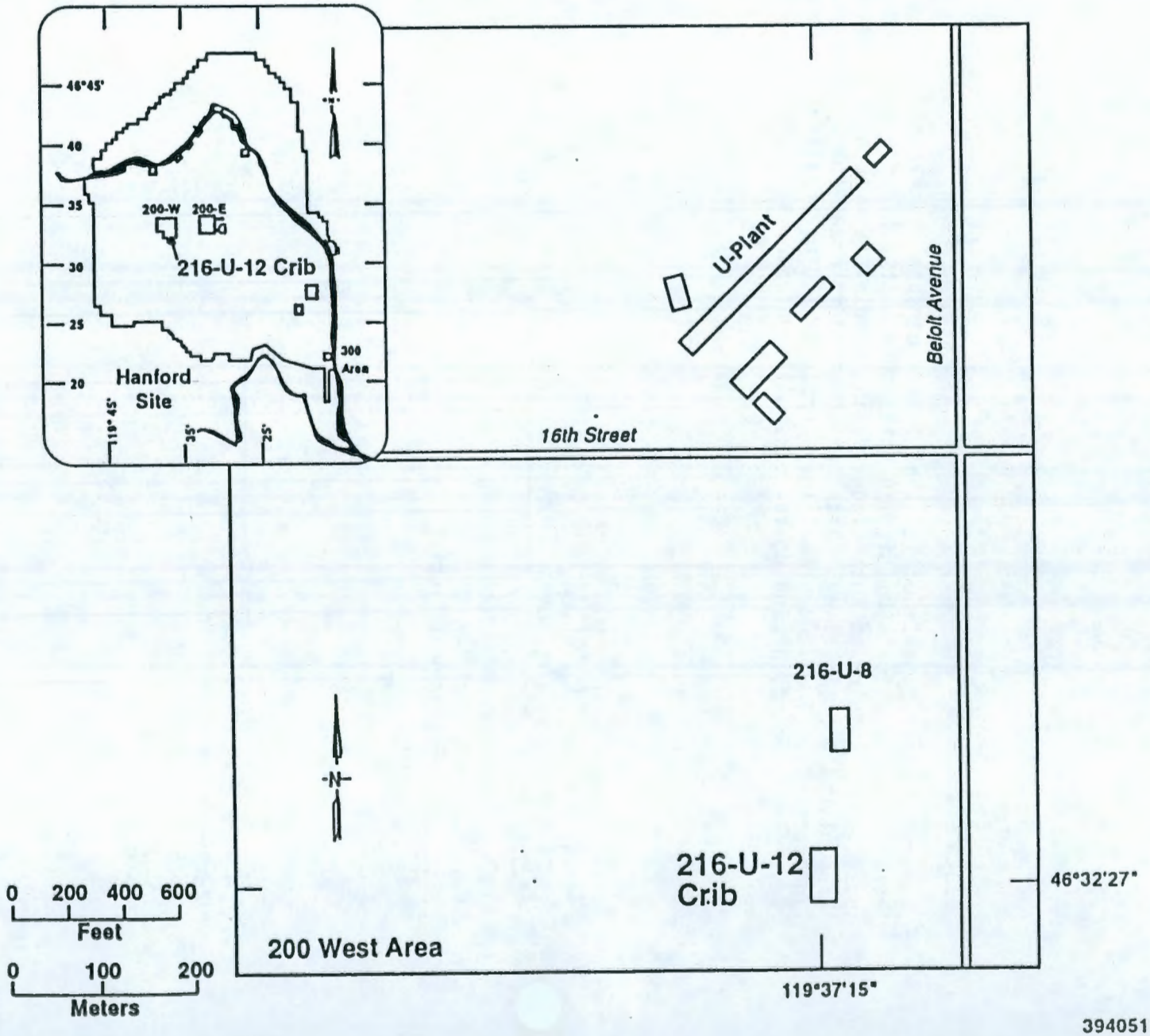
6/30/94
Date

Edward S. Keen

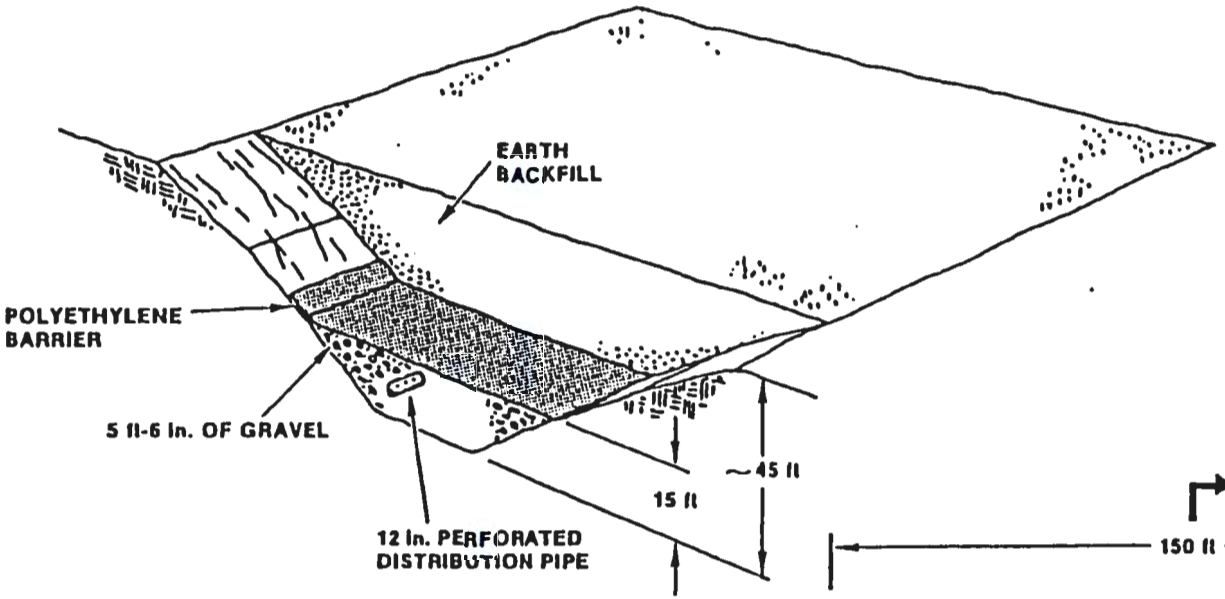
Co-operator
Edward S. Keen, President
Bechtel Hanford, Inc.

6/30/94
Date

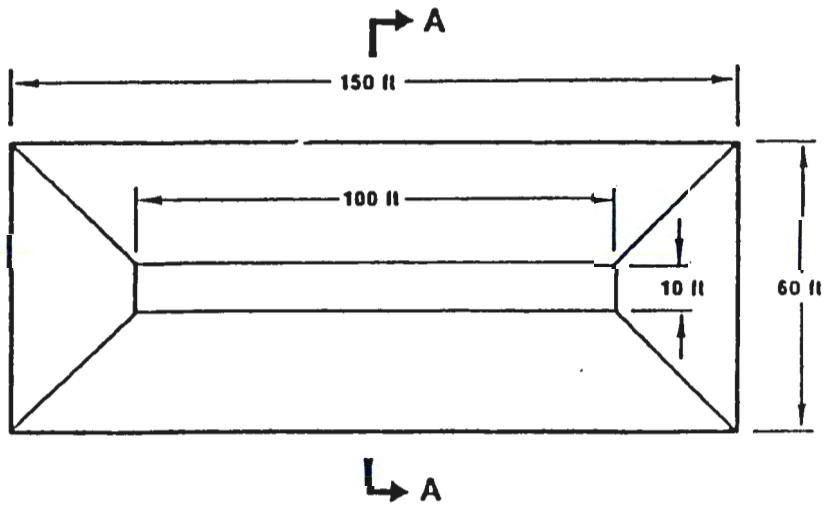
216-U-12 Crib
Site Plan



216-U-12 CRIB



SECTION A-A



PLAN

2B8707-13.80

For conversions, apply the following:

Feet to meters--multiply feet by 0.3048
Inches to centimeters--multiply inches by 2.54.

216-U-12 CRIB

46°32'27"
119°37'15"

8704509-1CN
(PHOTO TAKEN 1987)

APPENDIX B

ELECTRONIC FILE

SCREENING TABLES FOR HUMAN HEALTH AND ECOLOGICAL RISK

THIS PAGE
INTENTIONALLY LEFT BLANK

DISTRIBUTION

Number of Copies

ONSITE

20	M. E. Todd (ITH) (10)	H6-05
	M. A. Wasemiller (ITH)	H6-02
	J. G. Woolard (BHI)	H4-89
	G. R. Eidam (BHI)	H4-91
	BHI Document Control (3)	H4-79
	BHI Project File (3)	H6-08
	Environmental Resource Center	H6-07