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100 Area Feasibility Study Phases 1 and 2

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EXECUTIVE SUMMARY

Since the signing of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) in 1989, the parties to the agreement have recognized the need to modify the approach to conducting investigations and studies 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 Site Past Practice Strategy (DOE-RL 1991d). The principles of the strategy are embodied in the Hanford Federal Facility Agreement and Consent Order Change Package, dated May 13, 1991 (Ecology et al. 1991).

An important aspect of the past practice strategy and its associated TPA change package recognizes that the Hanford Site presents a number of unique circumstances that call for innovative approaches to conducting investigations and feasibility studies (FS). The 100 Area has been divided into 25 operable units (OU) based largely on location. While these units are separated geographically, they all contain sites which are very similar with regard to types of contaminants and methods of disposal. Consequently, the Hanford Site Past Practice Strategy as applied to the 100 Area defines an aggregate approach to evaluate groups of sites based on their similarity, as opposed to their geographical location and operable unit designation.

Thus the 1991 TPA change package mandates that, rather than performing separate feasibility studies for each of the 100 Area OUs, the feasibility studies should evaluate remedial alternatives for the entire 100 Area. To meet this objective, the change package called for three "base" reports which would consider: 1) source operable units (except 100-N Area), 2) groundwater operable units, and 3) 100-N Area, as it is distinctly different from the other 100 Areas. The 100 Area feasibility study presented in this document meets the objectives of the change package; however, the approach is further streamlined by condensing the "base" studies into a single document to avoid having to duplicate large amounts of common information, but at the same time provide separate sections to address definition of remedial alternatives by either media or area. This not only reduces the cost of document preparation, but also shortens the review times and reduces the potential for document inconsistencies as a result of separate reviews. This document separates the studies by three media: solid wastes, soil/riverbank sediments, and groundwater. Riverbank sediments are that portion of the vadose zone, on the shore of the river, which are contaminated as a result of fluctuating groundwater levels near the river. Additionally, the N Area is treated as a separate site based on its somewhat unique characteristics, making a total of four types of sites or units evaluated.

This 100 Area Phase I/II FS is built around existing data. In a typical Remedial Investigation/Feasibility Study (RI/FS), the Phase I/II FS is not completed until the RI Phase I is complete, although the Phase I/II FS is often started while the Phase I RI is being conducted. However, for the 100 Area, the size of the existing site characterization database is larger than the end result of many RIs and is adequate for identifying and screening remedial alternatives. Use of existing data to initiate and expedite the FS process is consistent with the past practice strategy. New site characterization data, while important for

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later detailed analysis, would not likely affect the outcome of the alternatives development and screening phases. Finally, waiting for Limited Field Investigation (LFI) data to start the FS process would cause unacceptable schedule delays in starting subsequent programs such as treatability studies.

The 100 Area Phase I/II FS evaluates the known characteristics of the Hanford 100 Area and identifies the range of remedial alternatives that are most appropriate for protection of human health and the environment for the entire aggregate area. The purpose of the 100 Area FS is to:

- Provide a more generalized view of applicable and workable remedial technologies as applied to the site contamination problems as a whole
- Evaluate groups of sites based on similarity, as opposed to geographical location and operable unit designation
- Develop and screen remedial alternatives to be used in the detailed analysis phase in focused feasibility studies for Interim Remedial Measures (IRMs) or final FSs for individual operable units.

BACKGROUND

Four areas of the Hanford Site (the 100, 200, 300, and 1100 Areas) have been included on the EPA's National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

The Hanford Site is a 560 mi^2 (1,434 km^2) tract of land located in the south-central portion of the State of Washington in the counties of Benton, Franklin, and Grant. The 100 Area lies along the southern shoreline of the Columbia River at the north end of the Hanford Site (See Figure 1-1).

Between 1943 and 1962, nine water-cooled, graphite-moderated plutonium production reactors were built along the shore of the Columbia River upstream from the now-abandoned town of Hanford. Eight of these reactors (B, C, D, DR, F, H, KE, and KW) are retired from service and are under evaluation for decommissioning. The ninth reactor, N, was recently taken out of standby status and will be retired.

Waste disposal practices associated with operations of the 100 Area reactors resulted in substantial releases of contamination to both soil and groundwater media in the vicinity of the reactors. The major sources of contamination stem from the use of large amounts of cooling water, which flowed through the reactor core. This cooling water was often contaminated with significant concentrations of radionuclides. As a result of leaks in the spent cooling water transfer systems and as a result of intentional water disposal in cribs and trenches, significant volumes of soil and underlying groundwater have become contaminated. In addition, solid wastes contaminated primarily with radionuclides were buried in unlined trenches.

Solid and liquid waste disposal units and groundwater plumes constitute the 100 Area past practice OUs. However, reactor and other major buildings are excluded from the past practice OUs. These will be decommissioned as part of the Surplus Reactors Decommissioning Program and are thus outside the scope of this FS.

Since shutdown of the production reactors, limited environmental investigations have been performed to characterize the nature and extent of the contamination. Such investigations, while not totally definitive, especially for non-radiological contaminants, have provided a reasonably solid database upon which studies of remedial approaches can be performed. The compilation of existing information on waste releases and environmental sampling is summarized in this report and forms the basis for conducting these phases of the feasibility study.

SUMMARY OF THE FEASIBILITY STUDY

The 100 Area Phase I/II FS consists of four principal tasks:

- Identify contaminants of concern for the media of concern
- Identify applicable or relevant and appropriate requirements (ARARs) pertinent to all general response actions including waste disposal
- Develop remedial alternatives (Phase I) applicable to the 100 Area including development of remedial action objectives, development of general response actions, identification and screening of technologies and process options, and assembly of remedial alternative from representative technology types
- Screen alternatives (Phase II) developed in Phase I for implementability, effectiveness, and costs to identify those alternatives which warrant advancement to the detailed analysis phase of future focused feasibility studies.

Seven sections are included in this FS report. Section 1.0 provides an introduction which also includes a summary of background and existing data, including:

- A history of 100 Area operations and descriptions of facility characteristics and waste generating processes
- Physical setting including such aspects as geology, hydrogeology, meteorology, environmental resources, etc.
- Nature and extent of contamination in the media of concern.

The sources of contaminants in the 100 Area consist of reactor cooling water effluent treatment, transfer, and disposal systems; sanitary sewage treatment, transfer, and disposal systems; solid waste burial grounds (including decommissioned facility sites); fuel fabrication waste handling areas; miscellaneous unplanned release areas; chemical storage areas;

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maintenance and decontamination areas; and experimental laboratory disposal areas. The major contaminants in the 100 Area are the radionuclides directly associated with reactor operations. However, as a result of utilities production as well as decontamination and maintenance operations, both organic and inorganic chemicals were used and disposed of, resulting in soil and groundwater chemical contamination. While substantial sampling data exist for radionuclide contamination, data on non-radiological contamination are somewhat limited. The major radiological contaminants present in the 100 Area environmental media include:

- Tritium
- Cobalt-60
- Strontium-90
- Cesium-137
- Europium-152/154/155
- Uranium-235/238
- Plutonium-239/240.

Chemical contaminants disposed to 100 Area soils as part of the liquid waste streams include, but are not limited to:

- Chromium from sodium dichromate added to reactor cooling water
- Decontamination fluids containing chromic, citric, oxalic, nitric, and sulfuric acids
- Mercury from manometers and thermometers
- PCBs from electrical equipment.

Solid wastes included irradiated components from the reactor such as graphite, thimbles, control rods, spacers, and process dummies as well as incidental soft wastes such as clothing and rags. In addition, decontamination and decommissioning activities created solid waste in the form of demolition materials which were buried in the 100 Area.

Section 2.0 of the report provides an assessment of contaminants of concern for the 100 Area. Since a baseline risk assessment has not yet been performed for the 100 Area, one objective of this study was to provide a uniform methodology for determining potential contaminants of concern to use as a starting point for developing remedial alternatives. The determination of potential contaminants of concern was conducted in two phases as follows:

- The identification of regulatory contaminants of concern by comparing concentration data for radiological and/or chemical substances potentially released in the 100 Area with background concentrations and established regulatory limits

- Evaluation of the toxicological significance of each regulatory contaminant of concern.

Decision logic diagrams were developed to determine the regulatory contaminants of concern. (Figures 1 and 2 of Appendix A) Contaminants which the data showed were below background were included on a suspect contaminant list, i.e., future characterization data

TABLE 1: POTENTIAL CONTAMINANTS OF CONCERN FOR THE 100 AREAS

RADIONUCLIDES	METALS	OTHER INORGANIC COMPOUNDS/IONS	VOCs	OTHER ORGANICS
Tritium	Arsenic	Ammonium/Ammonia	Acetone	Acetic Acid
Carbon-14	Barium	Asbestos	Benzene	Bis (2-ethyhexyl) phthalate
Calcium-41	Beryllium	Chlorine	Chlorobenzene	Ethylenediamine
Cobalt-60	Boron	Cyanide	Chloroform	Formic Acid
Nickel-63	Cadmium	Fluoride	Ethylbenzene	Hydrazine
Selenium-79	Chromium	Nitrate	Methylene Chloride	PCBs
Krypton-85	Lead	Nitrite	Methyl Isobutyl Ketone	Petroleum Products
Strontium-90	Manganese	Phosphoric Acid	Perchloroethylene	Thiourea
Zirconium-93	Mercury		Trans -1,2-Dichloroethene	
Niobium-94	Vanadium		Trichloroethene	
Technetium-99			Xylenes	
Palladium-107				
Cadmium-113				
Antimony-125				
Iodine-129				
Cesium-134				
Cesium-137				
Samarium-151				
Europium-152				
Europium-154				
Radium-226/228				
Uranium-235/238				
Plutonium-238				
Plutonium-239/240				
Plutonium-241				
Americium-241				

Note: Does not include suspect contaminants. Refer to Section 2.0 for breakdown of contaminants of concern by media.

may warrant their inclusion as contaminants of concern. The qualitative toxicity assessment further refined the contaminants of concern determination by evaluating the toxicological significance of each regulatory contaminant of concern. The end product of this effort was a list of potential contaminants of concern and suspect contaminants for sources, groundwater, and the 100-N Area (presented in Section 2.0 and in Appendix A). A composite list, including the potential contaminants of concern only, is provided in Table 1 below.

Section 3.0 documents the results of the effort to identify potential ARARs. Three categories of ARARs are defined in the U.S. Environmental Protection Agency document titled *CERCLA Compliance with Other Laws Manual* (EPA, 1988c): chemical-specific, location-specific, and action-specific ARARs. Table 2 lists some of the more prominent potential ARARs for the 100 Area. Determination of ARARs is an iterative process and thus the list of potential ARARs will be refined with additional data from future 100 Area investigations and studies.

Section 4.0 documents the Phase I effort to identify and screen remedial technologies and process options. This section also identifies remedial action objectives (RAOs), remedial action goals and general response actions (GRAs), and provides estimates of areas and volumes of contaminated materials.

TABLE 2: POTENTIAL FEDERAL AND STATE ARARs FOR THE 100 AREA		
CHEMICAL SPECIFIC	**ACTION SPECIFIC**	**LOCATION SPECIFIC**
Safe Drinking Water Act	Clean Air Act	Clean Water Act
Clean Water Act	Resource Conservation and Recovery Act (RCRA)	National Flood Insurance Program
State of Washington Ground Water Quality Standards	Clean Water Act	Endangered Species Act
Model Toxics Control Act	Hazardous Waste Management Act	RCRA
Clean Air Act	Water Pollution Control Act	Bald Eagle Protection Rules
	Model Toxics Control Act	
	State air pollution regulations	
Note: To-be-considered materials (TBCs) are not included. Additional ARARs are presented in Section 3.0 and Appendix B.		

The media of interest for the RAOs include soils, groundwater, riverbank sediments, solid wastes generated during site remediation activities. The same media and RAOs apply to the 100-N Area as well.

Remedial action goals are the target cleanup levels which satisfy the RAOs, and as such, are considered a subset of RAOs. These cleanup levels are driven by risk assessments and/or ARARs. In lieu of site-specific investigation and risk assessment data, assumptions were made to develop remedial goals. While the use of assumptions instead of site-specific data provides for a greater level of uncertainty, preliminary RAOs and remedial action goals can still be developed to a degree adequate for the Phase I/II alternatives development. However, site-specific data and definitive risk assessments will be necessary for future detailed analysis of alternatives. For purposes of this Phase I/II FS, the preliminary remedial action goals are based primarily on state and federal regulatory limits (potential ARARs) along with selected assumptions regarding cleanup levels as developed in the *Hanford Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991c).

Estimates of volumes of contaminated media were based primarily upon values presented in the *100 Area Hanford Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991e).

General response actions were identified as follows:

- No Action
- Institutional Actions
- Containment Actions
- Removal/Disposal Actions
- In situ Treatment Actions
- Removal/Treatment/Disposal Actions

The identification and screening of technologies considered the universe of technology types that would be potentially applicable to the identified general response actions. Technologies include general categories such as chemical treatment, thermal treatment, stabilization/solidification, or capping. Within each technology category are process options. Examples of process options within the chemical treatment technology category include precipitation, ion exchange, and oxidation/reduction.

Potentially-feasible, media-specific technologies and process options were identified for each of the GRAs by compiling information obtained from EPA documents, reference program sources, personal interviews, and other relevant technical references.

Technologies and process options were initially screened in the Phase I FS to eliminate those that are not technically implementable for the site conditions or contaminants encountered in the 100 Area. This first screening step only considered whether a technology and/or process option can be effectively implemented at the site, based on an assessment of existing site data on both contaminant types/concentrations and site characteristics.

A second screening step was performed on technologies/process options which considered effectiveness as a primary criterion with implementability (now including administrative implementability) and cost considered as secondary criteria.

Technologies and process options were identified for three media: solid wastes, groundwater, and soils/riverbank sediments. While the 100-N Area has been set apart as a separate medium in this FS, analysis of the applicability of technologies and process options indicated that there are no unique features of the 100-N Area which would present technologies or options differing from the three basic media which have been considered.

Section 5.0 documents the Phase II effort to 1) assemble screened technologies and process options into area-wide alternatives and 2) screen the alternatives with respect to implementability, effectiveness, and cost to arrive at a list for advancement to future focused feasibility studies.

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In Phase II of the FS, the list of technologies and process options which passed the Phase I screening steps was used to assemble 27 alternatives representing the entire range of general response actions as well as treatment and containment combinations. Tables 3, 4 and 5 below list the component technologies and process options for each of the 27 alternatives for the solid waste, groundwater, and soils media, respectively.

The Phase II FS also included an alternatives evaluation and screening step. The goal of the alternatives screening step was to limit the number of alternatives that must undergo detailed analysis while still preserving the range of response actions and technologies to be considered. Each of the 27 alternatives was described in sufficient detail such that they could be evaluated in the alternatives screening step. Descriptions were based upon the general process information developed for each technology/process option in Phase I. In addition, each alternative was described in view of known site conditions, contaminant ranges, volumes of contaminated media, and other factors.

In accordance with the CERCLA FS process (EPA 1988), each alternative was evaluated against established criteria. The criteria are essentially the same as used for technology screening, i.e., implementability, effectiveness, and cost. However, in the alternatives evaluation stage, the criteria were now viewed in more detail, considering more site-specific conditions, and as applied to the integrated remedial solution rather than to just a portion of the solution. The CERCLA evaluation criteria are listed as follows:

Effectiveness:

- Short-term protection of human health
- Short-term protection of the environment
- Long-term protection of human health
- Long-term protection of the environment
- Reduction of mobility, toxicity, or volume reduction.

Implementability - technical feasibility:

- Constructability
- Operational reliability
- Maintenance.

Implementability - administrative feasibility:

- Agency approvals
- Availability of services
- Specialized equipment and personnel.

Cost - relative cost:

The alternative evaluation step culminated in a formal scoring process to provide a numerical qualification of how each alternative met the evaluation criteria. An alternative's

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rating against a specific criterion was not a pass/fail situation but an indication of the degree to which the alternative meets the criterion. This degree, which considers the balance of pros and cons for each factor, is represented by a simple 1 to 5 scale, where "1" (poor) suggests that the criterion is not met at all while "5" (excellent) suggests that the criteria is met very well.

The scoring was performed independently by nine individuals who made up the FS project team. Multiple scoring was done to reduce the influence of personal bias in the final results. The individual scores were then averaged to form an initial composite alternative ranking score. The guidance document (EPA 1988a) directs that the effectiveness criterion should be weighted more heavily than implementability and cost criterion.

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TABLE 3: 100 AREA ALTERNATIVES FOR SOLID WASTES

TECHNOLOGY/PROCESS OPTION	NO ACTION	INSTITUTIONAL ACTION	CONTAINMENT ACTION	REMOVAL/ DISPOSAL ACTION			IN SITU TREATMENT ACTION		REMOVAL/ TREATMENT/ DISPOSAL ACTION	
ALTERNATIVE NUMBER	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7	SW-8	SW-9	SW-10
Monitoring (100 Area Groundwater)		•	•				•	•		
Access Restrictions		•								
Deed Restrictions		•								
Run-on/Run-off Control			•							
Capping: Hanford Barrier			•	•			•	•	•	•
Capping: RCRA Multi-media Cap			•	•			•	•		
Removal: Excavation/Demolition				•	•	•			•	•
Onsite Disposal: Vault, Trench				•					•	•
Onsite Disposal: Vault, RCRA Landfill						•				
Offsite Disposal					•					
Physical Treatment: Dynamic Compaction							•			
Stabilization/Solidification: Vibration-Aided Grout Injection							•	•		
Treatment: Thermal Desorption									•	
Treatment: Size Reduction by Compaction									•	
Stabilization/Solidification: Cement-based									•	
Treatment: Incineration										•
Stabilization/Solidification: Bitumen-based										•

• Indicates technology/option is selected for the alternative

TABLE 4: 100 AREA ALTERNATIVES FOR GROUNDWATER

TECHNOLOGY/PROCESS OPTION	NO ACTION	INSTITUTIONAL ACTION	CONTAINMENT ACTION	IN SITU TREATMENT ACTION	REMOVAL/TREATMENT/ DISPOSAL ACTION	
ALTERNATIVE NUMBER	GW-1	GW-2	GW-3	GW-4	GW-5	GW-6
Monitoring		•	•	•	•	•
Water-rights Restrictions		•				
Deed Restrictions		•				
Alternate Water Supply		•				
Vertical Barrier: Slurry Walls			•			
Hydraulic Control: Extraction Wells			•			
Biological Treatment: Biodenitrification				•	•	•
Physical Treatment: In Situ Air Stripping				•		
Removal: Extraction Wells					•	•
Chemical Treatment: Chem. Oxidation					•	
Chemical Treatment: Precipitation					•	
Chemical Treatment: Chemical Reduct.					•	
Physical Treatment: Media Filtration					•	•
Physical Treatment: Ion Exchange					•	
Stab./Solidif.: Cement-based					•	•
Disposal: Reinjection into Aquifer					•	
Physical Treatment: Air Stripping						•
Physical Treatment: Forced Evaporation						•
Physical Treatment: Reverse Osmosis						•
Disposal: Crib Disposal						•

• Indicates technology/option is selected for the alternative

TABLE 5: 100 AREA ALTERNATIVES FOR SOIL/RIVERBANK SEDIMENTS

TECHNOLOGY/PROCESS OPTION	NO ACTION	INSTITUT. ACTION	CONTAIN. ACTION	REMOVAL/ DISPOSAL ACTION			IN SITU TREATMENT ACTION			REMOVAL/ TREATMENT/ DISPOSAL ACTION	
ALTERNATIVE NUMBER	SS-1	SS-2	SS-3	SS-4	SS-5	SS-6	SS-7	SS-8	SS-9	SS-10	SS-11
Monitoring (100 Area Groundwater)		•	•				•	•	•		
Access Restrictions		•									
Deed Restrictions		•									
Run-on/Run-off Control: Grading, Diversion/collection, Revegetation			•								
Capping: Hanford Barrier			•	•		•				•	•
Capping: RCRA Multi-media Cap			•	•		•					•
Removal: Excavation/Demolition				•	•	•				•	•
Onsite Disposal: Vault, Trench				•						•	•
Onsite Disposal: Vault, RCRA Landfill						•					
Offsite Disposal					•						•
Biological Treatment: Biodenitrification							•		•		
Stabilization/Solidification: Vitrification							•	•	•	•	•
Physical Treatment: Steam Stripping							•				
Physical Treatment: Vapor Extraction									•		
Thermal Treatment: Thermal Desorption										•	•
Physical Treatment: Soil Washing by Attrition Scrubbing										•	
Chemical Treatment: Soil Washing by Chemical Leaching											•

• Indicates technology/option is selected for the alternative

For the purposes of this feasibility study, this was accomplished by first normalizing the sum of individual factors for each criterion to 100 (for example, a total of "25" was possible for the five factors considered for evaluating effectiveness; the effectiveness score was normalized by multiplying the new score by 4), and then by weighting (multiplying by a weighting factor).

The evaluation criteria were weighted as follows:

	Weight
• Effectiveness	0.6
• Implementability	0.3
• Cost	0.1
Total	1.0

The decision to discard alternatives at this point was made on the basis of retaining a broad range of general response actions for detailed analysis. This is deemed necessary for this particular feasibility study due to an incomplete set of input parameters that are specified in the guidance document for traditional feasibility studies. Alternatives recommended for consideration at the detailed analysis/focused feasibility study levels cover the spectrum of all potential remedial actions from "no action" (which would be applicable only if a risk assessment indicates acceptability of such an approach) to removal, treatment, and disposal actions, which reduce uncertainty and risk but at a high cost.

Based on composite scores, alternatives were selected which are considered representative of the range of general response actions for future FS evaluations. These are listed in Table 6 below.

The retained alternatives may serve as a baseline from which to evaluate the future impact of site characterization data and risk assessment results. Note that alternatives (and technologies) that were not retained may be revisited at any time as new information warrants, in accordance with FS guidance.

While the CERCLA Phase I/II FS process provides a rational process for developing and screening remedial alternatives, it is important to note that all this is done in the absence of a baseline risk assessment to comprehensively evaluate the inherent risks posed by the contamination. The baseline risk assessment will be a part of future studies. The Phase I/II process also does not allow much consideration of cost. Thus, the true cost/risk reduction benefit of each alternative has not yet been evaluated. This is an essential element in the ultimate decision-making process. While protection of human health and the environment is of utmost importance, the final remedial solutions must be found to be cost effective in view of their benefit to true risk reduction.

Section 6.0 of this report discusses development of a Treatability Study Program Plan for conducting treatability studies needed to support further analysis of remedial technologies.

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This section also provides an outline of the RI/FS program steps needed to advance the feasibility study process through future detailed analysis efforts to be conducted as part of FSs for OUs and/or IRMs.

In general, treatability studies are conducted for two purposes:

- To gather sufficient data to allow treatment alternatives to be fully developed and evaluated during the detailed analysis and to support detailed design of a selected alternative

- To reduce cost and performance uncertainties for treatment alternatives to acceptable levels so that a remedy can be selected.

The data collected from the treatability studies may provide information to help determine the following:

- Potential effectiveness in achieving target cleanup levels
- Contaminant removal (or destruction) efficiencies
- Achievable processing rates
- Selection of process reagents or additives, and formulations
- Pretreatment or post-treatment requirements for waste streams
- Treated-waste disposal requirements.

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Table 6
Phase II Screening Results
Recommended Alternatives

Media	Retained Alternative	Description
Solid Waste	SW-1	No Action General Response: No Action
	SW-2	Institutional Controls General Response: Access/Deed Restrictions
	SW-3	Containment Response: Run-on/run-off Control; Hanford Barrier/RCRA Multi-media Cap
	SW-4	Removal/Disposal Response: Excavation/Demolition; Vault/Trench Disposal; Hanford Barrier/RCRA Multi-media Cap
	SW-7	In situ Treatment Response: Dynamic Compaction; Vibration-aided Grout Injection; Hanford Barrier/RCRA Cap
	SW-9	Removal/Treatment Disposal Response: Excavation/Demolition; Thermal Desorption; Compaction; Cement Based Stabilization/Solidification; Vault/Trench Disposal; Hanford Barrier
Groundwater	GW-1	No Action General Response: No Action
	GW-2	Institutional Controls General Response: Water Rights/Deed Restrictions; Alternate Water Supply
	GW-3	Containment Response: Slurry Walls; Extraction Wells
	GW-4	In situ Treatment Response: Biodenitrification; Air Stripping
	GW-5	Removal/Treatment/Disposal Response (based on chemical treatment): Extraction Wells; Biodenitrification; Chemical Oxidation; Chemical Precipitation; Chemical Reduction; Media Filtration; Ion Exchange; Cement-based Stabilization/Solidification; Aquifer Reinjection
	GW-6	Removal/Treatment/Disposal Response (based on physical treatment): Extraction Wells; Biodenitrification; Media Filtration; Reverse Osmosis; Evaporation; Cement-based Stabilization/Solidification; Crib Disposal

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Table 6
Phase II Screening Results
Recommended Alternatives

Media	Retained Alternative	Description
Soils/ Riverbank Sediments	SS-1	No Action General Response: No Action
	SS-2	Institutional Controls General Response: Access/Deed Restrictions
	SS-3	Containment Response: Run-on/run-off Control; Hanford Barrier/RCRA Cap
	SS-4	Removal/Disposal Response: Excavation/Demolition; Vault/Trench Disposal; Hanford Barrier/RCRA Multi-media Cap
	SS-8	In situ Treatment Response: In situ Vitrification
	SS-10	Removal/Treatment Disposal Response: Excavation/Demolition; Thermal Desorption; Soil Washing By Attrition Scrubbing; Vitrification Stabilization/Solidification; Vault/Trench Disposal; Hanford Barrier

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ACRONYMS, ABBREVIATIONS AND INITIALISMS

ALARA	As Low As Reasonably Achievable
A/PEG	alkali metal/polyethylene glycols
ARAR	applicable or relevant and appropriate requirement
BCY	bank cubic yards
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	Curie
cm	centimeter
cm/sec	centimeters per second
CPP	CERCLA past-practice
CRBG	Columbia River Basalt Group
CSF	Cancer slope factor
CWA	Clean Water Act
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DQO	Data quality objective
DWPF	Defense Waste Processing Facility
Ecology	Washington Department of Ecology
EP	extraction procedure
EPA	Environmental Protection Agency
ERA	expedited response action
EHW	extremely hazardous waste
FFS	focused feasibility study
FS	feasibility study
ft	foot, feet
ft/day	feet per day
gal	gallon
GCD	Greater confinement disposal
gpd	gallons per day
gpm	gallons per minute
GRA	general response action
g	gram
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HLW	high-level waste
HMS	Hanford Meteorology Station
HQ	hazard quotient
HSBRAM	Hanford Site Baseline Risk Assessment Methodology
HSWA	Hazardous and Solid Waste Amendments
HWMA	Hazardous Waste Management Act
HWVP	Hanford Waste Vitrification Plant

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ACRONYMS, ABBREVIATIONS AND INITIALISMS (Cont)

ICR	incremental lifetime cancer risk
IRIS	Integrated Risk Information System
IRM	interim response measure
kg	kilogram
km	kilometer
L	liter
LCF	loose cubic feet
LCY	loose cubic yards
LDR	Land disposal restrictions
LFI	limited field investigation
LLW	low-level waste
m	meter
Ma	million years ago
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mCi	milli-Curie
mg	milligram
mg/kg	milligrams per kilogram
mi	mile
mR/hr	milli-rads per hour
mrem	milli-rem (radiation equivalent man)
mrem/hr	milli-rem per hour
mrem/yr	milli-rem per year
msl	mean sea level
MTCA	Model Toxics Control Act
nCi	nanocurie
NCP	National Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NTS	Nevada Test Site
OU	operable unit
PCB	polychlorinated biphenyl
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PNL	Pacific Northwest Laboratory
ppb	parts per billion
ppm	parts per million
QA/QC	Quality Assurance/Quality Control
R&D	research and development
RA	risk assessment
RAAS	Remedial Action Assessment System
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act

ACRONYMS, ABBREVIATIONS AND INITIALISMS (Cont)

RCW	Revised Code of Washington
RF	radio frequency
RfD	Reference dose
RFI/CMS	RCRA Field Investigation/Corrective Measures Study
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RL	Richland Field Office
ROD	Record of Decision
RPP	RCRA past-practice
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SITE	Superfund Innovative Technology Evaluation
SSM	shallow soil mixing
TBC	to-be-considered
TPA	Tri-Party Agreement (Hanford Federal Facility Agreement and Consent Order)
TRU	trans-uranic
TSCA	Toxic Substances Control Act
TSD	treatment, storage and disposal
UIC	Underground injection control
UMTRA	Uranium Mill Tailings Radiation Control Act
UNC	United Nuclear Corporation
UST	underground storage tank
μCi	microcuries
μg/g	micrograms per gram
μg/L	micrograms per liter
μR/h	microrad per hour
VOC	volatile organic compound
WAC	Washington Administrative Code
WHC	Westinghouse Hanford Company
WIDS	Waste Information Data System
WIPP	Waste Isolation Pilot Plant
WPPSS	Washington Public Power Supply System
WVDP	West Valley Demonstration Project

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1.0 INTRODUCTION

Four areas of the Hanford Site (the 100, 200, 300, and 1100 Areas) have been included on the Environmental Protection Agency's (EPA) National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The location of these areas is shown in Figure 1-1. Under the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement (TPA)), signed by the Washington State Department of Ecology (Ecology), the U.S. EPA, and the U.S. Department of Energy (DOE) (Ecology, et al., 1990a), more than 1000 inactive waste disposal and unplanned release sites have been grouped into source and groundwater operable units. These operable units contain contamination in the form of solely hazardous waste, solely radioactive waste, radioactive mixed waste, and other CERCLA hazardous substances. Also included within the TPA are 64 Resource Conservation and Recovery Act (RCRA) treatment, storage, or disposal (TSD) units which will be closed or permitted to operate in accordance with RCRA regulations under the authority of Chapter 173-303 of the Washington Administrative Code (WAC). Some of these TSD units are included within the operable units (OU).

The TPA requires that the cleanup programs at Hanford integrate the requirements of CERCLA, RCRA, and Washington's Dangerous Waste Program (the state's RCRA equivalent). The EPA maintains authority for CERCLA, and Ecology implements RCRA under the authority of the state's dangerous waste program. The state has also received authorization to implement the EPA's radioactive mixed waste program. The state does not yet have authority to implement the most recent amendments to RCRA, the Hazardous and Solid Waste Amendments (HSWA); this authority remains under EPA. The EPA and Ecology have determined that the EPA guidance for conducting a remedial investigation/feasibility study (RI/FS) under CERCLA may be used at the Hanford Site in the performance of a RCRA facility investigation/corrective measures study (RFI/CMS). Therefore, although RCRA terminology has been used where appropriate, the content and format of this feasibility study report conform to EPA guidance for CERCLA activities, even though the results of the studies may be applied to RCRA past practice operable units or to RCRA TSD units.

Since the signing of the TPA in 1989, the parties to the agreement have recognized the need to modify the approach to conducting investigations and studies 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 Site Past-Practice Strategy (DOE-RL, 1991d).* This strategy document describes the concepts and framework for streamlining the investigation and remedial study process in a manner that promotes a "bias-for-action" through optimizing the use of interim remedial actions, culminating with decisions on final remedies on both an operable-unit and aggregate-area scale. The principles of the strategy are embodied in the *Hanford Federal Facility Agreement and Consent Order Change Package,* dated May 13, 1991 (Ecology et al., 1991).

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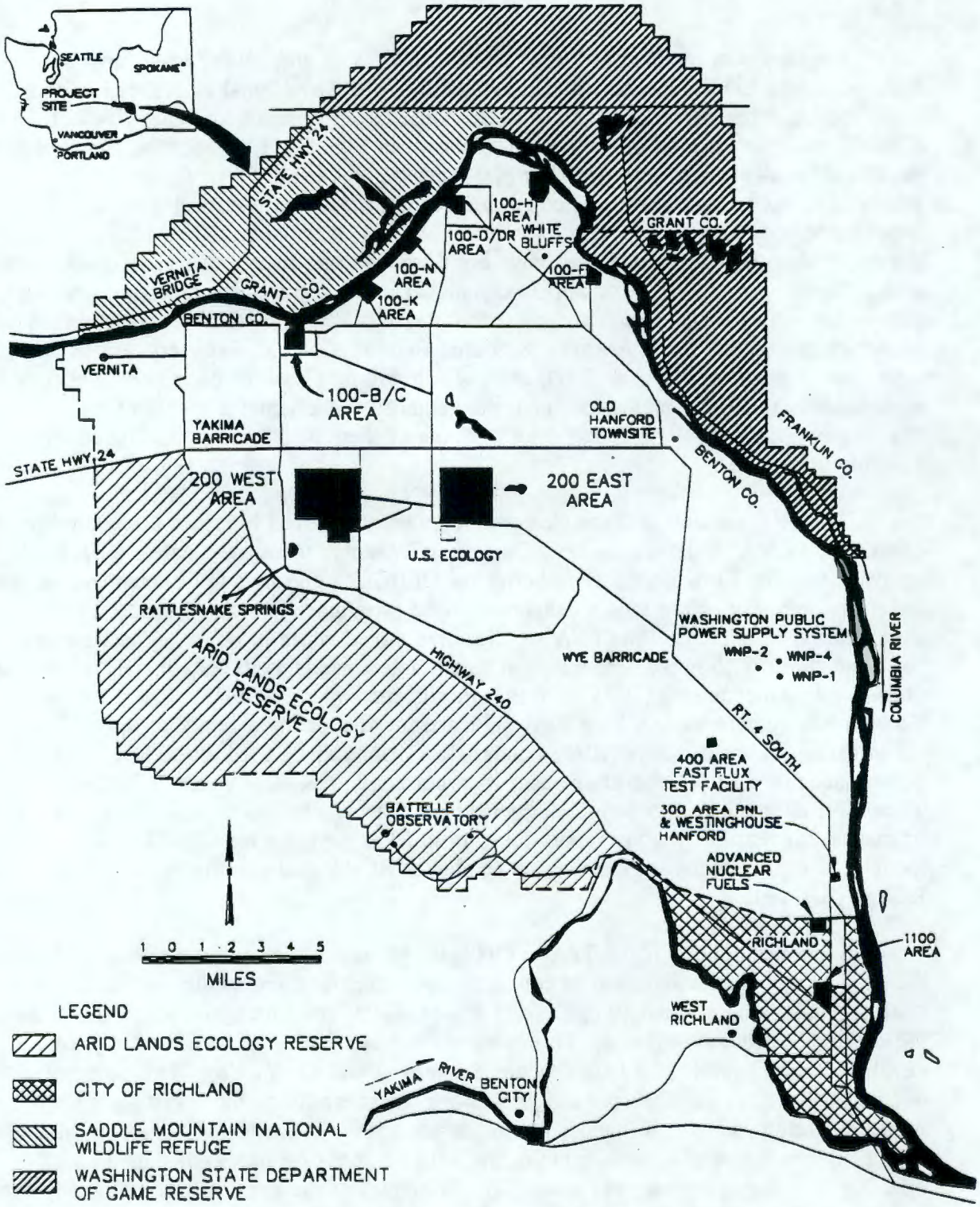

Figure 1-1. Hanford Site

An important aspect of the past practice strategy and the associated TPA change package recognizes that the Hanford Site presents a number of unique circumstances that call for innovative approaches to conducting investigations and feasibility studies. The 100 Areas have been divided into 25 OUs based largely on location. While these units are separated geographically, they all contain sites which are very similar with regard to types of contaminants and methods of disposal. Consequently, the past practice strategy as applied to the 100 Area defines an aggregate approach to evaluate groups of sites based on their similarity, as opposed to their geographical location and operable unit designation. Thus the 1991 TPA change package mandates that, rather than performing separate feasibility studies for each of the 100 Areas OUs, the feasibility studies should evaluate remedial alternatives for the entire 100 Area. To meet this objective, the change package called for three "base" reports which would consider: 1) source operable units (except 100-N Area), 2) groundwater operable units, and 3) the 100-N Area, as it is distinctly different from the other 100 Areas.

The 100 Area feasibility study presented in this document meets the objectives of the change package, however, the approach is further streamlined by condensing the "base" studies into a single document to avoid duplication of common information, while providing separate sections to address definition of remedial alternatives by either media or area. This not only reduces the cost of document preparation, but also shortens the review times and reduces the potential for document inconsistencies as a results of separate reviews. This document separates the studies by three media: solid wastes, soil/riverbank sediments, and groundwater. Riverbank sediments are that portion of the vadose zone, on the shore of the river, which are contaminated as a result of fluctuating groundwater levels near the river. Additionally, the 100-N Area is treated as a separate site based on its somewhat unique characteristics making a total of four types of sites or units evaluated in the remedial alternative evaluation process.

This 100 Area Phase I/II FS is built around existing data. In a typical RI/FS, the Phase I/II FS is not completed until the RI Phase I is complete, although the Phase I/II FS is often started while the Phase I RI is being conducted. However, for the 100 Area, the size of the existing site characterization database is larger than the end result of many RIs and is adequate for identifying and screening remedial alternatives. Use of existing data to initiate and expedite the FS process is consistent with the past practice strategy. New site characterization data, while important for later detailed analysis, would not likely affect the outcome of the alternatives development and screening phases. Finally, waiting for LFI data to start the FS process would cause unacceptable schedule delays in starting subsequent programs such as treatability studies.

The 100 Area feasibility study presented in this document completes the FS process only through the first two study phases: Phase I, Remedial Alternatives Development, and Phase II, Remedial Alternatives Screening. This Phase I/II study is intended to provide a more generalized view of applicable and workable remedial technologies as applied to the site contamination problems as a whole. After collection of more site-specific data for each OU, focused feasibility studies would then be performed. These studies would either select interim remedial measures or select final remedies, depending upon the stage of remediation being evaluated. Thus each focused FS constitutes the detailed analysis phase which

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completes the FS evaluation process for the targeted remedial action. In addition to the screened alternatives evaluated in this document, the detailed analysis phases of subsequent FSs would integrate the results of area-wide studies such as river impact, shoreline, ecological, cultural resources, treatability, and background studies; as well as, information from OU-specific limited field investigations (LFI) and risk assessments (RA).

1.1 PURPOSE AND SCOPE

The purpose of this Phase I/II feasibility study is to develop and screen a range of alternatives for remediation of 100 Area contamination present in solid wastes, soils/riverbank sediments and in groundwater. Remedial alternatives for the 100-N Area are to be addressed separately.

Surface water, including the Columbia River, and air contamination are not within the scope of this study.

The scope of work for this FS includes four primary tasks:

1. Identify contaminants of concern for each media

2. Identify applicable or relevant and appropriate requirements (ARARs) pertinent to all general response actions (including waste disposal)

3. Develop remedial alternatives (Phase I) applicable to the 100 Area including development of remedial action objectives (RAO), development of general response actions (GRA), identification and screening of technologies and process options, and assembly of remedial alternative, from representative technology types

4. Screen alternatives (Phase II) developed in Phase I for implementability, effectiveness, and costs to identify those alternatives which warrant advancement to the detailed analysis phase of future focused feasibility studies.

Feasibility studies presented in this document are performed in accordance with EPA guidance contained in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA,* (EPA 1988a).

Key assumptions for preparation of this document are given as follows:

- Performance of the tasks described above are based on existing site data, primarily as documented in the eleven draft 100 Area OU RI/FS work plans issued previously (DOE 1990a-e; 1991a-f), and supplemented by existing data given in other documents for sites not covered by draft work plans. New sampling or monitoring data produced as a result of current site investigations were unavailable to meet the FS schedule and are therefore, not incorporated.

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- All sites in the 100 Area are categorized within one of the four types of sites identified for this project (solid wastes, soils/riverbank sediments, groundwater, and the 100-N Area).

- Sampling and monitoring data reported in source documents are assumed to be of adequate quality to support the FS.

1.2 ORGANIZATION OF REPORT

Seven sections are included in this report, including this introduction.

Section 1.3 summarizes information on background and existing data, including:

- A history of 100 Area operations and descriptions of facility characteristics and waste generating processes
- Nature and extent of contamination in the media of concern.
- Physical setting including such aspects as geology, hydrogeology, meteorology, environmental resources, etc.

The information in this section represents a summarized compilation of data obtained from work plans and other source documents and is not intended as a comprehensive documentation of data or details. The intent of this section is to summarize the information in sufficient detail to support the discussion and evaluation of remedial alternatives.

Section 2.0 of the report provides an assessment of contaminants of concern for the 100 Area.

Section 3.0 documents the potential ARARs.

Section 4.0 documents the Phase I effort to identify and screen remedial technologies and process options. This section also identifies remedial action objectives and general response actions and provides estimates of areas and volumes of contaminated materials.

Section 5.0 documents the Phase II effort to 1) assemble screened technologies and process options into area-wide alternatives and 2) to screen the alternatives with respect to implementability, effectiveness, and cost to arrive at a list for advancement to future focused feasibility studies.

Section 6.0 discusses development of a Treatability Study Program Plan for conducting treatability studies needed to support further analysis and design of remedial systems. This section also provides an outline of the RI/FS steps needed to advance the feasibility study process through future detailed analysis efforts to be conducted as part of focused FSs for interim remedial measures (IRM) and final FSs for OUs.

Section 7.0 documents report references.

Appendices to this report include:

- Appendix A - Identification of Contaminants of Concern
- Appendix B - Identification of Potential ARARs
- Appendix C - Descriptions of Remedial Technologies and Process Options
- Appendix D - 100 Area Contaminated Soil and Groundwater Volume Estimations
- Appendix E - 100 Area Waste Units.

1.3 BACKGROUND/SUMMARY OF EXISTING DATA

1.3.1 100 Area Description

1.3.1.1 Location

The Hanford Site is a 560 mi^2 (1,434 km^2) tract of land located in the south-central portion of the State of Washington in Benton, Franklin, and Grant Counties. The 100 Area lie along the southern shoreline of the Columbia River at the north end of the Hanford Site (see Figure 1-1).

Identifying numbers were given to the buildings and facilities in the 100 Area. These are summarized as follows (Adams et al., 1984):

FACILITY CATEGORIES

CATEGORY	FACILITY DESIGNATION	FACILITY FUNCTION
Reactor Buildings	105	Housed reactor and fuel storage basin (irradiated)
Ground Disposal Facilities	116 (liquid) 118 (solid)	In-ground disposal of liquid and solid wastes
Effluent Systems	107	Retention basins
	1904/1908	Outfall structures
	1608	Pumping stations
Ancillary Facilities	103	Fuel element storage building (unirradiated)
	108	Laboratory
	115	Gas recirculation buildings
	116	Reactor stacks
	117	Exhaust filter buildings
	119	Exhaust sample buildings
	1706	Reactor loop testing facility

1.3.1.2 History of Operations

Between 1943 and 1962, nine water-cooled, graphite-moderated plutonium production reactors were built along the shore of the Columbia River upstream from the now-abandoned town of Hanford. Eight of these reactors (B, C, D, DR, F, H, KE, and KW) have been retired from service and are under evaluation for decommissioning. The ninth reactor, N, was recently taken out of standby status and will be retired. Table 1-1 lists the construction date, period of operation, and status of each reactor. In some of the reactor areas, after the reactor was retired from plutonium production service, the ancillary facilities were used as laboratories for special studies or for storage/treatment purposes. Post-production activities are listed in Table 1-2.

TABLE 1-1
REACTOR STATUS

REACTOR	CONSTRUCTED	OPERATED		STATUS
		FROM	TO	
B*	1943	1944	1968	Retired
C	1951	1952	1969	Retired
KE	1952 - 1954	1955	1971	Retired
KW	1952 - 1954	1955	1970	Retired
N	1959 - 1962	1963	1987	Shutdown in progress
D	1943**	1944	1967	Retired
DR	1949**	1950	1964	Retired
H	1948**	1949	1965	Retired
F	1943 - 1945	1945	1965	Retired

Source: DOE 1990a-e, DOE 1991a-f
* B reactor was held in standby status from 3/19/46 to 6/2/48, then restarted.
** Construction dates assumed in correlation with reactor operational dates.

1.3.1.2.1 Reactor Components (Excluding 100-N). The principal components of the original eight reactors consist of the reactor, the reactor cooling water loop, the reactor gas and ventilation system, and the irradiated fuel handling system. Each of these systems is briefly described below.

TABLE 1-2
POST-REACTOR OPERATIONS
(Excluxing N Reactor)

AREA	OPERATION	PERIOD OF OPERATION	ACTIVITY
100-F	Fish Studies	1945 - 1976	Exposing fish to reactor cooling water effluent. Water discharged to PNL outfall structure.
	Fish Studies	circa 1951	Additional Aquatic Biology Laboratory facility constructed with hatchery troughs and laboratories.
	Sheep Studies	late 1940s	Using about 1000 sheep in dose studies with iodine-131, strontium-90, and cesium-137.
	Pig Studies	1952	Similar exposure studies as those conducted with sheep.
	Miniature Goats, Milk Cows, Chickens, and Ducks	Various Times	Pilot Studies.
	Beagles	Unknown	300 - 400 dogs used to study affects of ionizing radiation. Mainly used plutonium-239
	Strontium Gardens	Unknown	Studied growth of cereal grains, alfalfa and other crops in soil containing controlled amounts of strontium-90 and cesium-137.
	Greenhouse	Unknown	Radioecological experiments: grew potted plants.
100-B/C	In Situ Vitrification	May 1990	116-B-6-1 Crib used for in situ vitrification experiment.
100-H	N Reactor Fuel Fabrication Waste Treatment	1973 to 1985	Treated, by solar evaporation in the 183-H Basins, waste solutions from N reactor fuel fabrication facilities in the 300 Area. Both routine and non-routine wastes were treated.
100-KE/KW	N Reactor irradiated fuel storage	1975 to present	The 105-KE and 105-KW storage basins are used to store N reactor irradiated fuel elements. After short-lived radioisotopes decayed, they were shipped to the 200 Areas for reprocessing.

Source: DOE 1991c

Reactor. Each reactor was graphite moderated and cooled with water pumped through on a single-pass basis. The reactor moderator stack consisted of graphite blocks, some of which were cored to provide channels for process tubes, control and safety rods, and other equipment. Aluminum process tubes held the aluminum-clad, uranium-metal fuel elements and provided channels for cooling water flow (Irradiation Processing Department 1963). Boron was the primary neutron absorber used in control and safety rods. The initial reactor design included a third safety system which used a tank filled with a boron solution suspended above the reactor. Aluminum sleeves, called thimbles, were inserted into the channels to protect the graphite from the boron.

After a few years of operation, the boron system was redesigned to utilize hoppers containing 3/8-inch (0.95 cm) nickel-plated boron balls instead of the liquid boron system (Irradiation Processing Department 1963). The balls emptied into the vertical safety rod channels when reactor shutdown was required. A vacuum system removed the balls when the reactor went back on-line.

Reactor Cooling Water Loop. Figure 1-2 presents a simplified process flow diagram for the original eight reactors. Cooling water for the reactor was pumped from the Columbia River to a water treatment facility either directly or via a reservoir. Additives, listed in Table 1-3, were introduced to the river water which then passed through flocculators to settling basins where an organic polyelectrolyte was added as a filter aid. The water was filtered through beds of gravel, sand, and crushed anthracite coal and stored in clearwells.

TABLE 1-3
WATER TREATMENT ADDITIVES

ADDITIVE	PURPOSE
Alum with excess sulfuric acid	Enhance removal of suspended particulates by flocculation.
Hydrated calcium oxide	Control pH (maintained at 7.5).
Chlorine	Control algae growth in settling basins (free chlorine residual: 0.2 ppm).

Source: DOE 1991c

The treated water was pumped to large-capacity storage tanks where about 2 ppm sodium dichromate was added as a corrosion inhibitor (Richards 1953). The water from the storage tanks was then pumped via electric pumps to the reactor. The water at that point contained residues of alum, sulfate, chlorine, calcium, sodium dichromate, electrolyte, and other impurities[1].

[1] Naturally present in the river water and not removed during treatment.

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The heated water passed from the reactor to a retention basin by gravity flow. The water was retained in the basin for a time sufficient to permit partial thermal cooling and radioactive decay of short-lived radionuclides. The water then flowed from the retention basin via the outfall structure and river pipelines where it was discharged to the middle of the river. The outfall structure contained a concrete or rip-rap spillway to divert the water to the river in case of an overflow.

A backup cooling system was provided by river water which was kept in a holding reservoir. This water was normally used to supply the powerhouse; however the water could be pumped to the water treatment facility or, in cases of emergencies, directly to the reactor. Steam was generated in the coal-fired powerhouse where the water was treated (to reduce formation of boiler scale) with sodium sulfite and trisodium phosphate and was subsequently passed through an ion exchange system[2].

Reactor Inert Gas and Ventilation Systems. The inert gas system was used to remove moisture and foreign gases, to serve as a heat transfer media between the graphite and process tubes, and to detect water leaks within the reactor. The reactor atmosphere was a mixture of helium with carbon dioxide or nitrogen. The composition of the gas mixture was varied to control the graphite temperature which in turn influenced reactivity conditions (Chattin and Powers 1985).

Irradiated Fuel Handling. Refueling occurred about once a month for about 10 percent of the process tubes in the reactor. Irradiated fuel elements removed from the reactor were sorted in a pickup chute area and transferred to the fuel storage basin for radioactive decay. Following the storage decay period, the fuel elements were placed in railroad cask cars for transport to the chemical reprocessing facilities in the 200 Areas (Miller and Steffes 1987).

1.3.1.2.2 100-N Reactor Components.

100-N Reactor. The 100-N reactor was a graphite moderated, light-water-cooled reactor and the newest of the 100 Area reactors. Its design and operation differ substantially from the other plutonium production reactors. Unlike the other eight single-pass reactors, the 100-N reactor was a dual purpose reactor which produced steam for electricity generation as well as plutonium. The 100-N reactor did not use once-through cooling as did the other eight production reactors. Instead water was recirculated through the reactor and steam generators.

The reactor core was a structure of interlocking graphite bars containing zirconium alloy pressure tubes which held the zirconium alloy-clad, uranium-metal fuel elements. Reactivity was controlled by horizontal control rods and the vertical ball system. Boron was the primary neutron absorber used in the rods and balls.

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[2] Sodium chloride was used as the regeneration solution for the ion exchange system (Irradiation Processing Department 1963).

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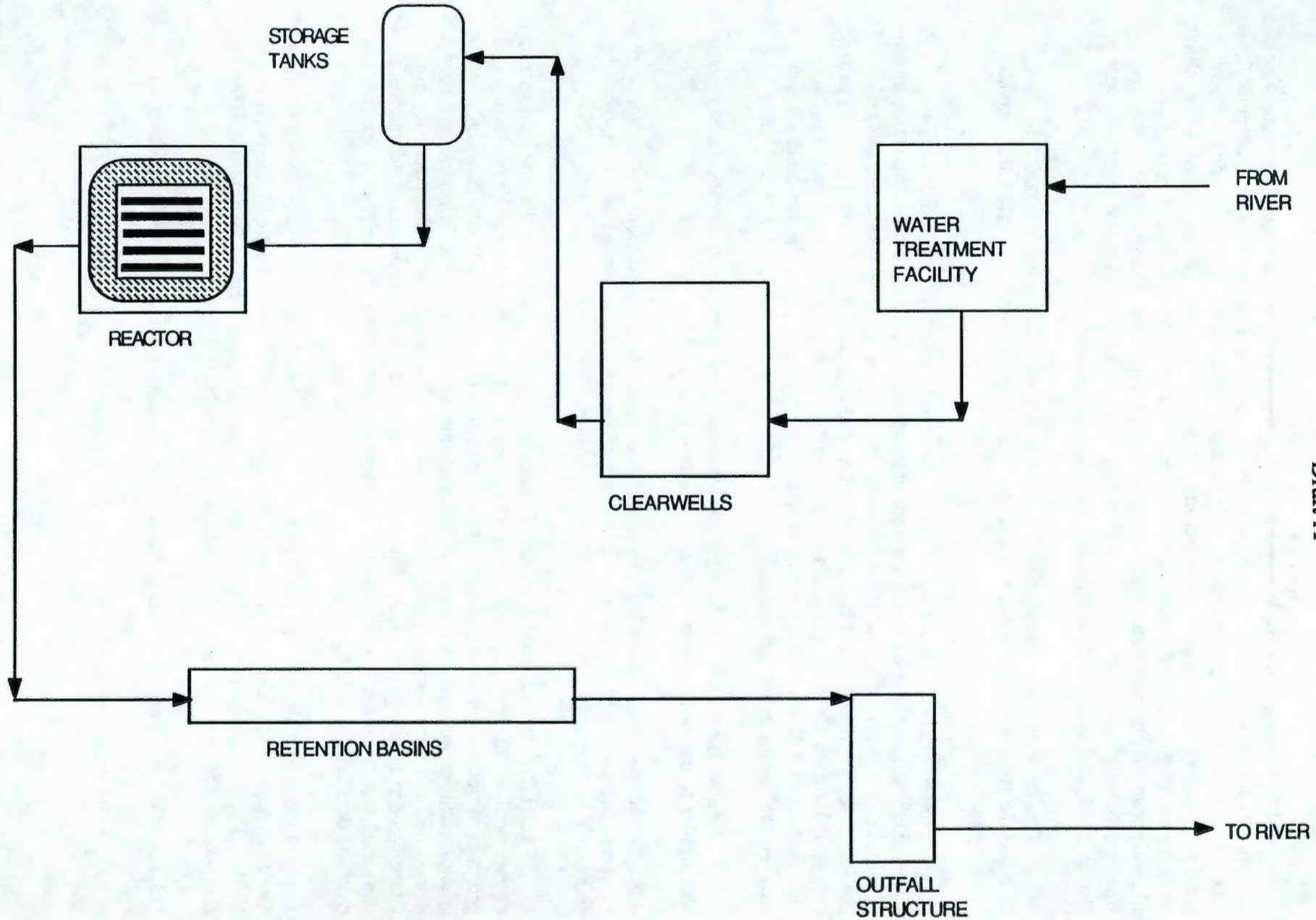

Figure 1-2. Cooling Water Process Flow Diagram

100-N Reactor Cooling Water Loop. Figure 1-3 presents a simplified process flow diagram for the 100-N reactor cooling water loop. Untreated water from the Columbia River was supplied to the emergency coolant pumps, dump condensers, and the water treatment facility. The water treatment system produced raw, sanitary, and demineralized water. Raw water received no treatment other than straining; all other water was passed through a filtration plant where coagulant chemicals and small amounts of chlorine were added. A filter aid was added and the water passed through gravity filters which consisted of layers of gravel, sand, and granulated anthracite.

Treated water from the demineralizer plant was stored in a holding tank. Its uses included the reactor (graphite and shield), and rod coolant systems as well as the secondary water system.

The secondary steam system removed the reactor heat from the primary cooling water. During operation solely for production of special nuclear materials, the major portion of this steam was routed to dump condensers. During dual purpose operation, the major portion of the generated steam was routed to the Washington Public Power Supply System (WPPSS) Hanford Generating Project for production of electricity, through steam turbines and condensers. The secondary steam system was closed-loop, i.e., the condensed steam was returned to the steam generator.

Reactor Inert Gas and Ventilation Systems. The inert gas system in the N reactor was similar to the systems used in the other production reactors.

Irradiated Fuel Handling. Irradiated fuel elements removed from the reactor were moved to the storage basins for short term radioactive decay then placed in rail-mounted shipping casks for transport to reprocessing or storage facilities.

1.3.1.2.3 Decontamination and Decommissioning. To reduce the potential spread of radioactive contamination from the reactors and associated facilities, DOE began a program of decontamination and decommissioning (D&D) of buildings and facilities after the reactor facilities were retired. Most of the contaminated buildings and facilities have been demolished and were buried in place, in the clearwells, or taken to the 200 Areas for burial. Clean wooden buildings and equipment were salvaged and uncontaminated buildings were converted for new programs or storage. In some instances, new buildings were constructed over the demolished building locations.

A photographic summary of D&D activities is presented in *Summary of the Hanford Site Decontamination, Decommissioning, and Cleanup FY 1974 Through FY 1990* (Wahlen 1991). The decommissioning plans for the 100 Area are presented in the *Hanford 100 Area Long-Range Decommissioning Plan* (Adams, et al., 1984).

1.3.1.3 100 Area Facility Characteristics and Contamination (excluding N Reactor)

Waste units included in this FS are listed in the tables in Appendix E.

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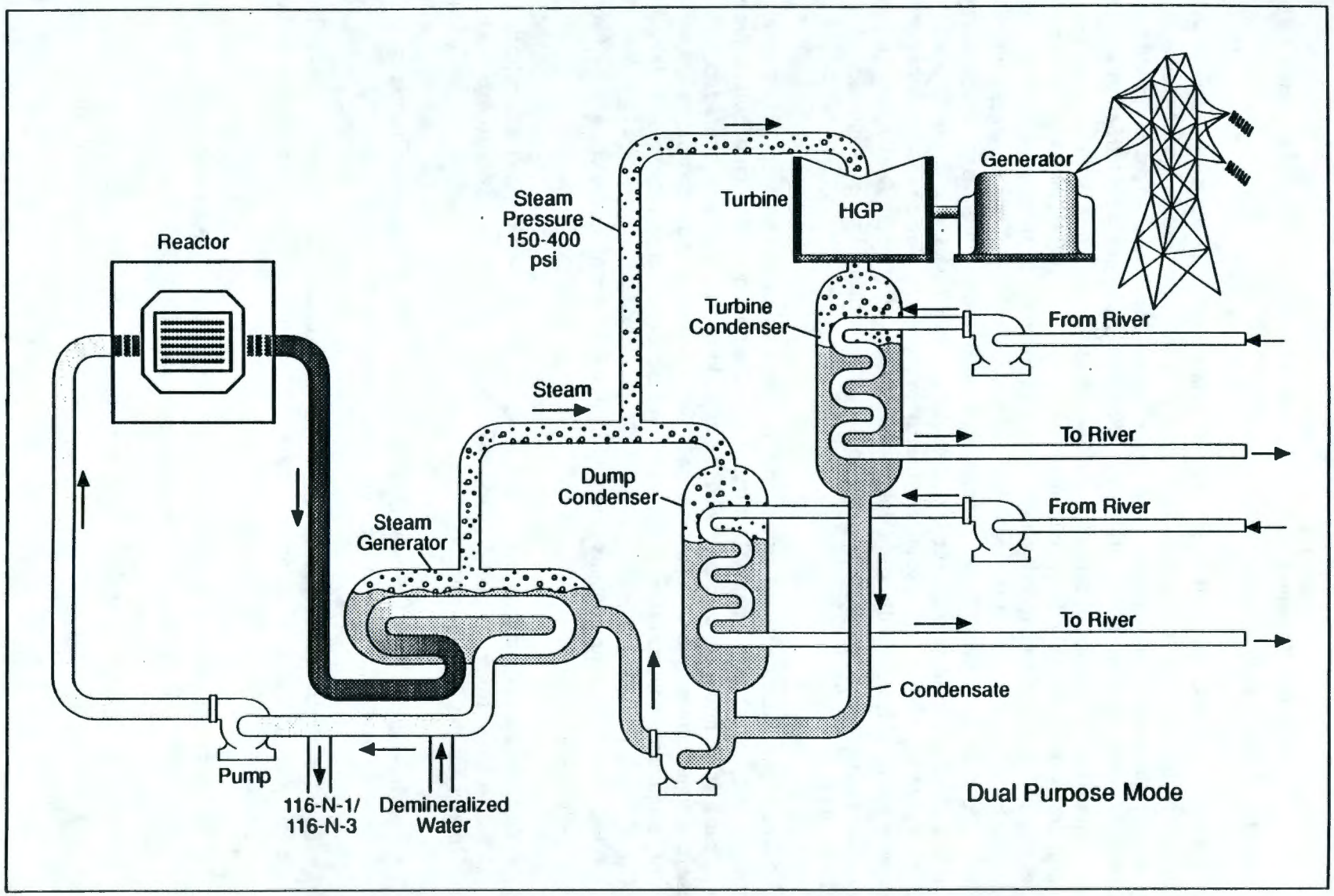

Figure 1-3. N Reactor Cooling Water Process Flow Diagram (DOE 1990d)

1.3.1.3.1 Effluent Handling. Facilities used in the handling of cooling water effluent included retention basins, pipelines, and outfall structures.

Retention Basins. The 100 Area retention basins were rectangular concrete or circular steel structures used to retain cooling water effluent from the reactor for radioactive decay and thermal cooling prior to discharge to the river. The basins ranged in capacity from 16 to 24 million gallons (DOE-RL 1991a). Some of the basins were baffled to provide separate compartments. In initial operations, effluent was directed to only one side of the basin at a time which allowed effluent contaminated by ruptured fuel elements to be diverted to other disposal facilities such as cribs and trenches. However, temperature differentials between the basin halves resulted in cracks and subsequent leakage. This leakage, coupled with increased production rates, forced simultaneous use of the retention basin compartments. This in turn precluded routing the more highly contaminated effluent to alternate disposal sites. Therefore all effluent was discharged directly to the river. Some of the retention basins were partially demolished and the rubble buried in-place after the Dorian and Richards study. The basins have also been used for disposal of contaminated piping and other demolition materials.

Some of the retention basins leaked, in some cases enough to produce surface ponds and streams that flowed to the river. This leakage resulted in contamination of soils adjacent to the basins. In addition, contaminated sludge was deposited on the basin floors and represents a significant source of contamination. The following summarizes the nature and extent of radionuclide contamination at the retention basins (Dorian and Richards 1978):

- Each retention basin contains from 1/4 inch to 3 inches of sludge covered by two to four feet of soil fill.

- Total radionuclide inventories for the B, C, D, DR, F, H, KE, and KW retention basins range from less than 10 curies for each of the K Area basins to over 400 curies for the B Area basin.

- For the B and C retention basins, approximately 90% of the contamination is located outside the basin in the soils beneath and adjacent to them.

- For all the reactors, Cesium-137, Cobalt-60, Europium-152, Europium-154, and Europium-155 account for approximately 97% of the radionuclide inventory located outside the retention basins.

- For the D, DR, F, and H basins, approximately 75% of the contamination is contained inside the basins in the sludge, the soil fill, and the concrete.

- For all the reactors, Cobalt-60, Europium-152, Europium-154, and Nickel-63 account for approximately 94% of the radionuclide inventory located within the retention basins.

- The KE and KW retention basins are much less contaminated than the others and have total inventories less than 10 curies each; approximately 85% of this contamination is located in soils adjacent to the basins.

Table 1-4 provides typical inventories for the areas of contamination related to the retention basins: basin sludge, basin fill, concrete, and surrounding areas.

In addition to radionuclide contamination, the basins may be contaminated with chemical constituents used as additives in the cooling water. A major contaminant is chromium which was used extensively in the 100 Area. Table 1-5 lists contaminant concentration ranges for the basins.

TABLE 1-4
RETENTION BASIN CONTAMINATION

Area of Contamination	Average Contamination (Ci)	Maximum Contamination (Ci)
Contamination inside the retention basins:		
- Sludge	42	92 (116-B-11)
- Soil Fill	6.6	18 (116-H-7)
- Concrete	10	13 (116-DR-9, 11-H-7)
Contamination outside the retention basins:		
- Soils Under Basins	84	280 (116-B-11)
- Soils Adjacent to Basins	12.6	27 (116-D-7)

Source: Dorian and Richards, 1978 (Activity as recorded in 1978; Values not decayed to present)

Pipelines. Effluent pipelines ran from the reactors to the retention basins, from the retention basins to the outfall structures, and from the outfall structures to the discharge point in the middle of the Columbia River. The 100 Area contained approximately 62,000 feet of effluent pipeline ranging in size from 12 to 84 inches in diameter (Adams, et al., 1984). The pipelines were constructed of carbon steel, reinforced concrete, or sometimes vitreous tile. The pipelines included manholes, junction boxes, tie-lines between parallel legs, and valves. Most of the on-land pipelines were buried although a portion of the effluent line in the 100-F Area was above-ground. This above-ground portion has been removed and placed in the 116-F-14, 107-F retention basin. The remaining land portions of the 100 Area effluent lines are still in place. Junction boxes have been sealed or filled with gravel and the effluent lines

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were sealed to prevent entry. The river pipelines are still in place except at F Area; approximately 50 feet of pipe has been dislodged and washed downstream.

Leaks occurred along the pipelines, mainly at the junction boxes of all the steel and concrete lines and the rubber joints of the tile lines. Contamination associated with the effluent lines is primarily in these leakage areas and in the accumulated sludge in the pipes. Radionuclide and chemical contaminants in the effluent lines and leakage areas are presumed to be the same as shown for the retention basins in Table 1-5.

Outfall Structure. Outfall structures were compartmentalized boxes used to direct the liquid effluent from the retention basin to the river pipelines for discharge to the middle of the Columbia River. The structures were constructed of reinforced concrete with concrete or rip-rap spillways (spillways were used only in case of overflow). With the exception of the structure at the 100-K Area, all the outfalls were 27 feet long by 14 feet wide with walls one foot above grade and 25 feet below grade. The 100-K Area outfall was 30 feet long by 40 wide with 30 foot walls above and below grade (DOE-RL 1991a). Most of the outfalls have been demolished to near-grade level and backfilled. An outfall structure in the F Area, the PNL outfall, was used by the Pacific Northwest Laboratory (PNL) for disposal of wash wastewater from the animal pens. Contaminants include strontium-90 and small amounts of cesium-137 and plutonium-239 (DOE 1991d).

Effluent was normally discharged via the outfall and river pipelines; however effluent discharges sometimes overflowed the outfall structure and exceeded the capacity of the spillways resulting in contamination of surrounding soils down to the river's edge. The residual radionuclides and chemical contaminants associated with the outfalls are presumed to be the same as those listed in Table 1-5 for the retention basins.

1.3.1.3.2 Liquid Waste Disposal. Liquid waste was disposed to the soil column through cribs, trenches, and French drains. Cooling water was routinely discharged to the river; however, during fuel cladding rupture events, the water was diverted to cribs and trenches for disposal to the soil column. This practice avoided direct disposal of transuranics to the river.

Site characterization activities were conducted in the 1970s by Dorian and Richards (1978). The characterization effort was aimed primarily at the liquid waste disposal facilities with lesser efforts expended on the solid waste disposal facilities. Samples were taken from the surface and at depths varying from 5 to 25 feet. Sample analysis was conducted primarily for radionuclides. Contamination information pertinent to liquid waste disposal facilities is summarized in Table 1-6. Based on the information obtained during this effort, the following generalizations can be made concerning the 100 Area liquid waste disposal facilities:

- The principal radionuclides in these facilities are generally:

  - Cobalt-60
  - Cesium-137

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TABLE 1-5
LIQUID EFFLUENT SYSTEM CONTAMINATION

LIQUID EFFLUENT SYSTEM COMPONENT	REACTOR AREA	PURPOSE/WASTE RECEIVED	TOTAL RADIONUCLIDE INVENTORY	MAJOR RADIONUCLIDES PRESENT	MAXIMUM PLUTIONIUM CONCENTRATION	POTENTIAL CHEMICAL CONTAMINANTS
Retention Basins	B, C, D, DR, F, H, KE, KW	Normal effluent from reactor production operations, occasional fuel element rupture effluent	5 - 400+ Curies per basin	^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{63}Ni, ^{90}Sr, $^{239/240}Pu$	340 pCi/g in sludge, 22 pCi/g in fill, 5.4 pCi/g in soils beneath basins, 13 pCi/g in soils adjacent to basins.	Chromium, water treatment chemical additives
Effluent Pipelines	B, C, D, DR, F, H, KE, KW	Transferred effluent from reactor to retention basin, to outfall structure, and to river	No inventory data available.	^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{63}Ni, ^{3}H, ^{155}Eu, ^{90}Sr	No sampling data available.	Same as retention basins
Outfall Structures	B, C, D, DR, F, H, KE, KW	Used to channel effluent from the retention basin to the middle of the river. Spillway used in case of overflow	No inventory data available.	^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{63}Ni, ^{3}H, ^{155}Eu, ^{90}Sr	No sampling data available.	Same as retention basins

Source: Dorian and Richards, 1978 (Activities as recorded in 1978; Values not decayed to present)

- Strontium-90
- Europium-152
- Europium-154
- Europium-155

- The radioactive waste is generally confined to within five to twenty feet below the facility.

- Plutonium-239/240 concentrations are generally less than 1 pCi/g but range as high as 1500 pCi/g at the 116-C-2C pluto crib sand filter. Plutonium-238 concentration at the sand filter is as high as 1600 pCi/g.

Cribs. Cribs were buried, generally rock-filled, structures. Early cribs were typically open-bottomed, buried boxes, constructed from timbers, which ranged in area from 100 to 200 square feet. Some of these timbered cribs had associated tile fields for overflow. Some were provided with a secondary cavity to handle overflow. The 116-C-2 crib was much larger than the other cribs, 140 feet by 100 feet at the bottom, and were provided with a sand filter. Figure 1-4 shows a typical crib with a tile drainage field (Adams et al. 1984). Interviews with operations personnel suggest that this schematic may not accurately represent certain cribs. Some of the 100 Area cribs may have been excavated pits which received waste through fire hoses.

Often a crib was dedicated to a specific building or process, and thus received a relatively uniform flow. Cribs can generally be categorized by the type of service provided. All data were obtained from Dorian and Richards 1978 or DOE-RL 1991a. Radionuclide quantities have not been decayed to current time. These are listed as follows:

- Pluto cribs

  Except for the 116-C-2 (105-C) pluto crib, these cribs were generally small, approximately 10x10x10 feet (Dorian and Richards 1978), and were operated for short time periods only (less than two years). The pluto cribs received effluent from individual process tubes following fuel cladding failures.

  The 116-C-2A crib was the last crib to be constructed and was approximately 14,000 square feet in area. Associated facilities included a sand filter and pump station.

  Pluto cribs contained radionuclide inventories ranging from less than 0.1 curie to 3 curies. The 105-C pluto crib, 116-C-2A, had an associated sand filter and pump station. The sand filter contained contamination two orders of magnitude higher than that of the crib and plutonium concentrations up to 1600 pCi/g. Chromium and other cooling water additives are potential contaminants in the pluto cribs.

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TABLE 1-6
LIQUID WASTE DISPOSAL FACILITIES

LIQUID WASTE DISPOSAL SITE TYPE	REACTOR AREA	PURPOSE/WASTE RECEIVED	TOTAL RADIONUCLIDE INVENTORY	MAJOR RADIONUCLIDES PRESENT	MAXIMUM PLUTONIUM CONCENTRATION	POTENTIAL CHEMICAL CONTAMINANTS
Pluto Cribs	B, C, D, DR, F, H	Effluent from fuel element ruptures	<0.1 to 3 Curies 260 Curies in 105-C pluto crib sand filter	^{90}Sr, ^{3}H, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{60}Co, ^{137}Cs	$^{239/240}Pu$: 110 pCi/g	Chromium, water treatment chemical additives
Dummy/Perf Decontamination Cribs	B, F, H	Liquid wastes from decontamination of process dummies	0.007 to 1.3 Curies	^{90}Sr, ^{3}H, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{60}Co, ^{137}Cs	$^{239/240}Pu$: 2.3 pCi/g	Chromic, citric, oxalic, nitric, sulfamic, and sulfuric acids used in decon.
108 Building Cribs	B, D	Contaminated liquid effluents from 108 buildings	116-B-5: 300 Curies 116-D-3, -4: <0.1 Curie	^{3}H	0.33 pCi/g	No data available.
115 Building Cribs	KE, KW	Condensate and liquid waste from reactor gas purification systems	240 Curies	^{3}H, ^{14}C	None	No data available.
117 Building Cribs	B, D, DR, F, H	Drainage from confinement system seal pits	0.0001 Curies at F Area, less than background at other Areas	^{90}Sr, ^{152}Eu, ^{137}Cs, ^{239}Pu	^{239}Pu: 0.1 pCi/g	No data available.
116-F-5, 100-F Ball Washer Crib	F	Wastes from decontamination of boron-steel balls	0.00092 Curies	^{90}Sr, ^{154}Eu, ^{155}Eu, ^{137}Cs	None	Nitric acid

TABLE 1-6
LIQUID WASTE DISPOSAL FACILITIES

LIQUID WASTE DISPOSAL SITE TYPE	REACTOR AREA	PURPOSE/WASTE RECEIVED	TOTAL RADIONUCLIDE INVENTORY	MAJOR RADIONUCLIDES PRESENT	MAXIMUM PLUTONIUM CONCENTRATION	POTENTIAL CHEMICAL CONTAMINANTS
116-KE-2, 1706-KER Crib	KE	Radioactive liquids from cleanup columns in 1706-KER loop	38 Curies	^{90}Sr, ^{60}Co	$^{239/240}Pu$: 2.1 pCi/g	Sodium hydroxide
116-DR-7, 105-DR Inkwell Crib	DR	Liquid potassium borate solution from the 3X system prior to the Ball 3X system upgrade	<0.1 Curies	^{90}Sr, ^{134}Cs, ^{137}Cs	None	Potassium borate
French Drains[a]	B, D, F, KE, KW	K Area: sulfuric acid sludge from the acid storage tanks, also mercury. Other areas received liquid wastes from various decontamination processes and effluent water from botany experiments in the F Area.	No radionuclide inventories available.	No radionuclide inventories available.	No radionuclide inventories available.	120-KE-1 contains about 200 kilograms of mercury. The 120-K drains have PNL Hazardous Ranking System Migration Scores of 40+, the other drains have scores of zero.
Liquid Waste Disposal Trenches	B, C, DR, F, H, K	Effluent from 107 retention basins during fuel element failures	3.1 to 79 Curies	^{90}Sr, ^{3}H, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{60}Co, ^{134}Cs, ^{137}Cs, U	$^{239/240}Pu$: 5.3 pCi/g	Chromium, water treatment chemical additives

TABLE 1-6
LIQUID WASTE DISPOSAL FACILITIES

LIQUID WASTE DISPOSAL SITE TYPE	REACTOR AREA	PURPOSE/WASTE RECEIVED	TOTAL RADIONUCLIDE INVENTORY	MAJOR RADIONUCLIDES PRESENT	MAXIMUM PLUTONIUM CONCENTRATION	POTENTIAL CHEMICAL CONTAMINANTS
K Trench	KE, KW	Fuel storage basin overflow, leakage from retention basin valves, wastes from contaminated floor drains, periodic other liquid waste streams	2100 Curies	^{63}Ni, ^{152}Eu, ^{154}Eu, ^{60}Co, ^{137}Cs	$^{239/240}Pu$: 130 pCi/g	Chromium (sodium dichromate); sulfamic acid, sulfuric acid, and copper sulfate disposed to trench
105 Storage Basin Trenches	B, D, DR, F	Water and sludge from fuel storage basins	0.0021 to 4.7 Curies	^{90}Sr, ^{3}H, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{60}Co, ^{137}Cs	$^{239/240}Pu$: 6.1 pCi/g	Sodium dichromate
1608 Trenches	DR, F, H	Effluent during Ball 3X Project	1.4 to 6.5 Curies	^{90}Sr, ^{3}H, ^{152}Eu, ^{155}Eu, ^{60}Co, ^{137}Cs	$^{239/240}Pu$: 0.76 pCi/g	Sulfamic acid, sodium dichromate
Sludge Trenches	B, D, DR	Sludge wastes from the B Area retention basin	No data available. Contamination may be similar to retention basin contamination	No data available. Contamination may be similar to retention basin contamination	No data available. Contamination may be similar to retention basin contamination	No data available. Contamination may be similar to retention basin contamination
Lewis Canal	F	Miscellaneous wastes from 185-F and 190-F buildings, decontamination wastes from 189-F building, occasional front and rear face reactor effluent	3.4 Curies	^{152}Eu, ^{154}Eu, ^{60}Co, ^{137}Cs, ^{3}H	$^{239/240}Pu$: 0.99 pCi/g	Chromium; sulfamic acid disposed to canal

Sources: Dorian and Richards, 1978 (unless otherwise noted) (All activities decayed through 1978)
*WIDS 1991 (All activities decayed through 4/1/86)

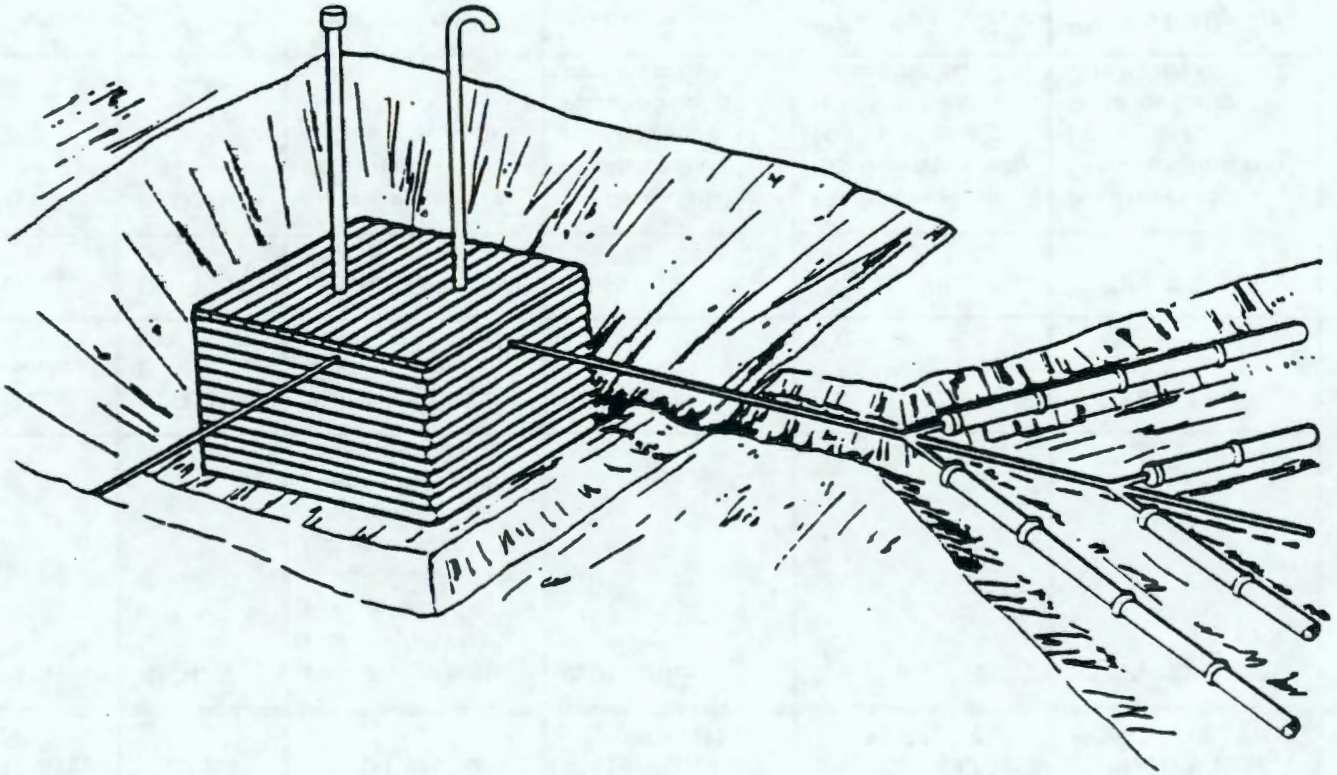

Figure 1-4. Typical Crib with Tile Drainage (Adams, et. al., 1984)

- Dummy/Perf Decontamination Cribs/Drains

  The dummy/perf decontamination cribs/drains received radioactive liquid wastes from the decontamination of dummy fuel element spacers in the 105-F, 105-H, and 111-B buildings. The cribs ranged in size from 4x8x8 feet to 12x8x15 feet and the drains were 3 to 4 foot diameter pipes 15 to 20 feet deep (DOE-RL 1991a).

  Acids, including nitric, sulfuric, oxalic, hydrofluoric, were used extensively in decontamination processes. Therefore, in addition to the radionuclides listed in Table 1-6, nitrate and other acid residues are likely contaminants in soils and groundwater beneath these cribs.

- 108 Building Cribs/Drains

  These cribs or underground drains received contaminated liquid effluents from the 108 laboratory building operations. The 116-B-5 crib was 84 feet long by 15 feet wide by 10 feet deep. The 116-D-3 crib was 3 foot diameter by 5 feet deep (DOE-RL 1991a). The 116-B-5 crib had 300 curies of tritium; the other 108 crib contained less than 0.1 curie of contamination.

- 115 Building Cribs

  The 115 building cribs were underground drains which received condensate and liquid waste from reactor gas purification systems. The cribs measured 40x40x26 feet. Each crib consisted of a four inch pipe leading into an 8-inch corrugated, perforated pipe 10.5 feet long. Two 5.4-ft sections branched off at 45 degrees (DOE-RL 1991a). Tritium and carbon-14 were the principal radionuclides disposed to these cribs. In 1978, the 116-KW-1 crib contained a total of 240 curies (Dorian and Richards 1978).

- 117 Building Cribs

  The 117 building cribs received drainage from the confinement system 117 building seal pits. The crib structures ranged from 125 to 1000 cubic feet (DOE-RL 1991a). Radioactive effluents disposed to these cribs generally contained only short-lived radionuclides. These cribs were released from radiological control prior to 1967.

Several special use cribs are described as follows:

- 116-F-5, 100-F Ball Washer Crib

  This crib received liquid wastes from the decontamination of the boron-steel balls used in the ball 3X system. The crib was 10 x 10 x 10 feet (DOE-RL 1991a). The crib contained 0.00092 curies; the principal radionuclides present included

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Strontium-90, Europium-154, Europium-155, and Cesium-137. No plutonium was detected.

- 116-KE-2, 1706-KER Crib

  This crib received radioactive liquid from the cleanup columns in the 1706-KER loop. The crib was 16 feet long by 16 feet wide by 32 feet deep. A wooden crib structure rests within the excavation 3 feet above the bottom. The bottom 10 feet are filled with crushed stone and backfilled with soil (DOE-RL 1991a). The crib contained 38 curies of Strontium-90 and Cobalt-60 with a 2.1 pCi/g maximum concentration of Plutonium-239/240.

- 116-DR-7, 105-DR Inkwell Crib

  This crib received liquid potassium borate solution from the 3X system prior to the ball 3X system upgrade. The crib was 5 feet long, 5 feet wide, and 10 feet deep (DOE-RL 1991a). The radiological contamination was found to be less than 0.1 curie.

French Drains. French drains were generally gravel-filled, concrete or vitreous clay pipe. These were 3 to 4 feet in diameter and ranged from 3 to 20 feet deep. French drains in the K Area received sulfuric acid sludge from the acid storage tanks. The 120-KE-1 French drain contains approximately 200 kilograms of mercury. French drains in the other areas received liquid wastes from decontamination processes. Drains in the F Area received effluent water from botany experiments (DOE-RL 1991a). Like cribs, they were usually dedicated to a specific building or process. Inventories for these French drains are unavailable (DOE-RL 1991a).

Trenches. Trenches were generally open excavations with sloped sides. The trenches ranged in length from 150 feet to 4000 feet, in width from 10 feet to 400 feet, and in depth from 6 feet to 25 feet. Each reactor area used a trench as backup to the retention basin when the effluent was too highly contaminated to be released to the river. Most of the trenches contain inventories of less than 10 curies. The liquid waste disposal trench at the K Area contained a total of 2100 curies with a maximum Plutonium-239/240 concentration of 130 pCi/g. Types of trenches are described as follows:

- Liquid Waste Disposal Trenches

  The liquid waste disposal trenches received effluent from the retention basins during fuel element cladding failures. The trenches ranged in size from 10 by 150 feet to 50 by 500 feet and in depth from 15 to 25 feet (DOE-RL 1991a). The trenches were used in early reactor operations until increased flow and leakage forced the parallel use of both sides of the retention basins. With the exception of the K Trench, the total contamination ranged from 3 to 79 curies with a maximum Plutonium-239/240 concentration of 5.3 pCi/g. Sodium dichromate was used

extensively as a corrosion inhibitor; therefore chromium contamination is expected in these trenches (DOE-RL 1991a).

- K Trench

The K trench (116-K-2) serviced both K Area reactors. The trench was 4000 feet long by 45 feet wide by 15 feet deep with a 4 foot bottom width (DOE-RL 1991a). The trench received wastes from all contaminated floor drains in the 105 buildings, approximately 500 gallons per minute of overflow from each metal storage basin, and an undetermined amount of 107 effluent basin leakage from valves in the tank bottoms. Periodic sources of contaminated flow to the trench included:

- Low volume neutralized dummy decontamination waste;
- Process cooling water during charge-discharge via metal storage basin and cross-under line;
- Approximately 700 gpm metal storage basin flow during charge-recharge;
- Occasional rear face decontamination wastes diluted with metal storage basin flow;
- Occasional "special" disposal such as waste from a single cross header through-reactor decontamination experiment; and
- An occasional tank-full of process cooling water collected after a fuel cladding failure.

The trench received large volumes of contaminated water and contained over 2000 curies of remaining activity. Maximum plutonium concentration was 130 pCi/g. Sodium dichromate, sulfamic acid, sulfuric acid, and copper sulfate were disposed to the trench (Dorian and Richards 1978).

- 1608 Trenches

The 1608 trenches were located in the F and H Areas and were used to receive effluent during the Ball 3X Project. Both trenches have overflowed in the past and contaminated nearby soils. The trenches have been backfilled with soil. The 1608-H trench is 275 feet by 100 feet by 6 feet deep and the 1608-F trench is 300 X 100 X 10 feet (DOE-RL 1991a). Total radioactivity ranges from 0.0021 curies to 1.4 curies. The major radionuclides include Strontium-90, tritium, Europium-152 and -154, Cobalt-60, and Cesium-137 with a maximum plutonium concentration less than 1 pCi/g (Dorian and Richards 1978).

- Sludge Trenches

The B Area contained two trenches, one 50 by 50 by 10 feet and one 120 by 10 by 10 feet that were used to bury low level sludge waste from the B Area retention basin (DOE-RL 1991a). Sampling data and contaminant inventories are not available for these trenches, although the contaminants and concentrations should be

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similar to those measured by Dorian and Richards 1978 for the B Area retention basin.

- 116-F-1, Lewis Canal

  The Lewis Canal, located in the 100-F Area, received miscellaneous wastes from the 105-F and 190-F buildings, as well as decontamination wastes from the 189-F building. On occasion, contaminated coolant from the reactor front and rear faces was also routed to the Lewis Canal. Effluent water from the 1953 ball 3X outage was channeled to the river through this trench. The trench was originally several thousand feet long, however, all but 1500 feet at the inlet end have been released from radiological control. Dorian and Richards 1978 estimated a total inventory of 3 curies and Plutonium-239/240 concentrations of 1 pCi/g. The major radionuclides include Europium-152 and -154, Cobalt-60, and Cesium-137. Sodium dichromate and sulfamic acid are known to have been disposed to the Lewis Canal (DOE-RL 1991a).

1.3.1.3.3 Solid Waste Disposal. Solid waste disposal units consisted of burial grounds, landfills, ash/burn pits, and storage caves/vaults. For the early operational years of the nuclear reactors at Hanford, few if any records are available on the materials sent to solid waste disposal facilities. Also, characterization efforts for these facilities are limited. Dorian and Richards 1978 sampled the 118-B-1 burial ground and developed the following generalizations:

- No measurable migration of radionuclides was found.
- Plutonium-239/240 was generally not detected.
- The primary radionuclide was Cobalt-60, comprising approximately 90 percent of the inventory; other radionuclides in significant concentrations included Europium-152, -154, -155, Cesium-134, -137, Strontium-90, and Nickel-63.

A total of 28 radioactive solid waste burial grounds have been identified in the 100 Area including seven major burial grounds associated with reactor operations, two burial grounds used for biological wastes, and one burial ground used during the tritium separations project at B reactor area. The remaining burial grounds were used for reactor upgrade projects, major maintenance projects, and special irradiation programs (Miller and Wahlen 1987). These special burial grounds generally contained low levels of radioactivity. Nonradioactive solid waste burial grounds in the 100 Area include ash and burn pits, demolition sites, and landfills. Estimated contamination inventories for the burial grounds are presented below and in Table 1-7.

Solid Waste Burial Grounds. Solid waste burial grounds which served the reactor facilities consisted of a series of trenches, pits, vertical pipes, and/or vault-like structures. The burial grounds ranged in size with the smallest being only a few feet wide and a few feet long to the largest being about 20 feet deep, 300 feet long, and 8 feet wide (at the bottom).

TABLE 1-7
SOLID WASTE DISPOSAL FACILITIES

SOLID WASTE DISPOSAL SITE TYPE	REACTOR AREA	PURPOSE/WASTE RECEIVED	TOTAL RADIONUCLIDE INVENTORY	MAJOR RADIONUCLIDES PRESENT	MAXIMUM PLUTONIUM CONCENTRATION	POTENTIAL CHEMICAL CONTAMINANTS
105 Burial Grounds (118 Burial Sites)	B, C, D, F, H, KE, KW	Low-level solid radioactive waste associated with reactor operations: aluminum spacers, lead-cadmium reactor poison pieces, boron splines, graphite, process tubes, lead	4000 tons of waste in 7 burial grounds, 3900* Curies in 7 burial grounds	^{90}Sr, ^{3}H, ^{152}Eu, ^{154}Eu, ^{60}Co, ^{137}Cs, ^{14}C, ^{63}Ni, ^{59}Ni, ^{108m}Ag, ^{133}Ba *3800 Curies from ^{60}Co, ^{63}Ni	1.0 pCi/g in 118-B-1, no data available on other burial grounds	Lead, cadmium, boron, mercury, graphite
Tritium Separations Project Burial Grounds	B	Aluminum cladding from target material, stainless steel container and remnants, palladium, natural and some depleted uranium, zirconium, solva beads, tritium contaminated pumps and oil, glass line components	562 tons of wastes, 11,000 Curies	^{3}H	No data available.	Metal hydrides of lithium, aluminum, and lead, mercury, activated charcoal, deliquescent compounds
Biological Burial Grounds	F	Sawdust and solids from dog kennels and swine pens: 118-F-5 Buried steel tanks used to incinerate carcasses: 118-F-6	10,000 yd^3 of sawdust, 15 Curies 10,000 cubic feet of waste volume in 118-F-6, 15 Curies	^{90}Sr	^{239}Pu: 0.3 Curies	No data available

TABLE 1-7
SOLID WASTE DISPOSAL FACILITIES

SOLID WASTE DISPOSAL SITE TYPE	REACTOR AREA	PURPOSE/WASTE RECEIVED	TOTAL RADIONUCLIDE INVENTORY	MAJOR RADIONUCLIDES PRESENT	MAXIMUM PLUTONIUM CONCENTRATION	POTENTIAL CHEMICAL CONTAMINANTS
Ash Pits[a]	B, D, F, H	Coal ash sluiced with river water	No radionuclide contamination expected	No radionuclide contamination expected	No radionuclide contamination expected	No sampling data available. Only one ash pit determined to be toxic using an EP toxicity test
Burn Pits[a]	B, C, D, F, H, K	Nonradioactive combustibles, glass, scrap metal, paints, solvents, lab wastes, office wastes	No radionuclide contamination expected	No radionuclide contamination expected	No radionuclide contamination expected	Asbestos may be present
Storage Caves/Vaults[a]	C, F, KE, KW	Horizontal control rods were temporarily stored for decay prior to disposal, one cave contains 4 rod tips, also miscellaneous reactor hardware	Radiation readings from 1mR/hr up to 50 mR/hr are present at tunnel entrances	Radionuclides are unknown	Radionuclides are unknown	No data available
Demolition Sites and Landfills[a]	B, D, DR, H, K	Low level construction wastes, demolition wastes	No radionuclide contamination expected	No radionuclide contamination expected	No radionuclide contamination expected	No sampling data available.

Source: Miller and Wahlen, 1987 (unless otherwise noted; Activities as recorded in 1987; Values not decayed to present)
[a]DOE-RL 1991a (Values decayed through 4/1/86)

The deep, narrow trenches contained high-dose large equipment; the pits and pipes were used for small, high-dose reactor hardware such as thermocouple stringers and horizontal control rod tips. A typical burial trench consisted of layers of hard waste (metal components such as irradiated process tubes and fuel charge spacers) and soft waste (such as contaminated paper, plastic, and clothing). Hard waste was usually placed in the bottom of the trench. Figure 1-5 is a schematic of a typical burial trench as presented in Adams et al., 1984. Interviews with operations personnel indicate that the layering of waste shown in the schematic may not accurately portray conditions in the burial trenches. Soft waste may have been disposed in different part of the trench than hard waste, or in some cases, hard waste was placed on top of the soft waste. Soft waste makes up more than 75% of the volume in the trenches but contains less than 1% of the radioactive inventory (Adams et al. 1984).

Each reactor had an associated burial ground. Miller and Wahlen 1987 estimated the total radionuclide inventory from reactor operations for these burial grounds to be about 4,000 curies, mostly from Cobalt-60 and Nickel-63. Metallic wastes include lead, cadmium, lead-cadmium alloy, boron, mercury, and graphite. The 118-B-1 burial ground also received an estimated 37.5 tons of wastes associated with the glass process lines used in the tritium separations program, including lithium-aluminum alloy. This waste contained a tritium inventory of about 3,800 curies and approximately 2,000 pounds of mercury.

Ball 3X Burial Grounds. The ball 3X burial grounds were located in the B, D, F, and H Areas and were used to dispose of highly contaminated waste removed from the reactor buildings during the Ball 3X Project. Wastes included thimbles (aluminum components used to provide a sealed access to the reactor for the control and safety rods and for a boron solution used as a shutdown device) and step plugs (an aluminum shielding device used in the reactor tubes). The burial grounds in the B, F, and H Areas consisted of a single trench; the D Area burial grounds contained two 40X20X10 foot trenches. The F Area burial ground was 175 feet by 50 feet by 15 feet deep, the B Area burial ground was 50 feet by 50 feet by 20 feet deep, and the H Area burial ground was 150 feet by 30 feet by 10 feet deep (DOE-RL 1991a).

Tritium Separations Project Burial Ground. Wastes associated with the metal lines used in the tritium separations project were disposed to this burial ground. An estimated 562 tons of waste, including 18 tons of lead and 25 tons of aluminum, were disposed. This included 11,000 curies of tritium.

Biological Burial Grounds. Two burial grounds in the F Area were used for the disposal of biological wastes. Each burial ground contained an estimated 15 curies of Strontium-90 and 0.30 curies of Plutonium-239/240.

Ash Pits. The ash pits received coal ash sluiced with water from the powerhouse. The ash pits received coal ash sluiced with water from the powerhouse. Ash from selected power plants at the Hanford Site has been characterized as nonradioactive and nonhazardous. Common sources of coal were used throughout the site so the ash in the pits will probably be comparable to these analyses. The ash was analyzed using the extraction procedure (EP)

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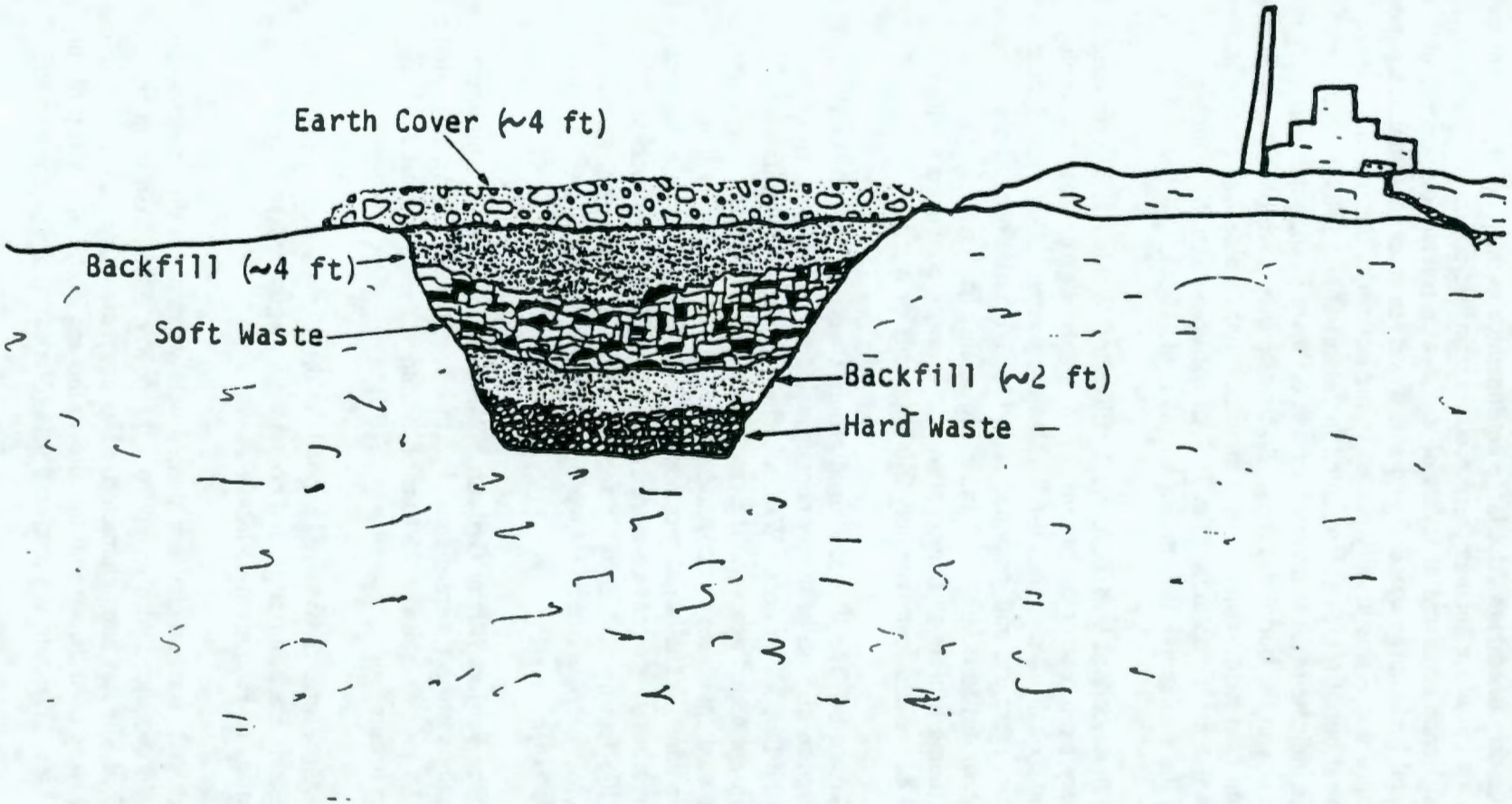

Figure 1-5. Cross Section of a Typical Solid Waste Burial Trench (Adams, et. al., 1984)

toxicity test in accordance with WAC 173-303 and no nonhazardous materials were found (DOE-RL 1991a).

Burn Pits. Burn pits in the 100 Area were used to dispose of nonradioactive combustibles such as paints, solvents, laboratory wastes, and office wastes. Evidence of burning exists at the sites and several of the pits are also believed to have been used to dispose of rubble from demolition projects and debris and soil from retention basin repairs. Other materials which may have been disposed to the burn pits include scrap metal, glass, and asbestos. Sizes of the burn pits range from 9,600 to 224,000 square feet.

Storage Caves/Vaults. The storage caves/vaults were used for temporary storage of horizontal control rods for decay prior to disposal. One vault was used for the storage of miscellaneous reactor hardware and the hardware still remains in the vault. The caves were 40 foot by 25 foot concrete tunnels covered with mounds of dirt. The vault in the F Area was a 16x8x8 foot concrete box with a wooden cover (DOE-RL 1991a). Exposure rates vary from 1 mR/hr up to 50 mR/hr at the tunnel entrances. No information is available on specific inventories of radionuclides.

Demolition Sites and Landfills. Demolition sites and landfills in the 100 Area received very low-level construction and demolition wastes. Little or no radiological contamination is expected in these sites.

1.3.1.3.4 Reactor Building. The reactor building housed the reactor core and a fuel storage basin which consisted of a water filled concrete structure used to temporarily hold spent fuel elements for decay of short-lived radionuclides. Some basins presently contain highly radioactive sludge. The reactor buildings are not included within the past practice operable units and thus are not within the scope of this FS; they are subject to actions as part of the Surplus Reactors Decommissioning Program.

1.3.1.3.5 Miscellaneous Facilities and Waste Sites.

Storage Tanks. Tanks were used in the 100 Area for storing hydrocarbon products, acids, and chemical wastes. The tanks range in size from approximately 30 gallons for an evaporation unit to 1,650,000 gallons for oil storage tanks. Many of the tanks are currently either empty or water-filled, although some contain small amounts of residual waste. A few of the tanks have been moved to the 200 Area. Contamination associated with the tanks includes leaks and spills (DOE-RL 1991a).

Unplanned Releases. Unplanned releases occurred in the 100-F, 100-K, and 100-N Area. The 100-N unplanned releases are discussed in further detail in Section 1.3.3.2.5. The 100-F Area release occurred on March 13, 1971 when the main sewer line between the 141-C and 141-M buildings became plugged. The spill consisted of wash water from the clean out of animal pens and contained an estimated 4.0E-5 Ci of Strontium-90 and 1.06E-6 Ci of Plutonium-239. The area was stabilized with clean gravel (DOE-RL 1991a).

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The unplanned release in the K Area occurred in April 1979 when the 105-KE pickup chute area of the fuel storage basin leaked approximately 450 gallons per hour of fuel storage basin effluent and debris for an unknown period of time. Total activity was estimated at 2,530 curies including 1.3 Ci of Plutonium-239/240. The release was completely below ground with no associated surface contamination (DOE-RL 1991a).

Undocumented releases of hydrocarbon products and chemicals may have resulted in contamination of the soils in the 100 Area. In addition, unplanned releases to the air occurred in the 100 Area but are outside the scope of this report.

100-K Area Brine Pits. The pits were concrete structures, either underground or partially underground, ranging in area from 160 to 390 square feet. Salt was unloaded to the pits and water was circulated through the salt to create a brine for use in the power house. The salt was also used in water softeners. Contamination includes salt brine and residue (DOE-RL 1991a).

White Bluffs Pickling Acid Crib. This crib is located in the 100-IU-5 operable unit and was used to treat (pickle) piping for the reactors during the construction phase. This process used several thousand gallons of nitric and hydrofluoric acid. Vent pipes protrude every 18 inches and the surface is covered with large cobbles (DOE-RL 1991b).

Septic Systems. Thirty septic systems serviced the first eight reactor areas. The systems received sanitary sewage from buildings and possible contamination could include mercury from manometers, thermometers, and electrical equipment or wastes from laboratories which may have been disposed in sinks and floor drains. In addition, waste water from change rooms and the decontamination of face masks may have contributed to radiological contamination of the septic systems. No sampling data are available for the septic systems (DOE-RL 1991a).

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1.3.1.4 100-N Area Facility Characteristics and Contamination

1.3.1.4.1 Liquid Waste Disposal Facilities. The liquid waste disposal facilities in the 100-N Area consist of cribs, French drains, ponds, emergency dump tank and basin, and miscellaneous liquid waste facilities. Available data on the nature and extent of liquid waste disposal facility contamination are given in Table 1-8.

Cribs. The 116-N-1 crib consisted of a rectangular basin 290x125x12 feet with a 50x1600 foot extension trench. The 116-N-3 crib consisted of a concrete diversion box with an associated 250x240 foot concrete header box and a 3,000x10x7 foot extension trench. A 36 inch diameter, 1,200 foot long pipeline connected the box to the header. The cribs received radioactive water containing both activation and fission products. Small quantities of corrosives and laboratory chemicals were also disposed of in these cribs.

Chemical wastes disposed to the cribs include:

- Hydrazine test solution

- Ammonia test solution
- Chloride test solution
- Fluoride test solution
- Lead-acetate battery fluid
- Nickel-cadmium battery fluid
- Hydrazine
- Sodium dichromate (DOE 1990d).

French Drains. The 100-N Area French drains were constructed of 2 to 8 foot diameter clay pipe packed with lime. One of the drains had an associated 8x25 foot concrete vault/neutralization pit. The drains received either spent sulfuric acid or sodium hydroxide wastes (DOE-RL 1991a).

Ponds. Ponds were used in the 100-N Area to treat corrosive regeneration effluent, to settle out solids from filter backwash, and to dispose of backwash effluent. The ponds were generally unlined sloped-sided trenches ranging in area from 5,500 square feet to 29,000 square feet. Exceptions are the 130-N-1 filter backwash discharge pond, which is a natural, marshlike basin, and the 120-N-2 surface impoundment, which was double lined. The 130-N-1 pond also received aluminum sulfate and polyacrylamide solutions. Flow rates to the ponds were as high as 430,000 gallons per day.

Miscellaneous Liquid Waste Facilities. The 116-N-2 (1310-N) radioactive chemical waste treatment and storage facility was a waste management unit consisting of a complex system of piping, pumps, a transfer tank, and a large treatment and storage tank. This facility was used to neutralize the pH of and temporarily store radioactive waste acid solution used in internal reactor decontamination. The transfer tank is a spherical metal structure with a 900,000 gallon capacity; it is partially buried and surrounded by a 25 foot high compacted soil radiation barrier on three sides. Decontamination wastes from the primary water loop of the reactor were transferred by a 6 inch diameter underground pipe to the transfer tank and then to the storage tank for neutralization.

The decontamination wastes included 70% phosphoric acid and diethylthiourea. Decontamination of the primary loop occurred once every three to five years and resulted in approximately 600,000 gallons of waste solution per decontamination event (DOE 1990d).

1.3.1.4.2 Solid Waste Disposal Facilities. The 128-N-1 burning pit is the only solid waste disposal facility listed in the Waste Information Data System (WIDS) for the 100-N Area. The burning pit was used to burn nonhazardous waste such as paper, wood, trash, etc. generated at 100-N Area. The dimensions and exact location of the unit are unknown (DOE-RL 1991a). No characterization data are available in WIDS or DOE 1990d.

1.3.1.4.3 Miscellaneous Waste Facilities. Miscellaneous waste facilities include the three 118-N-1 spacer storage silos, the 116-N-8 mixed waste storage area, and the 120-N-4 nonhazardous and nonradioactive storage area. Information on types and amounts of contamination in these facilities is unavailable.

TABLE 1-8
100-N AREA SOURCES

SOLID WASTE DISPOSAL SITE TYPE	PURPOSE/WASTE RECEIVED	TOTAL RADIONUCLIDE INVENTORY	MAJOR RADIONUCLIDES PRESENT	MAXIMUM PLUTONIUM CONCENTRATION	POTENTIAL CHEMICAL CONTAMINANTS
Cribs	Radiated water containing activation and fission products, small quantities of corrosives and laboratory chemicals	8,089 Curies for 116-N-1 (1988 Values) 1,932 Curies for 116-N-3 (1988 Values)	^{60}Co, ^{90}Sr, ^{106}Ru, ^{134}Cs, ^{137}Cs, ^{239}Pu	^{239}Pu: 18 Curies for 116-N-1 (1988 Values) 2.6 Curies for 116-N-3 (1988 Values)	Hydrazine, ammonia, chloride, and fluoride test solutions, lead-acetate battery fluid, nickel-cadmium battery fluid, sodium dichromate
French Drains	Sulfuric acid or sodium hydroxide	None expected	Not applicable	Not applicable	Acids, caustics, lead wastes found in some of the drains, others had no evidence of acid or heavy metal wastes.
Ponds	Used to treat corrosive regeneration effluent, to settle out solids from filter backwash, and to dispose of backwash effluent, the 130-N-1 pond also received aluminum sulfate and polyactylamide	None expected	Not applicable	Not applicable	Analysis of filter backwash effluent indicates that it does not contain any listed dangerous wastes. (Krug 1989) Other contaminant data was unavailable.
Miscellaneous Liquid Waste Facilities	Decontamination wastes containing 70% phosphoric acid and diethylthiourea	90,000 gallon spill, contained about 35 Curies (1972 Value)	^{60}Co (26 Curies) (1972 Value)	No data available	phosphoric acid, diethylthiourea, sodium hydroxide

Sources: DOE 1990d
DOE-RL 1991a

- 118-N-1

  The three 118-N-1 spacer storage silos were used for temporary storage of irradiated fuel spacers which came in direct contact with the fuel elements in the reactor. The silos were each 16 feet in diameter and 20 feet deep. Two of the silos were open-bottomed; the other had a concrete floor. All three were covered with concrete caps. The silos currently contain dry irradiated spacers (DOE 1990d).

- 116-N-8

  The 116-N-8 mixed waste storage area is a concrete-paved, mixed waste container storage pad. The pad is walled on two sides, covered by a roof, and surrounded by a curb and a mesh fence. The pad measured 60 feet by 152 feet. Drums and containers of radioactively contaminated oil and miscellaneous hazardous process chemicals are stored on the pad (DOE 1990d).

- 120-N-4

  The 120-N-4 nonhazardous and nonradioactive storage area is a 100 foot by 75 foot curbed concrete pad. The pad is used to store nonradioactive and nonhazardous oils and aqueous liquids. Prior to 1985, the unit was unpaved and used as a laydown yard for radioactively-contaminated equipment. Information on types and amounts of wastes for this time period are unavailable (DOE 1990d).

1.3.1.4.4 Sanitary Sewer Systems. The 100-N Area contains ten sanitary septic systems: one cesspool, one lagoon, one septic tank with an associated tile field, two septic tanks with seepage pits, and five septic tanks with associated drain fields. Flow rates to the septic systems ranged from 45 to 50,000 gallons per day.

The 124-N-4 sanitary sewer system has detectable surface contamination. No other characterization data are available for these facilities in WIDS or the 100-N Area work plans.

1.3.1.4.5 Unplanned Releases. The 100-N Area had 33 unplanned releases consisting primarily of line leaks and spills during transfers (DOE 1990d). One release resulted when a contaminated piece of equipment fell off a truck; the other releases involved spills/leaks of low level radioactive water, petroleum fuels, or nonradioactive chemicals. Unplanned releases are tabulated in Appendix E.

Radioactive Liquids. Releases of radioactive liquids ranged from less than 100 gallons to over 500,000 gallons. Contamination ranged from less than 1μCi to 35 curies. Many of the releases were remediated by removal of contaminated soil and/or covering with clean soil.

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Petroleum Fuels. Diesel and/or fuel oil leaked from pipelines or overflowed from storage tanks. The fuels were nonradioactive and ranged from 200 gallons up to 80,000 gallons. The extent of remediation on these releases is generally unknown.

Nonradioactive Chemical Liquids. Spills during the transfer of chemicals ranged from approximately 500 gallons to 3,500 gallons. The chemicals included phosphoric acid and diethylthiourea mixture, sulfuric acid, and sodium hydroxide. Acid spills were neutralized with soda ash. Cleanup included removal of contaminated soils and backfill in some spill areas. The extent of residual contamination is unknown (DOE-RL 1991a).

1.3.1.5 Soils

Most of the wastes generated during the operations of the 100 Area reactors were disposed to the soils, either intentionally or through leakage. Groundwater mounds existed in the 100 Area because of the volumes of liquids disposed to the soils. Available data on nature and extent of soil contamination are summarized in the subsections below. The 100-N Area soils are discussed in Section 1.3.1.5.4.

1.3.1.5.1 Background Soil Quality (excluding 100-N Area). Background soil quality data specific to the 100 Area are generally unavailable. Samples are collected periodically as part of the Hanford Environmental Management Program from locations both on and off the Hanford Site. These samples are limited in applicability for several reasons:

- No subsurface samples are collected.
- Those samples which are routinely obtained are analyzed for a limited range of radionuclides.
- Samples are generally collected near sources and are therefore influenced by past operations.

Data from the 1989 onsite and offsite sampling are presented in Table 1-9. No data have been developed for nonradioactive inorganic contaminants such as nitrate and chromium.

A characterization effort is currently underway at Hanford to determine background concentrations for soils. Available data from this effort are presented in Table 1-10.

1.3.1.5.2 Soil Contamination (excluding N Area). Soil contamination in the 100 Area has resulted from the following potential operational sources:

- Fallout from stack emissions
- Planned releases from waste handling and disposal facilities
- Unplanned releases (Jaquish and Mitchell 1988).

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TABLE 1-9
1989 DATA FROM ONSITE AND OFFSITE SOIL SAMPLING
HANFORD ENVIRONMENTAL MONITORING PROGRAM

Contaminant	Onsite[a] Average pCi/g (dry weight)[b]	Offsite[a] Average pCi/g (dry weight)[b]
Strontium-90	0.25 ± 0.33	0.13 ± 0.03
Cesium-137	2.48 ± 9.90	0.74 ± 0.27
Plutonium-239/240	0.061 ± 0.296	0.013 ± 0.033
Uranium	0.60 ± 0.51	0.73 ± 0.13

[a]12 onsite samples, 23 offsite samples.
[b]The values given after the ± sign are two standard errors of calculated mean.
Source: DOE 1990d (Activity as recorded in 1989; Values not decayed to present)

TABLE 1-10. HANFORD SITE SOIL BACKGROUND

CONSTITUENT	BACKGROUND VALUE (ppm)
Aluminum	15,100
Calcium	22,000
Copper	32.2
Iron	38,200
Lead	15.4
Sodium	167

Source: DOE/RL 1992

Table 1-11 contains surface soil data collected in 1987 as part of the Hanford Environmental Management Program. The environmental samples of surface soil collected in 1985 by United Nuclear Corporation (UNC) near the retired 100 Area reactor facilities indicated no release or biotransport of radionuclides to the immediate environment. Table 1-12 presents the range of contaminants found in the 100 Area soils in the 1985 sample collection (Jacques 1986).

Sampling for vadose zone contaminants was performed in the 1970s by Dorian and Richards (1978). Their investigation focused on the retention basins and liquid waste disposal facilities. Contaminant information given in Section 1.3.3.1, Section 1.3.3.2, and

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TABLE 1-11
CONTAMINANT CONCENTRATIONS IN THE 100 AREA SOILS
ENVIRONMENTAL MONITORING AT HANFORD FOR 1987
(pCi/g, dry weight)

Location	Strontium-90	Cesium-137	Plutonium-239/240	Uranium
1 Mile NE of 100-N Area	0.24 ± 0.01[a]	0.81 ± 0.05[a]	0.015 ± 0.001[a]	0.19 ± 0.06[a]
1 Mile E of 100-N Area	0.31 ± 0.01	1.1 ± 0.1	0.023 ± 0.002	0.34 ± 0.10
100 Area Fire Station	0.33 ± 0.01	1.3 ± 0.1	0.017 ± 0.001	0.35 ± 0.10
Southwest of B/C Cribs	0.02 ± 0.01	0.01 ± 0.02	0.001 ± 0.001	0.19 ± 0.05

[a]1986 data. Location sampled on alternating years.
Source: Jaquish and Mitchell 1988 (Values not decayed to present)

TABLE 1-12
SOIL CONTAMINATION RANGES IN THE RETIRED 100 AREAS
UNC ENVIRONMENTAL MONITORING PROJECT, FY 1985
(pCi/g, dry weight)

Area	Cobalt-60	Strontium-90	Cesium-137	Plutonium-238	Plutonium-239/240
B/C	0.13 - 0.49	0.014 - 0.050	<0.076 - 0.85	<0.00014 - 0.00040	0.00058 - 0.0011
D/DR	0.15 - 0.36	0.033 - 0.075	0.058 - 0.44	<0.00012 - 0.00031	0.0015 - 0.0052
F	0.16 - 0.64	0.050 - 0.56	0.19 - 2.8	<0.00017 - 0.0021	0.0015 - 0.032
H	0.14	0.086 - 0.11	0.23	<0.00013 - 0.00025	0.0039 - 0.0074
K	0.11 - 1.6	0.056 - 0.66	0.092 - 2.0	<0.00019 - 0.0051	0.0012 - 0.12

Source: Jacques, 1986 (Values not decayed to present)

Tables 1-5, 1-6, and 1-8 represents the available data for the 100 Area soils. Sampling data for nonradioactive contaminants are unavailable.

1.3.1.5.3 100-N Area Background Soil Quality. Background soil samples were collected at the 120-N-1 Surface Impoundment, the 120-N-2 Percolation Pond, and the north and south settling ponds. The analyses of these samples can be generalized as follows:

- Background radionuclide concentrations were low; the radionuclides present included:
  - Uranium
  - Potassium-40
  - Lead-212
  - Lead-214
  - Gross beta.

- Background soils contained metals, with low concentrations of volatile organics and no semi-volatiles (DOE 1990d).

Background values for other sites in the 100-N Area are unavailable.

1.3.1.5.4 100-N Area Soil Contamination. The findings from UNC's 1985 sampling campaign (Jacques 1986) are presented in Tables 1-11 and 1-12 and can be generalized as follows:

- Environmental samples of surface soil and direct radiation measurements collected near 100-N Area indicated no significant releases to the immediate environment.

- Radionuclides released to 116-N-1, the 1301-N liquid waste disposal facility, were detected in the surface soil adjacent to the facility.

- Sediment samples collected from the 1301-N liquid waste disposal facility and 116-N-3, the 1325-N crib, contained activation and fission products discharged from N Reactor.

Table 1-13 presents average radionuclide concentrations in the 100-N Area surface soil from 1981 to 1985.

Subsurface soils near the 116-N-1 crib and trench were sampled in 1982 (Robertson et. al., 1982) as part of a research project. Data from gamma logs of the boreholes indicate that very low concentrations of radionuclides such as Cobalt-60, Cesium-137, Antimony-125, and Ruthenium-106 were present above the water table in the borehole nearest the facility. Concentrations of the radionuclides in the unsaturated zone decreased in the other two boreholes which are farther from the crib and trench. Concentrations increased markedly in the soils at the water table in all three wells. Organics found in the samples include alkenes, alkanes, alkynes, elemental sulfur, and three cyclic sulfur species.

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TABLE 1-13
AVERAGE RADIONUCLIDE CONCENTRATIONS IN 100-N AREA SURFACE SOIL FROM 1981 TO 1985
(pCi/g, dry weight)

Year	Manganese-54	Cobalt-60	Strontium-90	Cesium-137	Plutonium-239/240
1980	0.24	0.85	0.18	0.50	0.018
1981	0.16	1.3	0.21	1.0	0.011
1982	0.13	1.6	0.099	0.34	0.0050
1983	0.21	2.7	0.29	0.44	0.0085
1984	NR	0.88	0.28	0.62	0.014
1985	.012	1.2	0.13	0.52	0.013

Source: Jacques, 1986 (Values not decayed to present)

Studies conducted on 100-N Area soils indicate that radionuclide-specific sorption will occur and that sorption is dependent upon ionic species; 100-N Area soils have no capacity to retain iodine and phosphorous and very low capacity to retain tritium. Strontium, cesium, and other radionuclides will be preferentially sorbed to varying degrees (DOE 1990d).

1.3.1.6 Groundwater

Groundwater contamination in the 100 Area is primarily a result of direct disposal of liquid wastes to the soil. The groundwater beneath the 100-N Area contains higher concentrations of a greater number of radionuclides because of its more recent operations.

1.3.1.6.1 Background Groundwater Quality. Groundwater in the unconfined aquifer on the Hanford Site is characterized as calcium bicarbonate dominant; primary inorganic constituents include calcium, bicarbonate, sulfate, silica, sodium, chloride, magnesium, and potassium. Secondary natural constituents occurring in trace amounts (<1 ppm) include ammonia, barium, fluoride, manganese, and strontium. The natural Hanford groundwater contains moderate total hardness, approximately 120 ppm, and total dissolved solids, approximately 250 ppm. Background levels for Hanford groundwater are presented in Table 1-14. Background concentrations have been estimated from groundwater samples collected as part of the Hanford Sitewide Groundwater Monitoring Project from areas judged to be unaffected by Hanford operations (Evans et al. 1990).

An effort is currently underway to determine sitewide groundwater background levels. The initial results from this study are presented in Table 1-15. The information in the table was taken from *Hanford Site Groundwater Background* (DOE-RL 1992b) and represents a compilation of data from the following sources:

- Basalt Waste Isolation Project Hydrochemistry Database
- The Hanford Groundwater Database
- U.S. Geological Survey Data
- Pacific Northwest Laboratories Summary (Evans et. al., 1990).

Background concentrations specific to the 100 Area are not available and use of the general Hanford Site groundwater data may not be appropriate for all comparisons. Because of the close proximity to the Columbia River, the river water influx may dominate the flow system in the vicinity of the reactors, such that background groundwater quality may be closer to river water quality.

1.3.1.6.2 Groundwater Contamination. Contamination in the groundwater of the 100 Area is a result of past waste disposal practices. Groundwater is monitored routinely for radioactive and inorganic contaminants. Tritium and nitrate are mobile contaminants found in the Hanford area groundwater and serve as indicators of the extent of contamination. Tritium was one of the major radionuclides found in the 100 Area waste streams and nitrate results from the nitric acid used in reactor decontamination. Hexavalent chromium is another mobile contaminant which can be used to estimate the extent of contamination. Sodium dichromate, used to control oxidation of aluminum parts, and chromic acid, used to

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TABLE 1-14
ESTIMATED BACKGROUND LEVELS FOR SELECTED CONSTITUENTS IN HANFORD GROUNDWATER

Constituent	Detection[a]	Background
Aluminum	2[b]	<2[b]
Ammonia	50	<50
Arsenic	0.2[b]	3.9 ± 2.4[b]
Barium	6	42 ± 20
Beryllium	0.3[b]	0.3[b]
Bismuth	0.02[b]	<0.02[b]
Boron	50[b]	<50[b]
Cadmium	0.2[b]	<0.2[b]
Calcium	50	40,400 ± 10,300
Chloride	500	10,300 ± 6,500
Chromium	2[b]	4.0 ± 2.0[b]
Copper	1[b]	<1[b]
Cyanide	10	<10
Fluoride	500	370 ± 100
Lead	0.5[b]	<0.5[b]
Magnesium	10	11,800 ± 3,400
Manganese	5	7 ± 5
Mercury	0.1	<0.1
Nickel	4[b]	<4[b]
Phosphate	1000	<1000
Potassium	100	4,950 ± 1,240
Selenium	2[b]	<2[b]
Silver	10	<10
Sodium	10	18,260 ± 10,150
Strontium	20	236 ± 102
Sulfate	500	34,300 ± 16,900
Uranium	0.5[c]	1.7 ± 0.8[c]
Vanadium	5	17 ± 9

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TABLE 1-14
ESTIMATED BACKGROUND LEVELS FOR SELECTED CONSTITUENTS IN HANFORD GROUNDWATER

Constituent	Detection[a]	Background
Zinc	5	6 ± 2
Alkalinity	--	123,000 ± 21,000
pH	--	7.64 ± 0.16
Total Organic Carbon	200	586 ± 347
Conductivity	1[d]	380 ± 82[d]
Gross Alpha	0.5[c]	2.5 ± 1.4[c]
Gross Beta	4[c]	19 ± 12[c]
Radium	0.2[c]	<0.2[c]
Tritium	--	200[c]

(a) Units in ppb unless otherwise noted.
(b) Based on Induction Coupled Plasma-Mass Spectrometry (ICP/MS) data.
(c) Units in pCi/L.
(d) Units in μmho/cm.
Source: DOE 1991c (Values reported for 1988)

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TABLE 1-15. HANFORD SITE GROUNDWATER BACKGROUND SUMMARY OF PROVISIONAL THRESHOLD VALUES

CONSTITUENT	UNITS	PROVISIONAL THRESHOLD VALUE
Aluminum	ppb	<200
Ammonium	ppb	120[b]
Arsenic	ppb	10[b]
Barium	ppb	68.5[b]
Beryllium	ppb	<5
Bismuth	ppb	<5
Boron	ppb	<100
Cadmium	ppb	<10
Calcium	ppb	63,600[b]
Chloride, Low	ppb	8,690[b]
Chloride, High	ppb	28,500[b]
Chromium	ppb	<30
Copper	ppb	<30
Fluoride, LDL	ppb	1,340[bc]
Fluoride, LDL[c]	ppb	775[b]
Iron, Low	ppb	86[b]
Iron, Mid	ppb	291[a]
Iron, High	ppb	818[a]
Lead	ppb	<5
Magnesium	ppb	16,480[a]
Manganese, Low	ppb	24.5[b]
Manganese, High	ppb	163.5[b]
Mercury	ppb	<0.1
Nickel	ppb	<30
Nitrate	ppb	12,400[b]
Phosphate[e]	ppb	<1.000[e]
Potassium	ppb	7,975[a]
Selenium	ppb	<5
Silver[d]	ppb	<10[d]
Silicon	ppb	26,500[b]
Sodium	ppb	33,500[b]
Strontium	ppb	264.1[a]

TABLE 1-15. HANFORD SITE GROUNDWATER BACKGROUND SUMMARY OF PROVISIONAL THRESHOLD VALUES

CONSTITUENT	UNITS	PROVISIONAL THRESHOLD VALUE
Sulfate	ppb	90,500[b]
Uranium	pCi/l	3.43[b]
Vanadium	ppb	15[b]
Zinc, Low	ppb	<50
Zinc, High	ppb	673[a]
Field Alkalinity	ppb	215,000[b]
Lab Alkalinity	ppb	210,000[b]
Field pH		[6.90, 8.24][a]
Lab pH		[7.25, 8.25][a]
TOC	ppb	2,610[b]
TOC[c]	ppb	1,610[b]
Field Conductivity	umho/cm	539[a]
Lab Conductivity	umho/cm	530[b]
TOX, LDL		60.8[b]
TOX, LDL[c]		37.6[b]
Total Carbon	ppb	50,100[b]
Gross Alpha	pCi/l	63[b]
Gross Alpha[c]	pCi/l	5.79[ac]
Gross Beta	pCi/l	35.5[b]
Gross Beta[c]	pCi/l	12.62[ac]
Radium	pCi/l	0.23[b]

Source: DOE-RL 1992b
[a]Based on normal distribution.
[b]Based on non-parametric tolerance interval, maximum value reported.
[c]Potential outlier observation(s) were removed.
[d]Based on inductively coupled plasma/mass spectroscopy (ICP/MS).
[e]From springs data (Early et. al., 1986).
<Indicates compound was analyzed for but not detected. Reported value after the "<" sign is the detection limit.

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decontaminate dummy fuel elements, account for the hexavalent chromium concentrations in the Hanford groundwater.

Groundwater monitoring efforts for 1989 included analyses of samples taken from 91 wells, 43 of which were in the 100-N Area. Contaminants found in the groundwater which exceeded (for comparison) the Safe Drinking Water Act (SDWA) Maximum Contaminant Level (MCL) (40 CFR 141) are presented below (Evans et al. 1990). Tables 1-16 through 1-18 present contaminant ranges for key inorganic constituents, radiological constituents, nitrate, and volatile organic compounds found the 100 Area groundwater (Evans, et al., 1990). Table 1-19 presents a list of constituents detected in the 100-N Area which exceeded drinking water standards (SDWA MCLs) for the period April 1987 to November 1989.

Hexavalent Chromium. Hexavalent chromium was detected in wells in the 100-B/C, -D/DR, -H, -F, and -K Areas. The maximum concentration, 692 μg/L, was found in a monitoring well in the 100-D Area. This concentration was lower by a factor of two from 1987. Chromium plumes are centered near the D reactor and south of 116-H-6, the 183-H solar evaporation basins.

Nitrate. Nitrate was measured at concentrations greater than the 45 mg/L MCL in all areas.

Tritium. Tritium concentrations greater than the 20,000 pCi/L MCL were detected in 100-B/C, -D/DR, and -K Areas with the maximum concentration of 882,000 pCi/L found in the 199-K-30 well.

Gross Alpha. The gross alpha MCL of 15 pCi/L was exceeded in the F and H Areas. The wells in the F Area with elevated gross alpha contained uranium at levels which would account for the gross alpha levels detected.

Gross Beta. The 50 pCi/L MCL for gross beta activity was exceeded throughout the Hanford Site. Gross beta levels in the 100 Area can be attributed mainly to a combination of uranium and technetium-99 activity. Strontium-90 also contributes to the gross beta activity in the 100-N Area.

Cobalt-60. Cobalt-60 concentrations were consistently at or below detection limits except in the 100-N Area.

Strontium-90. Strontium-90 concentrations in the 100-B/C, -D/DR, -F, -K, and -N Areas exceeded the MCL of 8 pCi/L. The highest concentration of 23,400 pCi/L was found at 116-N-1, the 1301-N liquid waste disposal facility.

Technetium-99. 100-H Area wells showed technetium-99 concentrations greater than the 900 pCi/L SDWA MCL.

TABLE 1-16
CONCENTRATION RANGES OF KEY INORGANIC CONSTITUENTS IN 100 AREAS GROUNDWATER 1989 SAMPLING DATA

Area	Number of Wells/Number of Samples	Nitrate* Concentration Range (μg/L) 45 μg/L MCL	Cyanide Concentration Range (μg/L)	Filtered Chromium Range (μg/L)
B/C	4/4	12,900 - 48,400	--	<10 - 18
D/DR	3/3	69,500 - 122,000	--	120 - 692
F	4/4	<500 - 151,000	--	<10 - 13
H	23/63	4,600 - 524,000	<10	12 - 420
K	8/8	3,000 - 51,300	--	<10 - 120
N	35/148	<500 - 87,900	<10	<10

Source: Evans et al., 1990 (Activities as recorded in 1989; Values not decayed to present)

* Taken from Table C.2, Evans et al., 1990

Ruthenium-106. Ruthenium-106 has a short half-life (367 days) and is generally associated with operating reactors. Ruthenium-106 has been detected in the past at the N Area but could not be detected by routine methods in 1989. The SDWA MCL for ruthenium-106 is 200 pCi/L.

Antimony-125. Antimony-125 was measured in the 100-N Area near 116-N-3, the 1325-N liquid waste disposal facility, with a maximum concentration of 93.6 pCi/L. The SDWA MCL for this radionuclide is 300 pCi/L.

Iodine-131. Iodine-131 has a half-life of just over 8 days. This radionuclide has been detected in the 100-N Area during operating periods but was not measured in 1989 due to the cold standby status of the 100-N reactor.

Uranium. Uranium levels in two F Area wells increased sharply in 1987 to a maximum of 414 pCi/L in January 1988. The levels have decreased since that time and a low of 91 pCi/L was measured in October of 1989. A uranium plume exists in the 100-H

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TABLE 1-17
CONCENTRATION RANGES OF RADIOLOGICAL CONSTITUENTS AND NITRATE IN 100 AREAS GROUNDWATER 1989 SAMPLING DATA

Area	Number of Wells/Number of Samples	Tritium (pCi/L)	Nitrate* (μg/L)	Gross Beta (pCi/L)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)
B/C	7/19	1,980 - 42,900	12,900 - 48,400	8.18 - 105	0.45 - 53.5	91.5 - 179
D/DR	3/10	3,690 - 53,300	57,000 - 122,000	5.14 - 94.7	0.42 - 45.2	0 - 0.51
F	7/20	56 - 9,550	<500 - 167,000	5.14 - 271	0 - 244	0 - 2
H	23/90	429 - 5,280	4,600 - 524,000	0.22 - 250	--	0.01 - 2440
K	8/27	491 - 882,000	3,000 - 66,000	3.4 - 29.8	0.16 - 3.39	2.85 - 18.9
N	43/171	27 - 218,000	<500 - 93,000	2 - 39,000	0.04 - 23,400	0.58 - 11.1

TABLE 1-17 (Continued)
CONCENTRATION RANGES OF RADIOLOGICAL CONSTITUENTS AND NITRATE IN 100 AREAS GROUNDWATER
1989 SAMPLING DATA

Area	Gross Alpha (pCi/L)	Total Uranium (pCi/L)	Cobalt-60 (pCi/L)	Cesium-137 (pCi/L)	Plutonium-239/240 (pCi/L)	Iodine-129 (pCi/L)
B/C	3.33	0.77 - 14.40	0 - 12.70	0 - 3.97	--	--
D/DR	--	0.57 - 2.39	0.81 - 10.90	0 - 7.01	--	--
F	--	0.16 - 143	0.89 - 3.02	0.44 - 5.26	--	--
H	0.18 - 133	0.74 - 145	1.65 - 7.44	0 - 6.2	--	--
K	--	1.14 - 5.89	0 - 5.68	0.62 - 3.3	--	--
N	0.01 - 6.49	0 - 6.41	0.38 - 57	0 - 9.19	0.0021 - 0.0036	0.003 - 0.047

Source: Evans, et al., 1990 (Values not decayed to present)
* Taken from Table C.3, Evans, et al., 1990

TABLE 1-18
CONCENTRATIONS OF VOLATILE ORGANIC COMPOUNDS IN 100 AREAS GROUNDWATER
1989 SAMPLING DATA

Area	Number of Wells/ Number of Samples	1,1,1 Trichloro-ethane (μg/L)	Chloroform (μg/L)	Perchloroethylene (μg/L)	Carbon Tetra-Chloride (μg/L)	Trichloro ethylene (μg/L)	Trans dichloro ethylene (μg/L)	Total Organic Halogens (μg/L)
H	23/53	<5	<3 - 28	<5	<5	<5	<5	<2 - 44
N	34/108	<5	<3 - 21	<5	<5	<5	<5	<2 - 4,690[a]

[a]Only four samples greater than 100 μg/L, only one sample greater than 500 μg/L. This number may not be representative.
Source: Evans, et al. 1990 (Values not decayed to present)

TABLE 1-19 SUMMARY OF CONSTITUENTS DETECTED ABOVE DRINKING WATER STANDARDS AT 100-N AREA, APRIL 1987 TO NOVEMBER 1989
Primary Water Quality Constituents
Arochlor 1016
Arochlor 1221
Benzene
Cadmium
Cobalt-60
Coliform
Gross Beta
Nitrate
Ruthenium-106
Strontium-90
Tritium
Turbidity
Secondary Water Quality Constituents
Iron
Magnesium
pH < 6.5
pH > 8.5
Specific Conductance
Sulfate
Source: DOE 1990d

Area near 116-H-6, the 183-H solar evaporation basins. The maximum concentration measured in 1989 was 89 pCi/L.

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Cesium-137, Plutonium. Concentrations for these contaminants were below detection limits in the 100 Area.

1.3.1.7 Surface Water and Sediments

Routine monitoring of the Columbia River water and sediments was initiated during 1945, shortly after the startup of the original plutonium production reactors, and continues today as part of the Hanford Environmental Monitoring Program (Jacquish and Bryce 1989). Throughout the years, sample locations upstream of the Hanford Site, outside the influence of site operations, and downstream of all site facilities have been maintained to provide information on the background conditions in the Columbia River and to identify influences from Hanford operations. The monitoring programs are not, however, designed to differentiate contributions of contaminants from individual operating facilities or areas.

1.3.1.7.1 Background Surface-Water Quality. Columbia River water samples were collected upstream of Hanford facilities at Priest Rapids Dam and near the Vernita Bridge to provide background data from locations unaffected by site operations (Jacquish and Bryce 1989). Samples collected at Priest Rapids Dam were analyzed for radiological constituents, while nonradiological analyses were performed on those samples collected near the Vernita Bridge as part of the Surface Environmental Monitoring Project. In addition to the Columbia River monitoring performed by Pacific Northwest Laboratories (PNL), the river-water quality is monitored by the U.S. Geological Survey as part of the national Stream Quality Accounting Network (McGavock et al. 1987), which provides primarily hydrologic and nonradiological water-quality data.

Results of the radiological analysis of Columbia River water samples collected at Priest Rapids Dam during 1988 are summarized in Table 1-20. This table shows that radionuclide concentrations in the river water are extremely low; several of the radionuclides identified are undetectable without the use of special sampling techniques and/or analytical procedures. The 1988 average radionuclide concentrations shown in Table 1-20 are more than an order of magnitude lower than the applicable drinking water standards in all cases.

Nonradiological water-quality data for the Columbia River upstream of the Hanford Site are summarized in Table 1-21. Some listed parameters have no regulatory limit but are useful as indicators of water quality. The results, where duplicated, were in general agreement and were comparable to levels observed in recent years. In all cases, applicable standards for Class A designated water were met.

Groundwater seeps are located along the riverbank throughout the 100 Area (McCormack and Carlile 1984). Because these seep areas reflect groundwater discharge to the river, background contaminant concentrations are best defined through the analysis of groundwater samples.

1.3.1.7.2 Surface-Water Contamination. Radiological and nonradiological pollutants are known to enter the Columbia River from the Hanford Site. In addition to

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direct discharges from Hanford facilities, contaminants in the groundwater from past effluent discharges are known to be transported into the river.

Columbia River water samples were collected at two locations downstream of Hanford, the 300 Area water intake and the Richland Pumphouse, to identify possible influence on contaminant concentrations from Hanford operations (Jacquish and Bryce 1989). Samples collected from the 300 Area water intake were analyzed for radiological constituents, while the Richland Pumphouse samples were analyzed for radiological and nonradiological parameters. The U.S. Geological Survey monitors the Columbia River water quality at the Richland Pumphouse and several locations farther downstream of the Hanford Site. Results of the radiological analyses of the Columbia River water samples collected from the Richland Pumphouse during 1988 are summarized in Table 1-22 (Jacquish and Bryce 1989). All radionuclide concentrations observed were well below applicable drinking water standards. Tritium, Strontium-90, and Iodine-129 concentrations were identified as statistically elevated at the Richland Pumphouse relative to Priest Rapids Dam, thus indicating an influence from Hanford operations. Concentrations of other constituents observed at the Richland Pumphouse were similar to those observed at Priest Rapids Dam (Jacquish and Bryce 1989).

Nonradiological river water quality data at the Richland Pumphouse for 1988 are summarized in Table 1-23. In general, concentrations of nonradiological water quality parameters were similar at Priest Rapids Dam and the Richland Pumphouse. No indication of any significant nonradiological deterioration of water quality along the Hanford Reach as a result of Hanford Site operations exists. As was the case at Priest Rapids Dam, applicable standards for Class A waters were met at the Richland Pumphouse.

1.3.1.7.3 Background Sediment Quality. Sediments in the Hanford Reach are typically sand intermixed with gravel and rock (ERDA 1975). The stream bed in deep channels is generally sand and gravel, while shallow areas have a bed consisting of sand, silt, and some clay. Stream beds in the eddying areas of this fast-water stretch are mostly composed of sand. Slack-water area sediments are made up of sand, silt, and some clay.

Columbia River sediment was sampled routinely from 1945 through 1960 at several locations along the Hanford Reach. Special studies of the river sediments have continued through the years and the State of Oregon and PNL have published reports (Beasley et al. 1981, Sula 1980) about radionuclide concentrations in the Columbia River sediments.

Background sediment samples were collected from behind Priest Rapids Dam in 1976 (Robertson and Fix 1977). Cesium-137 was the most abundant fallout radionuclide detected, with trace amounts of Plutonium-238, Plutonium-239/240, and Americium-241 also present.

Sediment sampling above Priest Rapids and McNary dams was recently reinitiated as part of the Surface Environmental Monitoring Project. Results of analyses of samples collected during 1988 were published in Jacquish and Bryce 1989. Concentrations observed above Priest Rapids Dam provide background information on sediment contamination for the 100 Area. Analyses of the sediment samples included gamma scans, Strontium-90, Uranium-

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Table 1-20
Radionuclide Concentrations Measured in Columbia River Water at Priest Rapids Dam in 1988, Upstream of the 100-B/C Area.

Radionuclide[a]		No. of Samples	Maximum	Minimum	Average
			Concentration (pCi/L)[b]		
Composite System					
Gross alpha		12	0.85 ± 0.81	-0.07 ± 0.20	0.31 ± 0.17
Gross beta		12	2.31 ± 1.00	0.06 ± 1.00	0.96 ± 0.48
^{3}H		12	89 ± 6	56 ± 4	70 ± 6
^{89}Sr		12	0.184 ± 0.084	-0.044 ± 0.072	0.019 ± 0.038
^{90}Sr		12	0.15 ± 0.03	0.05 ± 0.03	0.10 ± 0.02
^{234}U		12	0.27 ± 0.06	0.11 ± 0.03	0.20 ± 0.03
^{235}U		12	0.014 ± 0.013	-0.003 ± 0.008	0.006 ± 0.003
^{238}U		12	0.21 ± 0.04	0.11 ± 0.03	0.17 ± 0.02
Total uranium		12	0.48 ± 0.07	0.23 ± 0.05	0.37 ± 0.04
Continuous System					
^{60}Co	P	20	0.0018 ± 0.019	-0.0012 ± 0.029	-0.0006 ± 0.0008
	D	20	0.042 ± 0.041	-0.0027 ± 0.0042	-0.0009 ± 0.0011
^{129}I	D	4	0.000045 ± 0.000005	0.000006 ± 0.0000001	0.000017 ± 0.000019
^{131}I	P	11	0.0026 ± 0.0037	-0.0011 ± 0.0043	0.0008 ± 0.0008
	D	11	0.0038 ± 0.0073	0.0068 ± 0.00114	-0.0007 ± 0.0023
^{137}Cs	P	20	0.004 ± 0.0024	0.0002 ± 0.0014	0.0018 ± 0.0005
	D	20	0.0067 ± 0.0040	-0.0019 ± 0.0044	0.0028 ± 0.0011
$^{239,240}Pu$	P	4	0.00010 ± 0.00008	0.000002 ± 0.000007	0.00006 ± 0.00005
	D	4	0.00010 ± 0.00016	0.00002 ± 0.00005	0.00006 ± 0.00004

[a]Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on samples collected by the composite system.
[b]Maximum and minimum values ±2 sigma counting error. Average ±2 standard error of the calculated mean. It is not uncommon for individual measurements of environmental radioactivity to result in values of zero or negative numbers from subtracting out instrumental background.
Source: Jacquish and Bryce 1989

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Table 1-21
Nonradiological Water Quality Data for the Columbia River Upstream of the Hanford Site 1988.

Analysis	Unit	No. of Samples	Maximum	Minimum	Annual Average[a]
PACIFIC NORTHWEST LABORATORY ENVIRONMENTAL MONITORING					
pH	–	12	8.5	7.4	NA
Fecal coliform	#/100 mL	12	130	2	2[b]
Total coliform	#/100 mL	12	1,600	2	48[b]
Biological oxygen demand	mg/L	12	5.2	0.7	2.1 ± 0.8
Nitrate	mg/L	12	0.23	0.05	0.14 ± 0.03
U.S. GEOLOGICAL SURVEY SAMPLING PROGRAM[c]					
Temperature[d]	°C	365	19.6	1.8	11.3
Dissolved oxygen	mg/L	6	13.4	8.8	11.5 ± 1.4
Turbidity	NTU	6	1.8	0.4	1.0 ± 0.4
pH	–	6	8.8	8.0	NA
Fecal coliform	#/100 mL	6	3	<1	2[b]
Suspended solids, 105°C	mg/L	NR			
Dissolved solids, 180°C	mg/L	6	88	71	81 ± 6
Specific conductance	μmhos/cm	6	162	123	140 ± 15
Hardness, as $CaCO_3$	mg/L	6	77	58	68 ± 7
Phosphorus, total	mg/L	6	0.03	0.02	0.023 ± 0.004
Chromium, dissolved	μg/L	3	<1	<1	<1
Nitrogen, Kjeldahl	mg/L	6	0.5	<0.2	0.28 ± 0.11
Total organic carbon	mg/L	4	2.8	1.4	2.1 ± 0.7
Iron, dissolved	μg/L	3	65	9	28 ± 37
Ammonia, dissolved (as N)	mg/L	6	0.05	<0.01	0.02 ± 0.02

[a]Average values ±2 standard error of the calculated mean.
[b]Annual median.
[c]Provisional data subject to revision.
[d]Maximum and minimum represent daily averages.
Source: Jacquish and Bryce 1989
Legend:
NTU = Nephelometric turbidity units.
NA = not applicable.
NR = not reported.

Table 1-22
Radionuclide Concentrations for the Columbia River at the Richland Pumphouse, 1988.

			Concentration (pCi/L)[b]		
Radionuclide[a]		No. of Samples	Maximum	Minimum	Average
Composite System					
Gross alpha		12	0.76 ± 0.42	-0.04 ± 0.23	0.29 ± 0.13
Gross beta		12	1.62 ± 1.23	-0.02 ± 0.89	0.87 ± 0.29
^{3}H		12	160 ± 7	98 ± 5	132 ± 10
^{89}Sr		12	0.098 ± 0.083	-0.72 ± 0.68	0.002 ± 0.28
^{90}Sr		12	0.17 ± 0.03	0.08 ± 0.03	0.12 ± 0.02
^{234}U		12	0.28 ± 0.05	0.04 ± 0.02	0.22 ± 0.04
^{235}U		12	0.044 ± 0.020	-0.005 ± 0.000	0.009 ± 0.007
^{238}U		12	0.25 ± 0.05	0.07 ± 0.03	0.18 ± 0.03
Total uranium		12	0.57 ± 0.07	0.11 ± 0.04	0.41 ± 0.07
Continuous System					
^{60}Co	P	23	0.0059 ± 0.0038	-0.0002 ± 0.0013	-0.0014 ± 0.0005
	D	23	0.0113 ± -0.0071	-0.0010 ± 0.0036	0.0029 ± 0.0011
^{129}I	D	4	0.00014 ± 0.00002	0.000069 ± 0.000007	0.00010 ± 0.00003
^{131}I	P	12	0.0022 ± 0.0025	-0.0011 ± 0.0034	0.0005 ± 0.0006
	D	12	0.0101 ± 0.0164	-0.0116 ± 0.0205	0.0011 ± 0.0033
^{137}Cs	P	23	0.0057 ± 0.0017	-0.0004 ± 0.0014	-0.0019 ± 0.0005
	D	23	0.0130 ± 0.0059	-0.0012 ± 0.0034	-0.0031 ± 0.0014
$^{239,240}Pu$	P	4	0.00013 ± 0.00006	-0.00002 ± 0.00001	0.0007 ± 0.00005
	D	4	0.00005 ± 0.00011	0.000005 ± 0.000057	0.00003 ± 0.00003

[a]Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on samples collected by the composite system.
[b]Maximum and minimum values ±2 sigma counting error. Average ±2 standard error of the calculated mean. It is not uncommon for individual measurements of environmental radioactivity to result in values of zero or negative numbers from subtracting out instrumental background.
Source: Jacquish and Bryce 1989

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Table 1-23
Nonradiological Water Quality Data for the Columbia River at the Richland Pumphouse, 1988.

Analysis	Unit	No. of Samples	Maximum	Minimum	Annual Average[a]
Pacific Northwest Laboratory Environmental Monitoring					
pH	–	12	8.3	7.3	NA
Fecal coliform	#/100 mL	12	70	2	7[b]
Total coliform	#/100 mL	12	240	9	70[b]
Biological oxygen demand	mg/L	12	2.5	0.7	1.7 ± 0.4
Nitrate	mg/L	12	1.1	0.06	0.3 ± 0.2
U.S. Geological Survey sampling program[c]					
Temperature[d]	°C	365	20.0	1.4	11.6
Dissolved oxygen	mg/L	4	13.2	10.3	11.7 ± 1.5
Turbidity	NTU	3	1.5	0.6	1.0 ± 0.6
pH	–	4	8.7	7.9	NA
Fecal coliform	#/100 mL	4	8	<1	7[b]
Suspended solids, 105°C	mg/L	3	4	<1	<2.7 ± 1.8
Dissolved solids, 180°C	mg/L	3	91	74	83 ± 10
Specific conductance	μmhos/cm	4	156	122	139 ± 17
Hardness, as $CaCO_3$	mg/L	3	76	62	71 ± 9
Phosphorus, total	mg/L	3	0.03	0.02	0.023 ± 0.007
Chromium, dissolved	μg/L	3	<1	<1	<1
Nitrogen, Kjeldahl	mg/L	3	0.3	<0.2	0.27 ± 0.07
Total organic carbon	mg/L	4	3.1	1.3	2.2 ± 0.8
Iron, dissolved	μg/L	3	8	4	5.3 ± 2.7
Ammonia, dissolved (as N)	mg/L	3	0.04	<0.01	0.03 ± 0.02

[a]Average values ±2 standard error of the calculated mean.
[b]Annual median.
[c]Provisional data subject to revision.
[d]Maximum and minimum represent daily averages.
NTU = nephelometric turbidity units.
NA = not applicable.
Source: Jacquish and Bryce 1989

235, Plutonium-238, and Plutonium-239/240. Table 1-24 summarizes radionuclide concentrations detected in sediments collected at Priest Rapids Dam. Background information for chemical constituents in sediment is not available.

1.3.1.7.4 Sediment Contamination. Radionuclides, including neutron activation products, fission products, and trace amounts of transuranics, were discharged into the Columbia River as a result of plutonium production reactor operations in the 100 Area (Robertson and Fix 1977). The radioactive material was dispersed in the river water and sorbed onto detritus and inorganic particles, incorporated into the aquatic biota or, for larger particles of insoluble material, deposited on the riverbed. Some of this material has been deposited along the shoreline areas above the low river level (riverbank sediments). Radiation surveys of the exposed shorelines from the 100-B/C Area to the confluence of the Snake River during 1978 and 1979 revealed several areas with elevated ($>25\mu R/hr$) exposure rates (Sula 1980). The predominant radionuclides present in the riverbank sediments were Cobalt-60, Cesium-137, and Europium-152 (Sula 1980).

Results from recent sediment-sampling activities at McNary Dam are available for calendar year 1988 (Jacquish and Bryce 1989) and are summarized in Table 1-24. Surface sediments behind McNary Dam are known to contain low levels of Hanford-origin radionuclides (Robertson and Fix 1977, and Beasley et al. 1981) in addition to radionuclides from atmospheric fallout. As expected, concentrations of Cobalt-60, Strontium-90, Cesium-134, Cesium-137, Plutonium-238, and Plutonium-239/240 were higher in sediments from behind McNary Dam than from behind Priest Rapids Dam (Jacquish and Bryce 1989). Data on chemical characterization of sediments are not available.

1.3.1.8 Air

1.3.1.8.1 Background Air Quality. Background concentrations of airborne radionuclides have been measured at several distant communities in Eastern Washington at locations shown in Figure 1-6 (Jacquish and Mitchell 1988). The average values for these distant communities for 1987 are shown in Table 1-25.

1.3.1.8.2 Air Contamination. Concentrations of airborne radionuclides have been extensively monitored on the Hanford Site and in nearby offsite communities. Data for the 100 Area are available from four monitoring stations: one each in the 100-K, 100-N, and 100-D Area, and one at the 100 Area fire station. These monitoring locations are shown in Figure 1-6. The 1987 monitoring data for the 100 Area and nearby communities are included in Table 1-25.

1.3.1.9 Biota

Very little site-specific data concerning radiological or chemical contamination of biota in the 100 Area exists. However, the Hanford Environmental Monitoring Program provides data on radionuclide contamination in biota throughout the Hanford Site.

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Table 1-24
Radionuclide Concentrations in Sediments Collected at Priest Rapids Dam and McNary Dam, 1988.

Location	Radionuclide	No. of Samples	Concentration (pCi/L)[a]					
			Maximum		Minimum		Average	
Priest Rapids Dam	^{60}Co	4	0.014	± 0.018	-0.012	± 0.012	0.003	± 0.012
	^{90}Sr	4	0.072	± 0.006	0.00048	± 0.0037	0.026	± 0.031
	^{134}Cs	3	0.0098	± 0.018	-0.0021	± 0.011	0.0049	± 0.0072
	^{137}Cs	4	0.28	± 0.03	0.24	± 0.02	0.26	± 0.02
	^{235}U[b]	4	0.097	± 0.15	0.007	± 0.12	0.063	± 0.042
	^{238}U[b]	4	0.79	± 0.38	0.67	± 0.36	0.73	± 0.05
	^{238}Pu	4	0.00026	± 0.00017	0.00004	± 0.00006	0.00015	± 0.00009
	$^{239,240}Pu$	4	0.0028	± 0.0007	0.0015	± 0.0003	0.0023	± 0.006
McNary Dam	^{60}Co	4	0.36	±0.03	0.15	± 0.03	0.27	± 0.11
	^{90}Sr	4	0.058	± 0.006	0.036	± 0.005	0.046	± 0.009
	^{134}Cs	3	0.057	± 0.021	0.030	± 0.014	0.044	± 0.016
	^{137}Cs	4	0.79	± 0.05	0.63	± 0.04	0.69	± 0.07
	^{235}U[b]	4	0.22	± 0.14	-0.09	± 0.16	0.05	± 0.13
	^{238}U[b]	4	0.89	± 0.49	0.63	± 0.31	0.78	± 0.12
	^{238}Pu	4	0.00059	± 0.00028	0.00020	± 0.00020	0.00043	± 0.00018
	$^{239,240}Pu$	4	0.011	±0.001	0.009	± 0.001	0.010	± 0.001

[a]Maximum and minimum values ±2 sigma counting error. Average ±2 standard error of the calculated mean.
[b]Uranium-235 and ^{238}U by low-energy photon detector (LEPD) method.
Source: DOE 1991c

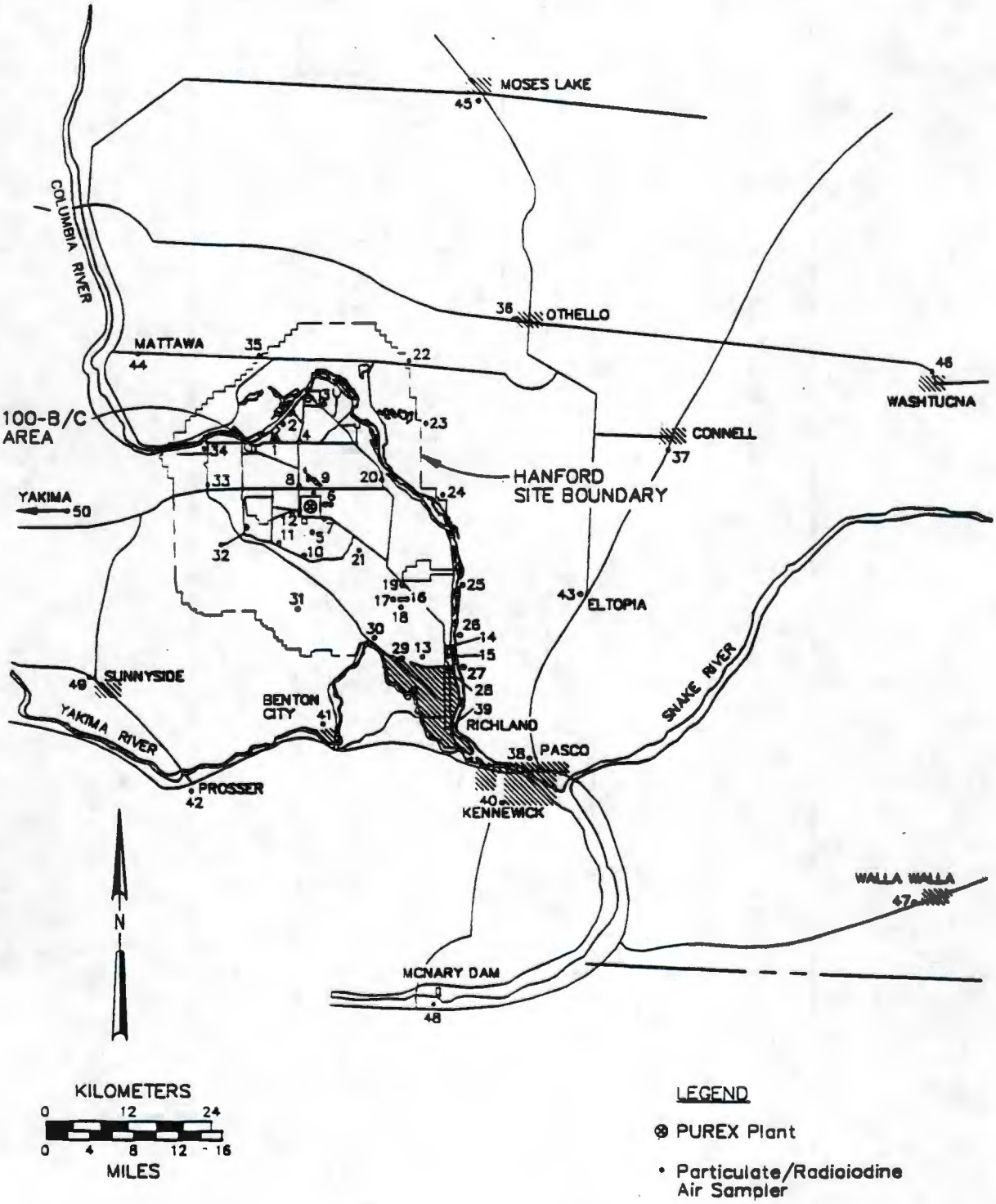

Figure 1-6. Air Sampling Locations (DOE 1991c)

Table 1-25
Air Quality Data for Eastern Washington and the Hanford Site, 1987.
Concentrations in Air (pCi/m^3)[a]

Constituent	Near 100 Areas	Onsite (general)	Site Perimeter	Nearby Communities	Distant Communities
Gross beta	0.026 ± 0.003	0.027 ± 0.0012	0.026 ± 0.0013	0.025 ± 0.0016	0.024 ± 0.0016
Gross alpha	0.0009 ± 0.0002	0.0010 ± 0.0001	0.0009 ± 0.0001	0.0009 ± 0.0002	0.0007 ± 0.0001
H-3	1.5 ± 1.1	2.1 ± 0.5	1.9 ± 0.4	1.5 ± 1.1	2.2 ± 0.8
C-14	--	1.3 ± 0.1	--	--	1.3 ± 0.1
Sr-90	0.00004 ± 0.00002	0.000061 ± 0.000037	0.000041 ± 0.000017	0.000059 ± 0.000041	0.000054 ± 0.000018
I-131	0.001 ± 0.001	0.0002 ± 0.0006	-0.0002 ± 0.0008	0.0005 ± 0.0017	-0.0007 ± 0.0011
Cs-137	0.004 ± 0.002	0.0000 ± 0.0002	0.0002 ± 0.0002	0.0002 ± 0.0002	0.0003 ± 0.0003

[a]Average values ±2 standard error of the calculated mean.
Negative values result from subtracting out instrumental background.
Source: Jacquish and Mitchell 1988

1.3.1.9.1 Terrestrial Biota. Strontium-90 concentrations in deer bones collected on the Hanford Site ranged from 0.7 to 58 pCi/g and were comparable to those concentrations measured in 1985. Cesium-137 concentrations were very low or nondetectable and were in the range attributable to worldwide fallout. Strontium-90 levels in cottontail rabbits collected near the 100-N Area indicated that the animals had at some time consumed food or water contaminated with the radionuclide. Cesium-137 levels in the muscle and Plutonium-239/240 levels in the liver were below detection limits. Mean concentrations of Strontium-90 and Cesium-137 were similar to levels in previous years (Woodruff, et al., 1991).

Tritium was measured in leaf water extracted from six locust trees growing near the 100-K Area. The maximum tritium concentration was 12,000 pCi/L and concentrations generally exceeded the concentrations from well water samples taken near the trees (Rickard and Price 1989).

Deep-rooted plants in the riparian zone may have some usefulness as biological indicators of radioactive materials in groundwater. These plants have roots deep enough to contact groundwater. However, uptake quantities depend on plant species, age of growth, and other factors.

1.3.1.9.2 Aquatic Biota. An extensive survey of the radionuclide concentrations in aquatic biota at the 100-F Area was done in 1966-1967 (Watson et al. 1970) while the reactors were still operating. The reported concentrations resulted from bioaccumulation of reactor generated radionuclides rather than from atmospheric fallout. These radionuclides would not be expected in samples collected above the Hanford Site.

Whitefish, carp, and bass were collected by Woodruff, et. al., (1991) from locations along the Columbia River. Whitefish were collected near the 100-D and -N Areas; bass were collected from the 100-F Area; and carp were collected near 100-N. Strontium-90 concentrations were detected in all the fish carcasses analyzed during 1990. Levels in whitefish samples collected near the 100-D Area were similar to those collected downstream of the Priest Rapids Dam. Bass and carp collected near the 100-N Area had higher concentrations of Strontium-90 than the whitefish. Cobalt-60, Strontium-90, and Cesium-137 concentrations in the fish muscle samples collected from the 100-F and 100-N Areas were typically below detection limit. Mean combined concentrations of Cobalt-60 and Cesium-137 in the fish muscle samples from the 100-D Area were similar to those collected above the Vernita Bridge (Woodruff, et. al., 1991).

Clams collected near 100-N had Cobalt-60 and Strontium-90 levels close to detection limits; Cesium-137 concentrations were below detection limits (Woodruff, et. al., 1991).

Tables 1-26 and 1-27 present radionuclide concentrations found in fish carcasses collected in 1988 from locations upstream and downstream of the Hanford Site. Table 1-28 presents research conducted on radionuclide contamination of aquatic biota.

1.3.1.9.3 Riparian Biota. The shoreline of the Columbia River adjacent to the 100 Area includes a narrow band of riparian vegetation dominated by reed canary grass and other

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Table 1-26
Radionuclide Concentrations in Columbia River Fish Collected Upstream of the Hanford Site, 1988.

	^{60}Co, pCi/g, Wet Weight[a]			^{90}Sr, pCi/g, Wet Weight[a]			^{137}Cs, pCi/g, Wet Weight[a]		
Type	No. of Samples	Maximum	Average	No. of Samples	Maximum	Average	No. of Samples	Maximum	Average
Whitefish Muscle	5	0.011 ± 0.023	0.005 ± 0.006	5	0.003 ± 0.003	0.001 ± 0.001	5	0.014 ± 0.021	0.008 ± 0.010
Whitefish Carcass	NS	--	--	5	0.054 ± 0.007	0.031 ± 0.016	NS	--	--

[a]Maximum values ±2 sigma counting error. Average ±2 standard error of the calculated mean.
NS = No sample.
Source: Jacquish and Bryce 1989

Table 1-27
Radionuclide Concentrations in Columbia River Fish Collected Downstream of the Hanford Site, 1988.

	^{60}Co, pCi/g, Wet Weight[a]			^{90}Sr, pCi/g, Wet Weight[a]			^{137}Cs, pCi/g, Wet Weight[a]		
Type	No. of Samples	Maximum	Average	No. of Samples	Maximum	Average	No. of Samples	Maximum	Average
Whitefish Muscle	10	0.035 ± 0.026	0.016 ± 0.012	10	0.005 ± 0.006	0.001 ± 0.003	10	0.039 ± 0.022	0.023 ± 0.010
Whitefish Carcass	NS	--	--	10	0.064 ± 0.005	0.026 ± 0.009	NS	--	--

[a]Maximum values ±2 sigma counting error. Average ±2 standard error of the calculated mean.
Notes: Samples collected in 100-D Area vicinity.
NS = No sample.
Source: Jacquish and Bryce 1989

grasses, sedges, and rushes. Strontium-90 was measured in the leaves and stems of reed canary grass in this zone at locations downstream from the 100-K Area. The highest concentrations were measured in samples collected near the 100-N Area and the lowest in those samples collected near Richland (Rickard and Price 1989).

Strontium-90 was measured in the eggshells of Canada geese nesting on islands, including Plow Island near Ringold, in the Columbia River. These data show that Strontium-90 of Hanford Site origin is available to geese. However, the concentrations are too low to observe health or reproductive defects in wild geese (Rickard and Price 1989).

The great blue herons that nest on the Hanford Site feed mostly on Columbia River fish and can serve as biological indicators of chemical contamination in the riparian environment (Rickard et al. 1978; Fitzner et al. 1981, 1988; Blus et al. 1985; Riley et al. 1986). Toxic metals, such as lead, cadmium, and mercury, have been measured in the nest debris (feces and food scraps) at one Hanford Site heron rookery. However, the levels of these metals found in herons on the Hanford Site are lower than these reported elsewhere in the Northwest (Fitzner et al. 1982). Heavy metal concentrations have also been examined in eggs and in young herons from Hanford (Blus et al. 1985). Although no elevated levels were detected for lead, copper, zinc, or mercury, these data provide a useful baseline for comparison in future studies.

Birds of prey, particularly owls, have been implicated in the spread of radionuclides near the 100-D, 100-F, and 100-H reactors (Caldwell and Fitzner 1984). Pellets and regurgitated undigestible prey remains were found that contained Manganese-54, Cobalt-60, Cesium-137, Europium-152,-154,-155, and two natural occurring radionuclides, Potassium-40 and Radium-226. The mean Cesium-137 concentration for barn owl pellets collected near the 100-D, 100-F and 100-H Areas was 3.1 ($\pm$1.1) pCi/g dry weight. Pellet analysis show these owls were feeding mostly on small mammals.

1.3.2 Physical Setting

1.3.2.1 Topography

The 100 Areas lie on a relatively flat bench between the Columbia River and Gable Mountain and Gable Butte. Gable Mountain and Gable Butte separate the 100 Area from the rest of the Hanford Site. Gable Mountain in an elongated anticline rising 1086 ft above mean sea level. The average elevation of the 100 Area is approximately 400 feet. The land surface slopes gently to the north from the bases of Gable Mountain and Gable Butte toward the Columbia River.

The Columbia River defines the northern boundary of past activities at the Hanford Site. However, contamination may extend beyond the riverbank to include sediments and surface water affected by releases from Hanford operations.

TABLE 1-28
RESEARCH DATA ON RADIONUCLIDE CONTAMINATION LEVELS OF AQUATIC BIOTA

AUTHOR	SUBJECT
Jacquish and Bryce (1989)	Whitefish muscle and carcasses collected near the 100-D Area.
Cushing et al. (1981)	Bass muscle and carcasses, other aquatic organisms collected just downstream from the 100-H Area in 1971 and 1972.
Annual radiological surveillance reports of the Hanford Site	Data similar to those presented in Jacquish and Bryce (1989) are available for years previous to 1988.
Watson et al. (1970)	An extensive survey of the radionuclide concentrations in aquatic biota at the 100-F Area (in 1966 and 1967). These data were obtained while the reactors were still operating and represent radionuclides collected under those conditions.
Cushing (1979)	Concentrations of 22 stable elements in phytoplankton, caddisfly larvae, and whitefish muscle. These samples were collected from the Columbia River downstream of the 100-B/C Area.
Source: DOE 1991c	

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1.3.2.2 Geology of the Hanford Site

Hanford Site geology has been studied extensively as part of site characterization activities for the Basalt Waste Isolation Project. Other geologic studies have been completed to support facility siting and groundwater studies. The following provides a summary of previous geologic studies compiled in Liikala et al. 1988.

The Hanford Site lies within the Columbia Plateau physiographic province. The province is underlain by the Miocene age Columbia River Basalt Group (CRBG). The geologic units beneath the Hanford Site are, in ascending order: the CRBG, the Ringold Formation, a Plio-Pleistocene unit, and the Hanford Formation. Locally, Pleistocene and Holocene alluvium, colluvium, and eolian deposits veneer the surface. The stratigraphy is shown in Figure 1-7.

1.3.2.2.1 Columbia River Basalt Group. The CRBG forms the bedrock of the Pasco Basin. The CRBG was emplaced between 6 and 17 million years before present (Ma) from fissures in southeastern Washington and adjacent parts of Idaho and Oregon. Five

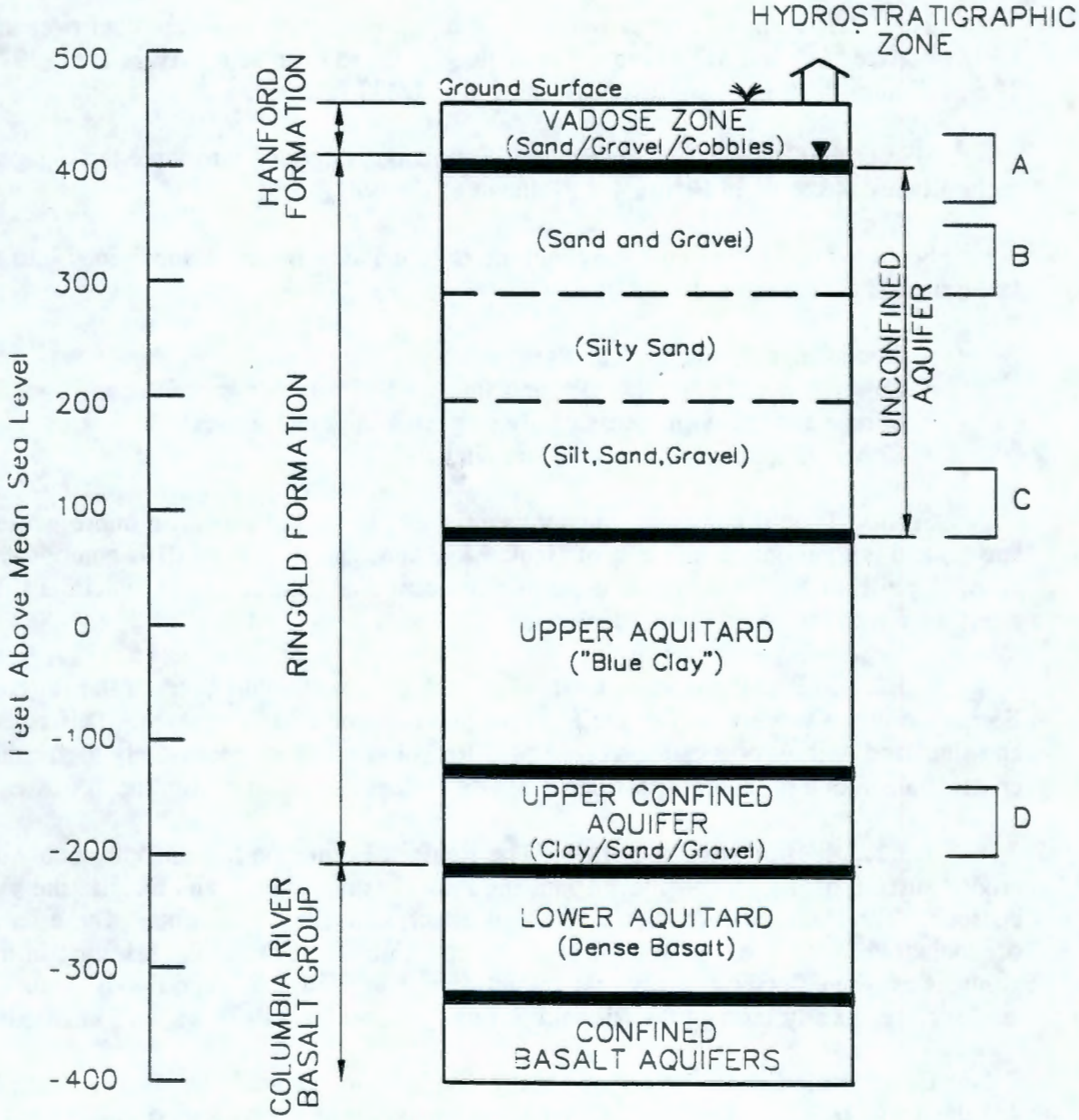

Figure 1-7. Conceptual Hydrostratigraphic Column for the 100 Area (DOE 1991c)

formations make up the Columbia River Basalt Group (Ledgerwood et al. 1978; Swanson et al. 1979). Beneath the Pasco Basin, the CRBG may be as thick as 14,000 ft (4,267 m). The upper flows of the CRBG may be interbedded with Miocene sediments of the Ellensburg Formation (Swanson et al. 1979).

1.3.2.2.2 Ringold Formation. The Ringold Formation was deposited over the CRBG between 8.5 and 3.7 Ma in a fluvial/flood plain environment (Myers et al. 1979). The maximum thickness is estimated at more that 1,200 ft (366 m).

Within the Pasco Basin, the Ringold Formation is divided into three stratigraphic section types as shown in Figure 1-8 (Tallman et al. 1981).

Section Type I, located throughout the central Pasco Basin, is subdivided into four textural units (Tallman et al. 1981):

- Basal Ringold unit, sand and gravel
- Lower Ringold unit, clay silt, and fine sand with minor gravel lenses
- Middle Ringold unit, occasionally cemented sand and gravel
- Upper Ringold unit, fine sand and silt.

Section Type II consists of predominantly silt, sand, and clay with minor gravel lenses, and is found north and east of Gable Mountain. Section Type III is composed of talus, slope wash, and side-stream deposits that occur along the flanks of anticlinal ridges and interfinger with the central basin deposits.

1.3.2.2.3 Plio-Pleistocene Unit. The Plio-Pleistocene unit overlies the Ringold Formation in the western part of the Hanford Site near the 200 West Area. This eolian silt and fine sand unit was deposited as reworked Ringold sediments. Relatively high caliche contents are found in much of this unit. This unit does not occur within the 100 Area.

1.3.2.2.4 Hanford Formation. The Hanford Formation lies unconformably on the eroded surface of the Ringold Formation, the Plio-Pleistocene unit, and locally, the basalt bedrock. The Hanford Formation consists of cataclysmic flood sediments. These sediments originated when ice dams in western Montana and northern Idaho broke resulting in massive volumes of water flooding across eastern and central Washington. The floods scoured the land surface, locally eroding the Ringold Formation, upper basalt flows, and interbeds.

Cataclysmic flood deposits are locally divided into two main facies, the Pasco Gravels and the Touchet Beds. The Pasco Gravels are composed of poorly sorted gravels and coarse sands. The Touchet Beds consist of rhythmically bedded sequences of graded silt, sand, and minor gravel units (Myers et al. 1979).

1.3.2.2.5 Surficial Deposits. Eolian sediments, consisting of loess, active and inactive sand dunes, alluvium, and colluvium, locally veneer the surface of the Hanford Site.

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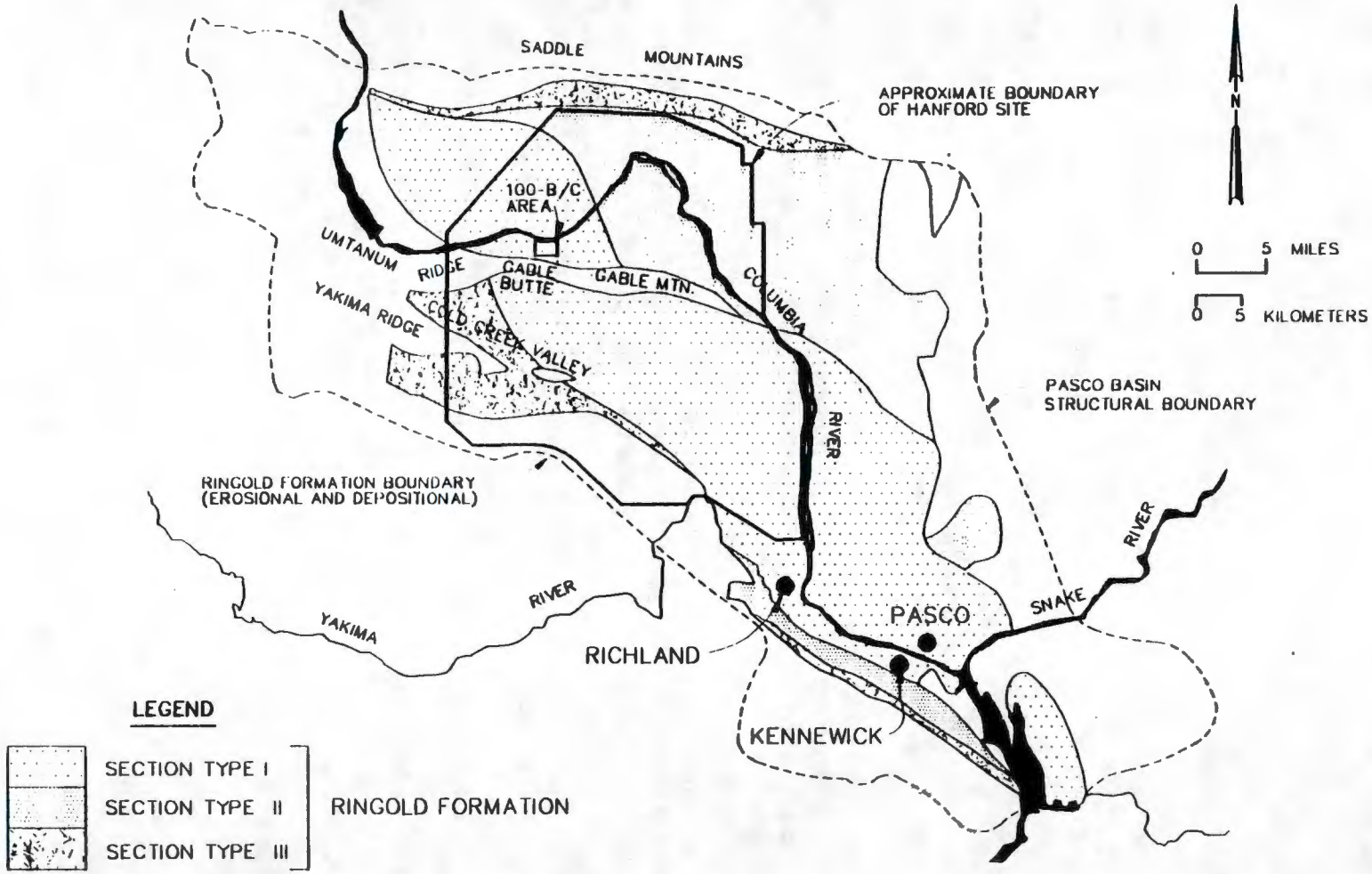

Figure 1-8. Distribution of the Ringold Section Types (DOE 1991c)

1.3.2.2.6 Geologic Structure. The major structural feature of the region is a series of sub-parallel, west-to-northwest-tending folds known as the Yakima Fold Belt. Umtanum Ridge and Cold Creek Valley, west of the 100 Area, are examples of structurally controlled anticlinal ridges and synclinal valleys. Gable Butte and Gable Mountain on the Hanford Site represent an eastward extension of the Umtanum Ridge structure (Fecht 1978). The 100 Areas lie in the Wahluke syncline of the Yakima Fold Belt. This syncline is a down-warped valley between the Gable Mountain and the Saddle Mountain anticlines.

1.3.2.3 Hydrogeology of Hanford Site

The Hanford Site lies near the center of the Pasco Basin. Groundwater at the Site occurs under both unconfined and confined conditions. The unconfined aquifer is within sedimentary deposits of the Ringold and Hanford Formations.

The depth to groundwater beneath the 200 Area plateau of the Hanford Site is generally 200 to 300 ft (61 to 91 m) below land surface (bls). However, north and east of Gable Butte in the 100 Area, the water table is shallower and lies within the Hanford Formation at depths of less than 200 ft (30 m) (Liikala et al. 1988).

The confined aquifers of the regional groundwater flow system are mostly contained in the rubbley interflow zones and in sedimentary interbeds of the CRBG. Intermediate or local confined systems also may occur in the Ringold Formation, where clay units act as aquitards.

A regional water table contour map is presented in Figure 1-9. Groundwater moves eastward across the Site and north to northeast beneath the 100 Area toward the Columbia River. The river serves as the regional discharge for both the unconfined and confined aquifers. The general eastward groundwater flow is interrupted by artificial recharge mounds near the 200 Areas. Precipitation and runoff provide natural recharge to the unconfined aquifer.

1.3.2.3.1 Hydrogeology of the 100 Area

Hydrostratigraphy. Six hydrostratigraphic units are identified beneath the 100 Area. They are: lower confined aquifer system, lower aquitard, upper confined aquifer system, upper aquitard, unconfined aquifer, and the vadose zone. Figure 1-7 shows the hydrostratigraphy for the 100 Area. The four upper hydrostratigraphic units are of importance to the 100 Area.

- Upper Confined Aquifer

  The upper confined aquifer is contained in the basal Ringold Formation and consists primarily of clays, sand, and gravel. The hydraulic conductivity of the basal Ringold Formation has not been measured in the 100 Area; however, since it contains significant quantities of clay and silts, conductivity is expected to be low.

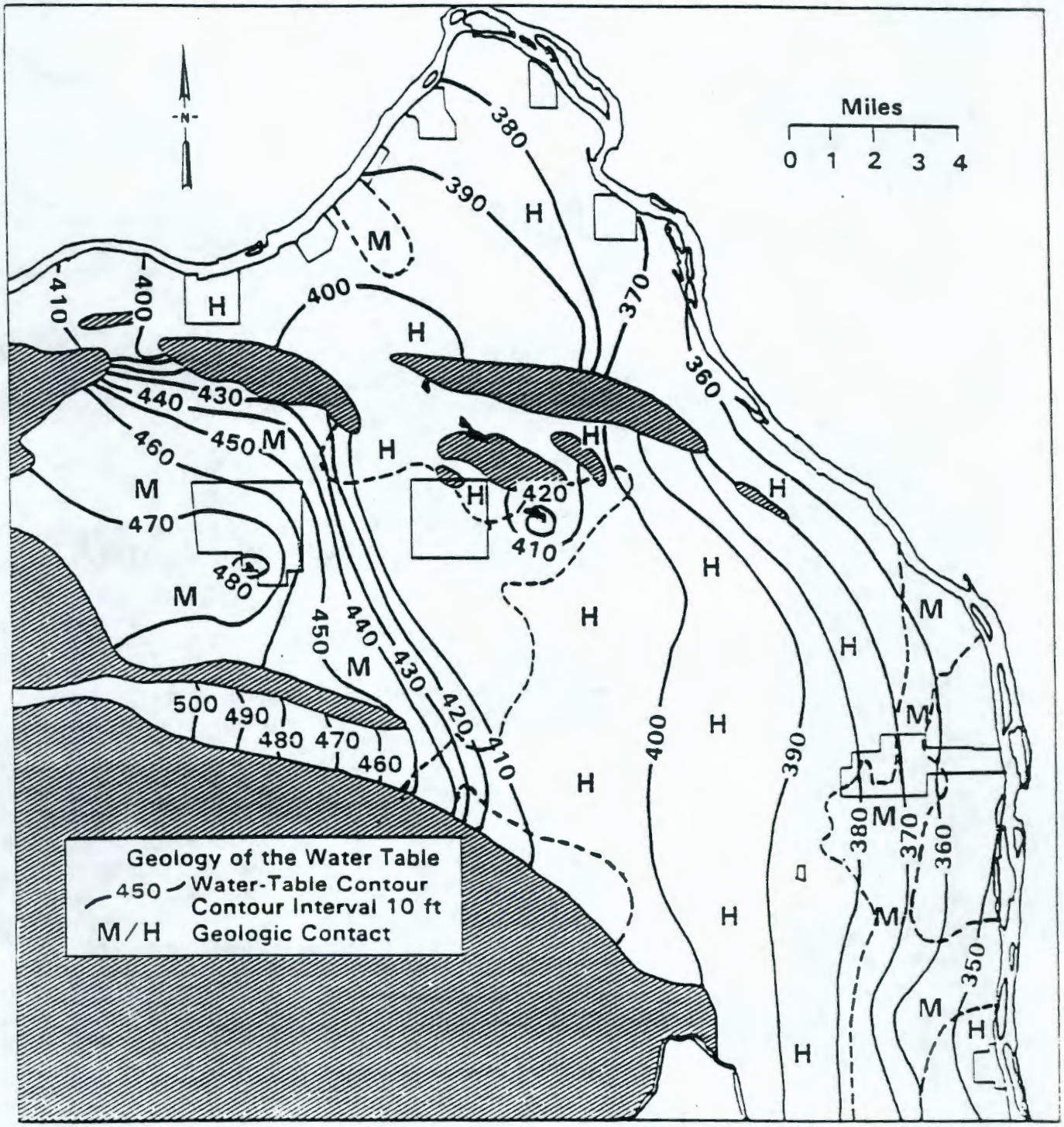

Figure 1-9. Geology of the Water Table (DOE 1991c)

- Upper Aquitard

  The upper aquitard is comprised of the clays, silts, and fine sands of the lower Ringold unit. The estimated vertical hydraulic conductivity of this zone from test results at 100-H Area is 10^{-4} ft/day (Liikala et al. 1988).

- Unconfined Aquifer

  The unconfined aquifer is primarily found within the Ringold Formation above the lower Ringold unit. Portions of the Hanford formation may be locally included. An important hydrostratigraphic zone in the unconfined aquifer is a silty sand zone that separates the relatively coarse upper and lower sand and gravel zones. This zone may act as an aquitard and restrict groundwater flow between the upper and lower portions of the unconfined aquifer. 100-H Area aquifer tests results provide a hydraulic conductivity range of 10 to 100 ft/day for the silty sand and gravelly silt sand units of the Ringold Formation (Liikala et al. 1988).

- Vadose Zone

  Vadose zone sediments range in particle size from boulders to silt. Field water contents of these sediments range up to 11 percent at the 100-H Area (Liikala et al. 1988).

Groundwater Flow. In general, groundwater flows toward the river. Studies at some 100 Area facilities show that gradient reversals occur near the river due to fluctuations in river stage. Depth to groundwater in the 100 Area ranges from about 40 ft (12 m) near the river to 200 ft (61 m) at the southern margin. The hydraulic gradient ranges from 0.001 to 0.0001 ft/ft (m/m).

1.3.2.4 Surface Water Hydrology

1.3.2.4.1 Drainage Patterns and Surface Run-off. No well-defined drainage channels exist within the 100 Area. The surficial deposits of the area are highly permeable and consist primarily of coarse sands, pebbles, cobbles, and boulders. Direct precipitation over the unit is mostly lost through evaporation, transpiration, and infiltration (ERDA 1975). Normal precipitation, 6.25 in. (15.9 cm) per year (Stone et al. 1983), and extreme precipitation events in combination with high evaporation and soil infiltration capacities, does not generate significant surface runoff. Any surface runoff, however, would flow toward the Columbia River.

1.3.2.4.2 Seeps and Springs. Small groundwater seeps have been seen during low river stage near many of the reactor areas (McCormack and Carlile 1984). Seepage is partly from bank storage and is affected by changes in river stage. During periods of high river stage, the flow of groundwater may be temporarily reversed. The volume of the seep discharges has not been quantified. No other naturally occurring surface water exists in the 100 Area.

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1.3.2.4.3 Streamflow Characteristics. The Columbia River is the largest river in the Pacific Northwest and the fifth largest river (by volume) in North America. Eleven dams regulate its flow within the United States: seven upstream and four downstream of the Hanford Site. Priest Rapids Dam, located at approximate river mile 397, is the nearest impoundment upstream of the Hanford Site. McNary Dam in the nearest dam downstream, at river mile 292.

The Hanford Reach extends from Priest Rapids Dam to the head of Lake Wallula, the impoundment behind McNary Dam, at approximate river mile 351. The Hanford Reach is not impounded; however, it is regulated by Priest Rapids Dam. River discharge peaks in June and is lowest in September and October. Table 1-29 describes the major characteristics of the Columbia River.

TABLE 1-29
COLUMBIA RIVER STREAMFLOW CHARACTERISTICS

CHARACTERISTIC	VALUE
Wetted width through the Hanford Reach.	1,000 to 2,600 ft (305 to 792 m)
Typical maximum river depths near the 100 Areas[a].	10 to 40 ft (3 to 12 m)
River elevation daily variance due to water releases from Priest Rapids Dam (ERDA 1975).	up to 5 ft (up to 2 m)
River surface velocities through the Hanford Reach (ERDA 1975).	<3 ft/s to >11 ft/s[b] (<0.85 m/s to >3.1 m/s)
Summer, fall, and winter typical daily flow rates.	36,000 to 250,000 ft^3/s (1,020 to 7,075 m^3/s)
Spring runoff peak flow rates.	up to 450,000 ft^3/s (12,700 m^3/s)
Recent annual flows at Priest Rapids Dam.	100,000 to 120,000 ft^3/s (2,830 to 3,400 m^3/s)
Long-term annual average flow at Priest Rapids Dam[c].	120,000 ft^3/s (3,400 m^3/s)

a) At normal flow rates.
b) Depending on discharge.
c) Based on 68 years of records (McGavock et al. 1987).
Source: DOE 1991c

1.3.2.4.4 Flooding Potential. Maximum Columbia River floods of historical record occurred in June 1894 and June 1948. Maximum flows during these floods were about 740,000 and 690,000 ft^3/s (20,900 to 19,500 m^3/s), respectively (McGavock et al. 1987). Construction of several dams upstream of the Hanford Site since 1948 has significantly reduced the likelihood of recurring floods of this magnitude (DOE 1987). The probable maximum flood has been calculated to be about 1.4 million ft^3/s (39,600 m^3/s) and would be expected to inundate the northern and eastern portions of the 100 Area (DOE-RL 1982, DOE 1987, Cushing 1988). The flooded area for a flood of this magnitude is shown in Figure 1-10. The 100-year and 500-year floods, which would be of lower flow volume than the probable maximum flow, are not expected to significantly affect the area.

1.3.2.5 Meteorology

Climatological data are available from the Hanford Meteorological Station (HMS), located between the 200 East and 200 West Areas in the central portion of the Hanford Site. Data have been collected at the HMS since 1945, and precipitation and temperature data from nearby locations are also available for the time period 1912 through 1943. Data from the HMS are assumed to represent the general climatic conditions for the entire site. The summaries presented in the following sections were extracted from DOE 1987. Data from the Vernita Bridge climatological station were not included.

1.3.2.5.1 Precipitation. The Hanford Site is located within a rain shadow formed by the Cascade Mountains to the west. The average annual precipitation at the site is 6.3 in. (16 cm). Most of the precipitation takes place during the winter, with nearly half of the annual amount occurring from November through February. Average winter monthly snowfall ranges from 0.3 in. (0.8 cm) in March to 5.3 in. (13.5 cm) in January.

Days with precipitation greater than 0.5 in. (1.3 cm) occur with a frequency of less than 1 percent during the year. The average annual relative humidity is 54 percent. Humidity is higher in winter than in summer, averaging about 75 and 35 percent, respectively.

1.3.2.5.2 Temperature. Average monthly temperatures at the Hanford Site range from 29°F (-1.5°C) in January to 76°F (24.7°C) in July.

1.3.2.5.3 Wind. In general, prevailing wind directions are from the northwest throughout the year. Monthly average wind speeds are lowest during the winter, averaging 6.2 to 6.8 mi/h (10 to 11 km/h). Monthly average wind speeds peak in the summer, averaging 8.7 to 9.9 mi/h (14 to 16 km/h). Wind speeds well above average are usually associated with southwesterly winds. In the summer, high-speed winds from the southwest are responsible for most of the dust storms in the region. High-speed winds are also associated with afternoon winds and thunderstorms. The summertime drainage winds are usually northwesterly and frequently reach 31 mi/h (50 km/h). An average of 10 thunderstorms occur each year, usually during the summer.

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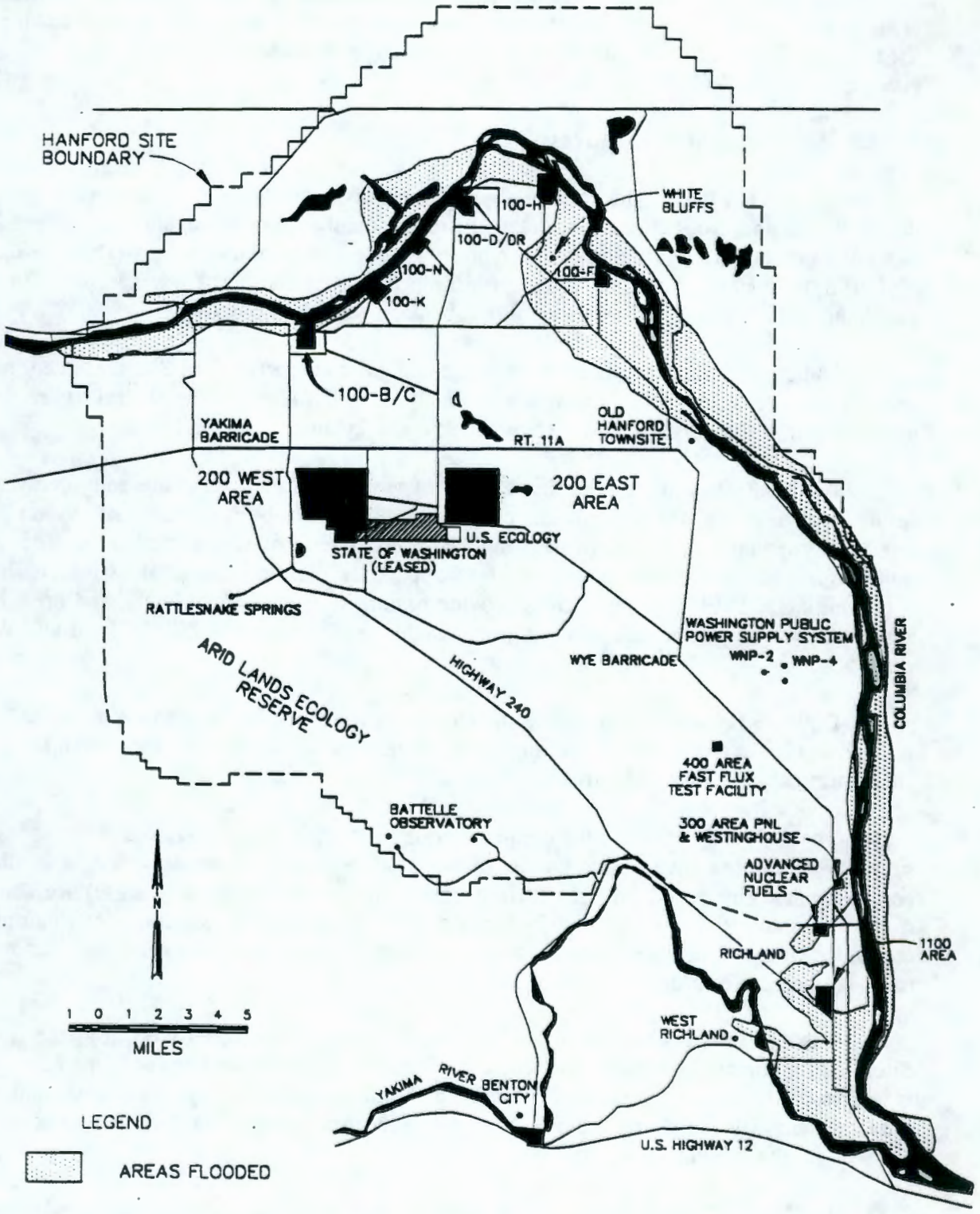

Figure 1-10. Flooded Area for the Probable Maximum Flood (DOE 1991c)

1.3.2.5.4 Evapotranspiration. Mean annual evapotranspiration for the Hanford area is about 60 in. (74 cm). The actual annual evapotranspiration rate under normal conditions for a 6-in. (15-cm) assumed available water capacity is estimated to be about 7 in. (18 cm) (USWB/USDOA 1962).

1.3.2.6 Environmental Resources

1.3.2.6.1 Flora. The natural vegetation consists mostly of a sparse covering of desert shrubs and drought-resistant grasses, predominantly from the sagebrush/cheatgrass/ bluegrass community. Bitterbrush and rabbitbrush are also common shrubs (DOE 1987; PNL 1988). A narrow riparian zone, consisting of grasses and herbs interspersed with a few deciduous shrubs and trees, exists along the banks of the Columbia River.

Endangered and threatened flora that could exist at the Hanford Site are listed in Table 1-30. Persistentsepal yellowcress is found along the Hanford Reach and has recently been located in the 100-B and -D Areas (Sackschewsky and Landeen, 1992).

1.3.2.6.2 Fauna. Predominant fauna of the sagebrush/grass community that may reside in or near the 100 Area are the cottontail rabbit, jackrabbit, Great Basin pocket mouse, horned lark, and western meadowlark. Mule deer, coyotes, and assorted species of raptors forage in this habitat type, and grasshoppers are the most conspicuous insects in the community (DOE 1987). Shade trees provide nesting sites for hawks, owls, and great blue herons as well as perches for wintering bald eagles (Rickard et al. 1980, Rickard and Watson 1985).

Dominant riparian fauna along the Columbia River include swallows, gulls, and waterfowl (ducks and geese). The long-billed curlew is also known to nest within the cheatgrass habitat in the 100 Area (Allen 1980).

The Columbia River is the dominant aquatic ecosystem on the Hanford Site and supports a large and diverse community of plankton, benthic invertebrates, fish, and other communities. Phytoplankton (free-floating algae) and periphyton (sessile algae) are abundant in the Columbia River and provide food for herbivores such as immature insects, that are consumed by carnivorous species. Game species in the Columbia River include salmon, bass, sturgeon, steelhead, and whitefish.

Table 1-30 lists endangered and threatened fauna that potentially occur at the Hanford Site. Of the threatened species that could be found at the Hanford Site, only the bald eagle is known to frequent the 100 Area. Endangered animal species likely to occur on and along the Columbia River in or near the 100 Areas are the American white pelican, the peregrine falcon, and the sandhill crane.

1.3.2.6.3 Critical Habitats. Bald eagle roost trees, and nesting and foraging areas are regarded as critical habitats for this species (Washington State Department of Wildlife 1987). No other critical animal habitats exist in the 100 Area due to the transient use of the 100 Area by other endangered and threatened animal species.

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TABLE 1-30. ENDANGERED AND THREATENED SPECIES POTENTIALLY FOUND ON THE 100 AREA

SPECIES	NOTES
Endangered Vascular Plants	
Persistentsepal yellowcress *(Rorippa columbiae)*	Known to have a scattered distribution because of specialized habitat requirements or habitat loss; generally occurs in marshy places; known to inhabit wetter shoreline of Hanford Reach in Benton County
Northern Wormwood *(Artemisia campertris ssp borealis var workskioldii)*	Rare, local endemic species near the river; not known from the Hanford Site but reported just to the north near Beverly, Grant County
Threatened Vascular Plants	
Columbia milk-vetch *(Astragalus columbianus)*	Locally endemic to area near Priest Rapids Dam; could potentially occur in Northwest portion of Hanford Site along the Columbia River
Hoover's desert parsley *(Lomatium tuberosum)*	Locally endemic to south-central Washington, including Benton County; known to inhabit rocky hillsides
Endangered Birds	
American white pelican *(Pelecanus erythrorhynchus)*	Flocks have recently become common in the Columbia Basin during all seasons foraging on fish, amphibians, and crustaceans, and roosting on islands
*Peregrine falcon *(Falco peregrinus)*	Breeds and winters in eastern Washington, inhabiting open marshes, river shorelines, wide meadows, and farmlands; nests on undistrubed cliff faces; an erratic visitor to the Hanford Site
Sandhill crane *(Grus canadensis)*	Inhabits open prairies, grainfields, shallow lakes, marshes, and ponds; common migrant during spring and fall in Washington; some known and suspected nesting sites in eastern Washington; an occasional visitor at Hanford
Threatened Birds	
*Bald eagle *(Haliaeetus leucocephalus)*	Regular winter visitor to the Columbia River, feeding on spawned-out salmon and waterfowl; they roost in the 100 Area and nest (unsuccessfully to date) along the Hanford Reach
Ferruginous hawk *(Buteo regalis)*	Inhabits open prairies and sagebrush plains, usually with rocky outcrops or scattered trees; known to nest in Benton and Franklin Counties including the Hanford Site; rarely winter in Washington, but are known to occasionally forage on small mammals, birds, and reptiles on sagebrush plains of the Hanford Site
Threatened Mammals	
Pygmy rabbit *(Sylvilagus idahoensis)*	Inhabits undistrubed areas of sagebrush with soils soft enough to permit burrows; once known to exist on the Hanford Site west of the 200 Area plateau

Source: DOE 1990a-f, DOE 1991a-f
* Indicates both state and federal designation

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1.3.2.6.4 Land Use. Access to the entire Hanford Site is administratively controlled by the DOE (DOE 1987). The site is zoned as an unclassified use district by Benton County and, under the county's comprehensive land-use plan, the Hanford Site may be used for nuclear-related activities. Nuclear and non-nuclear activities are authorized only on approval from DOE.

Land use in the area surrounding the Hanford Site consists primarily of irrigated and dry-land farming, livestock grazing, and urban and industrial development. (DOE 1987) Immediately north and across the river from the 100 Area are the 32,100-acre Saddle Mountain National Wildlife Refuge and the 55,600-acre State of Washington Department of Wildlife Reserve (Figure 1-1). These lands provide a buffer zone around the reactor complexes (DOE 1987).

1.3.2.6.5 Surface Water. The Hanford Reach of the Columbia River, near the 100 Area, is used for boating, fishing, hunting, and swimming (EPA 1988b). The 181-B pumphouse supplies portable and process water to the 100-B/C, 100-D, 100-N, 100-K, and 200 Areas. The nearest downstream water intake is the 181-D pumphouse; the next downstream water intake is the Ringold Fish Hatchery. The Richland pumphouse, the first point of withdrawal for public use, is located 12.5 miles downstream of the 100-F Area.

1.3.2.6.6 Groundwater. The nearest known non-Hanford groundwater well is located about 4 mi (6 km) upstream at the Vernita Bridge rest area. Because of the buffer zone and the surrounding land use, private wells would be located at a minimum of 5 mi (8 km) from the 100 Area to the northwest.

1.3.2.6.7 Sensitive Environments. The Hanford Reach is the only significant stretch of the Columbia River within the United States above Bonneville Dam that is not impounded by a dam (PNL 1988). The reach has also been designated as a Class A (excellent) surface water by the State of Washington (WAC 173-201). This designation requires that water quality be maintained for the following uses:

- Domestic, industrial, and agricultural water supply
- Stock watering
- Fish and shellfish migration, rearing, spawning, and harvesting
- Wildlife habitat
- Recreation (including primary contact recreation)
- Commerce and navigation.

1.3.2.7 Human Resources

The Hanford Reach is under consideration for designation as a Wild and Scenic River. This designation could have impacts on removal actions at Hanford.

1.3.2.7.1 Demography. No one resides on the Hanford Site. The working population for the entire 100 Area is about 760 persons (EPA 1988b).

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1.3.2.7.2 Archaeological Resources. Archaeological sites are found in several locations on the Hanford Site including locations along the Hanford Reach. Both the Ryegrass and the proposed Coyote Rapids Archaeological Districts are located on or near the 100 Area. Site 45BN153, lying partially within the 100-B/C Area, consists of house pits and an open campsite but is not considered eligible for the National Register of Historic Places. The other two sites lie on the opposite bank of the Columbia River across from the 100-B/C Area. The K Area includes two campsites and one cemetery, all three contained in the Ryegrass Archaeological District. The N Area has 8 sites, three of which are located north of the river. No information is available for sites in the D Area, but several sites are located in the vicinity of the 100-H Area. Archaeological sites at the Hanford and White Bluffs townsites, as well as old ferry crossings, are the only sites associated with the F Area.

1.3.2.7.3 Historical Resources. The 100-B reactor is listed on the Historic American Engineering Record and may be nominated to the National Register of Historic Places by DOE. Gable Butte is a part of the Gable Mountain/Gable Butte Cultural District. The district is being nominated to the National Register of Historic Places on the basis of its archaeological and Native American cultural/religious significance. (Chatters 1989).

1.3.2.7.4 Community Involvement. The involvement of the potentially affected community with respect to the RI/FS for the 100 Area is described in the Community Relations Plan (CRP) that has been developed for the Hanford Site Environmental Restoration Program. The CRP includes a discussion and analysis of key community concerns and perceptions about the project, with a list of all interested parties.

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2.0 POTENTIAL CONTAMINANTS OF CONCERN

An essential element of the feasibility study is to determine the contaminants that must be remediated in the 100 Area. Contaminants of concern were identified in each of the eleven draft 100 Area OU work plans. However, the approach for determining contaminants of concern was not consistent among the work plans. Therefore, one objective of this study was to provide a uniform methodology for the entire 100 Area so as to arrive at a defensible list of contaminants to be considered in the Phase I/II FS.

Data presented in the source OU work plans included both solid wastes and soil wastes. Therefore, for the determination of contaminants of concern, no distinction was made between these two media.

The results of this study are not intended to provide a final determination of contaminants of concern; that determination will be made as a result of collecting additional field data and conducting operable unit baseline risk assessments. Such risk assessments are not within the scope of this Phase I/II FS.

The determination of contaminants of concern for the 100 Area was conducted in two phases. The first phase entailed:

- Identification of radiological and/or chemical substances potentially released in the 100 Area

- Comparison of concentration data with background concentrations and established regulatory limits.

The end-product of the first phase is a list which is referred to as "regulatory contaminants of concern."

The second phase, utilizing the results of the first phase, consisted of a qualitative toxicity assessment. The purpose of this assessment was to determine which of the regulatory contaminants of concern were of toxicological significance. The end-product of the second phase is a list of potential contaminants of concern to be used for evaluating remedial alternatives. This list is provided in Table 2-1. The details of the approach used in both phases of the effort are given in Appendix A. The general methodology is summarized in the subsections below.

2.1 REGULATORY CONTAMINANTS OF CONCERN

The determination of regulatory contaminants of concern was based upon five key elements:

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- Data showing that a chemical or radionuclide was used or generated within an operable unit and subsequently was released or potentially released to the environment

- Regulatory status of radionuclides or chemicals and their constituents

- Sample concentration data

- Background concentration data

- Comparison of sample concentration data with background and regulatory limits.

Decision logic diagrams were developed to determine the regulatory contaminants of concern. Figures 1 and 2 of Appendix A provide the decision logic diagrams for nonradiological, chemical substances and radiological substances, respectively. Inputs used in the decision diagrams include:

- Chemical and radiological substances used and/or released
- Environmental sampling data
- Regulatory limits and background concentrations
- Inventory and disposal records.

The decision logic diagrams were also used to determine suspect contaminants. Suspect contaminants are contaminants that have been detected in environmental samples in the 100 Area at concentration levels below background concentrations or below regulatory limits. The suspect contaminant list identifies those contaminants for which subsequent data collection can confirm whether or not the contaminants are present in concentrations below regulatory concern. When subsequent data become available, the suspect contaminants would be re-evaluated.

Table 1 of Appendix A provides a list of the regulatory contaminants of concern and suspect contaminants. The contaminants are differentiated on the basis of groundwater versus source (e.g., soil) operable unit contaminants. 100-N Area contaminants are identified separately. Non-radiological (chemical) contaminants are identified separately from radiological contaminants.

Nonradiological contaminants are further categorized as:

- Metals;
- Nonmetallic inorganic ions and compounds;
- Volatile organic compounds; and
- Other organic compounds.

2.2 QUALITATIVE TOXICITY ASSESSMENT

The qualitative toxicity assessment further refined the contaminant of concern determination by evaluating the toxicological significance of each regulatory contaminant of concern. The toxicity assessment was based upon five key elements:

- Review of supplemental Region X EPA guidance (EPA Region X 1991) which eliminates certain metallic contaminants based upon previous determinations of low or negligible toxicity
- Determination of the carcinogenicity of each contaminant
- Determination of reference doses for each non-carcinogen
- Calculation of a hazard quotient for non-carcinogens based on an ingestion exposure route
- Assessment of calculation results based upon EPA guidance on contaminant screening.

The key assumptions and limitations regarding the qualitative toxicity assessment are listed as follows:

- The assessment only considered risk-based factors; compliance with ARARs was not considered.
- Only regulatory contaminants of concern were assessed in the qualitative toxicity assessment; suspect contaminants were not assessed.
- Contaminants dropped as a result of the toxicity assessment are placed on the suspect list.
- Assumptions on carcinogenicity:
  - All radionuclides were assumed to be carcinogenic
  - Carcinogens are defined by the Health Effects Assessment Summary Tables (HEAST) (EPA 1991) and from the Integrated Risk Information System (IRIS) on-line database. The following are descriptions of the groups of carcinogens as provided in HEAST, Table B, or by IRIS as a Group A, B1, or B2 carcinogen
  - Petroleum products are assumed to be carcinogenic because of benzene
  - All carcinogens are assumed to be of toxicological significance and thus are potential contaminants of concern.

- Assumptions for toxicity screening hazard quotient calculation (noncarcinogens):

  - The ingestion exposure route was assumed for all calculations (Equations 9 and 15 in EPA guidance).
  - A hazard quotient of 0.1 was assumed for screening as recommended by EPA guidance.
  - The equations utilized combine ingestion by both children and adults.
  - Individual hazard quotients were calculated for each contaminant; cumulative effects were not considered.
  - If an oral reference dose has not been established then the contaminant was placed on the suspect contaminants list.
  - For noncarcinogens with an established oral reference dose: if no sampling data are available then the contaminant was assumed to be a potential contaminant of concern as the hazard quotient could not be computed.

2.3 POTENTIAL CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

The final list of potential contaminants of concern represents a composite of those that are both of regulatory and of toxicological significance. The final listing is given in Table 2-1 below. This list is generated for the purpose of assembling possible remedial alternatives. That is, the contaminants identified are those which are most likely to require remediation if subsequent field sampling programs and risk assessments show their concentrations in the environment to result in unacceptable risk and/or are not in compliance with ARARs. The list provided here should not be construed as representing any final determination or basis for decision-making regarding selection of final remedies.

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TABLE 2-1: POTENTIAL CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

Potential Contaminant	Environmental Medium		
	Sources (e.g., soils)	Groundwater	N Area
RADIONUCLIDES			
Tritium	C	C	C
Carbon-14	C	C	
Calcium-41	C	C	
Cobalt-60	C	C	C
Nickel-63	C	C	
Selenium-79	C	C	
Krypton-85	C	C	
Strontium-90	C	C	C
Zirconium-93	C	C	
Niobium-94	C	C	
Technetium-99	C	S	C
Palladium-107	C	C	
Cadmium-113	C	C	
Antimony-125		S	C
Iodine-129	C	C	C
Cesium-134	C		C
Cesium-137	C	S	C
Samarium-151	C	C	
Europium-152	C	C	
Europium-154	C	S	
Radium-226/228			C
Uranium-235/238	C	C	
Plutonium-238	C	C	C
Plutonium-239/240	C	C	C
Plutonium-241	C	C	
Americium-241	C	C	

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TABLE 2-1: POTENTIAL CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

Potential Contaminant	Environmental Medium		
	Sources (e.g., soils)	Groundwater	N Area
METALS			
Aluminum	S		S
Arsenic	S	C	C
Barium	S	C	C
Beryllium	S	C	C
Boron	C	S	
Cadmium	S	C	C
Chromium	S	C	C
Cobalt		S	
Copper	S	S	
Iron	S		
Lead	C	C	C
Manganese	C	C	C
Mercury	S	C	
Nickel	S	S	S
Sodium	S	S	
Vanadium	C	S	C
Zinc	S	S	S
OTHER INORGANIC COMPOUNDS/IONS			
Ammonium/Ammonia	C	S	
Asbestos	C	C	
Chloride	S	S	
Chlorine		C	
Cyanide	C	C	C
Fluoride	C	C	C
Hydrochloric Acid		S	
Nitrate	C	C	C
Nitrite	C	C	
Phosphoric Acid			C
Sulfate	S	S	S

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TABLE 2-1: POTENTIAL CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

Potential Contaminant	Environmental Medium		
	Sources (e.g., soils)	Groundwater	N Area
VOCs			
Acetone	C	S	S
Benzene			C
Chlorobenzene			C
Chloroform	S	C	C
Ethylbenzene			C
Methylene Chloride	S		C
Methyl Isobutyl Ketone			C
Perchloro-ethylene	C	C	C
Toluene			S
Trans -1,2-Dichloroethene			C
1,1,1-Trichloro-ethane	S	S	
Trichloroethene	S	C	
Xylenes			C
OTHER ORGANICS			
Acetic Acid	C	C	
Bis (2-ethylhexyl) phthalate			C
Ethylenediamine	C	C	
Ethylenediamine tetraacetic acid (EDTA)	S	S	
Formic Acid	C	C	
Hydrazine	C	C	C
PCBs	C	C	C
Petroleum Products/Diesel oil	C		C
Tetraethylpyro-phosphate			S
Tetrahydrofuran			S
Thiourea	C	C	C

Note: Refer to Appendix A for detection limits, background concentrations, and contaminant concentrations.

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3.0 POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, requires that remedial actions at National Priorities List sites comply with federal and state environmental laws and regulations. This requirement is reiterated in Subpart E of the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 300), which establishes when and by whom the applicable or relevant and appropriate requirements (ARARs) must be identified.

Potential ARARs are those substantive, promulgated federal and state environmental requirements that are pertinent to a remedial action. ARARs may specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at the site; or they may be otherwise relevant and appropriate by addressing problems or situations sufficiently similar to those encountered at the site. State requirements must be more stringent than federal requirements to be considered ARARs.

In addition to ARARs, to-be-considered information (TBC) is also important to remedial planning, and TBCs are included in the evaluation of ARARs. TBCs are nonpromulgated criteria, advisories, guidance, and proposed standards that are not legally binding but may provide useful information or recommended procedures. TBCs may be used in the absence of ARARs or where ARARs are not sufficiently protective for developing cleanup goals. TBCs identified for the 100 Area include U.S. Department of Energy (DOE) Orders and county requirements.

The EPA may waive ARARs and instead concur with a selected remedial alternative that does not attain a level or standard of control at least equivalent to a legally applicable or relevant and appropriate standard, requirement, criteria, or limitation. Section 121 of Superfund Amendment Reauthorization Act identifies six circumstances under which ARARs may be waived:

- The action selected is only part of a total remedial action that will attain such level or standard of control when completed.
- Compliance with such requirement at that facility will result in greater risk to human health and the environment than alternative options.
- Compliance is technically impracticable from an engineering perspective.
- The action selected will result in a standard of performance that is equivalent to an applicable requirement through the use of another method or approach.

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- A state requirement has not been equitably applied in similar circumstances on other remedial actions within the state.

- A fund-financed remedial action does not provide a balance between available Superfund monies and the need for protection of the public health and environment at the sites where the need is more immediate.

This 100 Area Phase I/II feasibility study evaluates the known characteristics of the Hanford 100 Area and identifies the range of remedial alternatives that are most appropriate for protection of human health and the environment for the entire area. Consequently, the ARARs and TBCs identified in the tables in Appendix B encompass a broad range of potentially pertinent requirements. It is anticipated that the range of alternatives identified in Section 5.0 of this report will be subjected to detailed analysis in subsequent focused feasibility studies, at which time these ARARs can be culled to provide requirements that are specific to each operable unit.

3.1 IDENTIFICATION OF ARARS AND TBCS

Potential ARARs and TBCs for the 100 Area are presented in Appendix B. These tables are first divided by the three categories of ARARs: chemical-, action-, location-specific. These three categories of ARARs are defined in the U.S. Environmental Protection Agency document titled *CERCLA Compliance with Other Laws Manual* (EPA, 1988c) as follows:

Chemical-specific ARARs are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment.

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy.

Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they are in specific locations.

The ARARs tables are divided as follows:

- Tables 1A through 1C – Chemical-specific ARARs and TBCs
  - Table 1A – Federal ARARs
  - Table 1B – State ARARs
  - Table 1C – TBCs (federal, state, and local)

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- Tables 2A and 2B – Chemical-specific water quality requirements
  - Table 2A – Radionuclides
  - Table 2B – Nonradionuclides

- Tables 3A through 3C – Action-specific ARARs and TBCs
  - Table 3A – Federal ARARs
  - Table 3B – State ARARs
  - Table 3C – TBCs (federal, state, and local)

- Tables 4A through 4C – Location-specific ARARs and TBCs
  - Table 4A – Federal ARARs
  - Table 4B – State ARARs
  - Table 4C – TBCs (federal, state, and local).

The state hazardous waste management regulations promulgated under the Hazardous Waste Management Act closely mirror the federal regulations promulgated pursuant to RCRA. The State of Washington has been authorized to administer the federal RCRA program. Consequently, the majority of hazardous waste management regulations are provided as federal regulations in Tables 1A, 3A, and 4A. Where state regulations are equivalent to the RCRA regulations, the state citation is shown in brackets below RCRA citations. Where state hazardous waste management regulations are more stringent than RCRA regulations, the requirements are provided in Tables 1B and 3B as state ARARs.

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3.1.1 Potential Chemical-Specific Requirements

Potential chemical-specific ARARs and TBCs were taken from various federal, state, and local laws and regulations and applied to the list of contaminants of concern presented in Section 2.0 of this report. The list of potential chemical-specific ARARs are:

- Maximum contaminant levels (MCL) established pursuant to the federal Safe Drinking Water Act

- Water quality criteria established under the federal Clean Water Act

- Groundwater limitations from the State of Washington Ground Water Quality Standards

- Control, cleanup, and management standards of the Uranium Mill Tailings Radiation Control Act (UMTRA)

- Soil and groundwater limits of the state Model Toxics Control Act (MTCA) Regulations

- Radiation Protection Standards of the NRC
- Air emission standards under the federal Clean Air Act (CAA)
- Toxic Substance Control Act (TSCA)
- Resource Conservation and Recovery Act (RCRA).

Chemical-specific TBCs (Table 1C) include:

- DOE Order 5400.5 (Radiation Protection of the Public and the Environment)
- County air pollution control regulations
- Proposed MTCA regulations.

Normally, secondary drinking water standards and maximum contaminant level goals (MCLG) promulgated under the federal Safe Drinking Water Act are not considered ARARs. However, the state MTCA regulations require secondary drinking water standards and MCLGs for noncarcinogens be incorporated as cleanup standards. These requirements are treated in Table 1B as state chemical-specific ARARs and are also tabulated on Table 2B (Criteria and Limits for Nonradionuclides).

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3.1.2 Potential Action-Specific Requirements

Potential action-specific ARARs and TBCs constitute a large portion of the identified requirements, due in part to the broad spectrum of remedial alternatives under consideration for the 100 Area in the Phase I/II FS. At this point in the remedial planning process, remedial alternatives have been identified that are applicable to the 100 Area as a whole. Further, the broad range of contaminants of concern for the 100 Area (Section 2.0) make it necessary to consider multiple remedial technologies. Consequently, numerous action-specific ARARs are potentially applicable at this point but may be culled out later as more focused feasibility studies are performed for IRM and OU remedy selection.

The potential action-specific ARARs found in Table 3A include federal requirements under the:

- CAA
- RCRA
- Clean Water Act
- Other federal statutes.

Potential State of Washington action-specific ARARs are provided in Table 3B and include state requirements under:

- The Hazardous Waste Management Act
- The Water Pollution Control Act

- MTCA
- State air pollution regulations
- Other requirements promulgated under state law.

Potential action-specific TBCs provided in Table 3C include:

- DOE Orders
- County regulations.

3.1.3 Potential Location-Specific Requirements

Potential location-specific ARARs provided in Table 4A include the provisions of:

- The federal Clean Water Act
- The federal Endangered Species Act
- RCRA
- Other federal statutes.

The list of potential state location-specific ARARs is minimal and includes regulations under:

- The Shoreline Management Act
- The Bald Eagle Protection Rules
- Requirements for protecting endangered, threatened, or sensitive wildlife species.

Potential location-specific TBCs provided in Table 4C include:

- Floodplains/wetlands environmental review
- Executive orders.

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4.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

4.1 INTRODUCTION

This section discusses the development and screening of technologies and process options used to assemble the remedial action alternatives. The process used to develop and screen alternatives is described in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988a). The steps include:

- Developing contaminant-specific and medium-specific remedial action objectives (RAOs)
- Developing medium-specific general response actions (GRAs)
- Identifying volumes or areas of media to which the general response actions might be applied
- Identifying and screening the technologies applicable to each general response action
- Identifying and evaluating process options for selected technology types retained for consideration
- Assembling selected technologies into alternatives incorporating a range of treatment and containment combinations.

RAOs are the more general description of the objectives the remedial action will accomplish. Remediation goals are a subset of remedial action objectives and consist of medium-specific or operable unit-specific chemical concentrations that are protective of human health and the environment and serve as goals for the remedial action (55 FR 8666 et seq.). For the 100 Area, preliminary RAOs were considered for two land use options (1) general or residential use; and (2) industrial use. The general use option requires restoration of the site such that people living on the land would not be subjected to unacceptable risk, while the industrial use option requires site remediation to such a degree that those employed in the area would not be adversely affected by site contamination. However, since land use has not been determined for the 100 Area, development of RAOs focused on the general or residential use option. This is conservative, since this option is the most restrictive land use scenario, in accordance with the National Contingency Plan (NCP). Consideration of general/residential use covers all less restrictive options (e.g., industrial and recreational). In addition, the objective of the remedial action is to prevent receptor exposure, and the means of achieving this objective is through the general response actions (GRAs). Consequently, RAOs for different land use options are essentially the same, although the GRAs employed may be different.

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GRAs are those actions that, either singly or in combination, will satisfy the remedial action objectives. GRAs are medium-specific and may include institutional controls, containment, treatment, and/or disposal. GRAs are similar among all the media of interest in the 100 Area and thus, a single set has been specified as applicable to all media.

The identification and screening of technologies consider the universe of technology types that are potentially applicable to the identified GRAs. Technologies include general categories such as chemical treatment, thermal treatment, stabilization/solidification, or capping. Within each technology category are process options. Examples of process options within the chemical treatment technology category include precipitation, ion exchange, and oxidation/reduction.

Technology process options are initially screened in the Phase I FS to eliminate those that are not technically implementable for the site conditions or contaminants encountered in the 100 Area. A second screening step then focuses on effectiveness and cost but also considers broader issues of implementability, such as administrative aspects. Effectiveness screening includes aspects such as ability to handle the estimated volumes of material, reliability, accomplishment of remediation goals, potential short-term and long-term impacts to human health and the environment during implementation, and reduction of contaminant toxicity, mobility, and volume. At this stage of screening, only qualitative assessments of cost are made, i.e., options are ranked relative to each other with respect to cost as being low, moderate, or high. Completion of this step concludes the Phase I FS.

In the Phase II FS, the list of technologies and process options which passed the Phase I screening steps is used to assemble alternatives representing the range of GRAs. The objectives of the alternatives development step is to limit the number of alternatives that must undergo detailed analysis while still preserving the range of GRAs and technologies to be considered. The methodology and results of the Phase II alternatives development and screening process are given in Section 5.0.

The following sections provide more in-depth discussion of the process for identifying and screening technologies and process options.

4.2 REMEDIAL ACTION OBJECTIVES

RAOs are critical to evaluating the ability of a specific remedial alternative to achieve an acceptable risk level. RAOs provide the basis for developing GRAs that will satisfy the objectives of protecting human health and the environment. The RAOs are defined as specifically as possible, without limiting the range of GRAs that can be applied.

RAOs must address the contaminants of concern, the media of interest, potential exposure pathway(s) and receptor(s), and acceptable contamination levels (or range of levels) for each pathway. RAOs must identify preliminary remedial goals that permit development of a range of treatment and containment alternatives. RAOs specified for protecting human receptors express both a contaminant level and an exposure route because protection can be achieved by reducing exposure (e.g., capping or providing alternate water supplies) in

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addition to reducing contamination. RAOs specified for protecting the environment are expressed in terms of the medium of interest and target cleanup levels, since the intent of the remedial action is to preserve or restore the resource (medium) of interest (EPA 1988).

Final RAOs are determined on the basis of the results of a baseline risk assessment. Since the baseline risk assessment has not yet been performed for the 100 Area, these RAOs are to be considered preliminary until the risk assessment information is available. The preliminary RAOs developed here are based on state and federal standards, toxicity factors of the contaminants of concern, and criteria developed in *Hanford Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991c).

4.2.1 Affected Media

The media of interest for the RAOs includes soils, groundwater, riverbank sediments, solid waste (including buried solid waste and solid wastes generated during site remediation activities). The 100-N Area is distinguished as a medium for purposes of the FS, in accordance with the TPA 1991 Change Package (Ecology et al. 1991). However, it is recognized that all media specified above are also present in the 100-N Area. Although specific contaminants and/or concentrations may differ for the 100-N Area relative to the other areas due to the nature and time frame of operations conducted at 100-N, the contaminated media of the 100-N Area are similar to those of all other 100 Area sites; therefore, remedial alternatives development will only consider the general media of soil and riverbank sediments, solid waste, and groundwater.

4.2.1.1 Contaminants of Concern

Potential contaminants of concern for the 100 Area have been identified and are listed in Section 2.0, Table 2-1. These are specified separately for groundwater, source areas other than 100-N (e.g., soils, riverbank sediments, and solid waste), and the 100-N Area (including sources and groundwater). Suspect contaminants of concern are also listed. Suspect contaminants are those resulting from substances potentially released which were either: (1) detected in quantifiable amounts below natural background or regulatory limits, or (2) were detected in significant concentrations but are not of toxicological significance.

4.2.1.2 Exposure Pathways and Receptors

Consideration of exposure pathways and receptors is necessary for developing RAOs. The pathways and receptors are typically identified in the baseline risk assessment. Since a baseline risk assessment has not yet been performed for the 100 Area, assumptions must be made concerning exposure pathways and receptors. Exposure pathways and potential receptors for contamination from the media of interest are presented in Table 4-1.

Exposure pathways are the courses a contaminant can take in migrating from the source to the receptor. Receptors include both human and environmental receptors which have the potential for exposure to released contaminants. A complete exposure pathway must have the following elements:

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- Contaminant Source
- Release Mechanism
- Transport Mechanism
- Exposure Route
- Receptor.

The sources of contaminants in the 100 Area consist of reactor cooling water effluent treatment, transfer, and disposal systems; sanitary sewage treatment, transfer, and disposal systems; solid waste burial grounds (including decommissioned facility sites); irradiated fuel handling areas; miscellaneous unplanned release areas; chemical storage areas; maintenance and decontamination areas; and laboratory/experimental areas.

The primary release mechanisms in the 100 Area consist of intentional and unintentional infiltration of wastes into soils and the Columbia River. The most significant contributions are the result of reactor coolant effluents, fuel fabrication wastes (183-H), and sanitary sewage wastes. Secondary release mechanisms include contaminant infiltration into groundwater and fugitive emissions from contaminated soils.

Transport media are primarily groundwater, the Columbia River, and wind (air currents). Groundwater carries dissolved contaminants from source areas. The predominant direction of groundwater flow beneath the 100 Area is toward the Columbia River, which also serves as a transport medium. Wind can create airborne contamination, as well as transport contaminants in the form of fugitive dust emissions.

The *Hanford Baseline Risk Assessment Methodology* (DOE-RL 1991c) identifies four routes through which a human receptor may be exposed to contamination through the various media identified for the Hanford Site:

- Dermal exposure
- Inhalation
- Ingestion
- External radionuclide exposure.

The following primary exposure pathways contribute significantly to the overall risks to receptors:

- Direct ingestion of soil
- Inhalation of fugitive dust
- Ingestion of surface water or groundwater
- Dermal exposure to soil contaminants
- External exposure to radionuclides present in the soil
- Biota pathways (for recreational, residential, and agricultural scenarios).

Secondary exposure pathways contribute less to the overall risks to receptors and may include:

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- Inhalation of volatile organic compounds from surface water or groundwater
- Dermal exposure to contaminated sediments
- Dermal exposure to contaminated water.

As stated in the *Hanford Site Baseline Risk Assessment Methodology* (DOE-RL 1991c), exposure pathways not recommended for quantitative evaluation include the ingestion of contaminated particles or volatiles secondary to inhalation, and dermal exposure to airborne contaminants. Ingestion of contaminants is adequately evaluated by the soil ingestion pathway.

Exposure pathways for radionuclides can be ranked by considering the type of radiation (i.e., alpha, beta, gamma) (DOE/RL 1991c). Ingestion or inhalation of radionuclides are considered primary exposure pathways due to the risk of cancer associated with exposure to ionizing radiation. Dermal exposure to radiologically contaminated water might also be a primary exposure pathway. However, dermal exposure to alpha and beta emitters would probably not be considered primary exposure pathways, while dermal exposure to gamma emitters is generally a primary exposure pathway.

Risks to environmental receptors (other than human) are also incurred when a completed pathway exists. The elements of the pathway are the same as for human receptors, but in assessing the risk to environmental receptors, a different method is used. First, the contaminants of potential concern may be different for environmental receptors. The evaluation focuses on exposure assessment and toxicity assessment, with particular emphasis on habitats and species of potential concern. An environmental evaluation may also take into account indirect adverse effects, such as contamination of an element of the food chain for some predator.

The identification of exposure routes must also take into consideration contaminant characteristics, such as:

- Persistence
- Mobility
- Tendency to bioaccumulate.

Although a contaminant may have been released and a transport mechanism may exist, an adverse impact may or may not occur. For instance, nitrate is not always persistent in groundwater, as it may be converted to nitrous oxide and/or nitrogen and oxygen by denitrifying bacteria. Therefore, a release of nitrate may not necessarily cause a toxic effect to a receptor, depending on the location and/or time period of exposure. The half-life of radionuclides is another instance when environmental persistence should be considered when assessing exposures.

The mobility of a contaminant will influence the probability of completing the exposure pathway. For example, many ionic metal species are adsorbed on soil particle surfaces or form insoluble precipitates. Therefore, the environmental mobility of metals is typically

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retarded and, depending on the location of the receptors, an exposure pathway may not exist.

The tendency for a contaminant to bioaccumulate is a similar consideration. For those contaminants which do not tend to bioaccumulate, an exposure pathway may not exist, if, for example, ingestion of biota is a preferred exposure mechanism.

RAOs specify requirements for interrupting the exposure pathway at some point between the source and the receptor. This can be accomplished by eliminating one or more of the essential elements of each exposure pathway. The most conservative measure, which best ensures long-term safety, is to eliminate the source (e.g., remove the contamination). However, less conservative measures can be equally effective in protecting human health and the environment by simply removing receptors from the pathway, or by eliminating other elements from the exposure pathway. An intermediate measure might involve isolation of the source from transport mechanisms.

4.2.2 Point of Compliance

The point of compliance is the geographical location at which RAOs must be achieved. For most hazardous waste sites, the point of compliance is the nearest identified receptor location for each exposure pathway. Exposure pathways are typically identified as part of the baseline risk assessment but have been assumed for this study as shown in Table 4-1. The assumed point of compliance for radioactive species is the point where a member of the public would have unrestricted access to live and conduct business, and, consequently, to be maximally exposed. The specific point of compliance for the 100 Area wastes sites and groundwater plumes has not been determined but will need to be determined to facilitate the detailed evaluation and selection of remedial alternatives.

4.2.3 Remedial Action Goals

Remedial action goals are the target cleanup levels which satisfy RAOs, and as such, are considered a subset of RAOs. These cleanup levels are driven by the results of risk assessment evaluations and/or ARARs. In lieu of site-specific investigation and risk assessment data, assumptions have been made to develop the RAOs and associated remedial action goals for the purpose of this FS. While the use of assumptions instead of site-specific data results in a greater level of uncertainty, preliminary RAOs and remedial action goals can still be developed to a degree adequate for the Phase I/II alternatives development. However, site-specific data and definitive risk assessments will be necessary for future detailed analysis of alternatives.

For purposes of this Phase I/II FS, the preliminary remedial action goals are based primarily on state and federal regulatory limits (potential ARARs) along with selected assumptions regarding cleanup levels as developed in the *Hanford Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991c).

As stated in the preamble to the NCP (55 FR 8666 et seq.), chemical-specific ARARs are to be used to the degree possible to determine remediation goals. Where ARARs do not

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exist for a contaminant, risk-based cleanup goals will be developed, based upon risk assessment. Such risk assessment is beyond the scope of this Phase I/II FS. Chemical-specific ARARs and TBCs are presented in Tables 1A, 1B, 1C, and 2A, Appendix B. These potential ARARs were used in development of the RAOs given in Table 4-2 and until risk assessment work is completed, are assumed to form the basis for developing remedial action goals. Note also that remedial action goals need only be developed for the potential contaminants of concern given in Section 2.0.

Other criteria used in the development of the goals include:

- **Carcinogens** - doses posing cancer risk levels no greater than 1.0×10^{-4} to 1.0×10^{-6} (soils and groundwater),

- **Non-Carcinogens** - the potential for non-carcinogenic effects was evaluated by comparing an exposure level (E) over a specified time period (i.e., lifetime) with a reference dose (RfD), such that the ratio of E/RfD (hazard quotient) is less than one.

- **Radionuclides** - doses or exposures not exceeding 100 mrem/year for soils, 4 mrem/year for groundwater, and doses for air emissions not to exceed 10 mrem/year for all radionuclides, with the exception of Radium-222.

Toxicity-based factors include reference doses (RfDs) and cancer slope factors (CSFs). The RfD is an estimate of the daily exposure to the human population that is not likely to cause an appreciable risk of a deleterious effect over a lifetime. The CSF in the risk calculation provides an upper bound estimate of the risk. RfDs and CSFs are utilized to compute a concentration level consistent with preservation of human health. State or federal ARARs define MCLs for human health considerations. Where ARARs exist, they are assumed to be adequately protective of human health and are therefore used, for FS purposes, as cleanup levels (remedial action goals). In addition to protection of human health (WHC 1991c) it is assumed that contaminated groundwater beneath the Hanford Site must not cause constituent concentrations in the Columbia River to exceed chronic aquatic toxicity levels if the present ecology of the river is to be maintained.

Exposure effects are assumed to be additive for risk assessment purposes. Consequently, contaminant cleanup levels (based on MTCA limits derived by Method B formulae) are divided by the number of contaminants found at a site up to four (i.e., the target cleanup levels for a contaminant will never be less than 25% of the individual MTCA Method B limits) (WHC 1991c), except under the following circumstances:

- Radionuclides and chemicals are not considered additive (i.e., if 2 radionuclides and 2 chemicals are found at the same site, the target cleanup levels would be 1/2 of those presented in the tables, not 1/4).

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- Target cleanup levels will not be established that are below the natural background level for that contaminant (i.e., the contaminant will not be used in determination of cleanup levels for other compounds).

In considering land use, Superfund exposure assessments most often classify land use as either residential, commercial/industrial, or recreational (55 FR 8666 et seq.). EPA also considers the ecological use of the property and as appropriate, the agricultural use. The *Hanford Baseline Risk Assessment Methodology* (DOE/RL 1991c) poses four scenarios for exposure assessment: residential, commercial/industrial, recreational, and agricultural. For the purpose of developing cleanup goals for assessing remedial alternatives, this 100 Area FS considers only residential (also called general use) and commercial/industrial land uses. Cleanup goals for residential use would satisfy objectives for both recreational and agricultural uses since risk assessment criteria are most stringent for the residential scenario. This is consistent with the NCP principle (see 55 FR 8666 et seq.) that, while assumption of residential land use is not a requirement of the program, the assumption may be made, based on conservative but realistic exposures to ensure that remedies will be protective. Where the likely future land use is unclear, risks assuming residential land use can be compared to risks associated with other land uses, such as industrial. This is also consistent with the MTCA cleanup regulations which provide cleanup standards for both residential and industrial land uses.

4.3 GENERAL RESPONSE ACTIONS

The GRAs identified for the RAOs for each media address the exposure pathways and receptors identified in Table 4-1. Application of the GRAs presented in Table 4-2 is intended to prevent direct contact with the contamination and/or reduce or eliminate contaminant-specific contributions of the different media for protection of human health and the environment.

4.4 VOLUMES OR AREAS OF MEDIA OF INTEREST

The identification of areas or volumes of media affected includes a consideration of acceptable exposure levels, potential exposure routes, site characteristics, and the nature and extent of contamination. To arrive at a reasonable estimate of the area or volume of media affected, certain assumptions have been made. These are listed as follows:

- The in situ volume of affected groundwater was calculated using the pore volume of the aquifer extending from the unconfined water table down to the top of the Middle Ringold Formation. A 20% porosity was assumed in the calculations. The in situ volume calculations also were based on the lateral extent of the nitrate and tritium plumes as these were considered to be highly mobile contaminants. Specific details of the calculations are found in Appendix D.

- Riverbank sediments include all those vadose zone soils between the low and high water elevations of the Columbia River inland to the location where the difference between the high water and low water elevations is minimal. This varies from

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approximately 48 feet to 180 feet from the river. The riverbank sediments thus represent vadose soils near the river which have been contaminated as a result of fluctuation in the levels of contaminated groundwater (groundwater fluctuations caused by fluctuations in river stage). Calculation details are given in Appendix D.

- Aerial dispersion of reactor stack emissions was uniformly distributed throughout the 100 Area.

- The gross volume estimates for soils and solid wastes were taken directly from Figure 7-1 of *100 Area Hanford Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991e).

- All radioactive or radioactive mixed waste removed from contaminated solid media is considered low-level waste. However, for purposes of this study, radioactive waste is distinguished by levels of radioactivity as follows:

  - Low activity waste is defined as non-transuranic (TRU) waste, i.e., less than 100 nCi/g total TRU, and which emits beta/gamma radiation at any point resulting in a dose rate less than 200 mrem/hr. This is also considered "contact-handled" waste in accordance with Westinghouse Hanford Company requirements (WHC 1988).

  - High activity waste is defined as either TRU or non-TRU waste which emits beta/gamma radiation at any point resulting in a dose rate greater than 200 mrem/hr. This is also considered "remote-handled waste" in accordance with Westinghouse Hanford Company requirements (WHC 1988).

These definitions are consistent with those provided in the *100 Area Hanford Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991e).

Preliminary estimates of the volumes of contaminated media are summarized in Table 4-3.

4.5 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

The objective of this section of the FS is identify and screen viable technologies and process options which will then be developed into remedial alternatives. Technology type is a general term referring to a group of operations with common characteristics or results. Examples of technologies include chemical treatment, thermal treatment, stabilization/ solidification, and capping. A process option is a specific type of operation within a technology type which has a narrow focus for its application, e.g., precipitation or chemical oxidation are process options for the chemical treatment technology (EPA 1988a).

Technologies and process options are identified for three media: solid wastes, groundwater, and soils/riverbank sediments. While the 100-N Area has been set apart as a separate medium in this FS, analysis of the applicability of technologies and process options

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indicates that there are no unique features of the 100-N Area which would present technologies or options differing from the three basic media which have been considered. That is, even though the 100-N Area contains contaminants which may differ in their concentration levels, the types of contaminants are essentially the same as for other areas and thus the applicable remedial technologies are the same. It is possible that differences in site-specific applications of screened alternatives may result when a detailed analysis is performed, but this is beyond the scope of the current FS effort.

4.5.1 Identification and Screening of Technologies

Potentially feasible, media-specific technologies and process options are identified for each of the GRAs by compiling information obtained from EPA documents, reference program sources, and other relevant technical references. Specific sources of information included:

- EPA Office of Research and Development
- EPA Superfund Innovative Technology Evaluation (SITE) program
- Feasibility studies performed for other DOE sites
- Feasibility studies performed for other government and/or commercial sites
- Remedial Action Assessment System (RAAS) database developed by PNL
- WHC engineering studies and evaluations
- Vendors of process systems for site remediation
- Standard engineering texts.

In addition to these sources, interviews and information requests were made to PNL personnel involved in research and development of innovative technologies. Innovative technologies were considered to the extent that they have undergone development on at least a bench scale. The technologies and process options considered are described in Appendix C.

Each of the technologies and process options underwent an initial screening for technical implementability. This first screening step only considered, based on an assessment of existing site data on both contaminant types/concentrations and site characteristics, whether a technology and/or process option can be effectively implemented at the site. This serves to reduce the initial number of possible technologies to a smaller and more workable number of options that are applicable or appropriate for each medium. Descriptions, given in Appendix C, that form the basis for screening were prepared to summarize the applicability, and describe factors affecting effectiveness, implementability, and relative cost for each of the process options.

General information regarding the site conditions, contaminant types, and concentrations was used to support the screening process. In particular, information about the nature of the contaminants and the subsurface conditions were utilized.

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The results of the initial technical implementability screening step are documented in Sections 4.5.1.1 through 4.5.1.3 for each of the three media considered. A summary of the results is presented graphically in Figures 4-1, 4-2, and 4-3.

A second screening step was performed on technologies/process options which considered effectiveness as a primary criterion with implementability (now including administrative implementability) and cost considered as secondary criteria. Details of this screening step are given in Section 4.5.2.

4.5.1.1 Initial Screening for Solid Waste

All of the GRAs presented in Section 4.3 are considered applicable for this medium. Figure 4-1 summarizes the results of the initial screening of solid waste remedial options. The shaded blocks represent those technologies and process options which were eliminated at this screening stage and the remaining technologies represent the pool of options to be further evaluated for effectiveness, implementability, and relative cost in the second screening step. The following discussion presents the results of the initial technical implementability screening (the results are also presented graphically in Figure 4-1):

No Action. The NCP requires retaining a "no action" alternative to serve as a baseline for evaluating remedial action measures. The NCP (55 FR 8666 et seq., and EPA 1988a) further requires the assumption that current activities such as institutional controls, weed control, and monitoring are not maintained; i.e., no action implies a scenario of "walking away from the site." While such a scenario is unlikely, it does provide a worst case baseline for evaluation.

Institutional Actions. The institutional actions considered applicable for solid waste include:

- Access restrictions - Physical barriers, such as fencing, and deed restrictions, such as covenants restricting the future use of properties.

- Monitoring - Leachate monitoring equipment to continuously monitor contaminant migration from the waste sources. The leachate monitoring can be used to monitor the performance of collection or treatment systems for the groundwater or to provide regulatory compliance monitoring. The detection of leachate or the progressive decrease of contaminant concentration would provide a relative indication of collection or treatment success.

Containment Actions. The waste containment actions primarily consist of physical measures to restrict contaminant migration and/or minimize environmental impact. The technologies evaluated included:

- Capping - All cap types are retained at this initial screening stage with the exception of the vitrified cap. This vitrified cap was eliminated due to uncertainties associated with installation of a seamless cap using the in situ vitrification technology.

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- Horizontal barriers - Grout injection was retained as being a technically implementable and potentially applicable process option. Current technologies are potentially capable of creating a horizontal barrier below the solid wastes. Cryogenic barriers were eliminated for the following reasons:

  - The barrier requires addition of water, which increases the potential to mobilize contaminants

  - Operating costs would be very high because of the need to maintain the cryogenic systems over a very long-term.

  - The barrier may not work (may not prevent contaminant migration).

  Vitrification was also eliminated as a potential horizontal barrier because the technology has not been demonstrated for use as a containment method in the 100 Area.

- Vertical barriers - Slurry walls and grout curtains were judged to be potentially applicable and were retained. The presence of large boulders in the soils at the Hanford 100 Area precluded the use of sheet pilings as a viable vertical cut-off method because of the anticipated difficulty in driving the piles; therefore, sheet pilings were eliminated.

  A vertical cryogenic wall is not applicable for the same reasons as stated above for the cryogenic horizontal barrier; therefore, this option was screened out.

  The implementability of biological barriers has not been demonstrated on the potential scale required and also would involve significant injection of water and nutrients, increasing the potential for contaminant mobilization; therefore, biological barriers were eliminated.

- Run-on/run-off control - The process options of diversions/collection, grading, and revegetation have all been retained as being potentially applicable.

Removal/Disposal Actions. The removal/disposal actions evaluated include:

- Excavation and demolition methods for removal and size reduction of waste components

- On-site and off-site disposal comprised of engineered structures or facilities.

All of the process options in the removal and on-site/off-site disposal technologies are considered technically implementable for the given site conditions and were thus retained.

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In Situ Treatment Actions. In situ treatment actions include stabilization/solidification technologies as follows:

- Grout injection and vibration aided grout injection - These are process options capable of encapsulating the waste to form a monolithic block which resists leaching or migration of the waste contaminants to groundwater.

- Dynamic compaction - A method of reducing volume and the interstitial pore space to limit groundwater contact with the waste. Dynamic compaction is also used to control subsidence which is important for long-term integrity of caps or other surface barriers.

The grout injection methods and dynamic compaction process options were retained.

- Vitrification - This process option was eliminated at this screening step because it has not been sufficiently demonstrated for application in a heterogeneous waste potentially containing sealed containers which are expected to exist in the 100 Area burial grounds. Development results to date indicate that application to solid wastes with sealed containers creates operating problems with the off-gas control system which have not been resolved.

Removal/Treatment/Disposal Actions. Technology types evaluated in this category include:

- Removal
- Thermal treatment
- Stabilization/solidification
- Physical treatment
- Chemical treatment
- On-site and off-site disposal.

All of the process options associated with the technologies for removal/ treatment/disposal actions are considered technically implementable at this screening stage and have been retained (Figure 4-1).

4.5.1.2 Initial Screening for Groundwater

All of the GRAs presented in Section 4.3 are considered applicable for groundwater. Figure 4-2 summarizes the results of the initial screening of groundwater remedial options. The discussion of screening results is presented as follows:

No Action. A no-action alternative for groundwater is retained as a baseline for evaluation of other remedial action measures. Refer to Section 4.5.1.1 for a discussion.

Institutional Actions. Institutional control technologies considered applicable for the groundwater include:

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- Access restrictions - Water rights restrictions and deed restrictions such as covenants restricting the future use of the property and access to its underlying groundwater.

- Monitoring - Use of well systems to continuously monitor the groundwater quality for regulatory compliance and for monitoring remediation effectiveness. Well point monitoring was the only process option eliminated in this initial screening step. Well points were not considered technically implementable due the coarse nature of the 100 Area soils and the large cobbles and boulders expected in the subsurface. Well points are normally driven into the soil formation and cobbles and boulders would create difficulties in advancement.

- Alternate water supplies - Water supplies developed from other suitable water sources unaffected by the contamination.

Containment Actions. Groundwater containment actions primarily consist of physical measures to restrict groundwater (barriers prevent recharge) from contacting the waste sources and providing a pathway for contaminant migration. Several of the technologies and process options evaluated are similar to those shown for the solid waste medium and include:

- Horizontal barriers - The cryogenic wall was retained at the initial screening stage because the threat for contaminant mobilization is not an issue as was the case for solid waste. Grout injection was retained because it is an established technology that may have suitability to the 100 Area soils. Vitrification was eliminated because it has not been developed or tested as a containment technology.

- Vertical barriers - Slurry walls and grout curtains were retained as potentially applicable. Cryogenic walls were retained although their implementability is uncertain. Sheet pilings and biological barriers were eliminated from the vertical barrier options for the same reasons given for solid waste, i.e, rocky soils restrict penetration of the piles and large-scale injection of nutrients to support a biological barrier was judged to pose a risk for mobilization of contaminants.

- Hydraulic control - An additional technology unique to the containment of groundwater. Hydraulic control may involve the use of extraction wells or trenches to impact the hydraulic gradient at the site in the most desirable configuration (i.e., to direct flow away from the contaminated site). Both extraction wells and trenches were retained.

Removal/Disposal Actions. All of the removal and disposal actions considered for groundwater are identified as being technically implementable. Technologies for groundwater removal/disposal include:

- Groundwater Extraction Wells - Extraction wells, drains/trenches, aquifer mining and lixiviant extraction (for inorganic contamination) were evaluated. All options were retained.

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- Wastewater Disposal - Tank storage, pond evaporation, or reinjection into other suitable underlying aquifers. The technologies for wastewater disposal are well understood and were thus retained.

In Situ Treatment Actions. The following technologies were considered for in situ treatment actions:

- Biological Treatment - Enhanced groundwater bioremediation is used to destroy organic contaminants; biodenitirification is specific to reduction of nitrates. Both may have application in the 100 Area and were thus retained.

- In Situ Physical Treatment - Air stripping and vapor extraction, which both remove volatile organic compounds (VOC), were retained. Permeable treatment beds used to remove organics, metals, and radionuclides, and electro-kinetic separation used to remove ionic constituents, were also retained.

- In Situ Chemical Treatment - Used to form insoluble precipitates of inorganic species (in situ chemical precipitation). This option was retained.

Removal/Treatment/Disposal Actions. Technology types included in this category are:

- Groundwater Extraction - Extraction wells, drains, and trenches, aquifer mining, and lixiviant extraction.

- Biological Treatment - Bioreactors, biodenitrification, and biosorption.

- Physical treatment - Ion exchange, evaporation, media filtration, flocculation, carbon adsorption, air stripping, reverse osmosis, ultrafiltration, electrodialysis, dissolved air flotation, sedimentation, steam stripping, freeze crystallization, and supported liquid membrane process options.

- Chemical treatment - Chemical oxidation, precipitation, tritium treatment, wet air oxidation, and chemical reduction.

- Surface and subsurface disposal - Deep well injection, reinjection into aquifer, and crib disposal.

Numerous process options in these technology categories are available for contaminant removal from groundwater. All of the options were considered potentially applicable at this stage based upon technical implementability and were thus retained. Refer to Figure 4-2 and the discussion in Appendix C.

4.5.1.3 Initial Screening for Soils and Riverbank Sediments

All of the GRAs presented in Section 4.3 are considered applicable for this medium. Figure 4-3 summarizes the results of the initial screening of the soils and riverbank sediments

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remedial options. Shaded boxes in Figure 4-3 represent technologies and process options which have been eliminated at this screening stage, and the unshaded boxes represent the potential pool of options to be evaluated for assembly into remedial alternatives. The following discussion summarizes the technical implementability screening process for the soils and riverbank sediments medium:

No Action. A no-action alternative, similar to that posed for solid waste and groundwater, is retained as a baseline for evaluation of other remedial measures. Refer to Section 4.5.1.1 for additional discussion.

Institutional Actions. The institutional actions considered applicable for soils and riverbank sediments include the use of access restrictions and monitoring. These options are the same as presented for the solid waste medium. All process options were retained at this stage of the screening.

Containment Actions. These actions consist primarily of physical measures to restrict mobilization of the contaminated soils and riverbank sediments. These technologies and process options are similar to those presented previously for solid waste and groundwater. Containment technologies provide control of waters that may become contaminated through contact with soils and riverbank sediments. The technologies for containment actions include the following:

- Capping - Contains the soils and riverbank sediments or surface structures; could also be constructed to control and divert surface water flows. All types of caps are retained at this initial screening stage with the exception of the vitrified cap. This cap was eliminated due to uncertainties associated with installation of a seamless cap.

- Horizontal Barriers - Grout injection was retained because it is an established technology that may have suitability to the 100 Area site conditions. Vitrification was eliminated because it has not been demonstrated to the depths required for containment. Cryogenic barriers were screened out for the same reasons as discussed under solid waste (See Section 4.5.1.1).

- Vertical Barriers - Slurry walls and grout curtains were retained as being potentially applicable at the 100 Area. Sheet pilings were eliminated because of the installation difficulty posed by rocky soils. Cryogenic walls were screened out for the same reasons as discussed under solid waste (see Section 4.5.1.1). Large-scale injection of nutrients to support a biological barrier pose a risk of potential mobilization of contaminants, and thus, the biological barrier was eliminated.

Removal/Disposal Actions. Removal of contaminated material prevents migration of contaminants at the site. Excavation was identified as the only process option for removal of contaminated soils and riverbank sediments. On-site and off-site disposal options are comprised of engineered structures or facilities and would be implementable for the given site conditions. All these process options were retained for further consideration.

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In Situ Treatment Actions. In situ treatment actions are comprised of technologies to stabilize and solidify, or to biologically, chemically, or physically treat the waste.

- Stabilization/solidification - accomplished by application of process options that encapsulate loose waste to form a monolithic block. The monolithic block is not prone to leaching and subsequent migration of contaminants from the waste. All process options in this category were retained at this screening stage.

- Biological treatment - primarily limited to removal or destruction of the organic or nitrate constituents, Land farming was eliminated because the depth of effectiveness was determined to be limited; i.e., land farming is a near surface remediation method and would not have an impact on contaminants at depth.

- Chemical treatment - soil flushing using chemically reactive reagents may be used to remove organics and inorganic constituents. This option was retained as implementable.

- Physical treatment - processes to withdraw or drive the contaminant from the matrix. The process options include: vapor extraction, steam stripping, physical soil flushing (non-reactive reagents), RF heating, and electrical soil heating. All were retained at this stage.

Removal/Treatment/Disposal Actions. Several types of technologies and process options are represented in this GRA and are similar to those given for the solid waste medium. These technologies include removal, thermal treatment, stabilization/solidification, physical treatment, chemical treatment, biological treatment, and on-site and off-site disposal. The process options representing these technologies are listed in Figure 4-3 and are described in Appendix C. All of the process options were retained in this screening step.

4.5.2 Evaluation of Technologies and Selection of Representative Technologies

This section documents the further evaluation and screening of the process options that were retained in the initial screening step (Section 4.5.1). Only those options remaining after the initial screening continue through the process for a more thorough review based on effectiveness, implementability, and relative cost. This second screening evaluation leads to the selection of representative process options for each type of technology to be assembled into a group of remedial alternatives for the 100 Area. The results of the second screening are summarized in Figures 4-4 through 4-6 and are discussed below.

In the selection of representative technologies, CERCLA guidance (EPA 1988a, Section 4.2.5) suggests that only one process option be selected to represent a technology type. This simplifies the subsequent development and evaluation of alternatives without limiting flexibility during remedial design. That is, while the representative process provides a basis for developing performance specifications during preliminary design, the specific process actually used to implement the remedial action may not be selected until the remedial design phase. In some cases, more than one process option may be selected for a technology type,

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if two or more processes are sufficiently different in their performance that one would not adequately represent the other. The criteria used to evaluate technologies in the second screening step are described as follows:

Effectiveness Evaluation. This evaluation focuses on the potential effectiveness of each process option in remediating the volume of waste media and in meeting the RAOs with regard to protection of human health and the environment. Specific information considered includes types of contamination and concentration, volume of contaminated media, and rates of collection/removal of liquids or solids. Each process option was classified as being either highly effective, moderately effective, limited, or not effective.

Implementability Evaluation. During this screening step, implementability was not weighted as heavily as the effectiveness of the process option in accordance with CERCLA guidance (EPA, 1988a). The initial screening, described in Section 4.5.1, considered technical implementability more on a pass-fail basis, whereas this second screening rates the relative degree of technical implementability. In addition, in this second screening, implementability also includes the institutional feasibility (e.g., regulatory acceptability, public perception) of implementing the technology or option. These aspects may include necessary permits or issues such as capacities of treatment, storage, and disposal facilities. The implementability of options were classified as easy, moderate, difficult, or not implementable.

Cost Evaluation. In accordance with CERCLA guidance, cost plays a limited role at this screening stage. The cost analysis is made on the basis of engineering judgement and each process is evaluated in relation to other process options of the same technology type. Both capital costs and operating costs are considered. The cost of options were classified as very high, high, medium, or low in relation to other process options in the same technology grouping for each medium of concern.

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4.5.2.1 Evaluation of Process Options for Solid Waste

Solid waste remedial options were evaluated based on the criteria defined above. Figure 4-4 summarizes the results of the second screening step. A more detailed discussion of how each options meets the criteria is given in Appendix C. Results of the second screening step are discussed below.

<u>No Action Response for Solid Waste</u>:

No Action. This option may be useful for some sites provided that risk assessment indicates acceptability of leaving solid wastes in-place with no additional remediation or monitoring. However, for broad application, administrative implementability is questionable because of likely resistance to this solution by the public and the regulatory agencies. The effectiveness of a no action response may not satisfy the RAOs if contamination is left in-place. The alternative is not eliminated at this stage because

this option is required by the NCP as a baseline and because it may be an appropriate response for some sites.

Institutional Controls Response for Solid Waste:

Access Restriction Options. Both fencing and deed restrictions were retained at this screening stage. Their effectiveness, particularly in environmental protection is limited but they are easily implementable at low cost.

Monitoring Options. Leachate monitoring was eliminated as a potential option because current solid waste burial grounds cannot be monitored for leachate without construction of a leachate collection system beneath the contaminated sites. Implementation of leachate collection systems necessitates some technique to concentrate or sample the leachate that may be migrating below a waste source. The leachate collection system requires either a natural clay barrier or a constructed barrier. Placement of such a barrier beneath a disposal site is not considered practical without waste removal. Therefore, this option is screened out.

Containment Response for Solid Waste:

Capping Options. Capping involves the installation of a barrier over the surface of the contaminated area to control erosion and to prevent the generation of leachate caused by surface water infiltration. The asphalt, concrete, and soil/clay capping options were eliminated at this stage based on the need for extensive long-term maintenance to ensure the integrity of the cap. Without such maintenance, the effectiveness of these caps would be reduced considerably in a relatively short time due to surface degradation.

The synthetic cover was also eliminated. The expected design life of this option is uncertain and was judged as having limited effectiveness at best and medium to very high costs.

The two options retained were the RCRA multi-media cap and the Hanford Barrier. These options were selected as representative process options for the solid waste medium. The Hanford Barrier is a special design of the RCRA multi-media cap option. The Hanford Barrier is particularly well suited to the 100 Area site conditions and is specifically designed for isolation of radioactive wastes or mixed wastes for up to 10,000 years. These two retained options incorporate similar features and include the best characteristics of several capping designs. The Hanford Barrier would be constructed of natural materials which should 1) eliminate the need for long-term maintenance (provided that measures are taken to control subsidence), 2) resist erosion, and 3) provide features adaptable to a range of site conditions. The RCRA multi-media cap is considered applicable for hazardous only wastes or other applications, such as very small sites, where the RCRA cap would be technically adequate and/or more economical.

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Horizontal Barrier Option. Grout injection as a horizontal barrier was eliminated because of its limited effectiveness and difficult implementability. It has not been demonstrated in a field application at the Hanford Site. The emplaced lateral continuity of the barrier is uncertain and was the major factor in eliminating this process option. The horizontal barrier technology type was thus completely eliminated as a result of the two screening steps.

Vertical Barrier Options. The grout curtain was determined to be ineffective as a vertical barrier due to the expected uncontrollable nature of emplacing grout in the coarse Hanford soils. The soils would require viscous grout mixtures and a close pattern of injection boreholes to achieve adequate overlap of the grout columns.

The slurry wall was the only option retained for vertical barriers. Better control of construction is provided over grout curtains because slurry walls are continuously excavated and emplaced structures. The barrier is considered to be moderately effective, but for the distances and depths required at the 100 Area, the implementation would be difficult and highly costly. Slurry walls, however, were retained as a representative technology for further development of alternatives.

Run-On/Run-Off Control. The three process options for run-on/run-off control include diversion/collection, grading, and revegetation. At some point in the remedial process, each of these process options may be used to control surface water flow at the site. These process options may be employed to prevent flooding, control erosion, or direct surface runoff. All of the options were retained for development of alternatives. A representative process option was not chosen since each of the options differs significantly from the others in its application and performance.

<u>Removal/Disposal Response for Solid Waste</u>:

Removal Options. The process options of excavation and demolition of larger structural components were retained as being highly effective, moderately implementable, and relatively low cost. Both options are representative of the removal technology and both would be needed to handle the range of waste forms.

On-Site Disposal Options. On-site disposal in a tumulus was judged to have limited effectiveness relative to other options and was eliminated. A tumulus is an above grade structure that is considered to be more susceptible to surface degradation and also to have higher maintenance requirements relative to options where waste is buried below grade. The remaining process options--trenches/pits for low activity mixed waste, vaults for high activity waste, and RCRA landfills for hazardous-only wastes--are representative of the technology and are considered to be more effective as solid waste disposal options.

Off-Site Disposal Options. Off-site disposal in a geologic repository was determined to be highly effective but not implementable in a time frame necessary to meet the RAOs because a repository is currently not available and one is not likely to be

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available in the foreseeable future. The RCRA landfill and DOE facilities options were retained as being representative of the technology type required for the disposal of the variety of wastes to be encountered, i.e, a RCRA landfill could handle hazardous wastes and mixed and/or radioactive only wastes would have to be disposed at a DOE facility.

In Situ Treatment Response for Solid Waste:

Stabilization/Solidification Options. Grout injection was eliminated as an in situ stabilization/solidification process option for the same reasons discussed under horizontal barrier options. The high porosity of site soils could allow the grout to flow freely around the site and reduce the possibility for an effective solidified matrix in the solid waste areas. Vibration aided grout injection was retained because the function of vibration applied during grout injection was assumed to provide better control of grout migration to the desired locations. Vibration aided grout injection was classified as moderately effective and is the only technology option retained as representative of in situ stabilization treatment.

Dynamic compaction was retained as process option of limited effectiveness. The process would reduce the interstitial pore space and thereby reduce the potential for contamination migration through groundwater transport or leachate development from surface water infiltration in the short-term. However, its greatest benefit is in controlling subsidence, an important aspect to the effectiveness of surface barriers.

Removal/Treatment/Disposal Response for Solid Waste:

Removal Options. Refer to discussion above for Removal/Disposal GRA for solid waste. Both excavation and demolition were retained.

Thermal Treatment. The thermal treatment technology options retained include thermal desorption, incineration, and pyrolysis. These options were judged to be highly effective. The options eliminated included metal melting and molten solids processing. These options were screened out for the following reasons:

- A highly segregated waste stream would be needed (e.g., metal melting would require sorting into metal types such as lead, aluminum, and iron/steels)
- Cost associated with segregation activities would be very high.
- Using the processes for decontamination purposes is uncertain.
- The option is not considered to offer significant advantages over other process options (e.g., incineration followed by solidification).

Stabilization/Solidification. The stabilization technologies are intended to create a solid monolith of waste with low permeability and reduced leaching potential. All four

process options were retained. Cement is the most commonly used material although difficulties associated with formulation are typical. Bitumen is a thermodynamically stable material and highly resistant to moisture penetration; however, it is not as widely used as cement. Polymers are innovative materials which are most suitable for high waste loading applications. Vitrification provides the most robust waste form (glass), although the process is complex.

Physical Treatment. Segregation/sorting was judged to be technically difficult to implement to achieve a high degree of separation of solid waste by type of waste and/or waste form. This degree of sorting could probably only be accomplished with a slow item-by-item manual sorting, which would be very costly and could pose unnecessary risk to workers unless done remotely. Some limited waste segregation could be achieved, such as separating out intact drums, compressed gas cylinders or other special hazard materials which would not be expected in significant volumes. Segregation/sorting as a general process option was eliminated. Metal decontamination (as metal melting) also requires a highly segregated waste stream and was eliminated.

The options retained included size reduction and repackaging. Some limited size reduction may be accomplished with the compactible or loose materials in the solid waste. Repackaging of damaged, deteriorated, or inappropriate containers may be incorporated.

Chemical Treatment. Chemical oxidation and acid digestion process options were judged as having limited effectiveness, difficult implementability, and very high costs. These limitations did not warrant any further consideration of these process options.

Hydrolysis was identified as having limited effectiveness (it is effective for reactive metals only), difficult implementability, and high cost. However, it was retained as a potentially useful approach to remediate reactive metals should they be encountered during excavation and removal operations.

On-Site Disposal Option. The trenches/pits, vaults, and RCRA landfills are the same process options as proposed for on-site disposal in the removal/disposal general response action. All were retained.

Off-Site Disposal Option. Off-site disposal options for the removal/treatment/ disposal GRA are the same as discussed previously for the removal/disposal GRA. The RCRA landfill and the DOE disposal facilities were retained for use in developing alternatives.

4.5.2.2 Evaluation of Process Options for Groundwater

The results of the second screening step for groundwater technologies/process options are summarized in Figure 4-5. Treatment options are well known for most of the contaminants of concern in the 100 Area; however, no technology exists that could economically remediate tritium contamination. Natural attenuation appears to be the most viable alternative for the treatment of tritium.

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No Action Response for Groundwater:

No Action. This option for groundwater is retained to serve as the baseline for comparative evaluations of active remedial response actions. The viability of a no action response is highly dependent upon the results of future baseline risk assessments and cost/benefit studies.

Institutional Controls Response for Groundwater:

Access Restriction Options. The analysis of this option assumed that both water rights restrictions and deed restriction options could be maintained in the short-term and possibly in the long-term. Both process options were retained for alternatives development.

Monitoring Options. Groundwater monitoring is the only process option remaining from the first screening step. Monitoring is considered a highly effective method for detecting migration of contaminants. Monitoring will likely be required as part of the remediation and post-closure activities and thus was retained for development of alternatives.

Alternate Water Supply Options. The alternate water supply options consist of Columbia River water and development of nearby sources such as wells in unaffected areas. It was assumed that the necessary water rights could be obtained to make this a viable option. Both process options were retained for alternatives development.

Containment Response for Groundwater:

Horizontal Barrier Options. The two remaining horizontal barrier options were judged to be ineffective due to the existing natural aquitard in the area. There is an upward hydraulic gradient from the underlying aquifer, preventing a contaminant plume from migrating downward into the unaffected groundwater. The natural hydraulic conditions tend to bring clean water into the contaminated zones. No better control could be achieved with an additional barrier installation. The horizontal barrier technology was eliminated at this stage of screening.

Vertical Barrier Options. The three vertical barrier options remaining include slurry walls, cryogenic walls, and grout curtains. Slurry walls are highly effective in controlling the lateral migration of contamination in a geologic medium. Slurry walls would be very expensive to install in the 100 Area because of the depth required to reach the natural aquitard; however, slurry walls were retained.

Cryogenic walls could have the same effect on limiting lateral contaminant migration but at very high cost due to the expenditure of energy to maintain cryogenic temperatures over the long-term, (perhaps hundreds or thousands of years). It is also considered to be highly uncertain whether the effectiveness could be maintained in the

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long-term. For this reason, cryogenic walls were eliminated in favor of slurry walls which would not require long-term maintenance.

Grout curtains were eliminated as a process option based on the limited control of grout emplacement and the need for a very close pattern of injection boreholes.

Hydraulic Control Options. Extraction wells and extraction drains/trenches are two process options that can be utilized to provide the hydraulic control of the groundwater medium (in conjunction with injection wells). Extraction wells and trenches are highly effective in controlling the lateral diffusion and flow of a contaminated groundwater plume by controlling flow around or away from a site. Injection wells may be incorporated to modify the hydraulic gradient around a contaminated site and contain the plume for withdrawal and treatment. Both options have been retained for alternatives development.

Removal/Disposal Response for Groundwater:

Groundwater Extraction Options. Aquifer mining was eliminated because implementability would be very difficult and the cost would be extremely high. The quantities of sediments removed would be massive. Aquifer mining, while theoretically possible, is unprecedented on this scale. Lixiviant extraction was eliminated because of its unknown effectiveness (workable lixiviants for many Hanford contaminants have not yet been developed), potential uncontrollable mobilization of contaminants, and difficulty in recovering solutions. The retained process options for alternatives development in this category include extraction wells and extraction drains/trenches.

Wastewater Disposal Options. Deep-well injection into the aquifer was retained although implementability is difficult due to permitting restrictions. Above/below-ground storage tanks were eliminated because the very large of volumes of water would make this option impractical due to prohibitive costs. Evaporation ponds were eliminated because of the potential for release of contaminants such as tritium into the atmosphere and because of the potential exposure to biota.

In Situ Treatment Response for Groundwater:

Biological Treatment Options. Enhanced groundwater bioremediation and biodenitrification process options were judged to be moderately and highly effective, respectively. Both options were retained for further development of alternatives although their applications are limited to organic contaminants and nitrates.

Physical Treatment Options. Four physical treatment process options include permeable treatment beds, electro-kinetic separation, air stripping, and vapor extraction. The permeable treatment bed process option would require periodic replacement of the treatment bed and excessively large quantities of the treatment bed material; the option was thus eliminated on the basis of limited effectiveness, difficult implementability, and high cost.

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Electro-kinetic separation was judged to have limited effectiveness and an uncertain implementability (technology has not been demonstrated) and was eliminated.

Air stripping and vapor extraction were both retained as suitable, specifically for removing volatile organic compounds from groundwater. Vapor extraction is commonly used for soil remediation, but both process options have also been shown to remediate groundwater effectively.

Chemical Treatment Options. A single innovative in situ chemical treatment option was evaluated for treatment of heavy metal and radionuclide contamination of groundwater. Injection of chemical reagents into the groundwater to reduce hexavalent chromium and/or precipitate other heavy metals and radionuclides may potentially offer significant technical and cost advantages relative to ex situ treatment options. This technology needs considerable development to prove it viable for in situ application and, therefore, its implementability and effectiveness are highly uncertain at this time. For these reasons, the option is eliminated at this screening stage. See Section 5.3.5.4 for additional discussion of this innovative technology.

<u>Removal/Treatment/Disposal Response for Groundwater</u>:

Groundwater Extraction Options. For the same reasons as given in the removal/disposal response, aquifer mining and lixiviant extraction were eliminated. Extraction wells and extraction drains/trenches were retained for alternatives development.

Biological Treatment Options. Biosorption was eliminated as an option due to uncertain effectiveness (technology has not been demonstrated). Bioreactors and biodenitrification were retained as options for selected contaminants due to demonstrated effectiveness in similar applications.

Physical Treatment Options. Numerous physical treatment options were evaluated in this screening step. The retained options include: ion exchange, media filtration, flocculation, carbon adsorption, air stripping, reverse osmosis, ultrafiltration, steam stripping, and forced evaporation. All process options in this group are proven and widely used in the remediation of both organic and inorganic contaminants. These options are effective and provide a wide range of treatment choices for all the contaminants of concern except tritium.

Those options eliminated because they are ineffective or of limited/uncertain effectiveness include passive evaporation, electrodialysis, dissolved air flotation, sedimentation, freeze crystallization, and supported liquid membrane separation.

Chemical Treatment Options. Tritium separation, while theoretically possible, is not practical for groundwater remediation treatment, would be extremely costly, and was therefore eliminated.

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Wet air oxidation would not be effective because the level of contaminants is too dilute. The chemical treatment options retained include chemical oxidation, precipitation, and chemical reduction.

Surface Disposal Options. Surface discharge and Columbia River discharge were eliminated because of tritium contamination, which is not removed from the groundwater. Tritium contaminated water discharge to surface water is not a viable disposal consideration. Storage tanks are not practical for storage of very large volumes over a long period of time and were eliminated as a process option.

Subsurface Disposal Options. Crib disposal was retained as a process option due to its high effectiveness and ease of implementation at a low cost. Deep-well injection and reinjection into the aquifer were also retained but are considered more difficult and expensive to implement than the other process options.

4.5.2.3 Evaluation of Process Options for Soil and Riverbank Sediments

The results of the second screening evaluation for this medium are summarized in Figure 4-6. The evaluations performed for soil and riverbank sediments are similar to those given for the solid waste medium in Section 4.5.2.1.

No Action Response for Soil and Riverbank Sediments:

No Action. This option may be useful for some sites provided that risk assessment indicates the acceptability of leaving soils and/or riverbank sediments as-is with no additional remediation or monitoring. However, for broad applications, administrative implementability is questionable because of likely resistance to this solution by the public and the regulatory agencies. The effectiveness of a no action response may not satisfy the RAOs if contamination remains in place. The alternative is not eliminated at this stage because this option is required by the NCP as a baseline and because it may be an appropriate response for some sites.

Institutional Controls Response for Soil and Riverbank Sediments:

Access Restriction Options. Options of fencing and deed restrictions are effective, implementable, low cost, and were retained for development of alternatives for reasons similar to the other media.

Monitoring Options. Leachate monitoring was eliminated as a potential option because current soil and riverbank sediment sites cannot be monitored for leachate without construction of a horizontal barrier beneath the contaminated sites. Leachate collection systems require some method to concentrate or sample the leachate that may be migrating below a waste source. This would require either a natural clay barrier or a constructed barrier. Placement of such a barrier beneath a disposal site is not considered practical without waste removal. Therefore, this option was eliminated.

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Containment Response for Soil and Riverbank Sediments:

Capping Options. The two options retained were the RCRA multi-media cap and the Hanford Barrier for the same reasons as discussed above for the solid waste medium (refer to Section 4.5.2.1).

For similar reasons as given for solid waste (Section 4.5.2.1), the other process options were eliminated based on the need for significant maintenance to ensure the long-term integrity of the cap.

Horizontal Barrier Options. Grout injection was the only horizontal barrier evaluated at this screening stage. The horizontal barrier option was eliminated because of limited effectiveness and difficulty in implementation. The porous soils at the 100 Area would inhibit accurate grout placement.

Vertical Barrier Options. The grout curtain option as a vertical barrier was judged to be ineffective due to the expected uncontrollable nature of grout in the porous Hanford soils. It was therefore deleted. The slurry wall option is moderately effective, but would be costly to construct and difficult to implement at the required depths. It was retained as a representative process option of this technology category.

Run-on/Run-off Control Options. The three process options for run-on/run-off control include diversion/collection, grading, and revegetation. All three are effective for their intended applications, i.e., to control or direct surface water run-on/run-off, to prevent flooding, or to control erosion. All options were retained.

Removal/Disposal Response for Soil and Riverbank Sediments:

Removal Options. Excavation is the only process option considered for this medium. Numerous methods may be available to accomplish this objective. Excavation was retained because it is highly effective, moderately implementable, and relatively low in cost.

On-Site Disposal Options. On-site disposal in a tumulus was judged to have limited effectiveness and was eliminated. A tumulus is an above grade structure that is more susceptible to surface degradation and maintenance requirements relative to options where waste is buried below grade. The remaining process options, i.e., trenches/pits, vaults, and RCRA landfills, were retained as representative of the technology and are considered to be more effective as soil waste disposal options.

Off-Site Disposal Options. Off-site disposal in a geologic repository was determined to be highly effective but not implementable in the time frame necessary to meet the RAOs because a repository is currently not available and one is not likely to be available in the foreseeable future. The RCRA landfill and DOE facilities options were retained as being representative of the technology required for the disposal of the

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variety of wastes to be encountered, i.e, a RCRA landfill could only handle hazardous wastes but mixed wastes would have to be disposed of at a DOE facility.

In Situ Treatment Response for Soil and Riverbank Sediments :

Stabilization/Solidification Options. Grout injection as an in situ stabilization/ solidification technology process option was eliminated for the same reasons discussed for the solid waste medium (Section 4.5.2.1). It would be very difficult to control the grout flow and direction in soils to ensure complete encapsulation. The course grain nature of site soils would allow the grout to flow freely around the site. Vibration aided grout injection was retained for specific applications such as cribs because the function of vibration during grout injection was to provide a method to control grout migration to the desired locations.

Shallow soil mixing and fixants were eliminated due to depth limitations. However, either of these might be of limited use where contamination was known to be near-surface. Ground freezing was eliminated because of uncertain effectiveness factors: lack of adequate soil moisture and the need for maintaining a frozen state in perpetuity. Because of the latter, long-term operating costs are judged to be excessive.

Vitrification was retained because it would be highly to moderately effective for soils and unsaturated riverbank sediments although it has not been demonstrated for deeper contamination.

Dynamic compaction was retained as a process option for limited applications where subsidence control is desirable, such as in combination with surface barriers.

In Situ Biological Treatment Options. Enhanced soil bioremediation was eliminated. Effectiveness is uncertain because of the depth of contamination and because of the potential for mobilizing those contaminants which are not biodegraded.

Biodenitrification was retained as the representative option for treatment of nitrates. It was judged to be highly effective and has been successfully demonstrated in both in situ and ex situ applications.

In Situ Chemical Treatment Options. Soil flushing is the only representative in situ chemical treatment option evaluated in this screening step. It requires introduction of chemical solutions to the soil matrix to strip contaminants from the soil. The effectiveness is dependent upon recovery of the flushing solutions. A high potential exists for escape of some mobilized contaminants. For these reasons, soil flushing was judged to be difficult to implement and only of limited effectiveness, and was therefore eliminated.

In Situ Physical Treatment Option. Vapor extraction and steam stripping were retained as representative process options due to their moderate to high effectiveness.

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Soil flushing, RF heating, and electrical soil heating were eliminated due to limited effectiveness, high cost and/or difficult implementability.

Removal/Treatment/Disposal Response for Solid and Riverbank Sediments:

Removal Options. The process option of excavation is the only removal option considered for the medium. It was retained as being highly effective, moderately implementable, and relatively low cost.

Thermal Treatment. Thermal desorption was the only thermal treatment technology retained. This option was judged to have the potential for being highly effective with moderate costs (relative to incineration and pyrolysis) for soils application. The options eliminated included incineration, pyrolysis, and molten solids processing all based on economics relative to thermal desorption. These options were ranked as moderately to highly effective but were determined to have much higher capital and operating costs relative to thermal desorption, due to the need for higher temperatures (which increases fuel costs). Incineration requires raising the temperature of the soil to a level high enough to ensure destruction of organic contaminants. The thermal desorber, on the other hand, only volatilizes organics (at relatively low temperatures) which are then combusted in a secondary chamber (other options are also available for off-gas treatment).

Stabilization/Solidification. Bitumen-based, cement-based, and polymer-based options were eliminated because they would all result in a significant increase in the waste volume as a result of treatment.

Vitrification was retained as an option as an innovative technology for soil and riverbank sediments and shows promise as being highly effective although costly for large volumes of soil (significantly higher costs than incineration due to the need for melting, as opposed to merely destroying organics).

Physical Treatment. The three physical treatment options evaluated include vapor extraction, soil washing, and steam stripping. Vapor extraction and steam stripping are proven techniques for removing volatile organic compounds from soil and riverbank sediments and are therefore retained.

The effectiveness of soil washing is uncertain due to limited test data and the diversity of 100 Area contaminants. However, if it can be successfully proven, the technology shows promise as an innovative approach which could substantially reduce the volumes of waste required for disposal. It is therefore retained.

Chemical Treatment. Two of the process options, chemical oxidation and alkali metal dechlorination were eliminated due to limited effectiveness. Soil washing with chemicals was selected as the representative process option for similar reasons as given above for physical treatment.

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Biological Treatment Options. Land treatment was classified as having limited effectiveness because of the potential for mobilization of contaminants. Bioreactors and biodenitrification were retained as representative process options. Both options are highly effective in treatment of organics and nitrates.

On-Site Disposal Option. On-site disposal technology to satisfy the removal/treatment/disposal action includes the same process options that are discussed for on-site disposal under the removal/disposal response. The tumulus as an above ground facility was eliminated due to its limited long-term effectiveness. The options retained in this category were trenches/pits, vaults, and RCRA landfills.

Off-Site Disposal Option. Off-site disposal options for the removal/treatment/disposal action are the same as discussed under the removal/disposal response. The RCRA landfills and the DOE disposal facilities were retained for development of alternatives. A geologic repository was eliminated because it is not implementable in the time frame necessary to meet the RAOs.

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TABLE 4-1
HANFORD 100 AREA
MEDIA OF INTEREST, EXPOSURE PATHWAYS, AND RECEPTORS

	EXPOSURE PATHWAY	RECEPTORS
Soils	Direct contact Ingestion Consumption of plants grown on the land Water and wind erosion of contaminated soil particles Bioaccumulation in the food chain	Humans Terrestrial flora and fauna Aquatic flora and fauna Aerial fauna
Groundwater	Consumptive use Irrigation and bioaccumulation in the food chain Baseflow contributions to the Columbia River	Humans Terrestrial flora and fauna Aquatic flora and fauna Aerial fauna
Riverbank Sediments	Direct contact and ingestion Bioaccumulation in the food chain	Humans Aquatic flora and fauna Aerial fauna Terrestrial flora and fauna
Solid Wastes	Aerial dispersion Direct contact	Humans Terrestrial flora and fauna Aerial fauna

Note: The 100-N Area is not specified as a medium of interest since it is sufficiently similar in nature to the other sites in the 100 Area such that the other media listed also apply to the 100-N Area.

9 2 1 2 6 2 0 8 0 7

TABLE 4-2
MEDIA OF INTEREST, REMEDIAL ACTION OBJECTIVES, AND GENERAL RESPONSE ACTIONS

MEDIUM*	REMEDIAL ACTION OBJECTIVES	GENERAL RESPONSE ACTIONS
Soils	For Human Health: Prevent ingestion/direct contact with soil having an excess cancer risk of 10^{-04} to 10^{-06}, or radionuclide concentrations resulting in annual whole body radiation dose in excess of 25 mrem/year, or annual critical organ radiation dose in excess of 75 mrem/year (see Table 1A, Appendix B). Prevent inhalation of all contaminants of concern posing an excess cancer risk of 10^{-04} to 10^{-06}, or radionuclides in concentrations resulting in doses greater than 10 mrem/year (see Table 1A, Appendix B). For Environmental Protection: Prevent erosion of soil that would contribute to surface water concentrations greater than the standards for the contaminants of concern in surface water listed in Table 1B, Appendix B. Prevent release of contaminants of concern to groundwater that would result in concentrations in excess of the concentrations listed in Tables 2A and 2B, Appendix B, or above background concentrations listed in Tables AB-1 through AB-10, Appendix A.	No Action Institutional Controls Containment In Situ Treatment Removal/Disposal Removal/Disposal/Treatment
Groundwater	For Human Health: Prevent ingestion of water with carcinogen concentrations in excess of MCLs (Table 2B, Appendix B) and a total excess cancer risk for all contaminants of concern greater than 10^{-04} to 10^{-06}. Prevent ingestion of water with contaminant concentrations in excess of MCLs (see Tables 1B, 1C, 2A, and 2B, Appendix B), or background concentrations, as presented in Tables AB-1 through AB-10, Appendix A. Prevent ingestion of water with total radionuclide concentrations that would result in a radioactive exposure dose in excess of 4 mrem/year. For Environmental Protection: Prevent baseflow contributions to the Columbia River of all contaminants at concentrations that would exceed chronic aquatic concentrations presented in Table 2B, Appendix B. Restore groundwater quality to background concentrations for all contaminants presented in Tables AB-1 through AB-10, Appendix A.	No Action Institutional Controls Containment In Situ Treatment Removal/Disposal Removal/Disposal/Treatment

TABLE 4-2
MEDIA OF INTEREST, REMEDIAL ACTION OBJECTIVES, AND GENERAL RESPONSE ACTIONS

MEDIUM*	REMEDIAL ACTION OBJECTIVES	GENERAL RESPONSE ACTIONS
Riverbank Sediments	For Human Health: Prevent ingestion/direct contact with soil having an excess cancer risk of 10^{-04} to 10^{-06}, or radionuclide concentrations resulting in annual whole body radiation dose in excess of 25 mrem/year, or annual critical organ radiation dose in excess of 75 mrem/year (see Table 1A, Appendix B). Prevent inhalation of all contaminants of concern posing an excess cancer risk of 10^{-04} to 10^{-06}, or radionuclides in concentrations resulting in doses greater than 10 mrem/year (see Table 1A, Appendix B). For Environmental Protection: Prevent erosion of soil that would contribute to surface water concentrations greater than the standards for the contaminants of concern in surface water listed in Table 1B, Appendix B. Prevent release of contaminants of concern to groundwater that would result in concentrations in excess of the concentrations listed in Tables 2A and 2B, Appendix B, or above background concentrations listed in Tables AB-1 through AB-10, Appendix A.	No Action Institutional Controls Containment In Situ Treatment Removal/Disposal Removal/Disposal/Treatment
Solid Waste	For Human Health: Prevent ingestion/direct contact with solid waste having an excess cancer risk of 10^{-04} to 10^{-06}, or radionuclide concentrations resulting in annual whole body radiation dose in excess of 25 mrem/year, or annual critical organ radiation dose in excess of 75 mrem/year (see Table 1A, Appendix B). Prevent inhalation of all contaminants of concern posing an excess cancer risk of 10^{-04} to 10^{-06}, or radionuclides in concentrations resulting in doses greater than 10 mrem/year (see Table 1A, Appendix B). For Environmental Protection: Prevent erosion of solid waste that would contribute to surface water concentrations greater than the standards for the contaminants of concern in surface water listed in Table 1B, Appendix B. Prevent release of contaminants of concern to groundwater that would result in concentrations in excess of the concentrations listed in Tables 2A and 2B, Appendix B, or above background concentrations listed in Tables AB-1 through AB-10, Appendix A.	No Action Institutional Controls Containment In Situ Treatment Removal/Disposal Removal/Disposal/Treatment

*Note: The 100-N Area is not specified as a medium of interest since it is similar in nature to the other sites in the 100 Area such that the other media listed also apply to the 100-N Area.

TABLE 4-3
HANFORD 100 AREA
VOLUMES OR AREAS OF AFFECTED MEDIA

MEDIUM	VOLUME[a], Loose Cubic Feet
Low Activity(1) Soil (grain size <12 inches)	420,116,000
High Activity(2) Soil (grain size <12 inches)	13,495,000
Low Activity(1) Soil (grain size >12 inches)	22,112,000
High Activity(2) Soil (grain size >12 inches)	710,000
Groundwater, all low activity(1)	4.8×10^9 gallons
Riverbank Sediments, all low activity(1)	33,790,000
Low Activity(1) Solid Waste (except pipe >24 inches, diameter)	109,614,000
High Activity(2) Solid Waste (except pipe)	7,581,000
Low Activity(1) Pipe (diameter >24 inches)	31,935,000
High Activity(2) Pipe	394,000

(1) <200 mR/hr surface, <100 pCi/gram TRU
(2) >200 mR/hr surface and/or >100 pCi/gram TRU

[a] All volumes are taken from WHC (1991e) except for Groundwater and Riverbank Sediments which are derived in Appendix D.

Solid Waste General Response Actions	Remedial Technology	Process Options	Descriptions	Screening Comments
No Action	None	Not Applicable	No Action	Required for consideration by NCP
Institutional Actions	Access Restrictions	Fencing	Fencing of the site to restrict access	Potentially Applicable
		Deed Restrictions	Covenants for property use in the area of influence would include restrictions on property use	Potentially Applicable
	Monitoring	Leachate Monitoring	Continuous monitoring of leachate from buried waste sites	Potentially Applicable
Containment Actions	Capping	Asphalt-Based Covers	Asphalt layer over areas of contamination	Potentially Applicable
		Concrete-Based Covers	Concrete slab over areas of contamination	Potentially Applicable
		Soil/Clay-Based Covers	Compacted clay and soil layer over areas of contamination	Potentially Applicable
		RCRA Multi-Media Caps	Synthetic membrane, clay, sand, and vegetation layer over areas of contamination	Potentially Applicable
		Hanford Barriers	Multiple layers of natural materials (fine soil, sand, gravel, rip/rap) over areas of contamination	Potentially Applicable
		Synthetic Covers	Synthetic membrane and soil layer over areas of contamination	Potentially Applicable
		Vitrification	Vitrified soil layer over areas of contamination	Not yet developed to form seamless cap
	Horizontal Barriers	Grout Injection	Pressure injection of grout through closely spaced drill holes below areas of contamination	Potentially Applicable
		Cryogenic Walls	Freezing of interstitial moisture within soils by circulating coolant below areas of contamination	Addition of moisture to form wall can potentially mobilize contaminants
		Vitrification	Vitrified soil layer beneath areas of contamination	Inability to form seamless cap
	Vertical Barriers	Slurry Walls	Trenches around areas of contamination are filled with soil (or cement) bentonite slurry	Potentially Applicable
		Grout Curtains	Pressure injection of grout posts in a pattern surrounding area of contamination	Potentially Applicable
		Sheet Pilings	Sheets of concrete, wood, or steel are driven into the soils surrounding areas of contamination	Cannot be driven into rocky soils
		Cryogenic Walls	Freezing of interstitial moisture within soils surrounding area of contamination	Addition of moisture to form wall can potentially mobilize contaminants
		Biological Barriers	Barrier created by accumulation of biomass	Not applicable due to difficulty in maintaining stable barrier and potential to mobilize contaminants
	Run-On/Run-Off Control	Diversion/Collection	Surface water management by construction of dams, dikes, berms, channels, or levees	Potentially Applicable
		Grading	Modification of site topography to eliminate flooding, erosion, and ponding	Potentially Applicable
		Revegetation	Vegetation cover over areas of contamination to reduce/eliminate erosion	Potentially Applicable

Figure 4-1
Hanford 100 Area FS: Technical Implementability Screening of Process Options for Solid Waste

Solid Waste General Response Actions	Remedial Technology	Process Options	Descriptions	Screening Comments
Removal	Removal	Excavation	Uncovering and removal of buried solid waste with standard earth moving equipment	Potentially Applicable
		Demolition	Dismantling or size reduction of buried facilities, structures, and large objects	Potentially Applicable
Disposal	On-Site Disposal	Trenches/Pits	Disposal in excavated trenches and pits	Potentially Applicable
		Vaults	Disposal in conservatively designed, reinforced concrete vaults	Potentially Applicable
		Tumulus	Disposal by mounding waste placed on a stable structural pad	Potentially Applicable
		RCRA Landfills	Disposal of hazardous waste in on-site EPA approved landfill	Potentially Applicable
	Off-Site Disposal	RCRA Landfills	Disposal of hazardous waste in EPA approved hazardous waste landfill	Potentially Applicable
		DOE Disposal Facilities	Disposal of waste at other DOE facilities with EPA approved disposal areas	Potentially Applicable
		Geologic Repositories	Disposal of waste in EPA approved underground repository	Potentially Applicable
In Situ Treatment	Stabilization/ Solidification	Grout Injection	Pressure injection of grout through equally spaced drill holes into areas of contamination	Potentially Applicable
		Vibration Aided Grout Injection	Pressure injection of grout through equally spaced drill holes aided by vibration along I-beams	Potentially Applicable
		Vitrification	Electrically melt area of contamination to immobilize contaminants in glass form	Not yet developed adequately for solid waste with sealed containers
		Dynamic Compaction	Waste site stabilization by compaction using a large weight dropped repeatedly on the surface of the site	Potentially Applicable

Figure 4-1
Hanford 100 Area FS: Technical Implementabilit reening of Process Options for Solid Waste *(continu*

Solid Waste General Response Actions	Remedial Technology	Process Options	Descriptions	Screening Comments
Removal	Removal	Excavation	Uncovering and removal of buried solid waste with standard earth moving equipment	Potentially Applicable
		Demolition	Dismantling or size reduction of buried facilities, structures, and large objects	Potentially Applicable
Treatment	Thermal Treatment	Thermal Desorption	Removal and destruction of organic contaminants from waste by low temperature thermal treatment	Potentially Applicable
		Incineration	Destruction of organic contaminants by high temperature oxidation	Potentially Applicable
		Pyrolysis	Decomposition of organic contaminants at high temperatures under starved air conditions	Potentially Applicable
		Metal Melting	Melting metals to partition radionuclides in oxidizing slag	Potentially Applicable
		Molten Solids Processing	Destruction of organic contaminants and immobilization of remaining constituents	Potentially Applicable
	Stabilization/ Solidification	Bitumen-Based	Mixing of wastes with bitumen to form a stable waste form	Potentially Applicable
		Cement-Based	Mixing of wastes with water and portland cement to form a monolithic waste form	Potentially Applicable
		Polymer-Based	Encapsulation of waste constituents in polymeric materials to form monolithic waste form	Potentially Applicable
		Vitrification	Melting of waste materials with glass frit to form a solid, stable glassified waste form	Potentially Applicable
	Physical Treatment	Size Reduction	Reducing the size of solid waste materials to improve handling, enhance further treatment, or allow packaging for disposal	Potentially Applicable
		Segregation/Sorting	Separating solid waste materials into distinct radiological, physical, or chemical categories	Potentially Applicable
		Repackaging	Replacement of current solid waste containers which may have been damaged or deteriorated	Potentially Applicable
		Metal Decontamination	Physical removal of surface contamination from metal waste forms	Potentially Applicable
	Chemical Treatment	Chemical Oxidation	Oxidation of organic compounds into carbon dioxide and water	Potentially Applicable
		Acid Digestion	Conversion of combustible solid wastes to an inert solid form by chemical oxidation within a heated bath of sulfuric and nitric acids	Potentially Applicable
		Hydrolysis	Partial decomposition of organics or dissolution of reactive metals	Potentially Applicable
	On-Site Disposal	Trenches/Pits	Disposal in excavated trenches and pits	Potentially Applicable
		Vaults	Disposal in conservatively designed, reinforced concrete vaults	Potentially Applicable
		Tumulus	Disposal by mounding waste placed on a stable structural pad	Potentially Applicable
		RCRA Landfills	Disposal of hazardous waste in on-site EPA approved landfill	Potentially Applicable
	Off-Site Disposal	RCRA Landfills	Disposal of hazardous waste in EPA approved hazardous waste landfill	Potentially Applicable
		DOE Disposal Facilities	Disposal of waste at other DOE facilities with EPA approved disposal areas	Potentially Applicable
		Geologic Repositories	Disposal of waste in EPA approved underground repository	Potentially Applicable

LEGEND

Sample

Shaded Box: Technology or process option is screened from further consideration

Sample

Non-shaded Box: Technology or process option is retained at this screening stage

Figure 4-1
Hanford 100 Area FS: Technical Implementability Screening of Process Options for Solid Waste *(continued)*

Groundwater General Response Actions	Remedial Technology	Process Options	Descriptions	Screening Comments
No Action	None	Not Applicable	No Action	Required for consideration by NCP
Institutional Actions	Access Restrictions	Water Rights Restrictions	Deeds for property in the area of influence would include restrictions on wells and groundwater use	Potentially Applicable
		Deed Restrictions	Covenants for property use in the area of influence would include restrictions on property use	Potentially Applicable
	Monitoring	Well-Point Monitoring	Groundwater monitoring via well point	Well points cannot be installed in rocky soils
		Groundwater Monitoring	Groundwater monitoring via a drilled well	Potentially Applicable
	Alternate Water Supply	Columbia River	Water needed to support end use would be piped from the Columbia River upstream from the Hanford 100 Area	Potentially Applicable
		Extension of Nearby Sources	Water needed to support end use would be piped from a clean aquifer or from another surface source	Potentially Applicable
Containment Actions	Horizontal Barriers	Grout Injection	Pressure injection of grout through closely spaced drill holes below areas of contamination	Potentially Applicable
		Cryogenic Walls	Freezing of interstitial water within soils by circulating coolant below areas of contamination	Implementability Uncertain
		Vitrification	Vitrified soil layer beneath areas of contamination	Not applicable in saturated soils
	Vertical Barriers	Slurry Walls	Trench around areas of contamination are filled with soil (or cement) bentonite slurry	Potentially Applicable
		Grout Curtains	Pressure injection of grout posts in a pattern surrounding area of contamination	Potentially Applicable
		Sheet Pilings	Sheets of concrete, wood, or steel are driven into the soils surrounding areas of contamination	Cannot be driven into rocky soils
		Cryogenic Walls	Freezing of interstitial water within soils surrounding area of contamination	Implementability Uncertain
		Biological Barriers	Barrier created by accumulation of biomass	Not applicable due to difficulty in maintaining stable barrier and potential to mobilize contaminants
	Hydraulic Control	Extraction Wells	Control of subsurface hydraulic gradient by simultaneously extracting and injecting groundwater	Potentially Applicable
		Extraction Drains/Trenches	Drainage or infiltration trenches used to collect/direct groundwater flow by gravity	Potentially Applicable

Figure 4-2
Hanford 100 Area FS: Technical Implementa / Screening of Process Options for Groundwater

Groundwater General Response Actions	Remedial Technology	Process Options	Descriptions	Screening Comments
Removal / Disposal	Groundwater Extraction	Extraction Wells	Groundwater removal through wells	Potentially Applicable
		Extraction Drains/Trenches	Drainage or infiltration trenches used to collect/direct groundwater flow by gravity	Potentially Applicable
		Aquifer Mining	Removal of water bearing strata (and overburden) using mining technology	Potentially Applicable
		Lixiviant Extraction	Dissolution of adsorbed contaminants from saturated sediments	Potentially Applicable
	Wastewater Disposal	Deepwell Injection	Discharge of untreated groundwater below aquifers	Potentially Applicable
		Above-/Below-Ground Tanks	Indefinite storage of contaminated groundwater in above/below ground tanks	Potentially Applicable
		Evaporation Ponds	Solar Evaporation (Passive Evaporation)	Potentially Applicable
In Situ Treatment	Biological Treatment	Enhanced Groundwater Bioremediation	Process where nutrients and microbes are injected into an organically contaminated zone and byproducts are recovered for disposal	Potentially Applicable
		Biodenitrification	Injection of microbes that preferentially metabolize nitrate contamination	Potentially Applicable
	Physical Treatment	Air Stripping	Perforated pipe installed below the aquifer grade allows air to percolate through groundwater thereby stripping organic contamination	Potentially Applicable
		Permeable Treatment Beds	A trench is excavated below the aquifer and is backfilled with a treatment medium intended to intercept contaminants in the groundwater	Potentially Applicable
		Vapor Extraction	Vacuum extraction of VOCs from groundwater	Potentially Applicable
		Electro-Kinetic Separation	Migration of ions induced by direct current, similar to electro-dialysis but no membrane is used	Potentially Applicable
	Chemical Treatment	In Situ Chemical Precipitation	Addition of reagents to form insoluble (and thus, immobile) precipitates	Potentially Applicable

Figure 4-2
Hanford 100 Area FS: Technical Implementability Screening of Process Options for Groundwater *(continued)*

Groundwater General Response Actions	Remedial Technology	Process Options	Descriptions	Screening Comments
Removal, Treatment, Disposal	Groundwater Extraction	Extraction Wells	Groundwater removal through wells	Potentially Applicable
		Extraction Drains/Trenches	Drainage or infiltration trenches used to collect/direct groundwater flow by gravity	Potentially Applicable
		Aquifer Mining	Removal of water bearing strata (and overburden) using mining technology	Potentially Applicable
		Lixiviant Extraction	Dissolution of adsorbed contaminants from saturated sediments	Potentially Applicable
	Biological Treatment	Bioreactors	Biological destruction of organic contaminants in contained vessel	Potentially Applicable
		Biodenitrification	Mix nutrients, cultures and groundwater in process vessel under anaerobic conditions	Potentially Applicable
		Biosorption	Adsorption of heavy metals and potentially radionuclides onto a filter containing algae	Potentially Applicable
	Physical Treatment	Ion Exchange	Adsorption of ionic contamination on activated resin materials	Potentially Applicable
		Evaporation: Passive	Solar evaporation of aqueous wastes in ponds	Potentially Applicable
		Media Filtration	Introduction of diatomaceous earth to a groundwater waste stream for more efficient removal of suspended material	Potentially Applicable
		Flocculation	A method of removing dissolved materials and suspended solids by introducing compounds that coagulate contaminants	Potentially Applicable
		Carbon Adsorption	Removal of organic contamination from groundwater by adsorption on granular activated carbon	Potentially Applicable
		Air Stripping	A common unit operation in which VOCs dissolved in water are vaporized and removed	Potentially Applicable
		Reverse Osmosis	Removal of contaminants by forcing groundwater through a filter under pressure: the contaminants are adsorbed onto the filter and pure water is removed	Potentially Applicable
		Ultrafiltration	A variation of reverse osmosis using a more porous filter and less pressure	Potentially Applicable
		Electrodialysis	Ion migration is induced by direct current through a plastic membrane	Potentially Applicable
		Dissolved Air Flotation	Removal of suspended fines using frothing agents and air bubbles: the fines adhere to the bubbles and may then be skimmed off	Potentially Applicable
		Sedimentation	Settling of suspended materials by gravity	Potentially Applicable
		Steam Stripping	An enhancement to air stripping which removes semivolatile compounds in addition to VOCs	Potentially Applicable
		Evaporation: Forced	Uses heat for more rapid volume reduction	Potentially Applicable
		Freeze Crystallization	Concentration of contaminants by freezing and removing pure ice crystals	Potentially Applicable
		Supported Liquid Membrane	Use of high diffusivity liquid (organic liquid in micro-pores of a membrane) membrane for contaminant removal	Potentially Applicable

Continued

Figure 4-2

Hanford 100 Area FS: Technical Implementability Screening of Process Options for Groundwater *(continu*

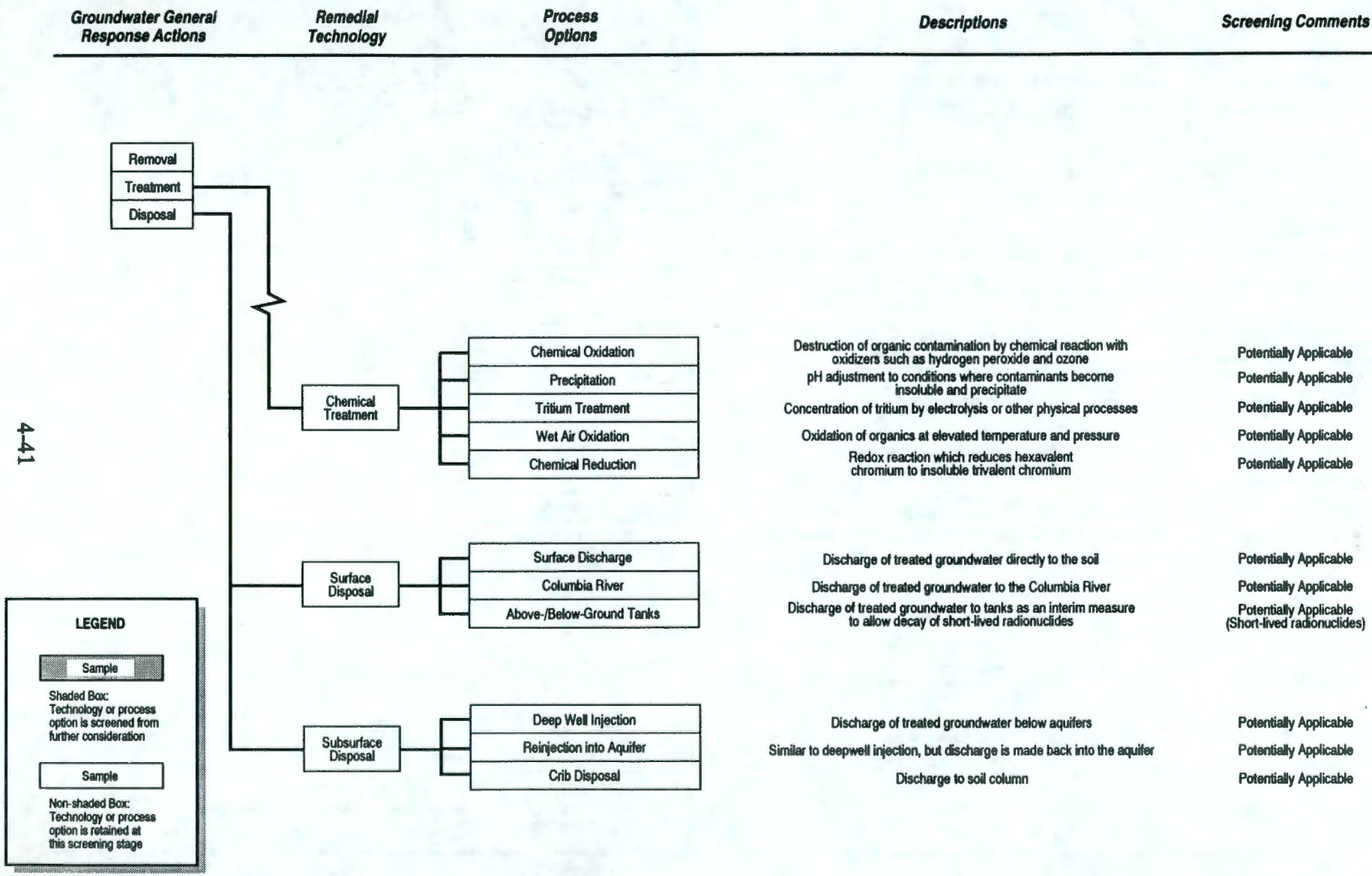

Figure 4-2
Hanford 100 Area FS: Technical Implementability Screening of Process Options for Groundwater *(continued)*

Soil/Sediments General Response Actions	Remedial Technology	Process Options	Descriptions	Screening Comments
No Action	None	Not Applicable	No Action	Required for consideration by NCP
Institutional Actions	Access Restrictions	Fencing	Fencing of the site to restrict access	Potentially Applicable
		Deed Restrictions	Covenants for property use in the area of influence would include restrictions on property use	Potentially Applicable
	Monitoring	Leachate Monitoring	Continuous monitoring of leachate from contaminated soils/sediments	Potentially Applicable
Containment Actions	Capping	Asphalt-Based Covers	Asphalt layer over areas of contamination	Potentially Applicable
		Concrete-Based Covers	Concrete slab over areas of contamination	Potentially Applicable
		Soil/Clay-Based Covers	Compacted clay and soil layer over areas of contamination	Potentially Applicable
		RCRA Multi-Media Caps	Synthetic membrane, clay, sand, and vegetation layer over areas of contamination	Potentially Applicable
		Hanford Barriers	Multiple layers of natural materials (fine soil, sand, gravel, rip/rap) over areas of contamination	Potentially Applicable
		Synthetic Covers	Synthetic membrane and soil layer over areas of contamination	Potentially Applicable
		Vitrification	Vitrified soil layer over areas of contamination	Inability to form seamless cap
	Horizontal Barriers	Grout Injection	Pressure injection of grout through closely spaced drill holes below areas of contamination	Potentially Applicable
		Cryogenic Walls	Freezing of interstitial moisture within soils by circulating coolant below areas of contamination	Addition of moisture to form wall can potentially mobilize contaminants
		Vitrification	Vitrified soil layer beneath areas of contamination	Not Applicable; has not been demonstrated at depths required
	Vertical Barriers	Slurry Walls	Trenches around areas of contamination are filled with soil (or cement) bentonite slurry	Potentially Applicable
		Grout Curtains	Pressure injection of grout posts in a pattern surrounding area of contamination	Potentially Applicable
		Sheet Pilings	Sheets of concrete, wood, or steel are driven into the soils surrounding areas of contamination	Cannot be driven into rocky soils
		Cryogenic Walls	Freezing of interstitial moisture within soils surrounding area of contamination	Addition of moisture to form wall can potentially mobilize contaminants
		Biological Barriers	Barrier created by accumulation of biomass	Not applicable due to difficulty in maintaining stable barrier and potential to mobilize contaminants
	Run-On/Run-Off Control	Diversion/Collection	Surface water management by construction of dams, dikes, berms, channels, or levees	Potentially Applicable
		Grading	Modification of site topography to eliminate flooding, erosion, and ponding	Potentially Applicable
		Revegetation	Vegetation cover over areas of contamination to reduce/eliminate erosion	Potentially Applicable

Figure 4-3
Hanford 100 Area FS: Technical Implementability Screening of Process Options for Soil and F bank Sediments

Soils/Sediments General Response Actions	Remedial Technology	Process Options	Descriptions	Screening Comments
Removal	Removal	Excavation	Uncovering and removal of contaminated soils/sediments with standard earth moving equipment	Potentially Applicable
Disposal	On-Site Disposal	Trenches/Pits	Disposal in excavated trenches and pits	Potentially Applicable
		Vaults	Disposal in conservatively designed, reinforced concrete vaults	Potentially Applicable
		Tumulus	Disposal by mounding waste placed on a stable structural pad	Potentially Applicable
		RCRA Landfills	Disposal of hazardous waste in on-site EPA permitted landfill	Potentially Applicable
	Off-Site Disposal	RCRA Landfills	Disposal of hazardous waste in EPA approved hazardous waste landfill	Potentially Applicable
		DOE Disposal Facilities	Disposal of waste at other DOE facilities with EPA approved disposal areas	Potentially Applicable
		Geologic Repositories	Disposal of waste in EPA approved underground repository	Potentially Applicable
In Situ Treatment	Stabilization/ Solidification	Grout Injection	Pressure injection of grout through equally spaced drill holes into areas of contamination	Potentially Applicable
		Vibration Aided Grout Injection	Pressure injection of grout through equally spaced drill holes aided by vibration along I-beams	Potentially Applicable
		Shallow Soil Mixing	Mixing soils/sediments with chemical compounds to produce a solidified mass	Potentially Applicable
		Fixants	Spray coating the soil surface to prevent airborne contamination	Potentially Applicable
		Vitrification	Electrically melt area of contamination to immobilize contaminants in glass form	Potentially Applicable
		Ground Freezing	Solidification of soils by freezing moisture in situ	Potentially Applicable
		Dynamic Compaction	Waste site stabilization by compaction using a large weight dropped repeatedly on the surface of the site	Potentially Applicable
	In Situ Biological Treatment	Enhanced Soil Bioremediation	Introduction of microbes and nutrients in a fluid to enhance organic contamination destruction followed by removal	Potentially Applicable
		Biodenitrification	Injection of microbes which preferentially metabolize nitrate contamination	Potentially Applicable
		Land Farming	Tilling and introduction of nutrients to the soil to enhance microbial destruction of organics	Not Applicable due to depth of contamination
	In Situ Chemical Treatment	Soil Flushing	Reactive in situ soil washing which dissolves adsorbed contaminants	Potentially Applicable
	In Situ Physical Treatment	Vapor Extraction	Vacuum extraction of VOCs	Potentially Applicable
		Steam Stripping	An enhancement to air stripping which removes semivolatile compounds in addition to VOCs	Potentially Applicable
		Soil Flushing	Non-reactive in situ soil washing to remove adsorbed contaminants	Potentially Applicable
		RF Heating	Use of RF energy to induce migration of organic contaminants	Potentially Applicable
		Electrical Soil Heating	Warming the soil to enhance VOC migration to the surface	Potentially Applicable

Figure 4-3
Hanford 100 Area FS: Technical Implementability Screening of Process Options for Soil and Riverbank Sediments (*continued*)

Soils/Sediments General Response Actions	Remedial Technology	Process Options	Descriptions	Screening Comments
Removal	Removal	Excavation	Uncovering and removal of contaminated soils/sediments with standard earth moving equipment	Potentially Applicable
Treatment	Thermal Treatment	Thermal Desorption	Removal and destruction of organic contaminants from waste by low temperature thermal treatment	Potentially Applicable
		Incineration	Destruction of organic contaminants by high temperature oxidation	Potentially Applicable
		Pyrolysis	Decomposition of organic contaminants under starved air conditions at high temperatures	Potentially Applicable
		Molten Solids Processing	Destruction of organic contaminants and immobilization of remaining constituents	Potentially Applicable
	Stabilization/ Solidification	Bitumen-Based	Mixing of soils/sediments with bitumen to form a stable waste form	Potentially Applicable
		Cement-Based	Mixing of soils/sediments with water and portland cement to form a monolithic waste form	Potentially Applicable
		Polymer-Based	Encapsulation of soils/sediments in polymeric materials to form a monolithic waste form	Potentially Applicable
		Vitrification	Melting of soils/sediments with glass frit to form a glassified waste form	Potentially Applicable
	Physical Treatment	Vapor Extraction	Vacuum extraction of VOCs	Potentially Applicable
		Soil Washing	Use of non-reactive extractants to remove contamination	Potentially Applicable
		Steam Stripping	An enhancement to air stripping which removes semivolatile compounds in addition to VOCs	Potentially Applicable
Disposal				

Continued

Figure 4-3
Hanford 100 Area FS: Technical Implementability Screening of Process Options for Soil and Riverbar ediments (*continued*)

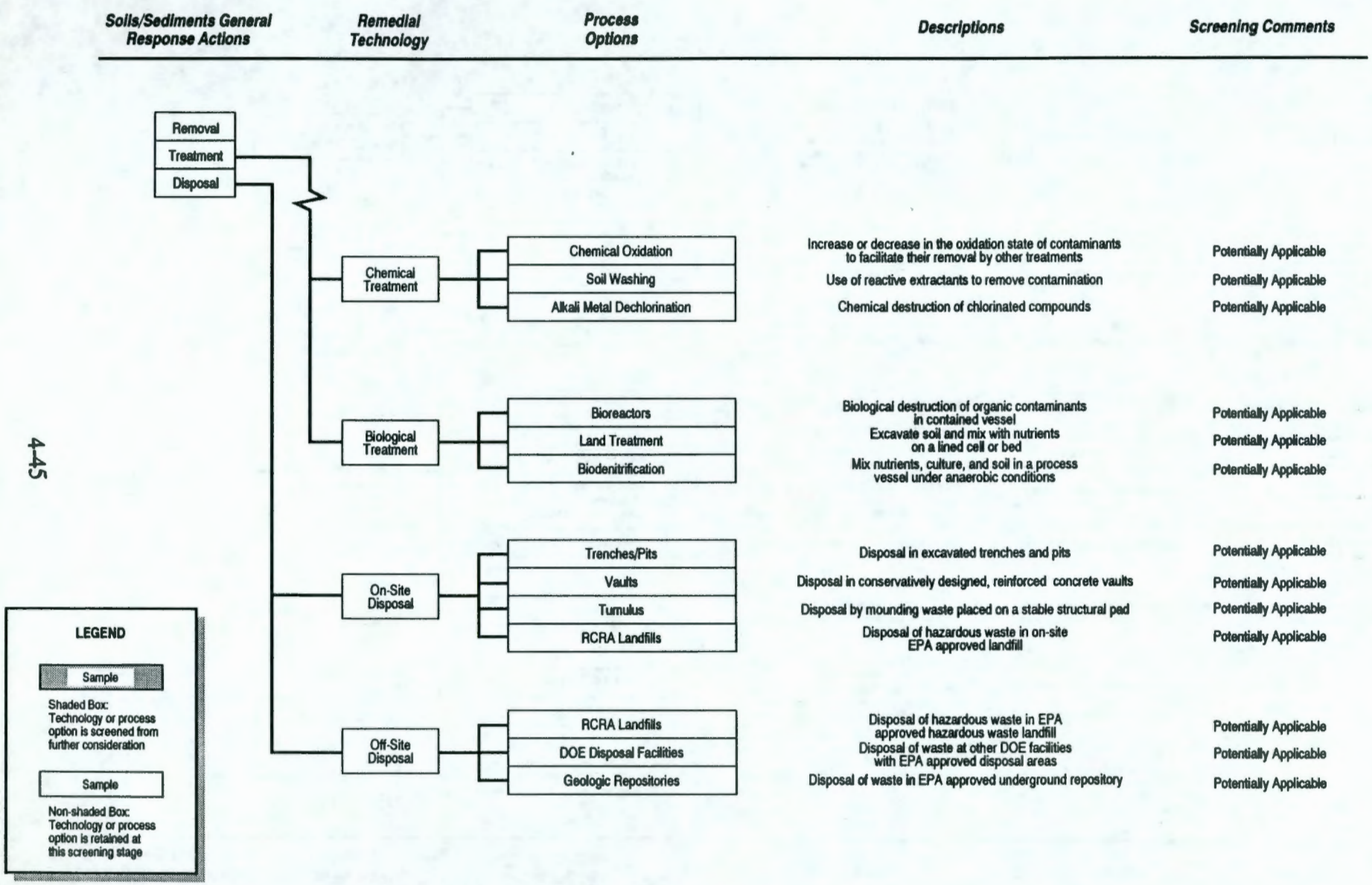

Figure 4-3
Hanford 100 Area FS: Technical Implementability Screening of Process Options for Soil and Riverbank Sediments (*continued*)

Solid Waste General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
No Action	None	Not Applicable	Limited - May not achieve RAO's	May not be acceptable to local public and regulators	None
Institutional Actions	Access Restrictions	Fencing	Limited - Provides a barrier but does not prevent access to restricted areas	Easy - Commonly used	Low - Inexpensive materials, easy installation
		Deed Restrictions	Limited - Effective in short term, uncertain in long term	Easy - Visual monitoring required	Low - Minimal resources required
	Monitoring	Leachate Monitoring	Limited - Installation difficulties beneath existing contaminated sites	Difficult - Installation beneath existing contaminated sites violates ALARA principles	High - Installation requires excavation through contaminated sites
Containment Actions	Capping	Asphalt-Based Covers	Limited - Inadequate long-term performance	Moderate - Commercially available	High - Low capital, high O & M
		Concrete-Based Covers	Limited - Inadequate long-term performance	Moderate - Commercially available	High - Low capital, high O & M
		Soil/Clay-Based Covers	Limited - Inadequate long-term performance	Easy - Commercially available	Low - Low equipment and material costs
		RCRA Multi-Media Caps	Moderate - Long-term performance is uncertain	Moderate - Synthetic materials and natural materials	Moderate - Mostly natural materials
		Hanford Barriers	High - Effective over long-term	Moderate - Innovative, natural materials available on site	Moderate - Moderate capital, low O & M
		Synthetic Covers	Limited - Inadequate long-term performance	Easy - Commonly used specialized installation required	Moderate - Moderate capital costs
	Horizontal Barriers	Grout Injection	Limited - Flow direction difficult to control; long-term performance uncertain	Difficult - Limited control of flow path for grout	Moderate - Moderate capital and O & M
	Vertical Barriers	Slurry Walls	Moderate - Effectiveness depends on uniform thickness to reduce groundwater flow	Difficult - Construction difficulties; slurry loss during excavation must be prevented	High - High capital due to depth required
		Grout Curtains	Not Effective - Difficulty in forming continuous curtain	Moderate - Dependent on soil characteristics and depth	High - High capital due to depth required
	Run-On/Run-Off Control	Diversion/Collection	Moderate - Effectiveness depends on frequent maintenance	Easy - Well developed techniques	Moderate - Low capital, high O & M
		Grading	Limited - Effective in preventing pooling; does not divert or prevent run-on/run-off	Easy - Widely used technique	Low - Easy to implement, minimal resource requirements
		Revegetation	Moderate - Effective in preventing erosion	Easy - Commonly used for site reclamation	Low - Once in place, no O & M required

Figure 4-4
Hanford 100 Area FS: Implementability, Effectiveness and Cost Screening of Process Options for Solid Wa

Solid Waste General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
Removal	Removal	Excavation	High - Effective for removal of solid waste at high capacities	Moderate - Equipment modification may be necessary; well developed technology	Low - Low capital, low O & M
		Demolition	High - Effective for size reduction	Moderate - Hydraulic demolition tools commercially available	Low - Low capital, low O & M
Disposal	On-Site Disposal	Trenches/Pits	Moderate - Effective for isolating contaminants from accessible environment	Easy - Commonly used waste management practice	Low - Standard construction; minimal maintenance
		Vaults	High - Effective for isolation from human contact	Moderate - Based on design to meet regulatory requirements	High - Conservative design safety features
		Tumulus	Limited - Susceptible to degradation	Moderate - Based on design to meet regulatory requirements	Low - Low capital, moderate O & M
		RCRA Landfills	Moderate - Effective in preventing migration of contaminants	Moderate - Well developed technology	Moderate - Specialized designs not required
	Off-Site Disposal	RCRA Landfills	High - Effective for disposal of non-radioactive waste forms	Easy - May use existing facilities	Low - Low capital and maintenance
		DOE Disposal Facilities	Moderate - Opposition from host state governments and local residents	Difficult - Opposition to importing waste for disposal	High - High maintenance, monitoring, and disposal
		Geologic Repositories	High - Effective for containment and isolation of radioactive wastes	Not Implementable; repository will not be available	Very High - Based on WIPP and Yucca Mountain Experience
In Situ Treatment	Stabilization/ Solidification	Grout Injection	Limited - Flow direction difficult to control long-term performance uncertain	Easy - Well developed technology for mixing soil and grout	Moderate - Moderate capital and O & M
		Vibration Aided Grout Injection	Moderate - Effective control of grout placement	Moderate - More difficult in rocky soil	High - More expensive due to installation requirements
		Dynamic Compaction	Limited - Should be effective in short term for porous materials	Easy - Commercially available and well developed	Low - Low capital, low O & M

Figure 4-4
Hanford 100 Area FS: Implementability, Effectiveness, and Cost Screening of Process Options for Solid Waste *(continued)*

Solid Waste General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
Removal	Removal	Excavation	High - Effective for removal of solid waste at high capacities	Moderate - Equipment modification may be necessary. Well developed technology	Low - Low capital, low O & M
		Demolition	High - Effective for size reduction	Moderate - Hydraulic demolition tools commercially available	Low - Low capital, low O & M
Treatment	Thermal Treatment	Thermal Desorption	High - Effective for organic contaminant removal and destruction	Moderate - Well developed technology	Moderate - Lower temperature required
		Incineration	High - Effective for destruction of organic contamination	Moderate - Well developed technology	High - High maintenance Off gas treatment needed
		Pyrolysis	High - Effective for destruction of organic contamination	Moderate - Commercially available	High - High maintenance Off gas treatment needed
		Metal Melting	Uncertain - Effective in removing TRU from metals. Tests needed for other radionuclides	Difficult - Requires segregated waste stream	High - High maintenance Off gas treatment needed
		Molten Solids Processing	Moderate - Effectiveness not demonstrated to scale	Difficult - Presently being developed and demonstrated	Very High - High energy requirement
	Stabilization/ Solidification	Bitumen-Based	Moderate - Treatability tests required to determine compatability with contaminants	Moderate - Well developed technology Adaptation to Hanford conditions necessary	Low - Inexpensive binding agent
		Cement-Based	Moderate - Treatability tests required to select mixes	Easy - Commonly used technology	Low - Low capital, low O & M
		Polymer-Based	Moderate - Effective for treating inorganic waste, polymerization may be retarded by organics	Moderate - Commercially available, but not generally used for S/S	High - High capital, high maintenance
		Vitrification	Moderate - Effective in destruction of organic and nitrate contaminants	Difficult - Innovative technology	Very High - Complex system requiring high capital and O & M.
	Physical Treatment	Size Reduction	Limited - Additional treatment required	Easy - Size reduction achievable but segregation required	Low - Low capital, readily available
		Segregation/Sorting	Limited - Effective for large volumes, dependent on degree of sorting	Difficult - ALARA considerations must be addressed	Very High - Due to personal protection equipment and exposure required
		Repackaging	Moderate - Dispersal of contaminants to the environment may still occur	Moderate - Size reduction or special handling required	Moderate - Labor intensive, low maintenance
		Metal Decontamination	High - Effectiveness based on level of contamination and physical condition of waste	Difficult - Segregation of waste stream required	High - Pretreatment may be required
	Chemical Treatment	Chemical Oxidation	Limited - Due to need for extraction of organics	Difficult - Dependent on need for extraction of waste material	Very High - Based on expensive reagents and energy consumption
		Acid Digestion	Limited - Effective for combustible wastes only; slow processing rates	Difficult - Not commercially available; dangerous operating conditions	Very High - Extensive process control required
		Hydrolysis	Limited - Effective for reactive metals only	Difficult - Requires reactive materials or insoluble organics	High - Dangerous operating conditions
	On-Site Disposal	Trenches/Pits	Moderate - Effective for isolating contaminants from accessible environment	Easy - Commonly used waste management practice	Low - Standard construction, minimal maintenance
		Vaults	High - Effective for isolation from human contact	Moderate - Based on design to meet regulatory requirements	High - Conservative design safety features
		Tumulus	Limited - Susceptible to degradation	Moderate - Based on design to meet regulatory requirements	Low - Low capital, moderate O & M
		RCRA Landfills	Moderate - Effective in preventing migration of contaminants	Moderate - Well developed technology	Moderate - Specialized designs not required
	Off-Site Disposal	RCRA Landfills	High - Effective for disposal of non-radioactive waste forms	Easy - May use existing facilities	Low - Low capital and maintenance
		DOE Disposal Facilities	Moderate - Opposition from host state governments and local residents	Difficult - Opposition to importing waste for disposal	High - High maintenance, monitoring, and disposal
		Geologic Repositories	High - Effective for containment and isolation of radioactive wastes	Not Implementable; repository will not be available	Very High - Based on WIPP and Yucca Mountain Experience

LEGEND

Sample

Shaded Box: Technology or process option is screened from further consideration

Sample

Non-shaded Box: Technology or process option is retained at this screening stage

Figure 4-4

Har 100 Area FS: Implementability, Effectiveness, and it Screening of Process Options for Solid Waste (co ed)

Groundwater General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
No Action	None	Not Applicable	Limited - May not achieve RAO's	May not be acceptable to local public and regulators	None
Institutional Actions	Access Restrictions	Water Rights Restrictions	Limited - Effective in short term, uncertain in long term	Easy - Visual monitoring required	Low - Low capital, low O & M
		Deed Restrictions	Limited - Effective in short term, uncertain in long term	Easy - Visual monitoring required	Low - Low capital, low O & M
	Monitoring	Groundwater Monitoring	High - Useful for monitoring changing conditions	Easy - Available and already in use at Hanford site	Moderate - Moderate capital, moderate O & M
	Alternate Water Supply	Columbia River	High - Effective replacement for groundwater; no contaminant reduction	Easy - Direct diversion or water	Moderate - Varies with water volume
		Development of Nearby Sources	High - Effective replacement for groundwater; no contaminant reduction	Moderate - Construction of pipelines necessary	High - Varies with volume, construction of pipelines
Containment Actions	Horizontal Barriers	Grout Injection	Not Effective - Natural barrier beneath aquifer already exists	Difficult - Limited control of flow path for grout	Moderate - Moderate capital and O & M
		Cryogenic Walls	Not Effective - Natural barrier beneath aquifer already exists	Difficult - Contaminant mobilization may occur	Very High - High capital, High O & M
	Vertical Barriers	Slurry Walls	Moderate - Effectiveness depends on uniform thickness to reduce groundwater flow	Difficult - Construction difficulties; slurry loss during excavation must be prevented	High - High capital due to depth required
		Grout Curtains	Not Effective - Difficulty in forming continuous curtain	Moderate - Dependent on soil characteristics and depth	High - High capital due to depth required
		Cryogenic Walls	Uncertain Effectiveness - Requires continuous coolant circulation	Difficult - Contaminant mobilization may occur	Very High - High capital, high O & M
	Hydraulic Control	Extraction Wells	High - Effective for extraction and injection	Easy - Coarse soil, relatively low depth to groundwater	Moderate - Well construction and installation
		Extraction Drains/Trenches	High - Effective for shallow contamination	Moderate - Large excavations required to intercept contaminant plume	High - Large excavations required

Figure 4-5
Hanford 100 Area FS: Implementability, Effectiveness, and Cost Screening of Process Options for Groundwater

Groundwater General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
Removal / Disposal	Groundwater Extraction	Extraction Wells	High - Effective for extraction and injection	Easy - Coarse soil, relatively low depth to groundwater	Moderate - Well construction and installation
		Extraction Drains/Trenches	High - Effective for shallow contamination	Moderate - Large excavations required to intercept contaminant plume	High - Large excavations required
		Aquifer Mining	High - Effective in removal of contaminated groundwater and source	Difficult - Large volumes of material require excavation	Very High - Requires excavation, treatment, and disposal
		Lixiviant Extraction	Limited - Uncertain effectiveness of lixiviant removal and recovery	Difficult - Due to potential for contaminant mobilization	High - Requires lixiviants and extraction/injection wells
	Wastewater Disposal	Deepwell Injection	High - Isolation allows decay and dilution	Difficult Implementabity - Due to regulatory constraints	High - Drilling, monitoring, and disposal permitting
		Above-/Below-Ground Tanks	Not Effective - Inadequate long-term disposal	Moderate - Technology available	Very High - Installation and monitoring costs
		Evaporation Ponds	Not Effective - Tritium will evaporate into atmosphere	Easy - Conventional technology	Low - Capital low, O & M low
In Situ Treatment	Biological Treatment	Enhanced Groundwater Bioremediation	Moderate - Difficult to maintain process parameters	Difficult - Potential to mobilize contaminants	High - Capital and O & M costs high
		Biodenitrification	High - Based on test results	Moderate - Both in situ and ex situ tests have proven successful	Moderate - Commercially available and relatively inexpensive
	Physical Treatment	Air Stripping	High - Effective for removing VOCs	Moderate - Venting of VOCs to atmosphere may not be a viable option	Moderate - Relative to other physical treatment
		Permeable Treatment Beds	Limited - Precip. can cause loss of permeability Variety of contaminant specific media needed	Difficult - Treatment media must adsorb large quantity/variety of contaminants	High - Secondary waste generation/excavations
		Vapor Extraction	Moderate - Influenced by thickness of the contaminant zone	Easy - Proven successful in past tests	Low - Low capital, low O & M
		Electro-Kinetic Separation	Limited - High hydraulic conductivity aquifer.	Uncertain - Limited application and demonstration.	High - Energy use; extraction/ treatment requirements.
	Chemical Treatment	In Situ Chemical Precipitation	Effectiveness - Uncertain, innovative approach; difficulty with adequate mixing	Difficult - Due to regulatory issues	High - Needs for reagents and injection system

Figure 4-5

H 'd 100 Area FS: Implementability, Effectiveness, ar ost Screening of Process Options for Groundwater tinued)

Groundwater General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
Removal Treatment Disposal	Groundwater Extraction	Extraction Wells	High - Effective for extraction and injection	Easy - coarse soil, relatively low depth to groundwater	Moderate - well construction and installation
		Extraction Drains/Trenches	High - Effective for shallow contamination	Moderate - Large excavations required to intercept contaminant plume	High - Large excavations required
		Aquifer Mining	High - Effective in removal of contaminated groundwater and source	Difficult - Large volumes of material require excavation	Very High - Requires excavation, treatment, and disposal
		Lixiviant Extraction	Limited - Uncertain effectiveness of lixiviant removal and recovery	Difficult - Due to potential for contaminant mobilization	High - Requires lixiviants and extraction/injection wells
	Biological Treatment	Bioreactors	High - Effective for organic contaminants, proper mixing required.	Moderate - Long residence time in reactor required	High - Number of reactors dependant on number of streams
		Biodenitrification	High - Based on test results	Moderate - Both in situ and ex situ tests have proven successful	High - High capital, high O & M
		Biosorption	Uncertain - New process, treatability tests required	Difficult - Treatability tests necessary	Moderate - Relative to similar processes
	Physical Treatment	Ion Exchange	High - Effective for low concentrations of ionic species	Easy - Pretreatment may be necessary	High - Requires disposal of ion exchange resins
		Evaporation: Passive	Not Effective - Tritium will evaporate into the atmosphere	Easy - conventional technology	Low - Capital low, O & M low
		Media Filtration	High - Effective for removal of solid from liquid	Easy - Pretreatment or concentration process	Low - Low maintainance
		Flocculation	Moderate - Preparatory for other processes	Moderate - additional processes necessary	Moderate - Require specification of coagulating agents and treatability tests
		Carbon Adsorption	Moderate - Effective for organics	Easy - Commercially available	Moderate - Disposal of spent carbon
		Air Stripping	Moderate - Effective for low solubility VOCs	Easy - Conventional technology	Low - Low capital and low O & M
		Reverse Osmosis	High - Effective for heavy metals and minerals	Moderate - Secondary treatment of effluent and concentrate	High - Secondary treatment of effluent and concentrate
		Ultrafiltration	Moderate - Not as effective for highly soluble species	Moderate - Secondary treatment of effluent and concentrate	High - Secondary treatment of effluent and concentrate
		Electrodialysis	Uncertain - Treatability tests required	Difficult - Treatability tests required	High - High capital, high O & M
		Dissolved Air Flotation	Limited - Effective for fines or suspended solids only	Moderate - Secondary treatment processes required	Moderate - High capital, low O &M
		Sedimentation	Limited - To large particles only	Easy - Commercially available	Low - Low capital, low O & M
		Steam Stripping	High - Effective for VOCs and semivolatiles	Easy - Commercially available	High - Requires secondary treatment
		Evaporation: Forced	High - Concentrates contaminants, and volume reduction	Moderate - Commercially available	High - Requires secondary treatment
		Freeze Crystallization	Limited - Contaminants remain in solution	Difficult - Dilute concentrations of contaminants	High - Requires secondary treatment
		Supported Liquid Membrane	Uncertain - Treatability tests needed	Uncertain - Treatability tests needed	Uncertain

Continued

Figure 4-5
Hanford 100 Area FS: Implementability, Effectiveness, and Cost Screening of Process Options for Groundwater *(continued)*

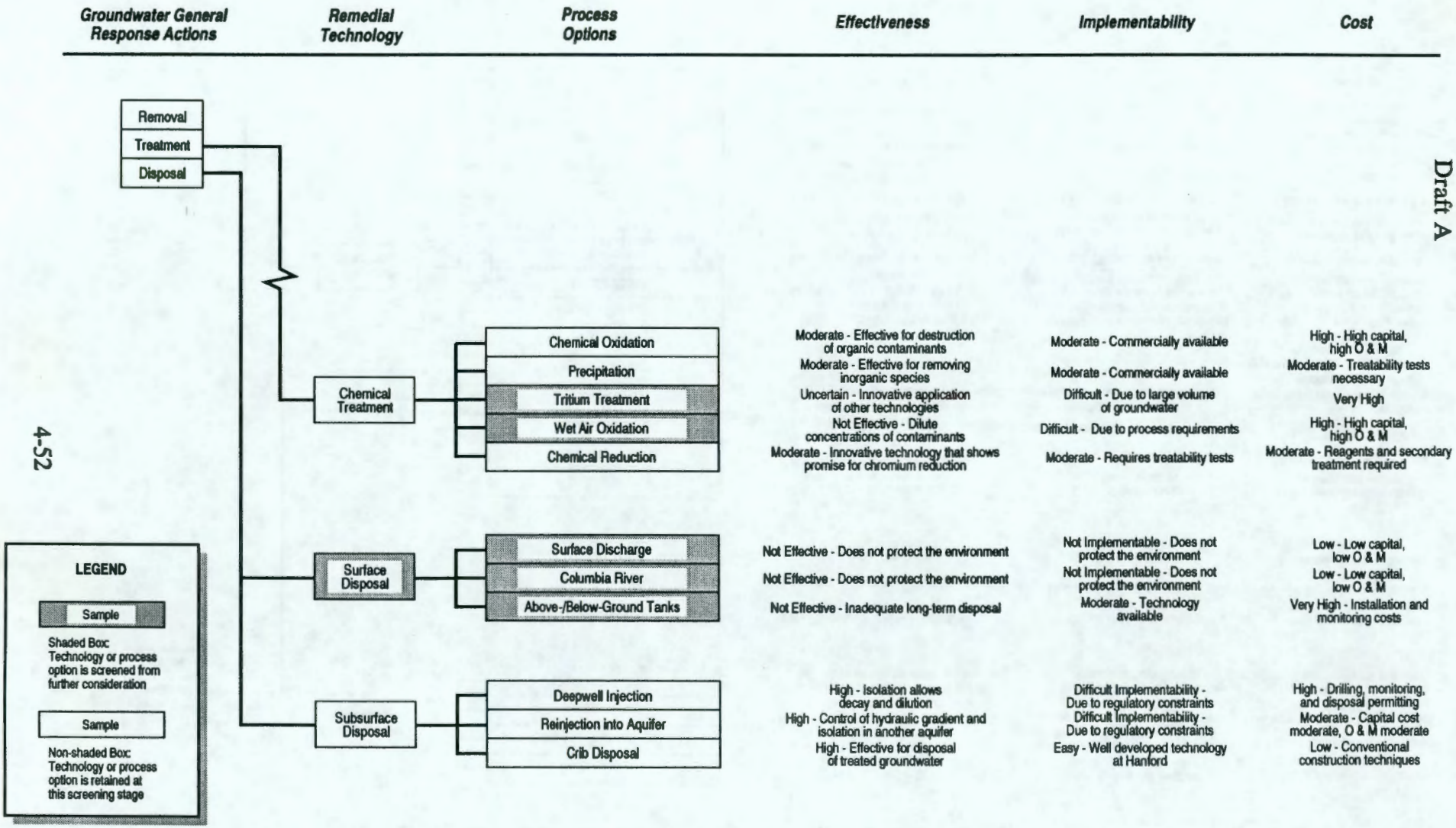

Figure 4-5

H rd 100 Area FS: Implementability, Effectiveness, a ost Screening of Process Options for Groundwate ntinued)

Soil/Sediments General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
No Action	None	Not Applicable	Limited - May not achieve RAO's	May not be acceptable to local public and regulators	None
Institutional Actions	Access Restrictions	Fencing	Limited - Provides a barrier but does not prevent access to restricted areas	Easy - Commonly used	Low - Inexpensive materials, easy installation
		Deed Restrictions	Limited - Effective in short term, uncertain in long term	Easy - Visual monitoring required	Low - Minimal resources required
	Monitoring	Leachate Monitoring	Limited - Installation difficulties beneath existing contaminated site	Difficult - Installation beneath existing contaminated sites violates ALARA principles	High - Installation requires excavation through contaminated sites
Containment Actions	Capping	Asphalt-Based Covers	Limited - Inadequate long-term performance	Moderate - Commercially available	High - Low capital, high O & M
		Concrete-Based Covers	Limited - Inadequate long-term performance	Moderate - Commercially available	High - Low capital, high O & M
		Soil/Clay-Based Covers	Limited - Inadequate long-term performance	Easy - Commercially available	Low - Low equipment and material costs
		RCRA Multi-Media Caps	Moderate - Long-term performance is uncertain	Moderate - Synthetic materials and natural materials	Moderate - Mostly natural materials
		Hanford Barriers	High - Effective over long-term	Moderate - Innovative, natural materials available on site	Moderate - Moderate capital, low O & M
		Synthetic Covers	Limited - Inadequate long-term performance	Easy - Commonly used specialized installation required	Moderate - Moderate capital costs
	Horizontal Barriers	Grout Injection	Limited - Flow direction difficult to control; long-term performance uncertain	Difficult - Limited control of flow path for grout	Moderate - Moderate capital and O & M
	Vertical Barriers	Slurry Walls	Moderate - Effectiveness depends on uniform thickness to reduce groundwater flow	Difficult - Construction difficulties; slurry loss during excavation must be prevented	High - High capital due to depth required
		Grout Curtains	Not Effective - Difficulty in forming continuous curtain	Moderate - Dependent on soil characteristics and depth	High - High capital due to depth required
	Run-On/Run-Off Control	Diversion/Collection	Moderate - Effectiveness depends on frequent maintenance	Easy - Well developed techniques	Moderate - Low capital, high O & M
		Grading	Limited - Effective in preventing pooling; does not divert or prevent run-on/run-off	Easy - Widely used technique	Low - Easy to implement, minimal resource requirements
		Revegetation	Moderate - Effective in preventing erosion	Easy - Commonly used for site reclamation	Low - Once in place, no O & M required

Figure 4-6
Hanford 100 Area FS: Implementability, Effectiveness, and Cost Screening of Process Options for Soil and Riverbank Sediments

Soils/Sediments General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
Removal / Disposal	Removal	Excavation	High - Effective for removal of soils and sediments at high capacities	Moderate - Equipment modification may be necessary; well developed technology	Low - Low capital, low O & M
	On-Site Disposal	Trenches/Pits	Moderate - Effective for isolating contaminants from accessible environment	Easy - Commonly used waste management practice	Low - Standard construction, minimal maintenance
		Vaults	High - Effective for isolation from human contact	Moderate - Based on design to meet regulatory requirements	High - Conservative design safety features
		Tumulus	Limited - Susceptible to degradation	Moderate - Based on design to meet regulatory requirements	Low - Low capital, moderate O & M
		RCRA Landfills	Moderate - Effective in preventing migration of contaminants	Moderate - Well developed technology	Moderate - Specialized designs not required
	Off-Site Disposal	RCRA Landfills	High - Effective for disposal of non-radioactive waste forms	Easy - May use existing facilities	Low - Low capital and maintenance
		DOE Disposal Facilities	Moderate - Opposition from host state governments and local residents	Difficult - Opposition to importing Waste for disposal	High - High maintenance, monitoring, and disposal
		Geologic Repositories	High - Effective for containment and isolation of radioactive wastes	Not Implementable; repository will not be available	Very High - Based on WIPP and Yucca Mountain Experience
In Situ Treatment	Stabilization/ Solidification	Grout Injection	Limited - Flow direction difficult to control; long-term performance uncertain	Easy - Well developed technology for mixing soil and grout	Moderate - Moderate capital and O & M
		Vibration Aided Grout Injection	Moderate - Effective control of grout placement	Moderate - More Difficult in rocky soil	High - More expensive due to installation requirements
		Shallow Soil Mixing	Limited - Effective only for shallow contaminent	Moderate - May require testing to determine penetration depth required	High - Dependent on extent of contamination
		Fixants	Not Effective - Not sufficient for long-term contaminant control	Easy - Common dust control for large areas	Low - Dependent on type of fixants
		Vitrification	High - Effective for contaminant containment	Difficult - Due to maturity of technology	Very High - Energy intensive
		Ground Freezing	Uncertain - Must maintain frozen state in perpetuity	Not Impementable - Insufficient soil moisture	Very High - Especially for operations
		Dynamic Compaction	Limited - Should be effective in short term for porous soils	Easy - Commercially available and well developed	Low - Low capital, low O & M
	In Situ Biological Treatment	Enhanced Soil Bioremediation	Uncertain - Due to depth of contamination	Difficult - Potential for mobilizing contaminants	High - High capital, high O & M
		Biodenitrification	High - Based on test results	Moderate - Both in situ and ex situ tests have proven successful	Moderate - Commercially available and relatively inexpensive
	In Situ Chemical Treatment	Soil Flushing	Limited - Treatability tests required; Effectiveness depends on recovery	Difficult - Flushing solutions must be recovered	Moderate - Flushing solutions require treatment
	In Situ Physical Treatment	Vapor Extraction	Moderate - Influenced by thickness of contaminant zone	Easy - Proven successful in past tests	Low - Low capital, low O & M
		Steam Stripping	High - Effective for VOCs and semivolatles	Moderate - Commercially available. Other treatment required	High - Secondary treatment required
		Soil Flushing	Limited - Treatability tests required; contaminants may not be easily removed	Difficult - Flushing solutions must be recovered	Moderate - Flushing solutions require treatment
		RF Heating	Limited - Effectiveness affected by soil moisture, and depth of contamination	Easy - Unobtrusive technology	High - Secondary treatment/ collection system needed
		Electrical Soil Heating	Limited - Effective for depth of contamination	Difficult - Innovative technology and limited operational experience	High - High capital, high O & M

Figure 4-6
Hanford 100 Area FS: Implementability, Effectiveness, and Cost Screening of Process Options for Soil and Riverba ediments (*continued*)

Soils/Sediments General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
Removal	Removal	Excavation	High - Effective for removal of soils and sediments waste at high capacities	Moderate - Equipment modification may be necessary; Well developed technology	Low - Low capital, low O & M
Treatment	Thermal Treatment	Thermal Desorption	High - Effective for organic contaminant removal and destruction	Moderate - Well developed technology	Moderate - Lower temperature required
		Incineration	High - Effective for destruction of organic contamination	Moderate - Well developed technology	High - High maintenance Off gas treatment needed
		Pyrolysis	High - Effective for destruction of organic contamination	Moderate - Commercially available	High - High maintenance Off gas treatment needed
		Molten Solids Processing	Moderate - Effectiveness not demonstrated to scale	Difficult - Presently being developed and demonstrated	Very High - High energy requirement
	Stabilization/ Solidification	Bitumen-Based	Not Effective - Due to waste volume increase	Moderate - Well developed technology Adaptation to Hanford conditions necessary	Low - Inexpensive binding agent
		Cement-Based	Not Effective - Due to waste volume increase	Easy - Commonly used technology	Moderate - Low capital, moderate O & M
		Polymer-Based	Not Effective - Due to waste volume increase	Moderate - Commercially available, but not generally used for S/S	High - High capital, high maintenance
		Vitrification	High - Effective for stabilization of waste	Difficult - Innovative technology	Very High - Complex system requiring high capital hig O & M
Disposal	Physical Treatment	Vapor Extraction	High - Effective as an ex situ process	Easy - Proven successful in past tests	Low - Pilot testing needed
		Soil Washing	Uncertain - Treatability tests required	Moderate - Innovative technology	Moderate - Secondary treatment required
		Steam Stripping	High - Effective for VOCs; and semi-volatiles	Moderate - Commercially available	High - Requires secondary treatment

Continued

Figure 4-6
Hanford 100 Area FS: Implementability, Effectiveness, and Cost Screening of Process Options for Soil and Riverbank Sediments (*continued*)

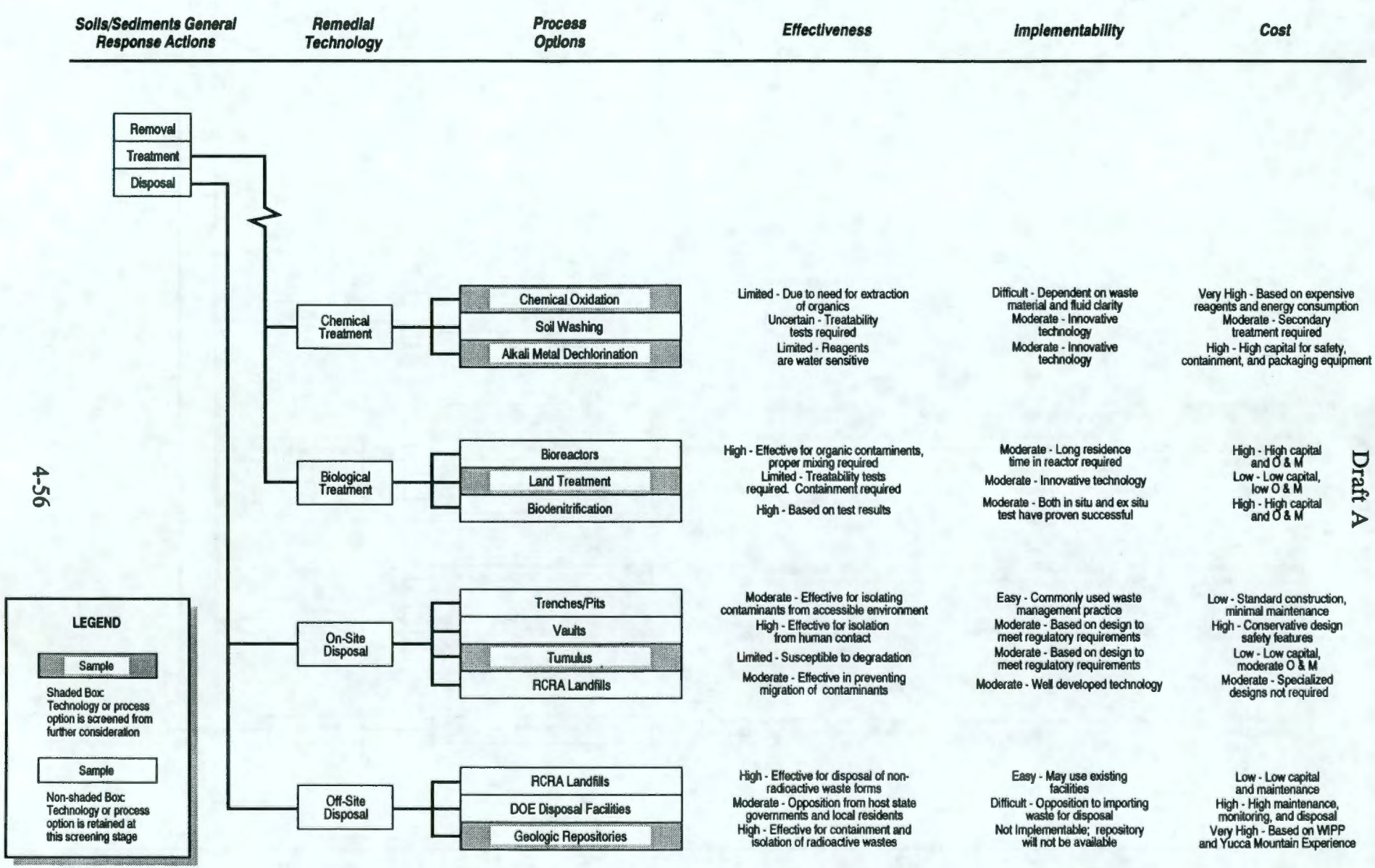

Figure 4-6
Hanford 100 Area FS: Implementability, Effectiveness, and Cost Screening of Process Options for Soil and Riverba ediments (*continued*)

5.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

5.1 INTRODUCTION

Following identification and screening of technologies and process options, remedial alternatives are assembled, developed, and screened, following the guidance provided by CERCLA (EPA 1988a).

This section of the FS is divided into the following topics:

- Development of alternatives (Section 5.2)
- Screening of alternatives (Section 5.3)
- Introduction to alternative screening (Section 5.3.1)
- Solid waste alternatives (Section 5.3.2)
- Groundwater alternatives (Section 5.3.3)
- Soil and riverbank sediment alternatives (Section 5.3.4)
- Summary of the alternatives evaluation (Section 5.3.5).

Section 5.3.5 provides a comparative analysis of the alternatives including the rationale for retention or elimination of specific alternatives.

5.2 DEVELOPMENT OF ALTERNATIVES

Remedial alternatives are developed by combining representative screened technologies and process options to provide integrated solutions for remediation of contaminated waste sites. In Section 4.0 of this report, the universe of potentially applicable technologies was screened twice: initially for technical implementability (refer to Figures 4-1, 4-2, and 4-3) and then for effectiveness, institutional implementability, and cost (refer to Figures 4-4, 4-5, and 4-6). Based on the results of these two screening steps, alternatives have been developed which span the range of GRAs and which combine technologies from different GRAs, if necessary to provide an integrated solution. For example, capping (a containment general response action) is combined with removal and disposal general response actions, so as to provide a complete solution for placing removed waste in a configuration which is most protective of human health and the environment.

The alternatives development process for this FS is shown graphically in Figure 5-1 for the solid waste media, in Figure 5-2 for groundwater, and in Figure 5-3 for soils/ riverbank sediments. A total of 27 alternatives have been assembled; however, only 18 of these are unique as some of the alternatives apply to both solid waste and soil media. Technologies and process options have been combined in such a way that representative groups of technologies can be compared. For example, some alternatives are established which differ only by the type of disposal, e.g. on-site vs. off-site. This is done so that the impacts of the disposal method can be evaluated stand-alone without involving parallel consideration of factors not relating to disposal.

Each of these alternatives is described in sufficient detail such that they can be evaluated in the alternatives screening step. Descriptions are based upon the general process information given for each technology/process option in Appendix C. In addition, each alternative is described in view of known site conditions, contaminant ranges, volumes of contaminated media, remediation times, etc. These descriptions are given in Sections 5.3.2 through 5.3.4 for each media.

CERCLA guidance (EPA 1988a) suggests a maximum of ten alternatives (from no action to removal, treatment, and disposal) be developed for detailed analysis. However, because this is an area-wide FS, encompassing many types of contaminants, media, and waste forms, more alternatives were developed overall to provide greater flexibility in subsequent detailed analysis phases to be performed as part of the focused feasibility studies for IRM or OU final remedy decisions.

Other considerations and assumptions used to develop alternatives are listed as follows:

- No attempt was made to formulate alternatives for groundwater in combination with other media. Such combinations will be considered in future focused feasibility study phases following completion of risk assessments indicating that combinations are required to eliminate source to receptor pathways.

- Soils and riverbank sediments are sufficiently similar to be considered a single media.

- 100-N Area media (groundwater, soils, riverbank sediments, and solid waste) are sufficiently similar to those of the other operable units and, therefore, are not considered separately for alternatives development purposes.

Alternative combinations which consider multiple media might be developed which combine source removal (e.g., contaminated soil) and containment of groundwater. The risk assessment provides specific information on the source to receptor pathway. It is important that multiple media transport of contaminants be defined which in turn suggests how the source/receptor pathway can be manipulated to control or eliminate contaminant migration.

5.3 EVALUATION AND SCREENING OF ALTERNATIVES

In accordance with the CERCLA FS process (EPA 1988a), each alternative is evaluated against established criteria. The criteria are essentially the same as used for technology screening, i.e., implementability, effectiveness, and cost. However, in the alternatives evaluation stage, the criteria are now viewed in more detail, considering more site-specific conditions, and as applied to the integrated remedial solution rather than to just a portion of the solution. The CERCLA evaluation criteria are listed as follows:

Effectiveness:

- Short-term protection of human health

- Assesses protection of the community during remedial action, including risks from dusts, transportation, air-quality impacts, etc. Also, assesses protection of workers during remedial action and the threats which may be posed to workers.

- Short-term protection of the environment
  - Addresses potential adverse environmental impacts resulting from construction and implementation and evaluates the reliability of the available mitigation measures in preventing or reducing the potential impacts

- Long-term protection of human health
  - Assesses the residual human risk remaining from untreated waste or treatment residuals at the conclusion of remedial activities; assesses the adequacy and reliability of controls if any that are used to manage treatment residuals or untreated wastes.

- Long-term protection of the environment
  - Same as long-term human health protection, but with applicability to impacts on the environment

- Reduction of mobility, toxicity, or volume reduction.
  - Assesses the extent to which the alternative achieves destruction or reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media.

Implementability - technical feasibility:

- Constructability
  - Relates to the technical difficulties and unknowns associated with a technology

- Operational reliability
  - Focuses on the likelihood that technical problems associated with implementation will lead to schedule delays

- Maintenance
  - Assesses the degree and difficulty of maintenance of the remedial system during the implementation period; also considers the time-frame for which maintenance is required.

Implementability - administrative feasibility:

- Agency approvals
  - Assesses the likelihood of gaining public and regulatory acceptance of the proposed remedial action including all necessary permits

- Availability of services
  - Assesses the availability of adequate off-site treatment, storage capacity, and disposal services; assesses the potential for obtaining competitive bids, which may be particularly important for innovative technologies; assesses availability of prospective technologies

- Specialized equipment and personnel
  - Assesses the availability of necessary equipment and specialists and provisions to ensure any necessary additional resources for accomplishing the remedial activities.

Cost - relative cost:

- Assesses the relative magnitude of both capital and operating cost over the period of the remediation.

Detailed descriptions of each of these criteria are given in CERCLA guidance (EPA 1988a, Section 6.0).

5.3.1 Alternative Screening Process

The alternative evaluation step culminated in a formal scoring process to provide a numerical qualification of how each alternative meets the evaluation criteria. The scoring process recognizes that how alternatives rate against a specific criterion is not a pass/fail situation, rather it is a matter of degree. This degree, which considers the balance of pros and cons for each factor, is represented by a simple 1 to 5 scale, whereby "1" (poor) suggests that the criterion is not met at all while "5" (excellent) suggests that the criterion is met very well.

The scoring was performed independently by multiple individuals who made up the FS project team. Multiple scoring was done so as to reduce the influence of personal bias in the final results. The individual scores were then averaged to form an initial composite alternative ranking score. Following this initial scoring step, discussions among project team members were held to resolve discrepancies between individuals. For example, should one team member have scored an alternative as a "5" and another team member scored the same alternative as a "1", a discussion ensued to resolve the difference of opinion. Following these discussions, each individual was given the opportunity to change his/her score(s), although changing of a score was not mandatory. The scores were then composited and averaged to arrive at final rankings which could then be compared.

To aid in defending the alternative evaluation scoring, each team member was asked to document the rationale for his/her scoring, providing both the pros and cons of each alternative and any additional comments as relating to the criteria. These comments were then composited and formed the basis for the evaluation of each alternative, the results of which are summarized for each alternative in the sections below immediately following the description for that alternative.

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Section 5.3.5 provides an overall summary of the alternatives evaluation and screening process.

5.3.2 Solid Waste Alternatives

5.3.2.1 Alternative SW-1: No Action for Solid Waste

5.3.2.1.1 Description. As explained in Section 4.0, the no action alternative is required by the NCP to serve as a baseline for evaluation of other alternatives. The no action alternative can also be applied to sites where contamination does not exceed the level of unacceptable risk and/or is in compliance with ARARs. This alternative represents a situation where no restrictions, controls, or active remedial measures are applied to the site and thus the contamination is allowed to dissipate through natural attenuation processes. The acceptability of this alternative would depend on a risk assessment.

5.3.2.1.2 Evaluation. This alternative involves no monitoring and no controls. In effect, the Hanford 100 Area would be administratively transferred for general or industrial use. This alternative must be evaluated from the risk assessment standpoint prior to incorporation.

Short-term effects are scored considering potential exposures to the populace and worker exposure. Since there would be no worker exposure, and the solid waste sites represent only a moderate exposure problem in the undisturbed state, short-term effects are given an intermediate score. Risk assessment results would make scoring much more meaningful. In the absence of risk assessment, it must be assumed that the long-term effects are very poor and the constituents are released into the environment. This alternative provides no benefits to reducing waste mobility.

The obvious factors related to construction and reliability are all given high scores, reflecting the availability and reliability of the equipment required for no action. Similarly, the alternative was given a high score for cost because there is essentially no cost associated with this alternative.

This alternative was given low scores for agency approval because the RAOs would not likely be met.

5.3.2.2 Alternative SW-2: Institutional Actions for Solid Waste

5.3.2.2.1 Description. This alternative involves access restriction to areas within the Hanford 100 Area which contain contaminated solid waste. Volume, toxicity, and mobility of contaminants associated with solid wastes are not reduced by institutional actions. However, access restriction to solid waste sites such as burial grounds or retention basis does reduce the potential for human exposure. Two types of institutional actions are considered for this alternative as follows:

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- Access restriction to solid waste sites may be accomplished by erecting fences around the Hanford 100 Area. Multiple fences could be placed around individual sites for additional security. Fences ensure that sufficient distance exists between waste sites and potential receptors to ensure that RAOs are satisfied. The height of the fences must be high enough to prevent larger animals such as deer from entering contaminated zones. Fences should be constructed of materials which are least susceptible to corrosion and degradation due to weathering. As an additional measure of protection, fences should include symbolic placarding which indicates potential hazards associated with the location. Periodic inspection and repair would be required to maintain the integrity of fences.

- Deed restrictions would be used to institute restrictions to land use in and around solid waste sites. Restrictions specify acceptable land use practices and may take the form of covenants which limit activities involving human contact with solid waste sites. Deed restrictions may include prohibition of groundwater use, excavation, and land-use limitations restricting farming and grazing.

In addition to the institutional restrictions, this alternative also includes continuation of monitoring and surveillance programs to track the migration of contamination.

5.3.2.2.2 Evaluation. This alternative involves the use of institutional controls over solid waste in perpetuity. The associated monitoring systems are assumed to be necessary for the same time period. Again, assumptions were made concerning the actual health effects of this alternative in the absence of a risk assessment which would assign the effects.

The short-term effects are assumed to be acceptable, based on monitoring, and no worker exposure is associated with retrieval. Therefore, an intermediate score is assigned. Long-term effects are again assumed to be undesirable and are scored low.

Constructability, reliability, availability of services, and special equipment all get high scores because fencing, monitoring and legal instruments are all readily available.

A medium score was assigned for maintenance because of the need for perpetual care. The low cost of the institutional actions results in a high score for cost on this alternative. A low score was given for agency approval because it is unlikely that RAOs can be met with institutional actions.

5.3.2.3 Alternative SW-3: Containment Actions for Solid Waste

5.3.2.3.1 Description. A single alternative has been developed for containment of solid waste.

- Run-On/Run-Off Control:
  - Grading
  - Diversion/Collection

- Revegetation

- Capping:
  - Hanford Barriers (radioactive buried waste sites)
  - RCRA Multi-media Caps (hazardous-only buried waste sites)

- Monitoring: 100 Area groundwater.

Size and Configuration. This containment action is intended to take advantage of low-cost surface modifications to protect the integrity of solid wastes buried below ground surface. The Hanford Barrier would be installed over buried wastes to prevent erosion, breaching by burrowing animals, and contact with precipitation. Other areas of the site would be contoured (by grading) to aid in channeling precipitation away from the wastes, thus ensuring adequate protection from erosion. Diversion and collection would also be used to prevent runoff from ponding over the solid wastes thereby reducing the potential for mobilization of contaminants by leaching. Native species vegetation would be planted over capped areas and adjacent areas of disturbed soil for erosion control.

Containment Objective. The objective of solid waste containment is to minimize mobilization of contaminants by erosion or leaching.

Disposal Method and Distance. Containment implies in situ disposal which avoids the need for disposal facilities. Solid wastes and associated contamination are isolated in situ without waste treatment.

5.3.2.3.2 Evaluation. The Hanford Barrier is considered to be well developed and effective, although it has not yet been employed in a full scale application. Because there are no long-term performance data available, uncertainty remains over the potential for failure from waste subsidence since this alternative makes no provisions to stabilize wastes. The potential for subsidence will necessitate perpetual care of a very large number of sites if the alternative is to remain effective.

RCRA caps are effective and have been applied at many hazardous waste sites nationwide, although numerous cap failures have occurred.

Short-term effects were scored slightly lower than for Alternatives SW-1 and SW-2 due to the need to work directly over the waste while installing the cap. The short-term environmental effects are worse due to disturbances associated with grading for run-on/run-off control. The long-term effects are given low to medium scores because the waste has not been modified or immobilized and the potential for contaminant mobilization effects remains. The alternative is superior to Alternative SW-1 or SW-2 because the Hanford Barrier and/or RCRA cap will inhibit leaching and intrusion.

Constructability was given high scores, reflecting the simplicity of the alternative. Similarly, services and equipment are readily available. This alternative was downgraded on

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maintenance due to the potential problem of subsidence and the associated need for perpetual care.

Medium to high scores were given to cost, reflecting a low capital cost and potentially high costs of perpetual care.

Low scores were assigned to agency approvals because the contaminants would not be immobilized and a multiplicity of sites exists.

5.3.2.4 Alternatives SW-4, SW-5, and SW-6: Removal and Disposal Alternatives for Solid Waste

5.3.2.4.1 Descriptions. Three alternatives have been developed for the removal and disposal general response action for solid waste.

Alternative SW-4:

- Removal: Excavation/demolition
- On-Site Disposal:
  - Vaults (high-activity radioactive and mixed waste)
    (high-activity waste = greater than 100 nCi TRU/gm or 200 mrem/hr; see Section 4.4)
  - Trenches/pits (hazardous-only, low-activity radioactive and mixed waste)
    (low-activity waste = less than 100 nCi TRU/gm or 200 mrem/hr; see Section 4.4)
- Capping:
  - Hanford Barriers (radioactive waste disposal sites)
  - RCRA Multi-media Caps (hazardous-only waste disposal sites)

Alternatives SW-5 and SW-6 are variations of Alternative SW-4 and differ only by the method of disposal.

Alternative SW-5:

- Removal: Excavation/demolition
- Off-Site Disposal:
  - DOE facilities (all radioactive mixed)
  - RCRA landfills (hazardous-only materials).

Alternative SW-6:

- Removal: Excavation/demolition

- On-Site Disposal:
  - Vaults (high activity radioactive and mixed)
  - RCRA Landfills (hazardous and low-activity radioactive wastes)

- Capping:
  - Hanford Barriers (radioactive waste disposal sites)
  - RCRA Multi-media Caps (hazardous-only waste disposal sites)

Size and Configuration. The *100 Area Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991e, Appendix A.4.0) presented an estimate of approximately 46 million loose (expanded after excavation) cubic feet (LCF) of buried waste in the 100 Area past practice sites. The referenced report also provided estimates on the distribution of wastes as follows:

- Forty percent of the buried waste consists of combustible materials such as wood, paper, rubber, and plastic.

- The remaining buried waste consists of 60 percent buried metal and 40 percent buried demolition wastes.

- In addition to buried waste, the study estimated that approximately 46 million LCF of discrete metal (e.g., from existing equipment, pipelines, reactor components)

- Approximately 57 million LCF of demolition wastes (from the demolition of existing structures consisting primarily of concrete rubble) in other than burial grounds.

Table 1-7 and Section 1.0 of this FS report provide more detailed information on solid waste forms and contaminants. A total of approximately 150 million LCF (See Table 5-1 below) would require removal from the combined 100 Area past practice sites.

The excavation and demolition system consists of heavy equipment, such as front-end loaders, excavators, and bulldozers. Approximately 2,500 loose cubic feet per hour (refer to Table 5-3 of the Flow Rate and Composition section below for a derivation of this value) must be excavated/demolished beginning in the year 1999 to complete remediation by the year 2018, the TPA Milestone for completion of site remediation. Conceptual details of this system are given in the *100 Area Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991e).

The disposal systems defined for Alternatives SW-4, SW-5, and SW-6 provide the opportunity to examine and compare the use of both on-site and off-site disposal strategies. Major unit operations and the objectives of their use for each alternative are discussed below:

Table 5-1
Solid Waste Inventory

Component	Volume (in Loose Cubic Feet)
Buried waste:	
Combustible material	18,512,000
Metal	16,661,000
Demolition waste	11,107,000
Total	46,281,000
Discrete metal	46,281,000
Demolition waste	56,962,000
Solid waste, total	149,524,000

Reference: 100 Area Past Practice Site Cleanup and Restoration Conceptual Study (WHC 1991e)

Alternatives SW-4, SW-5, and SW-6 Removal:

The objectives of Alternatives SW-4, SW-5, and SW-6 are common, i.e., removal of solid waste by excavation and demolition followed by disposal.

- Commercially available, large scale mining/construction equipment would be used to excavate solid waste and demolish structures (for ease of handling, packaging and transporting). The solid waste and demolition debris would be sorted by activity level and packaged in bulk containers for transport to the disposal site. Size of waste forms would be reduced only to the extent necessary to fit bulk containers. Large diameter pipe would not be containerized but would be cut, wrapped, and transported on racks. Dust control measures including containment structures, if necessary, would be provided to assure worker and environmental protection during remediation.

Alternative SW-4 Disposal:

- On-site vaults located at the Hanford 200 Area are defined for disposal of high-activity radioactive and mixed wastes. Low-activity radioactive and mixed wastes would be placed in disposal trenches or pits at the 200 Area.

- The Hanford Barrier would be used for final capping of the 200 Area radioactive (and mixed) waste disposal sites. The RCRA multi-media cap would be used to close the 200 Area sites containing only hazardous wastes.

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Alternative SW-5 Disposal:

- Off-site disposal is specified for all wastes. High and low activity radioactive and mixed wastes would be sent to disposal sites at other DOE facilities. Hazardous waste would be shipped to RCRA landfills, in accordance with current practice. A facility located in Arlington, Oregon, is currently used for this purpose, since no active RCRA landfills are currently operating in the State of Washington.

Alternative SW-6 Disposal:

- On-site vaults located at the Hanford 200 Area are specified for disposal of high-activity radioactive and mixed wastes. All other wastes would be shipped to new on-site RCRA permitted landfills for disposal.

- The Hanford Barrier and the RCRA multi-media cap would be used as necessary for capping the 200 Area disposal sites.

Flow Rates and Composition. Solid waste consists of combustibles, metal, and demolition debris contaminated primarily with low to moderate levels of radionuclides. Table 5-2 lists total volumes of solid wastes that would require excavation/demolition. Composition data are provided in Section 1.0. An excavation/demolition rate of approximately 2,500 LCF per hour must be achieved in order to meet the TPA milestones, assuming a 20 year remediation period. This cumulative flow rate consists of the components listed in Table 5-3.

Table 5-2
Solid Waste Volume By Component[a]

Component	Volume (Loose Cubic Feet)
Combustibles	18,512,000
Metal	62,942,000
Demolition waste	68,069,000

[a] Adapted from Table 5-1.

Disposal Distances and Methods. The proposed disposal methods for these alternatives include both on-site and off-site disposal options. Vaults and trenches/pits are proposed for use at the Hanford 200 Area. The Hanford Barrier and RCRA multi-media cap are specified for use, where appropriate, to cap these disposal sites. One RCRA landfill in the State of Oregon is currently being used for disposal of Hanford Site hazardous wastes. The Nevada

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Table 5-3

Solid Waste Removal Rate by Component[a]

Component	Rate[b], Loose Cubic Feet Per Hour
Buried waste:	
Combustible material	309
Metal	277
Demolition waste	185
Total	771
Discrete metal	771
Demolition waste	949
Total	2491

[a] Adapted from 100 Area Past Practice Site Cleanup and Restoration Conceptual Study (WHC 1991e).
[b] Assumes a 20-year remediation period ending 2018 (TPA milestone).

Test Site (NTS), which is approximately 1,000 highway miles away from the Hanford Site, is one potential location for a mixed waste disposal facility.

5.3.2.4.2 Evaluation. Alternatives SW-4, SW-5, and SW-6 all involve excavation of buried wastes, demolition of structures, and removal of the waste. No waste treatment is specified. In general, reduction in the number of disposal sites is advantageous. However, the waste remains untreated so these alternatives are less desirable than alternatives involving waste treatment.

The short-term effects are given medium scores reflecting significant exposures to operations personnel during excavation, demolition, and removal. The long-term effects are definite improvements over Alternative SW-3 due to the greatly improved disposition of buried wastes. Subsidence of the waste is not expected to be a problem for these alternatives.

Although the cap provides some improvement, the waste is not modified in form. Therefore the reduction of mobility factor was scored in the low to medium range.

The Alternative SW-4 system is relatively easy to construct using available equipment; availability of services and specialized equipment factors were generally scored high. Constructability was scored somewhat lower due to the large volumes to be moved and the problems of excavation in a radioactive environment. Reliability was downgraded for the same reasons. However, the alternative requires no long-term maintenance, so it scored in the medium to high range for this factor.

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Alternative SW-4 is better than Alternative SW-3 for agency approval and was given medium scores. However, all waste remains on-site and untreated (potentially not in compliance with the RCRA Land Disposal Restrictions) so public and agency acceptance could be limited.

In Alternative SW-5, the excavation, demolition, and removal phases present similar hazards to workers as the previous alternative. However, transport of large waste volumes off-site would have a substantial impact on safety. Acceptance of an off-site disposal site by the public is an additional concern.

This alternative is the least desirable for short-term effects and is scored substantially below Alternative SW-4. Waste is retrieved and shipped the greatest distance. The alternative also assumes that an identified disposal site would have favorable geology and that the long-term effects would be acceptable at that location. An intermediate score was assigned to reduction in mobility because the waste is merely removed with no change in the waste form.

Constructability, operational reliability, and maintenance were scored similar to Alternative SW-4, with a minor reduction for the transportation factor. The unlikelihood of identifying an off-site disposal facility resulted in low scores for availability of services. Specialized equipment was given a medium score because of the problems of transporting the large volume of material.

Agency approval was scored low because of public resistance expected at potential disposal sites and along the transport routes. The low score for cost reflects the high cost of transport to a remote location.

Alternative SW-6 is essentially the same as Alternative SW-4, modified with RCRA landfills for the low activity waste. Most of the scoring is very similar to Alternative SW-4. Problems associated with the limited lifetime of the RCRA liners cause some scoring differences from Alternative SW-4.

The liner is expected to improve the reduction in mobility factor over that of Alternative SW-4 so some improvement was noted there. The maintenance factor was lower due to the potential for routine maintenance on the liner. The cost factor is lower for this reason and for the increased transportation risk.

5.3.2.5 Alternatives SW-7 and SW-8: In situ Treatment for Solid Waste

5.3.2.5.1 Description. Two alternatives have been developed for the in situ treatment general response action for solid waste.

Alternative SW-7:

- Physical Treatment: Dynamic Compaction

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- Stabilization/Solidification: Vibration Aided Grout Injection

- Capping:
  - Hanford Barriers (radioactive waste disposal sites)
  - RCRA Multi-media Caps (hazardous waste disposal sites)

- Monitoring: 100 Area groundwater.

Alternative SW-8 is a variation of Alternative SW-7, where dynamic compaction is not used:

Alternative SW-8:

- Stabilization/Solidification: Vibration Aided Grout Injection

- Capping:
  - Hanford Barriers (radioactive waste disposal sites)
  - RCRA Multi-media Caps (hazardous waste disposal sites)

- Monitoring: 100 Area groundwater.

Size and Configuration. Refer to Section 5.3.2.4.1 for a discussion of the solid waste volumes and components. Figure 5-4 provides a conceptualization of the operations required for Alternative SW-7.

Alternatives SW-7 and SW-8 Unit Operations.

- The initial operation for Alternative SW-7 involves solid waste site stabilization by dynamically compacting the soils (above buried waste) and the solid wastes. This operation reduces bulk waste volume and reduces permeability relative to the surrounding soil. Dynamic compaction is accomplished by repeated lifting and dropping of a large weight, via a crane, onto the soil above a buried waste site.

- The second operation for Alternative SW-7 (and the initial operation for Alternative SW-8) is vibration aided grout injection. I-beams are driven through the soil around the perimeter of the site. A pipe running the length of the I-beam is used to transport grout to an injection nozzle. Grout is injected while simultaneously extracting and vibrating the I-beam. Grout is thus forced into the solid waste void spaces and cavities, where it solidifies and encapsulates contaminants into a monolithic concrete block.

- The final operation for both Alternative SW-7 and Alternative SW-8 is site closure by installation of either the Hanford Barrier or the RCRA multi-media cap depending upon the type of waste. The Hanford Barrier consists of a series of layers of natural material that act synergistically to seal the site. The initial layer consists of large

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rocks and boulders (rip-rap). Layers of coarse stone, sand, and soil are then added in progression to form a mounded cap. Native vegetation is then planted on the cap to control erosion and to control infiltration of moisture through evapotranspiration. The RCRA cap is similar to the Hanford Barrier in that the design relies on multiple layers to prevent water infiltration.

- Not all solid wastes in the 100 Area are directly amenable to the in situ treatment methods proposed in these alternatives. Pipelines and structures, for example, would not be dynamically compacted, and it is not conceivable that pipelines would be capped in-place with the Hanford Barrier. Some limited demolition of above ground structures and pipeline systems would be required for such structures.

Composition. Treatment is in situ, therefore, flow rates for waste treatment are not applicable. The in situ treatment rate, however, must be specified to complete activities by 2018. The total buried waste inventory which is subject to remediation by Alternatives SW-7 and SW-8, as shown in Table 5-2, is approximately 46 million LCF. The quantity of non-buried waste (e.g., pipelines and structures) amounts to about 104 million LCF; such would require some demolition prior to application of in situ stabilization methods. No assumption is made as to the amount of surrounding media, which would also be stabilized and solidified as part of this action.

Disposal Distances and Methods. The disposal method for both Alternatives SW-7 and SW-8 is in situ. Solid wastes are encapsulated in grout, and the environment is further protected from exposure by either the Hanford Barrier or RCRA multi-media cap. Limited demolition and excavation is required by necessity to prepare some solid wastes for stabilization and solidification. Such waste could be moved to another location at the Hanford Site, or buried at new locations within the 100 Area adjacent to the waste sites. Sites stabilized in accordance with Alternatives SW-7 and SW-8 also offer the added benefit of protection from long-term subsidence. This would ensure the long-term effectiveness of the Hanford Barrier or RCRA cap by preventing ponding of precipitation which could potentially mobilize contaminants by leaching.

5.3.2.5.2 Evaluation. The dynamic compaction step of Alternative SW-7 is intended to reduce the potential for subsidence and the subsequent impact on the Hanford Barrier or RCRA multi-media cap. Grout injection fills voids in the waste, again reducing the possibility of subsidence. Both compaction and grouting are assumed to be imperfect, but would still be an improvement over Alternative SW-3. The disadvantage of the large number of sites which must be treated remains.

Short-term effects are relatively good and scored medium to high because the exposure to workers is limited during operation on the unexcavated solid waste. Short-term protection of the environment is better than Alternative SW-3 primarily because extensive run-on control is not required. Long-term effects were judged to be medium because, although the waste is protected, it has not changed form. The compaction and grouting were judged to reduced mobility and scored higher than Alternative SW-3, which only involved capping.

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The combination of the capping and grout injection was given a medium score for reduction in mobility, a significant improvement over Alternative SW-3 which uses only the barrier.

The constructability scored lower than Alternative SW-3 due to the anticipated problems and specialized nature of the grout injection. Similarly, scores for operational reliability, services, and specialized equipment are reduced from the scores of Alternative SW-3.

Agency acceptability was scored slightly higher than for Alternative SW-3, but the large number of waste sites and the minimal change in waste form keep the score at medium. Although the caps are not expected to require routine maintenance in this application, the expense of the compaction and grouting services are expected to keep costs high, resulting in an overall assessment of a medium score.

Since the value of the compaction step was judged to be limited, most Alternative SW-8 scores were very similar to those of Alternative SW-7. Limited credit was taken for the value of the grout which changed the scores only minor amounts.

5.3.2.6 Alternatives SW-9 and SW-10: Removal, Treatment, and Disposal Alternatives for Solid Waste

5.3.2.6.1 Descriptions. Two alternatives have been developed for this general response action.

Alternative SW-9:

- Removal: Excavation and Demolition

- Thermal Treatment:
  - Thermal desorption (treatment for hazardous organically contaminated wastes only; this unit operation might require a shredder for feed preparation)

- Physical Treatment:
  - Size reduction by compaction (non-organically contaminated combustibles and other compactible materials only)

- Stabilization/Solidification:
  - Cement-based (non-organically contaminated non-compactible materials and thermal desorber residues only)

- On-Site Disposal:
  - Vaults (high-activity radioactive and mixed waste)
  - Trenches/pits (low-activity radioactive and mixed waste)

- Capping:
  - Hanford Barriers (radioactive and mixed waste disposal sites)

Alternative SW-10:

- Removal: Excavation and Demolition

- Thermal Treatment:
  - Incineration (treatment for hazardous organically contaminated materials and combustible wastes. This unit operation requires a shredder for feed preparation)

- Stabilization/Solidification:
  - Bitumen-based (inert materials and ash only - no hazardous organically contaminated materials)

- On-Site Disposal:
  - Vaults (high-activity radioactive and mixed waste)
  - Trenches/pits (low-activity radioactive and mixed waste)

- Capping:
  - Hanford Barriers (radioactive and mixed waste disposal sites)

Size and Configuration. Size and configuration are the same as discussed in Section 5.3.2.4.1 for Alternatives SW-4, SW-5, and SW-6. Alternatives SW-9 and SW-10 require remediation facilities capable of treating approximately 2,500 loose cubic feet per hour (on average) of solid wastes contaminated with radionuclides, heavy metals, and potentially organic contaminants. Process flow diagrams for the remediation processes of Alternatives SW-9 and SW-10 are presented in Figures 5-5 and 5-6. Major unit operations for each alternative are discussed below.

Alternative SW-9 Unit Operations. Figure 5-5 is a conceptual process flow diagram representing the removal, treatment, and disposal unit operations of Alternative SW-9. A description of each unit operation and its function is presented below.

- The excavation/demolition system proposed for removal of solid waste is common to both Alternatives SW-9 and SW-10 and is basically the same as described for Alternatives SW-4, SW-5, and SW-6. Refer to Section 5.3.2.4.1 for the description.

- The initial unit operation for volume reduction of combustible waste and miscellaneous material with large amounts of void volume such as pipe is supercompaction. Packaged waste (from excavation/demolition operations) of a composition amenable to supercompaction would be processed in this step; all other heterogeneous waste mixes would be processed by stabilization/solidification, as described below.

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- Organically contaminated solid wastes would be treated in a two-stage thermal desorber. The initial stage consists of an externally fired chamber in which organic compounds are vaporized. The vapors are then oxidized in a secondary combustion chamber, and off-gases are scrubbed to remove acid gases such as HCl, and vented to the atmosphere. Residues generated from the off-gas treatment process would be prepared for disposal by stabilization and solidification. The thermal desorber would also be designed to accept liquid wastes by injection into the secondary combustion chamber as a contingency should drums of organic liquids such as paints and solvents be encountered.

- Residues from the thermal desorption process and all other solid wastes including off-gas treatment residues would then be stabilized for disposal by solidification in a cement-based matrix. The stabilization and solidification process might be accomplished, for example, in a batch-operated mixer, which discharges a mixture of waste components and grout (consisting of cement and additives as appropriate) into disposal containers.

- The previous unit operations result in compacted and solidified forms of treated waste requiring disposal. On-site vaults located at the Hanford 200 Area would be used for disposal of high-activity radioactive and mixed wastes. Low-activity radioactive and mixed wastes would be placed in trenches or pits which would also be located in the 200 Area.

- The Hanford Barrier would be used as required for closure of disposal sites.

Alternative SW-10 Unit Operations. Figure 5-6 provides a conceptual process flow diagram of the removal, treatment, and disposal unit operations of Alternative SW-10. A description of unit operations and their functions which are unique to this remediation concept are presented below:

- The incineration unit operation of Alternative SW-10 replaces both the supercompaction and thermal desorption unit operations of Alternative SW-9. Combustibles, organically contaminated solids, and drummed liquid wastes would be incinerated in a two-stage rotary kiln. The feed material must be prepared by size reduction in a shredder prior to combustion. The initial stage of the rotary kiln may be operated in either an oxygen rich or oxygen deficient atmosphere. The secondary combustion chamber operates oxygen rich to complete the oxidation of kiln gases and may be equipped with liquid-feed spray nozzles for liquid wastes. Residues generated from the off-gas treatment process would be prepared for disposal by stabilization and solidification. The rotary kiln was selected at this level of definition because it is the most flexible design for heterogenous solid waste forms. Waste characterization may result in design requirements for an incineration system consisting of more than one incineration device that is designed to thermally treat different types of waste forms.

- Incineration residues and all other solid wastes (including off-gas treatment residues) would then be stabilized for disposal by solidification in a bitumen-based matrix. The stabilization and solidification process may be accomplished in a batch-operated mixer that discharges a mixture of waste components and heated bitumen into disposal containers.

- Alternative SW-10 treatment operations result in a bitumen-encapsulated waste form requiring disposal. On-site vaults located at the Hanford 200 Area are specified for disposal of high-activity radioactive and mixed wastes. Low-activity radioactive and mixed wastes would be placed in 200 Area trenches or pits.

- The Hanford Barrier would be used for closure of disposal sites.

Flow Rates and Composition. See the discussion given for Alternatives SW-4, SW-5, and SW-6.

Disposal Distances and Methods. The disposal method for both alternatives is on-site disposal at the Hanford 200 Area. Wastes that must be sent to the Hanford 200 Area result from solidification of solid wastes and thermal treatment residues. The disposal method selected for stabilized and solidified waste forms is dependent on the activity of the waste; vaults are used for high-activity radioactive and mixed waste, and trenches/pits are used for low-activity radioactive and mixed waste. The Hanford Barrier is specified for use, where appropriate, to seal disposal sites.

5.3.2.6.2 Evaluation. Alternative SW-9 is one of the alternatives providing waste form modification. Although this alternative results in a much improved waste form, the scale of required operations is large and costs will be high.

The short-term effects require demolition and retrieval followed by extensive treatment, so these scores are low to medium. However, the short-term effects are still judged to be better than for Alternative SW-5, which called for off-site shipment. Long-term effects and reduction in waste mobility factors are given high scores.

Constructability, reliability, availability of services, and specialized equipment all rated average scores, reflecting the complexity and special nature of the large-scale processing equipment.

Maintenance needs were scored in the average range for this alternative due to the stage of development for process options in this application.

The cost of processing will be very high and is reflected in low scores.

Alternative SW-10 differs from Alternative SW-9 in that combustible and organically contaminated wastes are incinerated, and residues are stabilized in bitumen instead of cement. Incineration leads to a more stable waste form than Alternative SW-9, but the

regulatory approvals are expected to be more difficult. Bitumen is assumed to be a stable waste form.

In general, the scores were very similar to those of Alternative SW-9, except for agency approval. The incinerator was thought to be more difficult to permit than the thermal desorber of Alternative SW-9.

5.3.3 Groundwater Alternatives

5.3.3.1 Alternative GW-1: No Action for Groundwater

5.3.3.1.1 Description. As explained in Section 4.0, the no action alternative is required by the NCP to serve as a baseline for evaluation of other alternatives. The no action alternative can also be applied to sites where contamination does not exceed the level of unacceptable risk and/or is in compliance with ARARs. This alternative represents a situation where no restrictions, controls, or active remedial measures are applied to the site and thus the contamination is allowed to dissipate through natural attenuation processes. The acceptability of this alternative would depend on a risk assessment.

5.3.3.1.2 Evaluation. This alternative involves no monitoring and no controls and is evaluated as a requirement of the NCP for the feasibility study process. As in the case of Alternative SW-1, a risk assessment would make the evaluation of such an alternative more quantitative.

Short-term effects are scored in the low to medium range since there would be no worker exposure, and the groundwater is not readily accessible in the undisturbed state. In the absence of a risk assessment, the long-term effects are assumed to be very poor and the release of contaminants to the environment are presumed to continue. This alternative provides no benefits to reduction of contaminant mobility.

The three factors related to construction and reliability are all given high scores because no equipment of any sort is required. Similarly, the alternative was given a high score for cost because, essentially no costs are associated with this alternative.

This alternative was given low scores for agency approval; the alternative is unlikely to actually meet the RAOs.

5.3.3.2 Alternative GW-2: Institutional Actions for Groundwater

5.3.3.2.1 Description. The institutional action alternative (designated Alternative GW-2) for groundwater involves restricting access to contaminated sites within the Hanford 100 Area, but restrictions are unique to the media. Types of restrictions are defined as follows:

- Water-rights restrictions limit access to contaminated groundwater. The water-rights restrictions could be imposed by deed restrictions, as discussed below, or by

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designated use should the title to the 100 Area remain with the federal government. Water-rights restrictions merely designate to what degree (if at all) 100 Area groundwater could be used for irrigation, drinking water, or for industrial activities. This action may require an additional change in water-rights administrators to make it effective. At this time no water-right is necessary if consumptive use is less than 5000 gpd.

- Deed restrictions are used to institute restrictions to groundwater use. Restrictions specify acceptable groundwater uses and may take the form of covenants that limit activities resulting in human contact. Deed restrictions may include prohibition of groundwater use and limitations to farming, grazing, and industrial activity.

- Water taken from the Columbia River or from wells in unaffected areas would be used to replace groundwater for industrial, domestic, and agricultural purposes.

In addition to restricting groundwater use and access to groundwater, the institutional-action alternative also includes groundwater and environmental monitoring.

5.3.3.2.2 Evaluation. Institutional controls and the use of an alternative water supply provide an improvement over the no action alternative. Continued monitoring is assumed and would probably be required in perpetuity.

The short-term effects are assumed to be acceptable based on the monitoring, and no worker exposure is associated with groundwater retrieval. Therefore, an intermediate to high score is assigned. Long-term effects, such as release of the contaminants to the river, result in low scores. Since no reduction in mobility is achieved with this alternative, a score of "1" was given by all project team members.

Constructability, maintainability, availability of services, and special equipment were all given high scores because the replacement water supplies and legal instruments necessary for this alternative are all readily available. Medium to high scores were assigned for maintenance because of the need for perpetual care. This alternative was given low to medium scores for agency approvals due to the potential for not meeting RAOs. The monitoring and institutional controls, however, are considered an improvement over no action.

A high score was given for cost due to the low costs associated with implementation of the institutional controls.

5.3.3.3 Alternative GW-3: Containment Actions for Groundwater

5.3.3.3.1 Description. A single alternative has been developed for containment of contaminated groundwater.

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Alternative GW-3:

- Vertical barrier: Slurry walls
- Hydraulic control: Extraction wells (also used for injection purposes).
- Monitoring: 100 Area groundwater.

Size and Configuration. The containment response action could be implemented in a number of different ways. Vertical barriers could be built around the perimeters of known plumes or around specific groundwater operable units. Similarly, the extraction/injection well hydraulic control system could be designed only to prevent influx to operable units or to prevent influx to the entire site. Modeling and economics analysis would be required to determine optimum containment characteristics such as slurry wall location and the number and location of extraction/injection wells. It is assumed for the purposes of this feasibility study that the containment alternative is implemented as follows: slurry walls would be built to prevent migration of contaminant plumes to the depth of a confining member, such as basalt or clay; groundwater extraction wells would be placed to intercept clean groundwater upgradient from contaminant plumes. The clean groundwater would be reinjected in a suitable location, preventing contact with contaminated groundwater. Slurry walls would be constructed of the most durable material possible in order to retain long-term effectiveness. A cement-based slurry would form a low-strength concrete barrier when combined with the cobbles and gravel present in 100 Area soils, which would exhibit better long-term performance than a clay-based slurry. The depth of slurry walls would vary; for example, Figure 1-4 (in Section 1.0) indicates that at the 100-B/C Area, depth to the upper aquitard blue-clay layer (part of the Ringold Formation) is approximately 160 feet. The concept of Alternative GW-3 is presented graphically in Figure 5-7.

Containment Objective. The objective of containment is to prevent migration of contaminated groundwater to environmental resources, such as the Columbia River and to uncontaminated aquifers. Thus the intent is to prevent introduction of contaminants to sources of drinking (or irrigation) water. Groundwater would be isolated by extraction of clean groundwater upgradient of contaminated plumes and reinjected elsewhere.

Disposal Distances and Location. Waste disposal is not applicable to Alternative GW-3. Hydraulic control (extraction) wells would remove uncontaminated groundwater from around the perimeter of the contaminant plumes. This water would be utilized in downgradient hydraulic control (injection) wells. While utilization of hydraulic control wells would require management of the extracted water, injection of this water does not constitute disposal of removed contamination.

5.3.3.3.2 Evaluation. Construction of slurry walls to depth and hydraulic controls have been demonstrated, but the depth and overall dimensions of slurry walls required at the Hanford 100 Area are unusual. A large volume of clean groundwater would be required for hydraulic control.

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The moderate score for short-term protection reflects the general inaccessibility of the groundwater. Long-term effects are only slightly lower due to the uncertainty of the actual risks involved when the groundwater reaches the river in dilute state. The low to medium score for reduction of mobility is an indication of the uncertainty of the actual effectiveness of the alternative.

The alternative was also given relatively low scores for constructability and maintainability due to the problems associated with installation and maintenance of the deep slurry walls. The services and specialized personnel factors were scored somewhat higher, indicating a belief that the technology is available. The alternative was given a low score for maintenance because maintenance of the slurry walls and pumping system would be required in perpetuity.

A medium to low score for agency approval reflects a poor probability that regulatory agencies would approve an alternative requiring perpetual care. Similarly, the cost of perpetual care resulted in the assignment of low to medium scores for the cost factor.

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5.3.3.4 Alternative GW-4: In Situ Treatment for Groundwater

5.3.3.4.1 Description. A single alternative has been developed for the general response action of in situ treatment of groundwater.

Alternative GW-4:

- Biological Treatment: Biodenitrification (nitrates)
- Physical Treatment: Air stripping (followed by venting of organics to the atmosphere).
- Monitoring: 100 Area groundwater.

Figure 5-8 conceptualizes the in situ treatment processes of Alternative GW-4.

Size and Configuration. Alternative GW-4 is specified to treat nitrate plumes, isolated areas of organic contamination, and dissolved heavy metals/radionulcides in situ. The *Hanford Ground Water Cleanup and Restoration Conceptual Study* (WHC 1991d) indicates that nitrate plumes of significant size are present at each of the reactor sites (WHC 1991d, Appendix A, Figures A-6 through A-11). Maximum concentration of nitrates ranges from 48,400 μg/L at the B/C Area up to 524,000 μg/L at the H Area (refer to Table 1-17 in Section 1.0 of this report). Also refer to Tables 1-16 and 1-17 for information on heavy metals and radionuclides.

The location of organic contamination in 100 Area groundwater is not as well defined as nitrate. Information presented in Table 1-18 indicates the presence of some halogenated compounds in groundwater at both the H and N Areas. In addition to the halogenated

compounds, the N Area groundwater also contains Arochlor 1016, Arochlor 1221, and benzene in concentrations greater than drinking water standards (Table 1-19).

Alternative GW-4 Unit Operations. The treatment objectives of Alternative GW-4 include in situ remediation of nitrates and VOCs. Process operations required for remediation are described below. Note that air stripping is not effective in stripping Arochlors from groundwater.

- Nitric acid has been used extensively for decontamination of reactor components. In situ biodenitrification would reduce nitrates to elemental nitrogen (which would then be released from groundwater for venting to the atmosphere). The denitrification process takes place according to the following simplified reaction:

$$NO_3^{-1} \xrightarrow{\text{Bacterial Metabolic Process}} N_2\uparrow$$

  Nutrients and bacteria culture must be injected into the nitrate contaminated aquifer. The bacterial life cycle metabolic processes require oxygen which is stripped from nitrate.

- Air stripping followed by venting of VOCs to the atmosphere is proposed for removal of organic contamination. Wells (trenches would also be appropriate) would be constructed in contaminated areas such as at the H and N Areas. Air would be bubbled through the groundwater, and VOCs would be subsequently stripped from the aqueous phase into the gas phase.

Flow Rates and Composition. Contamination is treated in place for Alternative GW-4. Nitrogen resulting from biodenitrification and hydrocarbon contaminants mobilized by air stripping would be vented to the atmosphere. If ARARs prohibit venting to the atmosphere, other process options such as vacuum extraction would be required. Engineering and treatability studies would be required to determine well (or trench) locations and quantity, injection rate of air, and effectiveness in removing VOCs. Similarly, injection rate, type of nutrients, bacteria culture, and location of injection wells must be determined by groundwater modeling and treatability studies for biodenitrification. Development work for in situ chemical precipitation is needed to determine the most appropriate reagents and the means of assuring adequate mixing of the reagent(s) with the groundwater.

Disposal Distances and Methods. In situ processes do not require waste disposal.

5.3.3.4.2 Evaluation. Alternative GW-4 provides nitrate and VOC stripping but does not remediate metals or radionuclides. Although the in situ alternative has some favorable features, the partial treatment makes it an incomplete solution.

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Medium effectiveness scores were given for both long- and short-term effectiveness. Venting of VOCs to the atmosphere was considered a negative factors keeping the short-term effectiveness scores from being higher. Similarly, long-term effectiveness and reduction of mobility factors were only given medium scores because of the limited applicability of the alternative.

Constructability, reliability, and specialized equipment were also given medium scores because of the uncertainty of biological treatment effectiveness for such contaminants as chlorinated organics and because of the large number of relatively deep stripper wells potentially required.

Permitting agencies were judged to favor the in situ alternative (as applied to nitrates and organics) and the scoring was in the medium to high range. The cost was judged to be high due to the number and depth of stripper wells.

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5.3.3.5 Alternatives GW-5 and GW-6: Removal, Treatment, and Disposal Alternatives for Groundwater

5.3.3.5.1 Descriptions. Two alternatives have been developed for this general response action.

Alternative GW-5:

- Removal: Extraction wells

- Biological Treatment:
  - Biodenitrification (nitrates)

- Chemical Treatment:
  - Chemical oxidation (organics)
  - Precipitation (heavy metals and radionuclides)
  - Chemical reduction (hexavalent chromium)

- Physical Treatment:
  - Media filtration (remove precipitates)
  - Ion exchange (polishing and any remaining inorganic contaminants)

- Stabilization/Solidification:
  - Cement-based solidification of secondary waste streams

- Disposal:
  - Reinjection into the aquifer (Disposal for S/S residues: Vaults—high-activity radioactive and mixed waste; trenches/pits — low-activity radioactive and mixed waste; trenches/pits to be capped with the Hanford Barrier

- Monitoring: 100 Area groundwater.

Alternative GW-6:

- Removal: Extraction wells

- Biological Treatment:
  - Biodenitrification (nitrates)

- Physical Treatment:
  - Air stripping/carbon adsorption (organics)
  - Forced evaporation (for volume reduction)
  - Media filtration (remove concentrated solids)
  - Reverse osmosis (polishing and any remaining inorganic contaminants)

- Stabilization/Solidification:
  - Cement-based solidification of secondary waste streams

- Disposal:
  - Crib disposal (Disposal for S/S residues: Vaults—high-activity radioactive and mixed waste; trenches/pits — low-activity radioactive and mixed waste; capped with Hanford Barrier).

- Monitoring: 100 Area groundwater.

Size and Configuration. The volume of contaminated groundwater potentially requiring treatment has been estimated as 4.8 billion gallons (refer to Appendix D). The extraction system design (for Hanford 100 Area contaminated groundwater plumes) presented in the *Hanford Ground Water Cleanup and Conceptual Study* (WHC 1991d) proposes a line of 255 extraction wells (Table C-1 of the report), located approximately 300 feet from the Columbia River. A 50-gpm pump was specified for each well. Modeling of the groundwater hydrology in this study resulted in a requirement for a cumulative extraction rate of 5,760 gpm (see Table 5-4 for derivation), in order to intercept contaminated plumes before contact with the Columbia River.

Alternatives GW-5 and GW-6 would require remediation facilities designed to treat 5760 gpm of groundwater contaminated with nitrates, hexavalent chromium, radionuclides, and potentially, other contaminants such as organics and heavy metals. Primary components of the unit operations required for both alternatives are presented schematically in Figures 5-9 and 5-10.

Alternative GW-5 Unit Operations. Figure 5-9 is a conceptual flow diagram of the unit operations proposed for Alternative GW-5. Each unit operation and its function is described below:

- The extraction system consists of 255 extraction wells equipped with 50-gpm pumps throttled to achieve a cumulative extraction rate of 5760 gpm.

- Groundwater is pumped to a storage tank to allow flow equalization and to allow particles—that may interfere with the efficiency of subsequent unit operations—to settle.

- A chemical oxidation system for organic contamination is the initial unit operation in the treatment system. Groundwater and reagents, such as combinations of hydrogen peroxide and ozone, are pumped into a process vessel where organic contaminants are oxidized (the reaction is enhanced by ultra violet light). Simplified reaction (for a hydrocarbon) of this process is:

$$C_xH_y + H_2O_2/O_3 \xrightarrow{uv} xCO_2\uparrow + \frac{y}{2}H_2O$$

- Following chemical oxidation, a source of carbonate ion (other reagents such as phosphates could also be used), and pH adjustment would be required depending on the chemical species which require treatment). The reagent is added to the process stream in a continuously stirred continuous flow (CSCF) reactor vessel. Addition of carbonate (at slightly elevated pH) or phosphates causes precipitation of reagent-specific radionuclides. An example of a precipitation reaction for strontium-90 as a carbonate salt, occurs as described by the following simplified reaction:

$$^{90}Sr + CO_3 \rightarrow {}^{90}SrCO_3\downarrow$$

- Clarifiers are used to concentrate precipitates by dewatering. Clear-water overflows from the clarifier and a concentrated stream containing suspended solids then flows to a rotary drum filter unit. A material such as diatomaceous earth is added to the waste stream to aid in the filtration process. The rotary drum filter is specified because it requires less hands-on operation than do other filter types (such as plate and frame filter presses).

- The next unit operation is specified for chemical reduction of hexavalent chromium (which is very soluble) to the trivalent oxidation state (which is highly insoluble). An acidic solution of ferrous sulfate is added to the process stream in a CSCF reactor vessel. The hexavalent chromium precipitates as a sulfate salt, according to the following redox reaction:

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$$Cr_2O_7^{2-} + 6Fe^{2+} + 6SO_4^{2-} + 14H^+ \rightarrow 2Cr^{3+}(SO_4^{2-})_3 \downarrow + 6Fe^{3+}$$

- Biodenitrification is proposed for reduction of nitrates to elemental nitrogen which may then be vented to the atmosphere. Clarified effluent from the hexavalent chromium reduction process flows to a biodenitrification reactor vessel where the denitrification occurs according to the following reaction:

$$NO_3^{-1} \xrightarrow{\text{Bacterial Metabolic Process}} N_2 \uparrow$$

- Some radionuclide species such as cesium-137 and technetium-99 are not readily precipitated (either by pH adjustment or by redox). Ion exchange is the final unit operation applied to treat this type of contaminant. Both cation and anion exchange resins are specified to remove primary contaminants and also to polish the water prior to discharge. Ion exchange resins require regeneration by stripping with high-concentration salt, acid, or other reagent solutions. The regeneration loop results in a large amount of secondary waste that must be treated and solidified prior to disposal.

- Residues are generated from filtration and ion-exchange regeneration steps described above. Prior to disposal, all residues would be solidified with cement.

- At this point, two waste streams are ready for disposal. The treated groundwater still contains tritium and would be reinjected into a 200 Area aquifer to allow sufficient travel time for natural attenuation of the tritium before it reaches the river. Solidified waste residues would also be sent to the 200 Area for disposal. Vaults would be used for high-level radioactive and mixed waste, and trenches or pits are specified for low-level radioactive and mixed waste. The Hanford Barrier would be used to cap all trenches/pits used for waste disposal.

Alternative GW-6 Unit Operations. Alternative GW-6 unit operations are all physical treatment options with the exception of biodenitrification. Figure 5-10 provides a conceptual flow diagram of the unit operations proposed for Alternative GW-6. This alternative differs from Alternative GW-5 in that physical treatment unit operations are not as contaminant specific as chemical treatment unit operations. Unit operations not described previously and their function in the remediation strategy are described below.

- Air stripping followed by carbon adsorption unit operations is proposed for remediation of VOCs. Groundwater and air are fed counter-current to each other in a packed bed (or tray) stripping column. Organic constituents are stripped from the aqueous phase into the gas phase which is then treated with organic carbon to prevent

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VOC emissions to the atmosphere. Organics other than VOCs are not treated by this alternative.

- The initial unit operation is forced evaporation to reduce the volume of water requiring treatment in subsequent unit operations. Enough water may be evaporated in commercial power plant evaporator-dryers to achieve 30 to 50 percent total solids. The vapor is then condensed and is pumped to a disposal line.

- A rotary drum filter is used to remove concentrates from the evaporation-dryer bottom waste stream. The concentrate would be solidified prior to disposal.

- Reverse osmosis would then be used on the filtered liquid effluent for removal of remaining soluble inorganic contaminants, especially those of higher molecular weight.

- Biodenitrification is specified for remediation of nitrates.

- Ion exchange is the final unit operation required, and both cation and anion exchange resins are specified to polish the water prior to discharge. Note that resin regeneration would result in a large amount of secondary waste, requiring solidification prior to disposal.

- Cement-based solidification is proposed for residues from incineration (if required), media filtration, reverse osmosis, and ion exchange.

- Two waste streams are ready for disposal. Treated groundwater still contains tritium and would be released to the soil via a crib in the Hanford 200 Area to provide sufficient travel time to the river to allow natural attenuation of the tritium. Solidified waste residues would also be sent to the 200 Area for disposal. Vaults would be used for high-activity radioactive and mixed waste and trenches or pits are specified for low-activity radioactive and mixed waste. The Hanford Barrier would be used to close all trenches/pits used for waste disposal.

Flow Rates and Composition. Tables 1-17 through 1-19 in Section 1.0 of this report provide the most recent analytical results for contaminants in groundwater. Section 1.3.1.6.2 discusses contaminants which exceed the EPA's maximum contaminant levels.

The *Hanford Ground Water Cleanup and Restoration Conceptual Study* (WHC 1991d), lists the estimated extraction rates and major contaminants by 100 Area plume (refer to Table 2-2 of the referenced report). The extraction flow rates vary according to the hydrology of the particular plume and the extent of contamination; for example, an extraction rate of 800 gpm is required for the 100-DR-1 plume, which is contaminated with strontium-90, tritium, chromium, and nitrates as primary contaminants. The estimated extraction rate for all 100 Area plumes is summarized in Table 5-4 below. Unit operations for Alternatives GW-5 and GW-6 may be specified with parallel trains to avoid cross

contamination, especially for waste streams containing tritium and waste streams which are not radioactive.

Disposal Distances and Methods. The proposed disposal method for both alternatives

Table 5-4

Estimated Groundwater Extraction Rates by 100 Area Plume

Area	Plume Identification	Extraction Rate, GPM
B/C	100BC-1 100BC-2	200 200
K	100K-1 100K-2 100K-3	500 500 1000
N	100N-1	700
D	100D-1 100D-2	800 1000
H	100H-1 100H-2	200 60
F	100F-1 100F-2	300 300
Total		5760

Adapted from Table 2-2 of "Hanford Ground Water Cleanup and Restoration Conceptual Study," (WHC 1991d Draft).

is on-site disposal at the 200 Area. The treated groundwater would be reinjected into the aquifer for Alternative GW-5 and would be disposed into the soil via a crib for Alternative GW-6. Both disposal methods would result in introduction of tritium into the environment, and natural attenuation of this contaminant is considered part of the remediation strategy since no practical treatment technology exists for tritium. Residues resulting from secondary waste stream treatment, such as media filtration (both alternatives), ion exchange (both alternatives), and reverse osmosis (Alternative GW-6), would be solidified and disposed of in the 200 Area. The method selected for waste disposal is dependent on the activity of the waste. Vaults are specified for disposal of high-activity radioactive and mixed waste, and trenches/pits are used for low-activity radioactive and mixed waste. The Hanford Barrier is used to close the trenches or pits.

5.3.3.5.2 Evaluation. Groundwater would be remediated with a complex system involving extraction wells and chemical, biological, and physical treatment followed by solidification of secondary wastes. The solidified wastes would be disposed on-site and treated water would be reinjected into a suitable aquifer.

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Due to the dilute contamination in the groundwater, worker exposure would be low in this treatment, and there would be only limited environmental disturbance. Medium to high short-term protection scores result. The long-term protection and reduction of mobility factors were all scored uniformly high as the contamination is removed and concentrated in disposal facilities. Concern over reinjection of untreated tritium kept the scores from being higher.

The alternative was judged to be relatively easy to construct using known processing systems and was, therefore, scored medium to high. Services were scored similarly, with only the scale of the problem inhibiting high scores. Due to the substantial complexity of the processing system, only medium scores were assigned for reliability and specialized equipment.

The problem of tritiated water reinjection kept the agency approval score only in the medium to high range, even though the treatment system is thorough. The cost factor score is very low, reflecting the high cost of this complex system.

In Alternative GW-6 a different treatment system is proposed to address all but tritium in the groundwater. The alternative was given scores very similar to Alternative GW-5 in all but two factors. Slightly lower scores for agency approval were assigned to reflect concern over the impact of the very large evaporator systems. This same concern kept the availability of services factor somewhat lower than for Alternative GW-5.

5.3.4 Soil and Riverbank Sediment Alternatives

5.3.4.1 Alternative SS-1: No Action

5.3.4.1.1 Description. As explained in Section 4.0, the no action alternative is required by the NCP to serve as a baseline for evaluation of other alternatives. The no action alternative can also be applied to sites where contamination does not exceed the level of unacceptable risk and/or is in compliance with ARARs. This alternative represents a situation where no restrictions, controls, or active remedial measures are applied to the site and thus the contamination is allowed to dissipate through natural attenuation processes. The acceptability of this alternative would depend on a risk assessment.

5.3.4.1.2 Evaluation. This no action alternative for soils and riverbank sediments was scored in a similar fashion to the two previous no action alternatives (Alternative SW-1 for solid waste and Alternative GW-1 for groundwater). A major concern was again raised in relation to the need for a risk assessment to confirm or override the judgements made in the scoring.

Short-term effects are scored considering potential exposures to the populace and worker exposure. Since there would be no worker exposure, and these sites represent only a moderate exposure problem in the undisturbed state, short-term effects are given an intermediate score. It is conservatively assumed that the long-term effectiveness is very poor

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and that the potential for releasing contaminants into the environment is high, although this may not be true for all sites. This alternative provides no benefits to reduction of waste mobility.

The factors related to construction, reliability, availability of services, and specialized equipment are all given high scores, which reflects the lack of requirement for any special equipment. Similarly, the alternative was given a high score for cost because essentially no costs are associated with this alternative.

This alternative was given low scores for agency approval because it is unlikely to actually meet the RAOs.

5.3.4.2 Alternative SS-2: Institutional Actions for Soil and Riverbank Sediment

5.3.4.2.1 Description. This alternative involves restricting access to contaminated areas of soils and riverbank sediments within the Hanford 100 Area. Volume, toxicity, and mobility of contaminants associated with soils and riverbank sediments are not reduced by institutional actions. Access restriction to areas containing contaminated soils and riverbank sediments (for example, cribs, disposal trenches, and drains) reduces the potential for human exposure. The institutional actions include fences, deed restrictions, and monitoring, the same as described for Alternative SW-2, in Section 5.3.2.2, Institutional Actions for Solid Wastes.

5.3.4.2.2 Evaluation. The limited effectiveness of institutional controls, even with perpetual monitoring, generally results in a low composite score. As in the previous alternative, a risk assessment is needed to confirm or refute the opinions indicated by these scores. The scores for this alternative are very similar to those for Alternative SW-2 using institutional controls for solid waste.

The short-term effects are assumed to be acceptable, based on monitoring, and there is no worker exposure associated with retrieval. Therefore, intermediate scores are assigned to these factors. It is conservatively assumed that the long-term effectiveness is very poor and that the potential for releasing contaminants into the environment is high, although this may not be true for all sites.

Constructability, reliability, availability of services, and special equipment all get high scores because fencing, monitoring, and legal instruments are all readily available.

An average score was assigned for maintenance because of the need for perpetual care. Cost of this alternative is low, so the cost score is high. This alternative, similar to Alternative SS-1, was given a low score for agency approval due to the potential for not meeting RAOs.

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5.3.4.3 Alternative SS-3: Containment Actions for Soil and Riverbank Sediment

5.3.4.3.1 Description. A single alternative has been developed for containment of soils and riverbank sediments.

This alternative is similar to Alternative SW-3, which applies to solid wastes.

Alternative SS-3:

- Run-On/Run-Off Control:
  - Grading
  - Diversion/collection
  - Revegetation

- Capping:
  - Hanford Barriers (radioactive waste disposal sites)
  - RCRA Multi-media Caps (hazardous-only waste disposal sites)

- Monitoring: 100 Area groundwater.

Size and Configuration. This containment action is intended to take advantage of low-cost surface modifications to protect the integrity of contaminated soils and riverbank sediments. The Hanford Barrier would be installed over buried wastes to prevent erosion, breaching by burrowing animals and contact with precipitation. Other areas of the site would be contoured (by grading) to aid in channeling precipitation away from the wastes, thus ensuring adequate protection from erosion. Diversion and collection would also be used to prevent runoff from ponding over the solid wastes thereby reducing the potential for mobilization of contaminants by leaching. Native species vegetation would be planted over capped areas and adjacent areas of disturbed soil for erosion control.

Containment Objective. The objective of containment is to prevent mobilization of contaminants that are adsorbed on soil particles as a result of erosion or leaching mechanisms.

Disposal Distance and Methods. Containment implies in situ disposal, which avoids the need for disposal facilities. Contaminated soils and riverbank sediments are isolated in situ without waste treatment and are protected from mobilization with the Hanford Barrier or RCRA Multi-media Cap, as required for the type of waste.

5.3.4.3.2 Evaluation. Run-on/run-off control, when coupled with the installation of Hanford Barriers or RCRA caps, leads to a relatively "low tech" alternative. Without the potential for subsidence (as in the case of solid waste), there should be little to no perpetual care for the Hanford Barrier for this application. It is anticipated that the number of individual sites where Hanford Barriers or RCRA caps would be required is very high. Multiple sites in close proximity may be more efficiently covered by one Hanford Barrier or

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RCRA cap. The large number of sites/caps is a negative factor when considering this containment alternative because individual, separately negotiated permits might be required for each site.

Short-term effects were scored slightly higher than the previous two alternatives because of the limited exposure of the workers to the low hazard problem and the effectiveness of the Hanford Barrier. The short-term environmental effects are worse than the short-term human health effects due to the disturbance associated with grading for run-on/run-off control. The long-term effects are given low to medium scores because the waste has not been modified or immobilized and the potential for contaminant release remains. The alternative scores higher than either Alternatives SS-1 or SS-2 on reduction of mobility, because the Hanford Barrier and RCRA multi-media cap will inhibit leaching and intrusion into contaminated zones.

The constructability factor was given high scores, reflecting the simplicity of the alternative. Similarly, services and equipment are readily available and scored high.

Medium to high scores were given to cost, reflecting moderate capital costs to handle the large number of sites.

Low scores were assigned to agency approvals. The alternative is better than the previous ones, but since the constituents have not been immobilized and due to the multiplicity of sites, it is not rated highly.

5.3.4.4 Alternatives SS-4, SS-5, and SS-6: Removal and Disposal Alternatives for Soil and Riverbank Sediments

5.2.4.4.1 Descriptions. Three alternatives have been developed for the removal and disposal general response action for soils and riverbank sediments. These three are similar to the solid waste Alternatives SW-4, SW-5, and SW-6.

Alternative SS-4:

- Removal: Excavation

- On-Site Disposal:
  - Vaults (high activity radioactive and mixed waste)
  - Trenches/pits (hazardous-only and low activity radioactive and mixed waste)

- Capping:
  - Hanford Barriers (radioactive waste disposal sites)
  - RCRA Multi-media Caps (hazardous-only waste disposal sites)

Alternatives SS-5 and SS-6 are variations of Alternative SS-4 and differ only by the method of disposal.

Alternative SS-5:

- Removal: Excavation

- Off-Site Disposal:
  - DOE facilities (all radioactive and mixed wastes)
  - RCRA landfills (hazardous materials).

Alternative SS-6:

- Removal: Excavation

- On-Site Disposal:
  - Vaults (high activity radioactive and mixed waste)
  - RCRA Landfills (low activity radioactive and mixed waste and hazardous materials).

- Capping:
  - Hanford Barriers (radioactive waste disposal sites)
  - RCRA Multi-media Caps (hazardous-only waste disposal sites).

Size and Configuration. The total volume of contaminated soil in the 100 Area has been estimated at about 456 million loose cubic feet in the *100 Area Past Practice Site Cleanup and Restoration Conceptual Study* (WHC, 1991e). This volume includes one third of the total overburden that must be removed to excavate soil; i.e., this volume of overburden must be treated or disposed of along with the contaminated soil because it would potentially be contaminated during excavation operations. The volume of contaminated riverbank sediments has been estimated at about 30 million LCF (refer to Appendix D).

The soil and riverbank sediments of the 100 Area are contaminated with a variety of toxic compounds including: radionuclides, heavy metals, nitrates, and to a lesser degree, organic compounds. Refer to Tables 1-5, 1-6, 1-7, and 1-8 and the discussion in Section 1.3.1 for detailed information pertaining to contaminants, concentration in soil, and waste generation processes. Major unit operations for Alternatives SS-4, SS-5, and SS-6 are discussed below.

Alternatives SS-4, SS-5, and SS-6 Removal. The objectives of Alternatives SS-4, SS-5, and SS-6 are common: removal of soils and riverbank sediments by excavation followed by disposal.

- Commercially available, large scale mining/construction equipment would be used to excavate soils and riverbank sediments. The excavated soils would be sorted by activity level and packaged in bulk containers for transport to the disposal site. Dust control measures including containment structures, if necessary, would be provided to assure worker and environmental protection during remediation.

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- The system specified would be capable of removing approximately 8,000 LCF/hour of soils and riverbank sediments to meet the 2018 TPA milestone for completion of remediation.

The disposal systems defined for Alternatives SS-4, SS-5, and SS-6 provide the opportunity to examine and compare the use of both on-site and off-site disposal strategies. Major unit operations and the objectives of their use for each alternative are discussed below:

Alternative SS-4 Disposal:

- On-site vaults located at the Hanford 200 Area are specified for disposal of high-activity radioactive and mixed wastes. Hazardous-only and low-activity radioactive and mixed wastes would be placed in disposal trenches/pits at the 200 Area.

- Closure of the trenches/pits would be accomplished with the Hanford Barrier or RCRA multi-media cap, depending upon the type of waste.

Alternative SS-5 Disposal:

- Off-site disposal is specified for high-activity radioactive and mixed wastes, low-activity radioactive and mixed wastes, and hazardous wastes. All radioactive and mixed wastes are would be shipped to disposal areas at other DOE facilities. Hazardous waste would be shipped to an off-site RCRA landfill in accordance with current practice.

Alternative SS-6 Disposal:

- On-site vaults located at the Hanford 200 Area are specified for disposal of high activity radioactive and mixed wastes. All other wastes would be shipped to new on-site RCRA landfills for disposal.

- The Hanford Barrier and RCRA multi-media cap would be used as required for closure of all waste disposal sites.

Flow Rates and Composition. The *100 Area Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991e) developed estimated excavation rates necessary to remediate contaminated soils by year 2018 assuming a 20 year remediation period. Sediment excavation rates were developed using the same assumptions. Contaminated soil and sediment volumes and excavation rates are presented in Table 5-5.

Hanford 100 Area soils and riverbank sediments (exclusive of contaminants) consist of Pasco gravels with small amounts of clay and humus materials. The mixture is very coarse with a small fraction of fines, approximately 20% < 0.125 mm. There is a significant concentration of carbonaceous minerals in Hanford 100 Area soils.

Table 5-5
Contaminated Soil and Sediment Volume for Excavation Purposes

Soil Type[a]	Bank Cubic Feet	Loose Cubic Feet	Excavation Rate (loose ft^3/hr)
Contaminated Soil	249,209,000	284,098,000	4,735
Contaminated Overburden	151,170,000	172,334,000	2,872
Total	400,379,000	456,432,000	7,607
Riverbank Sediments[b]	29,348,000	33,750,000	563

[a]Soils, 100 Area Past Practice Site Cleanup and Restoration Conceptual Study (WHC 1991c).
[b]Refer to Appendix D.

Disposal Distances and Methods. The proposed disposal methods for Alternatives SS-4, SS-5, and SS-6 include both on-site and off-site disposal options. Vaults and trenches or pits are proposed for use at the Hanford 200 Area. The Hanford Barrier and RCRA multi-media cap are specified for use where appropriate to cap disposal sites. One RCRA landfill in the state of Oregon is currently being used for disposal of Hanford Site hazardous wastes. The Nevada Test Site (NTS), which is approximately 1000 highway miles away from the Hanford Site, is one potential location for a DOE mixed waste disposal facility.

5.3.4.4.2 Evaluation. Alternatives SS-4, SS-5, and SS-6 all involve excavation and removal of the soils and riverbank sediments. No waste treatment is specified. In general, reduction in the number of contaminated sites was advantageous. However, the waste remains untreated so the alternatives are less desirable than alternatives involving treatment.

For Alternative SS-4, the short-term effects are given medium scores, reflecting significant exposures to operations personnel during excavation. The long-term effects are definite improvements over those of Alternatives SS-2 and SS-3 due to the improved disposal practices. The long-term effects are not scored high because there is no treatment to remove hazards associated with mobility and toxicity of contaminants.

The waste is not modified in form, but because the cap provides some improvement in mobility, the reduction of mobility factor was scored in the low to medium range.

The Alternative SS-4 system is relatively easy to construct using available equipment, so availability of services and specialized equipment factors were generally scored high. Constructability was scored somewhat lower due to the large volumes to be removed and

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problems associated with excavation in a radioactive environment. Reliability was scored in the medium to high range because of the low activity environment and the relatively simple excavation medium. However, the alternative requires no long-term maintenance, so it scored in the medium to high range on that factor.

Agency approval was given medium scores as it is better than Alternative SS-3, but all waste remains on-site and untreated (potentially not in compliance with the RCRA Land Disposal Restrictions) so public and agency acceptance may be difficult to acquire.

The use of off-site disposal in Alternative SS-5 results in the removal of soils and riverbank sediments from the Hanford Site, but the scoring generally considered the extra transportation to be a negative factor.

Due to the transportation requirements, this alternative is scored in the low range for short-term effects. All soil and riverbank sediments are removed and shipped great distances. The alternative also assumes that an identified disposal site would have acceptable long-term effectiveness. An intermediate score was assigned to reduction in mobility because the waste is not changed in form but merely removed from the Hanford Site.

Constructability, operational reliability, and maintenance were scored similarly to Alternative SS-4, with a minor reduction for the transportation factor. The improbability of identifying an off-site disposal area resulted in low scores for availability of services. Specialized equipment was given a medium score because of the problems associated with transporting the large volume of material.

Agency approval was also scored low because of the public resistance expected at potential disposal sites and along the transport routes. The low score for cost reflects the cost of retrieval and transport to a remote location.

Alternative SS-6 is similar to Alternative SS-4, except for the use of RCRA landfills at the Hanford Site. The addition of the RCRA permit, the associated landfill liners, and controls had a slight negative effect on the scores for maintenance and availability of services. All other scores are similar to, and explained in, the evaluation for Alternative SS-4.

5.3.4.5 Alternatives SS-7, SS-8, and SS-9: In situ Treatment for Soil and Riverbank Sediments

5.3.4.5.1 Descriptions. Three alternatives are presented for the in situ treatment of soils and riverbank sediments general response action.

Alternative SS-7:

- Biological: Biodenitrification
- Stabilization/Solidification: Vitrification

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- Physical Treatment: Steam stripping
- Monitoring: 100 Area groundwater.

Alternative SS-8 consists of a single treatment operation intended primarily for areas containing significant quantities of radioactive contamination:

Alternative SS-8:

- Stabilization/Solidification: Vitrification.
- Monitoring: 100 Area groundwater.

Alternative SS-9 closely resembles Alternative SS-7; however, vapor extraction is used for remediation of organic contamination instead of steam stripping.

Alternative SS-9:

- Biological: Biodenitrification
- Stabilization/Solidification: Vitrification
- Physical Treatment: Vapor extraction.
- Monitoring: 100 Area groundwater.

Size and Configuration. A discussion of soil/sediment volumes is given in Section 5.3.4.4.1.

Alternatives SS-8, SS-9, SS-10 Unit Operations. Major unit operations required for in situ treatment of soils and riverbank sediments alternatives are discussed below.

- In situ biodenitrification (discussed previously for Alternative GW-4) reduces nitrates to elemental nitrogen. The denitrification process for contaminated soil follows the same reaction as for groundwater:

$$NO_3^{-1} \xrightarrow{\text{Bacterial Metabolic Process}} N_2\uparrow$$

  The process requires injection of nutrients or bacteria culture into contaminated soils and riverbank sediments in order to enhance the denitrification process.

- In situ vitrification is proposed in Alternatives SS-7, SS-8, and SS-9 for stabilization and solidification of areas containing high amounts of radionuclide contamination. The in situ vitrification technique is well-suited for this application due to the homogenous (from a chemical perspective) nature of soils. Electrodes channel current to the soil which is resistively heated to temperatures in excess of the soil's melting point. The soil melts and retains contaminants, such as radionuclides (although lower

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molecular weight radionuclides may be volatile, and secondary treatment in the form of off-gas treatment is necessary) and heavy metals (some like mercury are volatile) within the melt zone. Residues generated from the off-gas treatment process would be prepared for disposal by stabilization and solidification. Backfilling of the site would be necessary due to subsidence during vitrification.

- Alternative SS-7 would remediate soils and riverbank sediments contaminated with volatile and some semivolatile organics by in situ steam stripping. Steam is injected into the soils to volatilize organic contaminants which then percolate upward through the soil and are released to the atmosphere.

- Alternative SS-9 would use vapor extraction for the remediation of volatile organic contamination in soils. A vacuum is drawn on the soil inducing the volatilization of organic compounds which may be adsorbed on the surface of soil particles. Vapor extraction is commonly used in conjunction with carbon adsorption or incineration to treat the off-gas; direct venting to the atmosphere may also meet ARARs, depending on the contaminants and concentrations in the extracted vapor.

Composition. The *100 Area Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991e) developed an approximation of the volume of contaminated soil at the Hanford 100 Area. The volume of riverbank sediments associated with the 100 Area operable units has been approximated for the purposes of this feasibility study. While significant effort has been made to quantify the volume of soil and riverbank sediments potentially contaminated with radionuclides (refer to Table 5-5), there is not sufficient information to quantify the volume of organically contaminated material. However, it is expected that only a small fraction of the volume presented in Table 5-5 is contaminated with organic materials, as Hanford records did not indicate handling or disposal of large quantities of organic materials. As is the case for Alternatives SW-7 and SW-8, waste treatment flow rates are not applicable for in situ treatment.

Disposal Distances and Methods. The proposed disposal method for Alternatives SS-7, SS-8, and SS-9 is in situ with varying degrees of treatment for organic and nitrate contamination. Radioactive waste sites would be stabilized by vitrification to ensure that the potential for mobilization of this type of contamination is reduced.

5.3.4.5.2 Evaluation. Alternative SS-7 proposed the use of three in situ treatment process options in order to provide long-term protection from the contaminants treated. However, the overall effectiveness is limited due to the limited application of the three options.

The short-term effects of steam stripping organics into the environment limits the short-term protection factor evaluations to a medium score. Because the alternatives do not address all contaminants, the long-term protection scores are in the medium to high range. The reduction of mobility score is in this same range.

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The development status of these technologies results in medium scores for constructability, reliability, and maintenance. The same issue resulted in low to medium scores for availability of services and specialized equipment.

Agency approval was given average scores, based on the development status and the possible release of organics to the environment. The cost for this process option is expected to be high and the resulting score is low.

The extensive use of in situ vitrification as part of Alternative SS-8 for areas of radioactive contamination is considered effective at destroying organic contamination while immobilizing most radionuclides and heavy metals.

It scores only in the medium range for short-term protection because of concern over potential problems with off-gas control. It scores in the high range for long-term protection because of its permanence in reducing contaminant mobility.

The developmental stage and complexity of in situ vitrification systems result in low to medium scores for constructability, reliability, service availability, and specialized equipment. It was assigned a medium score for agency approval, largely because of the uncertain development results. Costs are expected to be high.

The use of vapor extraction in Alternative SS-9 to replace steam stripping of Alternative SS-7 has the benefit of capturing the organics instead of releasing them to the environment. Vapor extraction however, cannot remove semivolatiles, such as PCBs.

The effectiveness factors, protection of health and the environment, and reduction of mobility, were all scored higher in Alternative SS-9 than in Alternative SS-7 based on the release of organics. The constructability and reliability factors were scored lower for this alternative because of the extensive collection system required for vapor extraction.

Agency approval was thought to be somewhat more difficult for this alternative, due to the failure to address semivolatiles.

5.3.4.6 Alternatives SS-10 and SS-11: Removal, Treatment, and Disposal Alternatives for Soil and Riverbank Sediments

5.3.4.6.1 Descriptions. Two alternatives have been developed for this general response action.

Alternative SS-10:

- Removal: Excavation

- Thermal Treatment:
  - Thermal desorption (organic contamination)

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- Physical Treatment:
  - Soil washing by attrition scrubbing (radionuclides adsorbed on soil particles)

- Stabilization/Solidification:
  - Vitrification (residues from soil washing and off-gas treatment)

- On-Site Disposal:
  - Vaults (high-activity radioactive and mixed waste)
  - Trenches/pits (low-activity radioactive and mixed waste)

- Capping:
  - Hanford Barriers (radioactive and mixed waste disposal sites).

Alternative SS-11:

- Removal: Excavation

- Thermal Treatment:
  - Thermal desorption (organic contamination)

- Chemical Treatment:
  - Soil washing by chemical leaching (radionuclides adsorbed on soil particles)

- Stabilization/Solidification:
  - Vitrification (soil washing and off-gas treatment residues)

- On-Site Disposal:
  - Vaults (high-activity radioactive and mixed waste)

- Off-Site Disposal:
  - RCRA Landfills (hazardous-only waste)
  - DOE Facilities (low-activity radioactive and mixed waste).

Size and Configuration. A discussion of soil/riverbank sediment volumes is given in Section 5.3.4.4.1. Process flow diagrams of Alternatives SS-10 and SS-11 are presented in Figures 5-11 and 5-12. Major unit operations for each alternative are discussed below.

Alternative SS-10 Unit Operations.

- Organically contaminated soils and riverbank sediments would be treated in a two-stage thermal desorber. The initial stage consists of an externally fired chamber in which organic compounds are vaporized. The vapors are then oxidized in a secondary combustion chamber, and off-gases are treated and vented to the atmosphere. Residues generated from the off-gas treatment process would be prepared for disposal by stabilization and solidification.

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- Physical soil washing consists of a series of treatment operations. Initially, soils are classified by particle size using a power screen (other types of equipment may also be appropriate). The purpose of this initial classification is to separate large particles (such as coarse sand, gravel, and rocks) from the finer-sized material (finer than about 200 mesh (0.075 mm)(DOE-RL 1992)). Because of higher cation exchange capacity, the bulk of radionuclide and heavy metal contamination is preferentially adsorbed on the surfaces of smaller-sized soil particles. Larger soil particles are removed from the waste stream at this stage (provided that it is clean enough to meet remedial goals) and may be used as fill material. Physical soil washing is particularly suited to soils which are predominantly sand and gravel. This is the case for Hanford soils which are predominantly coarse granitic sands and gravels, with less than 10% silts and clays. A high percentage of Hanford 100 Area material is of large particle size, therefore, physical soil washing is considered an effective volume reduction process (WHC 1990).

- Next, the smaller-sized fraction of particles is taken from the power screen to a soil washing unit similar to a ball mill (conceptual). The mill tumbles soil in the presence of a scrubber solution (any of a number of solutions that enhance separation of contaminants from the bulk soil; surfactants are an example). The tumbling action causes particles to abrade the surfaces of other particles, stripping away surface contamination. This process is referred to as attrition scrubbing.

- A centrifuge (other types of equipment may also be appropriate) is then used to separate contaminants, fines (resulting from attrition scrubbing), and scrubber solution from the relatively larger abraded soil particles. The cleaned abraded soil would be used as backfill material.

- Contaminated scrubber solution and fines are pumped to a rotating disk spray dryer for drying. A rotating disk spray dryer is best suited for this application, due to the high maintenance anticipated for other dryers (spray dryers using nozzles would require frequent replacement due to the nature of the feed; rotary dryers, for instance, tend to cake which leads to difficulties in removing the material). Vapor from the dryer is condensed and recycled back to the attrition scrubbing process.

- The final unit operation is stabilization and solidification of dewatered fines in a vitrification unit. Glass frit or glass formers are added to the fines and melted in a joule-heated vitrification unit to form a dense, glassified waste form (other reactors using other sources of heat, such as plasma torches, may also be appropriate).

- Alternative SS-10 operations result in a glassified waste form requiring disposal. On-site vaults located at the Hanford 200 Area are specified for disposal of high-activity radioactive and mixed wastes. The resulting low-activity radioactive and mixed wastes would be placed in pits or trenches, which are also located in the 200 Area.

- The Hanford Barrier would be used for closure of trenches and pits.

Alternative SS-11 Unit Operations. Figure 5-12 is a conceptual process flow diagram representing major unit operations of Alternative SS-11. Each unit operation unique to the Alternative SS-11 remediation process is discussed below.

- A thermal desorber is specified for treatment of organically contaminated soils and riverbank sediments. See discussion under Alternative SS-10.

- Chemical soil washing consists of a series of operations designed to chemically dissolve contaminants adsorbed on the surfaces of soil particles. The following discussion presents a simplified series of unit operations that may be used to chemically remove surface contamination.

- A lixiviant (or mixture of lixiviants) is added to the soil in a stirred tank reactor. Lixiviants are compounds that facilitate dissolution of contaminants, including chelators, by chemically bonding to species such as radionuclides, thus forming soluble complexes. Lixiviation is intended to strip adsorbed contaminants from soils into solution. Lixiviants such as ethylenediaminetetraacetic acid (EDTA), which is a common chelator, may be used for this purpose, but it should be noted that lixiviants are contaminant-specific, and more than one would be required to remove multiple contaminants. Additional stirred tank reactors may be necessary for removal of multiple contaminants. If multiple reactors are required, washing steps would be necessary between reactors.

- Following lixiviant treatment, a clarifier is used to separate soils from the treatment liquid. The liquid is pumped to an evaporator where contaminants are concentrated prior to drying (discussed below), and the soil is sent to another stirred tank reactor.

- Acid solution is added to the soil in the second stirred tank reactor. Most radionuclides and heavy metals would go into solution at low pH. At this stage of the process all remaining contaminants are dissolved, leaving clean soil.

- The second clarifier separates clean (but acidified) soil from the acid solution containing contaminants. The clean soil may be discharged for use as backfill (following neutralization). The liquid solution is first neutralized in a stirred tank reactor and then concentrated in an evaporator.

- A fluidized bed dryer is used to remove water from evaporator concentrates in preparation for stabilization and solidification. The fluidized bed consists of dry concentrates. Effluent from the evaporation is introduced into the fluidized bed dryer where all moisture is removed. The fluidized bed dryer is preferred for this application because of its reliability in a similar application at Idaho Chemical Waste Processing Plant.

- The final unit operation is stabilization and solidification of dry concentrates in a vitrification unit. Glass frit and glass formers are added to the fines and melted in a

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joule-heated vitrification unit to form a dense, glassified waste form (other reactors using other sources of heat, such as plasma torches may also be appropriate).

- Alternative SS-11 operations result in a glassified waste form requiring disposal. On-site vaults located at the Hanford 200 Area are specified for disposal of high-activity radioactive and mixed wastes. Low-activity radioactive and mixed wastes would be sent to other DOE facilities for disposal. Wastes which have been identified as hazardous-only at the excavation phase would be sent off-site for disposal at a RCRA landfill.

Flow Rates and Composition. Refer to the discussion in Section 5.3.4.4.1.

Disposal Distances and Methods. The proposed disposal method for any high-activity radioactive and mixed waste in both alternatives is on-site disposal in vaults at the 200 Area. Wastes result from vitrification of soil washing and off-gas treatment residues. On-site trenches or pits are proposed for low-activity radioactive and mixed waste in Alternative SS-10; an off-site disposal option has been specified for low-activity radioactive and mixed waste (disposal at a DOE facility) and hazardous-only wastes (RCRA landfill) in Alternative SS-11. The Nevada Test Site (NTS) is one potential location for a low level mixed waste disposal facility. NTS is approximately 1,000 highway miles away from the Hanford Site. A facility in the State of Oregon currently accepts Hanford hazardous wastes.

The Hanford Barrier is specified for use where appropriate to close trenches and pits in the 200 Area.

5.3.4.6.2 Evaluation. In Alternative SS-10, excavation and complex treatment for all contaminants, and disposal on-site in vaults, pits, and trenches provides a total solution to the contaminated soils and riverbank sediments problems. It does so at the expense of needs for high amounts of material handling and high cost.

The short-term effectiveness of these alternatives is similar to the solid waste excavation alternatives. Average scores were assigned to account for the risks of handling and processing. The long-term effectiveness is scored high because of the stable waste form in a single disposal facility.

Since the systems are reasonably well developed, but very large systems would be required, only medium scores were assigned to constructability and reliability. Similar scores apply to availability of services and specialized equipment for the same reason.

Average scores were assigned to agency approval to account for the excellent waste form and also for the difficulty in permitting the complex processes. Obviously, the complex system is costly.

Alternative SS-11, like Alternative SS-10, is a complex ex situ processing system for soils and riverbank sediments. This alternative differs from Alternative SS-10 primarily in

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the area related to disposal and in the use of chemical soil washing as opposed to physical soil washing. The on-site disposal of Alternative SS-10 was responsible for its higher score relative to Alternative SS-11 which relies on off-site disposal for the low-activity radioactive and mixed waste. The transportation of large volumes of waste over many miles to off-site disposal facilities raises issues of safety, questionable public acceptance, and potentially very high costs.

5.3.5 Summary of Alternatives Evaluation

The scoring rationale for each alternative (by general response action) is discussed in evaluation sections presented previously. Figures 5-13, 5-14, and 5-15 present average project team scores for each evaluation factor and weighted, normalized scores for effectiveness, implementability, and cost criteria. The sum of weighted, normalized scores represents the composite evaluation score of each alternative. The standard deviation of each composite score is also presented as a relative indication of the uncertainty associated with scoring a particular alternative: a large standard deviation is indicative of varied opinions by the nine member project team concerning how the alternative should be scored. A small standard deviation, on the other hand, reflects a better consensus among the nine project team members.

The guidance document (EPA 1988a) directs that the effectiveness criterion should be weighted more heavily than implementability and cost criteria. For the purposes of this feasibility study, this was accomplished by first normalizing the sum of individual factors for each criterion to 100 (for example, a total of "25" is possible for the five factors (See Figure 5-13) considered for evaluating effectiveness; the effectiveness score is normalized by multiplying the new score by 4), and then by weighting (multiplying by a weighting factor). The project team weighted evaluation criteria are as follows:

	Weight
• Effectiveness	0.6
• Implementability	0.3
• Cost	0.1
Total	1.0

The decision to discard alternatives at this point is made on the basis of retaining a broad range of GRAs for detailed analysis. This is deemed necessary for this particular feasibility study due to an incomplete set of input parameters that are specified in the guidance document for traditional feasibility studies. Alternatives recommended for consideration at the detailed analysis/focused feasibility study levels cover the spectrum of all potential remedial actions from "no action" (which would be applicable only if a risk assessment indicates acceptability of such an approach) to removal, treatment, and disposal actions, which reduce uncertainty and risk but at a high cost.

Based on composite scores, the following alternatives are considered representative of various GRAs for future evaluations that will be made during Hanford 100 Area operable unit focused feasibility studies. Note that "no action" Alternatives SW-1, GW-1, and SS-1 are retained at this point to serve as a baseline (per the NCP) for comparative purposes and for evaluation from the risk assessment standpoint at some future time. The retained alternatives may serve as a baseline from which to evaluate the future impact of site characterization data and risk assessment results. It should also be stressed that alternatives (and technologies) that are not retained may be revisited as new information warrants, in accordance with FS guidance.

While the CERCLA Phase I/II FS process provides a rational basis for developing and screening remedial alternatives, it is very important to note that all this is done in the absence of a baseline risk assessment to comprehensively evaluate the inherent risks posed by the contamination. The baseline risk assessment will be a part of future studies. The Phase I/II process also does not allow much consideration of cost. Thus, the true cost/risk reduction benefit of each alternative has not been evaluated or even considered. This is an essential element in the ultimate decision-making process. While protection of human health and the environment is of utmost importance, the final remedial solutions must be found to be cost effective in view of their benefit to true risk reduction.

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5.3.5.1 Solid Waste

Composite scores for Alternatives SW-1 through SW-10 range from 54.6 (no action) to 65.4 for Alternative SW-9 (a removal, treatment, and disposal alternative). Table 5-6 presents the solid waste alternatives retained for future analysis and the rationale for dropping alternatives from consideration at this time

The alternatives retained represent all GRAs. One representative alternative for each general response action has been retained for future evaluation.

5.3.5.2 Groundwater

Composite scores for groundwater alternatives range from a low of 52.2 for Alternative GW-1 to a high of 71.9 for Alternative GW-6 (a removal, treatment, and disposal action). Table 5-7 presents the groundwater alternatives recommended for future analysis and the rationale for not considering other alternatives further.

The spread in scores indicates that project team members were better able to make assessments concerning groundwater alternatives than had been the case for solid waste. Both removal, treatment, and disposal alternatives are recommended for detailed analysis due to the unique treatment approach taken in each case. An in situ treatment approach is also retained to maintain a range of different levels of remedial action and potentially for use in combination with alternatives for other media.

Table 5-6
Recommendations for Solid Waste Alternatives

Alternative	Description	Score	Recommendation
SW-1	No Action Alternative	54.7	Retain for detailed analysis and risk assessment data.
SW-2	Institutional: Fencing and Deed Restrictions	55.9	Retain to preserve range of GRAs.
SW-5	Removal & Excavation and Demolition Disposal: RCRA Landfills and DOE Disposal Facilities	57.8	Screened based on retaining Alternative SW-4.
SW-3	Containment: Grading, Diversion/Collection, and Revegetation Hanford Barriers and RCRA Multi-media Caps	62.5	Retain as a containment action.
SW-8	In Situ Vibration Aided Grout Injection Treatment: Hanford Barriers and RCRA Multi-media Caps	62.9	Screened based on retaining Alternative SW-7.
SW-7	In Situ Dynamic Compaction Treatment: Vibration Aided Grout Injection Hanford Barriers and RCRA Multi-media Caps	63.4	Retain as an in situ treatment action.
SW-6	Removal & Excavation and Demolition Disposal: Vaults and RCRA Landfills Hanford Barriers and RCRA Multi-media Caps	63.4	Screened based on retaining Alternative SW-4.
SW-10	Removal, Excavation and Demolition Treatment, Incineration (hazardous organics) & Disposal: Bitumen-based Stabilization/Solidification Vaults and Trenches/Pits Hanford Barriers	64.0	Screened based on retaining Alternative SW-9.
SW-4	Removal & Excavation and Demolition Disposal: Vaults and Trenches/Pits Hanford Barriers and RCRA Multi-media Caps	64.8	Retain as a removal and disposal action.
SW-9	Removal, Excavation and Demolition Treatment, Thermal Desorption (hazardous organics) & Disposal: Compaction Cement-based Stabilization/Solidification Vaults and Trenches/Pits Hanford Barriers	65.4	Retain as a removal, treatment, and disposal action.

Table 5-7
Recommendations for Groundwater Alternatives

Alternative	Description	Score	Recommendation
GW-1	No Action Alternative	52.2	Retain for detailed analysis and risk assessment data.
GW-3	Containment: Slurry Walls Extraction Wells	53.9	Retain to preserve range of GRAs.
GW-2	Institutional: Water-rights and Deed Restrictions Groundwater Monitoring Columbia River as Alternate Water Supply	57.2	Retain to preserve range of GRAs.
GW-4	In Situ Biodenitrification Treatment: Air Stripping	61.6	Retain as an in situ treatment action.
GW-5	Removal, Extraction Wells Treatment, Biodenitrification & Disposal: Chemical Oxidation, Precipitation, and Chemical Reduction Media Filtration and Ion Exchange Cement-based Solidification Reinjection into Aquifer, Vaults, and Trenches/Pits	71.6	Retain as a removal, treatment, and disposal action based on chemical treatment processes.
GW-6	Removal, Extraction Wells Treatment, Biodenitrification & Disposal: Air Stripping, Forced Evaporation, Media Filtration, and Reverse Osmosis Cement-based Solidification Crib Disposal, Vaults, and Trenches/Pits	71.9	Retain as a removal, treatment, and disposal action based on physical treatment processes.

Table 5-8
Recommendations for Soils and Riverbank Sediment Alternatives

Alternative	Description	Score	Recommendation
SS-1	No Action Alternative	55.4	Retain for detailed analysis and risk assessment data.
SS-2	Institutional: Fencing and Deed Restrictions	56.5	Retain to preserve range of GRAs.
SS-5	Removal & Disposal: Excavation RCRA Landfills and DOE Disposal Facilities	58.8	Screened based on retaining Alternative SS-4.
SS-6	Removal & Disposal: Excavation Vaults and RCRA Landfills Hanford Barriers and RCRA Multi-media Caps	62.2	Screened based on retaining Alternative SS-4.
SS-11	Removal, Treatment, & Disposal: Excavation Thermal Desorption (hazardous organics) Soil Washing Vitrification Vaults RCRA Landfills and DOE Disposal Facilities	62.4	Screened based on retaining Alternative SS-10.
SS-4	Removal & Disposal: Excavation Vaults and Trenches/Pits Hanford Barriers and RCRA Multi-media Caps	63.2	Retain as a removal and disposal action.
SS-3	Containment: Grading, Diversion/Collection, Revegetation Hanford Barriers and RCRA Multi-media Caps	63.5	Retain as a containment action.
SS-7	In Situ Treatment: Biodenitrification Vitrification Steam Stripping	64.5	Screened based on retaining Alternative SS-8.
SS-9	In Situ Treatment: Biodenitrification Vitrification Vapor Extraction	65.5	Screened based on retaining Alternative SS-8.
SS-8	In Situ Treatment: Vitrification	66.6	Retain as an in situ treatment action.
SS-10	Removal, Treatment, & Disposal: Excavation Thermal Desorption (hazardous organics) Soil Washing Vitrification Vaults and Trenches/Pits Hanford Barriers	67.4	Retain as a removal, treatment, and disposal action.

5.3.5.3 Soils and Riverbank Sediments

Composite scores for soils and riverbank sediments alternatives range from a low of 55.4 for Alternative SS-1 (no action) to a high of 67.4 for Alternative SS-10 (a removal, treatment, and disposal alternative). Table 5-8 presents the soil and riverbank sediments alternatives recommended for future analysis, and a rationale for a recommendation of not considering other alternatives is discussed below.

The alternatives retained include the entire range of possible GRAs that may be taken for Hanford 100 Area soils and riverbank sediments. All alternatives retained represent technologies and process options considered the best choices as a result of screening activities.

5.3.5.4 Potential Future Innovative Technology Applications

In Phase I (Section 4.0) of this FS, a number of innovative technologies were screened out for lack of demonstrated implementability and/or effectiveness. CERCLA FS guidance specifies that innovative remedial approaches be considered where use of such technologies offer cost or performance (effectiveness) advantages over more traditional approaches. However, many of these technologies which were screened out, while promising in theory, have not yet undergone sufficient development to prove their overall viability in site remediation applications. Many of these technologies are currently in some stage of development and most of these are probably some years away before development efforts come to fruition. The purpose of this section is to provide recommendations of specific innovative technologies whose development progress should be monitored. Performance data obtained from the development efforts may be then used in future feasibility studies in an iterative fashion to assess the conclusions arrived at during Phase I of this FS.

The technologies discussed below are specifically identified for monitoring of development progress based in part on technical comments received from reviewers to this document. This list is not necessarily all inclusive and others may be added as additional evaluations are performed.

Electro-kinetic Separation. (See Appendix C, Section 2.10.4) Electro-kinetic separation is an in situ physical treatment method used to enhance separation of adsorbed contaminants on saturated sediments using charged electrodes placed within the contaminated aquifer. Development on a laboratory scale has shown promising results. Significant research work is being conducted at Sandia National Laboratories and elsewhere.

In Situ Chemical Precipitation. (See Appendix C, Section 2.11.1) The application of precipitation reagents in situ may be applied to immobilize contaminants in groundwater and saturated sediments as an alternative to pump and treat technologies. Limited ex situ laboratory and bench studies have been performed. Much development work would

be needed to demonstrate in situ application. The principal difficulties of in situ application are attaining adequate mixing and distribution of chemical reagents.

Lixiviant Extraction. (See Appendix C, Section 2.7.4) Lixiviant extraction involves the introduction of chemical reagents to contaminated saturated sediments for removal of adsorbed contaminants so as to enhance the effectiveness of pump and treat systems. Lixiviants have been developed for solution mining of uranium. Lixiviants for site remediation applications require all phases of development and demonstration.

In Situ Vitrification/Grouting of Compacted Waste Forms. (See Appendix C, Section 1.10.3 and Section 1.10.1) These technologies are potentially applicable for use in stabilizing compacted waste for subsidence control in 200 Area burial trenches, an important aspect for the Hanford Barrier application. Development work and field demonstrations are needed to prove viability and generate performance data.

Supported Liquid Membranes. (See Appendix C, Section 2.13.15) Supported liquid membrane filtration is a process option similar in many respects to reverse osmosis and ultrafiltration. The key difference involves the use of carrier molecules in the supported liquid membrane for transport of contaminants out of groundwater into a concentrated liquor. The process has potential cost advantages relative to reverse osmosis. Some laboratory and bench scale testing has been done on Hanford groundwater for uranium, technetium, and chromium removal. Pilot scale demonstration is scheduled for FY 1994.

Biological Barriers. (See Appendix C, Section 1.5.5) Biological barriers are created by the accumulation of biomass to provide a barrier against migration of contamination. Maintaining stable barriers has not been demonstrated. The biological barrier is in the conceptual stage with much development work needed to prove its viability.

Biosorption. (See Appendix C, Section 2.12.3). The biosorption process is similar to ion exchange. Resins containing treated algae have been tested for removal of uranium. Additional testing may identify resins which are capable of removing additional contaminants.

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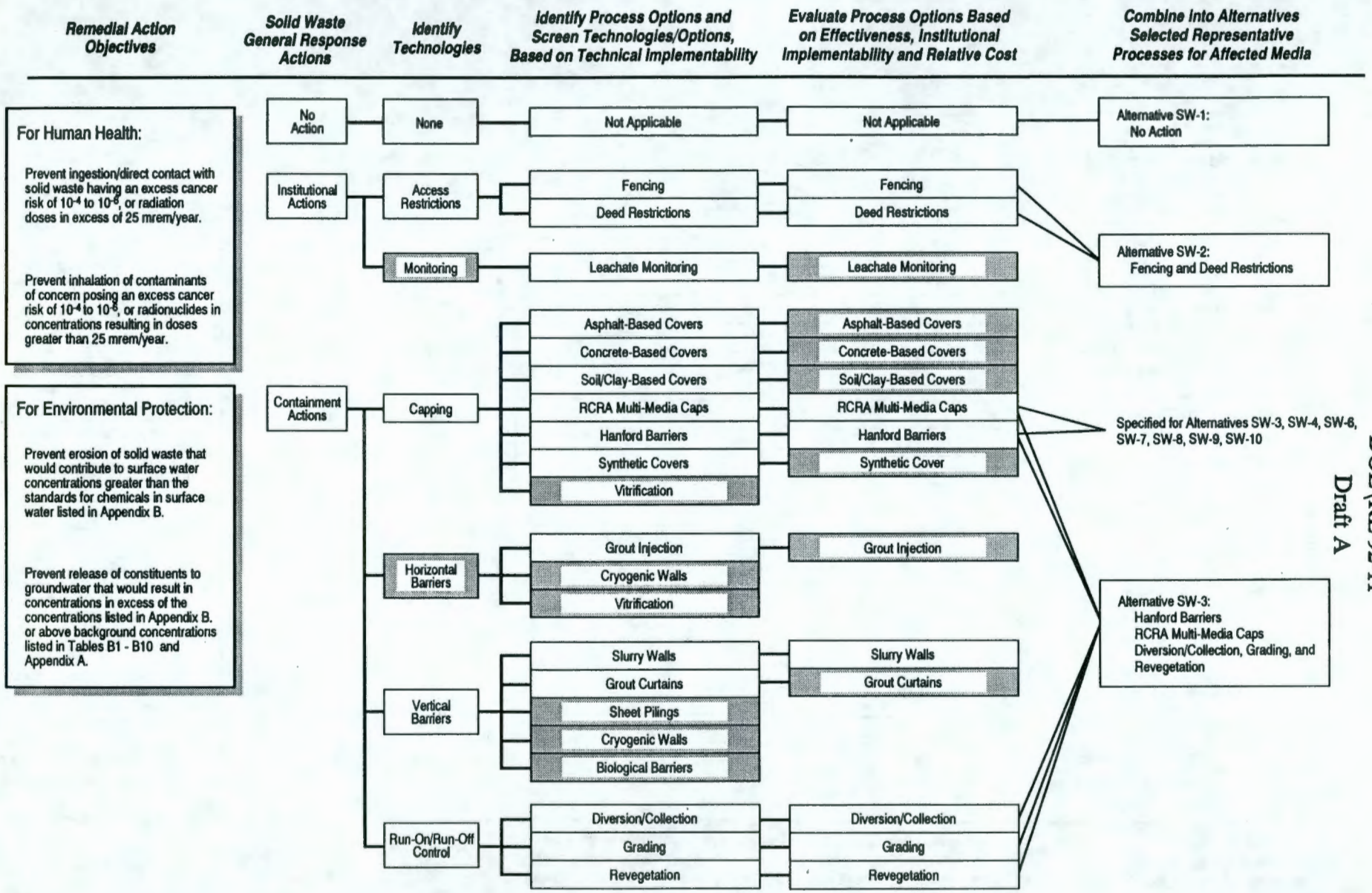

Figure 5-1
Hanford 100 Area FS: Development of Alternatives for Solid Waste

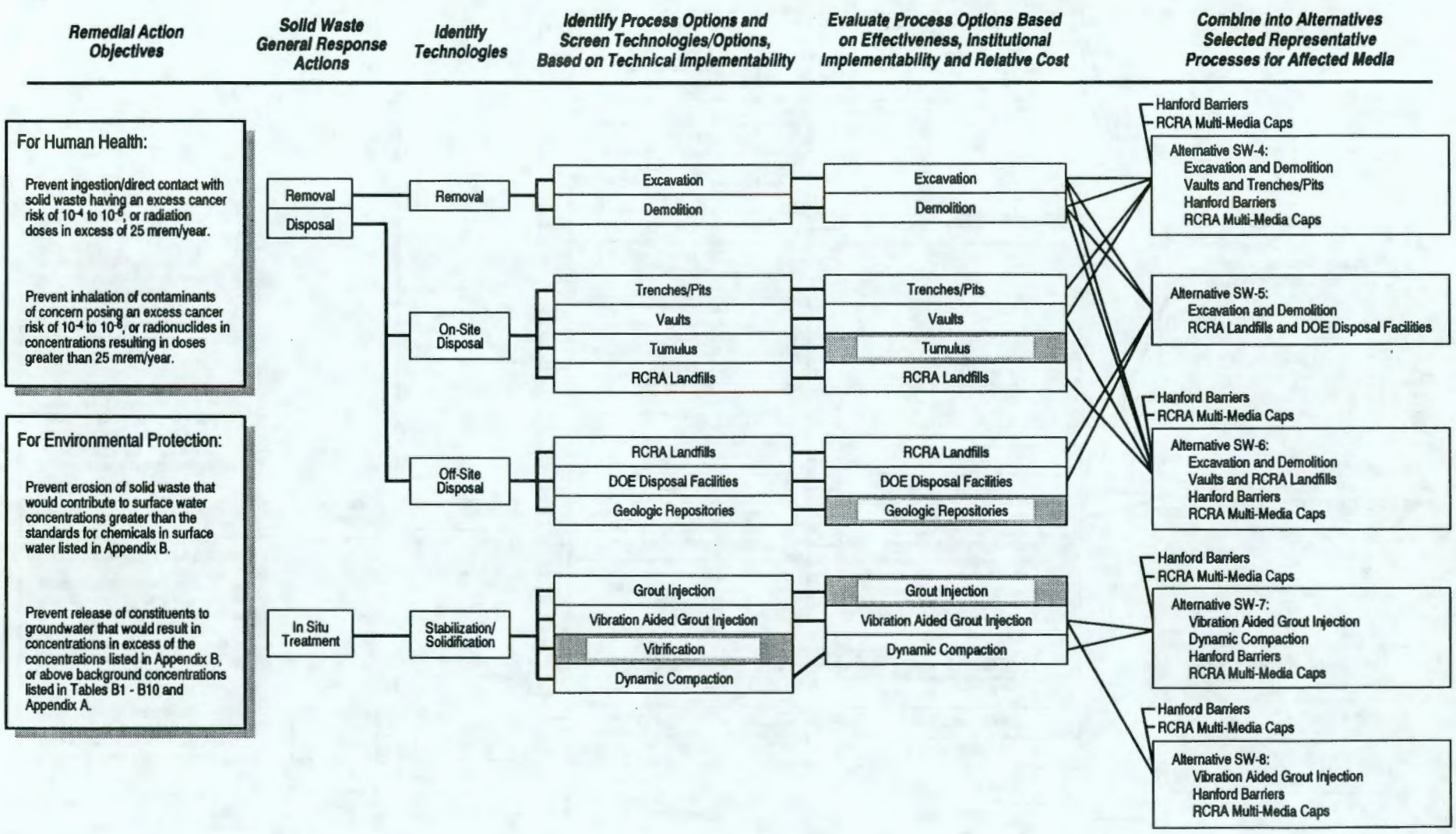

Figure 5-1
Hanford 100 Area FS: Development of rnatives for Solid Waste *(continued)*

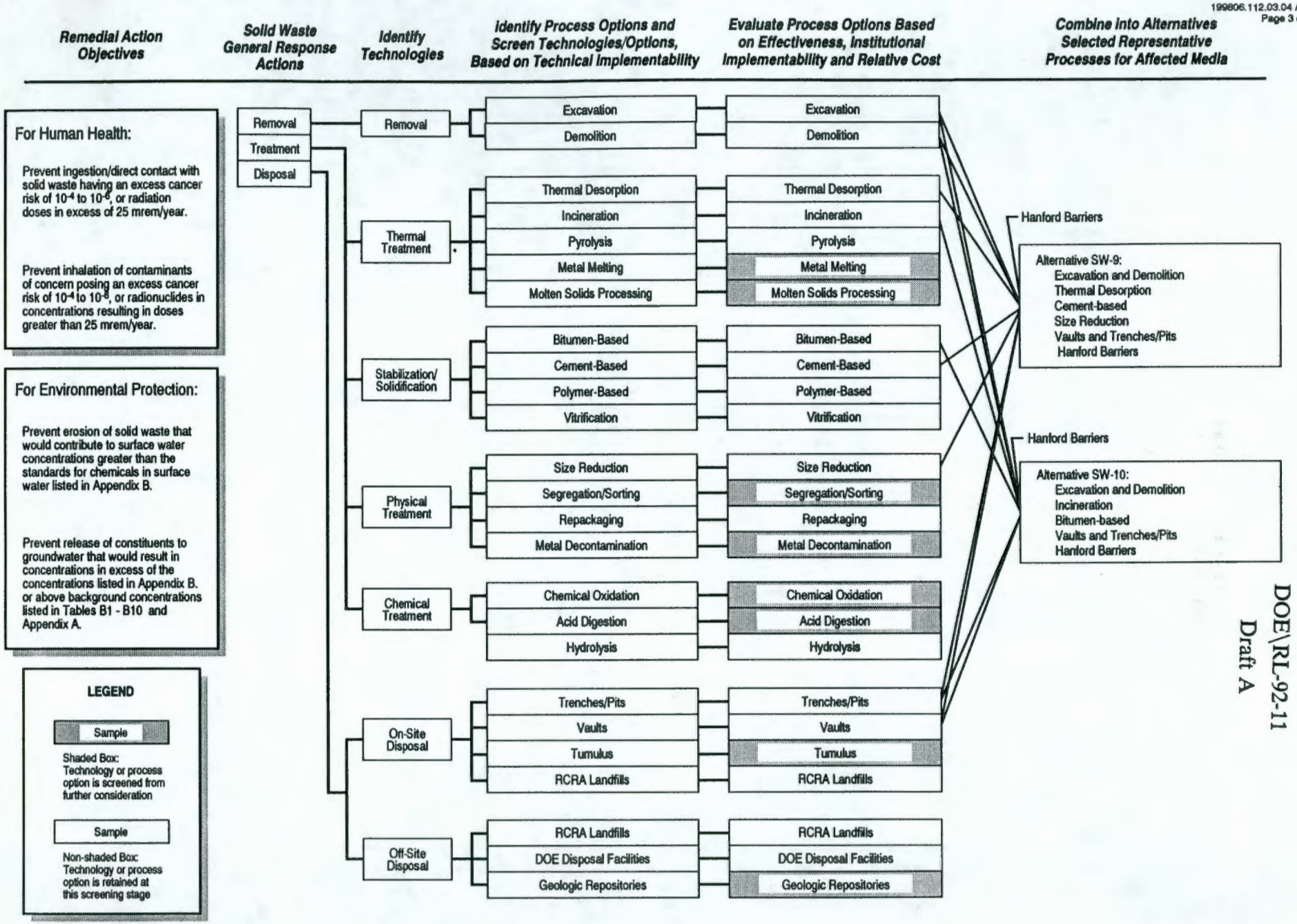

Figure 5-1
Hanford 100 Area FS: Development of Alternatives for Solid Waste *(continued)*

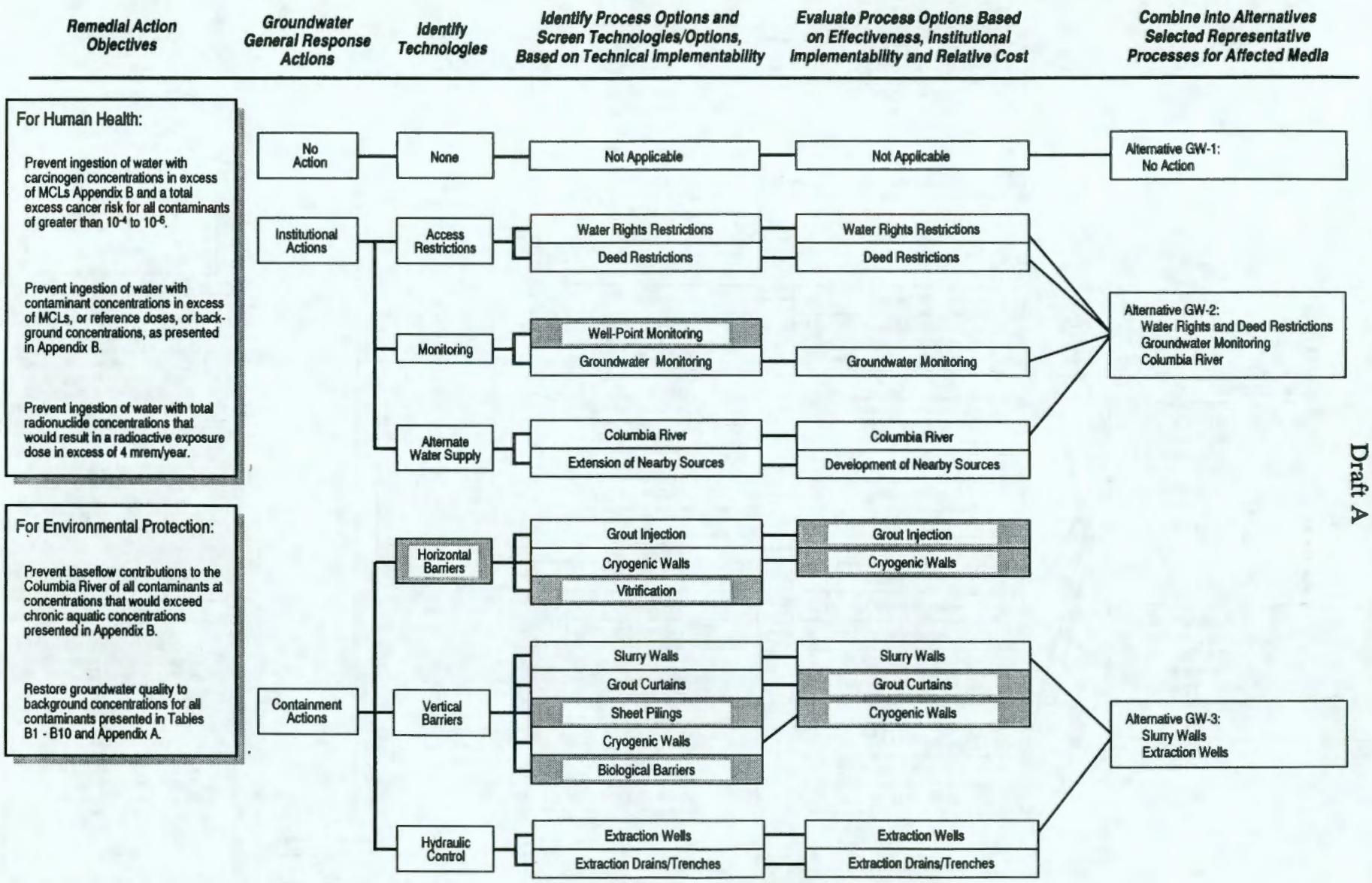

Figure 5-2
Hanford 100 Area FS: Develop[illegible]t of Alternatives for Groundwater

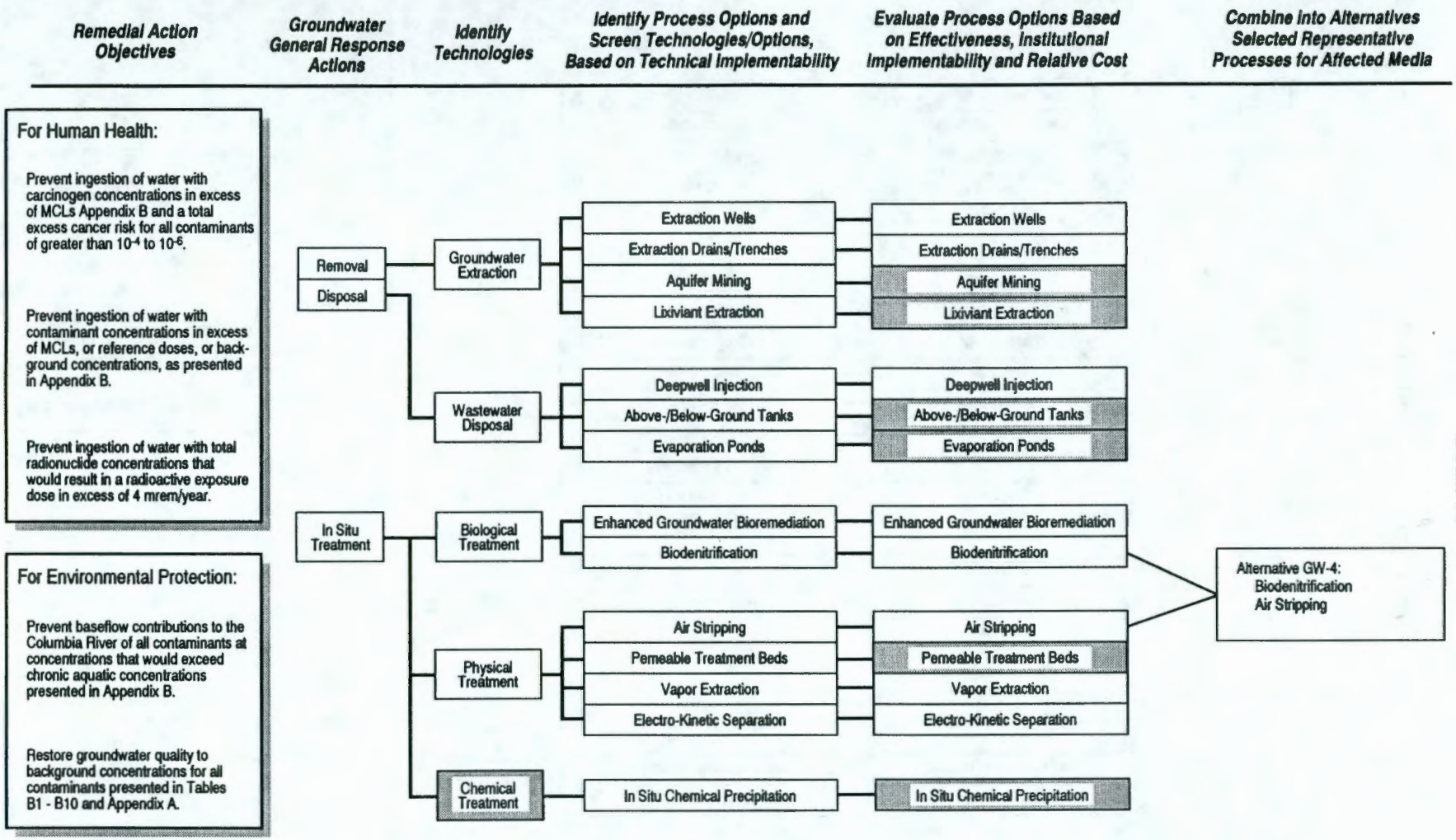

Figure 5-2
Hanford 100 Area FS: Development of Alternatives for Groundwater *(continued)*

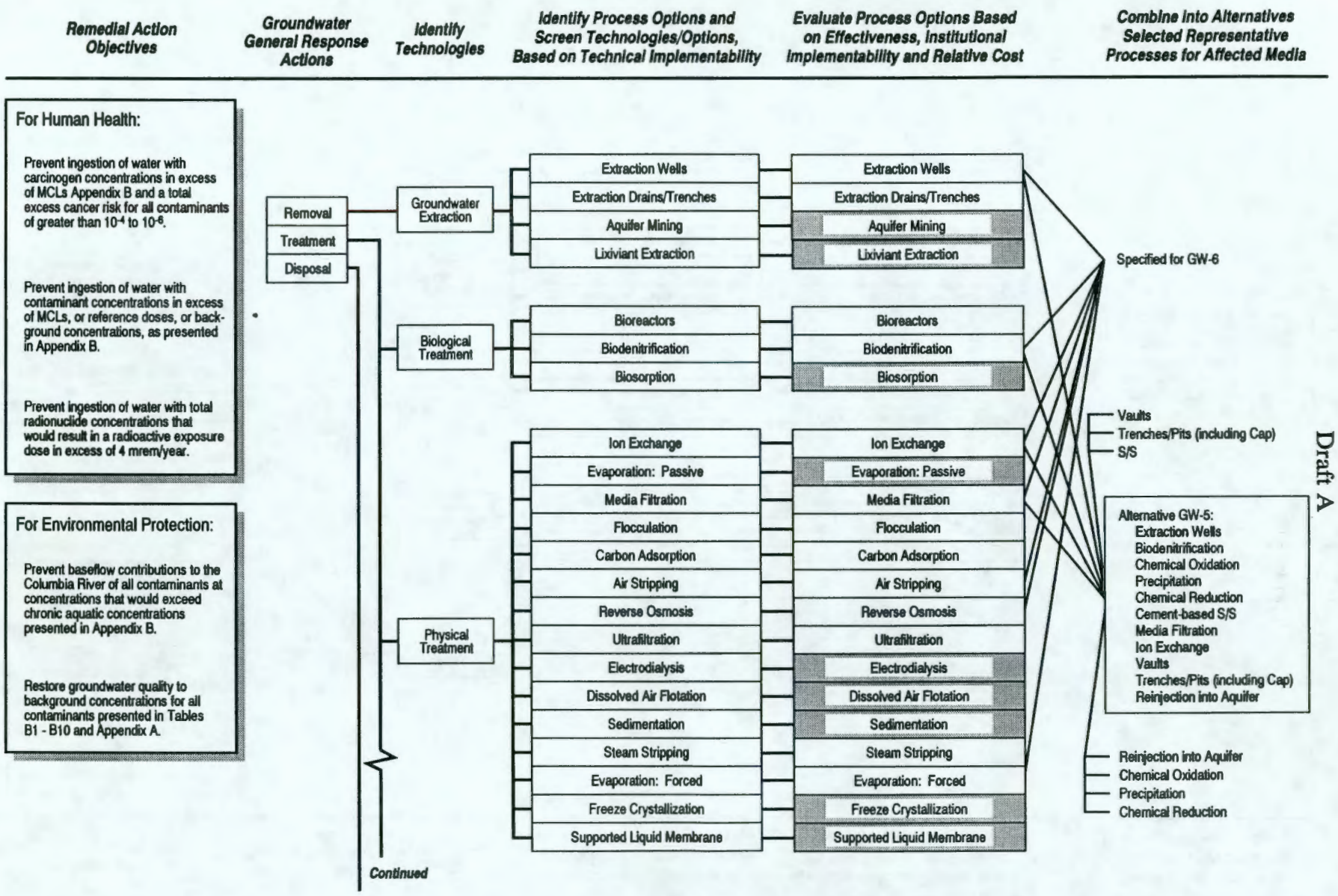

Figure 5-2
Hanford 100 Area FS: Developmen Alternatives for Groundwater *(continued)*

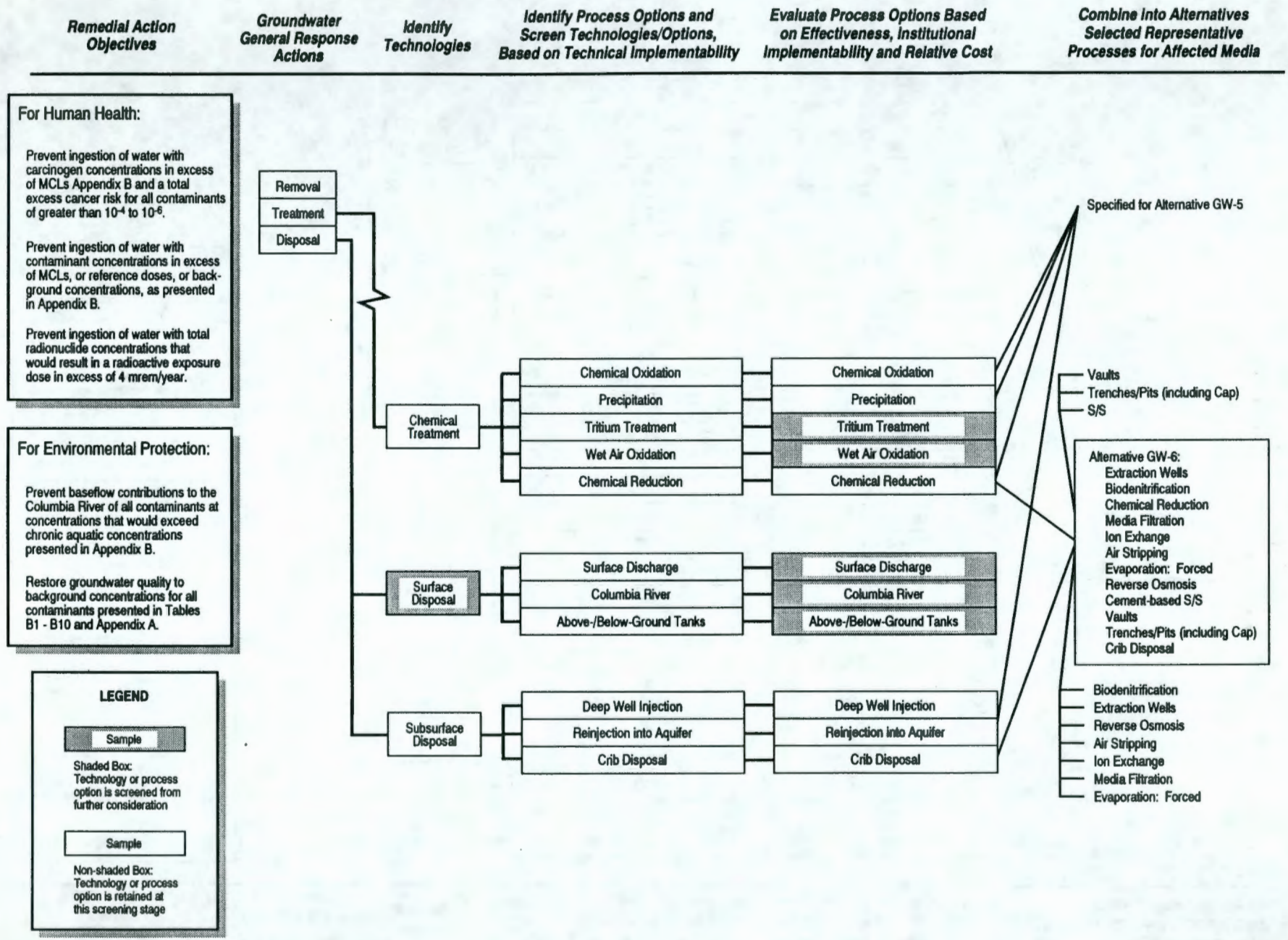

Figure 5-2
Hanford 100 Area FS: Development of Alternatives for Groundwater *(continued)*

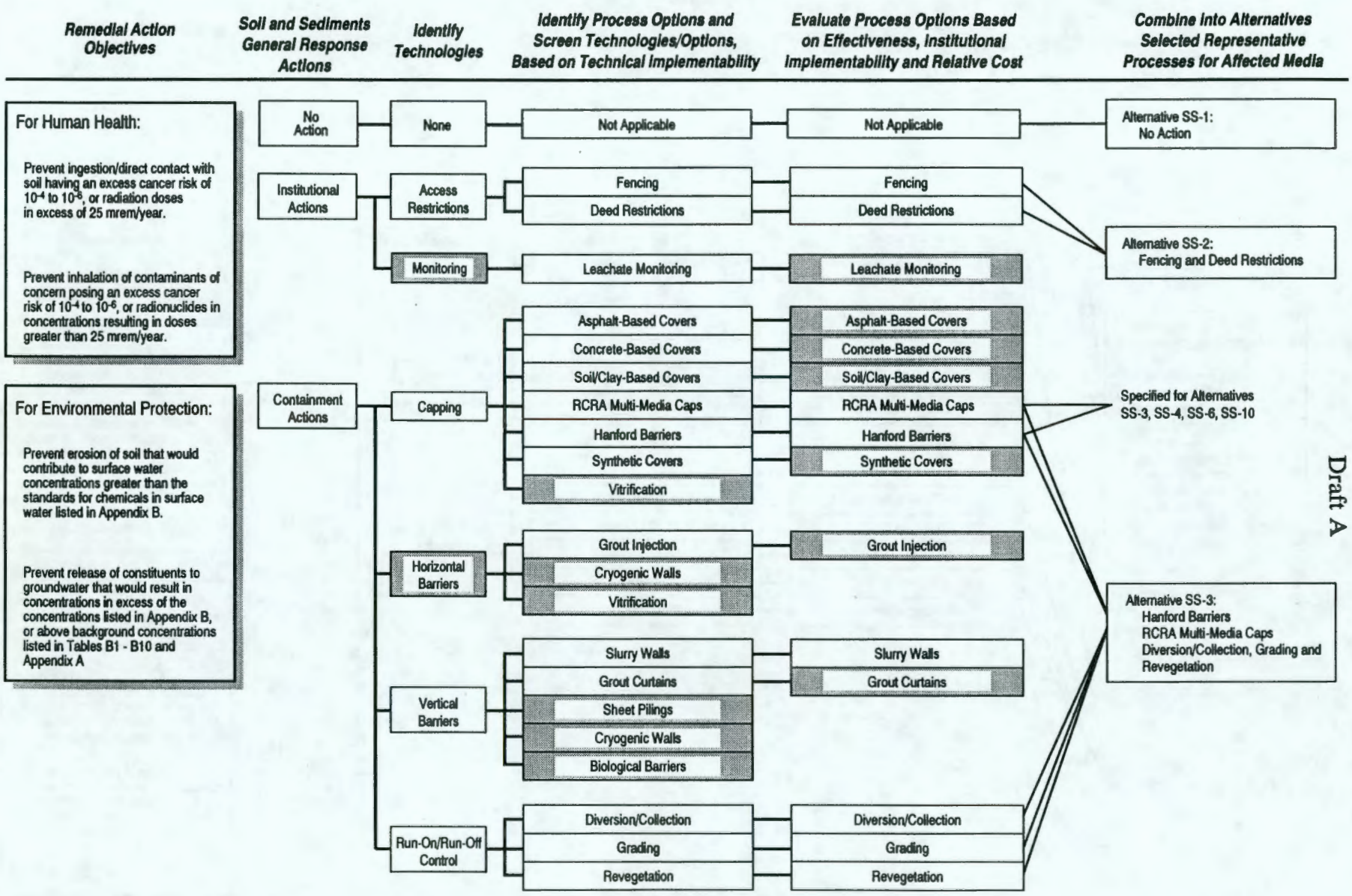

Figure 5-3
Hanford 100 Area FS: Development of Alternatives for Soil and Riverbank Sediments

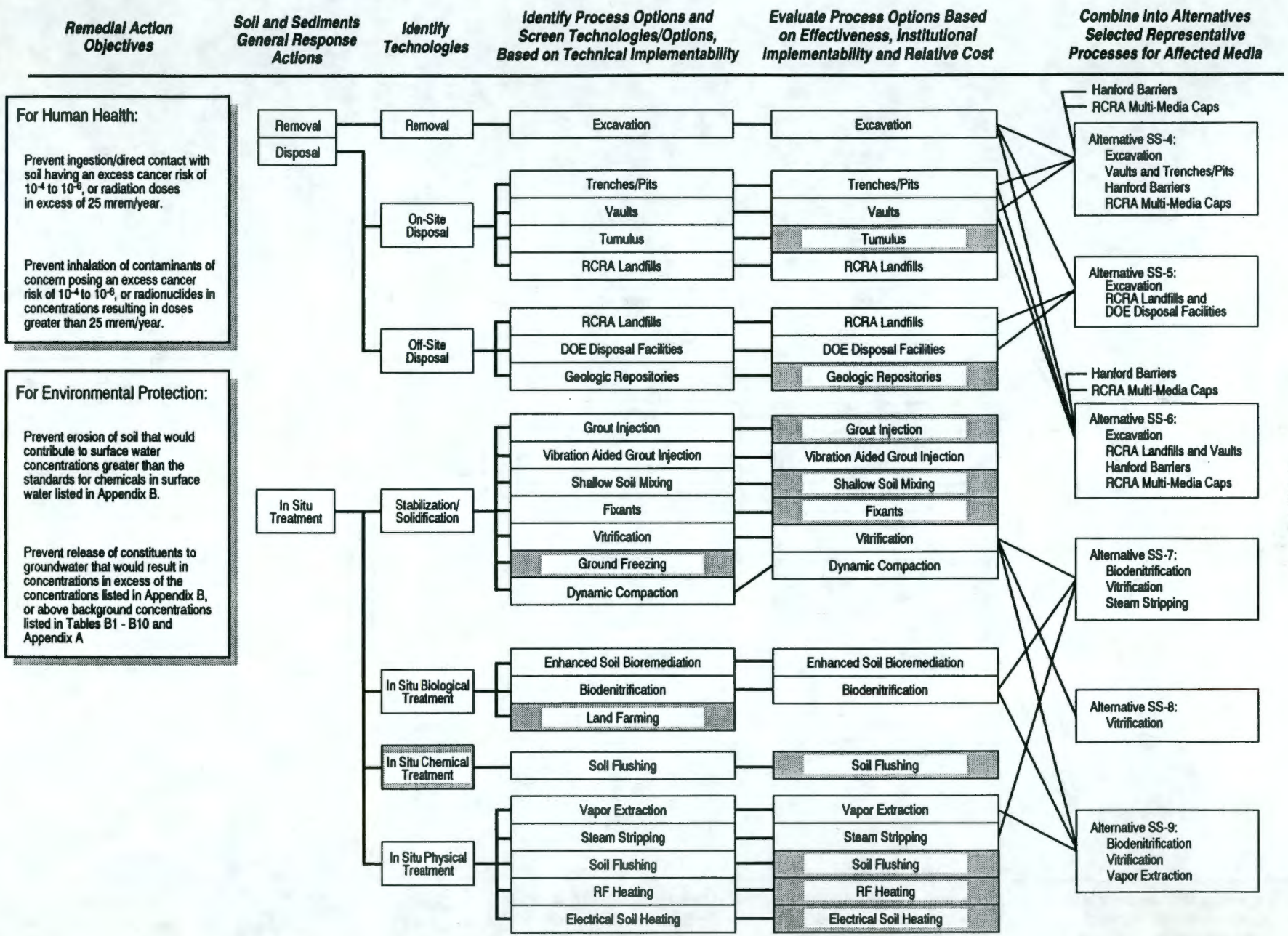

Figure 5-3
Hanford 100 Area FS: Development of Alternatives for Soil and Riverbank Sediments *(continued)*

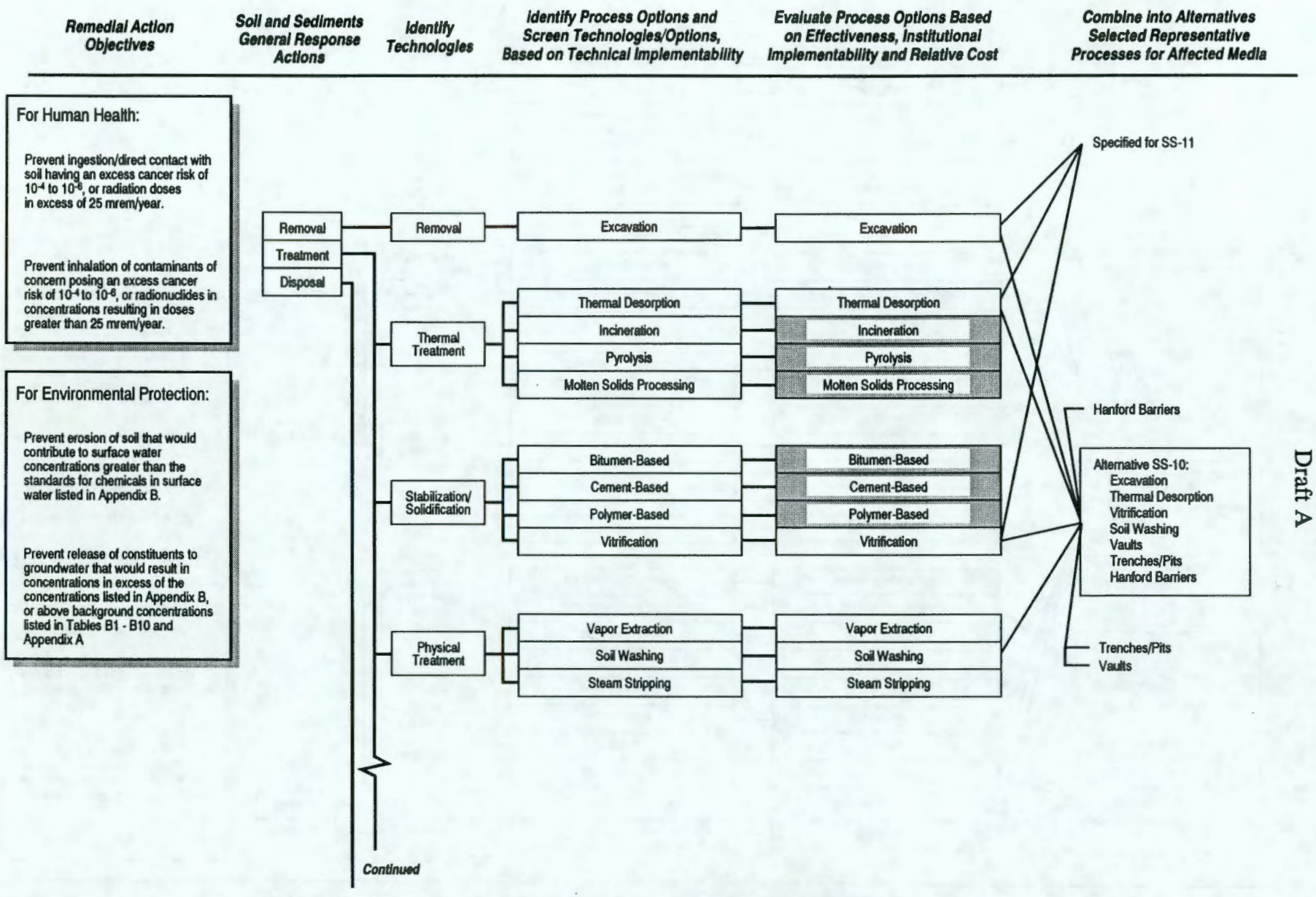

Figure 5-3
Hanford 100 Area FS: Development of Alternat for Soil and Riverbank Sediments *(continued)*

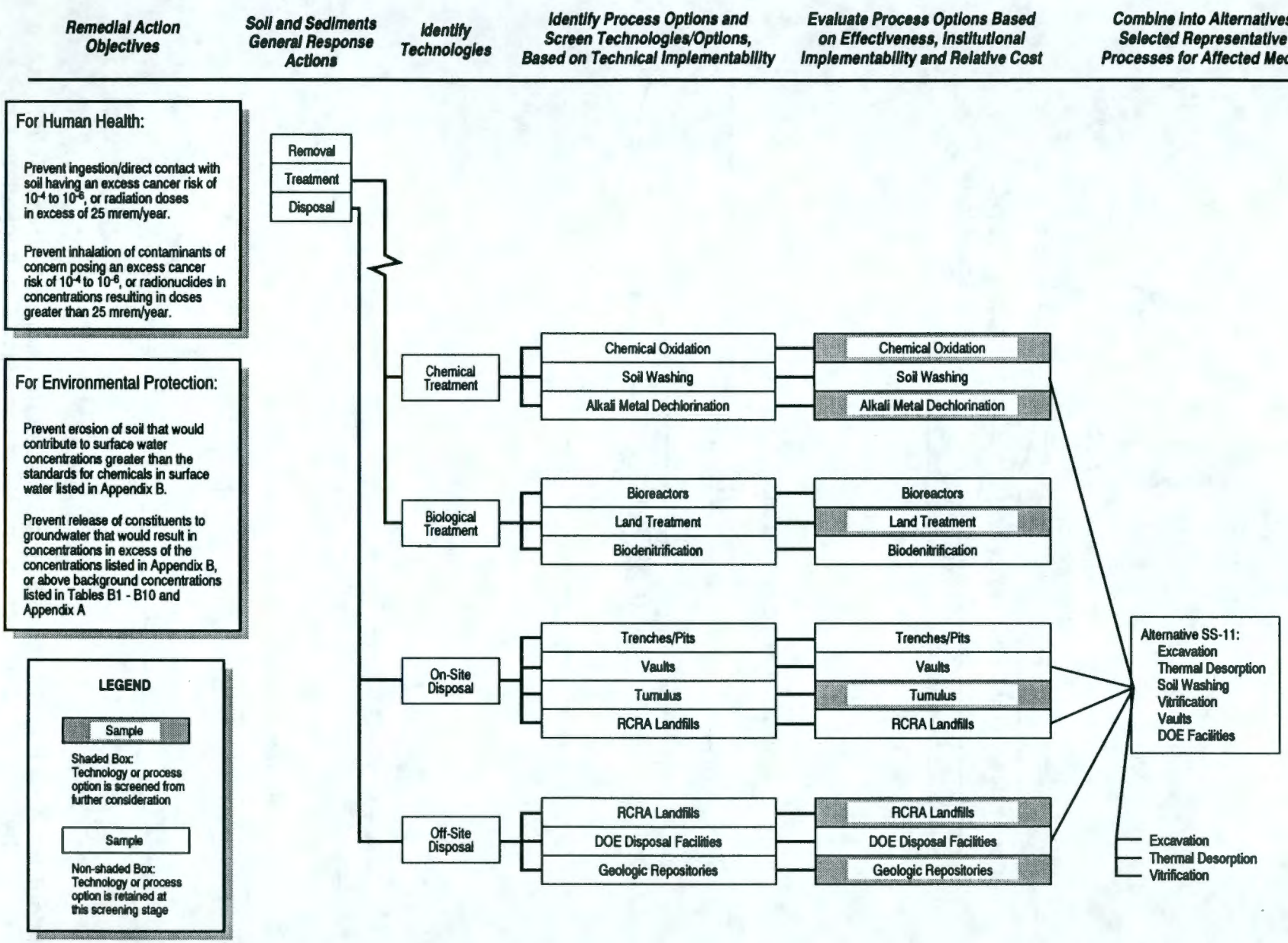

Figure 5-3
Hanford 100 Area FS: Development of Alternatives for Soil and Riverbank Sediments *(continued)*

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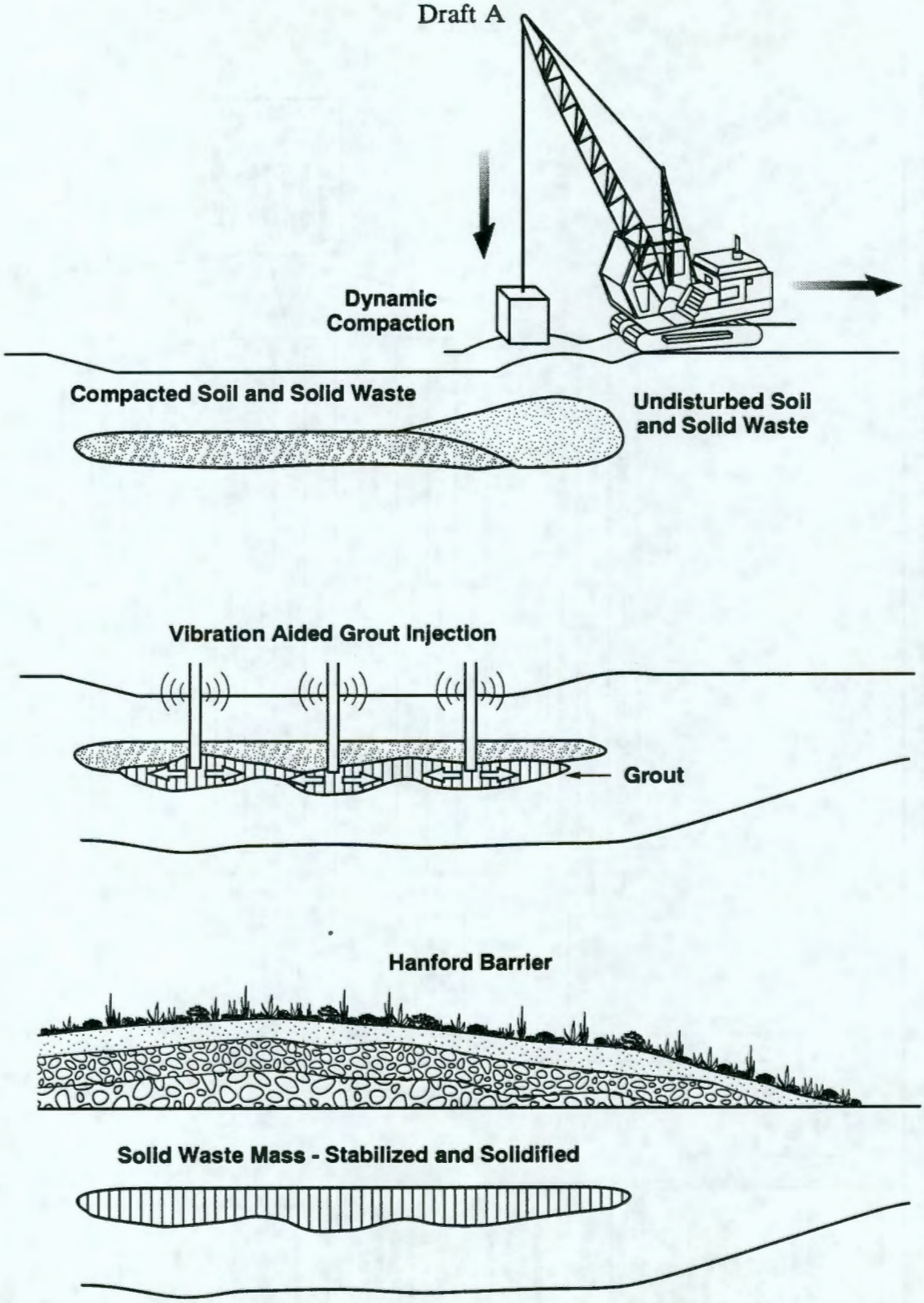

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Figure 5-4
Hanford 100 Area FS Alternative SW-7: Solid Waste Stabilization and Solidification by Dynamic Compaction, and Vibration Aided Grout Injection

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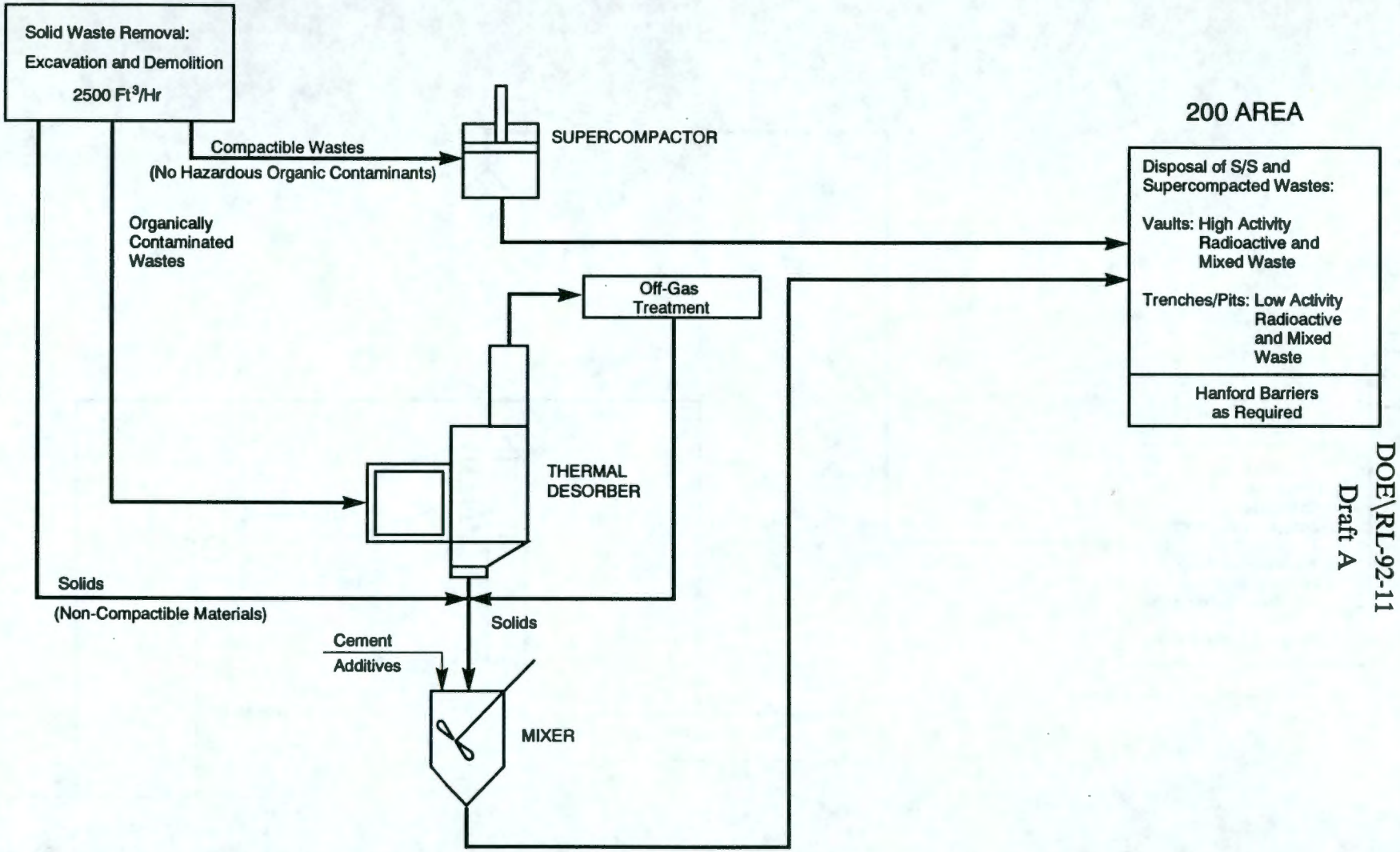

Figure 5-5
Hanford 100 Area FS Alternative SW-9: Process Flow Diagram

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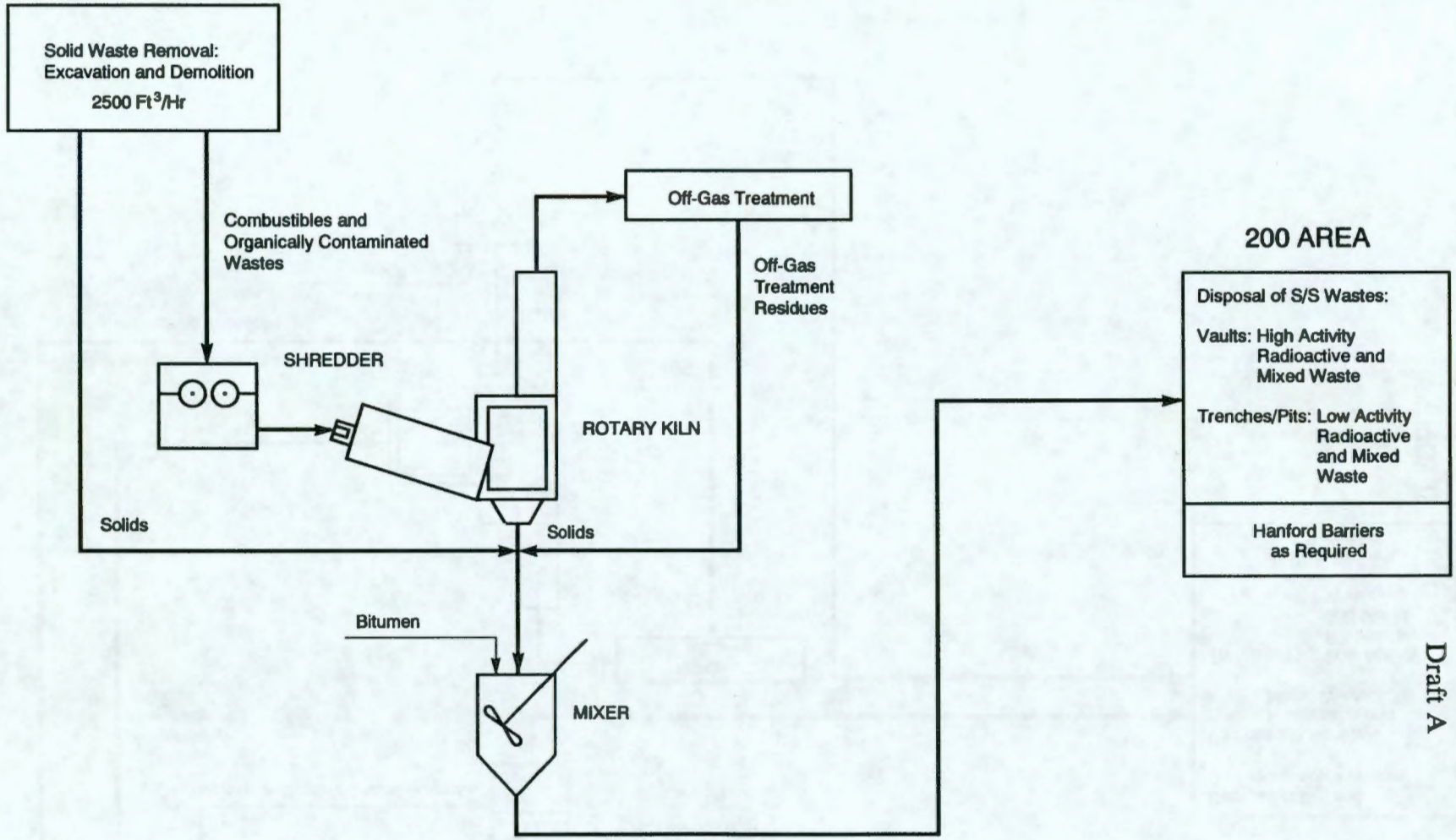

Figure 5-6
Hanford 100 Area FS Alternative SW-10: Process Flow Diagram

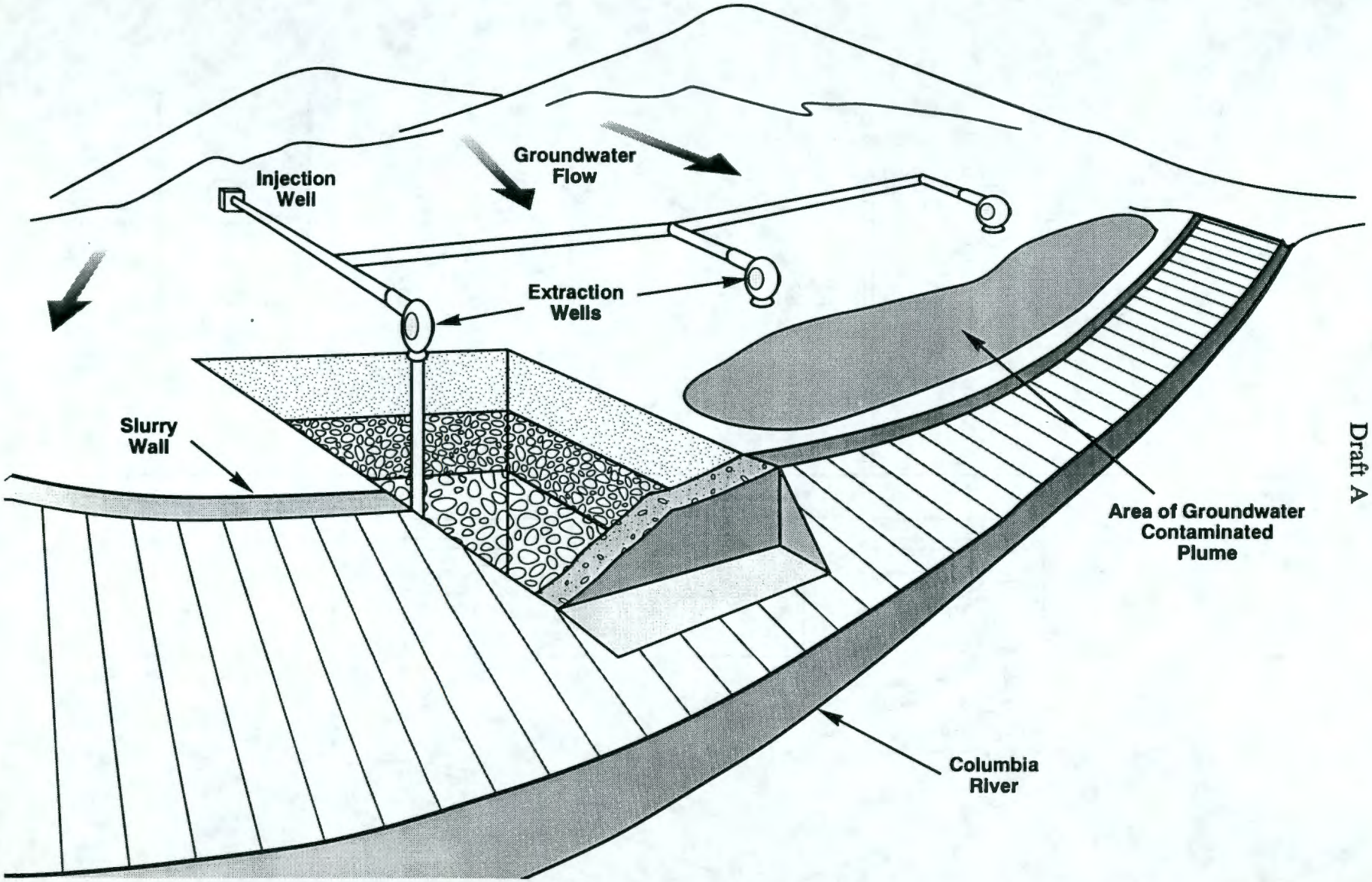

Figure 5-7
Hanford 100 Area FS Alternative GW-3: Conceptual Model for Containment of Groundwater (Slurry Wall) and Hydraulic Control, (Extraction, and Injection Wells)

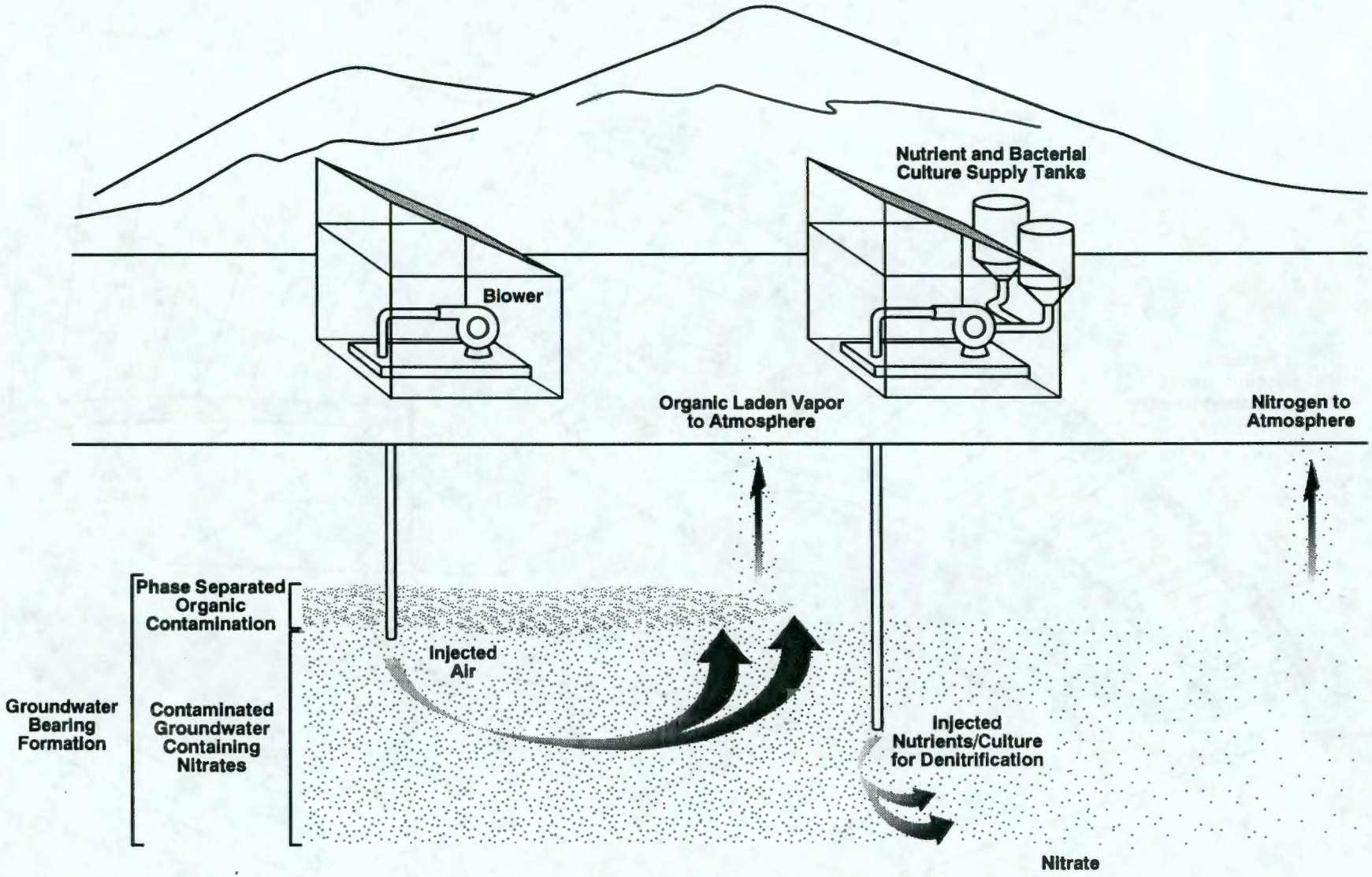

Figure 5-8
Hanford 100 Area FS Alternative GW-4: Conceptual Model of In Situ Air Stripping, and Biodenitrification

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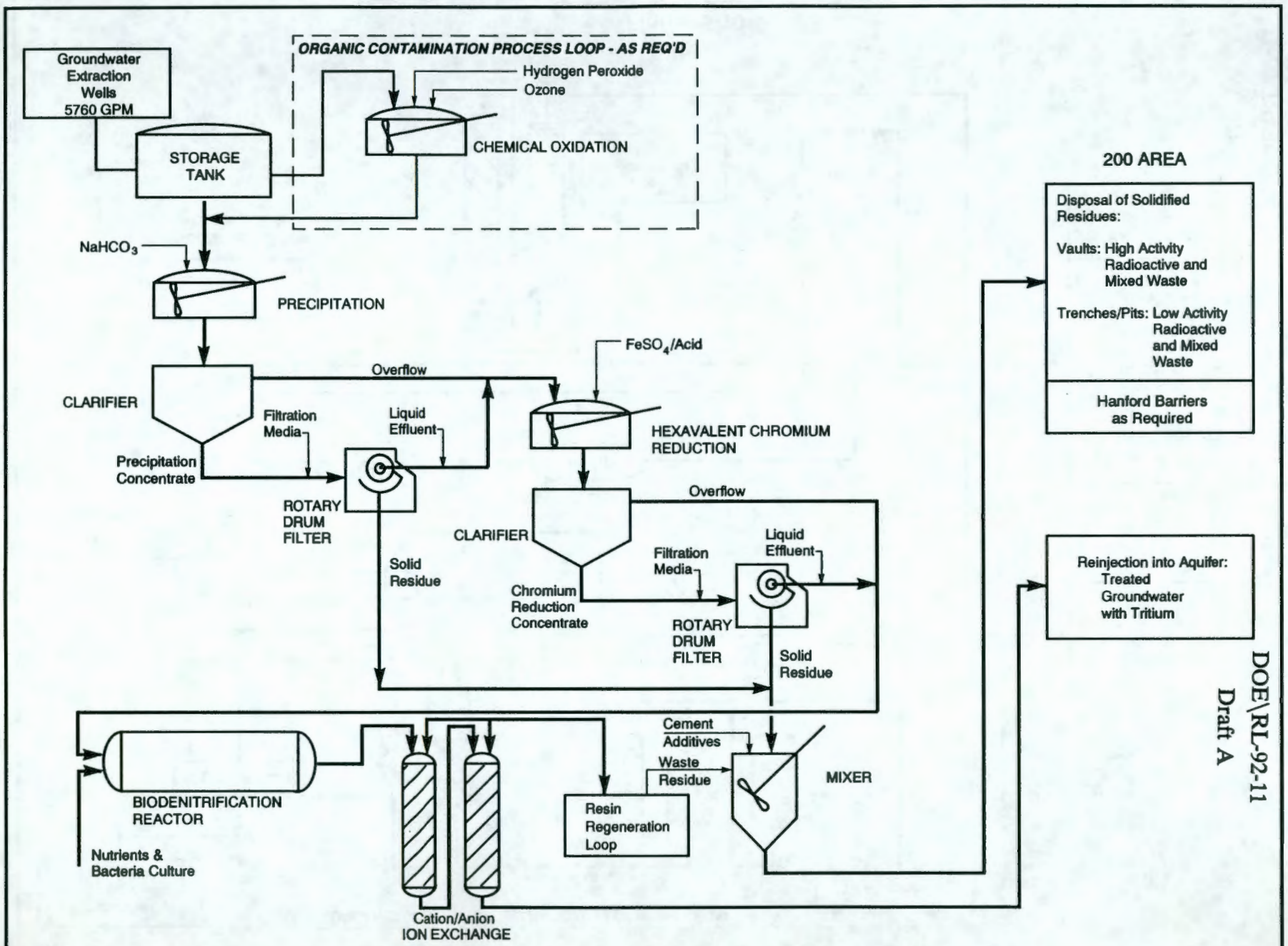

Figure 5-9
Hanford 100 Area FS Alternative GW-5: Process Flow Diagram

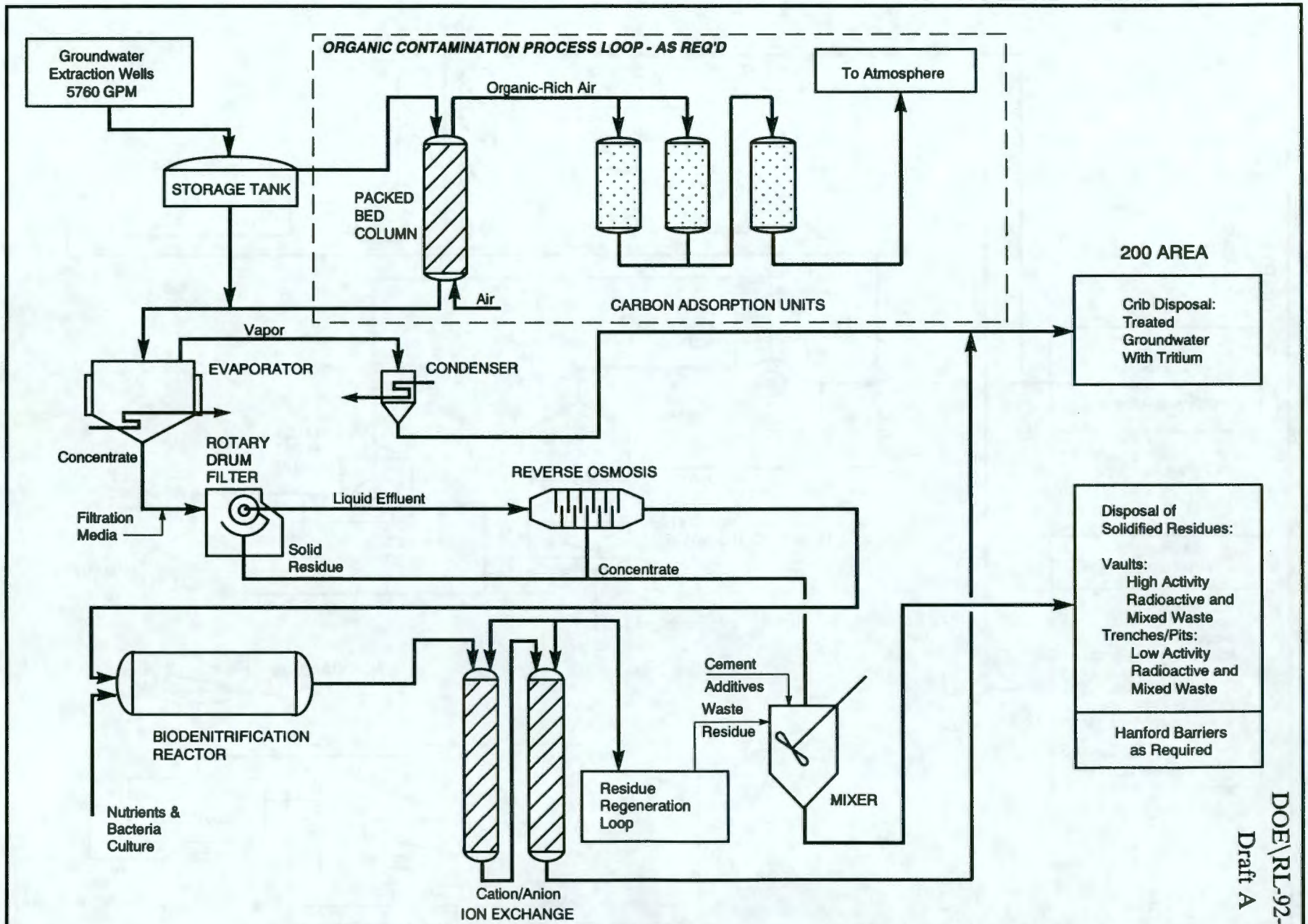

Figure 5-10
Hanford 100 Area FS Alternative GW-6: Process Flow Diagram

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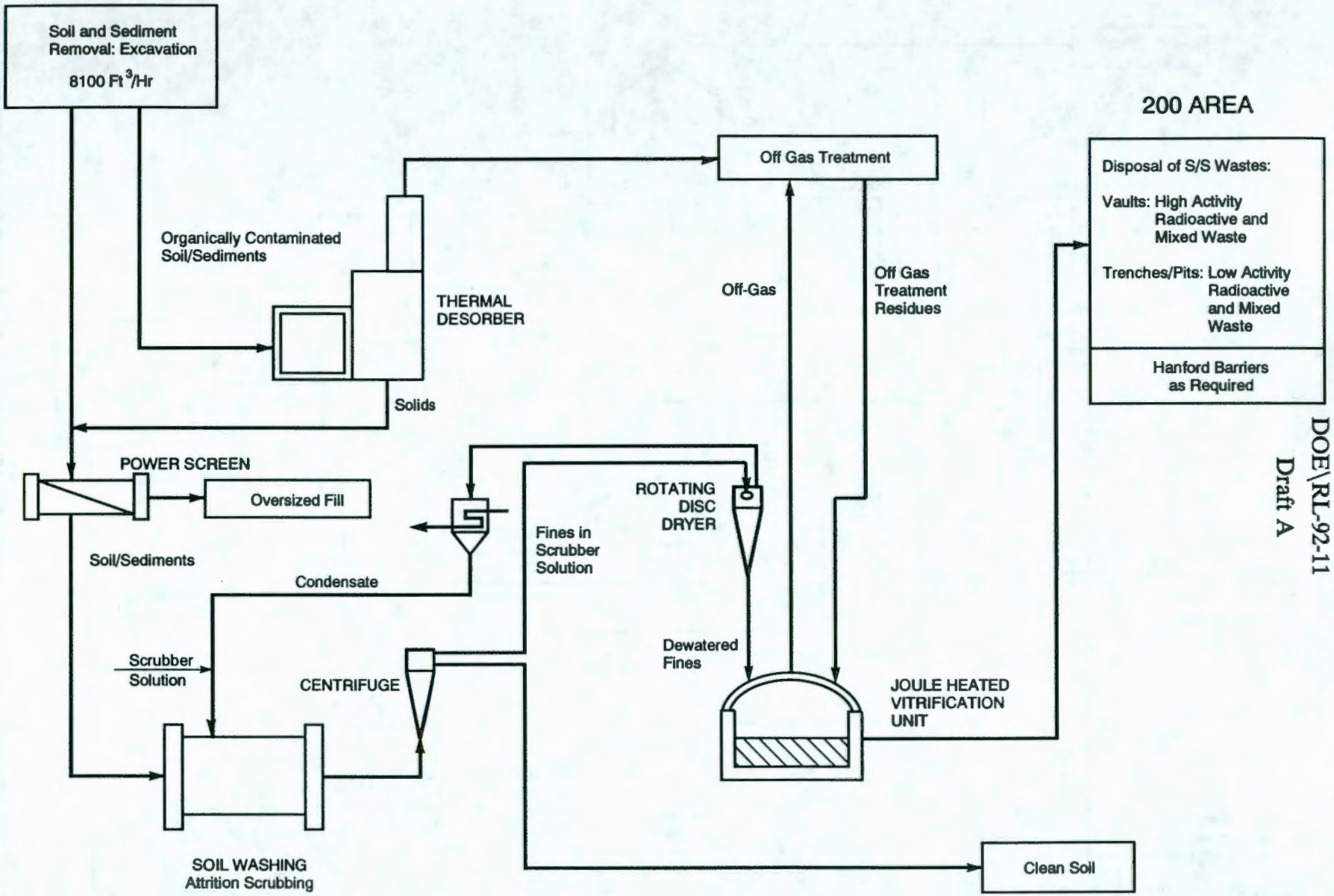

Figure 5-11
Hanford 100 Area FS Alternate SS-10: Process Flow Diagram

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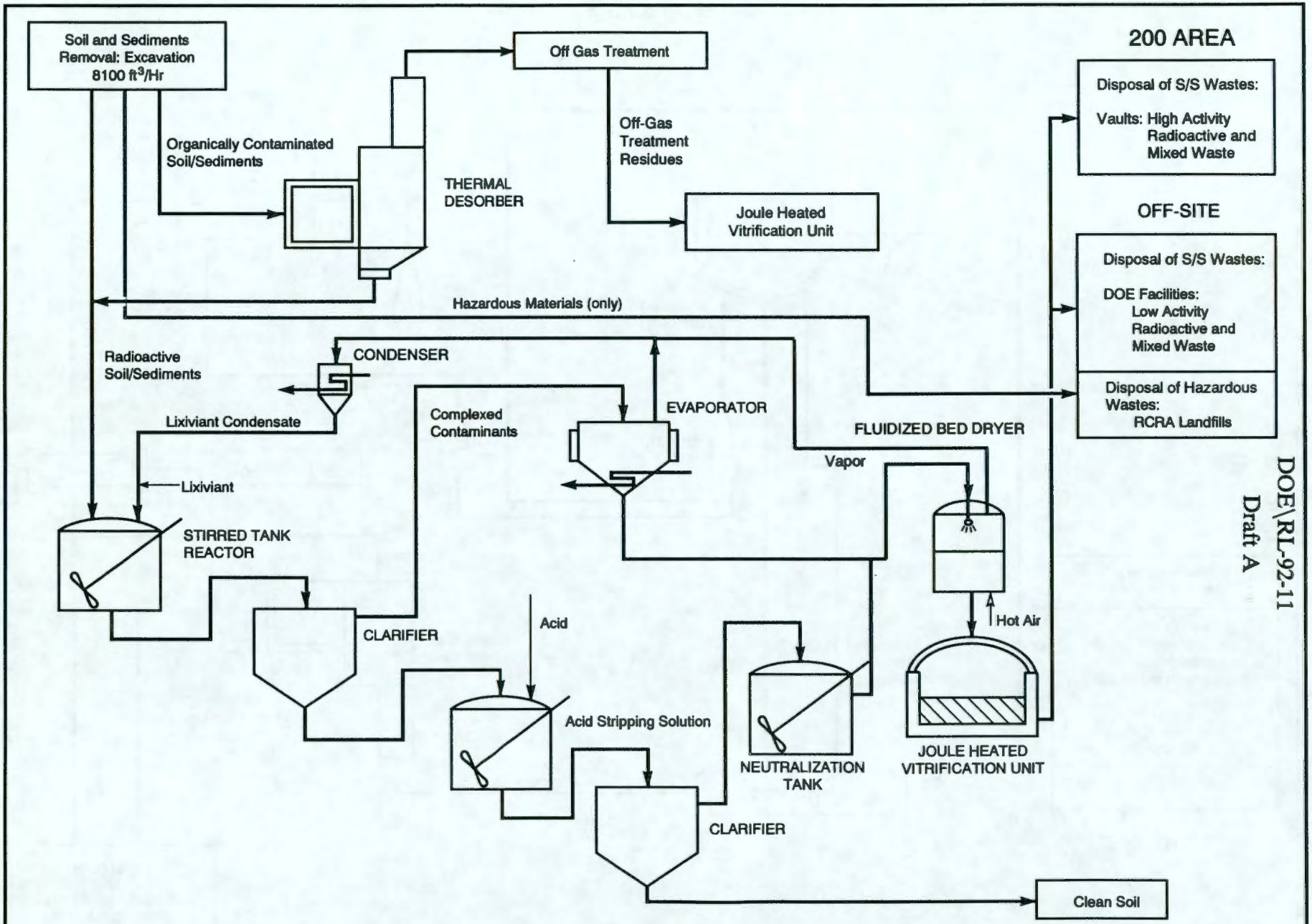

Figure 5-12
Hanford 100 Area FS Alternative SS-11: Process Flow Diagram

General Evaluation Criteria	Evaluation Factors	General Response Action: No Action	Institutional Actions	Containment Actions	Removal and Disposal			In Situ Treatment		Removal/ Treatment/Disposal	
	Alternative	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7	SW-8	SW-9	SW-10
Effectiveness	Short-Term Protection of Human Health	2.6	3.9	3.8	2.7	1.9	2.6	3.8	3.9	2.1	2.1
	Short-Term Protection of the Environment	2.2	2.2	3.3	2.9	2.2	2.8	3.7	3.8	2.6	2.6
	Long-Term Protection of Human Health	1.0	1.7	2.7	3.7	4.3	3.8	3.0	2.8	4.4	4.6
	Long-Term Protection of the Environment	1.0	1.0	2.2	3.6	4.2	3.7	2.9	2.8	4.3	4.4
	Reduction of Mobility, Toxicity or Volume of Waste	1.0	1.0	2.1	2.2	2.8	2.9	3.2	2.9	4.3	4.6
	Normalized, Weighted Effectiveness Total	18.7	23.5	33.9	36.0	37.1	37.6	39.7	38.7	42.7	43.7
Implementability Technical Feasibility	Constructability	5.0	4.7	4.3	3.4	3.1	3.3	3.2	3.3	2.8	2.6
	Operational Reliability	5.0	4.3	2.7	3.3	3.2	3.3	2.7	2.8	3.1	2.8
	Maintenance	4.9	3.4	2.9	4.1	4.2	3.6	3.1	3.0	2.8	2.4
Implementability Administrative Feasibility	Agency Approvals	1.1	1.4	1.9	3.3	1.6	2.9	2.1	2.3	3.7	2.9
	Availability of Services	5.0	4.7	4.7	4.2	1.9	3.8	3.2	3.1	3.3	3.0
	Specialized Equipment and Personnel	5.0	4.8	4.7	4.1	3.0	4.0	2.7	2.8	2.9	2.8
	Normalized, Weighted Implementability Total	16.0	14.3	14.1	15.8	10.6	14.2	11.1	11.2	12.7	11.1
Cost	Relative Cost	5.0	4.6	3.8	3.0	1.9	2.4	3.3	3.4	2.1	1.9
	Normalized, Weighted Cost Total	10.0	9.1	7.6	6.0	3.8	4.9	6.7	6.9	4.2	3.8
Normalized, Weighted Composite / Standard Deviation		54.7 / 6.5	55.9 / 5.5	62.5 / 3.6	64.6 / 6.3	57.8 / 9.2	63.4 / 5.9	63.4 / 6.3	62.9 / 6.5	65.4 / 7.7	64.0 / 4.7

Figure 5-13
Hanford 100 Area FS: Screening of Alternatives for Solid Waste

General Evaluation Criteria	Evaluation Factors	GW-1 (No Action)	GW-2 (Institutional Actions)	GW-3 (Containment Actions)	GW-4 (In Situ Treatment)	GW-5 (Removal/Treatment/Disposal)	GW-6 (Removal/Treatment/Disposal)
Effectiveness	Short-Term Protection of Human Health	2.0	3.6	3.0	2.9	3.4	3.3
	Short-Term Protection of the Environment	1.8	2.3	3.0	2.8	3.7	3.6
	Long-Term Protection of Human Health	1.0	2.0	2.9	3.0	4.3	4.4
	Long-Term Protection of the Environment	1.0	1.4	2.8	2.9	4.3	4.4
	Reduction of Mobility, Toxicity or Volume of Waste	1.0	1.0	2.3	3.0	4.3	4.3
	Normalized, Weighted Effectiveness Total	16.3	24.8	33.6	34.9	48.3	48.3
Implementability Technical Feasibility	Constructability	5.0	4.4	2.3	3.4	3.8	3.7
	Operational Reliability	4.7	4.1	2.3	3.3	3.1	3.2
	Maintenance	5.0	4.0	2.0	3.2	2.6	2.7
Implementability Administrative Feasibility	Agency Approvals	1.2	1.7	2.4	2.6	3.8	3.4
	Availability of Services	5.0	4.7	3.3	3.4	3.7	3.4
	Specialized Equipment and Personnel	5.0	4.7	3.0	3.6	3.2	3.1
	Normalized, Weighted Implementability Total	16.2	15.0	10.8	12.8	13.2	12.7
Cost	Relative Cost	5.0	4.4	2.4	3.3	1.8	1.9
	Normalized, Weighted Cost Total	10.0	8.9	4.9	6.7	3.6	3.8
Normalized, Weighted Composite / Standard Deviation		52.2 / 6.4	57.2 / 9.3	53.9 / 6.7	61.6 / 8.8	71.9 / 5.3	71.6 / 6.8

Figure 5-14
Hanford 100 Area FS: Screening of Alternatives for Groundwater

General Evaluation Criteria	Evaluation Factors	General Response Action	No Action	Institutional Actions	Containment Actions	Removal and Disposal				In Situ Treatment		Removal/ Treatment/Disposal
	Alternative	SS-1	SS-2	SS-3	SS-4	SS-5	SS-6	SS-7	SS-8	SS-9	SS-10	SS-11
Effectiveness	Short-Term Protection of Human Health	2.7	3.8	3.6	2.7	1.9	2.8	3.4	3.7	3.7	2.7	2.2
	Short-Term Protection of the Environment	2.3	2.4	3.1	2.9	2.3	3.0	3.3	3.7	3.7	2.9	2.6
	Long-Term Protection of Human Health	1.0	1.6	2.8	3.6	4.3	3.8	4.0	4.3	3.9	4.4	4.4
	Long-Term Protection of the Environment	1.0	1.0	2.6	3.4	4.2	3.7	3.9	4.3	3.8	4.4	4.6
	Reduction of Mobility, Toxicity or Volume of Waste	1.0	1.0	2.0	2.6	2.8	2.3	4.0	4.3	4.2	4.7	4.6
	Normalized, Weighted Effectiveness Total	19.2	23.5	33.6	36.3	37.3	37.3	44.8	48.8	46.1	45.9	44.0
Implementability Technical Feasibility	Constructability	5.0	4.7	4.0	3.3	3.2	3.2	2.6	2.3	2.2	3.1	2.8
	Operational Reliability	5.0	4.4	3.3	3.6	3.7	3.7	3.0	2.4	2.4	3.0	2.9
	Maintenance	4.9	3.8	3.4	3.7	3.8	3.2	2.6	2.8	2.7	2.7	2.4
Implementability Administrative Feasibility	Agency Approvals	1.3	1.6	2.3	3.1	2.1	2.9	2.9	2.7	3.0	3.2	2.2
	Availability of Services	5.0	4.7	4.6	3.9	2.0	3.3	2.1	2.1	2.2	3.0	2.1
	Specialized Equipment and Personnel	5.0	4.8	4.4	3.6	3.3	3.4	1.9	1.9	1.9	2.6	2.4
	Normalized, Weighted Implementability Total	16.2	14.8	14.8	14.2	11.2	12.9	9.4	9.4	9.8	11.4	9.2
Cost	Relative Cost	5.0	4.6	3.9	2.9	1.7	2.6	2.3	1.8	2.4	2.0	1.8
	Normalized, Weighted Cost Total	10.0	9.1	7.8	5.8	3.3	5.1	4.7	3.6	4.9	4.0	3.6
Normalized, Weighted Composite / Standard Deviation		55.4 / 6.7	56.5 / 5.7	63.5 / 3.0	63.2 / 5.4	58.8 / 8.0	62.2 / 5.0	64.5 / 4.8	66.6 / 5.5	65.5 / 4.8	67.4 / 6.0	62.4 / 5.0

Figure 5-15
Hanford 100 Area FS: Screening of Alternatives for Soils and Sediments

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6.0 FUTURE STUDY PHASES

While the scope of this document is limited to alternatives development and screening for the 100 Area, future study phases will include:

- Treatability studies for support of remedy screening, selection, and design
- Focused feasibility studies (detailed analysis) for IRM remedy selection and for final OU remedy selection.

This section provides an overview discussion of these future study phases, explaining the needs and approach for development of a treatability study program plan and explaining the general approach to conducting future focused FSs to bring 100 Area operable units through remedy selection and Record of Decision.

6.1 TREATABILITY STUDIES AND TECHNOLOGY DEMONSTRATIONS

In this Phase I/II FS, alternatives are developed and screened for remediating 100 Area contaminated media. The technologies and process options selected for the alternatives combine those that are conventional in the sense that they have been widely applied elsewhere in actual site remediations and those that are innovative in the sense that, while they may not have yet been applied, the technologies are promising and have been developed to some degree, but lack sufficient cost and performance data to validate their application to Hanford remediation. In either case, treatability data will be needed to support both the detailed analyses of alternatives and the remedial design efforts. In the case of conventional technologies, treatability data are needed to more thoroughly evaluate them for Hanford site-specific contaminants and conditions. In the case of innovative technologies, treatability data are needed to determine their fundamental viability as technology options.

Treatability studies are conducted for two purposes:

- Provide sufficient data to allow treatment alternatives to be fully developed and evaluated during the detailed analysis and to support the remedial design of a selected alternative
- Reduce cost and performance uncertainties for treatment alternatives to acceptable levels so that a remedy can be selected

The decision process for treatability investigations consists of:

- Determining data needs

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- Reviewing existing data on the site and available literature on technologies to determine if existing data are sufficient to evaluate alternatives

- Performing treatability tests, as appropriate, to determine performance, operating parameters, and relative costs of potential remedial technologies

- Evaluating the data to ensure that data quality objectives (DQOs) are met.

Treatability studies usually consist of a combination of information research, evaluation, and testing. Treatability testing is performed on different scales depending upon the DQOs which must be met. The three levels of testing are:

- Laboratory screening
- Bench scale testing
- Pilot scale testing.

Treatability tests may initially be conducted on a laboratory scale to determine the suitability of a technology quickly and inexpensively. Laboratory screening provides qualitative data that would be used to determine the validity of the technology for remediating the site. No cost or design information is provided from these tests.

Bench scale testing is usually performed using comparatively small volumes of waste. These tests are generally used to determine if the "chemistry" of the process works. Because small volumes and inexpensive equipment are used, bench tests can be used economically to test a relatively large number of both performance and waste-composition variables. Bench scale tests are performed to determine if a technology can meet the performance goals of the remediation. The bench-scale tests provide quantitative data which would permit more accurate cost, performance, and schedule estimation for the full-scale remediation. Most FS detailed analysis phases require testing on at least the bench scale.

Pilot scale studies are intended to simulate the physical as well as chemical parameters of a full-scale process. Therefore, the treatment unit sizes and the volume of waste to be processed in pilot systems greatly increase over those of bench scale. As such, pilot tests are intended to bridge the gap between bench scale testing and full scale operation, and are intended to more accurately simulate the performance of the full scale process. Pilot scale testing is expensive and time consuming relative to bench scale testing. Pilot scale testing may generally be warranted in the following situations:

- Where the nature of the process is such that the physical and geometric effects of the test equipment are important to simulate full-scale performance. That is, in such cases, bench scale equipment is too small to simulate critical performance parameters. An example is rotary kiln incineration where it is difficult to evaluate the ability to handle a new waste using a bench scale test.

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- For innovative technologies which are not well developed or have not been applied commercially or where scale-up information may be totally lacking

- When there is a need to investigate secondary effects of the process, such as air emissions, or when treatment residues are needed to test secondary treatment processes

To determine the need for pilot testing, the potential for improved performance or savings in time or money during the remedial implementation should be balanced against the additional time and cost for pilot testing. Technologies requiring pilot testing should also be compared to technologies that can be implemented without pilot testing. Innovative technologies should be considered if they offer the potential for more efficient treatment, waste destruction, or significant savings in time or money required to complete the remedial action.

It is anticipated that the multiplicity of data needs will need to be filled, where appropriate, by a combination of literature research, laboratory screening, bench scale testing, pilot scale testing, and field demonstrations. Specific implementation work plans will be required to define the specific scope and schedule of each study, test program, or demonstration.

The starting point for identifying treatability study data needs will be the list of screening alternatives developed in this Phase I/II FS. The number and scope of treatability studies does not necessarily correlate with the number of alternatives, as some alternatives may not need tests to support either detailed analysis or design. Further, once the list of treatability study data needs are identified, all the candidate studies need to be prioritized, focusing on the near-term needs associated with potential 100 Area IRMs. The initial focus also needs to be on those remedial alternatives which show the highest potential for meeting remedial action objectives as indicated by their relative evaluation scores.

The plan for treatability testing also needs to consider the need for engineering development and subsequent technology demonstrations to support design and operation of specialized equipment systems. As is the case with treatability studies which focus on the workability of a specific physical or chemical process, the remedial programs will also need development and demonstration of systems, hardware, and techniques associated with remedial activities. Examples of such activities which may need support include excavation, demolition, dust control, real-time instrumentation and analysis, remote operations, waste containerizing and transport, and systems integration.

Also important for treatability study planning is the identification of development needs for those promising innovative technologies and process options which were screened out in the FS because of a lack of sufficient development or operational data to validate their viability for Hanford remedial applications. While such development and testing needs may be of considerably lower priority in the overall program, it is important to the long-range program that promising technologies are given some share of

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attention, particularly if it is apparent that they offer significant technical or cost advantage. Limited additional treatability studies of these innovative technologies would be considered on a case-by-case basis. For example, considerable benefit might result from merely performing a comprehensive literature search and discussions with the inventors or developers of the technology.

The specific elements of treatability testing and technology demonstrations will be defined in the 100 Area Treatability Study Program Plan. This plan will be developed to meet the following objectives:

- Identify the list of technologies requiring treatability studies or technology demonstrations for the 100 Area contaminated media. This information will be extracted primarily from this FS report.

- Identify general data needs and test objectives to support detailed analysis of alternatives and remedial design efforts.

- Define the specific studies and/or tests which will meet those objectives, including defining the scale of the testing needed; include identification of existing development programs and describe their progress to date and future development plans; also identify treatability study programs being conducted for other Hanford areas (or other DOE sites) and discuss coordination needs.

- Prioritize the studies and/or tests focusing on near-term needs associated with 100 Area IRMs.

- Identify order-of-magnitude costs and schedules associated with each study or test program.

- Specify the methodology to be followed in conducting the studies and test programs.

The program plan will be prepared in accordance with the *Guide for Conducting Treatability Studies Under CERCLA (Interim Final)* (EPA 1989b) and the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Interim Final)* (EPA 1988a).

Since prioritization of the treatability studies is linked to the near-term needs of the 100 Area IRMs, the development of the Treatability Study Program Plan will be closely coordinated with development of a companion document, the 100 Area IRM Program Plan.

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6.2 FUTURE FEASIBILITY STUDY PHASES FOR 100 AREA OPERABLE UNITS

This 100 Area Feasibility Study provides alternatives development and screening for the entire 100 Area. The scope of this effort is thus limited to that portion of a CERCLA FS which is commonly referred to as Phases I and II. The detailed analysis phase of a CERCLA FS, which is referred to as Phase III, will not be conducted on an aggregate area basis as was the case for this Phase I/II effort. Instead, detailed analysis will take the form of individual Focused Feasibility Studies (FFS) to be performed either on a waste site or site-group basis for purposes of selecting Interim Remedial Measures (IRMs). To support the final ROD for the operable unit, the final FS will be performed which will consist of a detailed analysis for the entire OU to select the OU remedy. The IRM FFSs will be performed as further data become available from the Limited Field Investigations (LFI) being performed for each 100 Area OU and from the 100 Area-wide Studies. The IRM FFSs and the final OU FS will thus consist of waste site-specific analyses of the alternatives developed in the Phase I/II effort using a combination of site-specific and area-wide data generated by current and future investigation efforts. In addition, all of the FFSs and the final FS for the OU will utilize information obtained from specific technology treatability studies and technology demonstration projects (See Section 6.1).

The IRM FFSs and the final OU FS will include the following steps:

- Identify contaminants of concern for specific waste units
- Determine volumes or areas for specific waste units
- Determine the complexity of the site(s)
- Develop RAOs specific to the waste sites or OU
- Update and refine the list of ARARs
- Perform waste-site specific detailed analysis of alternatives.

While the IRM FFSs will generally follow the guidance prescribed by CERCLA for conducting a detailed analysis (EPA 1988a, Section 6.0), the FFSs will be focused in that the level of detail will be tailored to the level of complexity of a site(s). That is, uncomplex sites, e.g., those involving few contaminants, limited contamination volume, and/or low risk would require a less comprehensive evaluation. Conversely, complex sites, e.g., those involving multiple contaminants, extensive contamination volume, and/or substantial risk would require more comprehensive analysis, possibly including substantial fate and transport modeling and alternative risk assessment.

The detailed analysis steps will include an evaluation of each remedial alternative against the nine EPA evaluation criteria as required by CERCLA Section 121(b)(1). These are listed as follows:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume

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- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance.

Additional work beyond the IRM FFSs or final OU FS includes the preparation of reports leading to either an interim Record of Decision (ROD), in the case of the IRM, or a final ROD for the OU. The details of the RI/FS steps for the 100 Area operable units are discussed below.

Figure 6-1 depicts the interrelationships and sequencing of steps and activities which must be integrated to bring an operable unit from field investigation through ROD. The diagram is consistent with the approach outlined in the Hanford Site Past Practice Strategy (DOE-RL 1991d). This chart provides a graphical description of the entire process of characterization activities, risk assessments (RA), treatability studies, and feasibility studies for the high and low priority sites within an operable unit and for the operable unit as a whole.

To aid in understanding each of the figure activity elements and their interrelationships, each element is described in the steps below.

STEP 1: 100 AREA AGGREGATE AND HANFORD SITE STUDIES

The 100 Area and Hanford Site studies consist of a series of investigations being conducted on a 100 Area or Hanford-wide basis. These investigations include the river impact study, the shoreline studies, the ecological study, the cultural resources study, and the Hanford background study. These studies provide data to be used in the LFI Report and in all phases of risk assessment. The 100 Area-wide and Hanford Site Studies are conducted in parallel with the OU LFIs and the 100 Area Phase I/II FS.

The studies in this category also include development of a baseline risk assessment methodology. This document serves as the basis for all risk assessments to be performed at Hanford and ensures consistent application of risk assessment methodology in the 100 Area. The levels of risk assessment include:

- Risk assessment for IRM decisions
- Qualitative risk assessments for remedial alternatives assessments as part of focused feasibility studies
- Cumulative baseline risk assessment for final OU remedy selection.

STEP 2: LIMITED FIELD INVESTIGATIONS (LFI) AND REPORTS

The LFI is a data collection/characterization activity for the high priority sites in each 100 Area operable unit and consists of data compilation, non-intrusive

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investigations, intrusive investigations, and data evaluation subtasks based upon the 100 Area OU rescoped work plans.

The LFI includes qualitative risk assessments for purposes of determining the need for and/or selecting IRMs. This risk assessments utilize existing information, data collected during the LFIs for the high priority sites, and data from the aggregate and Hanford Site studies for use in IRM decisions prior to conducting the IRM focused FS.

The LFI reports are secondary documents summarizing data collection and analysis activities of the LFIs and the qualitative risk assessments.

STEP 3: 100 AREA FEASIBILITY STUDY (PHASES I/II) AND REPORT

The 100 Area Feasibility Study, Phases I and II, consists of four subtasks: contaminants of concern identification, ARARs identification, alternatives development, and alternatives screening. These subtasks are performed on an 100 Area-wide basis and provide screened alternatives as the starting point for subsequent focused FSs for IRM selection and for final feasibility studies for selection of the operable unit remedy. This Phase I/II study does not include detailed analysis of alternatives. Each focused FS (FFS) performs a detailed analysis using site-specific data.

STEP 4: TREATABILITY STUDIES AND TECHNOLOGY DEMONSTRATIONS

Needs for treatability studies and technology demonstrations to support future detailed analyses of remedial alternatives are based upon screened alternatives developed in the 100 Area Phase I/II FS. Specific treatability/demonstration recommendations and schedules are developed in a Treatability Study Program Plan. Information collected in these studies and demonstrations is used in the FFSs for IRM selection and in the final FSs for final OU remedy selection.

STEP 5: FOCUSED FEASIBILITY STUDIES

Each focused FS consists of a detailed analysis of the alternatives developed in the 100 Area FS for selection of the alternatives to be implemented for each 100 Area IRM. Modeling is performed as part of each detailed analysis, if required, and alternative risk analysis is performed at the same level as the IRM risk assessment discussed in Step 2. Information from the treatability studies and technology demonstration projects (See Step 4) is used in the analysis of remedial alternatives. The FFSs are documented in LFI/FFS Reports.

STEP 6: LFI/FFS REPORTS

The LFI/FFS Reports are primary documents summarizing information and data obtained from the 100 Area Phase I/II FS, the treatability studies and

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demonstration projects, and the detailed analyses conducted during the focused FS for each IRM. The LFI/FFS Reports are summarized in Proposed IRM Plans and IRM RODs for the respective IRMs.

STEP 7: PROPOSED IRM PLANS

The Proposed IRM Plans are primary documents describing the plans to implement each IRM. The Proposed IRM Plans, which are essentially the same as conventional CERCLA Proposed Plans, serve as the primary means of public notification for solicitation of comment on the proposed actions. These documents are prepared following the issuance of the LFI/FFS Reports.

STEP 8: IRM RODS

The IRM RODs are primary documents which summarize all information contained in each LFI/FFS Report and its associated IRM Plan. The IRM ROD is defined as the CERCLA document used to select the method of remedial action to be implemented at a site or group of sites after the FS/proposed plan process has been completed. For the 100 Area, the IRM ROD covers the high priority site(s) and the specific remedial actions implemented as IRMs.

For a given OU, the final operable unit RODs is issued after all the low priority sites within the OU have been characterized, if necessary, and the cumulative risk assessment and final FS for OU remedy selection have been completed for the operable unit as a whole (See Step 12).

STEP 9: IRM DESIGN REPORTS

The IRM Design Reports are secondary documents and provide engineering and technical specifications for implementing each IRM identified in the IRM ROD.

STEP 10: IRM IMPLEMENTATION

Implementation of each 100 Area IRM consists of construction and operations phases. These phases vary in scope and complexity among IRMs with respect to manpower needs, equipment expenditures, durations, etc. These activities can run concurrently with other activities such as final remedial investigations. Any data collected as a result of the IRM implementation are used in the cumulative risk baseline assessment and the final remedy selection for the operable unit (See Step 12).

STEP 11: FINAL RI AND REPORT

The final RI for each OU provides any additional data and characterization needed to support the final remedy selection process for the operable unit.

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Characterization activities are conducted, as agreed by the unit managers, on the remaining low priority sites and at high priority sites where final cleanup criteria were not achieved during the IRM.

A final RI may consist of data compilation, non-intrusive investigations, intrusive investigations, and data evaluation. Analyses conducted during the final RI use data collected during the LFI, during IRM implementation, and in previous investigations.

The final RI for each OU includes performance of the cumulative baseline risk assessment for the OU. This risk assessment is a quantitative evaluation of residual risk at the operable unit after completion of the IRMs and is conducted according to the Hanford Baseline Risk Assessment Methodology. The results are then used in the final feasibility study to evaluate alternatives for the final remediation of the operable unit.

STEP 12: FINAL FS FOR THE OU

The final FS for each OU is performed using the alternatives developed and screened in the 100 Area Phase I/II FS, information from the focused feasibility studies for IRMs, results of the IRMs, results of the treatability studies and technology demonstrations, and the cumulative baseline risk assessment. Modeling, if required, is performed as part of the detailed analysis. The studies are documented in the RI/FS Reports (Step 13).

STEP 13: RI/FS REPORT

The RI/FS Report for each OU is a primary document which summarizes all data collection and study activities conducted during the final RI and FS phases for the OU. The report supports development of the Proposed Remedial Action Plan (Step 14) and the Operable Unit ROD (Step 15).

STEP 14: PROPOSED REMEDIAL ACTION PLAN

The Proposed Remedial Action Plan for each OU presents a summary of all information contained in the OU RI/FS Report and identifies the remedial action selected for the OU. The Proposed Remedial Action Plan is brief and is written in simple layman's terms, since it is used primarily to inform members of the public. The primary reports generated during the process are referenced and a preferred final remedy for operable unit remediation is recommended for the OU.

STEP 15: OPERABLE UNIT ROD

The OU ROD summarizes the RI/FS report as well as any changes to the selected remedial action as a result of public comment on the proposed remedial action plan. The OU ROD is a primary legal document certifying that the

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remedial action selection process was carried out in accordance with the governing authority, i.e. CERCLA or RCRA, and committing the three parties to perform the remedial action in accordance with its specifications. The OU ROD presents a technical description of the remedial action; the final engineering, institutional, and remedial goals; and site information. The OU ROD is written and issued by the regulators.

STEP 16: REMEDIAL ACTION DESIGN REPORT

The remedial action design report for the OU is a secondary document and provides engineering and technical specifications for implementing the remedial action identified in the OU ROD.

STEP 17: REMEDIAL ACTION IMPLEMENTATION

The remedial action for the OU is implemented in a construction and operations phase. Depending upon the timing of individual OU RODs and the remedies selected for final remediation, the remedial action implementation phases for two or more OUs may be aggregated.

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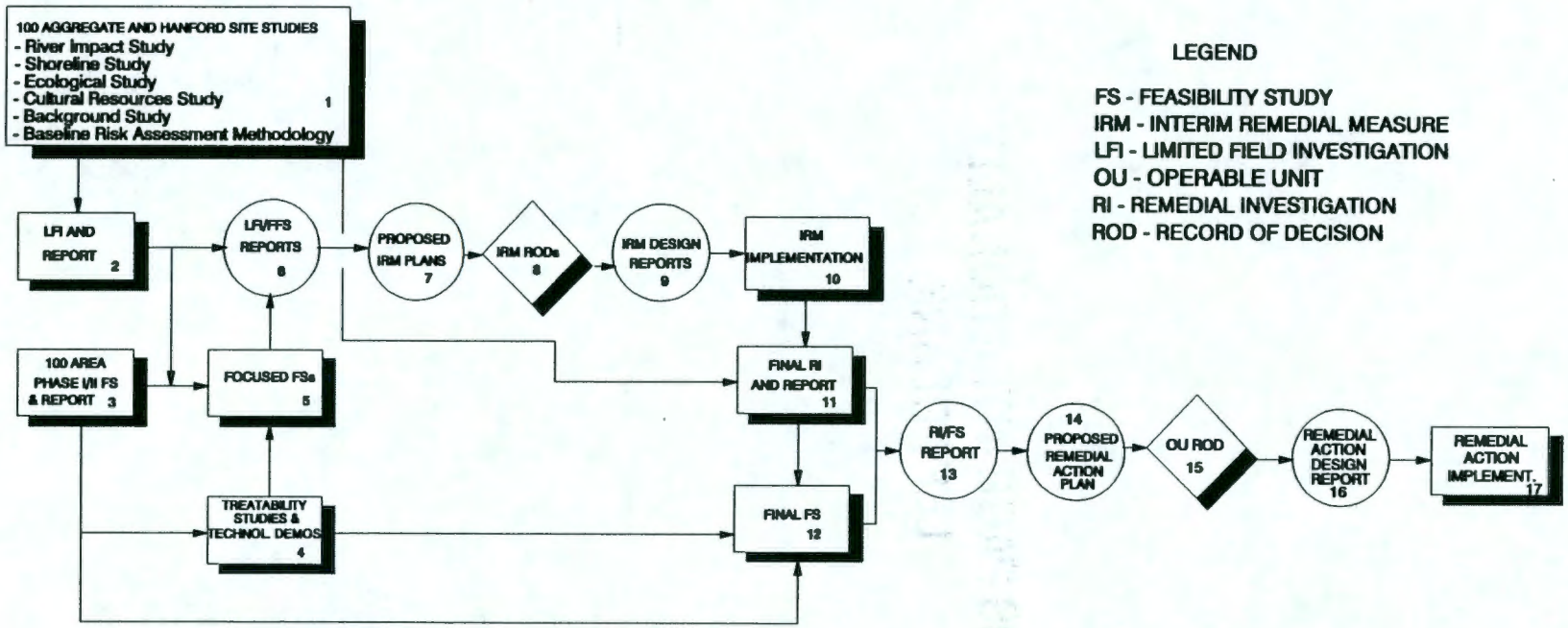
FIGURE 6-1

RI/FS STEPS FOR 100 AREA OPERABLE UNITS



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APPENDIX A

POTENTIAL CONTAMINANTS OF CONCERN

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ACRONYMS

ARARs	Applicable or Relevant and Appropriate Requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMS	Corrective Measures Study
CPP	CERCLA Past-Practice
EPA	Environmental Protection Agency
FS	Feasibility Study
HEAST	Health Effects Assessment Summary Tables
HQ	Hazard Quotient
IRIS	Integrated Risk Information System
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MTCA	Model Toxics Control Act
OU	Operable Unit
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RFI	RCRA Facility Investigation
RI	Remedial Investigation
RPP	RCRA Past-Practice
TPA	Tri-Party Agreement
TSD	Treatment, Storage, and Disposal
WAC	Washington Administrative Code

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GLOSSARY

Background Concentration - The concentration of a regulated substance (and/or its dissociated constituents) that:

- Is consistently present in the environment in the vicinity of a site; and
- Is either naturally occurring or the result of human activities unrelated to releases from that site.

Half-Life - The time required for an unstable element or nuclide to decay to or lose one-half of its radioactive intensity.

Operable Unit - A discrete portion of the Hanford Site, as identified in Section 3.0 of the Hanford Federal Facility Agreement and Consent Order, First Amendment (Ecology, 1990).

Potential Contaminant of Concern - A regulated substance (and/or its dissociated constituents) which:

- Was potentially released in the 100 Area,
- Has been detected in the environment at a concentration above the background concentration,
- Has been detected at a concentration equal to or greater than a regulatory limit, and
- Is of toxicological significance.

Potential Release - The possibility for any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of a radionuclide and/or chemical substance to the environment. All potentially released substances (and their dissociated constituents) are assumed to be contaminants.

Radiological Inventory - An estimate of radiological materials and concentrations potentially remaining in or released to a given source area.

Regulated Substance - All radiological substances, and those chemical substances (or constituents) which may be subject to the regulatory requirements of any one of the following:

- 40 CFR §302.4
- 40 CFR Part 761
- 40 CFR Part 300
- 40 CFR §§141.61 and 141.62

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- WAC 173-340
- WAC 173-200.

Regulatory Contaminant of Concern - A regulated substance (and/or its dissociated constituents) which:

- Was potentially released in the 100 Area,
- Has been detected in the environment at a concentration above the background concentration, and
- Has been detected at a concentration equal to or greater than a regulatory limit.

Source - The contaminated soils, sediments, or sludges in the immediate area of a release of a radionuclide and/or chemical substance.

Suspect Contaminant - A regulated substance (and/or its dissociated constituents) which:

- Was potentially released in the 100 Area, and
- Has been detected in the environment either in concentrations below background concentrations or less than regulatory limits, or
- Is not toxicologically significant.

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1.0 PURPOSE

This report has been prepared to support the Phase I/II Feasibility Study (FS) being conducted for the Hanford 100 Area. An essential element of the FS is to determine which contaminants must be remediated as part of the environmental restoration program in the 100 Area. The purpose of this report is to present a consistent methodology for determining potential contaminants of concern for use in evaluating remedial alternatives.

Contaminants of concern were identified in each of the draft 100 Area operable unit work plans. However, the approach for determining contaminants of concern was not consistent among the work plans. Therefore, one objective of this study was to provide a uniform decision-making process for the entire aggregate area so as to arrive at a defensible list of contaminants to be considered in the FS.

The results of this study are not intended to provide a final determination of contaminants of concern. That determination will be made as a result of collecting additional field data and conducting operable unit baseline risk assessments. Such risk assessments are not within the scope of this Phase I/II FS.

2.0 ORGANIZATION AND SCOPE

The determination of contaminants of concern for the 100 Area was conducted in two phases. The first phase entailed: 1) identification of radiological and/or chemical substances potentially released in the 100 Area and 2) comparison of concentration data with background concentrations and established regulatory limits. The end-product of the first phase is a list which is referred to as "regulatory contaminants of concern" (Table 1). Chapter 3.0 of this report addresses this first phase of the effort.

The second phase, utilizing the results of the first phase, performed a qualitative toxicity assessment. The purpose of this assessment in the second phase was to determine which of the regulatory contaminants of concern were of toxicological significance. The end-product of the second phase is a list of potential contaminants of concern to be used for evaluating remedial alternatives (Section 5.0, Table 2). Chapter 4.0 of this report provides the methodology and rationale for this second phase of the effort.

The following considerations form the fundamental bases upon which the decision logic was derived. The first three items pertain to the first phase and the last item pertains to the second phase.

- Radioactive half-life (radionuclides which have undergone ten half-lives were assumed to have decayed sufficiently to be of little concern (Gloyna and Ledbetter 1969);

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- Comparison of sample concentration versus background concentration;
- Comparison of sample concentration versus the most stringent, established regulatory limit, if any; and
- Toxicological characteristics.

Appendices AA through AD of this report provide data and rationale as backup to the determination of the regulatory contaminants of concern. The contents of each of the appendices are as follows.

- Appendix AA provides the resultant lists of regulatory contaminants of concern, suspect contaminants, and contaminants eliminated from further consideration.
- Appendix AB compares the most stringent numerical regulatory limits with the environmental sampling data for the regulatory contaminants of concern which pass the decision logic.
- Appendix AC indicates which of the nonradiological, chemical contaminants are regulated, and the regulatory authority for each.
- Appendix AD provides tables depicting how each contaminant passed through the decision logic diagrams (Figures 1 and 2) and the critical decision point where it was classified as a regulatory contaminant of concern, suspect contaminant, or eliminated from further consideration.

Appendix AE of this report pertains to the qualitative toxicity assessment. The tables in Appendix AE outline how each of the regulatory contaminants of concern passed through the decision logic diagram (Figure 3).

2.1 SCOPE OF IDENTIFICATION OF POTENTIALLY RELEASED SUBSTANCES

Identification of potentially released substances was confined to a review and evaluation of environmental data pertaining to the following two types of units.

- 100 Area Resource Conservation and Recovery Act (RCRA) Past-Practice (RPP) units as detailed in RCRA Facility Investigation/ Corrective Measures Study (RFI/CMS) draft work plans for the 100 Area
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Past-Practice (CPP) units as detailed in Remedial Investigation/ Feasibility Study (RI/FS) draft work plans for the 100 Area.

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Eleven RI/FS and RFI/CMS draft work plans were written for the priority liquid waste operable units in the 100 Area (DOE 1990a-e; 1991a-f). Data were obtained from these work plans to identify substances potentially released. For the remaining 14 operable units for which no work plans have yet been drafted (primarily lower priority solid waste units) the following sources of information were used:

- "Radiological Characterization of the Retired 100 Areas" (Dorian and Richards, 1978);
- "Estimates of Solid Waste Buried in the 100 Area Burial Grounds" (Miller and Wahlen, 1987); and
- "Engineered-Facility Sites (HISS Data Base)" (Stenner et al., 1988a).

Information on other units (e.g., RCRA treatment, storage, or disposal (TSD) units and currently undesignated units) was not reviewed or included in the identification of potentially released substances.

Key assumptions are listed as follows:

- The list of potentially released substances was derived from existing site data. Any new sampling or monitoring data produced after the initiation of this task were not considered.
- Sampling and monitoring data used were assumed to be of adequate quality to support this effort. Data were not evaluated for adequacy. The 100 Area documentation and environmental data reviewed for this report were compiled by many different companies and organizations over a period of several decades. Because of limitations on the scope of this project, no attempt was made to determine the adequacy of the sampling methodology, monitoring well locations, or laboratory quality assurance information.
- Only soils and groundwater data were evaluated. It is assumed that any contaminants released as air emissions are present in surface soils through deposition. Therefore, soils sampling data are assumed to account for past atmospheric contaminant releases.

2.2 SCOPE OF REGULATORY CONTAMINANTS OF CONCERN DETERMINATION

The determination of regulatory contaminants of concern is based upon five key elements:

- Data which show that a chemical or radionuclide was used or generated within an operable unit and subsequently was released or potentially released to the environment
- Regulatory status of radionuclides or chemicals and their constituents
- Sample concentration data
- Background concentration data
- Comparison of sample concentration data with background and regulatory limits.

Section 3.0 describes the details of the methodology used to determine which of the contaminants potentially present at the site are of concern with respect to background concentrations and regulatory limits.

2.3 SCOPE OF TOXICITY ASSESSMENT

The qualitative toxicity assessment further refines the contaminant of concern determination by evaluating the toxicological significance of each regulatory contaminant of concern. The toxicity assessment is based upon five key elements:

- Review of supplemental Environmental Protection Agency (EPA) guidance which eliminates certain metallic contaminants based upon previous determinations of low or negligible toxicity
- Determination of the carcinogenicity of each contaminant
- Determination of reference doses for each non-carcinogen
- Calculation of a hazard quotient for non-carcinogens based on an ingestion exposure route
- Assessment of calculation results based upon EPA guidance on contaminant screening.

Details of the methodology for the qualitative toxicity assessment are given in Section 4.0.

3.0 REGULATORY CONTAMINANTS OF CONCERN

Decision logic diagrams were used to determine the regulatory contaminants of concern and suspect contaminants. Figures 1 and 2 provide the decision logic diagrams for nonradiological, chemical substances and radiological substances, respectively. Inputs used in the decision diagrams include:

- Chemical and radiological substances used and/or released;
- Environmental sampling data;
- Regulatory limits and background concentrations; and
- Inventory and disposal records.

Suspect contaminants are contaminants that have been detected in environmental samples in the 100 Area at concentration levels below background concentrations or below regulatory limits. The suspect contaminant list identifies those contaminants for which subsequent data collection can confirm whether or not the contaminants are present in concentrations below regulatory concern. When subsequent data become available, the suspect contaminants would be re-evaluated via the decision logic at the input box entitled "Compile Environmental Sample Records" (see Figures 1 and 2).

Since the Phase I/II FS is divided by source, groundwater and N Area, the contaminants were differentiated on the basis of groundwater versus source (e.g., soil) operable unit contaminants. N Area contaminants were identified separately. Non-radiological (chemical) contaminants were identified separately from radiological contaminants.

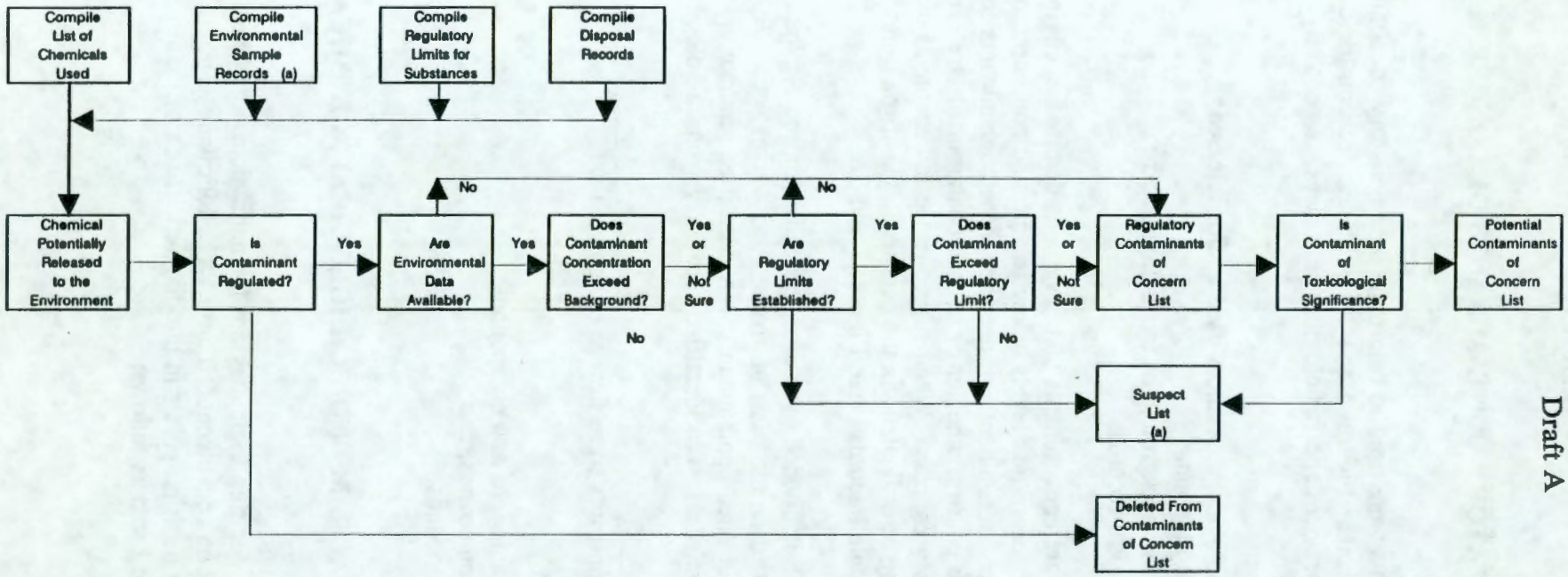
Nonradiological contaminants were further categorized as:

- Metals;
- Nonmetallic inorganic ions and compounds;
- Volatile organic compounds; and
- Other organic compounds.

3.1 DECISION LOGIC DIAGRAM - NONRADIOLOGICAL, CHEMICAL SUBSTANCES

Figure 1 provides the decision logic diagram for nonradiological, chemical substances (and their respective dissociation constituents, if any). The following sections explain each of the sequential steps and/or decision points in the diagram. Each of these points is numbered on the diagram and listed as follows:

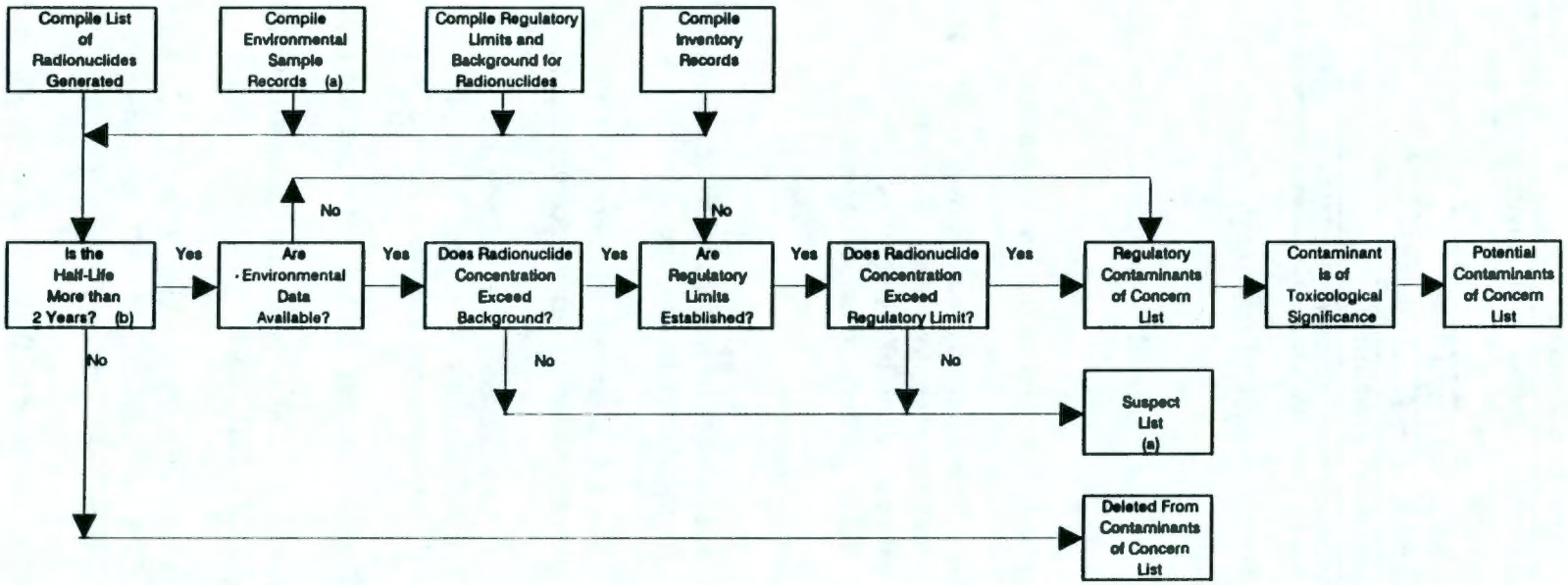
9 2 1 2 6 2 0 9 4 3



(a)Subsequently obtained data will require a re-evaluation of suspect contaminants.

FIGURE 1. DECISION LOGIC DIAGRAM - NONRADIOLOGICAL, CHEMICAL SUBSTANCES

RL/12-91/HJS/806.112/FIG1.XLS



(a) Subsequently obtained data will require a re-evaluation of suspect contaminants.
(b) Question not applicable to N-Area.

FIGURE 2. DECISION LOGIC DIAGRAM - RADIOLOGICAL SUBSTANCES

RL/12-91/HJS/806.112/FIG2.XLS

Diagram Description	Diagram Identifier
Chemical potentially released to the environment.	1
Is contaminant regulated?	2
Are environmental data available?	3
Does contaminant exceed background?	4
Are regulatory limits established?	5
Does contaminant exceed regulatory limit?	6

The final step, "Is contaminant of toxicological significance?", is addressed in Chapter 4.0 of this report.

Each step of Figure 1 is explained in more detail in the following subsections.

3.1.1 "Chemical Potentially Released to the Environment."

All nonradiological, chemical substances known to have been used in the 100 Area were considered as potentially released to the environment. That is, all chemical substances and constituents identified in the draft 100 Area work plans and the documents listed in Section 2.1 passed this step in the decision logic diagram.

3.1.2 "Is Contaminant Regulated?"

A chemical substance and/or its respective dissociation constituents was considered regulated if it is subject to or listed under any one of the following:

- Listed as a CERCLA hazardous substance (40 CFR §302.4). The statutory sources for the designation of a substance as hazardous under CERCLA include:
  - Clean Air Act and Amendments, Section 112
  - Clean Water Act Sections 307(a) and 311(b)(4)
  - Resource Conservation and Recovery Act (RCRA), Section 3001
- Subject to Toxic Substances Control Act regulation (40 CFR Part 761)
- Subject to National Oil and Hazardous Substances Pollution Contingency Plan guidelines (40 CFR Part 300)
- Listed as having a Primary Drinking Water Standard maximum contaminant level (MCL) (40 CFR §§141.61 and 141.62) under the Safe Drinking Water Act (SDWA) (42 U.S.C. 300f et seq.)
- Regulated under the State of Washington Model Toxics Control Act (MTCA) Cleanup Regulation (Chapter 173-340 Washington Administrative Code [WAC])

- Regulated under the State of Washington Ground Water Quality Standards (WAC 173-200).

Table AC-1, Appendix AC, lists all nonradiological, chemical contaminants known or suspected to have been released in the 100 Area. All substances used in the 100 Area have been assumed to have also been released and are, therefore, considered to be contaminants. The purpose of the table is to indicate pertinent federal and state environmental regulations applicable to the chemical substances.

In addition to substances used in the 100 Area, Table AC-1 also lists dissociation constituents for those substances that readily dissociate in the environment, e.g., acids and soluble salts.

For example, nitrate originating from nitric acid is considered as a distinct contaminant, as is chromium originating from sodium dichromate.

If the chemical substance or its dissociation constituent is regulated, it passes to the next decision point ("Are environmental data available?"). If not regulated, the contaminant is eliminated from further consideration as a regulatory contaminant of concern. Table AA-4, Appendix AA lists those contaminants which have been eliminated from further consideration on this basis.

3.1.3 "Are Environmental Data Available?"

If a contaminant is regulated, the next decision point utilizes information contained in the 100 Area work plans to determine whether or not environmental data exist for the contaminant. If environmental data for the contaminant do not appear in the work plans, the contaminant was considered a regulatory contaminant of concern because the concentration of that contaminant in the environment cannot be shown to be below background concentrations (diagram step 4) or regulatory limits (diagram step 5). If environmental data for the contaminant appear in the work plans, the contaminant passed to the next step in the logic diagram where environmental data were compared to established background concentration values.

3.1.4 "Does Contaminant Concentration Exceed Background?"

This step compares environmental sample concentration data to established background concentrations. If any sample concentration exceeded an established background concentration value, the contaminant was passed on to the next decision point (Are regulatory limits established?). If the contaminant concentration did not exceed an established background concentration value, the contaminant was classified as a suspect contaminant. Suspect contaminants are identified by the letter 'S' in the Appendix AA tables. Section 3.7 provides a discussion of background data.

9 2 1 2 6 2 0 9 4 7

The purpose of the suspect contaminant list is to retain the contaminants for re-evaluation pending future field data collection. The additional data would be incorporated into the input box entitled "Compile Environmental Sampling Records". The re-evaluation would be used to confirm whether or not the contaminant concentrations are of regulatory significance.

3.1.5 "Are Regulatory Limits Established?"

If the contaminant concentration exceeded an established background value or if the background level was not known, then a check was made to determine whether there are federal or state numerical limits established in the regulations. If there are no established regulatory limits, the contaminant was entered as a regulatory contaminant of concern. If there are established regulatory limits, contaminant concentrations were compared to those limits in the next step of the decision logic. Section 3.6 lists the regulations from which the numerical, regulatory limits were obtained.

3.1.6 "Does Contaminant Concentration Exceed Regulatory Limit?"

If there are numerical limits established in the regulations and the contaminant concentration exceeds the most restrictive of those limits, the contaminant was entered as a regulatory contaminant of concern. If there are established regulatory limits and the contaminant concentration is lower than the most restrictive regulatory limit, the contaminant was classified as a suspect contaminant. See Section 3.6 for further discussion of regulatory limits and Appendix AB for comparisons between contaminant concentrations and regulatory limits.

3.2 DECISION LOGIC DIAGRAM - RADIOLOGICAL CONTAMINANTS

All radiological contaminants known to have been generated in the 100 Area were potentially released to the environment and were subjected to the decision logic diagram for radiological constituents (Figure 2). The following subsections explain the sequential steps and decision points in the logic diagram for radionuclides.

3.2.1 "Is the Half-Life More than Two Years?"

Radioactive half-life was used as a decision criterion for all reactor areas except the N Area. Because operations in the N Area are more recent, half-lives were not used to eliminate radionuclides from further consideration for that area.

For the other reactor areas in the 100 Area, short-lived radionuclides (i.e., radionuclides with half-lives less than two years) are assumed to have decayed to concentrations well below the level of concern (Gloyna and Ledbetter 1969). That is, since it has been more than 20 years since the last reactor was shut down, the radionuclides would have undergone decay for at least 10 half-lives, which is sufficient to reduce concentration to

insignificant values. Therefore, these radionuclides are no longer considered in the contaminant of concern determination and were placed on Table A-4, Contaminants Eliminated from Further Consideration (see Appendix AA).

For N Area, all radionuclides were retained, since sufficient time has not yet elapsed for the short-lived radionuclides to have decayed.

3.2.2 "Are Environmental Data Available?"

This step follows the same approach as for chemical constituents.

3.2.3 "Does Radionuclide Concentration Exceed Background?"

This step follows the same approach as for chemical constituents.

3.2.4 "Are Regulatory Limits Established?"

This step follows the same approach as for chemical constituents, except that the federal regulations used for this step consist of the primary drinking water standards (40 CFR 141) and the environmental radiation protection standards for management and disposal of spent nuclear fuel, high-level and transuranic radioactive wastes (40 CFR 191, Radiation Protection Standards), as excerpted in the Westinghouse Hanford Company "Environmental Compliance Manual" (WHC-CM-7-5).

3.2.5 "Does Contaminant Concentration Exceed Regulatory Limit?"

This step follows the same approach as for the chemical constituents.

3.3 ESTIMATED RADIOLOGICAL INVENTORIES

Estimated operable unit radiological inventories are presented in Tables AB-1 and AB-6 (Appendix AB). These inventories are only presented for informational purposes, since the inventories were not used as a criterion for identifying regulatory radionuclide contaminants of concern. The radiological inventories were obtained from:

- Operable unit draft work plans (DOE 1990a-e; 1991a-f)
- "Radionuclide Inventory and Source Terms for the Surplus Production Reactors at Hanford" (Miller and Steffes, 1987)
- "Estimates of Solid Waste Buried in 100 Area Burial Grounds" (Miller and Wahlen, 1987)
- "Engineered-Facility Sites (HISS Data Base)" (Stenner et al., 1988a)

9 2 1 2 6 2 0 9 4 9

- "Unplanned-Release Sites (HISS Data Base)" (Stenner et al., 1988b)
- "Radiological Characterization of the Retired 100 Areas" (Dorian and Richards, 1978).

The estimated radiological inventories indicated in the Appendix AB tables represent data collected from 1978 through 1986. The radionuclide inventories used in this report were taken directly from the above listed sources of information and were not updated to account for radiological decay occurring since the inventories were last documented.

Radiological inventories are not available for all waste units within each operable unit and no attempt was made to estimate unavailable inventories. The inventories for each of the waste units were totaled to yield a single inventory value for an individual operable unit.

3.4 POTENTIAL RELEASES

Potential release or disposal data are presented in Tables AB-1 through AB-10 (Appendix AB) and are only provided for informational purposes. The potential release data were not used as a criterion for identifying regulatory contaminants of concern. That is, the decision logic assumed that all chemicals and radionuclides known to have been used in the 100 Area were considered as potentially released to the environment. The release and disposal information was obtained from:

- Operable unit draft work plans (DOE 1990a-e; 1991a-f)
- "Radionuclide Inventory and Source Terms for the Surplus Production Reactors at Hanford" (Miller and Steffes, 1987)
- "Estimates of Solid Waste Buried in 100 Area Burial Grounds" (Miller and Wahlen, 1987)
- "Engineered-Facility Sites (HISS Data Base)" (Stenner et al., 1988a)
- "Unplanned-Release Sites (HISS Data Base)" (Stenner et al., 1988b).

3.5 SAMPLE CONCENTRATION

A sample concentration column is included in the regulatory contaminants of concern tables (Tables AB-1 through AB-10, Appendix AB). This column contains a range of concentrations observed in groundwater or soil samples from the 100 Area for each listed contaminant, if such data exist. The range consists of a minimum and a maximum concentration and was derived from sampling data for all the listed operable units found to contain that contaminant.

9 2 1 2 6 5 2 0 9 5 0

Some of the concentrations shown did not exceed the regulatory limits or background levels. Additionally, environmental data are not available for many of the constituents. The environmental data were obtained from:

- Operable unit draft work plans (DOE 1990a-e; 1991a-f)
- "Treatability Investigation Work Plan for the 116-B-6A Crib ISV Demonstration Project" (Campbell et al., 1990)
- "Soil Sampling Test Results for 1324-N Pond" (Chou, 1989)
- "Radiological Status of the Ground Water Beneath the Hanford Site: January-December, 1981" (Eddy, et al., 1982)
- "Hanford Site Ground-Water Monitoring for January Through June 1988" (Evans, et al., 1989)
- "UNC Environmental Surveillance Report for the 100 Areas -- FY 1981" (Greager, 1981)
- "UNC Environmental Surveillance Report for the 100 Areas FY 1886" (Jacques, 1987)
- "Hanford Site Environmental Report for Calendar Year 1988" (Jacquish and Bryce [eds.], 1989)
- "Estimates of Solid Waste Buried in 100 Area Burial Grounds" (Miller and Wahlen, 1987).

9 2 1 2 6 2 0 9 5 1

3.6 REGULATORY LIMITS

Concentrations of contaminants from both groundwater and soil samples were compared to the most restrictive state or federal regulatory limit to identify regulatory contaminants of concern or suspect contaminants. Federal limits are available for a limited number of groundwater contaminants. State and federal regulatory limits were obtained from:

- "Washington Ground Water Quality Standards" (WAC 173-200)
- "The Model Toxics Control Act Cleanup Regulation" (WAC 173-340)
- Westinghouse Hanford Company "Environmental Compliance Manual" (limits taken from 40 CFR 191) (WHC-CM-7-5)

- Safe Drinking Water Act "Primary Drinking Water Rule" (maximum contaminants levels) (40 CFR 141).

The Model Toxics Control Act Cleanup Regulation (MTCA) was used to derive state regulatory limits for groundwater and soils for chemical constituents. Because the 100 Area is considered as an environmentally complex site, the Method B formulae were used to derive the state limits under MTCA.

In addition to limits derived by MTCA Method B, MTCA also may require consideration of the federal SDWA Secondary Drinking Water Standards (40 CFR 143) and the federal SDWA Drinking Water Standard maximum contaminant level goals (MCLGs) (40 CFR §141.50).

Maximum contaminant levels established by the Washington State Board of Health (Chapter 248-54 Washington Administrative Code [WAC]) are also required under MTCA, but are equal to or less stringent than the other regulatory limits required under MTCA.

If more than one state limit exists for a contaminant, the most restrictive state limit is presented in Appendix B tables. For example, arsenic has a more restrictive state groundwater limit (Washington Ground Water Quality Standards) (0.05 μg/L) than the MTCA Method B limit of 50 μg/L. Therefore, the Washington Ground Water Quality Standard for arsenic is given in the appropriate Appendix AB table.

In addition to currently codified SDWA MCLs, pending SDWA MCLs were utilized as federal regulatory limits in this report. The effective dates for the revised MCLs are as follows:

- Revised MCLs for cadmium, chromium, mercury, nitrate, and selenium will become effective on July 30, 1992

- The revised MCL for lead will become effective on December 7, 1991

- The revised MCL for barium will become effective on January 1, 1993.

If a numerical regulatory limit does not exist for the contaminant, then the contaminant was included by default as a regulatory contaminant of concern.

3.7 BACKGROUND CONCENTRATIONS

Established background concentrations given in the draft 100 Area work plans were compared to sample concentrations. Background concentration values are presented in Tables AB-1 through AB-10, Appendix AB and were obtained from:

- Operable unit draft work plans (DOE 1990a-e; 1991a-f)

- "Soil Sampling Test Results for 1324-N Pond" (Chou, 1989)
- "Status Report of Remedial Investigation of the Area 300 Process Ponds" (Dennison, et al., 1988)
- "Hanford Site Ground-Water Monitoring for April Through June 1987" (Evans, et al., 1988)
- "Hanford Site Ground-Water Monitoring for January through June 1988" (Evans et al., 1989)
- "Hanford Site Environmental Report for Calendar Year 1988" (Jacquish and Bryce (eds.), 1989)
- "Ground-Water Monitoring at the Hanford Site January-June 1988" (Pacific Northwest Laboratory, 1989)
- "Characterization and Use of Soil and Groundwater Background for the Hanford Site" (WHC, 1991).

3.8 DETECTION LIMITS

Detection limits vary over time due to the development of increasingly sensitive instruments and analytical methods. Detection limits for the groundwater and soil quality data reviewed in this report, if available, are shown in the detection limit column of the regulatory contaminants of concern tables. Detection limits are provided for information to help qualify data which are shown to be non-detect. The detection limits were obtained from:

- Operable unit draft work plans (DOE 1990a-e; 1991a-f)
- "Hanford Site Ground-Water Monitoring April through June 1987" (Evans et al., 1988)
- "Hanford Site Ground-Water Monitoring for January through June 1988" (Evans et al., 1989)
- "Hanford Site Ground Water Surveillance 1989" (Evans et al., 1990).

9 2 1 2 6 2 0 9 5 3

3.9 RESULTS AND CONCLUSIONS FOR REGULATORY CONTAMINANTS OF CONCERN

Table 1 provides a summary listing of the regulatory contaminants of concern and suspect contaminants. All contaminants listed as regulatory contaminants of concern are further evaluated for toxicological significance in Chapter 4.0, Qualitative Toxicity Assessment. The tables in Appendix AA provide additional detail regarding the regulatory contaminants as follows:

- Table AA-1 presents the regulatory contaminants of concern and suspect contaminants, sorted by operable unit, for all source operable units in the 100 Area, excluding N Area.

- Table AA-2 shows the regulatory contaminants of concern and suspect contaminants, sorted by operable unit, for all groundwater operable units in the 100 Area, excluding N Area.

- Table AA-3 gives the regulatory contaminants of concern and suspect contaminants for each of the N Area operable units.

- Table AA-4 lists the contaminants eliminated from further consideration based upon the regulatory analysis.

Tables AA-1 through AA-3 indicate the specific operable units for which a contaminant is either of concern or is suspect. However, care must be taken not to draw too many conclusions from these tables. Important qualifiers should be considered when evaluating these tables:

- Even though the tables indicate regulatory contaminants of concern and suspect contaminants by OU, the actual determination of these was not performed on an OU basis but on the 100 Area as a whole. For example, a contaminant may have qualified as a regulatory contaminant of concern because it exceeded background or the regulatory limit based on the highest concentration found in the 100 Area. In this case, the contaminant was listed as a regulatory contaminant of concern for each OU which reported that contaminant, even though the contaminant may not have exceeded background or regulatory limits in that OU. Thus, if a contaminant was listed as a regulatory contaminant of concern for a specific OU, it does not necessarily mean that this contaminant was actually found to be present in that OU in concentrations exceeding the levels of regulatory concern.

- The tables should be used for illustrative purposes to indicate the relative frequency of occurrence of a contaminant.

- The tables do not indicate which operable units must be remediated.

9 2 1 2 5 6 2 0 9 5 4

TABLE 1: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

POTENTIAL CONTAMINANT	ENVIRONMENTAL MEDIUM		
	SOURCES (E.G., SOILS)	GROUNDWATER	N-AREA
RADIONUCLIDES			
Tritium	C	C	C
Carbon-14	C	C	
Calcium-41	C	C	
Cobalt-60	C	C	C
Nickel-63	C	C	
Selenium-79	C	C	
Krypton-85	C	C	
Strontium-90	C	C	C
Zirconium-93	C	C	
Niobium-94	C	C	
Technetium-99	C	S	C
Palladium-107	C	C	
Cadmium-113	C	C	
Antimony-125		S	C
Iodine-129	C	C	C
Cesium-134	C		C
Cesium-137	C	S	C
Samarium-151	C	C	
Europium-152	C	C	
Europium-154	C	S	
Radium-226/228			C
Uranium-235/238	C	C	
Plutonium-238	C	C	C
Plutonium-239/240	C	C	C
Plutonium-241	C	C	
Americium-241	C	C	
METALS			
Aluminum	C		C
Arsenic	S	C	C
Barium	S	C	C

C = POTENTIAL CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

9 2 1 2 6 2 0 9 5 5

TABLE 1: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

POTENTIAL CONTAMINANT	ENVIRONMENTAL MEDIUM		
	SOURCES (E.G., SOILS)	GROUNDWATER	N-AREA
Beryllium	S	C	C
Boron	C	S	
Cadmium	S	C	C
Chromium	S	C	C
Cobalt		C	
Copper	S	S	
Iron	C		
Lead	C	C	C
Manganese	C	C	C
Mercury	S	C	
Nickel	S	S	S
Sodium	C	C	
Vanadium	C	S	C
Zinc	S	S	S
OTHER INORGANIC COMPOUNDS/IONS			
Ammonium/ Ammonia	C	S	
Asbestos	C	C	
Chloride	C	C	
Chlorine		C	
Cyanide	C	C	C
Fluoride	C	C	C
Hydrochloric Acid		C	
Nitrate	C	C	C
Nitrite	C	C	
Phosphoric Acid			C
Sulfate	C	C	C
VOCs			
Acetone	C	S	S
Benzene			C
Chlorobenzene			C
Chloroform	S	C	C

C = POTENTIAL CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

9 2 1 2 6 5 2 0 9 5 6

TABLE 1: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

POTENTIAL CONTAMINANT	ENVIRONMENTAL MEDIUM		
	SOURCES (E.G., SOILS)	GROUNDWATER	N-AREA
Ethylbenzene			C
Methylene Chloride	S		C
Methyl Isobutyl Ketone			C
Perchloro-ethylene	C	C	C
Toluene			S
Trans -1,2-Dichloroethene			C
1,1,1-Trichloro-ethane	S	S	
Trichloroethene	S	C	
Xylenes			C
OTHER ORGANICS			
Acetic Acid	C	C	
Bis (2-ethylhexyl) phthalate			C
Ethylenediamine	C	C	
Ethylenediamine tetraacetic acid (EDTA)	C	C	
Formic Acid	C	C	
Hydrazine	C	C	C
PCBs	C	C	C
Petroleum Products/Diesel oil	C		C
Tetraethylpyro-phosphate			C
Tetrahydrofuran			C
Thiourea	C	C	C

C = POTENTIAL CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

9 2 1 2 6 2 0 9 5 7

The first phase of the effort determined which of the radionuclide and chemical substances used in the 100 Area are of regulatory significance. However, while a contaminant may be of regulatory significance (such as based on CERCLA reportable quantities), it may not necessarily be of concern if the contaminant is not toxicologically significant as it exists in the environment. In the RI/FS process, contaminants are evaluated for toxicological significance by performing a toxicity assessment as part of a baseline risk assessment. Since this preliminary FS effort does not have the benefit of a completed baseline risk assessment, a second step is needed to at least qualitatively assess a contaminant's toxicity so as to arrive at a more realistic contaminant list for purposes of remedy assessment. This qualitative toxicity assessment step is the subject of Section 4.0 below.

4.0 QUALITATIVE TOXICITY ASSESSMENT

The qualitative toxicity assessment was performed on the regulatory contaminants identified in Section 3.0 of this report. Assumptions, methodology and results are described in the subsections below.

4.1 ASSUMPTIONS AND LIMITATIONS

The key assumptions and limitations regarding the qualitative toxicity assessment are listed as follows:

- The assessment only considered risk-based factors; compliance with applicable or relevant and appropriate requirements (ARARs) was not considered.

- Only regulatory contaminants of concern were assessed in the qualitative toxicity assessment; suspect contaminants were not assessed.

- Contaminants dropped as a result of the toxicity assessment are placed on the suspect list.

- Assumptions on carcinogenicity:

  - All radionuclides were assumed to be carcinogenic,
  - Carcinogens are defined by HEAST, Table B, or by IRIS as a Group A, B1, or B2 carcinogen,
  - Petroleum products are assumed to be carcinogenic because of benzene,
  - All carcinogens are assumed to be of toxicological significance and thus are potential contaminants of concern.

- Assumptions for toxicity screening hazard quotient calculation (noncarcinogens):

- The ingestion exposure route was assumed for all calculations (Equations 9 and 15 in EPA guidance).
- A hazard quotient of 0.1 was assumed for screening as recommended by EPA guidance.
- The equations utilized combine ingestion by both children and adults.
- Individual hazard quotients were calculated for each contaminant; cumulative effects were not considered.
- If an oral reference dose has not been established then the contaminant was placed on the suspect contaminants list.
- For noncarcinogens with an established oral reference dose: if no sampling data are available then the contaminant was assumed to be a potential contaminant of concern as the hazard quotient could not be computed.

4.2 DECISION LOGIC

The purpose of the decision logic for the qualitative toxicity assessment is to determine if the regulatory contaminants of concern are of toxicological significance. The decision logic for the qualitative toxicity assessment is diagrammed in Figure 3. The following sections explain each of the sequential steps and/or decision points in the diagram. Each of these points is numbered on the diagram and listed as follows:

Diagram Description	Diagram Identifier
"Known or suspected carcinogen?"	7
"Candidate for elimination per guidance?"	8
"Oral RfD in HEAST or IRIS?"	9
"Hazard Quotient greater than 0.1?"	10

4.2.1 "Known or suspected carcinogen?"

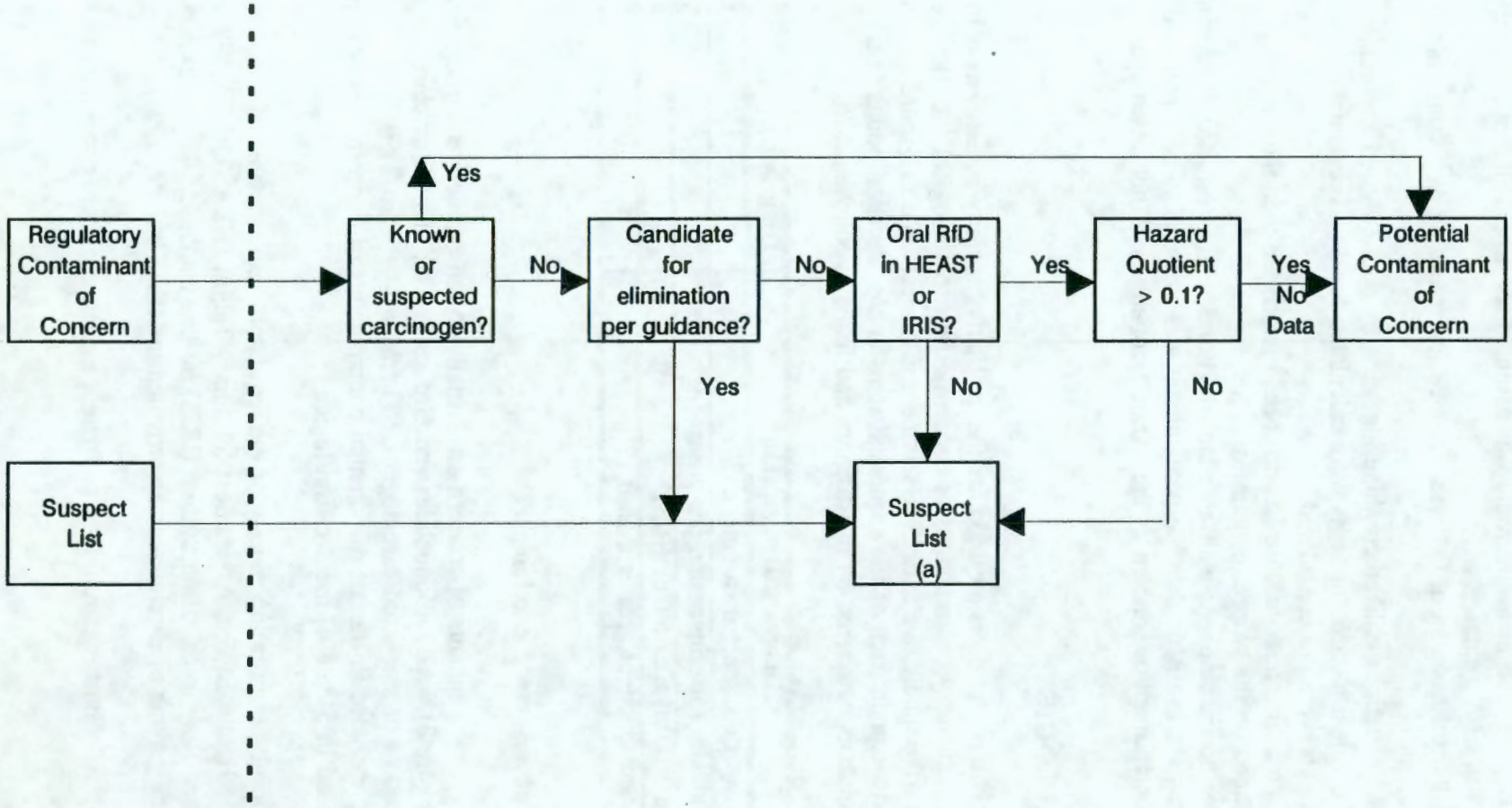
Regulatory contaminants of concern are initially sorted on the basis of carcinogenicity (see Step 7 of Figure 3). All radionuclides and Groups A, B1, and B2 carcinogens are assumed to be known or suspected carcinogens. Therefore, per step 7 of Figure 3, these contaminants are included in the list of potential contaminants of concern. Noncarcinogens are further assessed in Step 8 of the decision logic.

Information on the carcinogenicity of the regulatory contaminants of concern was obtained from the Health Effects Assessment Summary Tables (HEAST)(EPA 1991) and from the Integrated Risk Information System (IRIS) on-line database. The following are descriptions of the groups of carcinogens as provided in HEAST (EPA 1991):

- Group A - Human Carcinogen (sufficient evidence of carcinogenicity in humans).

9 2 1 2 6 2 0 9 5 9

Qualitative Toxicity Assessment: Is contaminant of toxicological significance?



(a) Subsequently obtained environmental data and/or toxicological data will require a re-evaluation of suspect contaminants. See Figures 1 and 2.

FIGURE 3. DECISION LOGIC DIAGRAM - QUALITATIVE TOXICITY ASSESSEMENT

RL/12-91/HJS/806.112/FIG3.XL

- Group B - Probable Human Carcinogen (B1 - limited evidence of carcinogenicity in humans; B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans).

4.2.2 "Candidate for elimination per guidance?"

Region X of the EPA has issued supplemental guidance for Superfund risk assessments. This guidance was also incorporated into the Hanford Site Baseline Risk Assessment Methodology document (DOE-RL 1991). The guidance states:

> "Six inorganic constituents which are often analyzed for but which are not associated with toxicity to humans under normal circumstances are aluminum, calcium, magnesium, potassium, iron and sodium. No quantitative toxicity information is available for these elements from EPA sources. These six elements can generally be eliminated from the human health risk assessment at the screening stage based on qualitative judgement." (EPA Region X 1991)

Noncarcinogenic, regulatory contaminants of concern were compared to this list of six to determine which are candidates for elimination from further consideration in the qualitative toxicity assessment. Contaminants thus eliminated were placed on the suspect contaminants list.

4.2.3 "Oral RfD in HEAST or IRIS?"

The next step in the qualitative toxicity assessment (Step 9) is to determine whether an oral reference dose (RfD) has been established for the contaminant. The IRIS database and HEAST were utilized as information sources for the reference doses. If an oral RfD has not been established, then the contaminant was placed on the suspect contaminants list. The supplemental guidance defines the RfD as "an estimate (with uncertainty spanning perhaps an order-or-magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" (EPA Region X 1991).

4.2.4 "Hazard Quotient greater than 0.1?"

The final step in the qualitative toxicity assessment was to compute a hazard quotient (HQ) for each of the remaining contaminants and to compare the HQ to a screening value. Standard default exposure factors, as established in the supplemental guidance, were utilized in the calculations. An ingestion route of exposure was assumed, therefore Equations 9 and 15 from the guidance were utilized for the calculations (EPA Region X 1991).

The supplemental guidance states that contaminants can be eliminated from further consideration in a risk assessment if the HQ is less than or equal to a screening value of 0.1 (EPA Region X 1991). The screening value has been conservatively set at 0.1 to account for the possibility of multiple pathways and multiple contaminants which might result in

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cumulative effects. As shown in Figure 3, contaminants with a HQ less than or equal to 0.1 were placed on the suspect contaminants list.

An HQ could not be computed for contaminants which do not have available sampling data. These contaminants were conservatively assumed to be potential contaminants of concern in this report. Subsequently obtained sampling data will require a re-evaluation at the input step labelled "Compile Environmental Sample Records" in Figures 1 and 2.

4.3 RESULTS OF THE QUALITATIVE TOXICITY ASSESSMENT

The tables in Appendix AE of this report outline how each of the regulatory contaminants of concern passed through the qualitative toxicity assessment decision logic. Table 2 in Section 5.0 below, presents the composite results after both the regulatory analysis and the toxicity assessment, i.e., the final list of potential contaminants of concern and suspect contaminants.

As indicated in Appendix AE, the following regulatory contaminants of concern were determined not to be of toxicological significance. That is, on Table 1 the contaminant is identified as a "C" (Regulatory Contaminant of Concern) but on Table 2 the contaminant is identified as a "S" (Suspect Contaminant) as a result of the toxicity assessment.

Soils, Sludges, and Sediments (Sources)
- aluminum
- iron
- sodium
- chloride
- sulfate
- ethylenediamine tetraacetic acid (EDTA).

Groundwater
- cobalt
- sodium
- chloride
- hydrochloric acid
- sulfate
- EDTA.

N Area
- aluminum
- sulfate
- tetraethylpyrophosphate
- tetrahydrofuran.

5.0 RESULTS AND CONCLUSIONS FOR POTENTIAL CONTAMINANTS OF CONCERN

The final list of potential contaminants of concern represents a composite of those that are both of regulatory and of toxicological significance. The final listing is given in Table 2 below. This list is generated for the purpose of assembling possible remedial alternatives. That is, the contaminants identified are those which are most likely to require remediation if subsequent field sampling programs and risk assessments show their concentrations in the environment to result in unacceptable risk and/or are not in compliance with ARARs. The list provided here should not be construed as representing any final determination or basis for decision-making regarding selection of final remedies.

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TABLE 2: POTENTIAL CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

POTENTIAL CONTAMINANT	ENVIRONMENTAL MEDIUM		
	SOURCES (E.G., SOILS)	GROUNDWATER	N-AREA
RADIONUCLIDES			
Tritium	C	C	C
Carbon-14	C	C	
Calcium-41	C	C	
Cobalt-60	C	C	C
Nickel-63	C	C	
Selenium-79	C	C	
Krypton-85	C	C	
Strontium-90	C	C	C
Zirconium-93	C	C	
Niobium-94	C	C	
Technetium-99	C	S	C
Palladium-107	C	C	
Cadmium-113	C	C	
Antimony-125		S	C
Iodine-129	C	C	C
Cesium-134	C		C
Cesium-137	C	S	C
Samarium-151	C	C	
Europium-152	C	C	
Europium-154	C	S	
Radium-226/228			C
Uranium-235/238	C	C	
Plutonium-238	C	C	C
Plutonium-239/240	C	C	C
Plutonium-241	C	C	
Americium-241	C	C	

C = POTENTIAL CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

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TABLE 2: POTENTIAL CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS (CONTINUED)

POTENTIAL CONTAMINANT	ENVIRONMENTAL MEDIUM		
	SOURCES (E.G., SOILS)	GROUNDWATER	N-AREA
METALS			
Aluminum	S		S
Arsenic	S	C	C
Barium	S	C	C
Beryllium	S	C	C
Boron	C	S	
Cadmium	S	C	C
Chromium	S	C	C
Cobalt		S	
Copper	S	S	
Iron	S		
Lead	C	C	C
Manganese	C	C	C
Mercury	S	C	
Nickel	S	S	S
Sodium	S	S	
Vanadium	C	S	C
Zinc	S	S	S
OTHER INORGANIC COMPOUNDS/IONS			
Ammonium/ Ammonia	C	S	
Asbestos	C	C	
Chloride	S	S	
Chlorine		C	
Cyanide	C	C	C
Fluoride	C	C	C
Hydrochloric Acid		S	
Nitrate	C	C	C
Nitrite	C	C	
Phosphoric Acid			C
Sulfate	S	S	S

C = POTENTIAL CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

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TABLE 2: POTENTIAL CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS (CONTINUED)

POTENTIAL CONTAMINANT	ENVIRONMENTAL MEDIUM		
	SOURCES (E.G., SOILS)	GROUNDWATER	N-AREA
VOCs			
Acetone	C	S	S
Benzene			C
Chlorobenzene			C
Chloroform	S	C	C
Ethylbenzene			C
Methylene Chloride	S		C
Methyl Isobutyl Ketone			C
Perchloro-ethylene	C	C	C
Toluene			S
Trans -1,2-Dichloroethene			C
1,1,1-Trichloro-ethane	S	S	
Trichloroethene	S	C	
Xylenes			C
OTHER ORGANICS			
Acetic Acid	C	C	
Bis (2-ethylhexyl) phthalate			C
Ethylenediamine	C	C	
Ethylenediamine tetraacetic acid (EDTA)	S	S	
Formic Acid	C	C	
Hydrazine	C	C	C
PCBs	C	C	C
Petroleum Products/Diesel oil	C		C
Tetraethylpyro-phosphate			S
Tetrahydrofuran			S
Thiourea	C	C	C

C = POTENTIAL CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

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WHC, See Westinghouse Hanford Company.

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APPENDIX AA
SUMMARY TABLES OF REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

TABLE AA-1: SOURCE OPERABLE UNITS: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

REFERENCES: 100-AREA DRAFT WORK PLANS; DORIAN AND RICHARDS, 1978

	OPERABLE UNIT													
CONTAMINANT	BC-1	BC-2	BC-3	BC-4	HR-1	HR-2	KR-1	KR-2	KR-3	DR-1	DR-2	DR-3	FR-1	FR-2
RADIONUCLIDES														
Tritium	C	C	C	C	C		C	C		C		C	C	C
Carbon-14				C				C						
Calcium-41							C							
Cobalt-60	C	C	C	C	C		C	C		C	C	C	C	C
Nickel-63	C	C		C	C		C			C		C		C
Selenium-79					C									
Krypton-85					C									
Strontium-90	C	C			C	C	C						C	C
Zirconium-93					C									
Niobium-94					C									
Technetium-99	C	C			C		C						C	
Palladium-107					C									
Cadmium-113					C									
Iodine-129							C							
Cesium-134					C						C			
Cesium-137	C	C		C	C	C	C			C			C	C
Samarium-151					C									
Europium-152	C	C		C	C	C	C	C		C		C	C	C
Europium-154	C	C		C	C	C	C			C		C	C	C

C = REGULATORY CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

TABLE AA-1: SOURCE OPERABLE UNITS: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS *(CONTINUED)*

	OPERABLE UNIT													
CONTAMINANT	BC-1	BC-2	BC-3	BC-4	HR-1	HR-2	KR-1	KR-2	KR-3	DR-1	DR-2	DR-3	FR-1	FR-2
RADIONUCLIDES														
Uranium-235/238					C		C			C				
Plutonium-238		C								C				
Plutonium-239/240	C	C			C		C			C			C	
Plutonium-241					C									
Americium-241					C		C							
METALS														
Aluminum					C									
Arsenic	S				S									
Barium	S				S									
Beryllium					S									
Boron				C										
Cadmium	S			S	S	S						S		S
Chromium	S	S			S		S			S	S		S	
Copper					S		S							
Iron		C												
Lead	C	C	C	C	C	C						C	C	C
Manganese					C					C				
Mercury	S		S	S			S							
Nickel	S				S								S	
Sodium	C	C												

C = REGULATORY CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

TABLE AA-1: SOURCE OPERABLE UNITS: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS *(CONTINUED)*

	OPERABLE UNIT													
CONTAMINANT	BC-1	BC-2	BC-3	BC-4	HR-1	HR-2	KR-1	KR-2	KR-3	DR-1	DR-2	DR-3	FR-1	FR-2
Vanadium										C			C	
Zinc	S				S									
OTHER INORGANIC COMPOUNDS/IONS														
Ammonium/Ammonia					C								C	
Asbestos		C												
Chloride		C												
Cyanide					C					C				
Fluoride	C	C			C					C			C	
Nitrate	C	C	C		C		C			C			C	
Nitrite					C									
Sulfate	C	C						C						
VOCs														
Acetone													C	
Chloroform					S									
Methylene Chloride													S	
Perchloroethylene					C									
1,1,1-Trichloro-ethane					S									
Trichloroethene													S	

C = REGULATORY CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

TABLE AA-1: SOURCE OPERABLE UNITS: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS *(CONTINUED)*

	OPERABLE UNIT													
CONTAMINANT	**BC-1**	**BC-2**	**BC-3**	**BC-4**	**HR-1**	**HR-2**	**KR-1**	**KR-2**	**KR-3**	**DR-1**	**DR-2**	**DR-3**	**FR-1**	**FR-2**
OTHER ORGANICS														
Acetic Acid					C									
Ethylenediamine					C									
Ethylenediamine tetraacetic acid (EDTA)					C									
Formic Acid					C									
Hydrazine					C									
PCBs	C	C					C							
Petroleum Products/Diesel oil	C						C							
Thiourea					C									

C = REGULATORY CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

TABLE AA-2: GROUNDWATER OPERABLE UNITS: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

REFERENCES: 100-AREA DRAFT WORK PLANS; DORIAN AND RICHARDS, 1978

CONTAMINANT	OPERABLE UNIT		
RADIONUCLIDES	BC-5	HR-3	KR-4
Tritium	C	C	C
Carbon-14	C		C
Calcium-41			C
Cobalt-60	C	C	C
Nickel-63	C	C	C
Selenium-79		C	
Krypton-85		C	
Strontium-90	C	C	C
Zirconium-93		C	
Niobium-94		C	
Technetium-99	S	S	S
Palladium-107		C	
Cadmium-113		C	
Antimony-125			S
Iodine-129			C
Cesium-137	S	S	S
Samarium-151		C	
Europium-152	C	C	C
Europium-154	S	S	S
Uranium-235/238		C	
Uranium-238		C	
Plutonium-238	C		
Plutonium-239/240	C		C
Plutonium-241		C	
Americium-241		C	C

C = REGULATORY CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

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TABLE AA-2: GROUNDWATER OPERABLE UNITS: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS *(CONTINUED)*

CONTAMINANT	OPERABLE UNIT		
METALS	BC-5	HR-3	KR-4
Arsenic		C	
Barium		C	
Beryllium		C	
Boron	S	S	S
Cadmium	C	C	
Chromium	C	C	C
Cobalt		C	
Copper		S	S
Lead	C	C	C
Manganese		C	
Mercury	C	C	C
Nickel		S	
Sodium	C	C	
Vanadium		S	
Zinc		S	S
OTHER INORGANIC COMPOUNDS/IONS	BC-5	HR-3	KR-4
Ammonium/Ammonia		S	
Asbestos	C		
Chloride		C	
Chlorine	C	C	
Cyanide		C	
Fluoride		C	
Hydrochloric Acid		C	
Nitrate	C	C	C
Nitrite		C	

C = REGULATORY CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

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TABLE AA-2: GROUNDWATER OPERABLE UNITS: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS *(CONTINUED)*

CONTAMINANT	OPERABLE UNIT		
Sulfate	C	C	C
VOLATILE ORGANIC COMPOUNDS	BC-5	HR-3	KR-4
Acetone	S		
Chloroform		C	
Percholethlyene (Tetrachloroethene, Tertachloroethlyene)		C	
1,1,1-Trichloroethane		S	
Trichloroethene	C	C	
OTHER ORGANICS	BC-5	HR-3	KR-4
Acetic Acid		C	
Ethylenediamine		C	
Ethylenediamine tetreacetic Acid		C	
Formic Acid		C	
Hydrazine		C	
PCBs	C		C
Thiourea		C	

C = REGULATORY CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

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TABLE AA-3: 100-N AREA: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS

REFERENCES: 100-AREA DRAFT WORK PLANS;
DORIAN AND RICHARDS, 1978.

CONTAMINANT	OPERABLE UNIT	
RADIONUCLIDES	NR-1	NR-2
Tritium	C	
Cobalt-60	C	
Strontium-90	C	
Technetium-99	C	
Antimony-125	C	
Iodine-129	C	
Cesium-134	C	
Cesium-137	C	S
Radium-226/228	C	
Plutonium-238	C	
Plutonium-239/240	C	
METALS	NR-1	NR-2
Aluminum	C	
Arsenic	C	
Barium	C	
Beryllium	C	
Cadmium	C	
Chromium	C	
Lead	C	
Manganese	C	C
Nickel	S	
Vanadium	C	C
Zinc	S	
INORGANIC COMPOUNDS/IONS	NR-1	NR-2
Cyanide	C	
Fluoride	C	

C = REGULATORY CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

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TABLE AA-3: 100-N AREA: REGULATORY CONTAMINANTS OF CONCERN AND SUSPECT CONTAMINANTS *(CONTINUED)*

CONTAMINANT	OPERABLE UNIT	
Nitrate	C	
Phosphoric Acid	C	
Sulfate	C	
VOLATILE ORGANIC COMPOUNDS	NR-1	NR-2
Acetone	S	
Benzene	C	
Chlorobenzene	C	
Chloroform	C	C
Trans-1,2-dichloroethene	C	
Ethylbenzene	C	
Methyl isobutyl ketone	C	
Methylene Chloride	C	C
Perchloroethlyene (Tetrachloroethene, Tetrachloroethylene)	C	
Toluene	S	S
Xylenes	C	
OTHER ORGANICS	NR-1	NR-2
Bis(2-ethylhexyl) phthalate	C	C
Hydrazine	C	
PCBs	C	
Petroleum Products, Diesel Oil, etc.	C	
Tetraethylpyrophosphate	C	
Tetrahydrofuran	C	
Thiourea	C	

C = REGULATORY CONTAMINANT OF CONCERN
S = SUSPECT CONTAMINANT

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TABLE AA-4: CONTAMINANTS ELIMINATED FROM FURTHER CONSIDERATION

Radionuclides Chromium-51 Manganese-54 Zinc-65 Ruthenium-103 Ruthenium-106 Iodine-131 Cerium-144 Europium-155	**Volatile Organic Compounds** Hexane	
Metals Calcium Lithium Magnesium Molybdenum Palladium Potassium Silicon Strontium Titanium Zirconium	**Nonvolatile Organic Compounds** Choline Chloride Citric Acid Citric Acid Solutions, Ammoniated Cyclotetrasiloxane, octomethyl Deoxylcholic Acid Diethanolamine Diethylthiourea Mercaptoacetic Acid Morpholine Oxalic Acid Sodium Acetate Sodium Citrate Sodium EDTA Sodium Formate Sodium Oxalate Trichloroacetic Acid Urea	
Inorganic Compounds Ammonium Monohydrogen Orthophosphate Ammonium Ceric Sulfate Ammonium Hydrogen Fluoride Ammonium Persulfate Boric Acid Ferric Oxide Graphite Hydrobromic Acid Hydroiodic Acid	Hydrogen Peroxide Hydrophosphorous Acid Lithium Fluoride Monohydrogen Orthoarsenate Perchloric Acid Peroxide Phosphomolybdic Acid Phosphorous Pentoxide Potassium Borate Potassium Chloride Potassium Nitrate	Sodium Aluminate Sodium Carbonate Sodium Chloride Sodium Hydrosulfite Sodium Hydroxide Sodium Hydrophosphite Sodium Nitrate Sodium Sulfamate Sodium Sulfate Sodium Sulfite Sulfamic Acid

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APPENDIX AB
REGULATORY CONTAMINANTS OF CONCERN
ENVIRONMENTAL SAMPLING DATA

TABLE AB-1: GROUNDWATER RADIONUCLIDE DATA

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SAMPLE QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCEN-TRATION[J] RANGE (pCi/L)	SOURCE[K]
			SAMPLE TYPE	SAMPLE CONCENTRA-TION RANGE[E,F] (pCi/L)	DETECTION LIMIT[G] RANGE (pCi/L)	STATE LIMIT[H] (pCi/L)	FEDERAL LIMIT[I] (pCi/L)		
Tritium	BC-1[L,M], BC-2[L,M], BC-3[L,M], BC-4[L,M], BC-5[L,M], DR-1, DR-3 FR-1, FR-2, HR-1, HR-3, KR-1, KR-2, KR-4, NR-1	Tritium [0.208 - 11,000] (BC-1, BC-2, BC-3, BC-4, BC-5, DR-1, DR-3, FR-1, FR-2, HR-1, HR-3, KR-1 KR-2, KR-4, NR-1) (DR-2 Operable Unit contains an inventory less than one Curie)	Well, Seeps	500 - 459,000	500	20,000 (Washington State Ground Water Quality Standards)	20,000[N] (Primary Drinking Water Limit)	200	1,3,4
Carbon-14	BC-4, BC-5, KR-2, KR-4	Carbon-14 [0.056 - 220] (BC-4, BC-5 KR-2, KR-4) (DR-1, HR-1, KR-1 Operable Units contain inventories less than one Curie)	Well	NA[O]	NA	NA	2800 (DOE Order 5400.5)	NA	1,2
Calcium-41	KR-1, KR-4	Used in Operable Unit KR-1, KR-4	NA	NA	NA	NA	4000 (DOE Order 5400.5)	NA	1,3,4

See footnote key at end of table.

TABLE AB-1: GROUNDWATER RADIONUCLIDE DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SAMPLE QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCEN-TRATION[J] RANGE (pCi/L)	SOURCE[K]
			SAMPLE TYPE	SAMPLE CONCENTRA-TION RANGE[E,F] (pCi/L)	DETECTION LIMIT[G] RANGE (pCi/L)	STATE LIMIT[H] (pCi/L)	FEDERAL LIMIT[I] (pCi/L)		
Cobalt-60	BC-1, BC-2, BC-3, BC-4, BC-5, FR-1, FR-2, DR-1, DR-2, DR-3, HR-1, HR-3, KR-1, KR-2, KR-4, NR-1[M]	Cobalt-60 [1.01128 - 767.3] (BC-1, BC-2, BC-3, BC-4, BC-5, FR-1, FR-2, DR-1, DR-2, DR-3, HR-1, HR-3, KR-1, KR-2, KR-4, NR-1)	Well, Seeps	22.5 - 554	22.5	NA	200 (DOE Order 5400.5)	NA	1,2,3
Nickel-63	BC-1, BC-2, BC-4, BC-5, DR-1, DR-3, FR-2, HR-1, HR-3, KR-1, KR-4	Nickel-63 [16 - 144.2] (BC-1, BC-2, BC-4, BC-5, DR-1, DR-3, FR-2, HR-1, HR-3, KR-1, KR-4)	NA	NA	NA	NA	12,000 (DOE Order 5400.5)	NA	1,2
Selenium-79	HR-1, HR-3	Used in Operable Unit HR-1, HR-3	NA	NA	NA	NA	800 (DOE Order 5400.5)	NA	1,3,4
Krypton-85	HR-1, HR-3	Used in Operable Unit HR-1, HR-3	NA	NA	NA	NA	NA	NA	1,3,4

See footnote key at end of table.

TABLE AB-1: GROUNDWATER RADIONUCLIDE DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SAMPLE QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCEN-TRATION[J] RANGE (pCi/L)	SOURCE[K]
			SAMPLE TYPE	SAMPLE CONCENTRA-TION RANGE[E,F] (pCi/L)	DETECTION LIMIT[G] RANGE (pCi/L)	STATE LIMIT[H] (pCi/L)	FEDERAL LIMIT[I] (pCi/L)		
Strontium-90	BC-1, BC-2, BC-5, FR-1, FR-2, HR-1, HR-2, HR-3, KR-1, KR-2[M,N], KR-4[M,N], NR-1[M,N]	Strontium-90 [0.35884 - 22.1] (BC-1, BC-2, BC-5, FR-1, FR-2, HR-1, HR-2, HR-3, KR-1, KR-4) (BC-4, BC-5, DR-1, DR-2 Operable Units contain inventories less than one Curie)	Well, Seeps	5 - 23,400	5 - 8	8 (Washington State Ground Water Quality Standards)	8[N] (Primary Drinking Water Standard)	236 ± 102	1,2,3
Zirconium-93	HR-1, HR-3	Used in Operable Unit HR-1, HR-3	NA	NA	NA	NA	3600 (DOE Order 5400.5)	NA	1,3,4
Niobium-94	HR-1, HR-3	Used in Operable Unit HR-1, HR-3	NA	NA	NA	NA	1200 (DOE Order 5400.5)	NA	1,3,4
Palladium-107	HR-1, HR-3	Used in Operable Unit HR-1, HR-3	NA	NA	NA	NA	40,000 (DOE Order 5400.5)	NA	1,3,4
Cadmium-113	HR-1, HR-3	Used in Operable Unit HR-1, HR-3	NA	NA	NA	NA	32 (DOE Order 5400.5)	NA	1,3,4
Iodine-129	KR-1, KR-4, NR-1	Used in Operable Units KR-1, NR-1	NA	NA	NA	NA	20 (DOE Order 5400.5)	NA	1,3,4

See footnote key at end of table.

TABLE AB-1: GROUNDWATER RADIONUCLIDE DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SAMPLE QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCEN-TRATION[J] RANGE (pCi/L)	SOURCE[K]
			SAMPLE TYPE	SAMPLE CONCENTRA-TION RANGE[E,F] (pCi/L)	DETECTION LIMIT[G] RANGE (pCi/L)	STATE LIMIT[H] (pCi/L)	FEDERAL LIMIT[H] (pCi/L)		
Cesium-134	NR-1	Cesium-134 [0.00001 - 14] (NR-1) (BC-1, DR-1, DR-2, HR-1, KR-1 Operable Units contain inventories less than one Curie)	NA	NA	NA	NA	80 (DOE Order 5400.5)	NA	1,3,4
Samarium-151	HR-1, HR-3	Used in Operable Unit HR-1, HR-3	NA	NA	NA	NA	16,000 (DOE Order 5400.5)	NA	1,3,4
Europium-152	BC-1 BC-2[M], BC-4, BC-5[M], DR-1, DR-3, FR-1[M], FR-2, HR-1, HR-2, HR-3, KR-1, KR-2, KR-4	Europium-152 [0.02285 - 729.57] (BC-1, BC-2, BC-4, DR-1, DR-3, FR-1, FR-2, HR-1, HR-2, HR-3, KR-1, KR-2, KR-4) (DR-2 Operable Unit contains inventory less than one Curie)	Well	6.7×10^{-1} - 1.3×10^{3}	NA	NA	800 (DOE Order 5400.5)	NA	1,2,3

See footnote key at end of table.

TABLE AB-1: GROUNDWATER RADIONUCLIDE DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SAMPLE QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCEN-TRATION[J] RANGE (pCi/L)	SOURCE[K]
			SAMPLE TYPE	SAMPLE CONCENTRA-TION RANGE[E,F] (pCi/L)	DETECTION LIMIT[G] RANGE (pCi/L)	STATE LIMIT[H] (pCi/L)	FEDERAL LIMIT[I] (pCi/L)		
Radium-226/228	NR-1	Used in Operable Unit NR-1	NA	NA	0.2	5 (Washington State Ground Water Quality Standards)	4 (DOE Order 5400.5)	0.2	1,3,4
Uranium-235/238	DR-1[M], HR-3	Uranium (Unspecified) [0.04343 - 0.321991] (BC-1, BC-2, FR-1, KR-1, HR-1 Operable Units contain inventory ranges less than one Curie)	Well	0.156 - 414	NA	NA	24 (DOE Order 5400.5)	NA	1,3
Uranium-238	HR-3[M]	Uranium-238 [0.024 - 0.0905] (BC-1, BC-5 Operable Units contain inventory ranges less than one Curie)	Well	3.1×10^{-1} - 66	0.5	NA	24 (DOE Order 5400.5)	NA	1,3

See footnote key at end of table.

TABLE AB-1: GROUNDWATER RADIONUCLIDE DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SAMPLE QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCEN-TRATION[J] RANGE (pCi/L)	SOURCE[K]
			SAMPLE TYPE	SAMPLE CONCENTRA-TION RANGE[E,F] (pCi/L)	DETECTION LIMIT[G] RANGE (pCi/L)	STATE LIMIT[H] (pCi/L)	FEDERAL LIMIT[I] (pCi/L)		
Plutonium-238	BC-2[AB], BC-5, NR-1	Plutonium-238 [0.005 - 420.195] (BC-2, NR-1) (BC-1, BC-5, DR-1, HR-1, KR-1, Operable Units contain inventory ranges less than one Curie)	Well, Seeps	2.3×10^{-3} - 1.9×10^{1}	NA	NA	1.6 (DOE Order 5400.5)	NA	1,3
Plutonium-239/240	BC-1, BC-2, BC-5, FR-1[AB] KR-1, KR-4, NR-1	Plutonium-239/240 [3.4×10^{-3} - 20.6] (BC-1, BC-2, BC-5, KR-1, KR-4, NR-1) (BC-5, DR-1, DR-2, FR-1, FR-2, HR-1, KR-2, KR-4 Operable Units contain inventory ranges less than one Curie)	Well, Seeps	5.8×10^{-3} - 110	NA	NA	1.2 (DOE Order 5400.5)	NA	1,3
Plutonium-241	HR-1, HR-3	Used in Operable Unit HR-1, HR-3	NA	NA	NA	NA	80 (DOE Order 5400.5)	NA	1,3,4
Americium-241	HR-1, HR-3, KR-1, KR-4	Used in Operable Unit HR-1, HR-3, KR-1	NA	NA	NA	NA	1.2 (DOE Order 5400.5)	NA	1,3,4

See footnote key at end of table.

TABLE AB-1: GROUNDWATER RADIONUCLIDE DATA FOOTNOTE KEY

[A] Only indicates inventory in greater than Curie quantities.

[B] Inventory range (in brackets) includes the minimum and maximum inventories for the listed operable units (in parentheses). For a single operable unit, the inventories for each waste unit within that operable unit were totaled to generate a single value.

[C] Inventories are not available for all the waste units.

[D] Radionuclide concentration has not been decayed to the present.

[E] Range includes the minimum and maximum concentrations in picoCuries per liter (pCi/L) found in water samples for the listed operable unit(s). Evaluated groundwater data collected between 1978 and 1986.

[F] Concentration based on both filtered and unfiltered samples.

[G] A single value indicates the minimum detection limit in picoCuries per liter (pCi/L) for all the groundwater quality detection limit concentrations in pCi/L for all the groundwater quality data reviewed.

[H] Most restrictive concentration in picoCuries per liter (pCi/L) which was obtained from the Washington Ground Water Quality Standards.

[I] Most restrictive concentration, in picoCuries per liter (pCi/L), which was obtained from the federal water quality standards 40 CFR 141 or DOE Order 5400.5 (DOE, 1990). Enforcement limits may exceed these values when the natural groundwater quality exceeds the criteria or when other exceptions contained in WAC 173-200-050(3)(b) apply.

[J] Background concentration in picoCuries per liter (pCi/L) from Pacific Northwest Laboratory, 1989; and Evans et al., 1989.

[K] Information source codes:

1. 100-Area Work Plans, in progress
2. Dorian and Richards, 1978
3. Stenner et al., 1988a,b
4. Miller and Wahlen, 1987

[L] Present in concentrations above state and/or federal limits.

[M] Present in concentrations above Hanford site background concentrations.

[N] The average annual concentration assumed to produce a total body or organ dose of 4 mrem/year.

[O] NA = Not Available

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TABLE AB-2: GROUNDWATER METALS DATA

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	GROUNDWATER QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCENTRATION [G] (µg/L)	SOURCE [H]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[B,C] RANGE (µg/L)	DETECTION LIMIT[D] (µg/L)	STATE LIMIT[E] (µg/L)	FEDERAL LIMIT[F] (µg/L)		
Arsenic	FR-1[I,J], HR-1, HR-3, NR-1	Arsenic (HR-1, HR-3) Used in Operable units FR-1, NR-1	Well	5 - 10	0.2	0.05 (Washington State Ground Water Standards)	50 (Primary Drinking Water Limit)	3.9 ± 2.4	1
Beryllium	HR-1, HR-3 NR-1	Beryllium (NR-1) Beryllium Sulfate (HR-1, HR-3)	NA[K]	NA	0.3	80 (Model Toxics Control Act - Method B)	NA	0.3	1
Barium	FR-1, HR-1, HR-3, NR-1, NR-2	Barium (FR-1, HR-1, HR-3, NR-1, NR-2) Barium Perchlorate (HR-1)	Well	11-1010	6	800 (Model Toxics Control Act - Method B)	2000 (Primary Drinking Water Limit)	42 ± 20	1
Cadmium	BC-2, BC-4 BC-5, DR-3 FR-1, FR-2 HR-1, HR-2 HR-3 NR-1[I,J] NR-2	Cadmium (BC-2, BC-4, BC-5, DR-3, FR-1, FR-2, HR-1, HR-2, HR-3, NR-1, NR-2)	Well	2 - 103	0.2	0.5 (Model Toxics Control Act - Method B, MCLG)	5 (Primary Drinking Water Limit)	< 0.2	1,3

See footnote key at end of table.

TABLE AB-2: GROUNDWATER METALS DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	GROUNDWATER QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCENTRATION[G] (µg/L)	SOURCE[H]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[B,C] RANGE (µg/L)	DETECTION LIMIT[D] (µg/L)	STATE LIMIT[E] (µg/L)	FEDERAL LIMIT[F] (µg/L)		
Chromium	BC-1, BC-2 BC-5[E,J] DR-1[E,J] DR-2 FR-1[E,J] HR-1 HR-3[E,J] KR-1 KR-4[E,J] NR-1	Chromium (BC-2, BC-5, DR-1, FR-1, HR-1, HR-3, KR-4, NR-1) Chromic Acid (BC-1, BC-2) Used in BC-5, DR-1, HR-1) Sodium Dichromate (BC-1, BC-2, BC-5, DR-1, DR-2, FR-1, HR-1, KR-1) Potassium Dichromate was used in HR-1	Well	< 10 - 1690	2 - 10	50 (Washington State Ground Water Standards)	100 (Primary Drinking Water Limit)	4.0 ± 2.0	1,3
Cobalt	HR-1, HR-3	Cobalt (HR-1, HR-3)	NA	NA	NA	NA	NA	NA	1
Lead	BC-2, BC-4 BC-5, DR-3 FR-2, HR-1 HR-2, KR-4 HR-3[E,J] NR-1	Lead (BC-2, BC-4, BC-5, DR-3, FR-2, HR-1, HR-2, HR-3, KR-4, NR-1) Lead Acetate Battery Fluid (NR-1) Lead Cadmium Poison Slugs (BC-4, DR-3, FR-2, HR-2)	Well	26	0.5	22.4 (Model Toxics Control Act - Method B)	50	< 0.5	1,3,4

See footnote key at end of table.

TABLE AB-2: GROUNDWATER METALS DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	GROUNDWATER QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCENTRATION [G] (µg/L)	SOURCE [H]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[B,C] RANGE (µg/L)	DETECTION LIMIT[D] (µg/L)	STATE LIMIT[E] (µg/L)	FEDERAL LIMIT[F] (µg/L)		
Manganese	FR-1, HR-1 HR-3, NR-1 NR-2	Manganese (HR-1, HR-3) Used in FR-1, NR-1, NR-2	Well	6 - 4380	5	50 (Washington State Ground Water Standards)	NA	7.0 ± 5.0	1,3,4
Mercury	BC-2, BC-4 BC-5, HR-1 HR-3, KR-4	Mercury (BC-2, BC-4, BC-5, KR-4) Mercury Chloride (HR-1, HR-3) Mercuric Nitrate used in HR-1	NA	NA	0.1	2 (Washington State Ground Water Standards)	2 (Primary Drinking Water Limit)	< 0.1	1,3

See footnote key at end of table.

TABLE AB-2: GROUNDWATER METALS DATA FOOTNOTE KEY

[A] Operable unit(s) where contaminant is considered a contaminant of concern. Information in parentheses indicates the operable units(s) which received the waste constituent in greater than one kilogram quantities. Also given are operable unit(s) in which the contaminant was used in unknown quantities.

[B] Range includes the minimum and maximum concentrations in micrograms per liter (μg/L) for the listed operable units. Evaluated ground water data was collected between 1978 and 1986.

[C] Concentration based on filtered samples.

[D] Range includes the minimum and maximum detection limit concentrations in micrograms per liter (μg/L) for all the groundwater quality data reviewed.

[E] Most restrictive concentration, in micrograms per liter (μg/L), which was obtained from the Washington Ground Water Quality Standards or was obtained in the Model Toxics Control Act Cleanup Regulation using Method B. Where the Washington Groundwater Quality Standards are the most restrictive, enforcement limits may exceed these values when the natural groundwater quality exceeds the criteria or when other exceptions contained in WAC 173-200-050(3)(b) apply.

[F] Concentration, in micrograms per liter (μg/L), which was obtained from drinking water regulation 40 CFR 141.

[G] Background concentration for the Hanford site, in micrograms per liter (μg/L), from Pacific Northwest Laboratory, 1989, and Evans et al., 1989.

[H] Information source codes:

1. 100-Area Work Plans, in progress
2. Dorian and Richards, 1978
3. Stenner et al., 1988a,b
4. Miller and Wahlen, 1987

[I] Present in groundwater above state and federal standards.

[J] Present in groundwater above Hanford site background concentrations.

[K] Not available.

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TABLE AB-3: GROUNDWATER NONMETALLIC IONS/COMPOUNDS DATA

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	GROUNDWATER QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCENTRATION[F] (µg/L)	SOURCE[G]
			SAMPLE TYPE	SAMPLE CONCENTRATION RANGE[B,C] (µg/L)	DETECTION LIMIT[D] (µg/L)	STATE LIMIT[E] (µg/L)	FEDERAL LIMIT (µg/L)		
Asbestos	BC-2, BC-5	Asbestos used in (BC-2, BC-5)	NA[H]	NA	NA	NA	7[I] (Primary Drinking Water Limit)	NA	1
Chloride	FR-1, HR-1, HR-3, FR-2	Aluminum Chloride (HR-1) Mercuric Chloride (HR-1, HR-3) Nickel Chloride (HR-1, HR-3) Potassium Chloride (FR-2) Sodium Chloride (HR-1, HR-3) Chlorine (HR-1) Used in BC-2 Perchloric Acid (HR-1, HR-3) Hydrochloric Acid (HR-1, HR-3) Used in BC-2, DR-1	NA	NA	500	250,000 (Washington State Ground Water Quality Standards)	NA	10,300 ± 6,500	1
Chlorine	BC-2, BC-5, HR-1, HR-3	Chlorine (HR-1, HR-3) Used in BC-2	NA	NA	NA	NA	NA	NA	1

See footnote key at end of table.

TABLE AB-3: GROUNDWATER NONMETALLIC IONS/COMPOUNDS DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	GROUNDWATER QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCENTRATION[F] (µg/L)	SOURCE[G]
			SAMPLE TYPE	SAMPLE CONCENTRATION RANGE[B,C] (µg/L)	DETECTION LIMIT[D] (µg/L)	STATE LIMIT[E] (µg/L)	FEDERAL LIMIT (µg/L)		
Cyanide	HR-1, HR-3	Cupric Cyanide Used in HR-1 Cyanide (HR-1, HR-3) Potassium Cyanide Used in HR-1 Sodium Cyanide Used in HR-1	NA	NA	10	320 (Model Toxics Control Act - Method B)	NA	< 10	1
Fluoride	DR-1, FR-1, HR-1, HR-3[H], NR-1	Fluoride (DR-1, FR-1, HR-3) Floride Test Solution (NR-1) Ammonium Fluoride (HR-1) Ammonium Hydrogen Fluoride (HR-1) Sodium Fluoride (HR-1)	Well	1300-2950	500	2,000 (Model Toxics Control Act - Method B) (Secondary Drinking Water Limit)	4000 (Primary Drinking Water Limit)	370 ± 100	1
Hydrochloric Acid	HR-1, HR-3	Hydrochloric Acid (HR-1, HR-3)	NA	NA	NA	NA	NA	NA	1

See footnote key at end of table.

TABLE AB-3: GROUNDWATER NONMETALLIC IONS/COMPOUNDS DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	GROUNDWATER QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCENTRATION[F] (µg/L)	SOURCE[G]
			SAMPLE TYPE	SAMPLE CONCENTRATION RANGE[B,C] (µg/L)	DETECTION LIMIT[D] (µg/L)	STATE LIMIT[E] (µg/L)	FEDERAL LIMIT (µg/L)		
Nitrate	BC-1, BC-5[J], DR-1, FR-1, HR-1, HR-3, KR-1, KR-4[J], NR-1	Aluminum Nitrate (HR-1) Nitric Acid (HR-1) Nitrate (BC-1, DR-1, FR-1, HR-3, KR-1, NR-1) Sodium Nitrate (HR-1)	Well	86 - 1,020,000	500	10,000 (Washington State Ground Water Quality Standards)	10,000 (Primary Drinking Water Limit)	NA	1
Nitrite	HR-1, HR-3	Nitrite (HR-1, HR-3)	NA	NA	NA	1,000 (Model Toxics Control Act - Method B, MCLG)	1,000 (Primary Drinking Water Limit)	NA	1
Phosphoric Acid	FR-2, NR-1	Phosphoric Acid (FR-2, NR-1)	NA	NA	NA	NA	NA	NA	1

See footnote key at end of table.

TABLE AB-3: GROUNDWATER NONMETALLIC IONS/COMPOUNDS DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	GROUNDWATER QUALITY DATA			REGULATORY CRITERIA		PRELIMINARY BACKGROUND CONCENTRATION[F] (µg/L)	SOURCE[G]
			SAMPLE TYPE	SAMPLE CONCENTRATION RANGE[B,C] (µg/L)	DETECTION LIMIT[D] (µg/L)	STATE LIMIT[E] (µg/L)	FEDERAL LIMIT (µg/L)		
Sulfate	BC-1, BC-2 BC-5, HR-1, HR-3, KR-1, KR-4, NR-1	Sulfate (FR-1, NR-1) Aluminum Sulfate (FR-1, HR-1) Ammonium Sulfate (HR-1) Cypric Sulfate (HR-1, KR-1) Ferric Sulfate Used in HR-1 Ammonium Ceric Sulfate (HR-1) Nickel Sulfate (HR-1) Sodium Sulfate (HR-1) Sulfuric Acid (BC-1, BC-2, NR-1) Used in FR-1, KR-1	Well	14 - 2,180,000	500	250,000 (Model Toxics Control Act - Method B, Secondary Drinking Water Limit)	NA	34,300 ± 16,900	1

See footnote key at end of table.

TABLE AB-3: GROUNDWATER NONMETALLIC IONS/COMPOUNDS DATA - FOOTNOTE KEY

[A] Operable unit(s) where contaminant is considered a contaminant of concern. Information in parentheses indicates the operable units(s) which received waste constituent in greater the one kilogram quantities. Also given are the operable units where the contaminants were used in unknown quantities.

[B] Range includes the minimum and maximum concentrations in micrograms per liter (μg/L) for the listed operable units. Evaluated groundwater data was collected between 1978 and 1986.

[C] Concentration based on both filtered and unfiltered samples.

[D] Detection limit concentration in micrograms per liter (μg/L) for all the groundwater data reviewed, if available.

[E] Most restrictive concentration, in micrograms per liter (μg/L), which was obtained from the Washington Ground Water Quality Standards or was obtained in the Model Toxics Control Act Cleanup Regulation using Method B. Federal standards do not exist. Where the Washington Groundwater Quality Standards are the most restrictive, enforcement limits may exceed these values when the natural groundwater quality exceeds the criteria or when other exceptions contained in WAC 173-200-050(3)(b) apply.

[F] Background concentration for the Hanford site, in micrograms per liter (μg/L), from Pacific Northwestern Laboratory, 1989, and Evans et al., 1989.

[G] Information source codes:

1. 100-Area Work Plans, in progress
2. Dorian and Richards, 1978
3. Stenner et al., 1988a,b
4. Miller and Wahlen, 1987

[H] Not available.

[I] Units are in MFL (million fibers per liter longer than micro molar).

[J] Present in groundwater above state and federal limits.

[K] Present in groundwater above Hanford site background concentrations.

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TABLE AB-4: GROUNDWATER VOLATILE ORGANIC COMPOUNDS DATA

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	GROUNDWATER QUALITY DATA			REGULATORY CRITERIA		SOURCE[E]
			SAMPLE TYPE	SAMPLE CONCENTRATION[B,C] RANGE (µg/L)	DETECTION LIMIT (µg/L)	STATE LIMIT[D] (µg/L)	FEDERAL LIMIT (µg/L)	
Benzene	NR-1	Benzene Used in Operable Unit NR-1	NA[F]	NA	NA	3 (Model Toxics Control Act - Method B)	5 (Primary Drinking Water Limit)	1
Chlorobenzene	NR-1	Chlorobenzene Used in Operable Unit NR-1	NA	NA	NA	160 (Model Toxics Control Act - Method B)	NA	1
Chloroform	HR-3[G], NR-1	Used in HR-3, NR-1	Well	15 - 35	NA	7 (Washington State Ground Water Quality Standards)	100 (Primary Drinking Water Limit)	1
Trans-1,2-dichloroethene	NR-1	trans-1,2-dichloroethene Used in Operable Unit NR-1	NA	NA	NA	100 (Model Toxics Control Act - Method B, MCLG)	100 (Primary Drinking Water Limit)	1
Ethylbenzene	NR-1	Ethylbenzene Used in Operable Unit NR-1	NA	NA	NA	700 (Model Toxics Control Act - Method B, MCLG)	700 (Primary Drinking Water Limit)	1
Methylene Chloride	FR-1[G], NR-1	Methylene Chloride Used in FR-1, NR-1	Well	34	NA	5 (Washington State Ground Water Quality Standards)	5 (Primary Drinking Water Limit)	1

See footnote key at end of table.

TABLE AB-4: GROUNDWATER VOLATILE ORGANIC COMPOUNDS DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	GROUNDWATER QUALITY DATA			REGULATORY CRITERIA		SOURCE[E]
			SAMPLE TYPE	SAMPLE CONCENTRATION[B,C] RANGE (µg/L)	DETECTION LIMIT (µg/L)	STATE LIMIT[D] (µg/L)	FEDERAL LIMIT (µg/L)	
Methyl Isobutyl Ketone (MIBK)	NR-1	Methyl Isobutyl Ketone Used in Operable Unit NR-1	NA	NA	NA	800 (Model Toxics Control Act - Method B)	NA	1
Perchlorethlyene (Tetrachloroethene, Tetrachloroethylene	HR-3, NR-1	Tetrachloroethene Used in Operable Units HR-3, NR-1	Well	13	NA	0.8 (Washington State Ground Water Quality Standards)	5 (Primary Drinking Water Limit)	1
Trichloroethene	BC-1, BC-2, BC-5, FR-1[G], HR-3	Trichloroethene (FR-1, HR-3) used in BC-1, BC-2, BC-5	Well	14 - 35	NA	3 (Washington State Ground Water Quality Standards)	5 (Primary Drinking Water Limit)	1
Xylenes	NR-1	Xylene	NA	NA	NA	1,000 (Model Toxics Control Act - Method B, MCGL)	10,000 (Primary Drinking Water Limit)	1

See footnote key at end of table.

TABLE AB-4: GROUNDWATER VOLATILE ORGANIC COMPOUNDS DATA FOOTNOTE KEY

[A] Operable unit(s) where contaminant is considered a contaminant of concern. Information in parentheses indicates the operable units(s) which received contaminant in greater than one kilogram quantities. Also given are operable units in which the contaminant was used in unknown quantities.

[B] Range includes the minimum and maximum concentrations in micrograms per liter (μg/L) for the listed operable units. Evaluated groundwater data was collected between 1978 and 1986.

[C] Concentration based on both filtered and unfiltered samples.

[D] Most restrictive concentration, in micrograms per liter (μg/L), which was obtained from the Washington Ground Water Quality Standards or was obtained in the Model Toxics Control Act Cleanup Regulation using Method B. Where the Washington Groundwater Quality Standards are the most restrictive, enforcement limits may exceed these values when the natural groundwater quality exceeds the criteria or when other exceptions contained in WAC 173-200-050(3)(b) apply.

[E] Information source codes:

1. 100-Area Work Plans, in progress
2. Dorian and Richards, 1978
3. Stenner et al., 1988a,b
4. Miller and Wahlen, 1987

[F] NA = Not available

[G] Present in concentrations above state or federal limits.

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TABLE AB-5: GROUNDWATER NONVOLATILE ORGANIC COMPOUNDS DATA

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASE[A] (Kilogram Quantities)	GROUNDWATER QUALITY DATA			REGULATORY CRITERIA		SOURCE[D]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[B] (µg/L)	DETECTION LIMIT (µg/L)	STATE LIMIT[C] (µg/L)	FEDERAL LIMIT (µg/L)	
Acetic Acid	HR-1, HR-3	Acetic Acid (HR-1, HR-3)	NA[E]	NA	NA	NA	NA	1
Bis(-2-ethylhexyl) phthalate	NR-1, NR-2	Bis-(2-ethylhexyl) phthalate Used in Operable Unit NR-1	Well	15 - 26	NA	6 (Washington State Water Quality Standards)	NA	1
Ethylenediamine	HR-1, HR-3	Ethylenediamine (HR-1, HR-3)	NA	NA	NA	NA	NA	1
Ethylenediamine tetraacetic Acid (EDTA)	HR-1, HR-3	EDTA (HR-1, HR-3)	NA	NA	NA	NA	NA	1
Formic Acid	HR-1, HR-3	Formic acid used in HR-1, HR-3	NA	NA	NA	NA	NA	1
Hydrazine	HR-1, HR-3, NR-1	Hydrazine (HR-1, HR-3) Used in NR-1	NA	NA	NA	.03 (Washington State Ground Water Quality Standards)	NA	1

See footnote key at end of table.

TABLE AB-5: GROUNDWATER NONVOLATILE ORGANIC COMPOUNDS DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASE[A] (Kilogram Quantities)	GROUNDWATER QUALITY DATA			REGULATORY CRITERIA		SOURCE[D]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[B] (µg/L)	DETECTION LIMIT (µg/L)	STATE LIMIT[C] (µg/L)	FEDERAL LIMIT (µg/L)	
PCBs Arochlor 1016 Arochlor 1221	BC-2, BC-5, KR-4, NR-1	PCBs Used in Operable Units BC-2, BC-5 KR-4, NR-1	NA	NA	NA	0.01 (Washington State Ground Water Quality Standards)	0.5 (Primary Drinking Water Limit)	1
Tetraethyl pyrophosphate	NR-1	Tetraethyl pyrophosphate Used in NR-1	NA	NA	NA	NA	NA	1
Tetrahydrofuran	NR-1, NR-2	Tetrahydrofuran Used in NR-1, NR-2	Well	60	NA	NA	NA	1
Thiourea	HR-1, HR-3, NR-1	Thiourea (HR-1, HR-3)	NA	NA	NA	NA	NA	1

See footnote key at end of table.

TABLE AB-5: GROUNDWATER NONVOLATILE ORGANIC COMPOUNDS DATA - FOOTNOTE KEY

[A] Operable unit(s) where contaminant is considered a contaminant of concern. Information in parentheses indicates the operable units(s) which received the contaminant in greater than one kilogram quantities. Also given are operable units in which contaminant was used in unknown quantities.

[B] Evaluated groundwater data was collected between 1978 and 1986; however, no data is available for the associated contaminants, except bis (-2-ethylhexyl) phthalate.

[C] Most restrictive concentration, in micrograms per liter (μg/L), which was obtained from the Washington Groundwater Quality Standards or was obtained in the Model Toxics Control Act Cleanup Regulation using Method B. Where the Washington Groundwater Quality Standards are the most restrictive, enforcement limits may exceed these values when the natural groundwater quality exceeds the criteria or when other exceptions contained in WAC 173-200-050(3)(b) apply.

[D] Information source codes:

1. 100-Area Work Plans, in progress
2. Dorian and Richards, 1978
3. Stenner et al., 1988a,b
4. Miller and Wahlen, 1987

[E] NA = Not Available.

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TABLE AB-6: SOURCES - RADIONUCLIDE DATA

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SOIL QUALITY DATA			PRELIMINARY BACKGROUND CONCENTRATION[H] RANGE (pCi/g)	SOURCE[B]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[E] RANGE (pCi/g)	DETECTION LIMIT[F,G] (pCi/g)		
Tritium	BC-1[J,K], BC-2[J], BC-3[J] BC-4, DR-1, DR-3 FR-1[J], FR-2, HR-1[J], KR-1, KR-2, NR-1	Tritium [0.208 - 11,000] (BC-1, BC-2, BC-3, BC-4, DR-1, DR-3, FR-1, FR-2, HR-1, KR-1, KR-2, NR-1) (DR-2 operable unit contains an inventory less than one Curie)	Soils, Sludges	2.7×10^{-1} - 7.3×10^{4}	NA[E]	2200 - 2400	1
Carbon-14	BC-4, KR-2	Carbon-14 [0.056 - 220] (BC-4, KR-2) (DR-1, HR-1, KR-1 operable units contain inventories less than one Curie)	Soils	4.1×10^{-1} - 4.3×10^{2}	NA	NA	1,3,4
Calcium-41	KR-1	Calcium-41 used in operable unit KR-1	NA	NA	NA	NA	1,3,4
Cobalt-60	BC-1[J,K], BC-2[J,K], BC-3, BC-4, DR-1[J,K], DR-2, DR-3, FR-1[K], FR-2, HR-1[J,K] KR-1[J,K], KR-2, NR-1	Cobalt-60 [1.01126 - 767.3] (BC-1, BC-2, BC-3, BC-4, FR-1, FR-2, DR-1, DR-2, DR-3, HR-1, KR-1, KR-2, NR-1)	Soils, Sludges	3.5×10^{-2} - 1.3×10^{7}	NA	0.00457 - 0.03550	1,3,4

See footnote key at end of table.

TABLE AB-6: SOURCES - RADIONUCLIDE DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SOIL QUALITY DATA			PRELIMINARY BACKGROUND CONCENTRATION[H] RANGE (pCi/g)	SOURCE[B]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[E] RANGE (pCi/g)	DETECTION LIMIT[F,G] (pCi/g)		
Nickel-63	BC-1, BC-2, BC-4, DR-1, DR-3, FR-2, HR-1, KR-1	Nickel-63 [16 - 144.2] (BC-1, BC-2, BC-4, DR-1, DR-3, FR-2, HR-1, KR-1)	Soils, Sludges	1.2×10^{-1} - 6.9×10^{4}	NA	NA	1,3,4
Selenium-79	HR-1	Selenium-79 used in operable unit HR-1	NA	NA	NA	NA	1,3,4
Krypton-85	HR-1	Krypton-85 used in operable unit HR-1	NA	NA	NA	NA	1,3,4
Strontium-90	BC-1, BC-2, FR-1[J,K], FR-2, HR-1[J,K], HR-2, KR-1[K]	Strontium-90 [0.35884 - 22.1] (BC-1, BC-2, FR-1, FR-2, HR-1, HR-2, KR-1) (BC-4, DR-1, DR-2 operable units contain inventories less than one Curie)	Soils, Sludges	2.2×10^{-2} - 1.3×10^{3}	NA	0.18 - 0.59 ± 0.5	1,3,4
Zirconium-93	HR-1	Zirconium-93 used in operable unit HR-1	NA	NA	NA	NA	1,3,4
Niobium-94	HR-1	Niobium-94 used in operable unit HR-1	NA	NA	NA	NA	1,3,4

See footnote key at end of table.

TABLE AB-6: SOURCES - RADIONUCLIDE DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SOIL QUALITY DATA			PRELIMINARY BACKGROUND CONCENTRATION[H] RANGE (pCi/g)	SOURCE[B]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[E] RANGE (pCi/g)	DETECTION LIMIT[F,G] (pCi/g)		
Technetium-99	BC-1, BC-2, HR-1, KR-1, FR-1, NR-1	Technetium-99 used in operable units BC-1, BC-2, HR-1, KR-1, FR-1, NR-1	NA	NA	NA	NA	1,3,4
Palladium-107	HR-1	Palladium-107 used in operable unit HR-1	NA	NA	NA	NA	1,3,4
Cadmium-113	HR-1	Cadmium-113 used in operable unit HR-1	NA	NA	NA	NA	1,3,4
Antimony-125	NR-1	Antimony-125 used in operable units NR-1	NA	NA	NA	NA	1,3,4
Iodine-129	KR-1, NR-1	Iodine-129 used in operable units KR-1, NR-1	NA	NA	NA	NA	1,3,4
Cesium-134	DR-2[K], HR-1[K], NR-1	Cesium-134 [0.00001 - 14] (NR-1) (BC-1, DR-1, DR-2, HR-1, KR-1 operable units contain inventories less than one Curie)	Soils, Sludges	1.8×10^{-2} - 1.2×10^{3}	NA	0.00429 - 0.6780	1,3,4

See footnote key at end of table.

TABLE AB-6: SOURCES - RADIONUCLIDE DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SOIL QUALITY DATA			PRELIMINARY BACKGROUND CONCENTRATION[H] RANGE (pCi/g)	SOURCE[I]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[E] RANGE (pCi/g)	DETECTION LIMIT[F,G] (pCi/g)		
Cesium-137	BC-1, BC-2, BC-4[K], DR-1 FR-1[K], FR-2 HR-1[K], HR-2 KR-1[K], NR-1 NR-3[J,K]	Cesium-137 [1 - 350] (BC-1, BC-2, DR-1, FR-1, FR-2, HR-1, HR-2, KR-1, NR-1) (BC-4, BC-5, HR-3 operable units contain inventories less than one Curie)	Soils, Sludges	2.7×10^{-2} - 6.3×10^{5}	0.5 - 0.6	0.00140 - 2.9 ± 3.2	1,3,4
Samarium-151	HR-1	Samarium-151 used in operable unit HR-1	NA	NA	NA	NA	1,3,4
Europium-152	BC-1[J], BC-2[J], BC-4[J], DR-1[J], DR-3, FR-1[J], FR-2, HR-1[J], HR-2, KR-1[J], KR-2	Europium-152 [0.02285 - 729.57] (BC-1, BC-2, BC-4, DR-1, DR-3, FR-1, FR-2, HR-1, HR-2, KR-1, KR-2) (DR-2 operable unit contains inventory less than one Curie)	Soils, Sludges	1.0×10^{-2} - 6.4×10^{4}	NA	NA	1,3,4

See footnote key at end of table.

TABLE AB-6: SOURCES - RADIONUCLIDE DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SOIL QUALITY DATA			PRELIMINARY BACKGROUND CONCENTRATION[H] RANGE (pCi/g)	SOURCE[I]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[E] RANGE (pCi/g)	DETECTION LIMIT[F,G] (pCi/g)		
Europium-154	BC-1[J,K], BC-2[J,K], BC-4[J,K], DR-1[J,K], DR-3, FR-1[K], FR-2, HR-1[J,K], HR-2, KR-1[J,K]	Europium-154 [0.00309 - 213.11] (BC-2, BC-3, BC-4, DR-1, DR-3, FR-1, FR-2, HR-1, HR-2, KR-1) (BC-1, DR-2 operable units contain inventories less than one Curie)	Soils, Sludges	9.5×10^{-4} - 2.9×10^{4}	NA	0.00197 - 0.07820	1,3,4
Radium-226/228	NR-1	Radium used in operable unit NR-1	NA	NA	NA	NA	1,3,4
Uranium (Unspecified)	DR-1[J,K], HR-1[K], KR-1[J,K]	Uranium (Unspecified) [0.04343 - 0.321991] BC-1, BC-2, FR-1, KR-1, HR-1 operable units contain inventory ranges less than one Curie)	Soils, Sludges	4.2×10^{-2} - 1.4×10^{4}	0.5 - 0.6	0.74 ± 0.15	1,3,4

See footnote key at end of table.

TABLE AB-6: SOURCES - RADIONUCLIDE DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	ESTIMATED INVENTORY RANGE[A,B,C,D] (Curie)	SOIL QUALITY DATA			PRELIMINARY BACKGROUND CONCENTRATION[H] RANGE (pCi/g)	SOURCE[B]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[E] RANGE (pCi/g)	DETECTION LIMIT[F,G] (pCi/g)		
Plutonium-238	BC-2, DR-1[J], NR-1	Plutonium-238 [0.005 - 420.195] (BC-2, NR-1) (BC-1, DR-1, HR-1, KR-1, operable units contain inventory ranges less than one Curie)	Soils, Sludges	8.1×10^{-5} - 1.6×10^{3}	NA	NA	1,3,4
Plutonium-239/240	BC-1, BC-2[J,K], DR-1[J,K], FR-1[J,K], HR-1[J,K], KR-1[K], NR-1	Plutonium-239/240 [3.4×10^{-3} - 20.6] (BC-1, BC-2, KR-1, NR-1) (DR-1, DR-2, FR-1, FR-2, HR-1, KR-2, KR-4 operable units contain inventory ranges less than one Curie)	Soils, Sludges	3.2×10^{-3} - 1.5×10^{3}	NA	4.2×10^{-2}	1,3,4
Plutonium-241	HR-1	Plutonium-241 used in operable unit HR-1	NA	NA	NA	NA	1,3,4
Americium-241	HR-1, KR-1	Americium-241 used in operable unit HR-1, KR-1	NA	NA	NA	NA	1,3,4

See footnote key at end of table.

TABLE AB-6: SOURCES - RADIONUCLIDE DATA FOOTNOTE KEY

[A] Indicates inventory in greater than Curie quantities, unless otherwise specified.

[B] Inventory range (in brackets) includes the minimum and maximum inventories for the listed operable units (in parentheses). For a single operable unit, the inventories for each waste unit within that operable unit were totaled to generate a single value.

[C] Complete inventories are not available for all of the operable units.

[D] Radionuclide concentration has not been decayed to the present.

[E] Range includes the minimum and maximum concentrations in picoCuries per gram (pCi/g) found in samples for the listed operable unit(s). Evaluated data was collected between 1978 and 1986.

[F] Range includes the minimum and maximum detection limit concentrations in picoCuries per gram (pCi/g) for all data reviewed.

[G] No state or federal limit is available.

[H] Range includes background concentrations in picoCuries per gram (pCi/g) from 100-Area Work Plans.

[I] Information source codes:

1. 100-Area Work Plans, in progress
2. Dorian and Richards, 1978
3. Stenner et al., 1988a,b
4. Miller and Wahlen, 1987

[J] Present in soils/sediments/sludges above state and federal limits.

[K] Present in soils/sediments/sludges above Hanford Site background concentrations.

[L] NA = Not Available.

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TABLE AB-7: SOURCES - METALS DATA

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	SOIL QUALITY DATA			REGULATORY CRITERIA	PRELIMINARY BACKGROUND CONCENTRATION[E] RANGE (µg/kg)	SOURCE[F]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[B] RANGE (µg/kg)	DETECTION LIMIT[C] (µg/kg)	STATE LIMIT[D] (µg/kg)		
Aluminum	HR-1, NR-1	HR-1, NR-1	NA	NA	NA	5,000 (Model Toxics Control Act - Method B)	NA	1
Boron	BC-4	Boron Splines (BC-4)	NA[G]	NA	NA	7,200,000 (Model Toxics Control Act - Method B)	NA	1
Iron	BC-2	Iron used in BC-2	NA	NA	NA	NA	NA	1
Lead	BC-1[H], BC-2, BC-3, BC-4, DR-3, FR-1, FR-2, HR-1, HR-2, NR-1	Lead (BC-3, BC-4, DR-3, FR-2, HR-1, HR-2, NR-1) Used in BC-2 Lead Acetate Battery Fluid (NR-1) Lead Cadmium Poison Slugs (BC-4, DR-3, FR-2, HR-2)	Soil	94,000 - 250,000	500	112,000 (Model Toxics Control Act - Method B)	2,580 - 12,700	1,3
Manganese	HR-1, DR-1, NR-1	Used in operable units HR-1, DR-1, NR-1	NA	NA	NA	8,000,000 (Model Toxics Control Act - Method B)	NA	1,3,4

See footnote key at end of table.

TABLE AB-7: SOURCES - METALS DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	SOIL QUALITY DATA			REGULATORY CRITERIA	PRELIMINARY BACKGROUND CONCENTRATION[E] RANGE (µg/kg)	SOURCE[F]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[B] RANGE (µg/kg)	DETECTION LIMIT[C] (µg/kg)	STATE LIMIT[D] (µg/kg)		
Sodium	BC-1, BC-2	Sodium Dichromate used in BC-1, BC-2 Fluoride (BC-2) Oxalate used in BC-1 Sulfamate used in BC-2	NA	NA	NA	NA	NA	1
Vanadium	DR-1, FR-1, NR-1	Used in operable units DR-1, FR-1, NR-1	NA	NA	NA	560,000 (Model Toxics Control Act - Method B)	NA	1,3,4

See footnote key at end of table.

TABLE AB-7: SOURCES - METALS DATA
FOOTNOTE KEY

[A] Operable unit(s) where contaminant is considered a contaminant of concern. Information in parentheses indicates the operable units(s) which received contaminant in greater than one kilogram quantities. Also given are operable units where the contaminant was used in unknown quantities.

[B] Range includes the minimum and maximum concentrations in micrograms per kilgram (μg/kg) found in soil, sediment, or sludge samples for the listed operable units. Evaluated data were collected between 1978 and 1986 and were obtained from DOE-RL, 1991a.

[C] Detection limit concentration in micrograms per kilogram (μg/kg) for all data reviewed, if available.

[D] Concentration, in micrograms per kilogram (μg/kg), which was obtained in the Model Toxics Control Act cleanup regulation using Method B. There are no federal limits.

[E] Background concentration range for the Hanford Site, in micrograms per kilogram (μg/kg), from Chou, 1989, and WHC, 1991. Because of the limited data available, these values have not been verified.

[F] Information source codes:

1. 100-Area Work Plans, in progress
2. Dorian and Richards, 1978
3. Stenner et al., 1988a,b
4. Miller and Wahlen, 1987

[G] NA = Not Available

[H] Present in concentrations within or above Hanford Site background concentrations.

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TABLE AB-8: SOURCES - NONMETALLIC IONS/COMPOUNDS DATA

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	SOIL QUALITY DATA			REGULATORY CRITERIA		SOURCE[F]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[B] RANGE (µg/kg)	DETECTION LIMIT[C] (µg/kg)	STATE LIMIT[D] (µg/kg)	PRELIMINARY BACKGROUND CONCENTRATION[E] RANGE (µg/kg)	
Ammonium/ Ammonia	FR-1, HR-1	Ammonium (FR-1) Ammonia/Ammonium Citrate/Ammonium Ceric Sulfate/Ammonium Fluoride/Ammonium Hydrogen Fluoride/ Ammonium Monohydrogen Orthophosphate/ Ammonium Persulfate (HR-1)	NA[G]	NA	NA	NA	Below Detection Limit[H] - 3000	1
Asbestos	BC-2	Asbestos used in operable unit BC-2	NA	NA	NA	NA	NA	1
Chloride	BC-2	Hydrochloric Acid used in BC-2	NA	NA	NA	NA	NA	1
Cyanide	HR-1, NR-1	Cupric Cyanide used in HR-1 Cyanide (HR-1, NR-1) Potassium Cyanide used in HR-1 Sodium Cyanide used in HR-1	NA	NA	NA	1,600,000 (Model Toxics Control Act - Method B)	NA	1

See footnote key at end of table.

TABLE AB-8: SOURCES - NONMETALLIC IONS/COMPOUNDS DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	SOIL QUALITY DATA			REGULATORY CRITERIA		SOURCE[F]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[B] RANGE (µg/kg)	DETECTION LIMIT[C] (µg/kg)	STATE LIMIT[D] (µg/kg)	PRELIMINARY BACKGROUND CONCENTRATION[E] RANGE (µg/kg)	
Fluoride	BC-1, BC-2, DR-1, FR-1, HR-1, NR-1	Fluoride (DR-1, BC-2, FR-1) Fluoride Test Solution (NR-1) Ammonium Fluoride (HR-1) Ammonium Hydrogen Fluoride (HR-1) Sodium Fluoride (HR-1) Used in BC-1, BC-2	NA	NA	1,000	NA	Below Detection Limit - 5	1
Nitrate	BC-1, BC-2, BC-3, DR-1, FR-1, HR-1, KR-1, NR-1	Aluminum Nitrate (HR-1) Nitric Acid (HR-1) Used in BC-1, BC-2 Nitrate (BC-1, BC-2, BC-3, DR-1, FR-1, KR-1, NR-1) Sodium Nitrate (HR-1)	NA	NA	1,000	NA	Below Detection Limit	1
Nitrite	HR-1	Nitrite (HR-1)	NA	NA	NA	NA	Below Detecion Limit	1
Sulfate	BC-1, BC-2, KR-2	Sulfuric Acid used in BC-1, BC-2, KR-3	NA	NA	NA	NA	NA	1

See footnote key at end of table.

TABLE AB-8: SOURCES - NONMETALLIC IONS/COMPOUNDS DATA FOOTNOTE KEY

[A] Operable unit(s) where contaminant is considered a contaminant of concern, based on potential releases and/or associated soil quality data. Information in parentheses indicates the operable unit(s) which reportedly received the waste constituent.

[B] Range includes the minimum and maximum concentrations in micrograms per kilogram (μg/kg) found in soil, sediment, or sludge samples for the listed operable units. Evaluated data were collected between 1978 and 1986.

[C] Range includes the minimum and maximum detection limit concentrations in micrograms per kilogram (μg/kg) for all data reviewed, if available.

[D] Concentration, in micrograms per kilogram (μg/kg), which was obtained in the Model Toxics Control Act Cleanup Regulation using Method B. Federal limits do not exist.

[E] Background concentration for the Hanford site, in micrograms per kilogram (μg/kg), from Pacific Northwestern Laboratory, 1989.

[F] Information source codes:

1. 100-Area Work Plans, in progress
2. Dorian and Richards, 1978
3. Stenner et al., 1988a,b
4. Miller and Wahlen, 1987

[G] NA = Not Available

[H] BDL = Below Detection Limit

9 2 1 2 6 2 1 0 1 7

TABLE AB-9: SOURCES - NONVOLATILE ORGANIC COMPOUNDS DATA

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	SOIL QUALITY DATA			REGULATORY CRITERIA	SOURCE[E]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[B] (µg/kg)	DETECTION LIMIT[C] (µg/kg)	STATE LIMIT[D] (µg/kg)	
Acetic Acid	HR-1	Acetic Acid (HR-1)	NA[F]	NA	NA	NA	1
Bis (2-ethylhexyl) phthalate	NR-1	Bis (2-ethylhexyl) phthalate Used in Operable Unit NR-1	NA	NA	NA	71,400 (Model Toxics Control Act - Method B)	1
Ethylenediamine	HR-1	Ethylenediamine (HR-1)	NA	NA	NA	NA	1
Ethlenediamine Tetraacetic Acid (EDTA)	HR-1	EDTA (HR-1)	NA	NA	NA	NA	1
Formic Acid	HR-1	Formic Acid (HR-1)	NA	NA	NA	NA	1
Hydrazine	HR-1, NR-1	Hydrazine (HR-1, NR-1)	NA	NA	NA	NA	1
PCBs Arochlor 1016 Arochlor 1221	BC-1, BC-2, KR-1	PCBs Used in Operable Units BC-1, BC-2, KR-1	NA	NA	0	130 (Model Toxics Control Act - Method B)	1

See footnote key at end of table.

TABLE AB-9: SOURCES - NONVOLATILE ORGANIC COMPOUNDS DATA (CONTINUED)

CONTAMINANT	OPERABLE UNITS	POTENTIAL RELEASES[A] (Kilogram Quantities)	SOIL QUALITY DATA			REGULATORY CRITERIA	SOURCE[E]
			SAMPLE TYPE	SAMPLE CONCEN-TRATION[B] (µg/kg)	DETECTION LIMIT[C] (µg/kg)	STATE LIMIT[D] (µg/kg)	
Petroleum Products/Diesel Oil	BC-1, KR-1, NR-1	Diesel Oil (NR-1) Petroleum Products (BC-1, KR-4)	NA	NA	NA	NA	1
Tetraethyl-pyrophosphate	NR-1	Tetraethyl-pyrophosphate Used in Operable Unit NR-1	NA	NA	NA	NA	1
Tetrahydrofuran	NR-1	Tetrahydrofuran Used in Operable Unit NR-1	NA	NA	NA	NA	1
Thiourea	HR-1, NR-1	Thiourea (HR-1) Diethylthiourea (NR-1)	NA	NA	NA	NA	1

See footnote key at end of table.

TABLE AB-9: SOURCES - NONVOLATILE ORGANIC COMPOUNDS DATA - FOOTNOTE KEY

[A] Operable unit(s) where contaminant is considered a contaminant of concern, based on potential releases and/or associated soil quality data. Operable units in parentheses are those which received the contaminant in greater than one kiolgram quantities. Also given are operable units in which the contaminant was used in unknown quantities.

[B] Evaluated data were collected between 1978 and 1986; however, no data are available for the associated contaminants.

[C] Detection limit concentrations in micrograms per kilogram (μg/kg) for all data reviewed, if available.

[D] Concentration, in micrograms per kilogram (μg/kg), which was obtained in the Model Toxics Control Act Cleanup Regulation using Method B.

[E] Information source codes:

1. 100-Area Work Plans, in progress
2. Dorian and Richards, 1978
3. Stenner et al., 1988a,b
4. Miller and Wahlen, 1987

[F] NA= Not Available

9 2 1 2 6 6 2 1 0 2 0

TABLE AB-10: SOURCES - VOLATILE ORGANIC COMPOUNDS DATA

CONTAMINANT	OPERABLE UNITS[A]	POTENTIAL RELEASES[B] (Kilogram Quantities)	SOIL QUALITY DATA			REGULATORY CRITERIA	SOURCE[E]
			SAMPLE TYPE	SAMPLE CONCENTRATION[C] RANGE (µg/kg)	DETECTION LIMIT (µg/kg)	STATE LIMIT[D] (µg/kg)	
Acetone	FR-1	Acetone (FR-1)	NA[F]	NA	NA	8,000,000 (Model Toxics Control Act - Method B)	1,2,3
Benzene	NR-1	Benzene Used in Operable Unit NR-1	NA	NA	NA	34,482 (Model Toxics Control Act - Method B)	1,2,3
Chlorobenzene	NR-1	Chlorobenzene Used in Operable Unit NR-1	NA	NA	NA	1,600,000 (Model Toxics Control Act - Method B)	1,2,3
Trans-1,2-dichloroethene	NR-1	Trans-1,2-dichloroethene Used in Operable Unit NR-1	NA	NA	NA	1,600,000 (Model Toxics Control Act - Method B)	1,2,3
Ethylbenzene	NR-1	Ethylbenzene Used in Operable Unit NR-1	NA	NA	NA	8,000,000 (Model Toxics Control Act - Method B)	1,2,3
Methyl Isobutyl Ketone	NR-1	Methyl Isobutyl Ketone Used in Operable Unit NR-1	NA	NA	NA	4,000,000 (Model Toxics Control Act - Method B)	1,2,3
Perchloroethylene	HR-1, NR-1	Perchloroethene Used in Operable Units HR-1, NR-1	NA	NA	NA	19,607 (Model Toxics Control Act - Method B)	1,2,3

See footnote key at end of table.

TABLE AB-10: SOURCES - VOLATILE ORGANIC COMPOUNDS DATA FOOTNOTE KEY

[A] Operable unit(s) where contaminant is considered a contaminant of concern.

[B] Information in parentheses indicates the operable units(s) which reportedly received the waste constituent. Also given are operable units in which the contaminant was used in unknown quantites.

[C] Range includes the minimum and maximum concentrations in micrograms per kilogram (μg/kg) for the listed operable units. Evaluated data were collected between 1978 and 1986.

[D] Concentration, in micrograms per kilogram (μg/kg), which was obtained in the Model Toxics Control Act Cleanup Regulation using Method B.

[E] Information source codes:

1. 100-Area Work Plans, in progress
2. Dorian and Richards, 1978
3. Stenner et al., 1988a,b
4. Miller and Wahlen, 1987

[F] NA = Not available

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9 2 1 2 6 2 1 0 2 3

APPENDIX AC
REGULATED CHEMICAL CONTAMINANTS

TABLE AC-1: REGULATORY DETERMINATION

CONTAMINANTS RELEASED IN THE 100-AREA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA) (40 CFR §302.4)	NATIONAL OIL AND HAZARDOUS SUBSTANCES POLLUTION CONTINGENCY PLAN (40 CFR §300.3[a][1])	TOXIC SUBSTANCES CONTROL ACT (TSCA) (40 CFR §761)	PRIMARY DRINKING WATER RULES (40 CFR §§141.61 AND 141.62)	WASHINGTON GROUNDWATER STANDARDS	STATE OF WASHINGTON MODEL TOXICS CONTROL ACT CLEANUP REGULATIONS	NOT REGULATED
1,1,1-Trichloroethane	X			X	X	X	
Acetic Acid	X						
Acetone	X					X	
Aluminum						X	
Aluminum Chloride							X
Aluminum Fluoride							X
Aluminum Nitrate							X
Aluminum Sulfate							X
Ammonium Monohydrogen Orthophosphate							X
Ammonium Ceric Sulfate							X
Ammonium Fluoride	X						
Ammonium Hydrogen Fluoride							X
Ammonium Persulfate							X
Arsenic	X			X	X	X	
Asbestos	X			X			
Barium	X			X	X	X	
Barium Perchlorate					X		
Benzene	X			X	X	X	
Beryllium	X					X	
Beryllium Sulfate	X						

TABLE AC-1: REGULATORY DETERMINATION (CONTINUED)

CONTAMINANTS RELEASED IN THE 100-AREA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA) (40 CFR §302.4)	NATIONAL OIL AND HAZARDOUS SUBSTANCES POLLUTION CONTINGENCY PLAN (40 CFR §300.3[a][1])	TOXIC SUBSTANCES CONTROL ACT (TSCA) (40 CFR §761)	PRIMARY DRINKING WATER RULES (40 CFR §§141.61 AND 141.62)	WASHINGTON GROUNDWATER STANDARDS	STATE OF WASHINGTON MODEL TOXICS CONTROL ACT CLEANUP REGULATIONS	NOT REGULATED
Bis (2-ethylhexyl) phthalate	X				X	X	
Boric Acid							X
Boron						X	
Cadmium	X			X	X	X	
Calcium							X
Chloride (including chloride ion from releases of Aluminum Chloride, Hydrochloric Acid, Mercuric Chloride, Nickel Chloride, Potassium Chloride, and Sodium Chloride)					X	X	
Chlorine	X						
Chlorobenzene	X					X	
Chloroform	X				X	X	
Choline Chloride							X
Chromic Acid	X						
Chromium, Hexavalent (including chromium ion from releases of Chromic Acid, Potassium Dichromate, Sodium Chromate, and Sodium Dichromate)	X			X	X	X	
Citric Acid							X
Citric Acid Solutions, Ammoniated							X

TABLE AC-1: REGULATORY DETERMINATION (CONTINUED)

CONTAMINANTS RELEASED IN THE 100-AREA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA) (40 CFR §302.4)	NATIONAL OIL AND HAZARDOUS SUBSTANCES POLLUTION CONTINGENCY PLAN (40 CFR §300.3[a][1])	TOXIC SUBSTANCES CONTROL ACT (TSCA) (40 CFR §761)	PRIMARY DRINKING WATER RULES (40 CFR §§141.61 AND 141.62)	WASHINGTON GROUNDWATER STANDARDS	STATE OF WASHINGTON MODEL TOXICS CONTROL ACT CLEANUP REGULATIONS	NOT REGULATED
Cobalt						X	
Copper	X				X	X	
Cupric Cyanide	X						
Cupric Oxide	X						
Cupric Sulfate	X						
Cyanide (including cyanide ion from releases of Cupric Cyanide, Potassium Cyanide, and Sodium Cyanide)	X				X	X	
Cyclotetrasiloxane, octomethyl							X
Deoxycholic Acid							X
Diesel Oil		X					
Diethanolamine							X
Diethylthiourea							X
Ethylbenzene	X			X		X	
Ethylenediamine	X						
Ethylenediamine tetraacetic Acid (EDTA)	X						
Ferric Oxide							X
Ferric Sulfate	X						

TABLE AC-1: REGULATORY DETERMINATION (CONTINUED)

CONTAMINANTS RELEASED IN THE 100-AREA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA) (40 CFR §302.4)	NATIONAL OIL AND HAZARDOUS SUBSTANCES POLLUTION CONTINGENCY PLAN (40 CFR §300.3[a][1])	TOXIC SUBSTANCES CONTROL ACT (TSCA) (40 CFR §761)	PRIMARY DRINKING WATER RULES (40 CFR §§141.61 AND 141.62)	WASHINGTON GROUNDWATER STANDARDS	STATE OF WASHINGTON MODEL TOXICS CONTROL ACT CLEANUP REGULATIONS	NOT REGULATED
Fluoride (including fluoride ion from releases of Aluminum Fluoride, Ammonium Fluoride, Ammonium Hydrogen Fluoride, Lithium Fluoride, and Sodium Fluoride)				X	X	X	
Formic Acid	X						
Graphite							X
Hexane							X
Hydrazine	X						
Hydrobromic Acid							X
Hydrochloric Acid	X						
Hydrogen Peroxide							X
Hydroiodic Acid							X
Hypophosphorus Acid							X
Iron (including iron ion from releases of Ferric Oxide and Ferric Sulfate)					X	X	
Lead	X			X	X	X	
Lithium							X
Lithium Fluoride							X
Magnesium							X
Manganese					X	X	
Mercaptoacetic Acid							X

TABLE AC-1: REGULATORY DETERMINATION (CONTINUED)

CONTAMINANTS RELEASED IN THE 100-AREA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA) (40 CFR §302.4)	NATIONAL OIL AND HAZARDOUS SUBSTANCES POLLUTION CONTINGENCY PLAN (40 CFR §300.3[a][1])	TOXIC SUBSTANCES CONTROL ACT (TSCA) (40 CFR §761)	PRIMARY DRINKING WATER RULES (40 CFR §§141.61 AND 141.62)	WASHINGTON GROUNDWATER STANDARDS	STATE OF WASHINGTON MODEL TOXICS CONTROL ACT CLEANUP REGULATIONS	NOT REGULATED
Mercuric Chloride	X						
Mercuric Nitrate	X						
Mercury	X			X	X	X	
Methyl Isobutyl Ketone (MIBK) (4-methy-2-pentanone)	X				X		
Methylene Chloride	X				X	X	
Molybdenum							X
Morpholine							X
Nickel	X					X	
Nickel Chloride	X						
Nickel Oxide	X						
Nickel Sulfate	X						
Nitrate (as Nitrogen) (including nitrate ion from releases of Aluminum Nitrate, Mercuric Nitrate, Potassium Nitrate, Sodium Nitrate, and Nitric Acid)				X	X		
Nitric Acid	X						
Nitrite (as Nitrogen) (including nitrite ion from releases of Sodium Nitrite)				X			
Oxalic Acid							X
Palladium							X

TABLE AC-1: REGULATORY DETERMINATION (CONTINUED)

CONTAMINANTS RELEASED IN THE 100-AREA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA) (40 CFR §302.4)	NATIONAL OIL AND HAZARDOUS SUBSTANCES POLLUTION CONTINGENCY PLAN (40 CFR §300.3[a][1])	TOXIC SUBSTANCES CONTROL ACT (TSCA) (40 CFR §761)	PRIMARY DRINKING WATER RULES (40 CFR §§141.61 AND 141.62)	WASHINGTON GROUNDWATER STANDARDS	STATE OF WASHINGTON MODEL TOXICS CONTROL ACT CLEANUP REGULATIONS	NOT REGULATED
Perchloric Acid							X
Perchloroethylene (Tetrachloroethene, Tetrachloroethylene)	X			X	X	X	
Petroleum Products		X					
Phosphate							X
Phosphomolybdic Acid							X
Phosphoric Acid	X						
Phosphorus Pentoxide							X
Polychlorinated Biphenyls (PCBs)	X		X	X	X	X	
Potassium							X
Potassium Borate							X
Potassium Chloride							X
Potassium Cyanide	X						
Potassium Dichromate	X						
Potassium Nitrate							X
Silicon							X
Sodium	X						
Sodium Acetate							X
Sodium Aluminate							X
Sodium Borate							X
Sodium Carbonate							X
Sodium Chloride							X

TABLE AC-1: REGULATORY DETERMINATION (CONTINUED)

CONTAMINANTS RELEASED IN THE 100-AREA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA) (40 CFR §302.4)	NATIONAL OIL AND HAZARDOUS SUBSTANCES POLLUTION CONTINGENCY PLAN (40 CFR §300.3[a][1])	TOXIC SUBSTANCES CONTROL ACT (TSCA) (40 CFR §761)	PRIMARY DRINKING WATER RULES (40 CFR §§141.61 AND 141.62)	WASHINGTON GROUNDWATER STANDARDS	STATE OF WASHINGTON MODEL TOXICS CONTROL ACT CLEANUP REGULATIONS	NOT REGULATED
Sodium Chromate	X						
Sodium Citrate							X
Sodium Cyanide	X						
Sodium Dichromate	X						
Sodium EDTA							X
Sodium Fluoride	X						
Sodium Formate							X
Sodium Hydrosulfite							X
Sodium Hydroxide							X
Sodium Hypophosphite							X
Sodium Monohydrogen Orthoarsenate							X
Sodium Nitrate							X
Sodium Nitrite	X						
Sodium Oxalate							X
Sodium Phosphate	X						
Sodium Sulfamate							X
Sodium Sulfate							X
Sodium Sulfite							X
Strontium							X
Sulfamic Acid							X

TABLE AC-1: REGULATORY DETERMINATION (CONTINUED)

CONTAMINANTS RELEASED IN THE 100-AREA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA) (40 CFR §302.4)	NATIONAL OIL AND HAZARDOUS SUBSTANCES POLLUTION CONTINGENCY PLAN (40 CFR §300.3[a][1])	TOXIC SUBSTANCES CONTROL ACT (TSCA) (40 CFR §761)	PRIMARY DRINKING WATER RULES (40 CFR §§141.61 AND 141.62)	WASHINGTON GROUNDWATER STANDARDS	STATE OF WASHINGTON MODEL TOXICS CONTROL ACT CLEANUP REGULATIONS	NOT REGULATED
Sulfate (including sulfate from releases of Aluminum Sulfate, Ammonium Ceric Sulfate, Ammonium Persulfate, Cupric Sulfate, Ferric Sulfate, Nickel Sulfate, Sodium Sulfate, and Sulfuric Acid)					X		
Sulfuric Acid	X						
Tetraethyl pyrophosphate	X						
Tetrahydrofuran	X						
Thiourea	X						
Titanium							X
Toluene				X		X	
trans-1,2-dichloroethene						X	
Trichloroacetic Acid							X
Trichloroethene, Trichloroethylene	X			X	X	X	
Urea							X
Vanadium						X	
Vanadium Pentoxide	X						
Xylenes	X			X		X	
Zinc	X				X	X	
Zirconium							X

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APPENDIX AD
REGULATORY CONTAMINANTS OF CONCERN
DECISION LOGIC TABLES

TABLE AD-1: GROUNDWATER RADIONUCLIDES - DECISION LOGIC
(Also see Table AB-1)

RADIONUCLIDE ⇒	HALF-LIFE >2 YEARS? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Tritium	Y	Y	Y	Y	Y→[COC]
Carbon-14	Y	Y→[COC]			
Calcium-41	Y	N→[COC]			
Chromium-51	N→[D]				
Manganese-54	N→[D]				
Cobalt-60	Y	Y	Y	Y	Y→[COC]
Nickel-63	Y	N→[COC]			
Zinc-65	N→[D]				
Selenium-79	Y	N→[COC]			
Krypton-85	Y	N→[COC]			
Strontium-90	Y	Y	Y	Y	Y→[COC]
Zirconium-93	Y	N→[COC]			
Niobium-94	Y	N→[COC]			
Technetium-99	Y	Y	Y	Y	N→[S]
Ruthenium-103	N→[D]				
Ruthenium-106	N→[D]				
Palladium-107	Y	N→[COC]			
Cadmium-113	Y	N→[COC]			
Antimony-125	Y	Y	Y	Y	N→[S]
Iodine-129	Y	N→[COC]			
Iodine-131	N→[D]				
Cesium-134	Y	N→[COC]			

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-1: GROUNDWATER RADIONUCLIDES - DECISION LOGIC (Continued)

RADIONUCLIDE ⇒	HALF-LIFE >2 YEARS? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Cesium-137	Y	Y	Y	Y	N→[S]
Cerium-144	N→[D]				
Samarium-151	Y	N→[COC]			
Europium-152	Y	Y	Y	Y	Y→[COC]
Europium-154	Y	Y	Y	Y	N→[S]
Europium-155	N→[D]				
Radium-$^{228}/_{228}$	Y	N→[COC]			
Uranium-$^{235}/_{238}$	Y	Y	Y	Y	Y→[COC]
Uranium-238	Y	Y	Y	Y	Y→[COC]
Plutonium	Y	Y	Y	Y	Y→[COC]
Plutonium-$^{239}/_{240}$	Y	Y	Y	Y	Y→[COC]
Americium-241	Y	N→[COC]			
Plutonium-241	Y	N→[COC]			

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-2: GROUNDWATER METALS - DECISION LOGIC
(Also see Table AB-2)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Aluminum	Y	N→[D]				
Arsenic	Y	Y	Y	Y	Y	Y→[COC]
Barium	Y	Y	Y	Y	Y	Y→[COC]
Beryllium	Y	Y	N→[COC]			
Boron	Y	Y	Y	Y	Y	N→[S]
Cadmium	Y	Y	Y	Y	Y	Y→[COC]
Calcium	Y	N→[D]				
Chromium	Y	Y	Y	Y	Y	Y→[COC]
Cobalt	Y	Y	N→[COC]			
Copper	Y	Y	Y	Y	Y	N→[S]
Iron	Y	Y	Y	N→[S]		
Lead	Y	Y	Y	Y	Y	Y→[COC]
Lithium	Y	N→[D]				
Magnesium	Y	N→[D]				
Manganese	Y	Y	Y	Y	Y	Y→[COC]
Mercury	Y	Y	N→[COC]			
Molybdenum	Y	N→[D]				
Nickel	Y	Y	Y	Y	Y	N→[S]

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-2: GROUNDWATER METALS - DECISION LOGIC (Continued)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Potassium	Y	N→[D]				
Silicon	Y	N→[D]				
Strontium	Y	N→[D]				
Titanium	Y	N→[D]				
Vanadium	Y	Y	Y	Y	Y	N→[S]
Zinc	Y	Y	Y	Y	Y	N→[S]
Zirconium	Y	N→[D]				

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-3: GROUNDWATER NONMETALLIC IONS/COMPOUNDS - DECISION LOGIC (Also see Table AB-3)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Ammonium/ Ammonia	Y	Y	Y	Y	Y	N→[S]
Asbestos	Y	Y	N→[COC]			
Chloride	Y	Y	N→[COC]			
Chlorine	Y	Y	N→[COC]			
Cyanide	Y	Y	N→[COC]			
Fluoride	Y	Y	Y	Y	Y	Y→[COC]
Hydrochloric Acid	Y	Y	N→[COC]			
Hydrogen Peroxide	Y	N→[D]				
Hydroiodic Acid	Y	N→[D]				
Hypophos- phourous Acid	Y	N→[D]				
Nitrate	Y	Y	Y	NS	Y	Y→[COC]
Nitrite	Y	Y	N→[COC]			
Perchloric Acid	Y	N→[D]				
Phosphate	Y	N→[D]				
Phosphoric Acid	Y	Y	N→[COC]			
Sulfate	Y	Y	Y	Y	Y	Y→[COC]
Sulfumic Acid	Y	N→[D]				

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-4: GROUNDWATER VOLATILE ORGANIC COMPOUNDS - DECISION LOGIC
(Also see Table AB-4)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Acetone	Y	Y	Y	NS	Y	N→[S]
Benzene	Y	Y	N→[COC]			
Chlorobenzene	Y	Y	N→[COC]			
Chloroform	Y	Y	Y	Y	Y	Y→[COC]
Ethylbenzene	Y	Y	N→COC			
Hexane	Y	N→[D]				
Methyl isobutyl Ketone	Y	Y	N→[COC]			
Methylene chloride	Y	Y	Y	Y	Y	Y→[COC]
Perchloroethylene	Y	Y	Y	Y	Y	Y→[COC]
Toluene	Y	Y	Y	NS	Y	N→[S]
Trans-1,2-dichloroethane	Y	Y	N→[COC]			
Trichloroethene	Y	Y	Y	NS	Y	Y→[COC]
Xylenes	Y	Y	N→[COC]			

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-5: GROUNDWATER NONVOLATILE ORGANIC COMPOUNDS - DECISION LOGIC
(Also see Table AB-5)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
4-Methyl-2-Pentanone	Y	N→[D]				
Acetic acid	Y	Y	N→[COC]			
Ammoniated citric acid solutions	Y	N→[D]				
Bis-(2-ethyl hexyl) phthalate	Y	Y	Y	NS	Y	Y→[COC]
Citric acid	Y	N→[D]				
Cyclotetrasiloxane, octamethyl	Y	N→[D]				
Deoxycholic acid	Y	N→[D]				
Diethanolamine	Y	N→[D]				
Diethylthiourea	Y	N→[D]				
Ethylene diamine	Y	Y	N→[COC]			
Ethylene diamine tetraacetic acid	Y	Y	N→[COC]			
Formic acid	Y	Y	N→[COC]			
Graphite	Y	N→[D]				
Hydrazine	Y	Y	N→[COC]			
Mercaptacetic acid	Y	N→[D]				
Morpholine	Y	N→[D]				

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-5: GROUNDWATER NONVOLATILE ORGANIC COMPOUNDS - DECISION LOGIC (Continued)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Oxalic acid	Y	N→[D]				
PCBs	Y	Y	N→[COC]			
Petroleum products/ diesel oil	Y	Y	Y	NS	N→[COC]	
Tetraethyl pyrophosphate	Y	Y	N→[COC]			
Tetrahydrofuran	Y	Y	N→[COC]			
Thiourea	Y	Y	N→[COC]			
Trichloroacetic acid	Y	N→[D]				
Urea	Y	N→[D]				

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-6: SOURCES - RADIONUCLIDES - DECISION LOGIC
(Also see Table AB-6)

RADIONUCLIDE ⇒	HALF-LIFE >2 YEARS? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Tritium	Y	Y	Y	Y	Y→[COC]
Carbon-14	Y	Y	Y	Y	Y→[COC]
Calcium-41	Y	N→[COC]			
Chromium-51	N→[D]				
Manganese-54	N→[D]				
Cobalt-60	Y	Y	Y	Y	Y→[COC]
Nickel-63	Y	Y	Y	Y	Y→[COC]
Zinc-65	N→[D]				
Selenium-79	Y	N→[COC]			
Krypton-85	Y	N→[COC]			
Strontium-90	Y	Y	Y	Y	Y→[COC]
Zirconium-93	Y	N→[COC]			
Niobium-94	Y	N→[COC]			
Technetium-99	Y	N→[COC]			
Ruthenium-103	N→[D]				
Ruthenium-106	N→[D]				
Palladium-107	Y	N→[COC]			
Cadmium-113	Y	N→[COC]			
Antimony-125	Y	N→[COC]			
Iodine-129	Y	N→[COC]			
Iodine-131	N→[D]				
Cesium-134	Y	Y	Y	Y	Y→[COC]

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-6: SOURCES - RADIONUCLIDES - DECISION LOGIC (Continued)

RADIONUCLIDE ⇒	HALF-LIFE >2 YEARS? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Cesium-137	Y	Y	Y	Y	Y→[COC]
Cerium-144	N→[D]				
Samarium-151	Y	N→[COC]			
Europium-152	Y	Y	Y	Y	Y→[COC]
Europium-154	Y	Y	Y	Y	Y→[COC]
Europium-155	N→[D]				
Radium-$^{226}/_{228}$	Y	N→[COC]			
Uranium-$^{235}/_{238}$	Y	Y	Y	Y	Y→[COC]
Plutonium-238	Y	Y	Y	Y	Y→[COC]
Uranium-238	Y	Y	Y	Y	Y→[COC]
Plutonium-$^{239}/_{240}$	Y	Y	Y	Y	Y→[COC]
Americium-241	Y	N→[COC]			
Plutonium-241	Y	N→[COC]			

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-7: SOURCES - METALS -DECISION LOGIC
(Also see Table AB-7)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Aluminum	Y	Y	N→[COC]			
Arsenic	Y	Y	Y	Y	Y	N→[S]
Barium	Y	Y	Y	Y	Y	N→[S]
Beryllium	Y	Y	Y	N→[S]		
Boron	Y	Y	N→[COC]			
Cadmium	Y	Y	Y	Y	Y	N→[S]
Calcium	Y	N→[D]				
Chromium	Y	Y	Y	Y	Y	N→[S]
Copper	Y	Y	Y	Y	Y	N→[S]
Iron	Y	Y	N→[COC]			
Lead	Y	Y	Y	Y	Y	Y→[COC]
Lithium	Y	N→[D]				
Magnesium	Y	N→[D]				
Manganese	Y	Y	N→[COC]			
Mercury	Y	Y	Y	Y	Y	N→[S]
Molybdenum	Y	N→[D]				
Nickel	Y	Y	Y	Y	Y	N→[S]
Palladium	Y	N→[D]				
Potassium	Y	N→[D]				

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-7: SOURCES - METALS - DECISION LOGIC (Continued)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Silicon	Y	N→[D]				
Sodium	Y	Y	N→[COC]			
Titanium	Y	N→[D]				
Vanadium	Y	Y	N→[COC]			
Zinc	Y	Y	Y	Y	Y	N→[S]
Zirconium	Y	N→[D]				

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-8: SOURCES - NONMETALLIC IONS/COMPOUNDS - DECISION LOGIC
(Also see Table AB-8)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Ammonium/ Ammonia	Y	Y	N→[COC]			
Asbestos	Y	Y	N→[COC]			
Chloride	Y	Y	N→[COC]			
Cyanide	Y	Y	N→[COC]			
Fluoride	Y	Y	N→[COC]			
Nitrate	Y	Y	N→[COC]			
Nitrite	Y	Y	N→[COC]			
Sulfate	Y	Y	N→[COC]			

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-9: SOURCES - NONVOLATILE ORGANIC COMPOUNDS - DECISION LOGIC
(Also see Table AB-9)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
Acetic acid	Y	Y	N→[COC]			
Ammoniated citric acid solutions	Y	N→[D]				
Bis-(2-ethylhexyl) phthalate	Y	Y	N→[COC]			
Citric acid	Y	N→[D]				
Cyclotetrasil, Oxane, Octomethyl	Y	N→[D]				
Deoxycholic acid	Y	N→[D]				
Diethanolamine	Y	N→[D]				
Diethylthiourea	Y	N→[D]				
Ethylenediamine	Y	Y	N→[COC]			
Ethylenediamine Tetraacetic acid	Y	Y	N→[COC]			
Formic acid	Y	Y	N→[COC]			
Graphite	Y	N→[D]				
Hydrazine	Y	Y	N→[COC]			
Mercaptoacetic acid	Y	N→[D]				
Morpholine	Y	N→[D]				
Oxalic acid	Y	N→[D]				

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-9: SOURCES - NONVOLATILE ORGANIC COMPOUNDS - DECISION LOGIC (Continued)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
PCBs Arochlor 1016 Arochlor 1221	Y	Y	N→[COC]			
Petroleum products/Diesel oil	Y	Y	N→[COC]			
Sodium EDTA	Y	N→[D]				
Tetraethyl pyrophosphate	Y	Y	N→[COC]			
Tetrahydrofuran	Y	Y	N→[COC]			
Thiourea	Y	Y	N→[COC]			
Trichloroacetic acid	Y	N→[D]				
Urea	Y	N→[D]				

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

TABLE AD-10: SOURCES - VOLATILE ORGANIC COMPOUNDS - DECISION LOGIC
(Also see Table AB-10)

CONTAMINANT ⇒	RELEASED TO ENVIRONMENT? ⇒	REGULATED? ⇒	RECORDS AVAILABLE? ⇒	EXCEED BACKGROUND? ⇒	LIMITS AVAILABLE? ⇒	EXCEED REGULATORY LIMIT?
1,1,1-Trichloroethane	Y	Y	Y	NS	Y	N→[S]
Acetone	Y	Y	N→[COC]			
Benzene	Y	Y	N→[COC]			
Chlorobenzene	Y	Y	N→[COC]			
Chloroform	Y	Y	Y	N[S]	Y	N→[S]
Ethylbenzene	Y	Y	N→[COC]			
Hexane	Y	N→[D]				
Methyl Isobutyl Ketone	Y	Y	N→[COC]			
Methylene chloride	Y	Y	Y	NS	Y	N→[S]
Perchlorethene	Y	Y	N→[COC]			
Trans-1,2-dichloroethane	Y	Y	N→[COC]			
Trichloroethene	Y	Y	Y	NS	Y	N→[S]

Y = Yes
N = No
NS = Not Sure
D = Deleted as a contaminant
S = Suspect contaminant
COC = Regulatory Contaminant of Concern

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APPENDIX AE
QUALITATIVE TOXICITY ASSESSMENT DECISION LOGIC TABLES

TABLE AE-1: SOURCE CONTAMINANTS OF TOXICOLOGICAL SIGNIFICANCE DECISION LOGIC

Regulatory Contaminant of Concern	7: Is the contamininant a carcinogen?	8: Candidate for elimination per guidance?	9: Oral reference dose in IRIS or HEAST?	10: Is the Hazard Quotient greater than 0.1 for ingestion?	Contaminant of toxicological significance?
RADIONUCLIDES					
Tritium	Y				Y
Carbon-14	Y				Y
Calcium-41	Y				Y
Cobalt-60	Y				Y
Nickel-63	Y				Y
Selenium-79	Y				Y
Krypton-85	Y				Y
Strontium-90	Y				Y
Zirconium-93	Y				Y
Niobium-94	Y				Y
Technetium-99	Y				Y
Palladium-107	Y				Y
Cadmium-113	Y				Y
Iodine-129	Y				Y
Cesium-134	Y				Y
Cesium-137	Y				Y
Samarium-151	Y				Y
Europium-152	Y				Y
Europium-154	Y				Y
Uranium-235/238	Y				Y

TABLE AE-1: SOURCE CONTAMINANTS OF TOXICOLOGICAL SIGNIFICANCE DECISION LOGIC *(CONTINUED)*

Regulatory Contaminant of Concern	7: Is the contamininant a carcinogen?	8: Candidate for elimination per guidance?	9: Oral reference dose in IRIS or HEAST?	10: Is the Hazard Quotient greater than 0.1 for ingestion?	Contaminant of toxicological significance?
Plutonium-238	Y				Y
Plutonium-239/240	Y				Y
Plutonium-241	Y				Y
Americium-241	Y				Y
METALS					
Aluminum	N	Y			N
Boron	N	N	Y	no data	Y
Iron	N	Y			N
Lead	Y				Y
Manganese	N	N	Y	no data	Y
Sodium	N	Y			N
Vanadium	N	N	Y	no data	Y

TABLE AE-1: SOURCE CONTAMINANTS OF TOXICOLOGICAL SIGNIFICANCE DECISION LOGIC *(CONTINUED)*

Regulatory Contaminant of Concern	7: Is the contamininant a carcinogen?	8: Candidate for elimination per guidance?	9: Oral reference dose in IRIS or HEAST?	10: Is the Hazard Quotient greater than 0.1 for ingestion?	Contaminant of toxicological significance?
OTHER INORGANIC COMPOUNDS/IONS					
Ammonium/ Ammonia	N	N	Y	no data	Y
Asbestos	Y				Y
Chloride	N	N	N		N
Cyanide	N	N	Y	no data	Y
Fluoride	N	N	Y	no data	Y
Nitrate	N	N	Y	no data	Y
Nitrite	N	N	Y	no data	Y
Sulfate	N	N	N		N
VOCs					
Acetone	N	N	Y	no data	Y
Perchloro-ethylene	Y				Y
OTHER ORGANICS					
Acetic Acid	N	N	Y	no data	Y
Ethylenediamine	N	N	Y	no data	Y
Ethylenediamine tetraacetic acid (EDTA)	N	N	N		N
Formic Acid	N	N	Y	no data	Y
Hydrazine	Y				Y
PCBs	Y				Y

TABLE AE-1: SOURCE CONTAMINANTS OF TOXICOLOGICAL SIGNIFICANCE DECISION LOGIC *(CONTINUED)*

Regulatory Contaminant of Concern	7: Is the contamininant a carcinogen?	8: Candidate for elimination per guidance?	9: Oral reference dose in IRIS or HEAST?	10: Is the Hazard Quotient greater than 0.1 for ingestion?	Contaminant of toxicological significance?
Petroleum Products/Diesel oil	Y a				Y
Thiourea	N	N	Y	no data	Y

HEAST = Health Effects Assessments Summary Tables (EPA 1991)
IRIS = Integrated Risk Information System (EPA on-line database)
Y = Yes
N = No

a Assumed to contain benzene

TABLE AE-2: GROUNDWATER CONTAMINANTS OF TOXICOLOGICAL SIGNIFICANCE DECISION LOGIC

Regulatory Contaminant of Concern	7: Is the contamininant a carcinogen?	8: Candidate for elimination per guidance?	9: Oral reference dose in IRIS or HEAST?	10: Is the Hazard Quotient greater than 0.1 for ingestion?	Contaminant of toxicological significance?
RADIONUCLIDES					
Tritium	Y				Y
Carbon-14	Y				Y
Calcium-41	Y				Y
Cobalt-60	Y				Y
Nickel-63	Y				Y
Selenium-79	Y				Y
Krypton-85	Y				Y
Strontium-90	Y				Y
Zirconium-93	Y				Y
Niobium-94	Y				Y
Palladium-107	Y				Y
Cadmium-113	Y				Y
Iodine-129	Y				Y
Samarium-151	Y				Y
Europium-152	Y				Y
Uranium-235/238	Y				Y
Plutonium-238	Y				Y
Plutonium-239/240	Y				Y
Plutonium-241	Y				Y
Americium-241	Y				Y
METALS					

TABLE AE-2: GROUNDWATER CONTAMINANTS OF TOXICOLOGICAL SIGNIFICANCE DECISION LOGIC *(CONTINUED)*

Regulatory Contaminant of Concern	7: Is the contamininant a carcinogen?	8: Candidate for elimination per guidance?	9: Oral reference dose in IRIS or HEAST?	10: Is the Hazard Quotient greater than 0.1 for ingestion?	Contaminant of toxicological significance?
Arsenic	Y				Y
Barium	N	N	Y	Y	Y
Beryllium	Y				Y
Cadmium	N	N	Y	Y	Y
Chromium	Y				Y
Cobalt	N	N	N		N
Lead	Y				Y
Manganese	N	N	Y	Y	Y
Mercury	N	N	Y	no data	Y
Sodium	N	Y			N
OTHER INORGANIC COMPOUNDS/IONS					
Asbestos	Y				Y
Chloride	N	N	N		N
Chlorine	N	N	Y	no data	Y
Cyanide	N	N	Y	no data	Y
Fluoride	N	N	Y	Y	Y
Hydrochloric Acid	N	N	N		N
Nitrate	N	N	Y	Y	Y
Nitrite	N	N	Y	no data	Y
Sulfate	N	N	N		N
VOCs					

TABLE AE-2: GROUNDWATER CONTAMINANTS OF TOXICOLOGICAL SIGNIFICANCE DECISION LOGIC *(CONTINUED)*

Regulatory Contaminant of Concern	7: Is the contamininant a carcinogen?	8: Candidate for elimination per guidance?	9: Oral reference dose in IRIS or HEAST?	10: Is the Hazard Quotient greater than 0.1 for ingestion?	Contaminant of toxicological significance?
Chloroform	Y				Y
Perchloro-ethylene	Y				Y
Trichloroethene	Y				Y
OTHER ORGANICS					
Acetic Acid	N	N	Y	no data	Y
Ethylenediamine	N	N	Y	no data	Y
Ethylenediamine tetraacetic acid (EDTA)	N	N	N		N
Formic Acid	N	N	Y	no data	Y
Hydrazine	Y				Y
PCBs	Y				Y
Thiourea	N	N	Y	no data	Y

HEAST = Health Effects Assessments Summary Tables (EPA 1991)
IRIS = Integrated Risk Information System (EPA on-line database)
Y = Yes
N = No

TABLE AE-3: N-AREA CONTAMINANTS OF TOXICOLOGICAL SIGNIFICANCE DECISION LOGIC

Regulatory Contaminant of Concern	7: Is the contamininant a carcinogen?	8: Candidate for elimination per guidance?	9: Oral reference dose in IRIS or HEAST?	10: Is the Hazard Quotient greater than 0.1 for ingestion?	Contaminant of toxicological significance?
RADIONUCLIDES					
Tritium	Y				Y
Cobalt-60	Y				Y
Strontium-90	Y				Y
Technetium-99	Y				Y
Antimony-125	Y				Y
Iodine-129	Y				Y
Cesium-134	Y				Y
Cesium-137	Y				Y
Radium-226/228	Y				Y
Plutonium-238	Y				Y
Plutonium-239/240	Y				Y
METALS					
Aluminum	N	Y			N
Arsenic	Y				Y
Barium	N	N	Y	Y	Y
Beryllium	Y				Y
Cadmium	N	N	Y	Y	Y
Chromium	Y				Y
Lead	Y				Y

TABLE AE-3: N-AREA CONTAMINANTS OF TOXICOLOGICAL SIGNIFICANCE DECISION LOGIC *(CONTINUED)*

Regulatory Contaminant of Concern	7: Is the contamininant a carcinogen?	8: Candidate for elimination per guidance?	9: Oral reference dose in IRIS or HEAST?	10: Is the Hazard Quotient greater than 0.1 for ingestion?	Contaminant of toxicological significance?
Manganese	N	N	Y	Y	Y
Vanadium	N	N	Y	no data	Y
OTHER INORGANIC COMPOUNDS/IONS					
Cyanide	N	N	Y	no data	Y
Fluoride	N	N	Y	Y	Y
Nitrate	N	N	Y	Y	Y
Phosphoric Acid	Y				Y
Sulfate	N	N	N		N
VOCs					
Benzene	Y				Y
Chlorobenzene	N	N	Y	no data	Y
Chloroform	Y				Y
Ethylbenzene	N	N	Y	no data	Y
Methylene Chloride	Y				Y
Methyl Isobutyl Ketone	N	N	Y	no data	Y
Perchloro-ethylene	Y				Y
Trans-1,2-Dichloroethene	N	N	Y	no data	Y

TABLE AE-3: N-AREA CONTAMINANTS OF TOXICOLOGICAL SIGNIFICANCE DECISION LOGIC *(CONTINUED)*

Regulatory Contaminant of Concern	7: Is the contamininant a carcinogen?	8: Candidate for elimination per guidance?	9: Oral reference dose in IRIS or HEAST?	10: Is the Hazard Quotient greater than 0.1 for ingestion?	Contaminant of toxicological significance?
Xylenes	N	N	Y	no data	Y
OTHER ORGANICS					
Bis (2-ethylhexyl) phthalate	Y				Y
Hydrazine	Y				Y
PCBs	Y				Y
Petroleum Products, Diesel Oil, etc.	Y a				Y
Tetraethylpyro-phosphate	N	N	N		N
Tetrahydrofuran	N	N	N		N
Thiourea	N	N	Y	no data	Y

HEAST = Health Effects Assessments Summary Tables (EPa 1991)
IRIS = Integrated Risk Information System (EPA on-line database)
Y = Yes
N = No

a Assumed to contain benzene

APPENDIX B

POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

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Table 1A
Potential Federal ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Atomic Energy Act of 1954, as amended	42 U.S.C. 2011 et seq.		Authorizes DOE to set standards and restrictions governing facilities used for research, development, and utilization of atomic energy.		
Radiation Protection Standards	40 CFR Part 191		Establishes standards for management and disposal of high-level and transuranic waste and spent nuclear fuel.		
Standards for Management and Storage	40 CFR §191.03	A	Requires that management and storage of spent nuclear fuel or high-level or transuranic radioactive wastes at all facilities for the disposal of such fuel or waste that are operated by the DOE and that are not regulated by the Commission or Agreement States shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation from such management and storage shall not exceed 25 millirems to the whole body and 75 millirems to any critical organ.	Applicable to wastes disposed of after November 18, 1985.	SW-4 SW-5, SW-6 SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Nuclear Regulatory Commission Standards for Protection Against Radiation	10 CFR Part 20				

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1A (Continued)
Potential Federal ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Radiation Dose Standards	10 CFR §§20.101-20.105	R&A	Sets specific radiation doses, levels, and concentrations for restricted and unrestricted areas.	May be relevant and appropriate, as radioactive materials in the 100 Area can contribute radiation doses, levels, and concentrations which could exceed the limits; however, Hanford is not an NRC-licensed facility.	All
Clean Air Act, as amended	42 U.S.C. 7401 et seq.		A comprehensive environmental law designed to regulate any activities that affect air quality, providing the national framework for controlling air pollution.		
National Primary and Secondary Ambient Air Quality Standards	40 CFR Part 50		Sets National Ambient Air Quality Standards for ambient pollutants which are regulated within a region.		
Standards for Sulfur Oxides (Sulfur Dioxide)	40 CFR §50.4	A	The primary ambient air quality standard for sulfur oxides measured as sulfur dioxide are 80 micrograms per cubic meter (0.03 ppm), annual arithmetic mean; 365 micrograms per cubic meter (0.14 ppm) maximum 24-hour concentration not to be exceeded more than once per year.	Applicable if remediation includes incineration of waste.	SW-9, SW-10, SS-10, SS-11
Air Standards for Particulates	40 CFR §50.6	A	Prohibits average concentrations of particulate emissions in excess of 50 micrograms/m^3 annually or 150 micrograms/m^3 per 24-hour period.	A potential for particulate emissions exists during material handling or treatment, including incineration.	SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1A (Continued)
Potential Federal ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Air Standards for Carbon Monoxide	40 CFR §50.8	A	The national primary ambient air quality standards for carbon monoxide are: (1) 9 parts per million (10 milligrams per cubic meter) for an 8-hour average concentration not to be exceeded more than once per year and (2) 35 parts per million (40 milligrams per cubic meter) for a 1-hour average concentration not to be exceeded more than once per year.	Applicable if remediation includes incineration of waste.	SW-9, SW-10, SS-10, SS-11
Standards for Nitrogen Dioxide	40 CFR §50.11	A	The level of the national primary and secondary ambient air quality standard for nitrogen dioxide is 0.053 parts per million (100 micrograms per cubic meter), annual arithmetic mean concentration.	Applicable if remediation includes incineration.	SW-9, SW-10, SS-10, SS-11
Air Standards for Lead	40 CFR §50.12	A	The national primary and secondary ambient air quality standard for lead and its compounds measured as elemental lead are 1.5 micrograms per cubic meter, maximum arithmetic mean averaged over a calendar quarter.	Applicable if particulates suspended during remedial activities are contaminated with lead, or if remediation includes incineration.	SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Standards for New Stationary Sources	40 CFR Part 60				
Incinerator Particulate Standards	40 CFR §60.52	A	Prohibits discharge of gases containing particulates exceeding 0.18 g/dry cubic meter at standard conditions corrected to 12 percent CO_2, on or after the date of the performance test.	Applicable to incinerators of more than 45 metric tons per day charging rate (50 tons per day).	SW-9, SW-10, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1A (Continued)
Potential Federal ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
National Emissions Standards for Hazardous Air Pollutants (NESHAP)	40 CFR Part 61		Establishes numerical standards for hazardous air pollutants.		
Emission Standard for Beryllium	40 CFR §61.32	A	Prohibits emissions of beryllium from stationary sources including incinerators in excess of 10 grams/day unless otherwise approved.	Beryllium is a potential contaminant of concern at the 100 Area. Remedial incineration of waste may result in emissions of beryllium.	SW-9, SW-10, SS-10, SS-11
Emission Standard for Mercury	40 CFR §61.52	A	Prohibits emissions of mercury from sludge incineration plants or sludge drying plants exceeding 3200 grams/day.	Applicable to drying of wastewater treatment plant sludge. Mercury is a potential contaminant of concern in the 100 Area.	SW-9, SW-10, GW-6, SS-10, SS-11
Radionuclide Emissions from DOE Facilities (except Airborne Radon-222)	40 CFR §61.92	A	Prohibits emissions of radionuclides to the ambient air exceeding an effective dose equivalent of 10 mrem per year.	Applicable to incinerators and other remedial technologies where air emission may occur.	SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Emission Standards for Asbestos for Waste Disposal Operations for Demolition and Renovation	40 CFR §61.150	A	States there must either be no visible emissions to the outside air during the collection, processing (including incineration), packaging, or transporting of any asbestos-containing waste material generated by the source, or specified waste treatment methods must be used.	Applicable to recovery and handling of asbestos wastes.	SW-4, SW-5, SW-6, SW-9, SW-10

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1A (Continued)
Potential Federal ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Asbestos Standard for Active Waste Disposal Sites	40 CFR §61.154	A	States there must either be no visible emissions to the outside air during the collection, processing (including incineration), packaging, or transporting of any asbestos-containing waste material generated by the source, or specified waste treatment methods must be used.	Applicable to landfill disposal of asbestos.	SW-4, SW-5, SW-6, SW-9, SW-10
Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977	33 U.S.C. 1251 et seq.		Creates the basic national framework for water pollution control and water quality management.		
Designation of Hazardous Substances	40 CFR Part 116	A	Designated hazardous substances are in Tables 116.4A and 116.4B of the regulations.	Designates hazardous substances in accordance with requirements of Clean Water Act Section 311(b)(2)(A). These are included in the CERCLA list of hazardous substances.	All
Determination of Reportable Quantities for Hazardous Substances	40 CFR Part 117	A	Establishes reportable quantities of substances.	Applicable if a release into or onto navigable waters adjoining shorelines or contiguous zone exceeds quantities listed in Table 117.3 of the regulations.	All
National Pollutant Discharge Elimination System (NPDES)	40 CFR Part 122		Establishes permitting requirements, technology-based limitations and standards, control of toxic pollutants, and monitoring of effluents to assure permit conditions and limits are not exceeded.	Permit may not be required for CERCLA actions; however, substantive requirements must be met.	

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1A (Continued)
Potential Federal ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Permit Conditions	40 CFR §122.41-122.50	R&A	Establishes conditions that apply to NPDES permits including effluent limitations and monitoring requirements.	Applicable to direct discharges of wastewaters to waters of the U.S. Treatment of process waters that will be discharged to waters of the U.S. will be required to meet all applicable effluent limitations, quality standards, and toxic pollutant discharge standards as determined by the state, and/or federal discharge permitting authority.	SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Safe Drinking Water Act	42 U.S.C. 300f et seq.		Creates a comprehensive national framework to ensure the quality and safety of drinking water.		
National Primary Drinking Water Regulations	40 CFR Part 141	R&A	Establishes maximum contaminant levels (MCL) and maximum contaminant level goals (MCLG) for organic, inorganic, and radioactive constituents. The MCL for combined radium-226 and radium-228 is 5 pCi/L. The MCL for gross alpha particle activity (including radium-226 but excluding radon and uranium) is 15 pCi/L. The average annual concentration of beta particle and photon radioactivity from manmade radionuclides in drinking water shall not produce an annual dose equivalent to total body or any internal organ in excess of 4 millirem/year. See Tables 2A and 2B for other MCLs.	Applicable to public water systems. Potential chemicals and radionuclides of concern may migrate to the drinking water supply as a result of remedial activities. Although federal MCLGs are not enforceable standards, they are potential ARARs under the Washington State Model Toxics Control Act when more stringent than other standards. See state ARARs.	All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1A (Continued)
Potential Federal ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
National Secondary Drinking Water Regulations	40 CFR Part 143	R&A	Controls contaminants in drinking water that primarily affect the aesthetic qualities relating to the public acceptance of drinking water.	Although federal secondary drinking water standards are not enforceable, they are potential ARARs under the Washington State Model Toxics Control Act when more stringent than other standards. See state ARARs.	All
Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act (RCRA)	42 U.S.C. 6901 et seq.		Establishes the basic framework for federal regulation of solid and hazardous waste.		
Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR §257.3-4	A	A facility or practice shall not contaminate an underground drinking water source beyond the solid waste boundary.	The courts or the state may establish alternate boundaries.	SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-4, GW-5, GW-6, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1A (Continued)
Potential Federal ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Groundwater Protection Standards	40 CFR §264.92 [WAC 173-303-645]	A	A facility shall not contaminate the uppermost aquifer underlying the waste management area beyond the point of compliance, which is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated area. The concentration of certain chemicals shall not exceed background levels, certain specified maximum concentrations, or alternate concentration limits, whichever is higher.	Groundwater concentration limits in this section do not exceed 40 CFR 141.	SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-4, GW-5, GW-6, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11
Land Disposal Restrictions	40 CFR Part 268 [WAC 173-303-140]		Generally, prohibits placement of restricted RCRA hazardous wastes in land-based units such as landfills, surface impoundments, and waste piles.		
Treatment Standards	40 CFR §§268.40 - 268.44 [WAC 173-303-140]	A	Establishes treatment standards which, when met, allow land disposal or storage of restricted wastes.	Applicable if remediation includes disposal and/or storage of restricted wastes.	SW-9, SW-10, GW-4, GW-5, GW-6, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11

*These are State of Washington regulatory citations which are equivalent to Title 40 Code of Federal Regulations, Parts 264 and 268 as stated in Washington Administrative Code 173-303.

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1A (Continued)
Potential Federal ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Toxic Substances Control Act	15 U.S.C. 2601 et seq.				
Regulation of Polychlorinated Biphenyls (PCB)	40 CFR Part 761		Establishes prohibitions of, and requirements for, management of PCBs and PCB items from manufacturing through disposal.		
Storage and Disposal	40 CFR §§761.60 - 761.79	A	Requires specified methods of storage and disposal of PCBs in concentrations exceeding 50 ppm. Methods vary depending on the type of PCB waste.		SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Uranium Mill Tailings Radiation Control Act of 1978	Public Law 95-604, as amended				
Standards for Uranium and Thorium Mill Tailings	40 CFR 192		Establishes standards for control, cleanup, and management of radioactive materials from inactive uranium processing sites.		

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1A (Continued)
Potential Federal ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Land Cleanup Standards	40 CFR §§192.10 - 192.12	R&A	Requires remedial actions to provide reasonable assurance that, as a result of residual radioactive materials from any designated processing site, the concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than 5 pCi/g, averaged over the first 15 cm of soil below the surface, and 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface. In any habitable building, a reasonable effort shall be made during remediation to achieve an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 Working Level (WL). In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL and the level of gamma radiation shall not exceed the background level by more than 20 microroentegens per hour.	May be relevant and appropriate, as any radium-226 encountered during remediation did not result from uranium processing.	All
Implementation	40 CFR §§192.20 - 192.23	R&A	Requires that when radionuclides other than radium-226 and its decay products are present in sufficient quantity and concentration to constitute a significant radiation hazard from residual radioactive materials, remedial action shall reduce other residual radioactivity to levels as low as reasonably achievable (ALARA).	May be relevant and appropriate, as any radium-226 encountered during remediation did not result from uranium processing.	All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1B
Potential State ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Department of Social and Health Services (Drinking Water)	43.20A RCW				
Public Water Supplies	WAC 248-54		Establishes requirements to protect users of public drinking water supplies.		
Maximum Contaminant Levels (MCL)	WAC 248-54-175	A	The MCL for radium-226 is 3 pCi/L.	The level for radium-226 exceeds the federal MCL in 40 CFR 192.	All
Model Toxics Control Act (MTCA)	70.105D RCW		Requires remedial actions to attain a degree of cleanup protective of human health and the environment.		
Cleanup Regulations	WAC 173-340		Establishes cleanup levels and prescribes methods to calculate cleanup levels for soils, groundwater, surface water, and air.		

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1B (Continued)
Potential State ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Groundwater Cleanup Standards	WAC 173-340-720	R&A	Requires that where the groundwater is a potential source of drinking water, cleanup levels under Method B must be at least as stringent as concentrations established under applicable state and federal laws, including the following: (A) Maximum contaminant levels established under the Safe Drinking Water Act and published in 40 CFR 141, as amended; (B) Maximum contaminant level goals for noncarcinogens established under the Safe Drinking Water Act and published in 40 CFR 141, as amended; (C) Secondary maximum contaminant levels established under the Safe Drinking Water Act and published in 40 CFR 143, as amended; and (D) Maximum contaminant levels established by the state board of health and published in Chapter 248-54 WAC, as amended. See Tables 2A and 2B for cleanup levels for groundwater.	Federal maximum contaminant level goals for drinking water (40 CFR Part 141) and federal secondary drinking water regulation standards (40 CFR Part 143) are potential ARARs under MTCA when they are more stringent than other standards. Method B cleanup levels are levels applicable to remediation at Hanford unless a demonstration can be made that method C (alternate cleanup levels) is valid.	All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1B (Continued)
Potential State ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements		Remarks	Alternatives Potentially Affected
Soil Cleanup Standards	WAC 173-340-740	R&A	MTCA Method B concentration limits in micrograms per kilogram for potential contaminants in soils, sediments, and sludges are:			SS-1, SS-2, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11
			Boron	7,200,000		
			Lead	112,000		
			Manganese	8,000,000		
			Vanadium	560,000		
			Cyanide	1,600,000		
			Bis (2-ethylhexyl) phthalate	71,400		
			PCBs	130		
			Acetone	8,000,000		
			Benzene	34,482		
			Chlorobenzene	1,600,000		
			Trans -1,2-dichloroethene	1,600,000		
			Ethylbenzene	8,000,000		
			Methyl Isobutyl Ketone	400,000		
			Perchloroethylene	19,607		
Solid Waste Management Recovery and Recycling Act	70.95 RCW					
Minimum Functional Standards for Solid Waste Handling	WAC 173-304		Establishes requirements to be met statewide for the handling of all solid waste.			

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1B (Continued)

Potential State ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Landfilling Standards	WAC 173-304-460	A	Prohibits an operator/owner from violating Chapter 90.48 RCW (Water Pollution Control) or any receiving water quality standards from discharges of surface run-off, leachate, or any other liquid associated with a landfill. Prohibits violation of any ambient air quality standard at the property boundary or emission standard from any emission of landfill gases, combustion, or any other emission associated with a landfill. Prohibits explosive gases whose concentration exceeds 100 ppm by volume of hydrocarbons (expressed as methane) in off-site structures.		SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Water Pollution Control	90.48 RCW				
Surface Water Quality Standards	WAC 173-201		Sets surface water quality standards for the state.		

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1B (Continued)
Potential State ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Water Criteria Classes	WAC 173-201-045	A	Standards for surface water designated "Class A" include: freshwater temperature shall not exceed 18.0°C due to human activities. Temperature increases shall not at any time exceed t = 28/T+7 where "t" represents the maximum permissible temperature increase measured at a dilution zone boundary; and "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge. When natural conditions exceed 18.0° (freshwater) and 16.0° (marine water), no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C. Provided that temperature increase resulting from nonpoint source activities shall not exceed 2.8°C, and the maximum water temperature shall not exceed 18.3°C (freshwater). pH shall be within the range of 6.5 to 8.5 (freshwater) with a man-caused variation within a range of less than 0.5 units.	The Hanford reach of the Columbia River is classified "Class A."	SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1B (Continued)
Potential State ARARs
Chemical-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Toxic Substances	WAC 173-201-047	A	Sets surface water limits for toxic substances. Freshwater limits in micrograms per liter for 100 Area contaminants are: Cadmium (acute): $\leq e^{(1.128 [\ln (\text{hardness})]-3.828)}$ [a] Cadmium (acute): $\leq e^{(0.7852 [\ln (\text{hardness})]-3.490)}$ [b] Lead (acute): $\leq e^{(1.273 [\ln (\text{hardness})]-1.460)}$ [a] Lead (acute): $\leq e^{(1.273 [\ln (\text{hardness})]-4.705)}$ [b] Nickel (acute): $\leq e^{(0.8460 [\ln (\text{hardness})]+3.3612)}$ [a] Nickel (chronic): $\leq e^{(0.8460 [\ln (\text{hardness})]+1.1645)}$ [b] (acute) (chronic) Chlorine 19.0[a] 11.0[b] Chromium 16.0[a] 11.0[b] Cyanide 22.0[a] 5.2[b] Mercury 2.4[a] 0.012[b] PCBs 2.0[c] 0.014[c] [a]A one-hour average concentration not to be exceeded more than once every three years. [b]A four-day average concentration not to be exceeded more than once every three years. [c]A 24-hour average not to be exceeded. NOTE: Hardness is a measure of the calcium and magnesium salts present in water, measured in milligrams per liter as calcium carbonate.		All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1C
Potential TBCs
Chemical-Specific

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
Benton-Franklin-Walla Walla Counties Air Pollution Control Authority	General Regulation 80-7			
Maximum Permissible Emissions	Section 400-040	Prohibits emission of air contaminants for more than 3 minutes/hour when emissions at or near the emission source exceed 20 percent opacity, except under special circumstances.		SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Maximum Allowable Emissions for Combustion and Incineration Sources	Section 400-050	Prohibits emissions exceeding 100 ppm of total carbonyls.		SW-9, SW-10, SS-10, SS-11
Maximum Emissions for General Process Sources	Section 400-060	Prohibits emissions of particulates from general process sources exceeding 0.10 grain (.0065 gram) per standard cubic foot of dry exhaust gas.	Pertinent to sources that result in a physical or chemical change in material (excluding combustion).	SW-9, SW-10, GW-5, GW-6, SS-10, SS-11
Model Toxics Control Act	70.105D RCW			
Cleanup Regulations	WAC 173-340	The State Department of Ecology is currently adapting the calculations in MTCA to be applicable to radioactive contaminants. These cleanup standards may become available prior to or during remediation.		

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1C (Continued)
Potential TBCs
Chemical-Specific

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
National Primary Drinking Water Regulations	40 CFR 141	Proposed maximum contaminant level goals (MCLGs) (Federal Register, July 18, 1991) are: Contaminant — MCLG Radium-226 — zero Radium-228 — zero Uranium — zero Gross alpha emitters — zero Beta and photon emitters — zero	Federal MCLGs are ARAR under MTCA when they are more stringent than other state standards.	All
U.S. Department of Energy Orders				
Radiation Protection of the Public and the Environment	DOE 5400.5	Establishes radiation protection standards for the public and environment.		
Radiation Dose Limit (All Pathways)	DOE 5400.5, Chapter II, Section 1a	The exposure of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an effective dose equivalent greater than 100 mrem from all exposure pathways, except under specified circumstances.	Pertinent if remedial activities are "routine DOE activities."	All
Radiation Dose Limit (Drinking Water Pathway)	DOE 5400.5, Chapter II, Section 1d	Provides a level of protection for persons consuming water from a public drinking water supply operated by DOE so that persons consuming water from the supply shall not receive an effective dose equivalent greater than 4 mrem per year. Combined radium-226 and radium-228 shall not exceed 5×10^{-9} μCi/mL and gross alpha activity (including radium-226 but excluding radon and uranium) shall not exceed 1.5×10^{-8} μCi/mL.	Pertinent if radionuclides may be released during remediation.	All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 1C (Continued)
Potential TBCs
Chemical-Specific

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
Residual Radionuclides in Soil	DOE 5400.5 Chapter IV, Section 4a	Generic guidelines for radium-226 and radium-228 are: • 5 pCi/g averaged over the first 15 cm of soil below the surface; and • 15 pCi/g averaged over 15-cm-thick layers of soil more than 15 cm below the surface. Guidelines for residual concentrations of other radionuclides must be derived from the basic dose limits by means of an environmental pathway analysis using specific property data where available. Procedures for these deviations are given in "A Manual for Implementing Residual Radioactive Material Guidelines" (DOE/CH-8901). Procedures for determination of "hot spots," "hot-spot cleanup limits," and residual concentration guidelines for mixtures are in DOE/CH-8901. Residual radioactive materials above the guidelines must be controlled to the required levels in 5400.5, Chapter II and Chapter IV.	Residual concentrations of radioactive material in soil are defined as those in excess of background concentrations averaged over an area of 100 m^2.	SS-1, SS-2, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 2A
Potential Water Quality Criteria and Limits for Radionuclides

Contaminant	Radiation Protection Standards (pCi/L)[a]	Safe Drinking Water Act Primary MCL (pCi/L)[b]	State Limit for Groundwater (pCi/L)[c]	DOE Order 5400.5[d]	Columbia River Concentration (pCi/L)[e]
Tritium		2.0 E+04	2.0 E+04	8.0 E+04	130.0
Carbon-14		8.0 E+06		2.8 E+03	
Calcium-41				4.0 E+03	
Cobalt-60		5.0 E+05		2.0 E+02	
Nickel-63		3.0 E+05		1.2 E+04	
Selenium-79				8.0 E+02	
Krypton-85					
Strontium-90		8	8	4.0 E+01	
Zirconium-93		8.0 E+06		3.6 E+03	
Niobium-94				1.2 E+03	
Palladium-107				4.0 E+04	
Cadmium-113				3.2 E+01	
Iodine-129		3.0 E+03		2.0 E+01	
Cesium-134		9.0 E+04		8.0 E+01	
Samarium-151		6.0 E+05		1.6 E+04	
Europium-152		8.0 E+05		8.0 E+02	
Radium-226/228	5	5	5	4.0 E+00	
Uranium-235/238				2.4 E+01	
Uranium-238		4.0 E+05		2.4 E+01	
Plutonium-238		5.0 E+04		1.6 E+00	
Plutonium-239/240				1.2 E+00	
Plutonium-241		2.0 E+06		8.0 E+01	
Americium-241		4.0 E+04		1.2 E+00	

See footnote key at end of table.

Table 2A
Potential Water Quality Criteria and Limits for Radionuclides (Footnotes)

[a] Source: 40 CFR 191.
[b] Source: 40 CFR §141.16.
[c] Source: Washington Ground Water Quality Standards. Enforcement limits may exceed these values when the natural ground water quality exceeds the criteria or when other exceptions contained in WAC 173-200-050(3)(b) apply.
[d] Four percent of the derived concentration guide values are shown because the DOE limit for each contaminant in drinking water is 4 mrem/year; the total of all contaminants is not to exceed the DOE exposure limit of 100 mrem/year.
[e] Source: Ebasco Services Incorporated, 1991, "Engineering Evaluation of Containment Alternatives for N-Springs Releases," WHC-SD-EN-EE-003, Rev. 0, Richland, Washington.

NOTE: Limits for gross alpha and beta particle and photon radioactivity are listed in Table 1A (40 CFR Part 141).

9 2 1 2 6 2 1 0 3 1

Table 2B
Potential Water Quality Criteria and Limits for Nonradionuclides

Contaminant (Metal)	Columbia River Concentration (μg/L)[a]	Water Quality Criteria (μg/L)			Safe Drinking Water Act	State Limit for Groundwater (μg/L)[e]
		Protection of Human Health[b]	Protection of Freshwater Aquatic Species (Chronic)[c]	Protection of Freshwater Aquatic Species (Acute)[e]	Primary MCL (μg/L)[d]	
Arsenic		0.018	190	360	50	0.05
Beryllium	0.0005	0.0077	5.3	130		80
Barium	0.0430	1 mg			2,000	200
Cadmium	<0.001	16	1.1	3.9	5	8.5
Chromium	<0.001	170	11	16	100	50
Cobalt						
Lead	0.0020	50	3.2	82	50[f]	22.4
Manganese	0.0050	50				50
Mercury	0.0001	0.14	0.012	2.4	2	2
Nickel	0.0020	610	160	1,400		320

See footnote key at end of table.

Table 2B (Continued)
Potential Water Quality Criteria and Limits for Nonradionuclides

Contaminant (Nonmetallic Ion or Compound)	Columbia River Concentration (μg/L)[a]	Water Quality Criteria (μg/L)			Safe Drinking Water Act	State Limit for Groundwater (μg/L)[e]
		Protection of Human Health[b]	Protection of Freshwater Aquatic Species (Chronic)[c]	Protection of Freshwater Aquatic Species (Acute)[c]	Primary MCL (μg/L)[d]	
Asbestos		7×10^6 fibers/L			7×10^6 fibers/L	
Chloride	6.0					250,000
Chlorine						
Cyanide		700	5.2	22.0		320
Fluoride	0.20				4,000	2,000
Hydrochloric Acid						
Nitrate	0.30				10,000	10,000
Nitrite					1,000	1,000
Phosphoric Acid						
Sulfate	14.0					250,000

See footnote key at end of table.

Table 2B (Continued)
Potential Water Quality Criteria and Limits for Nonradionuclides

Contaminant (Volatile Organic Compound)	Columbia River Concentration (μg/L)[a]	Water Quality Criteria (μg/L)			Safe Drinking Water Act	State Limit for Groundwater (μg/L)[e]
		Protection of Human Health[b]	Protection of Freshwater Aquatic Species (Chronic)[c]	Protection of Freshwater Aquatic Species (Acute)[c]	Primary MCL (μg/L)[d]	
Benzene		1.2		5,300	5	1.0
Chlorobenzene		680				160
Chloroform		5.7			100	7
Trans-1,2-dichloroethene		700			100	100
Ethylbenzene		3,100			700	700
Methylene Chloride		4.7			5	5
Methyl Isobutyl Ketone (MIBK)						800
Perchlorethlyene (Tetrachloroethene, Tetrachloroethylene		0.8	840	5,280	5	0-8
Trichloroethene		2.7	21,900	45,000	5	3
Xylenes (Total)					10,000	1,000

See footnote key at end of table.

Table 2B (Continued)
Potential Water Quality Criteria and Limits for Nonradionuclides

Contaminant (Nonvolatile Organic Compound)	Columbia River Concentration (μg/L)[a]	Water Quality Criteria (μg/L)			Safe Drinking Water Act	State Limit for Groundwater (μg/L)[e]
		Protection of Human Health[b]	Protection of Freshwater Aquatic Species (Chronic)[c]	Protection of Freshwater Aquatic Species (Acute)[c]	Primary MCL (μg/L)[d]	
Acetic Acid						
Ammoniated citric acid solutions						
Bis(-2-ethylhexyl) phthalate						6
Ethylenediamine						
Ethylenediamine tetraacetic Acid (EDTA)						
Formic Acid						
Oxalic Acid						
Hydrazine						0.03
PCBs		0.079 ng	0.014	2	0.5	0.01
Tetraethyl pyrophosphate						
Tetrahydrofuran						
Thiourea						

See footnote key at end of table.

Table 2B
Potential Water Quality Criteria and Limits (Footnotes)

[a] Source: Ebasco Services Incorporated, 1991, "Engineering Evaluation of Containment Alternatives for N-Springs Releases," WHC-SD-EN-EE-003, Rev. 0, Richland, Washington.

[b] Human health values shown are for consumption of water and organisms. The values are from the November 19, 1991, EPA-proposed toxics rule—the most current values available from the EPA as of this writing.

[c] Source: EPA "Quality Criteria for Water 1986" and EPA "Update #2 to Quality Criteria for Water 1986."

[d] Source: 40 CFR §§141.61-141.62 for all MCLs except lead and arsenic (40 CFR §141.11).

[e] The most restrictive concentration from the Washington Ground Water Quality Standards or the Model Toxics Control Act (MTCA) (Method B) is shown. In accordance with MTCA, state limits include federal maximum contaminant level goals (MCLG) from 40 CFR 141 and federal secondary drinking water standards (40 CFR 143), if these values are more stringent than state standards. Where the Washington Ground Water Quality Standards are the most restrictive, enforcement limits may exceed these values when the natural ground water quality exceeds the criteria or when other exceptions contained in WAC 173-200-050 (3)(b) apply.

[f] The MCL for lead (40 CFR §141.11) is in effect until December 7, 1992; no revised MCL for lead after that date is available.

9 2 1 2 6 5 2 1 0 3 6

Table 3A
Potential Federal ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Atomic Energy Act of 1954	42 U.S.C. 2011 et seq.		Authorizes DOE to set standards and restrictions governing the design, location, and operation of facilities used for research, development, and utilization of atomic energy.		
Radiation Protection Standards	40 CFR Part 191 Subpart B	A	Requires monitoring of spent nuclear fuel, high-level, or TRU disposal systems after disposal; specifies controls for disposal sites; requires barriers for disposal systems; sets criteria for selecting disposal sites and systems.	Applicable to waste disposed of after November 18, 1985.	SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Licensing Requirements for Land Disposal of Radioactive Waste	10 CFR Part 61		Establishes criteria for the land disposal of radioactive waste.		
Performance Objectives	10 CFR §§61.40-61.44	R&A	Land disposal facilities must be sited, designed, operated, closed, and controlled after closure to assure that exposure to humans is within established limits.	Applicable to on-site disposal of radioactive materials.	SW-4, SW-5, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Technical Requirements	10 CFR §§61.50-61.59	R&A	Establishes design criteria for land disposal sites and other requirements for site suitability, operation, closure, monitoring, waste classification, and waste characteristics.		SW-4, SW-5, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3A (Continued)
Potential Federal ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Clean Air Act	42 U.S.C. 7401 et seq.				
National Emission Standards for Hazardous Air Pollutants	40 CFR Part 61				
Asbestos Standard for Waste Disposal	40 CFR §61.150	A	Prohibits visible emissions to the outside air during incineration, packaging, or transporting of any asbestos-containing waste material generated by the source unless a specified emission control and waste treatment method is used.	Applicable if asbestos-containing waste will be incinerated, packaged or transported.	SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Asbestos Standard for Active Waste Disposal Sites	40 CFR §61.154	A	Sets requirements for covering of asbestos-containing waste, if requirements for no visible emissions are not met at sites where such waste is deposited. Requires a natural barrier or warning signs and fencing to deter public access to the site.	Applicable if waste sites receive asbestos-containing materials.	SW-9, SW-10, GW-4, GW-5, GW-6, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11
Federal Water Pollution Control Act (FWPCA), as amended by the Clean Water Act of 1977 (CWA)	33 U.S.C. 1251 et seq.		Creates the basic national framework for water pollution control and water quality management in the United States.	Applicable to discharges of pollutants to navigable waters.	
The National Pollutant Discharge Elimination System (NPDES)	40 CFR Part 122	A	Part 122 covers establishing technology-based limitations and standards, control of toxic pollutants, and monitoring of effluent to assure limits are not exceeded.	Applicable if remediation includes wastewater discharge; also applies to storm water runoff associated with industrial activities. Effluent limitations established by EPA and included in NPDES permit.	SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3A (Continued)
Potential Federal ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
NPDES Criteria and Standards	40 CFR §125.104		Best management practices program shall be developed in accordance with good engineering practice.		
Discharge of Oil	40 CFR Part 110	A	Prohibits discharge of oil that violates applicable water quality standards or causes a sheen of oil on water surface.	Runoff from site will need control for oily waste discharge to waters of the United States.	All
Safe Drinking Water Act (SDWA), as amended	42 U.S.C. 300f et seq.		Creates a comprehensive national framework designed to ensure the quality and safety of drinking water supplies.	Applicable to public water systems.	
Underground Injection Control (UIC) Program	40 CFR Part 144	A	Identifies the minimum requirements for UIC programs. Requires all UI wells to be permitted and describes permitting procedures.	Applicable for remedial action involving reinjection of groundwater.	GW-5
Criteria and Standards for the Underground Injection Control (UIC) Program	40 CFR Part 146	A	Establishes siting, construction, operating, monitoring, and closure requirements for all classes of injection wells. (Criteria and standards for class IV wells are reserved at this time.)	Applicable for remedial action involving reinjection of groundwater.	GW-5
Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act (RCRA)	42 U.S.C.6901 et seq.		Establishes the basic framework for federal regulation of solid waste. Subpart C of RCRA controls the generation, transportation, treatment, storage, and disposal of hazardous waste through a comprehensive "cradle to grave" system of hazardous waste management techniques and requirements.	Hazardous waste generated by site remediation activities must meet RCRA generator and treatment, storage, or disposal (TSD) requirements.	

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3A (Continued)
Potential Federal ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Guidelines for Thermal Processing of Solid Wastes	40 CFR Part 240		Sets guidelines for thermal processing of solid wastes	Applicable only to nonhazardous solid wastes.	
Solid Waste Excluded	40 CFR §240.201	R&A	Provision for storing, handling, and removing hazardous or excluded wastes left inadvertently at the facility should be considered in design.		SW-9, SW-10, SS-10, SS-11
Site Selection	40 CFR §240.202	R&A	Accessibility by permanent roads, and environmental, climatological, and socioeconomic criteria should be considered when siting a facility.		SW-9, SW-10, SS-10, SS-11
General Design	40 CFR §240.203	R&A	A plan for a new or modified facility, including a list of considerations and rationale for the decisions on the considerations, must be approved prior to construction.		SW-9, SW-10, SS-10, SS-11
Identification and Listing of Hazardous Waste	40 CFR Part 261 [WAC 173-303-016]	A	Identifies by both listing and characterization, those solid wastes subject to regulation as hazardous wastes under Parts 261-265, 268, and 270.	Applicable if remediation techniques result in generation of hazardous wastes.	SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262 [WAC 173-303]		Describes regulatory requirements imposed on generators of hazardous wastes who treat, store, or dispose of the waste on-site.	Applicable if remediation techniques result in generation of hazardous waste.	
General Requirements	40 CFR §262.20 [WAC 173-303-180]	A	Generators who transport hazardous waste for off-site treatment, storage, or disposal must originate and follow-up the manifest for off-site shipments.	Applicable if hazardous waste is transported off-site for treatment, storage, or disposal.	SW-5, SS-5, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3A (Continued)
Potential Federal ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Packaging	40 CFR §262.30 [WAC 173-303-190]	A	Before transporting a hazardous waste, the generator must package, label, mark, and placard the shipment in accordance with DOT regulations.	Applicable if hazardous waste is transported off-site for treatment, storage, or disposal.	SW-5, SS-5, SS-11
Accumulation Time	40 CFR §262.34 [WAC 173-303-200]	A	Allows a generator to accumulate hazardous waste on-site for 90 days or less without a permit, provided that all waste is containerized and labeled.	Hazardous waste removed from the 100-Area operable units, and waste treatment residues, are subject to the 90-day generator accumulation requirements if the waste is stored on site for 90 days or less. If hazardous waste is stored for more than 90 days, the full permitting standards for TSD facilities must be met.	SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	40 CFR Part 264 [WAC 173-303]		Establishes requirements for operating hazardous waste treatment, storage, and disposal facilities.	Applies to facilities put in operation since November 19, 1980. Facilities in operation before that date and existing facilities handling newly regulated wastes must meet similar requirements in 40 CFR Part 265. Applies if remediation technique results in on-site treatment, storage, or disposal of hazardous waste.	
General Facility Standards	40 CFR §§264.10-264.18 [WAC 173-303-060; 173-303-310; 173-303-320; 173-303-330]	A	Security fences, EPA ID number, inspection records, personnel training, geologic location standards.		SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3A (Continued)
Potential Federal ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Preparedness and Prevention	40 CFR §§264.30-264.37 [WAC 173-303-340]	A	Facility design; required equipment; testing and maintenance of equipment; alarms and access to communications; required aisle space; agreements with state emergency response teams, equipment suppliers; facility tours for fire and police department.		SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Contingency Plan and Emergency Procedures	40 CFR §§264.50-264.56 [WAC 173-303-350; 173-303-360]	A	Written plans for emergency procedures and named coordinator.	Applicable for active sites, reduced or eliminated for closed sites.	SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Ground-water Monitoring	40 CFR §§264.97-264.99 [WAC 173-303-645]	A	Owners and operators of new hazardous waste disposal facilities must conduct a groundwater monitoring program in accordance with 40 CFR 264.97. This must include, if necessary, a detection monitoring program under 40 CFR 264.99 and a corrective action program under 40 CFR 264.100 if a groundwater protection standard is exceeded or if the concentration limits established under 40 CFR 264.94 are exceeded between the compliance point and the downgradient facility property boundary.	Applicable to those alternatives where wastes are to be removed and placed in new, replacement, or expanded hazardous waste disposal facilities to ensure hazardous waste constituents are not leaching out to the soil or groundwater	SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3A (Continued)
Potential Federal ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Closure	40 CFR §§264.111-264.116 [WAC 173-303-610]	A	Performance standard which controls, minimizes, or eliminates, to the extent necessary to protect human health and the environment, postclosure escape of chemicals; closure plan; time limits; disposal or decontamination of equipment, structures, soils; certification of closure survey plat. All contaminated equipment, structures, and soils must be properly disposed.		SW-4, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-6, SS-10, SS-11
Postclosure	40 CFR §§264.117-264.120 [WAC 173-303-610]	A	Postclosure care must begin after completion of closure and continue for 30 years. During this period, the owner or operator must comply with all postclosure requirements, including maintenance of cover, leachate monitoring, and groundwater monitoring.	Applicable to waste remaining in place after closure. Requires postclosure care and monitoring to ensure elimination of escape of hazardous constituents, leachate, and contaminated runoff.	SW-4, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-6, SS-10, SS-11
Container Storage	40 CFR §§264.170-264.178 [WAC 173-160-173-161]	A	Condition of containers; compatibility of waste with containers; container management; inspections; containment; special requirements for ignitable or reactive wastes.	May be applicable if container storage is to occur. Inspection requirements may be in potential conflict with ALARA requirements.	SW-4, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-6, SS-10, SS-11
Tank Systems	40 CFR §§264.190 - 264.199 [WAC 173-303-640]	A	Assessment of tank integrity; design and installation of new tank systems or components; containment and detection of releases; inspections; closure/postclosure care; special requirements for ignitable or reactive wastes.	Applicable if remediation technique includes tank systems for storage or treatment.	GW-5, GW-6

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3A (Continued)
Potential Federal ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Landfills	40 CFR §§264.300-264.317 [WAC 173-303-665]	A	Design and operating requirements, including liner systems and control of rainfall run-on and runoff; monitoring and inspection; surveying and record keeping; closure/postclosure care, including final cover; special requirements for ignitable or reactive wastes incompatible wastes, bulk or containerized liquids and containers; disposal of small containers.	Applicable if remediation technique includes disposal in landfills. Land Disposal Restrictions, (40 CFR Part 268) apply.	SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Incineration	40 CFR §§264.340-264.351 [WAC 173-303-670]	A	Waste analysis; performance standards; specified principal organic hazardous constituents; incinerator permit; monitoring and inspections; closure.	Applicable if remediation technique includes incineration in hazardous waste incinerators, boilers, or industrial furnaces. See state ARARs for additional requirements.	SW-9, SW-10, SS-10, SS-11
Miscellaneous Units	40 CFR §§264.600-264.603 [WAC 173-303-680]	A	Environmental performance standards; monitoring; analysis; inspection; response; reporting; corrective action.	Applicable if remediation technique includes treatment, storage, and/or disposal in a unit not specified in 40 CFR §§264.190-264.351. Vaults may be determined to be miscellaneous units.	SW-4, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-6, SS-10
Land Disposal Restrictions (LDR)	40 CFR Part 268 [WAC 173-303-140-WAC 173-303-141]	A	Generally prohibits placement of restricted RCRA hazardous wastes in land-based units such as landfills, surface impoundments, and waste piles. Prohibits storage of restricted waste for longer than one year unless the owner/operator can prove storage is necessary to facilitate proper recovery, treatment, or disposal.	Applicable unless wastes have been treated, treatment has been waived, a treatment variance has been set for the waste, an equivalent treatment method petition has been approved, a no-migration petition has been approved, or the waste has been delisted.	SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3A (Continued)
Potential Federal ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Treatment Standards	40 CFR §§268.40-268.43 [WAC 173-303-140]	A	Establishes treatment standards that must be met prior to land disposal.	Applicable if wastes contain RCRA hazardous constituents.	SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Prohibitions on Storage	40 CFR §268.50 [WAC 173-303-141]	A	The storage of hazardous waste restricted from land disposal under RCRA Section 3004 and 40 CFR 268, Subpart C, is prohibited unless wastes are stored in tanks and containers by a generator or the on-site operator of a TSD facility solely for the purpose of accumulation of such quantities as to facilitate proper treatment or disposal. TSD facility operators may store wastes for up to one year under these circumstances.		SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11
Technical Standards for Underground Storage Tanks (UST)	40 CFR Part 280 [WAC 173-360]	R&A	Establishes design, construction, operating, release reporting, and closure requirements for USTs.	Relevant and appropriate if USTs containing petroleum are installed as part of the remedial action or are closed during the remedial action. Not applicable to UST systems holding hazardous wastes identified under the Solid Waste Disposal Act. See state ARARs for additional requirements.	SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-3, GW-4, GW-5, GW-6, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3A (Continued)
Potential Federal ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Toxic Substances Control Act (TSCA), as amended	15 U.S.C. 2601 et seq.				
Regulation of Polychlorinated Biphenyls (PCBs)	40 CFR Part 761	A	For spills occurring after May 4, 1987, spillage or disposal must be reported to EPA. Unless otherwise approved, PCBs at concentrations of 50 ppm or greater must be treated in an incinerator. Spills that occurred before May 4, 1987 are to be decontaminated to requirements established at the discretion of the EPA.	PCBs may have been disposed of in the landfill sites in electrical capacitors or transformers.	SW-9, SW-10, GW-5, GW-6, SS-10, SS-11
Uranium Mill Tailings Radiation Control Act of 1978	Pub. L. 95-604, as amended		Establishes controls of residual radioactive material at processing and depository sites.		
Health and Environmental Protection Standards for Inactive Uranium Processing Sites	40 CFR Part 192 Subpart A	R&A	Requires remedial action of residual radioactive material to be effective for at least 200 years.	Although Hanford is not a site designated by the Act, requirements of the Act are relevant and appropriate to the site.	All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3B
Potential State ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Department of Ecology	43.21A RCW		Vests the Washington Department of Ecology with the authority to undertake the state air regulation and management program.		
Air Pollution Regulations	WAC 173-400		Establishes requirements for the control and/or prevention of the emission of air contaminants.	Applicable if emission sources are created during remedial action.	
Standards for Maximum Emissions	WAC 173-400-040	A	Requires best available control technology be used to control fugitive emissions of dust from materials handling, construction, demolition, or any other activities that are sources of fugitive emissions. Restricts emitted particulates from being deposited beyond Hanford. Requires control of odors emitted from the source. Prohibits masking or concealing prohibited emissions. Requires measures to prevent fugitive dust from becoming airborne.	Applicable to dust emissions from cutting of concrete and metal and vehicular traffic during remediation.	SW-2, SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-2, GW-3, GW-4, GW-5, GW-6, SS-2, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11
Emission Standards for Combustion and Incineration	WAC 173-400-050	A	Restricts operation of incinerators to daylight hours unless otherwise authorized.	Applicable if incineration is part of the remedial action.	SW-9, SW-10, SS-10, SS-11
Emission Limits for Radionuclides	WAC 173-480		Controls air emissions of radionuclides from specific sources.	Applicable to remedial activities that result in air emissions.	

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3B (Continued)
Potential State ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
New and Modified Emission Units	WAC 173-480-060	A	Requires the best available radionuclide control technology be utilized in planning construction, installation, or establishing a new emission unit.	Applicable to remedial actions that result in air emissions.	SW-4, SW-5, SW-6, SW-9, SW-10, GW-3, GW-4, GW-5, GW-6, SS-4, SS-5, SS-6, SS-7, SS-9, SS-10, SS-11
Hazardous Waste Management Act of 1976 as amended in 1980 and 1983[1]	70.105 RCW		Establishes a statewide framework for the planning, regulation, control, and management of hazardous waste.		
Dangerous Waste Regulations	WAC 173-303		Establishes the design, operation, and monitoring requirements for management of hazardous waste.	Includes requirements for generators of dangerous waste. Dangerous waste includes the full universe of wastes regulated by WAC 173-303 including extremely hazardous waste.	
Siting Criteria	WAC 173-303-282	A	Prohibits location of a dangerous waste management facility within a 100-year floodplain or a land-based facility within a 500-year floodplain. Prohibits locating facilities within 500 feet of a fault with displacement during the Holocene. Establishes further siting criteria that supplement federal requirements.	Exceeds requirements of 40 CFR §264.18.	SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11

[1]The Hazardous Waste Management Act and regulations pursuant to the Act provide the statutory and regulatory basis for state authorization to implement RCRA. State of Washington regulations that are equivalent to RCRA regulations are cited in brackets in the federal ARARs. The WAC 173-303 regulations cited in this section are those judged to be more stringent than RCRA regulations.

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3B (Continued)
Potential State ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Incinerators	WAC 173-303-670	A	Requires incinerators burning dangerous waste to destroy designated byproducts so that the total mass emission rate of the byproducts is no more than .01 percent of the total mass feed rate of principal organic dangerous constituents fed into the incinerator.	Exceeds requirements in 40 CFR 264.343.	SW-9, SW-10, SS-10, SS-11
Model Toxics Control Act	70.105D RCW		Authorizes the state to investigate releases of hazardous substances, conduct remedial actions, carry out state programs authorized by federal cleanup laws, and to take other actions.		
Hazardous Waste Cleanup Regulations	WAC 173-340		Addresses releases of hazardous substances caused by past activities, and potential and ongoing releases from current activities.	Applicable to facilities where hazardous substances have been released, or there is a threatened release that may pose a threat to human health or the environment.	
Selection of Cleanup Actions	WAC 173-340-360	R&A	Establishes cleanup requirements to include in cleanup plans. Identifies technologies to be considered for remediation of hazardous substances.		All
Cleanup Actions	WAC 173-340-400	R&A	Ensures that the cleanup action is designed, constructed, and operated in accordance with the cleanup plan and other specified requirements.		All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3B (Continued)
Potential State ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Institutional Controls	WAC 173-340-440	R&A	Requires physical measures such as fences and signs to limit interference with cleanup, and legal and administrative mechanisms to enforce them.		SW-2, SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-2, GW-3, GW-4, GW-5, GW-6, SS-2, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11
Releases from Underground Storage Tanks	WAC 173-340-450	R&A	Requires interim actions to be performed within 20 days of confirmation of a UST release.	These requirements supplement those in WAC 173-360.	SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-3, GW-4, GW-5, GW-6, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11
Regulation of Public Groundwater	90.44 RCW	R&A	Sets requirements for withdrawal and management of state groundwater.	Applicable if remediation includes groundwater withdrawal.	GW-3, GW-5, GW-6
Solid Waste Management Act	70.95 RCW		Establishes a statewide program for solid waste handling, recovery, and/or recycling.	Applicable if management of solid waste occurs during remediation. Solid waste controlled by this Act includes garbage, industrial waste, construction waste, ashes, and swill.	

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3B (Continued)
Potential State ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Minimum Functional Standards for Solid Waste Handling	WAC 173-304		Establishes requirements to be met statewide for the handling of all solid waste.		
On-site Containerized Storage, Collection, and Transportation Standards	WAC 173-304-200	R&A	Sets requirements for containers and vehicles to be used on site; requires monthly inspections and retention of inspection records for at least two years.		All
Underground Storage Tanks Act	90.76 RCW		Establishes an administrative and enforcement program for underground storage tanks (UST).	Applicable if USTs are or will be associated with remedial activities.	
Underground Storage Tank Regulations	WAC 173-360		Sets implementing requirements for underground storage tanks.	Not applicable to UST systems holding hazardous waste, subject to Subtitle C of the Federal Solid Waste Disposal Act, or a UST system that contains a de minimis concentration of regulated substances. See WAC 173-340 for additional requirements.	
Release Detection for Tanks	WAC 173-360-34	R&A	Requires all methods of release detection used after December 22, 1990, except for methods in place prior to that date, to be capable of detecting a leak rate or quantity with a probability of detection of 0.95, and a probability of a false alarm of 0.05.	Exceeds requirements in 40 CFR §280.43	SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-3, GW-4, GW-5, GW-6, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3B (Continued)
Potential State ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Release Detection for Piping	WAC 173-360-350	R&A	Requires all methods of release detection used after December 22, 1990, except for methods in place prior to that date, to be capable of detecting a leak rate or quantity with a probability of detection of 0.95, and a probability of a false alarm of 0.05.	Exceeds requirements in 40 CFR §280.44.	SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-3, GW-4, GW-5, GW-6, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11
Release Investigation	WAC 173-360-370	R&A	Requires leak-testing of any tanks and piping that may or may not be in use but are connected to a UST system that routinely contains a regulated substance.	Exceeds requirements in 40 CFR §280.52.	SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-3, GW-4, GW-5, GW-6, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3B (Continued)
Potential State ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Temporary Closure of UST Systems	WAC 173-360-380	R&A	Any UST system temporarily closed for three months or more must be tightness-tested prior to being put back in service.	Exceeds requirements of 40 CFR §280.70.	SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-3, GW-4, GW-5, GW-6, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11
Permanent Closure	WAC 173-360-385	R&A	Permanent closure must be completed within 60 days after expiration of the 30-day notification of closure. If the tank system is permanently closed, piping must be removed or capped.	Exceeds requirements of 40 CFR §280.71.	SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-3, GW-4, GW-5, GW-6, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3B (Continued)
Potential State ARARs
Action-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Water Pollution Control Act	90.48 RCW		Prohibits discharge of polluting matter in waters.		
Underground Injection Control Program	WAC 173-218	A	Establishes permitting requirements for injection of fluids through wells. Prohibits injection of any dangerous or radioactive waste fluids. Prohibits injection of industrial or commercial waste fluids beneath the lowermost formation containing, within 1/4 mile of the well, an underground source of drinking water.	Federal Criteria and Standards for the Underground Injection Control Program (40 CFR 146) are reserved at this time.	GW-5
Water Well Construction Act	18.104 RCW				
Standards for Construction and Maintenance of Wells	WAC 173-160	A	Establishes minimum standards for design, construction, capping, and sealing of all wells. Sets additional requirements including disinfection of equipment, abandonment of wells, and quality of drilling water.	Applicable if water supply wells, monitoring wells, or other wells are utilized during remediation.	SW-2, SW-3, SW-7, SW-8, GW-2, GW-3, GW-4, GW-5, GW-6, SS-2, SS-3, SS-7, SS-8, SS-9

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3C
Potential TBCs
Action-Specific

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
Benton-Franklin-Walla Walla Counties Air Pollution Control Authority	General Regulation 80-7	Establishes a regional program of air pollution prevention and control.	These county regulations are authorized by the state Clean Air Act.	
Monitoring and Special Reporting	Section 400-120	Monitoring of any source may be required.		All
Residual Radioactive Material as Surface Contamination	U.S. NRC Regulatory Guide 1.86	Sets contamination guidelines for release of equipment and building components for unrestricted use, and if buildings are demolished, shall not be exceeded for contamination in the ground.		All
U.S. Department of Energy Orders				
Radiation Protection of the Public and the Environment	DOE 5400.5	Establishes standards and requirements for operations of DOE and DOE contractors respecting protection of the public and the environment against undue risk of radiation.		All
Discharge of Treatment System Effluent	DOE 5400.xy	Treatment systems shall be designed to allow operators to detect and quantify unplanned releases of radionuclides, consistent with the potential for off-property impact.	Required of all DOE-controlled facilities where radionuclides might be released as a consequence of an unplanned event.	SW-9, SW-10, GW-4, GW-5, GW-6, SS-7, SS-8, SS-9, SS-10, SS-11
Radiation Protection for Occupational Workers	DOE 5480.11 Section 9a	Establishes radiation protection standards and program requirements to protect workers from ionizing radiation.		All
Safety Requirements for the Packaging of Fissile and Other Radioactive Materials	DOE 5480.3 Sections 7 and 8	Establishes requirements for packaging and transportation of radioactive materials for DOE facilities		SW-4, SW-5, SW-6, SW-9, SW-10, SS-4, SS-5, SS-6, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 3C (Continued)

Potential TBCs
Action-Specific

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
Radioactive Waste Management	DOE 5820.2A Chapters III and IV	Establishes policies and guidelines by which DOE manages radioactive waste, waste by-products, and radioactive contaminated surplus facilities. Disposal shall be on the site at which it was generated, if practical, or at another DOE facility. DOE waste containing byproduct material shall be stored, stabilized in place, and/or disposed of consistent with the requirements of the residual radioactive material guidelines contained in 40 CFR 192.		All
Department of Ecology Liquid Effluent Consent Order	DE 91NM-177	Requires discharges of liquid effluent to the soil column to be eliminated, treated, or otherwise minimized.		SW-9 SW-10 GW-3 GW-5 GW-6 SS-10 SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 4A
Potential Federal ARARs
Location-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Archaeological and Historical Preservation Act of 1974	16 U.S.C. 469	A	Requires action to recover and preserve artifacts in areas where activity may cause irreparable harm, loss, or destruction of significant artifacts.	Applicable when remedial action threatens significant scientific, prehistorical, historical, or archeological data.	SW-2, SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-2, GW-3, GW-4, GW-5, GW-6, SS-2, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11
Endangered Species Act of 1973	16 U.S.C. 1531 et seq.		Prohibits federal agencies from jeopardizing threatened or endangered species or adversely modifying habitats essential to their survival.		
Fish and Wildlife Services List of Endangered and Threatened Wildlife and Plants	50 CFR Parts 17, 222, 225, 226, 227, 402, 424	A	Requires identification of activities that may affect listed species. Actions must not threaten the continued existence of a listed species or destroy critical habitat.	Requires consultation with the Fish and Wildlife Service to determine if threatened or endangered species could be impacted by activity.	All
Historic Sites, Buildings, and Antiquities Act	16 U.S.C. 461	A	Establishes requirements for preservation of historic sites, buildings, or objects of national significance. Undesirable impacts to such resources must be mitigated.		SW-2, SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-2, GW-3, GW-4, GW-5, GW-6, SS-2, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 4A (Continued)
Potential Federal ARARs
Location-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
National Historic Preservation Act of 1966, as amended.	16 U.S.C. 470 et seq.	A	Prohibits impacts on cultural resources. Where impacts are unavoidable, requires impact mitigation through design and data recovery.	Applicable to properties listed in the National Register of Historic Places, or eligible for such listing.	SW-2, SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-2, GW-3, GW-4, GW-5, GW-6, SS-2, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-9, SS-10, SS-11
Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act (RCRA)	42 U.S.C. 6901 et seq.		Establishes the basic framework for federal regulation of solid and hazardous waste.		
Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257		Sets criteria for determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health or the environment.		
Floodplains	40 CFR §257.3-1	A	Prohibits facilities or practices in floodplains from restricting the flow of the base flood, reducing the temporary water storage capacity of the floodplain, or causing washout of solid waste, so as to pose a hazard to human life, wildlife, or land or water resources.		SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, GW-5, GW-6, SS-3, SS-4, SS-5, SS-6, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 4A (Continued)
Potential Federal ARARs
Location-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Endangered Species	40 CFR §257.3-2	A	Prohibits facilities or practices from causing or contributing to the taking of any endangered or threatened species of plants, fish, or wildlife. Prohibits destruction or adverse modification of habitat of endangered or threatened species.		All
Hazardous Waste Treatment, Storage, and Disposal	40 CFR Part 264		Establishes standards for management of hazardous waste.	Applicable to owners and operators of all hazardous waste facilities.	
Location Standards	40 CFR §264.18	A	Prohibits new TSD facilities from being located within 61 meters (200 feet) of a fault displaced during the Holocene. Requires a facility located in a 100-year floodplain to be designed, constructed, operated, and maintsined to prevent washout or release of any hazardous waste by a 100-year flood.		SW-4, SW-5, SW-6, SW-9, SW-10, GW-5, GW-6, SS-4, SS-5, SS-6, SS-10, SS-11

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 4B
Potential State ARARs
Location-Specific

Description	Citation	A/ R&A*	Requirements	Remarks	Alternatives Potentially Affected
Habitat Buffer Zone for Bald Eagle Rules	RCW 77.12.655				
Bald Eagle Protection Rules	WAC 232-12-292	A	Prescribes action to protect bald eagle habitat, such as nesting or roost sites, through the development of a site management plan.	Applicable if the areas of remedial activities includes bald eagle habitat.	All
Regulating the Taking or Possessing of Game	RCW 77.12.040				
Endangered, Threatened, or Sensitive Wildlife Species Classification	WAC 232-12-297	A	Prescribes action to protect wildlife classified as endangered, threatened, or sensitive, through development of a site management plan.	Applicable if wildlife classified as endangered, threatened, or sensitive are present in areas impacted by remedial activities.	All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

Table 4C
Potential TBCs
Location-Specific

Description	Citation	Requirements	Remarks	Alternatives Potentially Affected
Floodplains/Wetlands Environmental Review	10 CFR Part 1022	Requires federal agencies to avoid, to the extent possible, adverse effects associated with the development of a floodplain or the destruction or loss of wetlands.	Pertinent if remedial activities take place in a floodplain or wetlands.	All
Protection and Enhancement of the Cultural Environment	Executive Order 11593	Provides direction to federal agencies to preserve, restore, and maintain cultural resources.	Pertains to sites, structures, and objects of historical, archeological, or architectural significance.	All

*NOTE: A = Applicable, R&A = Relevant and Appropriate

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APPENDIX C

DESCRIPTIONS OF SOLID WASTE, GROUNDWATER, AND SOILS/RIVERBANK SEDIMENTS REMEDIATION TECHNOLOGIES

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APPENDIX C

DESCRIPTIONS OF SOLID WASTE, GROUNDWATER, AND SOILS/ RIVERBANK SEDIMENTS REMEDIATION TECHNOLOGIES

The information in this Appendix includes descriptions of technologies which are potentially applicable for remediation of the Hanford 100 Area solid waste, groundwater, and soils/riverbank sediments. In accordance with CERCLA FS guidance, a broad range of technologies representing relatively simple responses, such as institutional actions, to more complex remediation approaches involving treatment is discussed.

The technology descriptions contain five general sections:

- Applicability (potential): The media or type of contamination which may be remediated by the specific technology.
- General Description: A brief discussion of technical characteristics.
- Implementability: Discussion and qualitative rating pertaining to both technical and institutional implementability of the technology.
- Effectiveness: A brief overview of the type of waste for which the technology is intended and a qualitative rating of its effectiveness in providing a remediation for this type of waste.
- Cost: Cost of the technology on a low, moderate, high, or very high scale. Cost is relative to other process option costs within the same technology group.

Tables 1, 2, and 3 present the technologies and process options which were analyzed in this feasibility study.

The order of presentation for technology descriptions in this Appendix coincides with the screening discussions in Chapter 4.0. The technologies are organized initially by applicable media and subsequently by general response action. The grouping of technologies is best illustrated by referring to Figures 4-1 through 4-6 which illustrate technology screening graphically.

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Technology	Process Option
Access Restrictions	Fencing Deed Restrictions
Monitoring	Leachate Monitoring
Capping	Asphalt Based Covers Concrete-Based Covers Soil/Clay Covers RCRA Multi-media Caps Hanford Barriers Synthetic Covers Vitrification
Horizontal Barriers	Grout Injection Cryogenic Walls Vitrification
Vertical Barriers	Slurry Walls Grout Curtains Sheet Pilings Cryogenic Walls Biological Barriers
Run-On/Run-Off Control	Diversion/Collection Grading Revegetation
Removal	Demolition Excavation
On-Site Disposal	Trenches/Pits Vaults Tumulus RCRA Landfills
Off-Site Disposal	RCRA Landfills DOE Disposal Facilities Geologic Repositories
In Situ Stabilization/Solidification	Grout Injection Vibration-Aided Grout Injection Vitrification Dynamic Compaction

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TABLE C-1

SOLID WASTE TECHNOLOGIES AND PROCESS OPTIONS

Technology	Process Option
Thermal Treatment	Thermal Desorption Incineration Pyrolysis Metal Melting Molten Solids Processing
Stabilization/Solidification	Bitumen-Based Cement-Based Polymer-Based Vitrification
Physical Treatment	Size Reduction Segregation/Sorting Repackaging Metal Decontamination
Chemical Treatment	Chemical Oxidation Acid Digestion Hydrolysis

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TABLE C-2

GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

Technology	Process Option
Access Restrictions	Water Rights Restrictions Deed Restrictions
Monitoring	Well-Point Monitoring Groundwater Monitoring
Alternate Water Supply	Columbia River Extension of Nearby Sources
Horizontal Barriers	Same as Solid Waste
Vertical Barriers	Same as Solid Waste
Hydraulic Control	Extraction Wells Extraction Drains/Trenches
Groundwater Extraction	Extraction Wells Extraction Drains/Trenches Aquifer Mining
Wastewater Disposal	Deep-Well Injection Above-/Below-Ground Tanks Evaporation Ponds
In Situ Biological Treatment	Enhanced Groundwater Bioremediation Biodenitrification
In Situ Physical Treatment	Air Stripping Permeable Treatment Beds Vapor Extraction Electrokinetic Separation
Biological Treatment	Bioreactors Biodenitrification Biosorption

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TABLE C-2

GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

Technology	Process Option
Physical Treatment	Ion Exchange Evaporation: Passive Media Filtration Flocculation Carbon Adsorption Air Stripping Reverse Osmosis Ultrafiltration Electrodialysis Dissolved Air Flotation Sedimentation Steam Stripping Evaporation: Forced Freeze Crystallization Supported Liquid Membrane
Chemical Treatment (Groundwater)	Chemical Oxidation Precipitation Tritium Treatment Wet-Air Oxidation Chemical Reduction
Surface Disposal	Surface Discharge Columbia River Above-/Below-Ground Tanks
Subsurface Discharge	Deep-Well Injection Reinjection into Aquifer Crib Disposal

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TABLE C-3
SOILS AND RIVERBANK SEDIMENTS
TECHNOLOGIES AND PROCESS OPTIONS

Technology	Process Option
Access Restrictions	Same as Solid Waste
Monitoring	Same as Solid Waste
Capping	Same as Solid Waste
Horizontal Barriers	Same as Solid Waste
Vertical Barriers	Same as Solid Waste
Run-On/Run-Off Control	Same as Solid Waste
Removal	Excavation
On-Site Disposal	Same as Solid Waste
Off-Site Disposal	Same as Solid Waste
In Situ Stabilization/Solidification	Grout Injection Vibration-Aided Grout Injection Shallow Soil Mixing Fixants Vitrification Ground Freezing Dynamic Compaction
In Situ Biological Treatment	Enhanced Soil Bioremediation Biodenitrification Land Farming
In Situ Chemical Treatment	Soil Flushing
In Situ Physical Treatment	Vapor Extraction Steam Stripping Soil Flushing RF Heating Electrical Soil Heating
Thermal Treatment	Thermal Desorption Incineration Pyrolysis Molten Solid Processing
Stabilization/Solidification	Same as Solid Waste

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TABLE C-3 SOILS AND RIVERBANK SEDIMENTS TECHNOLOGIES AND PROCESS OPTIONS	
Technology	Process Option
Physical Treatment	Vapor Extraction Soil Washing Steam Stripping
Chemical Treatment	Chemical Oxidation Soil Washing Alkali Metal Dechlorination
Biological Treatment	Bioreactors Land Treatment Biodenitrification

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1.0 SOLID WASTE TECHNOLOGY DESCRIPTIONS

1.1 ACCESS RESTRICTIONS

Two methods of access restriction are discussed below:

- Fencing
- Deed restrictions.

1.1.1 Fencing

Applicability. Contaminated soils, riverbank sediments, and solid waste.

General Description. Fencing is the construction of a physical barrier around a contaminated area with the intention of limiting access to the area (Merritt 1983). Note that monitoring of the site is also necessary if this option is used.

Implementability. Fencing is commonly used for limiting access to restricted areas such as private properties (Merritt 1983). Fencing would be easily implementable at the Hanford 100 Area operable units containing contaminated soil, riverbank sediments, and solid wastes.

Effectiveness. Fencing has limited effectiveness in preventing access to contaminated areas. A fence cannot prevent animals or humans from entering restricted areas, but does provide a barrier that would have to be crossed to gain access to an area.

Cost. The costs for erecting fences and monitoring a site in and around the Hanford 100 Area are low due to the relatively low cost of materials and the ease of installation.

1.1.2 Deed Restrictions

Applicability. All Media

General Description. Deed restrictions specify acceptable land uses and may take several forms, such as providing covenants against activities that may bring humans in contact with contaminants. Deed restrictions may include: provisions that prevent the use of groundwater (e.g., water right restrictions); requirements for approval of excavations beyond a specified depth; or limitations on land use by prohibiting activities such as grazing and farming.

Implementability. Implementation of deed restrictions requires only administrative resources and visual monitoring to ensure that covenants are being obeyed. Deed restrictions are therefore considered to be easily implementable.

Effectiveness. Deed restrictions may be effective in preventing short-term human contact with contaminated areas; however, the long-term effectiveness of deed restrictions is uncertain. In general, deed restrictions are considered to have limited effectiveness.

Cost. Deed restrictions involve only administrative resources in combination with visual monitoring and are considered to be low-cost methods for preventing human contact with contaminated regions of the Hanford 100 Area.

1.2 MONITORING

1.2.1 Leachate Monitoring

Applicability. Contaminated soils, riverbank sediments, and buried solid waste.

General Description. A leachate collection and removal system is required by the Resource Conservation and Recovery Act (RCRA) for all hazardous waste landfills. The collection and removal system could also be used to collect samples of leachate for monitoring purposes. Use of this approach avoids the use of more intrusive methods of monitoring contaminant migration from soil or solid waste disposal sites. The system consists of perforated pipe networks backfilled with gravel. The pipe network is sloped toward collection points located away from the contaminated media of concern. Other leachate detection systems besides the RCRA system may be used on a limited basis to indicate migration of contamination from solid waste burial sites.

Implementability. Leachate monitoring is a well developed technology and is considered to be easily implementable for new waste burial sites. However, a monitoring system for existing sites may be difficult or impossible to install without excavating through contaminated materials. In addition, evapotranspiration prevents formation of any significant quantity of leachate, thereby eliminating the need for leachate monitoring. Leachate monitoring is considered difficult to implement at existing contaminated areas such as solid waste burial sites.

Effectiveness. Leachate monitoring is considered to be an effective method for determining if contaminants are being mobilized in a leachate form if the system can be installed directly beneath a contaminated site. However, due to the difficulty of installing leachate monitoring systems beneath existing contaminated sites, the technology is ineffective for such cases.

Cost. The cost of installing leachate monitoring systems beneath existing contaminated sites within the 100 Area is judged to be high. Excavation through contaminated areas would require significant safety measures to protect workers and containment and packaging of any contaminated materials that are removed would be necessary. These requirements would increase both the cost and the time required for installing the system.

1.3 CAPPING

Capping involves the installation of a barrier over the surface of the contaminated area to control erosion and prevent contact between infiltrating precipitation and contaminated wastes. Capping is an applicable technology for the non-removal general response actions and has been used in combination with other technologies. The following capping techniques are discussed below:

- Asphalt-based covers
- Concrete-based covers
- Soil/clay-based covers
- RCRA multi-media caps
- Hanford barriers
- Synthetic covers
- Vitrification.

1.3.1 Asphalt-Based Covers

Applicability. All Media.

General Description. Asphalt caps are single-layered caps composed of bituminous asphalt. The thickness of the cap is dependent on design parameters that consider settling and weathering effects. The cap must be sloped for runoff in order to minimize infiltration into the contaminated zone. Surface treatments are often required during the long-term maintenance of asphalt-based caps in order to provide a lasting seal.

Implementability. The technology required for asphalt cap construction is commercially available (Merritt 1983). No specialized equipment is required and bituminous asphalt is a common construction material. However, in comparison to certain other capping techniques that employ naturally occurring materials, asphalt-based caps are considered to be moderately implementable. Asphalt-based caps are only implementable for localized areas and are not considered practical on a sitewide basis.

Effectiveness. Asphalt caps are considered an effective means of providing short-term, single-layer containment for vertical migration in contaminated areas. Asphalt-based caps are not effective in reducing lateral migration of contaminants in groundwater without the use of vertical barriers. Periodic maintenance of an asphalt cap is required to reduce the effects of weathering and cracking. The plastic properties of asphalt may be engineered to provide protection from subsidence. Overall, asphalt caps are considered to have limited effectiveness due to inadequate long-term performance.

Cost. The costs associated with the construction of an asphalt cap are high relative to other capping techniques. Although materials and equipment are inexpensive, periodic maintenance that would be essential throughout the life of the cap increases the total cost.

1.3.2 Concrete-Based Covers

Applicability. All Media.

General Description. Concrete caps are single-layered caps consisting of aggregate and cementitious material mixtures. Similar to asphalt covers, concrete caps must also be designed with adequate strength to resist collapse should subsidence occur, and must be sloped to promote drainage of infiltrating precipitation and surface water. These caps also require periodic maintenance to extend the life of the cover.

Implementability. The materials required to construct a concrete cap are locally available. Construction equipment may be used for concrete mixing and placement. Concrete caps are considered moderately implementable in comparison to other capping techniques due to the requirement of cementitious materials and installation equipment.

Effectiveness. Concrete caps are effective in maintaining a short-term barrier against precipitation and surface water intrusion into a contaminated area. However, they are susceptible to cracking, subsidence, and weathering over the long term. Thus, concrete caps are considered to have limited effectiveness.

Cost. The cost of implementing concrete caps at the Hanford 100 Area is judged to be high relative to other capping techniques. Although materials and equipment are relatively inexpensive, periodic maintenance will increase life cycle costs.

1.3.3 Soil/Clay Covers

Applicability. All Media.

General Description. Clay and soil caps are constructed by spreading soil/clay admixes over the contaminated area then compacting the soil/clay layer to achieve a specified permeability. The specified permeability of the compacted soil/clay layer is lower than that of the underlying soils. To achieve the design permeability, the soil/clay admixture may be modified with bentonite, lime, cement, or other material. The amount of the added material is determined through analysis of soil characteristics, compaction studies, and permeability

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tests. Soil/clay covers are usually not acceptable as a surface barrier due to uncertainties associated with long-term performance and the need for routine maintenance throughout the life of the cap.

Implementability. Soil/clay covers are considered to be easily implementable. General construction equipment may be used to place and compact the soil/clay mixture. Commercially available clay materials such as bentonite and soils from the site can be used to build the cap.

Effectiveness. Soil/clay covers may be used as interim measures for short-term protection and would be effective in temporarily inhibiting the inflow of surface water to a contaminated area. Soil/clay covers are not effective in reducing lateral groundwater flow and contaminant mobility unless a vertical barrier is used in conjunction with the cover. The long-term effectiveness of a soil/clay cover is limited because of its susceptibility to weathering and breaching by burrowing animals and vegetation. Clay-based covers are considered unsuitable for use as an impermeable barrier in the arid environment of the Hanford Site due to drying and subsequent cracking (Anderson et al., 1991). Therefore, the overall effectiveness of soil/clay caps is limited.

Cost. Costs associated with the construction of a soil/clay cap are low relative to other caps. Clay material and construction equipment are both readily available and inexpensive. As is the case with other caps, periodic maintenance increases life cycle costs.

1.3.4 RCRA Multi-Media Caps

Applicability. All Media.

General Description. A RCRA multi-media cover refers to a three-layer cap system recommended by EPA guidance under RCRA. The RCRA multi-media cap is often referred to as a "RCRA cap." The cap consists of an upper vegetation layer, a drainage layer, and a low permeability layer. Infiltrating liquids are diverted away from the underlying waste materials through the drainage layer. The vegetation layer is usually a grass layer which binds the drainage layer and provides a "self-healing" effect to minimize the impact of cracking and weathering. Sand is a common ingredient for the drainage layer followed by fine grain soil and clay admixes for the low permeability layer. Synthetic materials are also used for the low permeability layer and are recommended for use in combination with a natural admix of low permeability material.

Implementability. RCRA multi-media cap construction is a well developed technology and commonly used to cover nonradioactive hazardous waste disposal sites. RCRA multi-media caps consist primarily of natural materials that may be present on site. Application of a RCRA multi-media cap is readily implementable. However, if synthetic materials are used in the low permeability layer, specialized installation methods are necessary (see synthetic covers).

Effectiveness. The combined effects of low permeability, drainage, and a vegetation layer provide a highly impenetrable barrier that is weather resistant and impervious to freeze/thaw and shrink/swell cycles. The drainage layer is effective in removing standing water from the surface of the cap, thereby preventing infiltration. A RCRA multi-media cap is considered effective for reducing surface water infiltration through contaminated zones. However, RCRA multi-media caps are not effective for preventing lateral migration of contaminated groundwater. The long-term performance of RCRA multi-media caps is uncertain. Thus, RCRA multi-media caps are considered moderately effective.

Cost. In comparison with other capping technologies, RCRA multi-media cap costs are expected to be low due to the predominant use of natural materials that are available on site. Installation costs may be higher than concrete or asphalt due to construction techniques. However, should a synthetic layer be used, costs will increase.

1.3.5 Hanford Barrier

Applicability. All Media.

General Description. The Hanford Barrier is an innovative concept currently being developed for use at the Hanford Site. The barrier is constructed of natural materials and consists of a soil layer overlying other layers of relatively coarse material such as sand, gravel, and riprap. The soil layer stores moisture until evaporation and transpiration recycle it back to the atmosphere. Soil also provides a place to grow plants that are necessary for preventing erosion. The coarse materials placed below the soil layer create a capillary break. This break inhibits downward percolation of water through the barrier. The coarse materials also act as deterrents to burrowing animals, deep-rooting plants, and potential human intruders. Low-permeability layers, placed in the barrier profile below the capillary break, are also being considered for use. Low permeability layers provide two benefits: any percolating moisture that passes through the capillary break is diverted away from the waste and the upward migration of gases from the waste is also minimized. Solution grouts are being evaluated for use as a construction aid and to provide additional structural stability to the barrier. The goals of the barrier design are to:

- Function in an arid to semiarid climate
- Limit the infiltration and percolation of water through the waste zone to near-zero rates; the performance objective is 1.6×10^{-9} cm/sec, which is about two orders of magnitude lower than the RCRA cap infiltration objective of 1.0×10^{-7} cm/sec.
- Eliminate the necessity for maintenance (assuming loss of institutional control 100 years after disposal of the wastes)
- Provide waste isolation for a minimum of 1,000 years with a potential life of up to 10,000 years.

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Implementability. The technology and materials required for barrier construction are readily available on site. Therefore, no specialized equipment or materials are required. The Hanford Barrier is considered to be moderately implementable relative to other caps due to method of construction and the need to establish a vegetative layer. The Hanford Barrier would be an unconventional method of closure for a land disposal unit receiving RCRA-regulated wastes and regulatory approval must be obtained. A RCRA cap must be of equal or less permeability than a bottom liner system (by regulation); therefore, the acceptability of the Hanford Barrier as a RCRA landfill cap will depend upon the acceptability of an unlined land disposal unit (see Technology Description of Trenches/Pits).

Effectiveness. While it has been based on sound design principles, this technology has not been field tested. This barrier is specifically designed for application at Hanford. The use of natural materials in construction of a Hanford Barrier eliminates the need for maintenance and therefore offers a high degree of effectiveness against infiltrating moisture and surface waters over the long term. However, as with all other caps, the Hanford Barrier is not effective for preventing lateral migration of contaminated groundwater.

Cost. The cost of implementing Hanford Barriers at the 100 Area is expected to be moderate in comparison to other capping technologies. The equipment and natural materials required for construction are readily available and maintenance is not required.

1.3.6 Synthetic Covers

Applicability. All Media.

General Description. Flexible synthetic membranes (e.g., polyvinyl chloride, high density polyethylene, and neoprene) have been used as landfill liners and may be used as caps (Daniel and Estornell 1991). The synthetic barrier cover consists of a synthetic membrane liner covering a sloped soil base. The synthetic liner is installed in the field by splicing thin sheets together with the help of adhesives or heat.

Implementability. Sheets of synthetic membranes are commercially available and are manufactured in a range of thicknesses and widths. They can be reinforced, have UV protection, and have smooth or roughened surfaces. The method of joining the sheets (and the verification sampling requirements) are specific to the manufacturer and the type of liner material employed. Specialized installation methods are required for cap construction. This technology is considered to be easily implementable.

Effectiveness. Synthetic membrane barriers are effective in preventing surface water intrusion into contaminated areas for short-term applications (30 year design life) assuming proper installation. Synthetic membrane caps are not effective for preventing lateral migration of contaminated groundwater. Maintenance is difficult and deterioration is likely to require the replacement of the membrane. The chemical and weather resistance properties of synthetic materials must be evaluated to determine long-term effectiveness (Daniel and Estornell 1991). The thickness and flexibility of a synthetic liner are critical to barrier performance.

Cost. Synthetic liners are generally more expensive than other capping materials and thus material costs are considered to be high. Installation is labor intensive but large areas may be covered quickly using special field installation methods and sealing materials. Overall costs are moderate relative to other capping technologies due to speed of installation.

1.3.7 Vitrification

Applicability. All Media.

General Description. Refer to the in situ stabilization/solidification technology descriptions for solid waste for a discussion of this technology. Vitrification for capping involves the same process as in situ vitrification but not to the depth required for incorporating contaminants into the melt. The vitrification technique proposed here is simply used as a cap and is not intended for waste treatment as is the traditional use of this technology.

Implementability. Cap construction by in situ vitrification is an innovative concept. Installation of a vitrified cap over contaminated areas is considered not implementable because formation of a continuous and homogeneous cap of uniform thickness is not practical.

Effectiveness. Vitrification of soils would form a virtually impenetrable barrier to vertical migration of either precipitation or surface water. Lateral migration of contaminated groundwater would not be prevented. Difficulties in creating a continuous and homogeneous cap of uniform thickness suggest that this technique would have limited effectiveness for application to solid waste, soils, and riverbank sediments.

Cost. The costs associated with the installation of a vitrified cap are expected to be comparable to in situ waste vitrification costs. In comparison with other capping technologies, vitrification costs would likely be extremely high.

1.4 HORIZONTAL BARRIERS

The following types of horizontal barriers are discussed below:

- Grout injection
- Cryogenic walls
- Vitrification.

1.4.1 Grout Injection

Applicability. All Media

General Description. Grout injection provides a barrier to vertical migration of contaminants by forming an impermeable "floor" of cement-based material beneath a contaminated zone.

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Grout injection uses a jet nozzle to force grout into soils. Boreholes are drilled at regular intervals through the waste site or around its perimeter to a specified depth beneath the contaminated zone. Horizontal drilling techniques may be used to form the boreholes required for grout injection without disturbing the contaminated site. Grout is injected through the jet nozzle to form a lateral circular pattern. The nozzle is rotated to insure that the grout is spread evenly in all directions and the process is repeated at each drilling location until a uniform "floor" layer is installed.

Block displacement, which is a variation of grout injection, is intended to displace waste and make it easy to retrieve. A slurry trench is constructed around the contaminated zone to serve as horizontal containment. Grout injection wells are bored through the contaminated zone. The injected grout displaces a block of contaminated soil. (Note: The displacement of blocks in the 100 Area is impossible due to the porosity of soil. Therefore, this variation has not been evaluated further.)

Implementability. The formation of horizontal barriers by grout injection is an innovative technology which, although tested, has not been implemented on a large scale. This technology relies on forced grout injection to form a uniform, continuous layer beneath a contaminated zone. Formation of this continuous layer is dependent on the porosity of the soil at the site. The coarseness of Hanford 100 Area soils makes control of the grout flow path difficult. In addition, the potential for drilling through radioactive waste in order to install the barrier must be considered. This practice may not be consistent with As Low As Reasonably Achievable (ALARA) principles.

Effectiveness. The effectiveness of this barrier is dependent on the formation of a uniform, continuous grout layer beneath the contaminated zone. The long-term effectiveness of grout injection has not been determined. Tests in Hanford 100 Area soils would be required in order to determine the effectiveness of grout injection. The difficulties involved with controlling flow direction and the formation of a uniform barrier in highly permeable soils suggests that this technology will have limited effectiveness for application to solid waste, soils, and sediment. Grout injection is not considered effective as a horizontal barrier for groundwater at the Hanford 100 Area due to the existence of natural clay barriers (i.e., Blue Clay of the upper Ringold Formation).

Cost. Quantitative cost information is not readily available for implementation of grout injection. However, in comparison to other horizontal barrier technologies, the cost is expected to be moderate if the process is implementable.

1.4.2 Cryogenic Walls

Applicability. All Media

General Description. A horizontal cryogenic wall may be constructed by freezing interstitial water within the soil beneath the contaminated zone, forming a barrier to contaminant migration. Frozen soil is substantially less permeable than unfrozen soil and possesses more shear strength. The ground is frozen by installing steel pipes uniformly

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along a horizontal freeze line. A smaller diameter pipe placed within the steel pipe is used for coolant circulation. The outer pipe serves as a return line in this closed-loop system. The installation of a cryogenic horizontal barrier is similar to the vertical barrier with the exception that pipes are installed at an angle from the perimeter of the area to be contained. The pipes are angled to intersect beneath the waste site forming a continuous barrier to vertical migration.

Implementability. The formation of cryogenic barriers is an innovative technology. Cryogenic walls are not considered implementable for soils, riverbank sediments and solid waste sites for two reasons. One, the vadose zone soils of Hanford do not have sufficient interstitial moisture to form a cryogenic wall, and two, any addition of moisture is considered infeasible due to the potential for contaminant mobilization. Implementability of cryogenic walls beneath contaminated groundwater is judged to be difficult.

Effectiveness. The effectiveness of a cryogenic barrier is dependent on the ability to maintain a continuous frozen barrier around a contaminated zone. The process is considered ineffective for the same reasons that limit implementability. Furthermore, maintaining the cryogenic barrier requires continuous circulation of coolant. This continuous operating requirement for cryogenic walls makes the process ineffective for long-term containment. A horizontal cryogenic wall is not considered effective as a horizontal barrier for groundwater due to the existence of natural clay barriers.

Cost. The time required for the soil to freeze strongly influences the cost of constructing a cryogenic barrier. The energy costs for initial freezing is high, but maintenance of the frozen layer is less energy intensive. Circulation of coolant to maintain frozen conditions requires continuous energy consumption. Costs to construct and maintain a cryogenic barrier are very high relative to other horizontal barriers.

1.4.3 Vitrification

Applicability. All Media

General Description. Refer to the in situ stabilization/solidification technology descriptions for solid waste for a discussion of this technology. The application for horizontal barriers involves the same process of vitrification, except that the melt zone is beneath the contaminant source. The vitrification technique proposed here is simply used as a barrier and is not intended for waste immobilization.

Implementability. The formation of a horizontal barrier by in situ vitrification is an innovative concept. Installing a horizontal barrier beneath contaminated groundwater, soils, sediments, or solid waste sites using in situ vitrification requires electrode placement at depths dependent on the particular site. The maximum demonstrated melt depth of in situ vitrification is 19 feet (RAAS 1991). The depth of horizontal barriers required beneath some contaminated zones at the Hanford 100 Area would be in excess of 30 feet. In situ vitrification technology would require substantial modification to melt the zone below this

level. Thus, application of in situ vitrification as a horizontal barrier below contaminated zones is not considered implementable in the Hanford 100 Area at this time.

Effectiveness. Vitrification of soils would form a virtually impenetrable barrier against vertical migration of contaminants. However, the ability to form a continuous vitrified layer with current processes is uncertain. Failure to form a continuous layer would render the barrier ineffective.

Cost. The costs associated with the installation of a vitrified horizontal barrier are comparable to the in situ waste treatment technique. In comparison to other horizontal barrier technologies, vitrification costs would be extremely high.

1.5 VERTICAL BARRIERS

The following types of vertical barriers are discussed below:

- Slurry walls
- Grout curtains
- Sheet pilings
- Cryogenic walls
- Biological barriers.

1.5.1 Slurry Walls

Applicability. All Media

General Description. Slurry walls are the most common form of vertical subsurface barrier. Slurry walls are formed by excavation of a vertical trench using the slurry as a drilling fluid and to shore the trench to prevent collapse. The slurry reduces fluid losses into the surrounding soils through formation of a filter cake on the trench walls. Materials which have been used to construct slurry walls include soil-bentonite and cement-bentonite mixes.

Implementability. Slurry wall construction is a developed technology. The controlling factors for construction of a slurry wall include soil characteristics, such as grain size, uniformity, mineralogy, porosity, and permeability, and depth to the bottom confining layer. The sediments under the Hanford 100 Area are very coarse-grained and highly permeable. Installation of a slurry wall in this material would be very difficult due to the presence of large boulders (up to a few feet in diameter) in the formation. The physical removal of material of this nature would produce a wall with a highly variable cross sectional thickness. The depth of the slurry wall will affect the implementability of this technology. Typically, slurry walls are constructed from 100 to 140 feet deep in sandy or silty soils. At certain locations in the 100 Area, excavation depths of up to about 160 feet, in highly variable grain size material, would be required. The implementability of a standard slurry wall is highly suspect at these depths and under these conditions. Also, the coarse-grained nature of the Hanford Formation would result in significant losses of slurry from the

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excavation, thereby threatening wall stability during construction and requiring large slurry volumes with resultant increases in costs.

Effectiveness. Factors affecting performance of slurry walls include soil characteristics, contaminant compatibility, wall uniformity, and wall strength. The slurry wall should be of uniform thickness in order to provide a more effective barrier. Construction of a relatively uniformly thick wall in the riverbank sediments of the Hanford Formation is suspect, primarily due to the wide range of grain sizes in the formation material. To provide a core area of uniformity, the width of the slurry wall would have to be increased to accommodate variations in the wall excavation width. Soil-bentonite slurry walls are generally considered more effective in reducing contaminant migration than cement-bentonite slurry walls because of their wider range of chemical compatibility and lower permeability. The soil-bentonite slurry wall has high compressibility (low strength) and elasticity which would be a disadvantage if applied at the Hanford 100 Area. The cement-bentonite slurry would be more effective under these conditions. For these reasons, slurry walls are judged to be moderately effective in reducing groundwater flow in unconsolidated materials.

Cost. The cost of installing a slurry wall is dependent on the depth, length, and composition of the excavation trench. Cement-bentonite slurry wall construction costs are, on the average, 30 percent higher than those for soil-bentonite slurry walls. The cost of installing slurry walls at the Hanford 100 Area is considered to be high relative to other vertical barriers due to the depth of wall required, i.e., the wall must penetrate to confining layers such as the Blue Clay layer of the Ringold Formation.

1.5.2 Grout Curtains

Applicability. All Media

General Description. Grout curtains are vertical barriers used to reduce or contain groundwater flow. Grout curtains are formed by pressure injection of grout through pipes, augers, or beams that are inserted into the ground using a crane and hammer or a drill rig. The curtain is developed one "post" at a time along the containment boundary. A secondary line of grout posts are arranged behind the primary curtain to fill any gaps that may have been left during the first pass.

Implementability. Grout curtains are considered implementable at most sites. Soil characteristics such as grain size and uniformity will affect implementation of grout curtains. The presence of very coarse-grained or nonuniform materials in the Hanford Formation increases uncertainty in the proper positioning of the grout posts during installation and in the integrity of the grout coverage. Another consideration is the depth required to contain contaminants; this technology could be used with other barriers to contain contaminants with more certainty. High permeability soils in the 100 Area would inhibit formation of a grout curtain by reducing the ability to control continuity of grout placement. Thus, grout curtains are considered to be moderately implementable in the 100 Area.

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Effectiveness. Grout curtains are not considered as effective in controlling migration flow as other forms of subsurface barriers. Gaps may form in the curtain as a result of grout shrinkage during setting. The permeable nature of the soils will require significant quantities of grout to form a barrier and may also affect the overall performance of the grout curtain. The difficulties in forming a continuous curtain in the soils at the Hanford 100 Area suggest that this method would be ineffective as a vertical barrier.

Cost. The costs associated with the installation of grout curtains are dependent on the depth and length of the curtain. A significant amount of material would be required to contain contamination in the 100 Area operable units. Consistent other cement-based barrier technologies, the cost of grout curtains is considered to be high.

1.5.3 Sheet Pilings

Applicability. All Media

General Description. Sheet pilings are another type of vertical barrier used to limit lateral flow of groundwater. A sheet piling barrier can be made from an assortment of materials including wood, precast concrete, or steel. Steel is most commonly used since wood deteriorates and concrete is bulkier and more costly. The sheet piling forms a continuous barrier which reduces or eliminates subsurface water flow. The walls are typically assembled at the surface prior to installation and the piles are then driven a few feet into the ground over the length of the wall. The process is repeated until the entire wall is deep enough to contain contamination. Sheets are usually driven into the ground with either a drop hammer or a vibratory hammer. When the wall is initially installed, the interlocking posts are quite permeable. However, with the passage of time, fine silt and sand particles usually fill the void spaces between piles and the wall becomes impermeable.

Implementability. The applicability of sheet piling is limited to areas where soil type is conducive to use of the technology. Rocky areas will render installation nearly impossible by causing damage or deflection of the sheets. For this reason, sheet piling is not considered implementable at the Hanford 100 Area.

Effectiveness. The difficulty noted above for installing sheet pilings in the rocky soils of the 100 Area would result in unpredictable wall integrity. Therefore, sheet piling is considered to be ineffective.

Cost. The costs associated with installing sheet piling barriers are considered high relative to other vertical barriers due to implementation difficulties caused by the rocky soils of the Hanford 100 Area.

1.5.4 Cryogenic Walls

Refer to the discussion presented previously under Horizontal Barriers.

1.5.5 Biological Barriers

Applicability. All Media

General Description. Accumulation of a biomass around nutrient injection wells during in situ bioremediation is a widely recognized phenomenon. In situ bioremediation systems are designed to maximize microbial growth and thereby reduce the local hydraulic conductivity. However, extensive biomass accumulation could be made useful by establishing an impermeable barrier around a contaminated region. Conceptually, this barrier could be achieved by continuously introducing high concentrations of microbial nutrients into wells that surround the contaminated area. The integrity of the barrier can be maintained as long as nutrients are supplied to the bacteria. Bacteria indigenous to the Hanford Site may be used to form a biological barrier. Bacteria possess a surface layer that serves to aggregate individual microbes into large masses.

Implementability. Implementation of biological barriers has not been demonstrated. Maintaining a stable biological barrier is difficult. Injection of nutrients and organisms has potential to mobilize contaminants. Thus, biological barriers are not considered implementable.

Effectiveness. The technology is at the conceptual stage of development and only a few laboratory experiments have been completed. The effectiveness of a biological barrier at Hanford is unknown due to the experimental nature of the technology.

Cost. The cost of implementing and maintaining biological barriers is also unknown. However, the process is expected to have low capital costs but high operating costs for nutrient addition.

1.6 RUN-ON/RUNOFF CONTROL

The following methods of run-on/runoff controls are discussed below:

- Diversion/collection
- Grading
- Revegetation.

1.6.1 Diversion/Collection

Applicability. Contaminated soils, riverbank sediments, and solid waste.

General Description. Surface water diversion and collection are an essential part of surface water management and may include dams, dikes, berms, channels, waterways, terraces, benches, chutes, downpipes, seepage ditches, basins, levees, or floodwalls. Diversion/collection systems are commonly used during site work and can be effective in preventing the contact between surface runoff and contaminated material. These techniques

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can be used as either temporary or permanent measures to control surface water, to prevent recharge of contaminated zones, and to control erosion.

Implementability. The surface water diversion and collection techniques listed above are well developed and can be easily implemented.

Effectiveness. Surface water diversion and collection techniques are only moderately effective in preventing recharge and erosion control and in stabilizing sloped surfaces. Frequent maintenance is required to maintain effectiveness.

Cost. The construction costs of diversion/collection systems are low, but frequent maintenance to repair the effects of erosion and removal of settled materials would be required. The cost of diversion/collection systems is expected to be moderate in comparison with other run-on/runoff control technologies.

1.6.2 Grading

Applicability. Contaminated soils, riverbank sediments, and solid waste.

General Description. Grading modifies site topography to prevent infiltration and control erosion (Merritt 1983). This technology is often used in combination with surface sealing and revegetation.

Implementability. Grading is widely used for erosion control, road building and repair, and construction site leveling (Merritt 1983). Thus, grading can be easily implemented.

Effectiveness. Graded surfaces aid in reducing potential leachate formation by minimizing infiltration and promoting erosion-free drainage of surface run-on/runoff. Depressions and slumped or badly eroded slopes must be removed or repaired for grading to be effective. Compared to other run-on/runoff techniques, grading is considered to have limited effectiveness because it does not divert or collect run-on/runoff, but is only intended to prevent ponding.

Cost. Frequent maintenance is required on graded surfaces. However, due to the ease of implementation and minimal resource requirements, the cost of grading is low relative to other techniques.

1.6.3 Revegetation

Applicability. Contaminated soils, riverbank sediments, and solid waste.

General Description. Revegetation provides a cover which reduces erosion and helps in developing a stable surface environment. Revegetation may be applied for both short-term stabilization, including intermediate covers at waste disposal sites, and long-term site reclamation.

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Implementability. Revegetation is commonly used for site reclamation. Implementation of a revegetation scheme for run-on/runoff control involves the selection of suitable plant species, site preparation, and planting. Some irrigation may be required to establish plants. Revegetation with native plants should be easy to implement at the Hanford 100 Area.

Effectiveness. Revegetation can effectively stabilize the surface of a disposal site and prevent erosion. The selection of suitable native plants including grasses, legumes, shrubs, and possibly trees is critical to the effectiveness of revegetation. Revegetation is important to the integrity and performance of diversion/collection systems, sedimentation basins, capping, and grading. The effectiveness of native vegetation to control erosion and stabilize surface soils is expected to be moderate.

Cost. The cost of establishing a vegetation cover at the Hanford 100 Area is considered low. Once established, such a cover is not expected to require maintenance.

1.7 REMOVAL

The following removal techniques are discussed below:

- Excavation
- Demolition.

1.7.1 Excavation

Applicability. Contaminated soils, riverbank sediments, and buried solid waste.

General Description. Excavation refers to the process of removing contaminated materials with specially modified construction equipment. Refer to *100 Area Hanford Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991e) for a complete description of a conceptual excavation system.

Implementability. Excavation is a well developed technology commonly used in the mining and construction industry (Merritt 1983). Excavation equipment is commercially available with optional equipment for unique applications, for example a telescopic excavator boom for long-reach (Merritt 1983). Shielding and supplied air would be required for excavation equipment to protect workers. The need for equipment modifications and possibly large mobile dust containment structures makes excavation a moderately implementable technology for the Hanford 100 Area.

Effectiveness. Excavation would be a highly effective method for removal of solid waste, soils, and riverbank sediments in the Hanford 100 Area. Standard excavation equipment such as front end loaders are capable of handling a wide range of materials including rock, gravel, and bulk materials, such as solid waste, at relatively high capacities (Merritt 1983). Furthermore, excavation equipment modified to provide shielding and supplied air will protect workers during operations near radioactive or hazardous materials.

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Cost. Excavation equipment and accessories are commercially available. Capital costs will depend on equipment modifications such as shielding and supplied air required for worker protection. Maintenance and operating costs are a function of fuel requirements, operation schedules, and decontamination procedures. Excavation would be a relatively low cost approach to removal of soils, riverbank sediments, and solid waste.

1.7.2 Demolition

Applicability. Solid Waste (Large Objects)

General Description. Demolition is a removal process involving on-site size reduction of large, oversized objects that cannot otherwise be packaged for removal or transported using standard equipment. Demolition equipment applicable to the Hanford 100 Area include excavator mounted hydraulic hammers, grapples, shears, and concrete crackers. The particular demolition tool required would depend on the specific waste form. For example, concrete retention basins would require hydraulic hammers and concrete crackers for size reduction.

Implementability. Demolition tools are standard equipment used in commercial demolition. These tools are typically boom-mounted attachments for crawler-type excavators. Excavators would require modification to provide for operator safety in the presence of radioactive materials. This technology option is considered moderately implementable due to the need for equipment modification and the need to conduct work beneath a mobile containment structure.

Effectiveness. Demolition tools are highly effective in commercial applications and can be equally effective for demolition operations at the Hanford 100 Area.

Cost. Demolition tools are commercially available and are relatively inexpensive. The most significant cost for this removal technique would be excavators and safety modifications. Operation and maintenance costs would be moderate. The overall cost for demolition is expected to be low.

1.8 ON-SITE DISPOSAL

The following on-site disposal methods are discussed below:

- Trenches/pits
- Vaults
- Tumulus
- RCRA landfills.

1.8.1 Trenches/Pits

Applicability. Contaminated soils, riverbank sediments, and solid waste.

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General Description. Pits or trenches are unlined below grade excavations for waste disposal. This disposal approach, equivalent to past practice waste disposal at Hanford, is intended to be used in combination with other technologies such as capping and waste stabilization to avoid contaminant migration.

Implementability. Technically, disposal in trenches or pits would be easily implementable and has been frequently used in past waste management practices. As applied to disposal of hazardous or mixed wastes regulated by RCRA, an exemption to the liner requirements would be needed to implement disposal in trenches or pits provided that wastes meet the RCRA Land Disposal Restriction treatment requirements [40 CFR Part 268] or an exemption has been made to allow land disposal.

Effectiveness. Trench or pit disposal of solid wastes can be moderately effective for isolating contaminants from the accessible environment when used in combination with other technologies such as the Hanford Barrier or waste treatment.

Cost. The cost of trench/pit disposal of 100 Area wastes is expected to be low. Construction requires standard earth moving equipment. Trenches and pits require minimal maintenance and operating resources.

1.8.2 Vaults

Applicability. Contaminated soils, riverbank sediments, and solid waste.

General Description. The greater confinement disposal (GCD) vault is an on-site, permanent waste disposal facility. The GCD is constructed of reinforced concrete that provides unlimited disposal duration due to extremely conservative design criteria. These vaults are designed to accept bulk and/or containerized waste forms that are dry or solidified. No untreated, wet, or raw waste, or free liquids can be accepted for disposal in such a vault.

The GCD vault is designed as a maximum resistance structure with the ability to withstand earthquakes, tornados, explosions, and rainwater intrusion.

Implementability. Implementability of the GCD vault concept is dependent on regulatory acceptance. The permanent disposal of hazardous and radioactive waste requires compliance with the performance criteria outlined in several regulations including RCRA (mixed waste) and 10 CFR 61 (NRC 1990). The general objective of these regulations is to ensure that the facility is designed, operated, maintained, and closed such that the risk of human exposure is minimized. The performance objectives of 10 CFR 61 are to protect groundwater, protect against inadvertent intrusion, and include safety provisions for workers during operation. Therefore, disposal in GCD vaults is considered implementable assuming approval by regulatory agencies. The discussion concerning land disposal restrictions (see Implementability of Trenches/Pits) applies to disposal of mixed wastes in vaults also.

Effectiveness. The GCD vault concept isolates waste from groundwater and prevents human contact. The conservative design criteria provides a high level of isolation

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confidence. On-site disposal in GCD vaults is expected to be highly effective for disposal of Hanford 100 Area waste.

Cost. Construction costs of GCD vaults would be high relative to other disposal techniques due to conservative design safety features.

1.8.3 Tumulus

Applicability. Contaminated soils, riverbank sediments, and solid waste.

General Description. A tumulus is an above-grade structure for either permanent or temporary disposal. On-site tumulus disposal refers to mounding over waste that has been placed on a stable structural pad. A tumulus may be designed to accept solidified, bulk, or containerized waste forms for disposal.

The structural pad may consist of multiple layers of concrete, geotextile material, clay, drainage layers of sand, or coarse gravel. The structural pad is also equipped with a leachate collection/detection system. A tumulus would be closed with a RCRA multi-media cap (described previously) and high berms around the perimeter.

Implementability. Similar to the GCD vault, the implementability of the tumulus disposal concept is dependent on regulatory acceptance under the objectives and criteria defined in 10 CFR 61 (NRC 1990). Assuming approval by regulatory agencies, disposal within tumulus facilities is considered to be moderately implementable at the Hanford 100 Area. The discussion concerning land disposal restrictions (see Implementability of Trenches/Pits) applies to disposal of mixed and hazardous wastes in a tumulus also.

Effectiveness. The tumulus disposal concept offers isolation from groundwater, human contact, and the surface environment. In addition, the concept provides for shielding from radiation emissions and allows waste retrieval in the event that improved disposal techniques become available in the future. On the other hand, the tumulus disposal concept requires maintenance and monitoring throughout the lifetime of the facility. Long-term isolation cannot be ensured within tumulus facilities. Therefore, on-site disposal in tumulus facilities would have limited effectiveness for isolating radioactive wastes.

Cost. Construction costs for tumulus facilities are expected to be low. The potential for frequent maintenance is high. Overall, the total cost of tumulus disposal is judged to be low in comparison to other on site disposal techniques.

1.8.4 RCRA Landfills

Applicability. Hazardous or radioactive contaminated soils, riverbank sediments, and solid waste.

General Description. A RCRA landfill is an EPA permitted disposal facility for RCRA-regulated hazardous and mixed wastes. The design and operation of such a landfill is

defined in 40 CFR 264 (EPA 1990a). In general, a RCRA landfill must be designed to prevent migration of hazardous constituents out of the landfill to adjacent soils, groundwater, or surface water at any time during the operation and closure period of the facility. Facility design considerations include a suitable geologic location, liner system, and a leachate collection and removal system.

Implementability. Landfill disposal of nonradioactive hazardous waste is a well developed technology and commonly practiced in the commercial hazardous waste disposal industry. Landfill disposal sites for nonradioactive hazardous waste are located throughout the U.S. A significant permitting effort may be required for EPA approval of an on-site RCRA landfill. In addition, waste must meet the RCRA land disposal restriction treatment requirements (40 CFR Part 268) or an exemption must be received before disposal can occur. In general, implementation of on-site RCRA landfill disposal is considered moderately implementable.

Effectiveness. On-site disposal of 100 Area nonradioactive hazardous waste in RCRA landfills is judged to be moderately effective in preventing migration of hazardous constituents to the accessible environment. This method of disposal is generally accepted by the EPA and is commonly used in industry.

Cost. The cost of implementing RCRA landfills for on-site disposal of 100 Area nonradioactive hazardous waste is considered moderate relative to other on-site disposal options. Design, construction, operation, and maintenance of an on-site RCRA disposal facility may be based on existing commercial facilities. Specialized designs, equipment, and operating requirements are not required. However, postclosure monitoring and leachate collection will be required and will add to the cost of this disposal option.

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1.9 OFF-SITE DISPOSAL

The following off-site disposal methods are discussed below:

- RCRA landfills
- DOE disposal facilities
- Geologic repositories.

1.9.1 RCRA Landfills

Applicability. Nonradioactive contaminated soils, riverbank sediments, and solid waste.

General Description. Hazardous waste landfills are commercially operated off-site facilities for disposal of hazardous wastes. At the present time, no RCRA landfills are available in the State of Washington. One RCRA landfill located in Arlington, Oregon, has been used for Hanford Site waste disposal.

Implementability. Hazardous waste landfills are permitted to accept specific wastes. Land disposal restrictions (EPA 1990b) limit the type and form of wastes that can be disposed in landfills. Disposal in hazardous waste landfills is applicable to hazardous and mixed wastes. Off-site disposal of hazardous waste from the 100 Area is easily implementable at existing hazardous waste landfill facilities.

Effectiveness. Landfills are considered a highly effective method of disposal for nonradioactive hazardous waste forms because the design, operation, maintenance, and closure specifications of such facilities are required to comply with EPA regulations.

Cost. Disposal costs at off-site RCRA landfills are low for small volumes of hazardous waste in comparison to construction, operation, and maintenance of on-site disposal facilities.

1.9.2 DOE Disposal Facilities

Applicability. Radioactively contaminated soils, riverbank sediments, and solid waste.

General Description. Low-level waste (LLW) disposal facilities either exist or are planned at six DOE sites (DOE 1991a). These facilities potentially could also be used for disposal of Hanford 100 Area LLW. These sites include facilities at: Los Alamos National Laboratory, Savannah River Site, Idaho National Engineering Laboratory, Oak Ridge National Laboratory, Nevada Test Site, and the Hanford Site. These six sites would collectively provide LLW disposal capacity for approximately 68,000 m^3/yr, which is far less than the potential disposal needs of approximately 200,000 m^3/yr for solid waste assuming macroengineering study volume estimates and 20-year disposal phase.

Implementability. Off-site disposal for Hanford 100 Area wastes is considered implementable for limited volumes of waste. These facilities exist and accept LLW from other DOE generators. However, host state governments and local residents are becoming increasingly opposed to receiving off-site LLW for disposal (DOE 1991a). This opposition would make off-site disposal of Hanford 100 Area wastes at other DOE facilities difficult to implement.

Effectiveness. Off-site disposal of Hanford 100 Area wastes at other DOE sites is considered to be moderately effective.

Cost. The cost of disposal at DOE facilities is considered to be high relative to other disposal options. Some disposal facilities exist and others are planned, but maintenance, monitoring, and closure of disposal facilities would increase costs.

1.9.3 Geologic Repositories

Applicability. Radioactively contaminated soils, riverbank sediments, and solid waste.

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General Description. Two geologic repositories are currently under development by DOE. Yucca Mountain, Nevada, is the proposed site for disposal of defense high-level waste (HLW) and is in the conceptual stage of development. The Waste Isolation Pilot Plant (WIPP), near Carlsbad, New Mexico, is the proposed disposal site for defense transuranic (TRU) waste. Portions of the WIPP have been constructed and the project is awaiting congressional land withdrawal to begin a 5-year test phase prior to initiating operations.

Implementability. Implementability of off-site geologic disposal of 100 Area waste is dependent on the availability of facilities similar to the WIPP facility. WIPP would likely be in its operational phase by the time the 100 Area waste is ready for disposal. However, WIPP's mission only applies to TRU waste generated between 1970 and 2013. Yucca Mountain is many years away from operation and is not expected to be available in time for disposal of Hanford 100 Area waste. Therefore, geologic disposal is considered to be non-implementable.

Effectiveness. The objective of geologic disposal is to isolate waste within a stable geologic formation. Geologic disposal is judged to be a highly effective method of containment and isolation of radioactive wastes from groundwater, the surface environment, and human contact.

Cost. In comparison to other disposal options, the costs for the development and implementation of a geologic repository are extremely high based on costs associated with the WIPP and Yucca Mountain Projects.

1.10 IN SITU STABILIZATION/SOLIDIFICATION

The following in situ stabilization/solidification techniques are discussed below.

- Grout Injection
- Vibration-Aided Grout Injection
- Vitrification
- Dynamic Compaction.

1.10.1 Grout Injection

Applicability. Contaminated soils, riverbank sediments, and buried solid waste.

General Description. Grout injection is an in situ stabilization/solidification technique involving the injection of a cement grout into a contaminated zone. Hollow-stem augers are used to inject and blend grout with contaminated materials. The end product of this process is a monolithic block of contaminated material encapsulated in grout.

Implementability. Grout injection is a developed technology. This technique has been used for over 18 years in applications such as cutoff walls and soil stabilization (EPA 1989). The augers used for grout injection are usually mounted on crawler-type drill rigs which make the system easily implementable in virtually any terrain.

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Effectiveness. The technology is applicable to soils and buried wastes contaminated with heavy metals, semi-volatile organic compounds, and radionuclides. Typically a single system can mix 90 to 140 cubic yards of soil per 8-hour shift (EPA 1989a). This rate is achievable to depths up to 100 feet (EPA 1989a). However, the characteristics of the Hanford Formation would inhibit successful implementation of this technique and may produce a solidified/stabilized block that is not monolithic. Furthermore, grout coverage may not be as uniform as necessary to ensure containment. Thus, grout injection is considered to have limited effectiveness.

Cost. Based on the availability of materials and standard equipment, the cost to implement this technology would be moderate in comparison with other in situ stabilization/ solidification technologies.

1.10.2 Vibration-Aided Grout Injection

Applicability. Contaminated soils, riverbank sediments, and buried solid waste.

General Description. This technology is similar to grout injection with added vibration to enhance the effectiveness of the treatment to fill void space. The vibratory energy is transmitted through a vertical array of I-beams driven into the contaminated zone. A vibrating hammer-extractor system transmits vibratory energy to the array of I-beams. The vibration aids the penetration of grout into the soil or buried waste.

Implementability. Vibration-aided grout injection is an innovative technology. However, the technology would be moderately implementable due to difficulties involved with driving I-beams into the rocky soils of the Hanford 100 Area.

Effectiveness. The presence of vibration during grout injection provides increased control of grout placement and thus increased effectiveness over grout injection without vibration. This process should increase the ability to stabilize/solidify contaminated zones into uniform monolithic blocks. Thus, vibration-aided grout injection is considered to be moderately effective for stabilization/solidification of Hanford 100 Area contaminated sites.

Cost. The costs associated with vibration-aided grout injection are partially dependent upon the type of grout selected. The cost to implement this technology is expected to be high in comparison to other in situ stabilization/solidification technologies. For example, in comparison to grout injection alone, pile driving I-beams combined with vibration operations would result in increased costs.

1.10.3 Vitrification

Applicability. Contaminated soils, riverbank sediments, and buried solid waste.

General Description. In situ vitrification is an innovative process of melting wastes and soils in place to encapsulate inorganic contaminants into a glassy solid matrix. The glass is resistant to leaching and potentially more durable than other stabilization materials.

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Vitrification is accomplished by joule-heating to melt contaminated material. Melt temperatures, in the range of 1600 to 2000° C, are high enough to pyrolyze organic pollutants. Although the process was initially developed to provide enhanced isolation for buried radioactive wastes, destruction or removal by volatilization of organic hazardous wastes may also be accomplished. This technology is commercially available for hazardous chemical wastes and has been full-scale tested at actual mixed waste and radioactive waste sites at Hanford.

The in situ vitrification process requires insertion of electrodes into the contaminated soil. A conductive mixture of flaked graphite and glass frit is placed on the surface between the electrodes to provide a conductive starter path for electrical energy. Heat is generated from the resistance to electrical current passing between electrodes thereby creating a melt pool. The starter path material is eventually consumed by oxidation, and the current is transferred directly to the molten soil which is electrically conductive. As the melt grows downward and outward, nonvolatile elements are incorporated and organic components are pyrolyzed. The pyrolyzed byproducts migrate to the surface of the vitrified zone where oxidation may occur. Convective currents within the melt uniformly mix materials that are present in the soil. The molten pool cools and solidifies upon the termination of power input. A hood placed over the processing area provides confinement for the combustion gases, drawing the gases into an off-gas treatment system.

Implementability. In situ vitrification has been demonstrated on hazardous and radioactive contaminated sites. Specific site characteristics must be considered in determining the implementability of vitrification. The presence of groundwater severely limits the practicality of in situ vitrification. High concentrations of flammable liquids or solids have produced excessive amounts of gases that have overcome the capacity of the off-gas treatment system in tests. In situ vitrification is considered implementable for homogeneously contaminated materials such as soils and riverbank sediments. However, the process is not considered to be presently implementable for sealed containers that may be present in solid waste burial sites.

Effectiveness. In situ vitrification is an innovative process potentially applicable to Hanford soils and solid wastes. The radionuclides and heavy metals would be encapsulated in a glass matrix that has extremely high resistance to leaching and also has good mechanical integrity. The vitrified product should be stable for long periods of time. Vitrification of radioactive soils has been tested in a demonstration project at a crib in the 100-B area (report in preparation). However, additional development is required to determine whether off-gas problems can be resolved and adequate depth of melt can be achieved for the process to be effective at the Hanford 100 Area. In situ vitrification is considered to be highly effective for immobilizing contaminants in homogeneous waste materials such as soils.

Cost. The major factors affecting costs for in situ vitrification of Hanford 100 Area soils, riverbank sediments, and solid waste are the moisture content and resistivity of the material. Energy costs would the highest and most variable cost item for in situ vitrification. The cost of vitrification is expected to be very high in comparison with other in situ stabilization/solidification technologies.

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1.10.4 Dynamic Compaction

Applicability. Contaminated soils, riverbank sediments, and buried solid waste.

General Description. Dynamic compaction is an in situ stabilization technique for consolidating contaminated soils, riverbank sediments, and solid waste burial sites. The process involves dropping a weight from a predetermined height on the area to be compacted. The impact of the weight causes shock waves within the underlying media thereby consolidating soil particles (Schexnayder and Lukas 1992). The equipment required to perform dynamic compaction consists primarily of a steel or concrete weight suspended from a crane. The weight, ranging from 10 to 40 tons, would be dropped from heights up to 100 feet (WHC 1991e).

Implementability. Dynamic compaction is a developed technology with extensive use in the construction industry (Schexnayder and Lukas 1992). Equipment required to perform dynamic compaction is commercially available and mobile. Crawler mounted cranes should be capable of accessing all areas within the Hanford 100 Area. Dynamic compaction is therefore considered an easily implementable technology.

Effectiveness. In the construction of dam foundations, dynamic compaction has achieved consolidation depths of 30 feet or more in clay and silty soils (WHC 1991e). Although Hanford soils are porous and should be amenable to dynamic compaction, the technique has not been demonstrated on solid waste burial sites or soils within the 100 Area. Therefore, dynamic compaction is considered to have limited effectiveness.

Cost. Commercially available dynamic compaction equipment would have low capital costs. The process is neither labor nor maintenance intensive. In addition, the separation between operators and contaminated materials eliminates the need for high-cost safety equipment. Dynamic compaction is considered a low cost in situ stabilization/solidification technology.

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1.11 THERMAL TREATMENT

The following thermal treatment methods are discussed below:

- Thermal desorption
- Incineration
- Pyrolysis
- Metal melting
- Molten solids processing.

1.11.1 Thermal Desorption

Applicability. Organic contamination destruction in soils, riverbank sediments, and solid waste.

General Description. Thermal desorption is a relatively low temperature thermal treatment for separating water and organic contaminants from soils and solid waste. Organic constituents removed by thermal desorption are generally incinerated in a second stage combustion chamber (condensation and separation is also an option). The process has little effect on inorganic contaminants (EPA 1989a). The basic components of a thermal desorber are the dryer furnace, second stage incinerator, and off-gas collection/treatment system.

Implementability. The process is applicable to remediation of organic contamination only. Soils or solid wastes having moisture content above 60 percent may require dewatering prior to thermal desorption (RAAS 1991). The capacity of existing thermal desorption systems ranges from 3 to 50 tons/hour of soil type media (RAAS 1991). The technology is considered moderately implementable at Hanford 100 Area sites containing organic contamination.

Effectiveness. Pilot tests have shown the extraction efficiency of thermal desorption to be over 90 percent for polychlorinated biphenyls (PCBs) and 99 percent for phenols (RAAS 1991). However, full-scale remediation with this technology has not been demonstrated (RAAS 1991). The efficiency of thermal desorption is inversely affected by the moisture content of the feed waste stream. Treatability tests would be required to ensure the effectiveness of this process on Hanford soils and solid wastes. Due to the low moisture and organic content of Hanford soils and solid waste, thermal desorption has the potential to be highly effective for organic contaminant removal and destruction.

Costs. Thermal treatment technologies are generally high-cost options. However, the low temperatures involved with thermal desorption reduce the off-gas collection/treatment requirements as well as the fuel requirements of the system. Thus, the cost of a thermal desorption process with a secondary combustion chamber is expected to be moderate in comparison to other thermal treatment technologies.

1.11.2 Incineration

Applicability. Organic contamination destruction and volume reduction of combustible materials in solid waste, soils, and riverbank sediments.

General Description. Incineration is an ex situ, high-temperature-oxidation process in which organic materials are oxidized to carbon dioxide, water, and oxides of other elements in the waste. Examples of incineration technologies applied to radioactive waste include multiple hearth, rotary kiln, fluidized bed, and controlled air incinerators. Incineration systems may be designed for waste forms such as liquids, solids, sludges, soils, and containerized wastes. The advantages of incineration include maximum volume reduction, destruction of organics, and residuals that may be stabilized for disposal (RAAS 1991). The components of an incineration system include the feed system, primary and secondary combustion chambers, ash removal system, and an off-gas treatment system.

Implementability. Incineration is a well developed technology. Incineration systems are commercially available and can be either mobile or permanent installations. The

process is applicable to the treatment of organic contaminants only. Stationary incinerators have been designed for up to 21,000 pounds/hour and transportable incinerators up to 20,000 pounds/hour. Although a significant permitting effort would be required for implementation of an incineration system, the technology is considered moderately implementable at the Hanford 100 Area.

Effectiveness. Incineration is a highly effective method for treating organic contamination. Destructive and removal efficiencies greater than 99.9999 percent have been achieved (RAAS 1991). As is the case with all thermal treatment technologies, the melting point of inert components in the waste can present potential problems. For example, certain compounds containing phosphorus make high viscosity ash. Similarly, lead may vaporize and then re-solidify in the off-gas treatment system. Therefore, characterization of the feed material is essential for design. Reliable and environmentally safe systems are possible with proper design.

Cost. Thermal treatment technologies are typically high cost options. Incineration systems generally have high permitting costs with moderate operating costs in comparison to other thermal treatments. Maintenance costs are high due to the complexity of the system. The overall cost of incineration is expected to be high in comparison to other thermal treatment technologies.

1.11.3 Pyrolysis

Applicability. Organic contamination destruction and volume reduction of combustible materials in solid waste, soils, and riverbank sediments.

General Description. Pyrolysis is an ex situ, high temperature thermal treatment process in which organic compounds are thermally decomposed in the absence of sufficient oxygen for complete oxidation. Off-gases resulting from pyrolysis are usually oxidized with excess air in a secondary combustion chamber. Pyrolysis technologies in use today include conventional pyrolytic reactors, rotary hearth pyrolyzers, and starved-air combustion (RAAS 1991). Pyrolysis technology is flexible and may be applied to liquids, solids, sludges, and soils. Pyrolysis benefits are similar to incineration and include maximum volume reduction, destruction of organics, and residuals that may be stabilized for disposal (RAAS 1991).

Implementability. Pyrolysis is a well-developed technology and is commercially available (RAAS 1991). The process is applicable only to the treatment of organic contaminants. A significant permitting effort would be required (RAAS 1991), but the technology is considered moderately implementable at the Hanford 100 Area.

Effectiveness. Pyrolysis is a highly effective method for treating liquid and solid wastes contaminated with hazardous organic constituents. The process requires careful control of combustion air and feed material to ensure starved-air combustion. Heterogeneous waste forms at the Hanford 100 Area could present process control difficulties. As is the case with all thermal treatment options, the melting point of inert constituents in the waste is a concern (refer to the section on incineration for further discussion).

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Cost. Thermal treatment technologies are generally more expensive than other treatment technologies due to the complexity of the systems and energy and maintenance requirements. Pyrolysis technology requires an extensive off-gas treatment system. Thus, the overall cost of pyrolysis is expected to be high.

1.11.4 Metal Melting

Applicability. Decontamination of metal waste.

General Description. Metal melting is an ex situ treatment for decontaminating metal waste. Melting under an oxidizing slag has been shown to effectively remove transuranic contamination from metal wastes (Heshmatpour and Copeland 1981). With this treatment, metals are decontaminated and the radionuclides are partitioned into a much smaller volume of slag. The resulting waste form, or solidified slag, is a stable glass monolith.

Implementability. Metal melting as a decontamination process is an innovative technology. The process has been demonstrated on a laboratory scale. Additional development and testing would be required to demonstrate implementability of the process in treating the contaminated metal wastes at the Hanford 100 Area. At the present stage of development, the implementability of decontamination by metal melting is considered difficult because this process requires segregated waste streams of different types of metal. Such segregation efforts are expected to be difficult to implement, are manpower intensive, and could potentially conflict with ALARA principles.

Effectiveness. The metal melting decontamination process has been shown to effectively remove transuranic contamination from many metals (Heshmatpour and Copeland 1981). However, the effectiveness of this technique for removing other contaminants is uncertain. Additional testing would be required to demonstrate the effectiveness of the partitioning process in removing fission and activation products that are present in wastes at the Hanford 100 Area. Due to the variations in melting temperatures of dissimilar metals, the process requires a highly segregated feed stream. Therefore, the effectiveness of melting Hanford 100 Area metals is judged to be uncertain.

Cost. The cost of implementing a metal melting decontamination process is unknown due to the experimental status of the technology. However, thermal treatment technologies are generally expensive, as discussed in the incineration and pyrolysis descriptions. Additional costs are incurred by the requirement for a segregated feed stream. The overall cost of metal melting decontamination is estimated to be high in comparison to other thermal treatment technologies.

1.11.4 Molten Solids Processing

Applicability. Destruction of organic contaminants and immobilization of solid waste, soils, and riverbank sediments.

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General Description. Molten solids processes are ex situ, thermal treatment technologies designed to destroy organic contaminants and immobilize any remaining constituents. Examples of this technology include molten glass processes (vitrification), slagging incineration (pyrolysis), molten salt incineration, and plasma incineration (RAAS 1991).

Implementability. Molten solids processes are in the development and demonstration phase. Additional work is required to demonstrate full-scale capabilities for these processes. At the current stage of development, molten solids processes are judged to be difficult to implement at the Hanford 100 Area.

Effectiveness. Thermal treatments are generally highly effective for the destruction of organic contaminants, and molten solids processing provide the additional feature of immobilizing any remaining hazardous constituents in a vitrified matrix. However, technical constraints can limit the effectiveness of these processes for treating 100 Area solid wastes, soils, and riverbank sediments. Molten salt incineration requires low moisture and ash content feed waste, as well as preshredding of solids. Plasma incineration is generally limited to treatment of liquids (RAAS 1991). Slagging incineration process rates are slow (RAAS 1991). Molten solids processes may not entrain certain contaminants due to volatilization. Therefore, the technologies are considered to be only moderately effective for Hanford 100 Area wastes.

Cost. The cost of molten solids processing is judged to be very high in comparison with other thermal treatment technologies. Molten solids processing requires excessive energy for melting.

1.12 STABILIZATION/SOLIDIFICATION

The following stabilization/solidification techniques are discussed below:

- Bitumen-based
- Cement-based
- Polymer-based
- Vitrification.

1.12.1 Bitumen-Based

Applicability. Elimination of free liquids, immobilization of organic and inorganic contaminants in solid waste, soils, and riverbank sediments.

General Description. Bitumen-based stabilization/solidification is an ex situ treatment process of mixing waste materials with a bitumen (or asphalt) binder to immobilize contaminants, eliminate free liquids, and produce a solid monolithic waste form for disposal. Initially waste and bitumen are mixed together; any water present is evaporated by contact with hot liquid bitumen (DOE 1988). The mixing process coats the remaining waste materials with bitumen. The mixture is then allowed to cool and harden, thereby

immobilizing the contaminants within the bitumen matrix. Stabilization/solidification processes for mixing waste with bitumen can be in-line or in-container as well as stationary or mobile (Moghissi et al., 1986).

Bitumen-based solidification is generally applicable to treatment of liquid wastes, such as evaporator concentrates, decontamination liquids, and contaminated oils; wet waste, such as spent resins and sludges; and dry solid wastes, such as shredded trash, soils and riverbank sediments, incinerator ash, dryer residues, and other dried materials.

Implementability. Bitumen-based stabilization/solidification is a well developed technology and is used in the U.S. and European commercial nuclear power industries (DOE 1988). Bitumen has been accepted as a radioactive waste solidification agent at the three operating commercial radioactive waste burial sites in the U.S. (Moghissi et al., 1986). Bitumen-based stabilization/solidification is considered to be moderately implementable for treatment of Hanford 100 Area wastes.

Effectiveness. Bitumen-based stabilization/solidification techniques have been effectively used for treatment of low-level radioactive wastes from the commercial nuclear power industry (DOE 1988). However, the combustibility of asphalt must be considered during handling, storage, and disposal. In addition, concentrations of certain salts in excess of 40 weight percent may increase leaching rates of contaminants from bitumenized waste forms (Moghissi et al., 1986). Treatability tests to determine the sensitivity of the bitumen stabilization/solidification process to multiple contaminants and certain chemicals would be required. Thus, bitumen-based stabilization/solidification is judged to be moderately effective for immobilizing contaminants in Hanford 100 Area solid wastes. The technique is judged not effective for stabilization/solidification of soils due to a large increase in waste volume.

Cost. Bitumen is a reasonably inexpensive binding agent and is readily available (Moghissi et al., 1986). The equipment required for bitumen-based stabilization/solidification is commercially available (DOE 1988). Energy consumption of the processes may be significant because bitumen must be maintained at a temperature of 150°C to maintain fluid properties. Bitumenization processes are moderately labor and maintenance intensive. The overall cost of bitumen-based stabilization/solidification is expected to be low in comparison with other stabilization/solidification technologies.

1.12.2 Cement-Based

Applicability. Elimination of free liquids, immobilization of organic and inorganic contaminants in solid waste, soils, and riverbank sediments.

General Description. Cement-based stabilization/solidification is an ex situ treatment process of mixing waste materials with cement to immobilize contaminants, eliminate free liquids, and produce a solid monolithic waste form for disposal. Many formulations of cement, admixtures, such as plasticizers and hardeners, and waste have been developed for stabilization/solidification of radioactive wastes. Inorganic contaminants such

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as heavy metals and radionuclides are readily amenable to cement-based stabilization/solidification (Freeman 1989). Organic wastes containing solvents, grease, or oils interfere with hydration reactions, which in turn inhibit cement-based stabilization/solidification (Freeman 1989). Proprietary bonding agents that increase the effectiveness of treating organic contaminants have been developed to eliminate this problem (EPA 1989a).

Implementability. Cement-based stabilization/solidification is a developed technology and is commonly used for a variety of radioactive wastes. Cement-based treatment may be considered standard for the stabilization/solidification of many radioactive wastes (Freeman 1989). Proprietary bonding agents are currently being developed and demonstrated by commercial operations (EPA 1989a). Cement-based stabilization/ solidification is considered to be easily implementable at the Hanford 100 Area for soils and waste byproducts.

Effectiveness. Cement-based stabilization/solidification techniques have been effectively used for treatment of radioactive and hazardous wastes. However, the sensitivity of the cementation process to multiple contaminants and certain chemicals would require treatability tests to ensure effectiveness and to select appropriate bonding agents and mix ratios. Therefore, cement-based stabilization/solidification is considered to be moderately effective for treating 100 Area solid wastes. The method is considered not effective for stabilization/solidification of soils due to a large increase in waste volume.

Cost. Stabilization/solidification equipment is commercially available. Portland cement is readily available and relatively inexpensive (Roggenthen 1989). Additives, if required, may be expensive. Cementation processes are neither labor nor maintenance intensive (Roggenthen 1989). Thus, the overall cost of cement-based stabilization/solidification is expected to be low in comparison with other stabilization/solidification technologies.

1.12.3 Polymer-Based

Applicability. Elimination of free liquids, immobilization of organic and inorganic contaminants in solid waste, soils, and riverbank sediments.

General Description. Polymer-based stabilization/solidification is an ex situ treatment process of encapsulating waste materials with polymeric materials such as polyethylene, polybutadiene, or other thermosetting resins.

Implementability. Polymer-based stabilization/solidification is a developed technology and is commercially available for hazardous and radioactive applications (DOE 1988). Polymer encapsulation processes using polybutadiene and polyethylene have been developed and demonstrated for low-level radioactive waste (Freeman 1989). However, macroencapsulation has not generally been used for stabilization/solidification of waste materials. Polymer-based stabilization/solidification is considered moderately implementable

for Hanford 100 Area solid waste due to the stage of development and availability of processes.

Effectiveness. Polymer-based stabilization/solidification is generally effective for treating most inorganic waste streams. Organic materials in the waste may retard polymerization (Freeman 1989). The process offers increased waste loading ratios and improved contaminant containment over other stabilization/solidification processes (Freeman 1989). Treatability tests to determine the effects of organic constituents in the Hanford soils on the polymerization would be required. In the absence of polymerization retarding organic constituents, polymer-based stabilization/solidification is considered moderately effective for treating Hanford 100 Area solid wastes. The method is considered not effective for stabilization/solidification of soils due to a large increase in waste volume.

Cost. Polymer processing requires complex metering and mixing equipment. The capital cost of such equipment is high. The raw materials required for polymer stabilization/solidification are also expensive. Furthermore, maintenance costs would be high. Thus, the overall cost of polymer-based solidification/stabilization is expected to be high in comparison with other stabilization/solidification technologies.

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1.12.4 Vitrification

Applicability. Destruction of organic contaminants and immobilization of solid waste, soils, and riverbank sediments.

General Description. Vitrification is an ex situ stabilization/solidification treatment process of melting waste materials in a glass matrix. The high temperature molten glass (1000 to 2000°C) volatilizes or destroys the organic constituents as well as the nitrate components in the waste. The inorganic contaminants, such as heavy metals and radionuclides, are immobilized in a stable glass form that has mechanical and chemical properties similar to granite. Vitrification is a variation of molten solids processing.

Implementability. Vitrification is an innovative process that has been demonstrated on a pilot scale. The vitrification process is applicable to solid waste and soils (Freeman 1989). Vitrification technology has been selected for treatment of high-level nuclear waste at the Hanford Waste Vitrification Plant (HWVP), the Defense Waste Processing Facility (DWPF) at Savannah River, and the West Valley Demonstration Project (WVDP) (Gurley et al., 1988). A significant development effort would be required before implementation of a vitrification system on the range of wastes at the 100 Area. Vitrification is considered difficult to implement.

Effectiveness. Vitrification is a highly effective treatment option for removal and destruction of organic and nitrate contaminants and stabilization/solidification of inorganic contaminants found in soils. Vitrification is considered moderately effective for solid waste at the Hanford 100 Area. The resulting waste form is very stable and non-leachable (Roggenthen 1989).

Cost. Vitrification systems are complex and have not been demonstrated on a large scale. The system would require large amounts of electrical energy to maintain melt temperatures. The operating and maintenance requirements would be extensive. Hence, the cost of vitrification is expected to be very high in comparison with other stabilization/ solidification technologies and with other thermal treatment technologies.

1.13 PHYSICAL TREATMENT

The following methods of physical treatment are discussed below:

- Size reduction
- Segregation/sorting
- Repackaging
- Metal decontamination.

1.13.1 Size Reduction

Applicability. Solid waste.

General Description. Size reduction refers to ex situ physical treatment processes used to reduce volume, to make large objects amenable to handling, and as a preparatory step for treatment processes. Size reduction processes include shredding, cutting, and compacting.

Implementability. Size reduction processes are well developed and are used in nuclear power plants (EPRI 1988) for volume reduction of low-level dry-active wastes (DAW). Mobile or stationary shredding and compaction systems are available (EPRI, 1988; Kennerly et al., 1988). Size reduction of solid waste at the 100 Area is considered an easily implementable treatment option, although some segregation may be required.

Effectiveness. Size reduction does not affect the toxicity, mobility, or hazards of contaminants. The presence of free liquids complicates size reduction systems and thick metal would be difficult to process. Overall, due to the need for additional processing, size reduction is judged to have limited effectiveness as a treatment process.

Cost. Size reduction equipment is commercially available from many commercial vendors (EPRI 1988). Size reduction is typically a maintenance intensive process. The overall cost of size reduction technologies is expected to be low.

1.13.2 Segregation/Sorting

Applicability. Solid waste.

General Description. Segregation and sorting is an ex situ process of separating solid waste materials by physical or chemical attributes to facilitate additional treatment. Implementation of a metal melting process, for example, would require that metallic waste be

segregated/sorted into categories such as steels, lead, and aluminum, prior to melting (see Section 1.11.4). Sorting can be done manually, automatically, or by some combination of these depending on waste characteristics. Manual sorting might simply consist of an operator sorting waste with a robotic manipulator in a hot cell or by hand in a glove box. Air classification or magnetic separation are examples of automated sorting operations.

Implementability. The implementability of segregation/sorting processes for radioactive wastes would depend on site-specific parameters. Segregating and sorting retrieved buried waste would be very difficult to implement at the Hanford 100 Area. The age and condition of the waste may not be amenable to segregation and sorting and implementability would depend on the degree of sorting required for subsequent processes. Manual sorting is labor intensive and not considered consistent with ALARA principles.

Effectiveness. Sorting is only effective when used in conjunction with other waste treatment processes. The effectiveness of a segregation/sorting process at the Hanford 100 Area would be dependent on the degree of sorting required. A coarse segregation/sorting process that separates large items of waste during the excavation process would be very effective. However, more specific sorting processes, such as segregation by metal type, may not be practical. In general, segregation and sorting of solid waste materials is considered to have limited effectiveness and would be highly dependent on the type of sorting required for other operations.

Cost. Segregation and sorting processes for Hanford 100 Area solid waste are potentially complex. Manual processes would be labor intensive, whereas automated processes would be maintenance intensive. Therefore, segregation and sorting are expected to be very high cost processes in comparison to other physical treatment technologies.

1.13.3 Repackaging

Applicability. Solid waste.

General Description. Repackaging is the process of overpacking or replacing damaged or deteriorated waste containers. Overpacking involves placing a damaged or deteriorated waste container into a new oversized container. Repackaging is generally a manual operation, but lifting equipment may be required to handle heavy or oversized waste materials and containers.

Implementability. Repackaging can be accomplished, but may require size reduction or special handling for deteriorated containers. Demolition wastes were buried without packaging; reactor components and "soft" wastes were buried in packages intended to provide short-term containment (DOE 1991b; DOE 1991c). Repackaging of excavated or demolished solid wastes is considered a moderately implementable process option.

Effectiveness. Repackaging waste is only a moderately effective process because contaminants could disperse into the environment if the container is not adequately protected

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and because most containers have a limited lifetime. Repackaging is a necessary component of most disposal options.

Cost. Repackaging costs are primarily a function of labor and container requirements. Labor requirements are moderate and maintenance requirements are low. The cost for this process option is expected to be moderate in comparison with other physical treatment technologies for solid waste.

1.13.4 Metal Decontamination

Applicability. Metal wastes.

General Description. Metal decontamination is an ex situ physical treatment process for removing radioactive materials from contaminated metal surfaces such as reactor components and process equipment. Examples of metal decontamination processes are (Moghissi et al., 1986):

- Hone and brush abrasion
- Hand wiping/scrubbing
- High-pressure water jetting
- Steam cleaning
- Ultrasonic cleaning
- Abrasive blasting
- Electrochemical polishing
- Solvent cleaning
- Chemical cleaning
- Vibratory finishing.

The primary objective of metal decontamination is to reduce contamination levels to below release limits. By reducing the contamination levels, restrictions that would otherwise apply due to the presence of radioactivity would be bypassed (Moghissi et al., 1986). If contamination levels cannot be reduced to below release limits, the objective of metal decontamination becomes the reduction of contamination to a level such that the item can be disposed under less stringent requirements. For example, removal of TRU contaminants to a level that allows disposal of the metal as a low-level waste.

Implementability. Several decontamination techniques are available and used routinely for surface decontamination of tools and equipment from nuclear facilities (Moghissi et al., 1986). The methods are based on the nature and extent of the contamination and the characteristics of the material to be treated. Metal decontamination is judged to be difficult to implement at the Hanford 100 Area due to the types and concentration of radionuclide contamination, condition of buried metal waste, and the required segregation.

Effectiveness. High-pressure water jets and hone and brush abrasion have been shown to be effective in decontaminating inner surfaces of piping (Moghissi et al., 1986).

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Vibratory finishing, ultrasonic cleaning with acidic solutions, and solvent cleaning are also considered to be effective processes of decontamination (Moghissi et al., 1986). Other effective techniques include abrasive blasting and electro-polishing, but these produce large quantities of secondary wastes (Moghissi et al., 1986). The effectiveness of metal decontamination in treating Hanford 100 Area metal waste is dependent on the level of contamination and physical condition of the waste. Treatability tests would be required to determine the effectiveness of metal decontamination. The effectiveness of metal decontamination is judged to be high provided that little or no oxidation has occurred.

Cost. The capital cost of such decontamination equipment is expected to be high. The processes may or may not be labor intensive depending on the specific procedure. Waste from pretreatment, maintenance requirements and generation, collection, and treatment of secondary waste forms are additional cost considerations. The overall cost of metal decontamination is expected to be high in comparison to other physical treatments for solid waste.

1.14 CHEMICAL TREATMENT

The following methods of chemical treatment are discussed below:

- Chemical oxidation
- Acid digestion
- Hydrolysis.

1.14.1 Chemical Oxidation

Applicability. Organic contamination in groundwater, soils, riverbank sediments, and solid wastes.

General Description. Chemical oxidation is an ex situ chemical treatment for destroying organic contaminants. Commonly used oxidizing agents include ozone, chlorine, potassium permanganate, and hydrogen peroxide. Chemical oxidation is most efficient for dilute aqueous wastes and gases with limited application for slurries, tars, and sludges. Treatment chemicals are typically added in excess of stoichiometric requirements. Ultraviolet light has been found to increase the oxidizing power of peroxide and ozone (Min et al., 1991).

Implementability. Chemical oxidation processes are well developed and commercially available. Photolysis, one form of chemical oxidation, uses a light source to catalyze the oxidation reaction and is dependent on waste material and fluid clarity. Chemical oxidation is implementable in the liquid and gaseous phases (Min et al., 1991). Oxidation of solid wastes is difficult because the contamination must be extracted from the solid into a liquid or gaseous form prior to the oxidation. Chemical oxidation would be considered moderately implementable for groundwater.

Effectiveness. Chemical oxidation, including photolysis, is moderately effective for the destruction of organic contaminants in liquid waste streams. These processes are judged to have limited effectiveness in treating solid waste, soils, and riverbank sediments due to the need for extracting the organics.

Cost. Chemical oxidation and photolysis require high cost chemical reagents and treatment of secondary wastes. Electrical and equipment costs for UV-photolysis can be very expensive. Therefore, chemical oxidation is judged to have very high implementation and operating costs.

1.14.2 Acid Digestion

Applicability. Solid waste.

General Description. Acid digestion is an ex situ chemical treatment process which oxidizes organic materials and partially oxidizes metals by chemical reaction with acid (Lerch et al., 1981). Waste is digested in a heated bath of sulfuric acid. The sulfuric acid carbonizes and partially oxidizes organics (Lerch et al., 1981). Complete oxidation is accomplished by the addition of nitric acid to the reactor vessel at a rate proportional to waste feed requirements. The resulting residue must be separated from the acid bath by filtration or distillation (Lerch et al., 1981). These residues would require additional treatment such as solidification/stabilization by cementation or vitrification. Acid digestion is similar to a combustion process and requires off-gas collection and treatment.

Implementability. Acid digestion of contaminated combustible waste has been tested and demonstrated at the Hanford Engineering Development Laboratory (Allen and Lerch 1982). Immobilization of acid digestion residue has also been demonstrated (Greenhalgh and Allen 1983). The current status of development and the hazards associated with hot acid processing of this process suggests that implementation for treatment of 100 Area combustible waste would be difficult.

Effectiveness. The process can treat combustible wastes including PVC, polyethylene, paper, ion exchange resin, all types of rubber, and other cellulosic materials (Lerch et al., 1981). Process rates are very low (Lerch et al., 1981). Slow processing rates indicate limited effectiveness for acid digestion of wastes from the Hanford 100 Area.

Cost. Acid digestion systems are not fully developed or commercially available. The process is not labor intensive, although extensive process control is required. Sulfuric acid can be recycled in the process but treatment of secondary wastes is expensive. The complexity of such a system implies costly maintenance. The overall cost of implementing an acid digestion system would be very high in comparison with other chemical treatment technologies for solid waste.

1.14.3 Hydrolysis

Applicability. Solid reactive materials and insoluble solid organics.

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General Description. Hydrolysis is an ex situ chemical treatment process. Hydrolysis is a fragmentation/substitution reaction which may occur in pure water for reactive compounds such as alkali metals or in acidic or basic conditions for insoluble organics. The fragmentation/substitution reaction decomposes organic contaminants or reduces reactive materials into significantly less hazardous aqueous solutions. Hydrolysis as a waste treatment is most effective when applied to high concentrations of reactive materials or insoluble organics. This treatment is not intended for low concentrations of contaminants that may be present in groundwater, soils, or riverbank sediments.

Implementability. Hydrolysis is a well developed technology that has traditionally been used to synthesize organic chemicals such as alkyl halides and hydrogen sulfates (RAAS 1991). Hydrolysis is considered difficult to implement at the Hanford 100 Area because reactive materials and insoluble organics are not present in a relatively pure form.

Effectiveness. Hydrolysis is an effective method of partial reduction of insoluble organic materials into more soluble components and in decreasing the dangers associated with reactive materials. Hydrolysis is effective for a limited portion of the contaminants of concern. The effectiveness of hydrolysis in treating solid waste is limited due to unknown amounts of pure reactive and insoluble organic materials present in the Hanford 100 Area.

Cost. The capital costs for hydrolysis are considered to be high. Reagent solutions for acidic and/or basic solutions may significantly increase operating costs. Overall, the cost for implementing hydrolysis for treatment of Hanford 100 Area solid wastes is judged to be high relative to other chemical treatment technologies due to dangerous operating conditions.

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2.0 GROUNDWATER TECHNOLOGY DESCRIPTIONS

2.1 ACCESS RESTRICTIONS

2.1.1 Water Rights Restrictions

Refer to "Technical Descriptions for Solid Waste" under Deed Restrictions, discussed in Section 1.1.2.

2.1.2 Deed Restrictions

Refer to "Technical Descriptions for Solid Waste" under Deed Restrictions, discussed in Section 1.1.2.

2.2 MONITORING

The following monitoring techniques are discussed below:

- Wellpoint monitoring
- Groundwater monitoring.

2.2.1 Wellpoint Monitoring

Applicability. Groundwater

General Description. Wellpoint monitoring systems consist of a series of closely spaced wells connected to a header. Samples are withdrawn from the header with a small suction pump. The wellpoint monitoring system is installed in an aquifer on the downgradient side of a point source to collect samples of potentially contaminated groundwater.

Implementability. Wellpoint monitoring is a common technique for collecting groundwater samples. The presence of gravel and cobbles in Hanford 100 Area soils limits the installation of wellpoints. Wellpoints are installed by driving small diameter pipe through soil; rocks encountered would prevent proper installation or may damage the screen configuration. Wellpoint systems are not considered implementable at the Hanford 100 Area for this reason.

Effectiveness. The wellpoint monitoring system is most suitable for applications where depth to groundwater is low and soils are sandy. The system can be modified for deeper aquifers but cannot be used in soils containing cobbles or boulders. Wellpoint monitoring is therefore considered to be ineffective for the Hanford 100 Area.

Cost. The cost of implementing wellpoint monitoring systems is considered to be low relative to other monitoring technologies due to the availability and common use of standard well installation equipment.

2.2.2 Groundwater Monitoring

Applicability. Groundwater

General Description. Groundwater monitoring systems consist of a network of monitoring wells placed upgradient and downgradient of potential contaminant sources. The exact number, construction, depth, and locations of the wells is dependent upon site-specific hydrogeological characteristics and the potential contaminants of concern. Groundwater samples are collected from the well(s) using suction or submersible pumps or bailers, and analyzed for the parameters of interest. Upgradient wells are routinely installed to provide baseline groundwater quality for comparison purposes. Sidegradient wells are installed to assist in plume delineation.

Implementability. Groundwater monitoring networks are routinely installed at waste management facilities. Installation techniques are readily available and are well suited for use in the Hanford 100 Area.

Effectiveness. Properly designed, constructed, maintained, and operated groundwater monitoring networks are highly effective in assessing existence and extent of

contamination in the groundwater. These networks can also be used to gauge the success of groundwater remediation activities. Monitoring alone is not effective in protecting health and environment.

Cost. The cost of installing a groundwater monitoring network at the Hanford 100 Area is considered to be moderate in comparison to other monitoring techniques. Operating and maintenance costs depend on the analytical parameters to be determined, the monitoring frequency, and the data interpretation activities associated with the monitoring program.

2.3 ALTERNATE WATER SUPPLY

2.3.1 Columbia River and Development of Nearby Sources

Applicability. Replacement of groundwater for domestic, industrial, or agricultural uses.

General Description. The purpose of this option is to provide alternative water sources to locally contaminated groundwater. Two options are considered here: the use of Columbia River water by direct pumping from uncontaminated areas or by constructing a reservoir exclusively for this purpose; or the development of nearby uncontaminated groundwater sources.

Implementability. Direct diversion of river water would be easily implementable. Water rights could be purchased from nearby sources if future land use options include agricultural activities or grazing. Pipelines would be required for development of nearby sources. Therefore this option is considered moderately implementable.

Effectiveness. The options presented above provide effective replacements for groundwater. Prior to allowing practices, such as irrigation, that may recharge the aquifer, the possible mobilization of contaminants through the use of replacement water would require consideration.

Cost. The cost of implementing water replacement practices is a function of the amount of water required, irrespective of whether water rights must be purchased and dams and pipelines constructed. On this basis, the diversion of Columbia River water is considered a moderate cost option and development of other nearby sources is considered a relatively high cost option.

2.4 HORIZONTAL BARRIERS

Refer to "Solid Waste Technology Descriptions." under Horizontal Barriers, discussed in Section 1.4.

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2.5 VERTICAL BARRIERS

Refer to "Solid Waste Technology Descriptions" under Vertical Barriers, discussed in Section 1.5.

2.6 HYDRAULIC CONTROL

The following methods of hydraulic control of groundwater are discussed below:

- Extraction wells
- Extraction drains/trenches.

2.6.1 Extraction Wells

Applicability. Groundwater

General Description. Groundwater extraction wells are used to withdraw, and occasionally, isolate contaminated groundwater by manipulation of the hydraulic gradient (RAAS 1991). The extraction system design may include a single well for the withdrawal or containment of an isolated plume or multiple well to control a larger or more dispersed plume. The complexity of the design depends on the nature of the transporting medium, the depth of penetration of the contaminant, and the complexity of the geologic stratigraphy. The extraction process is the precursor to groundwater treatment or disposal alternatives. Injection wells work in a manner opposite to extraction wells but employ similar design and construction.

Implementability. Groundwater wells for injection or extraction are considered conventional technology. The extraction/injection methods and technologies are well established in the remediation industry (RAAS 1991). The coarse nature and high transmissivity of Hanford 100 Area soils and the shallow depths to groundwater make extraction wells easily implementable.

Effectiveness. The geology and the nature of soils in the Hanford 100 Area lend themselves to installation and operation of extraction wells. The technology is considered a highly effective method of extracting groundwater.

Cost. The capital costs for extraction wells is expected to be moderate relative to other extraction systems. The major expenditures would be the well construction, the piping, and pump installation. Operating costs for extraction wells are expected to be low.

2.6.2 Extraction Drains/Trenches

Applicability. Groundwater

General Description. Extraction drains/trenches include any type of buried conduit, equipped with pumps, or below-grade trench used to direct and collect contaminated

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groundwater by gravity flow (Freeman 1989). A subsurface drainage system may consist of a single extraction point or a series of extraction points, depending on the extent of contamination, to collect leachate for treatment or monitoring. Drains/trenches can be used as barriers to prevent contamination or to intercept a contamination plume downgradient from a source. The method can be utilized in conjunction with other groundwater treatment or disposal technologies.

Implementability. Subsurface drainage systems are generally limited to shallow contamination. Installation may require excavation into contaminated materials. Due to the depth of contamination in the Hanford 100 Area, extraction drains/trenches may have limited application for intercepting contaminant plumes. Extraction drains/trenches are difficult to implement beneath existing solid waste burial sites and contaminated soil areas. Extraction drains/trenches would be moderately implementable for directing and collecting groundwater, but would require excavation of large volumes of soil.

Effectiveness. Extraction drains/trenches would be highly effective when used for shallow groundwater contamination. Little or no infiltration would be expected for solid waste or soils; therefore, the technology would be ineffective for these applications.

Cost. The cost of installing extraction drains/trenches is expected to be high relative to other subsurface flow control technologies. Implementation costs are primarily a function of the amount of excavation required. Excavation through contaminated materials may require equipment modifications and additional safety precautions to protect workers which would increase costs.

2.7 GROUNDWATER EXTRACTION

The following methods of groundwater extraction are discussed below:

- Extraction wells
- Extraction drains/trenches
- Aquifer mining.

2.7.1 Extraction Wells

Refer to "Extraction Wells" under Hydraulic Control, discussed in Section 2.6.1.

2.7.2 Extraction Drains/Trenches

Refer to "Extraction Drains/Trenches" under Hydraulic Control, discussed in Section 2.6.2.

2.7.3 Aquifer Mining

Applicability. Groundwater

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General Description. Aquifer mining is a groundwater extraction technique that involves removal of an entire contaminated groundwater formation. Application of the technique in the 100 Area would involve the removal of uncontaminated overburden, contaminated soil, sediment, and solid waste, and the mining of the water bearing strata.

Implementability. Aquifer mining is very similar to strip mining, a well developed technology. This technique is considered a drastic approach that would be used in conjunction with removal of contaminated soil, sediment, and solid waste. The materials that must be removed include all soils, riverbank sediments, and solid waste above and within contaminated groundwater plumes. While earth removal is not considered a technical challenge, removal of such a large volume of material would be more difficult. The depth to confining layers beneath the unconfined aquifer may exceed 150 feet in certain areas. For these reasons, aquifer mining would be difficult to implement in the 100 Area.

Effectiveness. Aquifer mining involves simultaneous removal of contaminated groundwater and the soil in which it is present. The sources of groundwater contamination include trenches, cribs, and drains that must be removed prior to aquifer mining. Aquifer mining would be highly effective in eliminating groundwater contamination and the potential for contaminant leaching from aquifer material.

Cost. The cost of aquifer mining is very high relative to other groundwater removal technologies and is directly proportional to the volume of material to be removed and the depth of excavation required. In addition, protection of workers and containment of the excavation site are significant factors that would influence the cost.

2.7.4 Lixiviant Extraction for Groundwater Saturated Sediments

Applicability. Inorganic contamination in groundwater saturated sediments.

General Description. Lixiviant extraction is a combination in situ/ex situ treatment method. Lixiviant extraction involves injection of chemical reagents to contaminated aquifers to leach adsorbed contaminants from the sediments into the groundwater. Contaminated groundwater containing the leached constituents is recovered downgradient through conventional extraction wells. Recovered groundwater is subsequently treated ex situ to remove contaminants and the lixiviant solutions may then be recycled.

The lixiviant extraction process is similar to in situ leaching operations in the mining in industry where a chemical solution is allowed to percolate through the soil by gravity flow or forced injection. Lixiviants (e.g., sodium carbonate/bicarbonate) have been developed for extraction of uranium and commercial in situ uranium mines currently exist.

Implementability. Lixiviant extraction is considered an innovative technology for this application. Successful implementation of a lixiviant sediment flushing process in the 100 Area is dependent on the aquifer characteristics and the ability to recover lixiviated contaminants. Also, considerable R&D would be required to develop suitable lixiviants for many of the Hanford contaminants. Soil and groundwater characteristics must be conducive

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to injection and extraction of flushing solutions. Lixiviant extraction is considered difficult to implement due to the need for injecting flushing agents and the potential for mobilization of contamination in groundwater system.

Effectiveness. The effectiveness of lixiviant extraction depends on the aquifer characteristics, the ability to recover the contaminated groundwater, and the development of suitable chemical reagents. Difficulties involved with lixiviant extraction include limiting reactions to contaminants, monitoring and controlling progress, directing treatment through the soil, preventing soil pore plugging, and meeting current requirements for residual contaminant levels in the aquifer. R&D and treatability tests would be required to prove the effectiveness of lixiviant extraction for removing 100 Area contaminants from aquifer sediments. Thus the effectiveness of lixiviant extraction is rated as uncertain.

Cost. The large volume of contaminated sediments in the Hanford 100 Area would require multiple lixiviant extraction systems operating in parallel. The capital costs involved with lixiviant extraction are expected to be moderate in comparison with other groundwater extraction technologies. Costs associated with secondary treatment equipment for contaminated flushing solutions are also significant.

Operating costs for soil flushing are also expected to be high in comparison with other groundwater extraction technologies. Continuous operation of injection/extraction wells and continuous wastewater treatment would require frequent equipment maintenance, significant energy usage, and potentially large quantities of chemicals.

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2.8 WASTEWATER DISPOSAL

The following methods of wastewater disposal are discussed below:

- Deep-well injection
- Above-/below-ground tanks
- Evaporation ponds.

2.8.1 Deep-Well Injection

Applicability. Contaminated groundwater and treated effluent.

General Description. Deep-well injection involves the reinjection of waste water into the underlying geology for permanent disposal. This form of disposal is applicable to both treated and untreated waste waters. Waste water injection wells are constructed with the injection point in porous, permeable, saline-water-bearing rock stratum that is vertically confined by relatively impermeable beds (Freeman 1989). In general, the injection point is at a sufficient distance under the regional aquifer to minimize the potential of groundwater contamination.

Implementation. The implementability of deep-well injection for disposal of contaminated 100 Area groundwater is dependent on the local geology of the area. The geologic requirements for deep-well injection are:

- Confining layers that are sufficiently thick, extensive, and impermeable to contain the aqueous waste in isolation

- Stable regions that do not have any boreholes or other wells that may provide pathways for migration of contaminated groundwater.

Assessment of the local geology indicates that the Grand Ronde Formation would satisfy the geologic requirements for deep-well injection. This region lies within the basalt formations at approximately 3000 to 4000 feet beneath the surface of the Hanford Site. Deep-well injection of hazardous, radioactive, and mixed waste waters would require compliance with applicable regulations. Regulatory compliance would require a significant effort involving groundwater modeling, site characterization, permitting, and public acceptance. Therefore, deep-well injection is considered difficult to implement.

Effectiveness. Deep-well injection has been used for disposal of RCRA hazardous wastes (Freeman 1989). Disposal of contaminated 100 Area groundwater by deep-well injection is considered a highly effective method for isolating radioactive groundwater from uncontaminated groundwater, the surface environment, and human contact. Such isolation would allow time for decay of isotopes, such as tritium, and dilution of other contaminants.

Cost. The cost of deep-well injection is high in comparison with other groundwater disposal methods. Factors affecting the cost of deep-well injection include initial well drilling, pumping requirements, monitoring, and the process of securing disposal permits which would potentially contribute greatly to cost.

2.8.2 Above-/Below-Ground Tanks

Applicability. Contaminated groundwater and treated effluent.

General Description. Above- or below-grade tanks can be used for temporary storage of contaminated liquid waste. These tanks can be of single- or double-shell design depending on the containment requirements of the waste. Above-ground tanks are applicable to short-term storage, whereas below-ground tanks are more applicable to long-term storage. Tank storage can be used to allow natural attenuation of relatively short-lived contaminants or to provide temporary storage in anticipation of future treatment.

Implementation. Above- and below-ground tanks are currently used at Hanford for storage of high-level liquid wastes. The technology and resources for implementing liquid waste storage in above- and below-ground tanks are readily available. This method of storage and disposal is considered moderately implementable at the Hanford 100 Area.

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Effectiveness. Past history indicates difficulty in maintaining the integrity of tanks. The total volume of contaminated groundwater present in the Hanford 100 Area is estimated at 4.8 billion gallons (1 pore volume). Effectively containing this volume in above- and below-ground tanks for long periods of time is improbable.

Cost. The cost of waste water tank storage is very high in comparison with other disposal technologies. Underground tanks would require additional excavation and are more expensive to install than above-ground tanks. Operating costs are low and consist primarily of continuous monitoring to ensure containment integrity. Periodic maintenance would be required depending on the period of storage.

2.8.3 Evaporation Ponds (Evaporation: Passive)

Applicability. Nonvolatile inorganically and organically contaminated groundwater, effluents from other treatment processes.

General Description. Evaporation ponds refer to the disposal of wastewater by solar evaporation. This process is identical to passive evaporation which is described below. Passive evaporation is a physical treatment for volume reduction of groundwater. The process involves vaporization by solar energy to separate the volatile solvent, or water, from nonvolatile contaminants such as heavy metals, suspended solids, and radionuclides. The evaporation process reduces the volume of contaminated fluids and releases the volatile constituents as purified vapors. The contaminants are concentrated in a residue which may be solidified, dried, or calcined. Passive evaporation could be used for disposal of contaminated groundwater.

Implementability. Passive evaporation is a conventional technology. The process uses ponds to maximize the surface area of a given fluid volume and increase evaporation. Passive evaporation is best suited for small or moderate volumes of contaminated water. The process is considered easily implementable at the Hanford 100 Area.

Effectiveness. Passive evaporation is an effective volume reduction technology in arid regions such as the Hanford Site. However, tritium is a contaminant in groundwater which would also evaporate with water. Such a release is not desirable and thus passive evaporation is considered not effective in protecting health and environment.

Cost. A passive evaporation system would be a low cost treatment or disposal technique. Capital, operating, and maintenance costs are low in comparison to other physical treatment or disposal options for groundwater. However, secondary treatment requirements may increase costs.

2.9 IN SITU BIOLOGICAL TREATMENT

The following methods of in situ biological treatment are discussed below:

- Enhanced groundwater bioremediation

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- Biodenitrification.

2.9.1 Enhanced Groundwater Bioremediation

Applicability. Organic contamination in groundwater.

General Description. Enhanced groundwater bioremediation is an in situ biological treatment process for destruction of organic contaminants in groundwater. The treatment may use bacteria indigenous to the particular environment or bacteria that have been cultured to degrade particular contaminants. Adding nutrients to the groundwater enhances degradation by stimulating growth of indigenous bacteria. Bacteria that are specially cultured to degrade a particular contaminant can be added to the groundwater.

Enhanced groundwater bioremediation involves circulation of a treatment fluid containing nutrients or cultured bacteria through the area of contamination. The process may be conducted under aerobic or anaerobic conditions. Aerobic processes (e.g., hydrogen peroxide providing oxygen) are preferred because processing rates are increased. The treatment fluid is injected directly into the groundwater. Residual products are then extracted for surface treatment or recirculation into the site. Circulation is continued until the site is determined to be "clean." Collection of this water can be the most difficult aspect of the treatment. Another difficulty with this technology is ensuring that the contaminated area is contained during treatment.

Implementability. Bioremediation requires a site hydrology where injection and extraction can be performed without spreading contamination or leaving residual products. Due to the high permeability of Hanford 100 Area aquifers, circulation of the treatment fluid without mobilizing contamination would be difficult. Enhanced groundwater bioremediation treatability tests would be required to ensure process control and containment of inorganic and radioactive contaminants.

Effectiveness. Although enhanced groundwater bioremediation is a developed remediation technology, the process is complex and variables such as bacterial concentration, temperature, pH, nutrient concentration, and oxygen availability must be controlled. Enhanced groundwater bioremediation would be considered moderately effective if the process variables listed above can be maintained within acceptable tolerances.

Cost. The cost of enhanced groundwater bioremediation is high relative to other in situ organic contaminant treatment processes. The capital costs include an extensive injection/extraction well system and treatment fluid storage tanks. Operating costs include utilities, secondary waste treatment, and process materials such as nutrients, bacteria cultures, and hydrogen peroxide.

2.9.2 Biodenitrification

Applicability. Nitrate contamination in groundwater, soils, and riverbank sediments

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General Description. Biological denitrification is an anaerobic process where microbial metabolic action reduces nitrates to nitrogen gas. Bacteria use nitrate anions as a source of oxygen for metabolizing organic materials. Denitrification occurs as bacteria consume carbon (food source) supplied by organic material present in the contaminated media or waste stream or by introduction of compounds such as methanol or acetic acid.

Implementability. In situ and ex situ biological denitrification are developed technologies. Hydrocarbon contamination plumes have been biologically degraded under denitrifying conditions in groundwater (Hutchins and Wilson 1991; Mikesell et al., 1991). Tests of an ex situ denitrification process have been conducted at the Hanford Site where concentrations of nitrate were reduced from approximately 400 milligrams per liter to less than one milligram per liter (Brouns et al., 1991). Based on the results of these tests, an in situ process for treating contaminated groundwater is being developed (Brouns et al., 1991). In situ and ex situ biological denitrification processes are considered moderately implementable based on previous success.

Effectiveness. Results of the Hanford ex situ denitrification tests show that nitrate concentrations are reduced to levels that are within acceptable drinking water standards (Brouns et al., 1991). Factors influencing the effectiveness of denitrification include organic carbon availability, presence of dissolved solids, and concentration of nitrates. The organic carbon source is critical to the effectiveness of nitrogen removal. Typically, the ratio of organic carbon to nitrogen is maintained at 1.3 to 1. High levels of dissolved solids inhibit the biodenitrification process. The rate at which denitrification occurs is inversely proportional to the concentration of nitrates in the waste stream. In situ and ex situ biological denitrification processes are considered highly effective based on test results and previous remediation experience.

Cost. The large volume of nitrate contaminated groundwater in the Hanford 100 Area may require parallel operation of multiple ex situ denitrification systems. The capital costs for ex situ biodenitrification are expected to be high in comparison with other ex situ biological groundwater and soil treatment technologies. The capital costs for in situ biodenitrification are expected to be moderate in comparison with other in situ groundwater and soil treatment technologies.

Operating costs for ex situ biodenitrification are expected to be high in comparison with other groundwater and soil treatment technologies. Primary operating costs are incurred for nutrients, organic carbon additives, and maintenance. Operating costs for in situ denitrification are expected to be moderate in comparison with other in situ groundwater and soil treatment technologies. The primary operating costs for in situ denitrification result from injection of nutrients, organic carbon sources, and monitoring.

2.10 IN SITU PHYSICAL TREATMENT

The following in situ physical treatment methods are discussed below:

- Air stripping

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- Permeable treatment beds
- Vapor extraction
- Electro-kinetic separation.

2.10.1 Air Stripping

Applicability. VOC contaminated groundwater.

General Description. In situ air stripping is a variation of conventional air stripping which occurs in a tray or packed tower. The mass transfer operation from liquid to gas occurs in a subsurface trench excavated to a level below the water table or in a horizontal well containing a perforated pipe or tube backfilled with gravel. The gravel allows groundwater to percolate to the perforated pipe making contact with air bubbles that strip VOCs from solution. The VOCs and air migrate to the surface where they are vented to the atmosphere.

Implementability. The implementability of in situ air stripping technology is limited by three factors; the variation in depth of excavation to groundwater at the Hanford 100 Area; the potential for organic material adsorption in vadose zone soils; and the acceptability of venting VOCs to the atmosphere. Engineering design can overcome problems associated with depth. The technology is considered moderately implementable due to potential regulatory impacts on venting to the atmosphere.

Effectiveness. In situ air stripping is considered highly effective for removal of VOCs from groundwater. The effectiveness of the technology is complicated by the depth to groundwater. Compressors must be sized to overcome both the groundwater head and friction loss as air moves through the soil to the surface. The primary soil characteristic influencing the effectiveness of in situ air stripping is gas permeability. A gas permeability differential (i.e., clay barrier) above the air injection zone can reduce the effectiveness of this technique by causing lateral instead of vertical migration of contaminants (Angell 1992). The depth to groundwater is also a concern due to the decreasing control of air migration in the soil with increasing depth to groundwater. However, the actual effects of soil characteristics and depth to groundwater will be site-specific and requires treatability testing to define.

Cost. Cost for in situ air stripping is considered to be moderate relative to other in situ physical treatments for groundwater.

2.10.2 Permeable Treatment Beds

Applicable Media. Contaminated groundwater.

General Description. A permeable treatment bed is constructed by excavating a trench to a natural confining layer such as bedrock. The trench is then backfilled with a porous treatment media that intercepts contaminants in the groundwater. Examples of treatment media selected may include activated carbon for organic contamination, limestone, or sodium carbonate which alters the solubility of contaminants such as heavy metals and

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radionuclides. The permeable treatment bed is placed downgradient of contamination and adsorbs contaminants as the groundwater flows through the treatment media.

Implementability. Permeable treatment beds are most applicable where contaminated groundwater is shallow and contaminant concentrations are low. Implementability is difficult at the Hanford 100 Area because the large quantity of contamination would require treatment media replacement and the treatment media must adsorb, or form complexes with, a large range of contaminants.

Effectiveness. Effectiveness of this technology is limited due to the need for contaminant specific media. Precipitation of insoluble contaminant salts may also cause loss of the engineered permeability of the bed which could limit the effectiveness of this treatment.

Cost. This treatment has the potential of being very expensive due to the need for large quantities of treatment materials, extensive excavation, and removal of spent material. Based on this, the cost of using permeable treatment beds is considered high relative to other in situ physical groundwater treatment options.

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2.10.3 Vapor Extraction

Applicability. VOC contaminated groundwater, soils, and riverbank sediments.

General Description. Vapor extraction is an in situ treatment option for remediation of VOC contamination. A vacuum drawn on the vadose zone induces vaporization of VOCs. These contaminants are then drawn to an extraction well and ultimately to secondary treatment such as venting, carbon adsorption, or incineration (Kent et al., 1990). Refer to sections on steam stripping and air stripping (also in situ air stripping) for variations of this technology. The technology may also be applied on an ex situ basis to remove contaminants from containerized waste.

Implementability. Vapor extraction is considered a conventional technology with broad application. The technology has been successfully applied as an interim action for remediation of the carbon tetrachloride plume in the 200 Area of Hanford. The extraction process may be adapted to a wide range of site conditions at the Hanford 100 Area operable units where VOC contamination requires remediation. The technology is considered easily implementable.

Effectiveness. The physical properties of the contaminants that influence the effectiveness of vapor extraction include vapor pressure, vapor density, liquid specific gravity, vadose zone permeability, and contaminant solubility in water. The thickness of the contaminated zone could influence the success of vapor extraction as the effectiveness of the vacuum is inversely proportional to the contaminated zone thickness. The effectiveness of this technology is considered moderate for groundwater in situ application and highly effective for the porous soils at the Hanford 100 Area.

Cost. The cost per cubic yard of contaminated soil remediated is generally less than for excavation technology, but the cost per pound of organics removed can be high. The capital costs for the initial system set-up should be similar to that for air stripping technology. Extraction wells are required and certain capital equipment in the form of blowers, surface piping, and secondary treatment equipment are also needed. Depth of wells is difficult to estimate without pilot testing. The costs are low relative to other in situ physical treatments for organic contamination remediation.

2.10.4 Electro-Kinetic Separation

Applicability. Organic and inorganic ion contamination in groundwater.

General Description. Electro-kinetic separation is an in situ physical treatment method of separating contaminants and/or water from saturated soils. The process induces water and contaminant flow by passing a direct current through a soil mass between positive (anodes) and negative (cathodes) electrodes (Steude and Tucker 1991). This direct current induces movement of electricity (current flow), ions (ionic drift), charged particles (electrophoresis), and water (electro-osmosis) (RAAS 1991). Remedial applications of electro-kinetics rely on ionic drift and electro-osmosis. Through the use of extraction wells, water and ionic contaminants are extracted at the anodes and anionic contaminants are extracted at the cathodes.

Implementability. Remedial applications of electro-kinetics are in the demonstration phase of development. The technology has been used for over fifty years for industrial applications such as dewatering soils and sludges, removing salts from agricultural soils, and increasing petroleum production (Stuede and Tucker 1991). This method is considered applicable to saturated soils with a hydraulic conductivity less than $1x10^{-5}$ cm/sec (RAAS 1991). The implementability of electro-kinetic separation at the Hanford 100 Area is considered to be uncertain due to the relatively high hydraulic conductivity of the unconfined aquifer (approximately 10^{-1} cm/sec).

Effectiveness. Laboratory experiments have shown that the technology effectively mobilizes certain ionic species, such as acetic acid, while being ineffective for others, such as sodium chloride (Stuede and Tucker 1991). The technology can potentially have adverse effects on soil chemistry including mineral dissolution, precipitation of secondary minerals, and an increase in soil pH (RAAS 1991). In addition, electrolysis of water would generate hydrogen gas (RAAS 1991). The effectiveness of electro-kinetic separation for treating Hanford 100 Area groundwater is uncertain due to limited application and demonstration.

Cost. In situ electro-kinetic separation requires additional processes, such as extraction wells and treatment systems, to perform groundwater remediation. Power consumption is based on contaminant concentrations and the remedial time frame. The cost of electro-kinetic separation is considered high due to additional processing and high energy requirements.

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2.11 IN SITU CHEMICAL TREATMENT

2.11.1 In Situ Chemical Precipitation

Applicability. Groundwater contaminated with heavy metals and radionuclides

General Description. In situ chemical precipitation is an innovative groundwater treatment technique. The chemical precipitation reactions discussed here include any technique which results in the production of insoluble precipitates by processes such as chemical reduction and pH modification. Soluble contaminants such as heavy metals (in particular hexavalent chromium) and possibly radionuclides may be treated in situ (Thornton et al, 1991). Reagents are used which react with the metals to form relatively immobile precipitates. The reagents have been used commercially to treat plating wastes ex situ and include sodium sulfide and ferrous sulfate in a near neutral pH base. This combination of reagents has been used successfully at Tinker Air Force Base, Oklahoma (Beller et al., 1989) to treat plating shop waste. Such an approach extrapolated for in situ application is considered as an innovative process option.

A series of injection wells would be required to introduce the reagent(s) into the groundwater in such a manner that the reagents become well mixed within the contaminated plume.

Implementability. Implementability of this process option would be difficult with regard to achieving adequate mixing of the reagents in situ. In situ injection and flow are primarily plug flow processes and as such mixing would be difficult to achieve. Adequate mixing would likely have to be accomplished by a recirculating extraction/injection scheme. However, this poses difficulty of reinjecting water containing precipitates, i.e., aquifer plugging problems may occur. Further development and testing are required to prove the viability of the technique for in situ application.

Effectiveness. The approach described above has been validated by actual application to plating shop wastes containing heavy metals such as hexavalent chromium, cadmium, copper, and nickel (Beller et al., 1989). The effectiveness of this approach for treatment of groundwater contaminated with both heavy metals and radionuclides is uncertain at this time due to the lack of specific in situ data. However, if it could be demonstrated viable, the technical and cost benefits relative to conventional pump and treat approaches are potentially very large. Therefore, in accordance with CERCLA FS guidelines regarding consideration of innovative technologies, this approach is retained for further consideration in the FS process.

Cost. The cost of this in situ treatment option using the sodium sulfide/ferrous sulfate reagent is considered to be low relative to similar ex situ techniques (refer to chemical reduction in Section 2.14.5) due to elimination of the need for a groundwater treatment plant.

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2.12 BIOLOGICAL TREATMENT

The following biological treatment methods are discussed below:

- Bioreactors
- Biodenitrification
- Biosorption.

2.12.1 Bioreactors

Applicability. Organically contamination in soils, riverbank sediments, and groundwater.

General Description. Bioreactor technology refers to ex situ degradation of organic contaminants by microbial metabolic processes. Bioreactors used for processing solids are mixing vessels that blend cultured bacteria, nutrients, oxygen (if reactor conditions are aerobic), and contaminated waste under controlled temperature, pH, and moisture conditions. Aqueous waste bioreactors consist of reactor vessels containing an active bacteria population in suspension. Studies using porous materials have been conducted; the bacteria adhere to the porous materials thereby increasing their activity and available surface area. As the contaminated water flows through the reactor, contaminants are consumed by bacteria. Effluent from bioreactors may be discharged or removed for additional treatment.

Bioreactors enhance degradation by increasing the availability of contaminants and nutrients to bacteria. Bioreactors maximize the rate at which bacteria can degrade organic contaminants.

Implementability. Bioreactor technology is developed and commercially available for remediation of organic contamination in the wastewater treatment industry (Busch 1971). Bioreactors may be used to treat groundwater, soils, and riverbank sediments; however, residence time in reactors may be long. Bioreactor technology is considered moderately implementable for treatment of Hanford 100 Area groundwater, soils, and riverbank sediments.

Effectiveness. Bioreactors are highly effective in treating organic contaminants including halogenated materials, aromatics, and PCBs. Different types of soils (e.g. sand, loam, clay) may be remediated in bioreactors. In addition, bioreactors may also be used to treat fines, providing an advantage over other treatments such as soil washing.

The effectiveness of this technology is determined by the efficiency of mixing components (bacteria, contaminants, and nutrients) and control of process variables (e.g. temperature, pH, moisture content) (Bhattacharya 1992). Bioreactors are considered to be highly effective for treatment of organically contaminated Hanford 100 Area soils, riverbank sediments, and groundwater.

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Cost. The cost of implementing bioreactor technology is considered high in comparison to other ex situ biological treatment techniques. The number of reactors required would depend on the number of different waste streams to be treated and the process rate of each waste stream. Maintenance and operating costs are high and consist of utility and monitoring requirements.

2.12.2 Biodenitrification

Refer to "biodenitrification" under In Situ Biological Treatment, discussed in Section 2.9.2.

2.12.3 Biosorption

Applicability. Heavy metal ionic contamination in groundwater.

General Description. Biosorption is an ex situ biological treatment process for the removal of heavy metals from aqueous waste streams. The process is based on the natural affinity of microorganisms, such as algae cells, for heavy metal ions (EPA 1990c). The system functions on the same principle as ion exchange, except that the ion exchange resin is composed of algae-silica material. As with typical ion exchange resins, the biological exchange resin can be recycled (EPA 1990c). In contrast to present ion exchange technology, hard water constituents and monovalent cations do not significantly reduce the efficiency of binding heavy metal ions to the algae-silica material (EPA 1990c).

The process is generally applicable to removal of metallic ions from aqueous waste streams that are "hard" or contain high concentrations of solids in solution. Specifically, the process can remove heavy metals such as aluminum, cadmium, chromium, cobalt, copper, gold, iron, lead, manganese, mercury, molybdenum, nickel, platinum, silver, uranium, vanadium, and zinc (EPA 1990c).

Implementability. Biosorption is an innovative treatment, but process treatment systems are commercially available (EPA 1990c). Mobile and stationary treatment equipment has been designed and manufactured with treatment capacities ranging from 1 to 100 gallons per minute (gpm). Implementability of biosorption for treatment of Hanford 100 Area groundwater is considered difficult due to the limited operating history and low demonstrated capacity.

Effectiveness. Biosorption technology is relatively new and performance information is limited. The process has been successfully tested for remediation of mercury contaminated groundwater (EPA 1990c). Treatability tests would be required to establish the effectiveness of this process in removing heavy metal ions from Hanford 100 Area groundwater.

Cost. The cost of biosorption treatment of Hanford 100 Area groundwater is expected to be moderate in comparison with other biological treatment technologies. The capital cost for such a treatment system is expected to be moderate; however, operating and

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maintenance costs are expected to be high due to the unproven status of the technology. Spent biological exchange resins would require additional treatment that would increase the cost of this treatment technology.

2.13 PHYSICAL TREATMENT

The following methods of physical treatment are discussed below:

- Ion exchange
- Evaporation: Passive
- Media filtration
- Flocculation
- Carbon adsorption
- Air stripping
- Reverse osmosis
- Ultrafiltration
- Electrodialysis
- Dissolved air flotation
- Sedimentation
- Steam stripping
- Evaporation: Forced
- Freeze crystallization
- Supported liquid membrane.

2.13.1 Ion Exchange

Applicability. Inorganic contamination, such as heavy metals and radionuclides, in groundwater.

General Description. The ion exchange process binds ionic contaminants in exchange for mobile ions of similar charge that are contained on organic resin beads or powders, such as polystyrene, or on inorganic materials, such as zeolites. Both anions (e.g., nitrate) and cations (e.g., heavy metals, radionuclides) can be removed from solution by use of appropriate ion exchange media. The process involves pumping the contaminated solution through vessels containing ion exchange resins. Configurations and combinations of ion exchangers containing either cation or anion resins (or mixes) may be specified to operate either in series or parallel based on the volume of contaminated water to be treated. Resins are chemically regenerated using concentrated salt or acid solutions which result in a secondary waste requiring treatment.

Implementability. Ion exchange is commercially available and proven for radioactive wastewater treatment (RAAS 1991). The technology is used extensively at the Hanford Site for radionuclide separation in nuclear material processing operations. Pretreatment of the waste stream might be necessary to remove materials such as oils, suspensions, colloids, and bacteria (Moghissi et al., 1986). Thus, for aqueous waste streams with many contaminants such as those present at the Hanford 100 Area, ion exchange is

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considered easily implementable as a unit operation in wastewater and groundwater treatment systems.

Effectiveness. Ion exchange is highly effective for removal of low concentrations of ionic species (up to approximately 2,500 ppm) (RAAS 1991). Contaminants such as iron and manganese can precipitate and foul the resin beds. Based on the information reported in Section 2.0 of this report (Table B-1), ion exchange technology is considered to be a highly effective unit operation in groundwater and wastewater treatment systems.

Cost. Cost of ion exchange is considered to be high relative to other physical treatment technologies applicable to groundwater. Cost is influenced by the exchange media required, the regeneration process required for the exchange media, as well as the volume and condition of the stream requiring treatment. The key drawback of ion exchange is the large quantity of waste from the regeneration process that would require additional treatment for volume reduction and disposal. If the regeneration process is not used high costs associated with disposal and replacement are incurred.

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2.13.2 Evaporation: Passive

Refer to "Evaporation Ponds" under Wastewater Disposal, discussed in Section 2.8.3.

2.13.3 Media Filtration

Applicability. Suspended solids in groundwater.

General Description. Media filtration removes solids from suspension by using media, such as diatomaceous earth, to prevent clogging of porous filtration membranes by fine particulates and suspended solids. Filtration is a common pretreatment step for most other technologies such as ion exchange, membrane separation processes (e.g., reverse osmosis, ultrafiltration), and carbon adsorption (EPA 1987). Media filtration may also be used to dewater slurry or sludge byproducts from processes such as evaporation.

Implementability. Media filtration is commonly used in water treatment plants for solids removal. This technology is considered easily implementable as either a pretreatment operation or a concentration process.

Effectiveness. Media filtration is a highly effective method for removal of solids from a liquid. The technology has broad application in a range of wastewater treatment systems.

Cost. The cost of implementing this technology is low relative to other wastewater treatment technologies. Media filtration is neither maintenance nor labor intensive.

2.13.4 Flocculation

Applicability. Inorganic contamination, such as heavy metals and radionuclides, in groundwater.

General Description. Flocculation is a physical process where inorganic contaminants are coagulated by the addition of chemicals such as ferric chloride, aluminum sulfate, and high molecular weight polymers into particles large enough to facilitate removal (Freeman 1989). Flocculation is effective in removing suspended solids and has been used at LANL as a unit operation for concentration of alpha-emitting radionuclides (DOE 1990f). The process may be used in conjunction with other technologies such as precipitation and filtration. Residue from this process requires secondary sludge treatment to reduce volume and eliminate liquids for disposal.

Implementability. Flocculation systems are commonly used in the wastewater treatment industry and have been installed for treatment of radioactive wastewater. The process is moderately implementable due to the need for additional treatment processes and significant characterization of the waste stream.

Effectiveness. Flocculation is considered to be a moderately effective technology for use as a unit operation in a Hanford 100 Area groundwater treatment system. The process is typically used in conjunction with other processes as noted above.

Cost. The cost of this process is moderate relative to other physical treatment technologies for groundwater due to the need for coagulating reagents. Treatability tests would be required to determine types and dosages of flocculants, and both of these factors directly influence cost.

2.13.5 Carbon Adsorption

Applicability. Organic contamination in groundwater and VOC contaminated vapors.

General Description. Carbon adsorption is a treatment process used to remove organic contamination from aqueous wastes and extracted vapors. Activated carbon (processed to increase surface to volume ratio) possesses a natural affinity for adsorbing organic constituents (EPA 1987). The activated carbon is "spent" when its adsorptive capacity is depleted and can be regenerated or replaced. The process equipment consists of granular activated carbon beds housed in cylindrical columns or disposable canisters. The contaminated gas or liquid is fed through the media allowing adequate residence time to strip contaminants (Corbitt 1990).

Implementability. Carbon adsorption is commercially available and is easily implementable for organically contaminated groundwater and secondary gaseous effluent from vapor extraction or air-stripping processes. The process could be implemented at the Hanford Site 100 Area as a treatment for dissolved product in groundwater and as a secondary treatment step for vapor extraction.

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Effectiveness. Literature indicates that the process is best applied to VOCs and organic contaminants with the following physical properties: high boiling point, low solubility, and low polarity (EPA 1987). Contaminants in the Hanford 100 Area media that meet these characteristics include VOCs in soil and groundwater, and non-volatiles such as tetrahydofuran. Overall carbon adsorption is considered moderately effective for removing organic contaminants of concern at the Hanford 100 Area.

Cost. The capital cost of carbon adsorption is considered moderate relative to other physical treatments options. A significant factor that influences cost is the regeneration of spent carbon that requires steam-stripping and secondary treatment of contaminants. Activated carbon replacement costs are incurred if regeneration is not feasible. These costs are high and include disposal of the spent carbon. Overall, the cost of carbon adsorption for treatment of Hanford 100 Area groundwater is considered moderate relative to other physical treatment options.

2.13.6 Air Stripping

Applicability. VOC contamination in groundwater

General Description. Air stripping is a technique used to remove VOCs from water by transferring the contaminants to an air stream. A stripping tower consists of a cylindrical shell filled with either packing material or a series of perforated plates which promote contact between the air and water streams and enhance the mass transfer of VOCs. The waste stream flow is directed downward from the top of the tower, counter-current to the air flow. The dissolved compounds diffuse out of the water into the air and exit from the top of the tower. Depending on air emission requirements, the air leaving the system may need to be treated with carbon adsorption or thermal treatment units.

Implementability. Air stripping is considered an easily implementable, conventional technology. The process is well understood and has been implemented at many remediation sites. Implementation of air stripping at the 100 Area would be suited to several of the operable units where VOCs are contaminants of concern.

Effectiveness. Air stripping is highly effective for VOCs that have low water solubility and high vapor pressure, but has limited effectiveness for other hydrocarbons. Factors affecting design include: flow rate, contaminant versus effluent concentration stripping ratio, contaminant type, and concentration. The extent of secondary treatment processes required for the system would be dependent on water and air emission standards.

Cost. The cost of air stripping is influenced by the need for secondary treatment of effluents to meet emission requirements. Costs for the secondary treatment would be dependent on the replacement and handling of carbon units or costs for a thermal treatment unit. Capital and operating costs of the stripping unit are expected to be low. Many manufacturers produce the equipment in modular components for easy transport and assembly. Minor costs would be experienced in maintaining the packing material through

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acid cleaning or replacement. Operating costs of the unit consist primarily of power costs for the air blower.

2.13.7 Reverse Osmosis

Applicability. Low concentrations of inorganic contamination in groundwater and wastewater streams.

General Description. The reverse osmosis process is the application of high pressure to a concentrated solution, thereby forcing solvent (water) through a semipermeable membrane (EPA 1987) that filters contaminants from the waste stream. This separation process is used to remove all suspended solids and most dissolved minerals in the solution (Moghissi et al., 1986).

Implementability. The technique is commercially available and implementable as a unit operation in a Hanford 100 Area groundwater treatment system. The technology has been applied in the nuclear power industry as a pretreatment step prior to evaporation and solidification and could be used to concentrate Hanford 100 Area groundwater contaminants. The process is moderately implementable due to the need for secondary treatment of both concentrates and effluent.

Effectiveness. Reverse osmosis is a highly effective process for heavy metal and mineral concentrations. The membrane can be fouled by some suspended solids or organics and certain low solubility salts. Pretreatment would be required in such instances to effectively operate this technology. The reverse osmosis concentrate, and potentially the effluent, would require solidification prior to disposal.

Cost. The cost of reverse osmosis is considered high relative to other physical treatment technologies for aqueous waste. Costs are determined by factors such as secondary treatment of concentrate effluent (e.g., solidification, drying/calcination, vitrification), down time associated with membrane fouling, and system capacity requirements.

2.13.8 Ultrafiltration

Applicability. Contaminated groundwater (high molecular weight contaminants, greater than 100 grams/mole), and effluent from other treatment processes.

General Description. The ultrafiltration process is similar to reverse osmosis where contaminated aqueous waste is forced through a membrane under pressure, trapping colloids, suspended solids (Moghissi et al., 1986), and high molecular weight organic molecules. In contrast to reverse osmosis, this process uses a lower operating pressure and a more porous membrane, and is therefore less sensitive to fouling.

Implementability. The ultrafiltration process is commercially available and implementable for aqueous waste streams as described above. Like reverse osmosis, the

process is moderately implementable due to the need for secondary treatment of both concentrates and effluent.

Effectiveness. Ultrafiltration is more effective than reverse osmosis for the removal of colloids, suspended solids, and high molecular weight organic contaminants. Ultrafiltration would not capture soluble species with molecular weights less than 100 grams/mole, thus the effluent would still contain contaminants such as cobalt-60, nitrates, and strontium-90.

Cost. The cost of ultrafiltration is high relative to other physical waste treatment technologies for groundwater, due to the need for secondary treatment for both concentrate and effluent prior to disposal.

2.13.9 Electrodialysis

Applicability. Low concentrations of inorganic contamination in groundwater.

General Description. The electrodialysis process was first used to desalinize salt water for potable purposes. Salts and minerals, in ionic form, are removed by a direct current which induces ion migration through a plastic membrane (Corbitt 1990). The electrodialysis process concentrates inorganic contaminants into a brine which may then be treated further by evaporation and solidification.

Implementability. In principle, this technique would be applicable to Hanford 100 Area groundwater as an innovative application of a conventional technology. The technique is not proven in complex systems containing radionuclides, and treatability tests would be necessary to determine whether or not the technology is applicable to Hanford 100 Area groundwater.

Effectiveness. Effectiveness of this treatment has not been determined for the types of applications expected at the Hanford 100 Area. Treatability tests would be required to determine effectiveness.

Cost. Assuming that the treatment is both implementable and effective, costs for this treatment are of the same magnitude as other membrane filtration technologies, such as reverse osmosis, although operating costs for electrodialysis are higher due to power requirements.

2.13.10 Dissolved Air Flotation

Applicability. Fine solids or suspended solids in groundwater or other wastewater streams.

General Description. Dissolved air flotation involves saturating an aqueous waste with air then introducing the waste stream into a pressure reducing vessel. The reduced pressure atmosphere forces air out of solution forming bubbles. Fine solids adhere to the

bubbles, (an action that can be enhanced with froth forming agents), rise through the solution, and are skimmed off to concentrate the contaminant fines.

Implementability. The process described above is actually a variation of a common mining process in which metals are concentrated by froth flotation. The process is readily implementable on waste streams containing entrained fine solids with densities close to that of water (EPA 1987). Dissolved air flotation has limited application to Hanford 100 Area groundwater because fines and suspended solids are not the primary contaminants. If another treatment process produces such a waste stream, dissolved air flotation would become implementable.

Effectiveness. The technology is effective, under limited circumstances, to aqueous waste streams contaminated with fines or suspended solids having densities close to that of water.

Cost. The cost of implementation is considered moderate due to the availability of this technology in the mining industry. Operating and maintenance costs are also considered low due to the capability of automating such a system.

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2.13.11 Sedimentation

Applicability. Pretreatment of groundwater or process waste streams containing large particles in suspension.

General Description. Sedimentation is a physical separation of particles entrained in a liquid by inducing settling with gravitational or inertial forces (NRC 1981). Entrained particles may include particulates, colloidal solids, and flocculent suspensions (Corbitt 1990).

Implementability. The sedimentation process is readily implementable and is commercially available. This technology has limited applicability for the primary waste streams at the Hanford Site.

Effectiveness. The sedimentation process is highly effective on waste streams containing relatively large particles. However, the effectiveness for the contaminants of concern in the waste streams, such as groundwater, at the Hanford 100 Area is limited.

Cost. The cost of sedimentation is low relative to other treatment technologies. Sedimentation requires minimal energy, labor, maintenance, and capital costs.

2.13.12 Steam Stripping

Applicability. Organic contamination in groundwater, soils, and riverbank sediments.

General Description. Steam stripping is an enhancement to air stripping (refer to previous discussion under "air stripping") where steam is used to increase the efficiency of

organic transfer from contaminated aqueous waste to a vapor phase. The liquid-vapor extraction process occurs in a conventional air stripping packed or tray column using steam instead of air as the extraction media. The contaminated liquid feed and steam travel counter-current to each other resulting in an organic rich vapor and stripped liquid effluent. The vapor may then be condensed to separate organics from water. Steam stripping may also be used to strip adsorbed organics in media such as soil.

Implementability. Steam stripping is commercially available and would be an implementable technology for Hanford 100 Area groundwater and soil contaminated with organics. Other treatments would be required in conjunction with steam stripping, such as incineration or carbon adsorption of the organic-rich vapors.

Effectiveness. Steam stripping is considered to be highly effective in the removal of all contaminants that can be treated by air stripping and in addition, can also be used to remove more soluble and less volatile contaminants.

Cost. The cost for steam stripping is much higher than air stripping due to additional energy costs associated with steam and the energy required to heat the contaminated media. As is the case with air stripping, this unit operation requires secondary treatment before residues are in a final waste form. Such additional treatment also influences the cost for this technology.

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2.13.13 Evaporation: Forced

Applicability. Nonvolatile inorganic and organic contamination in groundwater, and effluents from other treatment processes.

General Description. Forced evaporation is a volume reduction technique that results in either a sludge or a concentrated solution of nonvolatile contaminants. The process involves vaporization to separate the volatile solvent (water) from nonvolatile contaminants such as heavy metals, suspended solids, and radionuclides (Moghissi et al., 1986). Vaporization is induced by raising the temperature of the waste stream mechanically by vapor recompression or in an evaporator. Vapor may then be separated, condensed, and discharged. The sludge or concentrate can be solidified, dried, or calcined. Forced evaporation is used extensively at Hanford in radioactive waste management.

Implementability. Forced evaporation is a moderately implementable, commercially available technology that has been applied in the nuclear power industry (Moghissi et al., 1986). Forced circulation evaporators in particular have been used successfully to concentrate low purity liquid wastes with conductivity higher than 100 μmho/cm (Moghissi et al., 1986).

Effectiveness. Forced evaporation is highly effective in concentrating nonvolatile contaminants into sludges or concentrated liquors. Contaminants such as tritium, iodine, and krypton isotopes as well as volatile organics would vaporize and thus may require additional treatment or pretreatment.

Cost. The cost of forced evaporation is considered high relative to other physical treatment technologies for groundwater. Key cost factors for application of this technology include energy, materials for reactor vessels, and secondary treatment systems required for disposal of sludges and concentrated liquors.

2.13.14 Freeze Crystallization

Applicability. Dissolved inorganic and organic contamination in groundwater.

General Description. Freeze crystallization concentrates solutes such as heavy metals and partially soluble organics by selectively freezing contaminated water into pure ice crystals. The ice crystals are mechanically separated, washed, and melted to produce clean water. The remaining concentrate requires additional treatment prior to disposal (RAAS 1991). Processes such as evaporation followed by solidification for inorganics and phase separation followed by incineration for organic contamination are examples of remediation technologies used in conjunction with freeze crystallization.

Implementability. Freeze crystallization is an innovative approach for reducing the volume of contaminated groundwater. The technology has not been applied to groundwater remediation where contaminant concentrations are very dilute. Based on these considerations freeze crystallization would be difficult to implement.

Effectiveness. The process may be capable of producing up to 99.9 percent removal efficiencies from different types of waste water. The process has been tested for metal-refinishing wastes, pickle liquors, acidic and basic solutions (Freeman 1989), paper mill bleach solutions, organically contaminated wastewater (examples of contaminants: acetic acid, methanol, aromatic compounds), arsenal redwater, and ammonium nitrate wastewater. Tests on Hanford 100 Area groundwater would be required to determine the effectiveness of freeze crystallization. The technology is considered to have limited effectiveness because contaminants could remain in solution and be frozen and because of the difficulties associated with eutectic mixtures.

Cost. The implementation of the freeze crystallization process would require freezing thousands of gallons of water per minute in order to treat all the groundwater. Secondary treatments such as incineration and solidification would be required. The cost of this treatment is considered to be high relative to other groundwater treatment technologies based on energy consumption and the need for secondary treatment systems.

2.13.15 Supported Liquid Membrane

Applicability. Dissolved inorganic contamination in groundwater.

General Description. Supported liquid membrane filtration is a variation of other membrane separation processes such as reverse osmosis and ultrafiltration. A supported liquid membrane consists of a micro-porous membrane containing a carrier (an organic phase) held in place by capillary forces. Liquid membranes typically have higher diffusion

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coefficients than do solid polymer-based membranes; therefore, higher flux rates can be obtained. Carriers are used to increase membrane selectivity and currently, experimental work is in progress to design carriers for specific applications.

Implementability. Supported liquid membrane implementability is uncertain at the present stage of development. The technology has been used for desalinization and hydrogen concentration. Work on more general classes of chemicals is still in the laboratory stage. Field testing would be required to determine implementability.

Effectiveness. Due to the current level of development, the effectiveness of this process as applied to the Hanford 100 Area contaminated groundwater is uncertain. Treatability studies would be necessary to determine effectiveness.

Cost. The cost of implementing supported liquid membrane processes at the Hanford 100 Area is uncertain due to the current level of development.

2.14 CHEMICAL TREATMENT (GROUNDWATER)

The following methods of chemical treatment are discussed below:

- Chemical oxidation
- Precipitation
- Tritium treatment
- Alkali metal dechlorination
- Wet-air oxidation
- Chemical reduction.

2.14.1 Chemical Oxidation

Refer to "Solid Waste Technology Descriptions" under Chemical Treatment, discussed in Section 1.14.1.

2.14.2 Precipitation

Applicability. Inorganic contamination in groundwater.

General Description. Precipitation is an ex situ chemical treatment that reduces the solubility of inorganic contaminants by pH adjustment and chemical reaction to produce insoluble salts (EPA 1987). Such salts may then be concentrated by filtration technologies (refer to various filtration processes described previously under Physical Treatment). In general, heavy metals in ionic form, including radionuclides, are readily precipitated as either sulfides (under acidic conditions) or hydroxides (under alkaline conditions) (Corbitt 1990). Precipitation is typically used in conjunction with other treatment processes such as filtration, ion exchange, or flocculation.

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Implementability. Precipitation is a readily implementable, commercially available treatment technology for removal of certain heavy metals and radionuclides from contaminated groundwater and other secondary wastewater streams. The process is considered moderately implementable at the Hanford Site for use in aqueous waste treatment systems.

Effectiveness. Precipitation is an effective method of removing inorganic contaminants that form insoluble salts (typically as hydroxides and sulfides); however, other contaminants of concern in Hanford aqueous wastes such as tritium and isotopes of iodine do not form precipitates. Also, lixiviating (chelating and complexing) agents can interfere with the precipitation process (EPA 1987). Therefore, precipitation is considered to be moderately effective in removing inorganic contaminants from Hanford 100 Area aqueous waste streams.

Cost. The cost of precipitation is considered moderate relative to other chemical treatment technologies for groundwater due to the need for additional treatment processes. Contaminants that do not readily form precipitates would require other treatment options. Also, removal and solidification of precipitate residues would be required.

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2.14.3 Tritium Treatment

Applicability. Tritium contamination in groundwater.

General Description. A number of tritium enrichment techniques have been used in the production of thermonuclear materials. These processes have been used to enrich and concentrate tritium (Jacobs 1968). Examples include: electrolysis which involves dissolution of water resulting in gaseous hydrogen, oxygen, and a concentrate containing tritium; thermal diffusion where partial demixing of gases occurs due to a temperature gradient and tritium migrates toward the cold region; and distillation, which is based on the principle that the rate of escape of an atom from a liquid is inversely proportional to its mass.

Implementability. The volume of groundwater requiring treatment in relation to the capacity of the tritium treatment systems make these process very difficult to implement.

Effectiveness. Very dilute tritium could possibly be concentrated by the processes described above; however, sufficient enrichment of the tritium to allow unlimited general use of the groundwater is uncertain. Therefore, the effectiveness of tritium separation is judged uncertain for groundwater cleanup applications.

Cost. The groundwater macroengineering report indicates that disposal of tritium in the PUREX Plant results in costs that are three orders of magnitude greater than NRC guidelines for cost effectiveness (WHC 1991d). On this basis, tritium treatment costs are judged to be extremely high relative to all other chemical treatment processes applicable to groundwater.

2.14.4 Wet-Air Oxidation (Supercritical Water Oxidation)

Applicability. Organic contamination in groundwater.

General Description. Organic contaminants may be oxidized to produce carbon dioxide and water under conditions of elevated temperature and pressure. Two variations of this technology are wet-air oxidation and supercritical water oxidation (presented in order of increasing temperature and pressure). Operating conditions of temperatures up to 600°F and pressures up to 200 atmospheres are necessary for wet-air oxidation (Min et al., 1991). Organic contaminants may be partially oxidized to lower molecular weight compounds or completely oxidized under these conditions. Supercritical water oxidation is similar to wet-air oxidation, but uses a temperature and pressure above the critical point of water (705.5°F and 218.3 atmospheres) (RAAS 1991). Most organic compounds are completely miscible in the water fluid above the critical point, and this ensures thorough mixing for more complete oxidation.

Implementability. Both wet-air (commercially available) and supercritical water (innovative process) oxidation techniques are best used for heavily contaminated non-halogenated aqueous waste streams that ensure self-sustaining reactions. Limited information concerning organic contamination exists. Should characterization efforts indicate organic contamination is present, this technology would be difficult to implement.

Effectiveness. Supercritical water oxidation is highly effective, yielding 99.99 percent oxidation efficiency for heavily contaminated waste streams (EPA 1987). Wet-air oxidation is not as effective, but offers cost savings. The technology would not be effective for the low concentrations such as those present at the Hanford 100 Area.

Cost. Wet-air and supercritical oxidation require reactor vessels capable of withstanding elevated temperatures and pressures. The reactor must be constructed of noncorroding material to prevent degradation by chemical attack. Both processes require large amounts of energy to maintain operating conditions. Capital and operating costs are considered high relative to other chemical treatment options.

2.14.5 Chemical Reduction

Applicability. Hexavalent chromium ion contamination in groundwater.

General Description. The hexavalent chromium species chromate and dichromate are prevalent in Hanford 100 Area groundwater. Chemical reduction of hexavalent chromium results in highly insoluble trivalent chromium compounds (Thornton et al., 1991; Thornton, 1991). Reagents such as ferrous sulfate under acidic conditions have been tested successfully for hexavalent chromium reduction. The work cited above proposed chromium reduction as an in situ treatment. The work done to this point also indicates that competing reactions in the presence of Hanford soils can be expected. For this reason, and due to the innovative nature of this process, the evaluation of this technology is based on using the process ex situ for groundwater under more controlled conditions.

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Implementability. Due to its similarity to other chemical treatments, chemical reduction of hexavalent chromium is considered moderately implementable as an ex situ process, but tests would be required to ascertain effects of other chemical species in groundwater.

Effectiveness. The chemical reduction process is innovative. Significant laboratory work has resulted in identification of several potentially useful reagents and operational conditions. This technique is considered moderately effective due to limited work and the lack of a large scale demonstration.

Cost. The costs for hexavalent chromium chemical reduction are considered moderate relative to other chemical treatment technologies for groundwater, due to the need for additional treatment processes, such as removal (by filtration) and solidification of the resulting suspended solids.

2.15 SURFACE DISPOSAL

The following methods of surface disposal are discussed below:

- Surface discharge
- Columbia River
- Above-/below-ground tanks.

2.15.1 Surface Discharge

Applicability. Groundwater

General Description. Surface discharge refers to the disposal of groundwater into a soil column. Historically, contaminated aqueous wastes were disposed to the soil column which theoretically acted as an absorptive filter for organic contaminants. This past practice has resulted in extensive soil and groundwater contamination and thus precludes its application for disposal of contaminated liquids. However, surface discharge would be applicable for the disposal of treated waste waters.

Implementability. Surface discharge of treated aqueous wastes may be implementable at the Hanford 100 Area. This form of disposal has been used extensively in past waste disposal practices and is well developed. Compliance with applicable regulatory standards would be required for implementation of surface discharge disposal for treated waste water. Public and regulatory acceptance is expected to be poor if the groundwater to be discharged contains contaminants above MCLs. This method of disposal is not considered implementable because the environment is not protected.

Effectiveness. Surface discharge is not an effective method of disposal for contaminated groundwater since it does not protect the environment. Discharge of treated groundwater may be acceptable if tritium decay in such a system is acceptable.

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Cost. The cost of surface discharge is low. Excavation would be required for construction of disposal facilities such as infiltration ponds. Inoperable disposal facilities would typically be decommissioned and replaced by a new facility. Gravity operated flow systems would not require operating resources and standard pumping systems would be required on other flow systems.

2.15.2 Columbia River

Applicability. Groundwater

General Description. Discharge to the Columbia River is another disposal method applicable only to treated groundwater. Historically, this method of disposal has been used for discharge of reactor coolant water. This past practice disposal method has resulted in the spread of contamination and thus precludes its application for the disposal of contaminated liquids. However, discharge to the Columbia River would be applicable for the disposal of treated waste waters which meet regulatory discharge standards.

Implementability. Discharge to the Columbia River of treated aqueous wastes which meet regulatory standards is implementable at the Hanford 100 Area. This form of disposal has been used extensively in past waste disposal practices and is well developed. Compliance with applicable regulatory standards, such as the National Pollutant Discharge Elimination System (NPDES) under the Clean Water Act (CWA), are required for discharge of treated waste water to the Columbia River. Discharge of contaminated groundwater to the Columbia River would not be acceptable since the practice would not protect the environment.

Effectiveness. Discharge to the Columbia River would be an effective method of disposal for treated waste water. The technique has been used effectively for disposal of contaminated aqueous wastes in past waste disposal practices at the Hanford 100 Area. As noted above, the practice would not be effective for disposal of contaminated groundwater.

Cost. The cost to discharge treated waste water to the Columbia River is low. This disposal technique may require construction of outfall structures, similar to those used in past disposal practices, or installation of a pipeline to the river. In either case, implementation of such a disposal system is relatively inexpensive.

2.15.3 Above-/Below-Ground Tanks

Refer to "Above-/Below-Ground Tanks" under Wastewater Disposal, discussed in Section 2.8.2.

2.16 SUBSURFACE DISCHARGE

The following subsurface discharge methods are discussed below:

- Deep-well injection

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- Reinjection into aquifer
- Crib disposal.

2.16.1 Deep-Well Injection

Refer to "Deep-Well Injection" under Wastewater Disposal, discussed in Section 2.8.1.

2.16.2 Reinjection into Aquifer

Applicability. Groundwater

General Description. Reinjection into the aquifer refers to the disposal of treated groundwater in an aquifer, or as proposed in the groundwater macroengineering study (WHC 1991d), injection of contaminated groundwater into a 200 Area aquifer to allow natural attenuation and dilution of contaminants. In this FS, groundwater is assumed to be returned to the unconfined aquifer beneath the 100 Area using injection wells or cribs.

Implementability. Injection well technology is well developed and considered to be technically implementable. Institutional implementability would depend on adequate removal of contaminants, acceptability of natural attenuation of tritium, and in the case of untreated groundwater, the acceptability of groundwater disposal in an aquifer that may not be isolated from receptors. Institutional implementability is considered difficult based on the acceptance by regulatory agencies.

Effectiveness. Benefits of reinjection include control of the hydraulic gradient. Groundwater could be effectively isolated in another aquifer.

Cost. The cost of reinjecting into the unconfined aquifer is moderate in comparison to other groundwater disposal techniques. Injection well construction and pumping requirements are the primary capital costs. Operating costs involve utility and labor requirements for continuous operation. Periodic maintenance of injection wells and pump replacement may also be required.

2.16.3 Crib Disposal

Applicability. Treated groundwater.

General Description. Crib disposal is a subsurface liquid discharge technique which allows wastewater to percolate through the soil column to the groundwater. The particles of the soil column essentially act as filters by adsorbing contaminants. A crib is generally a large width, shallow concrete box, open at the bottom and typically filled with rocks, sand, and/or gravel. Liquid is dispersed over the large area of rocks and allowed to percolate down to groundwater.

Implementability. Crib disposal is a well developed technology that has been used at Hanford since the 1940s. Regulatory acceptance of this disposal technique is questionable; however, crib disposal at Hanford would be easily implementable based on past experience with the method.

Effectiveness. The effectiveness of crib disposal in protecting human health and the environment is dependent on the contaminant concentrations present in the treated groundwater. In general, crib disposal is considered to be highly effective for disposal of treated groundwater.

Cost. The cost of implementing crib disposal for treated groundwater is judged to be low in comparison to other subsurface discharge techniques. Construction of crib disposal facilities involves excavation, concrete construction, rock emplacement, and installation of a liquid dispersion system. Each of these activities is standard practice in the construction and earth moving industry.

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3.0 SOILS AND RIVERBANK SEDIMENTS TECHNOLOGY DESCRIPTIONS

3.1 ACCESS RESTRICTIONS

Refer to "Solid Waste Technology Descriptions" under Access Restrictions, discussed in Section 1.1.

3.2 MONITORING

Refer to "Solid Waste Technology Descriptions" under Monitoring, discussed in Section 1.2.

3.3 CAPPING

Refer to "Solid Waste Technology Descriptions" under Capping, discussed in Section 1.3.

3.4 HORIZONTAL BARRIERS

Refer to "Solid Waste Technology Descriptions" under Horizontal Barriers, discussed in Section 1.4.

3.5 VERTICAL BARRIERS

Refer to "Solid Waste Technology Descriptions" under Vertical Barriers, discussed in Section 1.5.

3.6 RUN-ON/RUNOFF CONTROL

Refer to "Solid Waste Technology Descriptions" under Run-On/Runoff Control, discussed in Section 1.6.

3.7 REMOVAL

Refer to "Solid Waste Technology Descriptions" under Removal, discussed in Section 1.7.

3.8 ON-SITE DISPOSAL

Refer to "Solid Waste Technology Descriptions" under On-Site Disposal, discussed in Section 1.8.

3.9 OFF-SITE DISPOSAL

Refer to "Solid Waste Technology Descriptions" under Off-Site Disposal, discussed in Section 1.9.

3.10 IN SITU STABILIZATION/SOLIDIFICATION

The following methods of in situ stabilization/solidification are discussed below:

- Grout injection
- Vibration-aided grout injection
- Shallow soil mixing
- Fixants
- Vitrification
- Ground freezing
- Dynamic compaction.

3.10.1 Grout Injection

Refer to "Solid Wastes Technology Descriptions" under Grout Injection, discussed in Section 1.10.1.

3.10.2 Vibration-Aided Grout Injection

Refer to "Solid Wastes Technical Descriptions" under Vibration-Aided Grout Injection, discussed in Section 1.10.2.

3.10.3 Shallow Soil Mixing

Applicability. Contaminated soils and riverbank sediments.

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General Description. Shallow soil mixing (SSM) is an in situ method of mixing soils and riverbank sediments with chemical compounds to produce a solidified mass. SSM has been designed for applications up to 30 feet deep using a crane-mounted mixing head. The mixing head blades are enclosed within a cylinder that opens to introduce soil. The cylinder is closed, solidification additives are introduced, and the mixing head blades blend the materials into a uniform mixture. The mixture is then discharged and the process is repeated at an adjacent location until the entire site is treated. Negative pressure is maintained in the mixing head cylinder to induce flow of dust and vapor into an air treatment system.

Implementability. SSM technology is considered moderately implementable at the Hanford 100 Area. The technology may prove especially useful for preparing an area for a cover (refer to "capping" descriptions in Section 1.3) or for temporary stabilization of soils prior to removal. The SSM process has been demonstrated to depths of 30 feet or more, but may require site specific pilot testing to verify actual penetration depth at the Hanford 100 Area.

Effectiveness. The SSM process may not effectively contain contamination at depths required at the Hanford 100 Area, but may be suited to shallow containment or in conjunction with other capping technologies. The potential for weathering of the exposed surfaces of the solidified mass should be considered. SSM could be used in conjunction with other technologies such as caps to effectively contain contamination.

Cost. The cost of SSM is considered high relative to other in situ stabilization technologies. SSM uses solidification compounds similar to other in situ techniques. Operational costs would be a function of the size of contaminated sites to be stabilized.

3.10.4 Fixants

Applicability. Contaminated surface soils and riverbank sediments.

General Description. Fixants are in situ treatment methods to control fugitive dust from contaminated areas. They may be applied to the surface of soils and riverbank sediments to prevent airborne contamination and to suppress dust during operations, such as excavation. Many types of resins, polymers, foams, and bituminous materials are available for use as fixants. Application of fixants is a simple process utilizing readily available equipment such as water trucks equipped with spray heads. These trucks are commonly used for highway construction projects or for large scale construction operations where dust control is required.

Implementability. Application of fixants is a common dust control method and can be accomplished with readily available construction equipment. Fixants can be applied to large areas and would be considered easily implementable at the Hanford 100 Area.

Effectiveness. Fixants are effective for short periods of time and are affected by weather conditions, amount of traffic, and vegetation growth. The use of fixants is

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considered effective for short-term applications such as dust control during excavation. The benefits of long-term contaminant control would not be satisfied and other containment methods would be required. Fixants are considered to be ineffective for the Hanford 100 Area.

Cost. The cost of using fixants is considered low relative to other technologies. The cost is dependent on the type of fixant selected with polymer fixants generally the most expensive.

3.10.5 Vitrification

Refer to "Solid Wastes Technology Descriptions" under Vitrification, discussed in Section 1.10.3.

3.10.6 Ground Freezing

Applicability. Contaminated soils and riverbank sediments.

General Description. Ground freezing is an in situ stabilization/solidification technique for contaminated soils and riverbank sediments. The process can also be employed to create a subsurface barrier in saturated soils or riverbank sediments (refer to "cryogenic barriers" discussed previously). Moisture in soils and riverbank sediments may be frozen to trap contaminants within the frozen zone. The frozen ground is significantly less permeable to infiltration and also reduces the mobility of toxic contaminants.

Implementability. Ground freezing is an innovative technology. Hanford 100 Area soils do not have sufficient moisture to stabilize contaminated areas and addition of water could potentially mobilize contaminants. Therefore, ground freezing is judged not implementable.

Effectiveness. Ground freezing for stabilization/solidification is a new application of the technology. Based on experimental work, the approach is judged to be generally ineffective for application at the Hanford 100 Area but may potentially be effective where the contamination depth is shallow. Long-term effectiveness (even for shallow contamination), however, is highly questionable and this application is judged not effective for application at the Hanford 100 Area.

Cost. Ground freezing for stabilization/solidification purposes would be very expensive. Capital costs for an extensive coolant circulation system are high. Operating costs for maintaining soils and riverbank sediments in a cryogenic state for the entire Hanford 100 Area would be moderate. The overall cost of ground freezing is judged to be high for these reasons.

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3.10.7 Dynamic Compaction

Refer to "Solid Waste Technology Descriptions" under Dynamic Compaction, discussed in Section 1.10.4.

3.11 IN SITU BIOLOGICAL TREATMENT

The following methods of in situ biological treatment are discussed below:

- Enhanced soil bioremediation
- Biodenitrification
- Land farming.

3.11.1 Enhanced Soil Bioremediation

Applicability. Organic contamination in soils and riverbank sediments.

General Description. Enhanced soil bioremediation is an in situ biological treatment process to remove organic contaminants from soils and riverbank sediments. The treatment utilizes bacteria indigenous to the soil or bacteria that have been specifically cultured to degrade particular contaminants. Nutrients added to the soil can stimulate growth of indigenous bacteria and enhanced degradation capabilities. Bacteria specially cultured to degrade a particular contaminant can be added to the soil in controlled quantities.

Enhanced soil bioremediation involves circulating water that carries nutrients or cultured bacteria through the area of contamination. This water is typically allowed to percolate into the contaminated site from the surface. Hydrogen peroxide may also be injected as an oxygen source to sustain aerobic conditions. Residual products and additives are then recovered for recirculation into the site and the process is continued until contaminant concentrations at the site satisfy cleanup goals. The applicability of the treatment would be controlled by the effective circulation of the nutrient or cultured bacteria solutions. Barriers may be used to collect the percolated water for removal by extraction wells. Otherwise, construction of infiltration trenches or subsurface drains may be required.

Implementability. Enhanced soil bioremediation is an innovative technology. The process depends on the geologic and hydrologic characteristics of the site. These characteristics must be favorable to the recirculation of nutrient or cultured bacteria solutions. Ideal conditions include highly permeable soils and a relatively shallow groundwater table.

Implementation of enhanced soil bioremediation would ultimately depend on the presence of other contaminants within the soil. Inorganic contaminants such as heavy metals and radionuclides could be leached from the soil during injection and introduced into the groundwater. Regulatory acceptance of the methodology would need to be considered. Enhanced soil bioremediation is considered difficult to implement at the Hanford 100 Area due to the potential for spreading contamination into the groundwater.

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Effectiveness. Enhanced soil bioremediation has been demonstrated for remediation of petroleum contaminated sites in California (Molnaa and Grubbs, no date). The process is complicated and requires control of parameters including bacteria stimulation or augmentation, temperature, pH, nutrient concentration, moisture content, and oxygen availability. Treatability tests would be necessary to determine the effectiveness of this treatment at the Hanford 100 Area. The method is most effective when the subsurface soils are highly permeable, the soil to be treated is within 20 to 30 feet of the surface, and the groundwater table is within 30 feet of ground surface (Molnaa and Grubbs, no date). The effectiveness of this treatment technology is uncertain due to the depths of contamination and groundwater at the Hanford 100 Area.

Cost. The cost of soil bioremediation is high relative to other in situ degradation processes for soils and riverbank sediments. The capital costs for soil bioremediation system include an extensive injection/extraction well system with pumps, filters, and solution holding tanks. Operating costs result from utility requirements, continuous monitoring, and water additives such as nutrients, bacteria, and hydrogen peroxide.

3.11.2 Biodenitrification

Refer to "Groundwater Technology Descriptions" under Biodenitrification, discussed under Section 2.9.2.

3.11.3 Land Farming

Applicability. Organic contamination in soils and riverbank sediments.

General Description. Land farming is an in situ biological treatment using bacteria to degrade organic contaminants in soils. Bacteria indigenous to the soil or specially cultured can be used depending on the soil characteristics. Nutrients added to the soil can enhance degradation by indigenous bacteria. Cultured bacteria can be added to the soil in specified quantities.

Land farming involves the aeration of soils by tilling while simultaneously adding constituents required to induce and control biodegradation. These additives may include nutrients such as nitrogen and phosphorus, bacteria (if necessary), moisture, and pH modifiers. In situ land farming is limited to shallow contamination applications.

Implementability. Land farming is an innovative technology and implementation is limited by the ability to till soils. The process involves tilling contaminated soils to incorporate additives and ensure the presence of sufficient oxygen. Thus, land farming is only applicable to shallow contamination depths. In addition, land farming in the presence of inorganic contaminants such as heavy metals and radionuclides could potentially spread contamination to the groundwater or surface environment. Land farming is not considered implementable at the Hanford 100 Area due to the depth of contamination and the potential to spread contamination.

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Effectiveness. Land farming is a complicated process and requires control of parameters such as bacteria stimulation or augmentation, temperature, pH, nutrient concentration, moisture content, and oxygen availability. Treatability tests would be needed to determine effectiveness of land farming at the Hanford 100 Area. However, due to the depth of contamination and presence of heavy metals and radionuclides in soils and riverbank sediments, this treatment technology is considered ineffective.

Cost. The cost of land farming is low in comparison with other in situ biological treatment technologies. The process requires only occasional monitoring, tilling, and incorporation of additives. Land farming is neither maintenance nor labor intensive.

3.12 IN SITU CHEMICAL TREATMENT

3.12.1 Soil Flushing

Applicability. Organic and inorganic contamination in soils and riverbank sediments.

General Description. Soil flushing is an in situ treatment method similar to soil washing. Soil flushing uses extractant agents to remove contaminants from soils or riverbank sediments. Flushing agents may include water, surfactants, solvents, or detergents which dissolve contaminants physically or agents which remove contaminants chemically such as lixiviating agents, acidic/basic solutions, or reducing/oxidizing agents, whose effectiveness may be enhanced by heat.

The soil flushing process is similar to leaching operations in the mining industry where a solution is allowed to percolate through soil by gravity or forced injection. Contaminants are released from the soil and carried in the flushing solution to the groundwater. Contaminated flushing solution and groundwater are then recovered downgradient through extraction wells. Recovered wastewater is treated to separate contaminated flushing agents from clean water. Contaminated flushing agents can be treated for reuse in the process or treated for disposal while clean water may be injected back into the aquifer.

Implementability. Soil flushing is considered an innovative technology. Bench scale, pilot plant, and field tests have been conducted for removal of organic and heavy metal contaminants (Steude and Tucker 1991). Implementation of a soil flushing process at the Hanford 100 Area is dependent on the characteristics of the soil and the underlying aquifer. Soil and groundwater characteristics must be conducive to injection and extraction of flushing solutions. Soil flushing has not received widespread regulatory acceptance because of the need for injecting flushing agents and the potential for mobilization of contamination to the groundwater. The process requires that mobilized contaminants be withdrawn from the groundwater surface by extraction wells or galleries. Soil flushing is considered difficult to implement based on these factors.

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Effectiveness. The effectiveness of soil flushing depends on the characteristics of the soil and contaminants. Soil flushing is most effective for a single contaminant or multiple contaminants with similar solubility characteristics. Difficulties involved with soil flushing include limiting reactions to contaminants, monitoring and controlling progress, directing treatment through the soil, preventing soil pore plugging, and meeting current requirements for residual contaminant levels in treated soils. Treatability tests would be required to determine the effectiveness of soil flushing for removing contaminants of concern at the Hanford 100 Area. Due to the process difficulties described above, the effectiveness of soil flushing is limited.

Cost. The large volume of contaminated soils and riverbank sediments in the Hanford 100 Area may require multiple soil flushing systems operating in parallel. The capital costs involved with soil flushing are expected to be moderate in comparison with other in situ soil treatment technologies. However, costs associated with secondary treatment equipment for contaminated flushing solutions would be significant.

Operating costs for soil flushing are expected to be moderate in comparison with other in situ soil/sediment treatment technologies with the exception of flushing solution costs. Continuous operation of injection/extraction wells and continuous wastewater treatment would require frequent equipment maintenance, significant energy usage, and a large supply of flushing agents.

3.13 IN SITU PHYSICAL TREATMENT

The following methods of in situ physical treatment are discussed below:

- Vapor extraction
- Steam stripping
- Soil flushing
- RF heating
- Electrical soil heating.

3.13.1 Vapor Extraction

Refer to "Groundwater Technology Descriptions" under Vapor Extraction, discussed in Section 2.10.3.

3.13.2 Steam Stripping

Refer to "Groundwater Technology Descriptions" under Steam Stripping, discussed in Section 2.12.12.

3.13.3 Soil Flushing

Refer to "Soil Flushing" under In Situ Chemical Treatment, discussed in Section 3.12.1.

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3.13.4 RF Heating

Applicable Media. Organic contamination in soils and riverbank sediments.

General Description. Radio frequency (RF) heating is an in situ treatment process where organic compounds are volatilized by radio frequency energy transmissions to the soils or riverbank sediments. The technology is used to enhance the efficiency of contaminant removal by other technologies such as vapor extraction. The energy flux supplied by RF may be scaled from 2 to 45 megahertz depending on the application. A large energy flux is required for thermal decomposition of semi-volatile compounds, moderate energy flux to vaporize liquids, and low energy flux to provide a thermal driver for VOCs. The gases driven out of the ground are collected on the surface with a vapor barrier or collection system.

Implementability. RF heating is an innovative technology where electrodes placed horizontally on the surface above a contaminated zone transmit radio waves through the soil to contaminants. The technology is an unobtrusive method for enhancing migration of organic contaminants to the surface. Implementation of RF heating requires other technologies, such as vapor extraction, carbon adsorption, or vapor incineration, for collecting and processing the volatilized organic contaminants. RF heating is considered easy to implement at the Hanford 100 Area.

Effectiveness. This technology has not been tested for applications similar to the Hanford 100 Area. The maximum depth of radio frequency penetration that would effectively volatilize organic contaminants is unknown. Moisture in the soil increases energy flux requirements to volatilize both the moisture and contaminants. At this stage of development, no definitive statement can be made concerning the effectiveness of RF heating at the Hanford 100 Area. Treatability studies would be required to assess the effectiveness of the process. However, RF heating is considered to have limited effectiveness because of the depth of soil contamination in the 100 Area.

Cost. Cost for RF heating is considered to be high relative to other in situ physical treatment options based on high energy needs and the necessity for separate collection and treatment processes. Type of contaminants, soil moisture, and contamination depth all influence the energy requirements of the process. RF heating is not a complete treatment method and would require a collection system such as vapor extraction and a treatment system such as carbon adsorption.

3.13.5 Electrical Soil Heating

Applicability. Organic contamination in soils and riverbank sediments.

General Description. Electrical soil heating is an in situ soil treatment to extract and destroy organic contaminants. The process is under development at Battelle Pacific Northwest Laboratory (Stuede and Tucker 1991). The process occurs in two phases: soils are first heated to remove moisture and volatilize organic contaminants; then the organic

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compounds are decomposed by reaction with superoxide radicals and ozone (created by an air-ion system). Surface containment and subsurface vapor control are provided by an above grade off-gas system.

Implementation. Electric soil heating is an innovative treatment process which has been laboratory and bench-scale tested, with pilot-scale tests planned for 1992 (Stuede and Tucker 1991). Bench-scale tests were performed using sands, clays, and loams, with moisture contents ranging from 10 to 55 weight percent (Steude and Tucker 1991). Hanford 100 Area soils are mostly sand and cobbles with approximately 10 percent moisture by weight. The results of these tests suggest electrical soil heating may be applicable to Hanford 100 Area soils; however, treatability tests would be required to determine implementability. The process is considered to be difficult to implement due to limited operational experience.

Effectiveness. Laboratory and bench-scale tests have shown electrical soil heating to be effective in removing and destroying organic contaminants such as trichloroethane in sand. The maximum depth of contamination at which electric soil heating can be effectively applied is unknown. Because of the limited operational experience, treatability tests would be necessary to establish the effectiveness of the process. The technology is judged to have limited effectiveness due to the depth of contamination in soils at the Hanford 100 Area.

Cost. Electrical soil heating systems require high capital output for power generators (50-KW represents pilot-scale), off-gas collection systems, and off-gas treatment systems. The operating costs are very high due to energy consumption requirements. Overall, electrical soil heating is considered to be a very high cost process option in comparison to other in situ physical treatment methods.

3.14 THERMAL TREATMENT

Refer to "Solid Waste Technology Descriptions" under Thermal Treatment, discussed in Section 1.11.

3.15 STABILIZATION/SOLIDIFICATION

Refer to "Solid Waste Technology Descriptions" under Stabilization/Solidification, discussed in Section 1.12.

3.16 PHYSICAL TREATMENT

The following methods of physical treatment are discussed below:

- Vapor extraction
- Soil washing
- Steam stripping.

3.16.1 Vapor Extraction

Refer to "Groundwater Technology Descriptions" under Vapor Extraction, discussed in Section 2.10.3.

3.16.2 Soil Washing

Applicability. Organic and inorganic contamination in soils and riverbank sediments.

General Description. Soil washing is an ex situ treatment process that involves the removal of contaminants from soils or riverbank sediments using combinations of classification, mechanical scouring, and cleaning agents such as water, surfactants, and detergents (EPA 1990c; RAAS 1991). The soil washing process is most effective when contamination is concentrated in the fine fraction of soils. The fine fraction is separated for secondary treatment or disposal while coarse materials are washed. The coarse fraction may be rinsed, monitored for residual contamination, and returned to the site or recirculated through the washing process. Contaminated soil fines may be separated from the cleaning solution and treated for disposal by processes such as solidification or vitrification. The contaminated cleaning solution may be treated for reuse in the process or treated for disposal using processes such as ion exchange or precipitation. Physical washing of soil would use water only. Physical soil washing may be enhanced chemically using lixiviants, acidic/basic solutions, or reducing/oxidizing agents which promote dissolution of adsorbed contaminants. If chemicals are used the process is referred to as chemical soil washing.

Implementability. Soil washing is considered an innovative technology. Soil washing systems are currently being developed and tested for removal of organic and heavy metal contaminants (EPA 1989a; EPA 1990c). A smaller fraction of fines would remain for disposal or secondary treatment. A soil washing process at the Hanford 100 Area is considered moderately implementable but subject to treatability tests.

Effectiveness. The effectiveness of soil washing is dependent on the characteristics of the soil and contaminants. Radionuclides, organics, heavy metals, and inorganic ion contamination may be found in the Hanford 100 Area soils. Treatability tests would be required to determine the effectiveness of soil washing for removal of the contaminants of concern. The buffering capacity of soils can reduce the effectiveness of chemical soil washing. Limited information on Hanford soils indicates a fairly high buffering capacity. Although chemicals can be added to overcome this buffering capacity, the effectiveness of the process is considered uncertain in the absence of treatability test results.

Cost. The large volume of contaminated soils and riverbank sediments at the Hanford 100 Area may require multiple soil washing units operating in parallel. Soil washing system capacities range from 6 to 40 tons of soil per hour (RAAS 1991). The capital costs involved with soil washing are expected to be moderate in comparison with other ex situ soil treatment technologies. However, additional treatment equipment for contaminated cleaning solutions may significantly increase system costs.

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Operating costs for soil washing are expected to be moderate to high in comparison with other ex situ soil treatment technologies. The large scale equipment required for this process would be automated and therefore require a smaller labor force. The majority of operating costs would result from utility requirements and replenishment of cleaning agents. Maintenance costs would be a function of the operating requirements and life expectancy of the system as well as the corrosivity of the contaminants and cleaning agents.

3.16.3 Steam Stripping

Refer to "Groundwater Technology Descriptions" under Steam Stripping, discussed in Section 2.12.12.

3.17 CHEMICAL TREATMENT

The following methods of chemical treatment are discussed below:

- Chemical oxidation
- Soil washing
- Alkali metal dechlorination.

3.17.1 Chemical Oxidation

Refer to "Solid Waste Technology Descriptions" under Chemical Oxidation, discussed in Section 1.14.1.

3.17.2 Soil Washing

Refer to "Soil Washing" under Physical Treatment, discussed in Section 3.16.2.

3.17.3 Alkali Metal Dechlorination

Applicability. Halogenated contaminants in soils and riverbank sediments.

General Description. Chemical dechlorination strips chlorine from organic compounds by reaction with alkali metals or in the presence of a catalyst. Alkali metals possess great affinity for chlorine or any halide. A new dechlorination reagent is referred to as alkali metal/polyethylene glycols (A/PEG). A/PEG reacts rapidly to dehalogenate compounds.

Catalysts may also be used under ambient conditions to substitute hydrogen for chlorine but the process does not completely dechlorinate most organic chemicals. Catalysts include nickel chloride in alcohol and platinum-based catalysts. Catalytic processes occur at elevated temperatures and pressures (up to 375°C and 50 atmospheres).

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Implementability. The technology for alkali metal dechlorination is commercially available for small applications. The technology is innovative and is considered moderately implementable for soils and riverbank sediments.

Effectiveness. Dechlorination with an alkali metal is considered an effective method for dehalogenating organic materials. The effectiveness is limited because most reagents are reactive with water.

Cost. The costs associated with this technology are high due to safety and packaging requirements. Capital costs for equipment and operating costs for reagents and safety considerations are high.

3.18 BIOLOGICAL TREATMENT

The following methods of biological treatment are discussed below:

- Bioreactors
- Land treatment
- Biodenitrification.

3.18.1 Bioreactors

Refer to "Groundwater Technology Descriptions" under Bioreactors, discussed in Section 2.11.1.

3.18.2 Land Treatment

Applicability. Organic contamination in soils and riverbank sediments.

General Description. Land treatment is an ex situ biological treatment of organic contaminants in soils. The treatment involves the use of bacteria to degrade organic contaminants. Bacteria indigenous to the soil or specially cultured bacteria can be used depending on the soil characteristics. Added soil nutrients promote the growth of indigenous bacteria which enhances degradation. Cultured bacteria can be added to the soil in specified quantities.

Land treatment involves excavating contaminated soils and placing the soil on a lined treatment cell. This technique allows better control of treatment parameters such as depth of soil and exposed surface area, temperature, nutrient concentration, moisture content, and oxygen availability. The liner provides a barrier to contaminant migration, thereby protecting the groundwater.

Implementability. Land treatment is an innovative technology that has been demonstrated for remediation of petroleum contaminated sites (Molnaa and Grubbs, no date). Implementability of land treatment for degradation of organic contaminants is based on the depth of contamination and available space; the depth of contamination must be compatible

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with standard excavation practices and sufficient space must be available for placement on the lined cell. Land treatment is considered moderately implementable at the Hanford 100 Area due to the availability of excavation techniques and treatment space.

Effectiveness. Land treatment is a complicated process that requires control of parameters such as bacteria stimulation or augmentation, temperature, pH, nutrient concentration, moisture content, and oxygen availability. Treatability studies to determine effectiveness of land farming at the Hanford 100 Area would be required. Containment of the treatment area is essential to prevent airborne mobilization of contaminants such as heavy metals and radionuclides. Land treatment is therefore considered to have limited effectiveness for treatment of Hanford 100 Area soils and riverbank sediments.

Cost. The cost of land treatment is low in comparison with other biological treatment technologies. Lined treatment cells and process control additives are inexpensive. Land treatment requires occasional tilling to incorporate nutrients and monitoring to ensure process control and determine contamination concentrations. The process is neither maintenance nor labor intensive.

3.18.3 Biodenitrification

Refer to "Groundwater Technology Descriptions" under Biodenitrification, discussed in Section 2.11.2.

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APPENDIX D

100 AREA CONTAMINATED GROUNDWATER VOLUME ESTIMATES AND CONTAMINATED RIVERBANK SEDIMENT VOLUME ESTIMATES

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APPENDIX D
100 AREA CONTAMINATED GROUNDWATER VOLUME ESTIMATES

Objective

To estimate the volume of contaminated groundwater in the 100 Area.

Sources

1. Jacquish, R. E. and R. W. Bryce, May 1990, "Environmental Monitoring at Hanford for 1989," Pacific Northwest Laboratory, Richland, Washington, Tritium and Nitrate plume maps, pp. 5.7 through 5.17.

2. Ammerman, J., "Scaled Map of the 100 Area," 1991, Westinghouse Hanford Company (WHC).

3. Personal communication with Pacific Northwest Laboratory. Top of Ringold Middle Member and water table contour maps were obtained from an unpublished report.

Assumptions

1. Only groundwater above the top of the Middle Ringold Member is potentially contaminated (the groundwater in the unconfined aquifer).

2. The tritium and nitrate plumes (due to their mobility) encompass all other contaminant plumes.

3. The porosity of the Hanford Formation is 20%.

Conclusion

It is estimated that approximately 4.8 billion gallons of contaminated groundwater lie beneath the 100 Area.

Methodology

The plume maps for both tritium and nitrate were projected onto a map of the 100 Area (Figure D-1). The degree of matching was very good; however, there was some deviation near the southern end. This deviation was minimized by obtaining a best fit of the shoreline for each reactor area prior to tracing the plume on the map.

Once the maps were properly aligned, each contaminant plume was traced onto the map. The result combines individual contaminant plumes into a single composite plume. The horizontal extent could then be estimated.

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An overlay grid with 1/4 kilometer spacing was used to calculate the horizontal extent of each plume in Figure 1. The results for each reactor area are listed below.

Area	Area Estimate (km^2)
100 B/C	1.0
Northeast of 100 B/C	2.3
100 N and 100 D/DR	8.8
100 H	1.2
100 F	16.5
Total 100 Area	29.8

Finally, the thickness of the contaminated groundwater was estimated. Figure D-2 is a contour map of the Top Surface of the Middle Member of the Ringold Formation. Figure D-3 is a contour map of the water table. The potentially contaminated aquifer lies between the top of Ringold Middle Member and the water table (Assumption 1). By subtracting these surfaces, an aquifer thickness of approximately 10 feet was derived throughout the 100 Area and along the Columbia River to the 300 Area. The two maps have different scales (10 feet for the water table versus 100 feet for the Ringold Member) and this difference may have introduced some error in the estimate of the groundwater thickness.

Assuming a porosity of 20% for the Hanford Formation (Assumption 3), the contaminated groundwater volume can be estimated from the following equation.

$$\text{VOLUME (gallons)} = \text{AREA (ft}^2\text{)} * 10 \text{ ft} * 7.48 \text{ gal/ft}^3 * 0.20$$

The result is 4,800,000,000 gallons (641,000,000 ft^3 or 23,700,000 yd^3) of contaminated groundwater.

CONTAMINATED RIVERBANK SEDIMENT VOLUME ESTIMATES

Objective

To estimate the volume of contaminated riverbank sediments in the 100 Area.

Sources

1. Jacquish, R. E. and R. W. Bryce, May, 1990 "Environmental Monitoring at Hanford for 1989," Pacific Northwest Laboratory, Richland, Washington, Tritium and Nitrate plume maps, pp. 5.7 through 5.17.

2. Drawing H-1-52166, "100 Area Topographic Mapping," sheets 1 through 55.

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3. River stage information from conversations with Greg Rupert of the United States Geological Survey, Water Resources Division, Pasco, Washington.

4. Ammerman, J., "Scaled Map of the 100 Area," 1991, Westinghouse Hanford Company, (WHC), Richland, Washington.

Assumptions

1. Groundwater contaminants were distributed vertically through the soil as bank storage increased (as the river flooded).

2. Since the beginning of Hanford operations, no groundwater-contaminated soil has existed above the highest flood level.

3. No groundwater-contaminated soil exists below the minimum river level due to dilution of contaminants.

4. The difference between maximum flood and minimum river level is constant throughout the 100 Area, and equal to that at the recording station 2.6 miles down-stream of Priest Rapids Dam.

5. The average bank slope calculated is correct for the extent of each contamination plume.

6. Contamination exists where ever a contaminant plume intersects the Columbia River.

7. The tritium and nitrate plumes encompass all other contaminant plumes due to their mobility.

Conclusion

It is estimated that approximately 832,000 bank cubic meters of 100 Area riverbank sediments are contaminated. Using a swell factor of 15%, this is 956,800 loose cubic meters or 1.25 million loose cubic yards.

Methodology

The plume maps for both tritium and nitrate were projected onto a map of the 100 Area (Figure D-4). The degree of matching was very good; however, there was some deviation near the southern end. This deviation was minimized by obtaining a best fit of the shoreline for each area prior to tracing the plume on the map.

Once the maps were properly aligned, each contaminant plume was traced onto the map. The result combines individual tritium and nitrate plumes into composite plumes of contaminated groundwater. A single composite plume runs from the 100-N

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Area to the 100-D/DR Area. From these composite plumes, the face length of contamination was then estimated.

The face length was estimated by marking off fractions of a kilometer along the shoreline. A division of 100 meters (0.1 km) accurately matched the shoreline contour. Points chosen along each plume near obvious landmarks (fence line intersections, islands, etc.) were used for reference to the topographic maps (Reference 2). The 100 Area topographic mapping drawing (H-1-52166) was used to estimate the slope of the beach near the river at each point. At least three slopes were calculated for each composite plume (see Figure D-5). The slopes were then averaged for the composite plume.

River stage information was obtained from the United States Geological Survey, Pasco, Washington, for the maximum and minimum river elevations. The extremes are local and occurred after the reactors began operation (circa 1943). The difference in river stage is used as a basis for estimating the vertical extent of contamination in the riverbank (see Assumptions 1, 2 and 3). The maximum river level occurred on June 12, 1948 at 432 feet, national geodetic vertical datum (ngvd). The minimum river level occurred on November 3, 1985 at 396.53 feet (ngvd). The difference between the two levels is 35.5 feet or 10.8 meters.

The cross sectional area of potentially contaminated riverbank sediments was calculated as the area of a right triangle which has a height equal to the maximum flood stage minus the minimum flow stage and a base calculated using the average bank slope determined for each contaminant plume. A conservative five meters of additional horizontal extent was applied to all areas except 100-K. An exception was made at 100-K for two reasons: 1) the K-reactors were not in operation at the time of the 1948 maximum flood; and 2) the bank slope is sufficiently shallow at 100-K that the resulting estimate would be excessive. Data for these calculations are presented in Table D-1.

The volume of potentially contaminated sediments was estimated by multiplying the area of the above triangular cross section, Figure D-5, by the riverbank distance determined through the mapping exercise. The resulting volume is 832,000 cubic meters.

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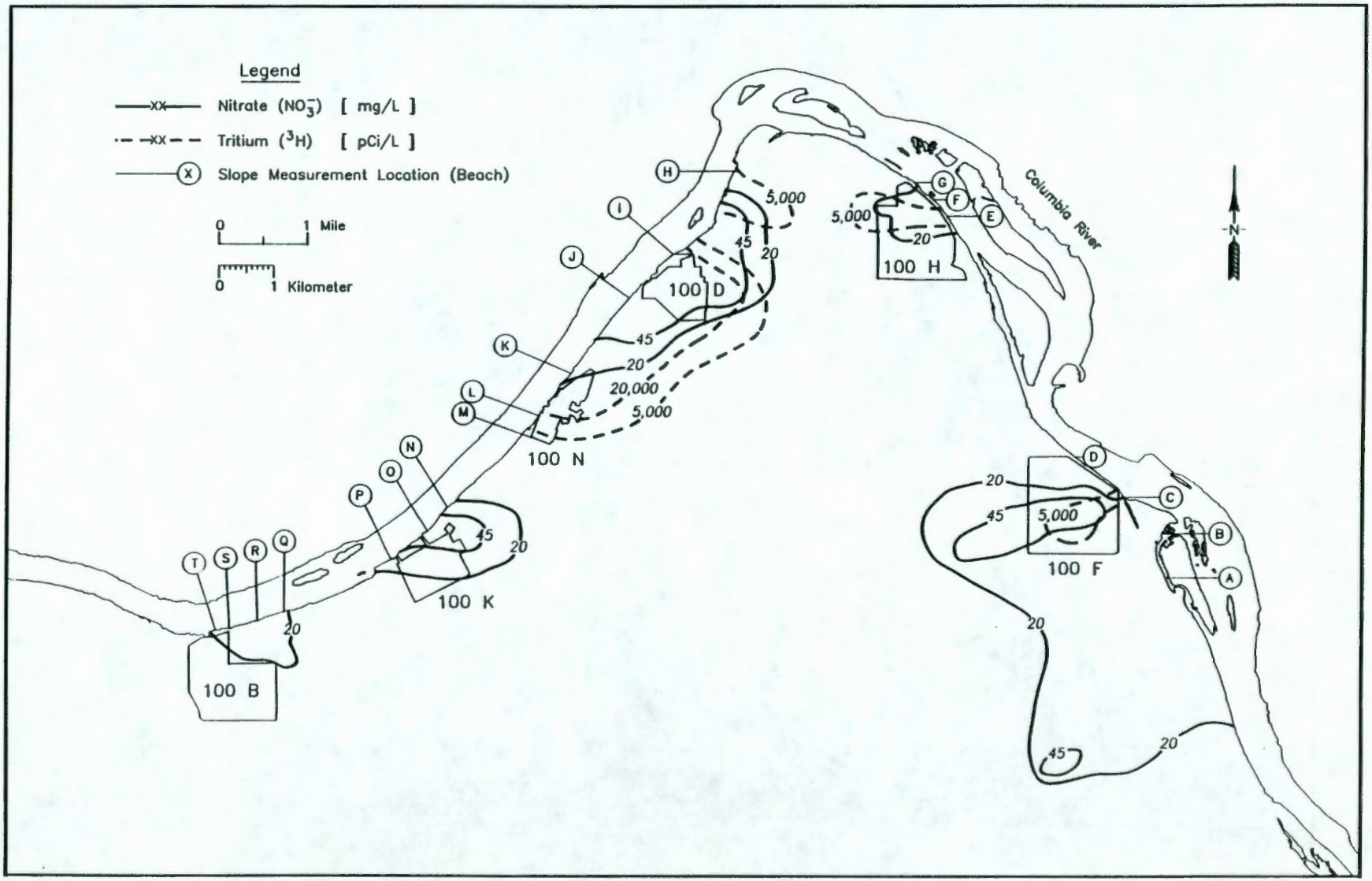
Figure D-1. 100 Area Map: Contaminated Groundwater Calculations



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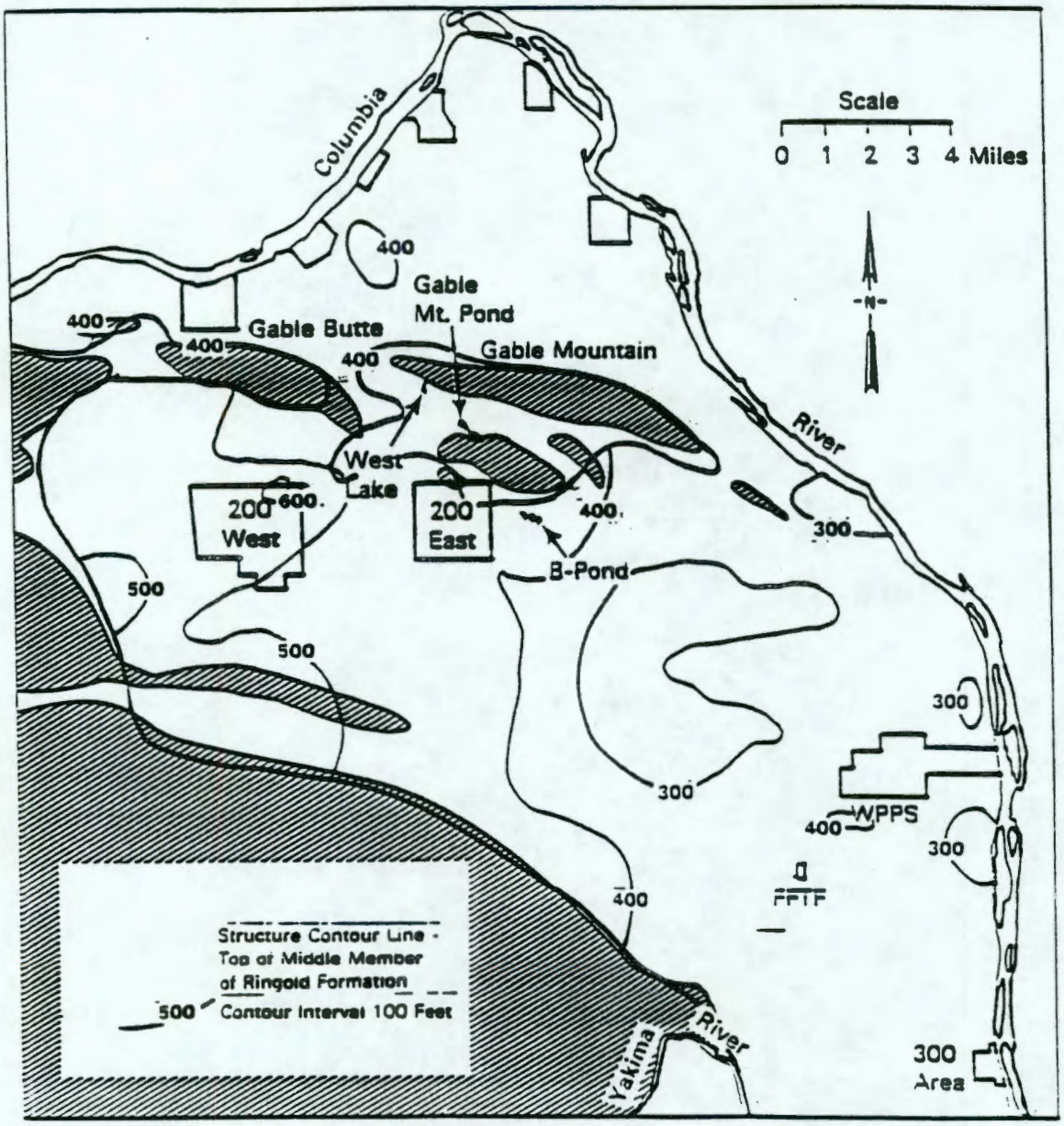

Figure D-2: Structural Top Surface of the Middle Member of the Ringold Formation

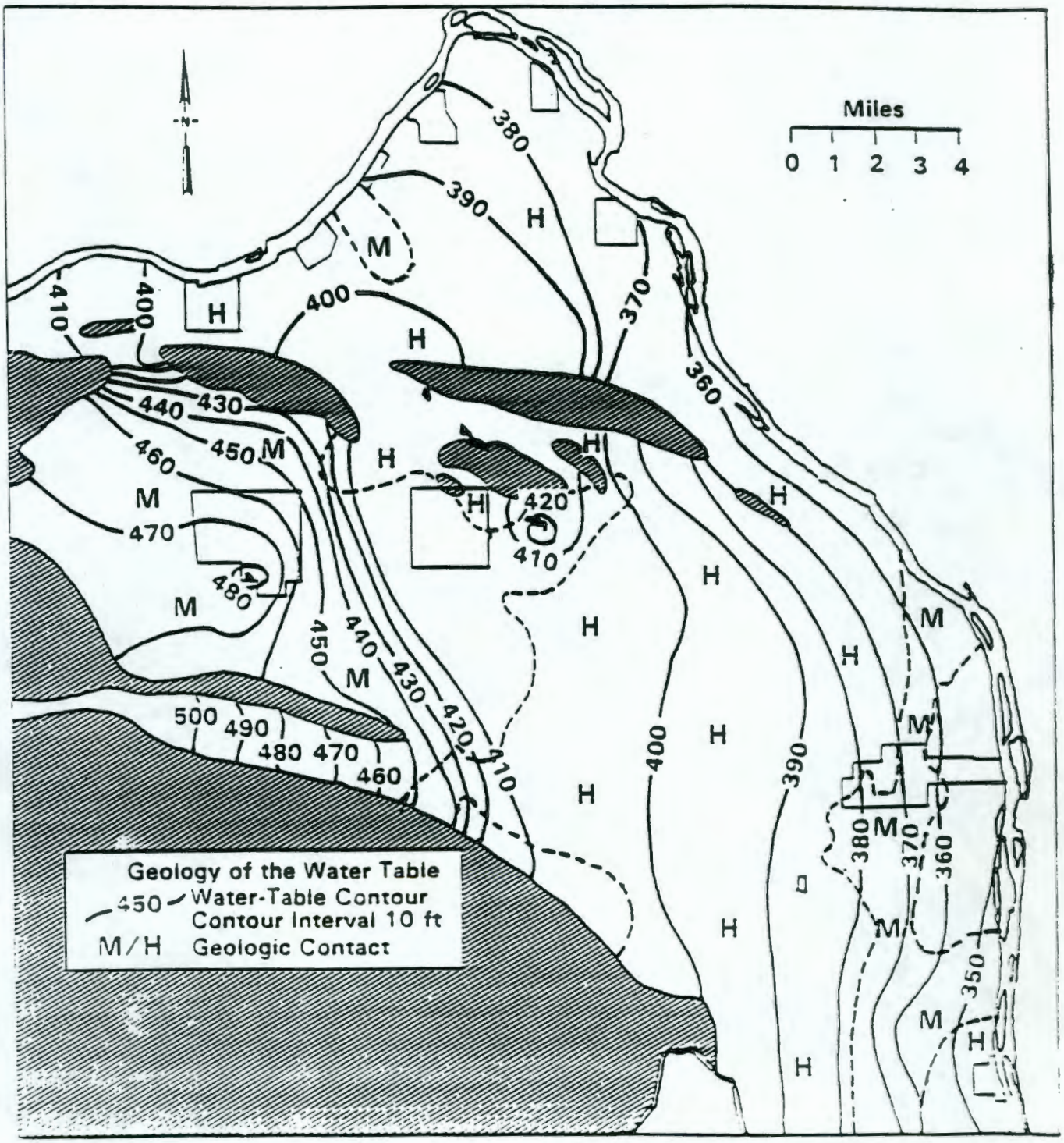

Figure D-3: Geology of the Water Table

Figure D-4. 100 Area Map: Contaminated Riverbank Sediments Calculations

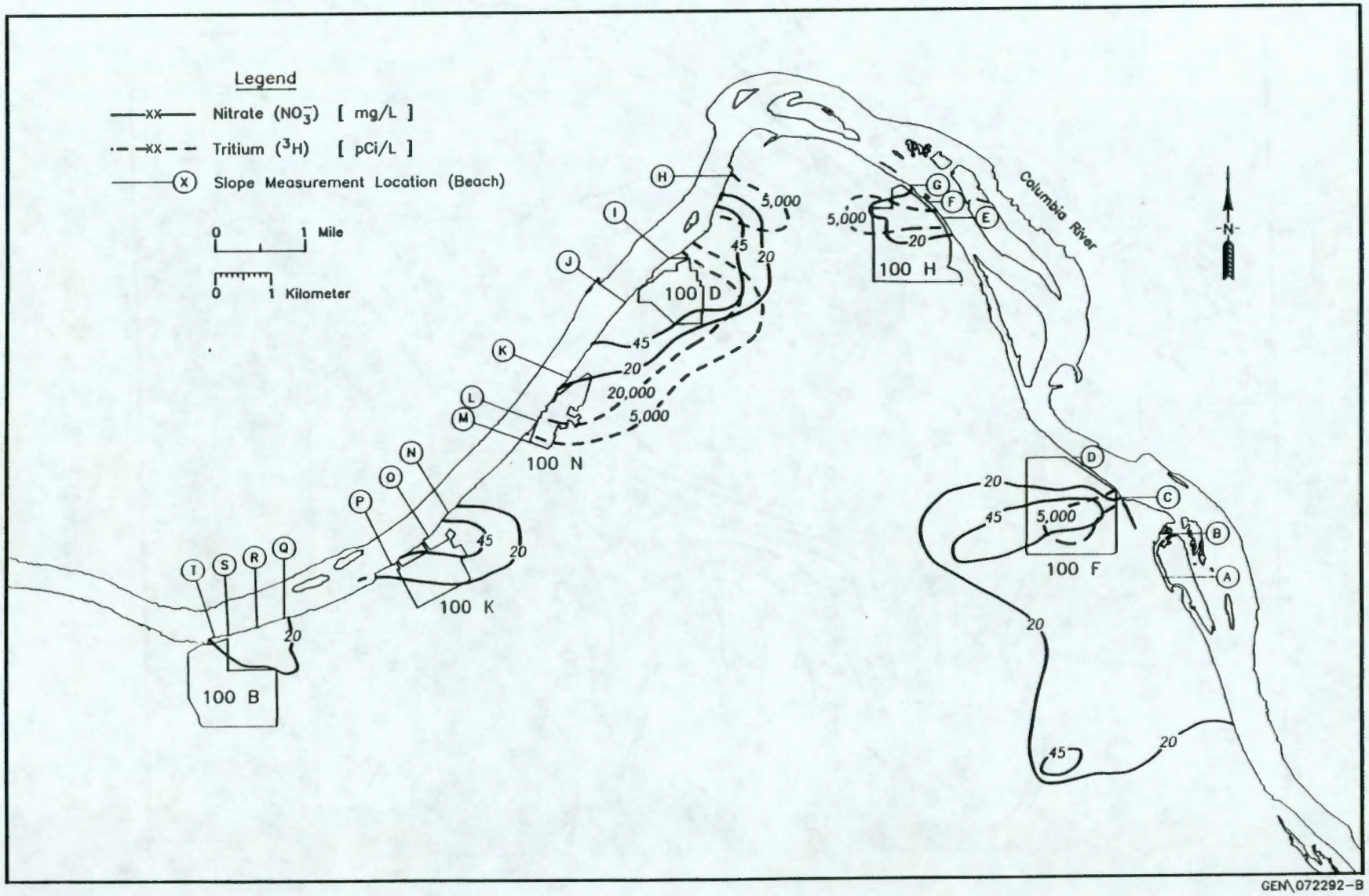

Figure D-5. Riverbank Volume Calculation

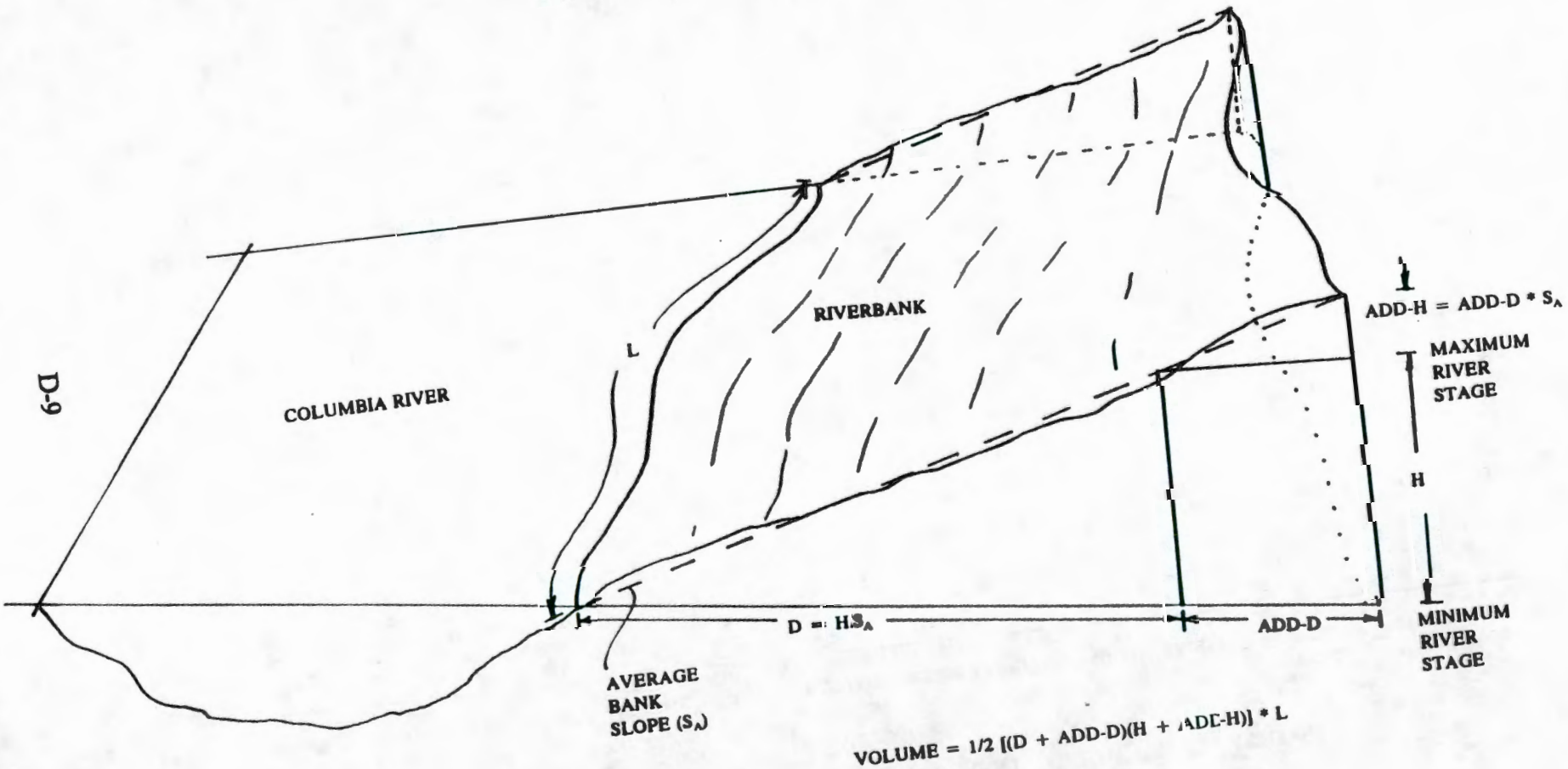

TABLE D-1. 100 AREA RIVER BANK SEDIMENT VOLUME CALCULATIONS

AREA	POINT	RISE (m)	RUN (m)	SLOPE	AVERAGE SLOPE	ANGLE (deg)	LENGTH (m)	HEIGHT (m)	DEPTH (m)	ADD-D (m)	ADD-H (m)	TOTAL HEIGHT (m)	TOTAL DEPTH (m)	VOLUME (m^3)
100 F	A	5	21	0.238										
	B	9	137	0.066										
	C	7.5	104.5	0.072										
	D	7.5	70	0.107										
					0.121	6.88	595	10.82	89.662	5.	0.603	11.423	94.662	321,704
100 H	E	3	80	0.038										
	F	8.5	38	0.224										
	G	8.5	80	0.106										
					0.122	6.98	120.	10.82	88.342	5.	0.612	11.432	93.342	64,028
100 D&DR	H	6.5	77	0.084										
	I	14	82	0.171										
	J	17.5	38	0.461										
100 N	K	17.5	47	0.372										
	L	10	52	0.192										
	M	6	85	0.071										
					0.225	12.69	603.	10.82	48.056	5.	1.126	11.946	53.056	191,091
100 KE&KW	N	2.5	95	0.026										
	O	2.5	58	0.043										
	P	5	150	0.033										
					0.034	1.96	205.	10.82	180.[1]	0.[2]	0.	10.82	180.	199,629
100 B&C	Q	7.5	37	0.203										
	R	5	30	0.167										
	S	10.5	41	0.256										
	T	6	50	0.12										
					0.186	10.56	150.	10.82	58.058	5.	0.932	11.752	63.058	55,578
TOTAL														832,030

1. Due to the shallow slope, the calculated depth was 315.9 m. This distance overlapped two source units and was therefore reduced to remove the overlap.
2. Zero additional depth added to ensure no overlap with existing source units.

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APPENDIX E

100 AREA WASTE UNITS

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TABLE E-1. LIQUID EFFLUENT SYSTEMS IN THE 100 AREA					
WIDS NUMBER	**ALIAS**	**OPERABLE UNIT**	**SERVICE DATES**	**FACILITY SIZE (feet)**	**HIGH PRIORITY SITE**
RETENTION BASINS					
116-B-11	107-B retention basin	100-BC-1	1944-1968	450 x 230 x 24	Yes
116-C-5	107-C retention basin	100-BC-1	1952-1969	16 x 330 (diameter)	Yes
116-D-7	107-D retention basin; 107-D	100-DR-1	1944-1967	467 x 230 x 24	Yes
116-DR-9	107-DR retention basin; 107-DR	100-DR-1	1950-1965	600 x 273 x ~20	Yes
116-F-14	107-F retention basin; 107-F	100-FR-1	1945-1965	450 x 230 x 24	Yes
116-H-6*	183-H solar evaporation basins	100-HR-1	1973-1985	26,400 sq. ft.	Yes
116-H-7	107-H retention basin; 107-H	100-HR-1	1949-1965	600 x 273 x 20	Yes
116-KE-4	107-KE retention basin; 107-KE	100-KR-1	1955-1971	25 x 250 (diameter)	Yes
116-KW-3	107-KW retention basin; 107-KW	100-KR-1	1944-1970	29 x 250 (diameter)	Yes
OUTFALL STRUCTURES					
116-B-7	1904-B1 outfall structure	100-BC-1	1944-1968	27 x 14	
116-B-8	1904-B2 outfall structure	100-BC-1	1944-1968	27 x 14	
132-C-2	1904-C outfall; 116-C-4	100-BC-1	1952-1969	Unknown	
116-D-5	1904-D outfall structure	100-DR-1	1944-1967	60 x 24	Yes
116-DR-5	1904-DR outfall structure; 1904-DR	100-DR-1	1950-1965	27 x 14	Yes
116-F-8	1904-F outfall structure	100-FR-1	1945-1965	27 x 14	

TABLE E-1. LIQUID EFFLUENT SYSTEMS IN THE 100 AREA

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
	PNL outfall	100-FR-1	?-1963	Unknown	
116-H-5	116-H-5 outfall structure; 1904-H outfall structure	100-HR-1	1949-1965	27 x 14	
116-K-3	1904-K outfall structure; 1908-K outfall structure	100-KR-1	1955-present	32 x 32	

Source: DOE-RL 1991a; DOE 1990a-f; DOE 1991a-f
? Exact service dates unknown.
* RCRA TSD Unit

TABLE E-2. LIQUID WASTE DISPOSAL FACILITIES IN THE 100 AREA

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
		PLUTO CRIBS			
116-B-3	105-B pluto crib	100-BC-1	1951-1952	10 x 10 x 11	Yes
116-C-2A	105-C pluto crib; 116-C-2	100-BC-2	1952-1968?	140 x 100 x 20	
116-C-2B	105-C pluto crib pump station; 116-C-2-1	100-BC-2	1952-1969	10 x 8	
116-C-2C	105-C pluto crib sand filter; 116-C-2-2	100-BC-2	1952-1969	23 x 16 x 6	
116-D-2	105-D pluto crib	100-DR-1	1950-1952	10 x 10 x 10	Yes
116-DR-4	105-DR pluto crib	100-DR-2	1952-1953	10 x 10 x 15	
116-F-4	105-F pluto crib	100-FR-1	1950-1956?	10 x 10 x 10	
116-H-4	105-H pluto crib	100-HR-1	1950-1952	4 x 4 x 2	Yes
		DUMMY/PERF DECONTAMINATION CRIBS			
116-B-4	105-B dummy decontamination french drain; 105-B dummy decontamination disposal crib	100-BC-1	1957-1968	20 x 4 (diameter)	
116-B-6A	111-B crib No. 1; 116-B-6-1	100-BC-1	1951-1968	12 x 8 x 15	Yes
116-B-6B	111-B crib No. 2; 116-B-6-2	100-BC-1	1950-1953	4 x 8 x 8	Yes
116-F-10	105-F dummy decontamination french drain; 105-F dummy/perf decontamination crib	100-FR-1	1948-1965	20 x 3 (diameter)	
116-H-3	105-H dummy decontamination french drain; perf decontamination drain	100-HR-1	1950-1965	15 x 3 (diameter)	Yes

TABLE E-2. LIQUID WASTE DISPOSAL FACILITIES IN THE 100 AREA

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
108 BUILDING CRIBS					
116-B-5	108-B crib	100-BC-1	1950-1968	84 x 16 x 10	Yes
116-B-10	108-B dry well; quench tank	100-BC-1	1950-1968	7 x 3 (diameter)	
116-D-3	108-D crib #1	100-DR-1	1951-1967	5 x 3 (diameter)	Yes
116-D-4	108-D crib #2	100-DR-1	1956-1957	5 x 3 (diameter)	Yes
115 BUILDING CRIBS					
116-KE-1	115-KE condensate crib	100-KR-2	1955-1971	40 x 40 x 26	
116-KW-1	115-KW condensate crib	100-KR-2	1955-1970	40 x 40 x 26	
117 BUILDING CRIBS					
116-B-12	117-B crib	100-BC-1	1961-1968	10 x 10 x 10	
116-D-9	117-D crib; 117-D	100-DR-1	1960-1967	10 x 10 x 10	Yes
116-DR-8	117-DR crib	100-DR-2	1960-1964	10 x 10 x 10	
116-F-7	117-F crib	100-FR-1	1960-1965	10 x 4 (diameter)	
116-H-9	117-H crib	100-HR-1	1960-1965	10 x 10 x 10	Yes
MISCELLANEOUS CRIBS					
116-DR-7	105-DR inkwell crib	100-DR-2	1953	5 x 5 x 10	
116-F-5	Ball washer crib	100-FR-1	1953-1964?	10 x 10 x 10	
116-KE-2	1706-KER waste crib	100-KR-2	1955-1971	16 x 16 x 32	

TABLE E-2. LIQUID WASTE DISPOSAL FACILITIES IN THE 100 AREA

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
		FRENCH DRAINS			
116-B-9	104-B-2 French drain	100-BC-1	1952-1954	3 x 4 (diameter)	
116-D-6	105-D cushion corridor French drain	100-DR-1	1961-1967	3 x 3 (diameter)	Yes
116-F-11	105-F cushion corridor French drain	100-FR-1	1953-1965	3 x 3 (diameter)	
116-F-12	148-F French drain	100-FR-1	1944-1964	6 x 3 (diameter)	
116-F-13	1705-F experimental garden French drain	100-FR-1	1952-1976	3 x 3 (diameter)	
	108-F French drain	100-FR-1	Unknown	Unknown	Yes
116-KE-3	105-KE storage basin French drain; 105-KE basin reverse well	100-KR-2	1955-1971	78 x 20 (diameter)	
116-KW-2	105-KW storage basin French drain, 105-KW basin reverse well	100-KR-2	1955-1970	78 x 20 (diameter)	
120-KE-1	183-KE filter waste facility dry well; 100-KE-1; 183-KE filter water facility	100-KR-3	1955-1971	4 x 4 x 4	
120-KE-2	183-KE filter waste facility French drain; 100-KE-2; 183 KE filter water facility	100-KR-3	1955-1971	3 x 3 (diameter)	
120-KW-1	183-KW filter water facility dry well; 100-KW-1	100-KR-3	1955-1970	4 x 4 x 4	
120-KW-2	183-KW filter water facility French drain; 100-KW-2	100-KR-3	1955-1970	3 x 3 (diameter)	

TABLE E-2. LIQUID WASTE DISPOSAL FACILITIES IN THE 100 AREA

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
LIQUID WASTE DISPOSAL TRENCHES					
116-B-1	107-B liquid waste disposal trench	100-BC-1	1946-1955	200 x 30 x 15	Yes
116-C-1	107-C liquid waste disposal trench	100-BC-1	1952-1968	500 x 50 x 25	Yes
116-DR-1	107-DR liquid waste disposal trench #1	100-DR-1	1950-1967?	300 x 15 x 20	Yes
116-DR-2	107-DR liquid waste disposal trench #2	100-DR-1	1952-1967	150 x 10 x 20	Yes
116-F-2	107-F liquid waste disposal trench	100-FR-1	1950-1965	300 x 50 x 15	Yes
116-H-1	107-H liquid waste disposal trench	100-HR-1	1952-1965	200 x 25 x 15	Yes
116-K-1	100-K crib; 100-K pond; 116-K-1 trench; 107-K pond; 107-K(E) sump	100-KR-1	1955	400 x 400 x ? at top	Yes
105 STORAGE BASIN TRENCHES					
116-B-2	105-B storage basin trench	100-BC-1	1946-1946	75 x 10 x 15	Yes
116-D-1A	105-D storage basin trench #1	100-DR-1	1947-1952	130 x 10 x 6	Yes
116-D-1B	105-D storage basin trench #2	100-DR-1	1953-1967	100 x 10 x 15	Yes
116-DR-3	105-DR storage basin trench	100-DR-2	1955	60 x 40 x 10	
116-F-3	105-F storage basin trench	100-FR-1	1947-1951	100 x (10 to 20) x (8 to 11)?	Yes

TABLE E-2. LIQUID WASTE DISPOSAL FACILITIES IN THE 100 AREA

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
		1608 TRENCHES			
116-DR-6	1608-DR liquid disposal trench	100-DR-2	1953-1965	50 x 10 x 10	
116-F-6	1608-F liquid waste disposal trench; 105-F cooling water trench	100-FR-1	1952-1965	300 x 100 x 10	Yes
116-H-2	1608-H liquid waste disposal trench, 1608-H crib and trench	100-HR-1	1953-1965	275 x 100 x 6	Yes
		SLUDGE TRENCHES			
116-B-13	107-B south sludge trench	100-BC-1	1952	50 x 50 x 10	
116-B-14	107-B north sludge trench	100-BC-1	1948	120 x 10 x 10	
	107-D, 107-DR sludge disposal trenches	100-DR-1	1953-unknown	5 trenches	
		MISCELLANEOUS TRENCHES			
116-F-1	Lewis Canal	100-FR-1	1953-1965	3000 x 40 x 10	Yes
116-F-9	Animal waste leaching trench	100-FR-1	1963-1976	~500 x 15 x 10	Yes
	EM bypass ditch	100-FR-1	1954-unknown	350 x unknown	
	Basin leak ditch	100-FR-1	1955-unknown	500 x unknown	
116-K-2	100-K mile long trench; K trench; 116-K-2 trench	100-KR-1	1955-1971	4000 x 45 x 15	Yes
120-KE-3	100-KE-3; 183-KE filter water facility trench	100-KR-3	1955-1970	40 x 3 x 3	

TABLE E-2. LIQUID WASTE DISPOSAL FACILITIES IN THE 100 AREA

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
MISCELLANEOUS LIQUID WASTE DISPOSAL UNITS					
120-B-1	105-B battery acid sump	100-BC-1	1944-1969		
120-D-1*	100-D ponds	100-DR-1	1977-present		Yes
132-D-3	1608-D waste water pumping station; 1608-D effluent pumping station	100-DR-1	1944-1965	20 x 20 x 36	Yes
132-H-3	1608-H waste water pumping station; 116-H-8; 1608-H effluent pumping station	100-HR-1	1949-1965	36 x 34	Yes
120-KE-8	165-KE brine pit	100-KR-2	1955-1971	16 x 10 x 10	
120-KE-9	183-KE brine pit	100-KR-3	1955-1971	23 x 17 x 10	
120-KW-6	165-KW brine pit	100-KR-2	1955-1970	16 x 10 x 10	
120-KW-7	183-KW brine pit	100-KR-3	1955-1970	23 x 17 x 10	

Source: DOE-RL 1991a; DOE 1990a-f; DOE 1991a-f
? Exact information is unknown.
* RCRA TSD Unit

TABLE E-3. SOLID WASTE DISPOSAL FACILITIES IN THE 100 AREA					
WIDS NUMBER	ALIAS(ES)	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
105 BURIAL GROUNDS					
118-B-1	105-B burial ground	100-BC-4	1944-1973	1000 x 321 x 20	
118-C-1	105-C burial ground	100-BC-4	1953-1969	510 x 400 x 15	
118-D-2	100-D burial ground #2	100-DR-3	1949-1970	1000 x 360 x 20	
118-D-3	100-D burial ground #3	100-DR-3	1956-1973	1000 x 250 x 20	
118-F-1	Minor construction burial ground #2; burial ground #1; solid waste burial ground No. 2	100-FR-2	1954-1965	600 x 500 x 20	
118-H-1	100-H burial ground No. 1	100-HR-2	1949-1965	700 x 350 x 20	
118-K-1	100-K burial ground; 118-K	100-KR-2	1953-1975?	1200 x 600 x 20	
TRITIUM SEPARATIONS PROJECT BURIAL GROUND					
118-B-6	108-B solid waste burial ground	100-BC-3	1952-1953	40 x 40 x 20	
BIOLOGICAL BURIAL GROUNDS					
118-F-5	PNL sawdust repository	100-FR-2	1954-1975	500 x 150 x 15	
118-F-6	PNL solid waste burial ground	100-FR-2	1965-1973	400 x 200 x 20	
ASH PITS					
126-B-1	184-B power house ash pit; 188-B ash disposal area	100-BC-1	1944-1969	Unknown	
126-D-1	184-D powerhouse ash pit; 188-D ash disposal area; 100-D ash disposal basin	100-DR-1	1950-1960	Unknown	
126-F-1	184-F powerhouse ash pit; 188-F ash disposal area	100-FR-2	1944-1965	Unknown	

TABLE E-3. SOLID WASTE DISPOSAL FACILITIES IN THE 100 AREA					
WIDS NUMBER	ALIAS(ES)	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
126-H-1	184-H powerhouse ash pit; 188-H ash disposal area	100-HR-2	1948-1965	Unknown	
BURN PITS					
128-B-1	100 B/C burning pit; 100-B burning pit	100-BC-1	1943-1950	100 x 100 x 10	
128-B-3	100-B dump site	100-BC-1	1944-1968	450 x 60	
128-C-1	100-C burning pit	100-BC-1	unknown	225 x 125	
128-D-1	100 D/DR burning pit	100-DR-3	1944-1967	100 x 100 x 10	
128-F-1	100-F burning pit; 100-F burning pit No. 1	100-FR-2	1945-1965	100 x 100 x 10	
128-F-2	Burning pit	100-FR-1	1945-1965	150 x 60	
128-H-1	100-H burning pit; 100-H burning pit No. 1	100-HR-2	1949-1965	100 x 100 x 10	
128-H-2	100-H burning ground #2	100-HR-2	Unknown-1965	120 x 80	
128-H-3	100-H burning ground #3	100-HR-2	Unknown	Unknown	
128-K-1	100-K burning pit	100-KR-3	1955-1971	100 x 100 x 10	
128-K-2	100-K construction dump	100-KR-3	unknown	800 x 280	
STORAGE VAULTS/CAVES					
118-C-4	105-C horizontal control rod storage cave	100-BC-2	1950-1969	1000 x 40 x 25	
118-F-7	100-F miscellaneous hardware storage vault	100-FR-2	1945-1965	16 x 8 x 8	
118-KE-2	105-KE horizontal control rod storage cave	100-KR-2	1955-1971	1000 x 40 x 25	
118-KW-2	105-KW horizontal control rod storage cave	100-KR-2	1955-1971	1000 x 40 x 25	

TABLE E-3. SOLID WASTE DISPOSAL FACILITIES IN THE 100 AREA					
WIDS NUMBER	ALIAS(ES)	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
BALL 3X BURIAL GROUNDS					
118-B-5	Ball 3X burial ground	100-BC-1	1953	50 x 50 x 20	
118-D-5	Ball 3X burial ground	100-DR-2	1954	2 - 20 x 40 x 10 each	
118-H-4	Ball 3X burial ground	100-HR-2	1953	150 x 30 x 10	
DEMOLITION SITES AND LANDFILLS					
126-B-2	183-B clearwells	100-BC-1	never used	751 x 135	
126-B-3	184-B coal pit	100-BC-1	1970's-present	400 x 225	
126-D-2	184-D coal pit	100-DR-1	1970's-1986		
126-DR-1	190-CR clearwell tank pit	100-DR-2	1970's-present	42 x 525	
126-H-2	183-H clearwells	100-HR-1	1970's-present	751 x 135	
126-K-1	100-K gravel pit	100-KR-2	1970's-present		
MISCELLANEOUS SOLID WASTE DISPOSAL SITES					
118-B-2	Construction burial ground No. 1	100-BC-3	1952-1956	60 x 30 x 10	
118-B-3	Construction burial ground No. 2	100-BC-3	1956-1960	350 x 275 x 20	
118-B-4	105-B spacer burial ground	100-BC-3	1956-1958	50 x 30 x 15	
118-B-6	108-B solid waste burial ground	100-BC-3	1952-1953	40 x 40 x 20	
118-B-7	111-B solid waste burial site	100-BC-1	1951-1968	8 x 8 x 8	
118-B-10	Pit	100-BC-1	unknown	48 x 18	
128-B-2	Sand blast disposal site	100-BC-1	unknown	unknown	

TABLE E-3. SOLID WASTE DISPOSAL FACILITIES IN THE 100 AREA

WIDS NUMBER	ALIAS(ES)	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
118-D-1	100-D burial ground No. 1	100-DR-3	1944-1967	450 x 375 x 20	
118-D-4	Construction burial ground	100-DR-3	1953-1967	600 x 200 x 20	
118-DR-1	105-DR gas loop burial ground	100-DR-3	1963-1964	125 x 75 x 15	
118-F-2	Burial ground No. 2; solid waste burial ground No. 1	100-FR-2	1945-1965	368 x 326 x 20	
118-F-3	Minor construction burial ground No. 1; burial ground No. 3	100-FR-2	1952	175 x 50 x 15	
118-F-4	115-F pit; 115-F crib	100-FR-2	1949	10 x 10 x 10	
120-F-1	Glass Dump	100-FR-2	?	30 x 8 x 4	
118-H-2	H-1 loop burial ground; 100-H burial ground No. 2	100-HR-2	1955-1965	140 x 50 x 15	
118-H-3	Construction burial ground	100-HR-2	1953-1957	300 x 200 x 20	
118-H-5	105-H thimble pit	100-HR-2	1953-1960	30 x 10 x 2	

Source: DOE-RL 1991a; DOE 1990a-f; DOE 1991a-f
? Exact information unknown.

TABLE E-4. 100-N AREA WASTE UNITS

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
116-N-1*	1301-N liquid waste disposal facility; 1301-N crib and trench	100-NR-1	1964-1985	125 x 290 x 12 w/ 1600 extension trench	
116-N-2	1310-N chemical waste storage tank; the golf ball; 1310-N waste storage area	100-NR-1	1964-present	900,000 gallons	Yes
116-N-3*	1325-N liquid waste disposal facility; 1325-N crib and trench	100-NR-1	1983-present	250 x 240 w/ 3000 x 10 x 7 extension trench	
116-N-4	1300-N emergency dump basin	100-NR-1	1963-1973 1963-1987 (1)	130 x 80 x 15 (1)	
116-N-8	163-N mixed waste and hazardous waste container storage pad; 116-N-8 storage pad	100-NR-1	1986-present	152 x 60	
118-N-1	100-N Area silos; 100-N Area spacer silos; 118-N	100-NR-1	1963-present	20 x 16 (diameter)	
120-N-1	1324-NA percolation pond	100-NR-1	1977-present	29,000 sq. ft.	Yes
120-N-2	1324-N surface impoundment	100-NR-1	1986-1988	140 x 75 x 15	Yes
120-N-3	163-N neutralization pit and French drain	100-NR-1	1963-1988 1963-present (1)	8 x 25 x 8 vault; 4-6 diameter drain (1)	
120-N-4	1310-N hazardous waste staging area; 1310-N waste oil storage pad; 1310-N non-hazardous waste pad	100-NR-1	1985-present	100 x 75	
120-N-5	108-N/163-N transfer line neutralization pit	100-NR-1	1963-present	2- 6 x 6 x 10 vaults (1)	

TABLE E-4. 100-N AREA WASTE UNITS

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
120-N-6	108-N acid tank vent French drains	100-NR-1	1963-1988	5- 2 ft diameter drains	
120-N-7	100-N acid unloading facility French drain	100-NR-1	1963-1987	4 x 3 (diameter) (1)	
120-N-8	163-N sulfuric acid tank vent French drain	100-NR-1	1963-1988	4-6 (diameter); depth unknown	
124-N-1	124-N-1 septic tank; 100-N sanitary sewer system No. 1	100-NR-1	1963-present	2300 gal/day; 200 sq. ft. infiltration area	
124-N-2	124-N-2 septic tank; 100-N sanitary sewer system No. 2	100-NR-1	1963-present	2300 gal/day; 200 sq. ft. infiltration area	
124-N-3	124-N-3 septic tank; 100-N sanitary sewer system No. 3	100-NR-1	1982-present	45 gal/day; 500 gallon cess pool	
124-N-4	100-N sanitary sewer system No. 4; 124-N-4 septic tank	100-NR-1	1963-1987	14,000 gallon; 8900 sq. ft. infiltration area	
124-N-5	100-N sanitary sewer system No. 5; 124-N-5 septic tank	100-NR-1	1981-1987	3700 gallon; 960 sq. ft. infiltration area	
124-N-6	100-N sanitary sewer system No. 6; 124-N-6 septic tank	100-NR-1	1979-1984	2000 gallon; 600 sq. ft. infiltration area (800 sq. ft. in (1))	

TABLE E-4. 100-N AREA WASTE UNITS

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
124-N-7	100-N sanitary sewer system No. 7; 124-N-7 septic tank	100-NR-1	1984-1987	7500 gallon; 5500 sq. ft. infiltration area	
124-N-8	100-N sanitary sewer system No. 8; 124-N-8 septic tank	100-NR-1	1983-1987	5000 gallon; 1650 sq. ft. infiltration area	
124-N-9	124-N-9 septic tank; 100-N sanitary sewer system No. 9	100-NR-1	1985-present	3000 gallon; 3500 sq. ft. infiltration area	
124-N-10	124-N-10 sanitary sewer system; 100-N central sewer system No. 10	100-NR-1	1987-present	50,000 gal/day	
128-N-1	100-N burning pit; 128-N-1 burning pit	100-NR-1	1963-1989 1962-1986 (1)	unknown	
130-N-1	183-N backwash discharge pond; 183-N filter backwash pond; 126-N-1	100-NR-1	1983-present		
	South settling pond	100-NR-1	1977-1983	110 x 50 x 15	Yes

Source: DOE-RL 1991a; DOE 1990d,e
* RCRA TSD unit
(1) Information from DOE-RL 1991a and DOE 1990d,e differs.

TABLE E-5. 100 AREA SANITARY SEWER SYSTEMS		
WIDS NUMBER	OPERABLE UNIT	SERVICE DATES
1607-B1	100-BC-1	1944-1960
1607-B2	100-BC-1	1944-present
1607-B3	100-BC-1	1944-1974
1607-B4	100-BC-1	1944-present
1607-B5	100-BC-1	1944-1988
1607-B6	100-BC-1	1944-present
1607-B7	100-BC-1	1951-1969
1607-B8	100-BC-2	1951-1969
1607-B9	100-BC-4	unknown
1607-D1	100-DR-3	1944-1965
1607-D2	100-DR-1	1944-present
1607-D3	100-DR-2	1944-present
1607-D4	100-DR-1	1944-1968
1607-D5	100-DR-1	1944-present
1607-F1	100-FR-2	1944-1960
1607-F2	100-FR-1	1944-1988
1607-F3	100-FR-1	1944-1965
1607-F4	100-FR-1	1944-1965
1607-F5	100-FR-1	1944-1965
1607-F6	100-FR-1	1945-1975
1607-H1	100-HR-2	1948-present
1607-H2	100-HR-1	1949-1965
1607-H3	100-HR-2	1948-1968
1607-H4	100-HR-1	1948-1965
1607-K1	100-KR-3	1955-present
1607-K2	100-KR-3	1955-present
1607-K3	100-KR-3	1955-1970

9 2 1 2 6 5 2 1 2 3 3

TABLE E-5. 100 AREA SANITARY SEWER SYSTEMS		
WIDS NUMBER	**OPERABLE UNIT**	**SERVICE DATES**
1607-K4	100-KR-2	1955-present
1607-K5	100-KR-3	1955-present
1607-K6	100-KR-2	1955-present
Source: DOE-RL 1991a		

9 2 1 2 6 2 1 2 3 4

TABLE E-6. MISCELLANEOUS WASTE UNITS IN THE 100 AREA

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
116-C-3	105-C chemical waste tanks	100-BC-2	Never used	27,000 gal	
118-C-2	105-C ball storage tank	100-BC-2	1969	5 x 6 (diameter)	
130-D-1	1716-D gasoline storage tank	100-DR-1	1944-1968	1,000 - 4,999 gallon	Yes
130-K-1	1717-K gasoline storage tank	100-KR-2	1955-1972	Unknown	
130-K-2	1717-K waste oil storage tank	100-KR-2	1955-1972	Unknown	
130-K-3	182-K emergency diesel oil storage tank; 182-K emergency cooling flow diesel tank	100-KR-3	1955-1971	17,500 gallons (2 tanks)	
116-KE-6A	1706-KE condensate collection tank; 1706-KE waste treatment system	100-KR-2	1986-present	96 gallon	
116-KE-6B	1706-KE waste treatment system; 1706-KE evaporation tank	100-KR-2	1986-present	30 gallon	
116-KE-6C	1706-KE waste accumulation tank; 1706-KE waste treatment system	100-KR-2	1986-present	550 gallon	
116-KE-6D	1705-KE waste treatment system; 1706-KE ion exchange column	100-KR-2	1986-present	5 cu. ft.	
120-KE-4	183-KE1 sulfuric acid storage tank	100-KR-3	1955-1971	10,109 gallon	
120-KE-5	183-KE2 sulfuric acid storage tank	100-KR-3	1955-1971	10,109 gallon	
120-KE-6	183-KE sodium dichromate tank	100-KR-3	1955-1971	Unknown	

TABLE E-6. MISCELLANEOUS WASTE UNITS IN THE 100 AREA

WIDS NUMBER	ALIAS	OPERABLE UNIT	SERVICE DATES	FACILITY SIZE (feet)	HIGH PRIORITY SITE
126-KE-2	183-KE liquid alum storage tank #2	100-KR-3	1955-1971	180,000 gallon	
126-KE-3	183-KE liquid alum storage tank #1	100-KR-3	1955-1971	Unknown	
130-KE-1	105-KE emegency diesel oil storage tank; 105-KE emergency diesel fuel tank	100-KR-2	1955-1971	2,000 gallon	
130-KE-2	166-KE oil storage tank	100-KR-2	1955-1971	1,650,000 gallon	
120-KW-3	183-KW1 sulfuric acid storage tank	100-KR-3	1955-1970	10,109 gallon	
120-KW-4	183-KW2 sulfuric acid storage tank	100-KR-3	1955-1970	10,109 gallon	
120-KW-5	183-KW sodium dichromate storage tank	100-KR-3	1955-1971	Unknown	
130-KW-1	105-KW emergency diesel oil storage tank; 105-KW emergency diesel fuel tank	100-KR-2	1955-1970	2,000 gallon	
130-KW-2	166-KW oil storage tank	100-KR-2	1955-1970	1,650,000 gallon	

Source: DOE-RL 1991a; DOE 1990a-f, DOE 1991a-f

TABLE E-7. SUMMARY OF UNPLANNED RELEASES IN THE 100 AREA

UNPLANNED RELEASE NUMBER	DATE	RELEASE AREA	NATURE AND QUANTITY OF WASTE RELEASED	REMEDIAL ACTIONS
UN-100-F-1	3/13/71	Main sewer lines from 141-C to 141-M buildings became plugged	4.0E-5 Ci Sr-90, 1.06E-6 Ci Pu-239	Area stabilized with clean gravel
UN-100-K-1	4/79	105-KE pickup chute area; no surface contamination	450 gal/h for unknown period of fuel storage basin effluent; soil beneath basin estimated total activity of 2,530 Ci with 1.3 Ci of Pu-239	None
UN-100-N-1	3/27/74	Line leak resulted in release of radioactive water to ground near 1304-N emergency dump tank	0.2 Ci of radioactive constituents	Contaminated soil reading greater than 1,000 ct/min was removed; remainder covered with clean fill
UN-100-N-2	2/19/80	Leak in relief drain line from FLV858 valve; area 17 x 17 x 10 feet was contaminated	Primary coolant water containing less than 1 Ci beta/gamma; 10 gal/min leak rate	Line repaired; groundwater monitored; accessible contaminated soil removed and covered with clean fill
UN-100-N-3	3/8/78	Leak in dummy fuel spacer transfer line from fuel storage basin; contaminated area 2.5 feet by 4 foot diameter	Storage basin water; released estimated 0.07 Ci Co-60, 0.8 Ci Sr-90, 0.25 Ci Cs-137, 0.14 Ci CePr-144, 0.0004 Ci Pu-239, 1 Ci of H-3; rate of 25 gal/min for about a week	Line repaired; contaminated soil removed and area covered with clean fill
UN-100-N-4	5/7/77	Overflow of radioactive water from 1322-A sump; contaminated about 1,500 sq. ft.	Total activity of 0.5 mCi	Most of the contaminated soil removed and replaced with clean fill
UN-100-N-5	6/27/72	Leak in piping at radioactive chemical waste handling facility	35 Ci total activity released including 26 Ci of Co-60	Contaminated soil reading greater than 1,000 ct/min removed; remainder covered with clean fill

TABLE E-7. SUMMARY OF UNPLANNED RELEASES IN THE 100 AREA

UNPLANNED RELEASE NUMBER	DATE	RELEASE AREA	NATURE AND QUANTITY OF WASTE RELEASED	REMEDIAL ACTIONS
UN-100-N-6	9/10/85	Leak in 1.5-in line between 105-N and 1310-N resulted in release of radiologically contaminated water	An estimated 0.2 Ci Co-60, 0.04 Ci Mn-54, 0.003 Ci Ru-103, and 0.003 Ci Cs-137	Line repaired; ~590 cu. ft. contaminated soil reading 7,000 to 25,000 ct/min removed; excavation backfilled with clean soil
UN-100-N-7	4/29/85	Leak in buried 10-in drain line between 105-N and 1304-N	Radioactive effluent containing 1 Ci Na-24, 0.5 Ci Co-60, 0.09 Ru-103, 0.4 Ci Cr-51, 0.2 Ci Zr-95, 0.3 Ci Te-132, 0.3 Ci Mn-54, 0.1 Ci Nb-95, 0.5 Ci I-131, 1.2 Ci Fe-59, 0.2 Ci Ce-141, 0.2 Ci Ce-144, 0.8 Ci Tc-99	Adjacent groundwater wells had increased levels of I-131; ~1,130 cu. ft. contaminated soil removed; area backfilled with clean soil
UN-100-N-8	5/11/75	Radioactive water was released from overflow at 1322-A sump contaminating 25 sq. ft.	Total activity was 0.5 mCi	Most of contaminated soil removed and replaced with clean fill
UN-100-N-9	10/14/74	Leak in 119-N cooling water drain line and valve	~500,000 pCi	Valve and line repaired; contaminated soils removed and area backfilled with clean soil
UN-100-N-10	5/13/75	Contaminated water leaked to ground during removal of 105-N check valve	0.001 Ci of mixed fission and activation products	Small dirt dam built to confine water within existing radiation zone
UN-100-N-11	10/2/75	East side of Highway 4 North; contaminated 500 lb valve bonnet fell onto the road, 8 cu. yd. of soil and a 30 x 1 foot strip of blacktop contaminated	1,000 mR where the bonnet hit the road; 5,000 to 20,000 ct/min on 200 sq. ft. of road; 25,000 to 50,000 on surface of field adjacent to valve bonnet	8 cu. yd. of soil and 0.5 cu. yd. of blacktop removed

TABLE E-7. SUMMARY OF UNPLANNED RELEASES IN THE 100 AREA

UNPLANNED RELEASE NUMBER	DATE	RELEASE AREA	NATURE AND QUANTITY OF WASTE RELEASED	REMEDIAL ACTIONS
UN-100-N-12	2/27/79	Leak in spacer transport line; same location as UN-100-N-3	Readings of 50 to 100 mR/h; basin water released contained 0.19 Ci Co-60, 0.4 Ci Cs-137, 0.00057 Ci Pu-239/240	Line repaired; sink hole filled with clean soil
UN-100-N-13	9/24/73	Overflow of spent decontamination solution at 1314-N loading station contaminated 20 sq. ft.	100 gallon containing ~0.011 Ci	Contaminated soil packaged for removal or covered with clean fill
UN-100-N-14	8/5/74	Leak in 119-N drain system; contaminated 800 sq. ft.	0.0008 Ci beta/gamma	Soil reading greater than 1,000 ct/min removed; remaining soil covered with clean fill
UN-100-N-15	3/20/81	108-N neutralization sump transfer line leak; contaminated less than 50 cu. ft.	Sulfuric acid	Acid neutralized with soda ash
UN-100-N-17	8/66	166-N diesel oil supply line leak	Diesel oil	Line repaired; oil near the river collected in interceptor trench and periodically burned
UN-100-N-18	8/73	Leak in diesel oil supply line between 166-N tank farm and 184-N day tank	Diesel oil	Line excavated and repaired
UN-100-N-19	4/84	Overflow of 184-N day tank	No. 6 fuel oil	Oil removed from ground surface and tank impoundment area cleaned up
UN-100-N-20	6/85	Leak in 166-N diesel oil return line	No. 2 diesel oil	Line repaired; oil-contaminated soil removed; groundwater monitored
UN-100-N-21	4/25/86	Overflow at 184-N day tank	No. 2 diesel oil	Level annunciator repaired; 650 gallon of oil removed; no oil detected in groundwater

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UNPLANNED RELEASE NUMBER	DATE	RELEASE AREA	NATURE AND QUANTITY OF WASTE RELEASED	REMEDIAL ACTIONS
UN-100-N-22	6/23/86	Leak in 184-N diesel oil supply line	No. 2 diesel oil	Line rerouted; contaminated soil removed; oil detected in groundwater
UN-100-N-23	1/10/87	Leak in 184-N diesel oil supply line	No. 2 diesel oil	Line excavated; oil detected in groundwater
UN-100-N-24	2/1/87	166-N fuel oil supply line leak	No. 6 fuel oil	None
UN-100-N-25	5/15/75	1310-N tank vented and released reactor decontamination solution to the ground	Primary loop water and decontamination solution containing phosphoric acid and diethylthiourea	Localized contamination covered with 6 inches of soil
UN-100-N-26	12/7/78	Reactor decontamination solution backflowed during pumping at the 1314-N load-out facility	Decontamination solution containing phosphoric acid and diethylthiourea	Remaining solution absorbed and sent to 200 Area burial ground
UN-100-N-29	4/23/74	Leaking check valve at 1304-N dump tank released radioactive water to ground	Primary coolant water containing radioactive fission and activation products, mostly Mn-56 and Na-24	Contaminated soil removed; area covered with clean fill
UN-100-N-30	7/22/74	Overflow at the 1304-N dump tank contaminated 2,500 sq. ft.	Primary coolant water containing radioactive fission and activation products; maximum of 500 ct/min	Contaminated soil stabilized in place with sand and fines
UN-100-N-31	7/22/74	Spill of radioactive effluent at 1301-N crib; contaminated area ~2,025 sq. ft.	Radioactive effluent containing fission and activation products; gross beta/gamma concentration was 700 dis/min/mL	Contaminated soil removed; area covered with clean fill
UN-100-N-32	9/16/74	Leaking check valve at 1304-N dump tank	Radioactive effluent containing fission and activation products; mud sample read 20,000 ct/min; estimate of less than 10 mCi of activity remaining on ground	Contaminated soil removed or covered with clean fill

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UNPLANNED RELEASE NUMBER	DATE	RELEASE AREA	NATURE AND QUANTITY OF WASTE RELEASED	REMEDIAL ACTIONS
UN-100-N-33	11/9/81	Acid spilled during transfer at 108-N	97% sulfuric acid; exceeded CERCLA requirement of 1,000 lb for sulfuric acid	Acid was neutralized with sodium hydroxide and soda ash
UN-100-N-34	5/12/80	Release of sulfuric acid during transfer at 108-N	94% sulfuric acid	Acid in encasement neutralized with 50% sodium hydroxide and pumped to clearwell overflow; acid in surrounding area neutralized with soda ash and liquid sodium hydroxide
UN-100-N-35	11/86	Leakage from sub-basin (fuel storage) drain line	Radioactively contaminated water containing 1.6 Ci Mn-56, 0.4 Ci Co-60, 0.3 Ci Nb-95, 0.1 Ci I-131, 0.4 Ci Cs-137, 0.3 Ci Ce-144; rate of 3 gal/min only during feed and bleed of the fuel basin	Basin weir and drain line grouted and sealed off

Source: DOE-RL 1991a; DOE 1990d,e